PROCEEDINGS OF THE YEAR 2010 ASIA-PACIFIC NETWORK FOR GLOBAL CHANGE RESEARCH

SCIENTIFIC WORKSHOP ON CLIMATE CHANGE AND DIMS TECHNOLOGY – CCD

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Edited by

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Preface

Climate change and global warming pose serious problems for sustainability of a sound human life in the world. Many hydrological disasters such as sea level rise, global warming, floods, droughts, glacier collapses and typhoons have caused big and frequent damages to human lives and societies both physically as well as economically.

Though natural amounts of CO_2 have varied from 180 to 300 parts per million (ppm), today's CO_2 levels are around 380ppm. That is 25% more than the highest natural levels over the past 650,000 years. Increased CO_2 levels have contributed to periods of higher average temperatures throughout that long record. If atmospheric concentrations of greenhouse gases double compared to pre-industrial levels, this would "likely" cause an average warming of around 3ºC, with a range of 2 – 4.5ºC. The National Academy of Sciences (NAS) said global warming could lead to "large, abrupt and unwelcome" changes in the climate, and the Intergovernmental Panel on Climate Change (IPCC) – which is made up of 2,500 scientists – warns of human-induced global warming. Global warming is having a significant impact on hundreds of plant and animal species around the world – although the most dramatic effects may not be felt for decades.

University of Nottingham is the Centre of Excellence in learning and research. It has educated and trained many world's most successful and famous people. Recently the University won the prestigious Times Higher Education of the Year award in recognition of development in international campuses principally the world class campus near Kuala Lumpur for the past 10 years.

The workshop serves as a platform to facilitate the creation of new knowledge and methodologies through the exchange of ideas, strategies and innovations in some areas of Climate Change and database development technologies. The workshop, thus, provides opportunities for networking among academics, scientists and researchers in paving their way for wider and more intensified knowledge in climate change and its environmental impact. Thank you and we look forward to your participation in CCD workshop at KLTC. The Chairman, coordinator and speakers of the workshop are confident that you will be impressed by the quality of lectures by facilities and by our learning environment during the scientific workshop in Kuala Lumpur.

Climate change is one of the key issues of today. The Climate change and DIMS technology - CCD workshop deliberations will provide you with some knowledge and solutions to live safe with the issue. Being the most important topic of everyone's life, we are proud to hold this event in our campus at Kuala Lumpur Teaching Centre at Chulan Tower in Kuala Lumpur. It is located in about a corridor way of Royale Chulan hotel in Kuala Lumpur. We cordially invite you all to join with me in the workshop and to get benefited by the lectures, discussions and materials delivered at the workshop. It is hosted by Department of Civil Engineering, University of Nottingham Malaysia Campus located at Semenyih town in Selangor State of Malaysia. We truly acknowledge the grant support provided by Asia Pacific Network, Japan to stage this event. The programme brochure with more information and updates of the project findings are available at www.globalclimate-engine.org link. The project webpage hosts a compendium of database information and useful documents related to climate change studies. Please contact me via vramanibai@gmail.com for any further enquiry on the webpage resources. The proceedings of the CCD workshop cover three broad divisions of studies in Climate change with most important issues / topics for today. There are 15 different lectures presented and the corresponding hand out and presentation slides are compiled for the benefit of participants. We wish to thank everyone who has been involved in preparing the proceedings and played their role effectively to see its successful compilation and printing.

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Workshop Speakers:

Professor Jon French
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Professor Jon French with a PhD from the University of Cambridge holds numerous positions in University College London, namely the Vice-Dean of Research for the Faculty of Social and Historical Sciences, Deputy Head of Department of Geography and the Director for Coastal & Estuarine Research Unit. His research interests among others include earth surface processes & landform morpho-dynamics, environmental system modeling & instrumentation, coastal & estuarine flood defense management and environmental sciences.

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Biography

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The climate, climate changes and their impact on food in the 21st century

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ABSTRACT

The `environment' encompasses all external factors that influence the life and activities of people, plants and animals. In relation to food, we can consider the `physical' environment through interactions between plants and animals and meteorological factors e.g. carbon dioxide, rainfall, solar radiation and temperature. We can also consider the `social' environment whereby production systems are influenced by factors such as human behaviour, consumer choices and government policies. This paper considers how climate – a component of the physical environment - sets boundaries and limits to the current and future extent and yields of major food crops.

Whilst the *potential* consequences of changes in physical environment (`climate change') are of topical interest, the *actual* consequences of how our social environment influences our selection of species (`crop choice') for food security and nutrition raise fewer concerns. Nevertheless, recent events illustrate the importance of crop choice and how much we rely on the productivity, health and promotion of a tiny range of plant species for our food. The so-called `Green Revolution,' with its reliance on a few major crops, has become the template for agriculture throughout the world. This paper considers the wisdom of this approach for future generations and climates. It then considers the potential to use underutilised plant species that have been cultivated across variable climates for generations. In reality, climate change and crop choice are inextricably linked. A major and overlooked issue facing humanity is how climate change will influence what, where and when we can grow crops and what options we have for food crop choices of the future.

Agricultural diversity

The human population has grown from between 0.001 to 0.1 billion people at the start of agriculture to about 2.4 billion at the start of the Green Revolution and about 6.67 billion people today [1], Over this period, there has been an unprecedented decline in the diversity of crop *species* on which we depend and a corresponding decline in the diversity of cropping *systems* in which they are grown. Agricultural diversity can be considered in terms of the number of crop (or animal) species grown and the range of systems within which they are cultivated. At a global scale, there are between 300,000 and 500,000 higher plant species [2,3]. Of these, about 30,000 are edible and approximately 7000 have been cultivated or collected by humans for food. However, fewer than 20 major species now account for more than 90% of global food production. Indeed only three crops - rice wheat and maize – provide more than 60% of the plant-derived energy in the human diet [3] Apart from soybean and groundnut, legumes – the major sources of protein in poor countries – contribute less than 2.5% to the global diet.

This intensification of a few crop types has profoundly influenced the range and diversity of crop species and cropping systems in modern agriculture. In particular, it has resulted in the displacement of indigenous or `minor' species and local cropping systems by more favoured `major' species and at the same time a move towards more globally uniform systems of cultivation.

Early *agrocecosystems* were a complex mixture of annual crops, perennial species and animals. These *agri-silvo-pastoral* systems have largely given way to a separation and specialisation into animal and crop farming. Cropping systems include diverse forms such as *agroforestry* (crops interplanted within tree canopies) or mixtures of annual crops (*intercrops*) through to uniform *solecrops* (single crops stands composed of the same variety of a single species) [4]. In some cases, the same annual species, e.g. wheat, is cultivated in the same field as a *monoculture* over a number of years. Thus, we can see a trend within modern agroecosystems towards a greater reliance on uniform crops, varieties and systems that are less diverse or complex than their predecessors. Oddly, despite their reliance on sophisticated technologies, modern agroecosystems are the simplest forms of agriculture in our history. This reduction in the diversity of species and systems has inevitable but often unintended consequences on the range of natural biological diversity that exists within them.

The Green Revolution

Evolution requires the repeated interaction of multiple generations of a species with its environment. By contrast, revolution implies a rapid and sometimes traumatic change between or even within a generation. In `natural' environments, we understand evolution to be a process of `natural selection', in which components of the environment apply selection pressures on successive generations of a species. Specific genetic traits may be positively or negatively selected in response to these environmental selection pressures. When the components of the `natural' environment remain fairly uniform, `stabilizing selection' ensures that genetic traits are maintained that correspond to the optimal average of the population genome. When environmental components change, `directional selection' moves the average population genome to a new value that corresponds more closely to the new combination of environmental conditions.

In `agricultural' environments, we have at least three potential conditions that influence the stabilizing and directional selection of the natural environment. First, we can manipulate the specific environment in which a crop grows. For example we can supplement rainfall with irrigation, soil nutrients with fertilizers and/or use enclosures (glasshouses and polytunnels) to manipulate temperature, humidity and windspeed. Second, we can move crops to more favourable resource environments, either in space (e.g. to better locations, more productive soils) or in time (e.g. by changing sowing date). Third we can manipulate the crop itself. This can be through the selection and conventional breeding of *cultivars* (`cultivated varieties') with more desirable genetic traits or more recently by the introgression of specific traits into crop species. Whilst it is still too soon to assess the contribution of the latter `Gene Revolution,' it is appropriate to evaluate the contribution of its predecessor the `Green Revolution' to food production in general and food security in particular.

It can be argued that no single development in agriculture and possibly throughout human history has had more impact on humanity than the Green Revolution. Indeed, Dr Norman Borlaug, who is widely acknowledged as the `father of the Green Revolution,' was awarded the Nobel Peace Prize in 1970. The title of his oration, `The Green Revolution: Peace and Humanity,' indicates the huge significance that this paradigm shift had on global food production and the consequences for the wealth and security of some nations and the relative poverty of others. There are numerous historical records and analyses of the Green Revolution (see, for example, [5]). For our purposes, we need only refer to two characteristics of the Green Revolution that relate to agricultural diversity.

Species diversity

Whilst not its intent, the Green Revolution has resulted in our increasing interdependence on the productivity of only three species i.e. wheat, rice and maize. At the end of the Second World War, there was much sense in prioritizing these cereal crops in the race to meet the food requirements of a rapidly growing global population. Their determinate growth habit, response to inputs and ability to allocate more than half their total weight to grain, i.e. `food', made them ideal candidates for the technologies required in the Green Revolution. They also produced relatively consistent, uniform and synchronous yields of seeds that were palatable and could be easily processed into a variety of popular products. It is a measure of their success that postwar food production not only met but has actually outpaced world population growth.

System diversity

The Green Revolution is a package that combines the availability of potentially High Yielding Varieties (HYV's) of specific major crops and technologies to help them achieve their potential yield. For this, it requires mechanization to support cultivations, sowing and harvesting of crops and the application of fertilizers, herbicides, pesticides and agrochemicals. Where necessary, rainfall has to be supplemented or even replaced by irrigation.

Crucially, for Green Revolution technologies to be applicable, we need crops that are architecturally simple and uniform in space and time so that the management of operations can be planned, synchronized, mechanized and standardized. For subsequent harvesting, transport and processing, we also need seeds that have identical characteristics of size, composition, maturity and moisture content. To achieve all of the above, Green Revolution agriculture now relies on monocultures of specific cultivars of major crops. Multiple complex mixtures of many species (i.e. those that most closely resemble natural ecosystems) simply do not fit the uniform model of mechanized agriculture required by the Green Revolution. As a result, whilst they must still obey the ecophysiological principles of vegetation/environment interactions, modern agroecosystems bear little relation to temporal and spatial structures of natural ecosystems.

The environment, climate change and food production

The five principle environmental resources that govern the growth and yield of field crops are solar radiation (or `light'), atmospheric carbon dioxide (CO_2), temperature, soil moisture and atmospheric humidity. Of these, light, water and CO_2 principally determine the *amount* of growth or dry matter that crops produce and temperature sets the rate of development or *speed* at which crops complete their life cycle. At any location, the yield of each crop is set by the total availability of the principle five environmental resources and the skill of farmers in manipulating the flows of each of these resources to and through the crop. Whilst the climate sets the overall boundaries of where and when crops can be grown, it is important to remember that in any one year each crop grows in response to seasonal *weather* not long-term *climate*. In other words, it is short term changes in climate factors in the order of hours and days that determine the productivity of crops in any one season. Where short-term weather is out of phase with long-term local climate we get departures from the expected performance of each crop at any location.

Modelling climate change

Rising levels of two climate resources, CO_2 and its influence on temperature (`global warming') now attract widespread interest and concern. However, `Climate Change' encompasses perturbations in all five environmental resources. Indeed, it could be argued that the rate of change in CO_2 and temperature are the most predictable of the five resources. However, it is their coupling with changes in the global hydrological cycle and, in turn, the effects of these changes on the amount and distribution of rainfall that are least understood, most difficult to predict and potentially of greatest concern for much of the world. Where irrigation is not available, most of the variability in crop production can be explained by the variability in rainfall or more precisely by the availability of soil moisture. By extending high yielding varieties onto more vulnerable soils that are too shallow to store water, even small variations in rainfall can have disproportionate consequences on food production and security.

In many regions, farming depends entirely on the amount and distribution of rain. Even where it is now prevalent, irrigated agriculture may decline both because water will become scarcer in many regions and because the demands from domestic and non-agricultural users will grow with population. Without irrigation, any increase in the likelihood, duration or severity of droughts will increase the vulnerability of national yields to climatic variations.

We should remember that the earth's climate has varied and changed with timescales over millions of years. Throughout our farming history, short and long-term variations in climate have always affected agricultural production [(6)]. Green Revolution technologies, such as fertilisers and irrigation, crop production is variable with risks and uncertainties both to agricultural communities and to the consumers who depend on them. However, apparent departures from expected climate have stimulated scientific debate, research and, more recently, public and policy-level interests in climate `change' and its likely impacts on agricultural productivity [7, 8]. Because climate change influences local weather systems, it will affect the global distribution of crop production as well as its total productivity. Where crops are traded, regional and international supplies and markets are influenced by both the total amount of crop production and the discrepancies in crop productivity across regions.

Modelling climate change and crop production

Climate change will transform agriculture; exactly how and by how much is unclear. Our problem as scientists, modellers and decisions makers is to be able to predict with any confidence what will happen to crops in climates of the future where CO_2 and temperature will be elevated but available moisture may or may not. A logical first step is to conduct experiments on crops that are exposed to the possible permutations of future climatic variables.

The effects of temperature and water on crop growth and productivity can be studied experimentally in conventional field environments by selecting locations and sowing dates and/or by adding and sometimes excluding water. However, the interactions of temperature, water and CO_2 at the field scale cannot easily be manipulated. One option is to use Free-Air CO_2 Enrichment (FACE) systems to fumigate the air above crops with CO_2. In such systems, the specific effect of elevated CO_2 can be compared with adjacent locations where CO_2 remains at ambient concentrations. However, a drawback of FACE systems is that they cannot easily provide simultaneous control of other `climate-change factors' such as temperature, humidity and soil moisture. In addition, the accuracy with which CO_2 is distributed within FACE systems depends on windspeed and direction. To study the complex interactions between CO_2 and other environmental variables, we must retreat to controlled-environments (C-E) where each factor can be independently manipulated. However, most C-E facilities, e.g. cabinets and chambers, are only suitable for single plants growing in pots, which of course cannot be easily extrapolated to field situations. As a result, there are major discrepancies between the CO_2/yield responses reported for FACE experiments and plants grown in enclosures. For example, Ainsworth et al. [9] report mean elevated CO_2/yield increases in FACE experiments of 1.14 compared with 1.31 in enclosure studies for a range of crops. They argue that FACE experiments provide the most realistic conditions for estimating crop yield responses to elevated CO_2 because such systems better represent `real world' plot sizes that are an order of magnitude greater than chambers. Whilst FACE experiments may provide realistic simulations of atmospheric CO_2, their inability to manipulate temperature and moisture still limits their applicability in climate change studies.

Despite its critical importance, there remains no universal consensus on which experimental system is best suited to quantify climate change at the crop scale. However, irrespective of where and how collected, crop simulation models rely on data and, in the case of climate change, model parameterization and validation must depend on limited datasets. In these circumstances, the choice of experimental system is critical to the reliability of model predictions with huge implications for policies and adaptation and mitigation strategies.

The fact is that, in terms of food crops and vegetation in general, the primary evidence for the impacts of changing environmental factors on crop yields is slender. Whilst we can look back into past episodes of climate disturbance for clues as to how climate change will affect agriculture, we cannot use these experiences to predict the future. Climate drivers, such as CO_2 coupled with temperature and/or moisture and their impacts on modern cultivars and management operations take us into novel territory. It is also important to remember that changes in climate not only have complex effects on crop performance but also affect management operations such as land preparation, sowing, irrigation, pest and disease control and harvesting. A further uncertainty is how climate change will influence the prevalence and impact of crop pests, diseases and weeds.

What is to be done?

In recent decades, agriculture has focused on methods to ensure the adequate supply of food for the human population measured as tonnes of yield per hectare of land multiplied by the area of land under cultivation. This has provided us with global food security. Until recently, the very success of agriculture has removed it from the lexicon of researchers, donors, policy makers and the general public. However, even in his acceptance speech for the Nobel Peace Prize in 1970, Dr Norman Borlaug warned that `*The only crops which have been appreciably affected up to the present time are wheat, rice and maize. Yields of other important cereals, such as sorghums, millets and barley, have been only slightly affected; nor has there been any appreciable increase in yield or production of the pulse or legume crops, which are essential in the diets of cereal-consuming populations. Moreover, it must be emphasised that thus far the great increase in production has been in irrigated areas'*

Almost 40 years later, the situation is little changed; we remain preoccupied by extracting the maximum potential `yield' from a few elite species growing on irrigated soils and/or in benign climates. In their review, Evenson and Gollin ([5]) point out that for many crops, breeding work aimed at the developing world simply could not use the template of research in developed countries because there was no available elite germplasm for species such as cassava and tropical beans in the 1960's. Although they claim that, by 2000, improved varieties of eleven major species were released in over 100 countries, they recognise the important disparities between agroecological regions and species in the release and uptake of modern varieties. It is rainfed and low input agricultural systems where these disparities are most evident. Interestingly, Borlaug himself saw the Green Revolution as a `three decade breathing space' in the battle to provide sufficient food for sustenance and the `menace and magnitude of the Population Monster'. It is to his credit and that of his successors that despite regional variations, the temporary battle between global food security for human sustenance and population growth has largely been won.

We have now exceeded Borlaug's 30 year breathing space and global food security for `peace and humanity' is again on the agenda. However, the new frontier is the battle between human wellbeing and the `menace and magnitude of the Climate Change Monster'. Much of this battle will take place on marginal lands where rainfall is inadequate and irrigation unavailable for elite crops to achieve their yield potential. Whilst in the past, the amount and calorific content i.e. food energy was the priority, in the future, the nutritional and social value of food will be critical. For this, we need a new armoury of crops and cropping systems that are robust enough to cope with future climates and diverse enough to provide real dietary choices for populations.

How should food production strategies plan for the climates of the future? IPCC ([8]) gives a recent, comprehensive assessment of climate change predictions. We cannot here rehearse the various scenarios and possible permutations of future climate change impacts on food production. However, the following observations may provide some pointers.

<u>Volatility.</u> Future climates will be more volatile, with more frequent extremes of drought (with or without heat stress) and/or periods of waterlogging. Even with modern cultivars, high levels of inputs and management, crop yields will vary more than at present between sites and seasons. Food production will increasingly depend on crop species and cultivars that are `climate-proofed' i.e. resilient to extreme events both between and within the same season.

We now need to identify crops that can withstand periods of cold *and* heat stress and still provide a viable yield in most circumstances. Selection for yield *potential*, for so long the stock-in-trade of plant breeders, will have to be complemented by breeding for yield *stability* across volatile and variable environments.

Vulnerability. The impacts of climate change will be greatest in those regions least able to adapt. Those regions who have contributed least to climate change, the semi-arid and arid tropics, the developing tropics in general and Africa in particular, will suffer most. Not only will climate change have a disproportionate effect on tropical ecosystems but also poor farmers in the tropics – 30% of whom are food insecure - will be less able to cope with it [(10)]. Lobell et. al [(11)] predict that these undernourished communities will be doubly penalized by decreased local yields and a global increase in commodity prices of the main staples i.e. maize, rice and wheat. In fact, whilst these three species provide about half of the calories consumed by the worlds poor, they contribute only 31% of the calories consumed in sub-Saharan Africa. [(11)].

We now need to reconsider the species and products that contribute to more than two thirds of the sub-Saharan diet. It is these underutilised and local species that have survived in the most hostile environments without the support or advocacy of advisors and policy makers. It seems reasonable that these species and the indigenous knowledge of the communities who have protected them for so long should guide future research strategies. More importantly, we need to find out what it is about these species that has contributed to their survival and identify where else they can be grown beyond their current cultivation.

Uncertainty. CO_2 elevation is evident for all climate change scenarios and, in terms of agriculture, adaptation rather than mitigation is the priority. However, to exactly what set of conditions does agriculture have to adapt? The full range of anticipated temperature change is between +1.1 and +6.4 C [(8)]. Temperature rise is therefore already locked into future climates but by how much depends on location and future human activities. However, the biggest uncertainties are the links between CO_2, temperature and the global hydrological cycle.

Future agriculturalists will have to contend with uncertain soil moisture available from rainfall and uncertain evaporative demand through air humidity and temperature. It is these uncertainties that make rainfed agriculture even more precarious. Again, we need to consider nutritious non-cereal crops as part of future strategies. For example, Tingem *et. al.*, [(12)] present estimates of climate change on crop production in Cameroon for various scenarios. For maize and sorghum (C4 species), yields are expected to decrease by between 14 and 40% respectively across the whole country under various scenarios. In contrast, the yields of leguminous (C3) crops such as bambara groundnut (*Vigna subterranea*), groundnut (*Arachis hypogaea*) and soybean (*Glycine max*) demonstrated increases in yield under all climate change scenarios. Enhanced crop yields were explained by projected increases in CO_2 concentrations, whilst lower yields were explained by a shortened growing season ranging from 2 to 29 days as a result of temperature elevation. In this case, the effect of temperature was much greater than that of rainfall which ranged between about 800 and 3000mm per year [(12)] across the country.

We can't keep eating like this

The reduction of agriculture to a small cohort of elite varieties of major crops grown as monocultures has been justified on the grounds that for much of the world it has ensured the availability of adequate and cheap food. A diverse and ecologically sustainable food system has been subordinated to the pressure to produce enough food for a rapidly growing population. However, in many cases, an over reliance on major species is simply the result of lazy science and technology and unimaginative sponsorship. It is always easier to construct and justify a research project or a `new' product from a familiar species than to propose work on a crop of unknown potential. However, good science needs to continuously question the *status quo*. In the case of food in the 21st century, we need to reconsider the vast repository of underutilised and potentially valuable food crops that have survived despite rather than because of science and technology.

The many good reasons for diversifying agricultural and food systems for the future include;

Evolution. The profound changes in our choice of crops since the advent of agriculture and the composition of our diet since the Industrial Revolution have occurred on an evolutionary timescale that is simply too short for the human genome to adapt to. Our genome for virtually all human history has been `wired' to a diverse and varied diet and it is hubris to assume that we can ignore our evolutionary past and find yet more ways to repackage the same ingredients.

Energy. The sudden crises in the availability of cheap food and fuel illustrate the risks inherent in relying on the globalisation of so few species for so many people. Fossil fuel underpins industrial agriculture and food production whether it is in the manufacturing and use of fertilizers, the cultivation of crops or in the processing and movement of food products. It is reasonable to assume that food and fossil fuel will never be cheap again. Again diversification, the sourcing of local foods and the development of low cost processing technologies all need to be part of our future strategy.

Environment. We have seen that the environments of the future will be increasingly volatile, variable and, in many cases, vulnerable in terms of food production. There are risks in relying on only the crops that feed most of us now. We need a `Plan B' that includes a range of crops and cropping systems that are robust enough to cope with unpredictable environments. In these cases, we need to reconsider not just which crops to grow but in what combinations to grow them. Complex cropping systems such as agroforestry and intercrops have been rejected or marginalised in recent years because they are ill-suited to mechanisation. It is certainly more difficult to sow, manage and harvest a combination of species each with its own requirements, susceptibilities and duration than a uniform population of near identical individuals. In recent years, the economic or mechanical advantages of monocultures have justified their domination over intercrops. However, in our evolutionary history, sole crops composed of a single cultivar are very much the exception rather than the rule in terms of farming systems. Complex cropping systems are not just a quirk of evolution. They are inherently more stable and resilient in variable environments than monocultures. There is also evidence that they are biologically more productive than sole crops [(4)]. This can be explained by the patterns of resource capture and use by component species that overlap so that demands for limiting resources, such as water, are better distributed in space and time. In this way, overall system performance across species is optimized at the expense of the maximum performance of any one species. Whilst this may not suit the imperative to secure maximum yields from specific crops, it does better match the objectives of food security where there is at least some yield every year across a range of species.

In fact, the *relative* advantages of multiple systems tend to become greater than sole crops where the environment is increasingly hostile or variable. Of course, the difficulties of mechanisation still mean that the (current) economic or social penalties (e.g. high labour requirements) of intercropping may still outweigh their biological advantages. Rather than reject them out of hand, we need innovative and imaginative ways to reconstruct multiple combinations of species e.g. blends and mosaics of genotypes in forms that are manageable whilst retaining their inherent stability.

Crops of the future

If we accept the need to expand our future basket of crop species, the question remains `which presently underutilised crops are best suited to become `crops of the future'? Whether there should be a comprehensive (inclusive) or a definitive (exclusive) list of priority underutilised crops for different environments is a subject of much debate (see, for example, http://www.dgroups.org/groups/cta/Underutilisedplants2008/index.cfm). In terms of climate change adaptation, there is no consensus on which crops are best suited to particular scenarios. Of course, as the combinations of climate change factors are themselves uncertain, it is already difficult to specify exactly which *major* let alone *minor* crops are suitable for specific locations. Under*utilised* crops are under *researched* crops and therefore their potential has not been fully evaluated even for present climates. However, we can at least consider which *approach* is most appropriate to assess the potential of candidate underutilised species. In other words, what do we really need to know about any particular crop that will allow us to rapidly evaluate whether it would be a suitable option for a specific set of environmental and management conditions and end-uses?

Unfortunately, there are few examples of integrated research on any single underutilised crop. Therefore, no generally accepted framework yet exists for assessing a whole range of potential crops of the future**.** One attempt to develop such a comprehensive approach involves a multidisciplinary and multinational programme on bambara groundnut (*Vigna subterranea*). Further details of this research approach appear in [(13)].

In 2002, a mechanistic simulation model of bambara groundnut was linked with GIS and a weather generator to produce the first globally mapped predictions of bambara groundnut on 50 x 50 km scale. The map [(14)] predicted yield potential in America, Australia, Europe and Asia as well as Africa. When the model was fitted against temperature, rainfall and daylength, agro-ecological environments for bambara groundnut were predicted where biomass could exceed that in its current centres of cultivation. Much of the Indian sub-continent was assessed as `suitable' or `moderately suitable' for production and, crucially, marginal areas in the semi-arid tropics were found to be suitable for existing (unimproved) landraces. It is important to mention that the modelling and mapping exercise are predictions rather than validations and they do not include any climate change scenarios. However, this approach illustrates that there is significant potential for an underutilised crop such as bambara groundnut far beyond its current cultivation. It also demonstrates that a combined research effort on a range of promising species linked with a modelling and mapping approach could be used to identify and match a range of suitable crops for changing climates and particularly marginal climates of the future.

Conclusions

In terms of food production and human nutrition, we need to recognise that;

1) Climate change is a reality and we will *all* need to adapt to climates that will be different and more volatile in the future.
2) `*Business as usual'* is not an option because persevering with a limited range of major species as monocultures is simply too risky for food security and development.
3) For future food production systems, we need to evaluate a wide range of underutilised species that have been cultivated and used without significant research effort. Where specific crops show real promise for a range of uses, we need to improve their genotypes and management practices.
4) We need `*a paradigm shift'* from conventional reductive approaches to one that combines local knowledge, qualitative and quantitative techniques and novel technologies such as molecular characterization, modelling and mapping tools.
5) As researchers we need to agree a common, transparent method by which promising species can be evaluated, compared and promoted as real options for agricultural diversification in the future.

REFERENCES

1. US Census Bureau (2008). available at http://www.census.gov/main/www/popclock.html

2. Wilson, E.O. (1999). The diversity of life. W.W. Norton, New York, London, 413pp.

3. Collins, W.W. and G. C. Hawtin. 1999. Conserving and Using Crop Plant Biodiversity in Agroecosystems. Pp. 267-281 in Biodiversity in Agroecosystems (W.W. Collins and C.O. Qualset, eds). CRC Press, Boca Raton, Washington.

4. Azam-Ali, S.N. (2003). Multicropping. *Enc App Pl Sci* pp 978-984. Elsevier Ltd.

5. Evenson, R.E. and Gollin, D. (2003). Assessing the impact of the green revolution, 1960 to 2000. *Sci* **2**, 300, no. 5620 pp 758-762.

6. Alexandrov, V. A. and Hoogenboom G. (2000) The impact of climate variability and change on crop yield in Bulgaria. *Ag For Met*, 104, 315-327.

7. IPCC (1996) Climate Change. In Houghton, J. T., Meira Flho, L. G., Callander, B. A., Harris, N., Kattenberg, A. and Maskell, K. (Eds.) The Science of Climate Change. Cambridge, MA, Cambridge University Press.

8. IPCC (2007). IPCC Fourth Assessment Reports: Working group I report "The physical science basis". Available online at http://www.ipcc.ch.

9. Ainsworth, E.A., Davey, P.A., Bernacchi, C.J., Dermody, O.C., Heaton, E.A., Moore, D.J., Morgan, P.B., Naidu, S.L., Yoo Ra, H.S., Zhu, X.J., Curtis, P.S., Long, S.P. (2002). A meta-analysis of elevated [CO_2] effects on soybean (*Glycine max*) physiology, growth and yield. *Glob Change Biol*, Vol **8**, 8, pp 695-709.

10. Brown, M.E. and Funk, C.C. (2008). Food security under climate change. *Sci* **1,** 319, no 5863, pp 580-581.

11. Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P., and Naylor, R.L. (2008). Prioritizing climate change adaptation needs for food security in 2030. *Sci* **1**, 319 no. 5863, pp 607-610.

12. Tingem, M., Rivington, M., Bellocchi, G., Azam-Ali, S.N. and Colls, J. (2008). Effect of climate change on crop production in Cameroon. *Clim Res* **36**, 65-77.

13. Azam-Ali, S.N. Sesay, A. Karikari, S., Massawe, F.J., Aguilar-Manjarrez, J., Bannayan, M. and Hampson, K.J. (2001a). Assessing the potential of an underutilised crop – a case study using bambara groundnut. *Exp Agric*, **37**, 433-472.

14. Azam-Ali, S.N., Aquilar-Manjarrez, P. and Bannayan, M. (2001b). A Global Mapping System for Bambara Groundnut, FAO Monograph. 56pp (FAO, Rome). http://www.fao.org/DOCREP/003/Y0494E/Y0494E00.HTM

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System approaches to understand meso-scale coastal responses to climate change

Jon French
Coastal & Estuarine Research Unit
Environmental Modelling Group

Earth System Science .. a global perspective

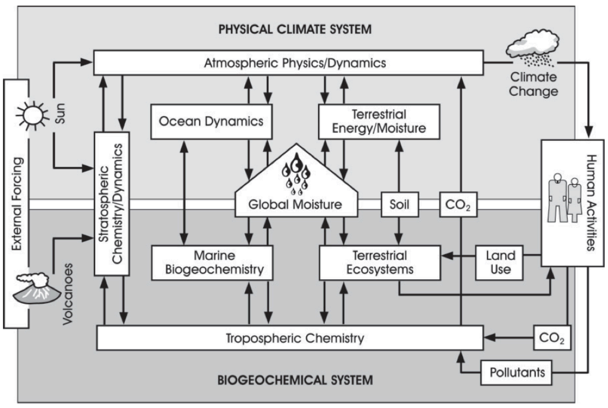
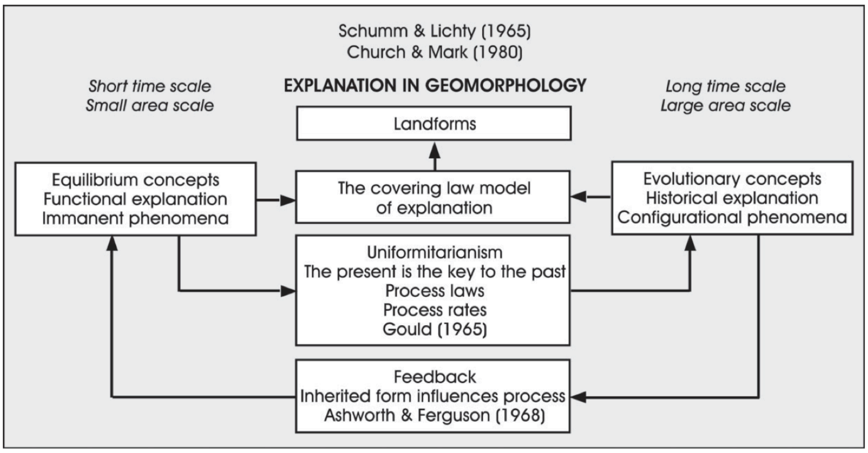


Figure 1. Schematic diagram of the Earth system and its interactions, encompassing the physical climate system, biogeochemical cycles, external forcing and the effects of human activities (adapted from Earth System Science: Overview, NASA). (Source: http://terra.nasa.gov/Brochure/images/physical_climate.gif.)

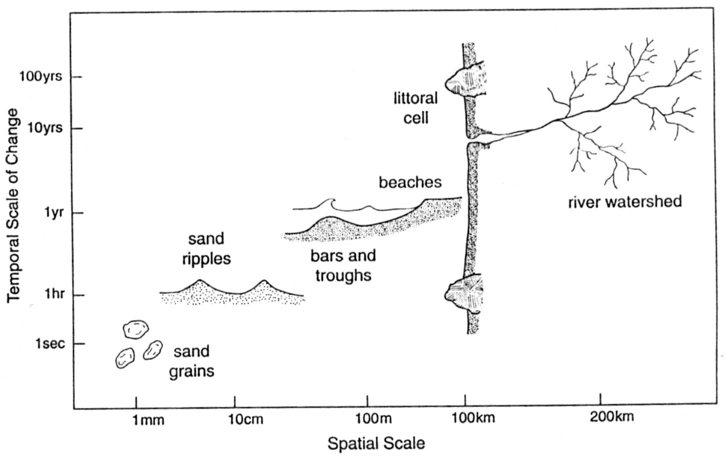
Richards and Clifford (2008)

Geomorphic systems are defined not only by short-term process-form interaction but also by their history



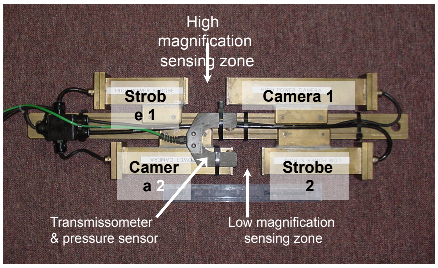
Richards and Clifford (2008)

Spatial and temporal scales of catchment - coastal system behaviour (Komar, 1999)

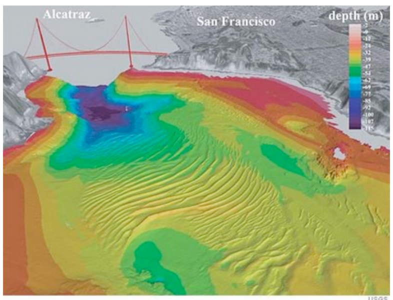


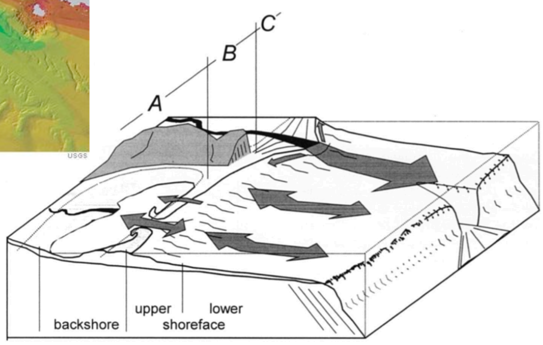
Physical processes – micro-scale

- Fluid dynamics
- Sediment transport
- Sediment – water interface
- Specialist instrumentation



Geological timescales

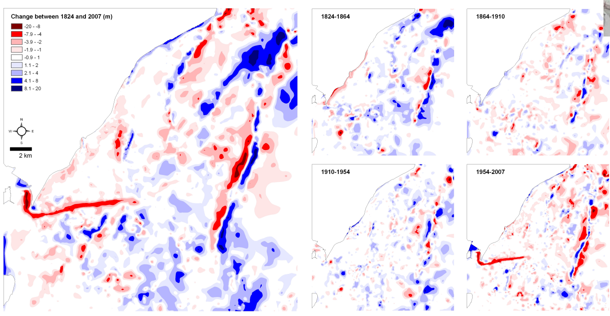




Coastal tract, from Cowell et al. (2003)

Historical scales

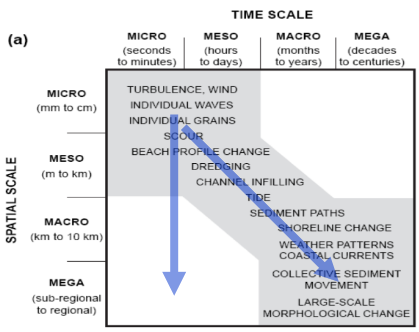
- GIS analysis of maps, charts, imagery
- Scales: from estuary to coastal shelf



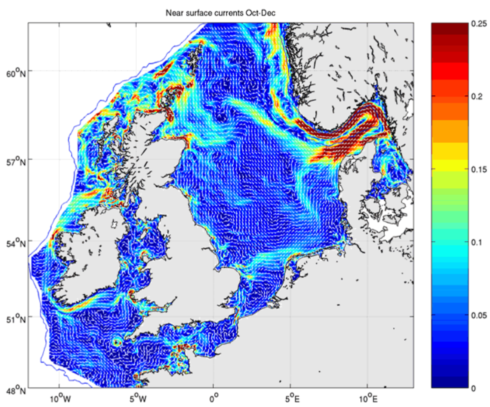
Burningham and French (2009)

7

Challenge of large-scale coastal modelling

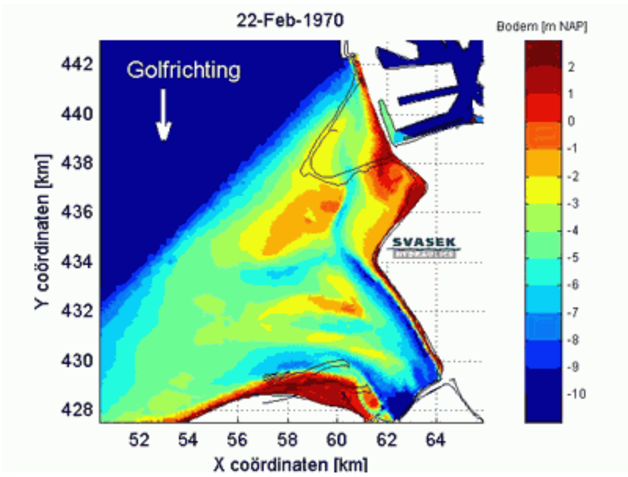


Kraus et al 1991
Coastal Sediments 91, ASCE



POLCOMMS
www.pol.ac.uk

Morphodynamic model of Haringvliet estuary, SW Netherlands

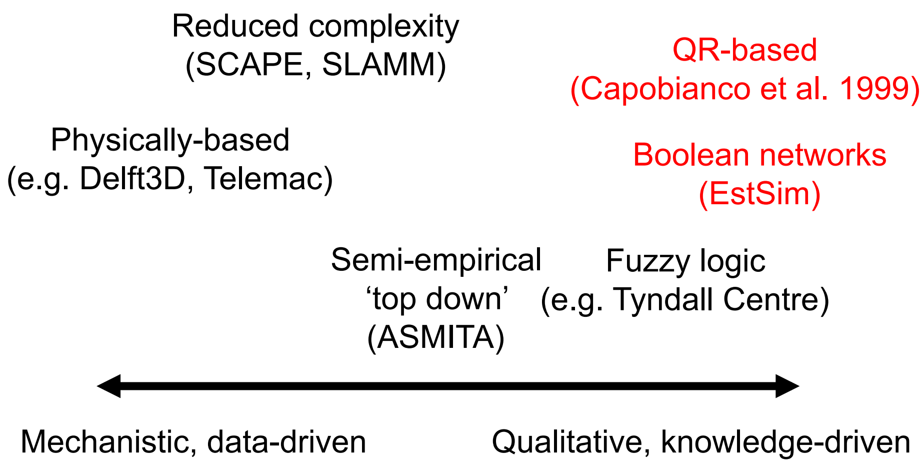


2D flow model
↕
SWAN wave model
↕
MORFIN sediment transport model

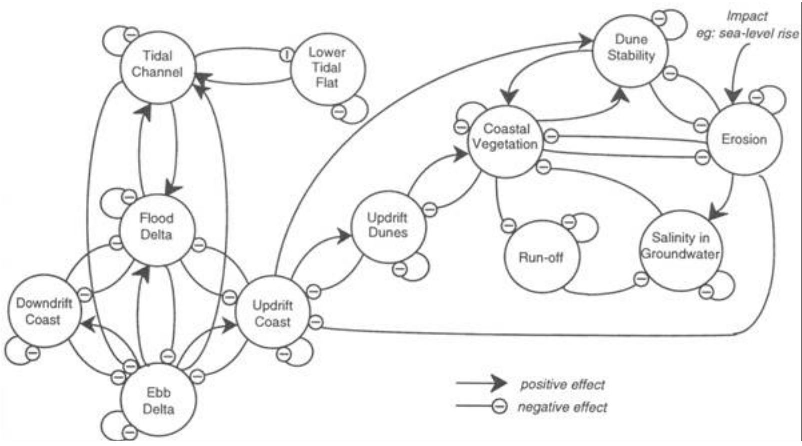
SVASEK HYDRAULICS

www.svasek.nl

Spectrum of approaches to modelling coastal change



Qualitative model of impact of sea-level rise on a generic tidal inlet (Capobianco *et al.*, 1999). Inter-linkages represented as directed influences (a 'signed graph').



Potential of qualitative systems-based approach

- other approaches unsuited to modelling of complex systems for which functional relationships between morphological components and driving processes cannot be mathematically specified in physically realistic way
- a qualitative approach offers an alternative basis for modelling system behaviour at scales relevant to estuary management ('engineering scale' of Cowell & Thom, 1994; 'meso-scale' of Townend ,2003)
- formal systems-based approach to conceptualisation, supported by technical vocabulary of **general systems theory** (von Bertalanffy, 1968; Bennett and Chorley, 1978), advocated by Townend (2003)
- potential of **qualitative models** as a basis for **indicative rather than quantitative insights** into system behaviour has been highlighted by Capobianco *et al.* (1999).

Potential to develop a qualitative model

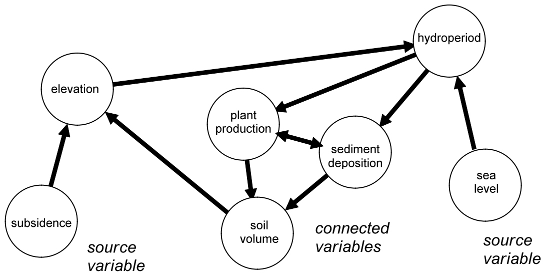
Hayle estuary, Cornwall

- Can we find a way to represent whole system behaviour mathematically?
- Can we obtain qualitative or indicative predictions of system behaviour?

Qualitative system modelling (after Capobianco *et al.*, 1999)

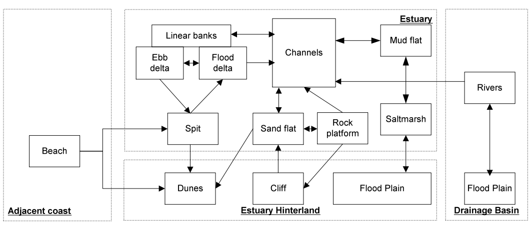
- identification of qualitative variables and causal linkages between them typically involves **system diagram**
- transfer rules and **knowledge formalisation** convert quantitative understanding (e.g. empirical relationships) or linguistic understanding (e.g. behavioural statement) of system linkages into a set of cause-effect relations
- employment of **mathematical analyses** that treat the **system as an interconnected network** (graph) to predict the direction of change in state of any/all of the variables in response to a change

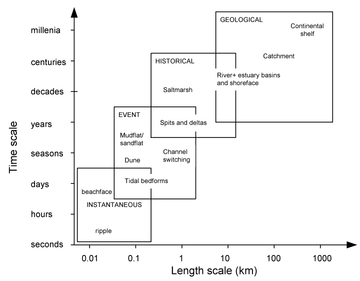
Minimal network representation of saltmarsh



Includes **source variables** (that influence the network dynamics but are not influenced by the network) and **connected variables** (that both influence and are influenced by network dynamics).

Qualitative behavioural model requires transition from system description to mathematical formulation of functional interactions in a way that is consistent with level of abstraction





Defra ESTSIM project (FD2117; 2006-2007)

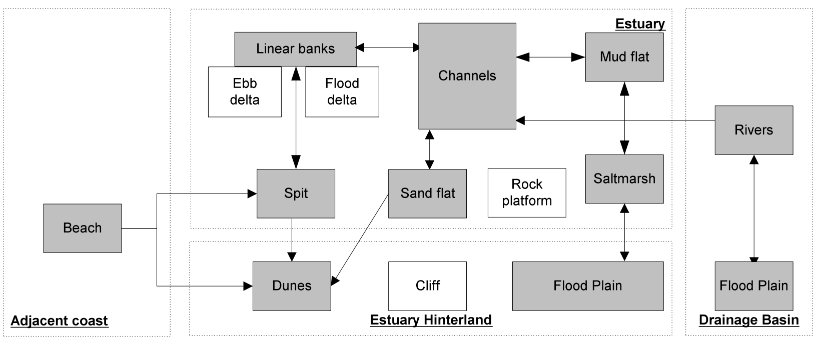
Generic estuary system at meso-scale level of abstraction

Defra ESTSIM project identified 7 generic estuary types for all 163 UK estuaries

Differ in terms of external forcing and morphological features

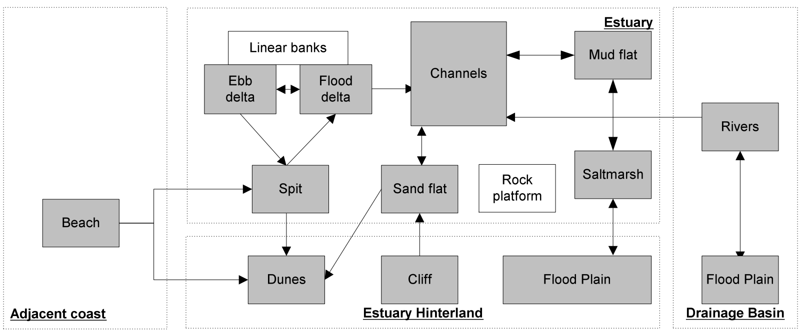
- **Fjord** – imposed cliffs and rock platforms
- **Fjard** – as fjord, but with external sediment supply
- **Ria** – imposed cliffs and bathymetry
- **Spit-enclosed** – sediment rich, with longshore wave power
- **Funnel-shaped** – sediment rich, no longshore wave power
- **Embayment** – low fluvial influence, wave action significant
- **Tidal inlet** – no river input, partly infilled with tidal deltas

Generic funnel-shaped estuary-coast system



Funnel-shaped estuary: The Ribble, northwest England

Generic spit-enclosed estuary-coast system

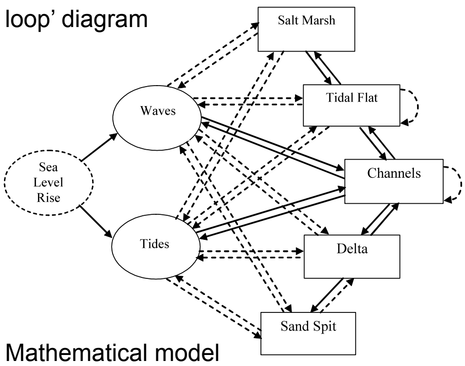


Spit-enclosed estuary: Teign, southern England

Boolean network behavioural system model

Reeve and Karunarathna (2008)

Influence or 'causal loop' diagram



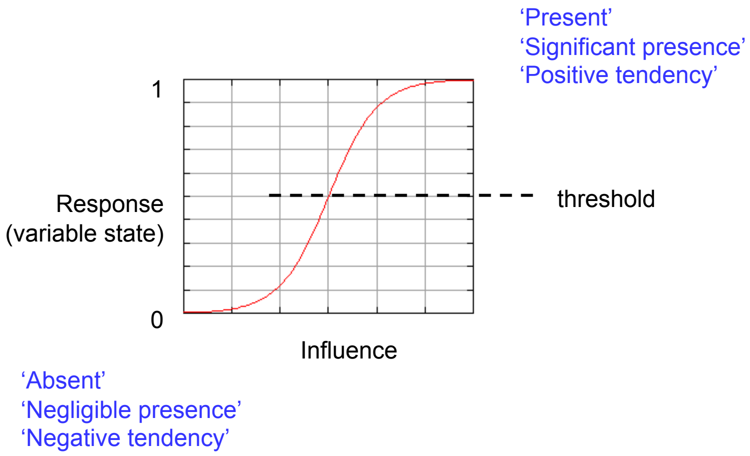
Mathematical model

- Binary representation
- Synchronous updating
- Suited to system for which consistent physically-based functional interactions not available

Tidal flat TF = ((sm | cc) & t) | (~tf & ~w)

~ = NOT | = OR & = AND

Boolean variables



Boolean (logical) operators

INPUT		OUTPUT
A	B	A **AND** B
0	0	0
0	1	0
1	0	0
1	1	1

INPUT		OUTPUT
A	B	A **OR** B
0	0	0
0	1	1
1	0	1
1	1	1

INPUT	OUTPUT
A	**NOT** A
0	1
1	0

Truth tables for AND, OR, NOT

How do we run this model?

- Identify variables and define functions
- Specify initial states (0, 1 or ‘off’, ‘on’)
- Compute all functions and reset variables to value given by function
- Repeat until
  - No change (steady state)
  - Repeating cycle (oscillatory state)

Logical framework and truth table

W = tf ′

T = tf '

S = tf + w + t

TF = ~w & s | t

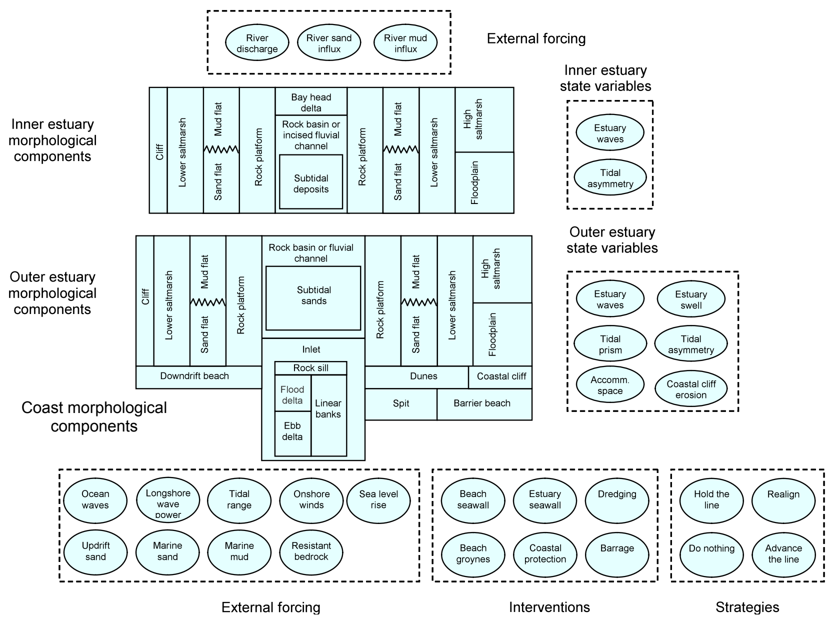
Boolean variable	Boolean function
w (waves)	W
t (tides)	T
s (sediment)	S
tf (tidal flat)	TF

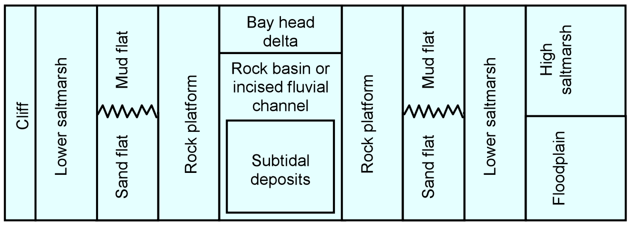
	w	t	s	tf	W	T	S	TF
1	0	0	0	0	1	1	0	1
2	1	0	0	0	1	1	1	0
3	0	1	0	0	1	1	1	1
4	1	1	0	0	1	1	1	0
5	0	0	1	0	1	1	0	1
6	1	0	1	0	1	1	1	0
7	0	1	1	0	1	1	1	1
8	1	1	1	0	1	1	1	1
9	0	0	0	1	0	0	1	1
10	1	0	0	1	0	0	1	0
11	0	1	0	1	0	0	1	1
12	1	1	0	1	0	0	1	0
13	0	0	1	1	0	0	1	1
14	1	0	1	1	0	0	1	0
15	0	1	1	1	0	0	1	1
16	1	1	1	1	0	0	1	1

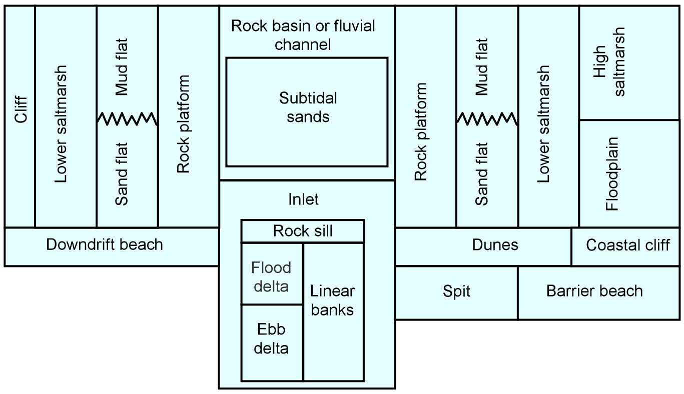
Development of Boolean approach: variable set

- External (imposed) forcing [8+ variables]
  - waves, longshore wave power, wind regime
  - sediment supply (mud, sand)
  - sea-level rise and/or anthropogenic influences
- Process state variables [8+ variables]
  - outer and inner estuary waves and tidal prism
  - residual transport / tidal asymmetry
- Morphological components [25+ variables]
  - beach, dune, spit, deltas (etc.) of outer estuary
  - outer and inner estuary intertidal / subtidal sedimentary units
  - inherited features (cliffs, rock platforms, rock sills)

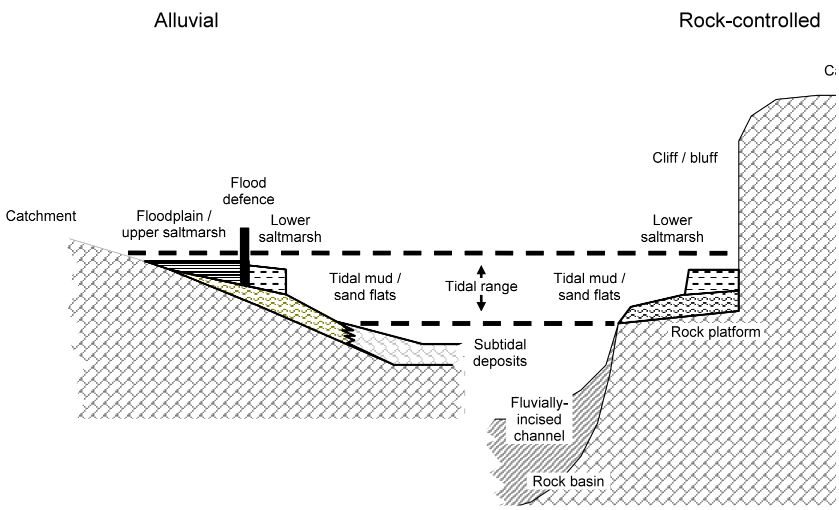
EstSim variable set





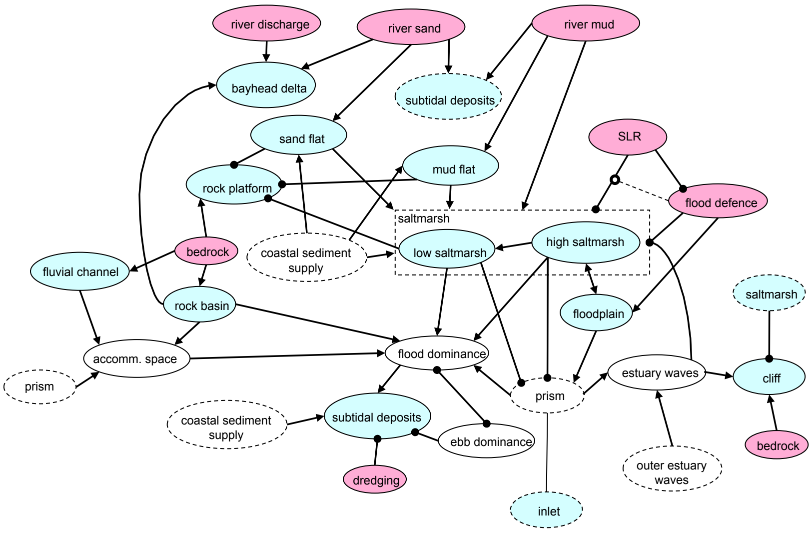


EstSim stratigraphic framework



Inspired by Dalrymple *et al.* (1992) estuarine facies model: outer and inner estuary wave and tide-dominated respectively

Influence diagram, inner estuary



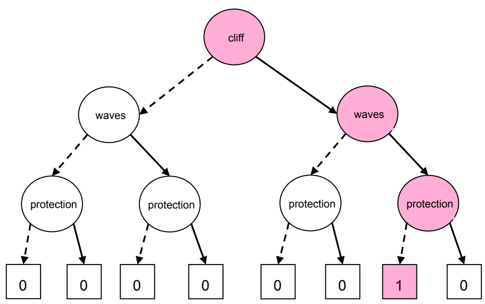
Knowledge formalisation: simple example of coastal cliff erosion

Qualitative reasoning

Coastal cliff erosion requires presence of both cliff and significant wave action but erosion ceases with cliff toe protection

Boolean function

CLIFF_EROSION = cliff AND waves AND (NOT protection)

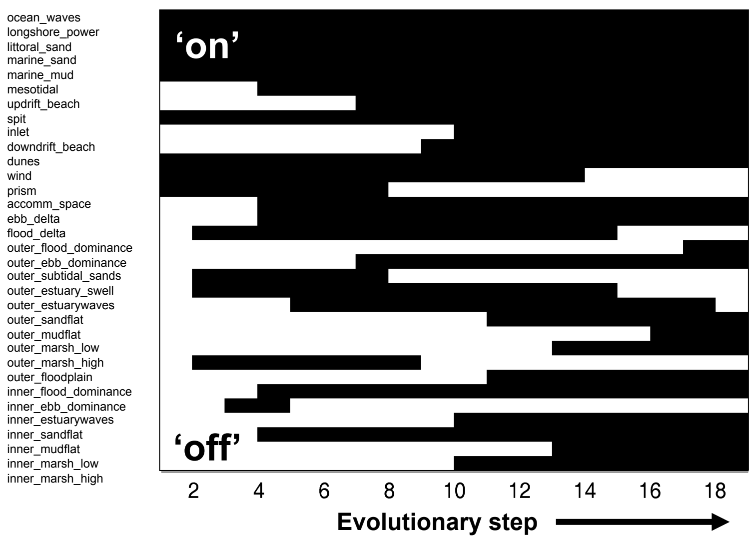


Decision tree

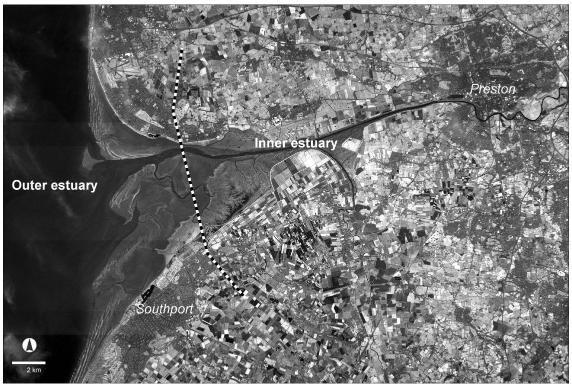
Time evolution of morphology

- Variable states updated synchronously
  - Fixed ‘timestep’
  - No absolute timescale assigned
- Morphological response lags process forcing
  - Process must be sustained to effect change
  - ‘Rapid’ elements (e.g. beach)
  - ‘Slow’ elements (e.g. saltmarsh)
- Endpoints (equilibria) easier to interpret than intermediate steps

Example: evolution of tidal inlet



Results: Ribble Estuary case study



- Type 5 Funnel-shape
- Moderate onshore wave energy
- Large marine sediment supply
- Modelled with no major river inputs

1840 – 1904	1904 – 1951	1951 – 1994	1994 –
Reclamation	Dredging & training	Dredging	Dredging ceased
Outer estuary infilling	Outer sand flats	Inner flats & marshes	Marshes, silting

Ribble Estuary case study

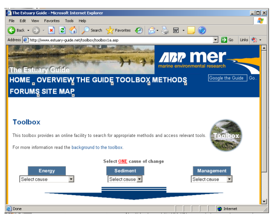
- 1840 state modelled well (estuary infills to classic funnel-shaped steady state equilibrium in 6 steps from minimal initial configuration)
- 1904 – 1951 epoch sees estuary deepen through dredging, but return of saltmarsh is effectively instantaneous given that model has no rate terms
- 1951 – 1994 epoch thus subsumed in preceding one
- Post-1994, cessation of dredging causes infilling of subtidal channel
- Climate change: SLR – removes inner estuary marsh (‘coastal squeeze’)
- Wave climate change: addition of LWP – transition to spit enclosed estuary
- Overall: captures generic behaviour of this kind of system well enough (including outer and inner estuary contrasts and major perturbations), but progressive time-evolution not reproduced in detail

How can we use this model?

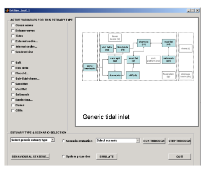
- Generic estuary-coast system behaviour
  - Fjords, Fjards, Ria, Spit-enclosed, Funnel-shaped, Embayment, Tidal inlets (FD2117 UK classification)
  - Can we predict equilibrium morphology from forcing / constraints? … yes
- Case studies and scenarios
  - Can we replicate historic behaviour (e.g. Ribble, Southampton Water)? … broadly, yes (see also Reeve and Karunarathna, 2008)
  - Can we predict indicative responses to climate and human-induced change? … in general terms yes, but generic templates require customisation for real case studies

Estuary behavioural system simulator implementation: alternative software architectures

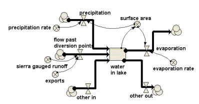
1. Web-based simulator / decision support system
   - Brower interface to generic system diagrams, behavioural statements and UK estuary classification
   - Pre-computed evolutionary trajectories for given management Qs
   - Worked historical case studies to demonstrate robustness



2. Web-based simulator with server-side computation
   - Added support for user-specific scenarios including customisation of system diagrams to suit specific estuaries and management Qs

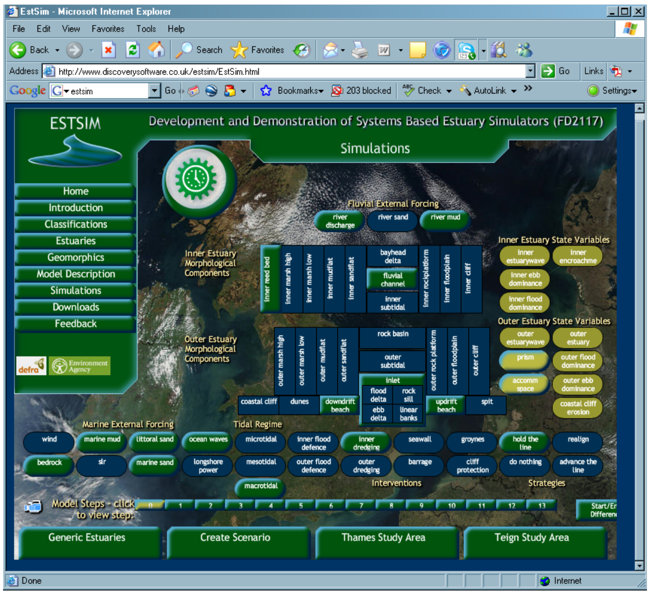


3. Standalone estuary simulator
   - Pre-compiled simulator tool with GUI
   - Pre-defined generic types & scenarios but customisable
   - May have more advanced visualisation (cf *FloodRanger*)

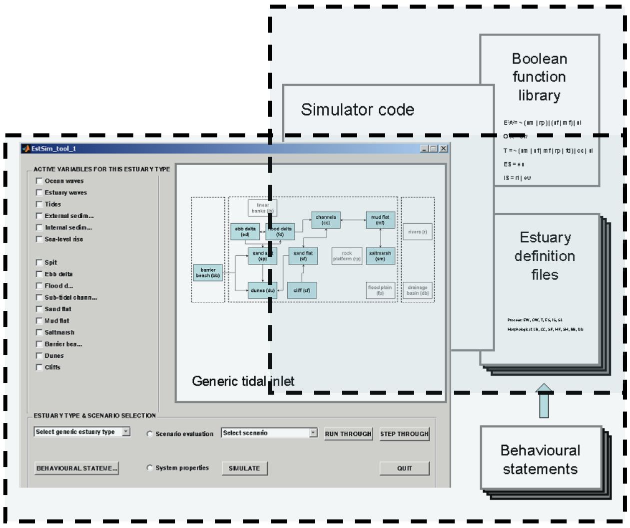


4. Semi-standalone estuary simulator
   - Pre-defined models in proprietary format (*Simile*, *Extend*..)
   - Could make use of free-ware viewer / runtime version

www.discoverysoftware.co.uk/estsim/EstSim.html



Research version: www.geog.ucl.ac.uk/ceru/estsim



- Functions are generic
- Each estuary type or case study has set of components
- Generic types have linked behavioural statement

Summary

- Systems framework can provide a basis for qualitative models formulated at scales relevant to coastal and estuary management
- Network models suited to complex systems for which functional relationships between morphological components and driving processes cannot be specified in physically realistic way
- Boolean approach is computationally simple and fast to execute
- Our prototype architecture is infinitely customisable without any re-coding of solver … "I don't like the geomorphological rules!" … easy to customise and evaluate alternative views
- No explicit timescale … could explore more complete Boolean delay equation model (non-synchronous; specified timescales)
- Binary representation restrictive … other mathematical formulations possible and could use same basic simulator architecture

Acknowledgements

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- Project website:

  www.discoverysoftware.co.uk/estsim/EstSim.html

  www.geog.ucl.ac.uk/ceru/estsim

DATABASE AND INFORMATION MANAGEMENT SYSTEM - DIMS DOCUMENTATION

Submitted by:

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INTRODUCTION

Climate change might effect mean sea level, tidal characteristics, ocean currents, storm surge probability, as well as sea surface temperature and salinity. The overall objective of this study is to collect publicly available sources of data suitable for analyze of past trends and variability of sea level and other relevant ocean parameters in Singapore region and adjacent coasts of Malaysia. IPCC Fourth Assessment Report findings are critically analyzed with respect to the region of interest. Assessment of the data availability includes expert analysis of the sources of sea level data and wind wave products for the further derivation of the regional climate projections for the area.

Latest measurements indicate that the climate is changing, the Earth's surface is warming up over both oceans and land, and there is now a strong scientific consensus that the processes are likely human-induced. With global warming on the increase and the abundance of species and their habitats on the decrease, the chances for ecosystems to adapt naturally are diminishing. Many are agreed that climate change may be one of the greatest threats facing the planet and is the hottest issue of the modern world. Recent years show increasing temperatures in various regions, and/or increasing extremities in weather patterns.

For the detection of the global warming in the ocean, the most important oceanic parameters recommended by the Intergovernmental Oceanographic Commission (IOC, 1994) and explored in the IPCC (2007) are Mean Sea Level (MSL), Sea Surface Temperature (SST), and Salinity (SSS), ocean wind waves, surface velocity fields and sea ice coverage. The detailed study of the behavior of the above parameters is the essential part of global warming research.

The most important direct physical effects of a climate change and significant rise in mean sea level are coastal erosion, shoreline inundation owing to higher normal tide levels plus increased temporary surge levels during storms, and saltwater intrusion primarily into estuaries and groundwater aquifers. However, the relations between the mean sea level rise coastal Bio-physical system need to be analyzed quantitatively through visual representations, which will result in useful information for planning. The potential impacts of sea level rise are site-specific, depending on the coastal and socio-economic characteristics. Over the last decade, research has greatly increased into the use of information technology especially on GIS in a variety of applications including climate change studies. Thus, enabling the extraction of data for specific locations or time periods as well as facilitating data export for spatio-temporal modeling of processes and events. The present study aims to develop a web based database a content management system and spatial information system on coastal systems for Asia to study the impact of climate change and sea level rise impact on the coastal ecosystems.

DATABASE AND INFORMATION SYSTEM – CONTENT MANAGEMENT SYSTEM

1.0 Introduction

The Database and information system http://www.globalclimate-engine.org uses the open source content management system JOOMLA. A Content Management System - CMS is a tool that enables users to create, edit, manage and finally publish a variety of content such as text, graphics, video, documents etc, whilst being constrained by a centralized set of rules, process and workflows that ensure coherent, validated electronic content. This document detailed out the technical and functional characteristics of each module and also it is linked with database schema.

- Hardware
- Software
- System Architecture
- Application Architecture
- Database Design and Schema
- Workflow Management
- Search Engine
- GIS

2.0 Hardware

VMWARE CPU Intel(R) Xeon(R) CPU E5335 @ 2.00GHz
VMWARE Memory 1024Mb

Filesystem	Size	Used	Avail	Use%	Mounted on
/dev/sda2	3.9G	3.2G	571M	85%	/
/dev/sda5	49G	2.0G	44G	5%	/storage
/dev/sda1	122M	24M	92M	21%	/boot
Tmpfs	502M	0	502M	0%	/dev/shm

The http://www.globalclimate-engine.org website is located at /storage/www folder.

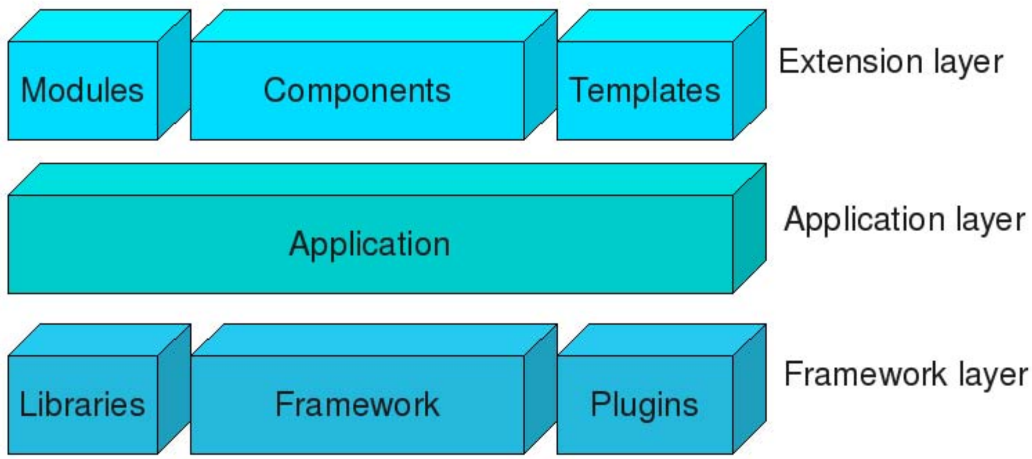
3.0 Software

The JOOMLA CMS has been developed using the following software components:

Technologies / Software	PHP 5.1.6
	JOOMLA Content Management System
IDE	Dreamweaver
Web Server	Apache 2.2.3
Database Server	MySQL Ver 14.12 Distrib 5.0.77

4.0 System Architecture

A JOOMLA framework is a reusable design for a software system (or subsystem). This is expressed as a set of abstract classes and the way their instances collaborate for a specific type of software. Software frameworks can be object-oriented designs. Although designs don't have to be implemented in an object-oriented language, they usually are. A software framework may include support programs, code libraries, a scripting language, or other software to help develop and glue together the different components of a software project. Joomla 1.5 Block Diagram is shown below with the its three tiered system.



The top, Extensions layer, consists of Extensions to the Joomla Framework and its applications:

- Modules
- Components
- Templates

The middle, Application layer, consists of applications that extend the Framework JApplication class. Currently there are four applications included in the Joomla distribution:-

- JInstallation is responsible for installing Joomla on a web server and is deleted after the installation procedure has been completed.
- JAdministrator is responsible for the back-end Administrator.
- JSite is responsible for the front-end of the website.
- XML-RPC supports remote administration of the Joomla website.

The bottom, Framework layer, consists of:-

- the Joomla Framework itself, whose classes are listed below.
- Libraries that are required by the Framework or are installed for use by third-party developers.
- Plugins extend the functionality available in the Framework.

MySQL:

JOOMLA database is created using open source RDBMS(Relational Database Management System) called MySQL. The version used for this development is V5.077. MySQL supports several storage engines that act as handlers for different table types. MySQL storage engines include both those that handle transaction-safe tables and those that handle nontransaction-safe tables. The default MySQL storage engine and the one that is used the most in Web, data warehousing, and other application environments. MyISAM is supported in all MySQL configurations, and is the default storage engine unless you have configured MySQL to use a different one by default.

Apache Webserver:

The Apache webserver is used in APACHE V2.2.3. JOOMLA CMS are deployed in Apache Server Environment. The Apache HTTP Server Project is a collaborative software development effort aimed at creating a robust, commercial-grade, featureful, and freely-available source code implementation of an HTTP (Web) server. Apache is primarily used to serve both static content and dynamic Web pages on the World Wide Web. Many web applications are designed expecting the environment and features that Apache provides.

4.1 Content Management System:

JOOMLA have chosen by the University Of Nottingham Malaysia technical personnel over other CMS available in the market.

"A Content Management System (CMS) - JOOMLA is a tool that enables many features even for non technical staff to create, edit, manage and finally publish a variety of content such as text, graphics, video, documents etc, whilst being constrained by a centralized set of rules, process and workflows that ensure coherent, validated electronic content."

Joomla is known for scalability, or ease of growing a Web site from a small set of users to an enterprise level. The framework also has the ability to 'throttle' areas of the site that could cause potential problems during heavy traffic situations.

4.2 Application Architecture

The following is the application architecture for the Graph Generator and Flood Prediction application.

Application Architecture

The application architecture of Graph Generator and Flood Prediction has 4 different layers: Client Layer, Presentation Layer, Business Layer and Data Access & Integration Layer.

Client Layer:
Client layer is a application front-end that provides communication with application users using web browser (IE, Mozilla, Firefox, and Netscape) that renders pages built with HTML, PHP and JavaScript. It is a thin client which gives the advantage that no additional software needs to be installed on client side, so a thin client requires minimum support for client platform.

Presentation Layer:

Presentation Layer presents the information to the user in the form of Graphical user interfaces. The presentation layer connects to business layer in order to process the user request and displays the responses from the Business layer.

Business Layer:

Business logic layer provides data and transaction processing logic (business logic) for .. application. This layer coordinates the application, processes requests from presentation layer and provide the response to the user.

Data Access & Integration Layer:
Data layer involves the relational database which stores the Graph Generator and the Flood Prediction application data. All interactions to this layer are done through business logic tier to prevent any potential security issues from arising. PHP connection logic is used to access this layer.

4.2 Database Design and Schema

The main aim is to design a robust schema in order to accommodate the dataset from the national data collection sheet template and regional data collection sheet template. The template will cover, a large and diverse range of coastal and marine aspects including quantitative and qualitative natural and social-economic parameters. In order to host all collected information a detailed robust database schema was designed to accommodate the contents of both national and regional data collection sheet. A detailed schema diagram will be presented at the workshop.

4.3 Graph Generator

Graph generator is a Joomla Component that we developed and integrate into Joomla website.

Its main function is to generate a graph based on the tabular data that will be uploaded by application user.

Graph Generator can be separated into 2 sections:

1. **FRONTEND**
2. **BACKEND ADMINISTRATION**

FRONTEND is the normal application user interface, once user reached this frontend page, it will be forced to choose either one of the following options :

1. In Built Data
2. Upload New Data

For **"In-built data"**, the graph generator system will actually read the data from the local database from where it has been uploaded and recorded from the Graph Generator Admin Page. It is shown in Figure -1.

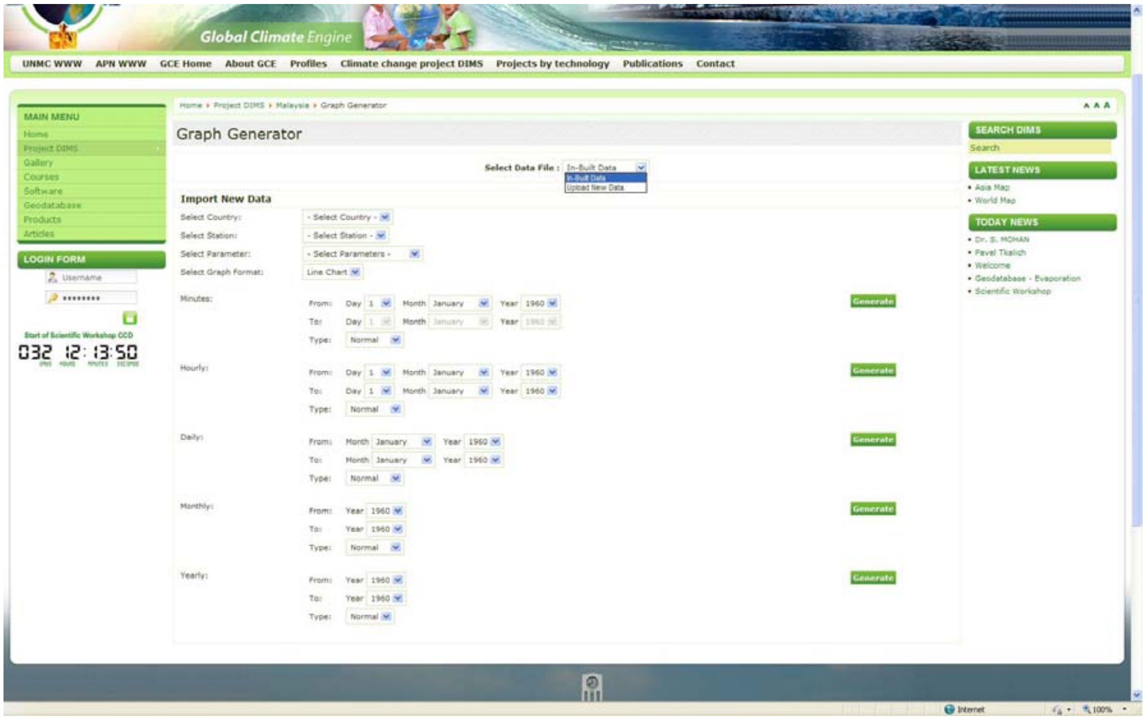


Figure – 1 Graphical User Interface – In built data

The user can generate the graph based on the inbuilt data and will able to filter according to the following:

- Country
- Station
- Parameter
- Graph Format
- Minutes, Hourly, Daily, Monthly, and Yearly

User also able to select Graph Type as follows:

- Normal
- Average
- Minimum
- Maximum

Normal graph will produce graph as per in the database.

Average graph will produce average plot graph in selected period.

Minimum graph will produce minimum plot graph in selected period.

Maximum graph will produce maximum plot graph in selected period.

Once the user click “Generate” button after all filter has been selected, the Graph Generator will produce the graph in Flash format in which can be exported to JPEG image format.

The “**Upload New Data”** will force user to upload their own data in CSV format as shown in Figure -2.

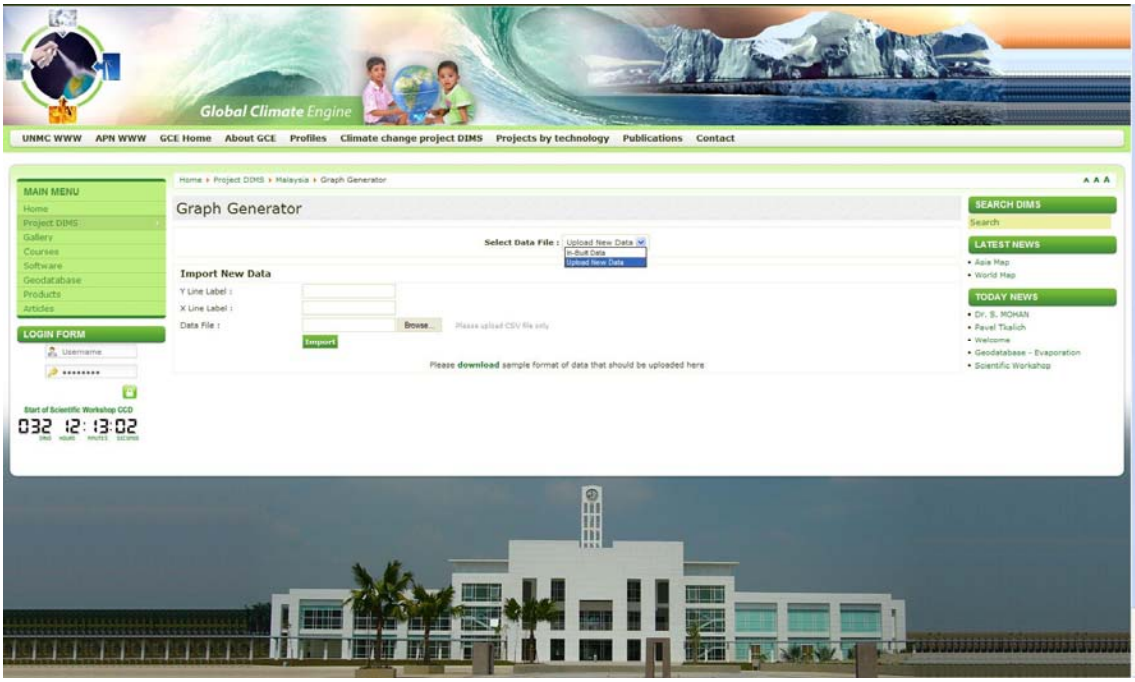


Figure – 2 Graphical User Interface – Upload New data

The sample CSV format is as follows: The columns are,
year,Jan,Feb,Mar,Apr,May,Jun,Jul,Aug,Sec,Oct,Nov,Dec separated by , between them.

1962,285.38,352.76,351.268,352.76,242.428,352.76,349.943,349.943,349.943,349.943,352.76,351.268
1963,301.202,242.428,267.923,242.428,331.51,242.428,352.76,352.76,352.76,352.76,242.428,267.923
1965,349.943,331.51,295.798,331.51,352.76,242.428,301.202,331.51,352.76,242.428,352.76,295.798
1972,352.76,285.38,351.268,351.268,242.428,285.38,349.943,285.38,242.428,285.38,242.428,351.268
1975,242.428,351.268,242.428,267.923,331.51,301.202,267.923,301.202,331.51,301.202,331.51,352.76
1984,331.51,267.923,331.51,295.798,285.38,349.943,295.798,349.943,285.38,349.943,349.943,242.428
1991,351.268,295.798,285.38,351.268,301.202,351.268,351.268,351.268,301.202,351.268,352.76,352.76
1995,267.923,351.268,301.202,242.428,349.943,267.923,267.923,267.923,349.943,267.923,242.428,242.428
1996,295.798,242.428,242.428,242.428,352.76,295.798,295.798,295.798,352.76,295.798,242.428,331.51
1999,351.268,331.51,331.51,331.51,242.428,351.268,351.268,351.268,242.428,351.268,331.51,242.428

The sample CSV file also can be downloaded here at http://www.globalclimate-engine.org/components/com_graphgenerator/assets/sample/newdata_sample.csv

Once the user uploaded the csv file, the graph generator will plot the graph in FLASH format, in which later can be exported to JPEG image format.

BACKEND ADMINISTRATION, is the administration page for the application admin. In this page, the application admin can upload new data for “Inbuilt Data” selection in the front end page.

Figures -3, 4,5,6,7 and 8 are the screen shots of Backend Administration and development of the graph editor for Graph Generation.

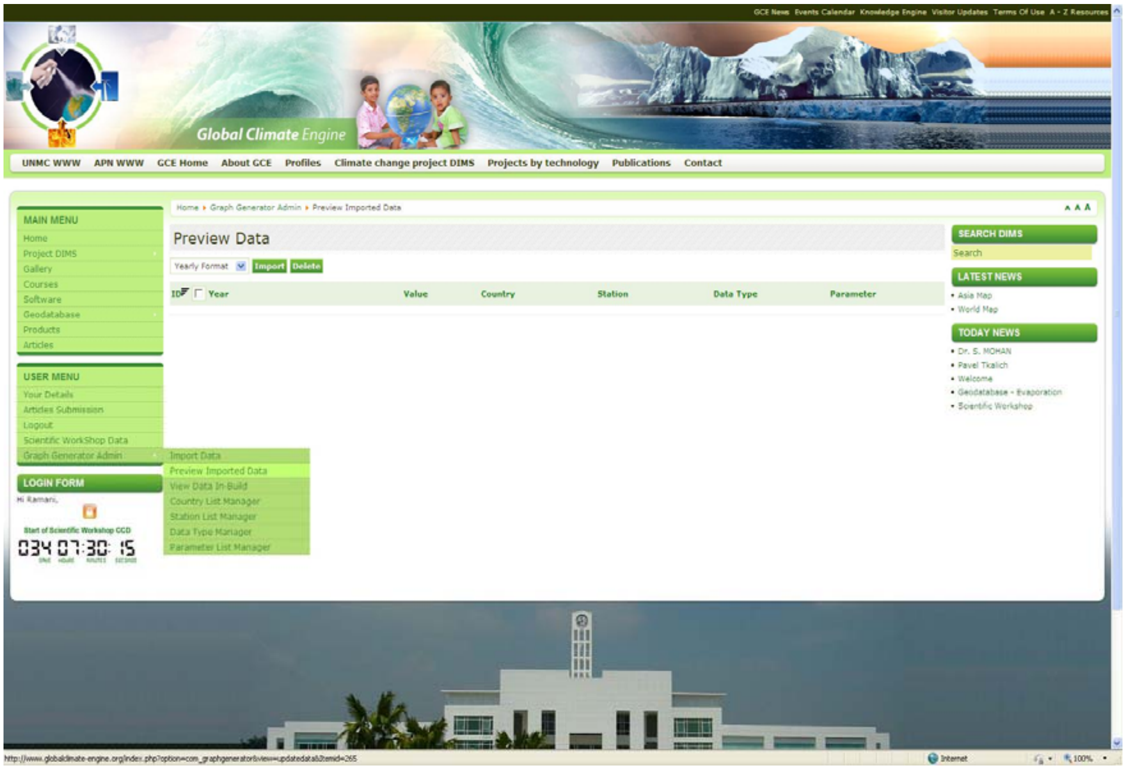


Figure – 3 Graphical User Interface – Graph generator

Figure – 4 Graphical User Interface – Graph generator

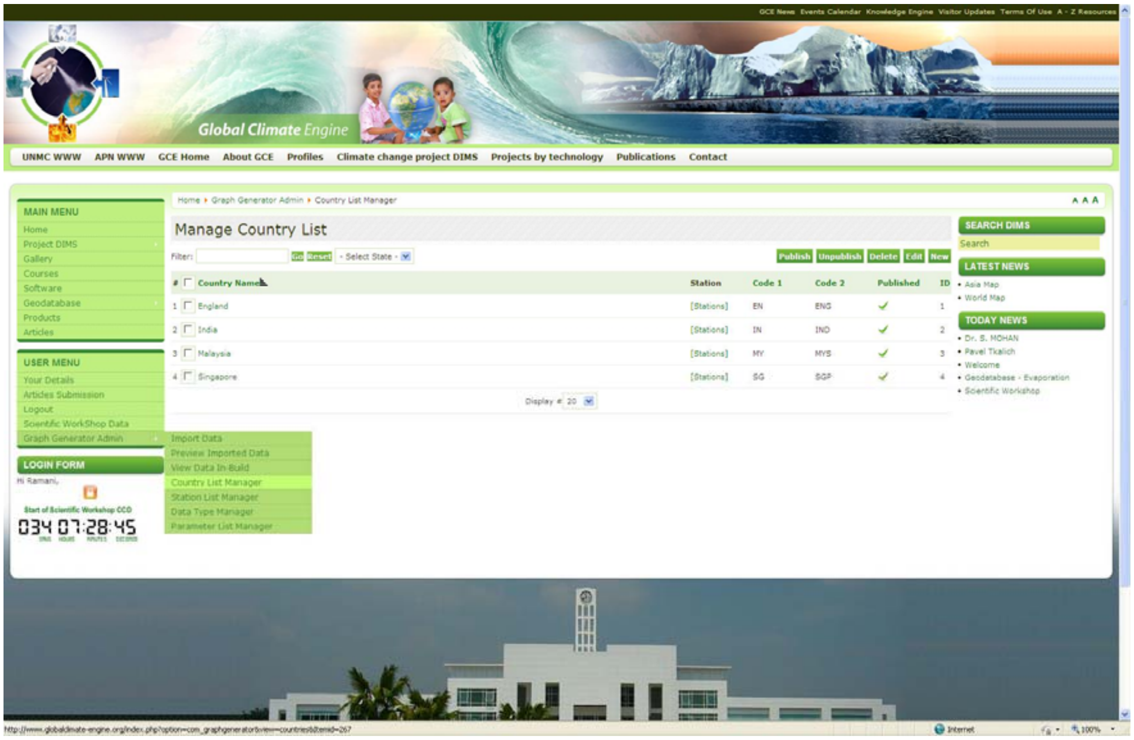


Figure – 5 Graphical User Interface – Graph generator

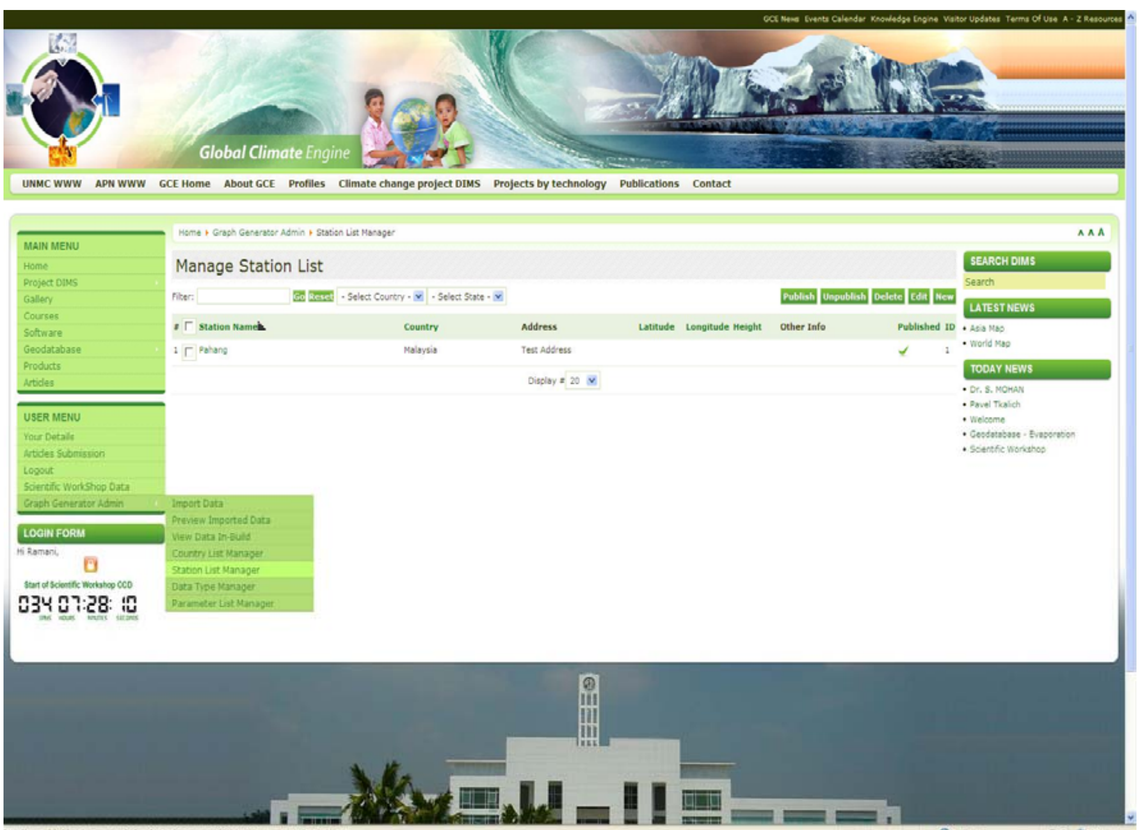


Figure – 6 Graphical User Interface – Graph generator

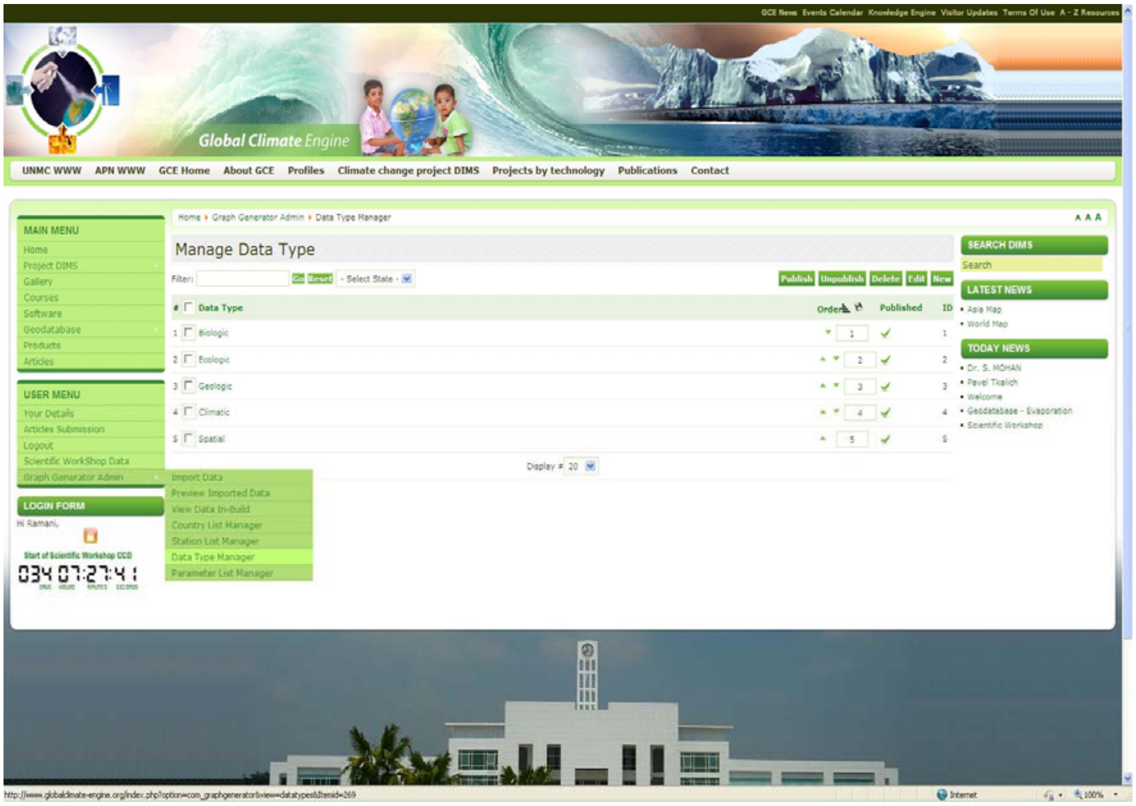


Figure – 7 Graphical User Interface – Graph generator

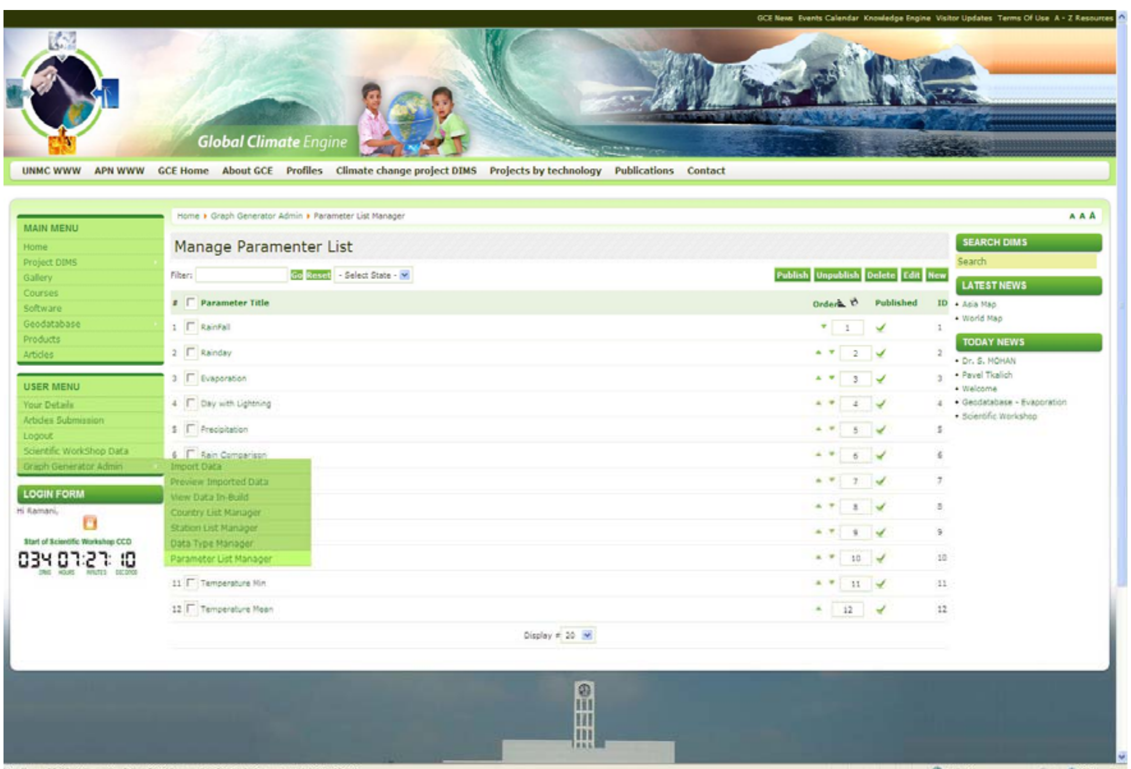


Figure – 8 Graphical User Interface – Graph generator

4.3 Flood Prediction

Flood Prediction is a Joomla Component that we developed and integrate into Joomla CMS website.

Its main function is to generate a graph based on the tabular data that will be uploaded by application user and predict the flood based on the number of years entered in the input box.

sample calculations:

$$\beta = \frac{t_2 k \sin \pi k}{k\pi(k + t_2) - t_2 \sin \pi k}$$

$$\beta = \frac{0.075 \times 0.211 \times \sin(180 \times 0.211)}{0.211 \times 3.14 \times (0.211 + 0.075) - 0.075 \times \sin(180 \times 0.211)}$$

$$\beta = \frac{0.075 \times 0.211 \times 0.615}{(0.211 \times 3.14 \times 0.286) - (0.075 \times 0.615)}$$

$$\beta = \frac{0.009732}{0.14336}$$

$$\beta = 0.067$$

$$x_T = 1 + \frac{\beta}{k}[1 - (T - 1)^{-k}]$$

$$x_T = 1 + \frac{0.067}{0.211}[1 - (1.06 - 1)^{-0.211}]$$

$$x_T = 1 + \frac{0.067}{0.211} \times [-.8105]$$

$$x_T = 0.7426$$

This Flood Prediction application will be based on data uploaded in CSV format.
Sample data are as follows in CSV format:

Yearly Data
1962,285.38
1963,301.202
1965,349.943
1972,352.76
1975,242.428
1984,331.51
1991,351.268
1995,267.923
1996,295.798
1999,351.268

Sample CSV format data for Flood Prediction application also can be downloaded here at http://www.globalclimate-engine.org/components/com_graphgenerator/assets/sample/unmc2.csv

After the data is uploaded, the graph will be generated and user can then enter the no of years they would like to predict in the “Enter number of years you would like to predict based on the uploaded data :” input box.

The graph also can be exported to a jpeg image by clicking “Export Image” link.

CHAPTER 1 DATABASE AND INFORMATION SYSTEM – GEOGRAPHIC INFORMATION SYSTEM

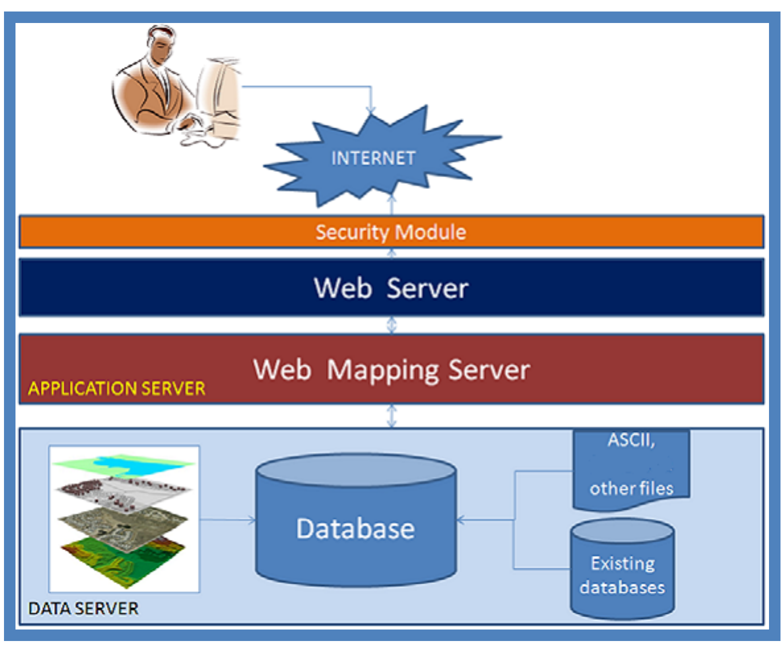
1.0 Introduction

DIMS-GIS is a online Geographic Information System (- GIS) allows to display climate change related data and information on interactive maps using web mapping server called Mapserver (Open source webGIS server). The mapserver having the web map serving program, the application requests GIS data and MapServer-specific files, namely, Map file and HTML template files. In fact, this file defines every object for the online map, including data layer, scalebar, map, legend, projection and web object. The objective of object definition is to define how the map will look like and be presented. The defined objects such as map, legend and scale bar are presented on the online map interface. But, the Map file is not used for the designing of the interface, the Template files are used instead. The template file P.Mapper is used for the following tasks, namely, designing the interface, generating mapping tools. This DIMS – GIS framework uses all open source datasets as well as dataset provided by country representatives.

1.1 System Development

The system development include the organization of spatial data, GUI and interactive Web mapping and development of data management tools - catalog tools to provide meta data information about the spatial layers.

The development of the system is based on web based client-server architecture. The server side software components consist of several servers working in tandem, including Apache, web mapping server, and Java applications for visualization. The web mapping server handles the linkage between spatial objects and non-spatial attribute data stored in a relational database. The web based system will allow the users to interactively query and visualize data



1.2 Graphical User Interface

The Graphical User Interface (GUI) design contains four parts 1) Map Viewer 2) Tool box 3) Table of Contents 4) Index map. The map viewer will display the various thematic layers compiled through map composition and controlled by set of scripts based on the user selection. The tool box consists of basic and advanced controls for thematic layers in map display. The table of contents basically list the thematic layers and their display properties such as legend and symbol properties. The Index map provides the thumbnail view of the each countries like India, Malaysia and Singapore. The map viewer contains the below thematic layers for each country.

Thematic Layers – India:

- Country Boundary
- Coast Line
- City Locations
- State Boundary
- Coral Reef – Boundary
- River_Drainage Network
- Land Cover – Classification
- WMS service - Satellite image from NASA

Thematic Layers – Malaysia:

- Country Boundary
- Coast Line
- City Locations only for West Malaysia
- State Boundary
- Land Cover Classification
- WMS service - Satellite image from NASA
- Elevation – SRTM
- Climate Parameters
    - Annual Rainfall
    - Annual Rainfall Rain day
    - Wind Speed
    - Max. Wind Direction
    - Evopotransportation
    - Normal Precipitation
    - Rain Comparison
    - RH
    - Solar Radiation
    - Temperature Radiation
    - Max. Temperature
    - Mean. Temperature
    - Min. Temperature
    - Temperature Comparison

Thematic Layers – Singapore:

- Country Boundary
- Coast Line
- Land Cover Classification

- ➢ Elevation – SRTM
- ➢ Population Class
- ➢ WMS service - Satellite image from NASA

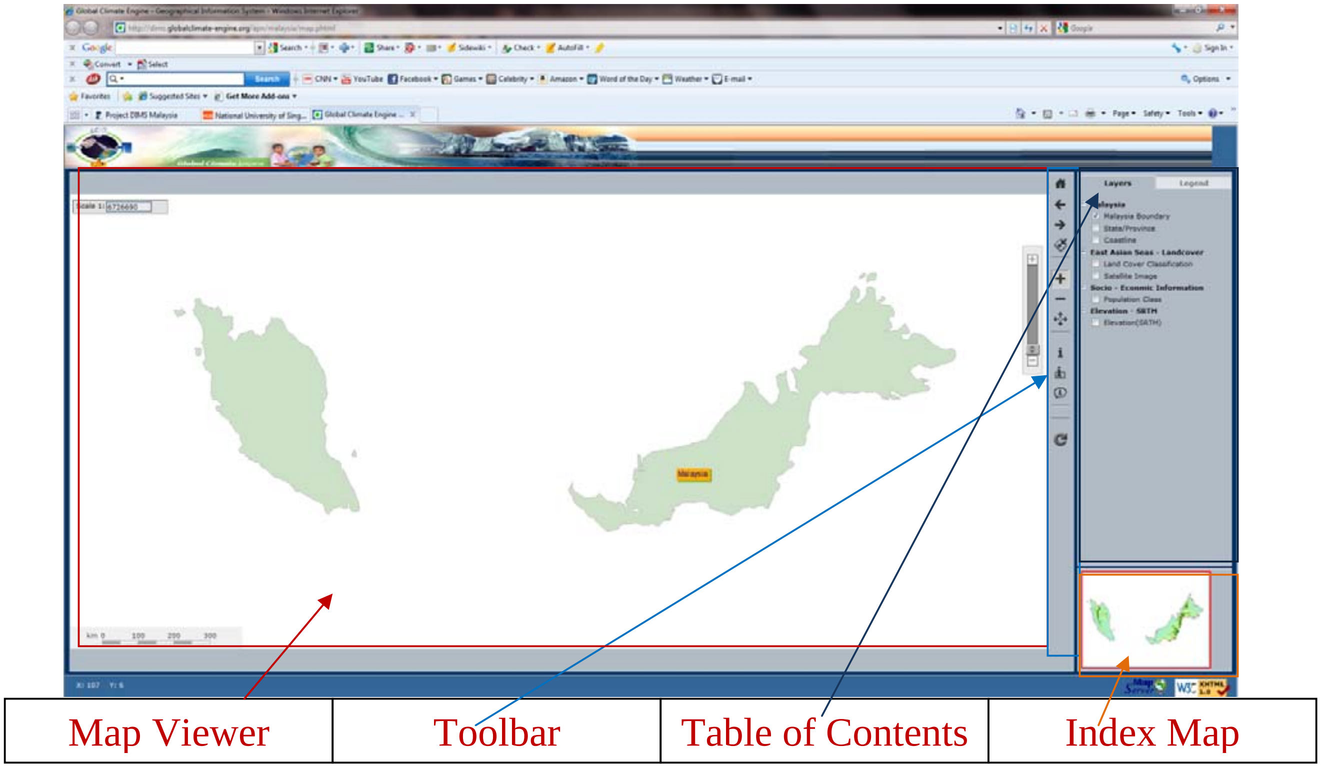


Figure – 9 **Graphical User Interface - GIS**

In the middle of the screen is a toolbar with a variety of mainly navigation-oriented buttons. They perform fundamental operations that one would expect to be able to perform. Some of these buttons require interaction with the display panel in addition to the selection of the button; others just require selection of the button. From the top to bottom, the functions available on the toolbar are:

Navigation Tools

1. Zoom to Full Extent
2. Zoom to Previous
3. Zoom to Forward
4. Zoom to Selected
5. Zoom in
6. Zoom out
7. Pan
8. Info tools
9. Clear Selection and Zoom to Full Extent

The table of contents is named as “Layers” tab. The purpose of this is to allow the user to select and de-select layers of the map. Multiple layers can be selected at any one time as well as allowing for any depth of nested layers.

Legend tab, displays the names of the selected layer and the associated colors of the each layer. To access the each countries datasets CMS will have the link to web mapping server. Below the URL to access the each countries web map portal.

For India: http://dims.globalclimate-engine.org/apn/india/map.phtml

For Malaysia : http://dims.globalclimate-engine.org/apn/malaysia/map.phtml

For Singapore: http://dims.globalclimate-engine.org/apn/india/map.phtml

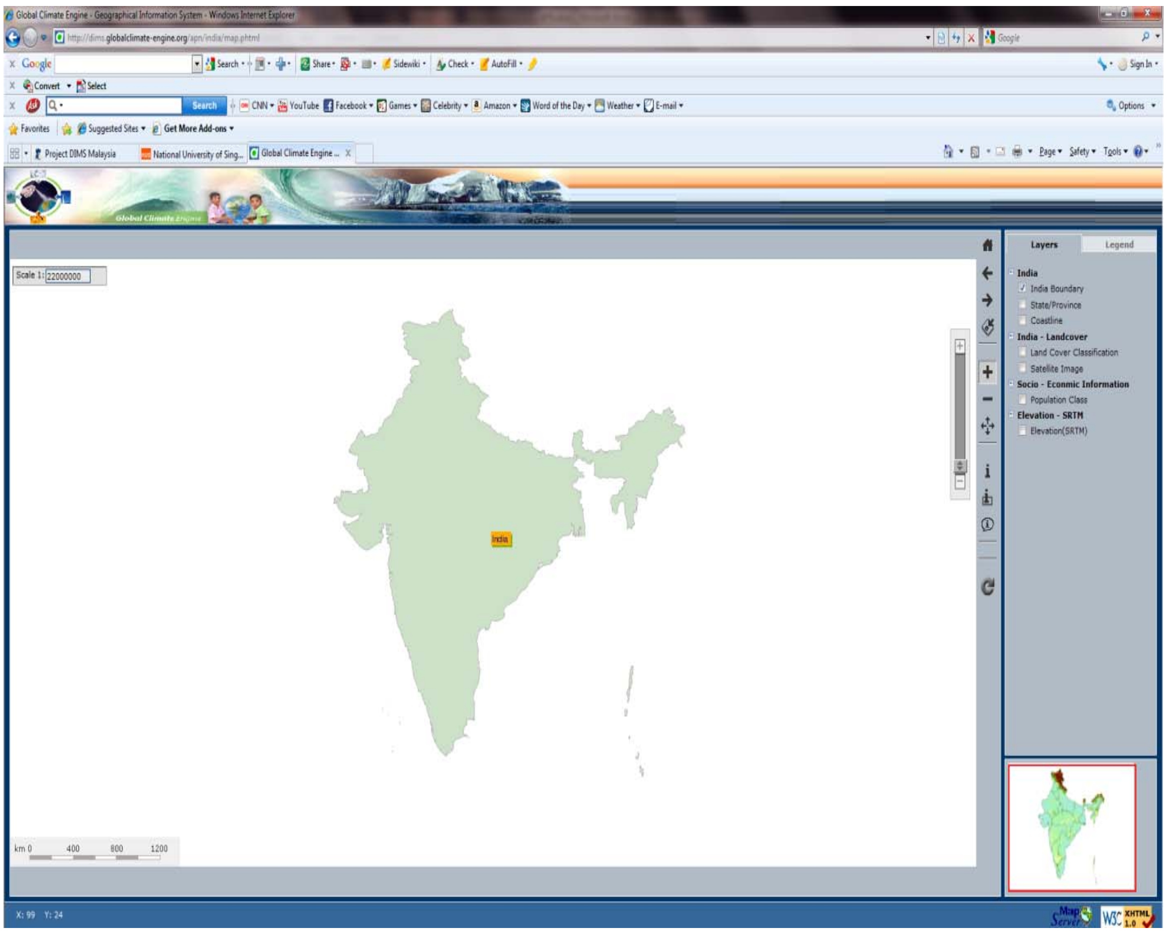


Figure – 10 **Graphical User interface for India**

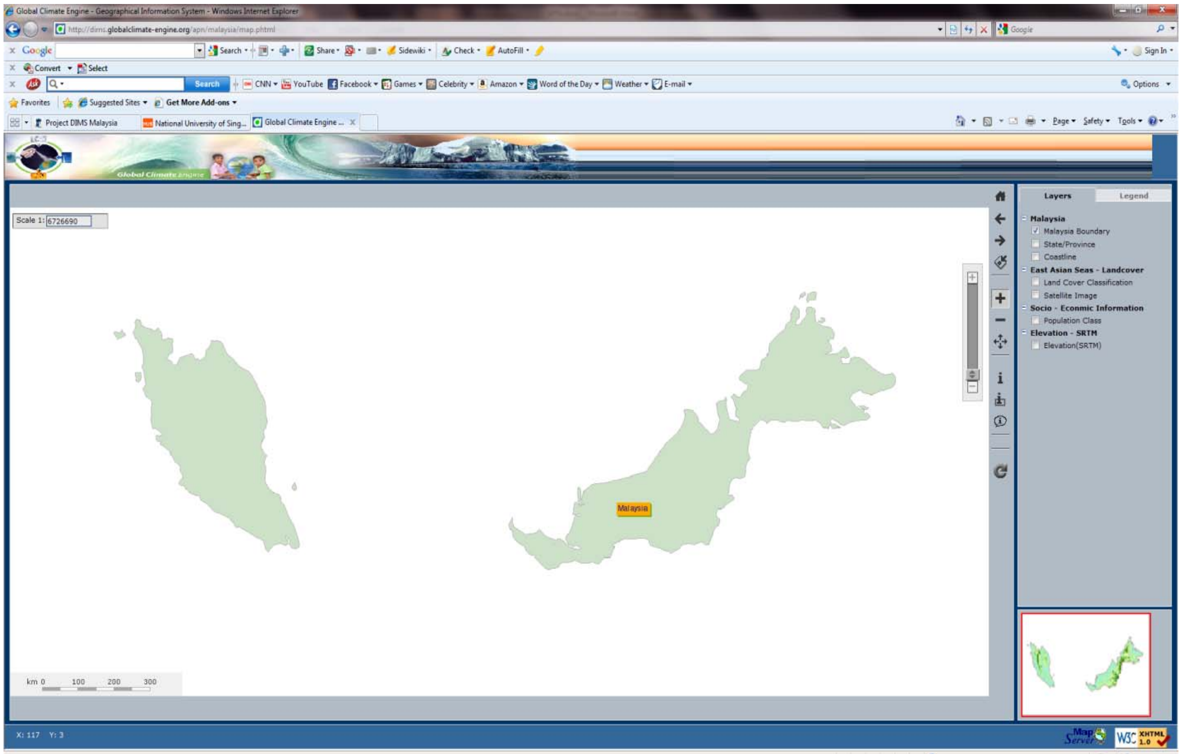


Figure – 11 **Graphical User interface for Malaysia**

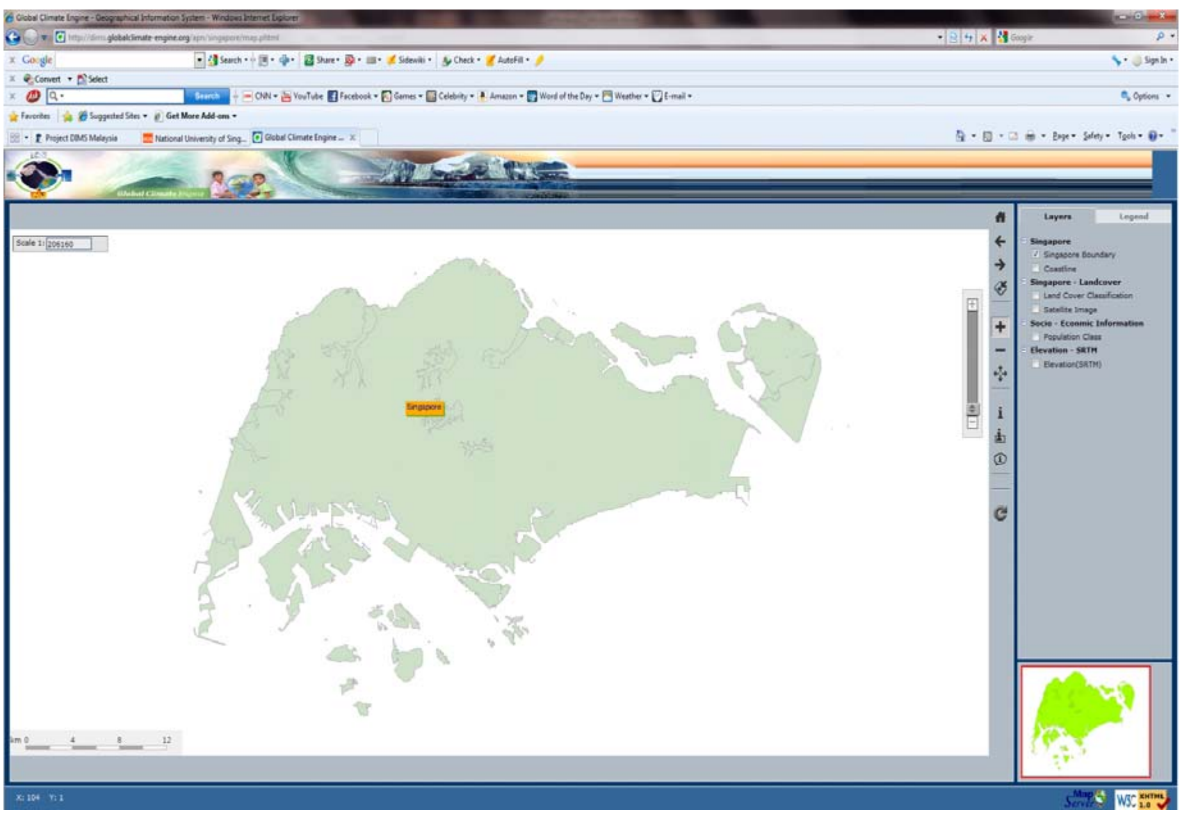


Figure – 12 **Graphical User interface for Singapore**

DATABASE INFORMATION AND MANAGEMENT SYSTEM: CATALOG & METADATA SYSTEM

1.0 Introduction

A metadata catalogue system is developed to store, update, and search for metadata that describe the datasets used in the project. The screenshot below shows the metadata population page where data custodians can use this page to create metadata for their dataset. The standard for the metadata is based on the ISO 19115 standard (http://www.iso.org/iso/catalogue_detail.htm?csnumber=26020).

