Final Report
ARCP2014-02CMY-Li

Development of an integrated climate change impact assessment tool for urban policy makers (UrbanCLIM)

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"Development of an integrated climate change impact assessment tool for urban policy makers (UrbanCLIM)"

Final Report Submitted to the APN

Part One: Overview of Project Work and Outcomes

Non Technical Summary

UrbanCLIM was designed as a decision support system for climate change in urban areas, to enable risk assessment and socio-economic analysis of climate change impact, adaptation and mitigation. Its design enables it to easily extend to other major sectors such as climate related hazards, resilience, water, transport, and health as we work to serve the needs of the UrbanCLIM community of practice.

The UrbanCLIM architecture was designed to provide robust support for three classes of users – Developers, Modellers and Analysts/Policy Makers. Developers are able to reach into the deepest software layers to extend existing, or build new, simulation, modelling and interactive capabilities that integrate seamlessly with the UrbanCLIM application. Modellers are able to use blocks and connectors, user interaction and model aggregation capabilities to create robust models, and Analysts and Policy Makers use simple and powerful analytical tools that smoothly integrate models and other decision making tools into a decision support engine for formulating practical approaches to real world challenges. System dynamics simulation core, climate change datasets, models and applications, are integrated in one platform. Therefore, the UrbanCLIM core can act as a generic platform for many other areas other than climate change issues by adding additional components.

Keywords

Climate change, urban planning, decision support systems, impact models

Objectives

(1) Development of high resolution climate change projections based on regional climate model (RCM) output from RMIP3 and CMIP5.

(2) Development of an integrated impact assessment system including the major sectors in urban areas through working closely with the urban policy makers and planners, based on the co-evolutionary decision support system FAWSIM and SimCLIM 2013 software packages applying system dynamics approaches.

(3) Training workshops, dissemination and publications carried out during the latter stages of the project.

Amount Received and Number of Years Supported

The