Metadata Population and Update

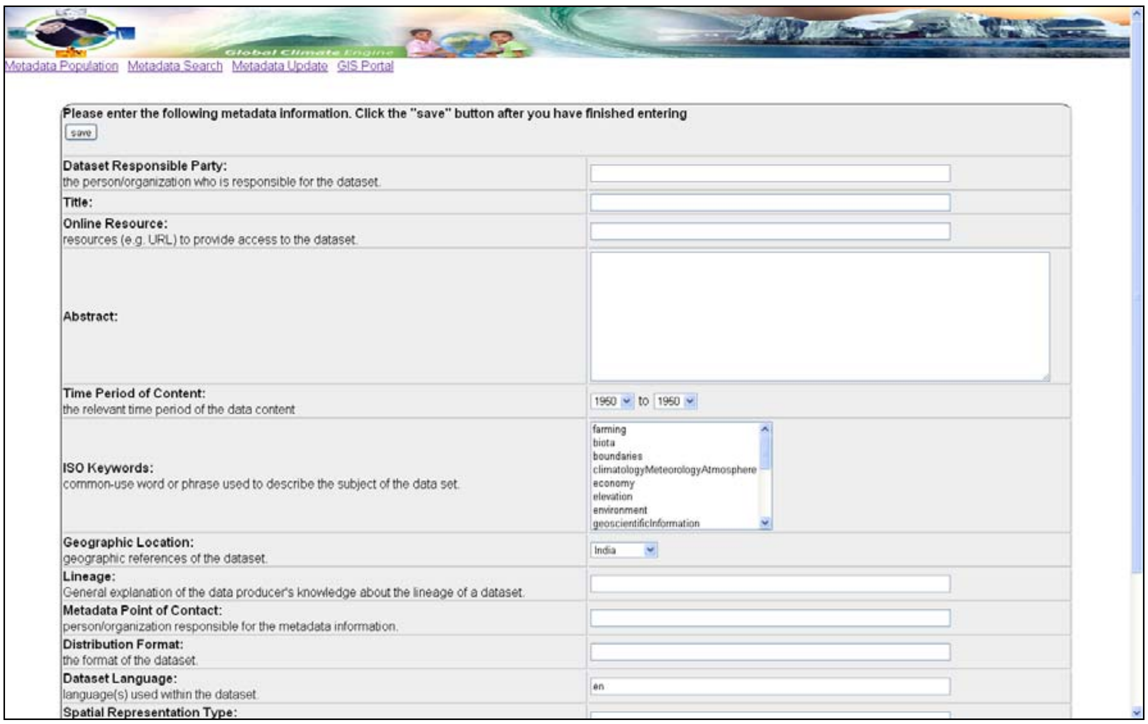


Figure – 13 Metadata Population Page
(http://dims.globalclimate-engine.org/Metadata_UNM/MetadataForm)

After populating the metadata, in later times, the custodians can update their metadata through the metadata update page. Below shows the metadata update page that demonstrates a list of metadata that are previously entered. The custodians can click on the buttons, which are located at the end of each metadata record, to either edit or delete the respective record. If the edit button is clicked, a page similar to the metadata population page will be displayed with the metadata information previously entered by the custodians. When the delete button is clicked, the record will be deleted otherwise.

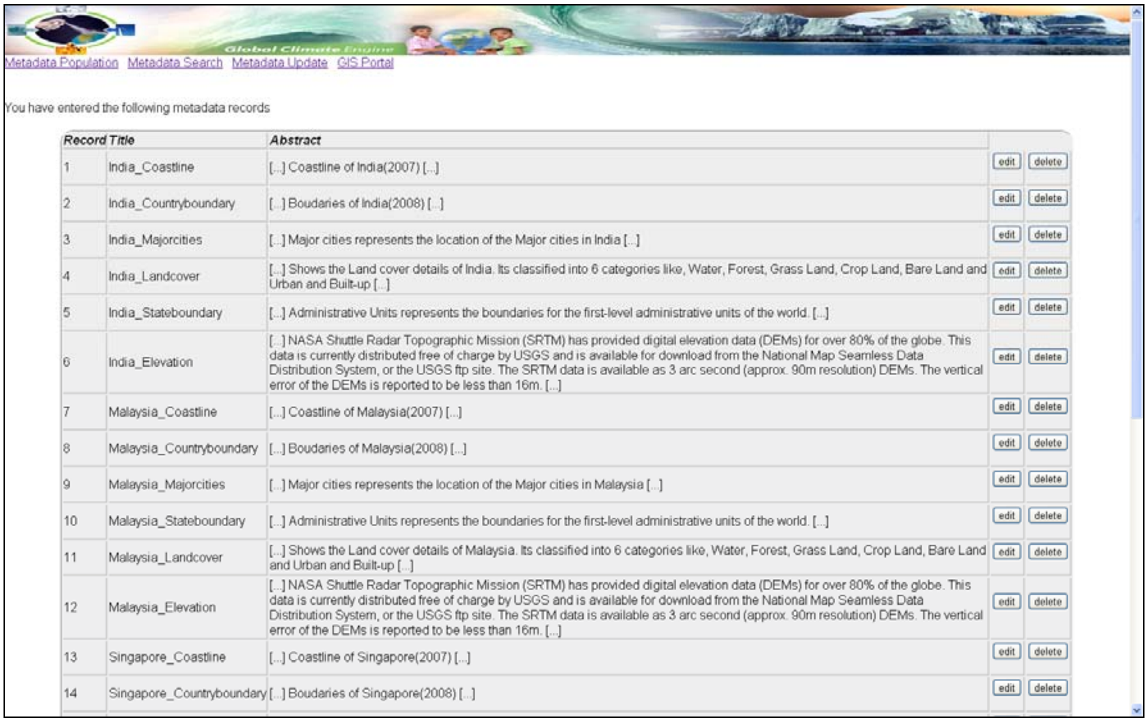


Figure – 14 **A list of previously entered metadata in the metadata update page**

1.1 Metadata Search

The screenshot below shows the search page for metadata. Using this page, the users can search metadata with the search term appeared in the ISO keywords and/or title and/or abstract of the metadata. As can be seen in the screenshot, the user entered "landcover" as the search term.

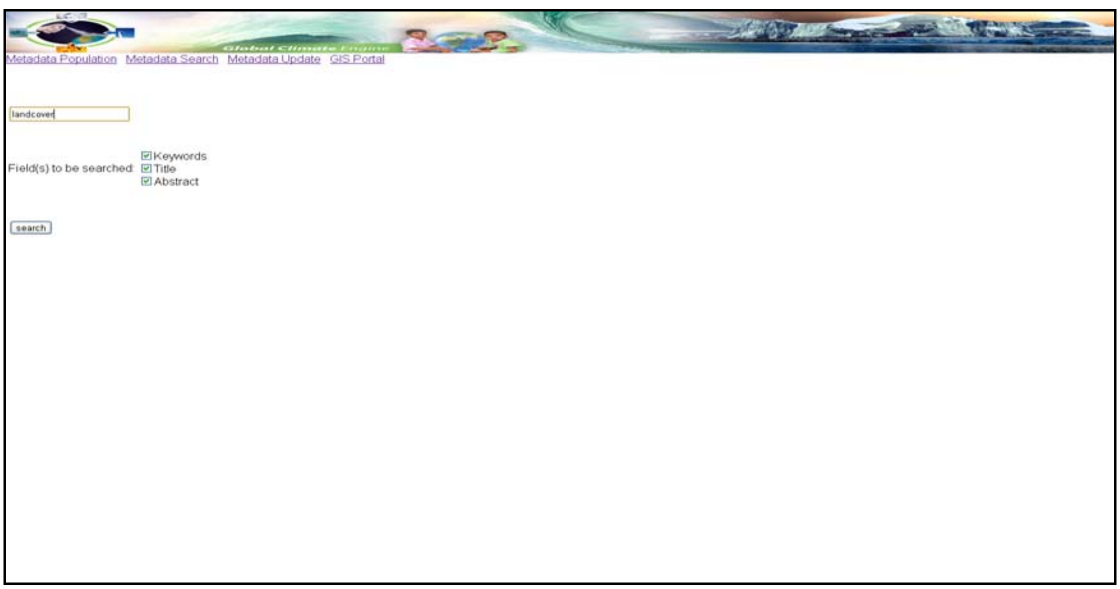
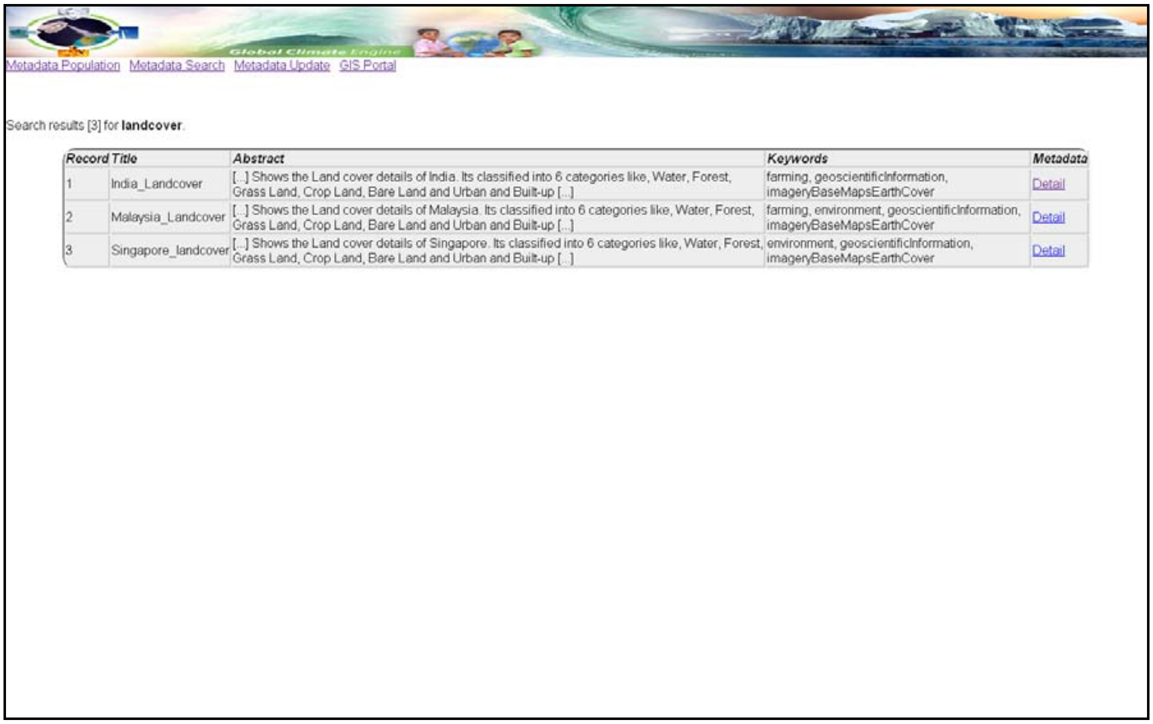


Figure – 15 **Search Interface**

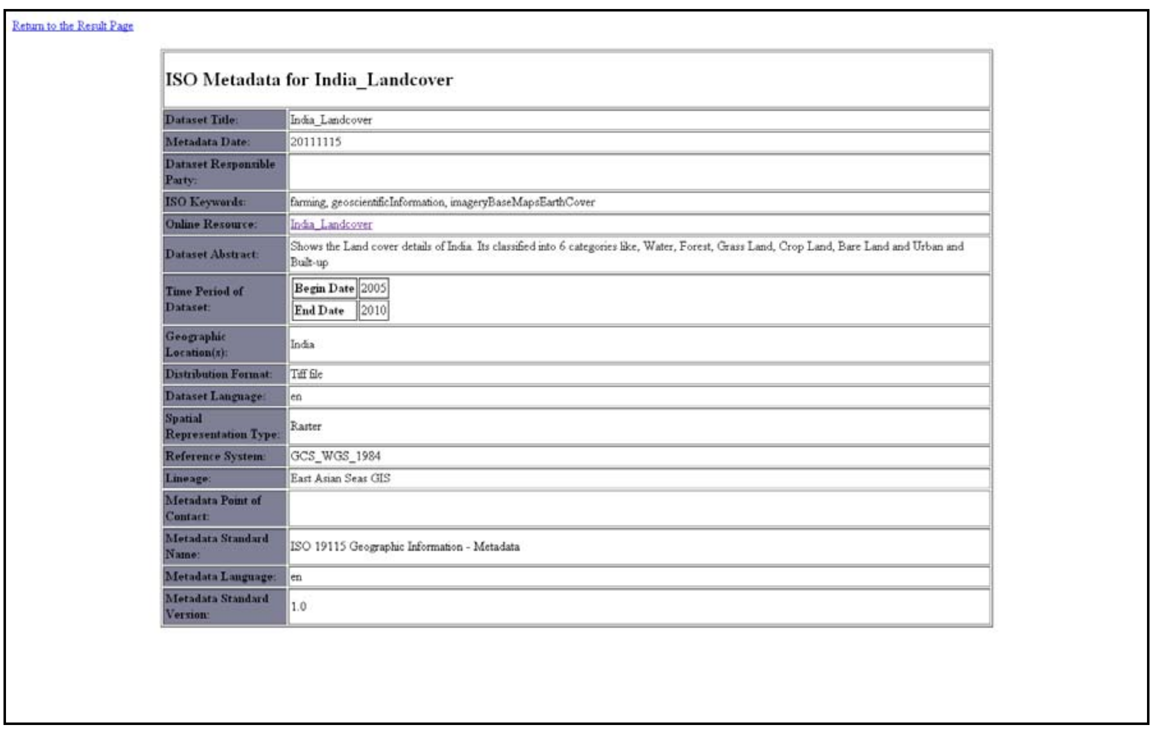
When the search button is hit, the returning result as demonstrated in the screenshot below shows the metadata that contain the search term "landcover".



Record	Title	Abstract	Keywords	Metadata
1	India_Landcover	[...] Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	farming, geoscientificInformation, imageryBaseMapsEarthCover	Detail
2	Malaysia_Landcover	[...] Shows the Land cover details of Malaysia. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	farming, environment, geoscientificInformation, imageryBaseMapsEarthCover	Detail
3	Singapore_landcover	[...] Shows the Land cover details of Singapore. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	environment, geoscientificInformation, imageryBaseMapsEarthCover	Detail

Figure – 16 **Result Return Page**

When the "detail" link is clicked, the full detail of that metadata will be displayed, as illustrated in the page below.



Dataset Title:	India_Landcover
Metadata Date:	20111115
Dataset Responsible Party:	
ISO Keywords:	farming, geoscientificInformation, imageryBaseMapsEarthCover
Online Resource:	India_Landcover
Dataset Abstract:	Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up
Time Period of Dataset:	Begin Date 2005 End Date 2010
Geographic Location(s):	India
Distribution Format:	Tiff file
Dataset Language:	en
Spatial Representation Type:	Raster
Reference System:	GCS_WGS_1984
Lineage:	East Asian Seas GIS
Metadata Point of Contact:	
Metadata Standard Name:	ISO 19115 Geographic Information - Metadata
Metadata Language:	en
Metadata Standard Version:	1.0

Figure – 17 **Metadata Details**

1.2 The Metadata GIS Portal

The meta data GIS Portal, is also developed to visualize the spatial data along with their metadata. The below screenshot is the main interface of the meta data GIS Portal. The interface is divided into three panels. The left panel shows a list of spatial data available, the middle panel shows the spatial data, and the right panel demonstrates corresponding metadata.

To include the spatial data for display, the users need only check on the checkbox of the spatial data, as shown in the left panel. After hitting the “Display Map with Metadata” button at the bottom of the left panel, the spatial data and their respective metadata will be retrieved from the database and displayed in the middle and right panels respectively. Please note that any update done in the metadata update page, will be instantly refreshed in this GIS Portal page.

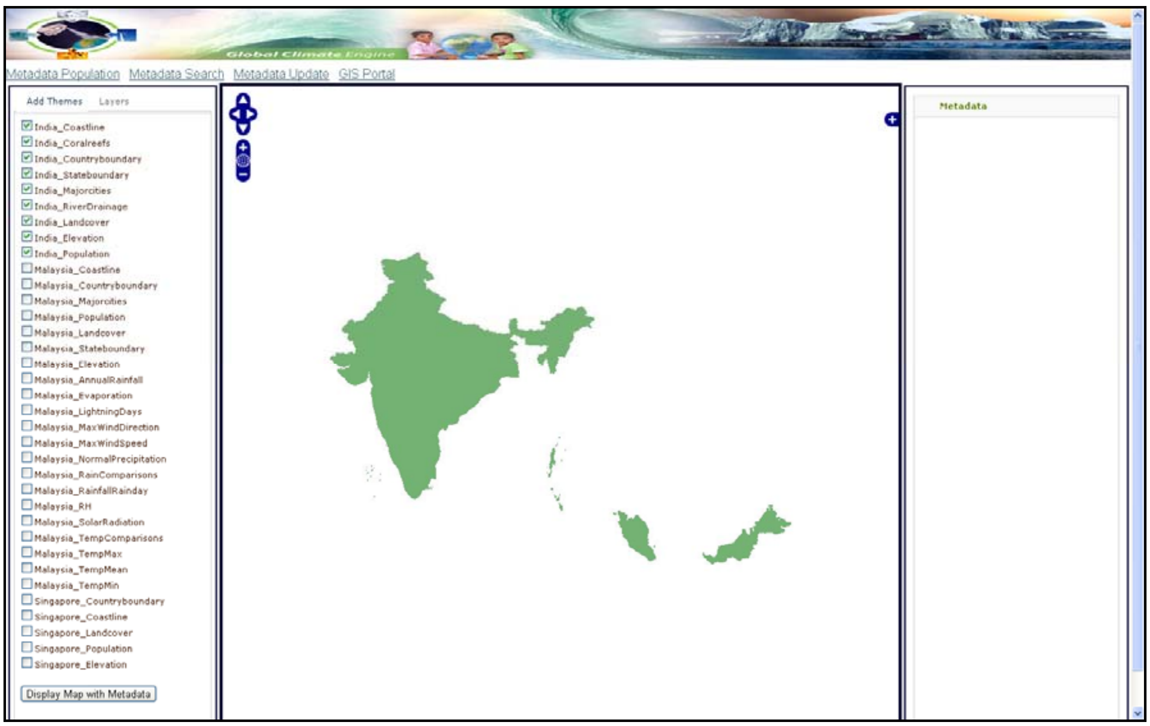


Figure – 18 **The main interface of the GIS Portal (http://dims.globalclimate-engine.org/Metadata_UNM/GISServer)**

The following three screenshots illustrate the examples where the spatial data describing the specific country are included in the portal.

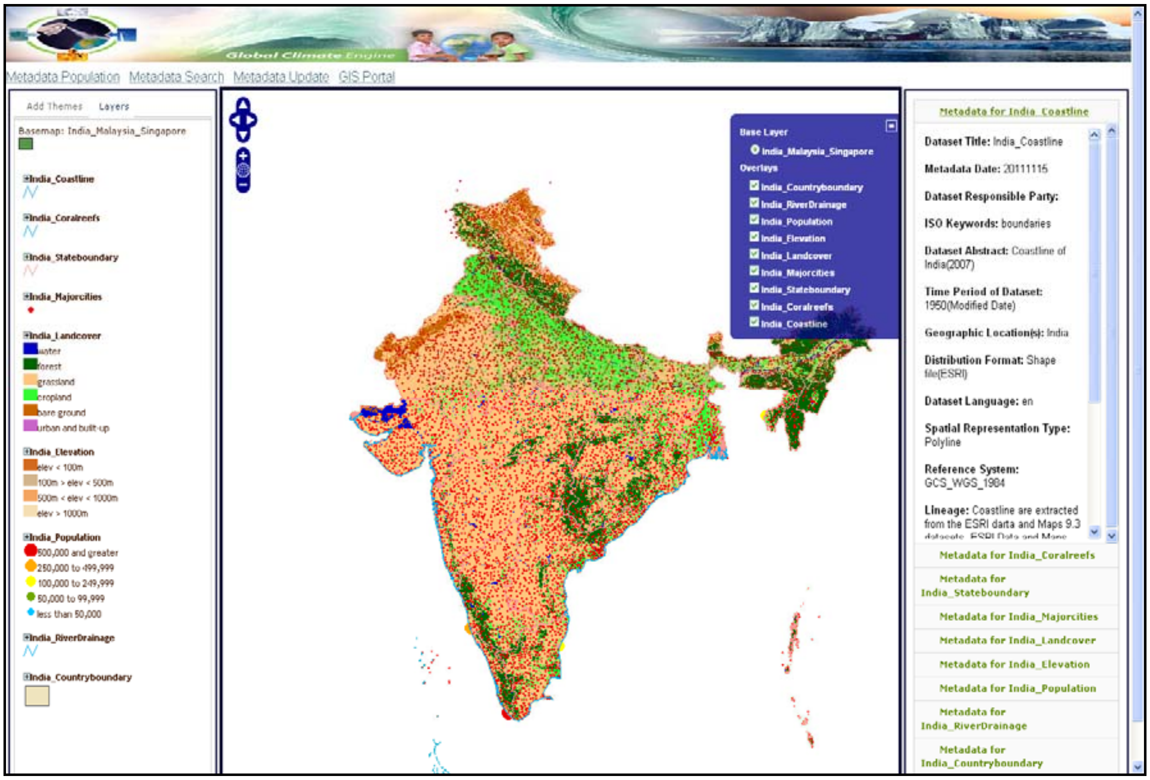


Figure – 19 **The GIS Portal displays the spatial data for India with metadata**

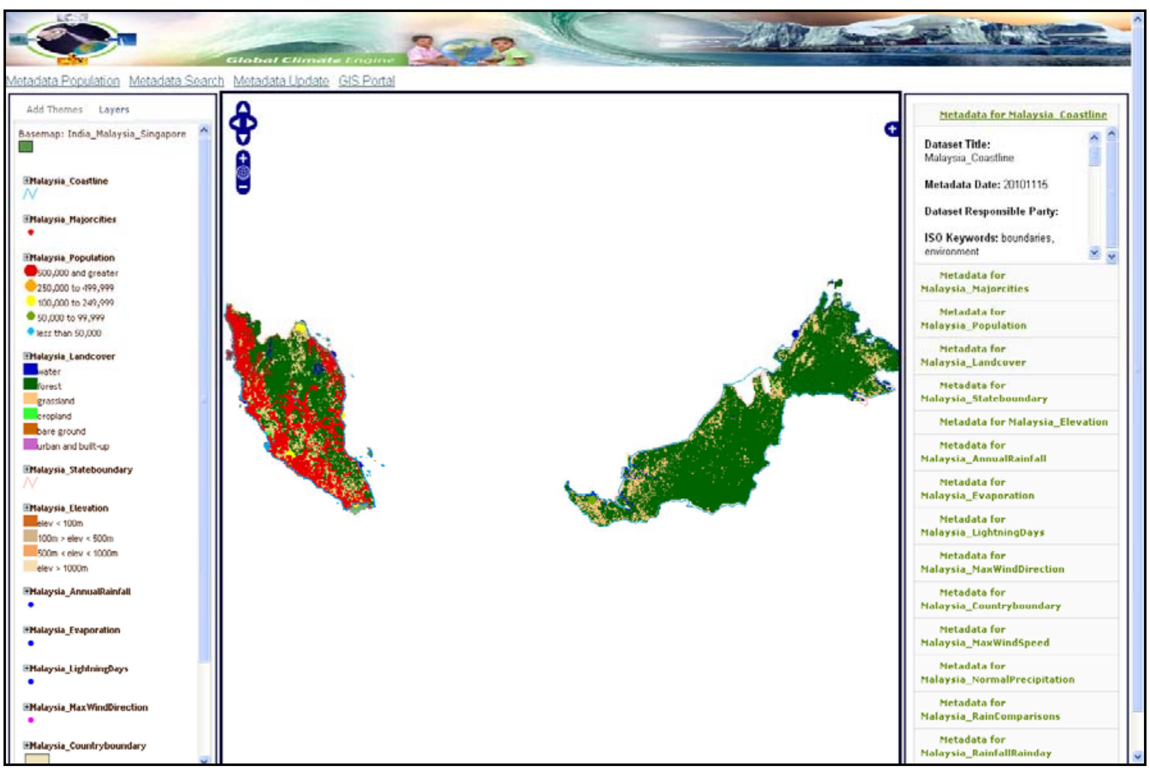


Figure – 20 **The GIS portal with and their metadata for Malaysia**

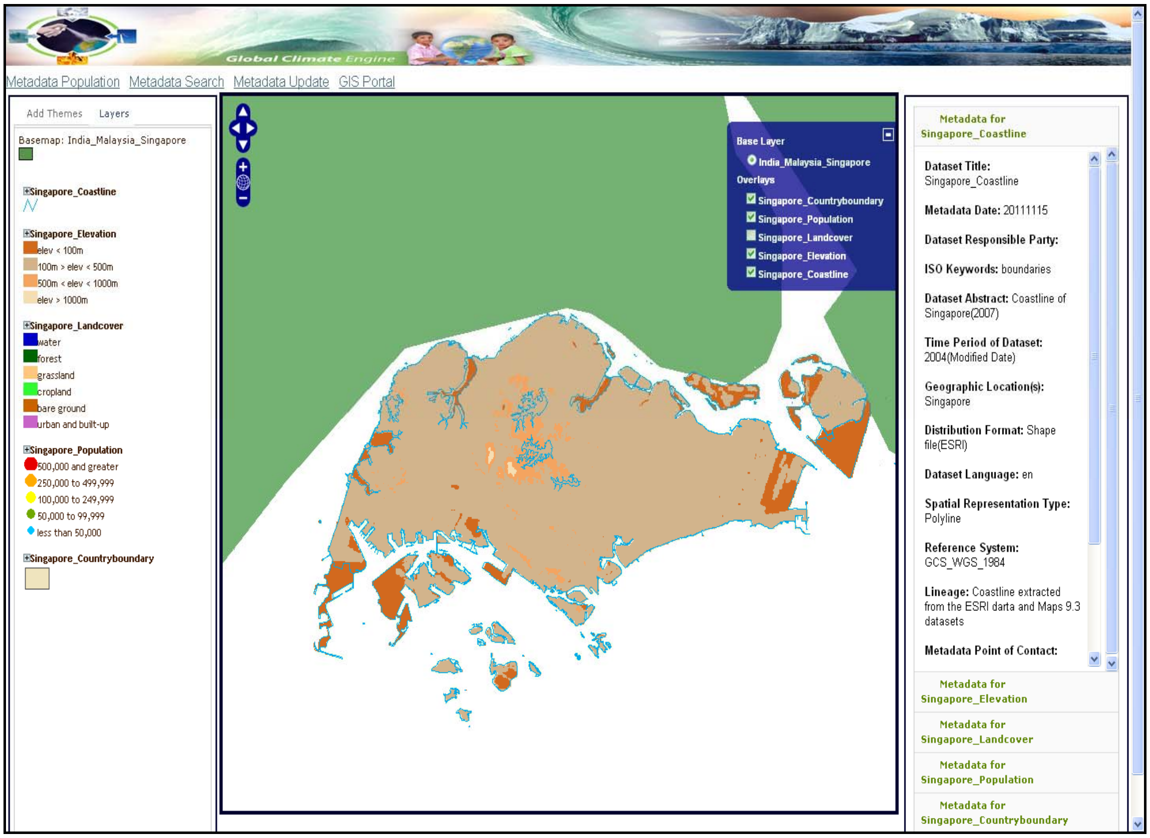


Figure – 21 **The GIS Portal shows spatial data with their metadata for Singapore**

APPENDIX- A DATABASE SCHEMA

This below figure shows the database schema for http://www.globalclimate-engine.org , database name globalclimate .

```
--
-- Database: 'globalclimate'
--

-- --------------------------------------------------------

--
-- Table structure for table 'jos_avrbak_avr_player'
--

TABLE NAME jos_avrbak_avr_player
  id int11 NOT NULL auto_increment,
  version int11 NOT NULL default '0',
  minw int11 NOT NULL default '0',
  minh int11 NOT NULL default '0',
  isjw int1 NOT NULL default '0',
  `name` varchar25 NOT NULL,
  `code` mediumtext NOT NULL,
  description varchar255 NOT NULL default '',
  PRIMARY KEY  id
  ENGINE=MyISAM  DEFAULT CHARSET=utf8;

-- --------------------------------------------------------
```

NOTE: The complete database schema and programme codes can be obtained on demand. For any further enquiry related to the materials provided in the section please contact Ramani Bai via vramanibai@gmail.com

---------------------oOo---------------------

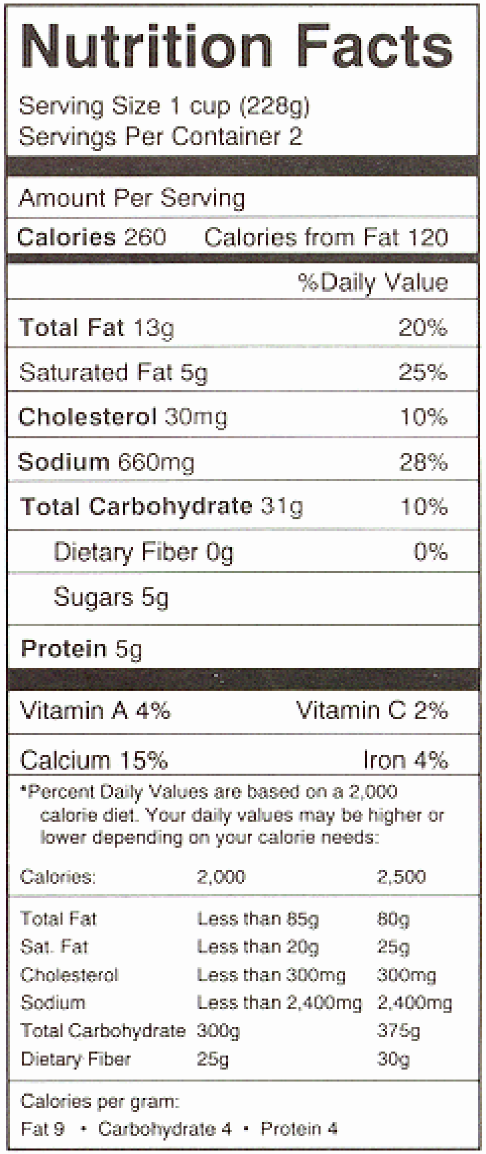
Geospatial Metadata

Outline

- **Introduction to geospatial metadata**
  - Why we need metadata
  - Some examples of metadata standards
- **DIMS metadata system framework**
  - ISO metadata standard
  - Metadata database
- **Metadata system**
  - Metadata population
  - Metadata update
  - Metadata search
  - GIS Portal
- **Demonstration**

What are Metadata?

- **Commonly defined as “data about data”**
- **Metadata inform what the content is**



Why We Need?

- Data handling and maintenance
- We can learn more about the dataset from an external source
- Help to integrate datasets when we know what the datasets are about
- Facilitate search for relevant datasets
- Prevent from data redundancy by various agencies

Geospatial Metadata

- Metadata that describe geospatial/geographic data
- Geospatial metadata are specialized with information like positional accuracy, spatial reference system

Geospatial Metadata (contd.)

Positional accuracy (example)

Positional_Accuracy:

Horizontal_Positional_Accuracy:

Horizontal_Positional_Accuracy_Report: The ESI data use USGS 1:63,3600 topographic quadrangles as the basemap. It is estimated that the ESI shoreline classification has a minimum mapping unit of 100 feet.

Spatial Reference System (example)

Spatial_Reference_Information:

Horizontal_Coordinate_System_Definition:

Planar:

Map_Projection:

Map_Projection_Name: Albers Conical Equal Area
Albers_Conical_Equal_Area:

Standard_Parallel: 55.000000
Standard_Parallel: 65.000000
Longitude_of_Central_Meridian: -154.000000
Latitude_of_Projection_Origin: 50.000000
False_Easting: 0.000000
False_Northing: 0.000000

Planar_Coordinate_Information:

Planar_Coordinate_Encoding_Method: coordinate pair
Coordinate_Representation:

Abscissa_Resolution: 0.000100
Ordinate_Resolution: 0.000100

Planar_Distance_Units: meters

Geodetic_Model:

Horizontal_Datum_Name: North American Datum of 1983
Ellipsoid_Name: Geodetic Reference System 80
Semi-major_Axis: 6378137.000000
Denominator_of_Flattening_Ratio: 298.257222

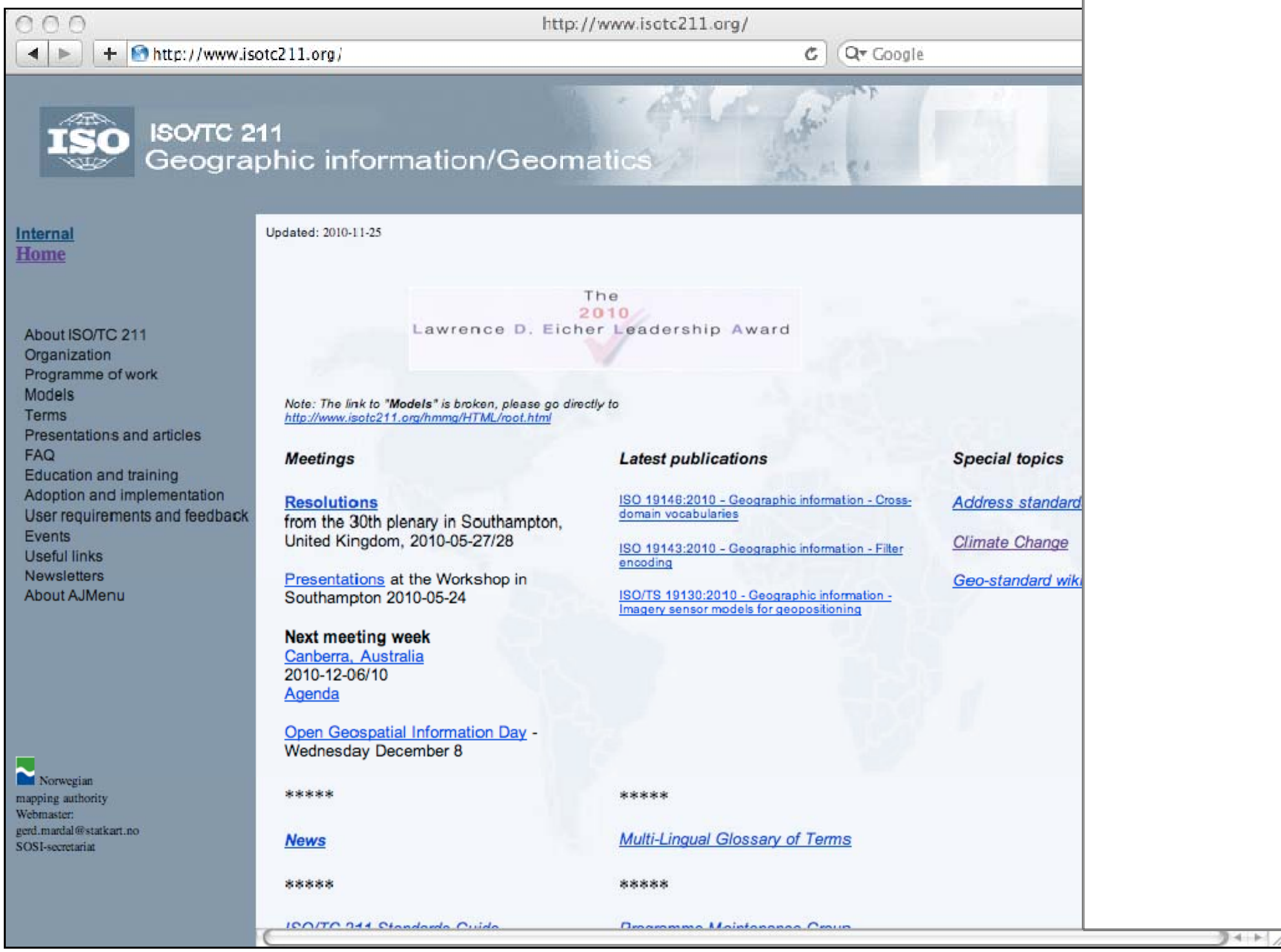
Obtained from http://www.asgdc.state.ak.us/

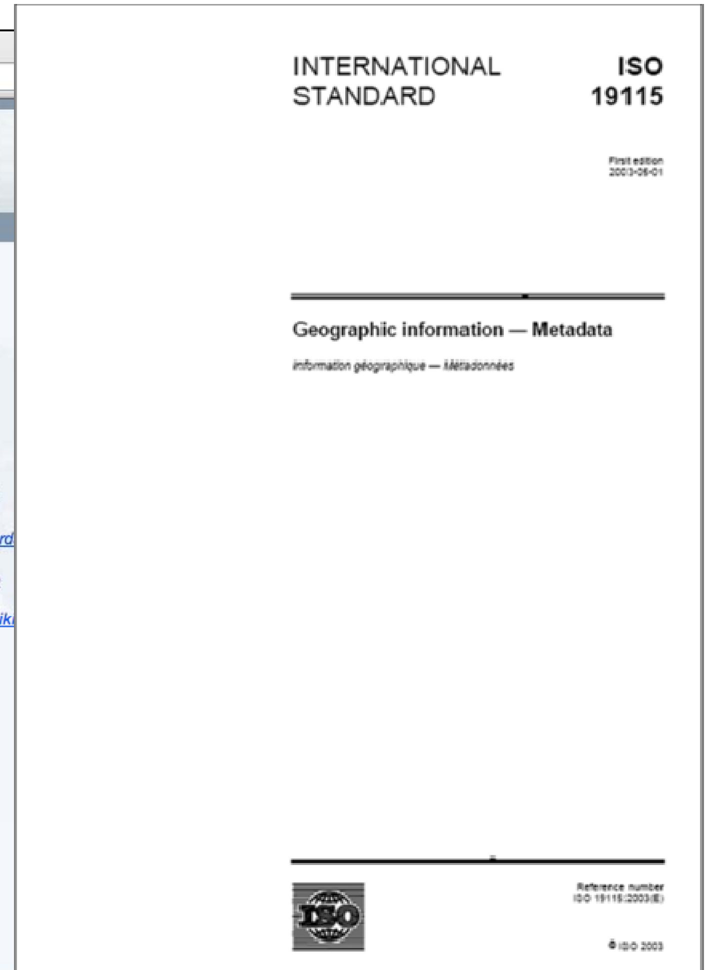
Core Metadata Elements

- Identification Information (e.g. title, abstract)
- Data Quality Information (e.g. positional accuracy, consistency)
- Spatial Reference System Information (e.g. coordinate system, map projection)
- Distribution Information (e.g. online resource, format)
- Entity or Attribute Information (e.g. entity type)
- Metadata Reference Information (e.g. who created the metadata and when)

Geospatial Metadata Standard Examples (1)

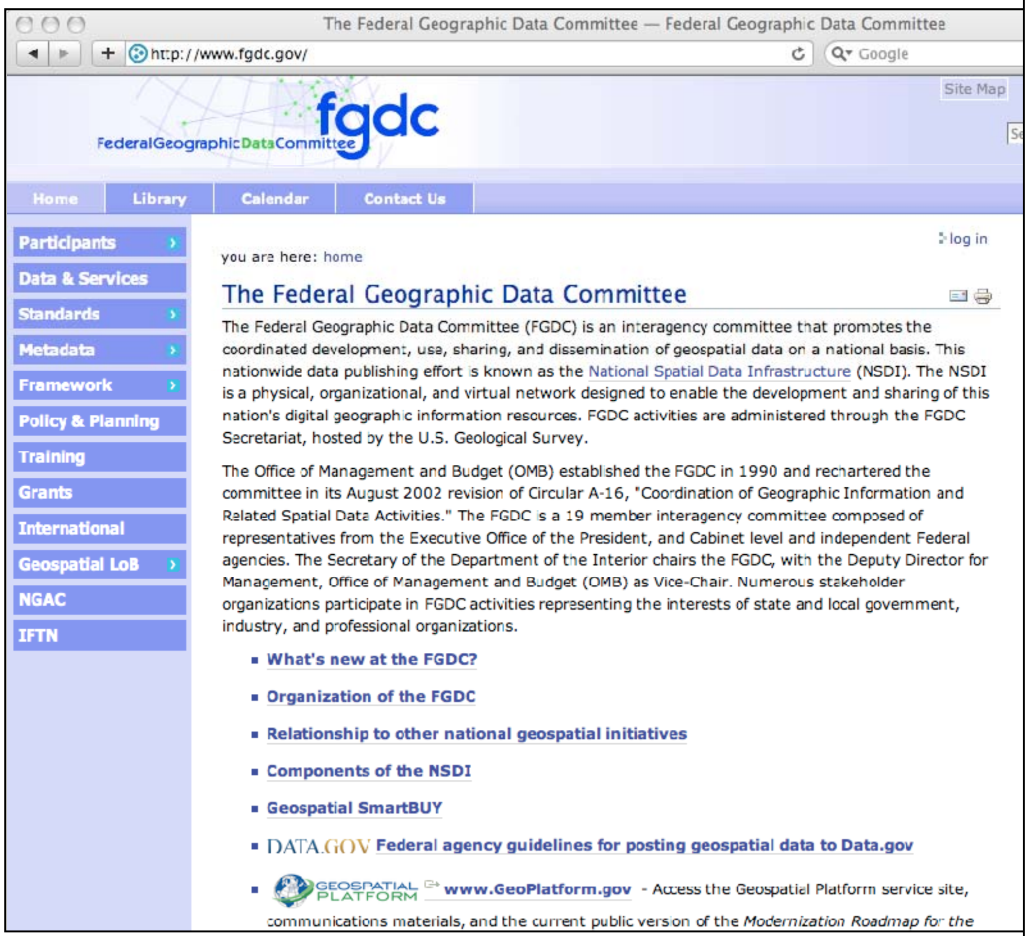
- **International Standard Organization (ISO) – ISO 19115 (http://www.iso.org/)**

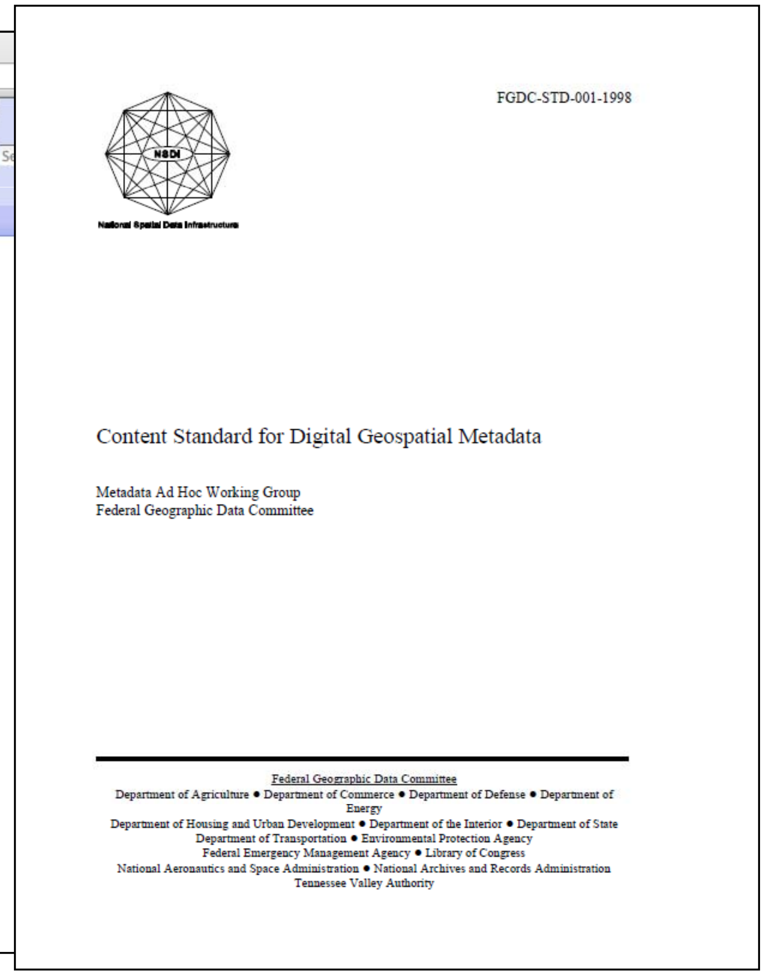




Geospatial Metadata Standard Examples (2)

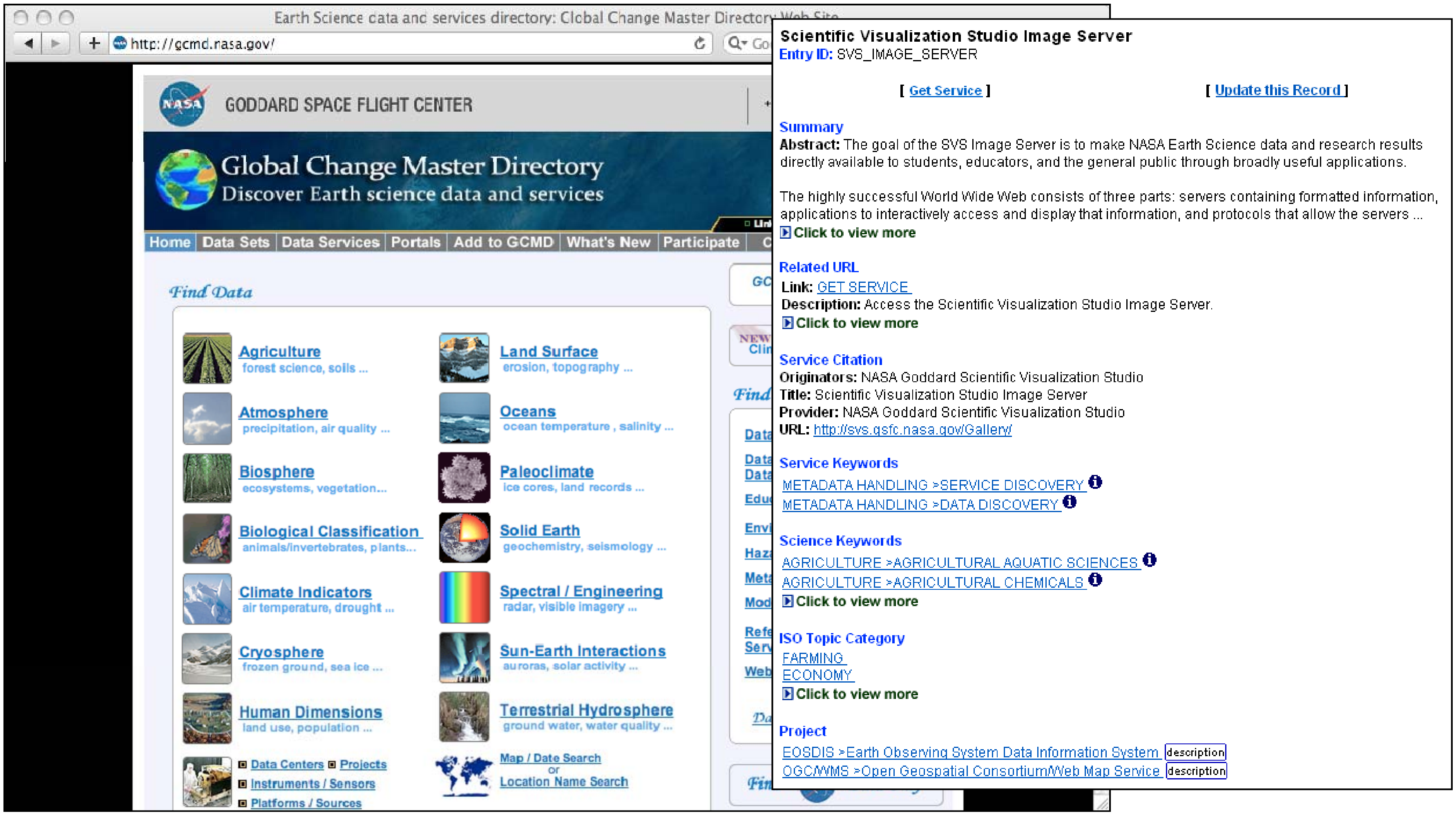
- **Federal Geographic Data Committee (FGDC) (http://www.fgdc.gov/) – Content Standard for Digital Geospatial Metadata (CSDGM)**





Geospatial Metadata Standard Examples (3)

- **Global Change Master Directory (GCMD) (NASA) (http://gcmd.nasa.gov/)**



Geospatial Metadata Standard Examples (4)

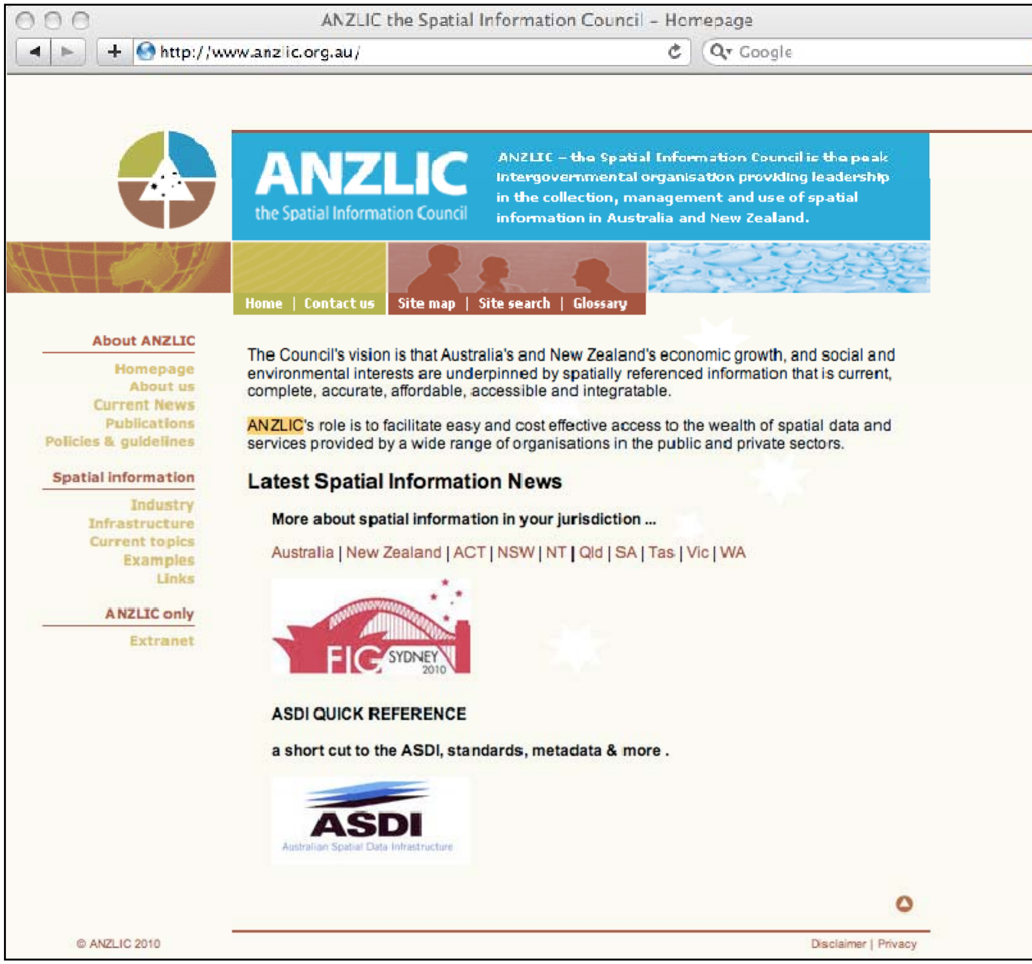
- **Dublin Core Metadata Initiative (http://dublincore.org/)**

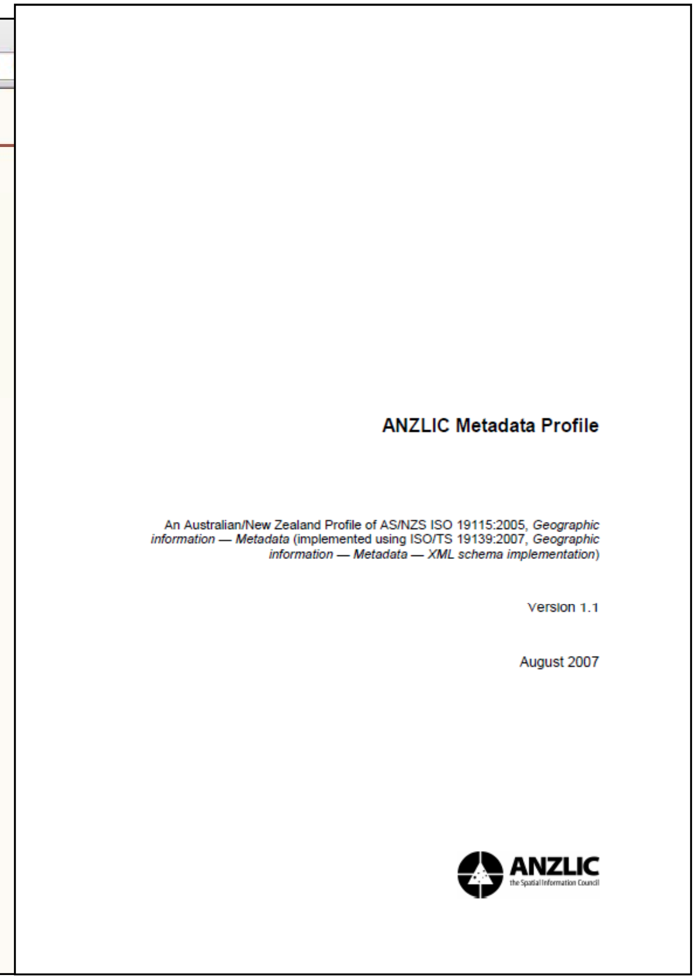
An example set of Dublin Core elements

```
<head profile="http://dublincore.org">
<title> ... </title>

<link rel="schema.DC" href="http://purl.org/dc/elements/1.1/" />
<link rel="schema.DCTERMS" href="http://purl.org/dc/terms/" />

<meta name="DC.Identifier" schema="DCterms:URI"
        content="http://tutorialsonline.info/Common/DublinCore.html" />
<meta name="DC.Format" schema="DCterms:IMT" content="text/html" /> <meta name="DC.Title" xml:lang="EN" content="Dublin Core Tutorial" />
<meta name="DC.Creator" content="Alan Kelsey" />
<meta name="DC.Subject" xml:lang="EN" content="Dublin Core Meta Tags" />
<meta name="DC.Publisher" content="Alan Kelsey, Ltd." />
<meta name="DC.Publisher.Address" content="alan@tutorialsonline.info" />
<meta name="DC.Contributor" content="Alan Kelsey" />
<meta name="DC.Date" scheme="ISO8601" content="2007-01-06" />
<meta name="DC.Type" content="text/html" />
<meta name="DC.Description" xml:lang="EN"
        content="Learning Advanced Web Design can be fun and easy! Look at a site designed specifically to help you learn how to design web pages with proper tags, styles, and
        scripting." />
<meta name="DC.Identifier" content="http://tutorialsonline.info/Common/DublinCore.html" />
<meta name="DC.Relation" content="TutorialOnline.info" scheme="IsPartOf" />
<meta name="DC.Coverage" content="Hennepin Technical College" />
<meta name="DC.Rights" content="Copyright 2007, Alan Kelsey, Ltd.  All rights reserved." />
<meta name="DC.Date.X-MetadataLastModified" scheme="ISO8601" content="2007-01-06" />
<meta name="DC.Language" scheme="dcterms:RFC1766" content="EN" />
```

Geospatial Metadata Standard Examples (5)

- **Australia New Zealand Land Information Council (ANZLIC) (http://www.anzlic.org.au/)**




ANZLIC Metadata Profile

An Australian/New Zealand Profile of AS/NZS ISO 19115:2005, *Geographic information — Metadata* (implemented using ISO/TS 19139:2007, *Geographic information — Metadata — XML schema implementation*)

Version 1.1

August 2007

ANZLIC
the Spatial Information Council

ISO 19115 Metadata Standard

Our metadata were modelled after the ISO 19115 standard because the participated countries - India, Malaysia and Singapore are the ISO members and the standard is commonly used in many countries

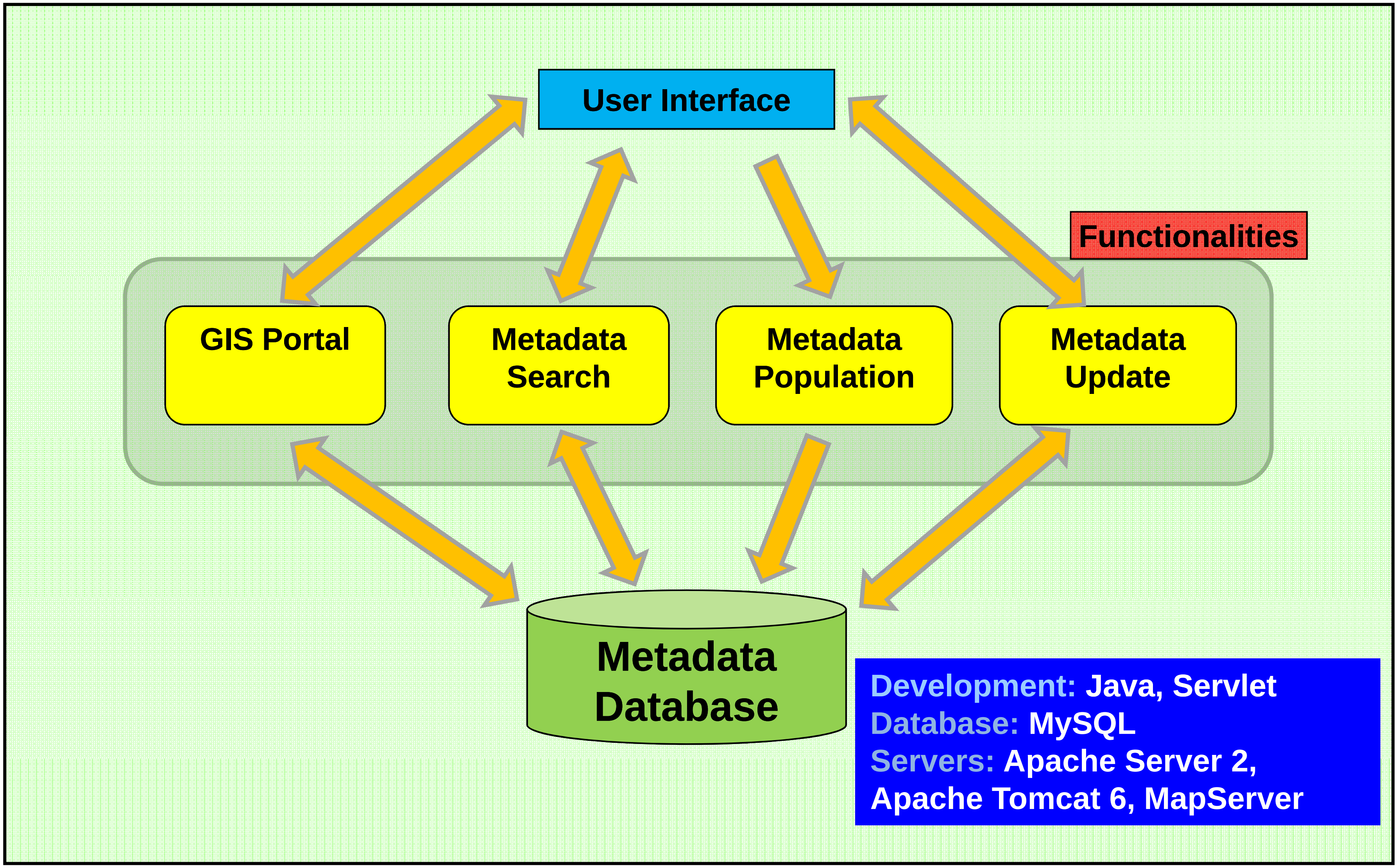
Three types of elements – *mandatory*, *optional*, and *conditional*

Table 3 — Core metadata for geographic datasets

Dataset title (M) (MD_Metadata > MD_DataIdentification.citation > CI_Citation.title)	**Spatial representation type** (O) (MD_Metadata > MD_DataIdentification.spatialRepresentationType)
Dataset reference date (M) (MD_Metadata > MD_DataIdentification.citation > CI_Citation.date)	**Reference system** (O) (MD_Metadata > MD_ReferenceSystem)
Dataset responsible party (O) (MD_Metadata > MD_DataIdentification.pointOfContact > CI_ResponsibleParty)	**Lineage** (O) (MD_Metadata > DQ_DataQuality.lineage > LI_Lineage)
Geographic location of the dataset (by four coordinates or by geographic identifier) (C) (MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_GeographicExtent > EX_GeographicBoundingBox or EX_GeographicDescription)	**On-line resource** (O) (MD_Metadata > MD_Distribution > MD_DigitalTransferOption.onLine > CI_OnlineResource)
Dataset language (M) (MD_Metadata > MD_DataIdentification.language)	**Metadata file identifier** (O) (MD_Metadata.fileIdentifier)
Dataset character set (C) (MD_Metadata > MD_DataIdentification.characterSet)	**Metadata standard name** (O) (MD_Metadata.metadataStandardName)
Dataset topic category (M) (MD_Metadata > MD_DataIdentification.topicCategory)	**Metadata standard version** (O) (MD_Metadata.metadataStandardVersion)
Spatial resolution of the dataset (O) (MD_Metadata > MD_DataIdentification.spatialResolution > MD_Resolution.equivalentScale or MD_Resolution.distance)	**Metadata language** (C) (MD_Metadata.language)
Abstract describing the dataset (M) (MD_Metadata > MD_DataIdentification.abstract)	**Metadata character set** (C) (MD_Metadata.characterSet)
Distribution format (O) (MD_Metadata > MD_Distribution > MD_Format.name and MD_Format.version)	**Metadata point of contact** (M) (MD_Metadata.contact > CI_ResponsibleParty)
Additional extent information for the dataset (vertical and temporal) (O) (MD_Metadata > MD_DataIdentification.extent > EX_Extent > EX_TemporalExtent or EX_VerticalExtent)	**Metadata date stamp** (M) (MD_Metadata.dateStamp)

(http://www.iso.org/iso/catalogue_detail.htm?csnumber=26020)

DIMS Metadata System Framework



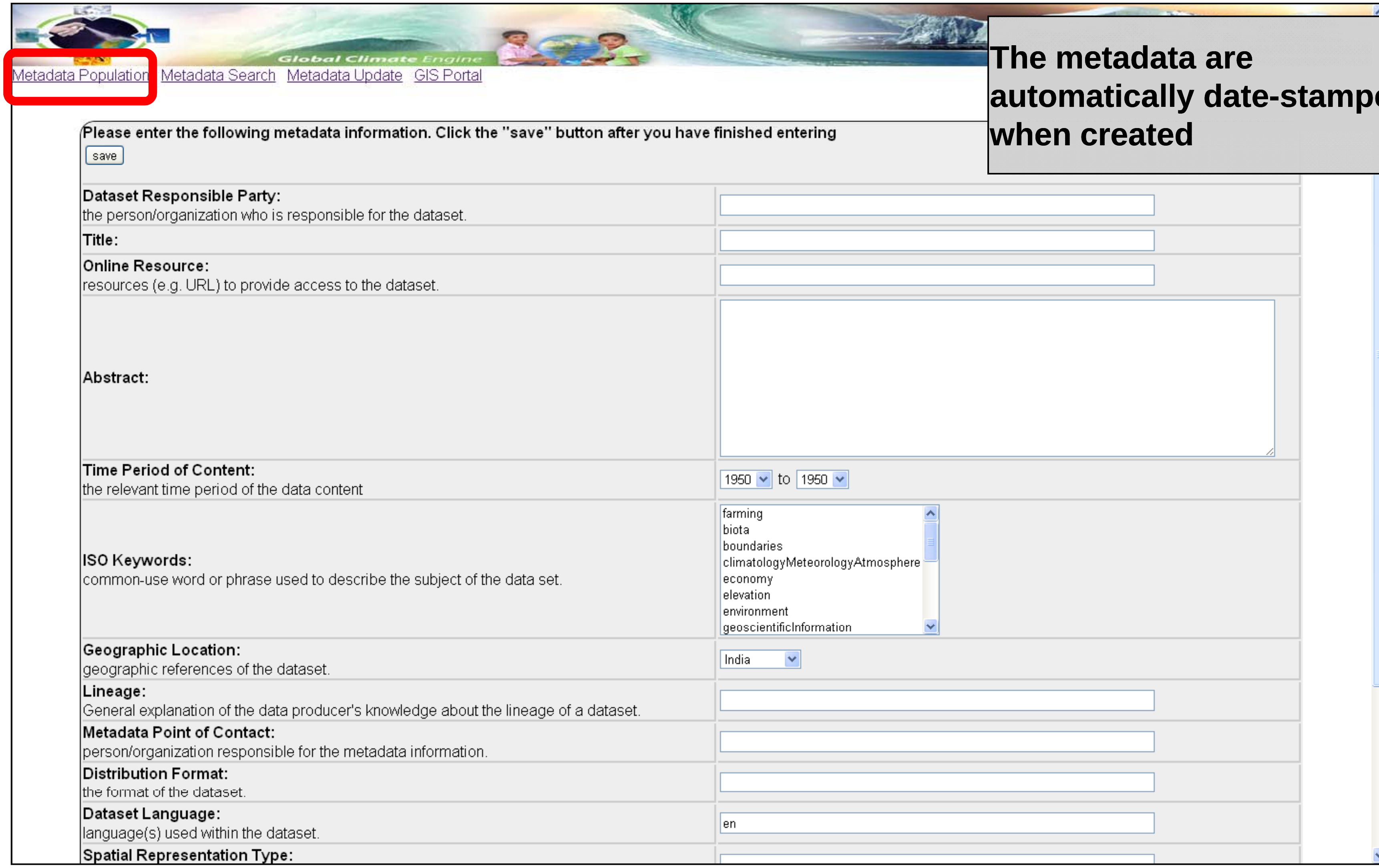
Development: Java, Servlet
Database: MySQL
Servers: Apache Server 2, Apache Tomcat 6, MapServer

Metadata Database

The columns in the metadata database follow the standard's mandatory elements

```
MySQL Command Line Client

mysql> describe metadata;
+---------------------+--------------+------+-----+---------+-------+
| Field               | Type         | Null | Key | Default | Extra |
+---------------------+--------------+------+-----+---------+-------+
| METADATA_ID         | int(11)      | NO   |     | NULL    |       |
| DATASET_TITLE       | varchar(250) | YES  |     | NULL    |       |
| TIMEPERIOD_START    | int(11)      | YES  |     | NULL    |       |
| TIMEPERIOD_END      | int(11)      | YES  |     | NULL    |       |
| DATASET_RESPARTY    | varchar(300) | YES  |     | NULL    |       |
| GEO_LOC             | varchar(200) | YES  |     | NULL    |       |
| DATASET_LANG        | varchar(50)  | YES  |     | NULL    |       |
| DATASET_CHARSET     | varchar(50)  | YES  |     | NULL    |       |
| DATASET_TOPCAT      | varchar(200) | YES  |     | NULL    |       |
| DATASET_SPATIALRES  | varchar(200) | YES  |     | NULL    |       |
| DATASET_ABS         | varchar(900) | YES  |     | NULL    |       |
| DISTRI_FORMAT       | varchar(100) | YES  |     | NULL    |       |
| SPATIAL_REPTYPE     | varchar(100) | YES  |     | NULL    |       |
| REF_SYSTEM          | varchar(100) | YES  |     | NULL    |       |
| LINEAGE             | varchar(300) | YES  |     | NULL    |       |
| ONLINE_RESOURCE     | varchar(100) | YES  |     | NULL    |       |
| META_STANDARDNAME   | varchar(100) | YES  |     | NULL    |       |
| META_STANDVERSION   | varchar(50)  | YES  |     | NULL    |       |
| META_LANG           | varchar(50)  | YES  |     | NULL    |       |
| META_CHARSET        | varchar(50)  | YES  |     | NULL    |       |
| META_PNTOFCONTACT   | varchar(300) | YES  |     | NULL    |       |
| META_DATE           | int(11)      | YES  |     | NULL    |       |
+---------------------+--------------+------+-----+---------+-------+
22 rows in set (0.17 sec)
```

Metadata Population


Global Climate Engine

Metadata Population Metadata Search Metadata Update GIS Portal

Please enter the following metadata information. Click the "save" button after you have finished entering

save

Dataset Responsible Party: the person/organization who is responsible for the dataset.	
Title:	
Online Resource: resources (e.g. URL) to provide access to the dataset.	
Abstract:	
Time Period of Content: the relevant time period of the data content	1950 to 1950
ISO Keywords: common-use word or phrase used to describe the subject of the data set.	farming biota boundaries climatologyMeteorologyAtmosphere economy elevation environment geoscientificInformation
Geographic Location: geographic references of the dataset.	India
Lineage: General explanation of the data producer's knowledge about the lineage of a dataset.	
Metadata Point of Contact: person/organization responsible for the metadata information.	
Distribution Format: the format of the dataset.	
Dataset Language: language(s) used within the dataset.	en
Spatial Representation Type:	

The metadata are automatically date-stamped when created

(http://dims.globalclimate-engine.org/Metadata_UNM/MetadataForm)

Metadata Update

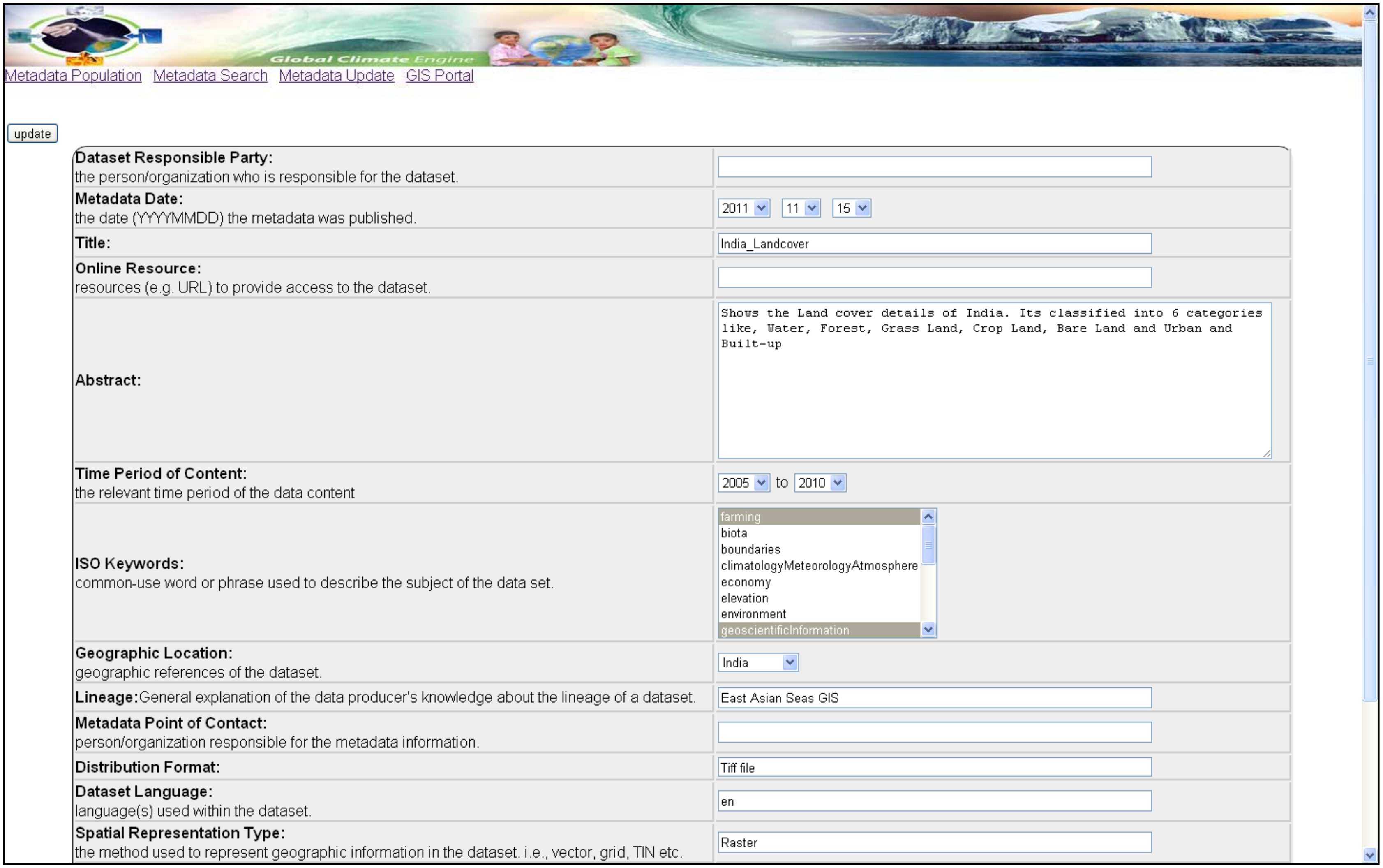
Metadata Population   Metadata Search   Metadata Update   GIS Portal

You have entered the following metadata records

Record	Title	Abstract		
1	India_Coastline	[...] Coastline of India(2007) [...]	edit	delete
2	India_Countryboundary	[...] Boudaries of India(2008) [...]	edit	delete
3	India_Majorcities	[...] Major cities represents the location of the Major cities in India [...]	edit	delete
4	India_Landcover	[...] Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	edit	delete
5	India_Stateboundary	[...] Administrative Units represents the boundaries for the first-level administrative units of the world. [...]	edit	delete
6	India_Elevation	[...] NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. The vertical error of the DEMs is reported to be less than 16m. [...]	edit	delete
7	Malaysia_Coastline	[...] Coastline of Malaysia(2007) [...]	edit	delete
8	Malaysia_Countryboundary	[...] Boudaries of Malaysia(2008) [...]	edit	delete
9	Malaysia_Majorcities	[...] Major cities represents the location of the Major cities in Malaysia [...]	edit	delete
10	Malaysia_Stateboundary	[...] Administrative Units represents the boundaries for the first-level administrative units of the world. [...]	edit	delete
11	Malaysia_Landcover	[...] Shows the Land cover details of Malaysia. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	edit	delete
12	Malaysia_Elevation	[...] NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. The vertical error of the DEMs is reported to be less than 16m. [...]	edit	delete
13	Singapore_Coastline	[...] Coastline of Singapore(2007) [...]	edit	delete
14	Singapore_Countryboundary	[...] Boudaries of Singapore(2008) [...]	edit	delete

(http://dims.globalclimate-engine.org/Metadata_UNM/Edit)

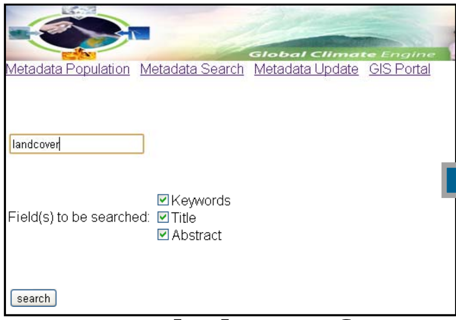
Metadata Update (cont.)



Dataset Responsible Party: the person/organization who is responsible for the dataset.	
Metadata Date: the date (YYYYMMDD) the metadata was published.	2011 / 11 / 15
Title:	India_Landcover
Online Resource: resources (e.g. URL) to provide access to the dataset.	
Abstract:	Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up
Time Period of Content: the relevant time period of the data content	2005 to 2010
ISO Keywords: common-use word or phrase used to describe the subject of the data set.	farming, biota, boundaries, climatologyMeteorologyAtmosphere, economy, elevation, environment, geoscientificInformation
Geographic Location: geographic references of the dataset.	India
Lineage: General explanation of the data producer's knowledge about the lineage of a dataset.	East Asian Seas GIS
Metadata Point of Contact: person/organization responsible for the metadata information.	
Distribution Format:	Tiff file
Dataset Language: language(s) used within the dataset.	en
Spatial Representation Type: the method used to represent geographic information in the dataset. i.e., vector, grid, TIN etc.	Raster

(http://dims.globalclimate-engine.org/Metadata_UNM/Edit)

Metadata Search



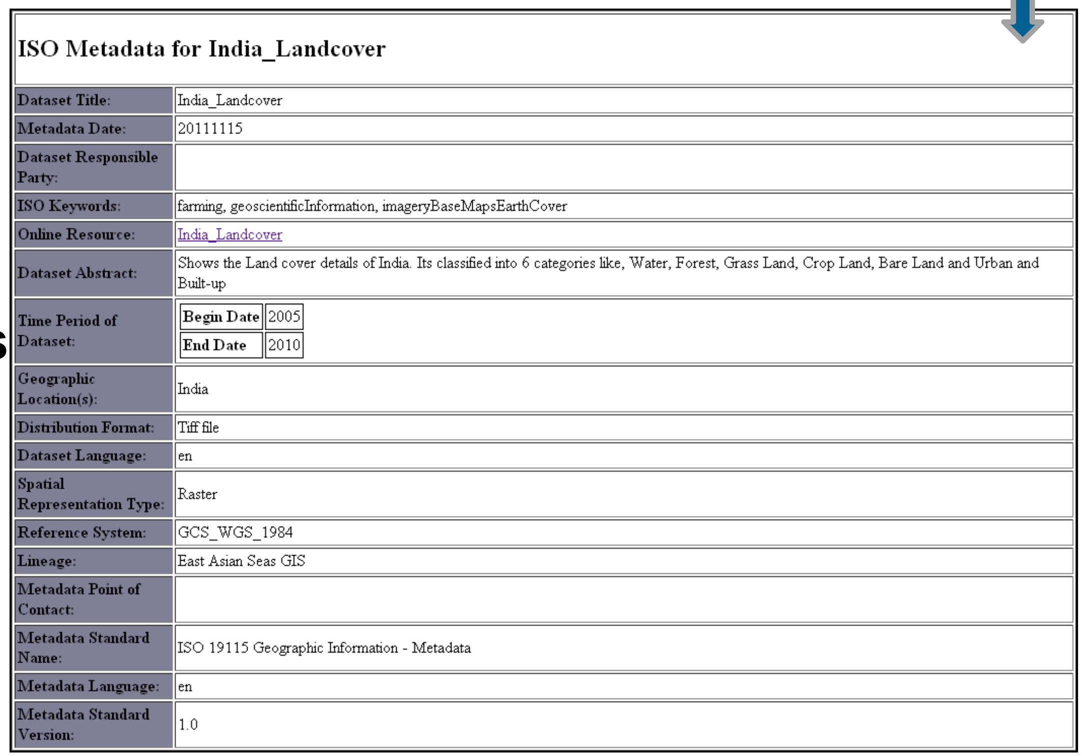
Search interface

Search results [3] for **landcover**.

Record	Title	Abstract	Keywords	Metadata
1	India_Landcover	[...] Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	farming, geoscientificInformation, imageryBaseMapsEarthCover	Detail
2	Malaysia_Landcover	[...] Shows the Land cover details of Malaysia. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	farming, environment, geoscientificInformation, imageryBaseMapsEarthCover	Detail
3	Singapore_landcover	[...] Shows the Land cover details of Singapore. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	environment, geoscientificInformation, imageryBaseMapsEarthCover	Detail

Search results

Metadata details

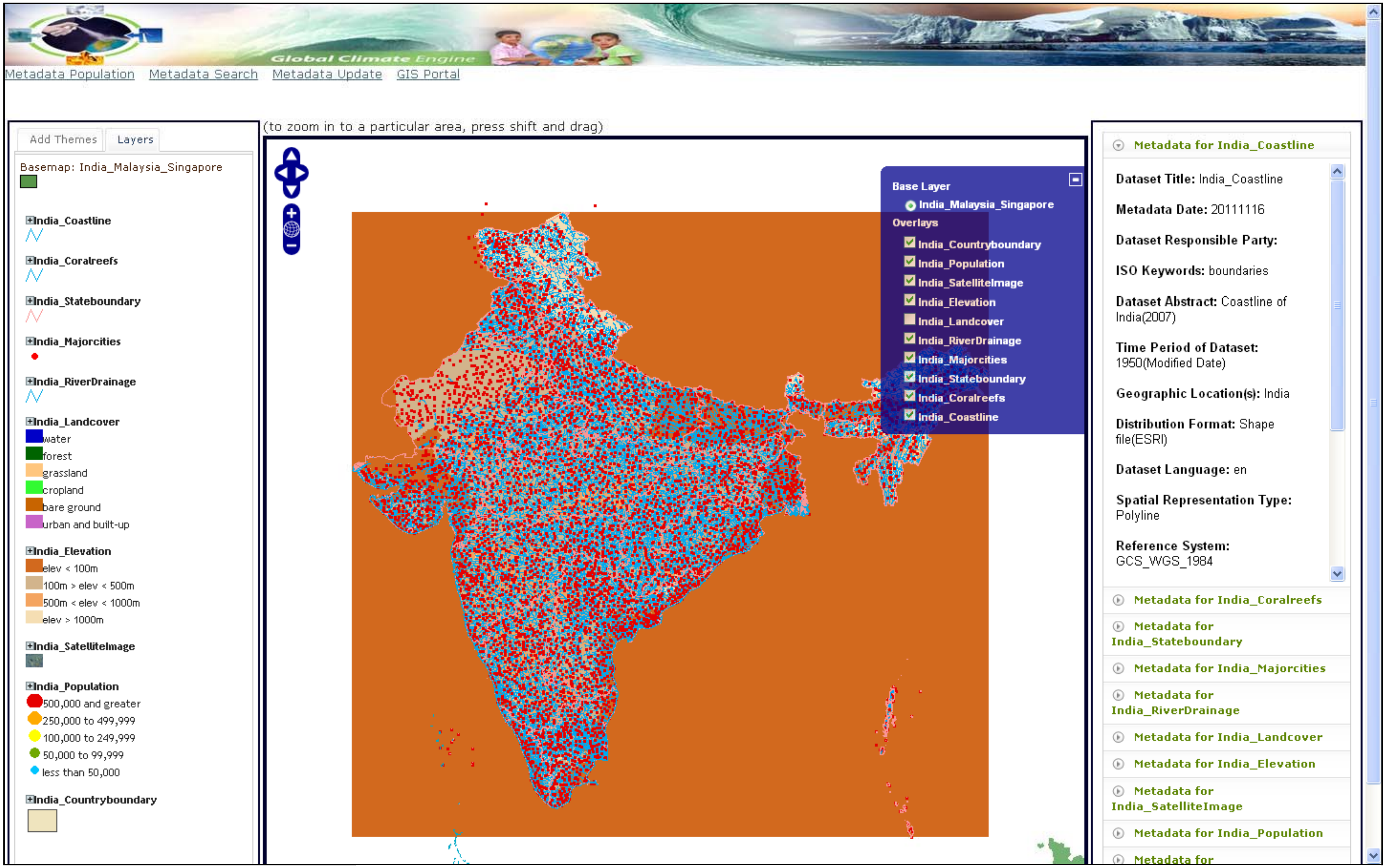


ISO Metadata for India_Landcover

Dataset Title:	India_Landcover
Metadata Date:	20111115
Dataset Responsible Party:	
ISO Keywords:	farming, geoscientificInformation, imageryBaseMapsEarthCover
Online Resource:	India_Landcover
Dataset Abstract:	Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up
Time Period of Dataset:	Begin Date 2005 End Date 2010
Geographic Location(s):	India
Distribution Format:	Tiff file
Dataset Language:	en
Spatial Representation Type:	Raster
Reference System:	GCS_WGS_1984
Lineage:	East Asian Seas GIS
Metadata Point of Contact:	
Metadata Standard Name:	ISO 19115 Geographic Information - Metadata
Metadata Language:	en
Metadata Standard Version:	1.0

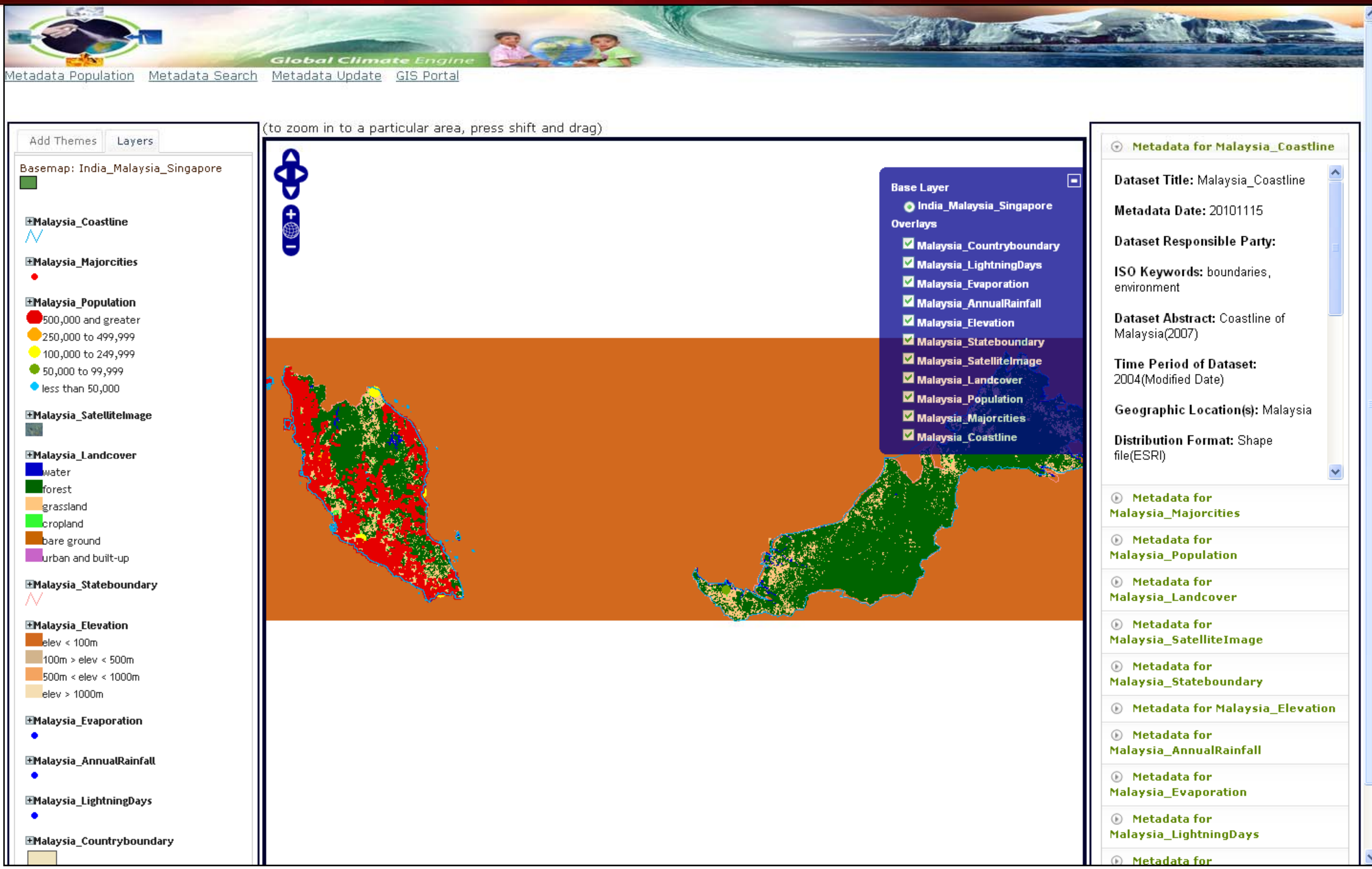
(http://dims.globalclimate-engine.org/Metadata_UNM/SearchForm)

GIS Portal (India)

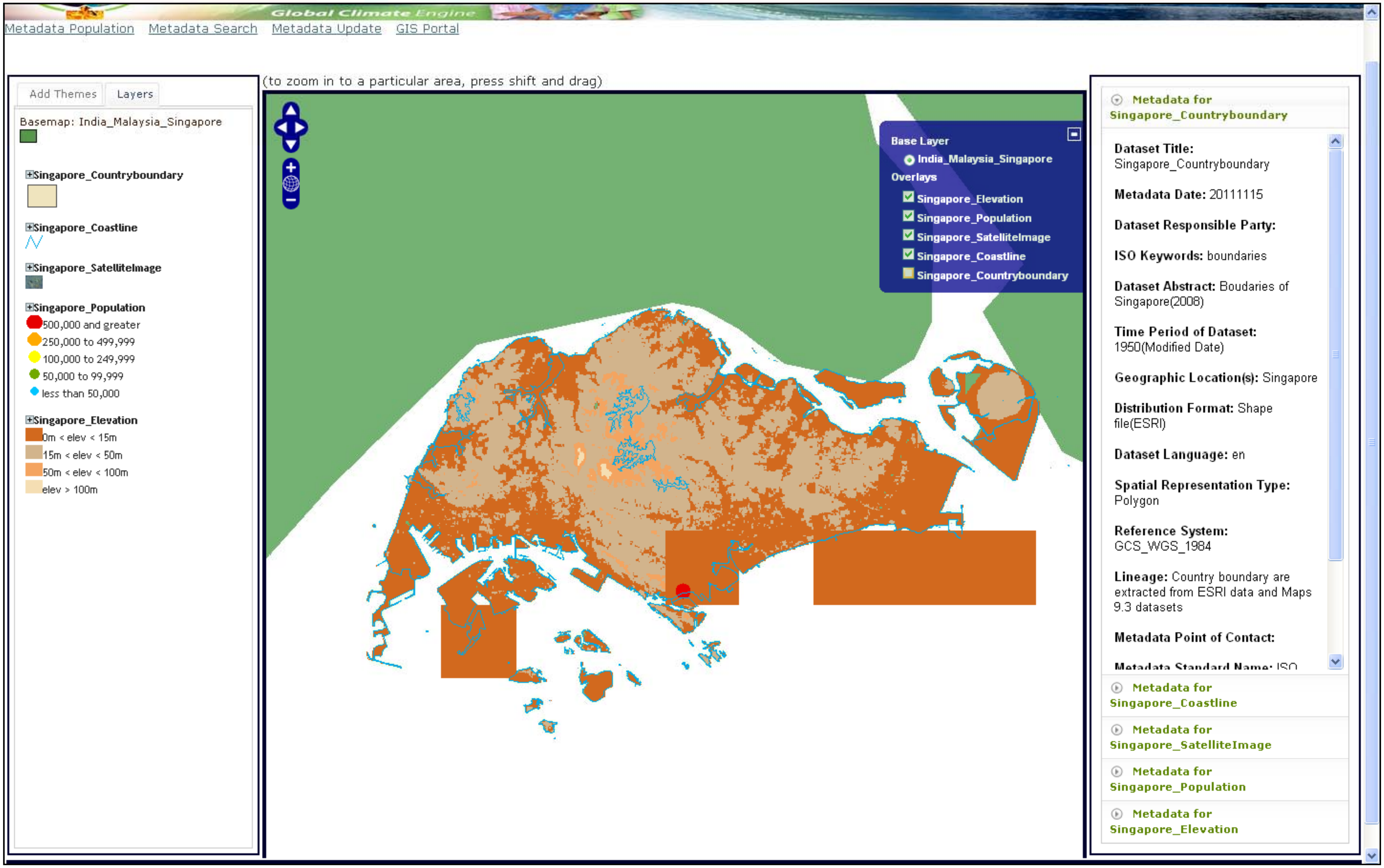


(http://dims.globalclimate-engine.org/Metadata_UNM/GISServer)

GIS Portal (Malaysia)

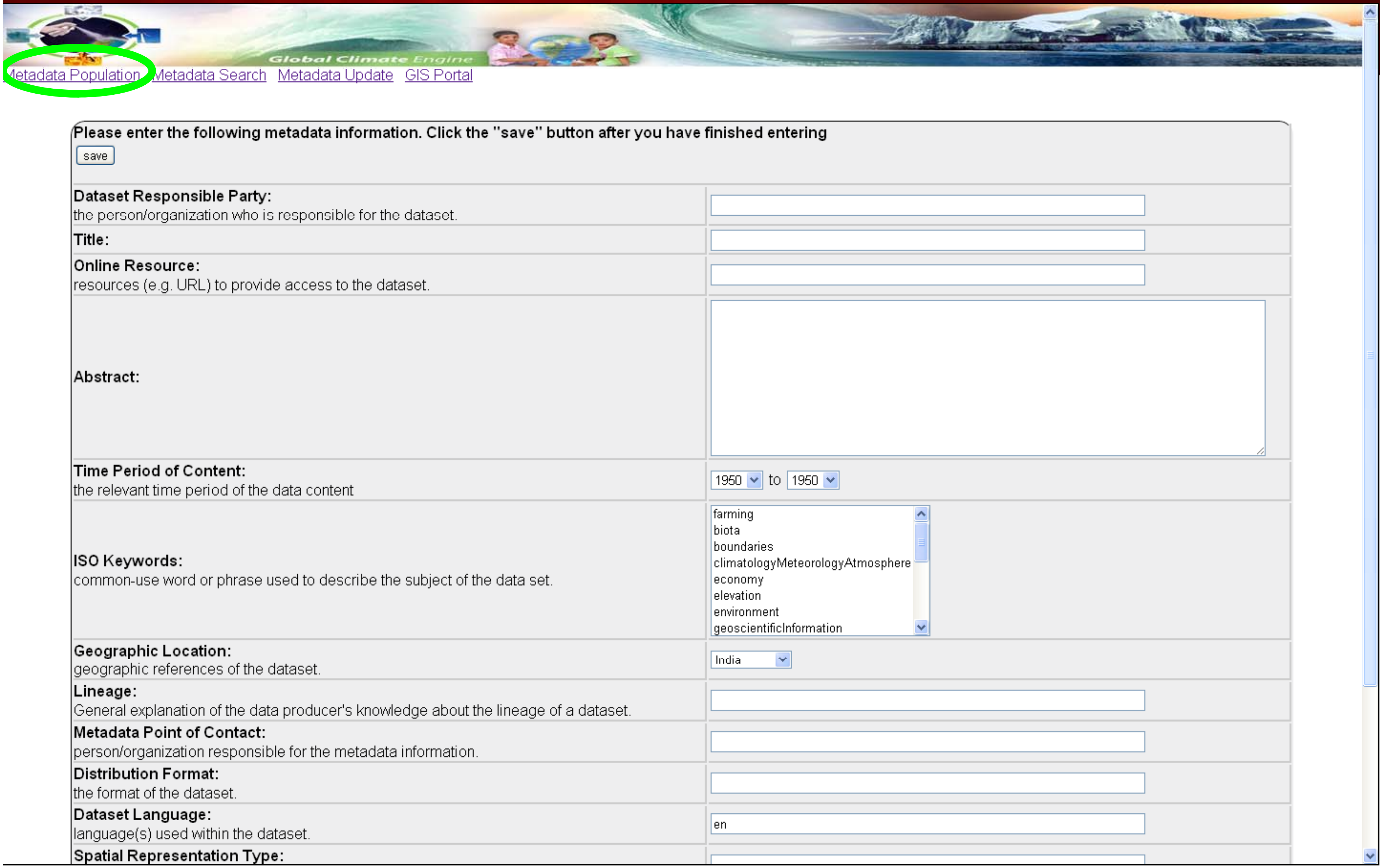


GIS Portal (Singapore)



Demonstration

Metadata Population

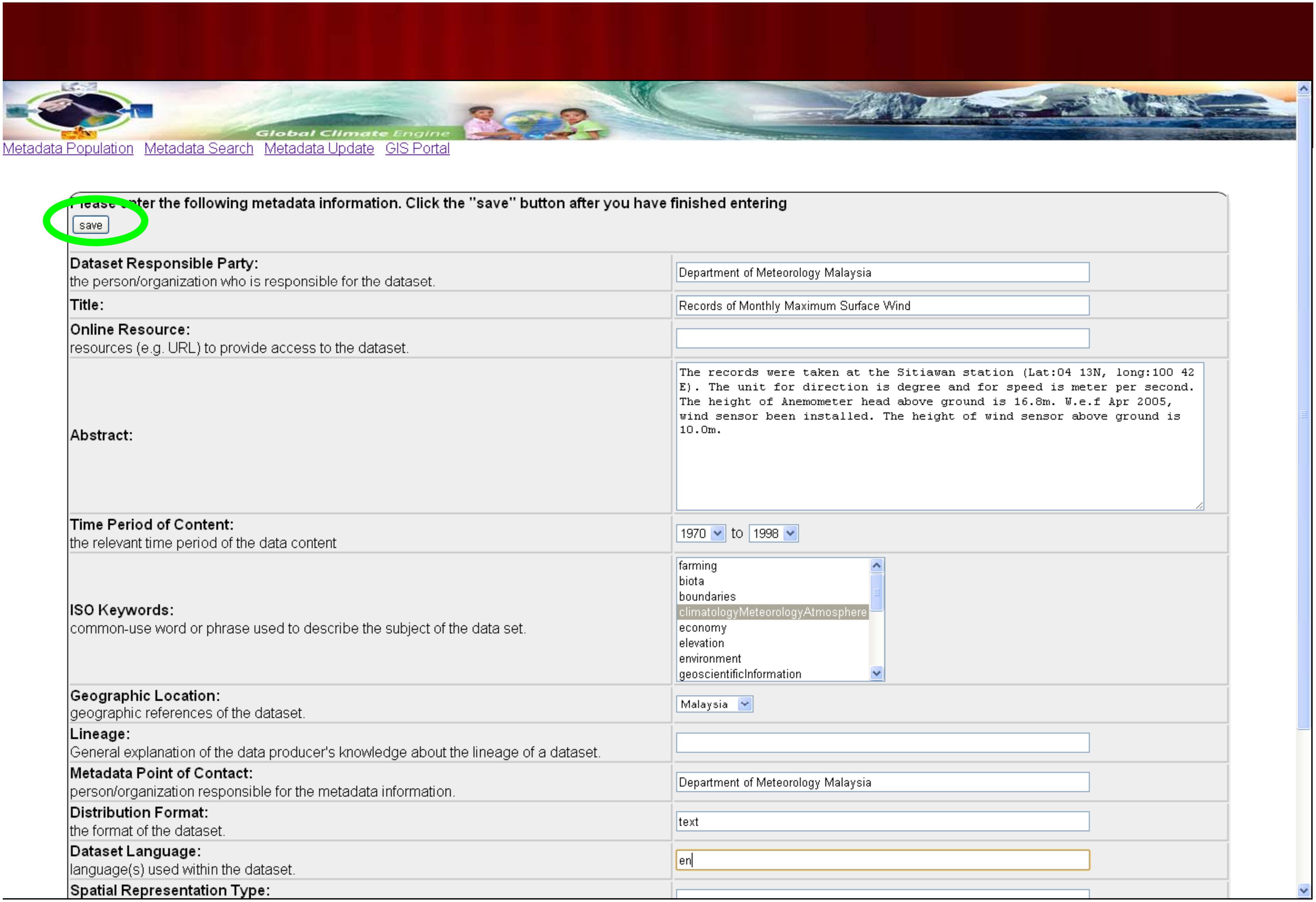


Metadata Population Metadata Search Metadata Update GIS Portal

Please enter the following metadata information. Click the "save" button after you have finished entering

save

Dataset Responsible Party: the person/organization who is responsible for the dataset.	Department of Meteorology Malaysia
Title:	
Online Resource: resources (e.g. URL) to provide access to the dataset.	
Abstract:	
Time Period of Content: the relevant time period of the data content	1950 to 1950
ISO Keywords: common-use word or phrase used to describe the subject of the data set.	farming biota boundaries climatologyMeteorologyAtmosphere economy elevation environment geoscientificInformation
Geographic Location: geographic references of the dataset.	India
Lineage: General explanation of the data producer's knowledge about the lineage of a dataset.	
Metadata Point of Contact: person/organization responsible for the metadata information.	
Distribution Format: the format of the dataset.	
Dataset Language: language(s) used within the dataset.	en
Spatial Representation Type:	


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Please enter the following metadata information. Click the "save" button after you have finished entering
save
Dataset Responsible Party:
the person/organization who is responsible for the dataset.
Department of Meteorology Malaysia
Title:
Records of Monthly Maximum Surface Wind
Online Resource:
resources (e.g. URL) to provide access to the dataset.
Abstract:
The records were taken at the Sitiawan station (Lat:04 13N, long:100 42 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 16.8m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m.
Time Period of Content:
the relevant time period of the data content
1970 to 1998
ISO Keywords:
common-use word or phrase used to describe the subject of the data set.
farming
biota
boundaries
climatologyMeteorologyAtmosphere
economy
elevation
environment
geoscientificInformation
Geographic Location:
geographic references of the dataset.
Malaysia
Lineage:
General explanation of the data producer's knowledge about the lineage of a dataset.
Metadata Point of Contact:
person/organization responsible for the metadata information.
Department of Meteorology Malaysia
Distribution Format:
the format of the dataset.
text
Dataset Language:
language(s) used within the dataset.
en
Spatial Representation Type:

Thank you! You have just entered one metadata record into the database

Metadata Update

Metadata Population Metadata Search Metadata Update GIS Portal

You have entered the following metadata records

Record	Title	Abstract		
1	India_Coastline	[...] Coastline of India(2007) [...]	edit	delete
2	India_Countryboundary	[...] Boudaries of India(2008) [...]	edit	delete
3	India_Majorcities	[...] Major cities represents the location of the Major cities in India [...]	edit	delete
4	India_Landcover	[...] Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	edit	delete
5	India_Stateboundary	[...] Administrative Units represents the boundaries for the first-level administrative units of the world. [...]	edit	delete
6	India_Elevation	[...] NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. The vertical error of the DEMs is reported to be less than 16m. [...]	edit	delete
7	Malaysia_Coastline	[...] Coastline of Malaysia(2007) [...]	edit	delete
8	Malaysia_Countryboundary	[...] Boudaries of Malaysia(2008) [...]	edit	delete
9	Malaysia_Majorcities	[...] Major cities represents the location of the Major cities in Malaysia [...]	edit	delete
10	Malaysia_Stateboundary	[...] Administrative Units represents the boundaries for the first-level administrative units of the world. [...]	edit	delete
11	Malaysia_Landcover	[...] Shows the Land cover details of Malaysia. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	edit	delete
12	Malaysia_Elevation	[...] NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. The vertical error of the DEMs is reported to be less than 16m. [...]	edit	delete
13	Singapore_Coastline	[...] Coastline of Singapore(2007) [...]	edit	delete
14	Singapore_Countryboundary	[...] Boudaries of Singapore(2008) [...]	edit	delete

Metadata Population Metadata Search Metadata Update GIS Portal

update

Dataset Responsible Party: the person/organization who is responsible for the dataset.	Department of Meteorology Malaysia
Metadata Date: the date (YYYYMMDD) the metadata was published.	2010 11 16
Title:	Records of Monthly Maximum Surface Wind
Online Resource: resources (e.g. URL) to provide access to the dataset.	
Abstract:	The records were taken at the Sitiawan station (Lat:04 13N, long:100 42 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 16.8m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m.
Time Period of Content: the relevant time period of the data content	1970 to 1998
ISO Keywords: common-use word or phrase used to describe the subject of the data set.	farming biota boundaries climatologyMeteorologyAtmosphere economy elevation environment geoscientificInformation
Geographic Location: geographic references of the dataset.	Malaysia
Lineage: General explanation of the data producer's knowledge about the lineage of a dataset.	
Metadata Point of Contact: person/organization responsible for the metadata information.	Department of Meteorology Malaysia
Distribution Format:	text
Dataset Language: language(s) used within the dataset.	en
Spatial Representation Type: the method used to represent geographic information in the dataset. i.e., vector, grid, TIN etc.	

Metadata Population Metadata Search Metadata Update GIS Portal

You have entered the following metadata records

Record	Title	Abstract		
1	India_Coastline	[...] Coastline of India(2007) [...]	edit	delete
2	India_Countryboundary	[...] Boudaries of India(2008) [...]	edit	delete
3	India_Majorcities	[...] Major cities represents the location of the Major cities in India [...]	edit	delete
4	India_Landcover	[...] Shows the Land cover details of India. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	edit	delete
5	India_Stateboundary	[...] Administrative Units represents the boundaries for the first-level administrative units of the world. [...]	edit	delete
6	India_Elevation	[...] NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. The vertical error of the DEMs is reported to be less than 16m. [...]	edit	delete
7	Malaysia_Coastline	[...] Coastline of Malaysia(2007) [...]	edit	delete
8	Malaysia_Countryboundary	[...] Boudaries of Malaysia(2008) [...]	edit	delete
9	Malaysia_Majorcities	[...] Major cities represents the location of the Major cities in Malaysia [...]	edit	delete
10	Malaysia_Stateboundary	[...] Administrative Units represents the boundaries for the first-level administrative units of the world. [...]	edit	delete
11	Malaysia_Landcover	[...] Shows the Land cover details of Malaysia. Its classified into 6 categories like, Water, Forest, Grass Land, Crop Land, Bare Land and Urban and Built-up [...]	edit	delete
12	Malaysia_Elevation	[...] NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe. This data is currently distributed free of charge by USGS and is available for download from the National Map Seamless Data Distribution System, or the USGS ftp site. The SRTM data is available as 3 arc second (approx. 90m resolution) DEMs. The vertical error of the DEMs is reported to be less than 16m. [...]	edit	delete
13	Singapore_Coastline	[...] Coastline of Singapore(2007) [...]	edit	delete
14	Singapore_Countryboundary	[...] Boudaries of Singapore(2008) [...]	edit	delete

Metadata Search

Metadata Population Metadata Search Metadata Update GIS Portal

Field(s) to be searched: ☑ Keywords ☑ Title ☑ Abstract

search

Metadata Population Metadata Search Metadata Update GIS Portal

wind

Field(s) to be searched:
- [x] Keywords
- [x] Title
- [x] Abstract

search

Search results [8] for **wind**.

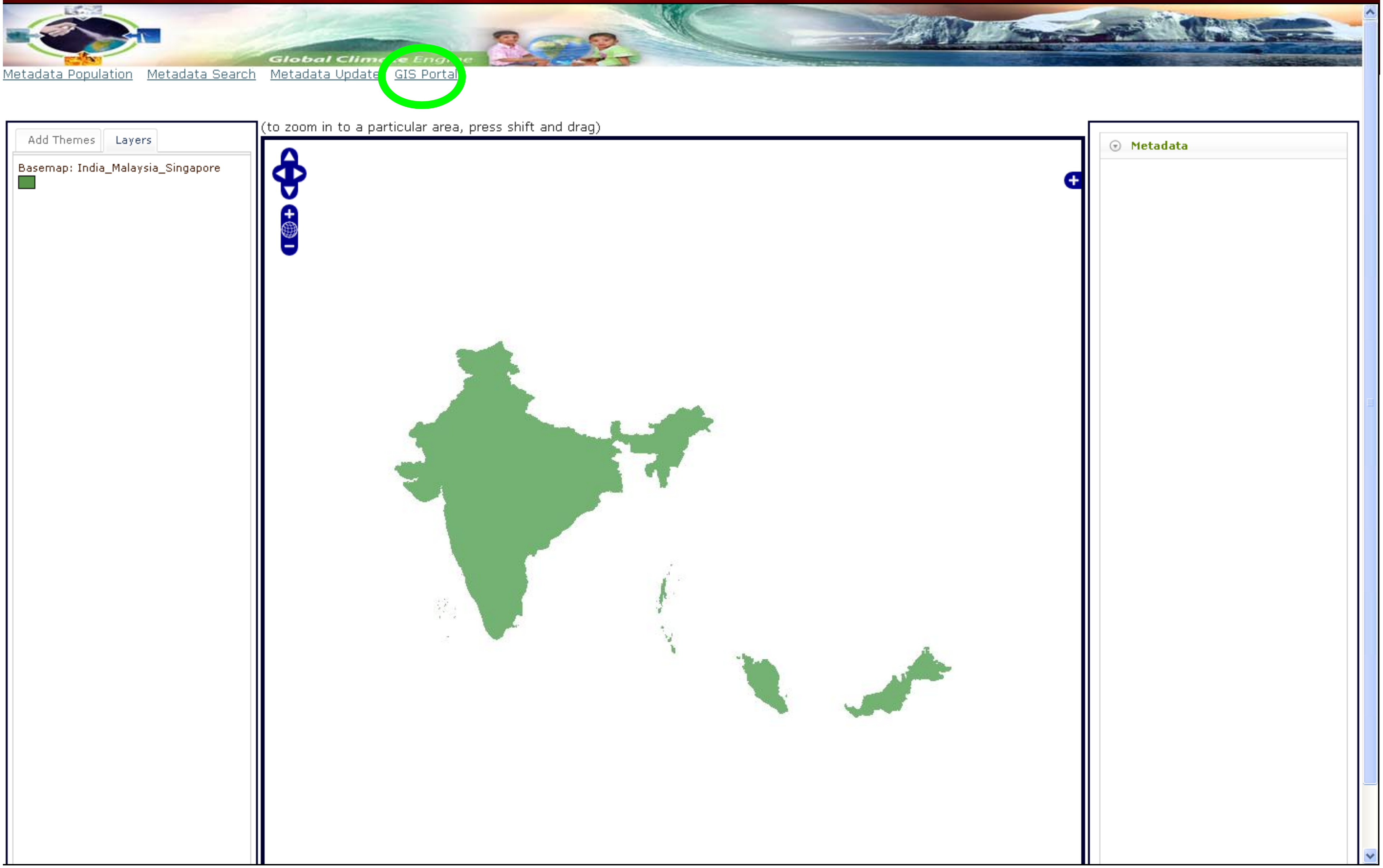
Record	Title	Abstract	Keywords	Metadata
1	Records of Monthly Maximum Surface Wind	[...] The records were taken at the Sitiawan station (Lat:04 13N, long:100 42 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 16.8m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
2	Records of Monthly Maximum Surface Wind - Kota Bahru	[...] The records were taken at the Kota Bahru station (Lat:06 10N, long:102 17 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 14.0m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
3	Records of Monthly Maximum Surface Wind - Kuala Terengganu Airport	[...] The records were taken at the Kuala Terengganu Airport (Lat:05 23N, long:103 06 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 14.0m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
4	Records of Monthly Maximum Surface Wind - Kuantan	[...] The records were taken at the Kuantan station (Lat:03 47N, long:103 13 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 14.0m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
5	Records of Monthly Maximum Surface Wind - Kuching	[...] The records were taken at the Kuching station (Lat:01 29N, long:110 20 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 12.2m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
6	Records of Monthly Maximum Surface Wind - Kota Kinabalu	[...] The records were taken at the Kota Kinabalu station (Lat:05 56N, long:116 03 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 14.5m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
7	Records of Monthly Maximum Surface Wind - Mersing	[...] The records were taken at the Mersing station (Lat:02 27N, long:103 50 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 13.4m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail
8	Records of Monthly Maximum Surface Wind	[...] The records were taken at the Sitiawan station (Lat:04 13N, long:100 42 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 16.8m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m. [...]	climatologyMeteorologyAtmosphere	Detail

Return to the Result Page

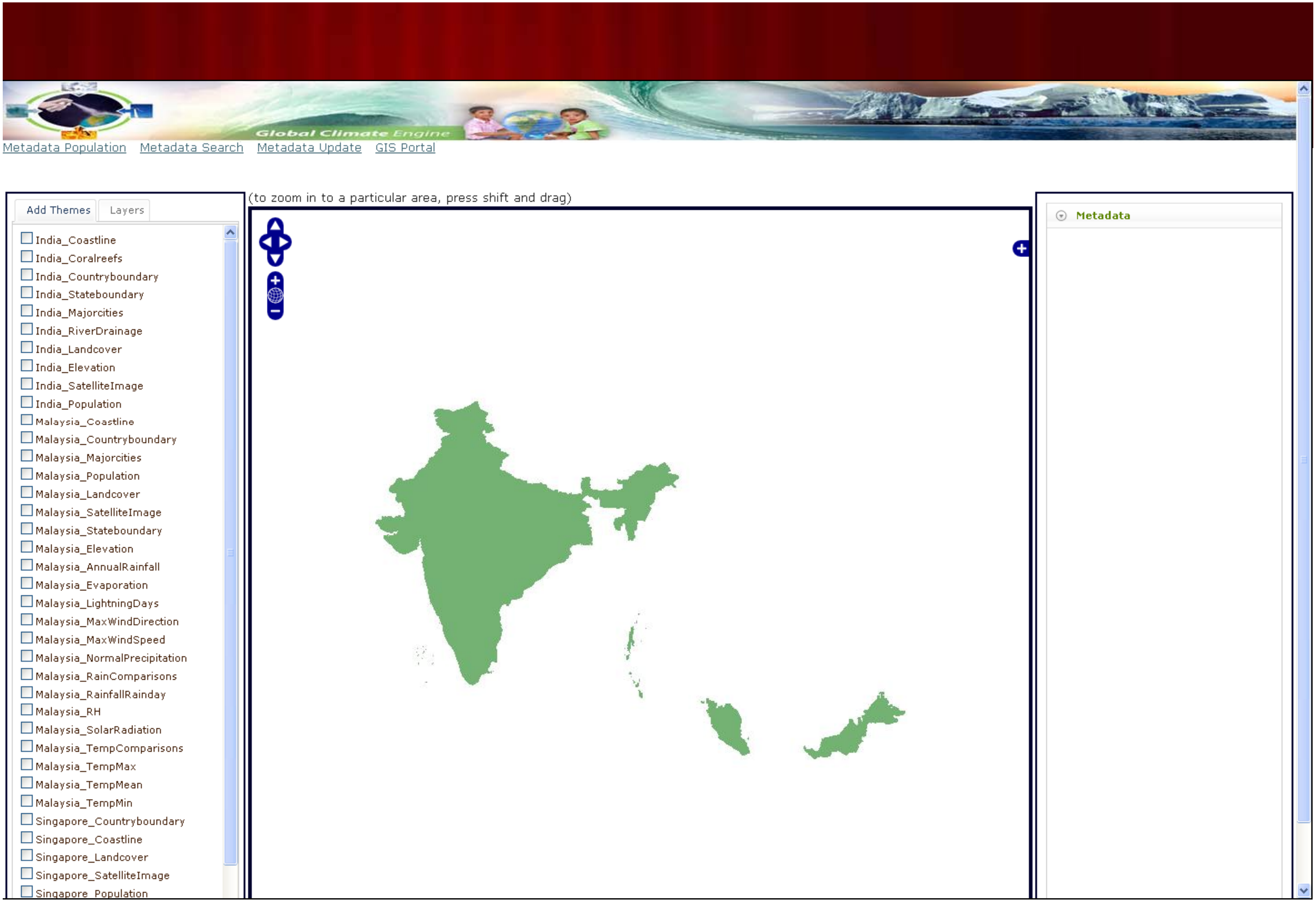
ISO Metadata for Records of Monthly Maximum Surface Wind

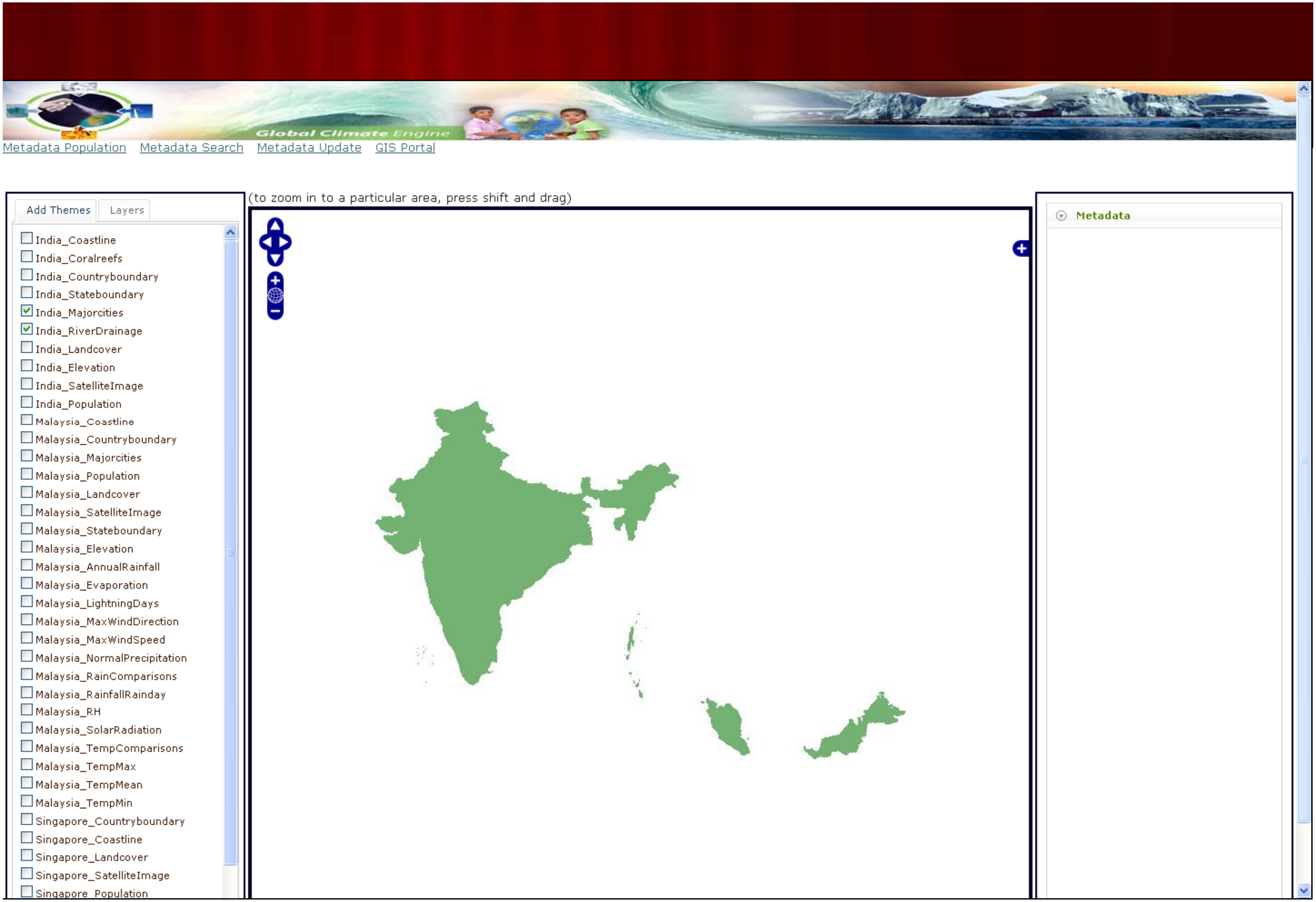
Dataset Title:	Records of Monthly Maximum Surface Wind
Metadata Date:	20101116
Dataset Responsible Party:	Department of Meteorology Malaysia
ISO Keywords:	climatologyMeteorologyAtmosphere
Online Resource:	Records of Monthly Maximum Surface Wind
Dataset Abstract:	The records were taken at the Sitiawan station (Lat:04 13N, long:100 42 E). The unit for direction is degree and for speed is meter per second. The height of Anemometer head above ground is 16.8m. W.e.f Apr 2005, wind sensor been installed. The height of wind sensor above ground is 10.0m.
Time Period of Dataset:	**Begin Date** 1970 **End Date** 1998
Geographic Location(s):	Malaysia
Distribution Format:	text
Dataset Language:	en
Spatial Representation Type:	
Reference System:	
Lineage:	
Metadata Point of Contact:	Department of Meteorology Malaysia
Metadata Standard Name:	ISO 19115 Geographic Information - Metadata
Metadata Language:	en
Metadata Standard Version:	1.0

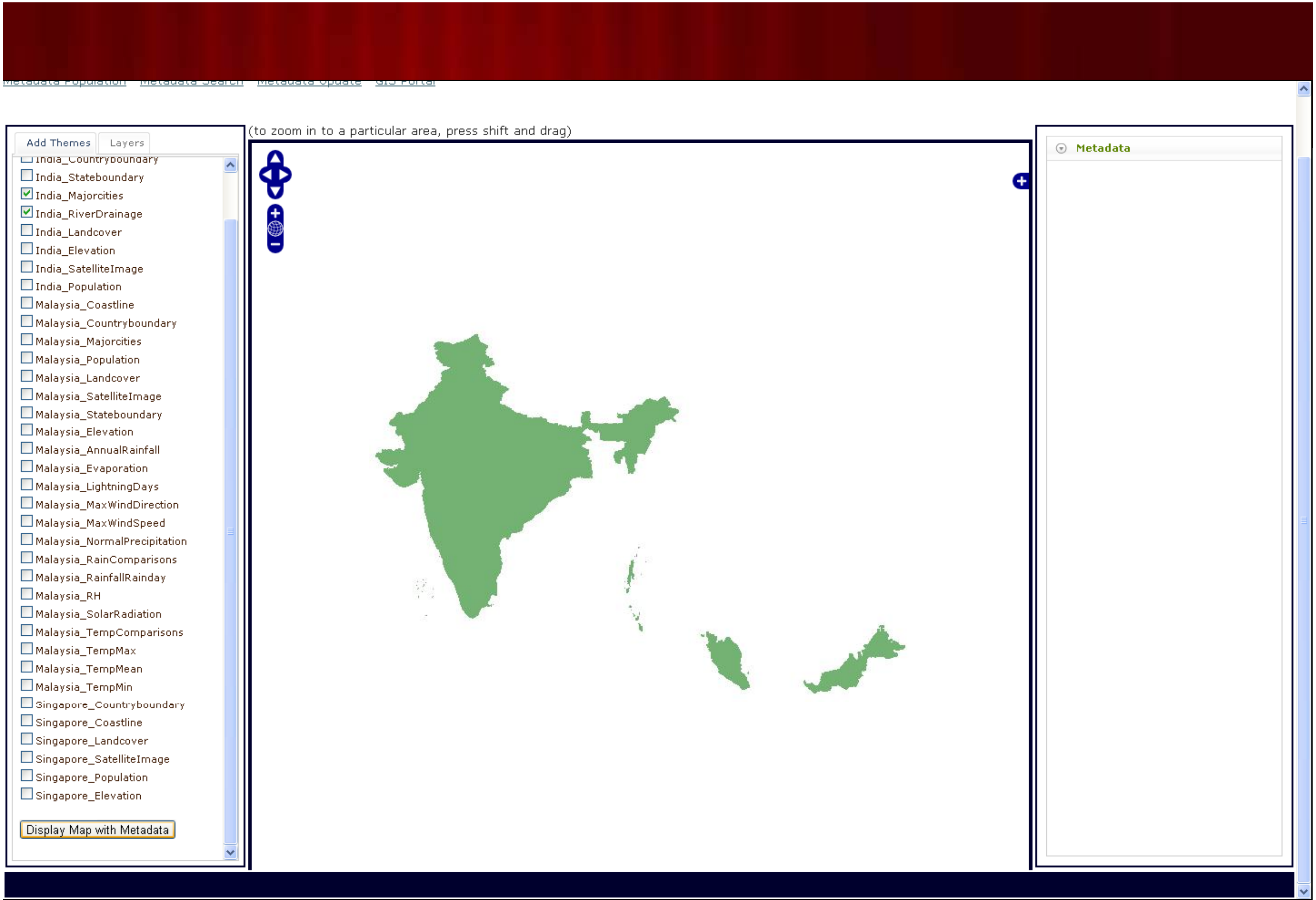
GIS Portal

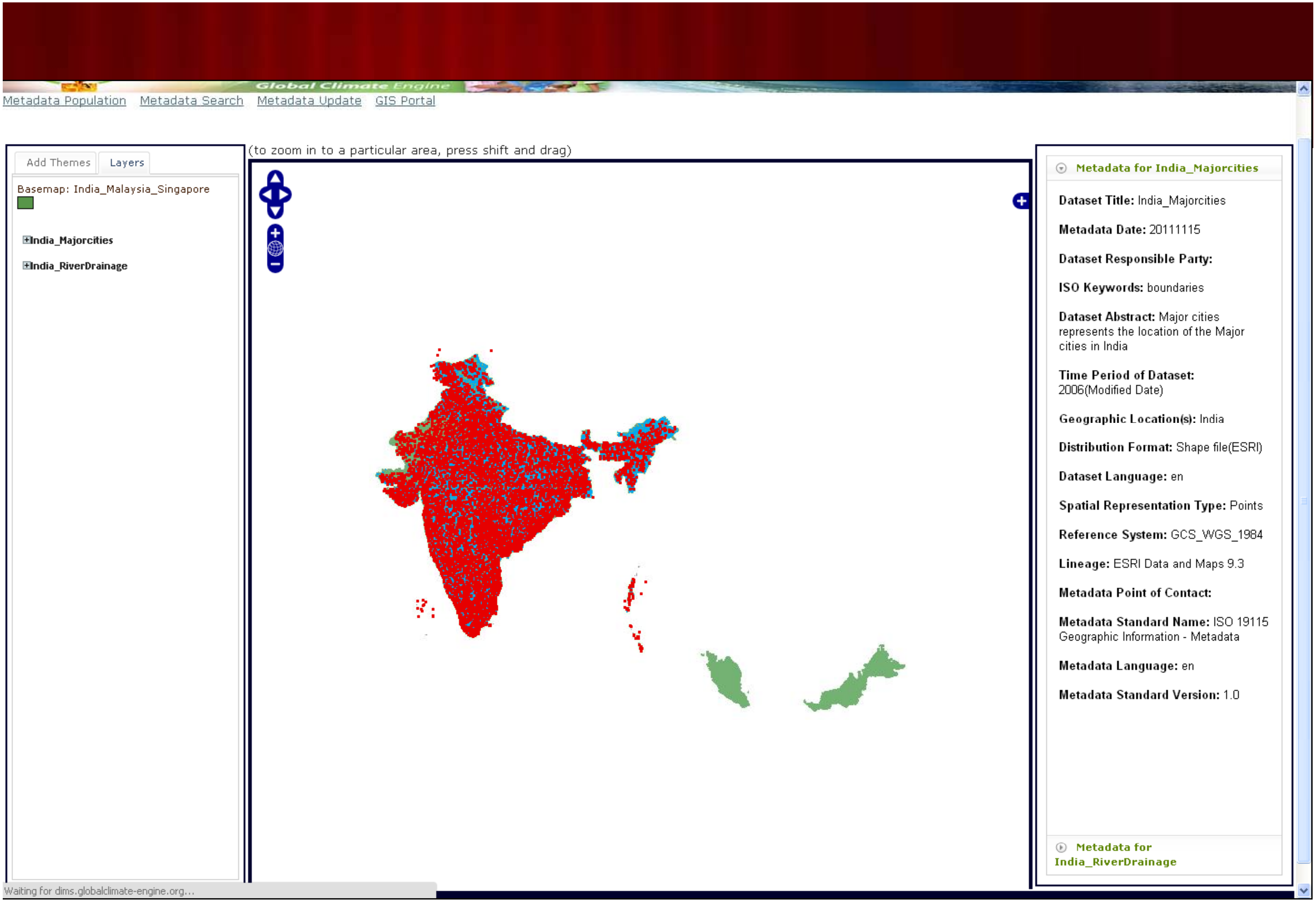


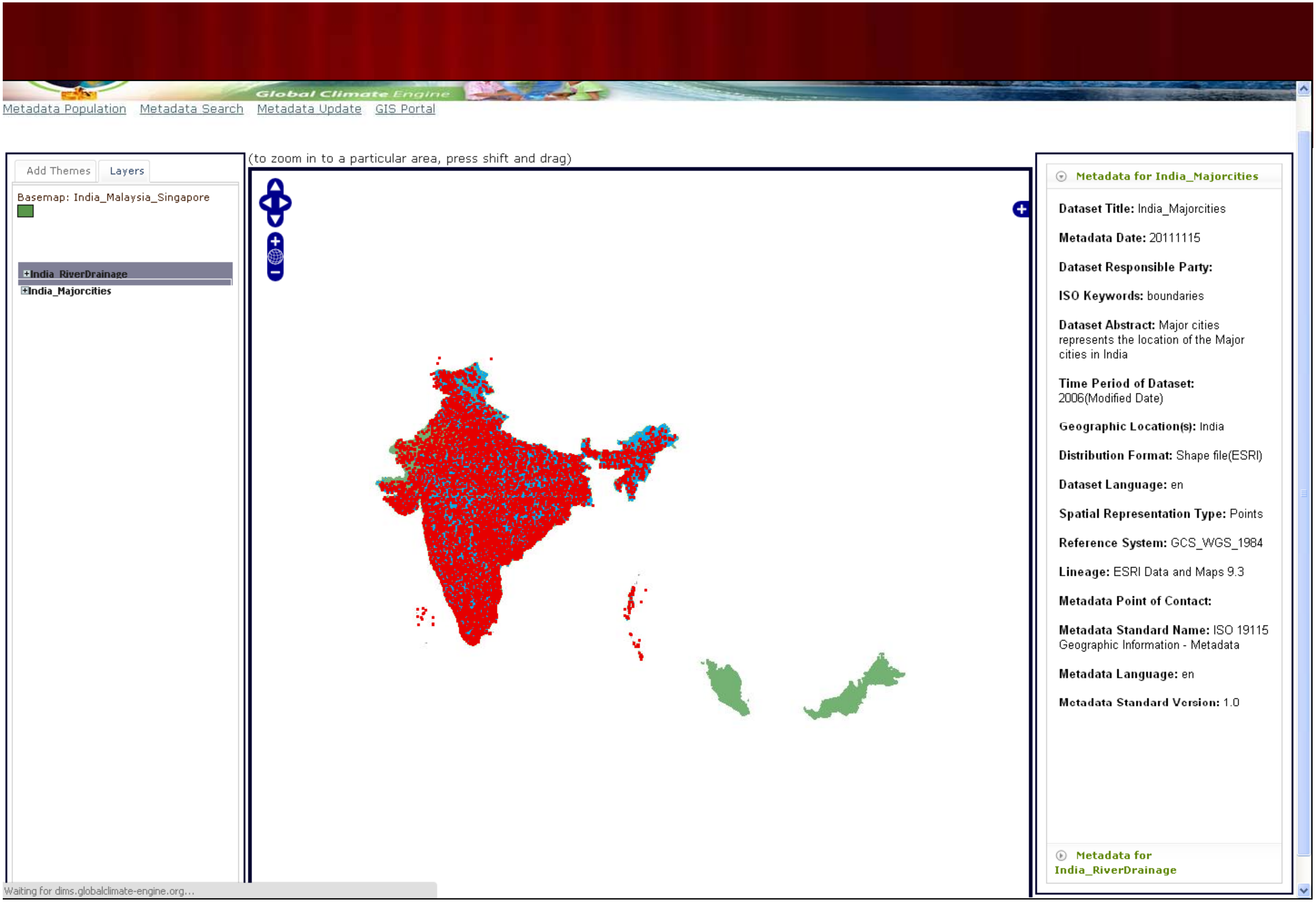
Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
(to zoom in to a particular area, press shift and drag)
Metadata

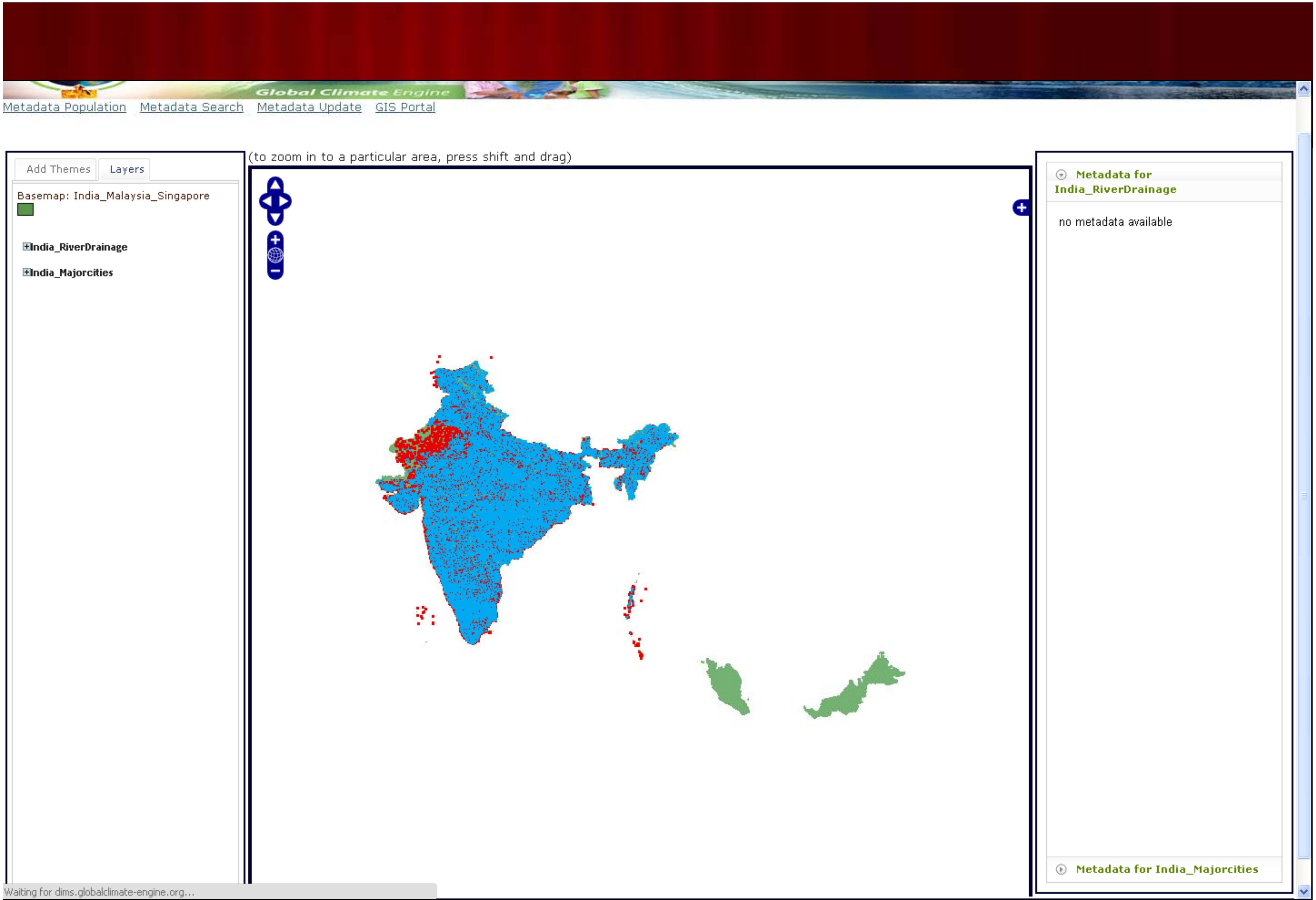

Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
India_Coastline
India_Coralreefs
India_Countryboundary
India_Stateboundary
India_Majorcities
India_RiverDrainage
India_Landcover
India_Elevation
India_SatelliteImage
India_Population
Malaysia_Coastline
Malaysia_Countryboundary
Malaysia_Majorcities
Malaysia_Population
Malaysia_Landcover
Malaysia_SatelliteImage
Malaysia_Stateboundary
Malaysia_Elevation
Malaysia_AnnualRainfall
Malaysia_Evaporation
Malaysia_LightningDays
Malaysia_MaxWindDirection
Malaysia_MaxWindSpeed
Malaysia_NormalPrecipitation
Malaysia_RainComparisons
Malaysia_RainfallRainday
Malaysia_RH
Malaysia_SolarRadiation
Malaysia_TempComparisons
Malaysia_TempMax
Malaysia_TempMean
Malaysia_TempMin
Singapore_Countryboundary
Singapore_Coastline
Singapore_Landcover
Singapore_SatelliteImage
Singapore_Population
(to zoom in to a particular area, press shift and drag)
Metadata

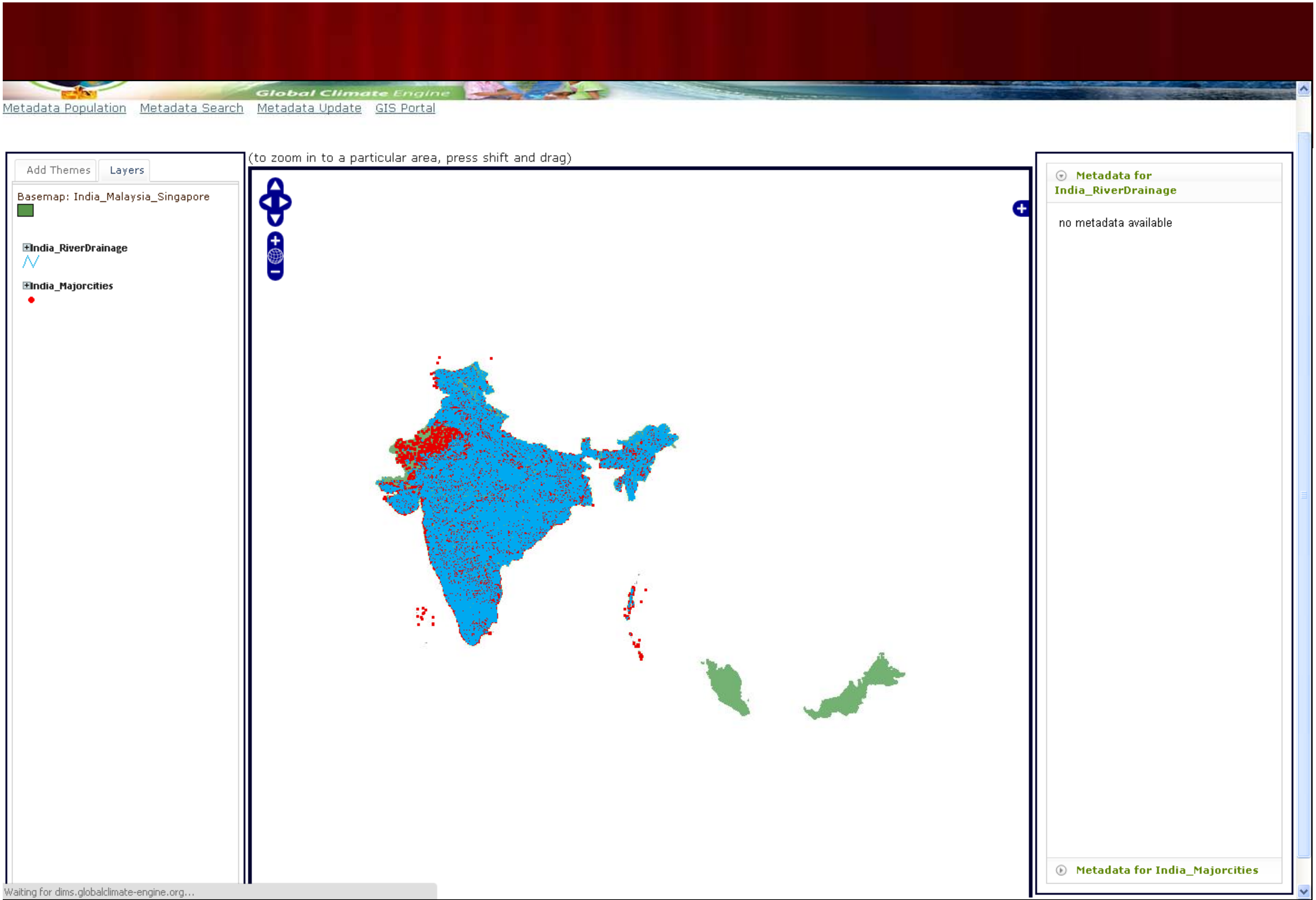

Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
India_Coastline
India_Coralreefs
India_Countryboundary
India_Stateboundary
India_Majorcities
India_RiverDrainage
India_Landcover
India_Elevation
India_SatelliteImage
India_Population
Malaysia_Coastline
Malaysia_Countryboundary
Malaysia_Majorcities
Malaysia_Population
Malaysia_Landcover
Malaysia_SatelliteImage
Malaysia_Stateboundary
Malaysia_Elevation
Malaysia_AnnualRainfall
Malaysia_Evaporation
Malaysia_LightningDays
Malaysia_MaxWindDirection
Malaysia_MaxWindSpeed
Malaysia_NormalPrecipitation
Malaysia_RainComparisons
Malaysia_RainfallRainday
Malaysia_RH
Malaysia_SolarRadiation
Malaysia_TempComparisons
Malaysia_TempMax
Malaysia_TempMean
Malaysia_TempMin
Singapore_Countryboundary
Singapore_Coastline
Singapore_Landcover
Singapore_SatelliteImage
Singapore_Population
(to zoom in to a particular area, press shift and drag)
Metadata

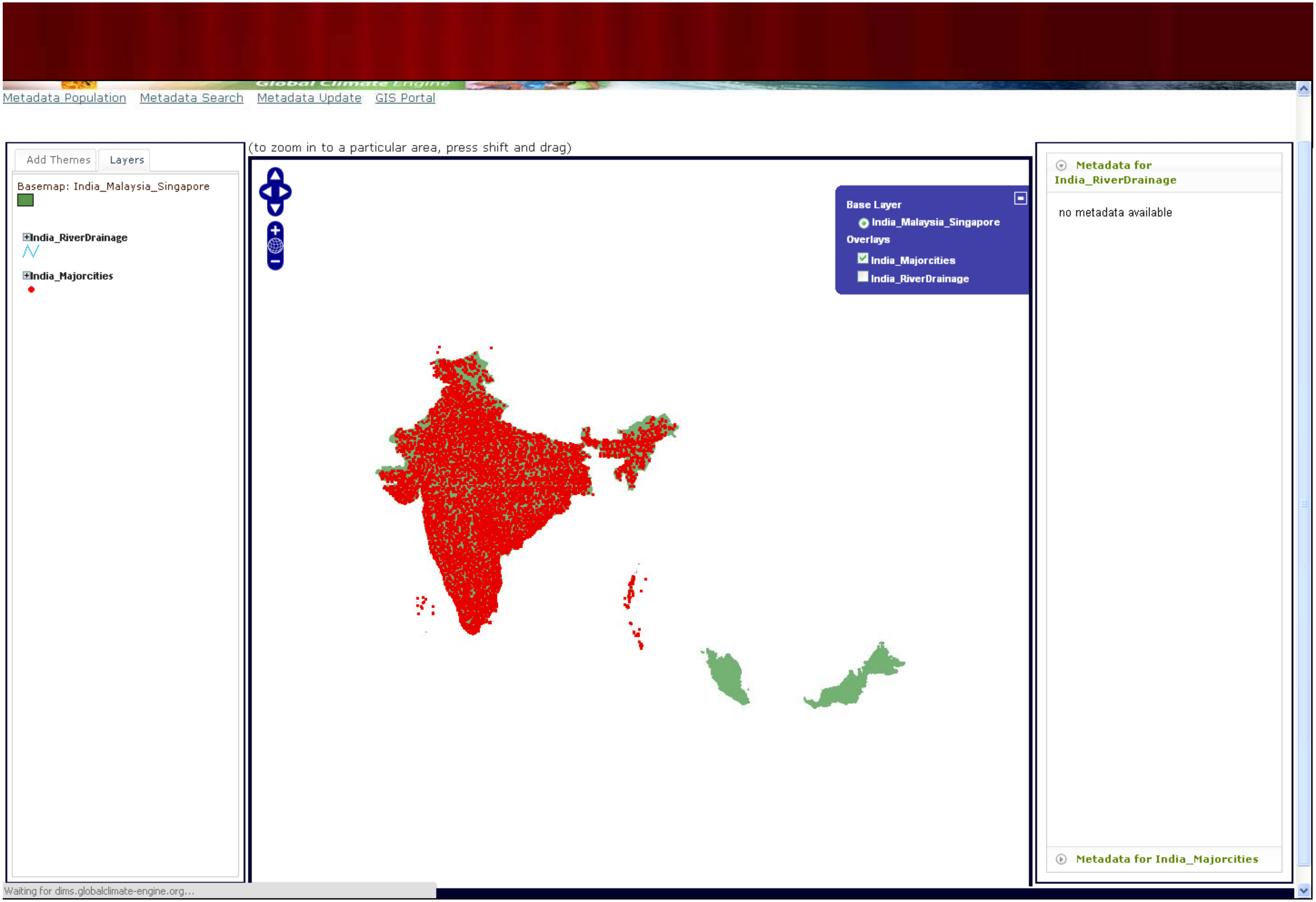

Add Themes
Layers
India_Stateboundary
India_Majorcities
India_RiverDrainage
India_Landcover
India_Elevation
India_SatelliteImage
India_Population
Malaysia_Coastline
Malaysia_Countryboundary
Malaysia_Majorcities
Malaysia_Population
Malaysia_Landcover
Malaysia_SatelliteImage
Malaysia_Stateboundary
Malaysia_Elevation
Malaysia_AnnualRainfall
Malaysia_Evaporation
Malaysia_LightningDays
Malaysia_MaxWindDirection
Malaysia_MaxWindSpeed
Malaysia_NormalPrecipitation
Malaysia_RainComparisons
Malaysia_RainfallRainday
Malaysia_RH
Malaysia_SolarRadiation
Malaysia_TempComparisons
Malaysia_TempMax
Malaysia_TempMean
Malaysia_TempMin
Singapore_Countryboundary
Singapore_Coastline
Singapore_Landcover
Singapore_SatelliteImage
Singapore_Population
Singapore_Elevation
Display Map with Metadata
(to zoom in to a particular area, press shift and drag)
Metadata

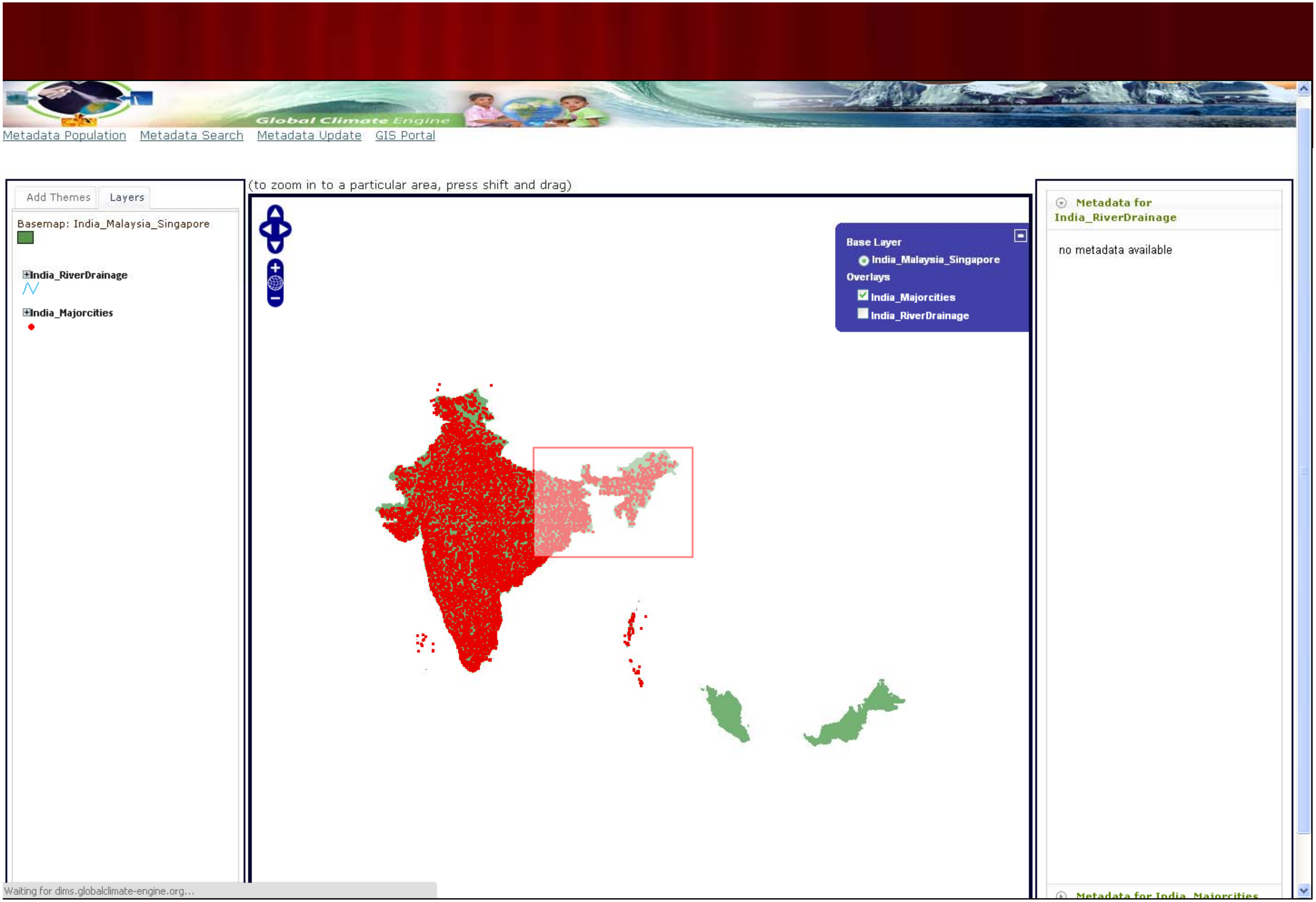

Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_Majorcities
India_RiverDrainage
(to zoom in to a particular area, press shift and drag)
Metadata for India_Majorcities
Dataset Title: India_Majorcities
Metadata Date: 20111115
Dataset Responsible Party:
ISO Keywords: boundaries
Dataset Abstract: Major cities represents the location of the Major cities in India
Time Period of Dataset: 2006(Modified Date)
Geographic Location(s): India
Distribution Format: Shape file(ESRI)
Dataset Language: en
Spatial Representation Type: Points
Reference System: GCS_WGS_1984
Lineage: ESRI Data and Maps 9.3
Metadata Point of Contact:
Metadata Standard Name: ISO 19115 Geographic Information - Metadata
Metadata Language: en
Metadata Standard Version: 1.0
Metadata for India_RiverDrainage
Waiting for dims.globalclimate-engine.org...

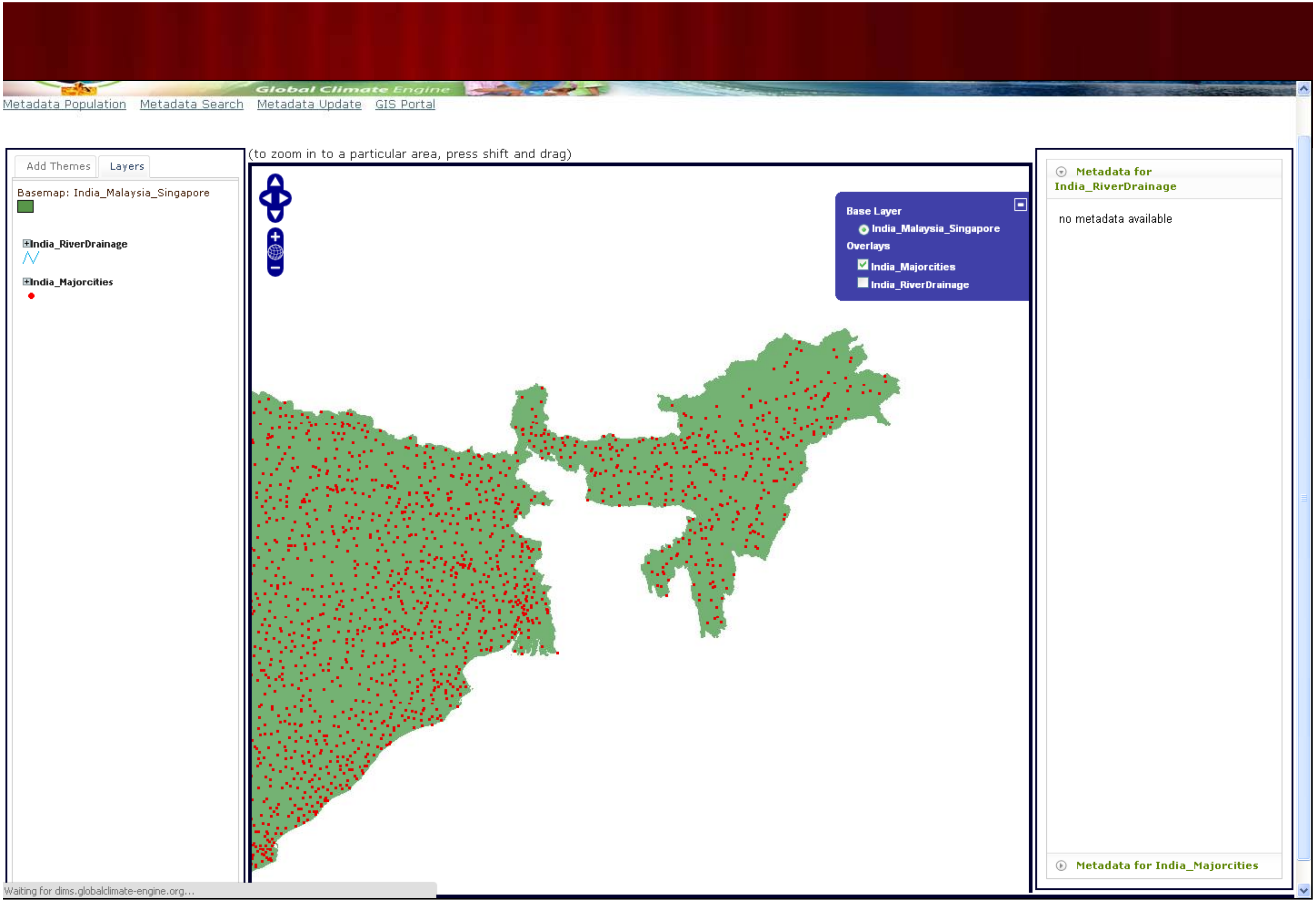

Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
(to zoom in to a particular area, press shift and drag)
Metadata for India_Majorcities
Dataset Title: India_Majorcities
Metadata Date: 20111115
Dataset Responsible Party:
ISO Keywords: boundaries
Dataset Abstract: Major cities represents the location of the Major cities in India
Time Period of Dataset: 2006(Modified Date)
Geographic Location(s): India
Distribution Format: Shape file(ESRI)
Dataset Language: en
Spatial Representation Type: Points
Reference System: GCS_WGS_1984
Lineage: ESRI Data and Maps 9.3
Metadata Point of Contact:
Metadata Standard Name: ISO 19115 Geographic Information - Metadata
Metadata Language: en
Metadata Standard Version: 1.0
Metadata for India_RiverDrainage
Waiting for dims.globalclimate-engine.org...


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
(to zoom in to a particular area, press shift and drag)
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
Metadata for India_RiverDrainage
no metadata available
Metadata for India_Majorcities
Waiting for dims.globalclimate-engine.org...


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
(to zoom in to a particular area, press shift and drag)
Metadata for India_RiverDrainage
no metadata available
Metadata for India_Majorcities
Waiting for dims.globalclimate-engine.org...

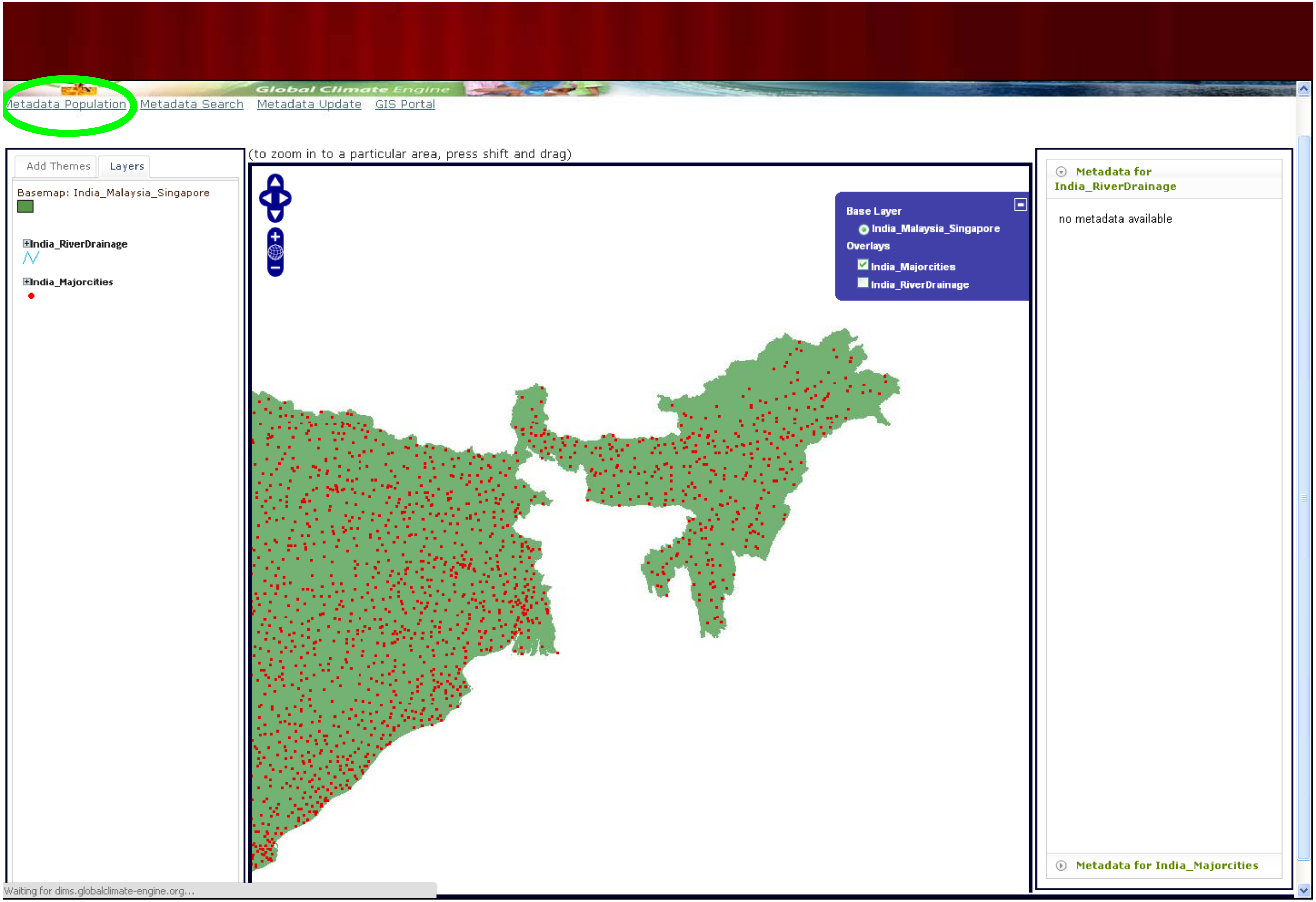

Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
(to zoom in to a particular area, press shift and drag)
Base Layer
India_Malaysia_Singapore
Overlays
India_Majorcities
India_RiverDrainage
Metadata for India_RiverDrainage
no metadata available
Metadata for India_Majorcities
Waiting for dims.globalclimate-engine.org...


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
(to zoom in to a particular area, press shift and drag)
Base Layer
India_Malaysia_Singapore
Overlays
India_Majorcities
India_RiverDrainage
Metadata for India_RiverDrainage
no metadata available
Metadata for India_Majorcities
Waiting for dims.globalclimate-engine.org...


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
(to zoom in to a particular area, press shift and drag)
Base Layer
India_Malaysia_Singapore
Overlays
India_Majorcities
India_RiverDrainage
Metadata for India_RiverDrainage
no metadata available
Metadata for India_Majorcities
Waiting for dims.globalclimate-engine.org...

Example:

Populating metadata for the "India_RiverDrainage" spatial data

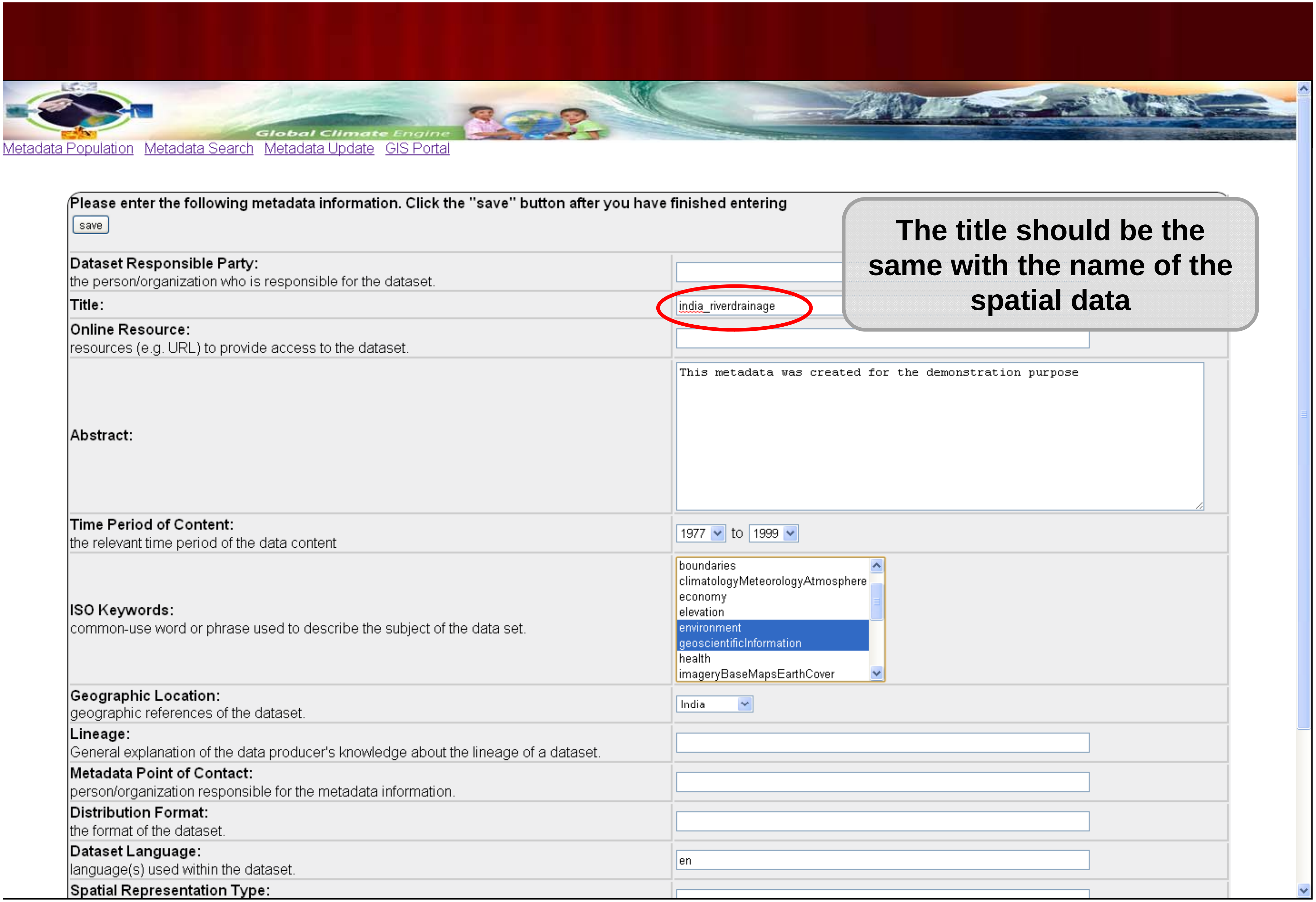

Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
(to zoom in to a particular area, press shift and drag)
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
Base Layer
India_Malaysia_Singapore
Overlays
India_Majorcities
India_RiverDrainage
Metadata for India_RiverDrainage
no metadata available
Metadata for India_Majorcities
Waiting for dims.globalclimate-engine.org...

Metadata Population Metadata Search Metadata Update GIS Portal

Please enter the following metadata information. Click the "save" button after you have finished entering

save

Dataset Responsible Party: the person/organization who is responsible for the dataset.	
Title:	
Online Resource: resources (e.g. URL) to provide access to the dataset.	
Abstract:	
Time Period of Content: the relevant time period of the data content	1950 to 1950
ISO Keywords: common-use word or phrase used to describe the subject of the data set.	farming biota boundaries climatologyMeteorologyAtmosphere economy elevation environment geoscientificInformation
Geographic Location: geographic references of the dataset.	India
Lineage: General explanation of the data producer's knowledge about the lineage of a dataset.	
Metadata Point of Contact: person/organization responsible for the metadata information.	
Distribution Format: the format of the dataset.	
Dataset Language: language(s) used within the dataset.	en
Spatial Representation Type:	

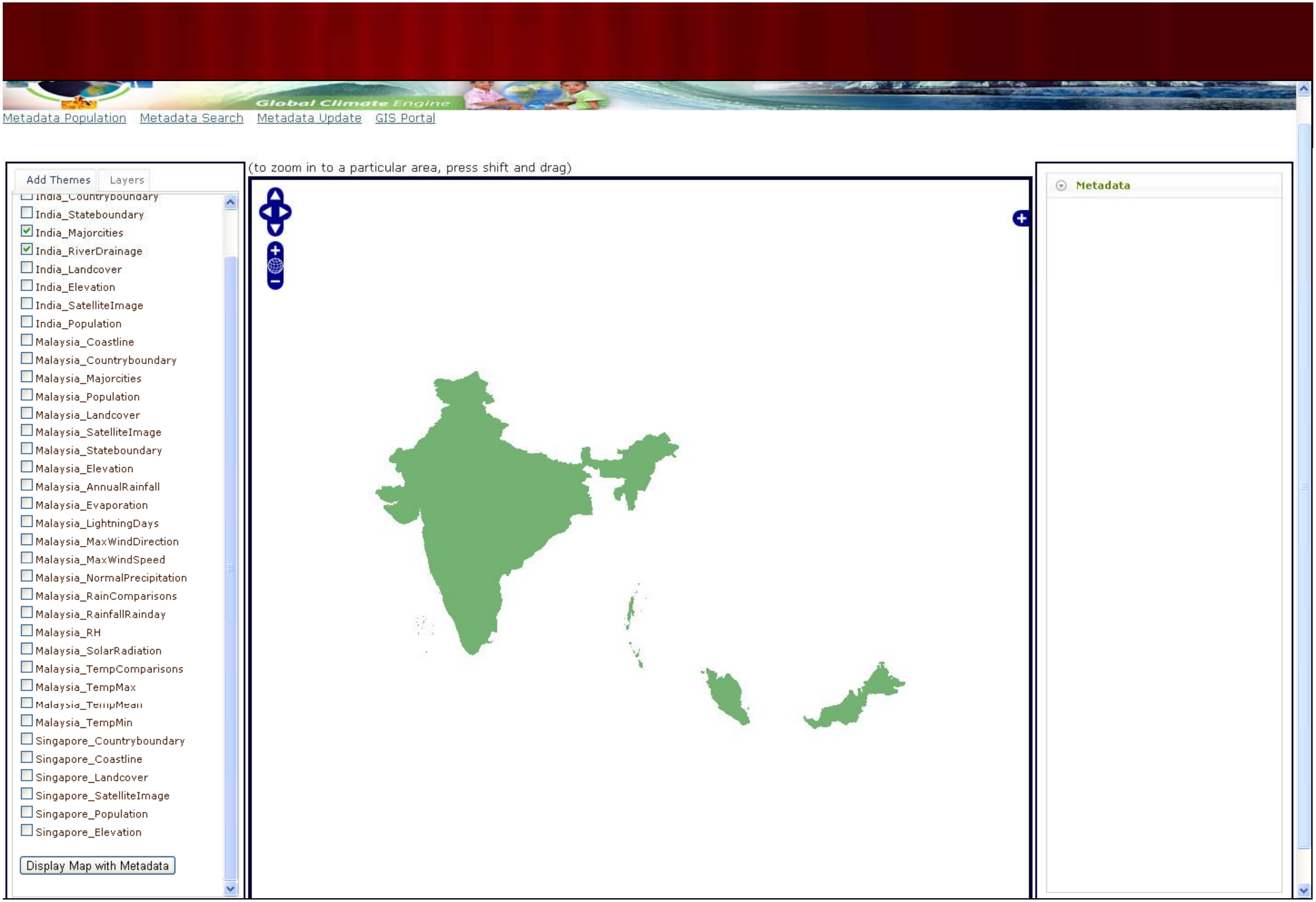


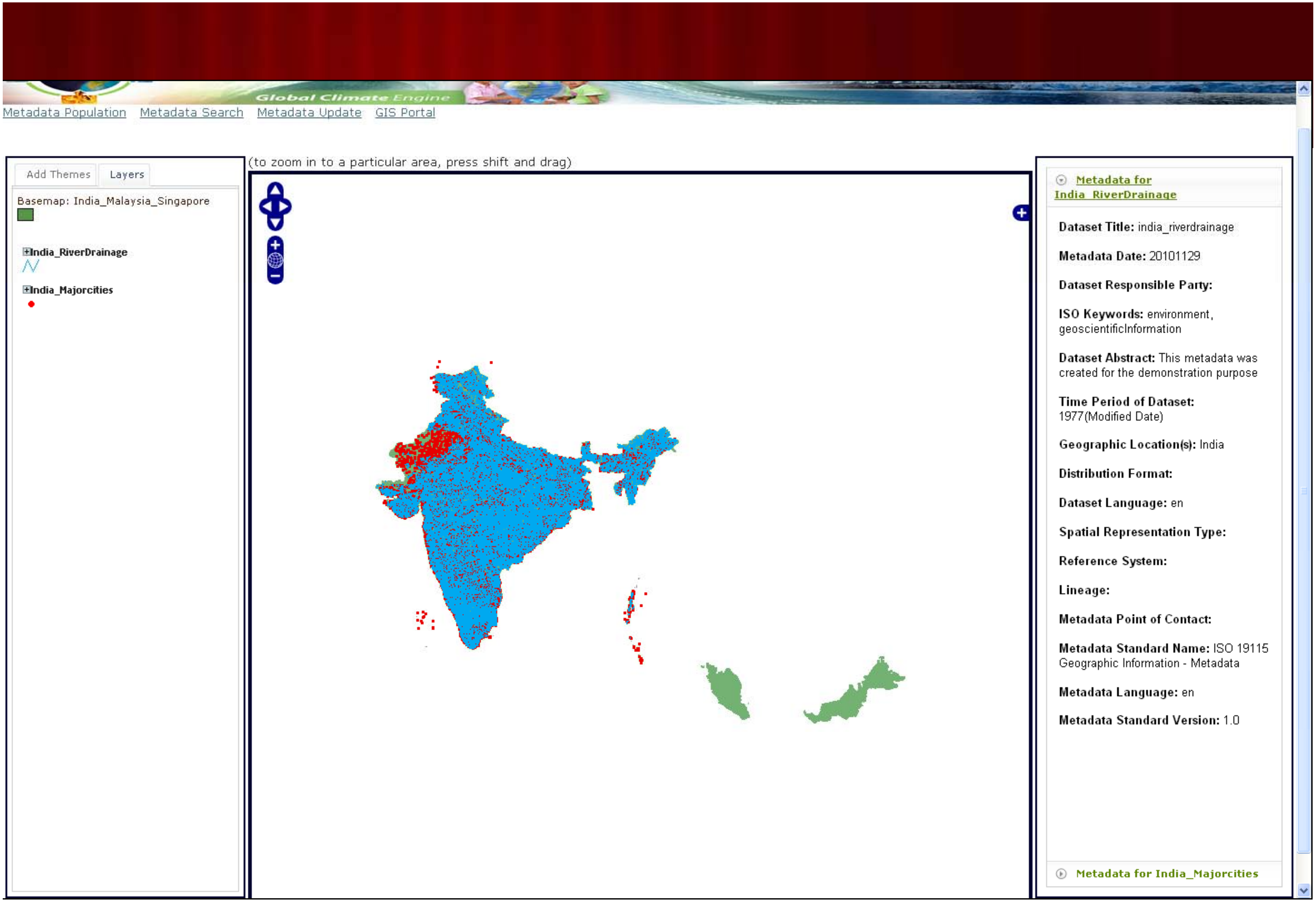
Please enter the following metadata information. Click the "save" button after you have finished entering

save

Dataset Responsible Party: the person/organization who is responsible for the dataset.	
Title:	india_riverdrainage
Online Resource: resources (e.g. URL) to provide access to the dataset.	
Abstract:	This metadata was created for the demonstration purpose
Time Period of Content: the relevant time period of the data content	1977 to 1999
ISO Keywords: common-use word or phrase used to describe the subject of the data set.	boundaries climatologyMeteorologyAtmosphere economy elevation environment geoscientificInformation health imageryBaseMapsEarthCover
Geographic Location: geographic references of the dataset.	India
Lineage: General explanation of the data producer's knowledge about the lineage of a dataset.	
Metadata Point of Contact: person/organization responsible for the metadata information.	
Distribution Format: the format of the dataset.	
Dataset Language: language(s) used within the dataset.	en
Spatial Representation Type:	

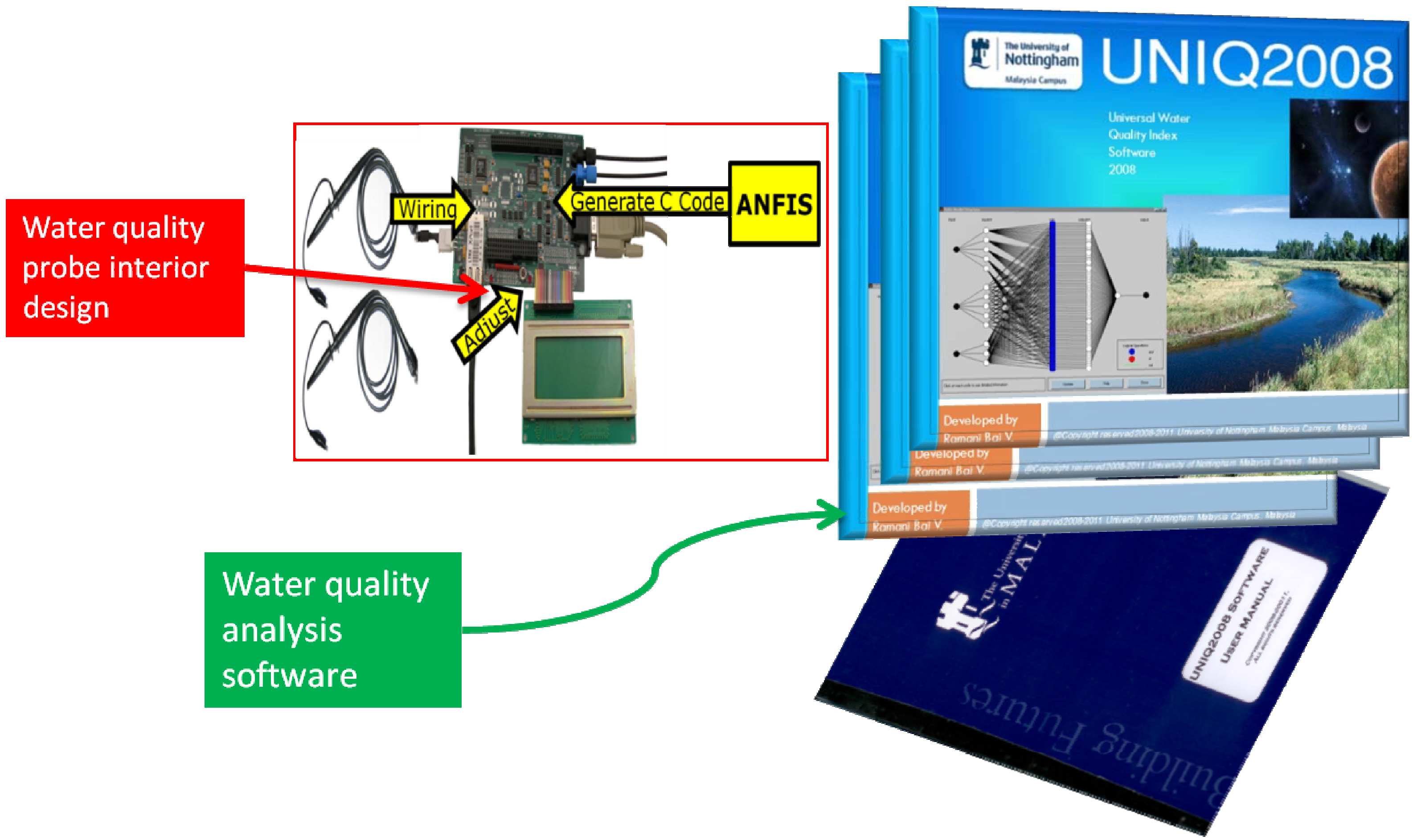
The title should be the same with the name of the spatial data


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
India_Countryboundary
India_Stateboundary
India_Majorcities
India_RiverDrainage
India_Landcover
India_Elevation
India_SatelliteImage
India_Population
Malaysia_Coastline
Malaysia_Countryboundary
Malaysia_Majorcities
Malaysia_Population
Malaysia_Landcover
Malaysia_SatelliteImage
Malaysia_Stateboundary
Malaysia_Elevation
Malaysia_AnnualRainfall
Malaysia_Evaporation
Malaysia_LightningDays
Malaysia_MaxWindDirection
Malaysia_MaxWindSpeed
Malaysia_NormalPrecipitation
Malaysia_RainComparisons
Malaysia_RainfallRainday
Malaysia_RH
Malaysia_SolarRadiation
Malaysia_TempComparisons
Malaysia_TempMax
Malaysia_TempMean
Malaysia_TempMin
Singapore_Countryboundary
Singapore_Coastline
Singapore_Landcover
Singapore_SatelliteImage
Singapore_Population
Singapore_Elevation
Display Map with Metadata
(to zoom in to a particular area, press shift and drag)
Metadata


Global Climate Engine
Metadata Population
Metadata Search
Metadata Update
GIS Portal
Add Themes
Layers
Basemap: India_Malaysia_Singapore
India_RiverDrainage
India_Majorcities
(to zoom in to a particular area, press shift and drag)
Metadata for India_RiverDrainage
Dataset Title: india_riverdrainage
Metadata Date: 20101129
Dataset Responsible Party:
ISO Keywords: environment, geoscientificInformation
Dataset Abstract: This metadata was created for the demonstration purpose
Time Period of Dataset: 1977(Modified Date)
Geographic Location(s): India
Distribution Format:
Dataset Language: en
Spatial Representation Type:
Reference System:
Lineage:
Metadata Point of Contact:
Metadata Standard Name: ISO 19115 Geographic Information - Metadata
Metadata Language: en
Metadata Standard Version: 1.0
Metadata for India_Majorcities

Thank you!

Water quality probe



Scientific Workshop on Climate Change and DIMS Technology

1-3 December 2010
Kuala Lumpur Teaching Center
University of Nottingham Campus

Asia-Pacific Network for Global Change Research: *An OVERVIEW*

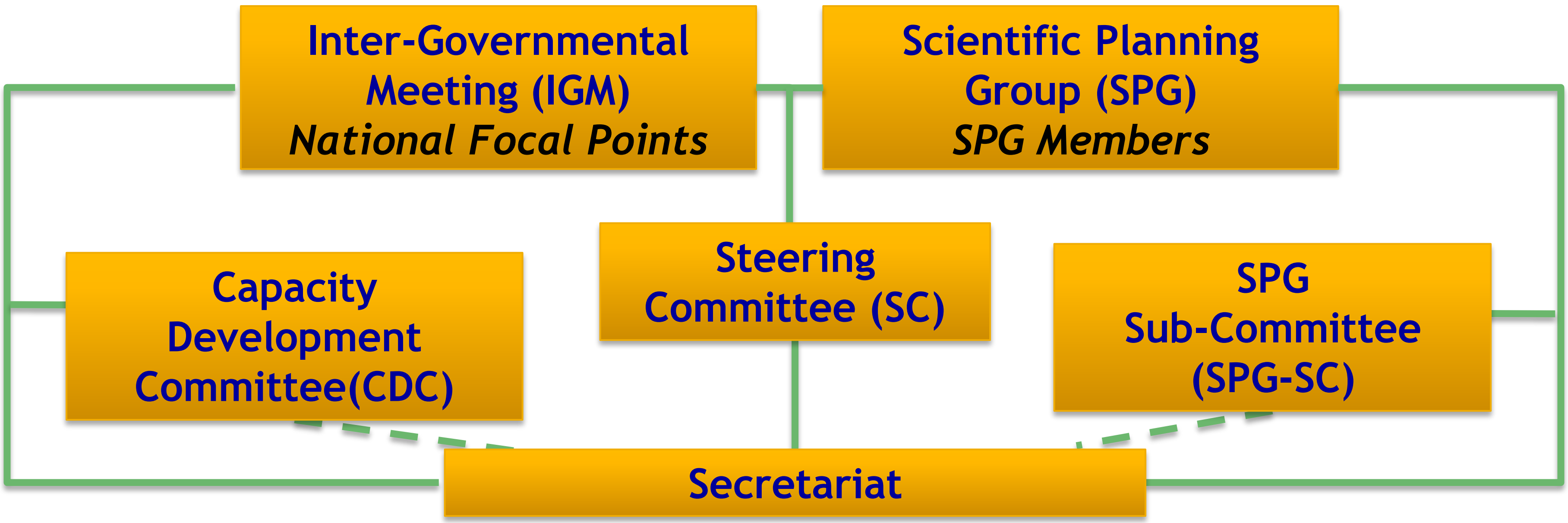
Kristine Garcia
Coordinator
APN Secretariat
Email: kgarcia@pn-gcr.org

Contents

APN established in 1996 ,is a network of **22 member governments** in the Asia Pacific supporting **regional global change research** and **enhancing scientific capacity** in developing countries to improve decision-making in focus areas of global change and sustainable development.

We define global change as the set of natural and human-induced changes in the Earth; in its physical, biological, and social systems that, when aggregated, are significant at a global scale.

Structure



Inter-Governmental Meeting (IGM)
National Focal Points
Scientific Planning Group (SPG)
SPG Members
Capacity Development Committee(CDC)
Steering Committee (SC)
SPG Sub-Committee (SPG-SC)
Secretariat

Member Countries

Pacific Island Countries and Singapore are approved countries whose scientists are eligible to receive funding under APN awards.

Financial Resources

The APN is sponsored by the governments of:

- **Japan**

  Ministry of the Environment and Hyogo Prefecture

- **New Zealand**

  Ministry for the Environment

- **Republic of Korea**

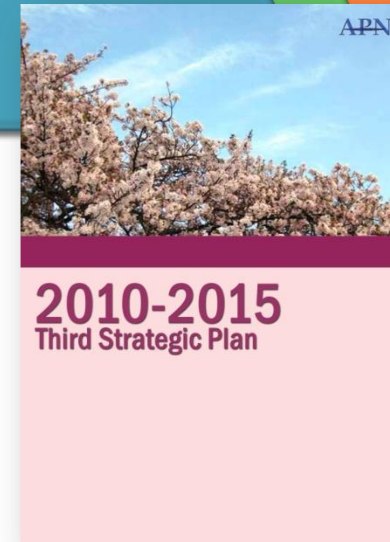
  Ministry of Environment

- **United States of America**

  National Science Foundation

  US Global Change Research Program

3RD STRATEGIC PHASE



APN GOALS

- Supporting regional cooperation in global change research on issues particularly relevant to the region
- Strengthening appropriate interactions among scientists and policy-makers, and providing scientific input to policy decision-making and scientific knowledge to the public
- Improving the scientific and technical capabilities of nations in the region, including the transfer of know-how and technology
- Cooperating with other global change networks and organisations

Partners

OPPORTUNITIES

Calls for Proposals

Seeking for Proposals Reviewers

Connect to APN

APN Activities

APN

ANNUAL CALLS FOR PROPOSALS

ARCP

CAPaBLE

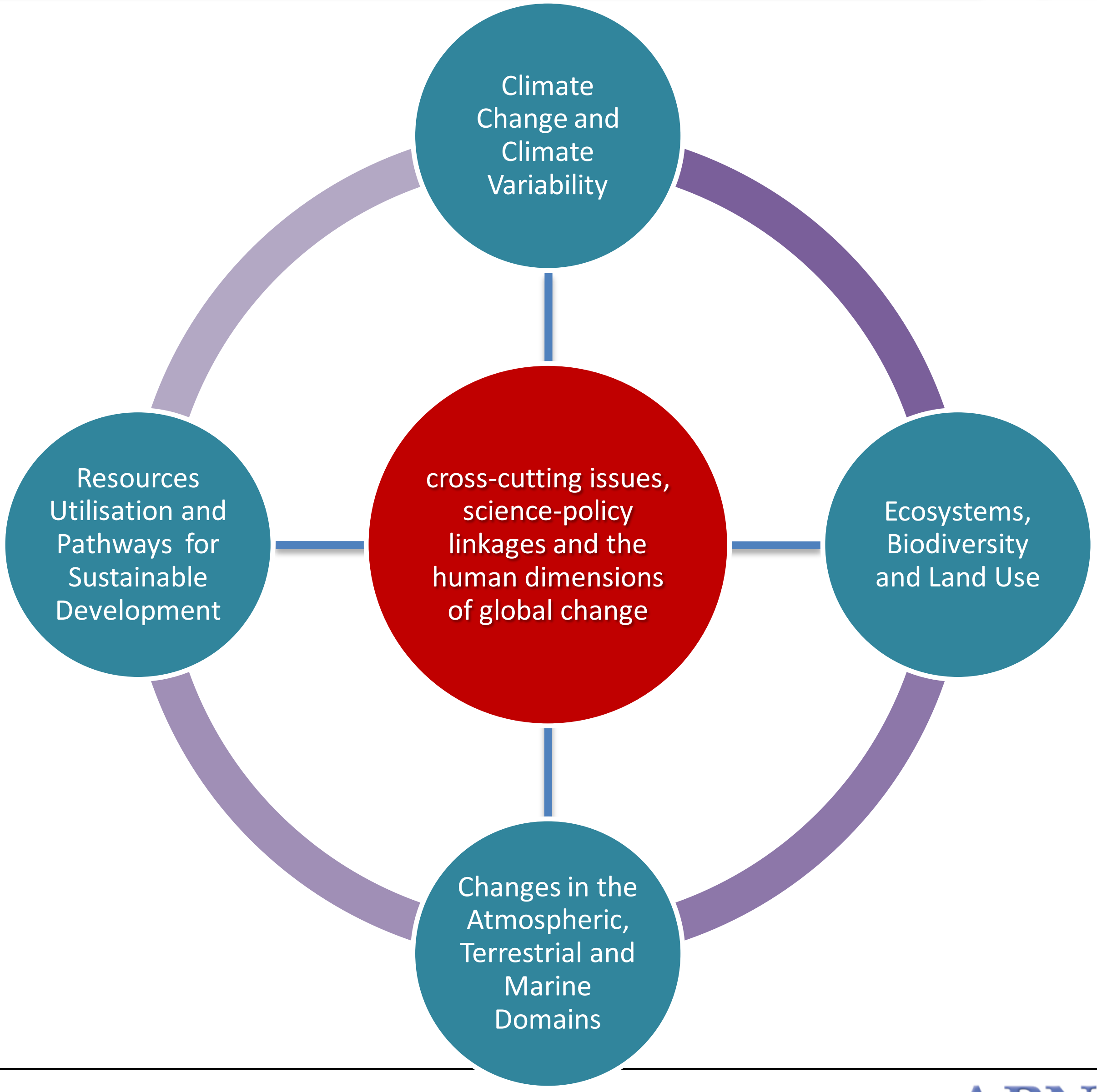
Visit:

http://www.apn-gcr.org/newAPN/opportunities/opportunities.htm

Annual Regional Call for research Proposals (ARCP)

One of the scientific pillars of the APN to **support global change research** in the Asia-Pacific region

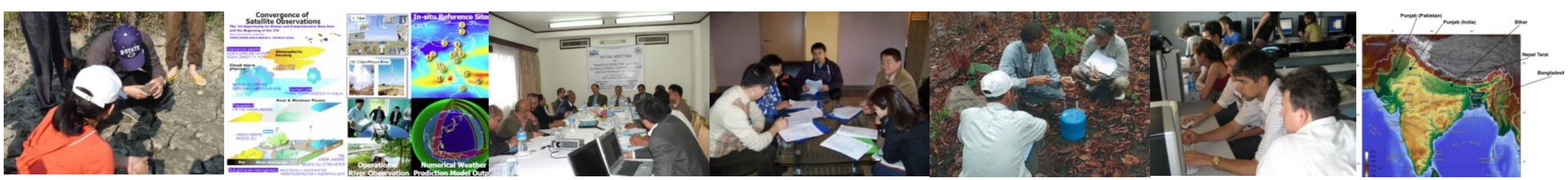
Competitive process launched in 1998 to select projects for funding under the Science Agenda.



APN

Types of Activities Eligible for Funding

- New research which addresses knowledge gaps in key areas
- Synthesis and analysis of existing research
- Research planning/scoping activities
- The development of policy products such as integrated assessments, impact assessments, climate models, etc.



Scientific Capacity Building and Enhancement for Sustainable Development in Developing Countries

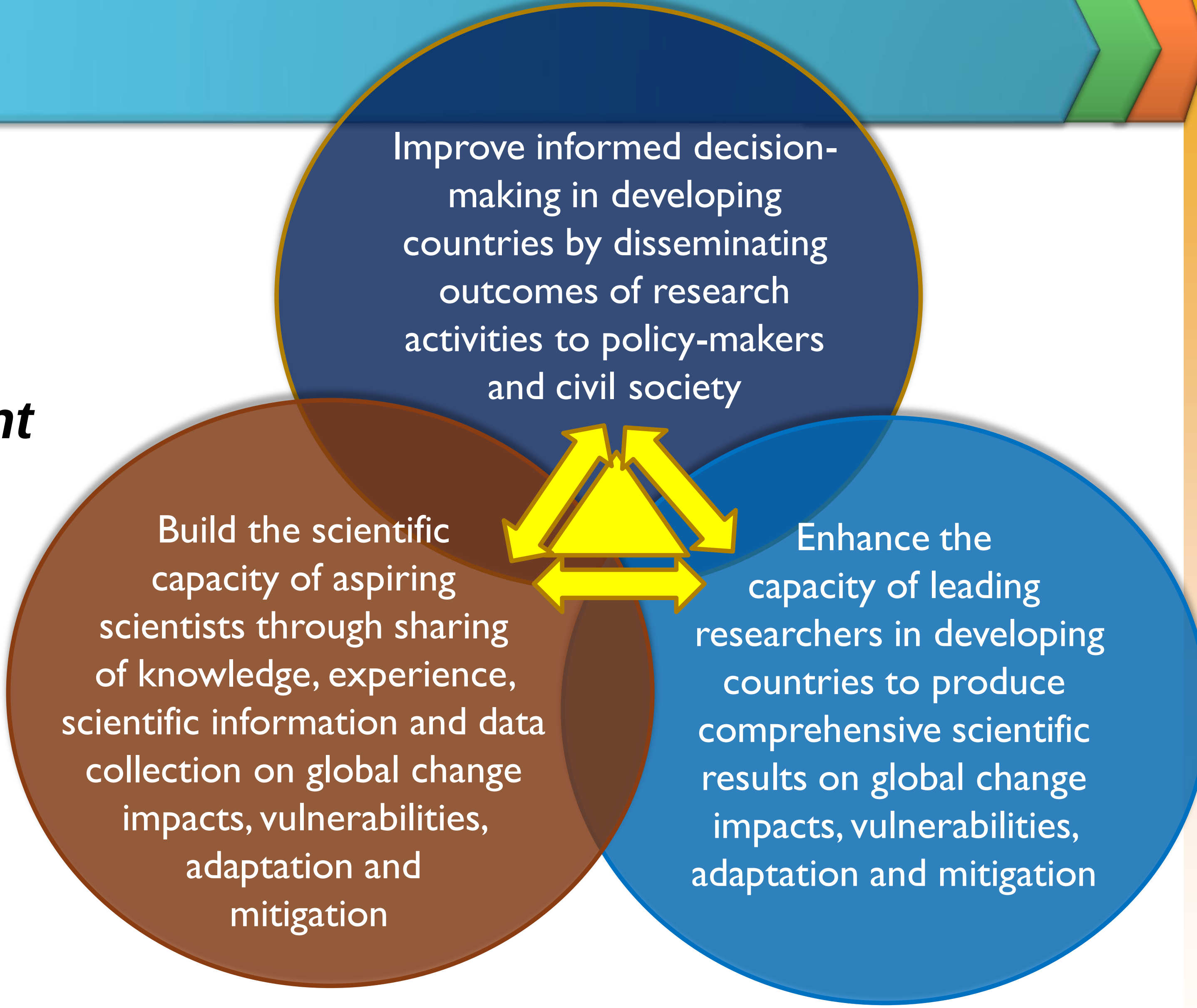
CAPaBLE

The second pillar of APN supporting capacity development projects/ activities

Registered as a World Summit on Sustainable Development (WSSD) Type II Partnership/Initiative

Launched in 2003 as a concrete initiative to realize part 107 to 114 of the Plan of Implementation for the WSSD

CAPaBLE supports capacity development projects/ activities



OBJECTIVES

Types of Activities Eligible for Funding

- Scientific capacity development for sustainable development
- Science-policy Interfacing
- Awareness raising Activities
- Dissemination Activities

APN Activities

- Sub-regional Cooperation (SRC)
- Synthesis Activities
- Selected APN-funded projects
- Scoping Workshops

Sub-Regional Cooperation Activities (SRC)

- **Organised the PDTW back-to-back with the South Asia SRC Meeting and the Training Workshop on Downscaling of South Asian Climate Projections, 1-5 November 2010, Pune, India**

  - ✓ ***Indian Institute of Tropical Meteorology hosted and provided support for conducting these events***

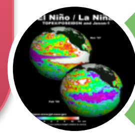
Sub-Regional Cooperation Activities (SRC)

- **Organised the PDTW back-to-back with the APN 3rd Southeast Asia SRC Meeting, 8-12 November 2010, Manila, Philippines**
  - ✓ ***Host institutions co-organised the events and provided support: Ecosystems Research and Development Bureau, Department of Natural Resources and Environment (DENR-ERDB)***

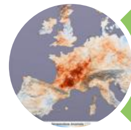
Synthesis Activity

- **Two-year synthesis activity: *Climate in Asia and the Pacific* synthesising the work of over 50 APN-funded climate projects**

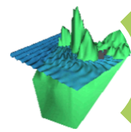
Food, Agriculture & Climate



Seasonal Climate Predictions & Applications



Climate Variability, Trends & Extremes

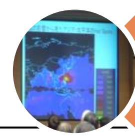


Regional Climate Change Modelling

Vulnerability & Adaptation to Climate Change

Climate Change Mitigation

Coastal Cities & Climate Change



Climate Change Policy Outreach

APN

Climate Change Challenges

- Climate change is the foremost concern particularly **vulnerabilities, impacts and adaptation**
- **lack of human & institutional capacity** & limited financial resources are the main challenges in implementing climate research
- **mainstreaming** climate research results into national policy

Risks and APN Response

Sectors Most at Risk

Agriculture, Water (floods, drought, security), Forests, Coastal zones, Mangroves, Maritime resources

↓

mainstreaming adaptation strategies most challenging

↓

APN's Response

Scientific Capacity Building for Impact and Vulnerability Assessments

APN

SCBCIA

Scientific Capacity Development for Climate Change Impact and Vulnerability Assessment

7 *Ongoing projects*

Countries:

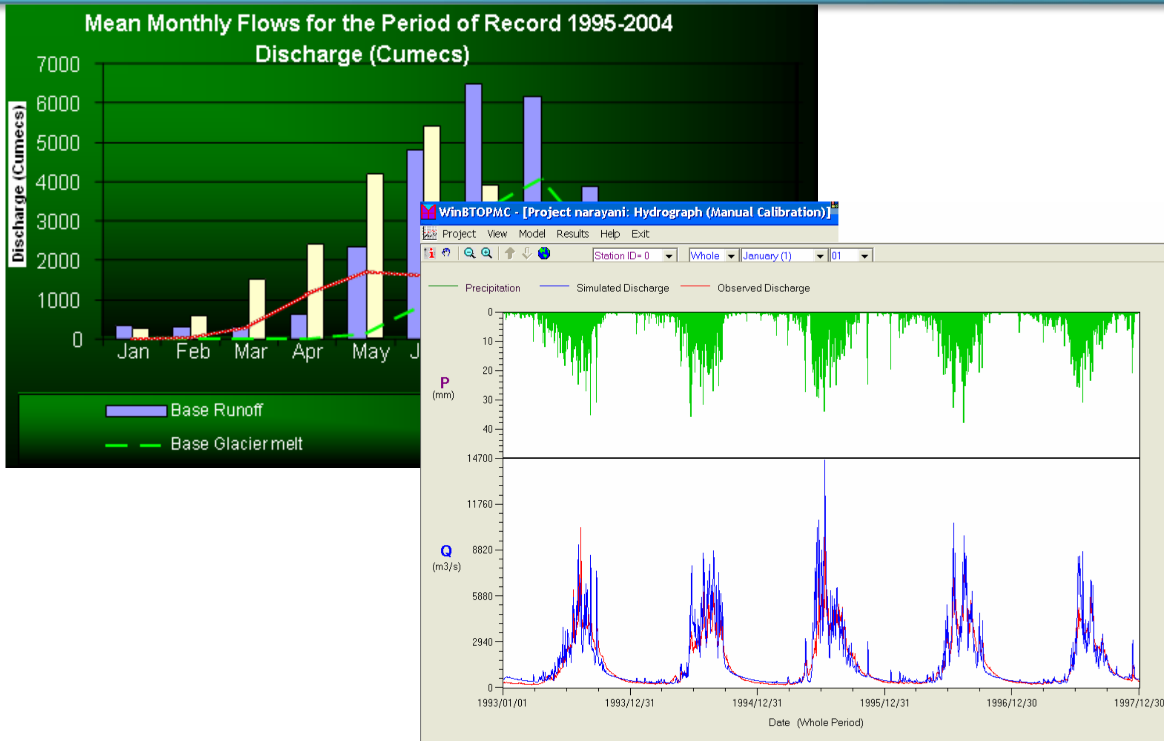
- China
- Indonesia
- Philippines
- Pakistan
- Viet Nam
- Thailand

Training in the Concepts of Climate Change Impacts and Vulnerability and use of SIMCLIM

Capacity Building on Integration of Science and Local Knowledge for Climate Change Impacts and Vulnerability Assessments

APN

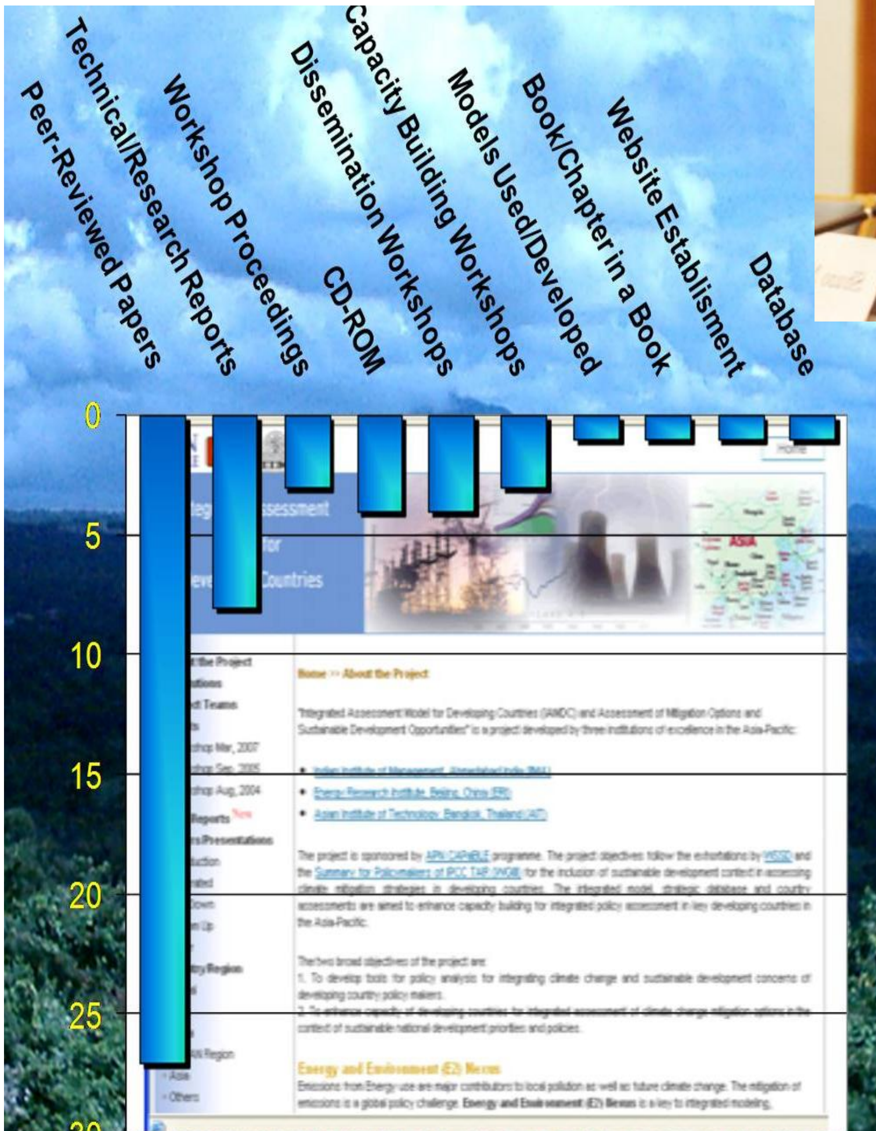
Modelling on Impacts on Food & Water Resources

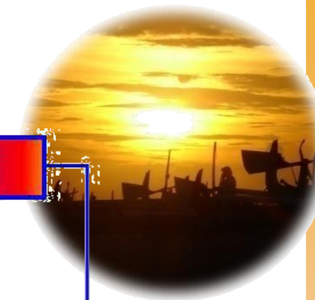


- Until recently a major weakness in South Asian countries in climate change research has been the lack of expertise and experience in ***climate simulation modelling.***

- The APN project undertaken by GCISC has played a key role in ***empowering scientists from Pakistan, Nepal and Bangladesh*** to become active players with climate change researchers globally through their capacity enhancement

IAM Model Development & Mitigation





IPCC TAR 2001

↓

WG III

Integrated Assessment Model for Developing Countries and Analysis of Mitigation Options and Sustainable Development Opportunities

↓

IPCC AR4 2007

Developed a new framework for policy modelling and analysis to align sustainable development & climate change for climate change action plans

Regional Trends in Climate Extremes

POSSIBLE THROUGH THE USE OF GIS & COMPUTER MODELS

OBJECTIVES:

- Develop and <u>compute indicators of trends in climate extremes</u> for the Asia-Pacific region
- Build regional capacity in systematic <u>handling and analyzing of climate data</u>
- Promote the application of climate trend indicators for <u>government policy development</u>

By obtaining the indices and indicators of climate extremes, we can provide useful information and support the government taskforces in establishing countermeasures for the Climate Change Convention.

ICT and Global Earth Observations

ICT – Massive developments in ICT for earth observations – but more needs to be done - particularly in digitising & archiving historical data in the developing nations of the Asia-Pacific Region

Asian Water Cycle Initiative (AWCI)

Development/adaptation of effective tools for enhanced data collecting and data management including: ***software for data processing, quality control and format conversion, sophisticated database systems, and other tools***

Development/adaptation of advanced technologies for data integration and data dissemination to research groups including: ***data integration systems based on Internet technologies and capable of integrating data from various sources such as satellite, in-situ, and model output data, metadata schemes following ISO standards, etc.***

Cooperating with GEOSS and the APN

More Needs to be Done

Problematic situations related to global earth observations and climate change research in developing nations of the Asia-Pacific:

- Still considerable ***lack of observational data*** (meteorological, oceanographic, socio-economic, etc.);
- ***Lack of accessibility to existing data*** for researchers of the region;
- Scarcity of experienced scientists, ***lack of infrastructure***; and
- ***Lack of familiarity*** with relevant methods and models; and
- ***Limited archived data and analytical interpretation***

Sectors identified as most vulnerable: Food and fibre; Biodiversity; Water resources; Coastal ecosystems; Human health and settlements; and land degradation.

Areas where APN can assist and collaborate

- Funding support for research and capacity building activities through the annual calls for proposals
- Establishing channel/mechanism for sharing research results/accessing data, etc.
- Training activities and technology transfer in the region in cooperation with other institutions
- Encouraging involvement of scientists, end-users, decision-makers in the region in research and CB activities
- Facilitating science-policy linkages
- Linking with partner research programmes and facilitating regional collaboration.

Contact APN

For more information, please visit

http://www.apn-gcr.org

or email

info@apn-gcr.org

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Thank You !

GIS and its Application for Climate Change Prediction

by
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Dr. G. JANARDHANAN Ph.D (USA)., E. I
Centre for Environmental Management
National Institute of Technical Teachers Training & Research
Chennai, India

2nd December 2010

Disclaimer:
In this lecturer, contents expressed are purely my personal technical perspective…it does not represent the organization to which I am affiliated.

Protect Our Environment

It's A Team Effort

Climate Change Is a Global Challenge

- Climate change issues are discussed widely around the world.
- Many scientists relate global warming and its consequences to human activities and not to natural fluctuations.
- The reasoning of this approach is the time scale of climate change.
- Recent warming of the earth is considered to be abrupt compared to the time scale usually accompanied with natural climate change episodes.
- Earth's natural climate changes happen gradually in a long period of time (tens of thousands to millions of years), but we are witnessing an abrupt change over the past 200 years.

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Climate Change Is a Global Challenge

- **The industrial revolution with fossil fuels as its main source of energy is setting a steady emission increase of Carbon dioxide and other greenhouse gases which trap heat causing an increase of temperature in the lower atmosphere.**
- **Climate change is recognized as an important issue, and international communities through the United Nations created special groups to focus on climate change effects and initiated protocols to organize a global response to deal with its consequences.**

Climate Change Is a Global Challenge

- **Unusually strong tropical storms, heavy precipitations causing a devastating floods, more frequent heat waves, frequents drought and other similar events are connected to a modern climate change.**

- **The UN Secretary-General Ban Ki-moon, refer to climate change as the "defining issue of our era,"**

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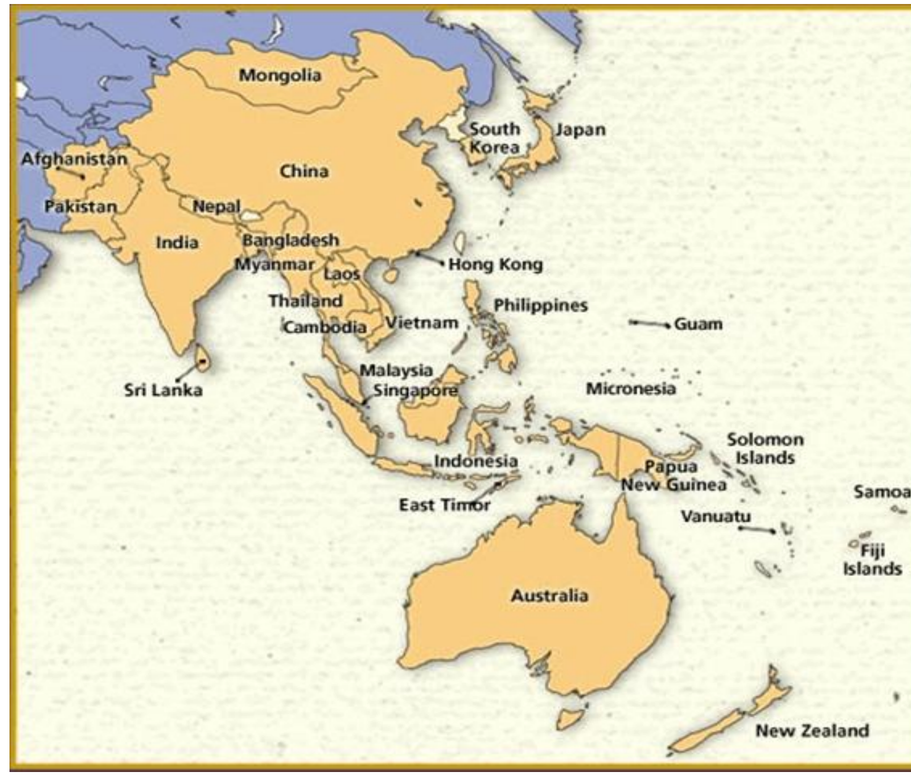
Asia and the Pacific is vulnerable to climate change

Climate change will impinge on the sustainable development of most developing countries of Asia-Pacific






Climate Change Is a Global Challenge

- Reducing the risks caused by climate change is an immense challenge.
- Scientists, policy makers, developers, engineers and many others have used Geographical Information System (GIS) technology to better understand a complex situation and offer some tangible solutions.
- Technology offers a means to assess, plan and implement sustainable programs that can affect us 10, 20, and 100 years into the future.

Climate Change Is a Global Challenge

- Climate is a geographic problem and we believe solving it takes a geographical solution.
- GIS users represent a vast reservoir of knowledge, expertise and best practices in applying this cornerstone technology to the science of climate change and understanding its impact on natural and human systems.

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Climate Change Is a Global Challenge

- A GIS based framework helps us to gain a scientific understanding of earth systems at a truly global scale and leads to more thoughtful, informed decision making.
  - Deforestation analysis spurs successful reforestation programs and sustainable management.
  - Study of potential sea level rise leads to adaptive engineering projects.
  - Emissions assessment brings about research into alternative energy sources such as wind turbing, siting and residential solar rooftop programs.

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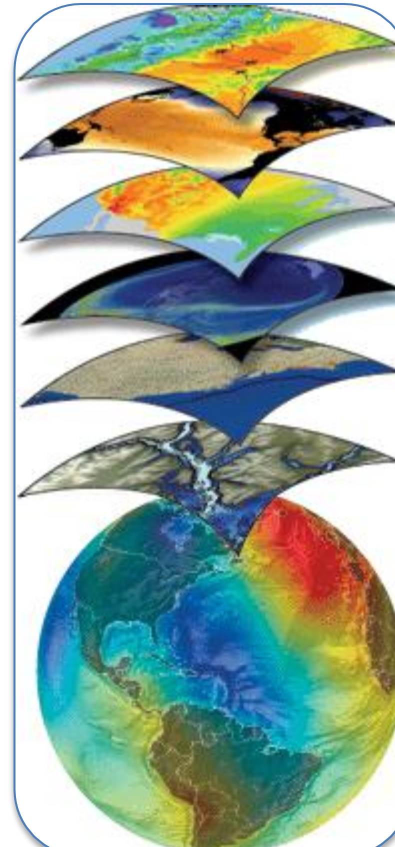
Geographic Information Systems

- A science and a technology that includes elements of computer visualization, database management and spatial analysis of geographically referenced data.

- A GIS stores information as a collection of thematic layers that can be linked together by geography.

- In many disciplines and sectors GIS is used for data integration, analysis and decision making (common tool for many stakeholders, i.e., local and state governments).



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Georeferenced Data

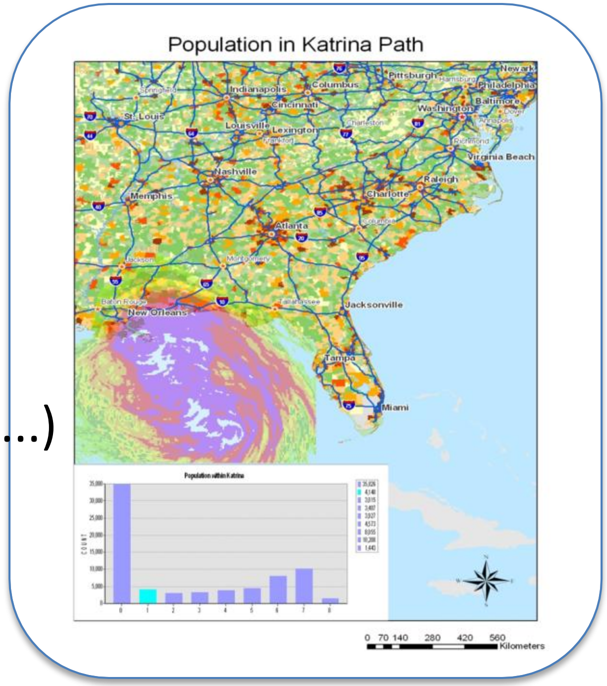
- Coordinates (X, Y) or geographic identifier (place name) that can be linked to GIS data
- Vast collection of geographically referenced data already exists in digital format
  - Google for “*your keyword* GIS data download”
- Remotely sensed data – important source of georeferenced data
- Paper maps can be scanned
- Data acquisition is usually the most time consuming task
  - Data quality
  - Appropriate use of data (completeness, scale, content, etc.)

What can a GIS do?

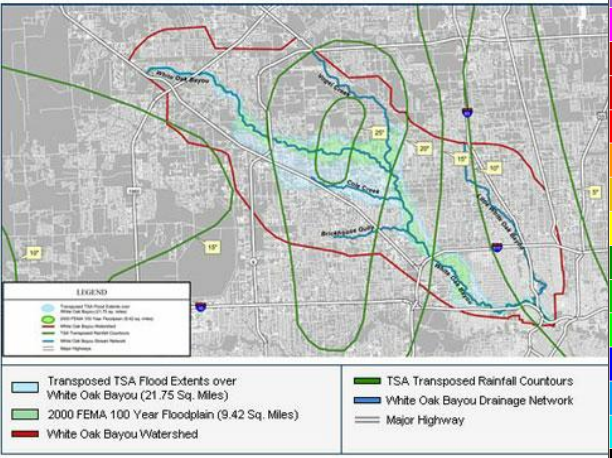
- **Geographic information links a place (and often a time), with some property of that place**
  - "The temperature at 40 N, 105 W at noon local time on 07/16/07 was 25 Celsius."
- **GIS can store a vast number of these properties**
  - The GIS term is *attributes.*
  - Attributes are non spatial information about a geographic feature in a GIS, usually stored in a table and linked to the feature by a unique identifier.
  - They can be physical, social, economic, demographic, environmental, etc.

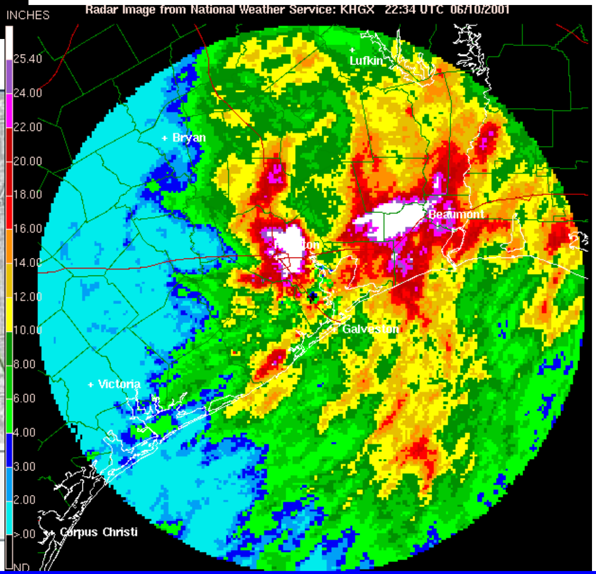
GIS Applications

- Visualization of information
- Spatial analysis
  - Location (Where is it...)
  - Condition (What is it...)
  - Trend (What has changed...)
  - Pattern (What is the pattern...)
  - Routing (Which is the 'best' way ...)
  - Modeling (What if...)
- Integration of information (interdisciplinary research; quantitative and qualitative)
- Data distribution

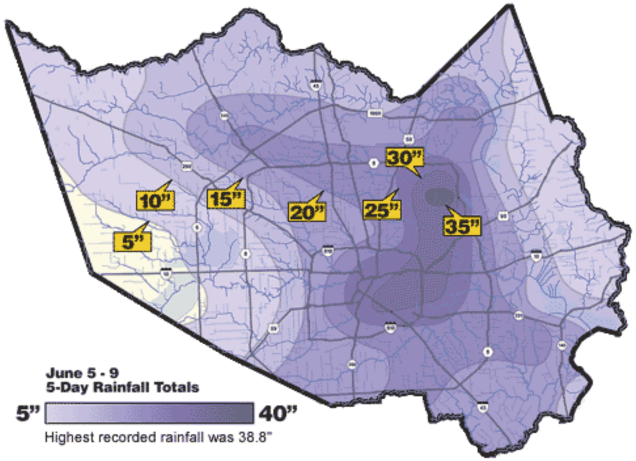


GIS Analysis and Integration





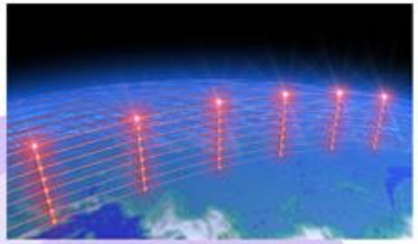
Tropical Storm Allison

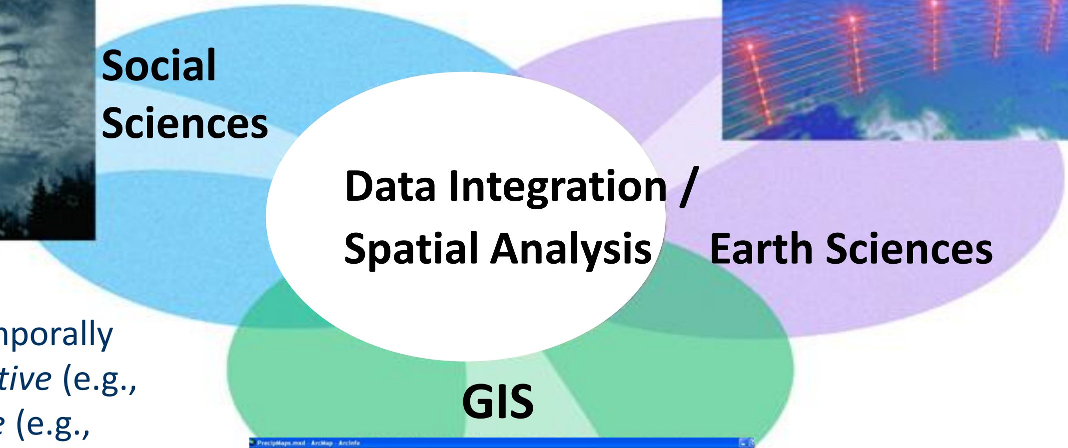


Research studies on and emergency management of hurricane-induced flooding involve integrating data from atmospheric sciences, oceanography, hydrology, geology, geography, and social sciences.

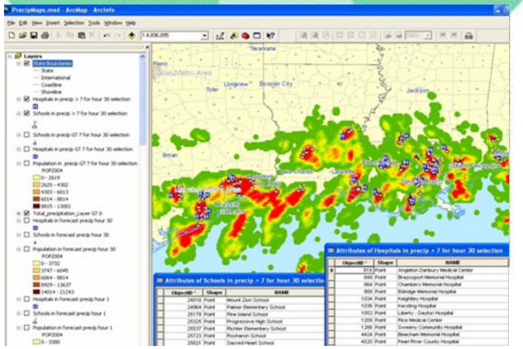
GIS - Integration

A set of *parameters* (e.g., pressure, temperature, wind speed) which vary as *continuous functions* in 3-dimensional space and time.





Spatially and/or temporally structured *quantitative* (e.g., surveys), *qualitative* (e.g., interviews), often context-specific pieces of information.

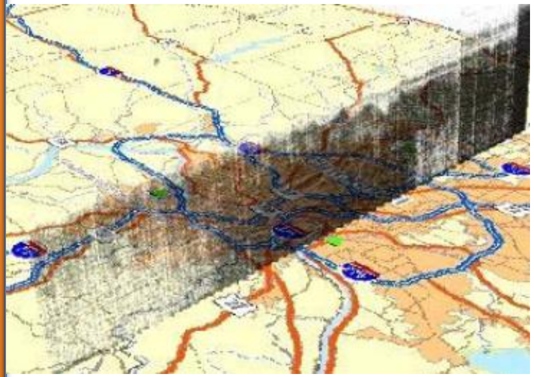


Collection of *features* (e.g., roads, soil types, census blocks) with *geographic footprints* on the Earth surface.
Data can be *vector* (points, lines, polygons) or *raster* (grid cells).

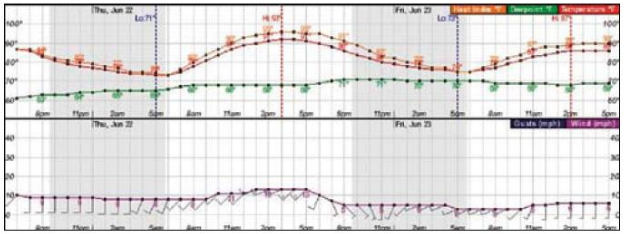



Data classified by usability in GIS

- GIS Ready
  - fully described, *point and click* ------



❖ **GIS Friendly**
  - some effort to make GIS-Ready



- GIS Alien
  - cannot be fully described -----▶

Summary by Scott Shipley, GMU in

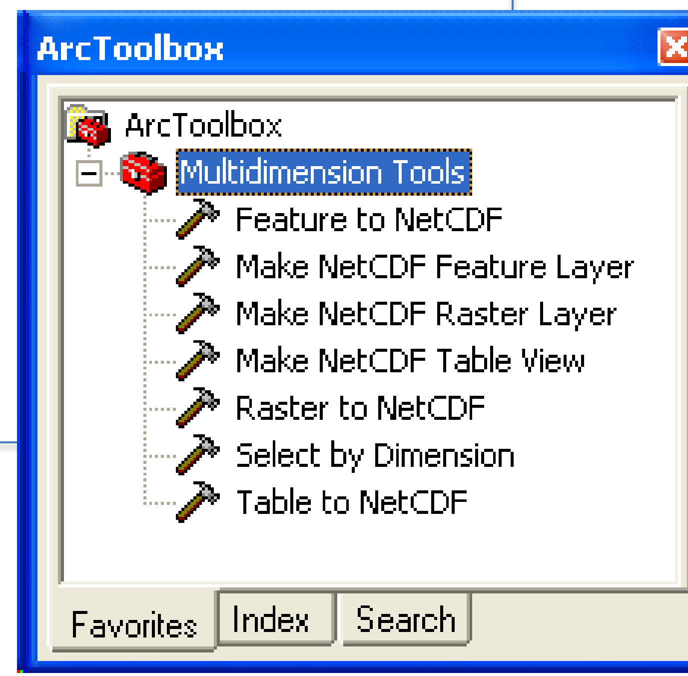
http://www.esri.com/library/newsletters/atmosphericfront/atmospheric-front-fall06.pdf



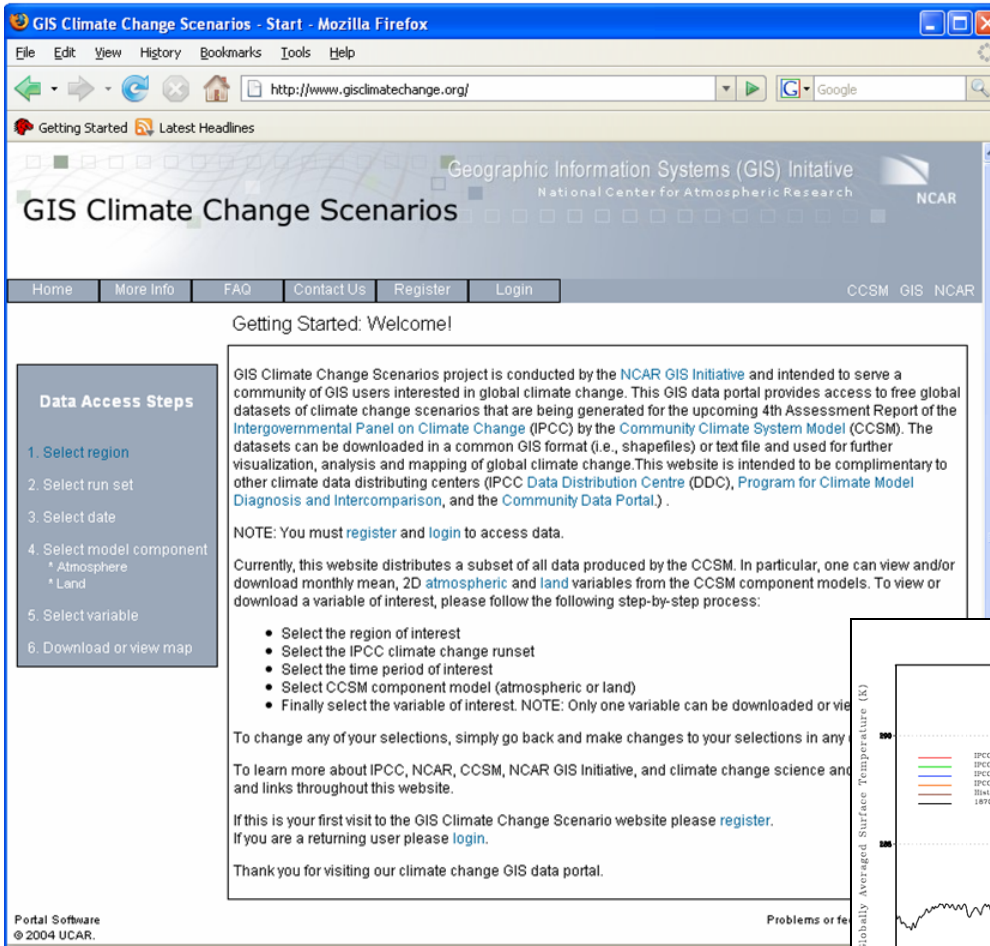

NetCDF Tools in ArcGIS 9.2

Toolbox: Multidimension Tools

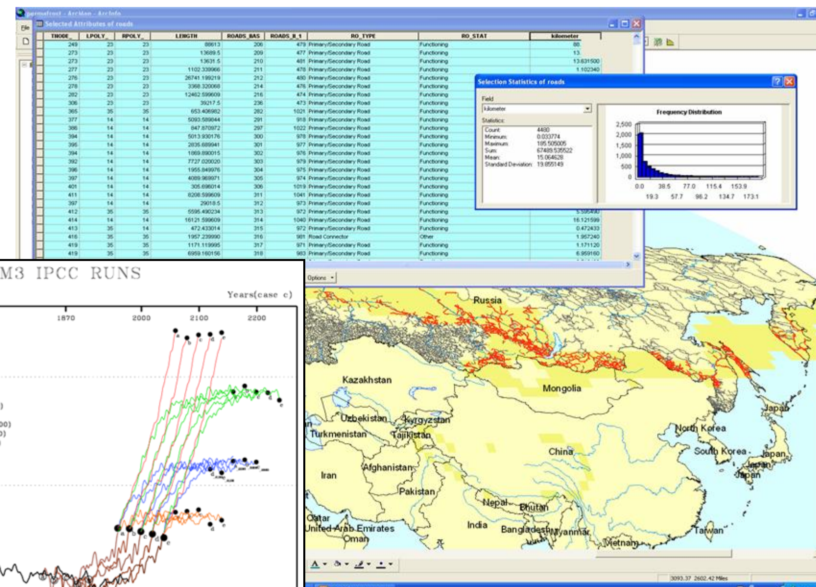
- Make NetCDF Raster Layer
- Make NetCDF Feature Layer
- Make NetCDF Table View
- Raster to NetCDF
- Feature to NetCDF
- Table to NetCDF
- Select by Dimension

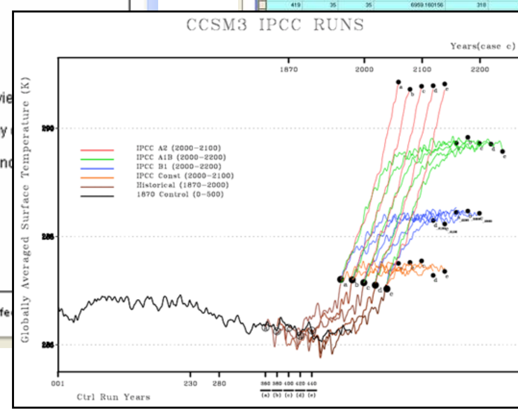


Climate Change in a GIS



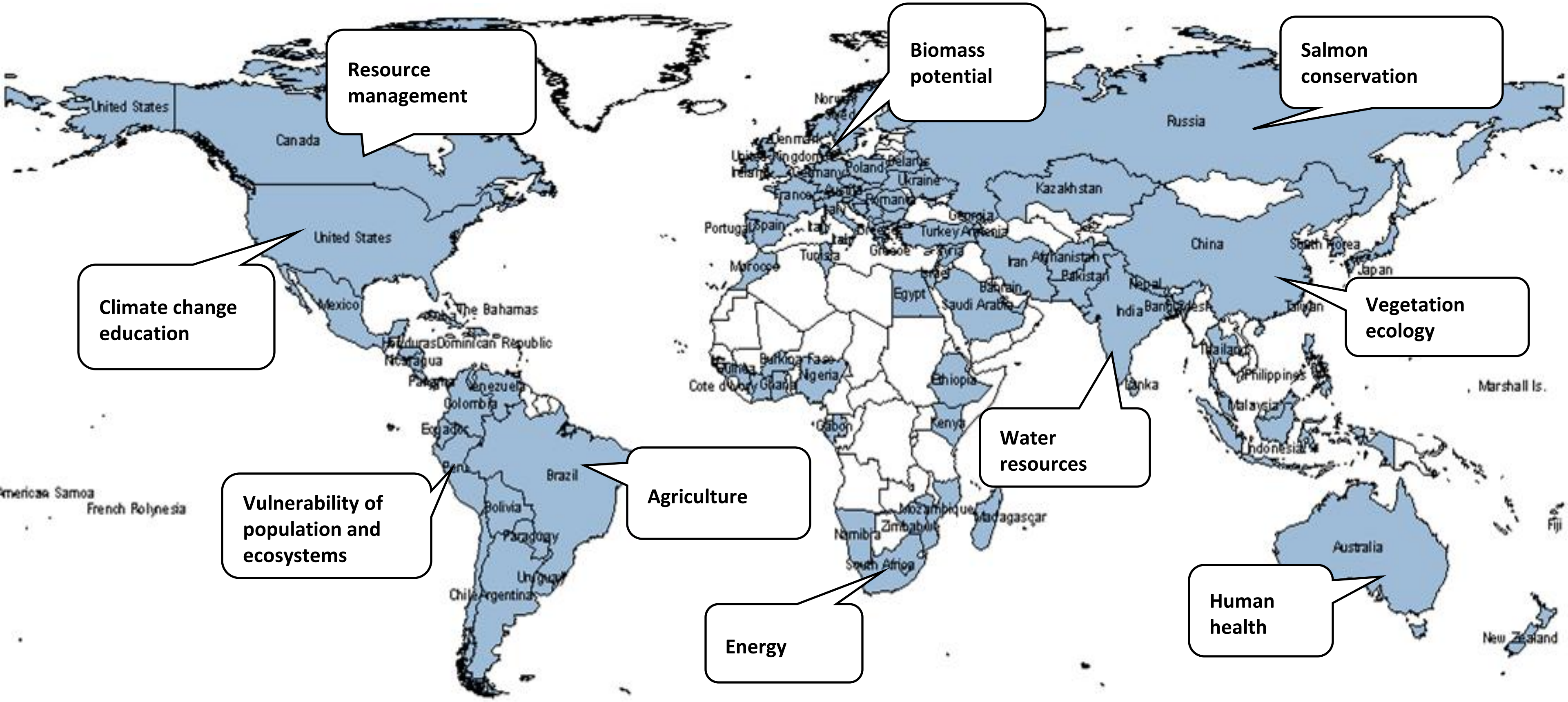
- NCAR GIS Initiative distributes CCSM IPCC projections (monthly averages) in a GIS format





http://www.gisclimatechange.org

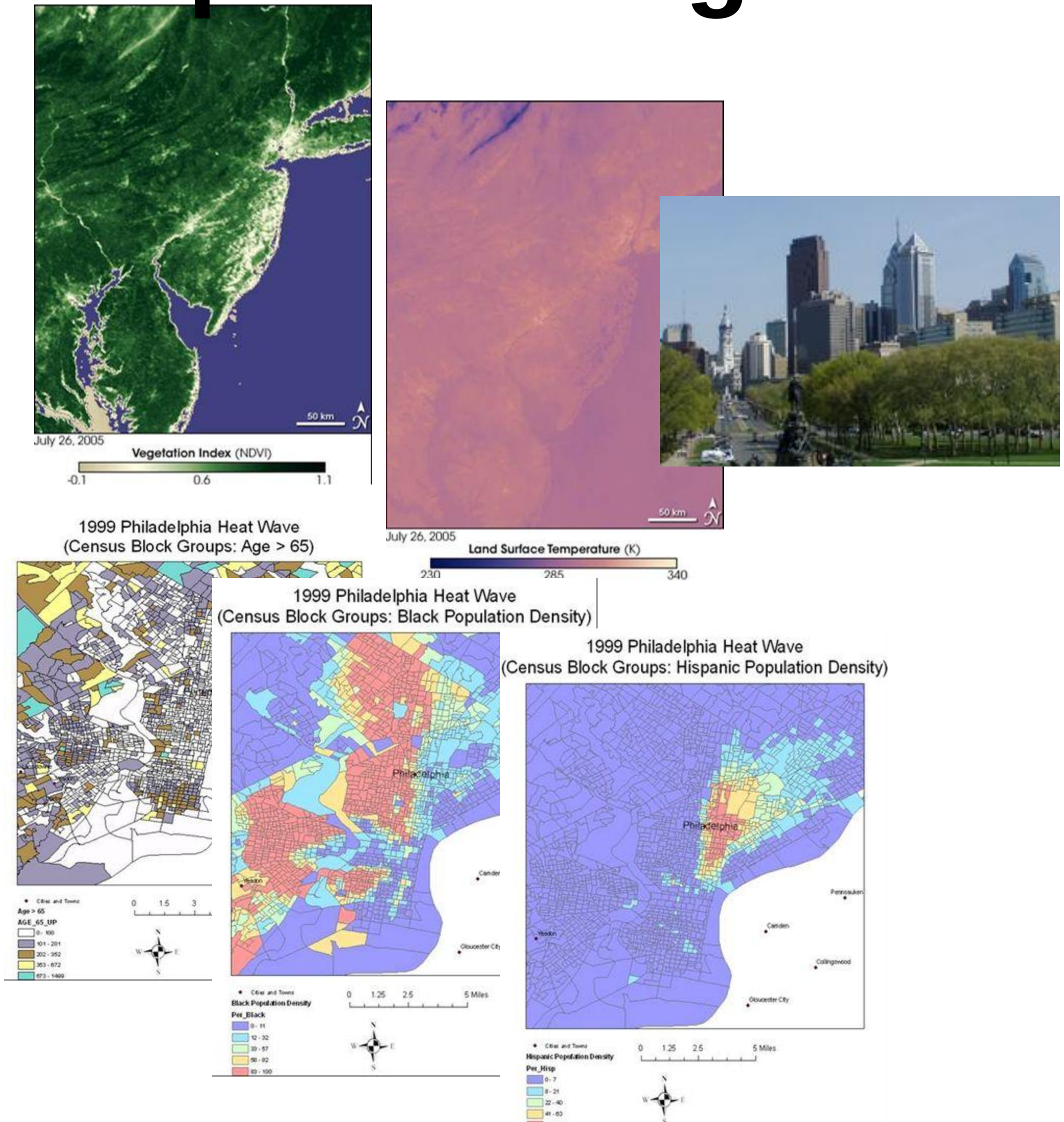
Users of NCAR GIS Portal

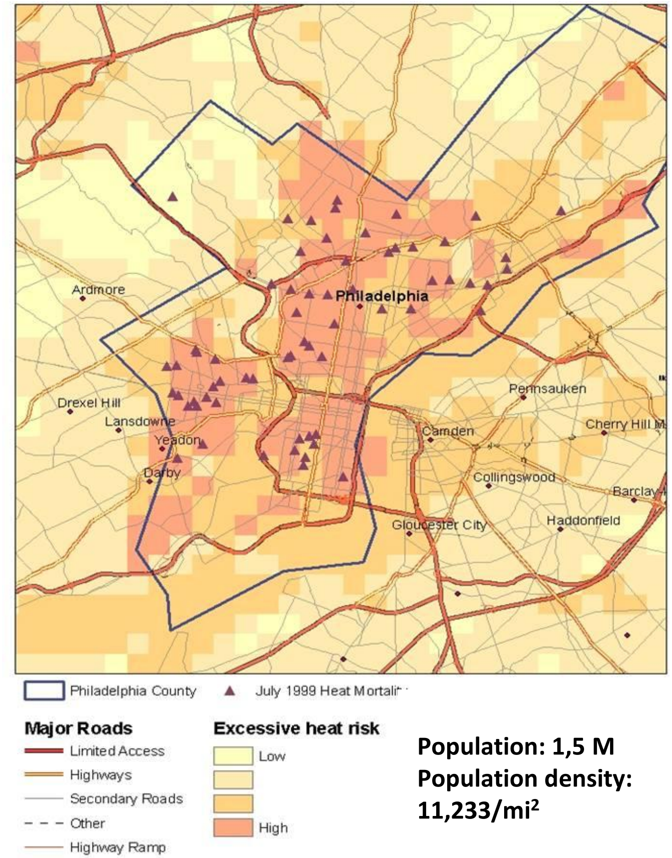


~ 2000 registered users from 108 countries;
~ 30K CCSM files downloaded

Types of users: Research; Education; Government; GIS; Environmental; Military and defense; Industry; Regional planning and economic development; Native American Tribes, Other…

GIS-based Risk Assessments: Spatial Integration and analysis





Population: 1,5 M
Population density: 11,233/mi^2

Wilhelmi, Uejio, Samenow (2007)

Case Study - India

- Indian coastline is about 7517 km long with rocky shores, sandy spits, barrier beaches, open beaches, embayment, estuaries, inlets, bays and wetlands.
- One quarter of the Indian population is living along the coastal area of India (MoEF, 2007)

Case Study - India

- In the East coast of India, the state of Tamil Nadu has the longest coastline (1076 km).
- In coastal regions, the hazards are aggravated by the climate change.
- The impact of global warming induced sea level rise due to thermal expansion of near surface ocean water has great significance to India due to its extensive low lying densely populated coastal zone.

Case Study - India

- Observations suggest that the sea level has risen at a rate of 2.5 mm per year along the Indian Coastline since 1950s.
- In the Bay of Bengal increasing sea surface temperatures since 1951 has resulted in a n increased cyclone intensive accompanied by higher storm surges.
- At present, about 23% of the shoreline along the Indian mainland is affected by erosion.

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APN Research Project

- A major component of the project includes designing and implementing an information management system, providing a flexible environment in which each collaborator can customize and maintain their specific database of coastal resources.

The major objectives of this collaborative research are as follows:

- To create, use and maintain a coastal information inventory (sea level, temperature, weather conditions, geologic, ecologic, biologic (both quality and quantity) information and spatial data).
- To facilitate storage, retrieval, updating, analysis and manipulation of coastal resource data, including spatially referenced information.

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APN Research Project

It consists of two parts

(a) database for storing the spatial and monitoring data of the study area and

(b) simple set software will provide users with basic querying, updating and reporting capabilities.

The Database Information Management System (DIMS) is designed to be used by two broad groups: regular end users (e.g., scientists and project leaders) and system administrators.




Approaches and Model

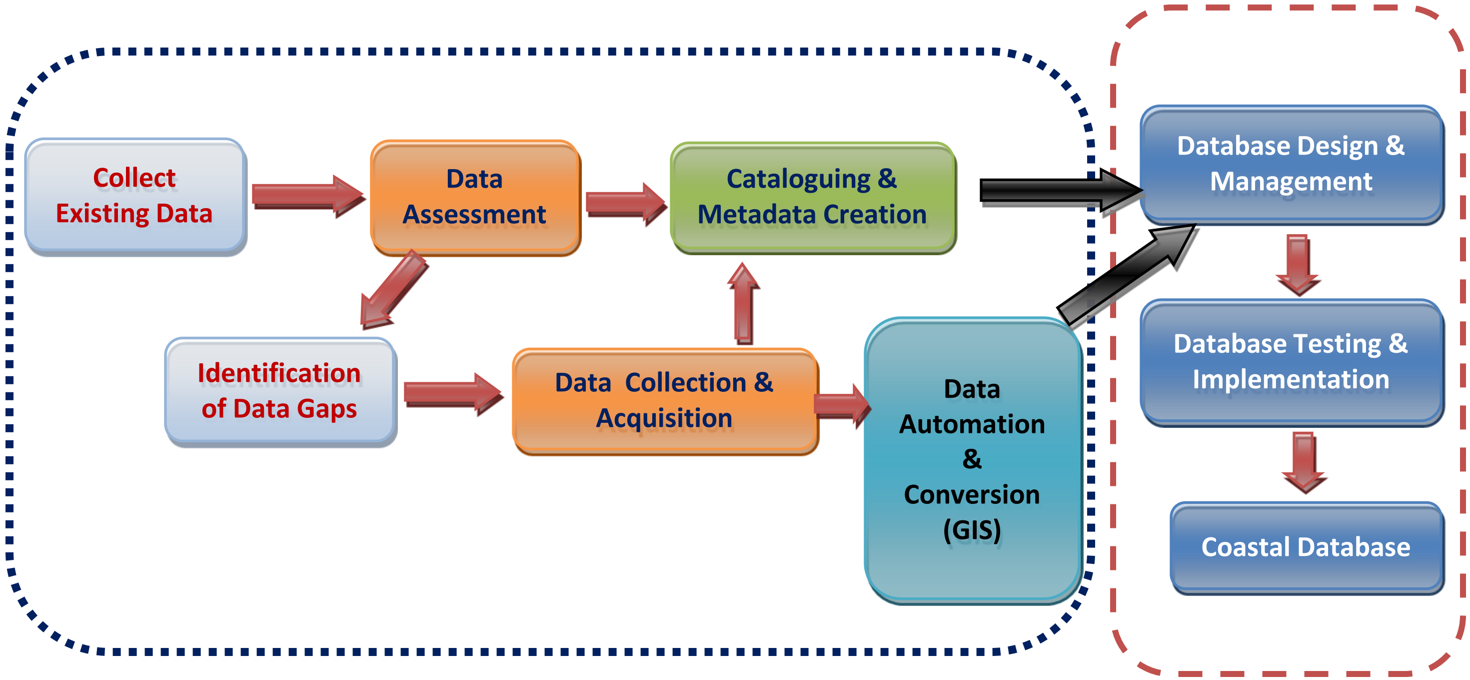
- IPCC – Seven steps for the assessment of the vulnerability of coastal areas to sea level rise – A common methodology.
- SURVAS (Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies)

Approaches and Model




- An extensive database supports the entire process with the aid of statistical and modeling tools.
  - Define study area
  - Generate primary thematic layers using satellite imagery and collateral data.
  - Collect Spatial and non-spatial data relating to the process.
  - Create a database in GIS consisting of thematic layers
  - Identify major components and criteria contribute to climate change.
  - Model the changes.

Methodology



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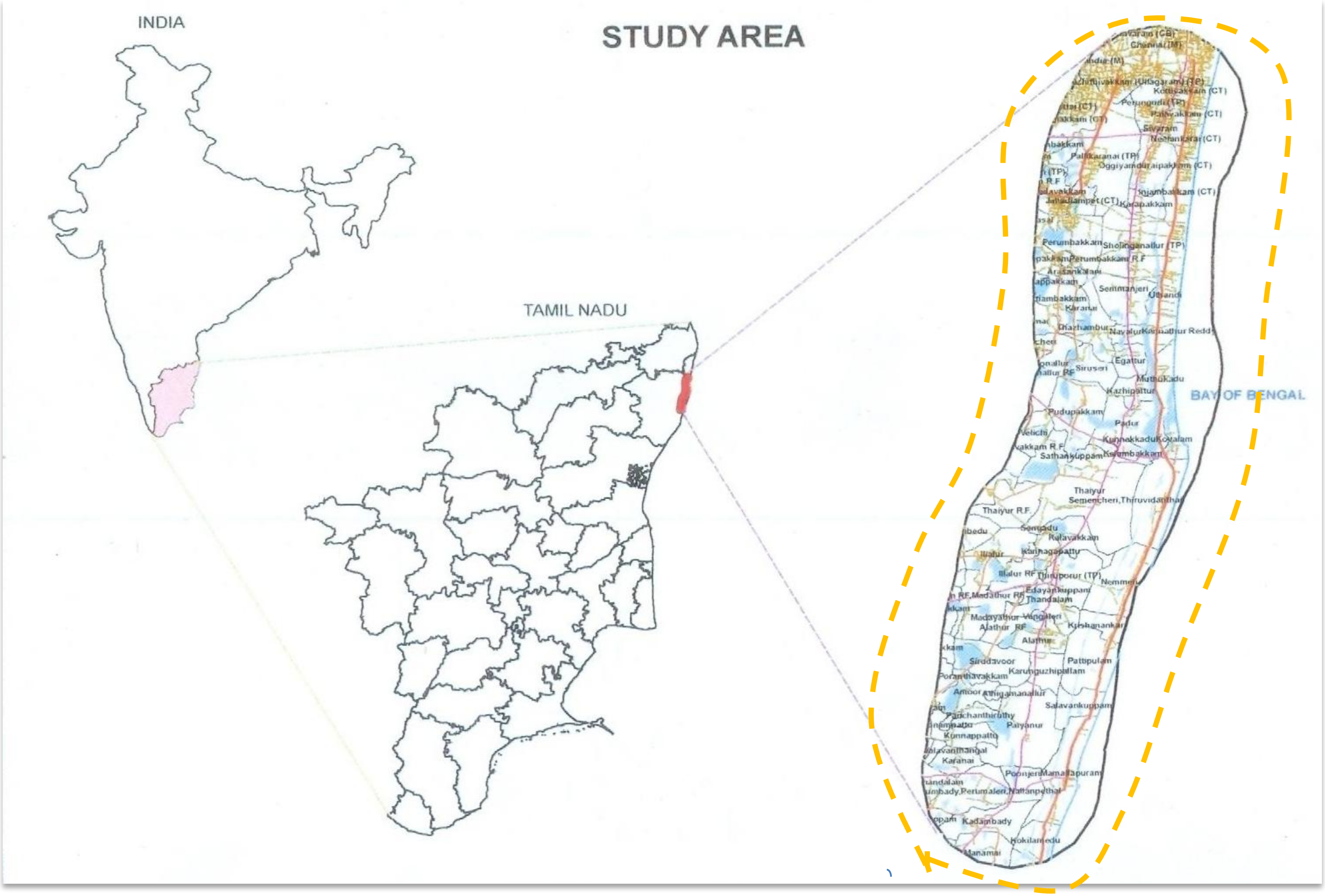
Study Area



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Study Area

- The entire study area is occupied by settlements mainly belonging to coastal community.
- Northeast coast of Chennai has major industries like fertilizer, steel rolling industries and petrochemical.
- Southeast coast of Chennai has beach resorts, farmhouses, aquaculture ponds, theme parks.

Database generation

- The data related to the study area has collected from various sources and a detailed database creation is in progress.
- The data used in the study comprises of Satellite data, collateral data and attribute data.

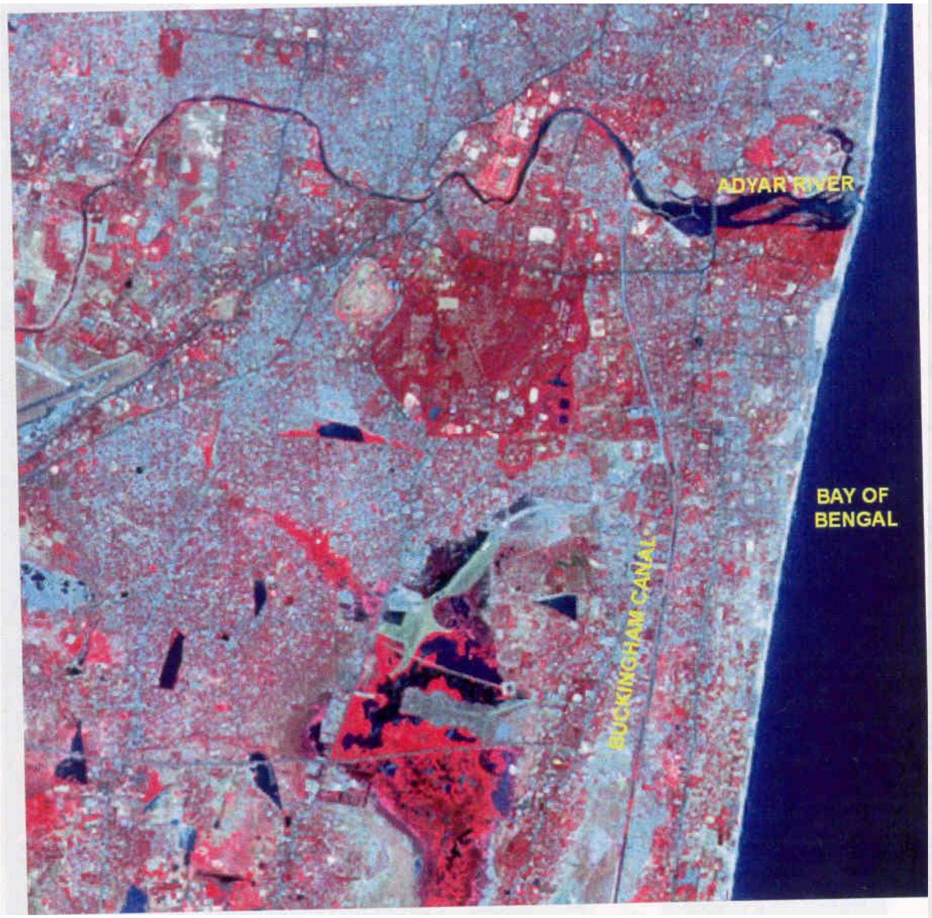
Database generation

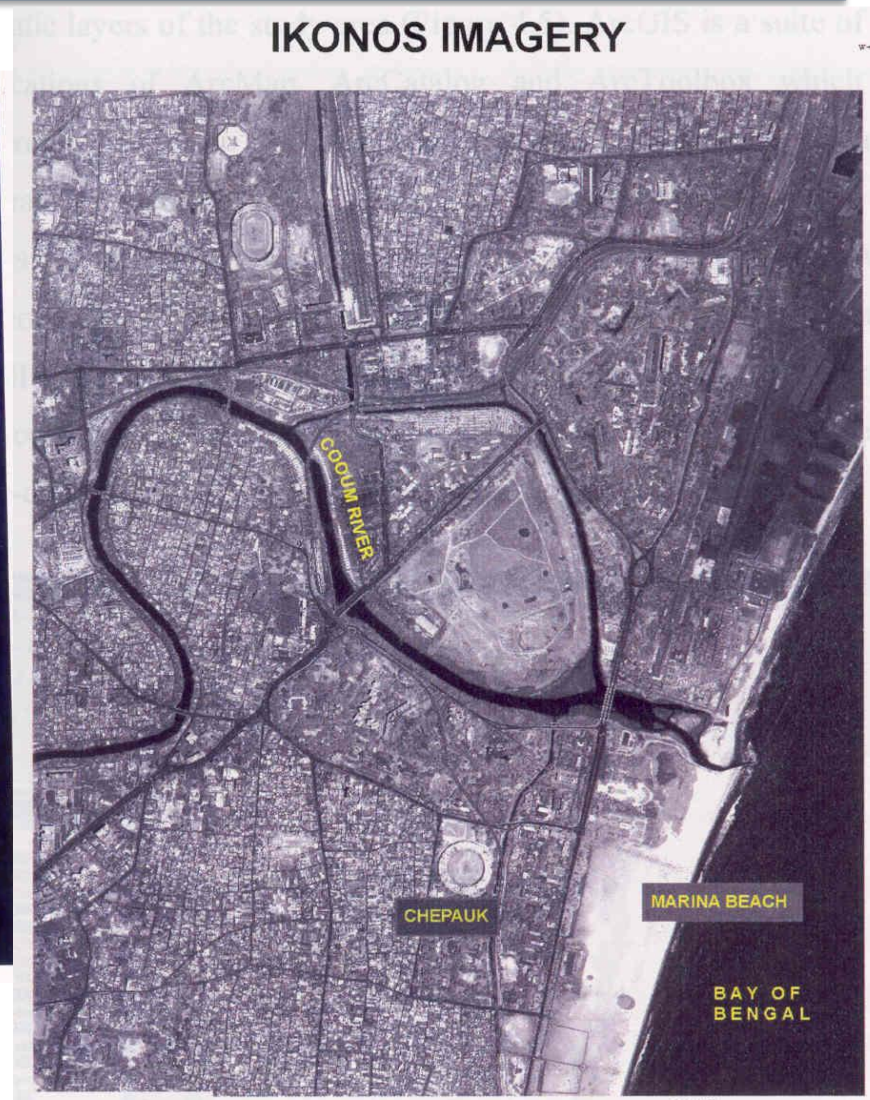
- Base map is obtained from Survey of India topographical sheets numbering 66C04, 66C08,66D01 and 66D05.
- Transverse Mercator projection with WGS84 datum has been used for the maps.

Database generation

- Georeferenced satellite imagery of IRS-1C (LISS III) + IRS-P6 (LISS IV) and IKONOS-2 PAN data with a spatial resolution of 1m have been used for creating a spatial database for landuse/landcover and other thematic layers.

Satellite Imagery





Details of Data Collected

Data	Period	Purpose	Source
Demographical data	2001	Estimation of population density and socio-economic parameters	Census Department, GoI
Erosion rate	2001	Coastal erosion trend in the study area	PWD, GoTN
Rainfall data	1995-2005	Precipitation Variability	IMD
Elevation data	1998	Elevation model	US NGDC and UNEP/GRID Centre
Wave height	1997-2009	Mean wave and tidal height	Port Trust of India
Cylcone Tracks	1994-2007	Proximity of land to cyclone tracks	Joint Typhoon Warning Centre
Bathymetry	1991	Continental Shelf-Slope Pattern	Navel Hydrographic Office

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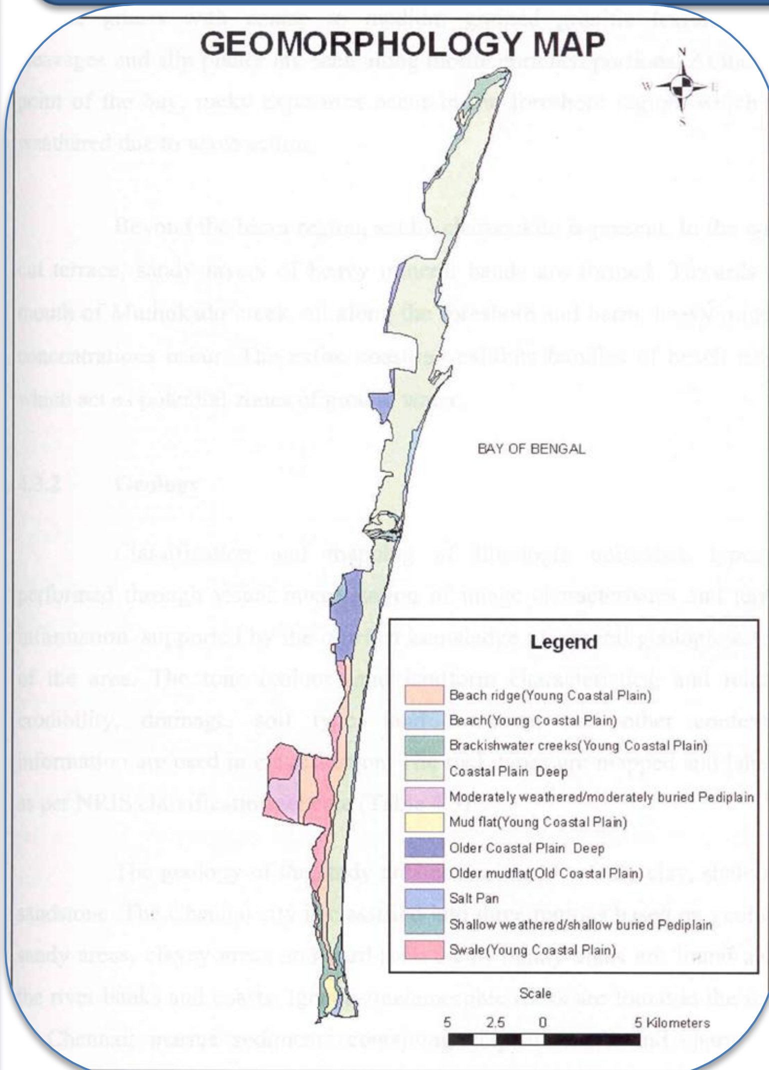
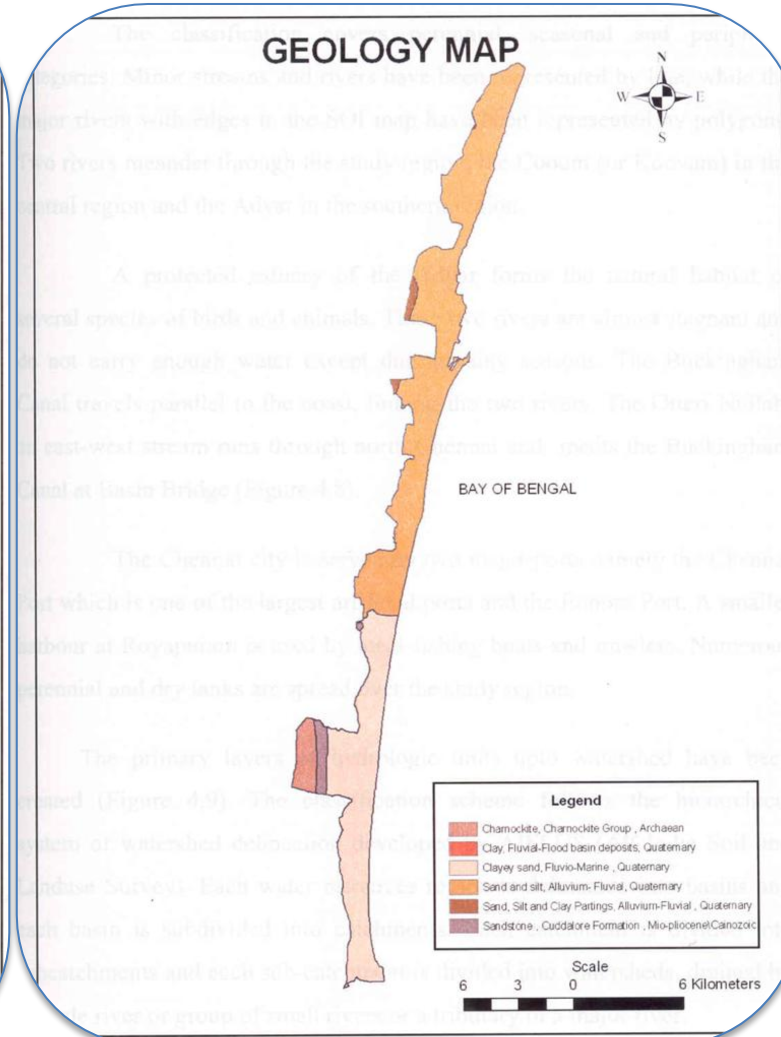
Geomorphology & Geology Map





Geomorphology

- Geomorphologically, the study area comprises younger and older coastal alluvial plains.
- Younger Coastal plain is characterized by narrow to wider beaches .
- Vast coastal plain is characterized by strandlines, lagoons, mangroves, salt mash, estuaries, creek, barred dunes, spits and beach terraces.

Geomorphology

Zone	Geomorphic Unit	Sub-category
Pediplain	Pediplain weathered/buried	Shallow weathered/shallow buried pediplain
		Moderately weathered/moderately buried pediplain
Coastal Plain	Old Coastal Plain	Older Mudflat (Old Coastal Plain)
		Older Coastal Plain Deep
	Young Coastal Plain	Beach Ridge
		Swale
		Brackishwater Creeks
		Coastal Plain Deep
		Mudflat
		Beach
		Salt Pan

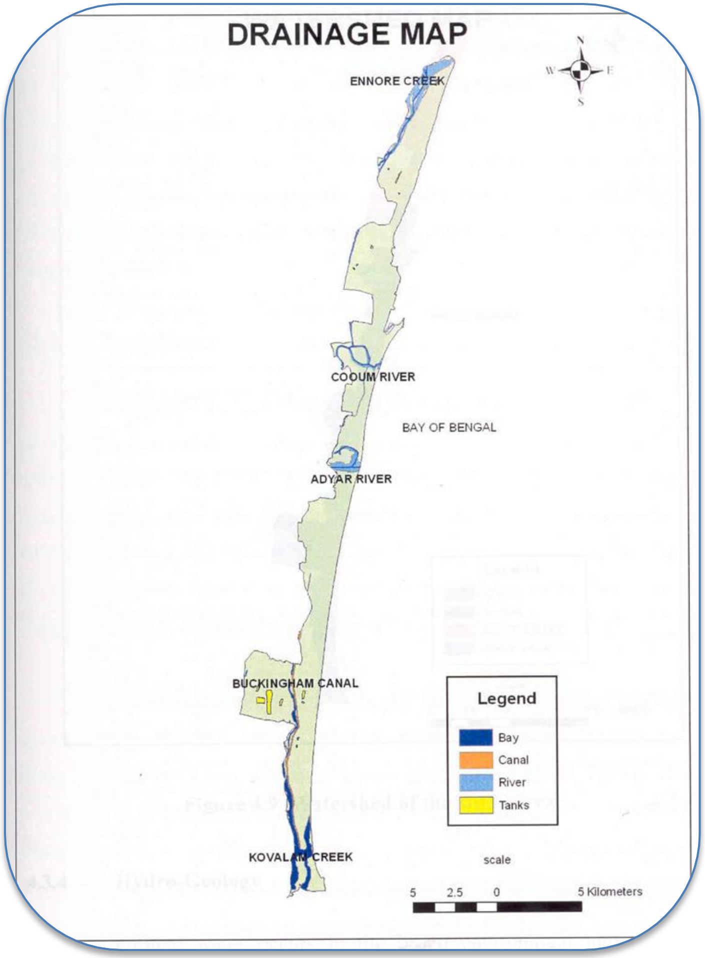
Geology

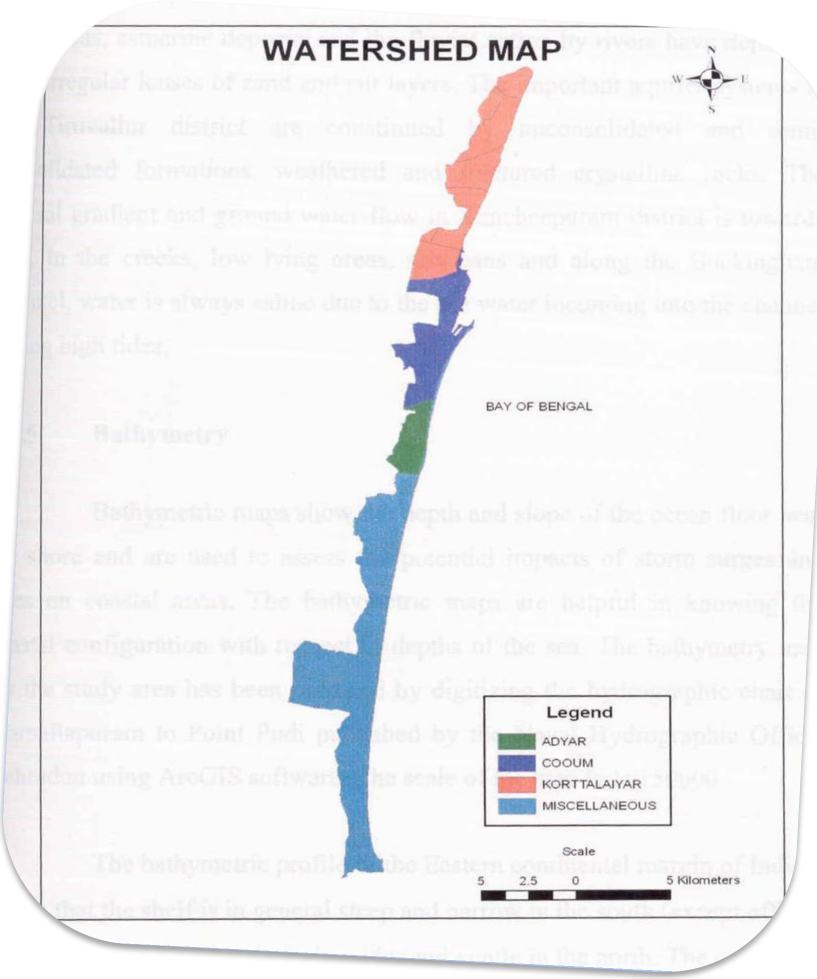
- Geology of the study area comprises of mostly clay, shale and sandstone.
- Sandy areas are found along the riverbanks and coasts.
- Igneous /Metamorphic rocks are found in south
- Clay silt sands and charnockite rocks in eastern and northern parts.
- Western Parts composed of alluvium and sedimentary rocks.

Lithologic Unit Classification

Lithologic Unit	Rock Type	Stratigraphy
Clay	Fluvial-Flood Basin Deposits	Quaternary
Clayey sand	Fluvio-Marine	Quaternary
Sand, Silt and Clay Partings	Alluvium-Fluvial	Quaternary
Sand and Silt	Alluvium-Fluvial	Quaternary
Sandstone	Cuddalore Formation	Mio-pliocene/Cainozoic
Charnockite	Charnockite Group	Archaean

Drainage and Hydrology Map

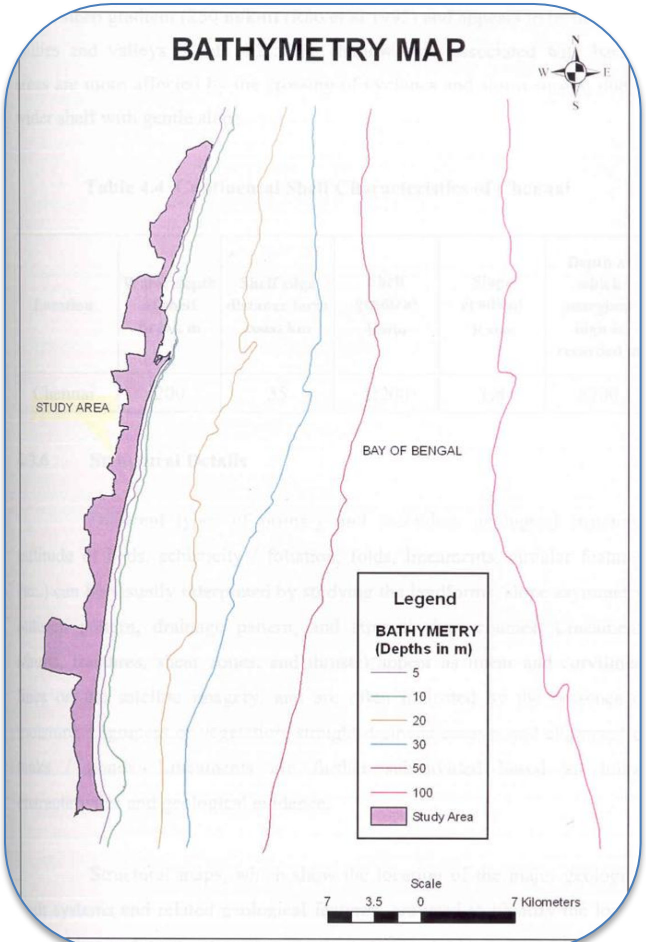




Drainage and Hydrology

- Classification Covers perennial, seasonal and peripheral categories.
- Minor streams and rivers have been represented by line, while the major rivers represented by polygons.
- Watershed classification follows AISLUS (All India Soil and Landuse Survey).

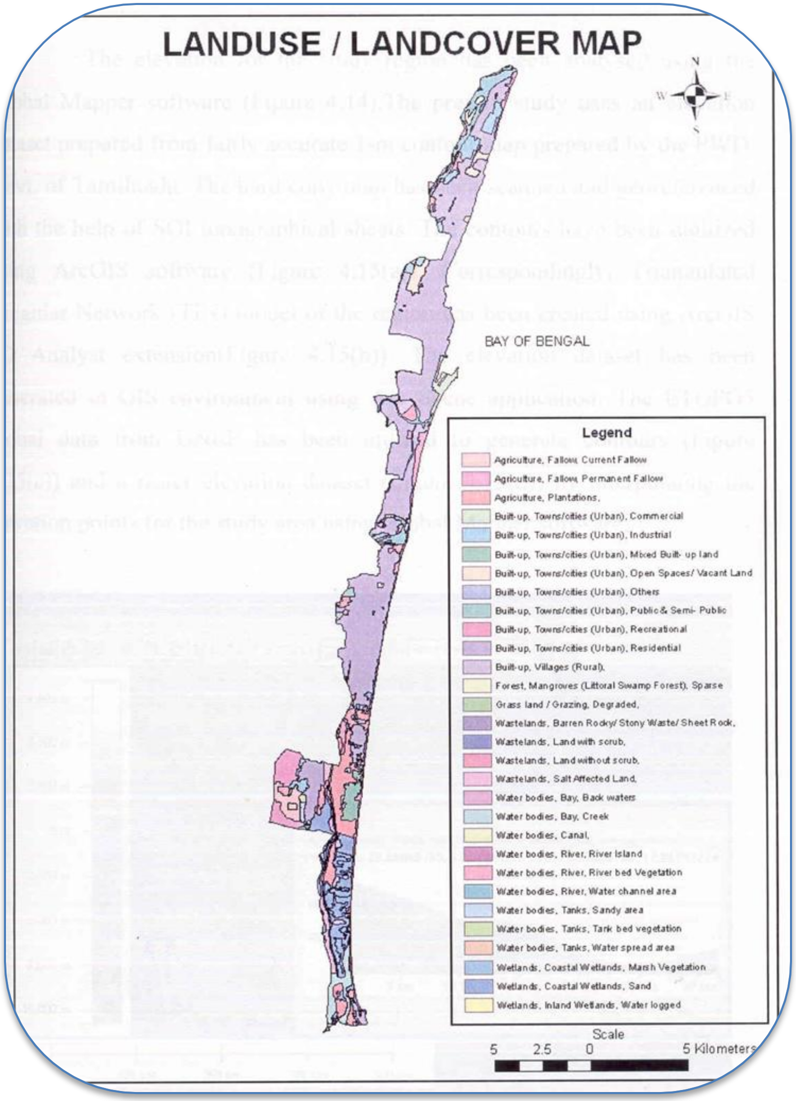
Bathymetry Map



- Width of Continental shelf is 43 km off Chennai and depth at which Shelf-break occurs is 200m at Chennai.

Water depth at shelf break, (m)	200
Shelf edge distance from coast (km)	55
Shelf gradient Ratio	1:200
Slope Gradient Ratio	1:8
Depth at which marginal high is recorded (m)	2700

Landuse/Landcover Map



Landuse/Landcover Map

- Landuse /Cover map has been prepared as per the NRIS Classification Scheme.
- It is visually interpreted using ERDAS Imagine Software and Classified.
- Interpretation process has involved reference to collateral data such as SOI toposheets.

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Landuse/Landcover Classification

Level I	Level II	Level II	Level IV
Built up	Townes/Cities (Urban)	Residential	
		Industrial	Salt Pans
		Commercial	
		Recreational	Parks/grounds, gardens, stadium, racecourse, beaches
		Public & Semi Public	Educational Institution
		Mixed builtup	
	Rural		
Agricultural	Fallow	Current Fallow	
	Plantations	Permanent fallow	

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Landuse/Landcover Classification

Level I	Level II	Level II	Level IV
Forest	Mangroves (littoral Swamp Forest)	Sparse	
Wastelands	Salt Affected Land		
	Land with Scrub		
	Land Without Scrub		
	Barren Rocky/Stony Waste/Sheet Rock		
Water Bodies	River	Water channel area, river island, river bed vegatation	
	Tanks	Water spread area, tank bed vegetation	
	Bay	Back water, creek	
	Canal		

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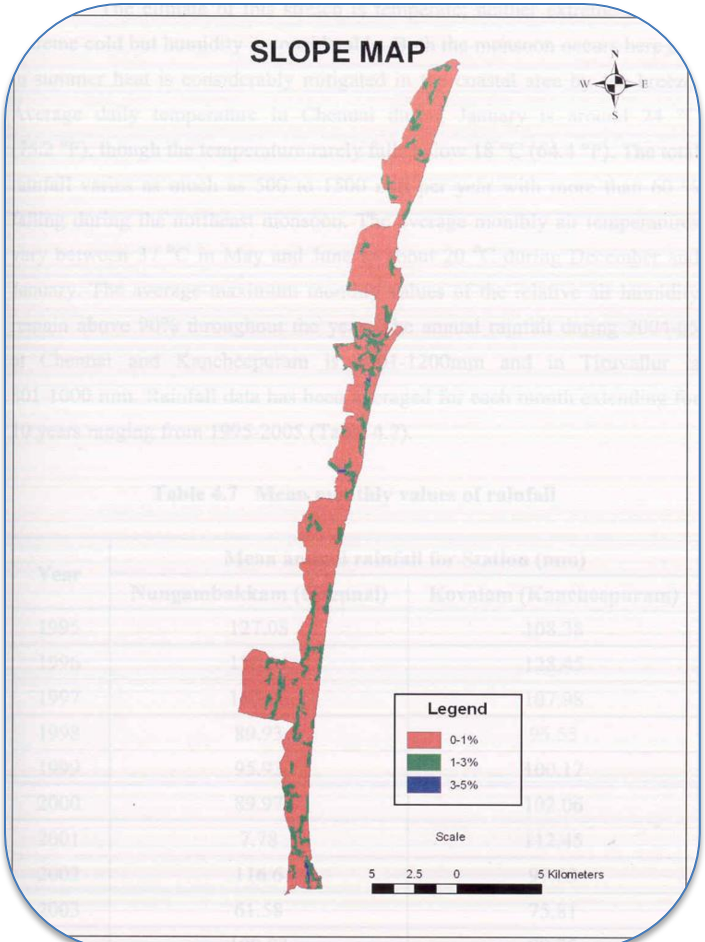
Slope Map



- Study region is located on a flat coastal plain known as the Eastern Coastal Plains.
- Chennai 25.60 km of sea coast which is flat and sandy
- Bed of the sea is about 42' deep and slopes further to depth of 63'
- Study region has an almost flat terrain with slope between 0-1%

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Climate and Rainfall

- Climate of the study area is temperate; nether extreme heat nor extreme cold but humidity is considerable.
- Average Monthly values of relative air humidity remain above 90%.
- Total rainfall varies as much 500 to 1400 mm per year.
- Average monthly air temperatures vary between 37 °C in May and June to about 20°C during December and January.

Mean Monthly Values of Rainfall

Year	Mean Annual Rainfall in Chennai (mm)	Mean Annual Rainfall in Kovalam (mm)
1995	127.08	108.38
1996	130.54	128.45
1997	167.96	107.98
1998	89.93	95.55
1999	95.93	100.17
2000	89.97	102.06
2001	7.78	112.45
2002	116.6	97.63
2003	61.58	75.81
2004	100.83	89.55
2005	10.09	10.82

Winds

- Predominant wind directions in the study area are NE, ENE, SSW, SW, ESE and SE.
- Northeast monsoon the wind blow predominantly from northeast with a speed of 5.8-7.5 m/s and direction of 49-87° with respect to north.
- During the SW monsoon winds blow predominantly from the southwest, with a speed of 2-12m/s and direction of 153-263°


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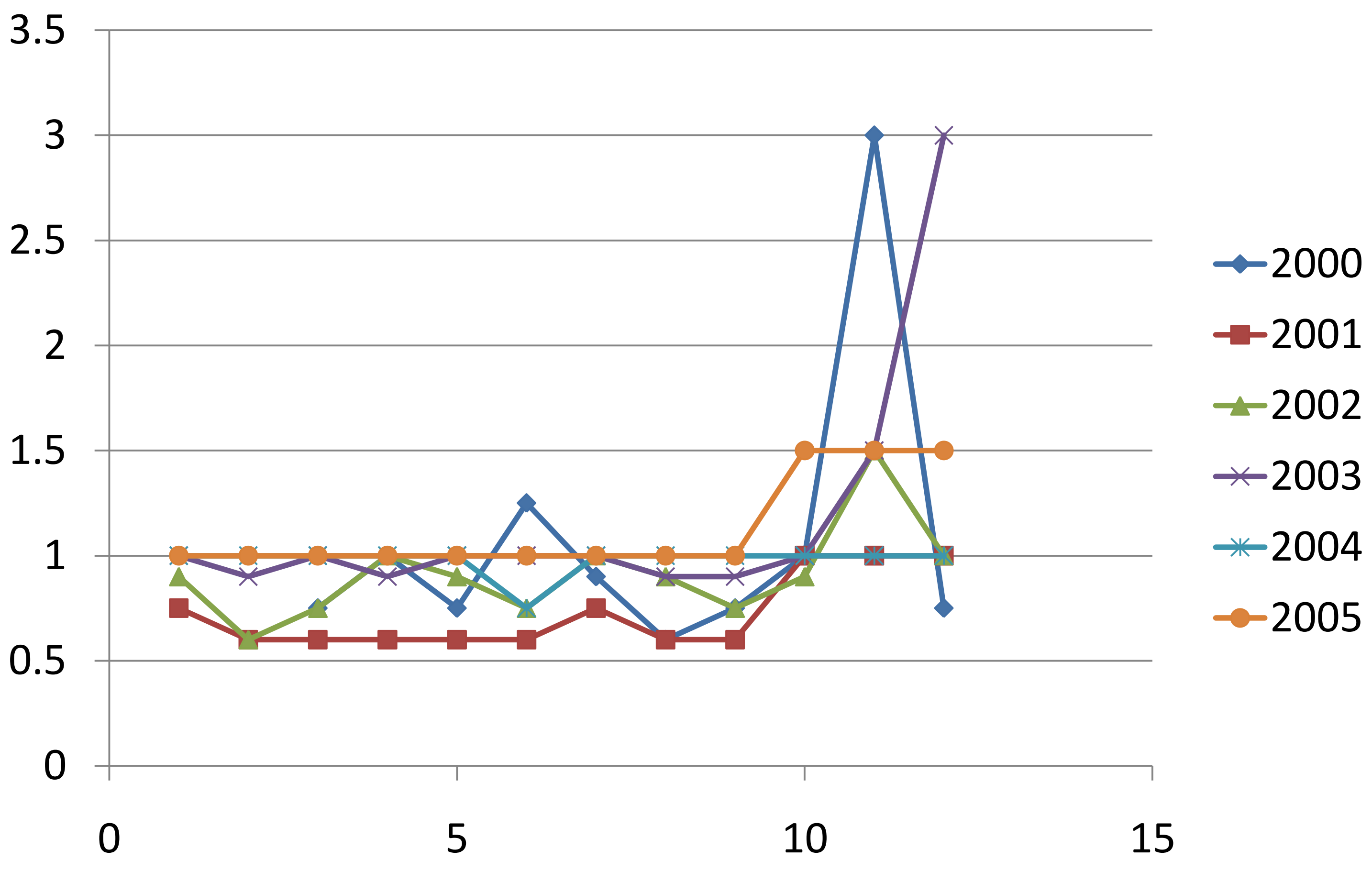
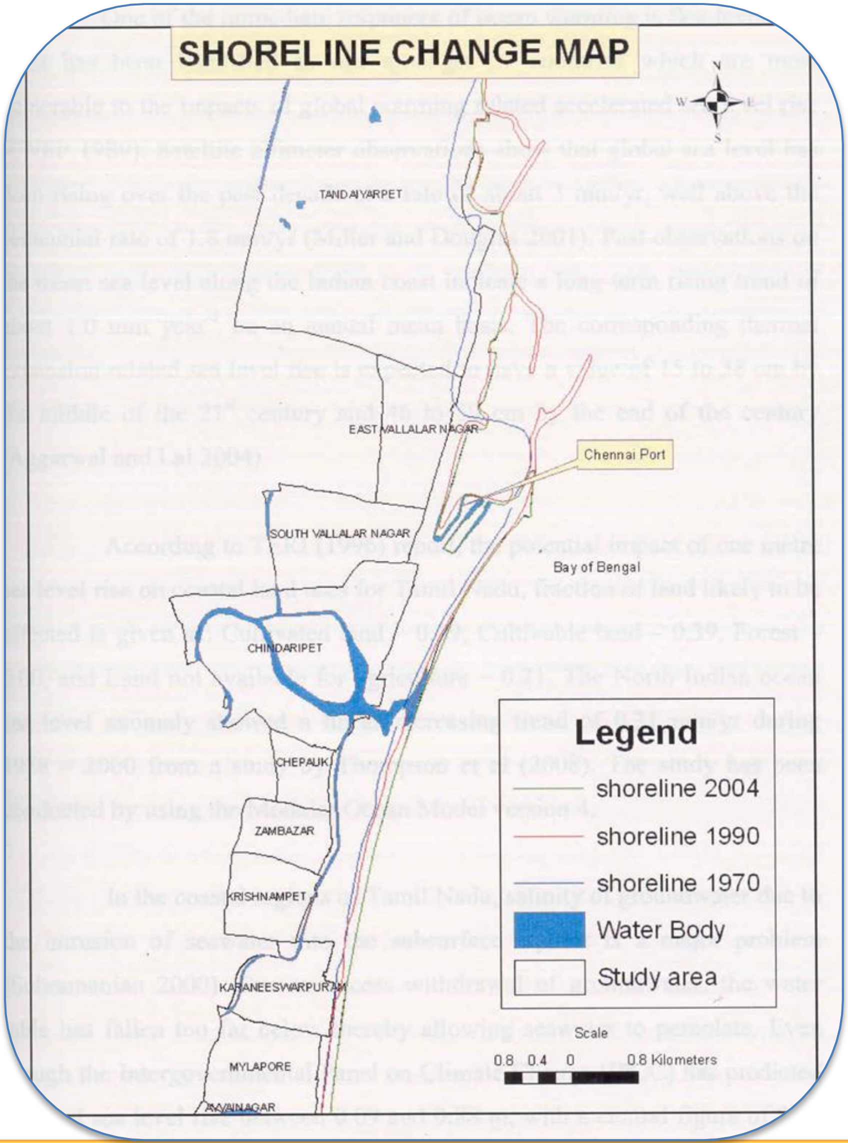
Wave Height


3.5
3
2.5
2
1.5
1
0.5
0
0
5
10
15
2000
2001
2002
2003
2004
2005

Shoreline Change Map



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Multi Criteria Decision Making

- A decision is based on a set of rules by which criteria are combined to arrived at a particular decision.
- The design of multi-criteria environment attempted to use a variety of evaluation techniques to data from GIS and presented them in a manner familiar to decision makers.

Multi Criteria Decision Making

- By integrating the evaluation techniques with GIS, it has been intended that the effective factors would be evaluated more flexibly and thus more accurate decision would be made in a shorter time by the decision makers.

Multi Criteria Decision Making

- By integrating the evaluation techniques with GIS, it has been intended that the effective factors would be evaluated more flexibly and thus more accurate decision would be made in a shorter time by the decision makers.

- Using statistical functions available in GIS systems, the values of various properties have been computed.

Multi Criteria Decision Making

- The threat maps generated for various hazards have been be suitably overlayed with population, landuse and other thematic maps to arrive at meaningful conclusions.

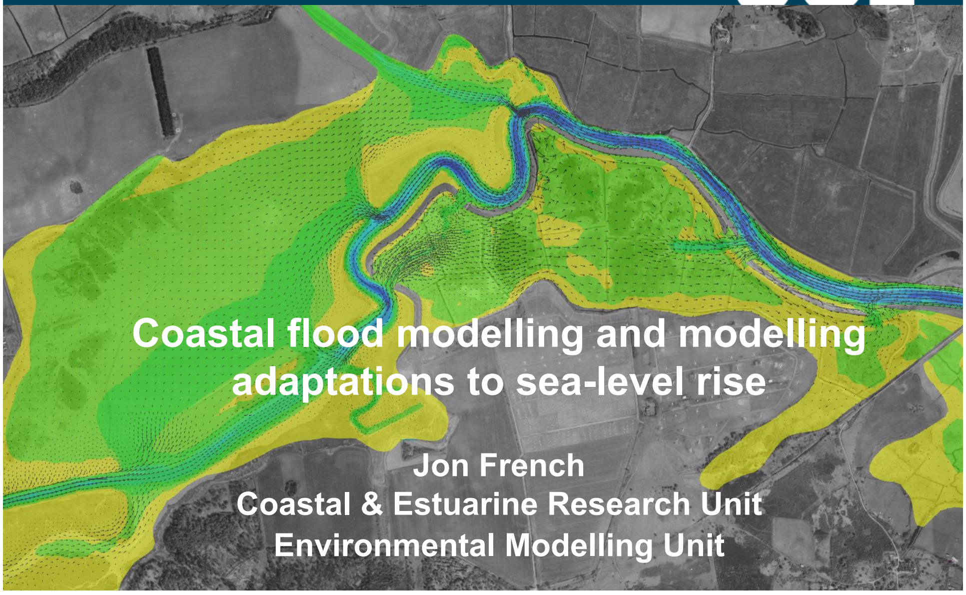
Any doubts??

Further comments ??

Unanswered questions ??

Unresolved issues

Thank You



Coastal flood modelling and modelling adaptations to sea-level rise

Jon French
Coastal & Estuarine Research Unit
Environmental Modelling Unit

Themes covered

Spectrum of coastal modelling approaches

High spatial resolution numerical modelling
- Surface Water Modeling System (SMS)
- Telemac 2D and FVCOM models
- Case study: impacts of management response to erosion and sea-level rise in UK estuaries

Reduced complexity models
- SLAMM model of erosion and inundation in coastal wetlands
- Demo: impacts of IPCC sea-level rise scenarios

Spectrum of approaches to modelling coastal change

Reduced complexity
(SCAPE, SLAMM)

QR-based
(Capobianco et al. 1999)

Physically-based
(e.g. Delft3D, Telemac)

Boolean networks
(EstSim)

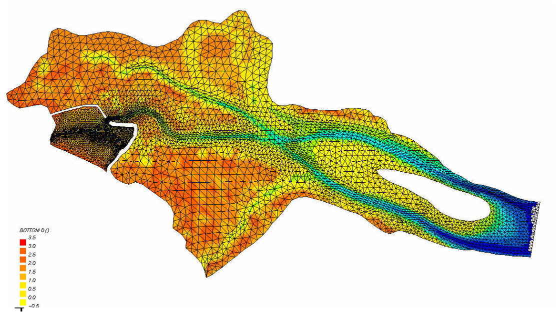
Semi-empirical
'top down'
(ASMITA)

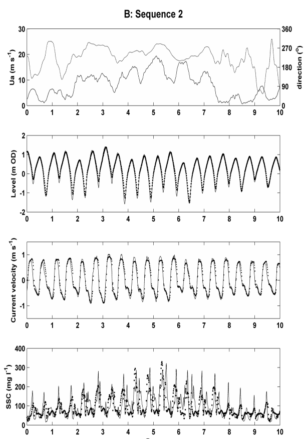
Fuzzy logic
(e.g. Tyndall Centre)

Mechanistic, data-driven ⟷ Qualitative, knowledge-driven

High spatial resolution models

- Complex computational grids/meshes
- Boundary condition and validation data
- Require sophisticated pre- and post-processing tools

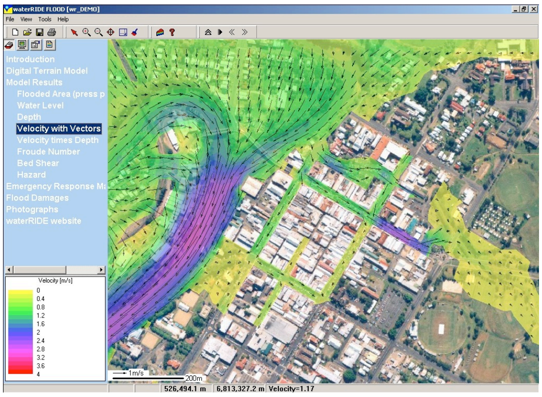




Telemac2D mesh and validation example

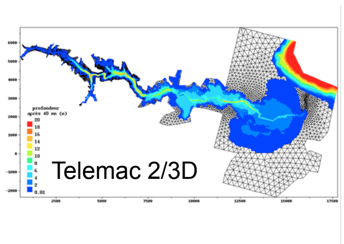
Increasing number of commercial products specifically aimed at inundation modelling

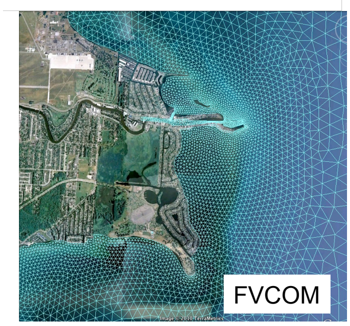
e.g. waterRIDE FLOOD package (www.waterride.net)

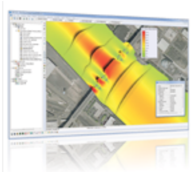


- import hydraulic model results
- specialised GIS functionality
- distribution of flood damage
- flood hazard maps
- interactive flood animations
- emergency response planning

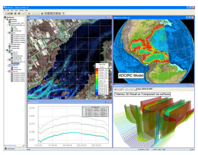
Models and software tools in use at UCL



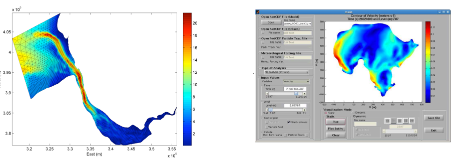




Surface Water Modeling System (SMS)

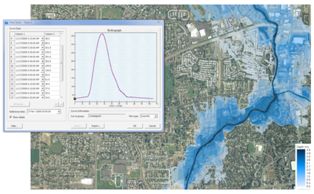


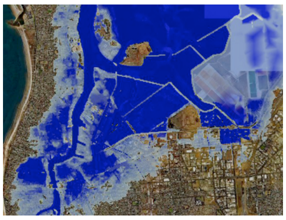
Blue Kenue



Telemac Tools and FVCOM model builder

www.aquaveo.com/sms

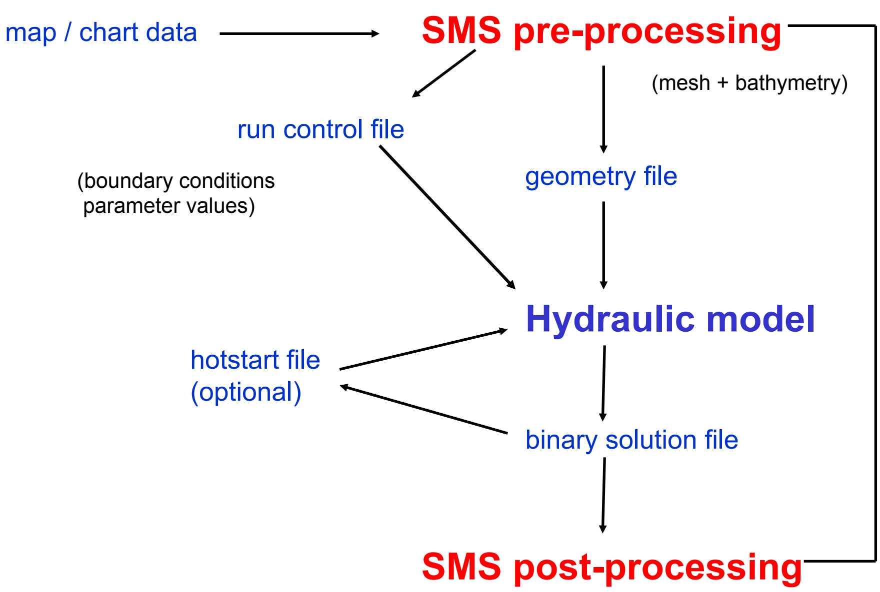




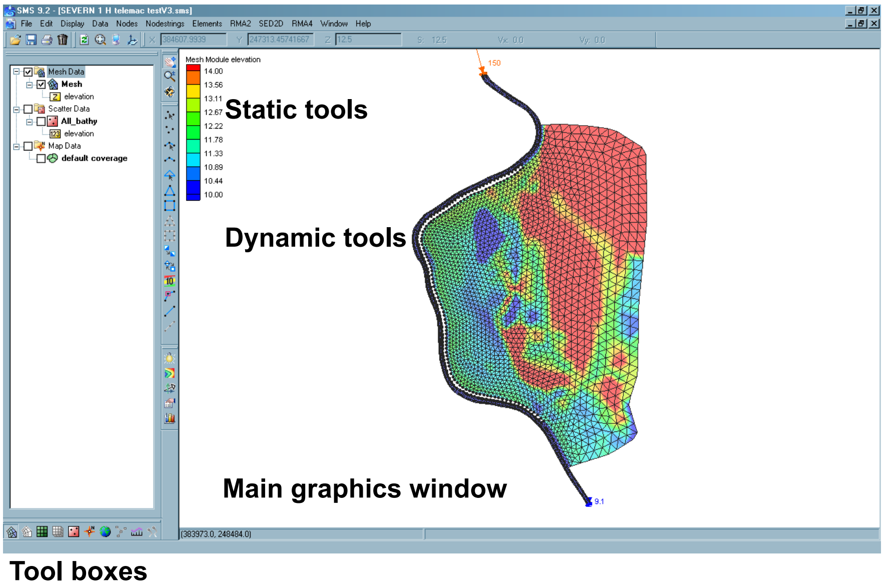
SMS is a powerful tool for managing the entire surface water modelling process, from importing topographic and hydraulic data to visualizing and analyzing solutions. SMS interfaces with a wide range of numerical models for applications including river flow analysis, contaminant transport, sediment transport, particle tracking, rural & urban flooding, estuarine, coastal circulation, inlet and wave modeling.

Supported models:

RMA2, RMA4, FESWMS, TUFLOW, HYDRO AS-2D, ADCIRC, CMS Flow, CMS Wave, STWAVE, BOUSS-2D, CGWAVE



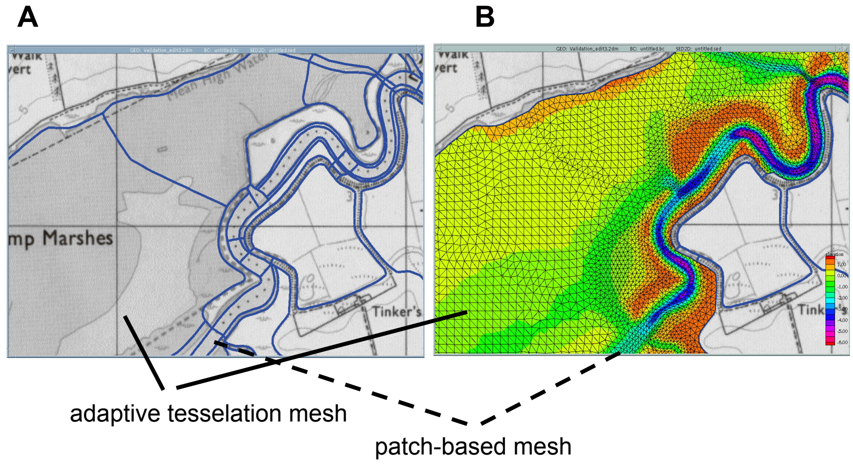
SMS desktop



Main modules

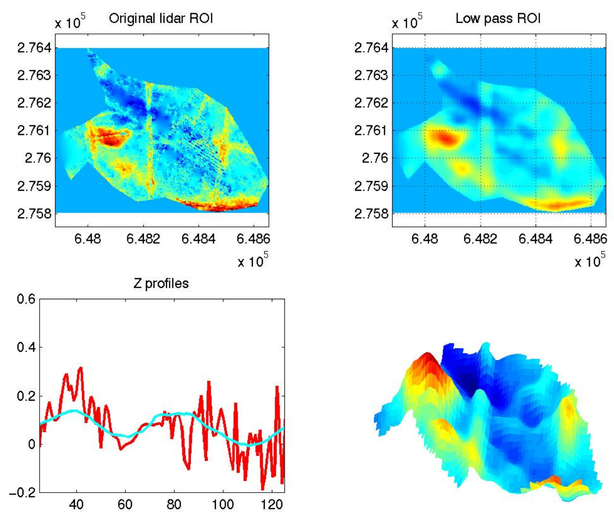
- GIS module
  - import a large map files and clip / filter content
- Map module
  - import a base map (e.g. TIFF image of chart)
  - generate conceptual model (polygons, features)
  - assign bottom friction by feature
  - specify mesh type and convert polygons to mesh
- Mesh module
  - display and (if required) manually edit mesh
  - define strings of nodes at which to define boundary conditions
  - check mesh quality
- Scatter point module
  - select bathymetric data set and interpolate onto mesh nodes

GIS functionality is vital for complex problems



A) Use of polygons to define morphological units and mesh types; B) resulting mesh with interpolated bathymetry (SMS screenviews). French (2008, *J. Coastal Research*).

Integrating sparse bathymetric soundings and altimetry data: 'bare earth' LIDAR



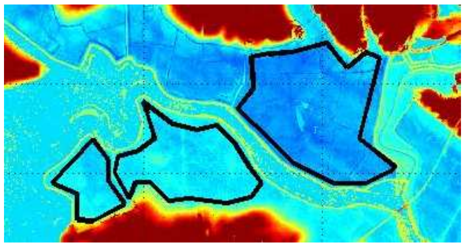
French & Clifford (2000 *Hydrological Processes*): French (2003 *Earth Surf Proc Landf*)

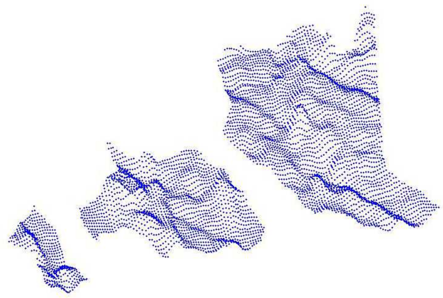
Raster to vector data reduction

12 x 4 km mosaic
  12 x 10^6 values (≈24-96MB)

Sub-image containing 17 ROIs
  8 x 10^6 values (≈16-64MB)

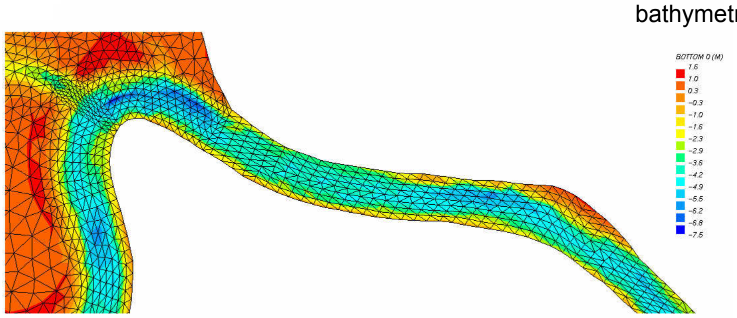
17 re-sampled vector datasets drawn from sub-image
  12 x 10^3 values (≈24-96KB)

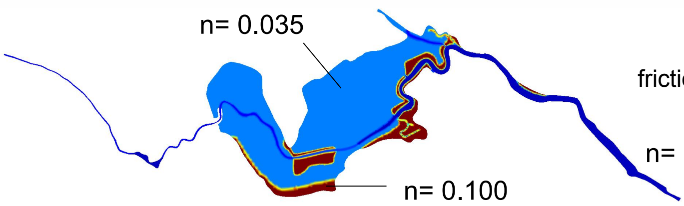




French (2003 *Earth Surf Proc Landforms*)

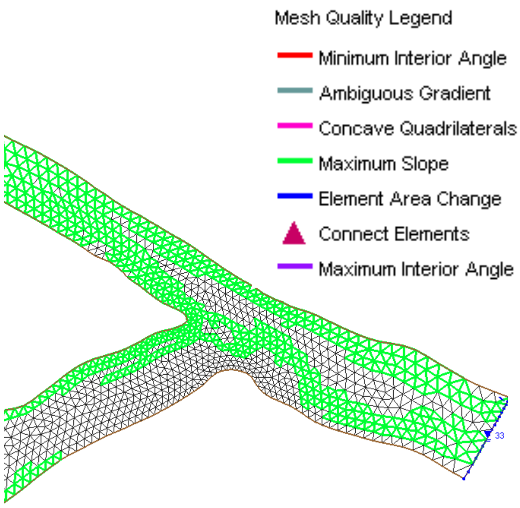
Spatial zoning of mesh type and associated friction parameters



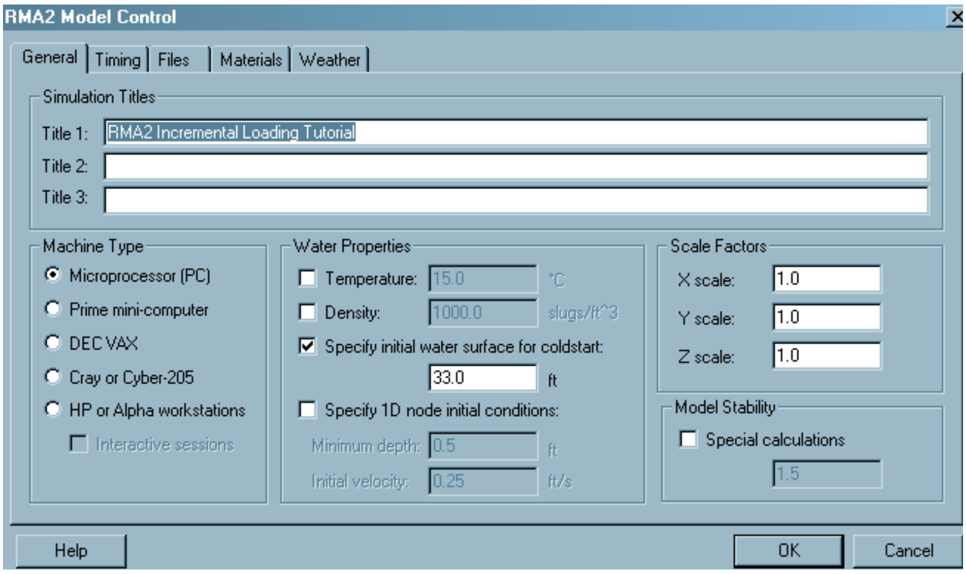


Mesh quality checking

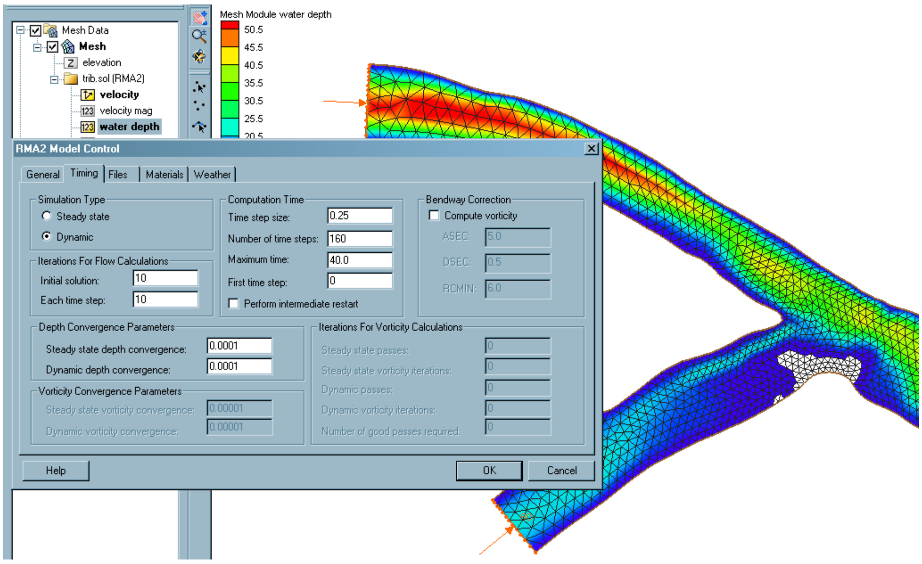
- Elements angles >10 deg°
- No abrupt changes in element area
- Avoid bottom slopes of >20% along flow
- Bathymetric contours should be smooth
- Wetting/drying elements need special care



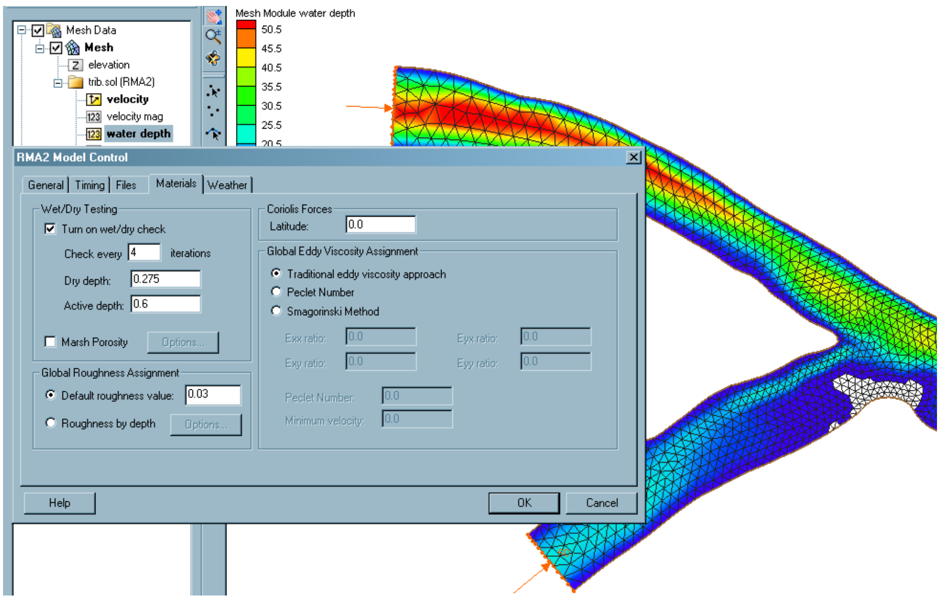
SMS – model integration



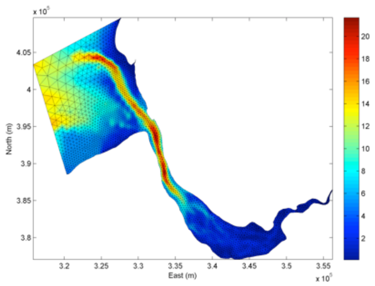
Run control: timing

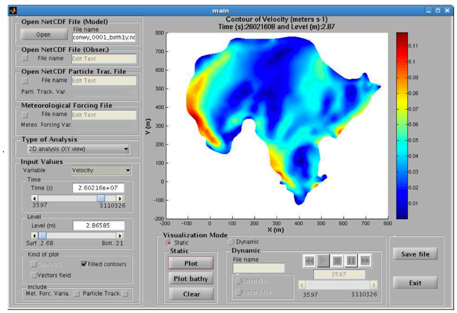


Run control: wet/dry check option



Interfaces to other models





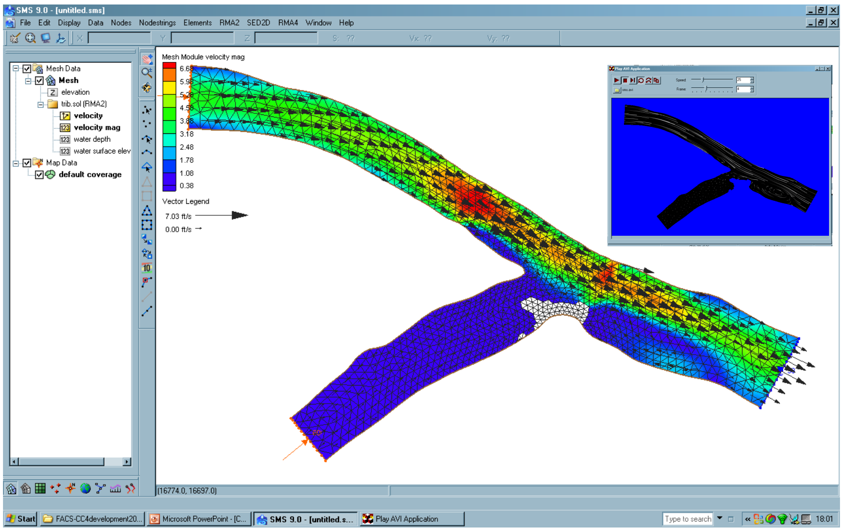
Telemac Tools and FVCOM model builder

Post-processing

- Static 2-D views
  - vector or scalar plots
- 1-D time-series extraction
  - scalar variables at points of interest
  - comparison of modelled versus observed data
- Dynamic 2-D animations
  - vector and/or scalar variables with timestep
  - flow trace animations (particle ‘seeding’)

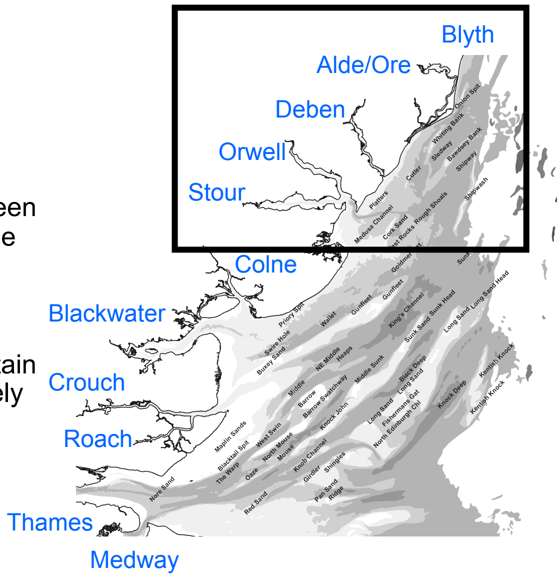
SMS

Post-processing



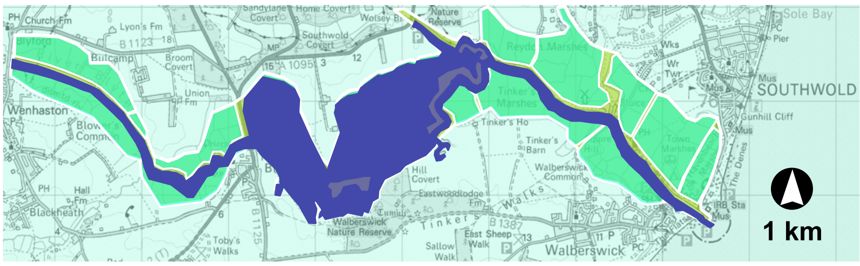
Case study: impacts of sea-level rise on estuaries in southeast England

- SE England has a highly indented estuarine shoreline, much of it protected by artificially elevated flood defences
- Whilst the Thames has been intensively researched, the smaller estuaries are less well understood
- The smaller systems contain large areas at a moderately high risk from flooding



Alde/Ore estuary with and without flood defences and Slaughden coastal frontage maintained (source: Suffolk Estuary Strategy)

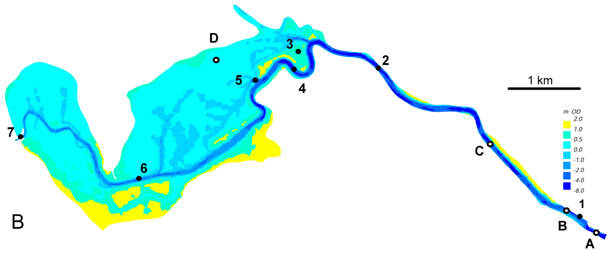
Blyth estuary: reclamation, harbour siltation, flood defence failures, erosion and potential inundation of lowland margins



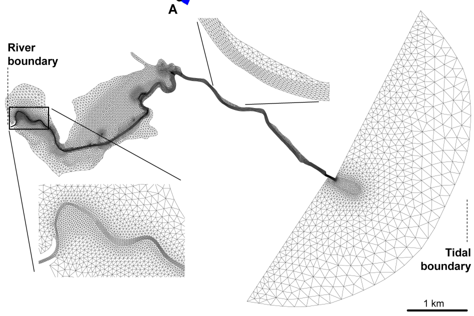
estuary area pre-reclamation
reclamation by 1840
reclamations abandoned in 1926-41
current estuary area



Hydrodynamic modelling of managed realignment as an adaptive response to sea-level rise

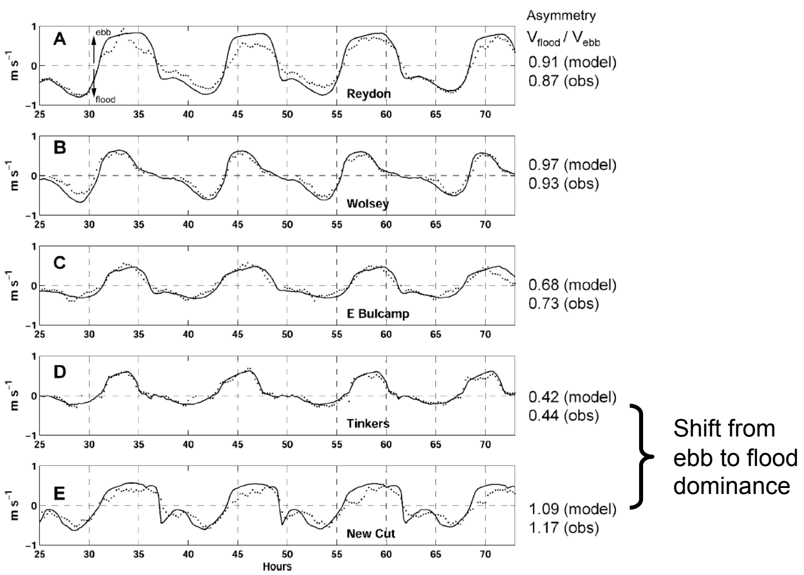


Finite element mesh
- ~22,000 elements
- 10 to 100 m resolution
- 53% intertidal

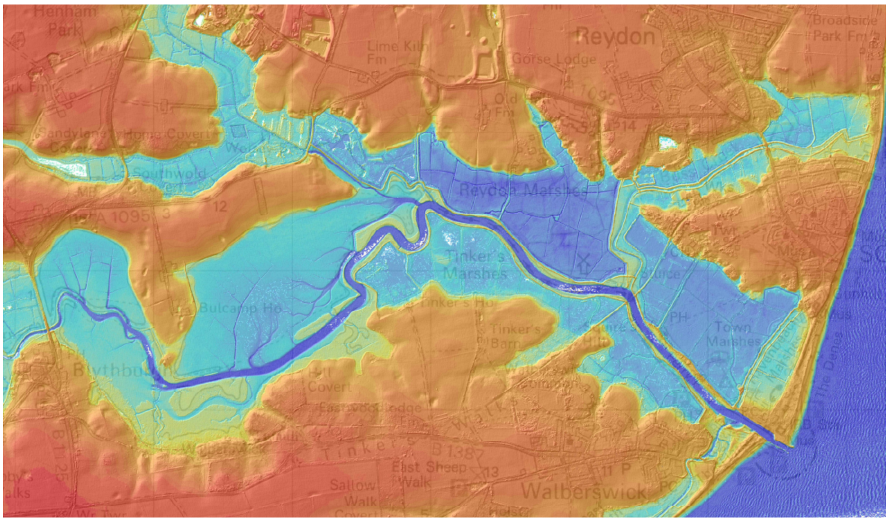


(French 2008 *J. Coast. Res*)

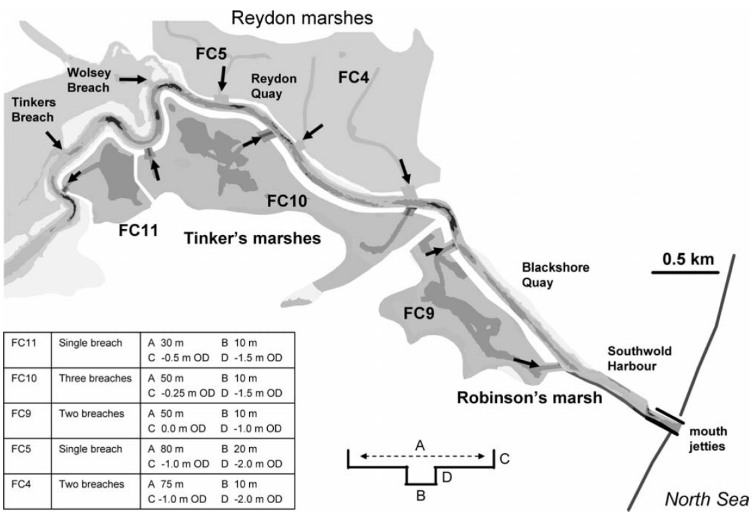
Model evaluation: tidal velocity asymmetry



LIDAR-derived DEM showing variation in elevation between flood compartments

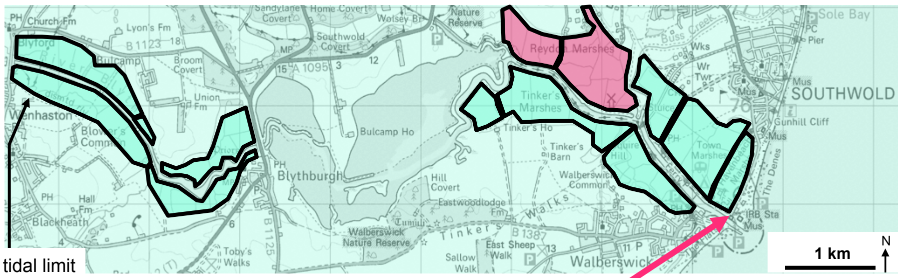


Hypothetical sea defence removal



FC11	Single breach	A 30 m C -0.5 m OD	B 10 m D -1.5 m OD
FC10	Three breaches	A 50 m C -0.25 m OD	B 10 m D -1.5 m OD
FC9	Two breaches	A 50 m C 0.0 m OD	B 10 m D -1.0 m OD
FC5	Single breach	A 80 m C -1.0 m OD	B 20 m D -2.0 m OD
FC4	Two breaches	A 75 m C -1.0 m OD	B 10 m D -2.0 m OD

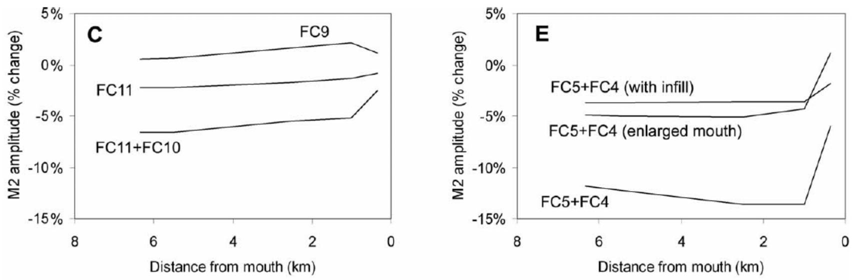
Impact of seawall removal and sea-level rise on outer estuary hydrodynamics (French 2008 *J. Coast. Res*)

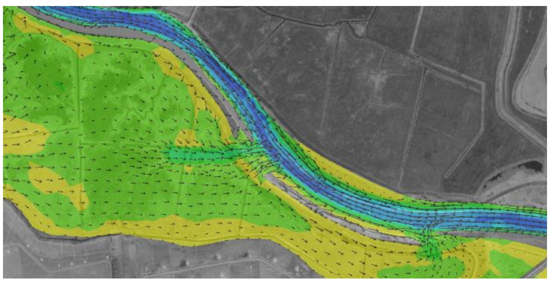


reclamations

	Tidal volume x 10^6 m^3	Peak ebb velocity (m/s)	Peak flood Q (m^3/s)
Present estuary	2.86	1.16	124
Red area flooded	4.10 (+44%)	1.54 (+33%)	162 (+31%)
0.3 m (~2050) SLR	3.10 (+8.4%)	1.22 (+5%)	156 (+27%)

Effect of sea defence removal on tidal amplitude



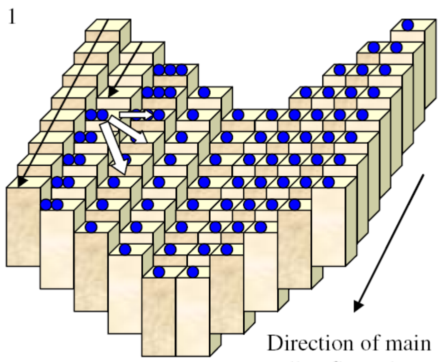


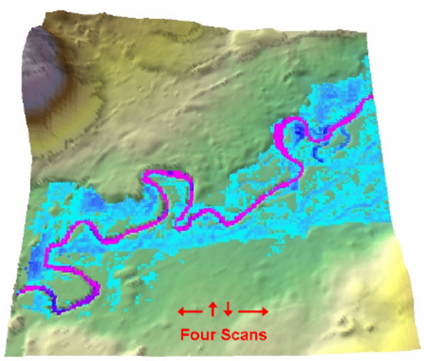
Strengths and weaknesses of high spatial resolution hydraulic models

- Strengths
  - Robust representation of wetting/drying processes over complex topographies at 'engineering' or 'event' scales
  - Capable of resolving structures, including built-up areas (e.g. Brown *et al*. 2007)
  - Capture subtleties of inundation – flood extent and inundation depth (damage in urban settings) and nonlinear effects on tidal propagation (e.g. in estuaries)

- Weaknesses
  - Computationally intensive, especially for large coastal area problems
  - May be sensitive to poor quality data (especially bathymetry / terrain) .... important to 'validate' data as well as model
  - Hard to incorporate feedbacks between morphology and processes – morphodynamic models still restricted in their range of application

Large-scale coastal change: reduced complexity modelling





RC models of fluvial systems include TOPMODEL, LISFLOOD, CAESAR spatial landscape model; for coastal systems, SCAPE and SLAMM

Sea **L**evel Rise **A**ffecting **M**arshes **M**odel

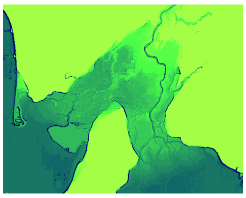
- simulates suite of processes involved in wetland habitat type and shoreline changes under sea-level rise
- raster-based representation of coastal topography and habitat type
- empirical parameterisation of key processes
- decision tree-based rules determine transitions from one habitat type to another in response to changing environmental conditions (inundation, erosion, salinity etc.)

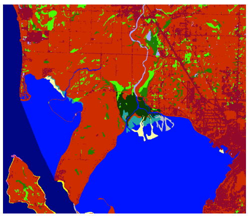
SLAMM history

- EPA-funded project in 1980s and used for large-scale simulation of climate change impacts on US coast (e.g. Park et al. 1991, 1993)
- later versions used for San Francisco Bay (Galbraith et al. 2002) and South Carolina and Georgia (Craft et al. 2009)
- also being used at UCL as platform for studying estuary-scale response to sea-level rise (south coast of UK)

SLAMM architecture

- Raster DEM (with separate slope raster)
- Classification by pre-defined habitat type (e.g NWI in USA)
- Dry land and impounded area masks
- Parameterisations for processes and pre-defined rules for habitat type transitions





Processes modelled

Inundation Computed from minimum elevation and slope of cell

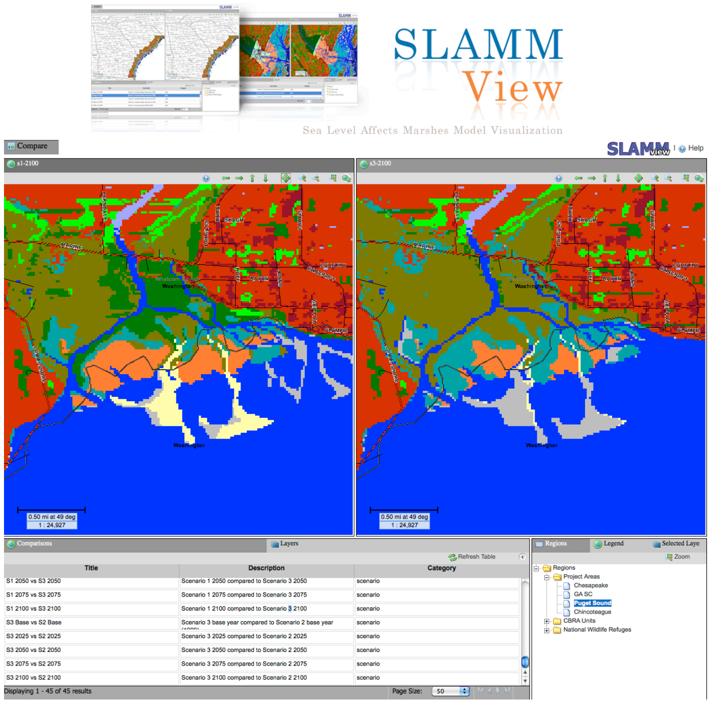
Erosion Based on exceedance of threshold fetch and proximity of wetland cell to open water

Overwash Barrier islands < 500m wide undergo overwash at a fixed storm interval. Beach migration and sediment transport computed

Accretion Spatial function or as function of elevation, salinity and distance to channel.

Saturation Migration of coastal swamps and fresh marshes in response to adjustment of water table to rising sea level

Salinity Based on simple salt wedge model



Strengths and weaknesses of spatial landscape models and SLAMM in particular

- Strengths
  - Computationally efficient for large-scale simulations
  - Takes advantage of new high resolution topographic data (Lidar)
  - Reduced complexity approach allows multiple sets of processes to be modelled and complex outcomes determined at a broad scale
  - Excellent tool for conveying impacts of climate change to stakeholders
  - SLAMM is open source (but GUI components tied to Windows)
- Weaknesses
  - Process parameterisation remains largely empirical
  - Often require substantial pre-processing effort (e.g. SLAMM requires separate GIS processing of input raster datasets)
  - Porting to other locations may require modification of source code and recomiplation (e.g. changes to rule base in SLAMM)

METHODS AND APPLICATION OF DOWNSCALING GLOBAL CLIMATE CHANGE AND ADAPTATION STRATEGIES

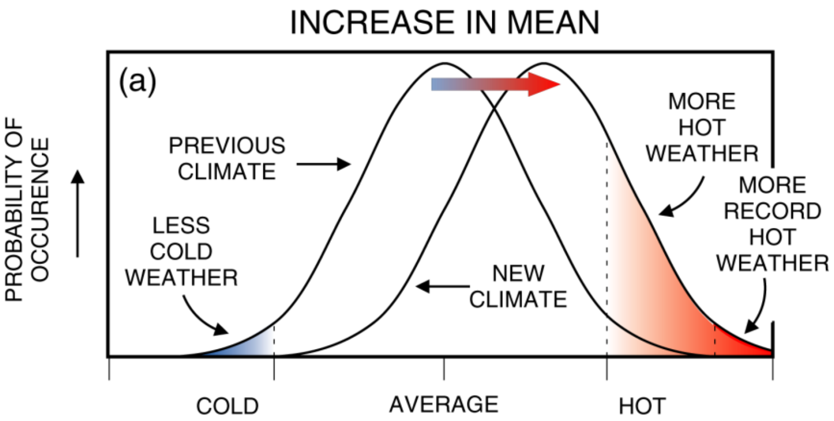
Dr. S. MOHAN
DIRECTOR, NITTTR, Chennai
&
Professor,
Environmental and Water Resources Engineering
IIT Madras, Chennai - 36

- **What is Climate**
  - Why is climate different from weather and forecasting
- **Hierarchy of atmospheric modeling strategies**
  - Focus on 3D General Circulation models (GCMs)
- **Conceptual Framework for General Circulation Models**
- **Parameterization of physical processes**
  - concept of resolvable and unresolvable scales of motion
  - approaches rooted in budgets of conserved variables
- **Model Validation and Model Solutions**

Question 1: What is Climate?

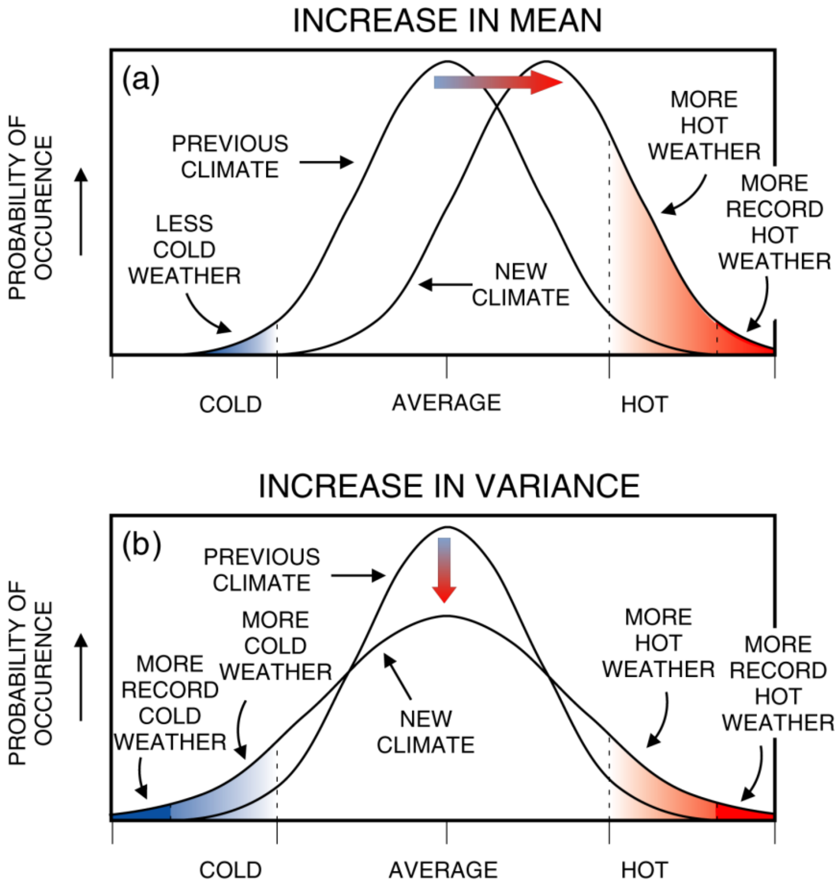
A. Average/Expected ‘Weather’
B. The temperature & precipitation range
C. Distribution of all possible weather
D. Record of Extreme events

(1) What is Climate?

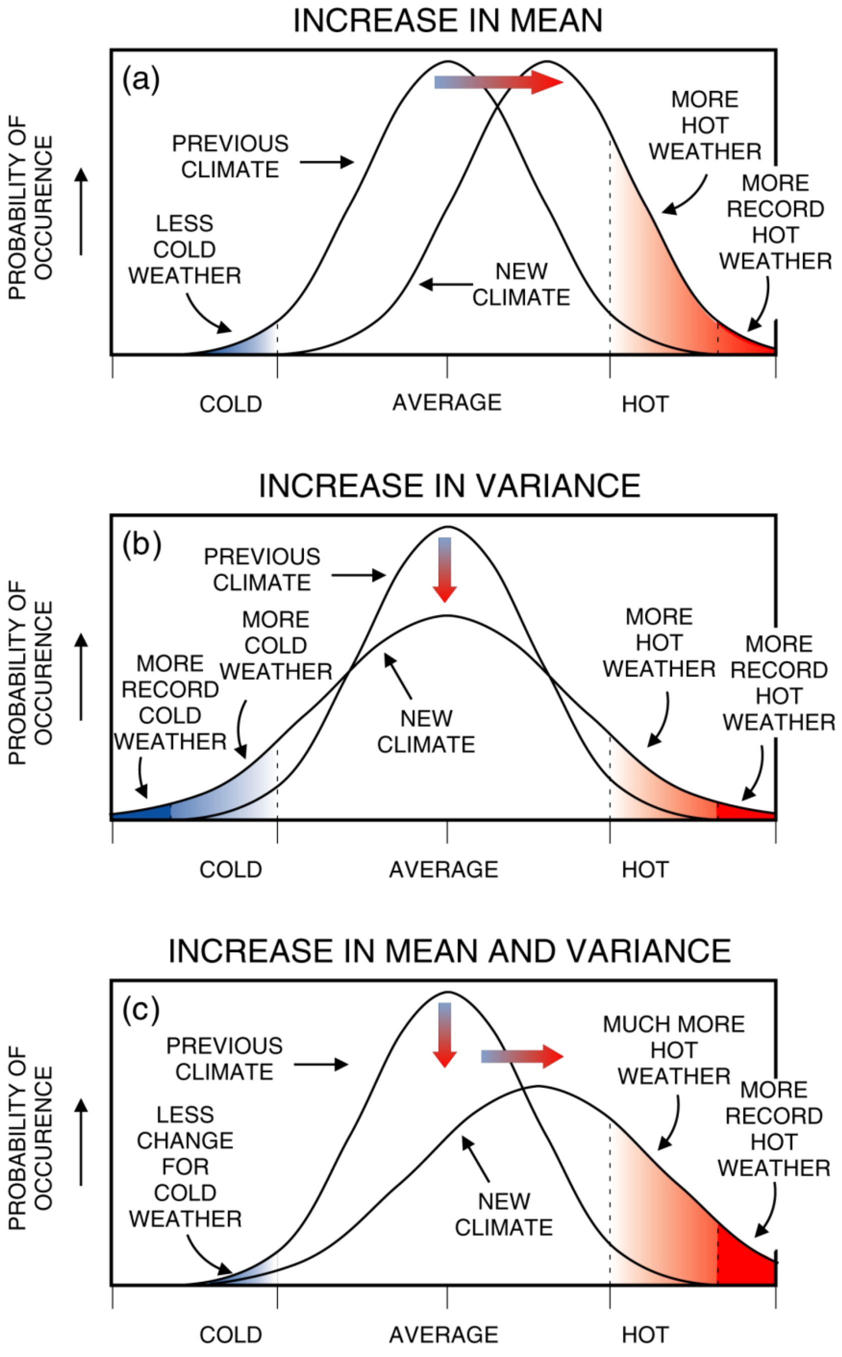


Climate change
and its manifestation
in terms of weather
(climate extremes)

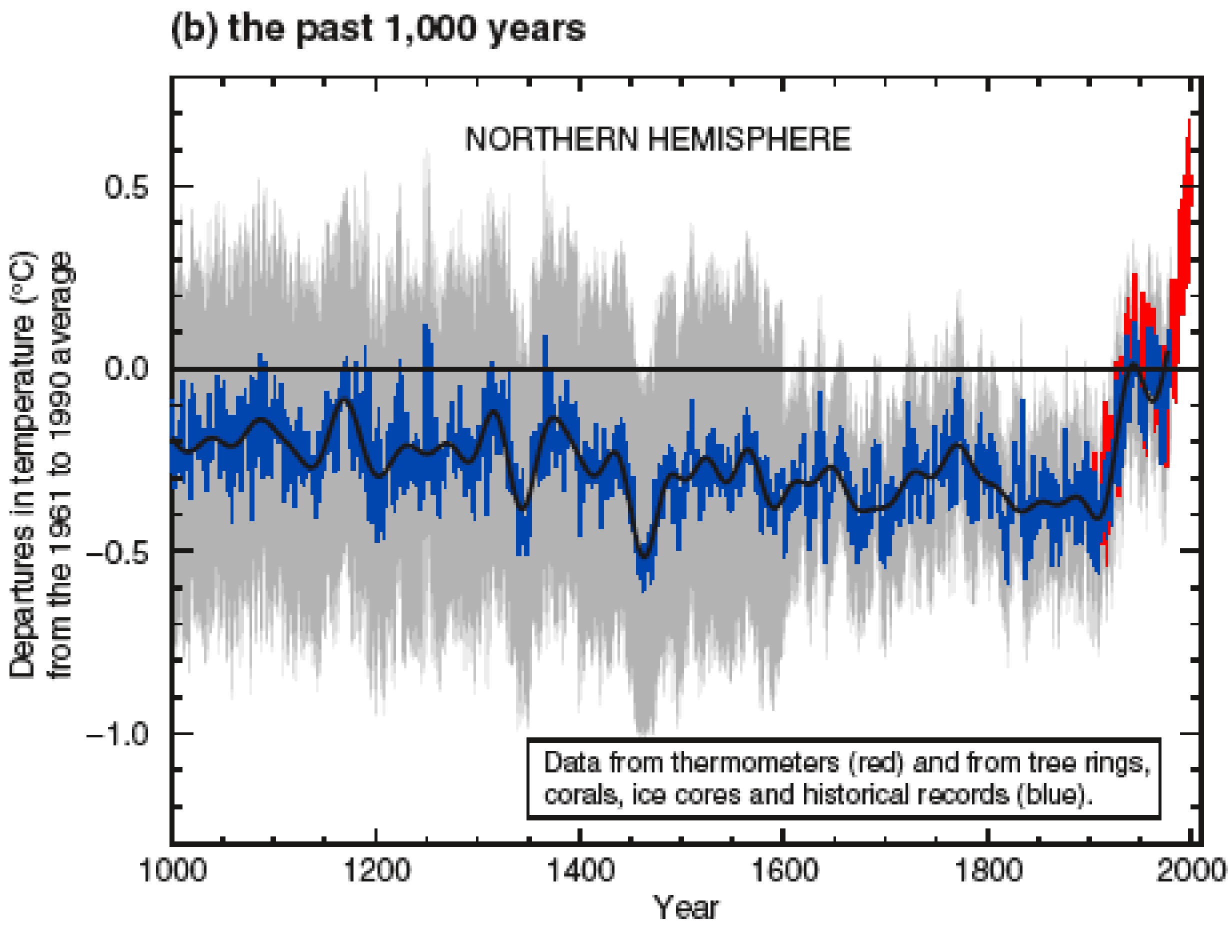
Climate change and its manifestation in terms of weather (climate extremes)



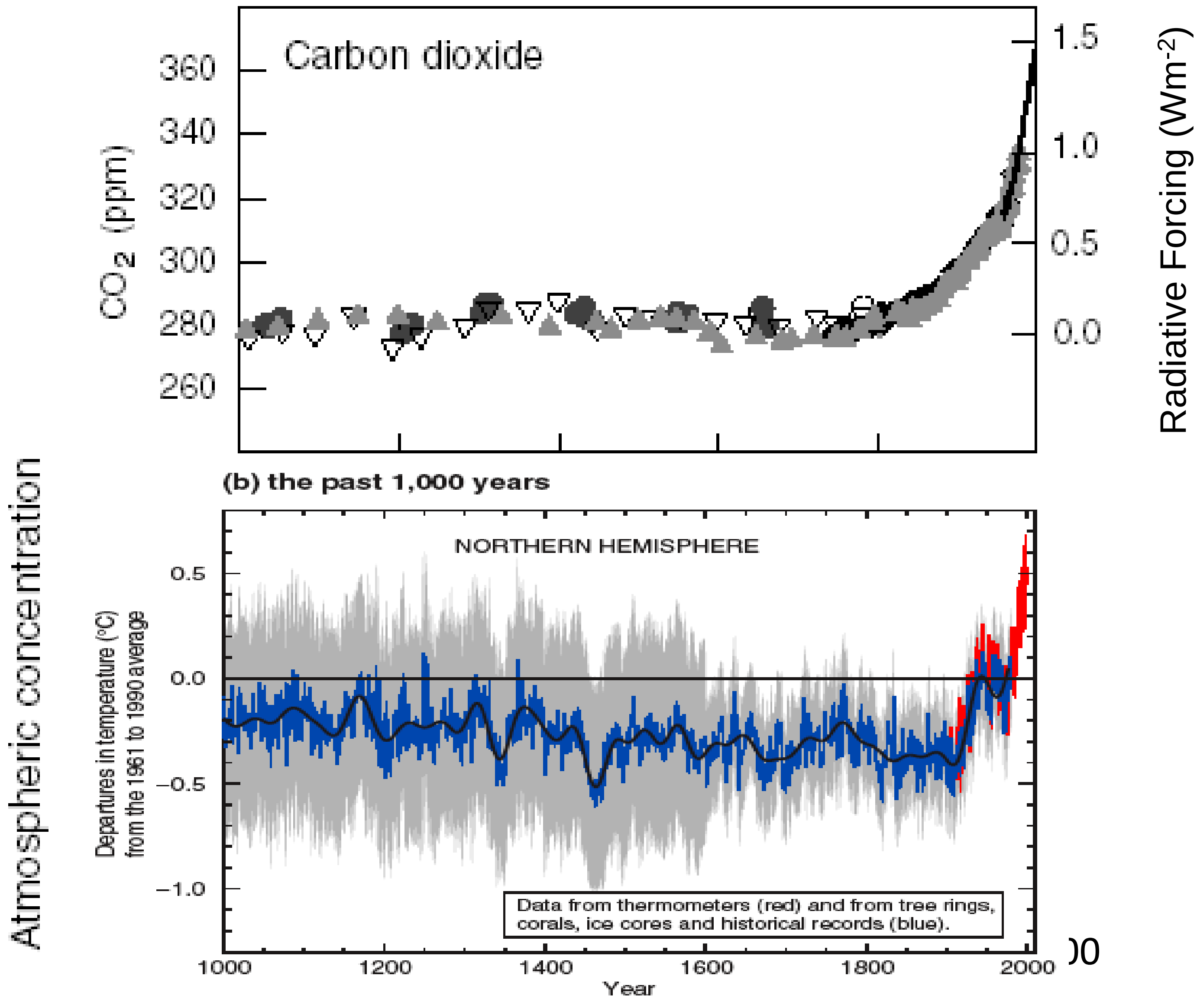
Climate change and its manifestation in terms of weather (climate extremes)



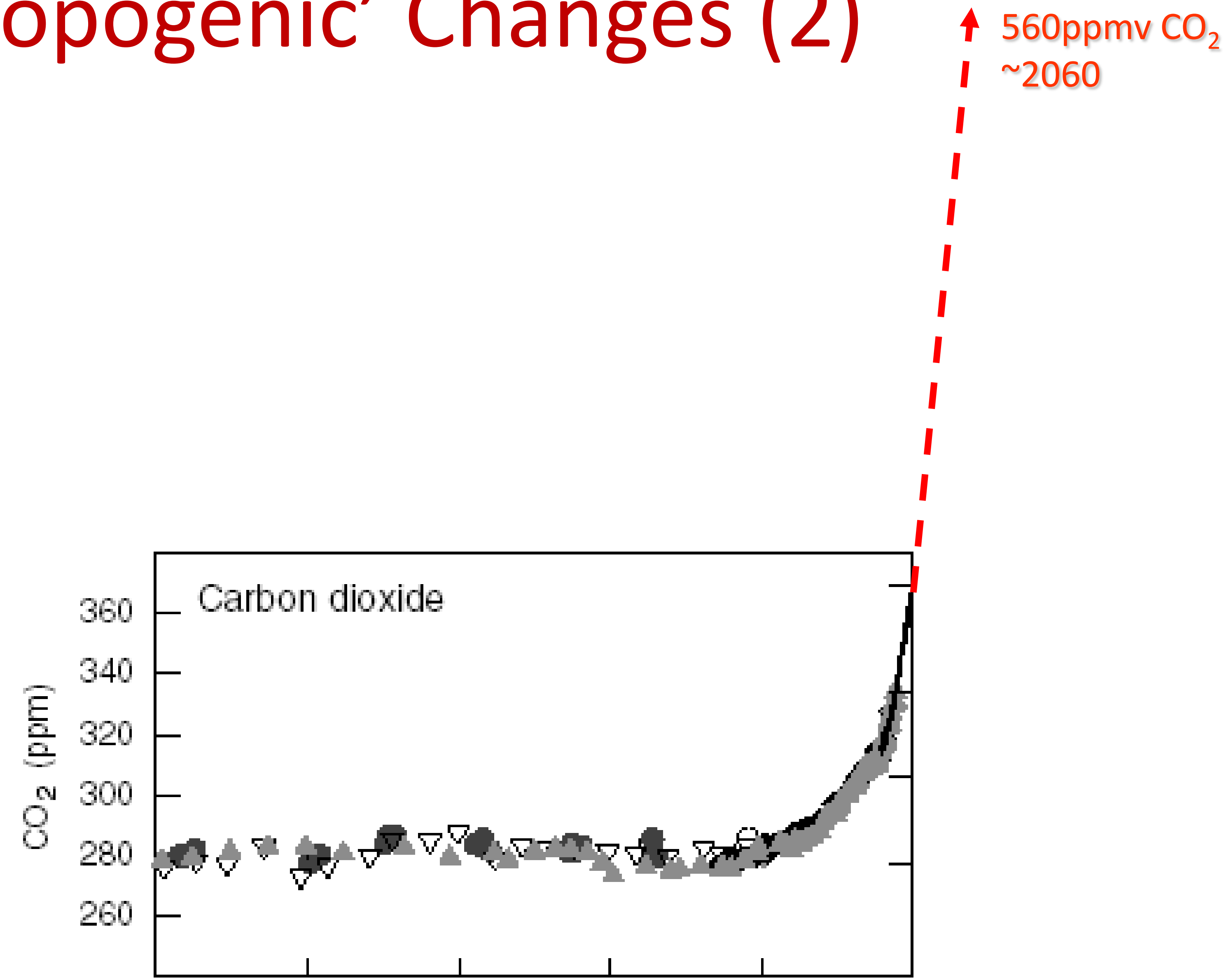
Observed Temperature Records



'Anthropogenic' Changes



‘Anthropogenic’ Changes (2)



Brief Primer on Regional Climate Change

- **Temperatures over most land areas are likely to rise**
  - **Other factors, e.g., land use change, may also be important**
  - **Warmer temperatures mean increases in heat waves and evaporation**
- **Global-mean sea level rise: 0.1 to 0.9 m**
  - Modified by local subsidence/uplift
- **Precipitation will change; increase globally**
  - **Local changes uncertain: critical uncertainty**
  - **Increase in storm intensity in some regions**

Question 2

- **What is the difference between Numerical Weather Prediction and Climate prediction?**

Climate v. Numerical Weather Prediction

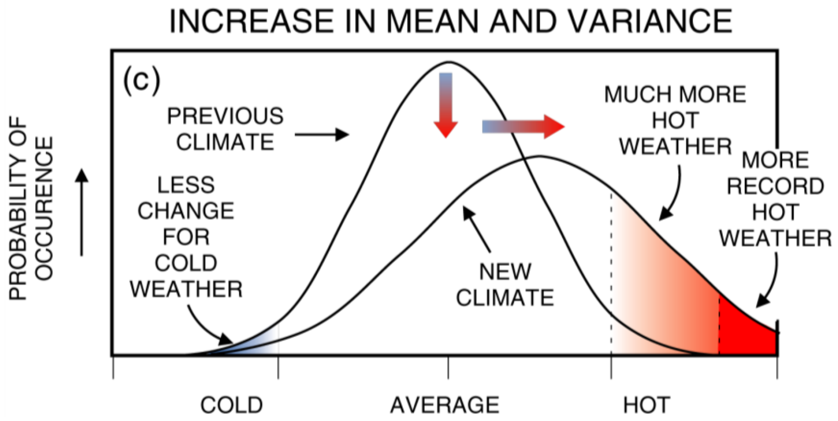
- NWP:
  - Initial state is CRITICAL
  - Don’t really care about whole PDF, just probable phase space
  - Non-conservation of mass/energy to match observed state

- Climate
  - Get rid of any dependence on initial state
  - Conservation of mass & energy critical
  - Want to know the PDF of all possible states
  - Don’t really care where we are on the PDF
  - Really want to know tails (extreme events)

Question 3

How can we predict Climate (50 yrs) if we can't predict Weather (10 days)?

Statistics!

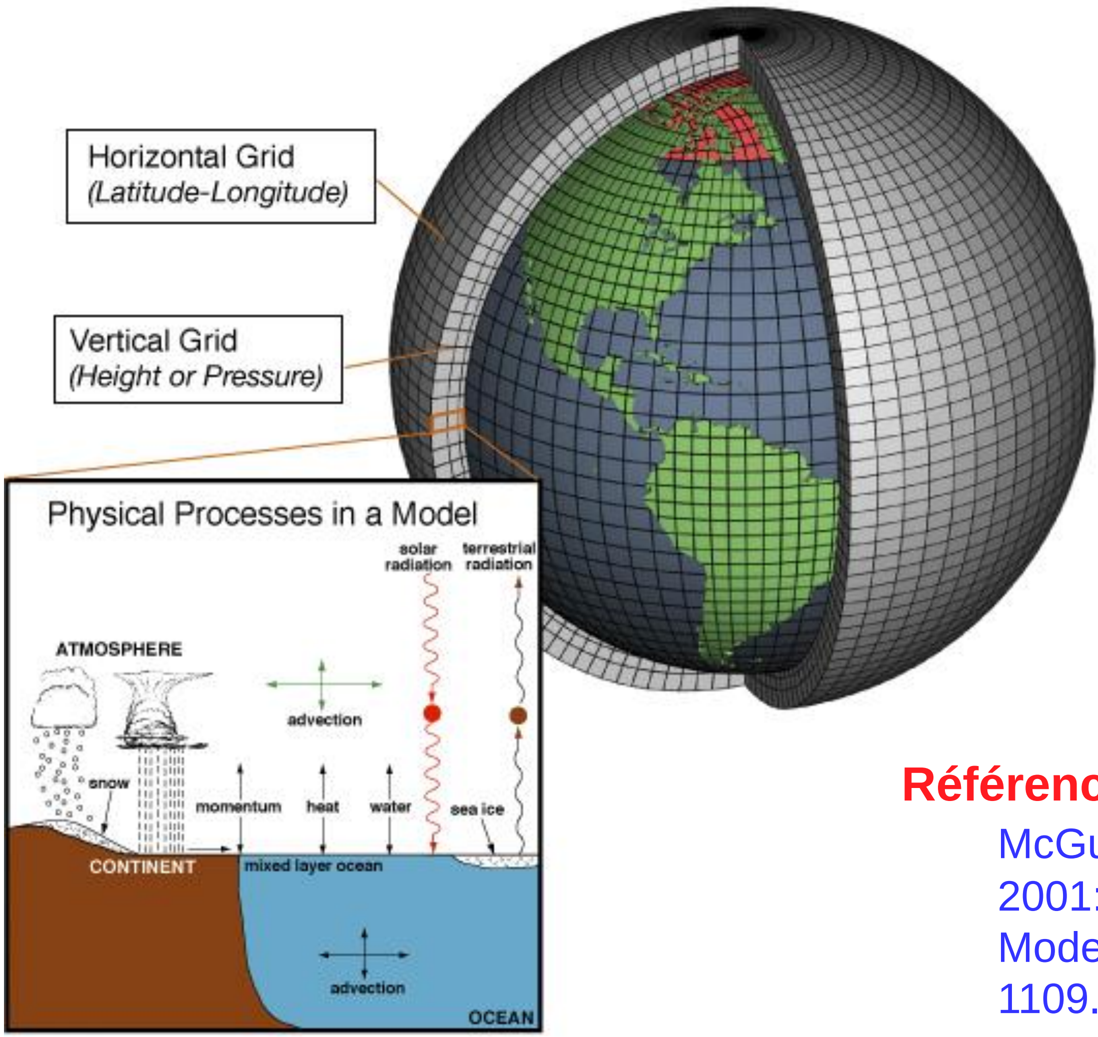


Conceptual Framework for Modeling

- Can't resolve all scales, so have to represent them
- Energy Balance / Reduced Models
  - Mean State of the System
  - Energy Budget, conservation, Radiative transfer
- Dynamical Models
  - Finite element representation of system
  - Fluid Dynamics on a rotating sphere
  - Basic equations of motion
  - Advection of mass, trace species
  - Physical Parameterizations for moving energy
- Scales: Cloud Resolving/Mesoscale/Regional/Global
  - Global= General Circulation Models (GCM's)

How do we model climate system?

- Climate models: system of differential equations based on well-established laws of physics **(physically based)**



3 Dimensional Discretisation of the atmosphere

source: http://www.oar.noaa.gov

-GCMs are the most sophisticated tools designed to simulate Earth's climate system;

-Coarse horizontal resolution: limited ability in reproducing regional climate;

Référence:

McGuffie K. and A. Henderson-Sellers, 2001: Forty Years of Numerical Climate Modelling, *Int*. *J*. *Climatol*., 21, 1067–1109.

Physical processes regulating climate

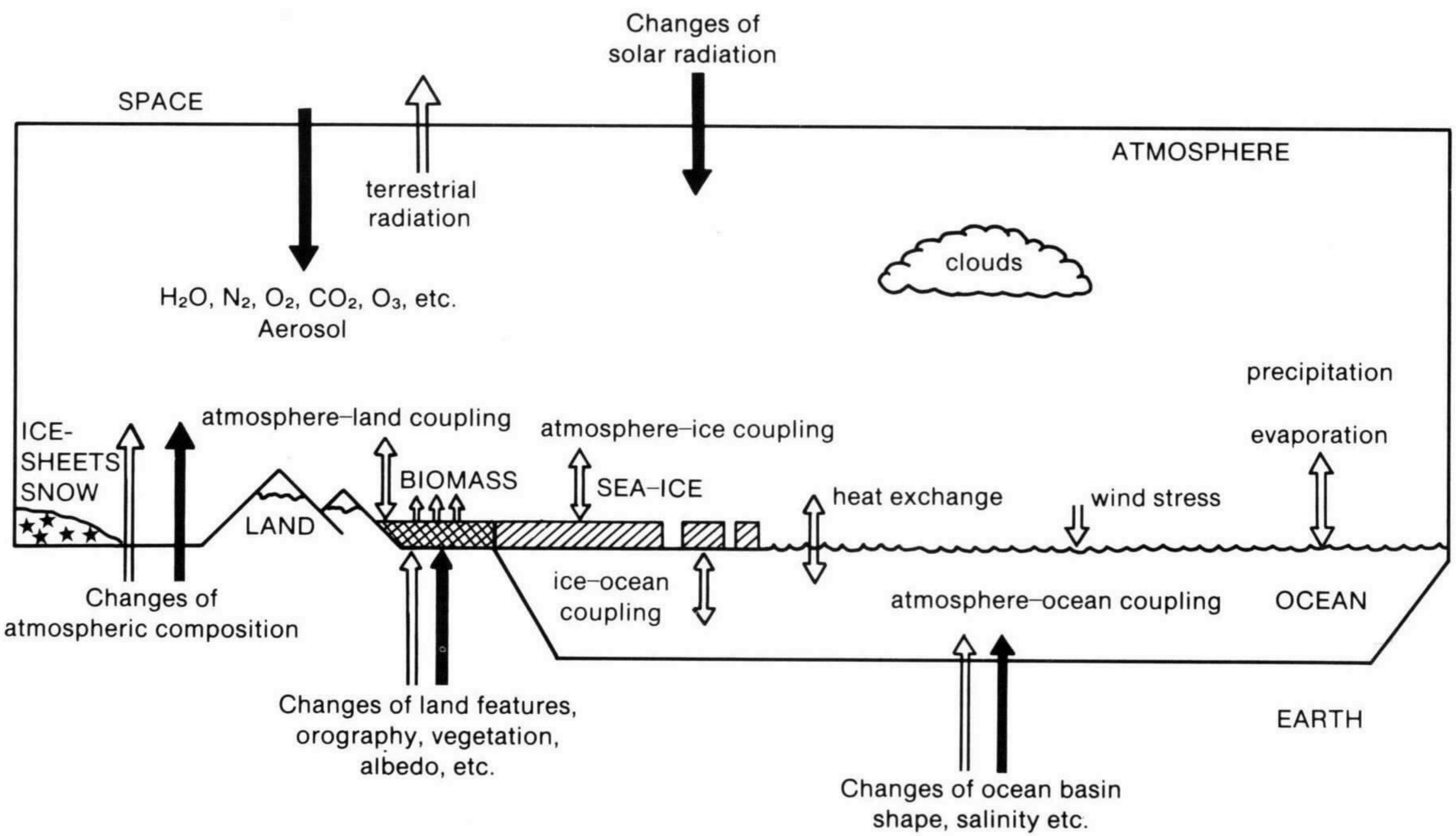
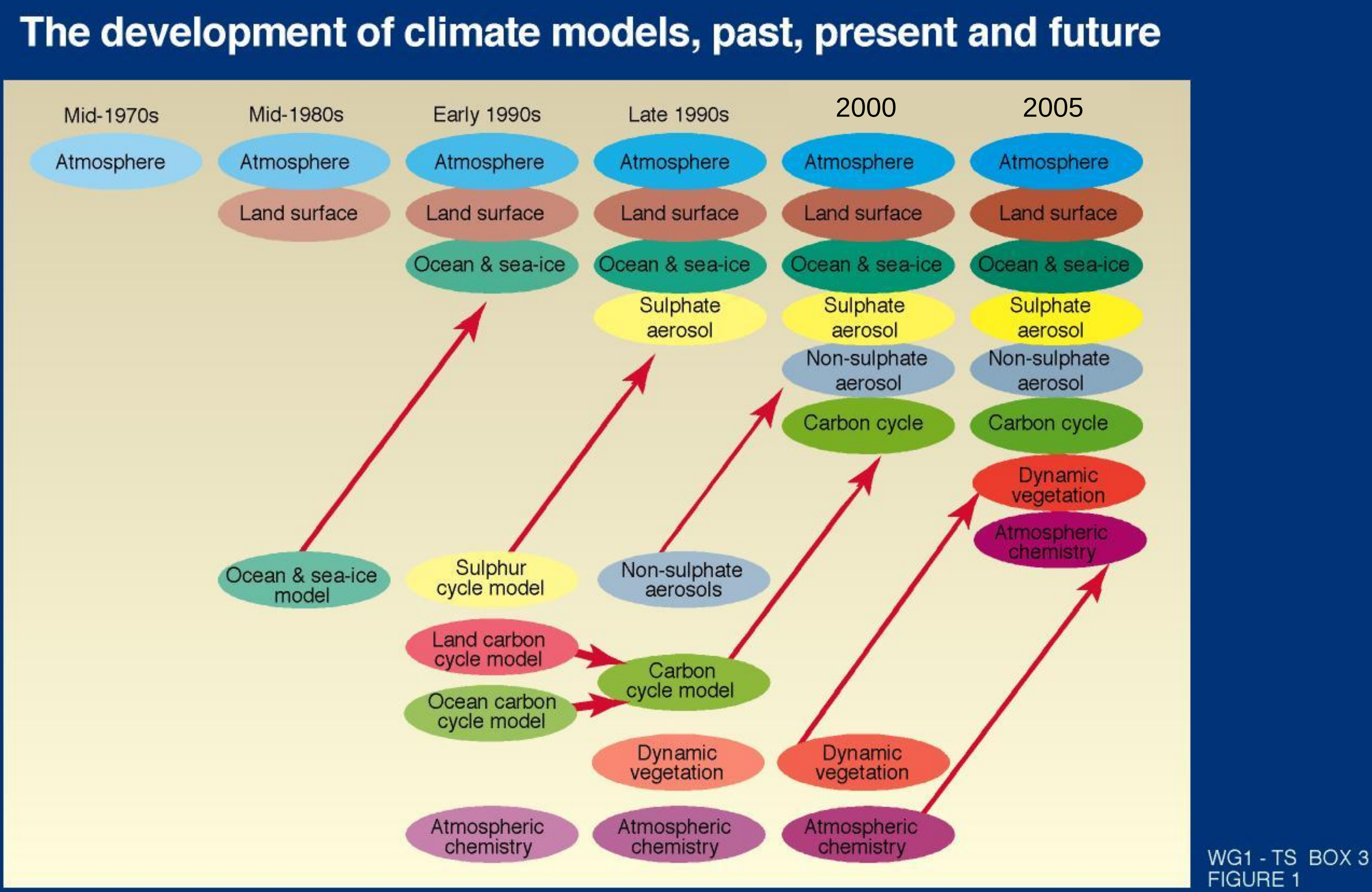


Figure 3.1: Schematic illustration of the components of the coupled atmosphere-ocean-ice-land climatic system. The full arrows are examples of external processes, and the open arrows are examples of internal processes in climatic change (from Houghton, 1984).

Earth System Model 'Evolution'



Modeling the Atmospheric General Circulation

Requires **understanding of :**

- **atmospheric predictability/basic fluid dynamics**
- **physics/dynamics of phase change**
- **radiative transfer (aerosols, chemical constituents, etc.)**
- **interactions between the atmosphere and ocean (El Nino, etc.)**
- **solar physics (solar-terrestrial interactions, solar dynamics, etc.)**
- **impacts of anthropogenic and other biological activity**

Basic Process:

- iterate finite element versions of dynamics on a rotating sphere
- Incorporate representation of physical processes

Meteorological Primitive Equations

- Applicable to wide scale of motions; > 1hour,

$$d\overline{\mathbf{V}}/dt + fk \times \overline{\mathbf{V}} + \nabla\overline{\phi} = \mathbf{F}, \qquad \textit{(horizontal momentum)}$$

$$d\overline{T}/dt - \kappa\overline{T}\omega/p = Q/c_p, \qquad \textit{(thermodynamic energy)}$$

$$\nabla \cdot \overline{\mathbf{V}} + \partial\overline{\omega}/\partial p = 0, \qquad \textit{(mass continuity)}$$

$$\partial\overline{\phi}/\partial p + R\overline{T}/p = 0, \qquad \textit{(hydrostatic equilibrium)}$$

$$d\overline{q}/dt = S_q. \qquad \textit{(water vapor mass continuity)}$$

Harmless looking terms $\mathbf{F}$, Q, and $S_q \Longrightarrow$ "physics"

Global Climate Model Physics

Terms *F*, *Q*, and S_q represent physical processes

- Equations of motion, *F*
  - turbulent transport, generation, and dissipation of momentum
- Thermodynamic energy equation, *Q*
  - convective-scale transport of heat
  - convective-scale sources/sinks of heat (phase change)
  - radiative sources/sinks of heat
- Water vapor mass continuity equation
  - convective-scale transport of water substance
  - convective-scale water sources/sinks (phase change)

Grid Discretizations

Equations are distributed on a sphere

- **Different grid approaches:**
  - **Rectilinear (lat-lon)**
  - **Reduced grids**
  - **'equal area grids': icosahedral, cubed sphere**
  - **Spectral transforms**

- **Different numerical methods for solution:**
  - **Spectral Transforms**
  - **Finite element**
  - **Lagrangian (semi-lagrangian)**

- **Vertical Discretization**
  - **Terrain following (sigma)**
  - **Pressure**
  - **Isentropic**
  - **Hybrid Sigma-pressure (most common)**

Model Physical Parameterizations

Physical processes breakdown:

- **Moist Processes**
  - **Moist convection, shallow convection, large scale condensation**
- **Radiation and Clouds**
  - **Cloud parameterization, radiation**
- **Surface Fluxes**
  - **Fluxes from land, ocean and sea ice (from data or models)**
- **Turbulent mixing**
  - **Planetary boundary layer parameterization, vertical diffusion, gravity wave drag**

Basic Logic in a GCM (Time-step Loop)

For a grid of atmospheric columns:

1. ‘Dynamics’: Iterate Basic Equations

   Horizontal momentum, Thermodynamic energy,

   Mass conservation, Hydrostatic equilibrium,

   Water vapor mass conservation
2. Transport ‘constituents’ (water vapor, aerosol, etc)
3. Calculate forcing terms (“Physics”) for each column

   Clouds & Precipitation, Radiation, etc
4. Update dynamics fields with physics forcings
5. Gravity Waves, Diffusion (fastest last)
6. Next time step (repeat)

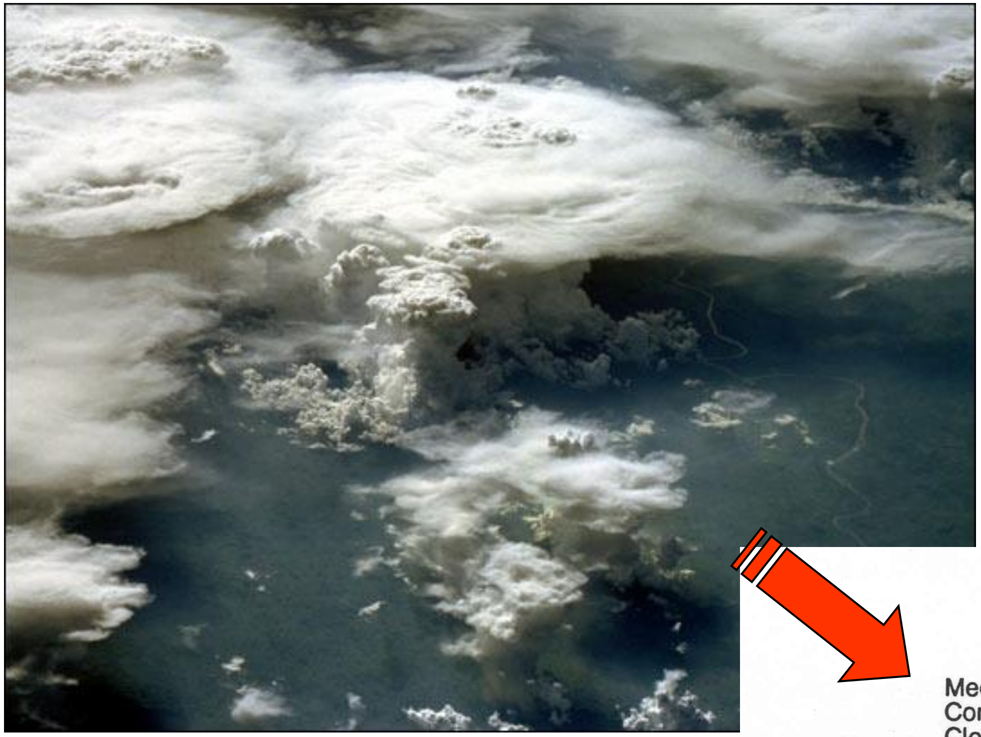
Physical Parameterization

To close the governing equations, it is necessary to incorporate the effects of physical processes that occur on scales below the numerical truncation limit

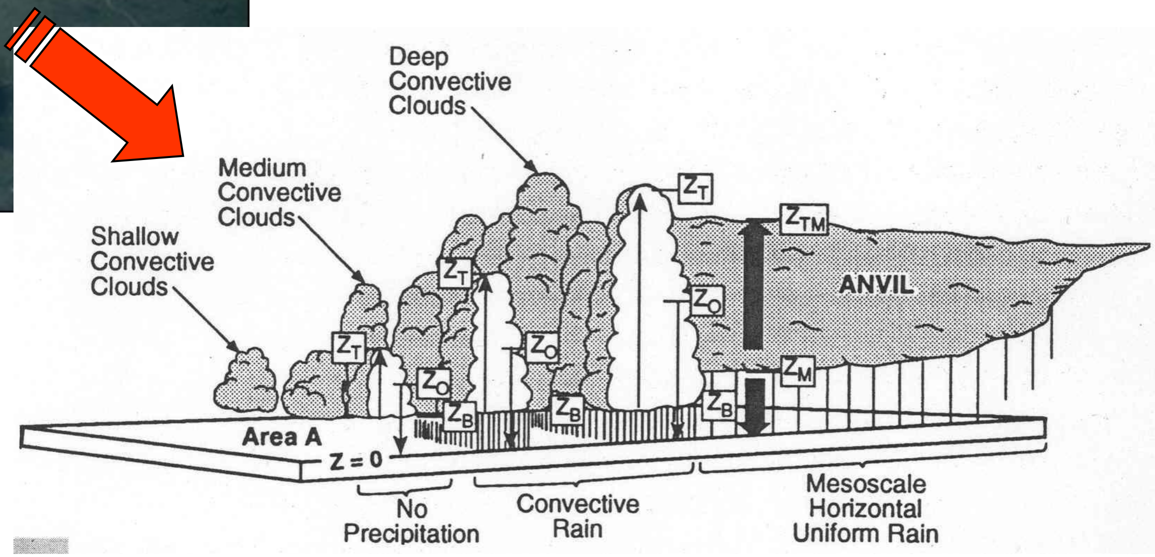
- **Physical parameterization**
  - **express unresolved physical processes in terms of resolved processes**
  - **generally empirical techniques**

- **Examples of parameterized physics**
  - **dry and moist convection**
  - **cloud amount/cloud optical properties**
  - **radiative transfer**
  - **planetary boundary layer transports**
  - **surface energy exchanges**
  - **horizontal and vertical dissipation processes**
  - **...**

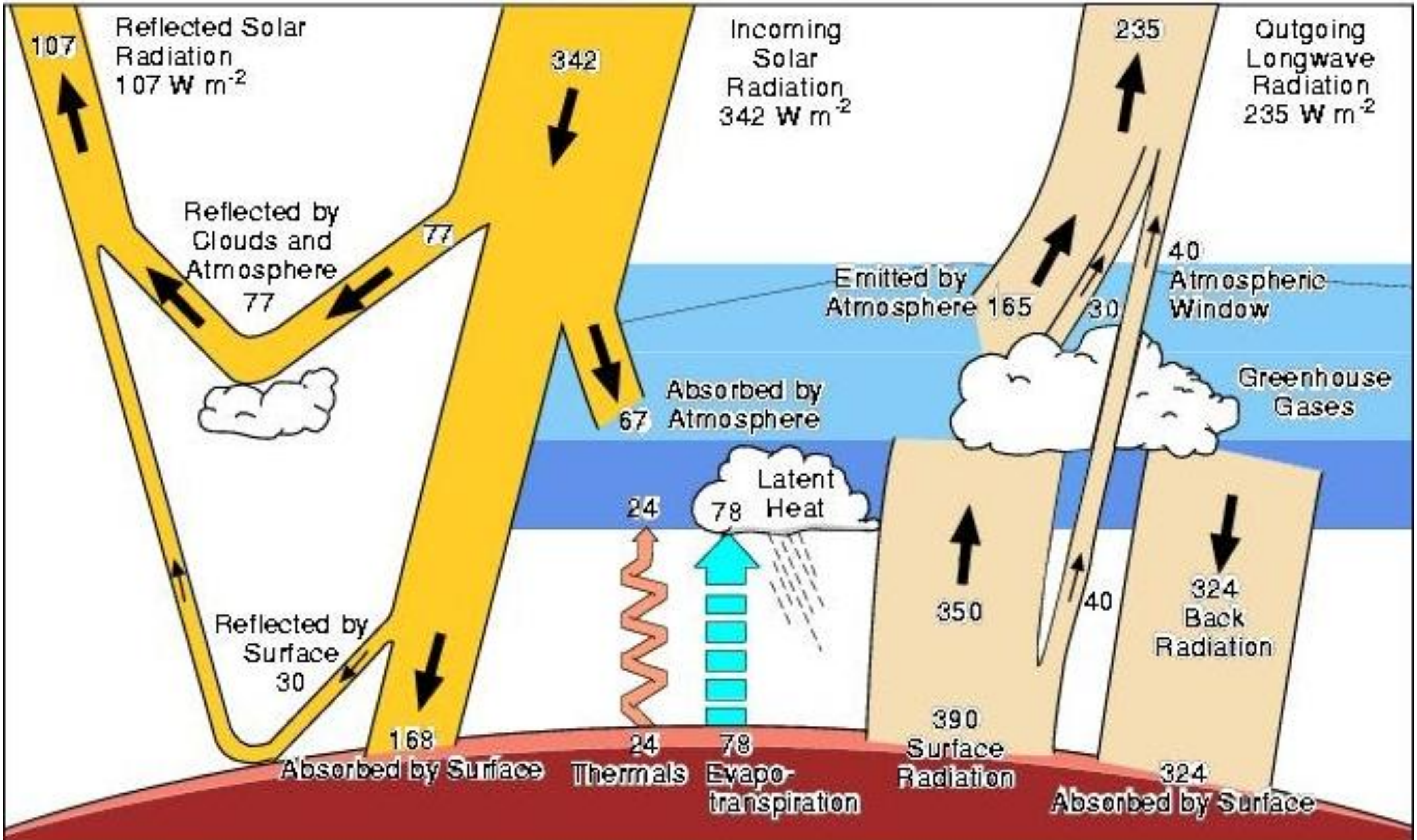
Process Models and Parameterization



- Boundary Layer
- Clouds
  - Stratiform
  - Convective
- Microphysics

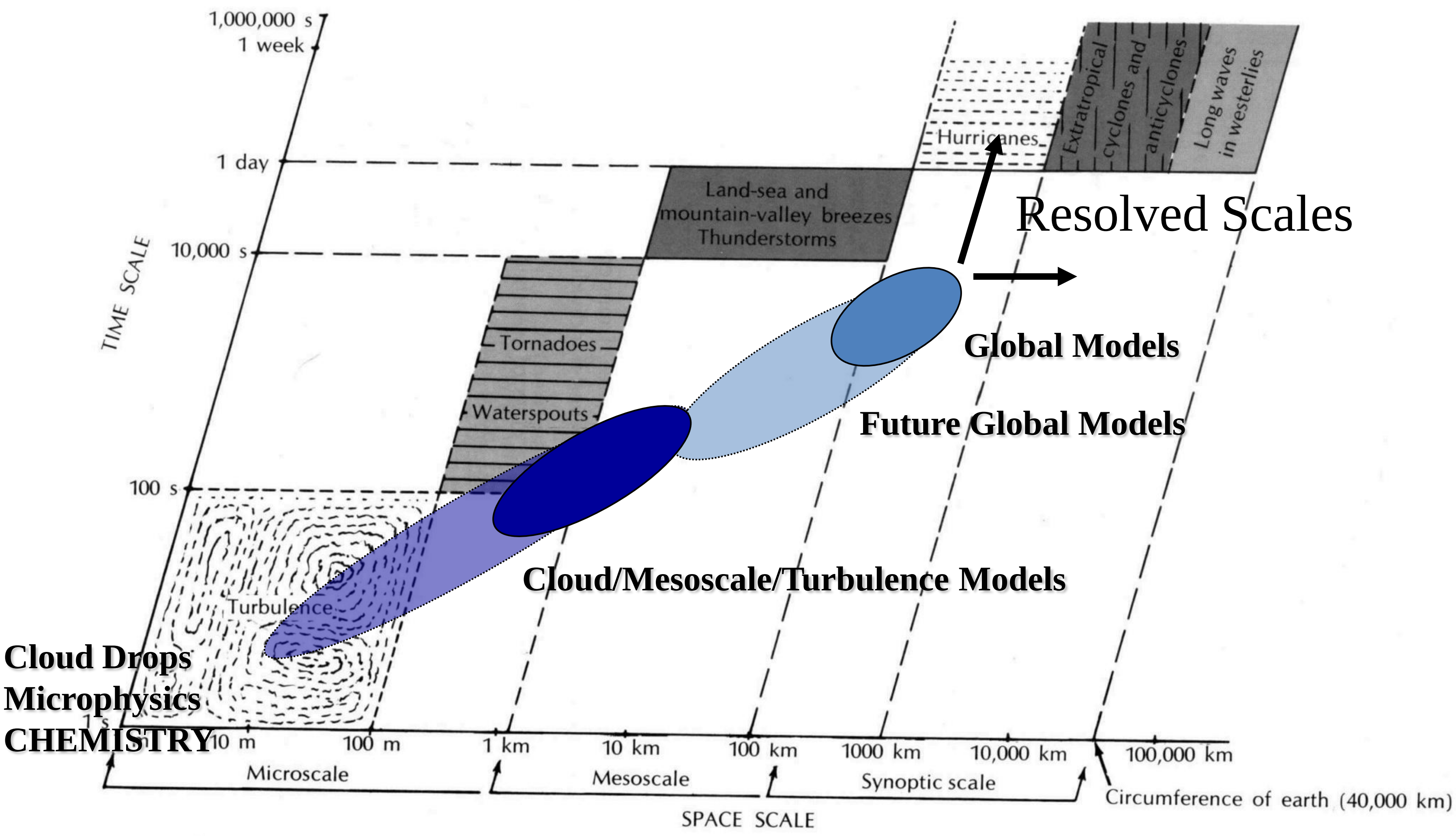


Radiation



Kiehl and Trenberth 1997

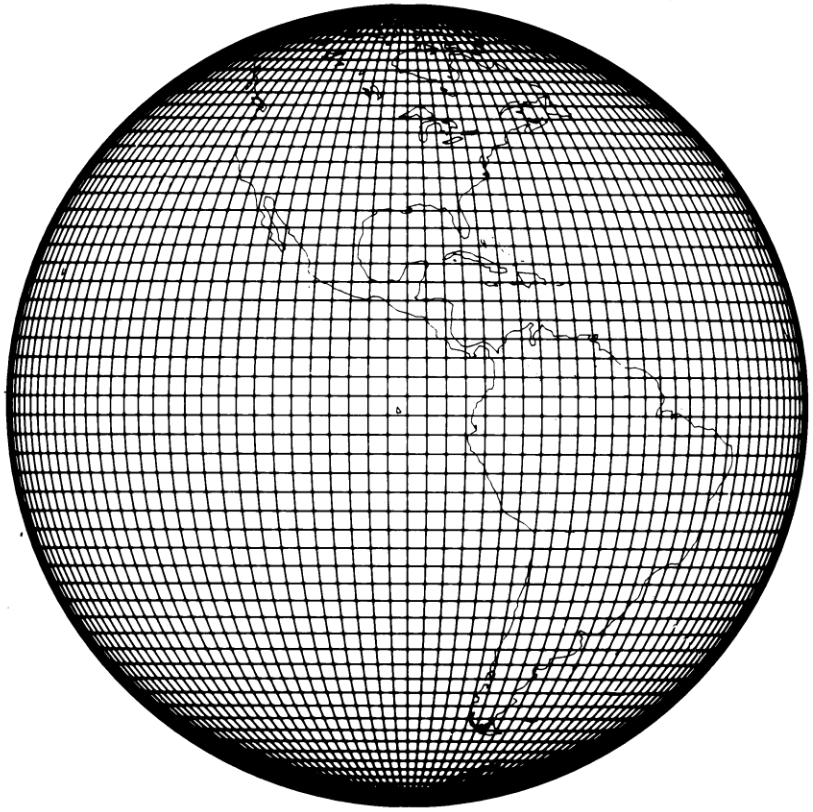
Scales of Atmospheric Motions/Processes



Anthes et al. (1975)

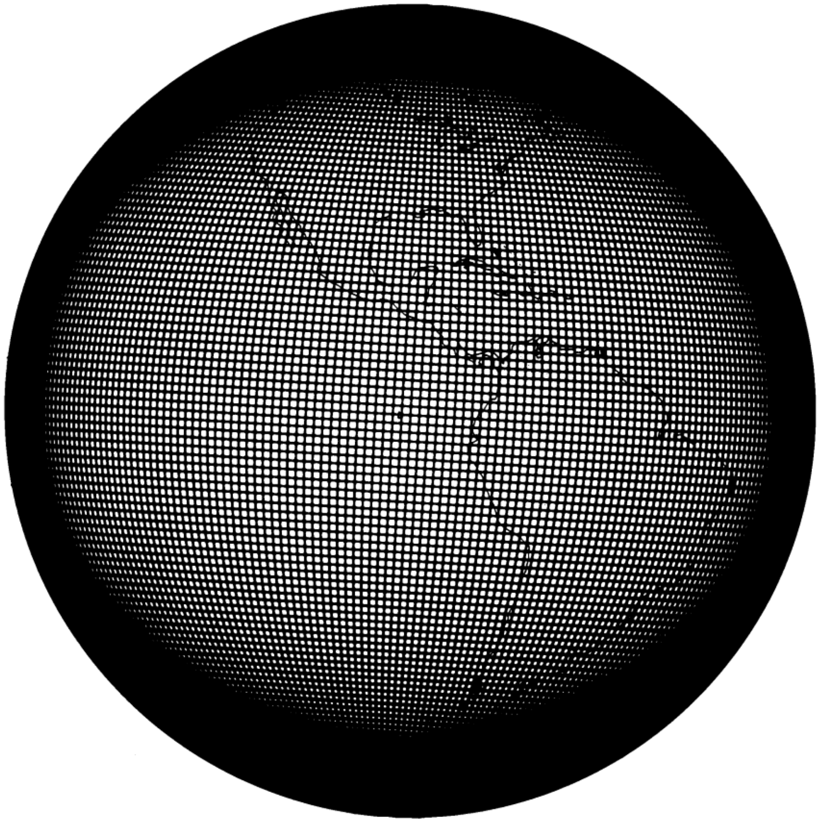
Examples of Global Model Resolution

~300km



Typical Climate Application

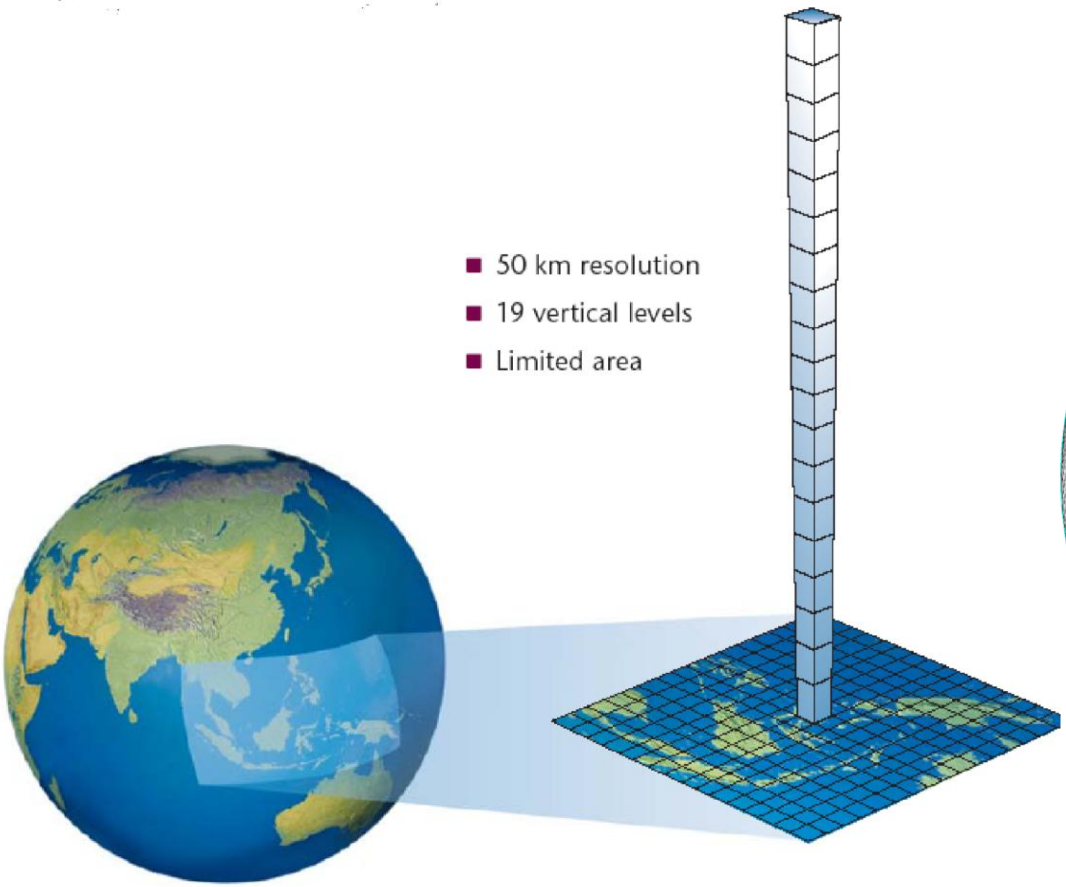
50-100km



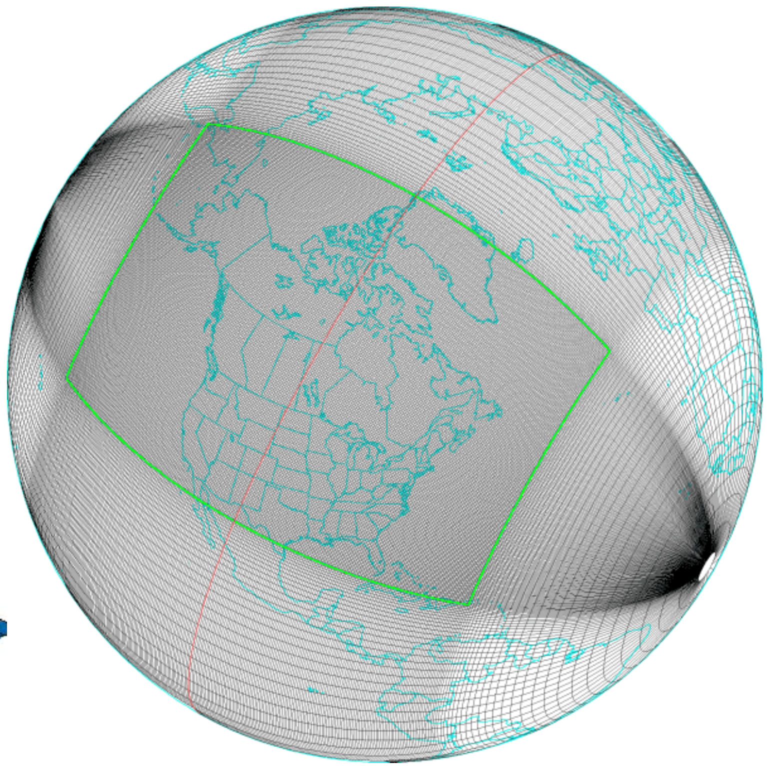
Next Generation Climate Applications

Regional Climate Modeling
Dynamical Downscaling

- *Nested modeling: RCMs*
- *Variable-resolution stretched-grid global models (VRGMs)*



source: Hadley Center for Climate Prediction Research



Why Use Climate Change Scenarios?

- We are unsure exactly how regional climate will change
- Scenarios are plausible combinations of variables consistent with what we know about human-induced climate change
- One can think of them as the prediction of a model, contingent upon the GHG emissions scenario
- Since estimates of regional change by models differ substantially, an individual model estimate should be treated more as a scenario

What Are Reasonable Scenarios?

- Scenarios should be:
  - Consistent with our understanding of the anthropogenic effects on climate
  - Internally consistent
    - e.g., clouds, temperature, precipitation
- Scenarios are a communication tool about what is known and not known about climate change
  - Should reflect plausible range for key variables

Scenarios for Impacts Analysis

- Need to be at a scale necessary for analysis
- Spatial
  - e.g., to watershed or farm level
- Temporal
  - Monthly
  - Daily
  - Sub-daily

Options for Creating Scenarios

- Past climates: analogues
- Spatial analogues
- Arbitrary changes; incremental
- Climate models

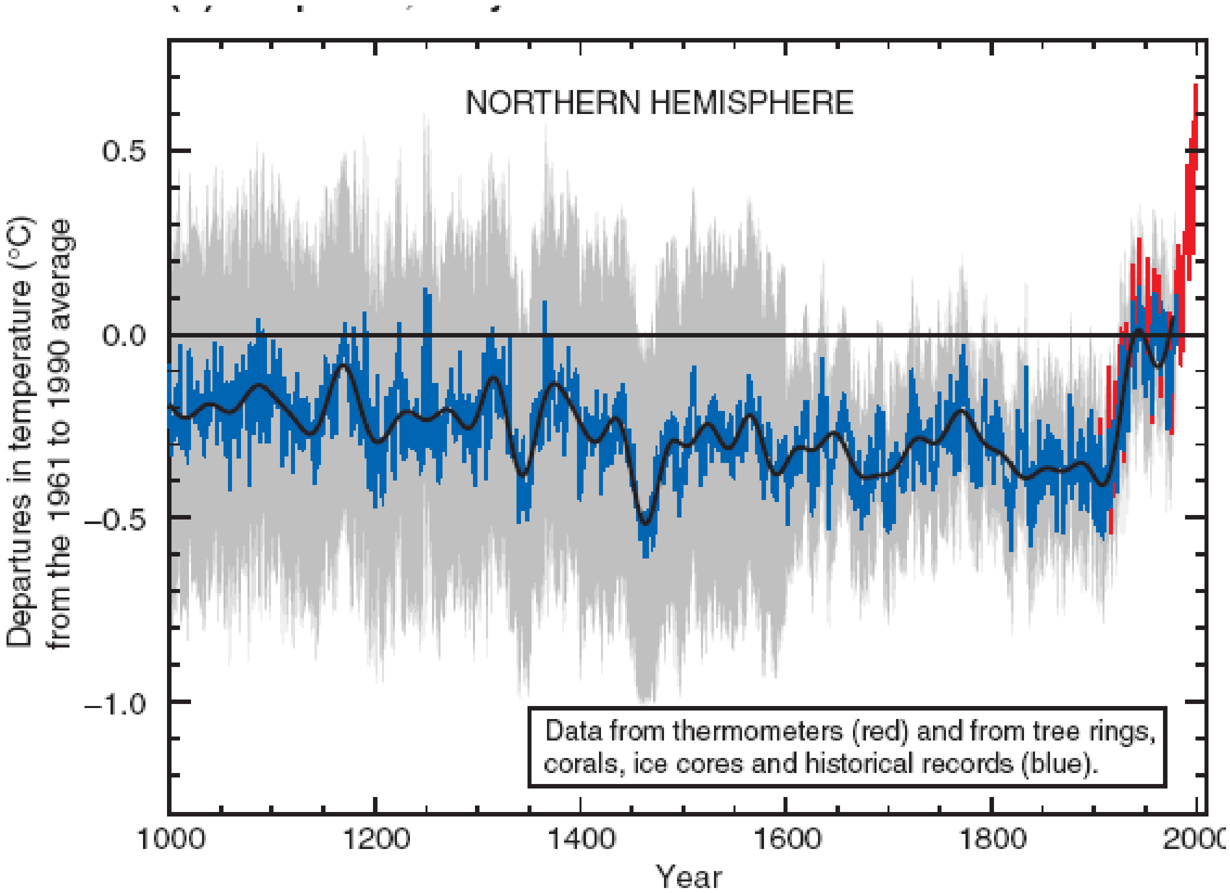
Past Climates

- Options
  - Instrumental record
  - Paleoclimate reconstructions
- Instrumental record
  - Pros
    - Can provide daily data
    - Includes past extreme events
  - Cons
    - Range of change in past climate is limited
    - Data can be limited

Past Climates (continued)

- Paleoclimate reconstructions
  - From tree rings, boreholes, ice cores, etc.
  - Can give annual, sometimes seasonal, climate
  - Can go back hundreds of years
- Pro
  - Wider range of climates
- Cons
  - Incomplete data
  - Uncertainties about values

Mann et al. Reconstruction of N. Hemisphere Temperatures



Spatial Analogues

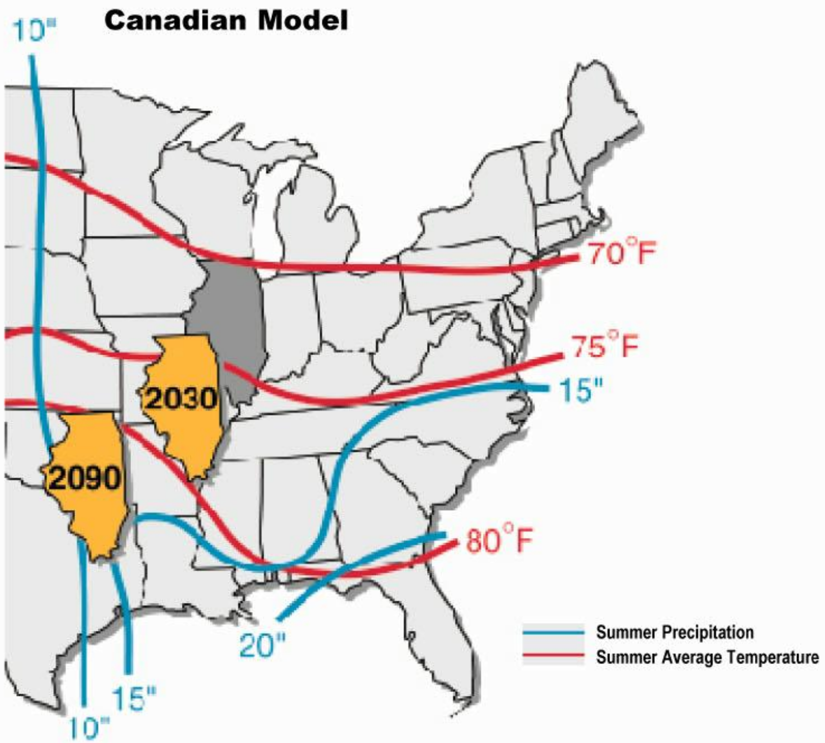


Illustration of how the summer climate of Illinois would shift under the Canadian and Hadley model scenarios. Under the Canadian scenario, the summer climate of Illinois would become more like the current climate of southern Missouri in 2030 and more like Oklahoma's current climate in 2090. The primary difference in the resulting climates of the two models relates to the amount of summer rainfall.

Spatial Analogues (continued)

- Advantage
  – Communication tool: perhaps easier to understand
- Disadvantages
  – Require using a model result to choose the spatial analogue region
  – Do not capture changes in variability

Arbitrary/Incremental Scenarios

- Assume uniform annual or seasonal changes across a region
  - e.g., +2°C or +4°C for temperature
  - +/-10% or 20% change in precipitation
  - Can also make assumptions about changes in variability and extremes

Arbitrary/Incremental Scenarios (continued)

- **Pros**
  - **Easy to use**
  - **Can simulate a wide range of conditions**
- **Cons**
  - **Assuming a uniform change over the year or across a region may fail to capture important seasonal or spatial details**
  - **Combinations of changes in climate for different variables can be physically implausible**

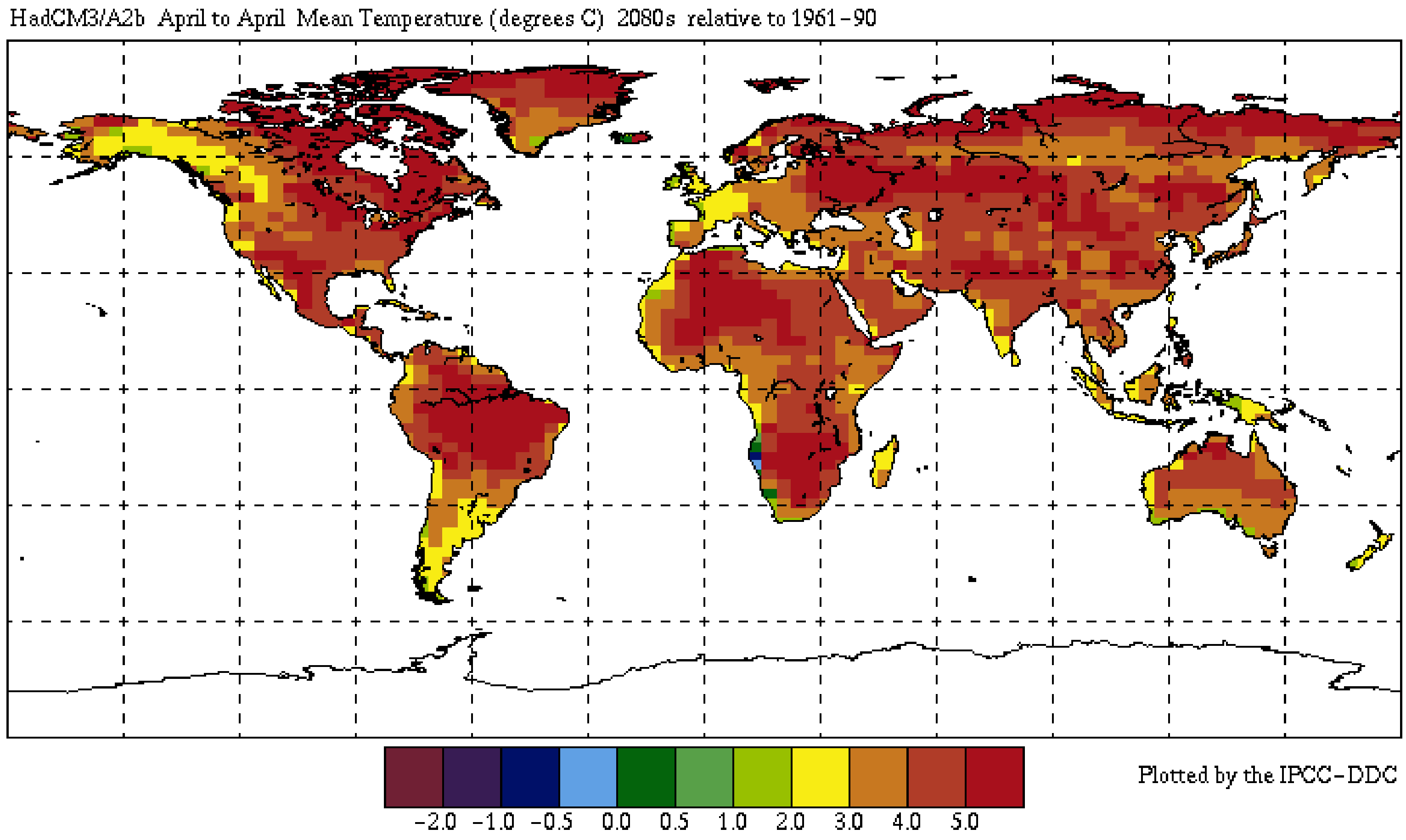
Climate Models

- **Models are mathematical representations of the climate system**
- **They can be run with different forcings, e.g., higher GHG concentrations**
  - **Models are the only way to capture the complexities of increased GHG concentrations**

General Circulation Models

- **Pros**
  - **Can represent the spatial details of future climate conditions for all variables**
  - **Can maintain internal consistency**
- **Cons**
  - **Relatively low spatial resolution**
  - **May not accurately represent climate parameters**

Example of GCM Output



Downscaling from GCMs

- Downscaling is a way to obtain higher spatial resolution output based on GCMs
- Options include:
  - Combine low-resolution monthly GCM output with high-resolution observations
  - Use statistical downscaling
    - Easier to apply
    - Assumes fixed relationships across spatial scales
  - Use regional climate models (RCMs)
    - High resolution
    - Capture more complexity
    - Limited applications
    - Computationally very demanding

Combine Monthly GCM Output with Observations

- An approach that has been used in many studies
- Typically, one adds the (low resolution) average monthly change from a GCM to an observed (high resolution) present-day "baseline" climate
  - 30 year averages should be used, if possible
    - e.g., 1961-1990 or 1971-2000
    - Make sure the baseline from the GCM (i.e., the period from which changes are measured) is consistent with the choice of observational baseline

Combining Monthly GCMs and Observations

- This method can provide daily data at the resolution of weather observation stations
- Assumes uniform changes within a GCM grid box and over a month
  - No spatial or daily/weekly variability

How Many GCM Grid Boxes Should Be Used

- Using the single grid box that includes the area being examined would be ideal, but
  - There can be model noise at the scale of single grid boxes
  - Many scientists do not think single box results are reliable
- Hewitson (2003) recommends using 9 grid boxes: the grid being examined plus the 8 surrounding grid boxes
- Need to consider the total area covered by all those grid boxes. Does it include topography or climates not similar to the area being studied?

Statistical Downscaling

- Statistical downscaling is a mathematical procedure that relates changes at the large spatial scale that GCMs simulate to a much finer scale
  - For example, a statistical relationship can be created between variables simulated by GCMs such as air, sea surface temperature, and precipitation at the GCM scale (predictors) with temperature and precipitation at a particular location (predictands)

Statistical downscaling

- methods
  - linear – MLR, CCA
  - nonlinear – NNs, local models, classification-based
- database
  - predictors: ERA-40
  - predictands: local daily data (temperature, precipitation, …), network of stations along CZ / SK / AT / HU borders

Statistical downscaling

Three categories:

(i) Transfer Function;

(ii) Weather typing;

(iii) Stochastic Weather Generators

Major advantage: computationally inexpensive => consideration of large number of GCM outputs;

Major theoretical weakness:

-cross-scale relationships derived for present climate are assumed to be valid under future climate conditions

Statistical Downscaling (continued)

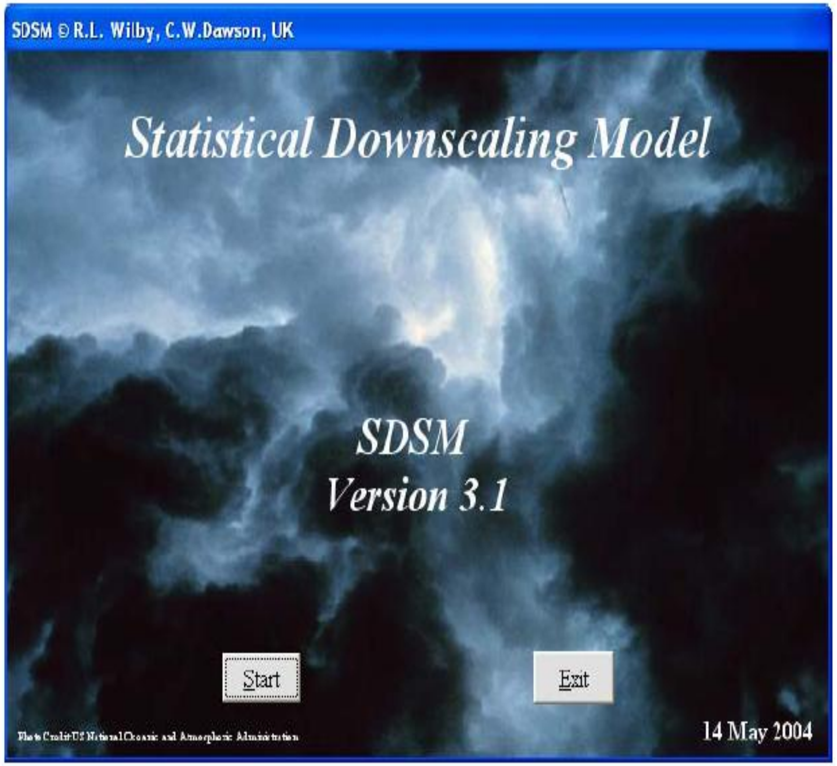
- Is most appropriate for
  - Subgrid scales (small islands, point processes, etc.)
  - Complex/heterogeneous environments
  - Extreme events
  - Exotic predictands
  - Transient change/ensembles
- Is not appropriate for
  - Data-poor regions
  - Where relationships between predictors and predictands may change
- Statistical downscaling is much easier to apply than regional climate modeling

Statistical Downscaling (continued)

- Statistical downscaling assumes that the relationship between the predictors and the predictands remains the same
- Those relationships could change
- In such cases, using regional climate models may be more appropriate

Statistical Downscaling Model (SDSM)

- Currently, only feasible based on outputs from a few GCMs



User Manual

Robert L. Wilby[1] and Christian W. Dawson[2]

August 2004

Global Data to Use in Downscaling with SDSM

- Canadian site
  – Go to scenarios, then SDSM
- Only has HadCM3
- Get output for individual grid

Validation

- SDS models, RCMs
- common criteria → detailed comparison of their performance possible
  - mean, stdev
  - correspondence with observations
  - distributions, higher-order moments
  - temporal + spatial structure
  - trends
  - relationships among variables
  - impact-specific characteristics (e.g., threshold exceedances)

Output localization

- **Main task – how to transfer RCM outputs to station (truly local) scale?**
- Potential methodology:
  - regression against geographical varibles (Benestad)
- techniques to be developed separately for individual datasets

Climate change scenarios

- two time horizons
  - 2021-2050
  - 2071-2100
- by SDS methods
- in the joint region – most impact target areas located there

DIFFICULTIES ENCOUNTERED

- creating common database: national met. services not willing to make their data available
- some downscalers refusing to put their methods into “competition”
- communication with (some) impacters
  - climatic data they need
  - impact-specific criteria for validation

Regional Climate Models (RCMs)

- These are high resolution models that are "nested" within GCMs
  - A common grid resolution is 50 km
    - Some are higher resolution
  - RCMs are run with boundary conditions from GCMs
- They give much higher resolution output than CCMs
  - Hence, much greater sensitivity to smaller scale factors such as mountains, lakes

Downscaling from GCMs

- Downscaling is a way to obtain higher spatial resolution output based on GCMs
- Options include:
  - Combine low-resolution monthly GCM output with high-resolution observations
  - Use statistical downscaling
    - Easier to apply
    - Assumes fixed relationships across spatial scales
  - Use regional climate models (RCMs)
    - High resolution
    - Capture more complexity
    - Limited applications
    - Computationally very demanding

RCM Limitations

- Can correct for some, but not all, errors in GCMs
- Typically applied to one GCM or only a few GCMs
- In many applications, just run for a simulated decade, e.g., 2040s
- Still need to parameterize many processes
- May need further downscaling for some applications

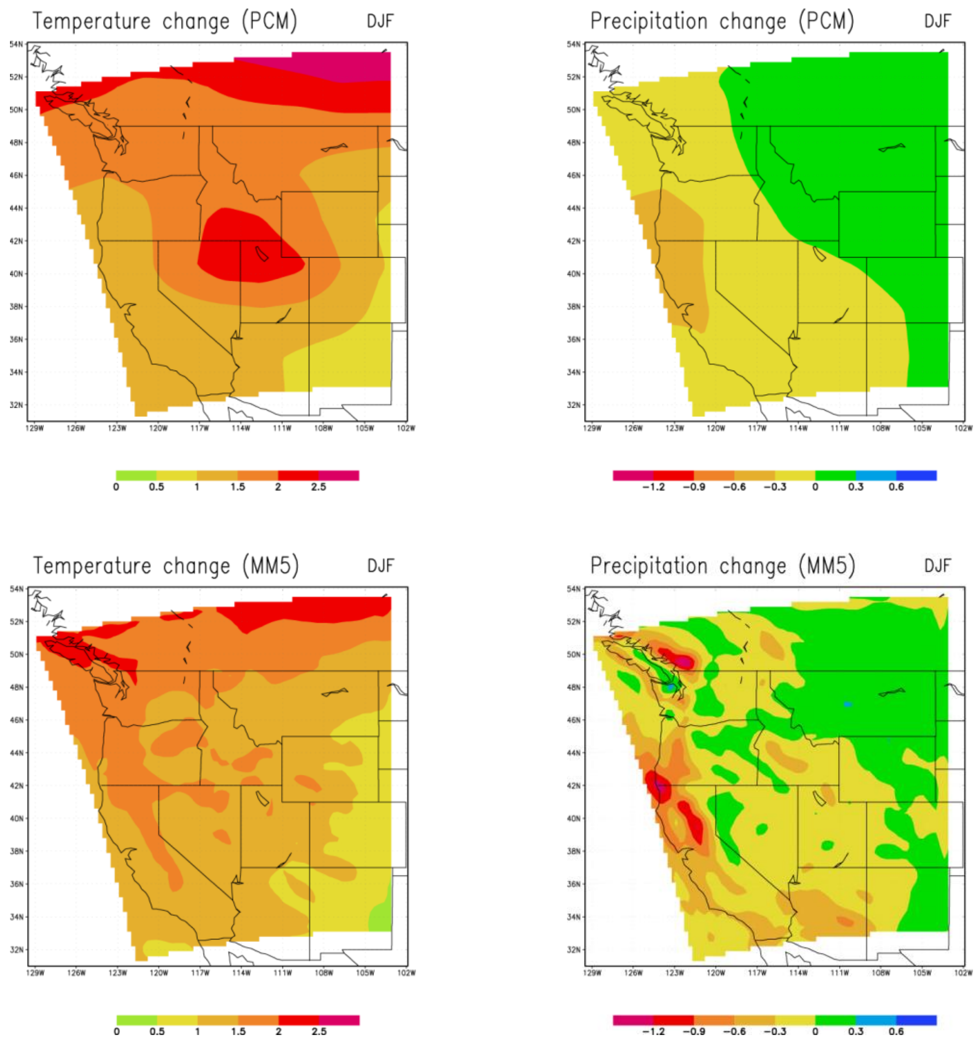
GCM vs. RCM Resolution

Temperature

Precipitation

GCM

RCM



By Now You May Be Confused

- So many choices, what to do?
- First, let's remember the basics
  - Scenarios are essentially educational tools to help:
    - See ranges of potential climate change
    - Provide tools for better understanding the sensitivities of affected systems
- So, we need to select scenarios that enable us to meet these goals

Tools for Assessing Regional Model Output

- It is useful first to compare results from a number of GCMs that might be used to drive an RCM
- Normalized GCM results allow comparison of the relative regional changes
- Can analyze the degree to which models agree about change in direction and relative magnitude
  - A measure of GCM uncertainty

Tools for Assessing Regional Model Output (continued)

- Agreement between GCMs does not necessarily mean that they are all correct – they may all be repeating the same mistakes
- Still, GCMs are the primary tool for estimating the range of future possibilities

Normalizing GCM Output

- Expresses regional change relative to an increase of 1°C in mean global temperature
  - This is a way to avoid high sensitivity models dominating results
  - It allows us to compare GCM output based on relative regional change
- Normalized temperature change = $\Delta T_{RGCM}/\Delta T_{GMTGCM}$
- Normalized precipitation change = $\Delta P_{RGCM}/\Delta T_{GMTGCM}$

Pattern Scaling

- Is a technique for estimating change in regional climate using normalized patterns of change and changes in GMT
- Pattern scaled temperature change:
  - $\Delta T_{R\Delta GMT} = (\Delta T_{RGCM}/\Delta T_{GMTGCM}) \times \Delta GMT$
- Pattern scaled precipitation
  - $\Delta P_{R\Delta GMT} = (\Delta P_{RGCM}/\Delta T_{GMTGCM}) \times \Delta GMT$

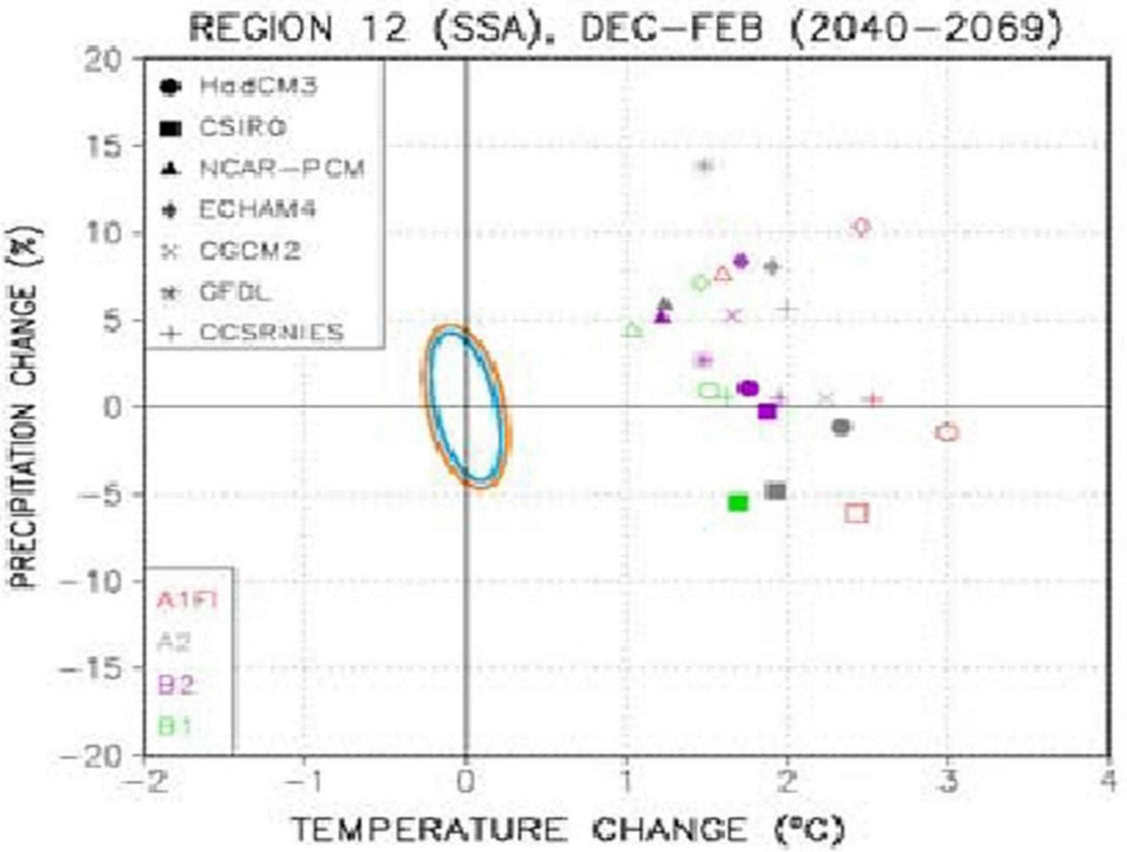
Tools to Survey GCM Results

- Finnish report: “Future climate . . .”
- COSMIC
- MAGICC/SCENGEN

Finnish Publication

- Shows regional output on temperature and precipitation for a number of models
  - For three time slices over 21st century
  - Uses some scaling
- Useful as a look-up to see degree of model agreement or disagreement
- MAGICC/SCENGEN and COSMIC provide more flexibility to users

Finnish Environment Example



COSMIC

- Developed by M. Schlesinger, R. Mendelsohn, and L. Williams
- Can choose from 28 emission scenarios
- Select individual GCM model
  - Results scaled
- Select country
  - Area or population weighted
- Yields annual change in GHGs, SO_2, SLR, and temperature

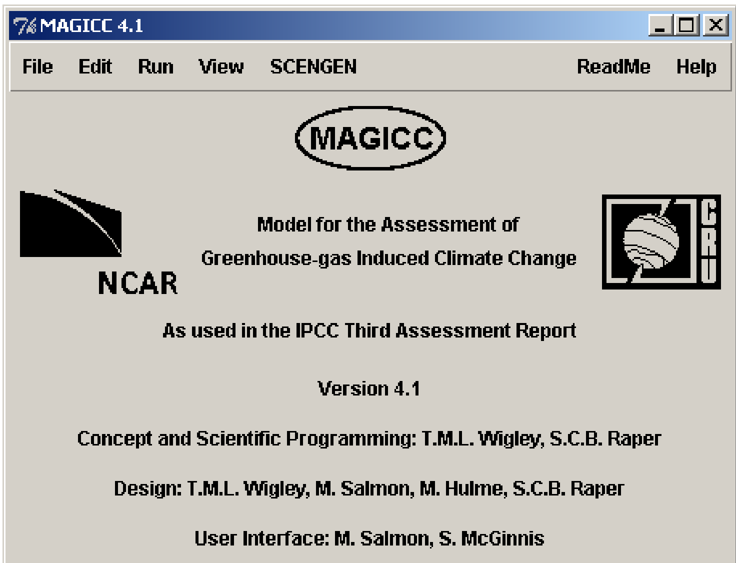
COSMIC Output

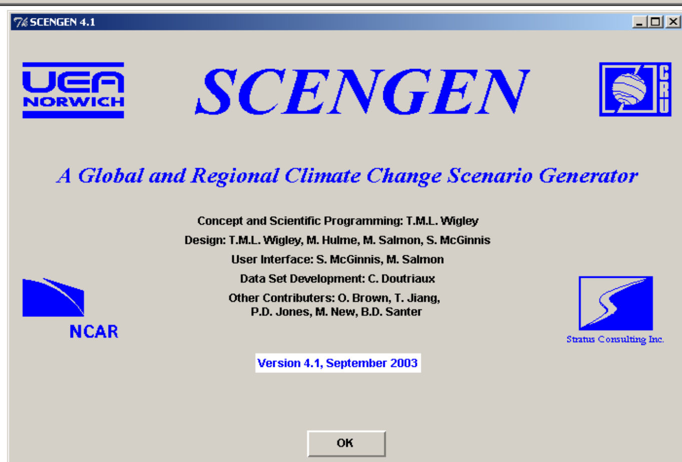
- Will give global changes in CO_2, SO_4, temperature, and sea level rise
- Will also give month-by-month temperature and precipitation at the country level
- Easy to use and obtain data
- Analyst should not use raw output, but compute *changes* in temperature and precipitation

COSMIC Limitations

- Since results are scaled, change will be smooth and will not reflect interannual variability
  - Since results are smoothed, it is sufficient to use a single year output as representative of average climate change
- GCMs tend to be older than in SCENGEN
  - Are 2 x CO_2; not transients
- Does not have mapping capabilities of SCENGEN

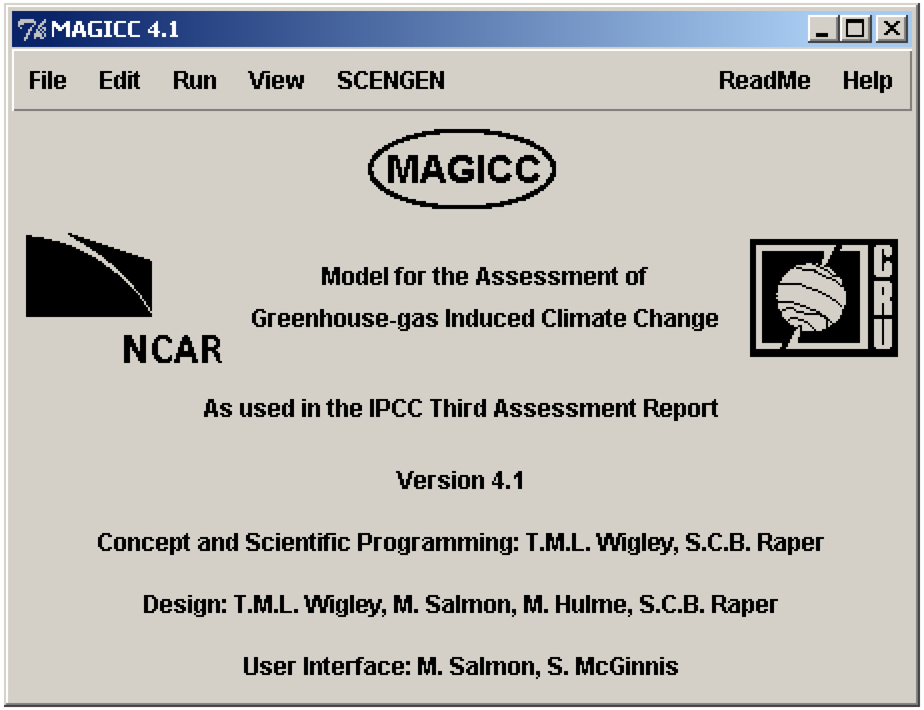
MAGICC/SCENGEN





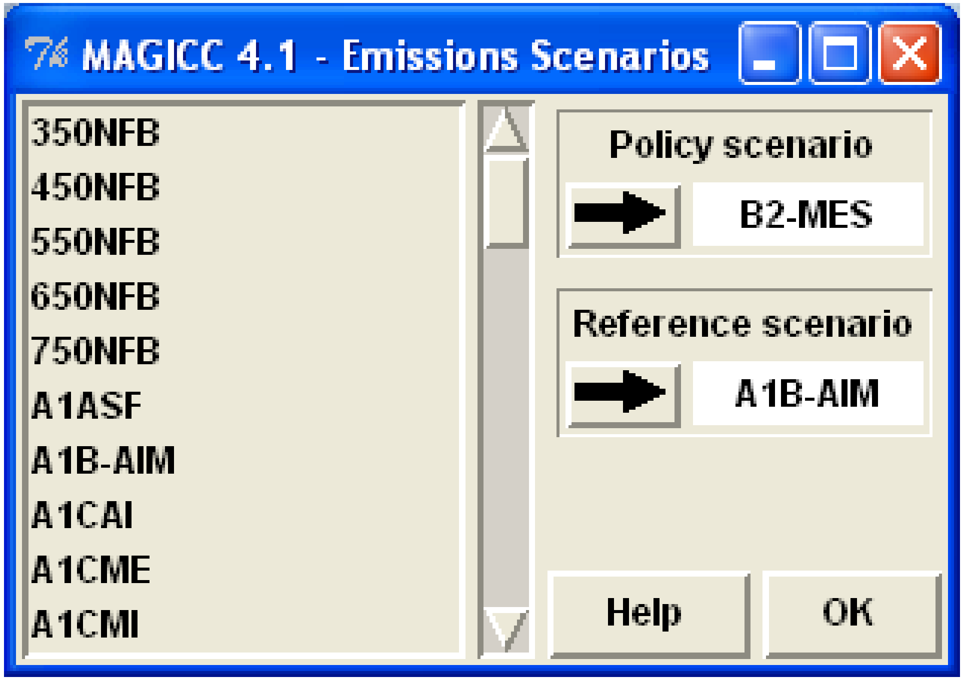
- MAGICC is a simple model of global T and SLR
- Used in IPCC TAR
- SCENGEN uses pattern scaling for 17 GCMs
- Yield
  - Model by model changes
  - Mean change
  - Intermodel SD
  - Interannual variability changes
  - Current and future climate on 5 x 5°grid

Using MAGICC/SCENGEN

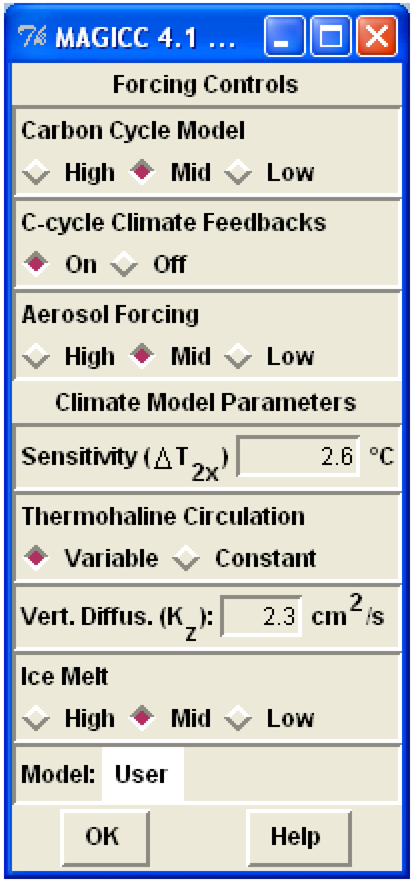


MAGICC: Selecting Scenarios

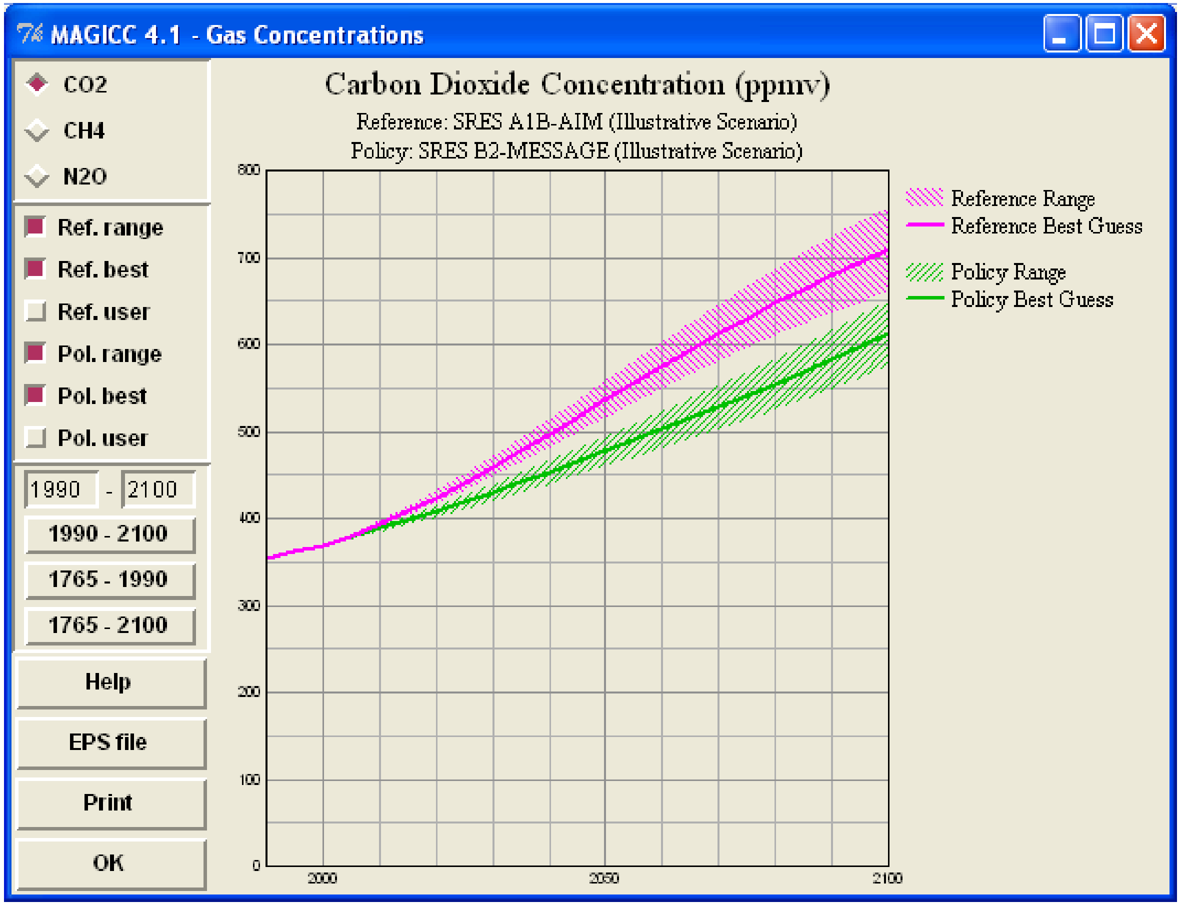
MAGICC: Selecting Scenarios (continued)



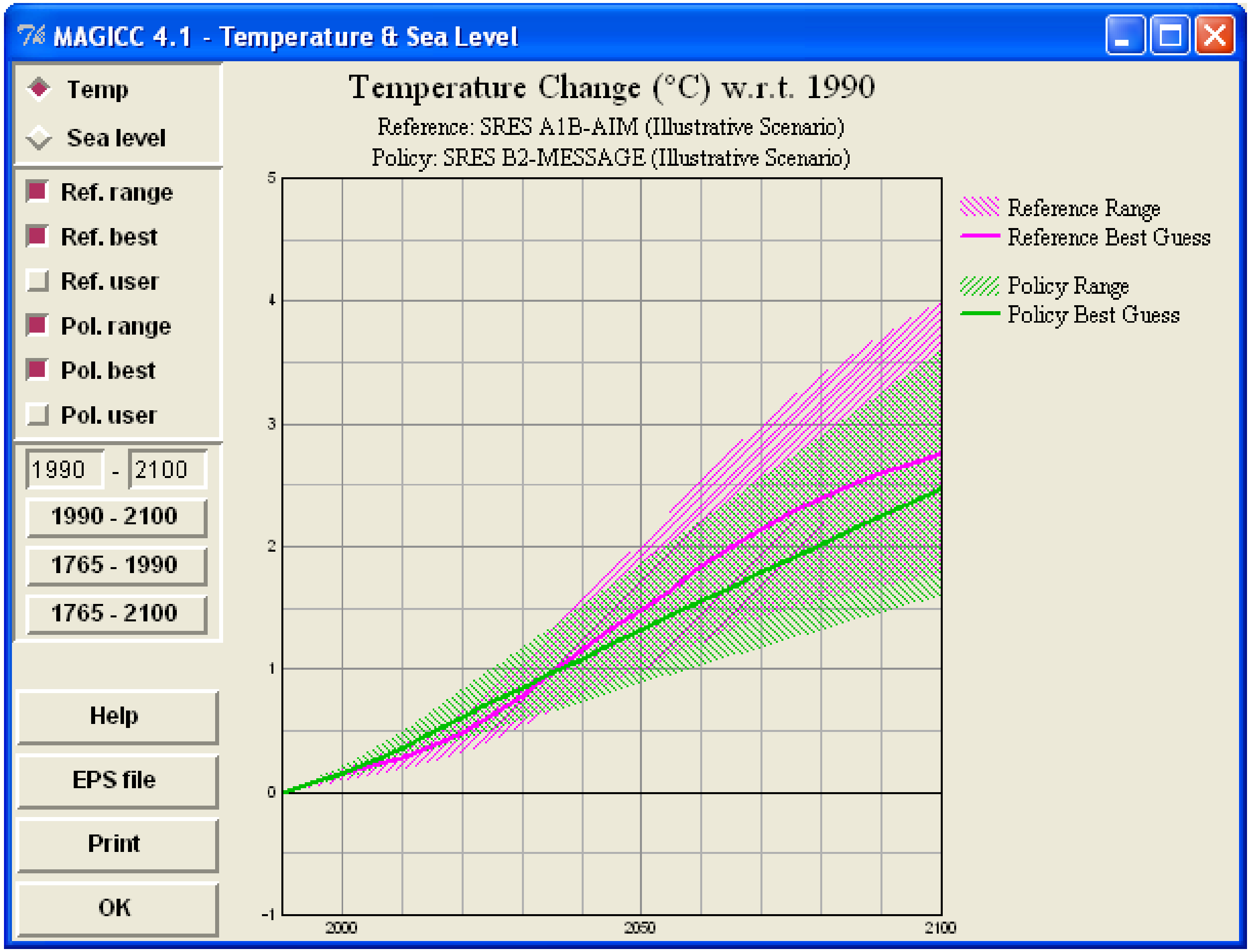
MAGICC: Selecting Forcings



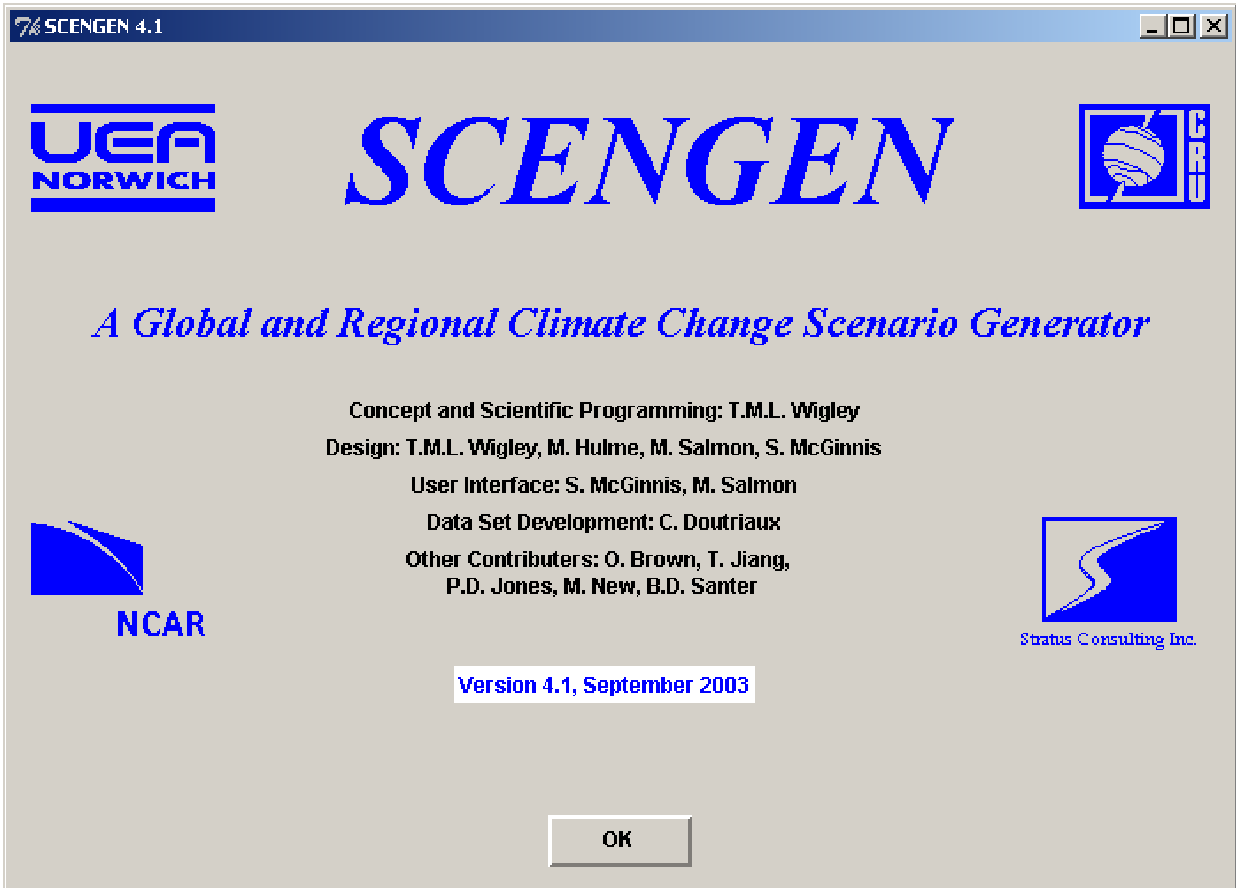
MAGICC: Displaying Results



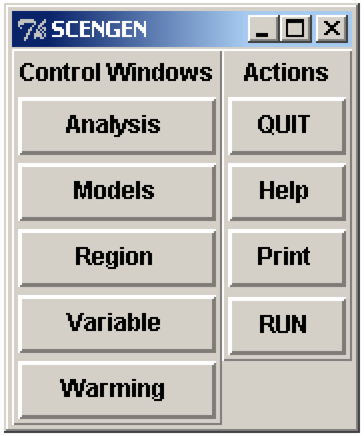
MAGICC: Displaying Results (continued)

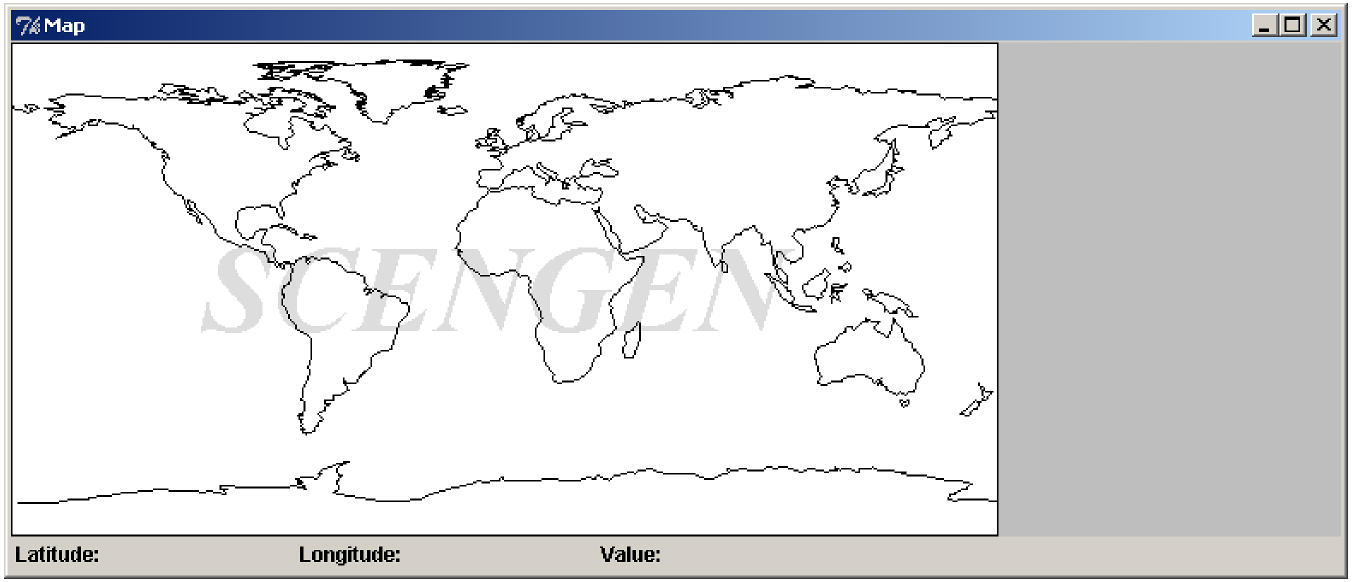


Running SCENGEN

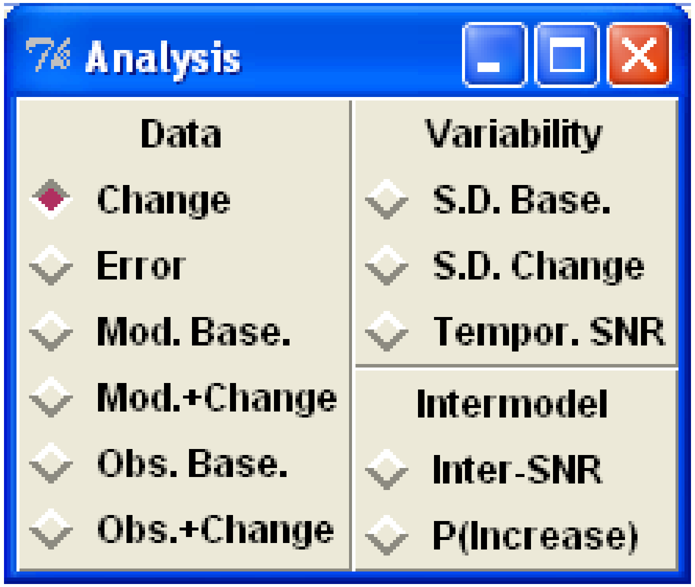


Running SCENGEN (continued)

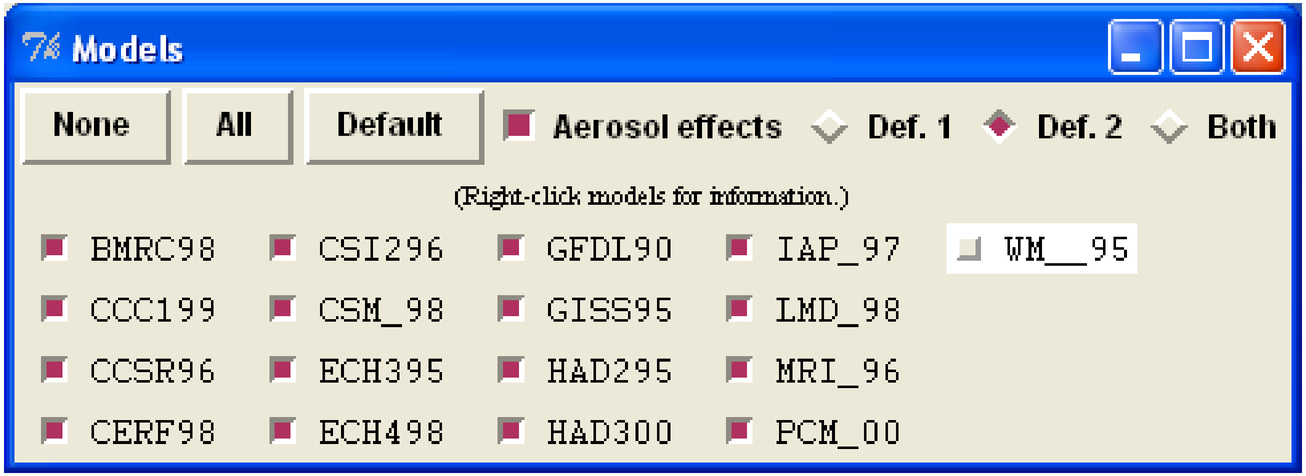




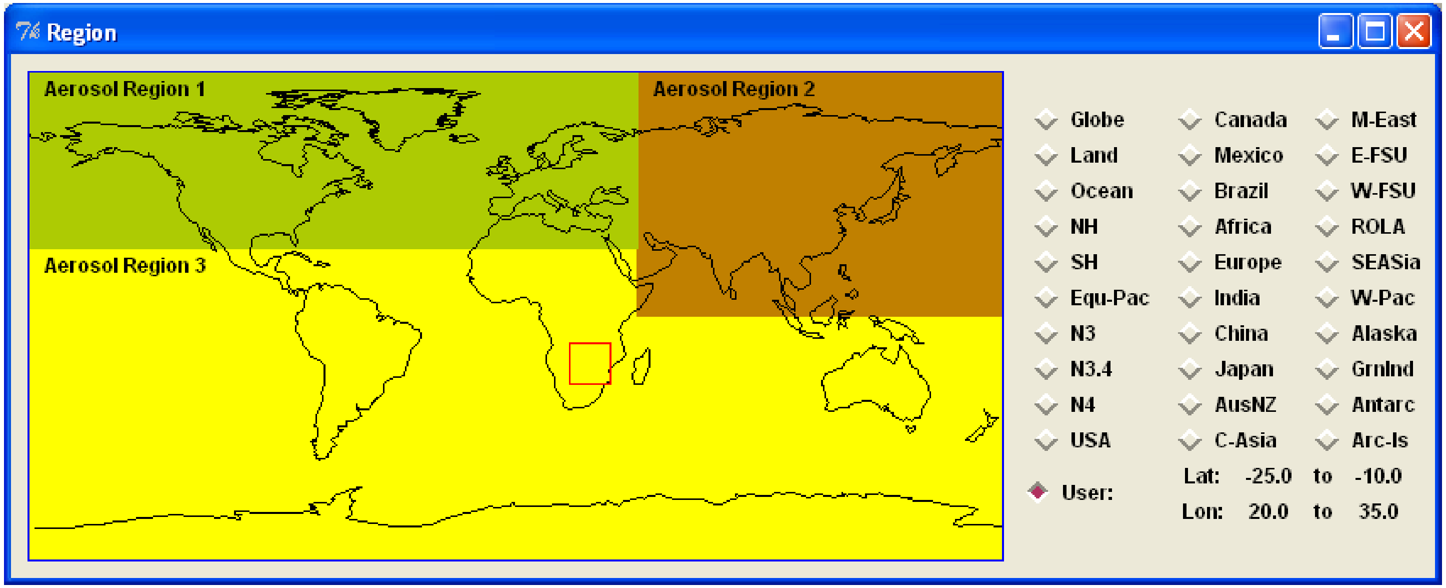
SCENGEN: Analysis



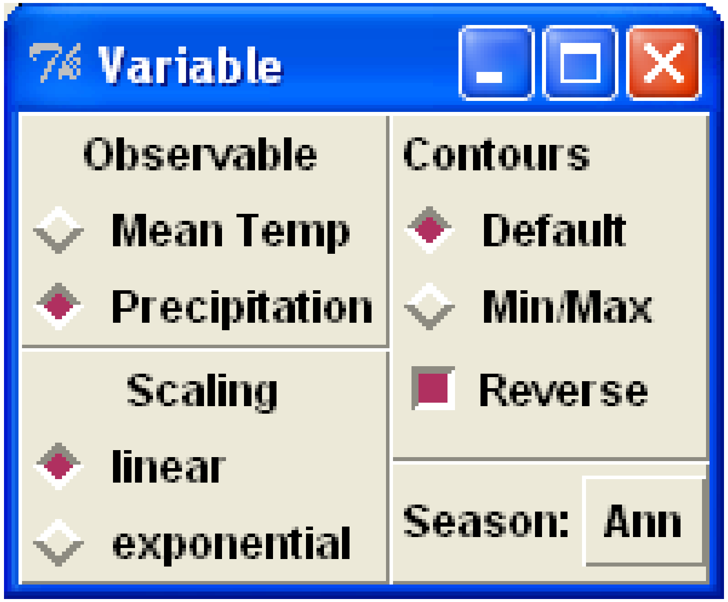
SCENGEN: Model Selection



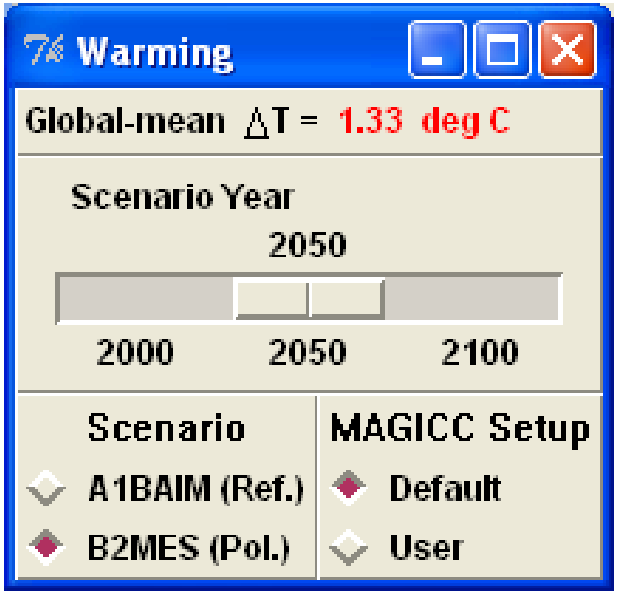
SCENGEN: Area of Analysis



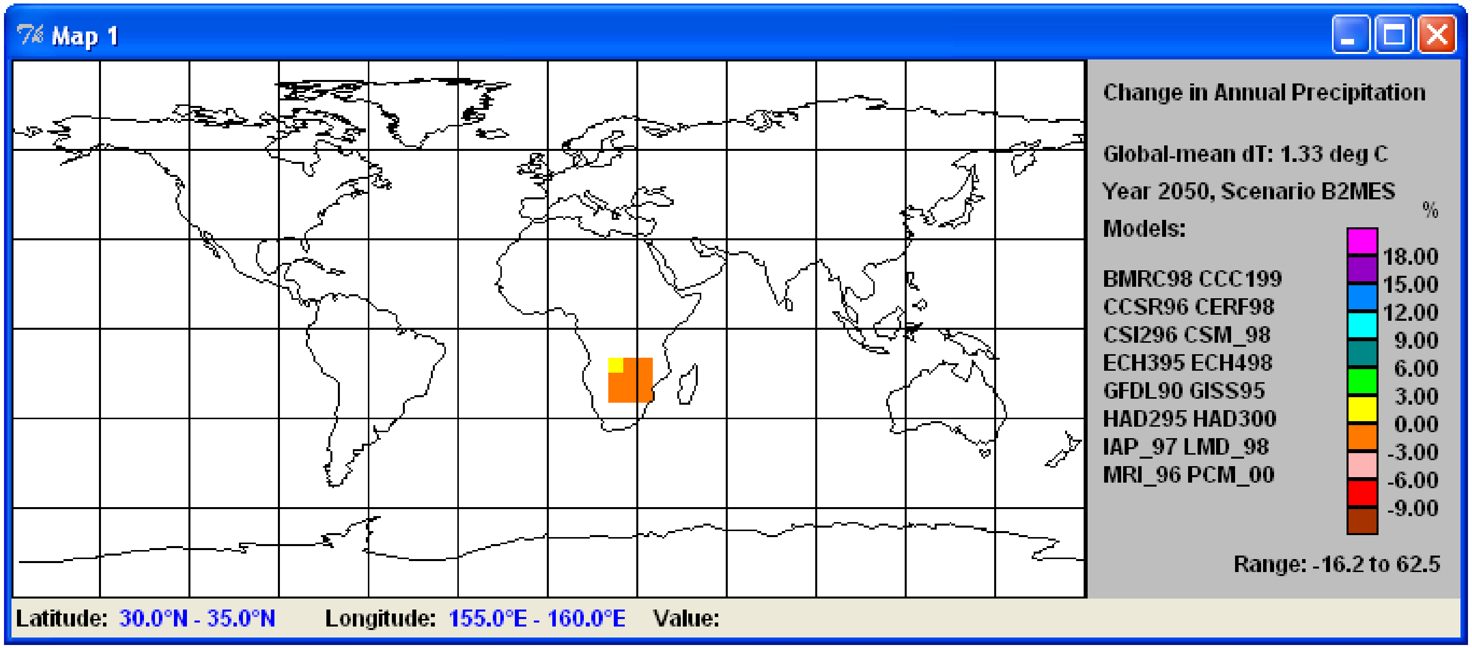
SCENGEN: Select Variable



SCENGEN: Scenario



SCENGEN: Map Results



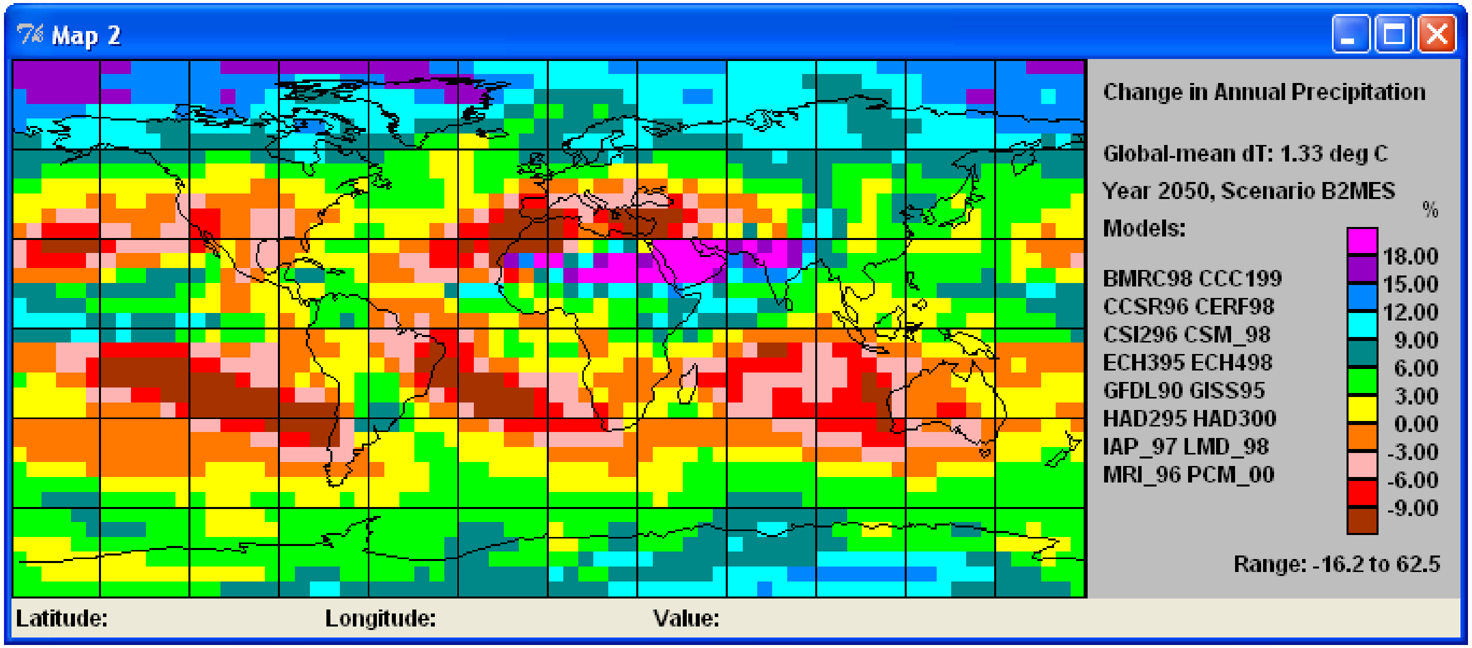
SCENGEN: Quantitative Results

INTER-MOD S.D. : AREA AVERAGE = 5.186 % (FOR NORMALIZED GHG DATA)
INTER-MOD SNR : AREA AVERAGE = -.067 (FOR NORMALIZED GHG DATA)
PROB OF INCREASE : AREA AVERAGE = .473 (FOR NORMALIZED GHG DATA)
GHG ONLY : AREA AVERAGE = -.411 % (FOR SCALED DATA)
AEROSOL ONLY : AREA AVERAGE = -.277 % (FOR SCALED DATA)
GHG AND AEROSOL : AREA AVERAGE = -.687 % (FOR SCALED DATA)

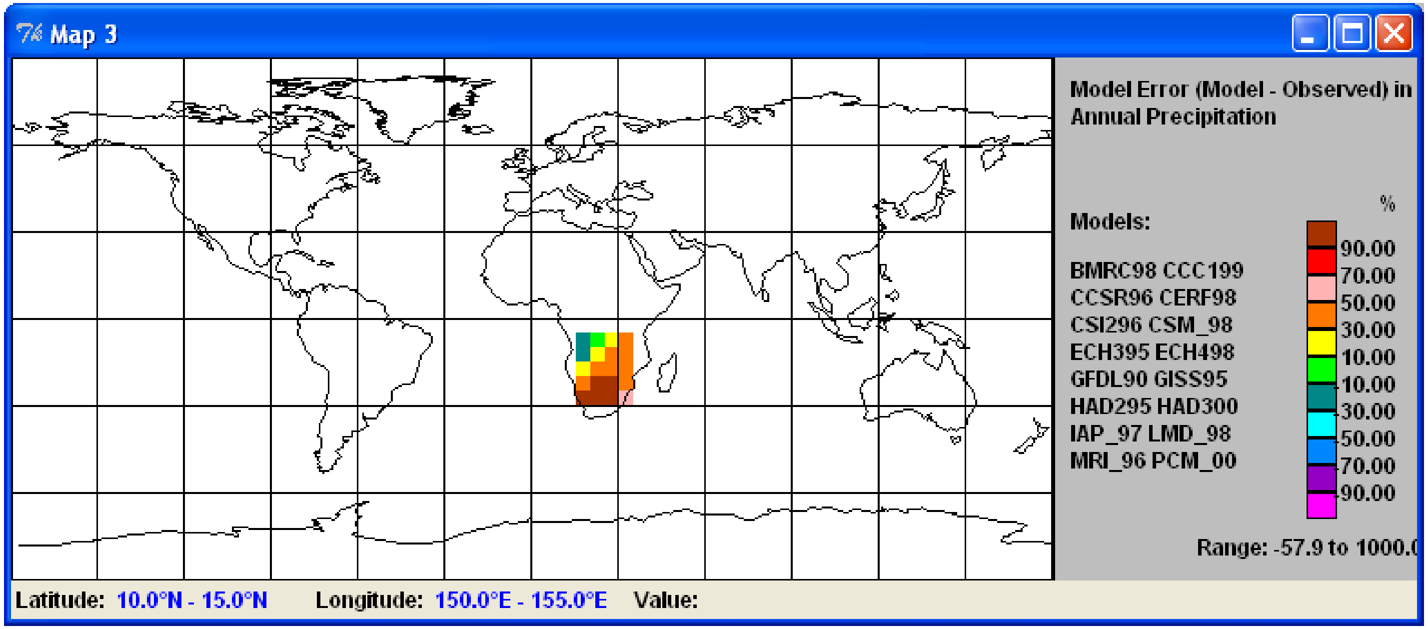
*** SCALED AREA AVERAGE RESULTS FOR INDIVIDUAL MODELS ***
(AEROSOLS INCLUDED)

MODEL = BMRCD2 : AREA AVE = 2.404 (%)
MODEL = CCC1D2 : AREA AVE = -5.384 (%)
MODEL = CCSRD2 : AREA AVE = 6.250 (%)
MODEL = CERFD2 : AREA AVE = -2.094 (%)
MODEL = CSI2D2 : AREA AVE = 6.058 (%)
MODEL = CSM_D2 : AREA AVE = 1.245 (%)
MODEL = ECH3D2 : AREA AVE = .151 (%)
MODEL = ECH4D2 : AREA AVE = -1.133 (%)
MODEL = GFDLD2 : AREA AVE = 1.298 (%)
MODEL = GISSD2 : AREA AVE = -3.874 (%)
MODEL = HAD2D2 : AREA AVE = -5.442 (%)
MODEL = HAD3D2 : AREA AVE = -.459 (%)
MODEL = IAP_D2 : AREA AVE = -.088 (%)
MODEL = LMD_D2 : AREA AVE = -6.548 (%)
MODEL = MRI_D2 : AREA AVE = .065 (%)
MODEL = PCM_D2 : AREA AVE = -3.451 (%)
MODEL = MODBAR : AREA AVE = -.687 (%)

SCENGEN: Global Analysis



SCENGEN: Error Analysis



SCENGEN Error Analysis (continued)

UNWEIGHTED STATISTICS

MODEL	CORREL	RMSE	MEAN DIFF	NUM PTS
		mm/day	mm/day	
BMRCTR	.632	1.312	1.026	20
CCC1TR	.572	1.160	-.207	20
CCSRTR	.587	.989	.322	20
CERFTR	.634	1.421	-1.167	20
CSI2TR	.553	1.112	-.306	20
CSM_TR	.801	1.044	-.785	20
ECH3TR	.174	1.501	-.649	20
ECH4TR	.767	1.121	-.881	20
GFDLTR	.719	.954	-.553	20
GISSTR	.688	.799	.123	20
HAD2TR	.920	.743	-.598	20
HAD3TR	.923	.974	-.883	20
IAP_TR	.599	1.408	-.734	20
LMD_TR	.432	2.977	-2.103	20
MRI_TR	.216	2.895	-2.026	20
PCM_TR	.740	1.372	-1.041	20
MODBAR	.813	.879	-.654	20

How to Select Scenarios

- Use MAGICC/SCENGEN, COSMIC, or the Finnish study to assess the range of temperature or precipitation changes
- Models can be selected based on
  - How well they simulate current climate
    - SCENGEN has a routine
  - How well they representing a broad range of conditions

How to Select Scenarios (continued)

- One can use results from actual GCM data or scaled data
- Can include other sources for scenarios, e.g., arbitrary, analogue

Selecting GCMs

- Some factors to consider in selecting GCMs
  - Age of the model run
    - More recent runs tend to be better, but there are exceptions (see comments on slide 54)
  - Model resolution
    - Higher resolution tends to be better
  - Model accuracy in simulating current climate
    - MAGICC/SCENGEN has a routine

What to Use under What Conditions?

- Nothing wrong with using combinations of different sources for creating scenarios, e.g., models and arbitrary scenarios
- The climate models tend to be better for longer run analyses, e.g., beyond several decades (beyond 2050)
- Climate analogues tend to be better for near term, e.g., within several decades (2010-2030)

Scenarios for Extreme Events

- Difficult to obtain from any of these sources
- Options
  - Use long historical or paleoclimate records
  - Incrementally change historical extremes
    - Try to be consistent with transient GCMs
  - These methods are primarily useful for sensitivity studies

Data Sources
Climate Models and Observations

Some Climate Data Sources

- IPCC Data Distribution Centre
- http://ipcc-ddc.cru.uea.ac.uk/
- Program for Climate Model Diagnosis and Intercomparison
- http://www-pcmdi.llnl.gov/

IPCC Data Distribution Center

- The IPCC Data Distribution Centre is probably the best site for public-access climate model data
- Observed climate data 1901-1990
  - – Gridded to 0.5 x 0.5°
  - – 10 and 30 year means
- http://ipcc-ddc.cru.uea.ac.uk/

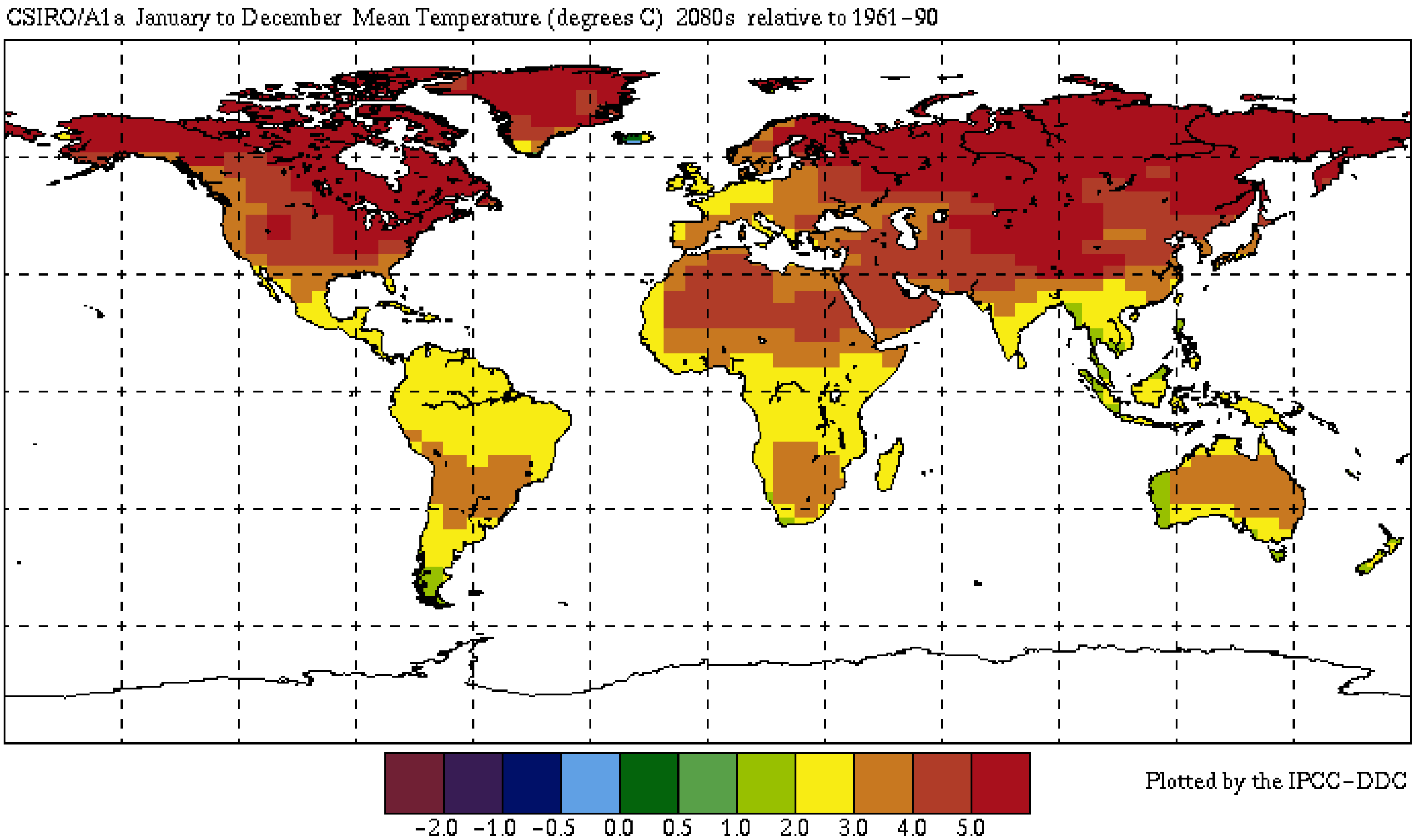
IPCC Data Distribution Center (continued)

- GCM data from
  - CCC (Canada)
  - CSIRO (Australia)
  - ECHAM4 (Germany)
  - GFDL-R30 (U.S.)
  - HadCM3 (UK)
  - NIES (Japan)
- Can obtain actual (not scaled) GCM output

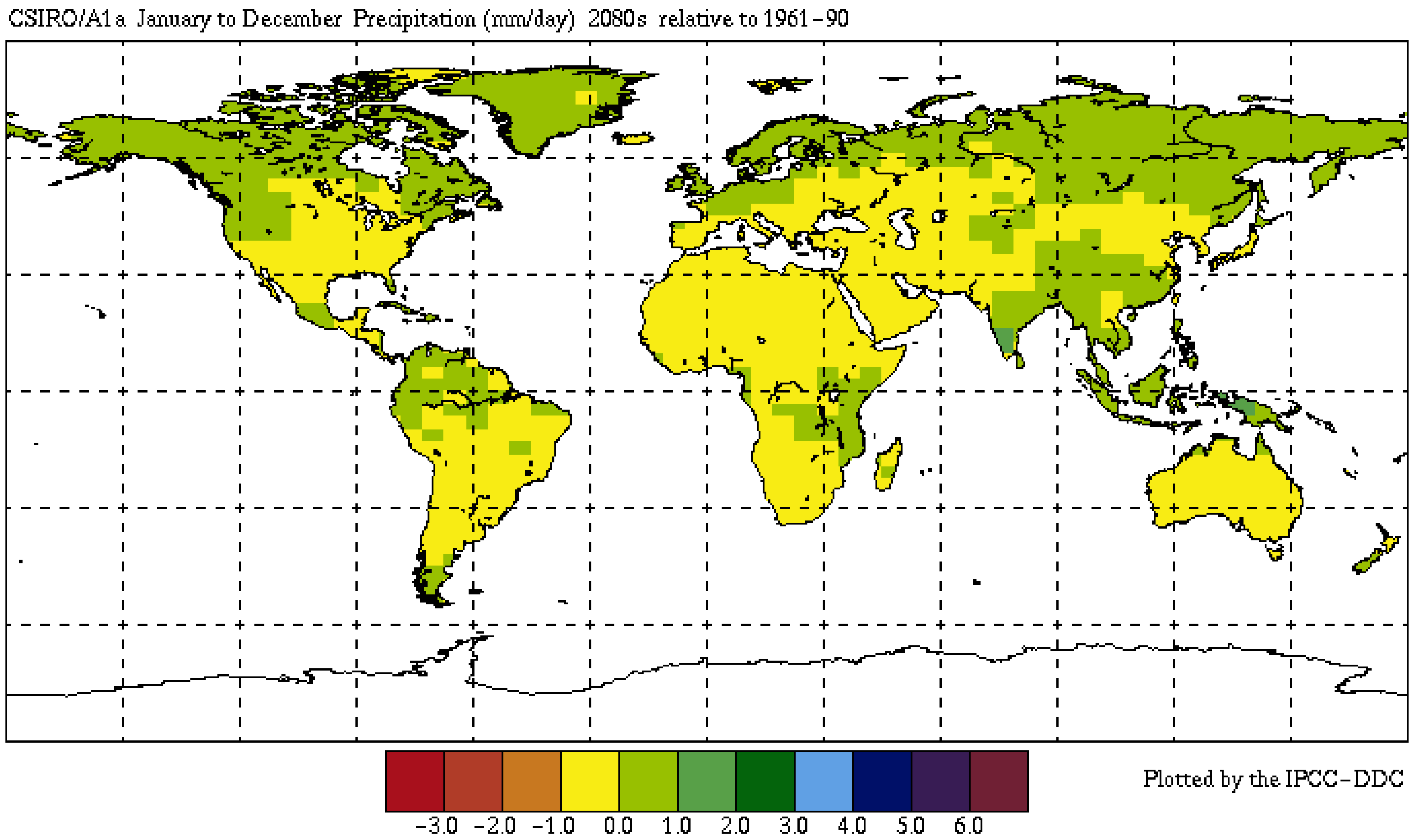
IPCC Data Distribution Center (continued)

- Contains monthly-mean data from GCMs on
  - Mean temperature (°C)
  - Maximum temperature (°C)
  - Minimum temperature (°C)
  - Precipitation (mm/day)
  - Vapor pressure (hPa)
  - Cloud cover (%)
  - Wind speed (m/s)
  - Soil moisture

Example Data from DDC – Temperature



Example Data – Precipitation



Observational Record

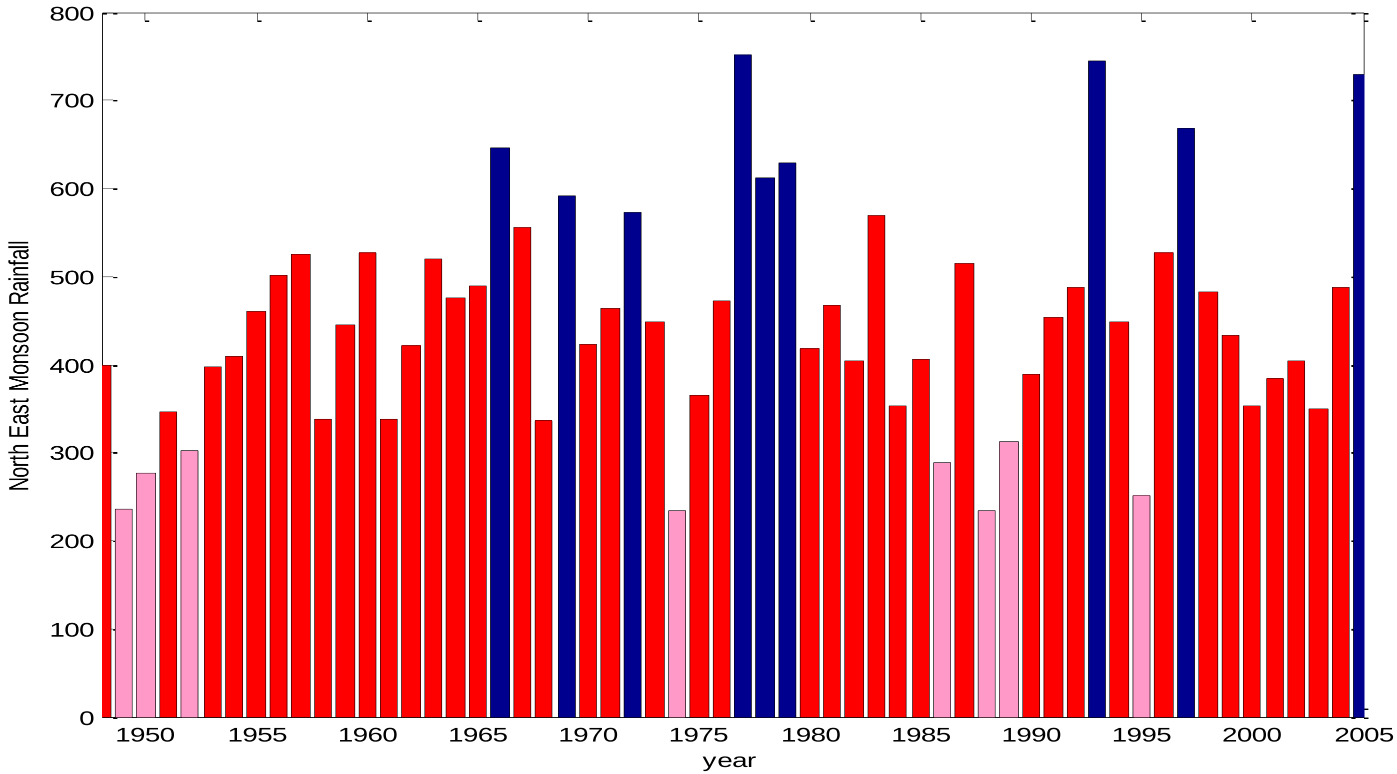
- National meteorological offices
- MARA/ARMA has 1951-1995 monthly temperature and precipitation
  - Developed by Climatic Research Unit, University of East Anglia, UK
  - 3 minute scale
- http://www.mara.org.za/

Indian Monsoon Modeling

Motivation

- To develop appropriate indices for North East monsoons in Tamilnadu
- Useful to study the climate change in monsoon seasons
- Convenient to solve the teleconnection problem related to North East monsoons

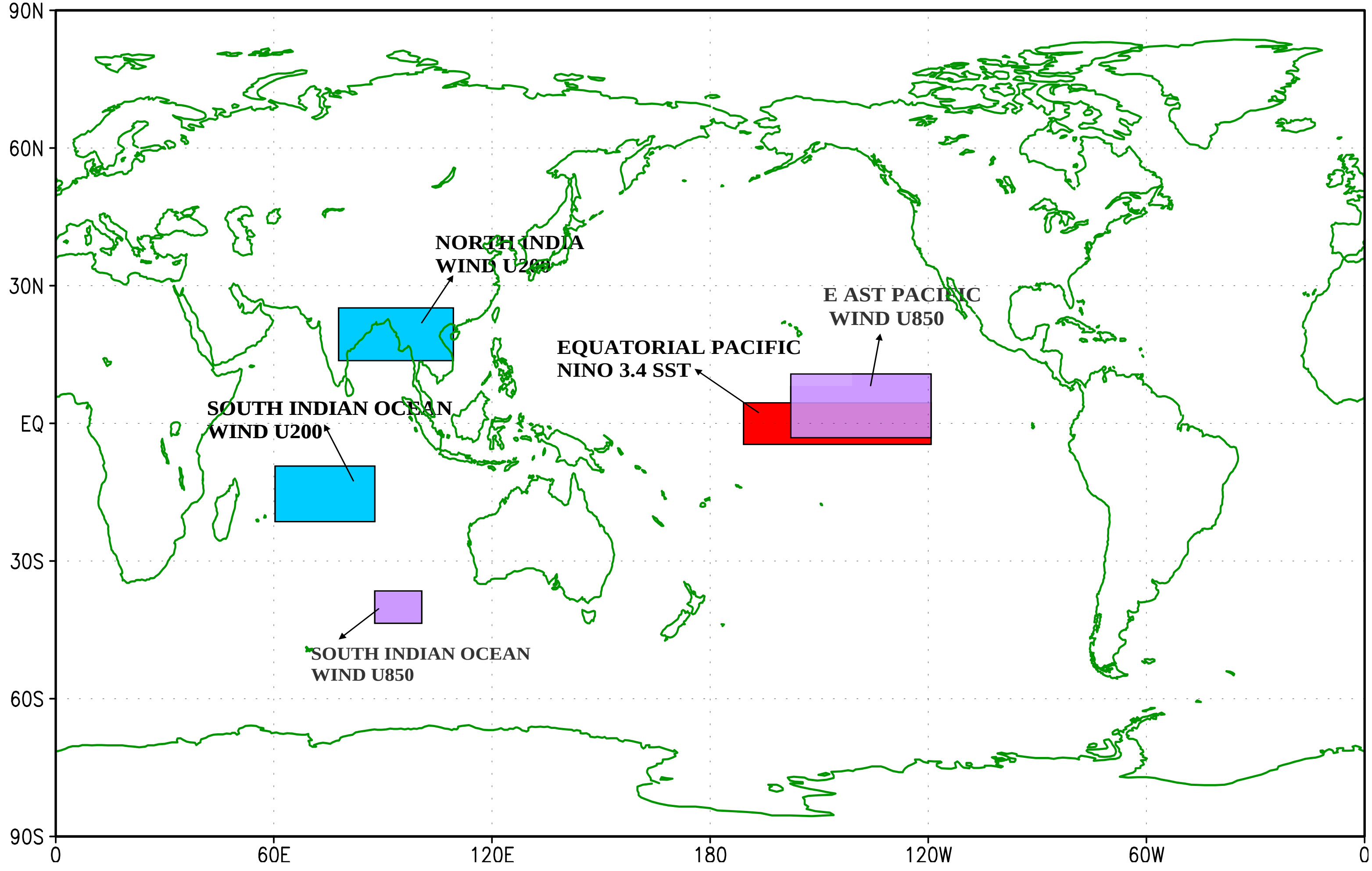
NE Monsoon (Oct-Dec) rainfall

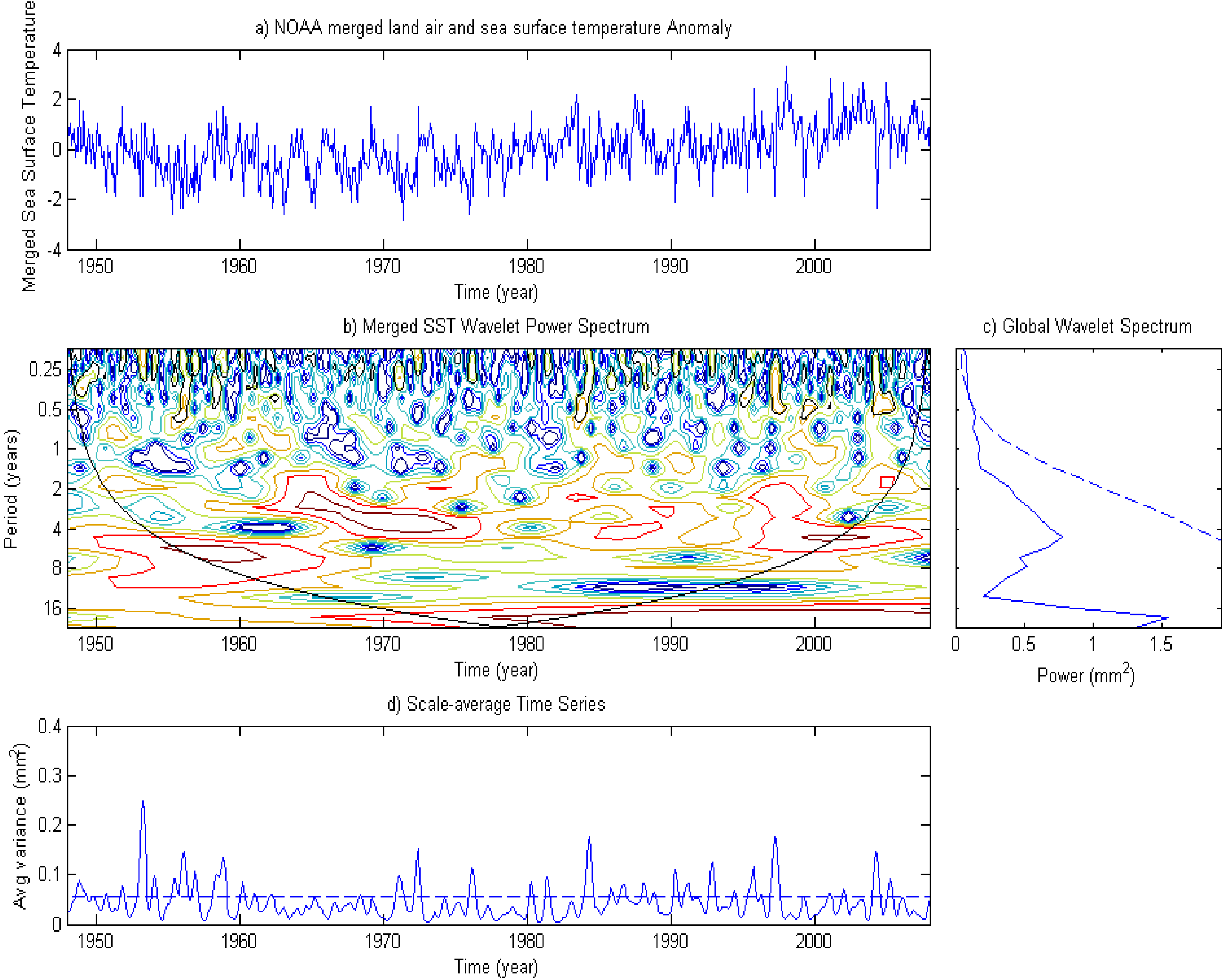


- NE monsoon rainfall during the period October-December is important for South Peninsula, especially for Tamil Nadu.

- NE Monsoon is not getting attention that it deserves.

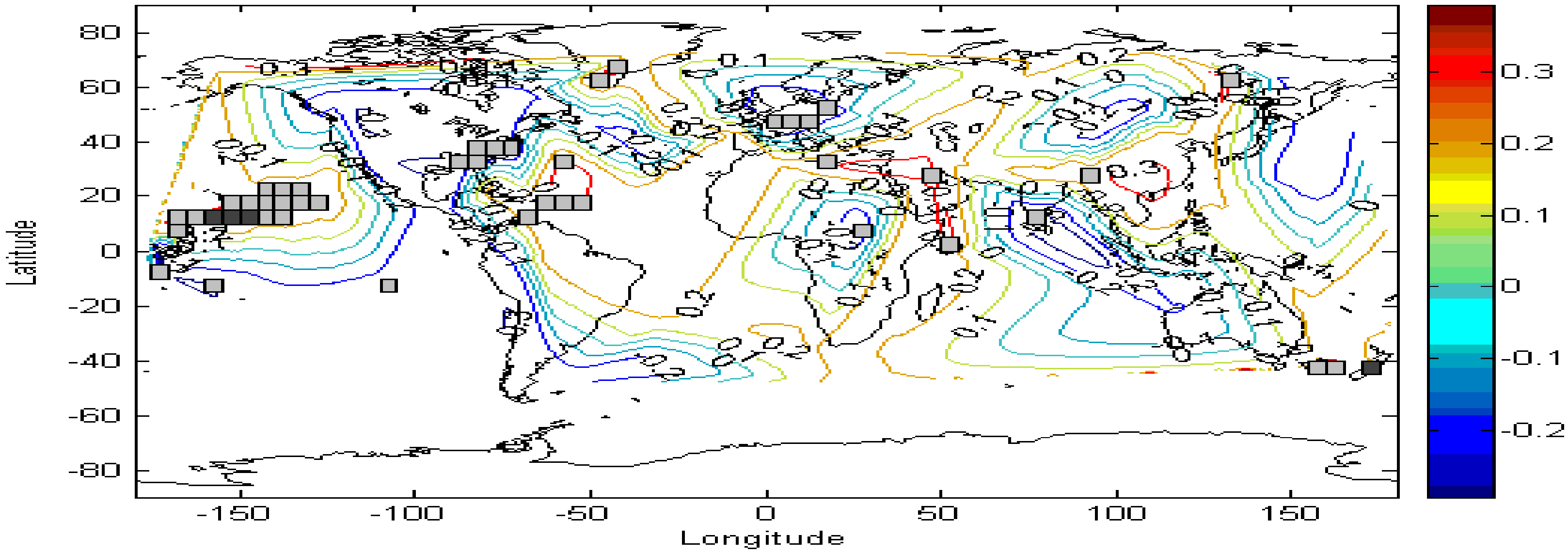
NE Monsoon Statistical forecasts



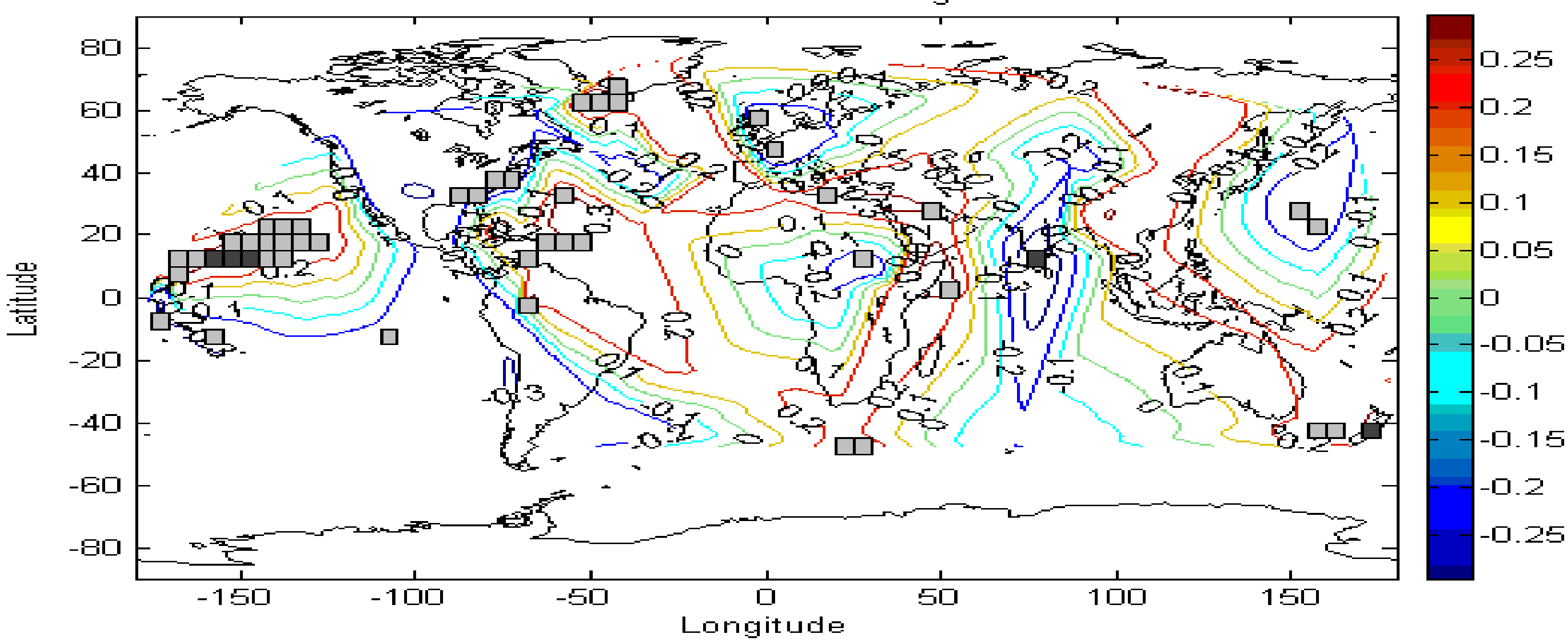


a) NOAA merged land air and sea surface temperature Anomaly
Merged Sea Surface Temperature
4
2
0
-2
-4
1950
1960
1970
1980
1990
2000
Time (year)
b) Merged SST Wavelet Power Spectrum
Period (years)
0.25
0.5
1
2
4
8
16
1950
1960
1970
1980
1990
2000
Time (year)
c) Global Wavelet Spectrum
0
0.5
1
1.5
Power (mm2)
d) Scale-average Time Series
Avg variance (mm2)
0.4
0.3
0.2
0.1
0
1950
1960
1970
1980
1990
2000
Time (year)

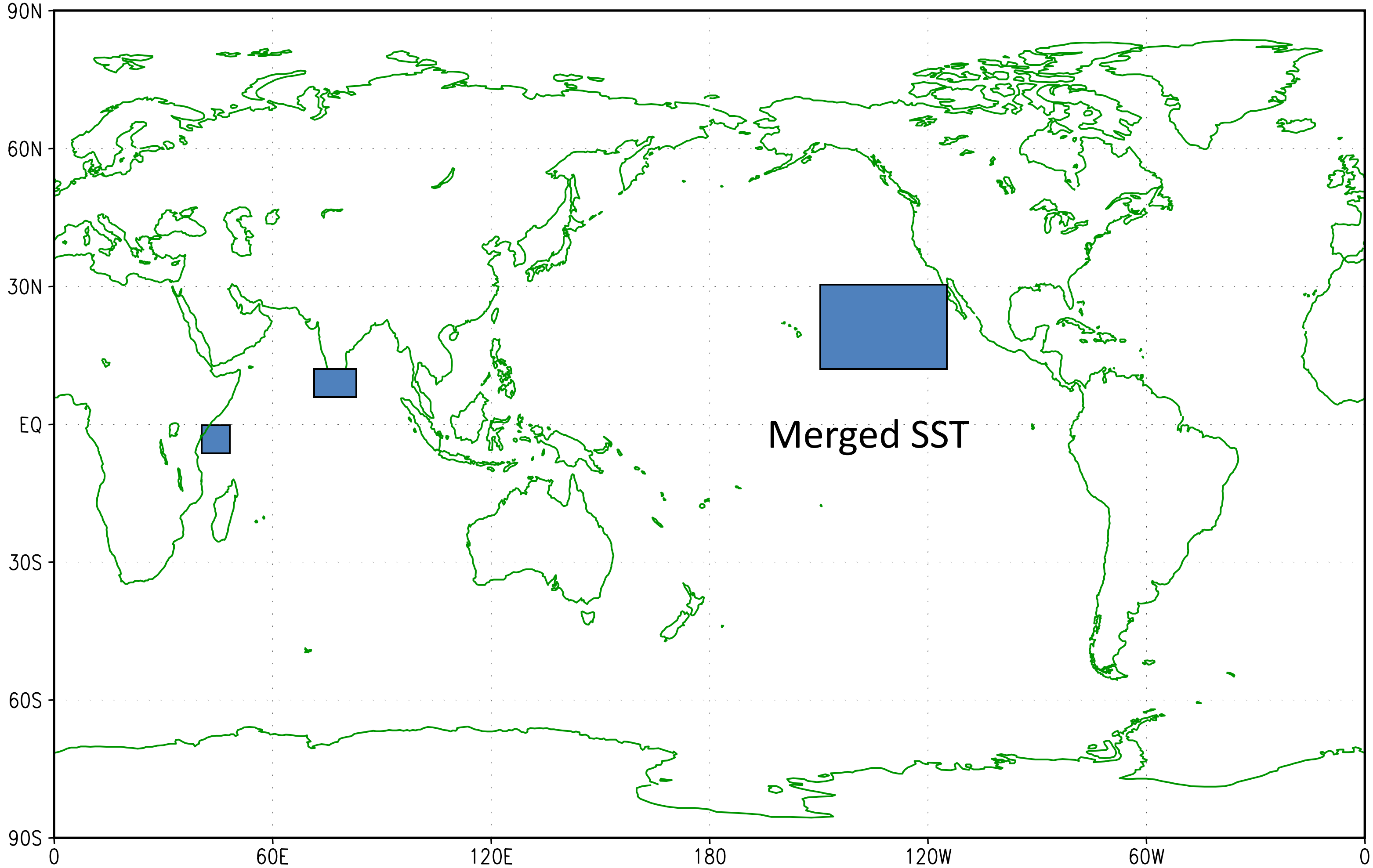
Correlation Coefficient Between NEMR and NOAA Merged Land and SST Data in September



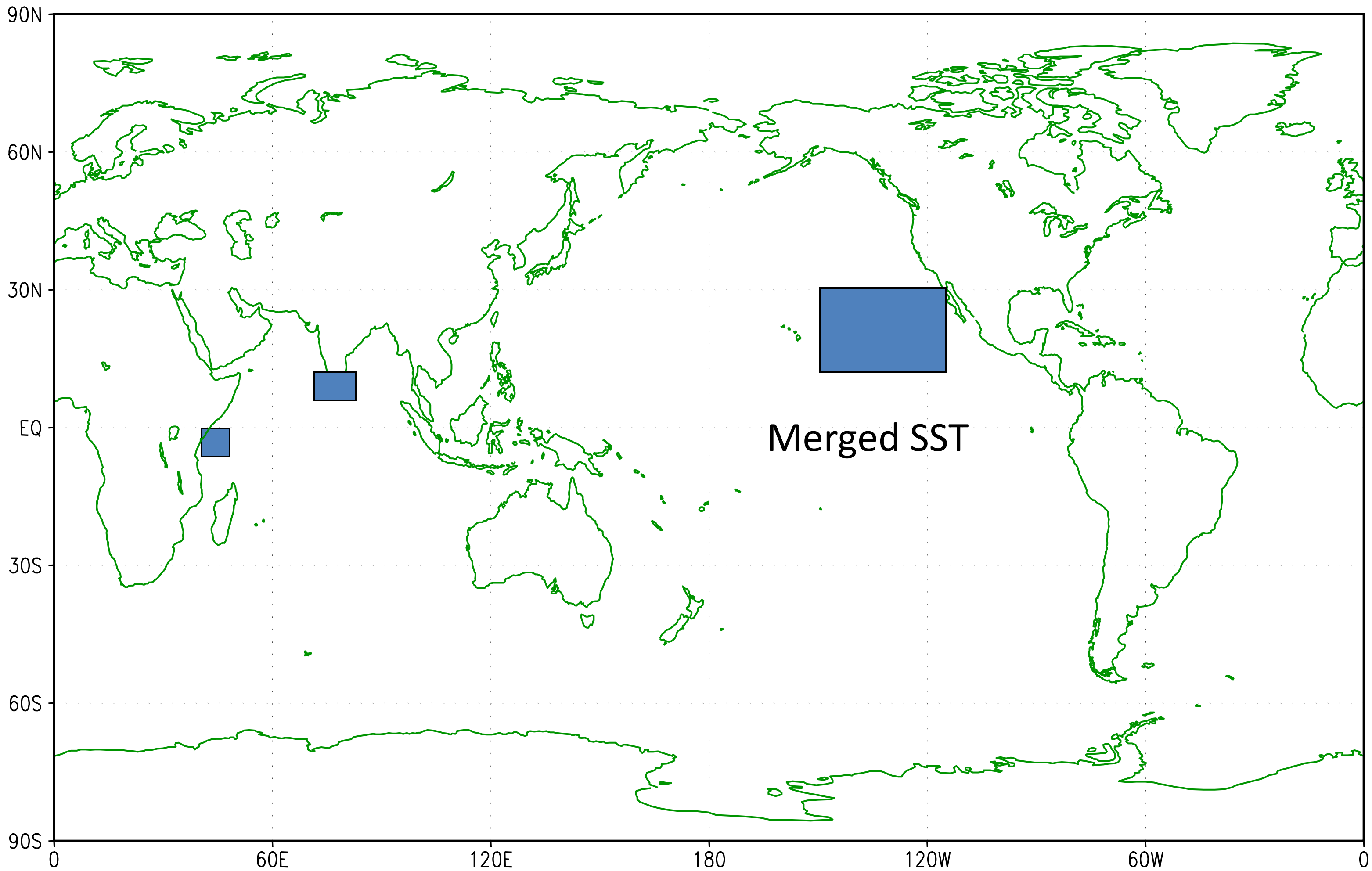
Correlation Coefficient Between NEMR and NOAA Merged Land and SST Data in October

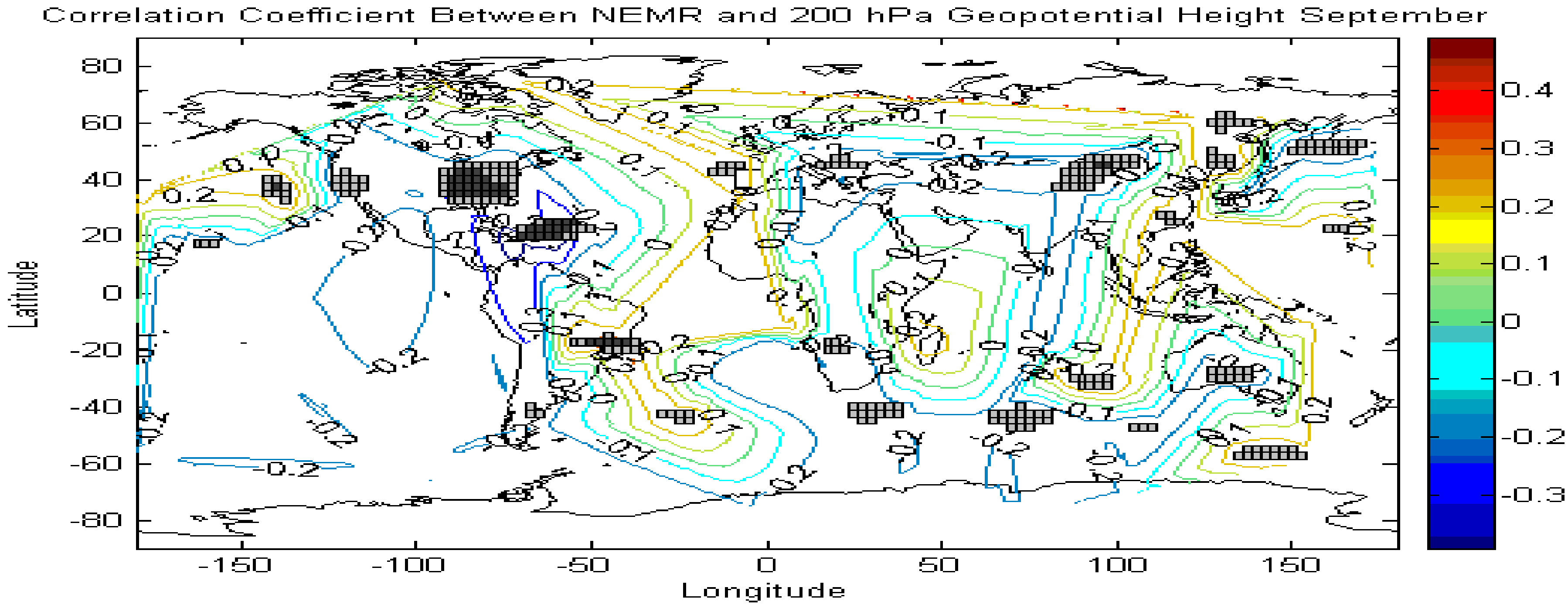


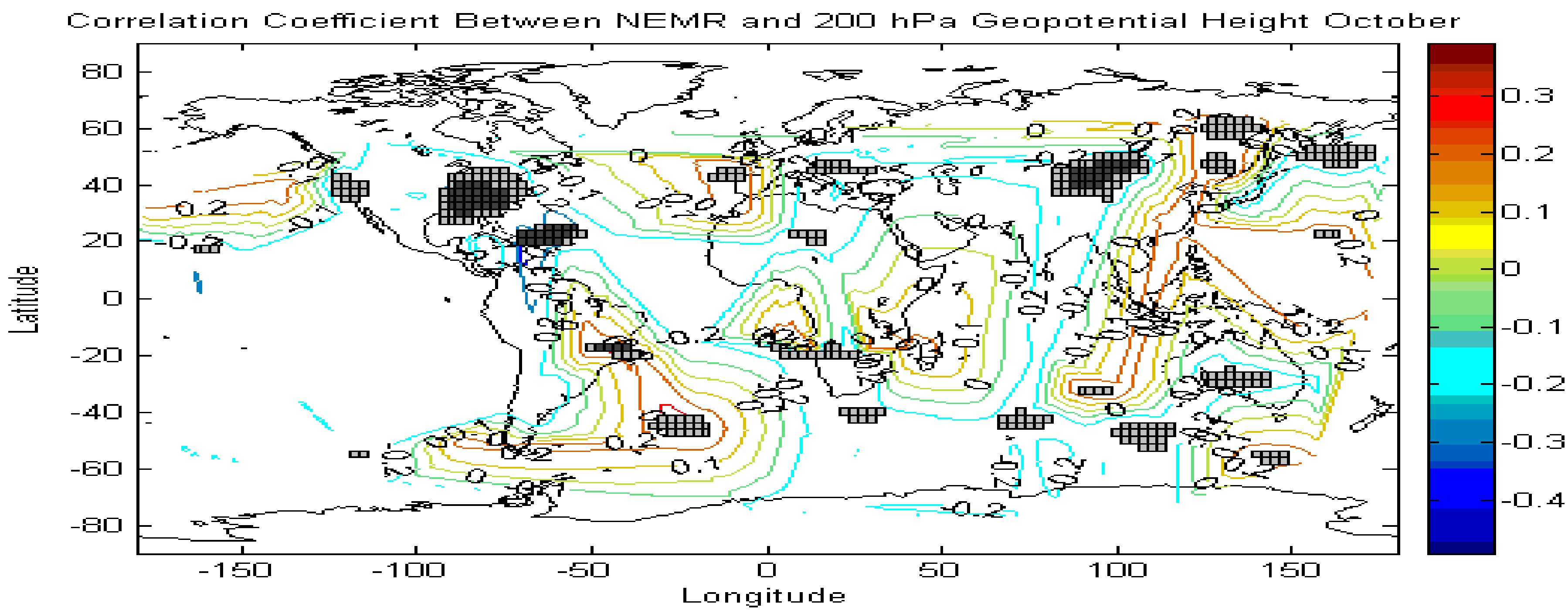
Identified Teleconnected Region



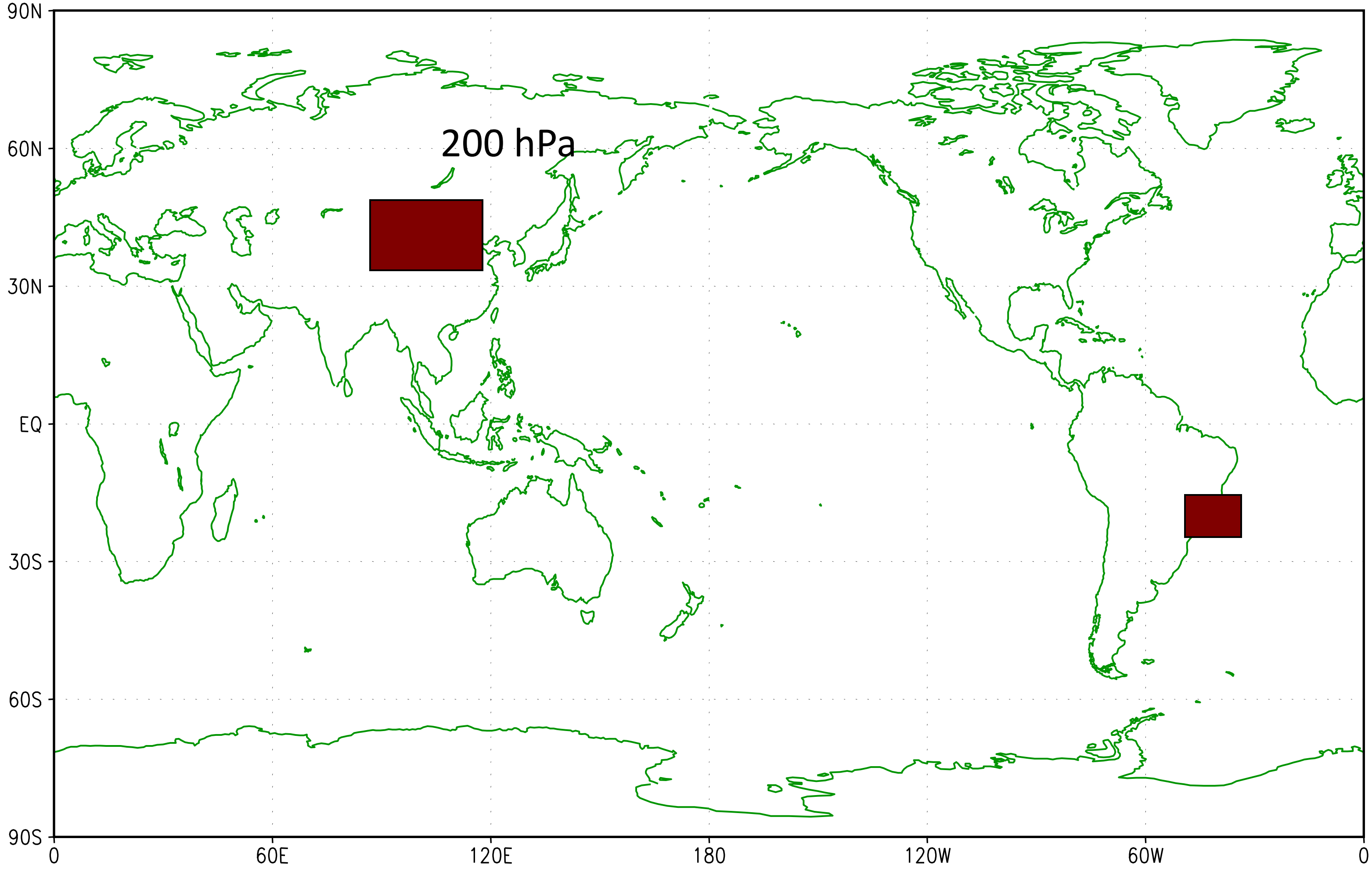
Identified Teleconnected Region




Correlation Coefficient Between NEMR and 200 hPa Geopotential Height September
Latitude
Longitude
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3

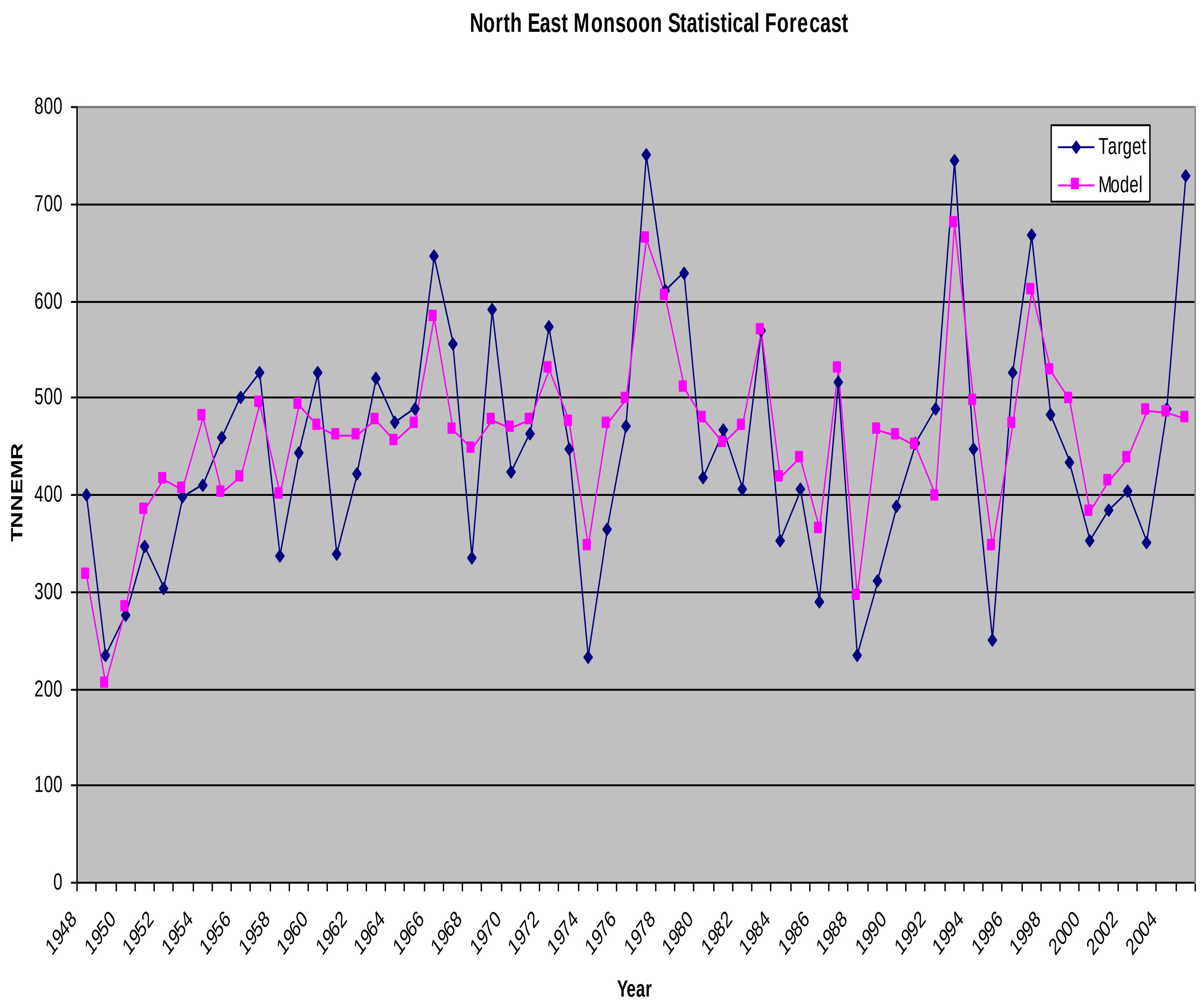

Correlation Coefficient Between NEMR and 200 hPa Geopotential Height October
Latitude
Longitude
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4

Identified Teleconnected Region



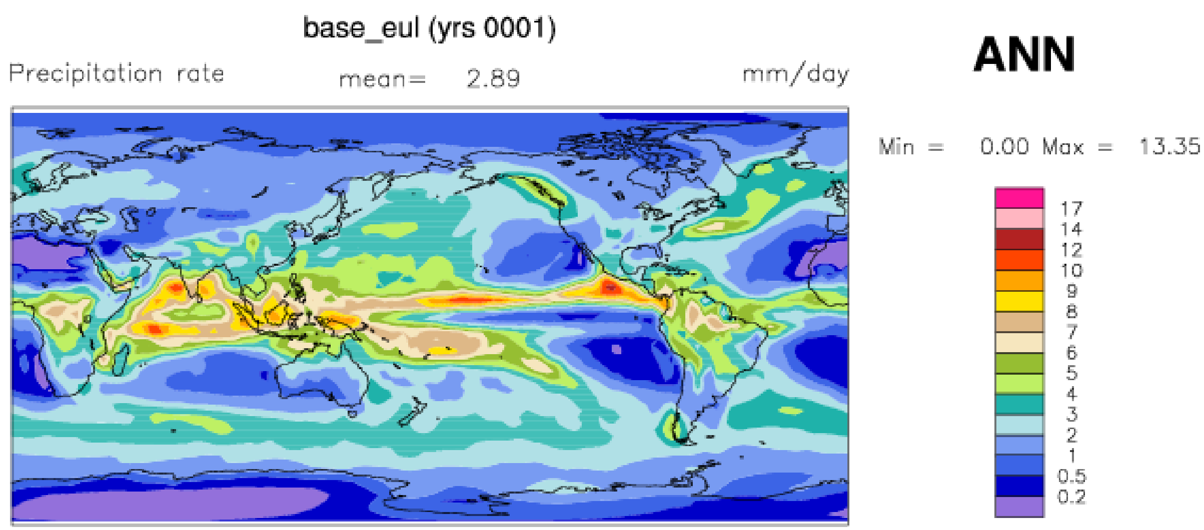
Identified Region

- **North East Pacific Ocean SST Anomaly (12^o N – 25^0 N, 135^o W – 155 ^{o} W)**
- **Indian Ocean Temperature Anomaly Gradient between South Asia (12.5^o N 77.5 ^{o} E) and North East of South Africa (2.5 ^{o} N , 52.5^o E).**
- **200 hPa Geopotential head difference between Russia (37.5 ^{o} N - 50 ^{o} N , 82.5 ^{o} E to 100 ^{o} E) and North East of South America (18.75^o S - 23.75 ^{o} S , 36. 25^o W - 46.25 ^{o} W)**

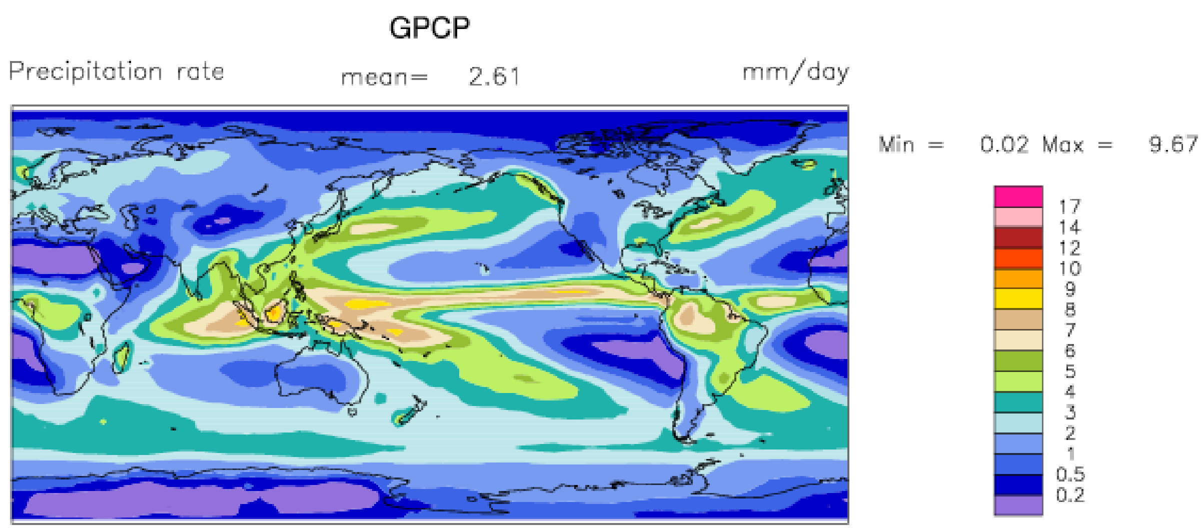

North East Monsoon Statistical Forecast
Target
Model
TNNEMR
Year
0
100
200
300
400
500
600
700
800
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004

Comparison of Mean Simulation Properties 1

Simulated Precipitation

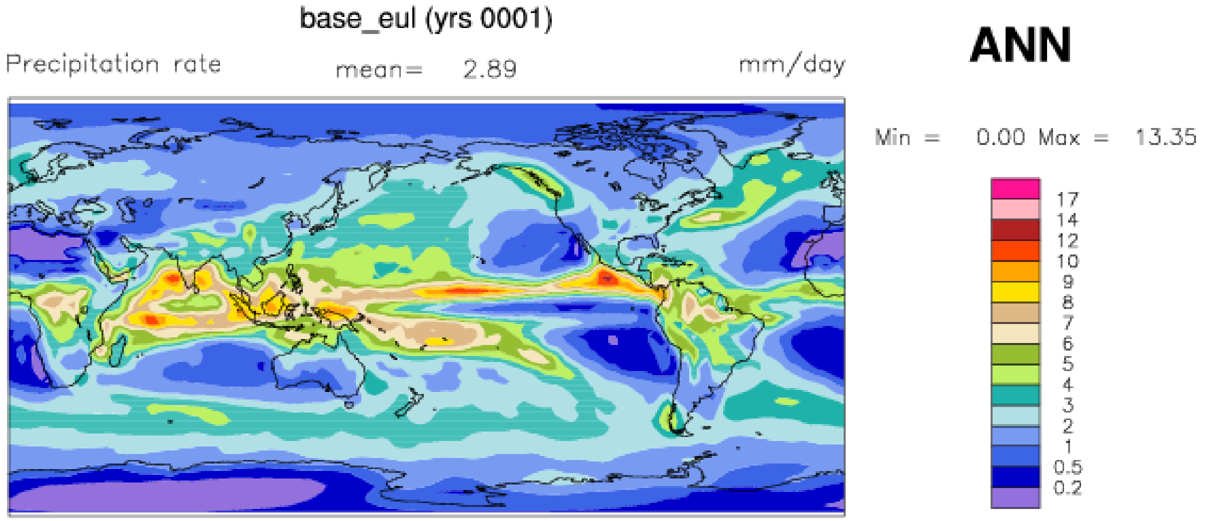


Observed Precipitation

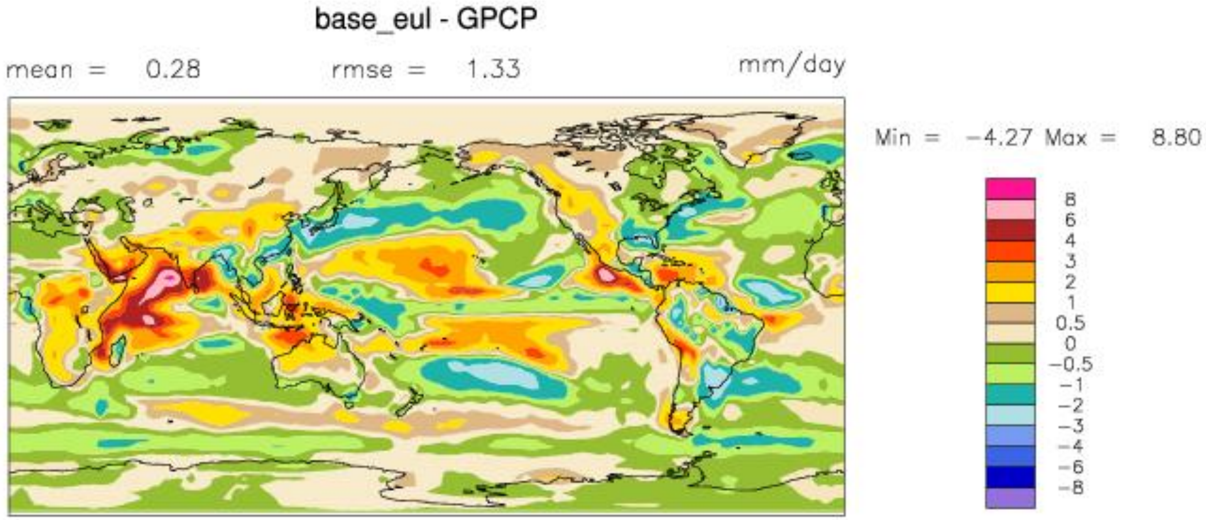


Comparison of Mean Simulation Properties 1

Simulated Precipitation

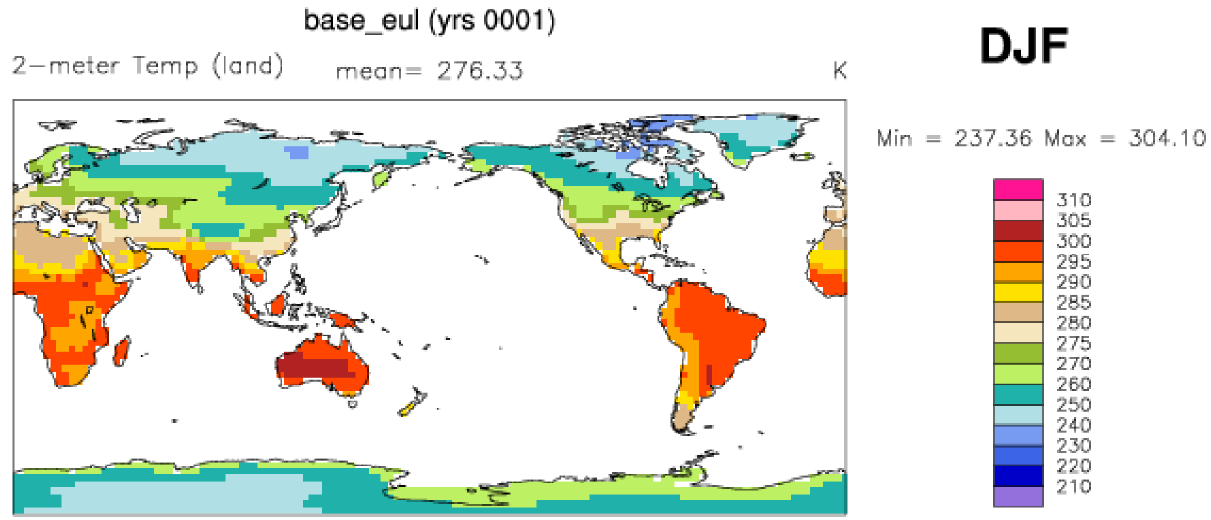


Difference:
Sim- Observed

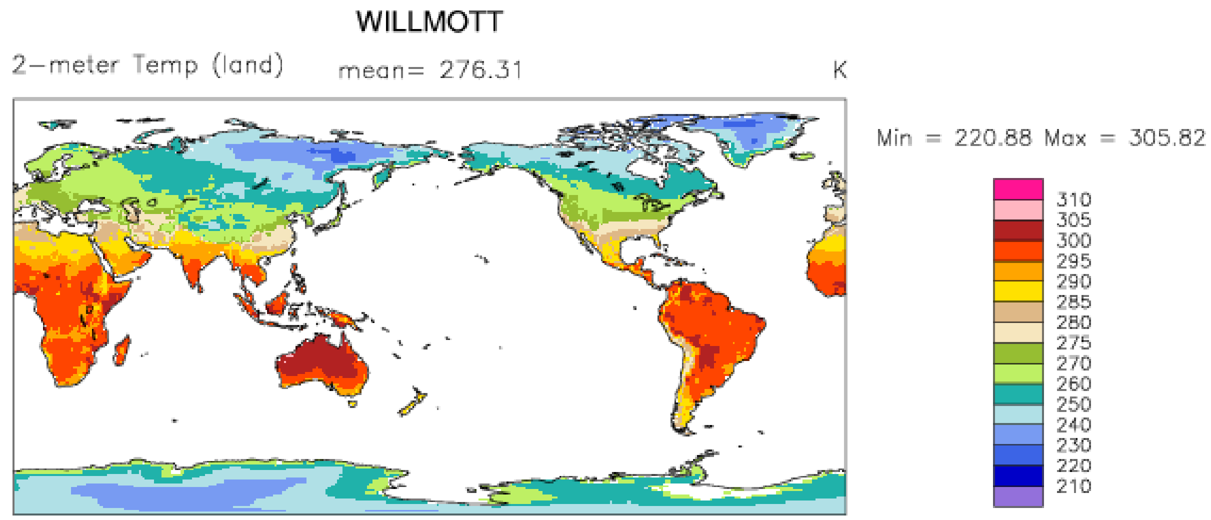


Comparison of Mean Simulation Properties 2

Simulated Land Temp

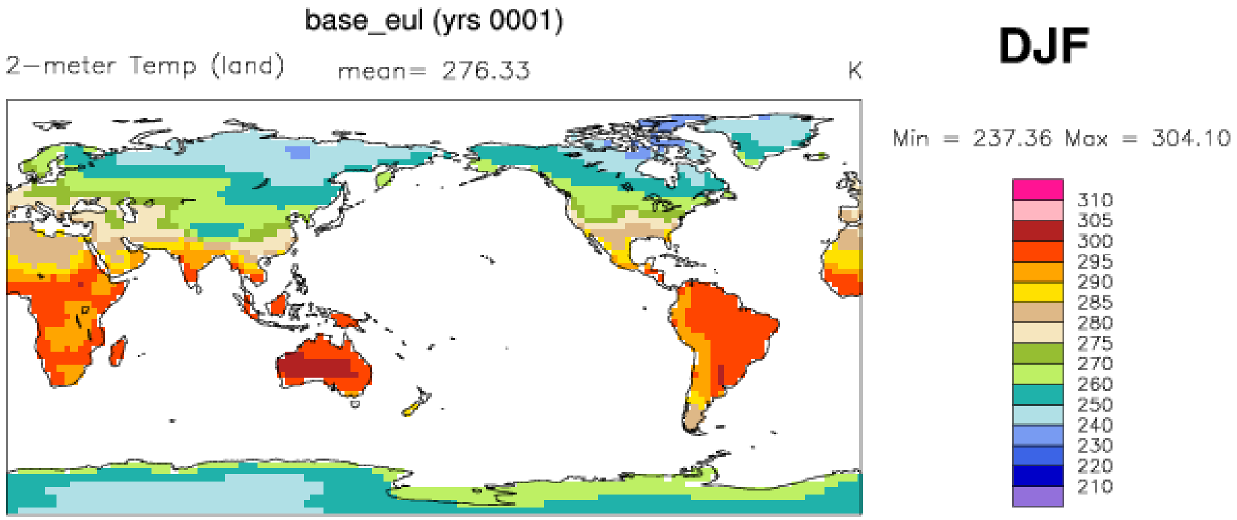


Observed Land Temp

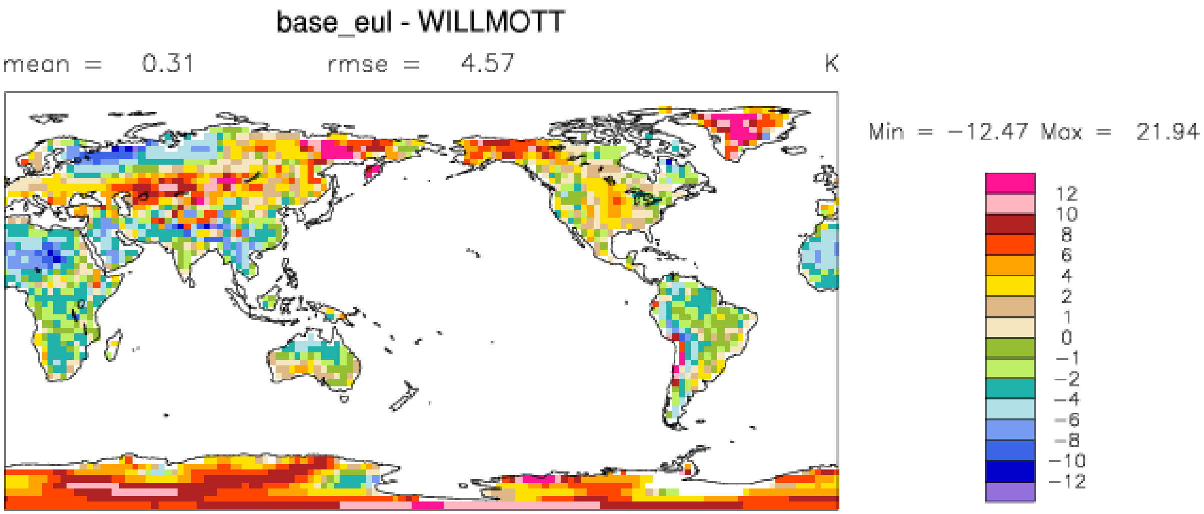


Comparison of Mean Simulation Properties 2

Simulated Land Temp

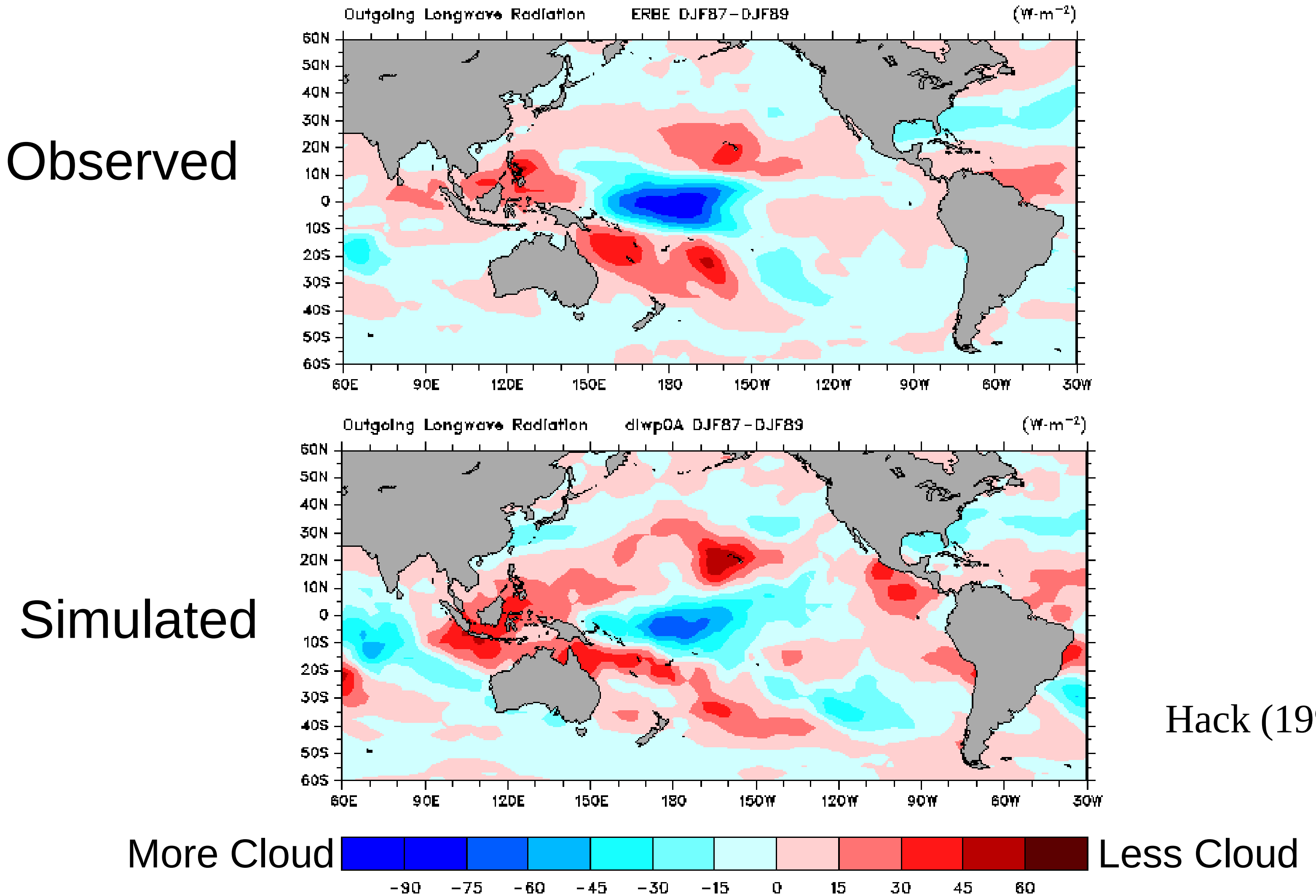


Difference:
Sim- Observed



Testing AGCM Sensitivity

Cloud (OLR) Anomalies and ENSO



Hack (1998)

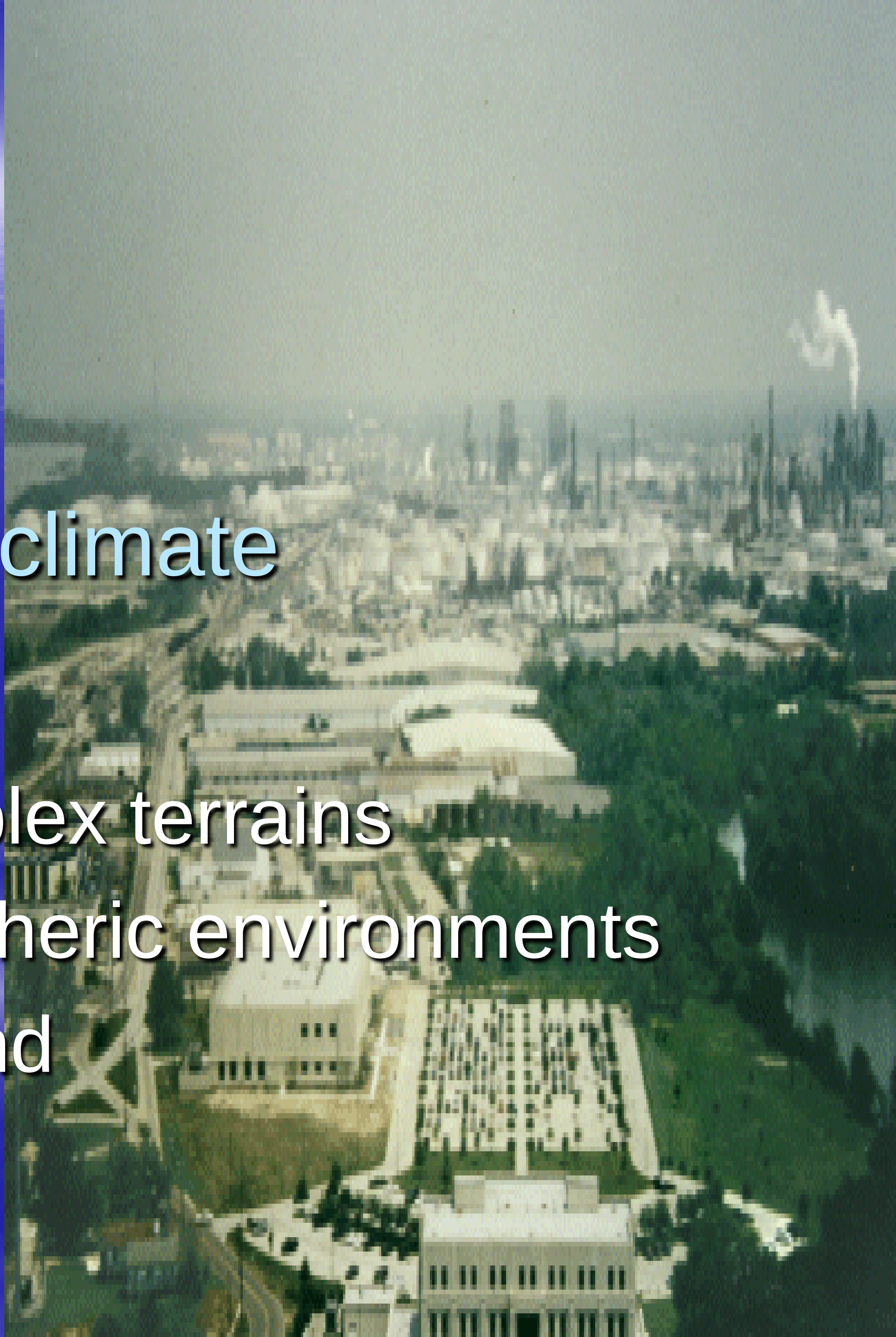
Final Thoughts

- Remember that individual scenarios are not predictions of future regional climate change
- If used properly, they can help us understand and portray
  - What is known about how regional climates may change
  - Uncertainties about regional climate change
  - The potential consequences

Uses

- If assessing vulnerability, scenarios ought to reflect a wide, but realistic range of climate change
  - Serves education purpose
- If examining adaptation, it is important to reflect a wide range of climate change
  - If the selected uncertainty range is too narrow, this could lead to ill-informed decisions

Urban climate

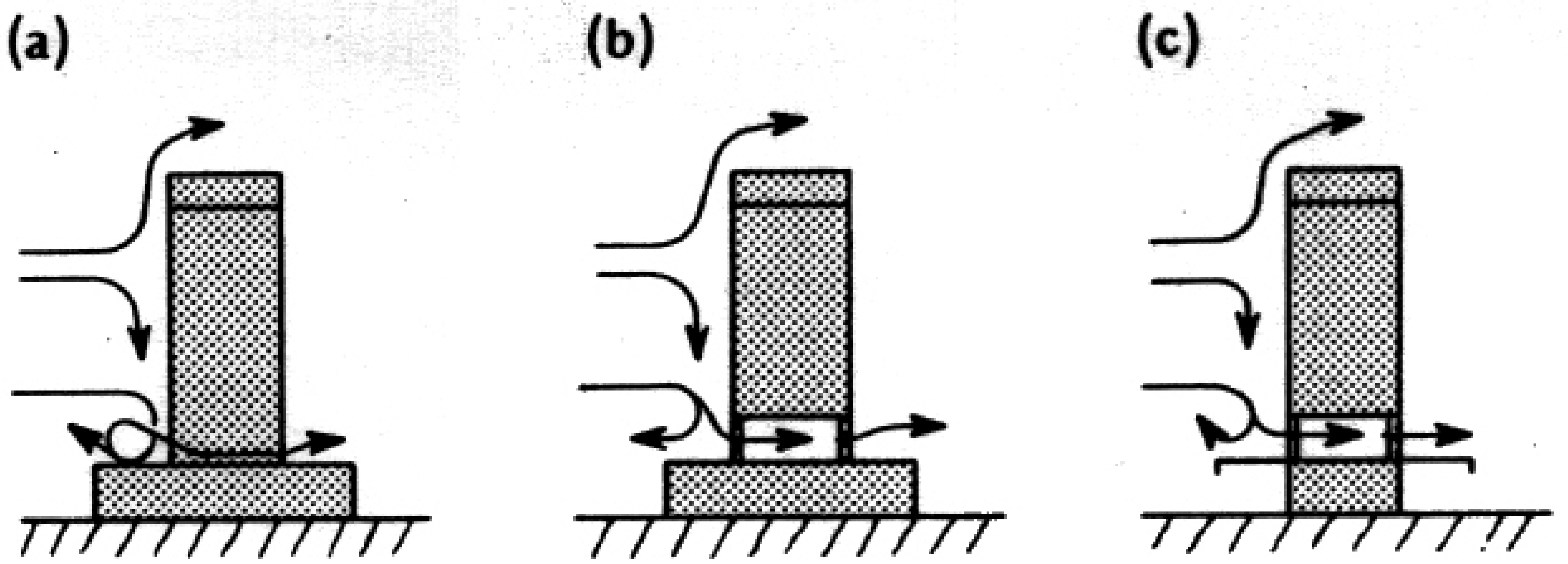


- Climate of complex terrains
- Artificial atmospheric environments
- Urban heat island

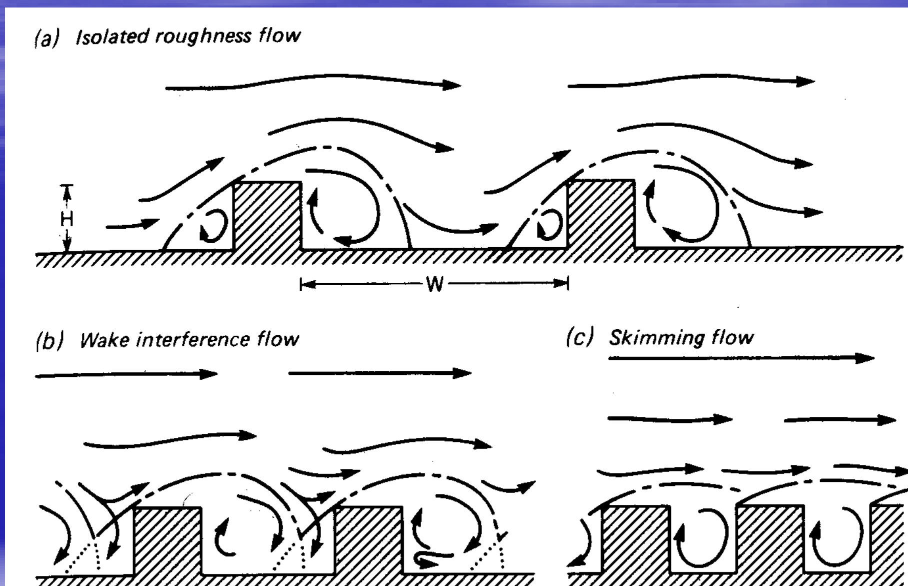
6. Urban modifications

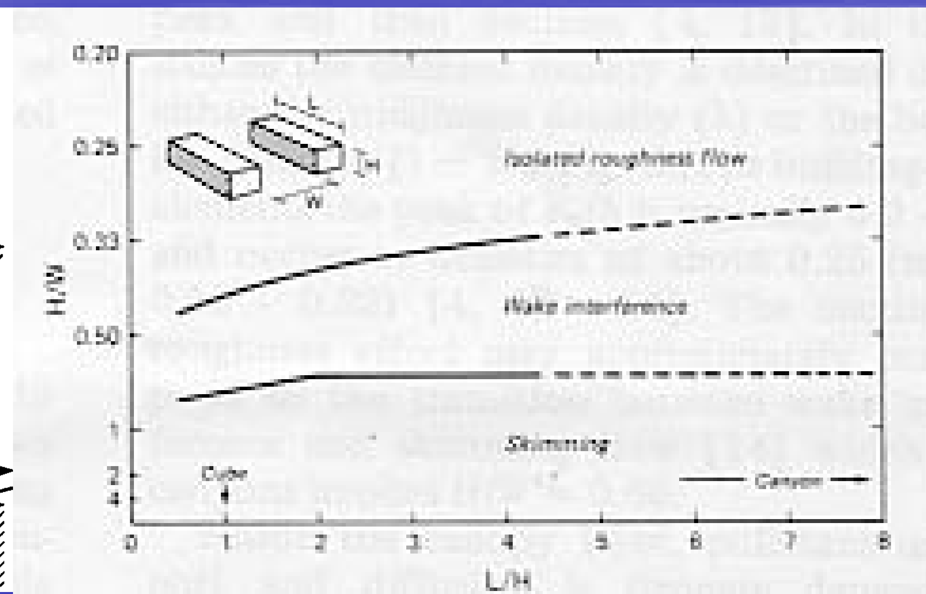
- Roofs are prone to being ripped off in strong winds because the offside experiences suction due to high velocity and interior pressure is positive
- Opening windows permit cross-ventilation and thus encourages equalisation of pressure but may be unacceptable on heat loss and other practicalities
- Areas most prone to damage are where separation occurs where suction is greatest

- Pedestrian comforts: high winds favour pollutant dispersion but create hostile environments; small winds stagnate air; this also relates to location
- Western countries work more on reducing winds in urban areas, whereas Hong Kong works more on increasing ventilation
- Most consensus is avoid tall buildings…

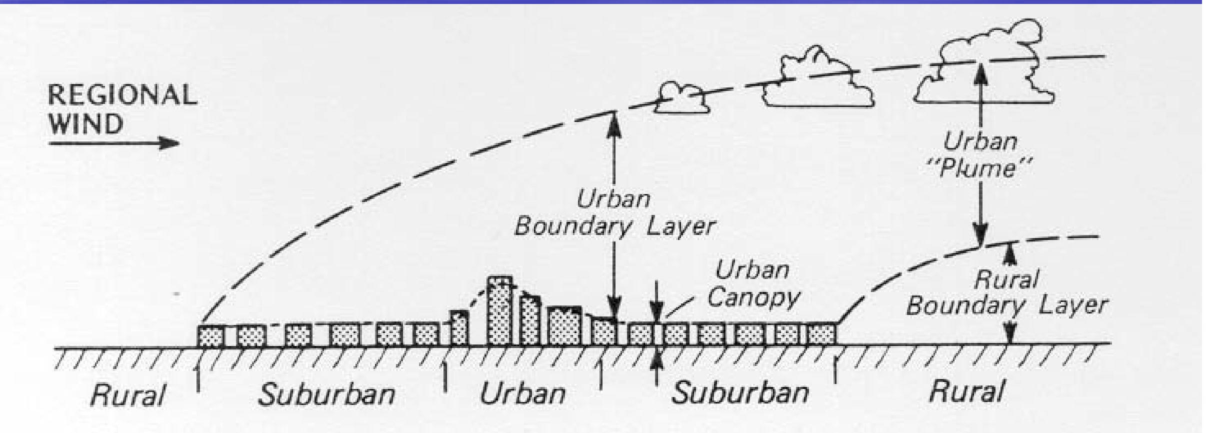


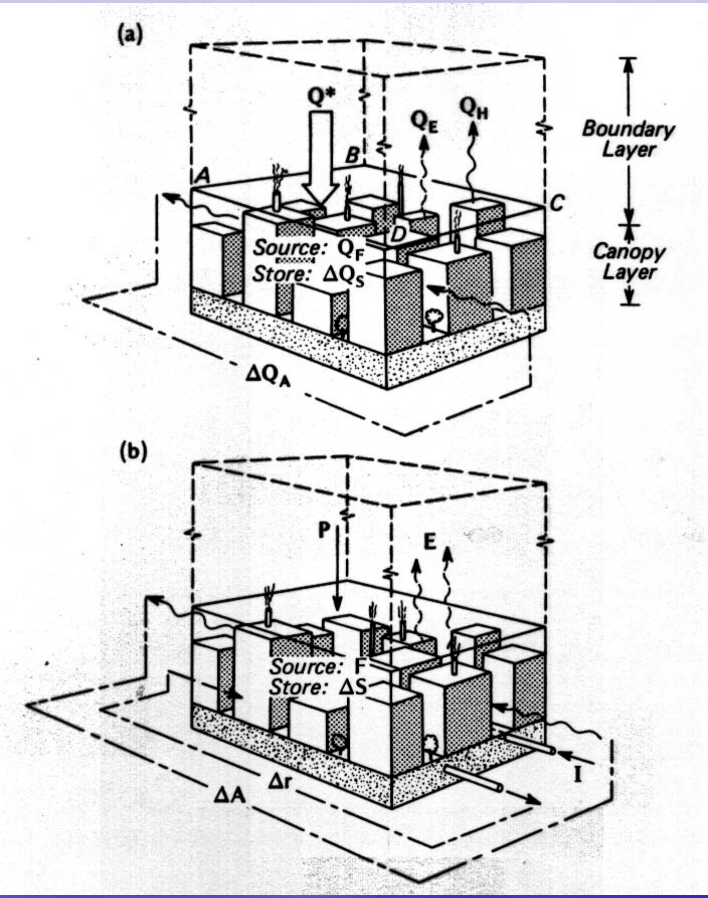
6.1. Urban flow regimes





7. Urban heat islands





Combustion / fuel sources

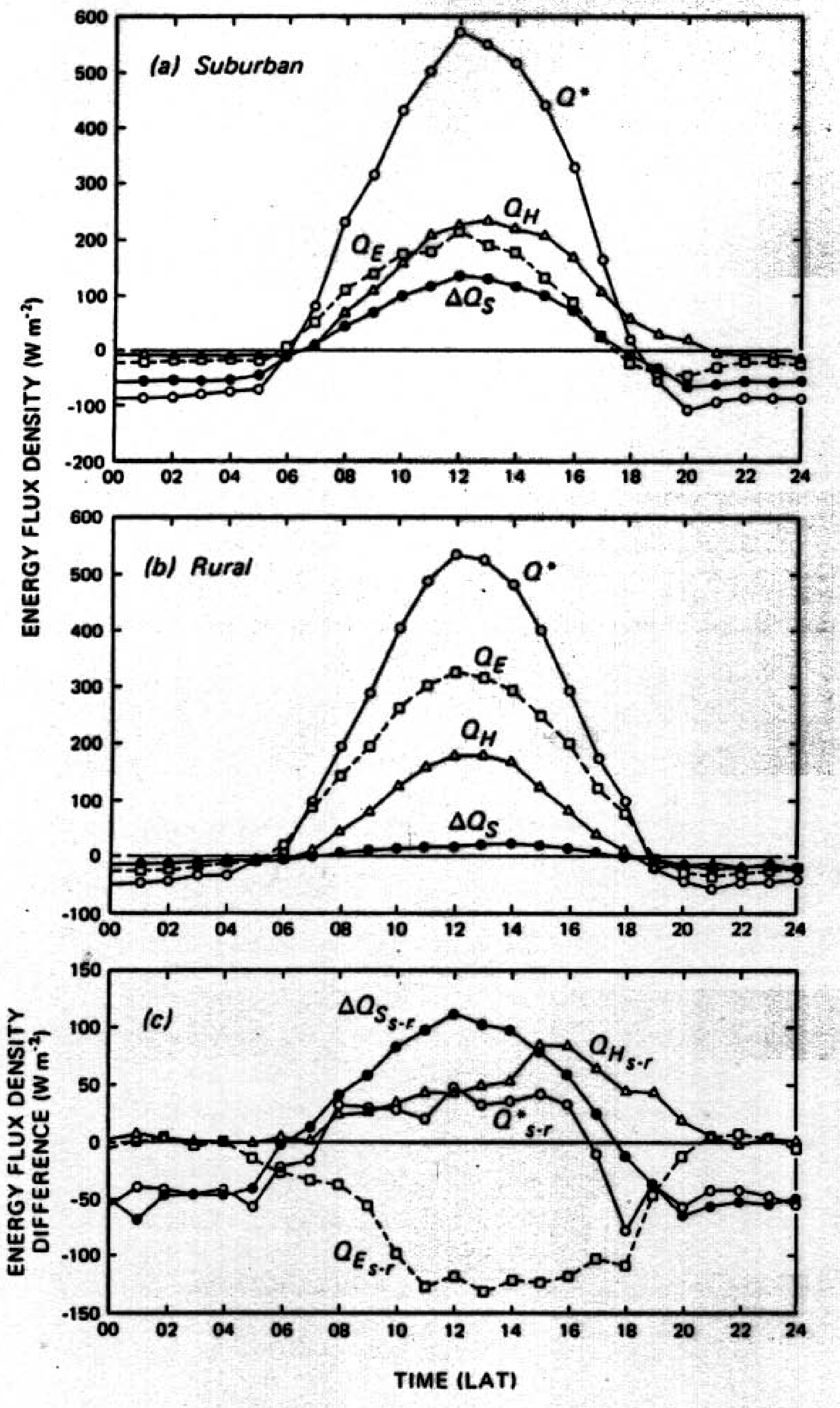
$$Q^* + Q_F = Q_H + Q_E + \Delta Q_S + \Delta Q_A \qquad W_P + W_F + W_I = W_E + \Delta W_R + \Delta W_S + \Delta W_A$$

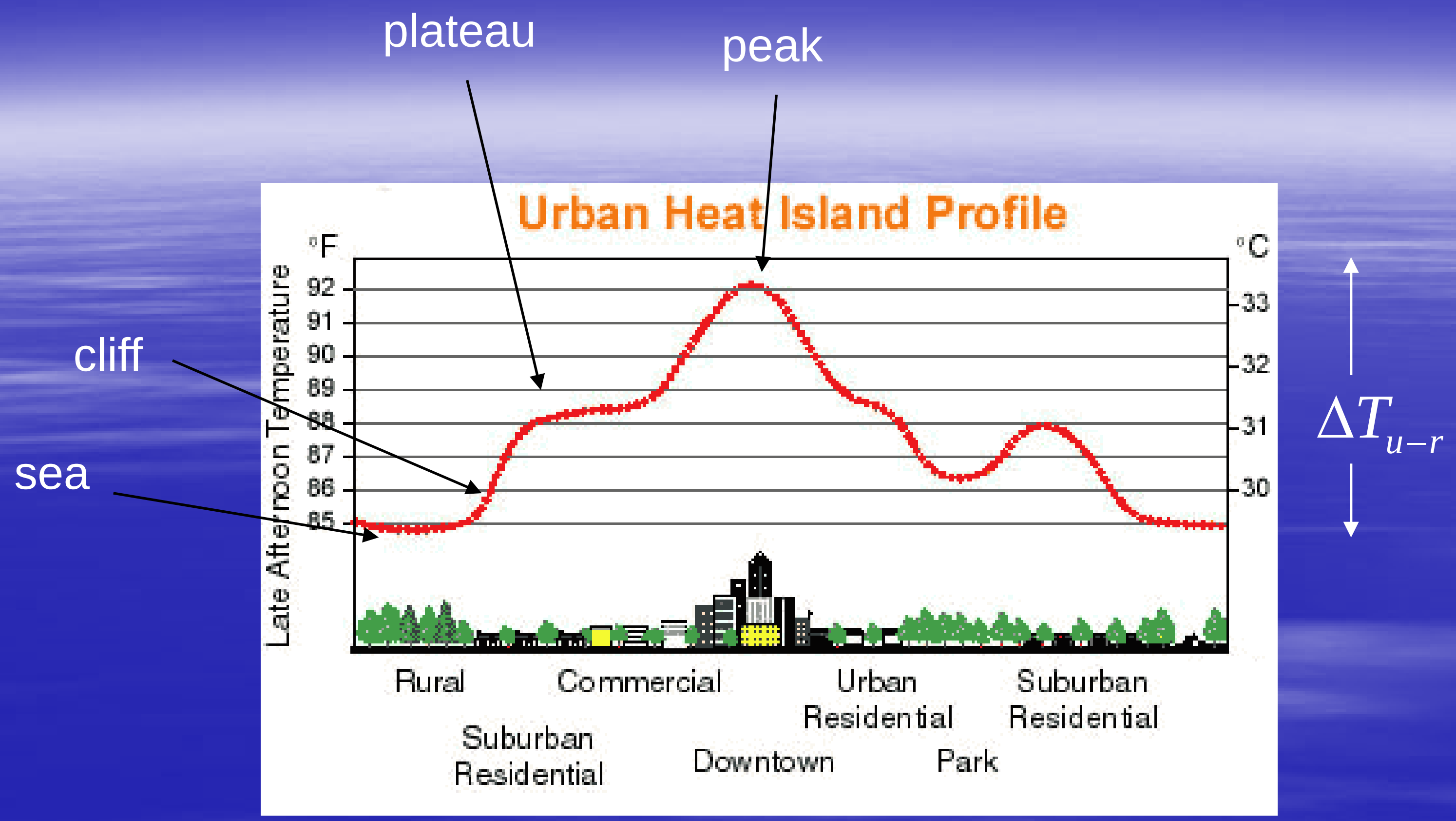
Advection in city

Table 8.1 Average anthropogenic heat release (Q_F) from selected urban areas

Urban area	Year	Period	Population ($\times 10^6$)	Population density (persons km^{-2})	Per capita energy use ($MJ \times 10^3$)	Q_F ($W\ m^{-2}$)	Q^* ($W\ m^{-2}$)
Manhattan (40°N)	1967	Year	1·7	28,810	169	159	93
		Summer				53	
		Winter				265	
Montréal (45°N)	1961	Year	1·1	14,102	221	99	52
		Summer				57	92
		Winter				153	13
Budapest (47°N)	1970	Year	1·3	11,500	118	43	46
		Summer				32	100
		Winter				51	−8
Sheffield (53°N)	1952	Year	0·5	10,420	58	19	56
West Berlin (52°N)	1967	Year	2·3	9,830	67	21	57
Vancouver (49°N)	1970	Year	0·6	5,360	112	19	57
		Summer				15	107
		Winter				23	6
Hong Kong (22°N)	1971	Year	3·9	37,200	28	33	~110
Singapore (1°N)	1972	Year	2·1	3,700	25	3	~110
Los Angeles (34°N)	1965–70	Year	7·0	2,000	331	21	108
Fairbanks (64°N)	1967–75	Year	0·045	550	314	6	18

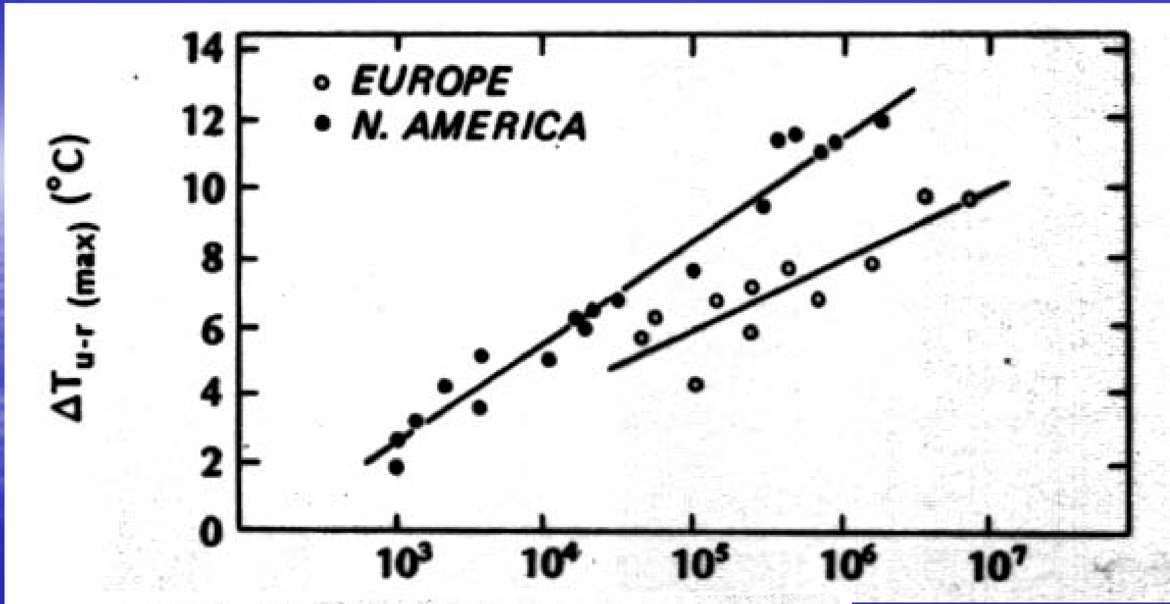
Sources: Oke, 1974; Kalma and Byrne, 1975.


(a) Suburban
Q*
Q_H
Q_E
ΔQ_S
(b) Rural
Q*
Q_E
Q_H
ΔQ_S
(c)
ΔQ_S s-r
Q_H s-r
Q* s-r
Q_E s-r
ENERGY FLUX DENSITY (W m⁻²)
ENERGY FLUX DENSITY DIFFERENCE (W m⁻²)
TIME (LAT)

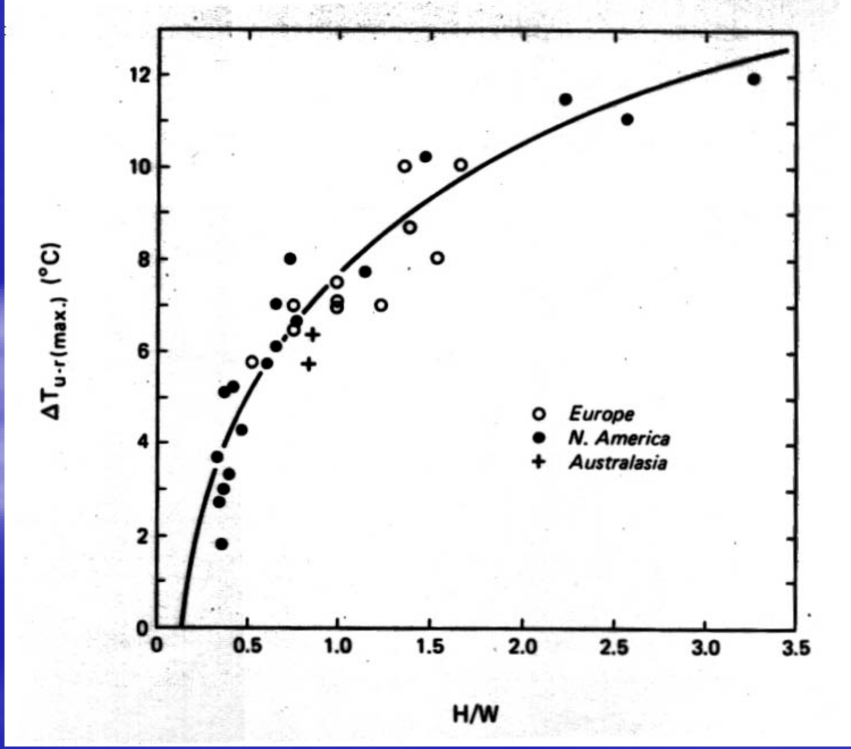


- Air temperature traversing from countryside to urban area shows aptness of geomorphic analogy with an island

ΔT_{u-r} urban heat island intensity

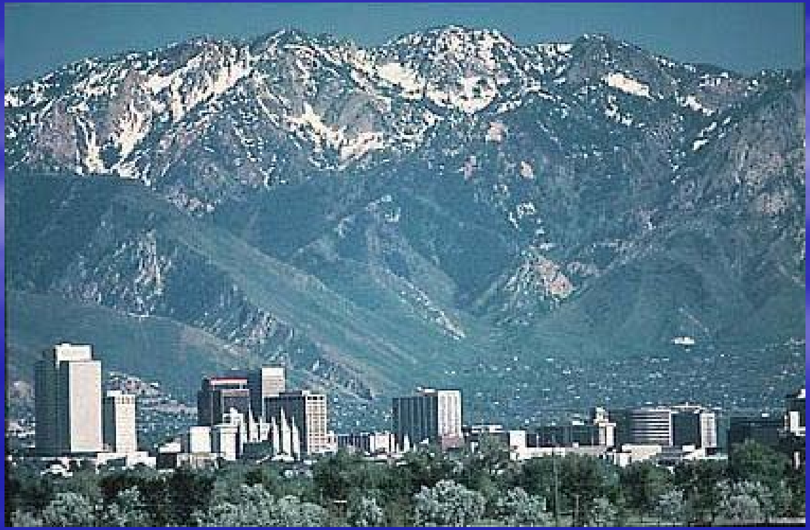


$$\Delta T_{u-r} \approx \frac{P^{0.27}}{4.0\overline{u}_{10}^{0.56}}$$



$$\Delta T_{u-r} \approx 7.54 + 3.97 \log \frac{H}{W}$$

- Urban warmth is responsible for the earlier budding and blossoming of floras in cities, with a longer growing season
- Attracts more birds, pests and insects
- Humans usually find the extra warmth a stress
- Urban heat island is beneficial in colder regions because of reduced heating, but bad in summer and hotter regions due to demand in air-conditioning and thus further aggravating the issue
- Speedup of erosion and wearing



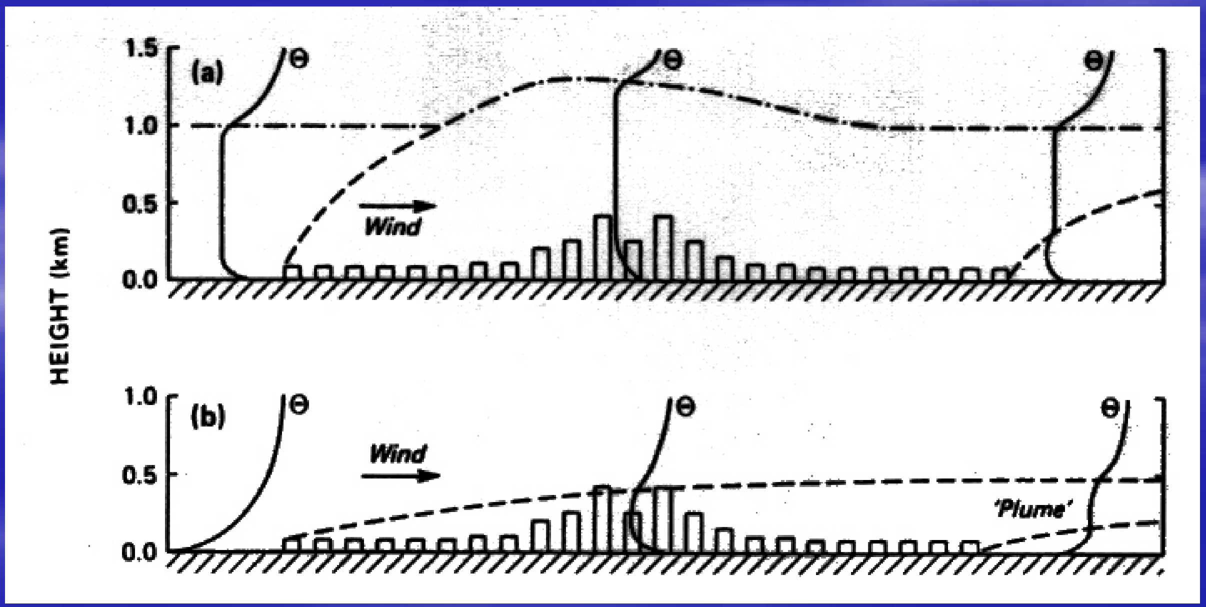
7.1 Common causes of urban heat island

Altered energy balance terms	Features of urbanisation responsible
Increased absorption of short-wave radiation	Canyon geometry: increased surface area, canyon effect and multiple reflection
Increased long-wave radiation from sky	Air pollution: greater absorption and re-emission
Decreased long-wave radiation loss	Canyon geometry: reduction of skyview factor
Anthropogenic heat sources	Building, machineries and traffic heat
Increased sensible heat storage	Construction materials: increased thermal admittance; Canyon: lack of plantation
Decreased evapotranspiration	Construction material: increased water proofing; Canyon: lack of plantation
Decreased turbulent heat transport	Canyon geometry: reduction in wind speed

7.2 Urban boundary layer

Table 8.5 **Typical roughness length (z_0) of urbanized terrain**

Terrain	z_0 (m)
Scattered settlement (farms, villages, trees, hedges)	0·2–0·6
Suburban	
– (low density residences and gardens)	0·4–1·2
– (high density)	0·8–1·8
Urban	
– (high density, <5 storey row and block buildings)	1·5–2·5
– (urban high density plus multi-storey blocks)	2·5–10



Air pollution in urban street canyon

Rundown

- Introduction
- CFX-5
- 6 cases studied
- Discovery
- Application
- Conclusion

Introduction

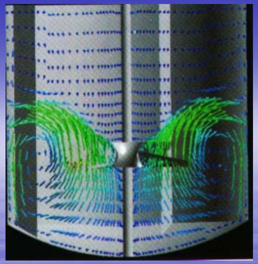
Admiralty

Causeway Bay

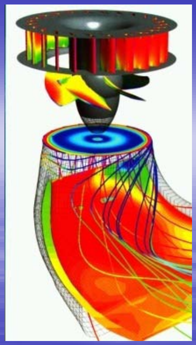
"Urban Geometries" may be one of the main factors that affect the air quality

Objectives

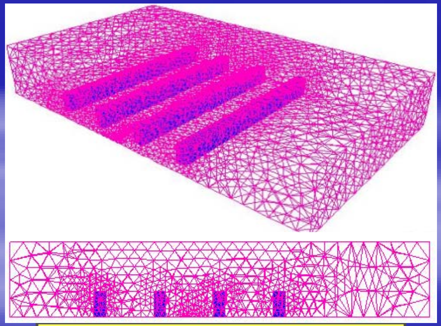
- To investigate the dispersion of airborne pollutants under varies canyon configurations through the application of computational software CFX-5
- To apply the investigation results on a real urban area and prove the validity of them



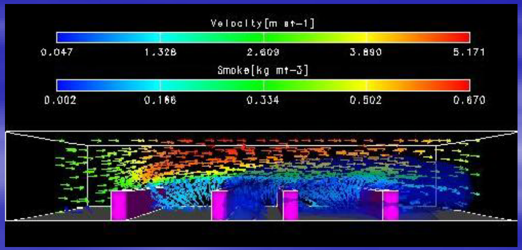
Introduction to CFX-5



- A software based on the technique of Computational Fluid Dynamics (CFD)
- Solve all the hydrodynamics equations as a single system with a coupled solver
- Fast predict the flow and pressure fields around buildings
- Accuracy up to 4^{th} order



CFX-5 Solver Manager
(CFD job manager)



CFX-Build
(Pre-processor)

CFX-5 Solver
(Solver)

CFX-Visualize
(Post-processor)

Case 1,2 ---- Variation of distance between canyons

Case 3 ---- Variation of canyon width

Case 4 ---- Variation of canyon height

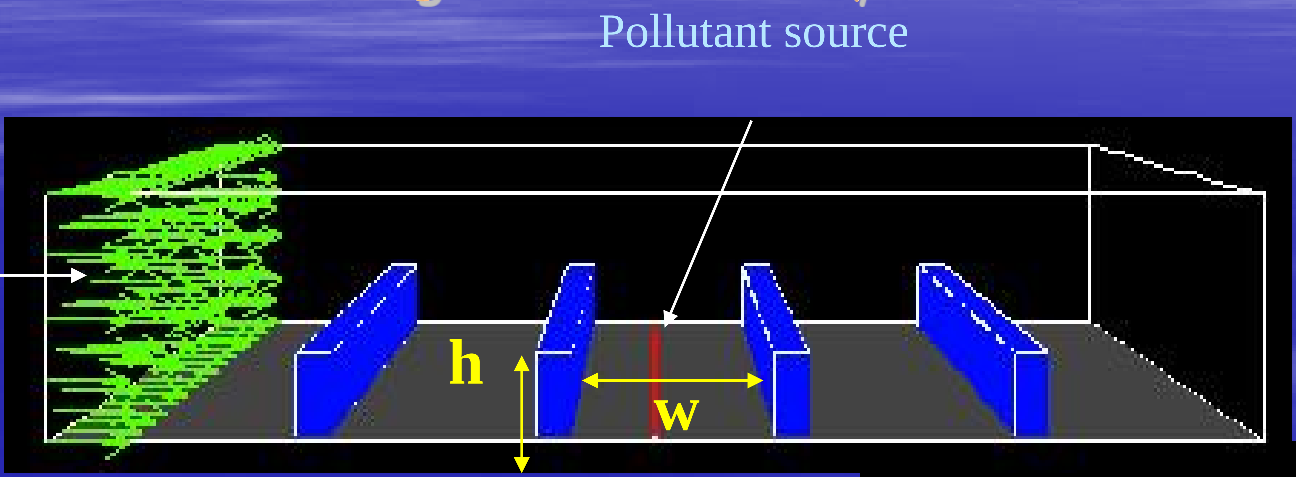
Case 5 ---- Presence of cross road

Case 6 ---- Variation of distance between 2 canyon arrays

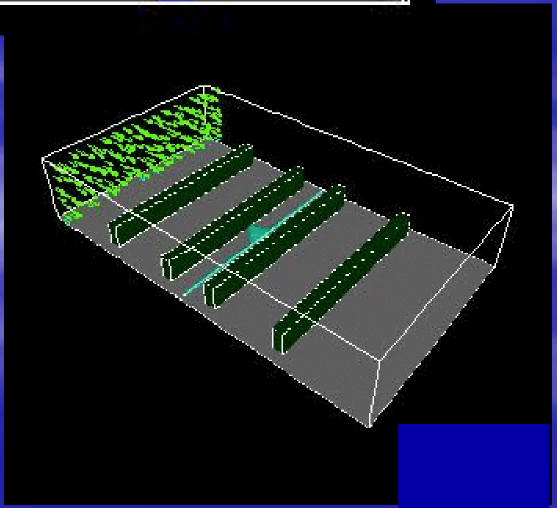
Variation of distance between canyons

Case 1

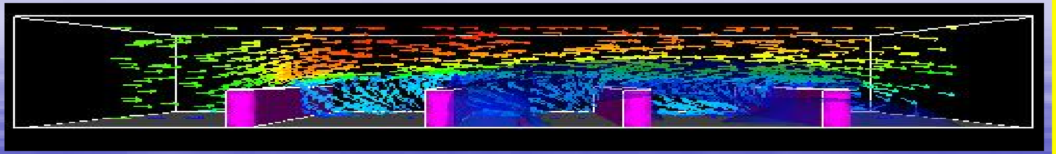
Distance between Building 2&3 varied only



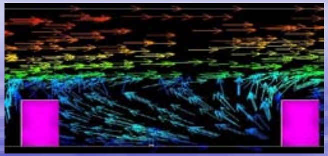
H / W : 0.33, 0.5, 0.75, 1.0, 2.0



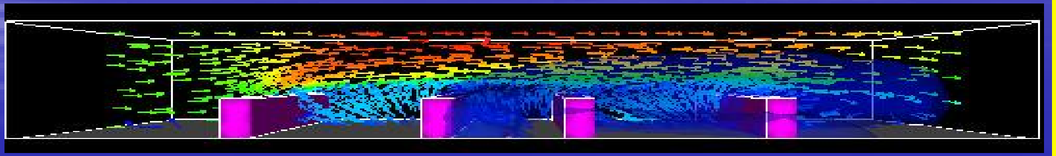
Visualized Result



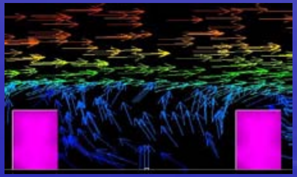
H/W : 0.33



Isolated roughness flow



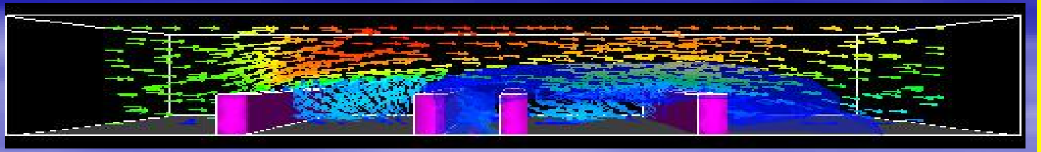
H/W : 0.5



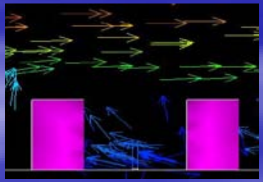
Isolated roughness flow

H/W : 0.75

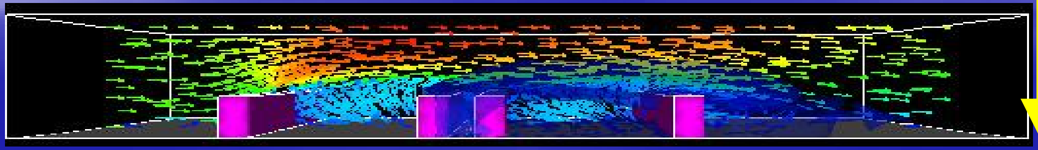
Wake interference flow



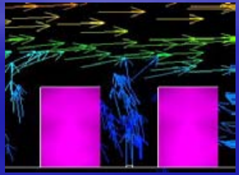
H/W : 1.0



Skimming flow

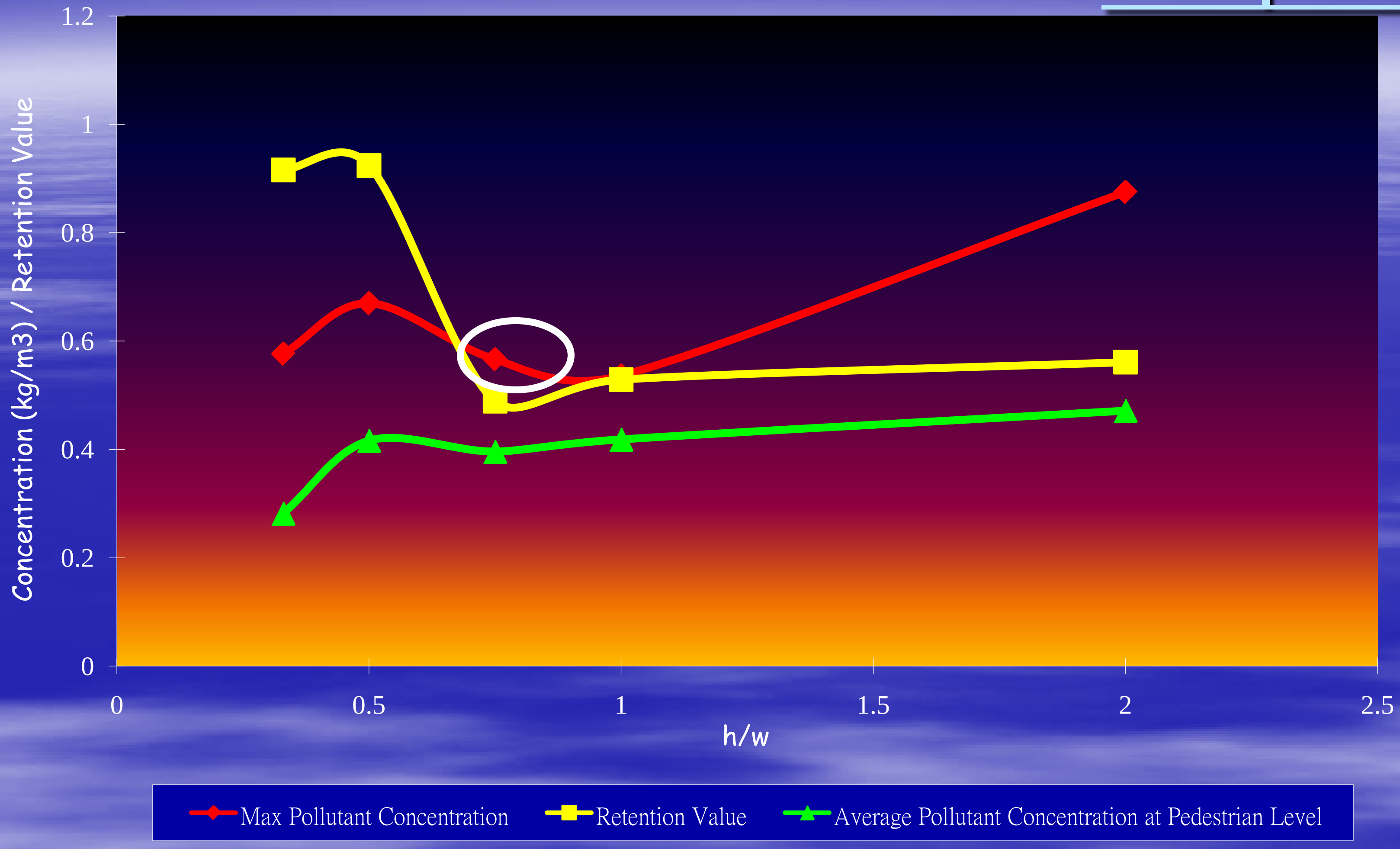


H/W : 2.0



Skimming flow

Graph 1



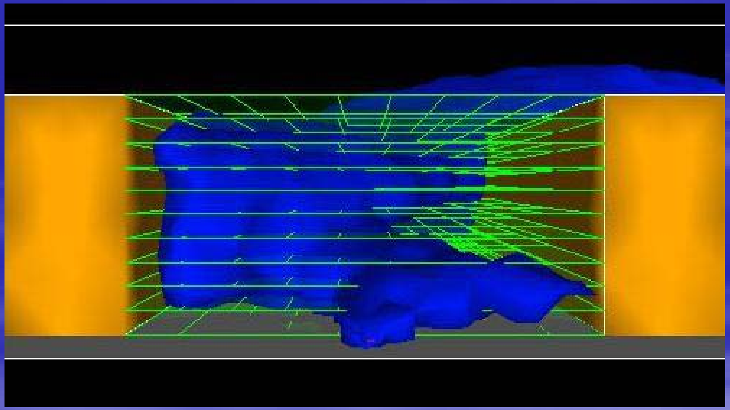
The retention value is minimum at h/w = 0.8

Retention Value

$$R = \frac{C}{Qt}$$

Where
C = Total pollutants between two buildings
Q = Total pollutants emitted per unit time from sources
t = Transient time

The value indicates how many pollutants are trapped between the buildings.



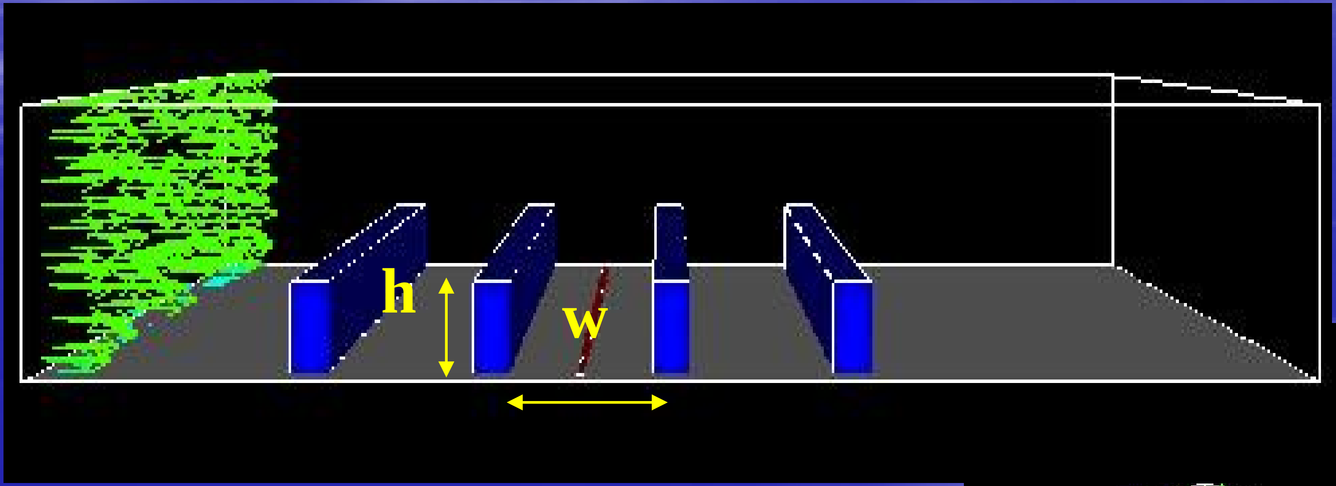
By using Trapezoidal rule of the numerical integration, C can be found.

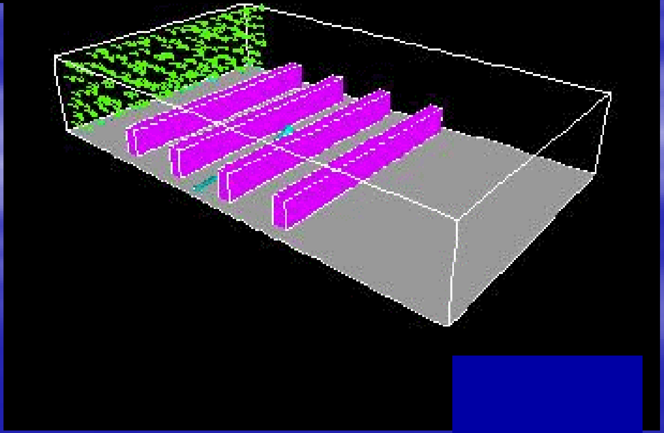
Program

Variation of distance between canyons

Case 2

Distance between buildings varied equally

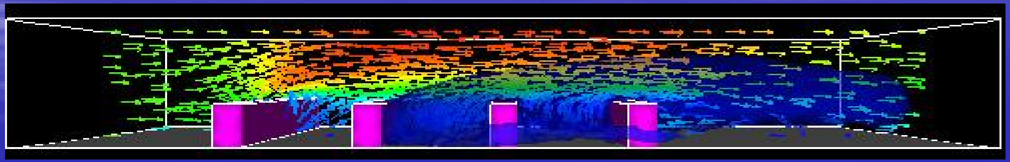




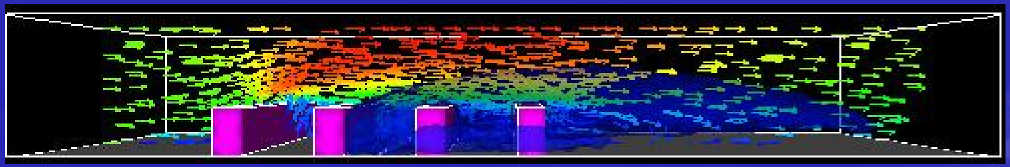
H / W : 0.33, 0.5, 0.75, 1.0, 2.0

Visualized Result

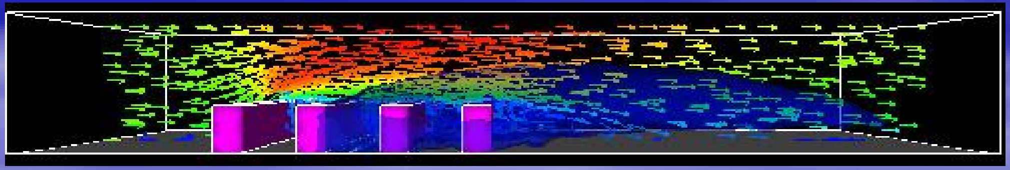
H/W: 0.33



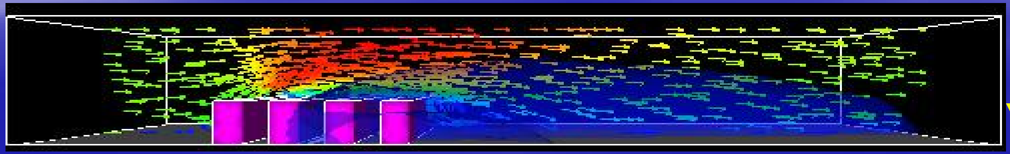
H/W: 0.5



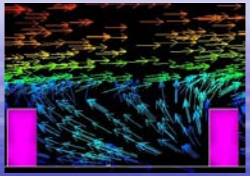
H/W: 0.75



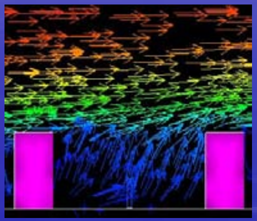
H/W: 1.0



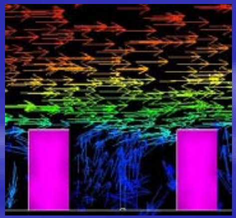
H/W: 2.0



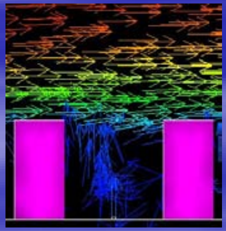
Isolated roughness flow



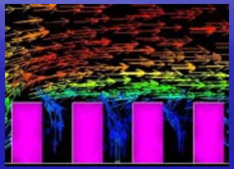
Isolated roughness flow



Wake interference flow

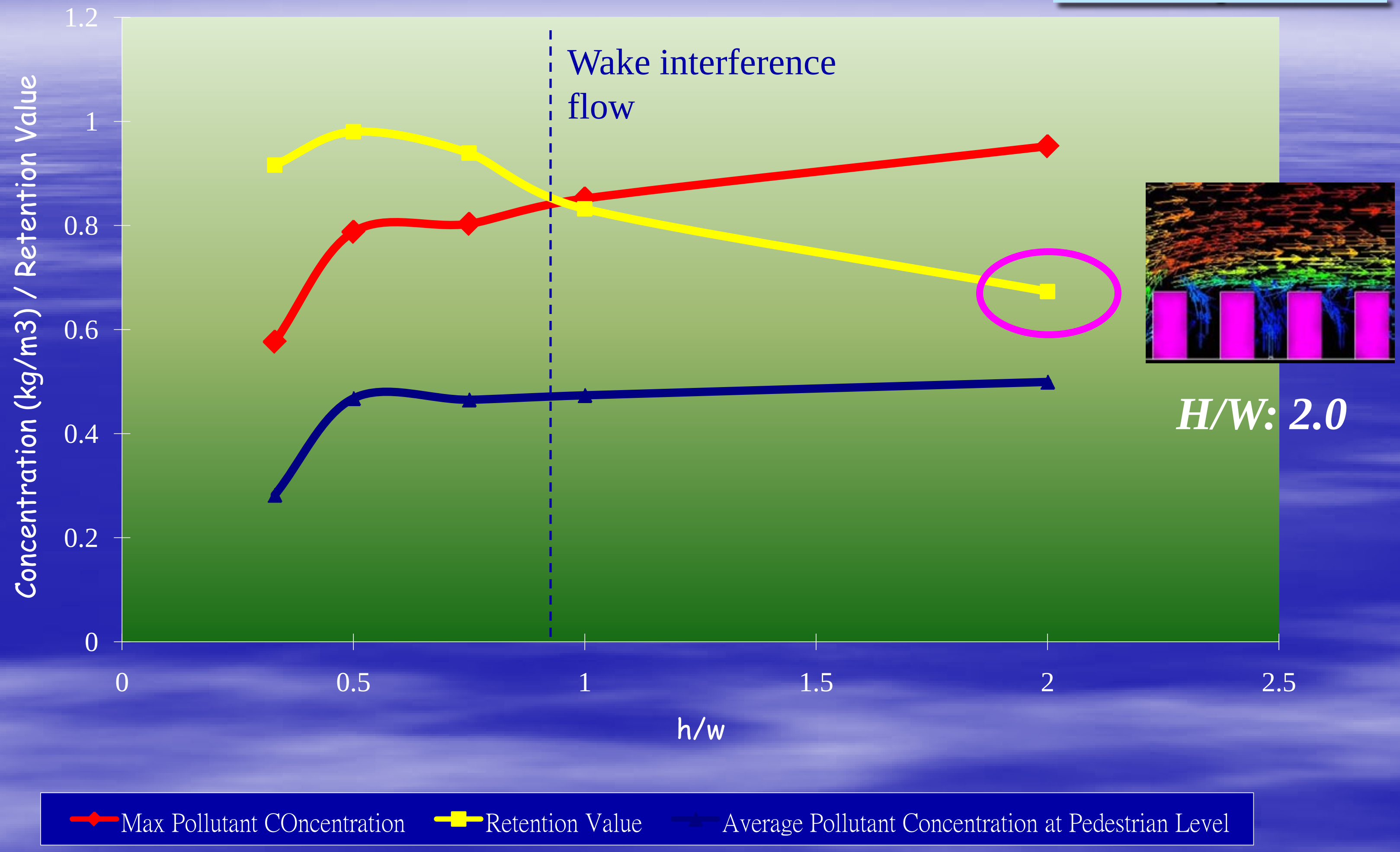


Skimming flow



Skimming flow

Graph 2



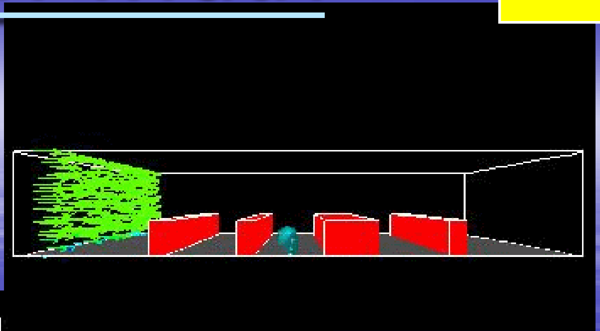
H/W: 2.0

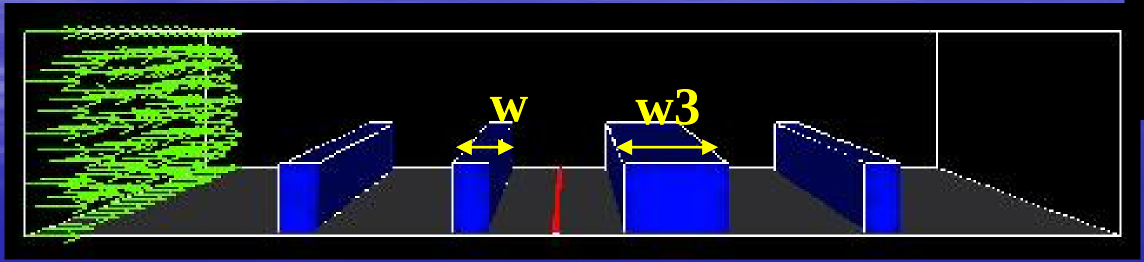
The retention value is minimum at h/w = 2

Variation of canyon width

Case 3

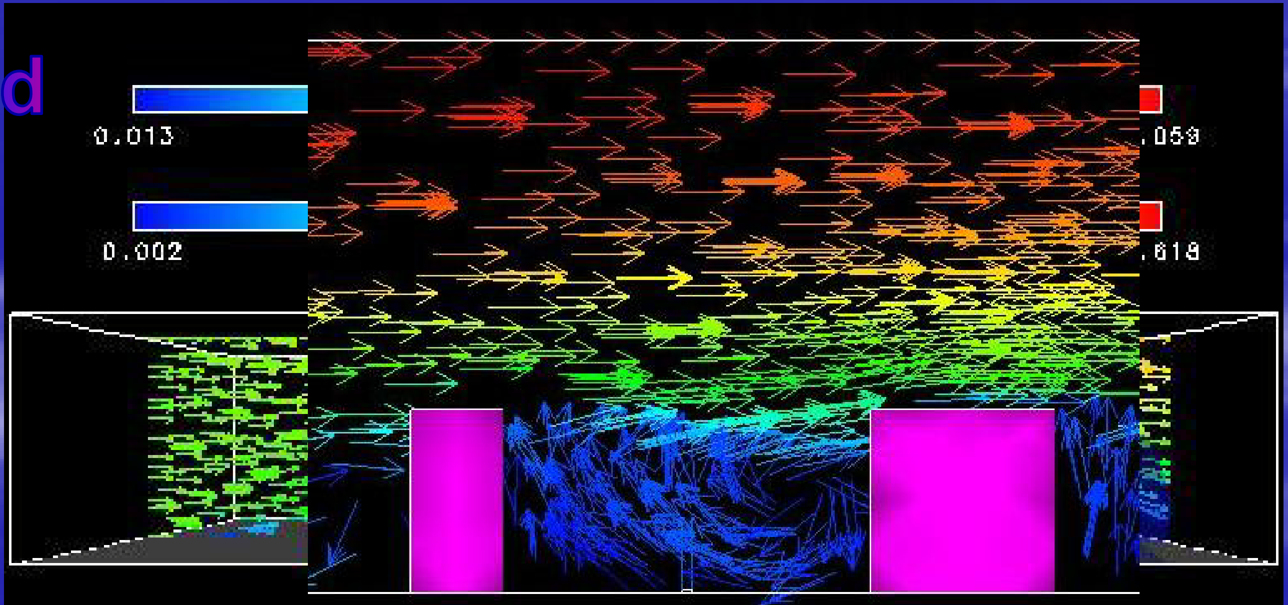
Width of Building 3 varied only





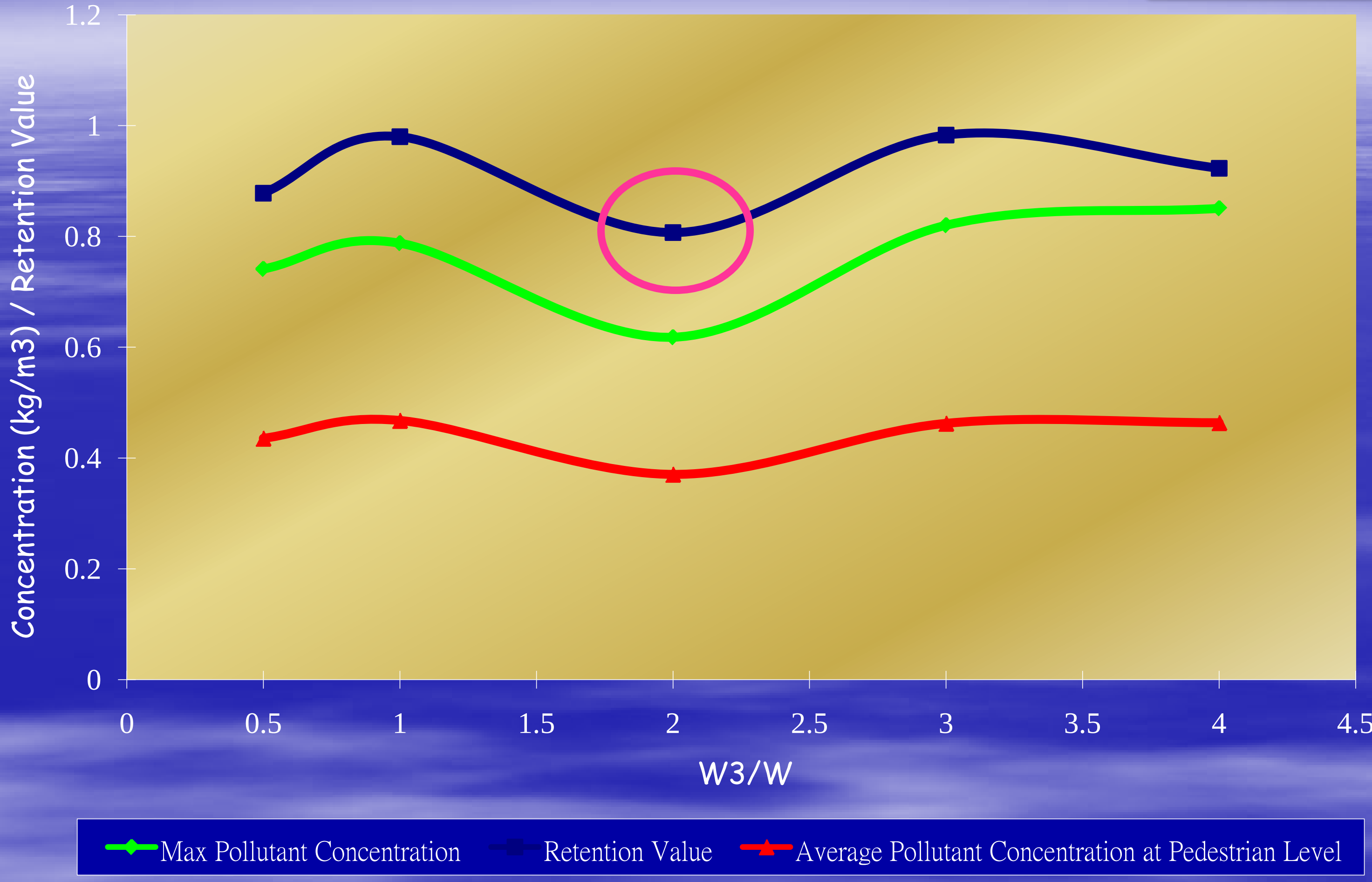
W3 / W :
0.5, 1.0, 2.0, 3.0, 4.0

Visualized Result



Wake interference flow

Graph 3

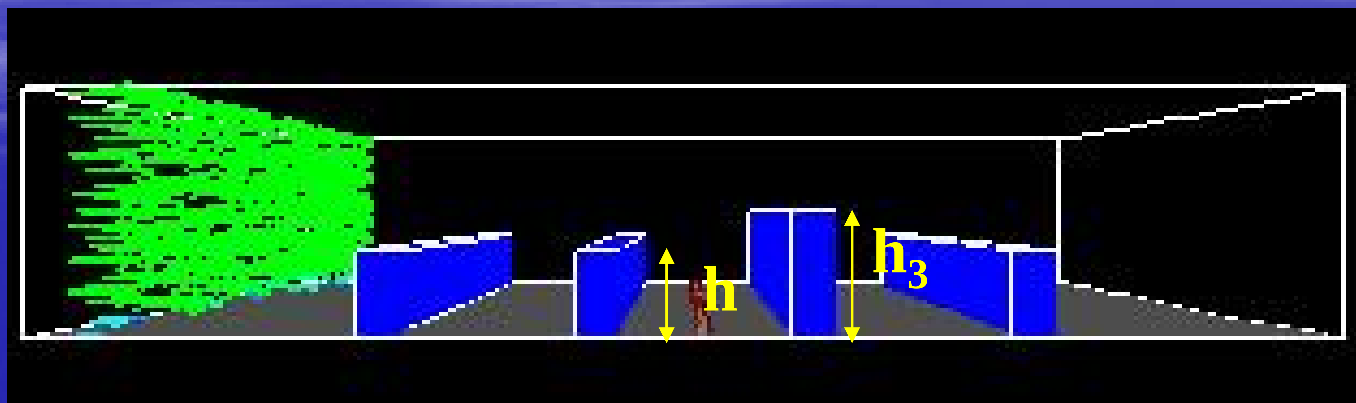


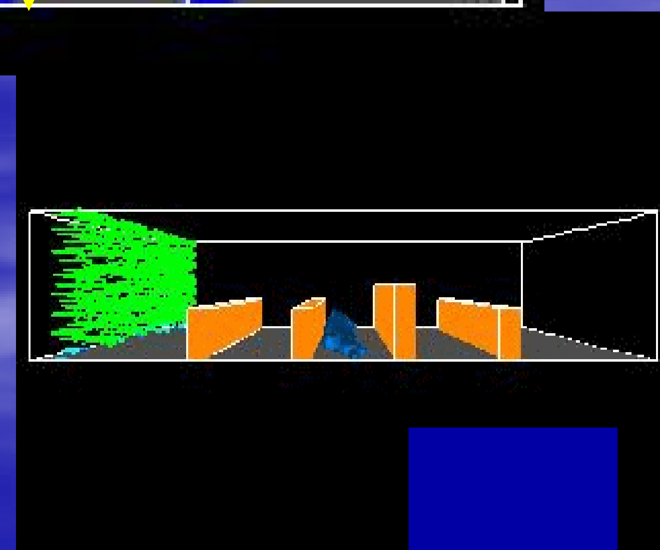
The retention value is minimum at $W_3/W = 2$

Variation of canyon height

Case 4

Height of Building 3 varied only

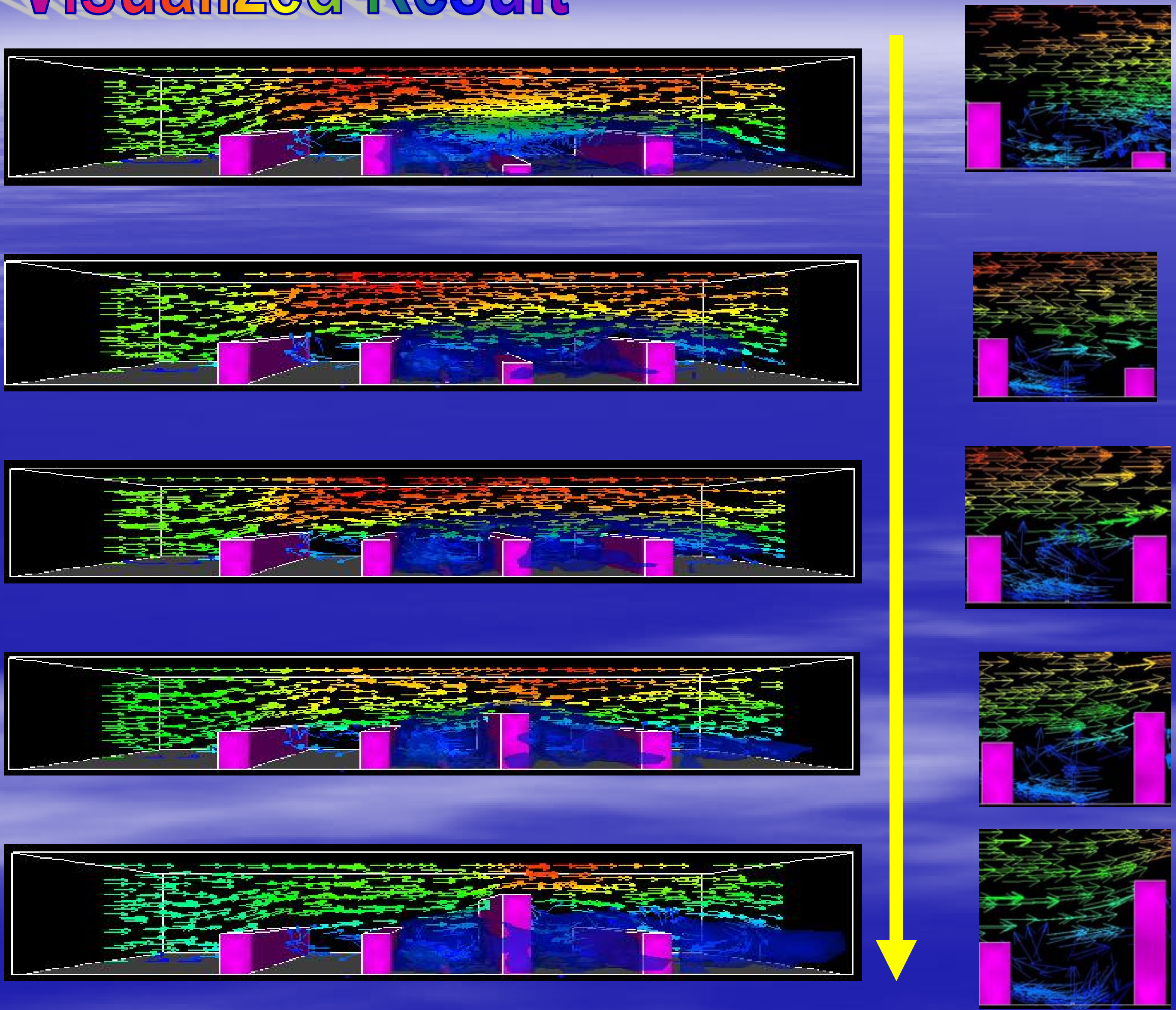




H_3 / H :

0.25, 0.5, 1.0, 1.5, 2.0

Visualized Result



H_3/H : 0.25

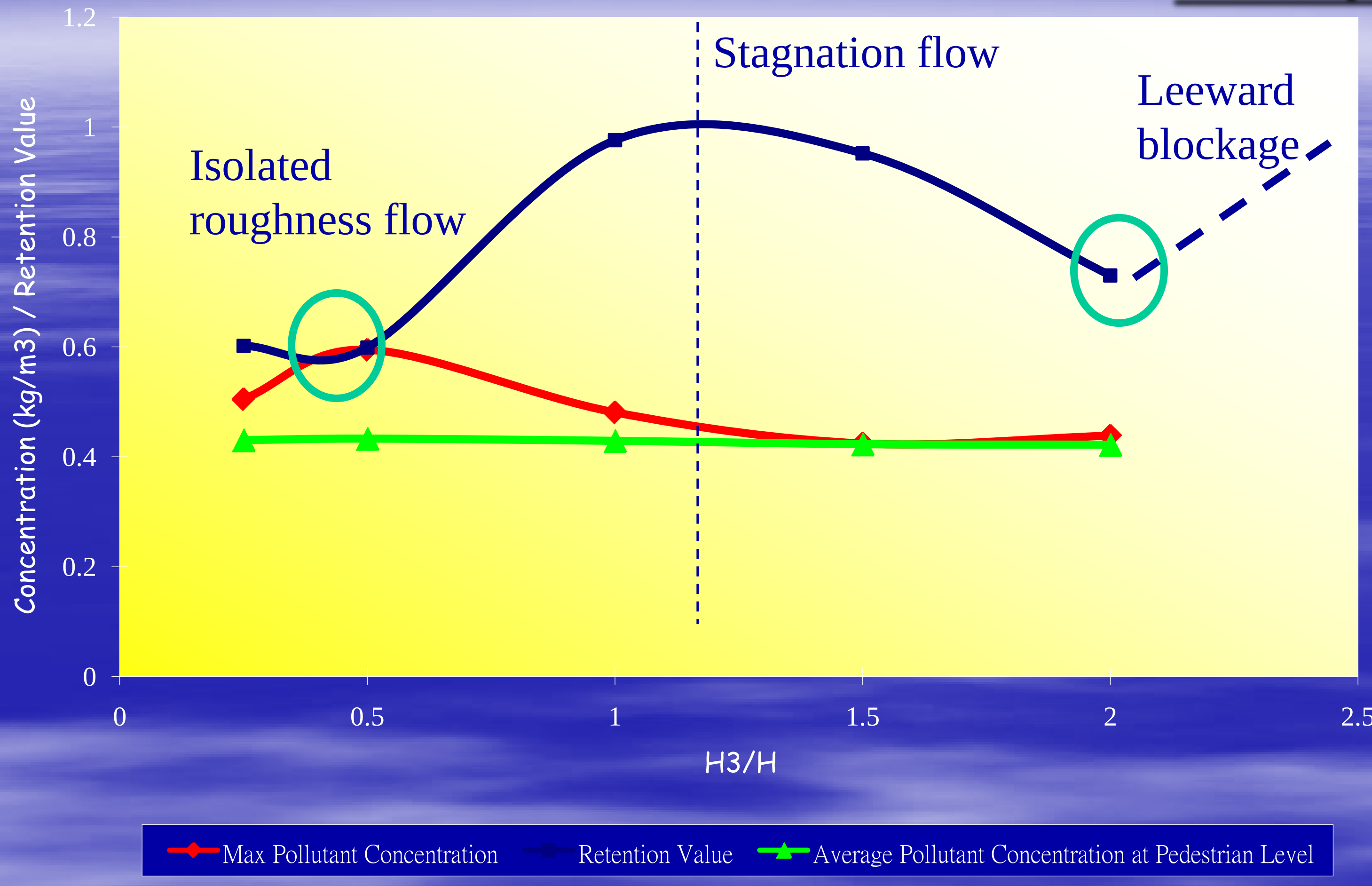
H_3/H : 0.5

H_3/H : 1.0

H_3/H : 1.5

H_3/H : 2.0

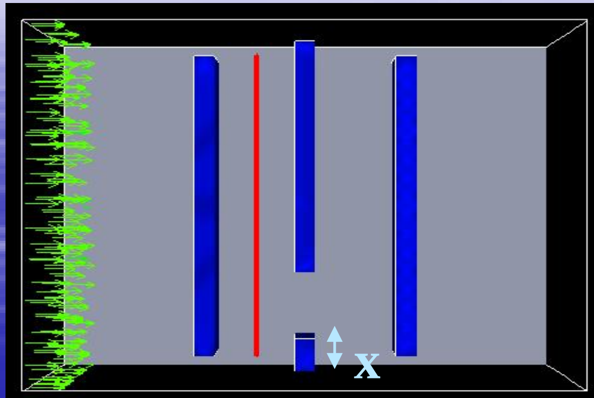
Graph 4

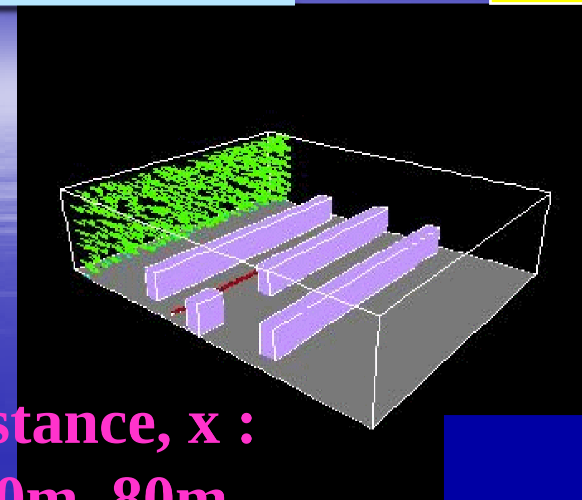


The retention value is minimum at about $H_3/H = 0.5$

Presence of cross road

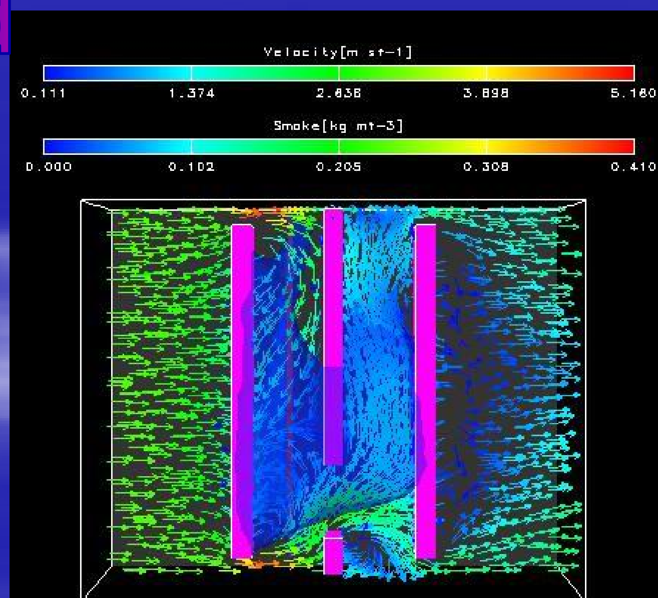
Case 5



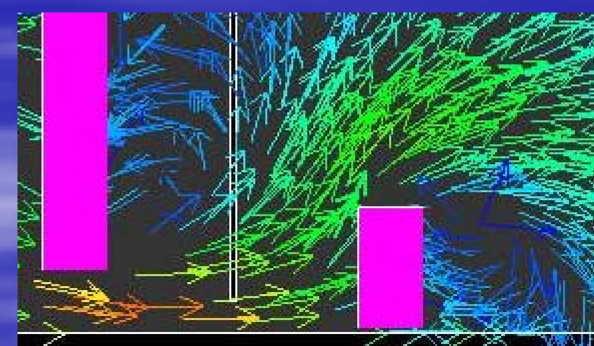


Shift upwards distance, x :
0m, 10m, 20m, 40m, 80m

Visualized Result

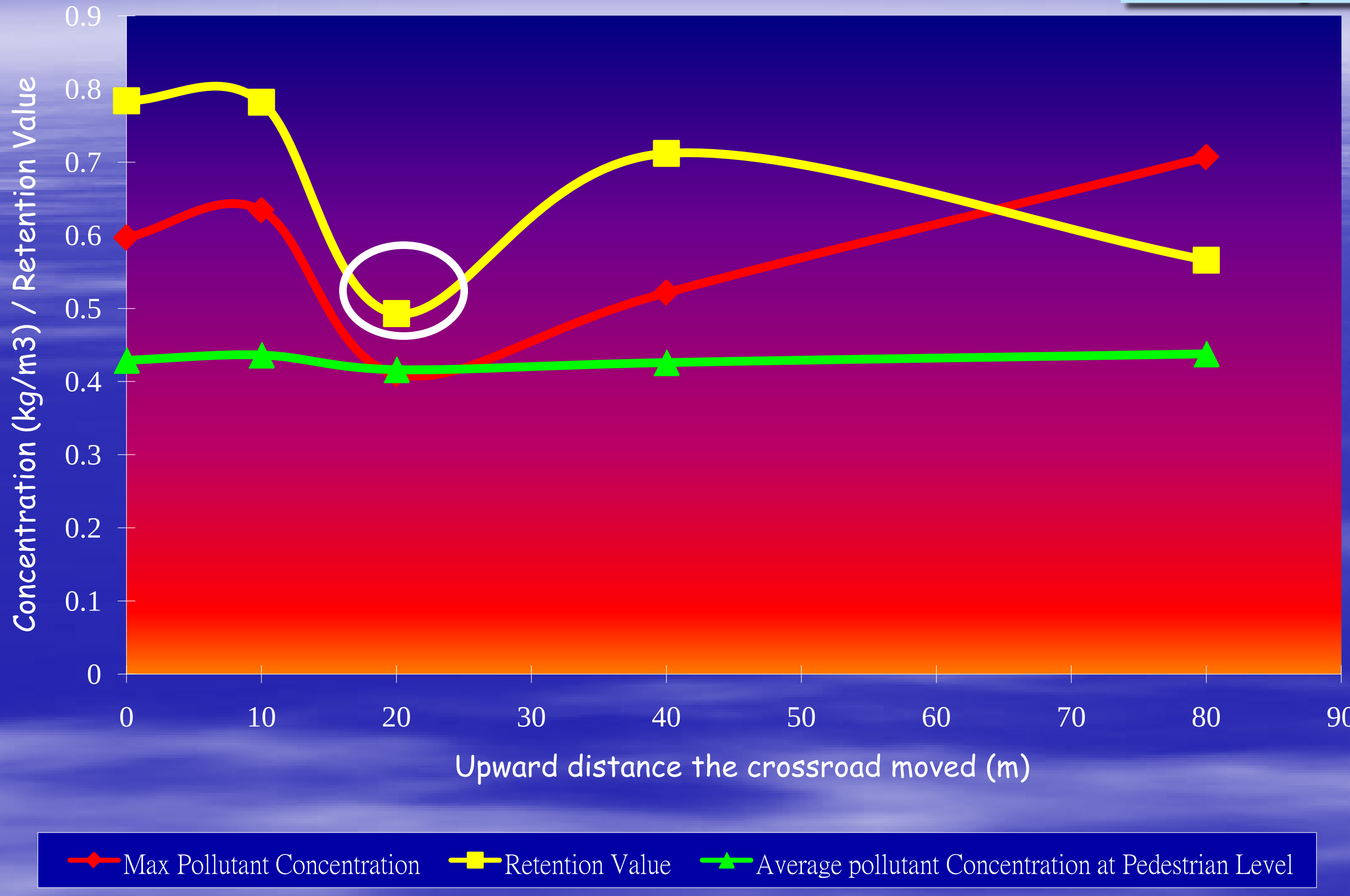


X = 20m



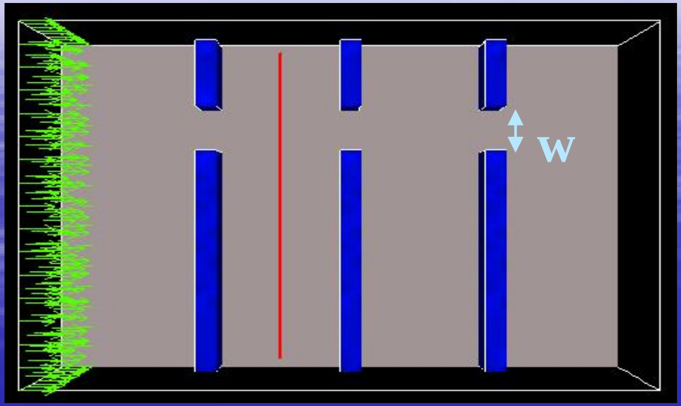
Wake interference flow

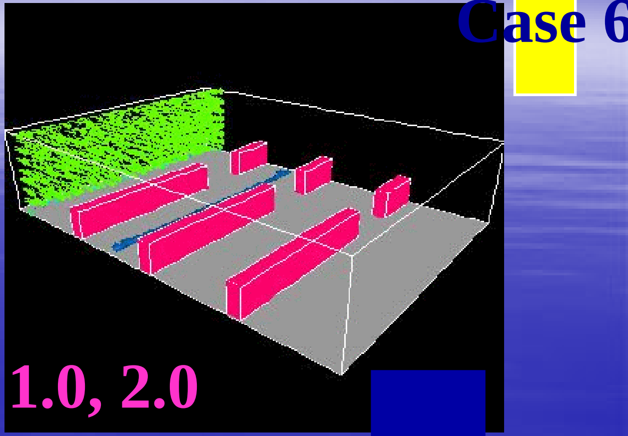
Graph 5



The retention value is minimum when the upward distance = 20m

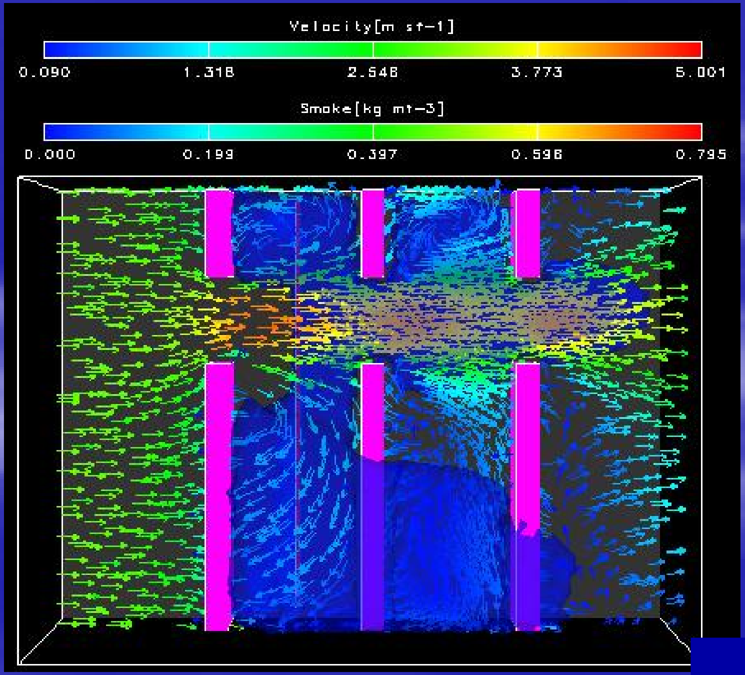
Variation of distance between 2 canyon arrays



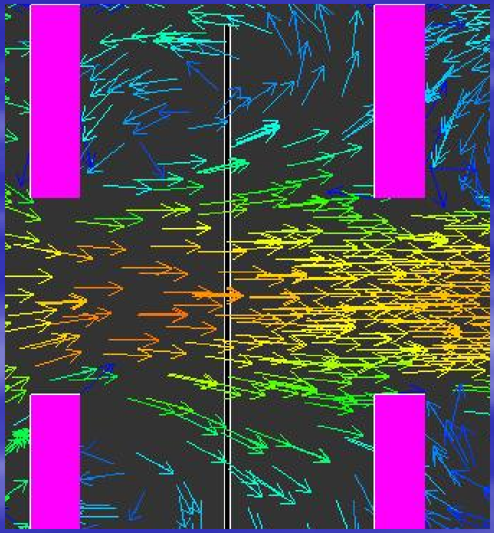


H / W :
0.33, 0.5, 0.75, 1.0, 2.0

Visualized Result

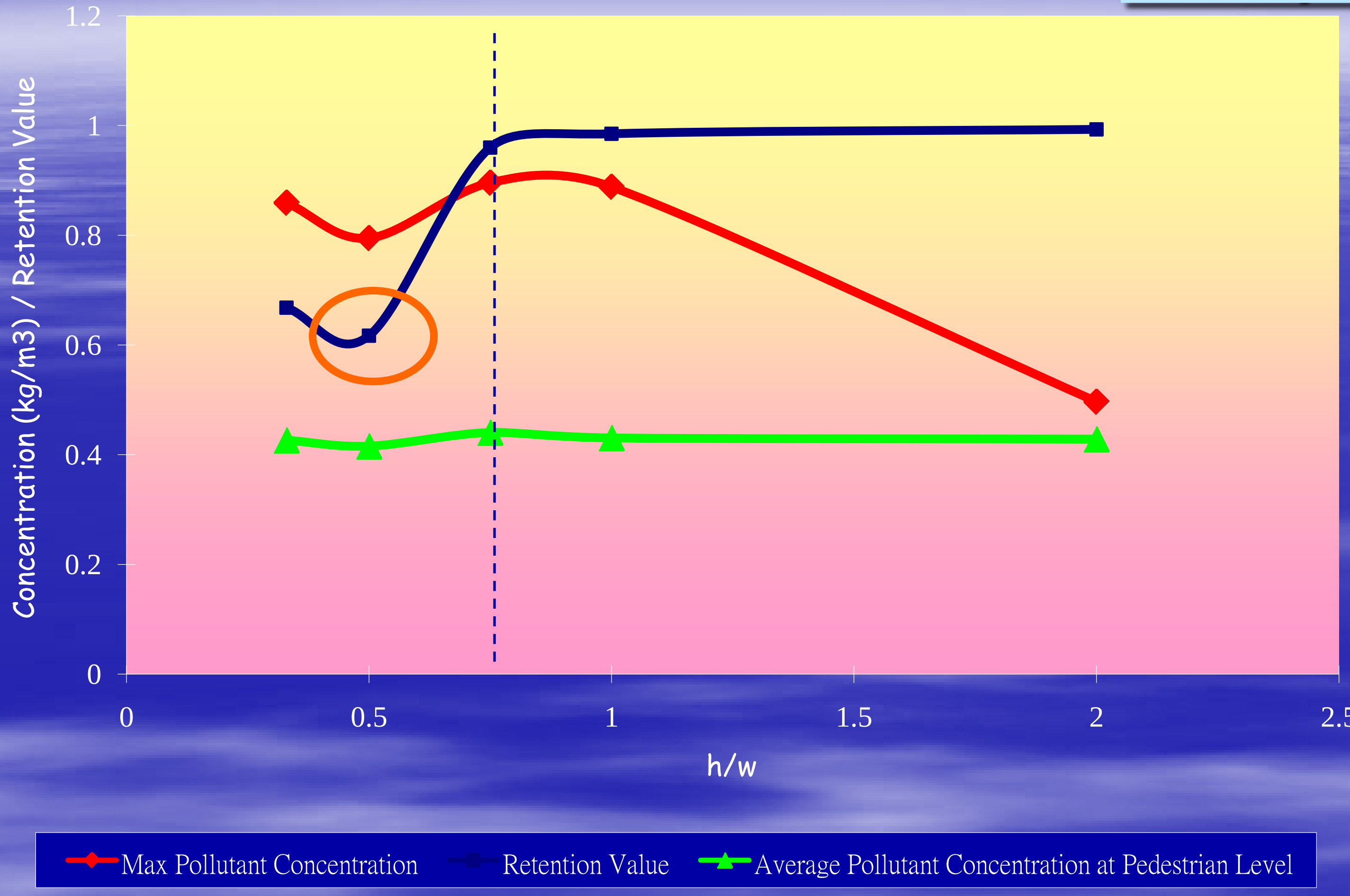


H/W: 0.5



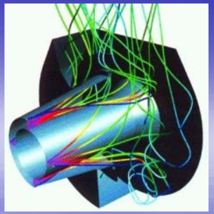
Wake interference flow

Graph 6



The retention value is minimum at H/W = 0.5

Discovery



- **Wake interference flow can enhance the pollutants dispersion**
- **Best Canyon Configurations (Consider two buildings only)**
  - H/W is 0.8 when buildings around them are fixed
  - H/W is 2 when width between all buildings are flexible
  - Buildings' width ratio is around 2
  - Buildings' height ratio is about 0.5
  - Crossroad is present 60m away from the center line
  - H/W between two canyon arrays is 0.5

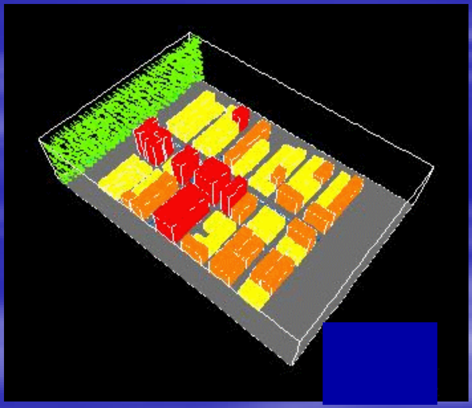
Application – Study of MongKok

Aim of study:

- To investigate how the pollutants disperse and find out the most serious pollutants affect zone
- Apply the cases studied to modify the canyon configurations and improve the air quality in that zone

Nathan Road

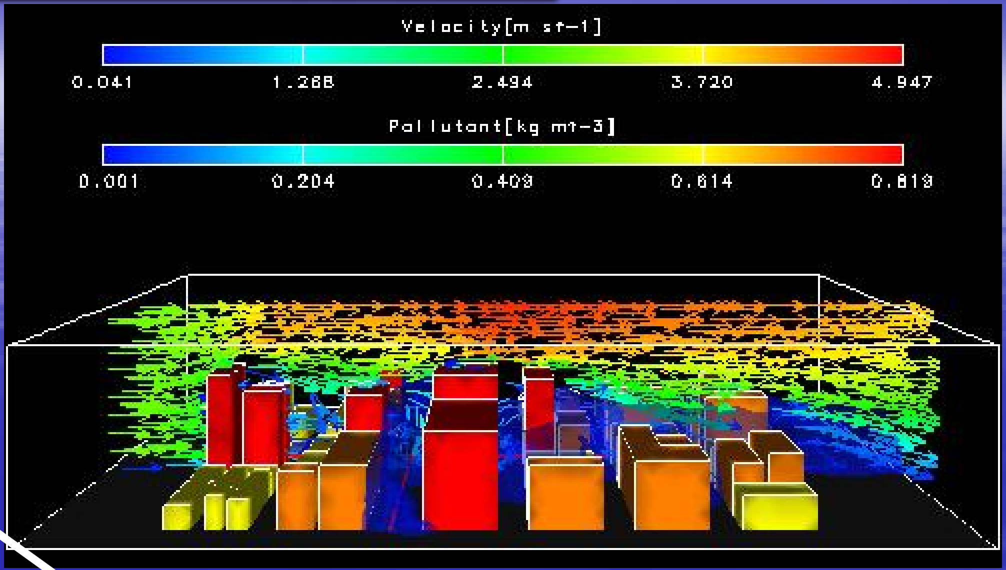
- 0-30 m
- 31-60 m
- >60 m

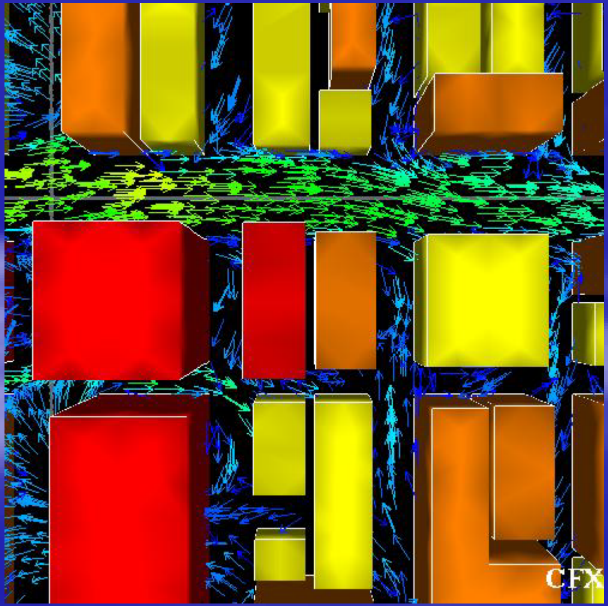


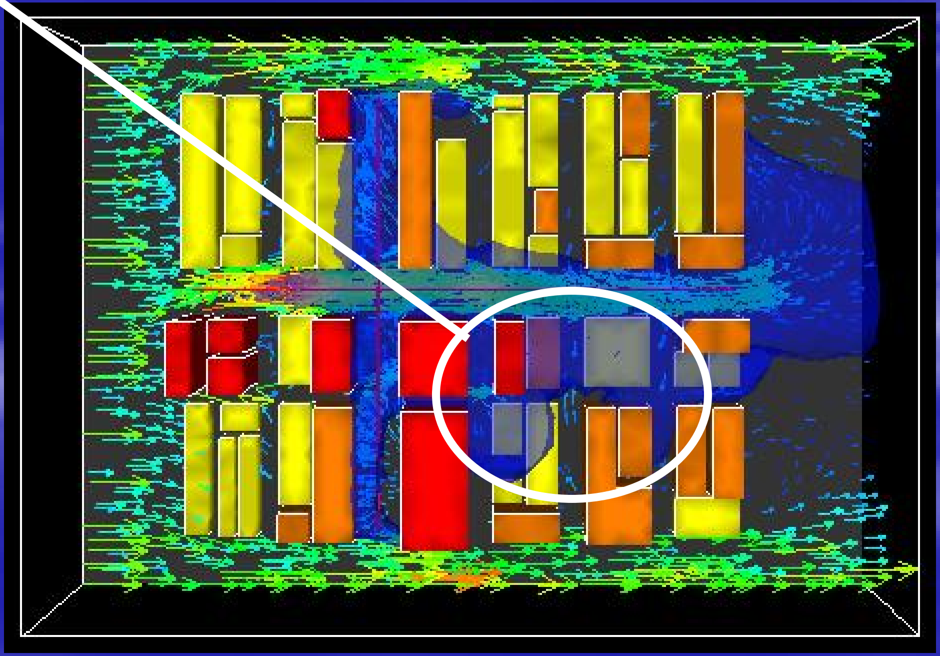
MongKok Road

Simulation Result

The part of the plume is accumulated at Fife Street and Tung Choi Street







Pollutants affected zone

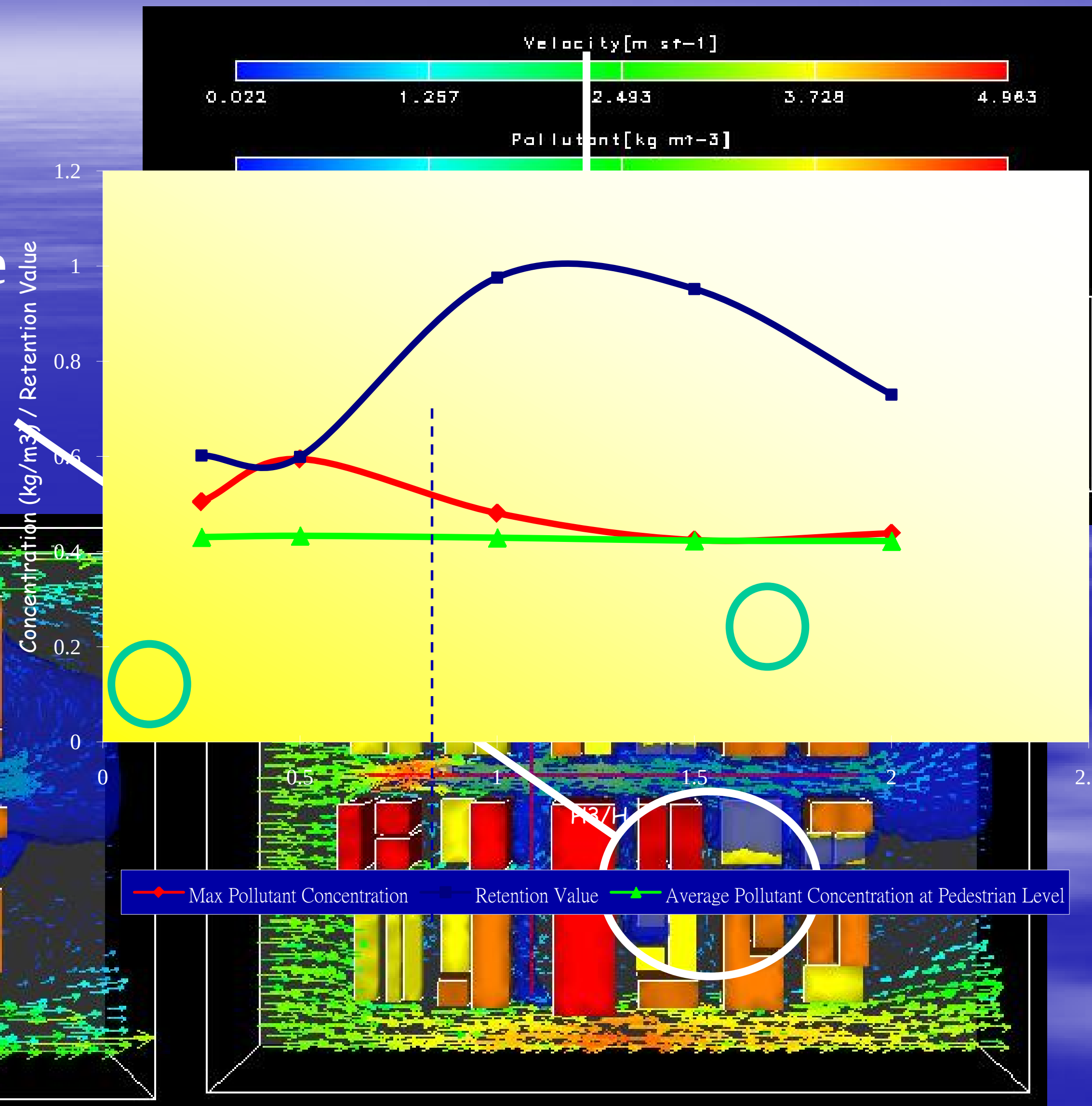
Tung Choi Street

Fife Street

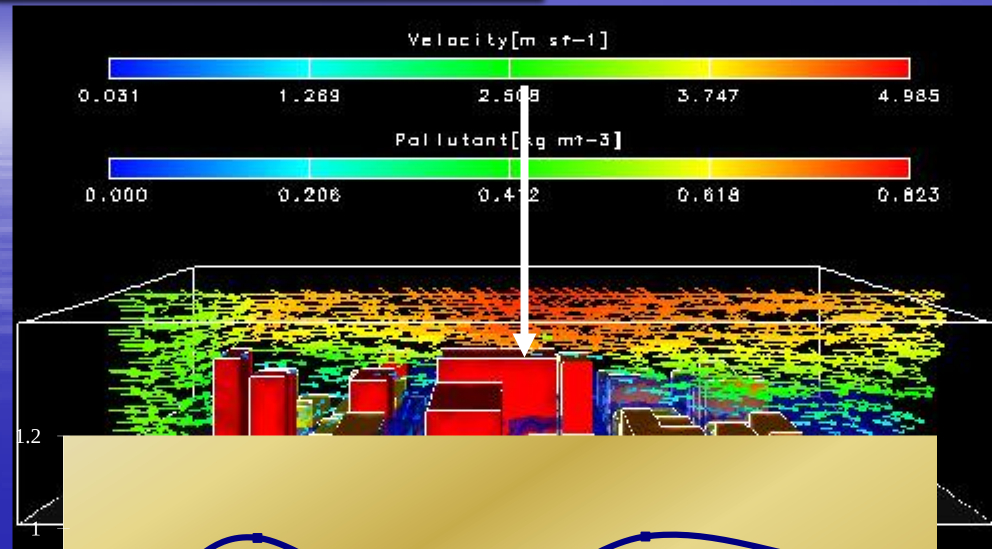
1st Modification

Apply Case 4, increase the height of that building to about twice to that of the opposite side building

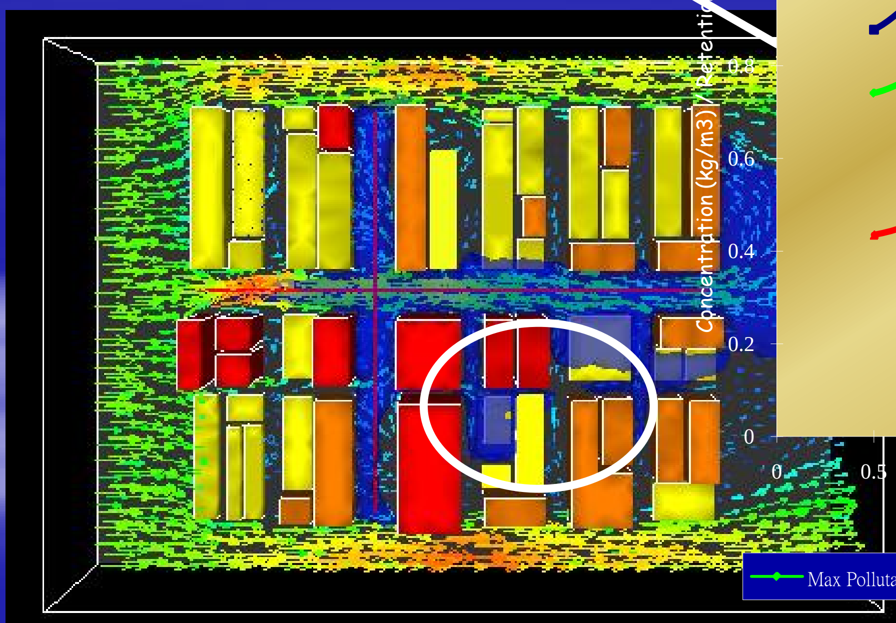
1st Simulation

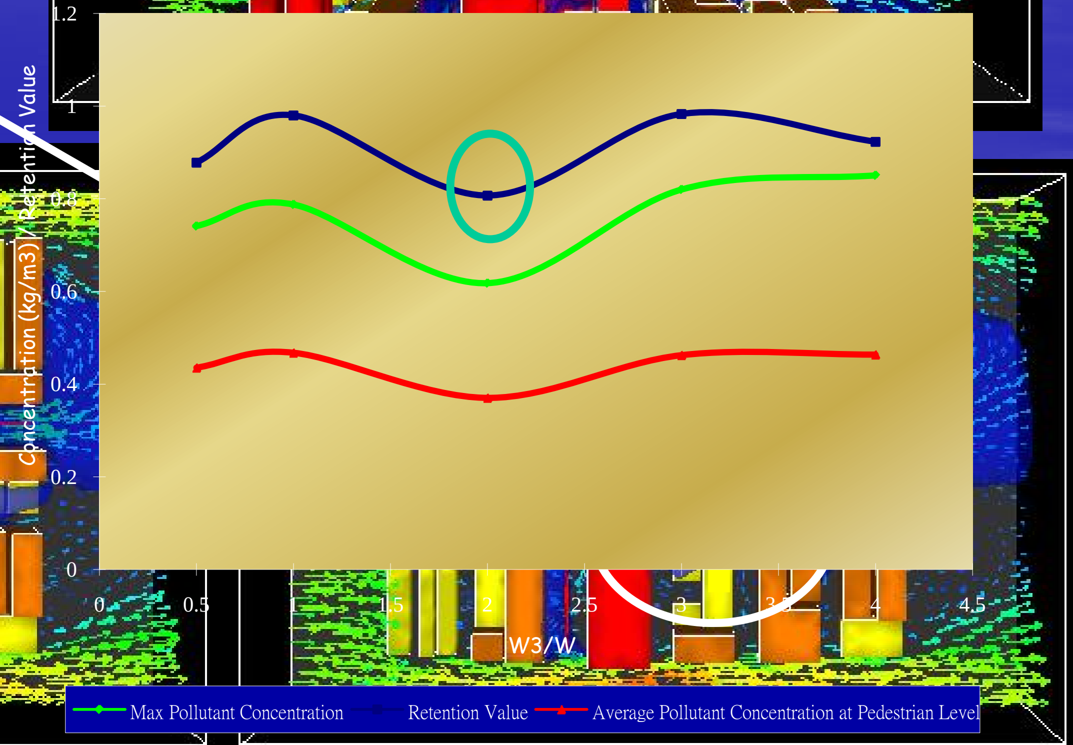


2nd Modification



Apply Case 3, increase the width of that building to about twice to that of the opposite building

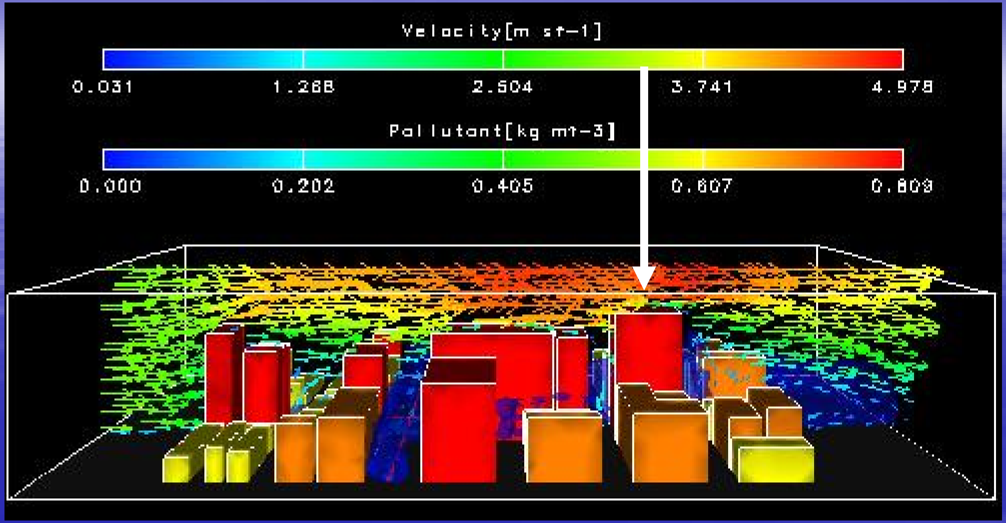


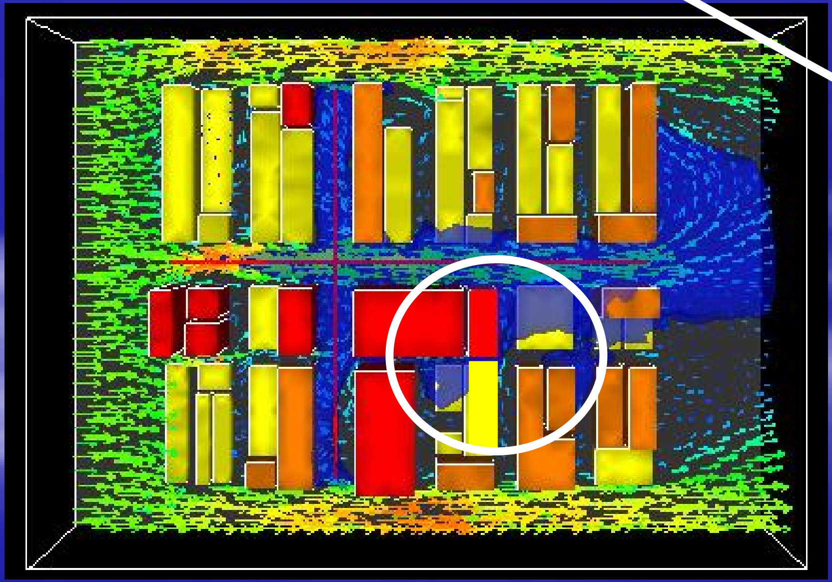


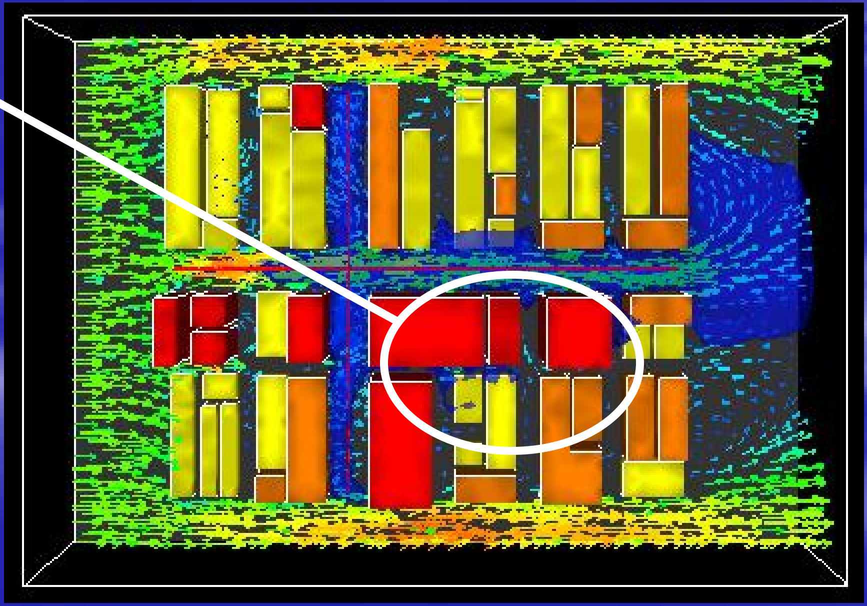
1st Modification

3rd Modification

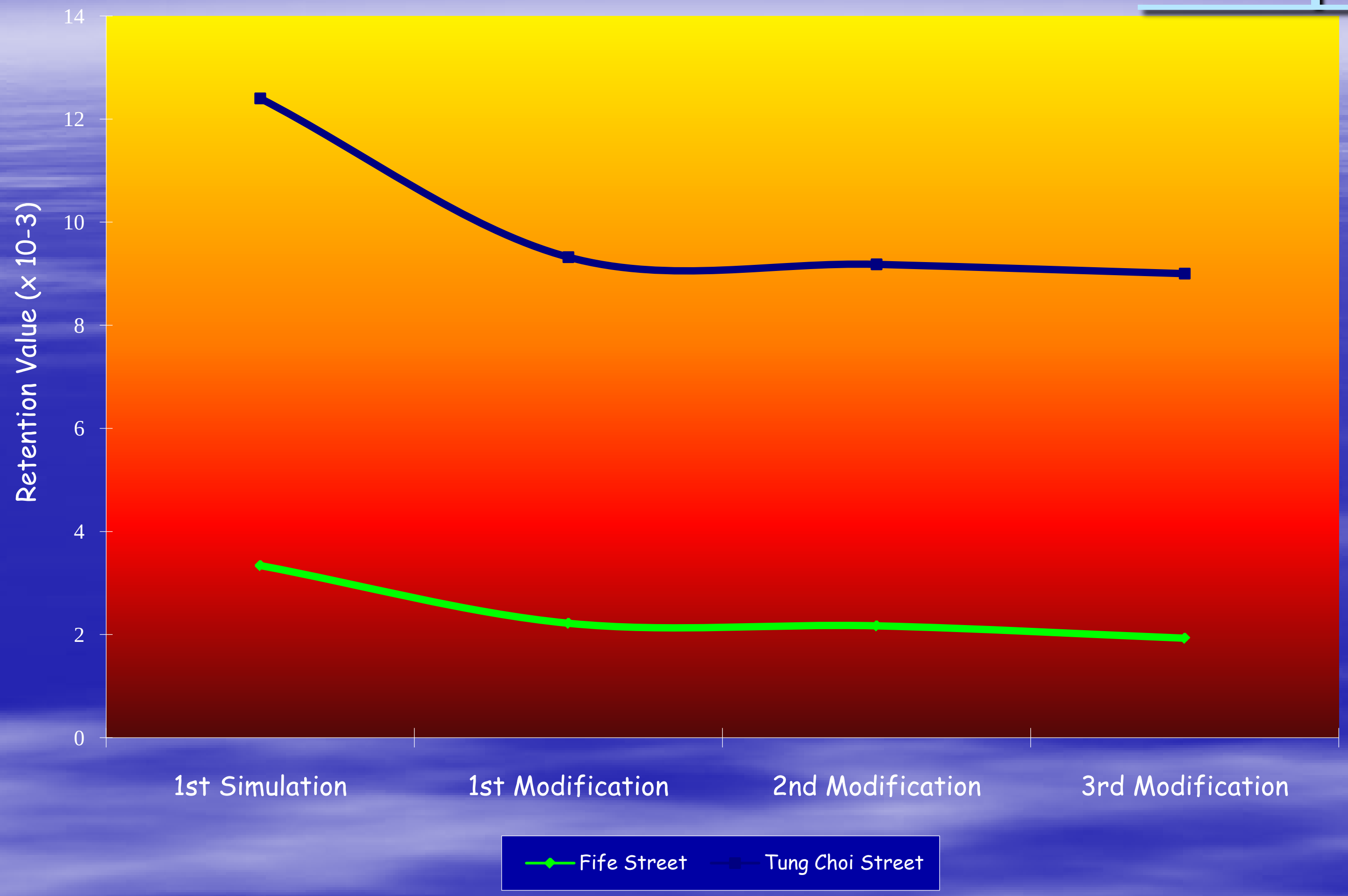
Apply Case 4, increase the height of that building to about twice to that of the opposite building







Graph 7



For Fife Street, the retention value decreased 40%

For Tung Choi Street, the retention value decreased 30%

Summary of Studying MongKok

- There are certain limitations when applying the cases studied on modifying MongKok
- It is not realistic to change the road size
- The building size is more flexible and can even be restricted by Government
- It is much better to modify the height and width of the buildings before considering the road size
- The pollution problem cannot be solved by modifying just one building
- The investigation results are workable when they are applied on modifying MongKok

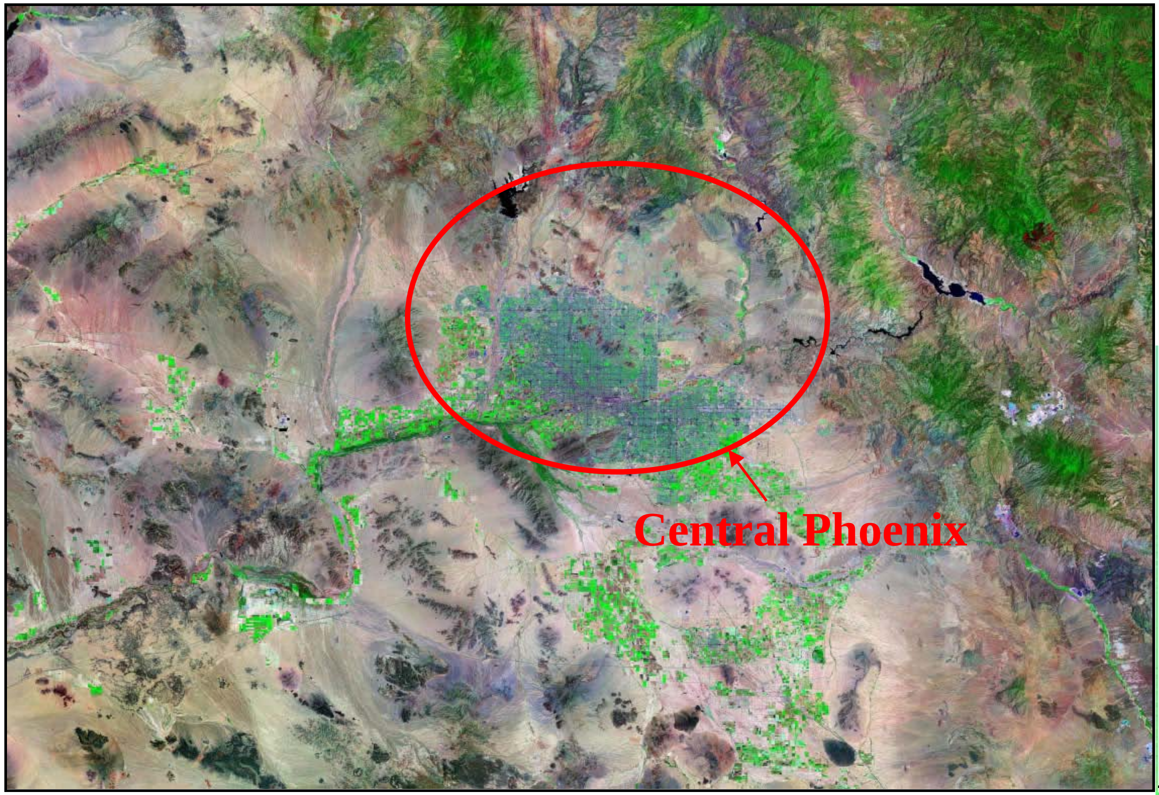
Conclusion

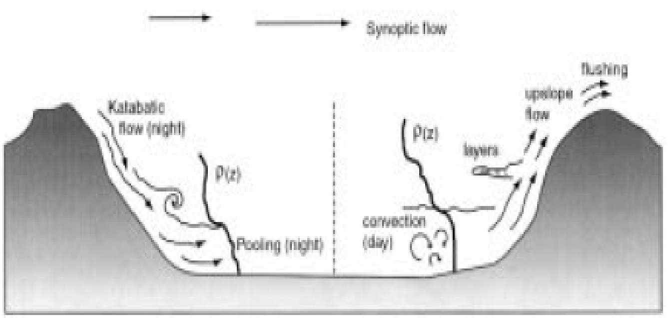
- Urban geometries have close relationship with the air quality
- Several canyon configurations have been studied, the results are workable when applied on a real urban area
- There are so many combinations of canyon configuration in the real situation, the cases studied that can be applied on a real urban area are quite limited
- This project can give a general idea for the purpose of the urban planning consideration

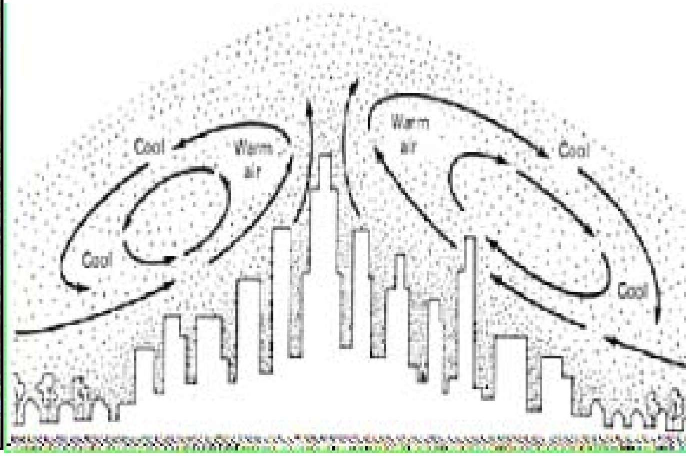
Implementation and Modification of MM5/Urbanized Version for Phoenix

Andy T. Chan
Environmental Fluid Dynamics
Arizona State University

Meteorological Characteristics of Phoenix







- ➢**The diurnal circulation - upslope winds during the day and downslope winds at night**
- ➢**Urban Heat Island effect causes intense convergence to central Phoenix surface layer during the night.**

Motivation and Objectives

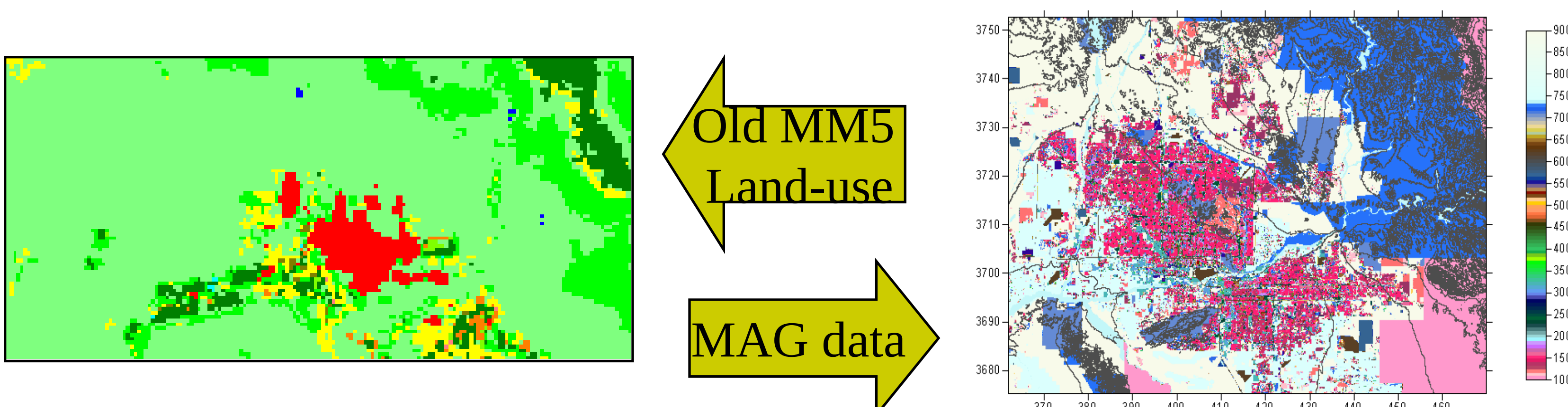
- **Motivation**
  - The rapid urbanization in metro Phoenix area has led to UHI and other transient events at night.
  - Simulation of meteorological fields within and above an urban canopy is important in dealing with urban air pollution and in evaluating the impacts of future growth scenarios.
  - Realistic simulation in neighborhood scale (~1km) is particularly required to account for regions with high gradients.
- **Objectives**
  - **How can the meteorological phenomena including UHI and surface front of Phoenix be simulated by MM5-normal and MM5-UCP during the night ?**
  - **How can the UHI with complex terrain affect air pollutants at night?**

Preparing Urban Data for Phoenix

- The classification of urban area
  - Detailed classified urban category : 5 categories depending on the height and density of buildings
  - Consider roads and the Salt river
  - Urban morphology : Building plan area density / rooftop area / frontal area density / wall-to-plan are ratio / building height-to-width ratio / fraction ratio / roughness length
  - Required data for roads and Salt river : Distribution / Heat Capacity / roughness length
- Reclassification of fine-scale land-use data with 30m horizontal resolution from MAG (Maricopa Association of Governments)

Preparing Urban Data for Phoenix

- Urban morphology follows Burian et al. (2003) work
  - GIS analysis for Metro Urban Phoenix (Sample urban morphology for 16.7 km^2 in downtown Phoenix, based on 3D building data (7997 buildings), digital orthophotos, detailed land use/cover information, bald-earth topography, road etc.)
- Heat characteristics of road is referred to by Clapp (1978)'s data in ENVI-met.
- Heat from vehicular traffic (Qv) in the road follows methodology of Sailor (2004).



….. Urban Data for Phoenix

- Heat from vehicular traffic (Qv)

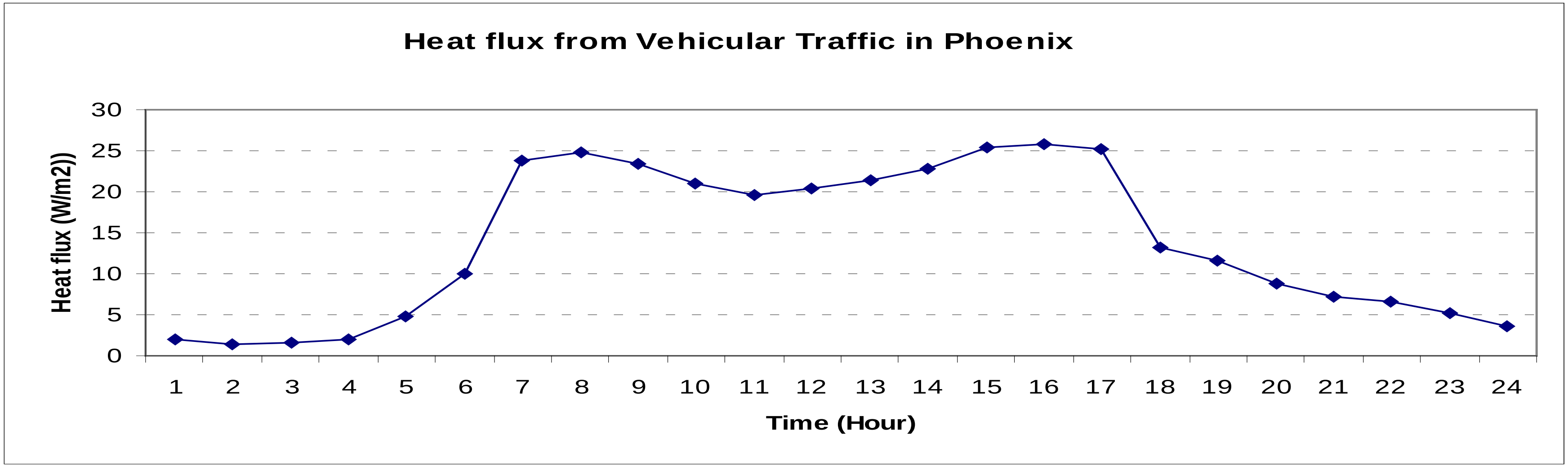
$$Q_v = DVD \times F_t(h) \times \rho_{pop}(h) \times EV$$

DVD: *Per capita daily vehicle distance* (US DOT, 2000)

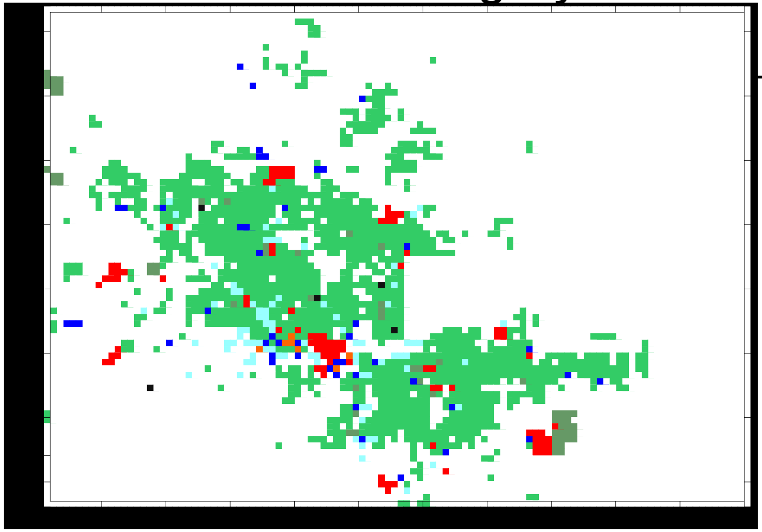
$F_t(h)$: *hourly fractional traffic profiles depended on hourly traffic amount*

$\rho_{pop}(h)$: *hourly population density* (US Census, 2000)

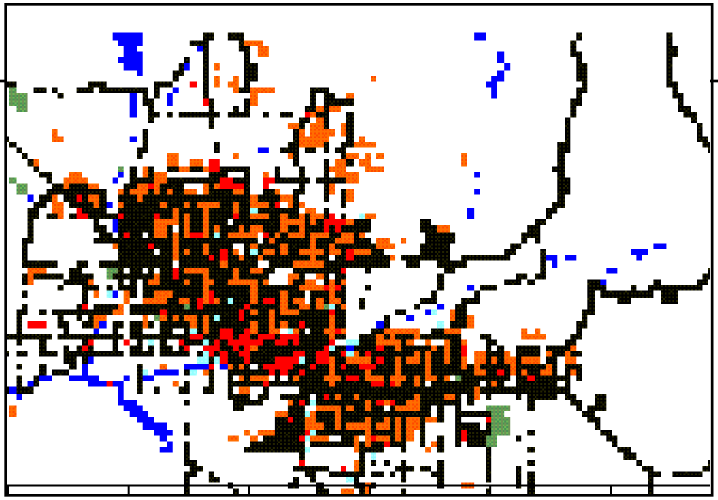
EV: *Energy release per vehicle per meter of travel* $\left(= \dfrac{NHC \times \rho_{fuel}}{FE}\right)$, $3975 J/m$



New urban category considering the Salt River and Road



Old Categories



New Categories : Including River and roads

- Urban area not included in Ellefsen's study
- Low commercial and residential houses
- APT. less than 4-stories and low industrial
- Low shopping center and modern commercial ribbon development
- Administrative and cultural (low to medium)
- Commercial officers and retail, 4 or more stories high APT. and hotel
- Commercial offices (high)

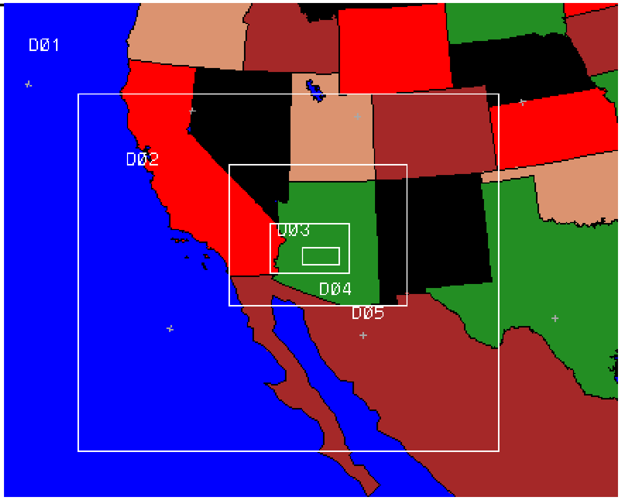
→

- Urban area not included in Ellefsen's study
- Low commercial and residential houses
- APT. less than 4-stories and low industrial
- Low commercial, administrative and cultural building
- **Salt River**
- **Freeway and Road**
- Commercial offices (high)

UCP classes for Phoenix

Urban Category	Definition of urban surface type	Percent. of total area (%)	Canyon fraction	Roughness length (m)	Maximum Building Height (m)	Max. anthropogenic heat flux(W/m^{-2})
1	Urban area not included in Ellefsen's study	40.8	0.70	0.17	6	50
2	Low commercial and residential houses	22.2	0.87	0.38	6	100
3	APT. less than 4-stories and low industrial	5.1	0.80	0.51	11	100
4	Low shopping center and modern commercial ribbon development, Administrative and cultural (low to medium), Commercial officers and retail, 4 or more stories high APT. and hotel	3.8	0.96	1.08	8	100
5	Salt River	1.8	-	0.01	-	-
6	Freeway and Road	16.2	0.87	0.51	5	30
7	Commercial offices (high)	10.1	0.78	2.63	150	100

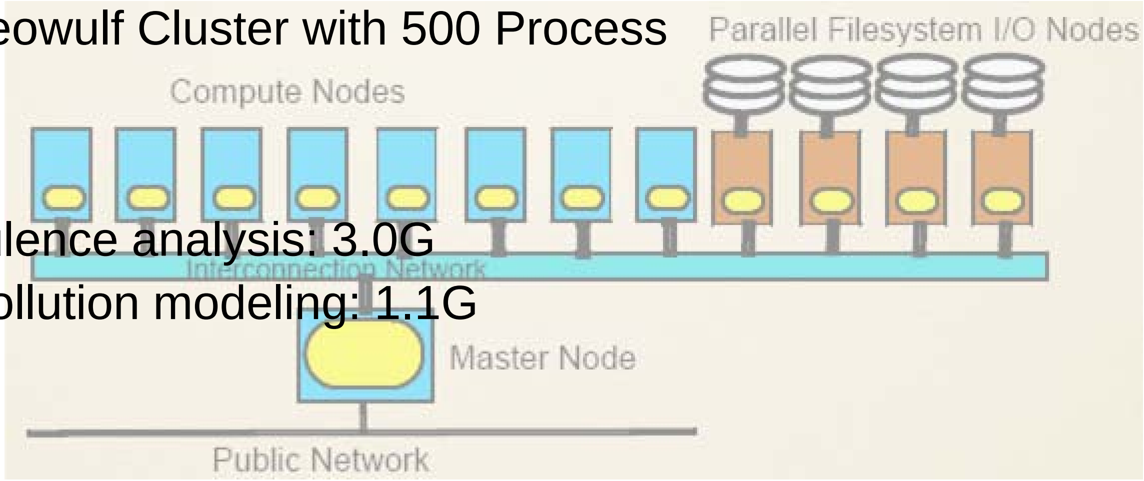
Simulation Conditions



- 5 Domains for nesting
  - Horizontal resolution : 81, 27, 9, 3, 1km
  - Vertical layer : 23 layers
  - FDDA with surface data
  - 2-way nesting
- DO5 : Fine resolution (1km)
  - Horizontal domain : 181 km X 85 km
  - Vertical domain : 23 layers included 7 layers below BL(1.5km), 10m is the lowest level.
  - NESTDOWN using Domain 4
  - Calculation Time Resolution : 3 sec
- Simulation Cases
  - **Using the MM5-normal version Without UCP (NoUCP)**
  - **Using the Final Modified version of MM5-UCP (UCP)**

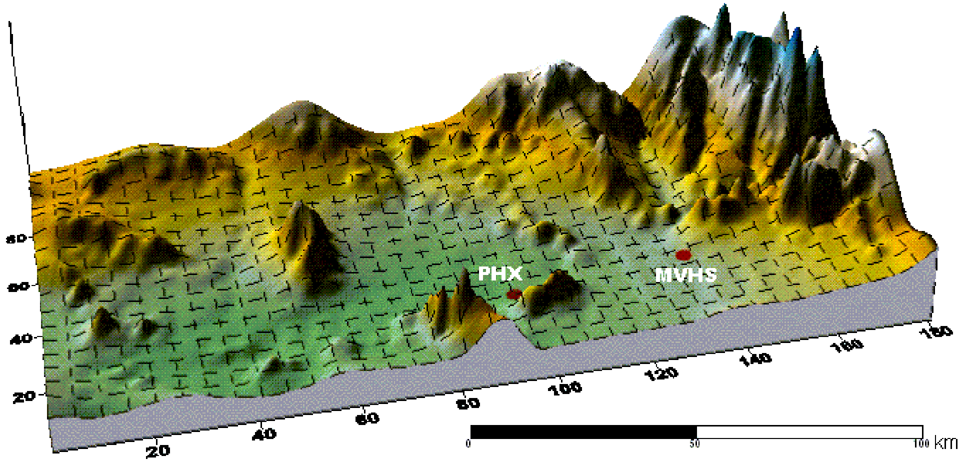
Simulation Conditions

- Simulation Period: 01/12_00 hour – 01/14_00hour, 2006 (72h)
- Air Pollution Modeling: CMAQ4.5
  - Emission Data ← Output of SMOKE using summer source inventory (2001)
  - 1km data ← Interpolation of 2km emission data
- Spin-up Time for MM5 and CMAQ: 44 Hours
  - Focusing Time : from Jan. 13, 02 PM (14 Hour) to Jan. 14, 12 PM
- Various
  - Computational Condition: Fulton High Performance Linux system
    - 130 CPU Scyld Beowulf Cluster with 500 Process
  - Data Size
    - Urban data: 61K
    - OUTPUT for turbulence analysis: 3.0G
    - OUTPUT for air pollution modeling: 1.1G



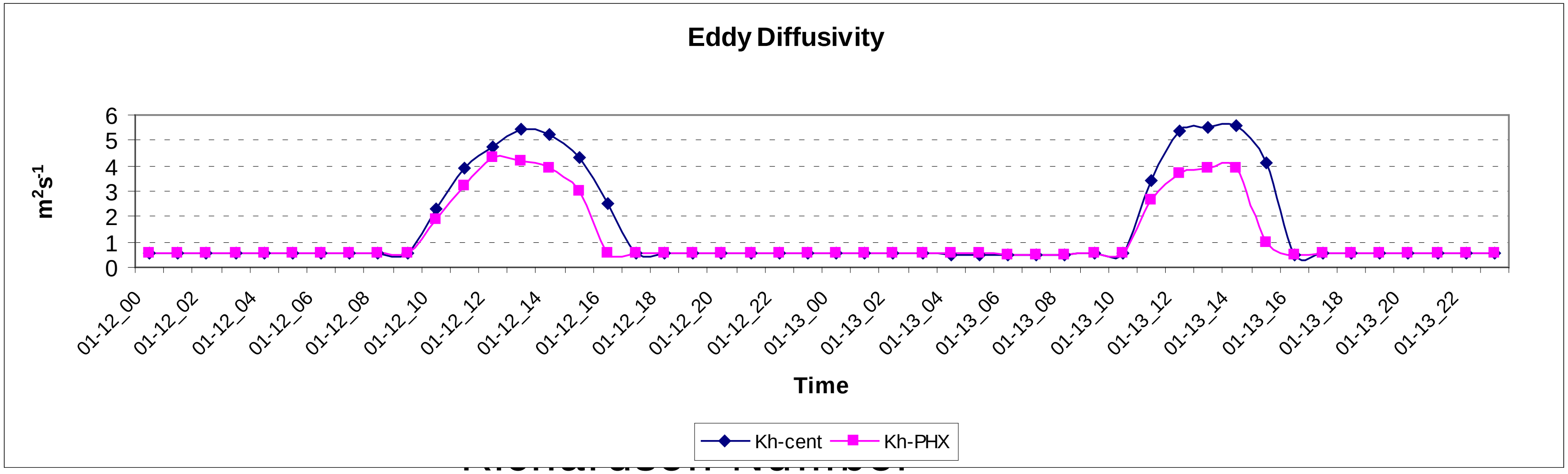
Comparison with Observational Data

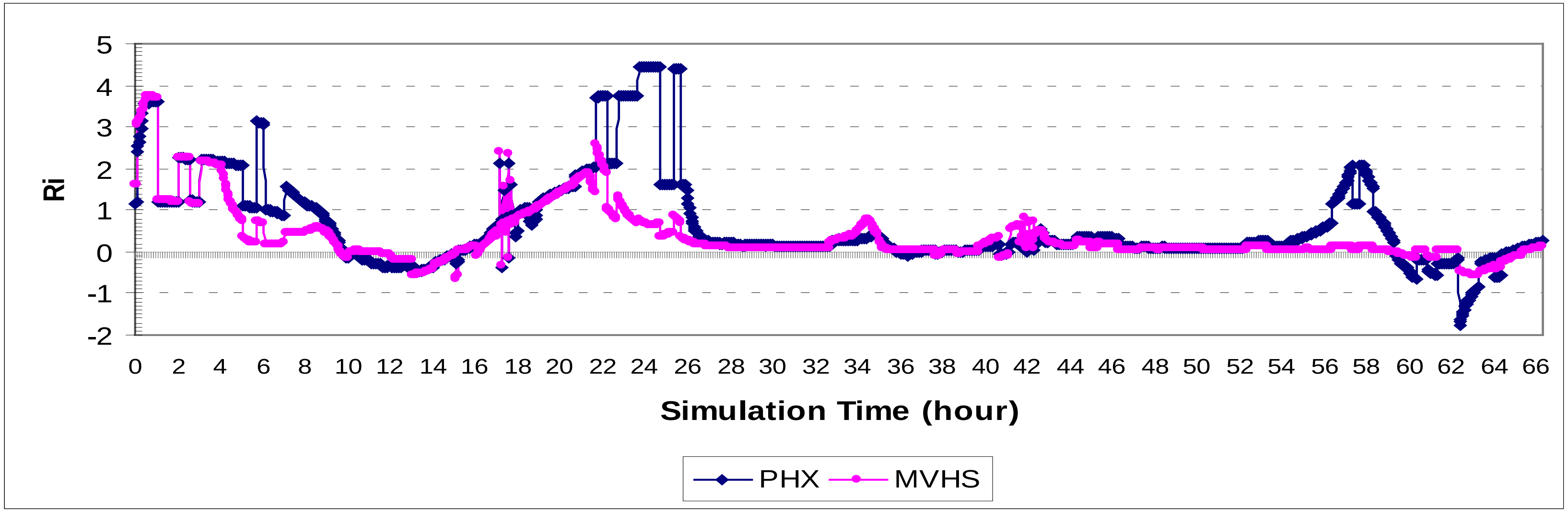
- TRANSFLEX : Transition Flow Experiment
  - Field study on evening transition in complex terrain
  - Period : 01/07 - 01/15, 2006
  - Location
    - MVHS : Mountain View High School
    - PHX : South Phoenix
  - Measurement
    - 3 Wind components, Temperature
    - Heat and Momentum flux
    - PM10 concentrations



Why the K_m and K_h were modified ?

Assumption of Eddy Diffusivity at original MM5/Urbanized





Issue of MM5/Urbanized

- Eddy diffusivity and Mixing length

$$K_m = C_k l_m k^{1/2}$$

K_m : *Momentum eddy diffusivity*

C_k : 0.4

l_m : *mixing length for momentum*

$$\varepsilon = \frac{k}{t_0}$$

ε : *dissipation rate*

t_0 : *dissipation time scale*

← **Turbulent Prandtl number is considered unity at all stabilities.**

← **Dissipation time scale problem**

- Roughness length

$$z_d = f_d \overline{z_H}\ ,\ z_o = f_o \overline{z_H}$$

z_d : *displacement height*

z_o : *roughness length*

f_d, f_o : *empirical coefficient* (0.5, 0.1)

← **Roughness length is calculated by simple rule-of-thumb.**
(Grimmomd and Oke, 1999)

Modification for MM5/Urbanized (1)

- Modification of eddy diffusivity
  - In k-l model, the dissipation rate ($\varepsilon = \frac{k}{t_0}$) is relatively steady or that the time scale is large compared to flow time-scales.
  - The numerical time scale of meso-scale model by Lax Equivalent Theorem for numerical stability is inconsistent with the steady nature of k-*l* model.

- Eddy diffusivity is calculated by k-ε model scheme

$$\varepsilon = C_D \frac{k^{3/2}}{l_e}$$

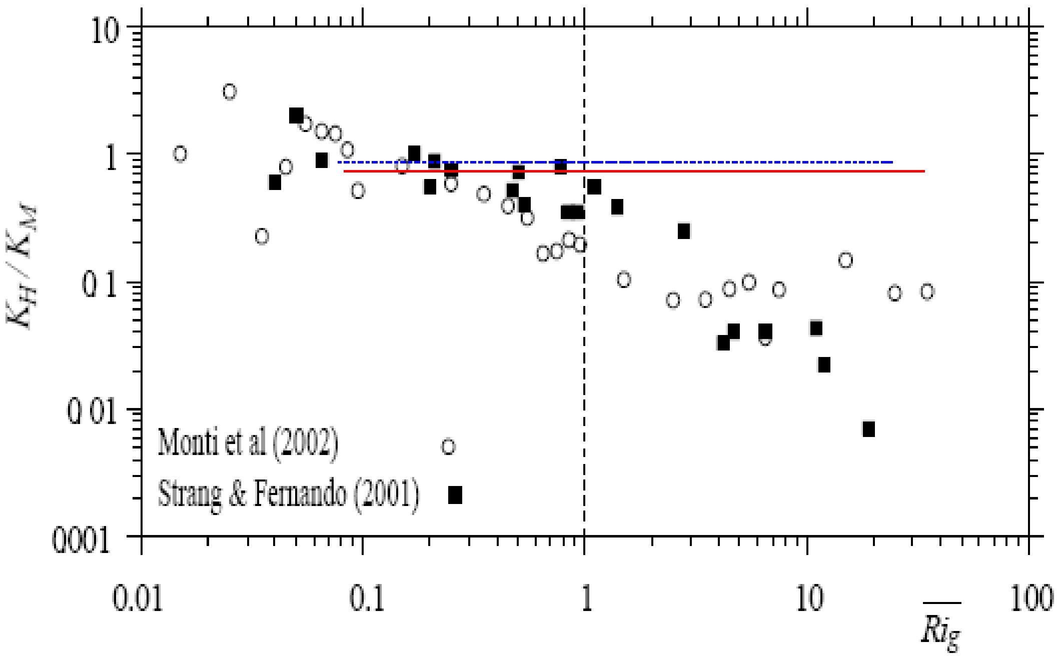
$$K_m = C_\mu \frac{k^{3/2}}{\varepsilon}$$

$$C_D \ : 0.7(\textit{Bougeault et.al}, 1989)$$

$$C_\mu \ : 0.09(\textit{Launder et.al}, 1974)$$

Modification for MM5/Urbanized (2)

- Modification of momentum flux at stable stability
  - In near neutral and stable case (R_{ig} > 0.2)
    - Monti et al. (2002) work
    - The momentum and heat transfer by turbulent eddies diminished
    - The Momentum diffusivity can even slightly increase with R_{ig}



$$K_m = \frac{\sigma_w^{\ 2}}{\left|\frac{dU}{dz}\right|} \times 0.34 \times R_{ig}^{\ -0.34}$$

$$K_h = \frac{\sigma_w^{\ 2}}{\left|\frac{dU}{dz}\right|} \times 0.08 \times R_{ig}^{\ -0.49}$$

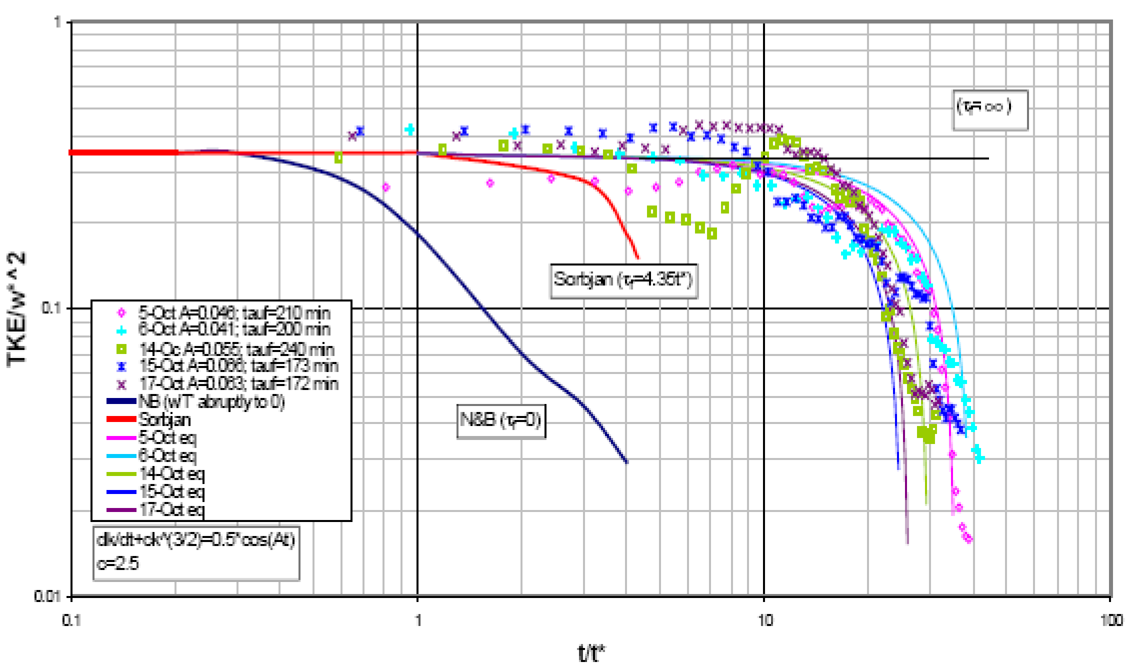
$$\sigma_w^{\ 2} = \overline{w'^2} = u_*^{\ 2} \times 2.5 \times \left[1 - (\frac{z}{h})^{0.6}\right] \text{ by Stull (1988)}$$

R_{ig} : gradient Richardson Nnumber

σ_w : variance of vertical velocity

Modification for MM5/Urbanized (3)

- Modification of heat flux at neutral stability inside the PBL
  - Near the neutral stability
    - Fernando et al. work (2003)
    - In the absence of significant mean wind ($\frac{w_*}{u_*} \rangle\ 0.9$)
    - If the decay of TKE occurs in a series-steady steps
    - The bottom buoyancy flux change as function of time scale of the decay heat flux



$$\frac{\partial K}{\partial t} = \overline{b'w'} - \varepsilon$$

$$Q(z,t) = \alpha g\ \overline{b'w'} = Q_0(0,t)\left[1 - \frac{z}{H}\right]$$

$$Q_0(0,t) = Q_m \cos\left(\frac{\pi t}{2\tau_f}\right)$$

$\alpha = \frac{1}{\theta}$, θ : *reference temp*

$Q_0(0,t)$: *surface buoyancy flux*

Q_m : max. *buoyancy flux*

τ_f : *time scale of the decay heat flux*

Modification for MM5/Urbanized (4)

- Modification of roughness length scale
  - Macdonald et al. (1998)

$$\frac{z_d}{z_H} = 1 + \alpha^{-\lambda_p}(\lambda_p - 1)$$

$$\frac{z_0}{z_H} = \left(1 - \frac{z_d}{z_H}\right)\exp\left\{-\left(0.5\beta\frac{C_D}{k^2}\left(1-\frac{z_d}{z_H}\right)\lambda_f\right)^{0.5}\right\}$$

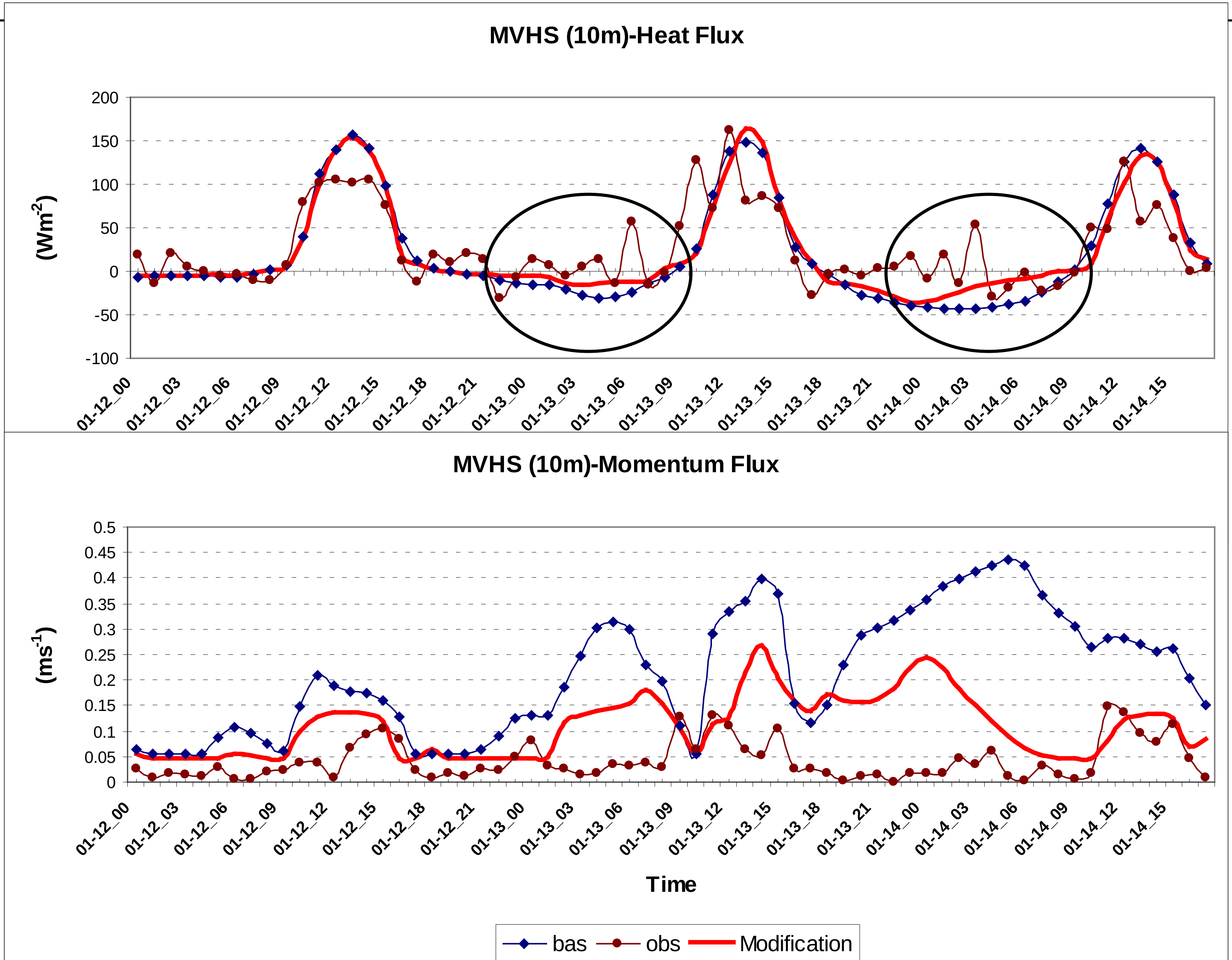
α, β : empirical coefficient (4.43, 1.0)

C_d : 1.2

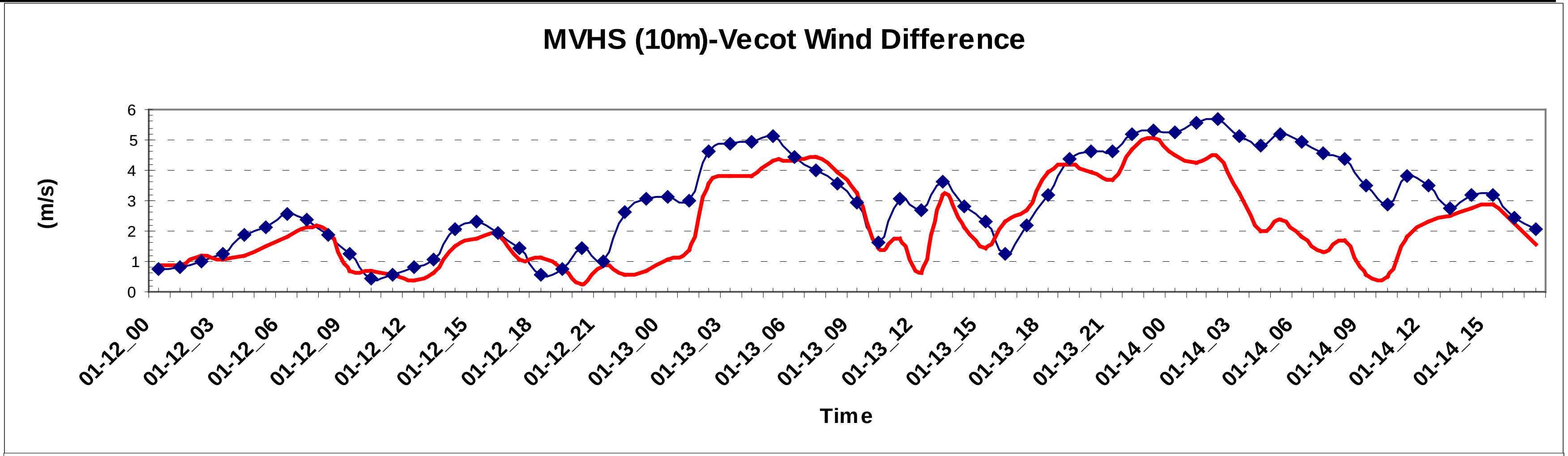
k : von Karman constant (0.4)

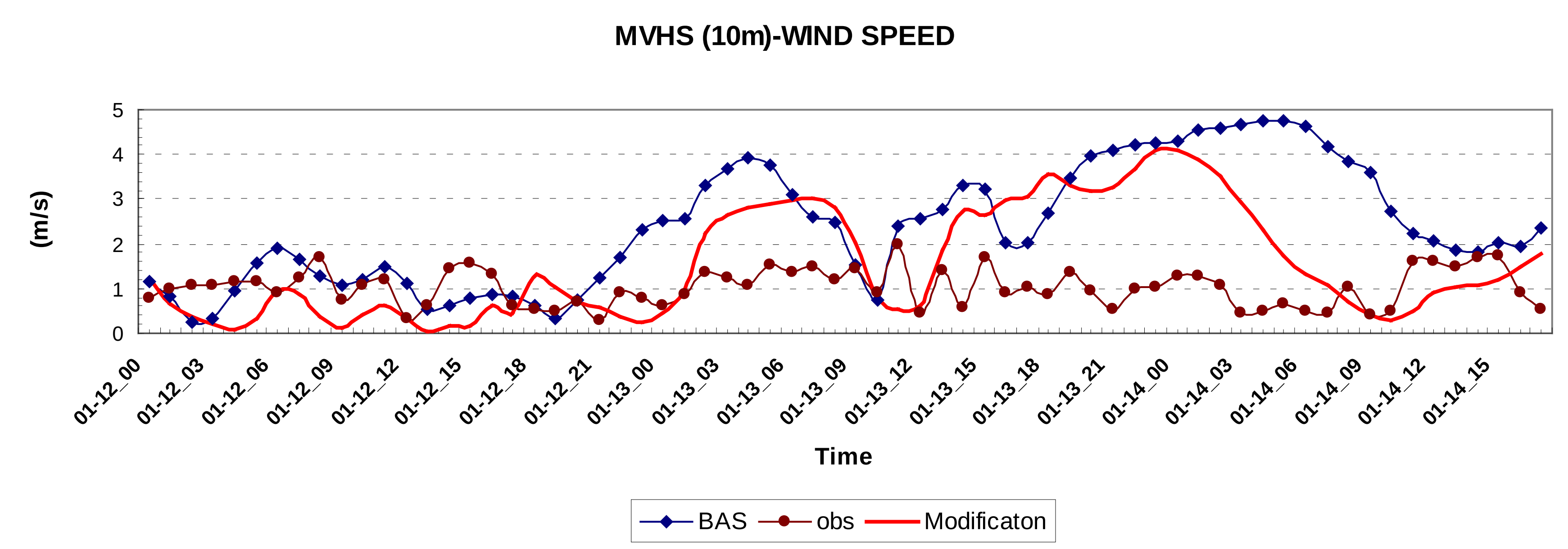
Urban Category	Before (Grimmond)	Modification (Macdonald)
1	0.17	0.19
2	1.08	1.03
3	1.51	1.71
4	0.36	0.26
5	0.01	0.01
6	1.46	1.51
7	3.20	3.11

Improvement of Heat and Momentum Flux by modification



Comparison of Surface wind





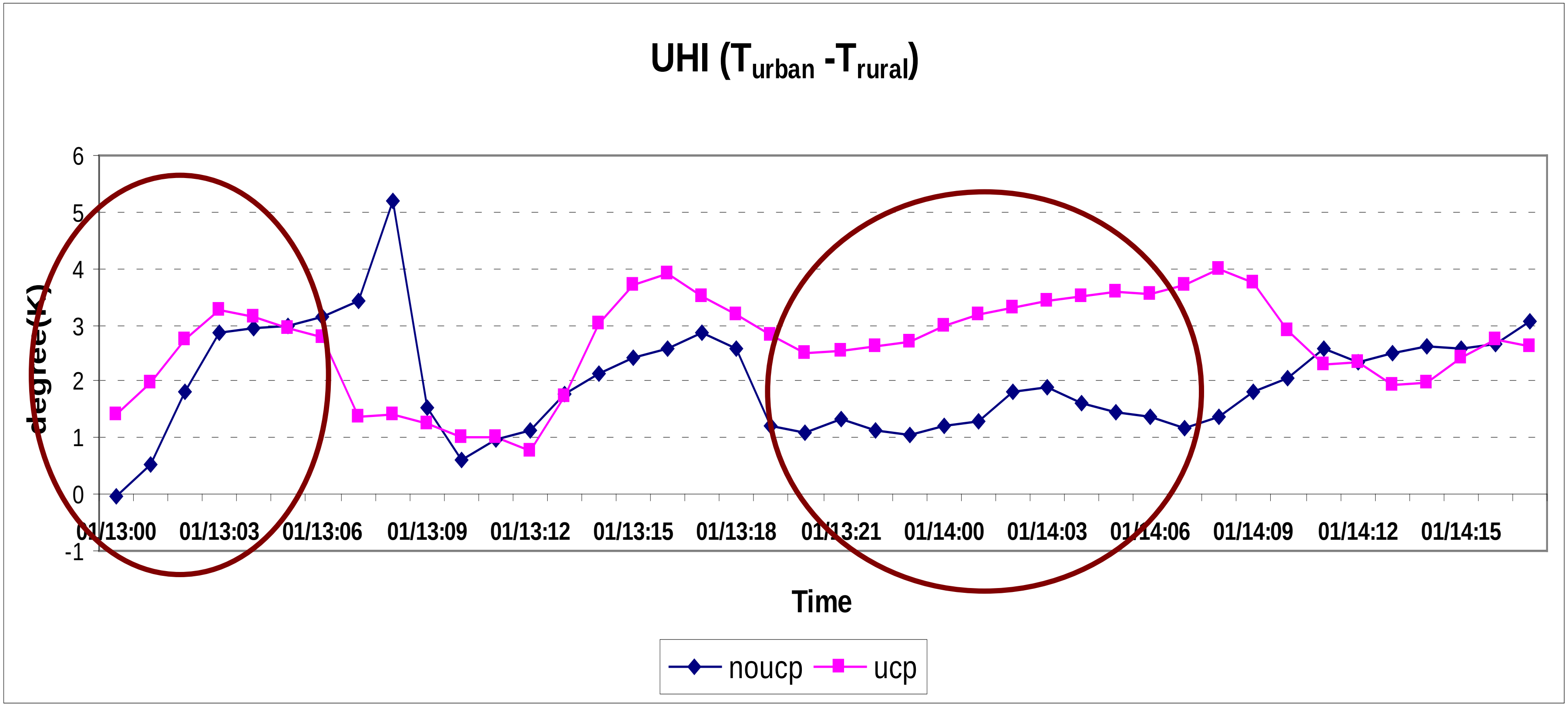
Statistics of Numerical Results

		T(K)	WS(ms^{-1})	VWD(ms^{-1})	Sensible Heat Flux ((w't'), Kms^{-1})	Momentum Flux ($\sqrt{u_*^2}$, ms^{-1})
MEAN/STD	OBS	285.83/5.17	1.02/0.41	-	25.39/44.38	0.041/0.038
	BAS	287.90/3.64	1.77/1.29	2.508/1.364	25.16/60.55	0.144/0.093
	Modified	286.78/3.33	1.54/1.01	2.179/1.355	23.33/53.95	0.109/0.059
RMSE	BAS	3.45	1.62	1.725	42.618	0.239
	Modified	1.92	1.35	1.476	33.173	0.095

RMSE (Root Mean Square Error) : $\sqrt{\frac{1}{N}\sum_{1}^{N}(P_i - O_i)^2}$ **NMB (Normalized Mean Bias) :** $\frac{\sum_{1}^{N}(P_i - O_i)}{\sum_{1}^{N} O_i} \times 100\ (\%)$

VWD (Vector Wind Difference) : $\sqrt{(u_p - u_o)^2 + (v_p - v_o)^2}$ (Otte(2004) and Stauffer(1990))

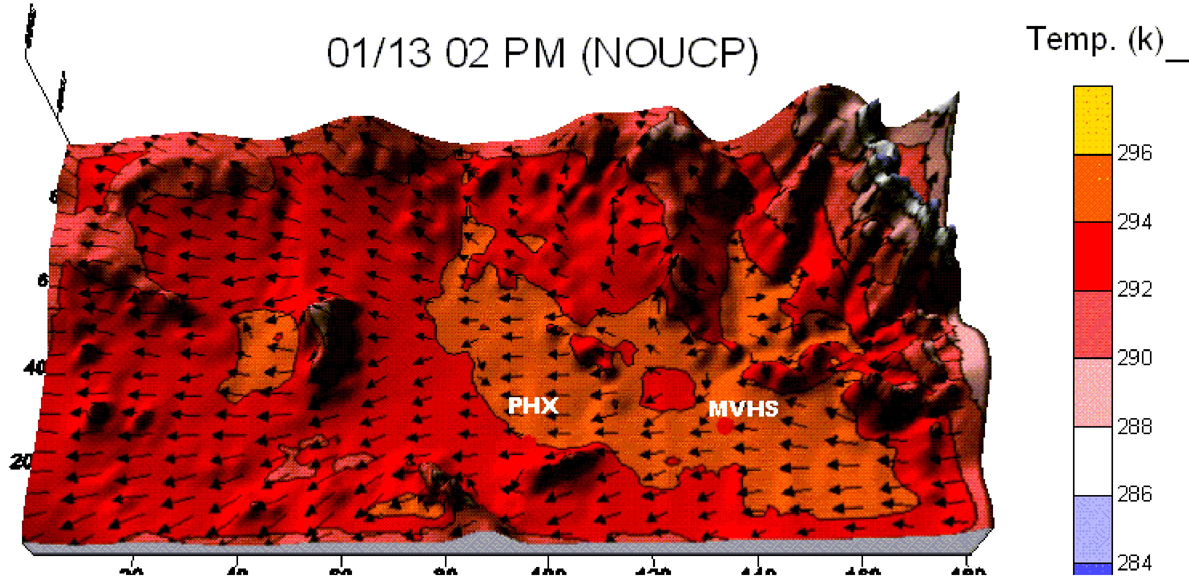
UHI Effect



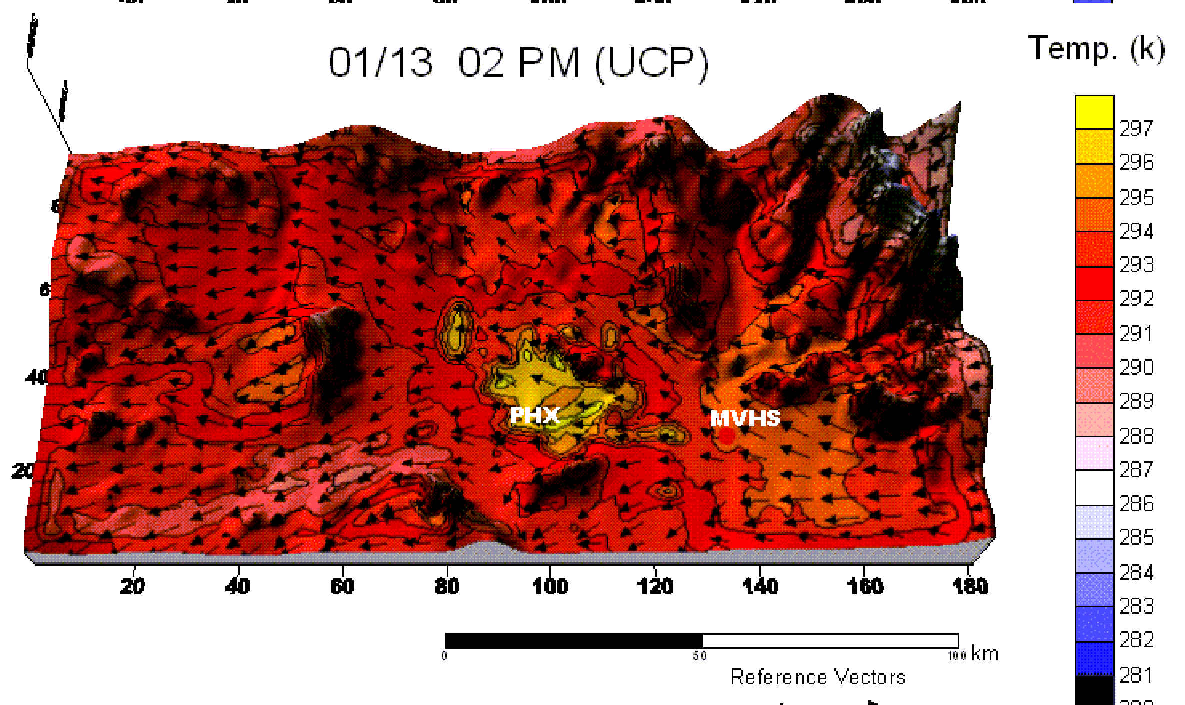
- During the night, The temperature difference between Urban and Rural is 1° (NoUCP), but, UHI is simulated as 3° by MM5/UCP(modifed).

Surface Wind and Temperature

NoUCP

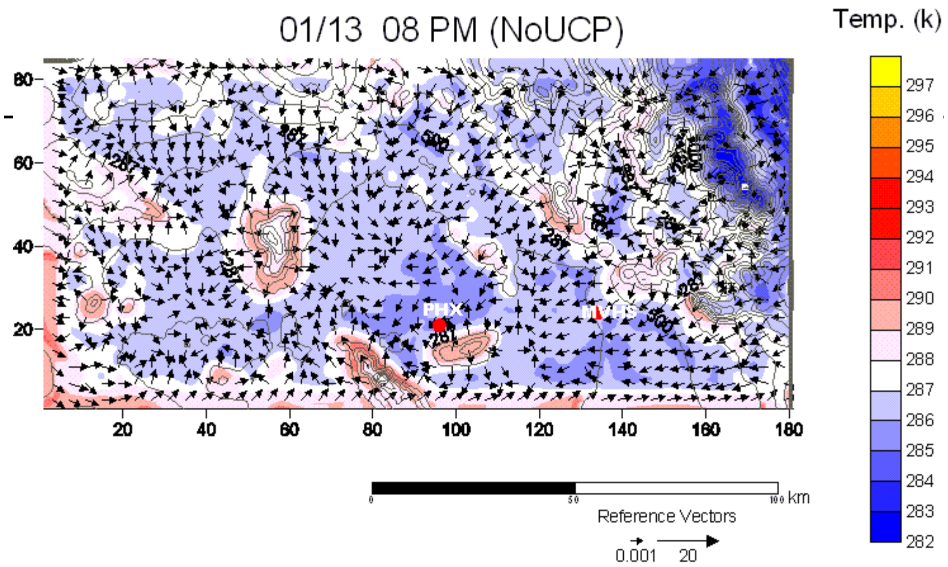


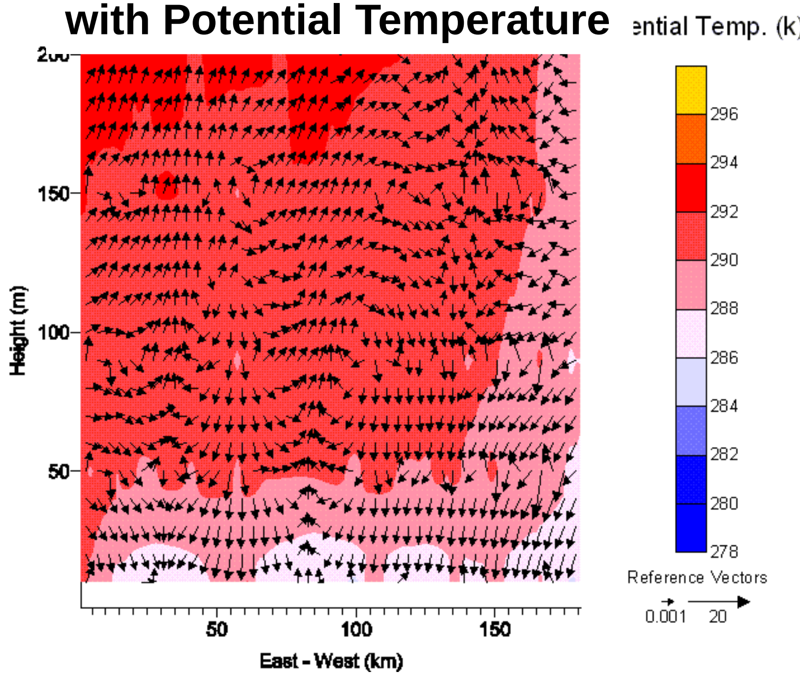
UCP

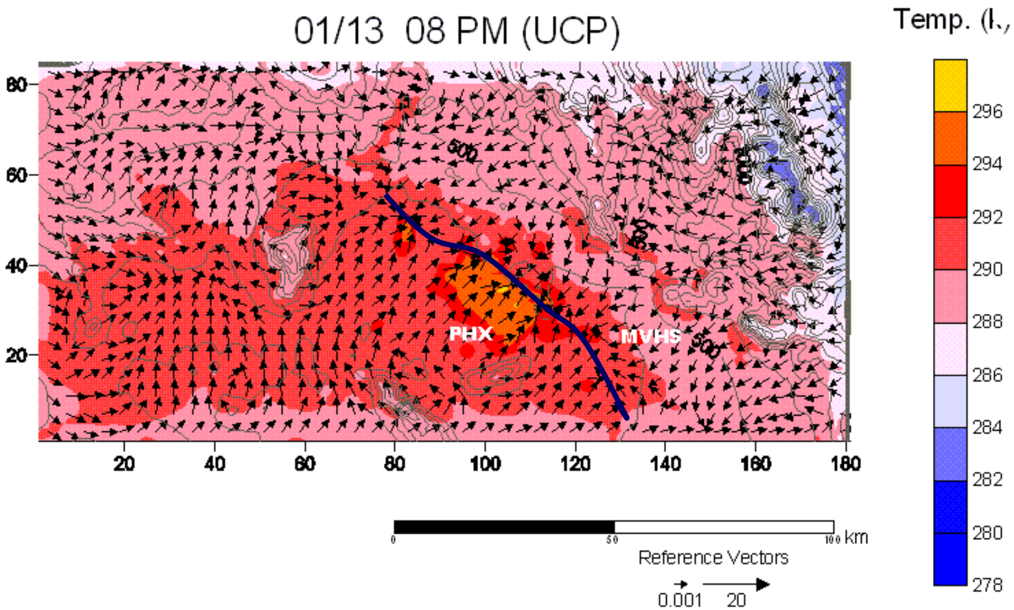


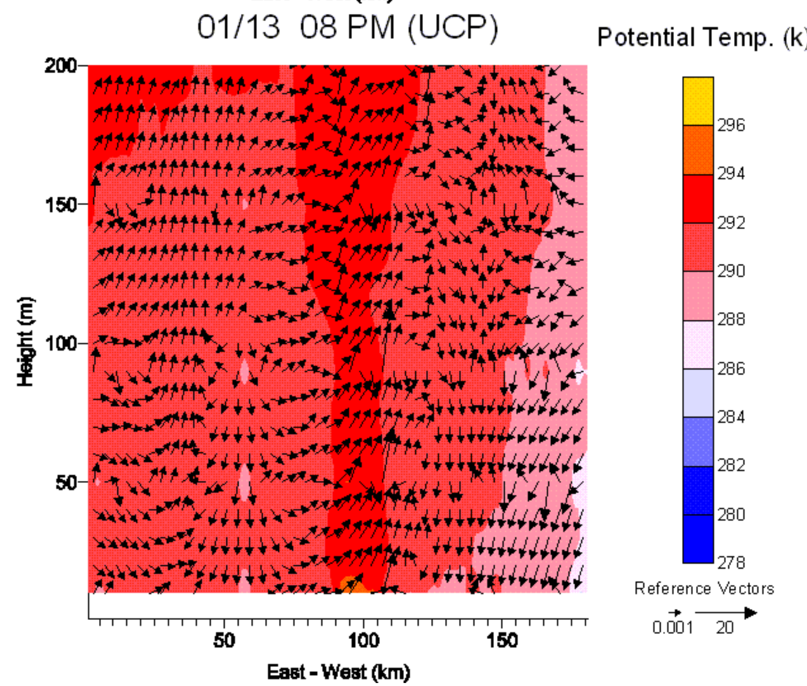
Surface Wind and Temperature

Vertical Cross-section with Potential Temperature



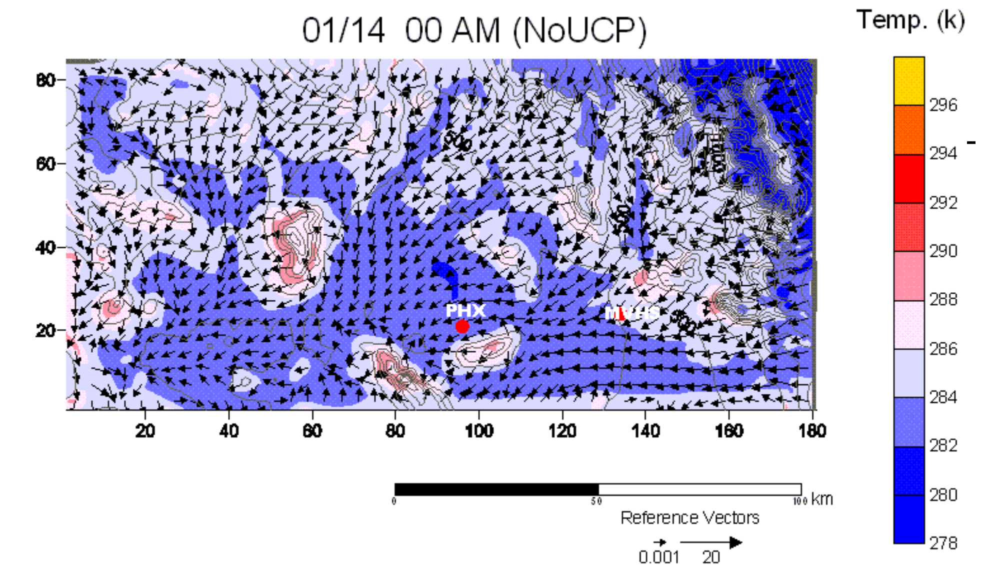


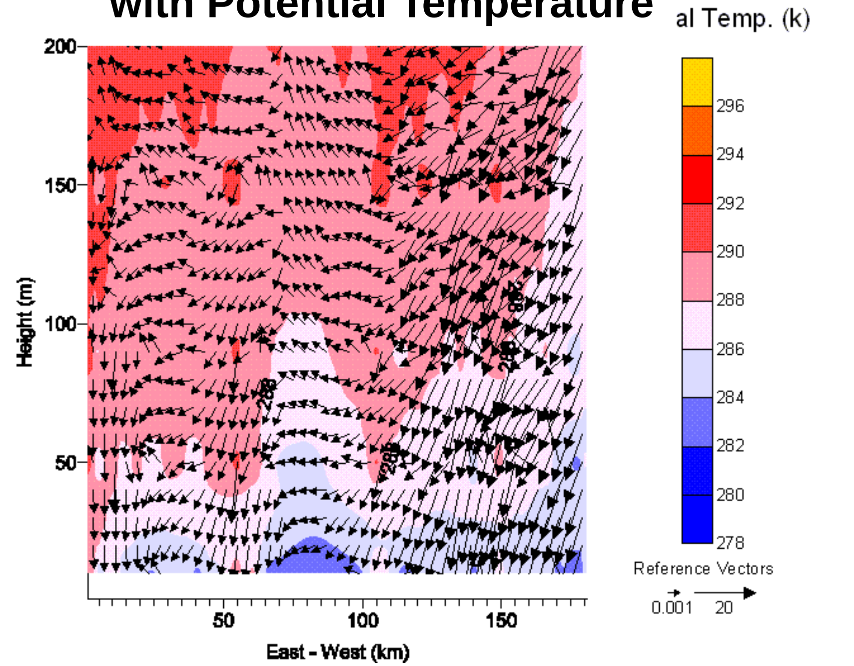


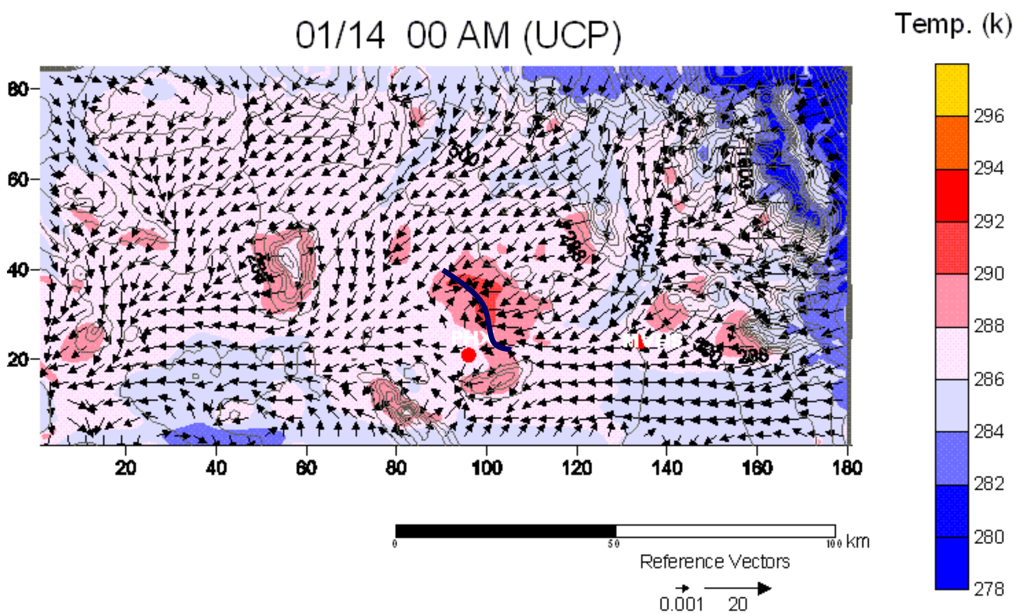


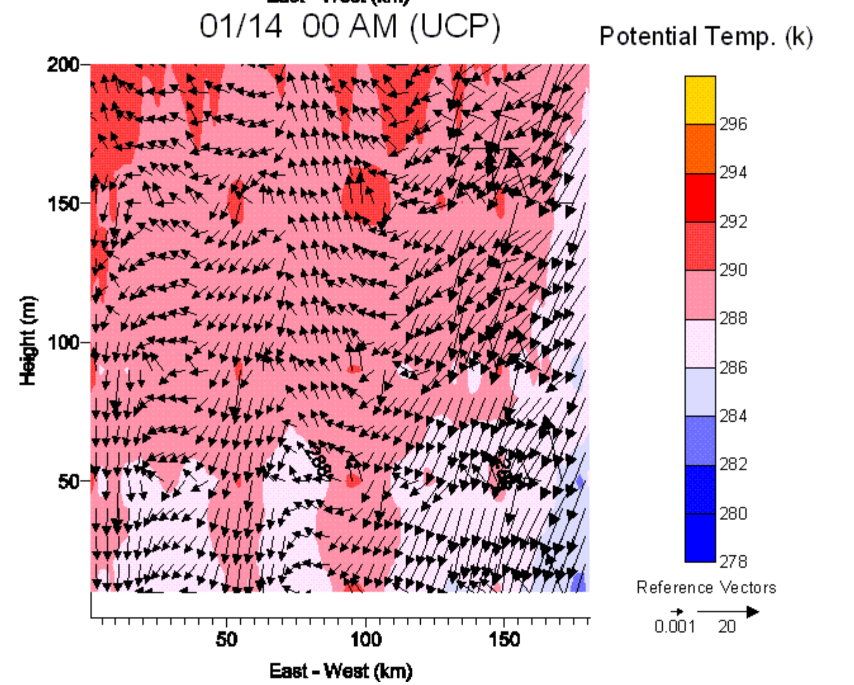
Surface Wind and Temperature

Vertical Cross-section with Potential Temperature



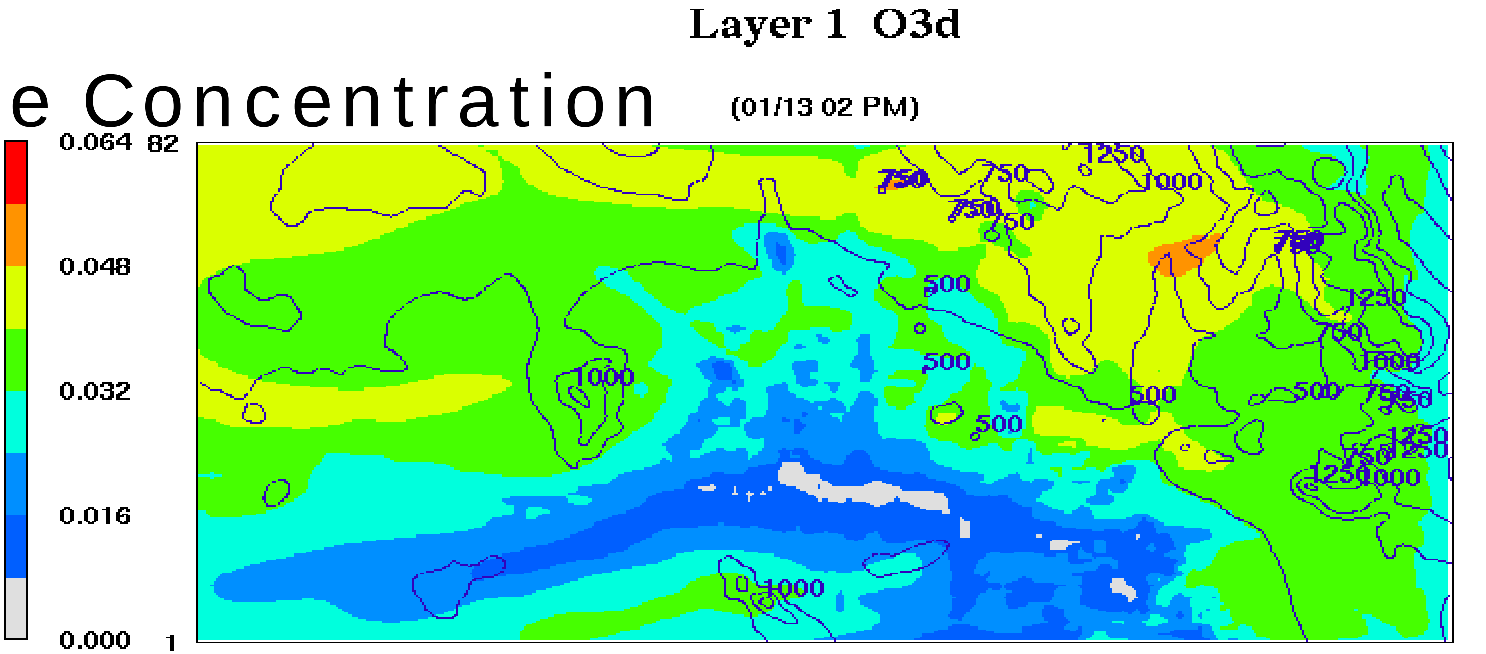




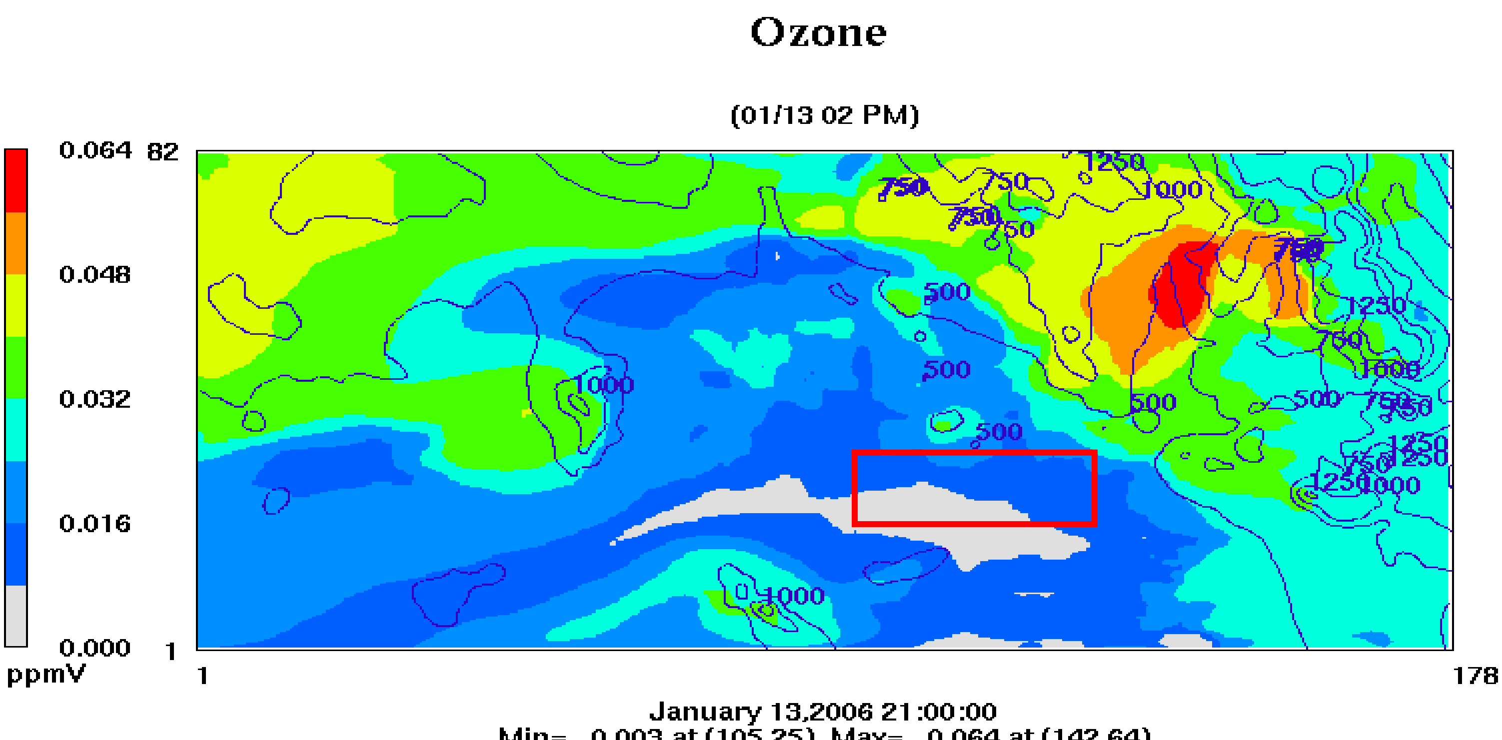


Ozone Concentration

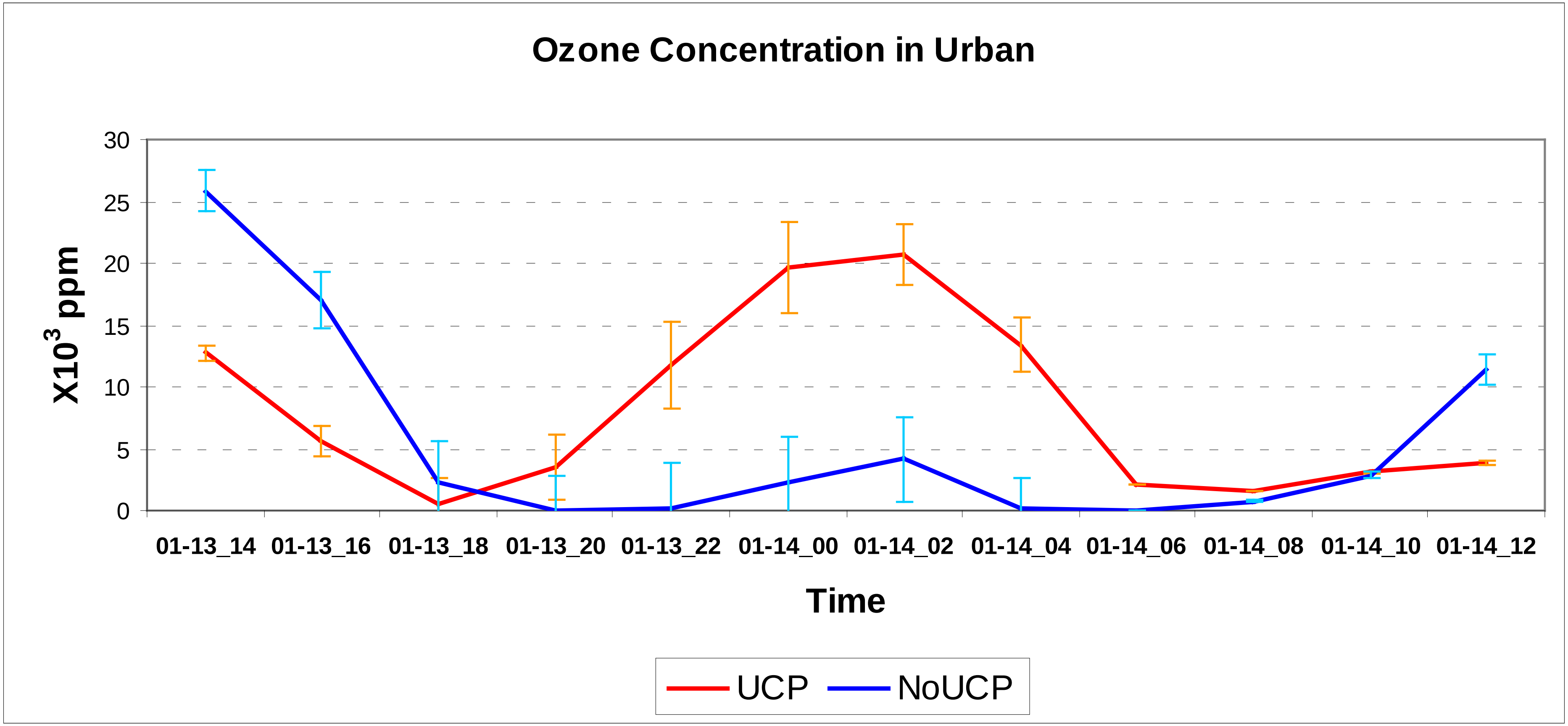
NoUCP



UCP



Maximum Concentration of Ozone

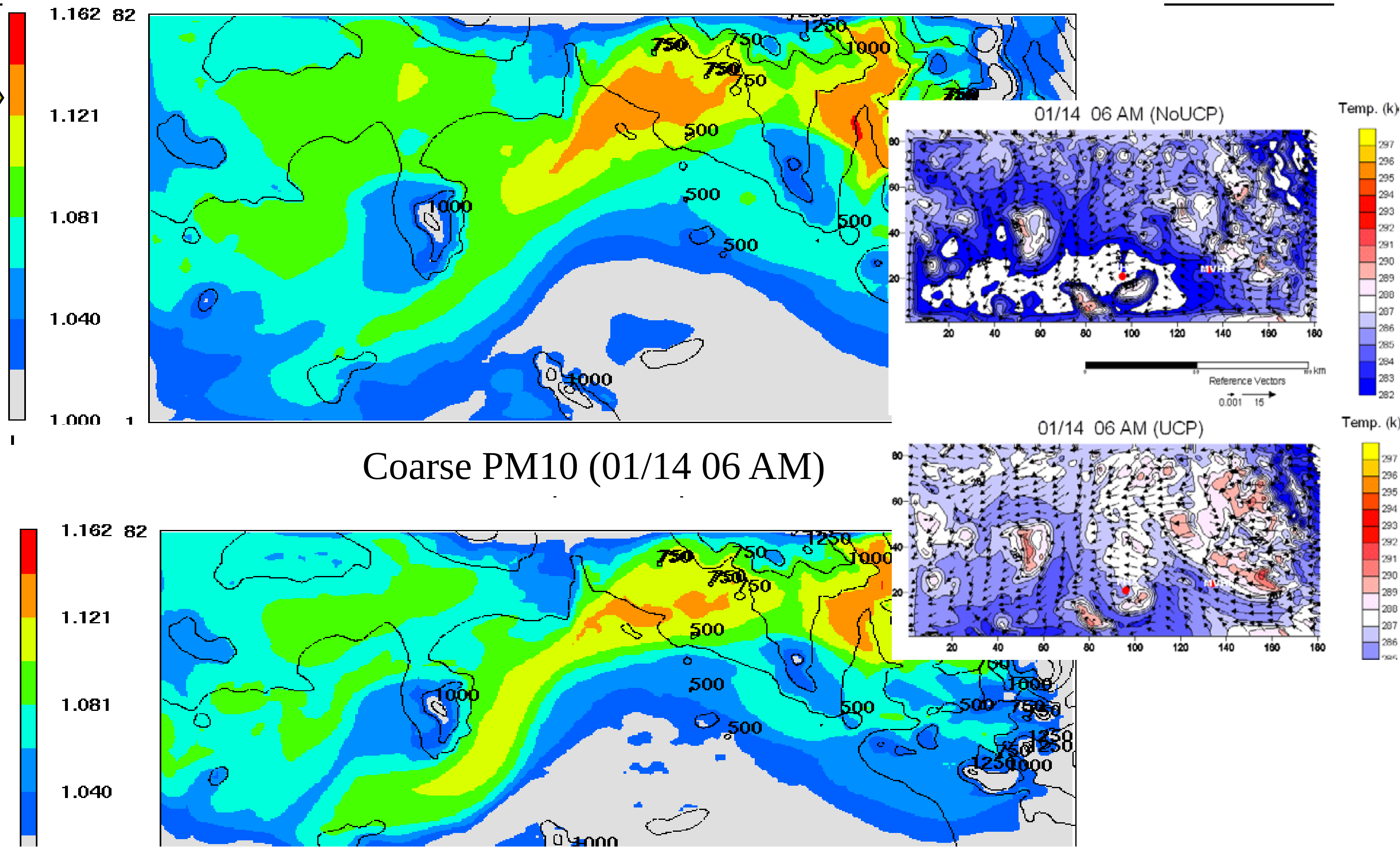


- The maximum concentration of O3 in the northeastern urban area by UCP case is higher than the NoUCP in the night, because the developed local down-slope flow could be simulated by UCP version.

Transportation of Coarse PM10 in the Early Morning

NoUCP

UCP



Coarse PM10 (01/14 06 AM)

- Because of valley winds + UHI, high PM10 is moved to the urban area in the early morning. This, coupled with high PM2.5 formed during nighttime, may cause low visibility.

Conclusion

- **MM5/urbanized model was applied to the Phoenix area**
  - **Successful implementation of the model**
  - **Urban data for Phoenix considered the anthropogenic heat flux of roads and the effects of a river.**
- **MM5/Urbanized was modified as follows**
  - **Changing the eddy diffusivity using k-ε equation**
  - **Modifying the parameterization of momentum eddy diffusivity for stable stability**
  - **Modifying the parameterization heat flux for transition event in neutral cases**
  - **Changing the roughness length**
- **After modification, the RMSE of simulation result of momentum flux and the other variables is decreased about 50% and over.**

The 2nd Thammasat University
International Conference on Chemical, Environmental and Energy Engineering

STATISTICAL ANALYSIS OF URBAN MORPHOLOGICAL INDICATORS AND STREET-LEVEL AIR POLLUTION IN HONG KONG

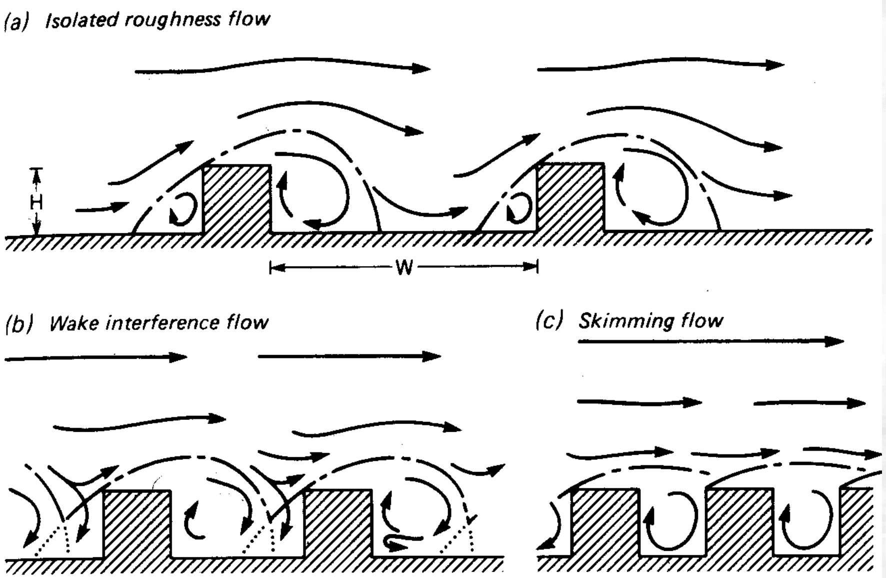
The University of Nottingham

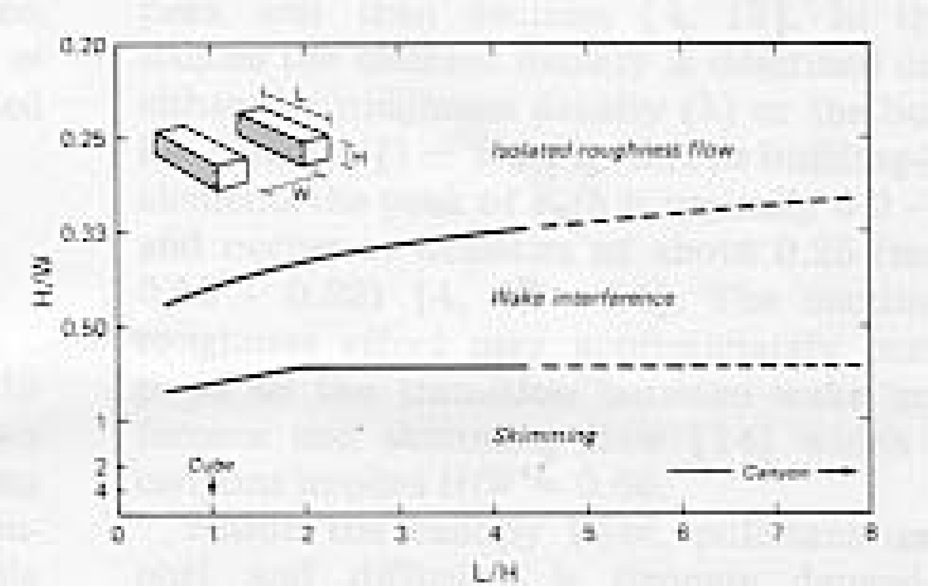
Andy Chan, University of Nottingham
Priyantha Edussuriya, Leigh and Orange
Arlen Ye, University of Hong Kong

Introduction and motivation

- Urban density and geometries are often considered as the main factor of poor urban air quality.
- Which aspects of urban geometries then?

Simplistic urban geometries





- Oke's (1988) flow classifications
- Modern urban layouts are not lego
- Too idealistic for real situations

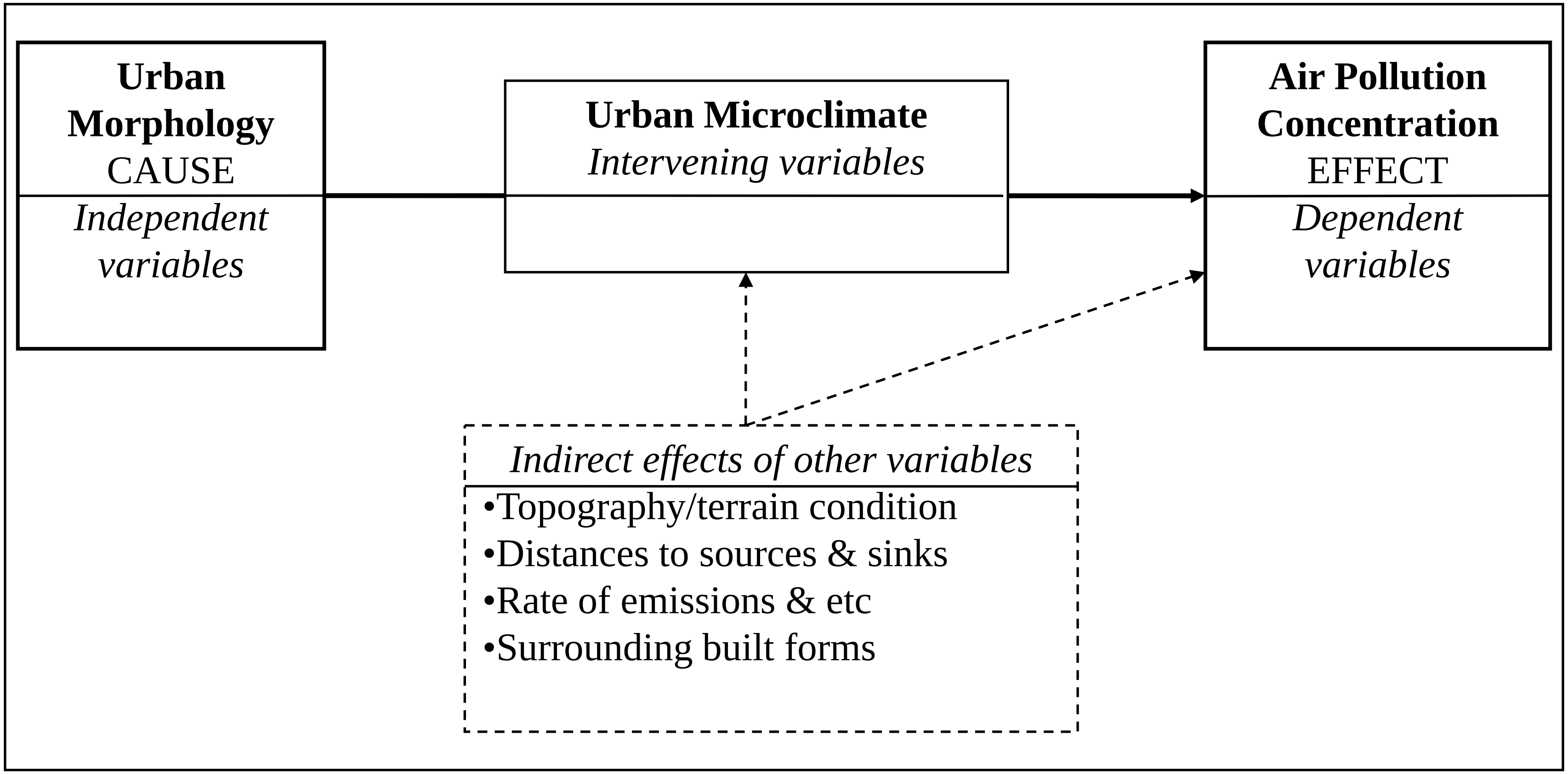
Modern urban geometries

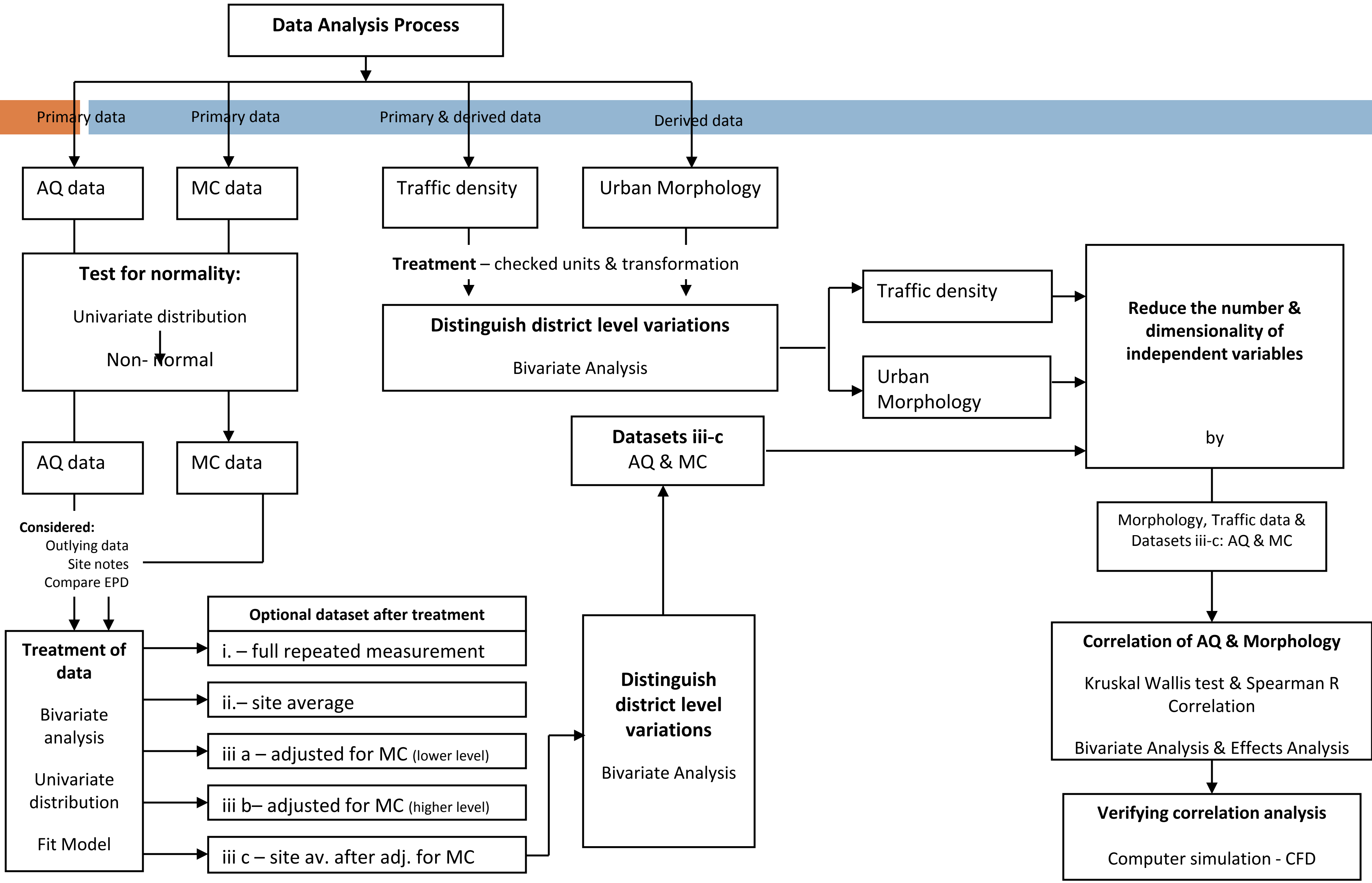
- Modern building geometries and urban layouts are more complex
- There are definitely more than just length, width and height

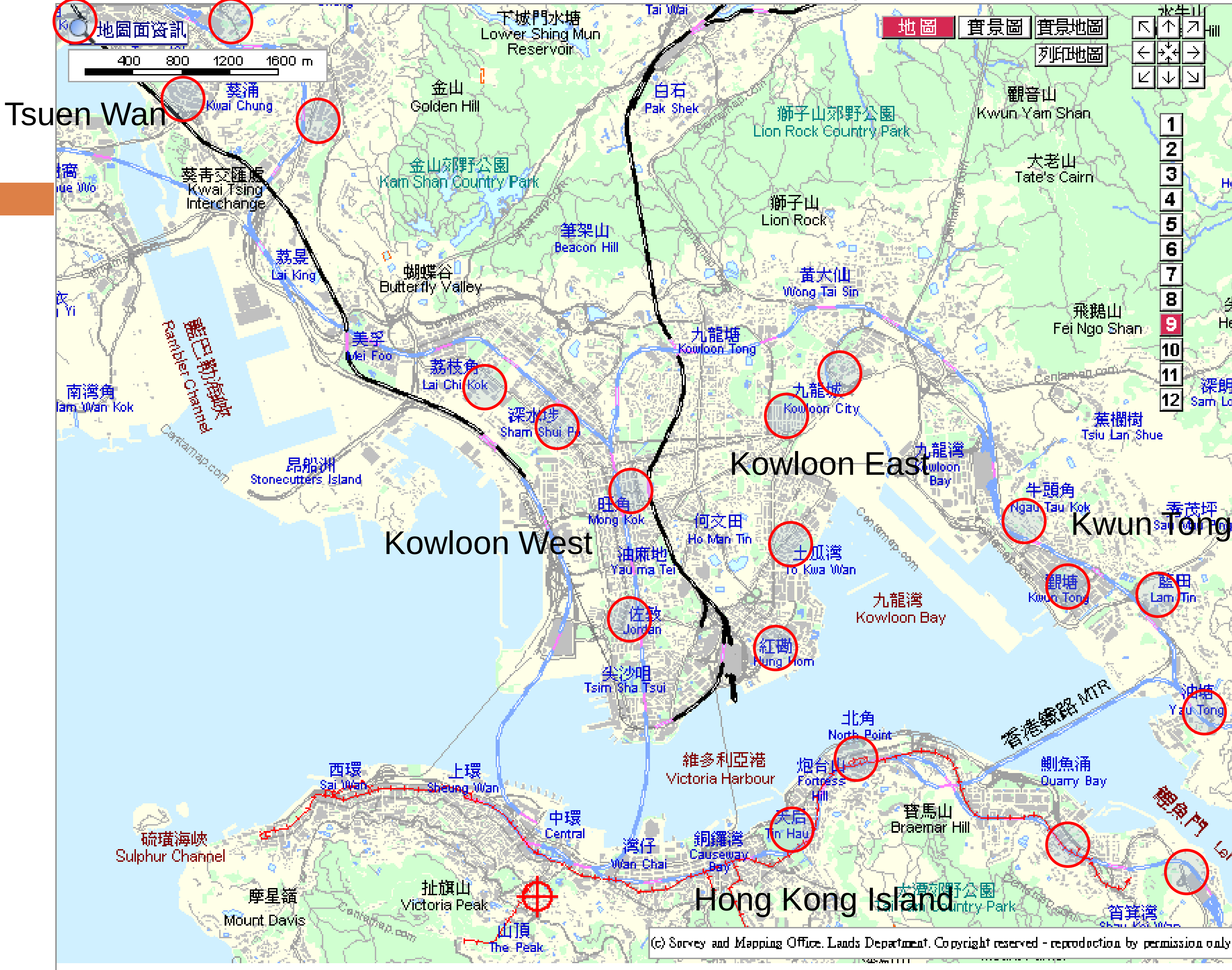
Urban morphological indicators

Affect variables	Independent variables	
	Development factors	Built form factors
1. Regional factors - topography / urban terrain - altitude - distance from water body	1. Land coverage / utilisation -plot ratio, packing ratio - mineralisation factor / percentage of impervious surface	1. Street and building dimensions - canyon aspect ratio - street aspect ratio - canopy breadth ratio - street block ratio - mean building height - mean canyon width
2. City-level factors - urban layout: layout, development, street form, open spaces, roof - city size / quotient - proximity to pollution sources and sinks	2. Land use intensity - compacity factor - complete aspect ratio - mean contiguity factor - frontal area density	2. Canyon / building orientation - wind angle to longer-street axis of buildings
3. Site composition / locality factors - population density quotient - urban land use - traffic load - location	3. Roughness related intensity - urban density, rugocity or floor area ratio - roughness height - zero-plane displacement height - mean built volume - urban porosity - sinuosity - occlusivity	

Research question




Data Analysis Process
Primary data
Primary data
Primary & derived data
Derived data
AQ data
MC data
Traffic density
Urban Morphology
Test for normality:
Univariate distribution
Non- Normal
Treatment – checked units & transformation
Distinguish district level variations
Bivariate Analysis
Traffic density
Urban Morphology
Reduce the number & dimensionality of independent variables
by
AQ data
MC data
Datasets iii-c
AQ & MC
Morphology, Traffic data & Datasets iii-c: AQ & MC
Considered:
Outlying data
Site notes
Compare EPD
Optional dataset after treatment
i. – full repeated measurement
ii.– site average
iii a – adjusted for MC (lower level)
iii b– adjusted for MC (higher level)
iii c – site av. after adj. for MC
Treatment of data
Bivariate analysis
Univariate distribution
Fit Model
Distinguish district level variations
Bivariate Analysis
Correlation of AQ & Morphology
Kruskal Wallis test & Spearman R Correlation
Bivariate Analysis & Effects Analysis
Verifying correlation analysis
Computer simulation - CFD



Tsuen Wan
Kowloon West
Kowloon East
Kwun Tong
Hong Kong Island
地圖面資訊
400 800 1200 1600 m
下城門水塘
Lower Shing Mun Reservoir
地圖
實景圖
實景地圖
列印地圖
葵涌
Kwai Chung
金山
Golden Hill
白石
Pak Shek
獅子山郊野公園
Lion Rock Country Park
觀音山
Kwun Yam Shan
葵青交匯處
Kwai Tsing Interchange
金山郊野公園
Kam Shan Country Park
大老山
Tate's Cairn
獅子山
Lion Rock
筆架山
Beacon Hill
荔景
Lai King
蝴蝶谷
Butterfly Valley
黃大仙
Wong Tai Sin
飛鵝山
Fei Ngo Shan
藍巴勒海峽
Rambler Channel
美孚
Mei Foo
九龍塘
Kowloon Tong
南灣角
Nam Wan Kok
荔枝角
Lai Chi Kok
九龍城
Kowloon City
深水埗
Sham Shui Po
葉欄樹
Tsiu Lan Shue
昂船洲
Stonecutters Island
九龍灣
Kowloon Bay
牛頭角
Ngau Tau Kok
旺角
Mong Kok
何文田
Ho Man Tin
土瓜灣
To Kwa Wan
油麻地
Yau ma Tei
觀塘
Kwun Tong
藍田
Lam Tin
九龍灣
Kowloon Bay
佐敦
Jordan
紅磡
Hung Hom
尖沙咀
Tsim Sha Tsui
油塘
Yau Tong
香港鐵路 MTR
北角
North Point
西環
Sai Wan
上環
Sheung Wan
維多利亞港
Victoria Harbour
炮台山
Fortress Hill
鰂魚涌
Quarry Bay
中環
Central
天后
Tin Hau
寶馬山
Braemar Hill
硫磺海峽
Sulphur Channel
灣仔
Wan Chai
銅鑼灣
Causeway Bay
鯉魚門
扯旗山
Victoria Peak
摩星嶺
Mount Davis
山頂
The Peak
筲箕灣
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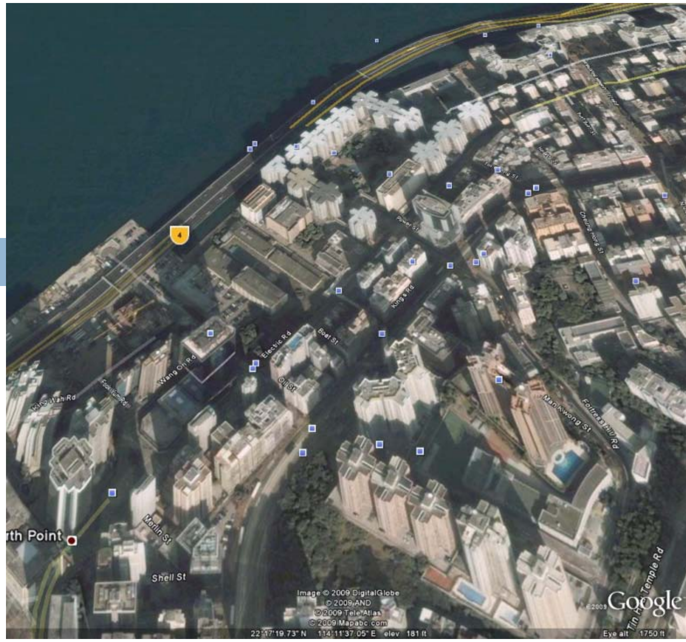
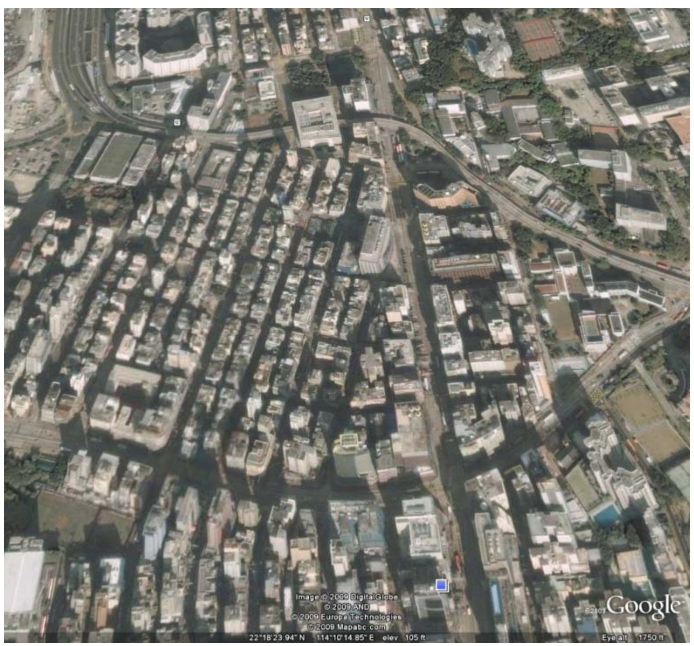
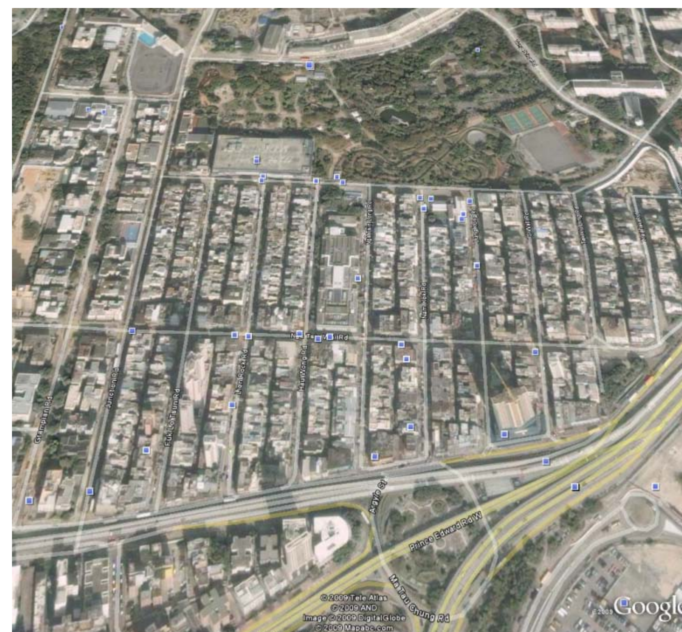


North Point

Kwun Tong



Jordan

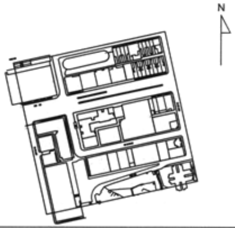
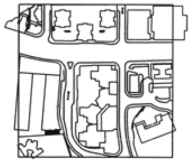
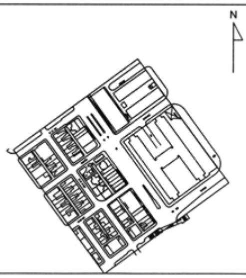
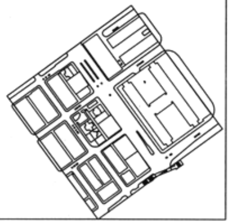


Kowloon City

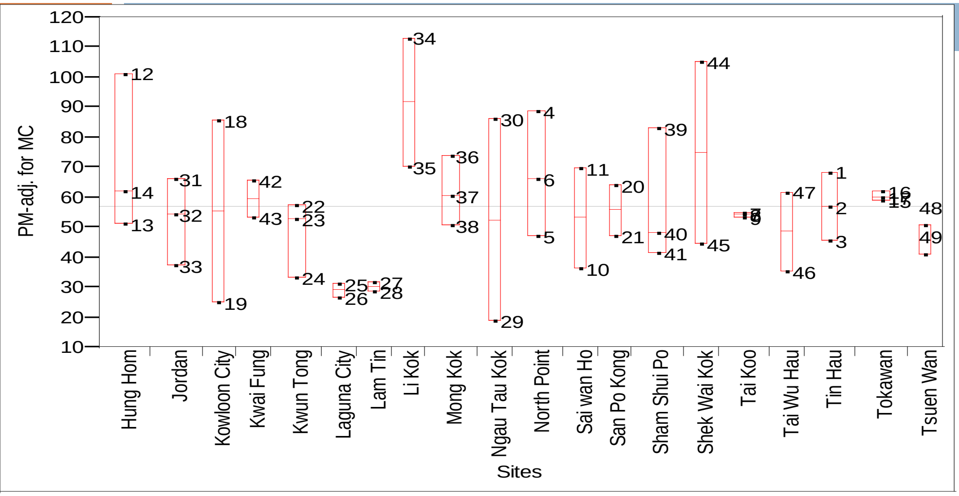
Data measurements

Dustscan Sentinel Model 3030 Aerosol Monitor

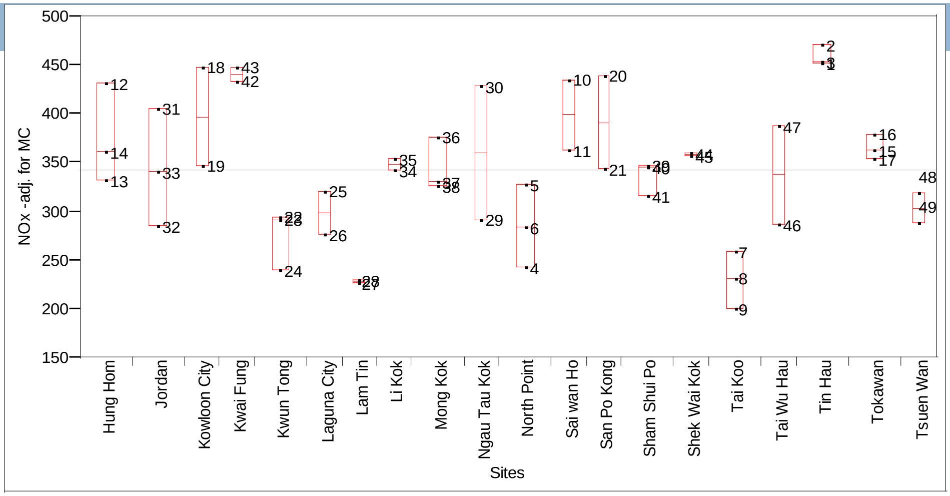
ETL 2000 Multi-component Air Quality Monitor

Site	Original sites	After simplified
Tin Hau		
North Point		
Tai Koo Shing		
Sai Wan Ho		

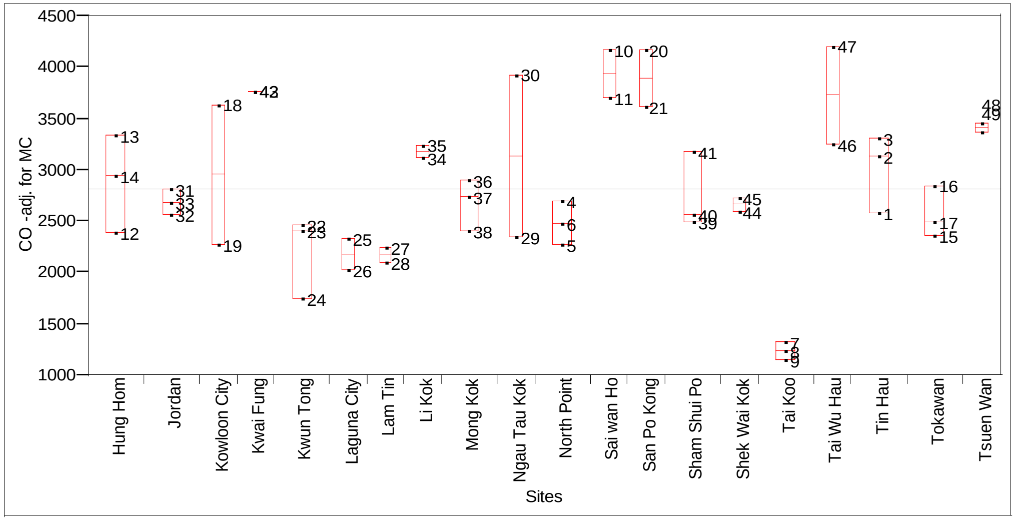
Field measurement results



One-way analysis of PM by sites



One-way analysis of NOx by sites

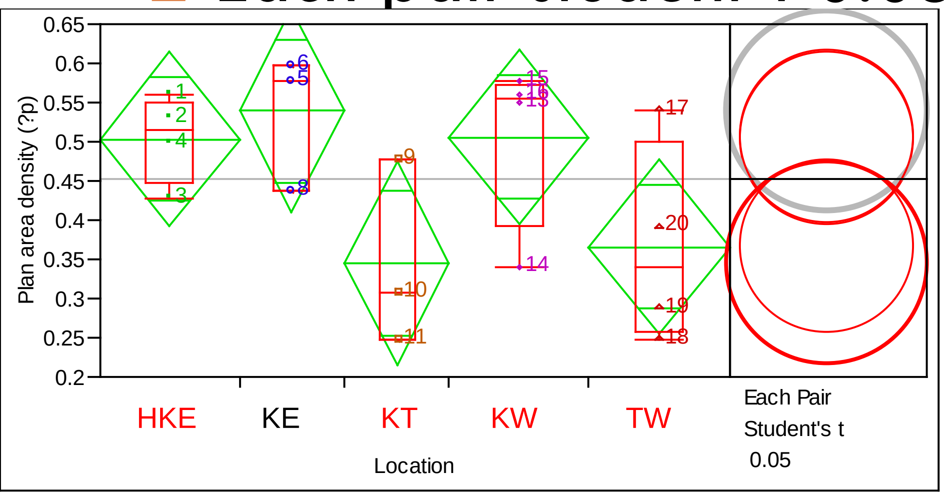


One-way analysis of CO by sites

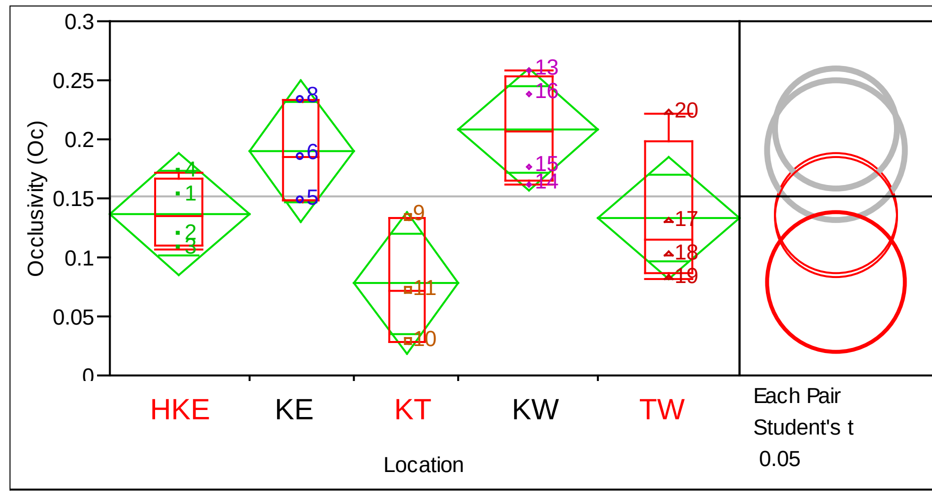
Stage 1: District-level analysis

	Test Parameters	R2	Adjusted. R2	F. ratio	P. value	Mean variance of location	Significance at district level variability	Significance at site level variability	Similar groups
Land utilisation factors									
1	Plan area index (λ_p)	0.4350	0.2612	2.503	0.093	0.3466 – 0.5400	- KWE vs. KT: district level differences - KW-HKE and KT-TW: similar group means.	- distance to group means in sites in all districts report distinguishable differences within district	2
Land-use development factors									
9	Occluvisity (Oc)	0.5457	0.4060	3.905	0.0269	0.0778 – 0.2095	- KT vs. KE and KW: district level differences - HKE-TW: similar group means	- all districts report moderately distinguishable differences within district	2
11	Roughness height z_0	0.4450	0.2743	2.606	0.0840	2.757 – 15.308	- KT vs. KE & KW: district level differences -distances to grand mean insignificant -KE and KW: similar district means	- two districts report distinguishable differences within district and others moderate or less	4
12	Zero-displacement height z_d	0.2937	0.0764	13519	0.3034	26.89 – 44.77	- distances to grand mean from group means are less significant - HKE and KT: similar group means	- all districts report significant distinguishable differences within district	1
13	Σ mean built volume	0.4447	0.2739	2.6033	0.085	26.125 – 64.53	- KW vs. KT & KW: district level differences - distances to grand mean from group means are moderately significant	- two districts report distinguishable differences within district and others moderate or less	3
Built and Street geometrical factors									
20	Standard deviation of building height	0.5243	0.3780	3.5831	0.0352	16.32 – 41.16	- KW vs. KE and KT: district level differences - distances to grand mean from group means are significant	- KW and HKE report moderately distinguishable differences within district within district	3

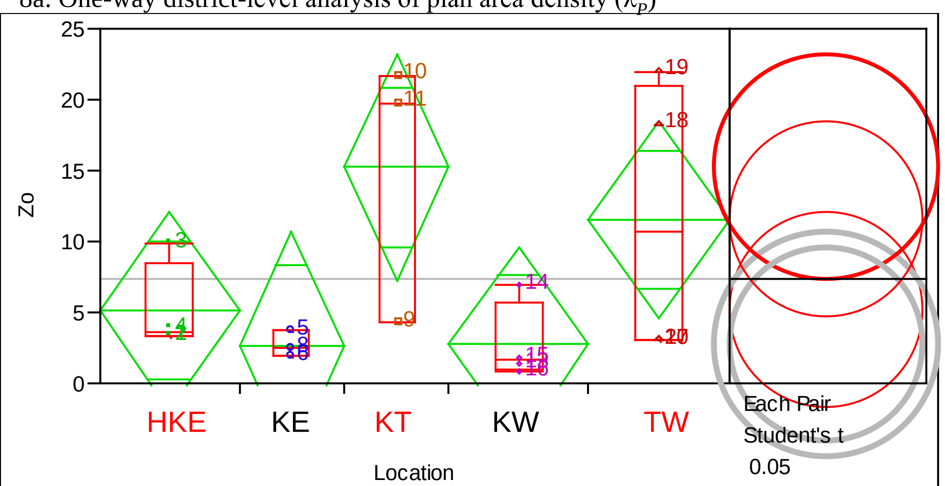
□ Each pair student-t 0.05



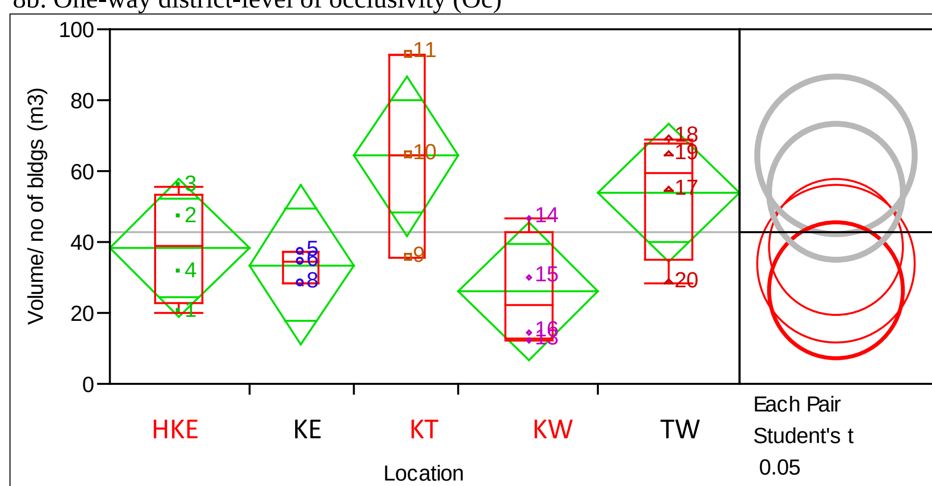
8a: One-way district-level analysis of plan area density (λ_p)



8b: One-way district-level of occlusivity (Oc)



8c: One-way district-level of roughness height (z_0)



8e: One-way district-level of mean building volume

Interpratation I

- At district level, only 6 out of the so many variables report distinguishable variability
- Complete aspect ratio, occlusivity, roughness height, zero-plane displacement height, mean building volume and height standard deviation
- In spite of the large in-district variations, air pollution variations are insignificant across different districts.
- Air quality are not distinguishable at district level.

Stage 2: Identifying the important indicators

- Use of principal component analysis (PCA)

Variable	Axis 1	Axis 2
Compactness factor - Cf	0.389479	-0.717278
Complete aspect ratio	-0.045834	-0.180839
Mean contiguity factor	0.020864	-0.944146
Frontal area density (λf)	0.096882	0.093286

Variable	Axis 1	Axis 2
Porosity (Po)	-0.049398	0.986747
Sinuosity (So)	-0.14207	0.022855
Occlusivity (Oc)	0.504334	-0.027774

Variable	Axis 1	Axis 2
Canyon ratio	0.362131	0.866877
Aspect ratio - Lst. / H	-0.911254	-0.105221
Breadth ratio	-0.191212	0.726656
Block ratio (street)	0.767251	-0.11076

Variable	Axis 1	Axis 2
Rugosity (m)	0.114996	-0.972244
Zo	0.950985	0.189386
Zd	0.339208	0.88706
Volume/ no of bldgs (m3)	0.870117	0.307544

Variable	Axis 1	Axis 2
D - distance between bldgs. (m)	0.832141	0.29075
Mean bldg.height (m)	0.906032	0.160549
Std# deviation of bldg# height	0.816188	0.021371

	Analyses	**Outcomes of PCA decision** (variables to be removed marked as X)				**Multivariate analysis results:** with significant relationship	**Selected variables**
	Variables	Approach 1 Multivariate Analysis	Approach 2 PCs Variance	Approach 3 PCs Loadings	Variables to remove		
Factors							
	Traffic						
1	# cars on road	X	?	X	X	X	-
2	VKT (200 grid)	-	-	-	-	PM, NOx	Yes
3	AADT (1000 grid)	-	-	-	-	PM	Yes
Co-variants							
	Land utilization Indicators						
1	Plan area density (λp)	?	-	-	-	NOx & PM	Yes
2	Mineralisation factor	X	X	-	?	PM	Yes -?
	Compactness effects						
1	Compactness factor	?	-	-	-	NOx & PM	Yes
2	Complete aspect ratio	X	-	X	X	-	-
3	Mean contiguity factor	-	-	-	-	NOx & PM	Yes
4	Frontal area density (λf)	X	-	X	X	-	-
	Pores effects						
1	Porosity (Po)	-	-	-	-	PM	Yes
2	Sinousity (So)	X	-	X	X	-	-
2	Occlusivity (Oc)	X	-	-	-	NOx & PM	Yes
	Roughness effects						
1	Rugosity or FAR	-	-	-	-	PM	Yes
2	Zo	-	-	-	-	NOx & PM	Yes
3	Zd	X	-	-	X	NOx	-
4	Σ mean built volume	?	-	-	-	PM	Yes
	Canyon indicators						
1	Canyon ratio (H / Wst)	-	-	-	-	PM	Yes
2	Aspect ratio (Lst / H)	X	-	-	-	-	Yes
3	Breadth ratio	X	-	X	X	NOx & PM	-
4	Block ratio (street)	-	-	X	X - ?	CO	-
	Bldg & Street Geometry						
1	Distance between bldg	X	-	-	-	NOx & PM	Yes
2	Mean bldg. height	X	-	-	-	NOx & PM	Yes
3	Std. dev. of bldg. ht.	-	X	-	-	NOx & PM	Yes

Interpretation II

- At site level, more variables seem to play a role in affecting air quality
- Traffic factors, land utilisation factors, compactness factors, porous factors, roughness factors, canyon factors, building geometry

Stage 3: Testing hypothesis

- The hypothesis: There is a correlation between street-level air pollution and urban morphological variables.
- Use Kruskal-Wallis rank-sum analysis (examines the correlation variables)
  - Null hypothesis H_0: Urban morphological parameters have no effects on street-level air pollution
  - Alternative hypothesis H_1: Urban morphological parameters have effects on street-level air pollution
  - Critical values for confidence level $(P>\chi^2)$ 0.05 – 0.1

Test statistics PM	Kruskal-Wallis Test H - chi-sq	DF	Prob>H	Dunn's test	Reject / accept *Ho*
Factors					
I Traffic					
Near field traffic	7.632	2	0.0220	means of 1 < 2/3 & 2 # 3	Reject Ho
Intermediate field traffic	6.615	2	0.0366	means of 1 < 2 & 2 # 3	Reject Ho
II Location					
Latitude	0.883	2	0.6428	-	Accept Ho
Longitude	0.239	2	0.8874	-	Accept Ho
III Microclimate					
Level of Temperature	1.551	2	0.4605	-	Accept Ho
Level of RH	3.923	2	0.1406	-	Accept Ho?
Level of wind effect (E-W)	0.283	2	0.8679	-	Accept Ho
Level of wind effect (N-S)	2.753	2	0.2524	means of 1 < 3 & 2 # 1	Accept Ho?
Co-variants					
IV Land utilization indicators					
Plan area density (λp)	9.964	2	0.0069	means of 1 < 2 & 3	Reject Ho
Mineralisation factor	4.833	2	0.0892	-	Accept Ho?
Land use intensity indicators					
Compactness factor	5.027	2	0.0810	means of 1 < 3 & 2 # 3	Accept Ho?
Mean contiguity factor	4.393	2	0.1114	-	Accept Ho?
Porosity (Po)	1.185	2	0.5529	-	Accept Ho
Occlusivity (Oc)	9.172	2	0.0102	means of 1 < 3 & 2 # 3	Reject Ho
Rugosity or FAR	4.587	2	0.1009	-	Accept Ho?
Zo	9.063	2	0.010	means of 1 < 2/3 & 2 # 3	Reject Ho
Σ mean built volume	9.550	2	0.0084	means of 1 < 2 & 2 # 3	Reject Ho
Building & Street Geometry					
Canyon ratio (H / Wst)	2.203	2	0.2233	-	Accept Ho?
Aspect ratio (Lst / H)	6.458	2	0.0396	means of 1 < 2 & 2 # 3	Reject Ho
Distance between building	7.067	2	0.0292	means of 1 < 2/3 & 2 # 3	Reject Ho
Mean building height	8.338	2	0.0155	means of 1 < 2/3 & 2 # 3	Reject Ho
Std. dev. of bldg. height	7.370	2	0.0251	means of 1 < 3 & 2 # 3	Reject Ho
Building & Street Orientation					
Wind angle to longer axis	5.40 (G^2)	10	0.858	n/a	Accept Ho?

Test statistics NOx	Kruskal-Wallis Test H - chi-sq	DF	Prob>H	Dunn's test	Reject /accept *Ho*
Factors					
I Traffic					
Near field traffic	6.830	2	0.032	means of 1 < 2 & 2 # 3	Reject Ho
Intermediate field traffic	6.852	2	0.032	means of 1 < 2 & 2 # 3	Reject Ho
II Location					
Latitude	0.002	2	0.998	-	Accept Ho
Longitude	0.500	2	0.778	-	Accept Ho
III Microclimate					
Level of Temperature	0.417	2	0.811	-	Accept Ho
Level of RH	5.221	2	0.073	means of 2 < 3 & 2 # 1	Reject Ho
Level of wind effect (E-W)	0.536	2	0.764	-	Accept Ho
Level of wind effect (N-S)	3.263	2	0.195	-	Accept Ho?
Co-variants					
IV Land utilization indicators					
Plan area density (λp)	9.231	2	0.009	means of 1 < 3 & 2 # 3	Reject Ho
Mineralisation factor	4.139	2	0.126	-	Accept Ho?
Land use intensity indicators					
Compactness factor	4.331	2	0.114	means of 1 < 3 & 2 # 3	Accept Ho?
Mean contiguity factor	5.829	2	0.054	means of 1 < 2/3 & 2 # 3	Reject Ho
Porosity (Po)	0.662	2	0.718	-	Accept Ho
Occlusivity (Oc)	11.27	2	0.003	means of 1 < 2 & 2 # 3	Reject Ho
Rugosity or FAR	3.651	2	0.161	-	Accept Ho
Zo	10.263	2	0.005	means of 1 < 2/3 & 2 # 3	Reject Ho
Σ mean built volume	10.35	2	0.005	means of 1 < 2/3 & 2 # 3	Reject Ho
Building & Street Geometry					
Canyon ratio (H / Wst)	1.045	2	0.593	-	Accept Ho
Aspect ratio (Lst / H)	8.540	2	0.014	means of 1 < 2 & 2 # 3	Reject Ho
Distance between building	8.559	2	0.013	means of 1 < 2/3 & 2 # 3	Reject Ho
Mean building height	11.30	2	0.003	means of 1 < 2/3 & 2 # 3	Reject Ho
Std. dev. of bldg. height	11.27	2	0.003	means of 1 < 2 & 2 # 3	Reject Ho
Building & Street Orientation					
Wind angle to longer axis	8.38 (G^2)	10	0.596	n/a	Accept Ho?

Interpretations III

- The Kruskal-Wallis test results support the assignment of the alternative hypothesis H_1.
- Traffic variables report significant difference amongst NOx and PM.
- CO data cannot be further pursued.
- 5 land development and 4 street and geometrical variables affect street level air pollution directly
- 6 developments (with three marginal) and 2 street and geometrical (with one marginal) variables affect street level air pollution directly through urban climate.

Stage 4: Testing the strengths of correlation

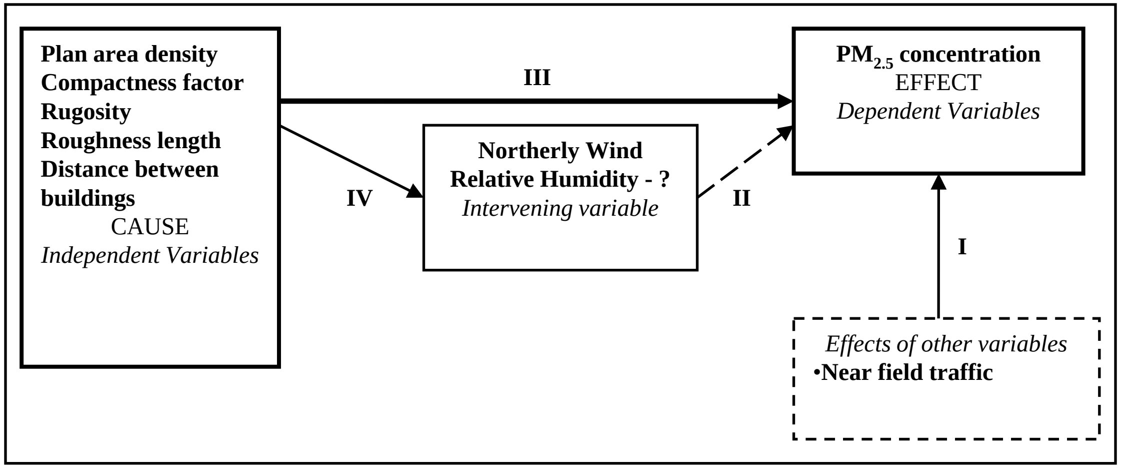
- Spearman R correlation analysis (test of strength of correlation)
  - Null hypothesis (H_0): There is no correlation between street level air pollutant concentration and urban morphological variables
  - Alternative hypothesis (H_2): There is correlation between street level air pollutant concentration and urban morphological variables

Test statistics PM	Spearman's rank analysis results			Reject /accept *Ho*
	Spearman's = r_s	DF	Prob>	
Factors				
I Traffic				
Near field traffic	0.470	17	0.048	Reject Ho
Intermediate field traffic	0.318	17	0.197	Accept Ho
II Microclimate				
Level of Temperature	0.108	17	0.667	Accept Ho
Level of RH	-0.244	17	0.327	Accept Ho-?
Level of wind effect (E-W)	-0.034	17	0.893	Accept Ho
Level of wind effect (N-S)	0.341	17	0.165	Accept Ho-?
Co-variants				
III Land utilization indicators				
Plan area density (λp)	0.739	17	0.0005	Reject Ho
Mineralisation factor	0.443	17	0.065	Accept Ho-?
Land use intensity indicators				
Compactness factor	0.633	17	0.005	Reject Ho
Mean contiguity factor	0.429	17	0.075	Accept Ho-?
Porosity ()	-0.134	17	0.595	Accept Ho
Occlusivity (Oc)	0.363	17	0.132	Accept Ho
Rugosity or FAR	0.500	17	0.034	Reject Ho
Zo	-0.581	17	0.011	Reject Ho
Σ Vblg. /no. of blg	-0.401	17	0.099	Accept Ho-?
Building & Street Geometry				
Canyon ratio (H / Wst)	0.435	17	0.070	Accept Ho-?
Aspect ratio (Lst / H)	0.180	17	0.473	Accept Ho
Distance between building	-0.494	17	0.036	Reject Ho
Mean building height	-0.336	17	0.102	Accept Ho-?
Std. dev. of bldg. height	-0.215	17	0.390	Accept Ho
Building & Street Orientation				
Wind angle to longer axis	-0.192	17	0.445	Accept Ho

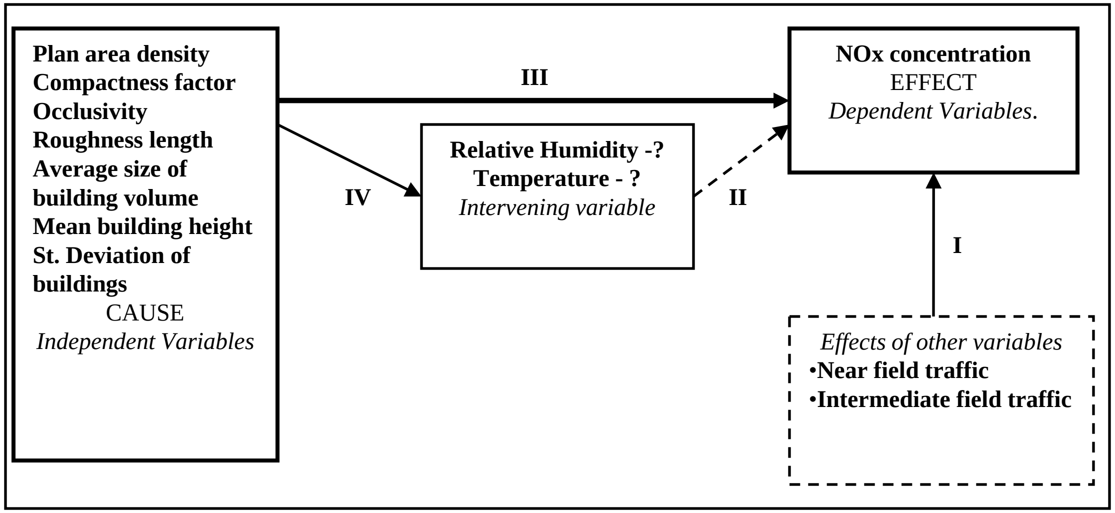
Test statistics NOx	Spearman's rank analysis results			Reject /accept *Ho*
	Spearman's = r_s	DF	Prob>	
Factors				
I Traffic				
Near field traffic	0.380	17	0.11	Accept Ho
Intermediate field traffic	0.589	17	0.010	Reject Ho
II Microclimate				
Level of Temperature	0.353	17	0.110	Accept Ho-?
Level of RH	-0.015	17	0.951	Accept Ho
Level of wind effect (E-W)	0.133	17	0.598	Accept Ho
Level of wind effect (N-S)	0.153	17	0.542	Accept Ho
Co-variants				
III Land utilization indicators				
Plan area density (λp)	0.662	17	0.002	Reject Ho
Mineralisation factor	0.369	17	0.131	Accept Ho
Land use intensity indicators				
Compactness factor	0.585	17	0.011	Reject Ho
Mean contiguity factor	0.453	17	0.058	Reject Ho
Porosity ()	0.063	17	0.804	Accept Ho
Occlusivity (Oc)	0.632	17	0.005	Reject Ho
Rugosity or FAR	0.063	17	0.804	Accept Ho
Zo	-0.653	17	0.003	Reject Ho
Σ Vblg. /no. of blg	-0.661	17	0.002	Reject Ho
Building & Street Geometry				
Canyon ratio (H / Wst)	-0.058	17	0.816	Accept Ho
Aspect ratio (Lst / H)	0.387	17	0.112	Accept Ho
Distance between building	-0.434	17	0.072	Accept Ho-?
Mean building height	-0.585	17	0.011	Reject Ho
Std. dev. of bldg. height	-0.484	17	0.041	Reject Ho
Building & Street Orientation				
Wind angle to longer axis	-0.404	17	0.096	Accept Ho-?

Interpretations IV

- PM2.5



- Nox

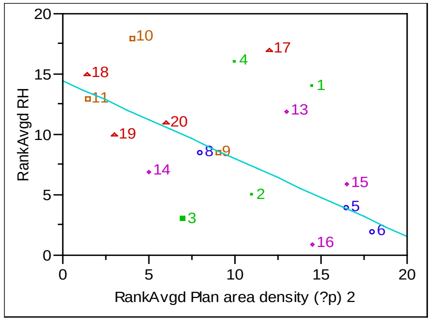


- But which affects which?

Stage 5: Testing the relationships

- Bivariate analysis of rank data…

Box 5.Fa: Bivariate Fit of Rank Av. RH by Rank Av. Plan area density



Linear Fit: Rank Av. RH = 14.520493 - 0.6453875 Rank Av. Plan area density

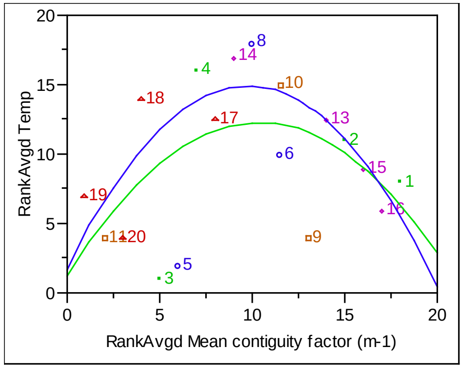
Summary of Fit

RSquare	0.59018
RSquare Adj	0.556029

Analysis of Variance

Source	DF	Sum of Sq.	Mean Sq	F Ratio
Model	1	184.55778	184.558	17.2812
Error	12	128.15651	10.680	Prob > F
C. Total	13	312.71429		0.0013

Box 5.H1: Bivariate Fit of Rank Avgd Temp By Rank Avgd Mean contiguity factor



Polynomial Fit Degree=2 : Rank Avgd Temp = 14.271237 + 0.073644 Rank Avgd Mean contiguity factor (m-1) - 0.1386323 (Rank Avgd Mean contiguity factor-9.)^2

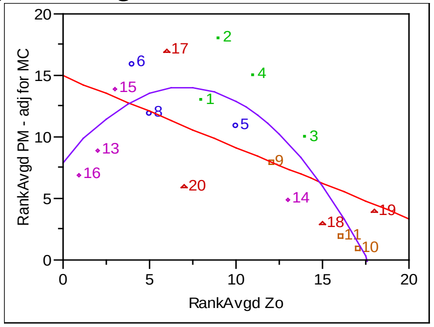
Summary of Fit

RSquare	0.654713
RSquare Adj	0.597165

Analysis of Variance

Source	DF	Sum of Sq.	Mean Sq.	F Ratio
Model	2	191.45979	95.7299	11.3768
Error	12	100.97354	8.4145	Prob > F
C. Total	14	292.43333		0.0017

Box 5.J1: Bivariate Fit of Rank Avgd PM By Rank Avgd Zo



Polynomial Fit Degree=2: Rank Av. PM = 19.221837 - 0.622721 Rank Av. Zo - 0.1247151 (Rank Av. Zo-9.5)^2

Summary of Fit

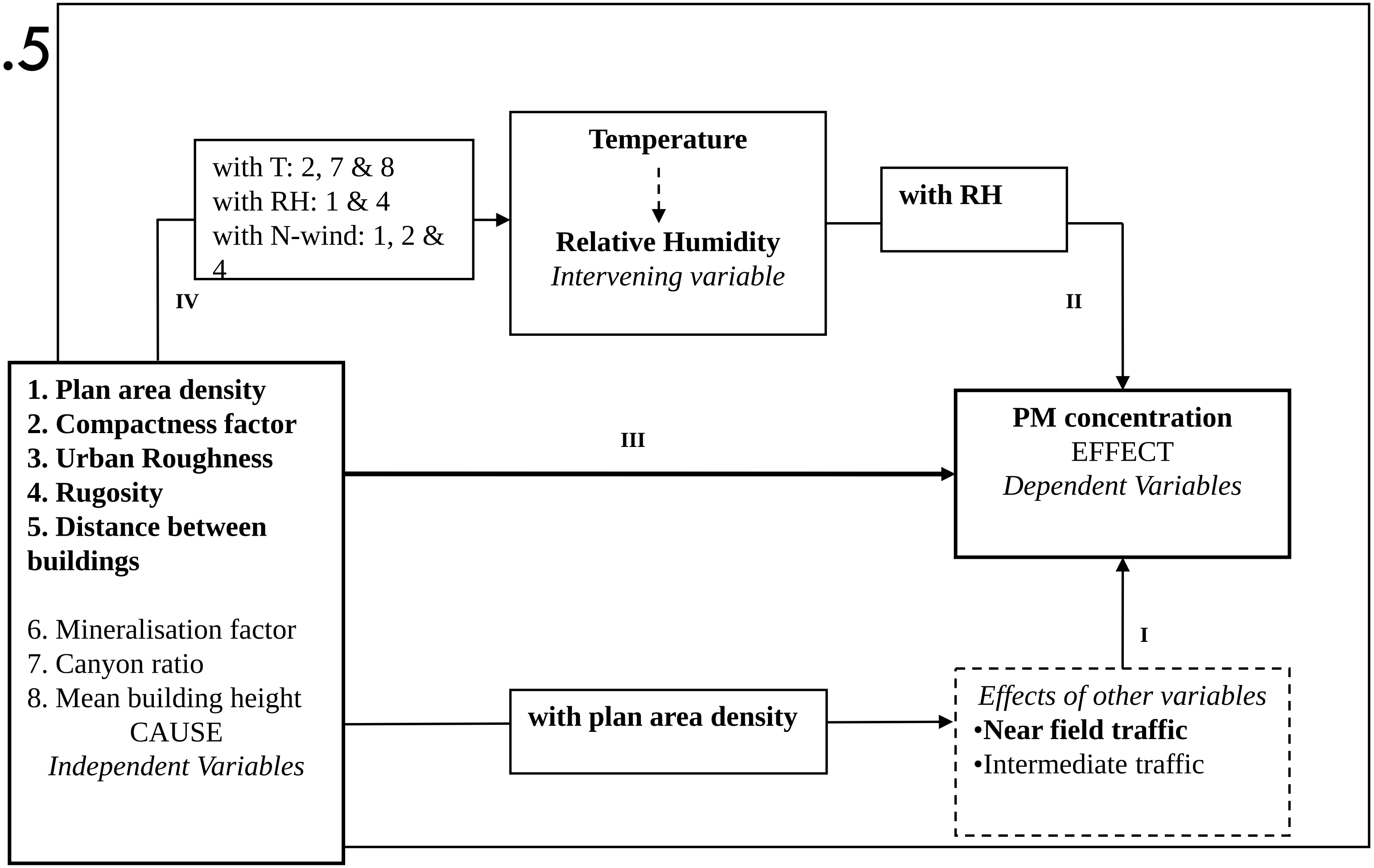
RSquare	0.701011
RSquare Adj	0.658298

Analysis of Variance

Source	DF	Sum of Sq.	Mean Sq.	F Ratio
Model	2	330.54733	165.274	16.4122
Error	14	140.98208	10.070	Prob > F
C. Total	16	471.52941		0.0002

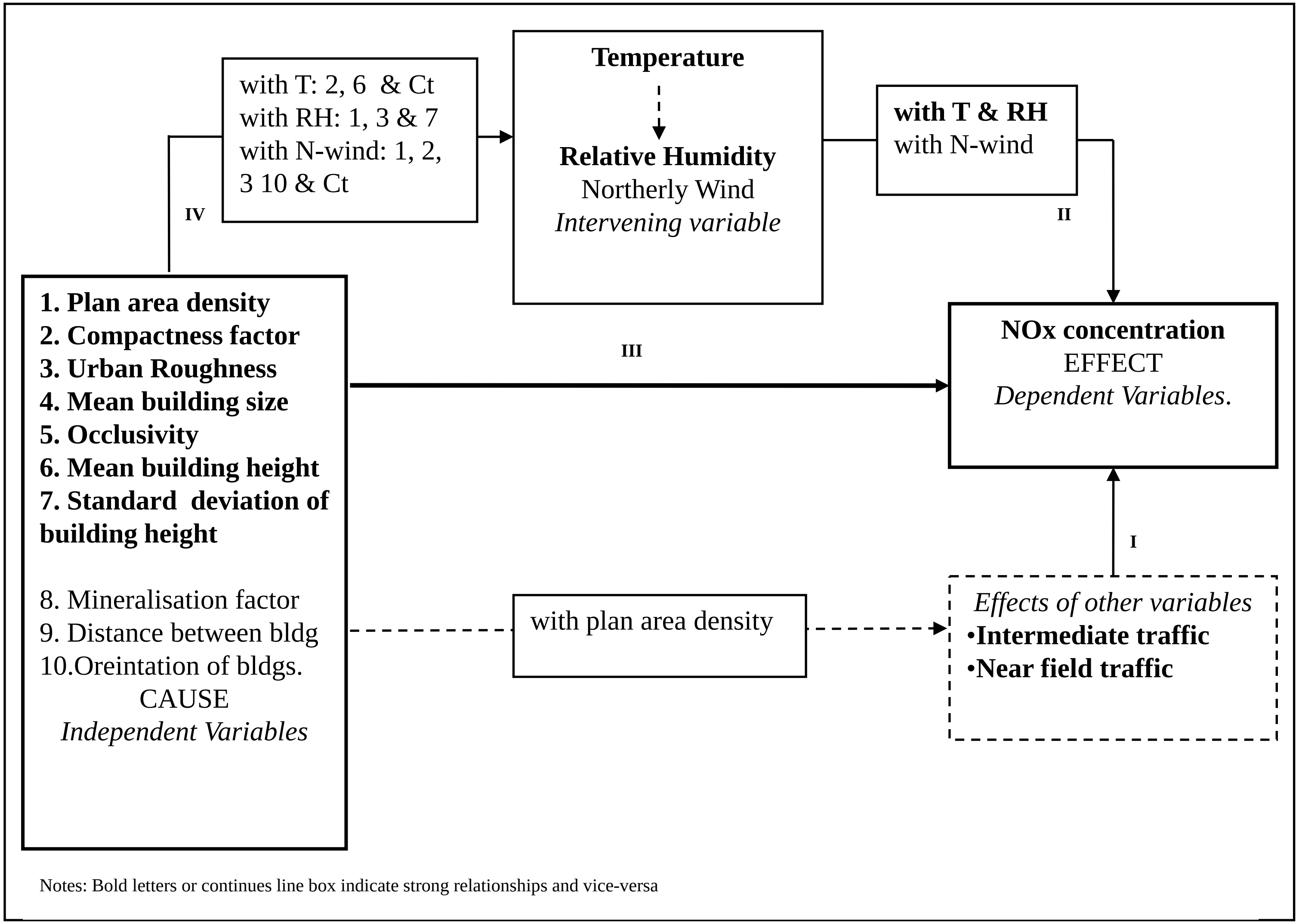
Concluding everything

- PM2.5



Notes: Bold letters or continues line box indicate strong relationships and vice-versa

- NOx


Temperature
Relative Humidity
Northerly Wind
Intervening variable
with T: 2, 6 & Ct
with RH: 1, 3 & 7
with N-wind: 1, 2, 3 10 & Ct
IV
with T & RH
with N-wind
II
1. Plan area density
2. Compactness factor
3. Urban Roughness
4. Mean building size
5. Occlusivity
6. Mean building height
7. Standard deviation of building height
8. Mineralisation factor
9. Distance between bldg
10.Oreintation of bldgs.
CAUSE
Independent Variables
III
NOx concentration
EFFECT
Dependent Variables.
I
with plan area density
Effects of other variables
•Intermediate traffic
•Near field traffic
Notes: Bold letters or continues line box indicate strong relationships and vice-versa

Conclusions

- The correlation between urban morphological variables and street-level air pollution is studied by performing a field measurement campaign and statistical analyses.
- Using various statistical tools, the key urban morphological variables, their effects and their correlations are identified.
- Future works include generalisation to other metropoli of different pollution nature and study of other cities with non-conventional urban forms and layouts

Urban morphological indicators

Regional factors

- Topography
- Altitude
- Distance from water body

City-level factors

- Urban layout
- City size / quotient
- Proximity to pollution sources

Site composition

- Population density quotient
- Urban land use
- Traffic load
- Location

Land utilisations

- Plan area density $\lambda_P = \frac{\sum \text{built area}}{\sum \text{built area} + \sum \text{unbuilt area}}$

- Mineralisation factor

$$\lambda_P = \frac{\text{total area - } \sum \text{area of water, green or open spaces}}{\text{total area}}$$

Land use intensity

- Compacity factor $C_F = \sum \frac{\text{area of building envelope}}{\text{volume of building}}$
- Complete aspect ratio $\lambda_C = \sum \frac{\text{area of building envelope}}{\text{site area}}$
- Mean contiguity factor

$$C_C = \frac{\sum \frac{(\text{adjacent area})(\text{building floor area})}{\text{vertical area}}}{\sum \text{building floor area}}$$

- Frontal area density $\lambda_F = \sum \frac{\text{area of building front}}{\text{site area}}$

Roughness related intensity

- Rugosity $\dfrac{\sum(\text{built area})(\text{building height})}{\sum(\text{building area} + \text{unbuilt area})}$

- Roughness height $\dfrac{z_0}{z_H} = \left(1 - \dfrac{z_d}{z_H}\right) e^{-\left(\frac{0.5 C_D}{\kappa^2}\left(1 - \frac{z_d}{z_H}\right)\lambda_f\right)^{-0.5}}$

- Zero-plane displacement height

$$\frac{z_d}{\text{mean height}} = 1 + \alpha^{\lambda_p}\left(\lambda_p - 1\right)$$

- Mean built volume $\dfrac{\sum(\text{built area})(\text{building height})}{\sum \text{number of building area}}$

- Urban porosity

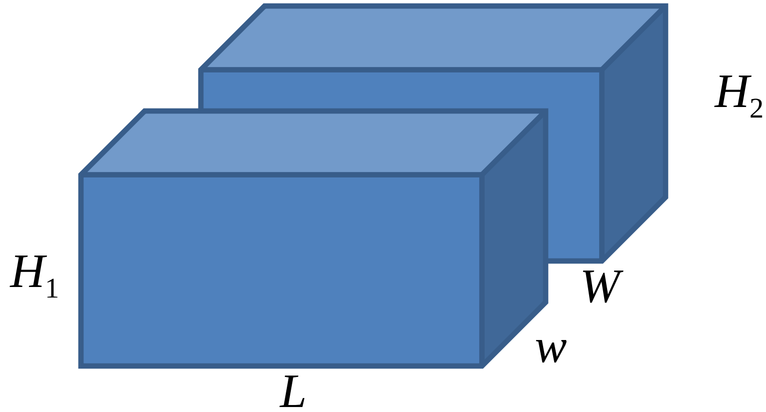
$$\text{Po} = \frac{\sum(\text{useful cross-section of open areas})(\text{length of open space})}{\sum \text{volume of open space} + \sum \text{building volume}}$$

- Sinuosity $$\text{Si} = \frac{\sum(\text{length of street segment})\cos^2\theta}{\sum \text{length of street segment}}$$

- Occlusivity

$$\text{Oc} = \frac{\sum \frac{\text{perimeter of built area}}{\text{perimeter of unbuilt area}}}{\sum \text{number of horizontal cuts}}$$

Street and building dimensions



- Canyon aspect ratio H / W
- Street aspect ratio L / H
- Street block ratio L / w
- Mean building height $\overline{H}$
- Mean canyon width $\overline{W}$
- Canyon height ratio H_1 / H_2
- Wind angle

CLIMATE CHANGE MODELING FOR ENVIRONMENTAL WEALTH

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- **MAGICC is a simple model of global T and SLR**
- **Used in IPCC TAR**
- **SCENGEN uses pattern scaling for 17 GCMs**
- **Yield**
  - Model by model changes
  - Mean change
  - Intermodel SD
  - Interannual variability changes
  - Current and future climate on 5

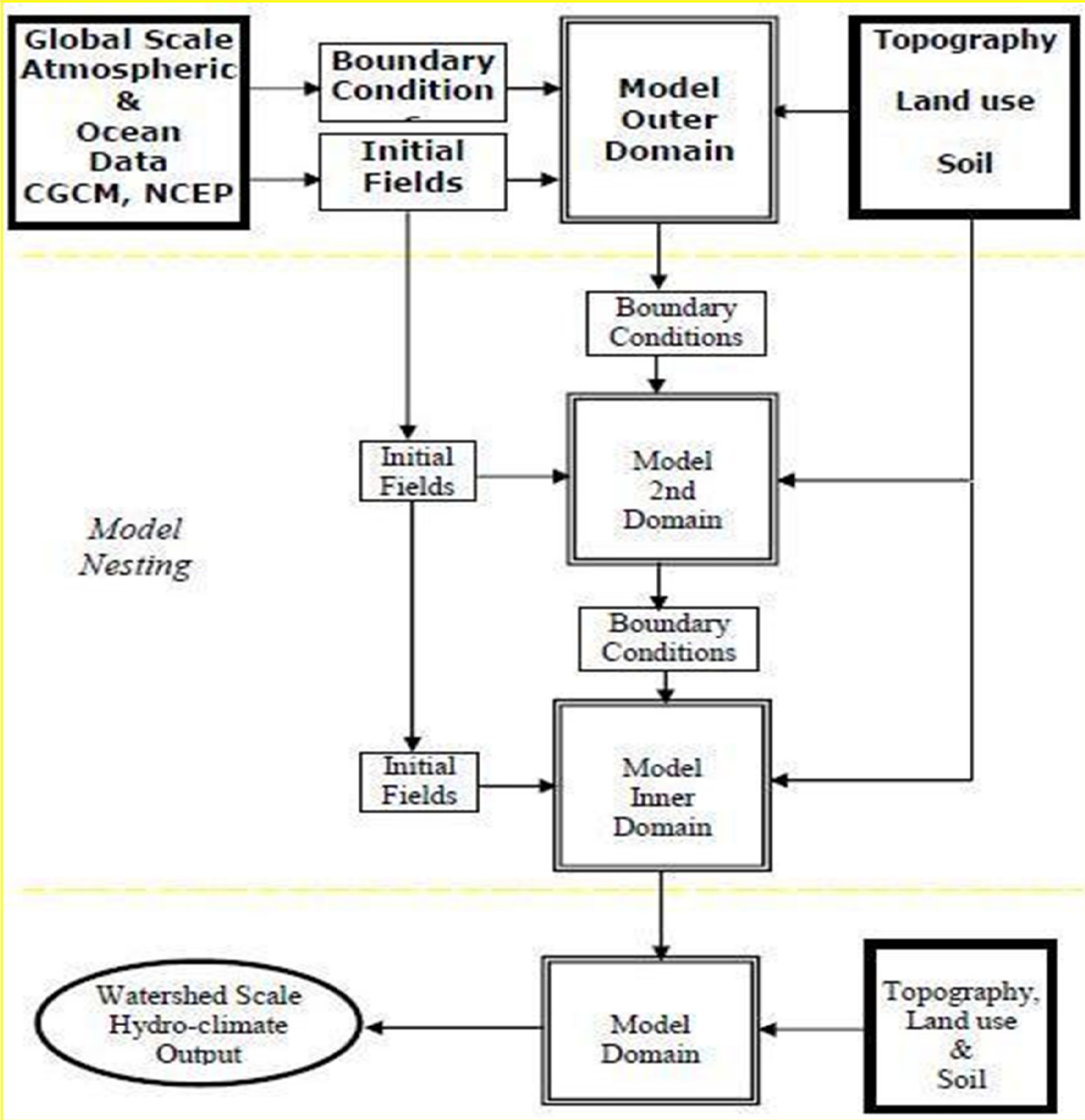

Figure1- Regional Scale Model Configuration

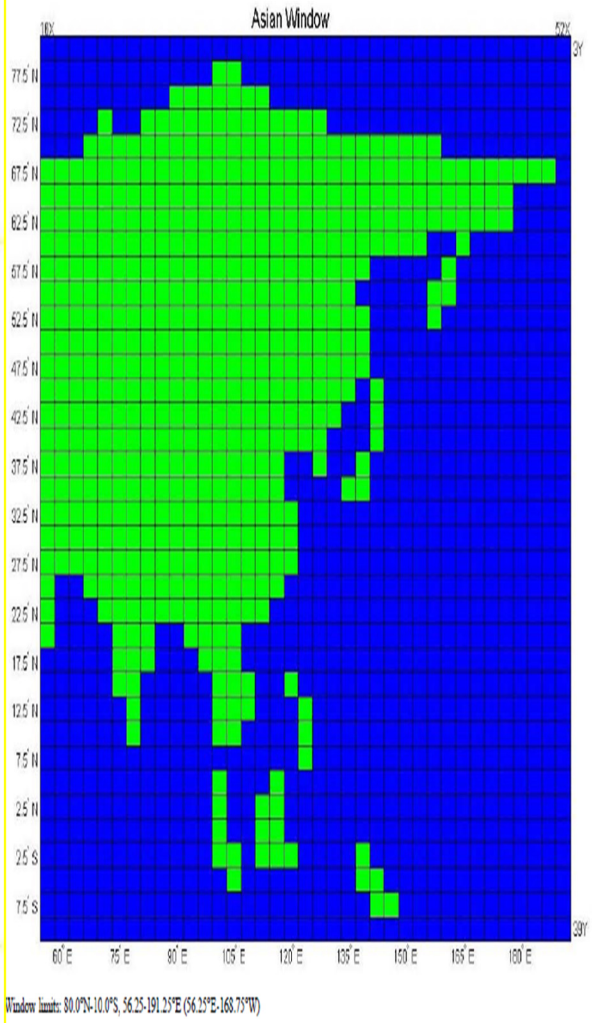

Figure 2 Scenario tools – SDSM used for downscaling

Regional Scale Model

CGCM spatial grid resolution on the order of 410 km over Regional and watershed scales:

more refined topographic & land surface characteristics have profound impact on regional climate

land use patterns/changes impact regional climate conditions

A new Regional Hydro climate Model developed in order to *downscale* the global climate change simulation data (Canadian CGCM current and future climate data) that are at very coarse resolution (~ 410km), to Malaysia at fine spatial resolution.

To be able to quantify the impact of the complex topographical and land surface features of Malaysia on its climate conditions.

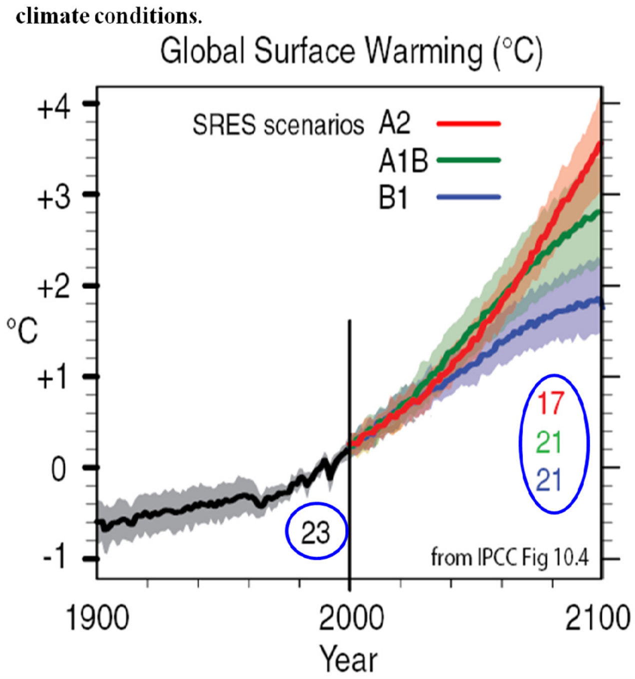

Figure 4 dAnnual global average surface air temperature increase from 1900 to 2100 for different emission scenarios (IPCC AR4 WG1: Summary for policy makers)

Combining Monthly GCMs and Observations

- *This method can provide daily data at the resolution of weather observation stations*
- *Assumes uniform changes within a GCM grid box and over a month*

The Regional model is nested into the Generation Coupled General Circulation Model of the Canadian GCM.

The CGCM provides the initial fields and boundary conditions to the model, and then the CGCM simulation results are downscaled to the region of Malaysia through several nesting procedures.

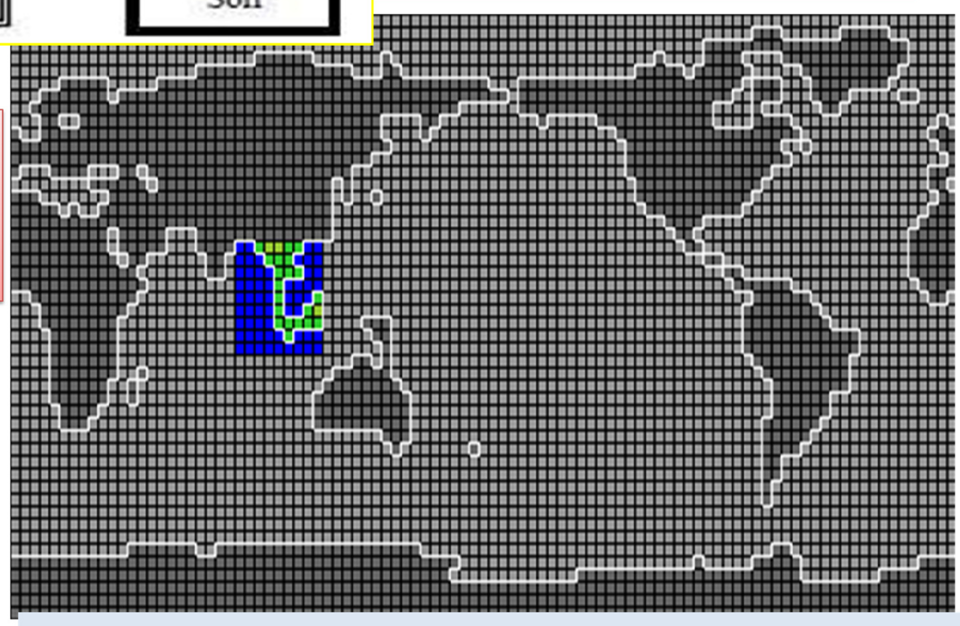

Figure3- Nesting Domains

Global Data used in Downscaling with SDSM

- Downscaling is a way to obtain higher spatial resolution output based on GCMs
- Opions include:

Combine low-resolution monthly GCM output with high-resolution observations

Use statistical downscaling

Easier to apply

Assumes fixed relationships across spatial scales

Use regional climate models (RCMs)

High resolution

Capture more complexity

Limited applications

Computationally very demanding

since 1995 Global Circulation Model (GCMs) started simulating gradually changing climate conditions where the CO_2 and other atmospheric trace concentrations are assumed to increase in the atmosphere by 1% per year. Such simulations are run usually for a single realization, starting at a present date (such as January 1, 1990) and then simulating the global atmosphere and oceans for about 100 years, usually until the year 2100

Combine Monthly GCM Output with Observations

- An approach that has been used in many studies
- Typically, one adds the (low resolution) average monthly change from a GCM to an observed (high resolution) present-day "baseline" climate

30 year averages should be used, if possible

e.g., 1961-1990 or 1971-2000

Make sure the baseline from the GCM (i.e., the period from which changes are measured) is consistent with the choice of observational baseline

Acknowledgement: APN Asia-Pacific Network for Global Change Research

Impact of climate change on the physiological - biochemical processes and yield of wheat

Abdullaev A., Kasimova G.F., Ergashev A., Karimov Kh. H. , Saboiev I.A., Abdullaev S. F., Maniyazova
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It is known that in recent years the attention of many researchers intended to study the effect of global climate change on ecosystems. Higher temperatures greatly increase droughts in the air for a long time can increase evaporation from the soil surface and transpiration can lead to drying of the root layer of soil and increase the salt content in it. Heated air-dried soil and soiled it can significantly affect the growth, development and productivity of wheat. Warming to the accompaniment of the soil and atmospheric drought may severely affect the production processes of crop plants. For more in-depth study of the physiology of plant resistance to stress factors induced climate change, in terms of research involves various plant sites. One of the objects characteristic of the Central Asian republics is wheat. Wheat is the major food crop in all continents of the globe as a source of food for humans, including in Tajikistan. It is known that changes in meteorological parameters of the atmosphere: air temperature, relative humidity and monthly precipitation totals in the complex with the properties of the soil, of course, affect the conditions of growing wheat. In this report will be submitted experimental data about effect of different climatic years and the influence of stress factors induced by climate change on the parameters of the physiological, biological and economic productivity of plants, and biochemical quality grain promising varieties of wheat .The analysis of seasonal temperature changes shows that 2007 year is characterized by the fact that the seasonal temperatures somewhat higher than the mid-season, the temperature values over the past decade (in winter 0.920 C, spring and summer at 0.520 C above the mid-season values, and autumn temperatures - 0.17^0 C less than a mid-season values per decade) during 2008 year is characterized by the fact that winter temperatures at -5.41^0 C colder than the mid-seasonal temperatures in a decade, spring at $1,45^0$ C and $1,02^0$ C in the summer and fall to 0, 2^0 degrees warmer than the mid-season, the temperature values over the decade, during 2009 and spring temperatures -0.15^0 C in summer - 0.33^0 C and fall to -0.03^0 C colder than the mid-season, the temperature values per decade. In last three years, were experienced low seasonal temperatures in 2009 year due to heavy rainfall. Overall, this year may be considered for the growth and development of wheat favorable. The analysis shows that January and November 2006 year, February and March 2007 year and February 1 - March 2009 year were periods with high monthly rainfall in the range. The results show that if the period-September 2007 to August 2008 year, annual precipitation was 358.7 mm, this value in the period September 2008-August 2009 year amounted to 905.6 mm, which is 2.53 times higher. During all these periods the monthly precipitation totals exceeded the norm from 1,3 to 1,73 times. The report discusses the impact of stress factors induced by climate change: temperature rise, the concentration of CO_2, O_3, atmospheric and soil drought on growth, development and yield of wheat, as well as physiological and biochemical properties of wheat and biochemical evaluation of the content and quality of protein in wheat grain. Also discusses the influence of these parameters on the electrophoretic separation and identification of proteins in polyacrylamide gel.

This work was supported by the International Science and Technology Center (Project T-1635).

CLIMATE CHANGE AND DIMS TECHNOLOGY WORKSHOP
1- 3 Dec 2010

* Information correct as at 30 Nov 2010

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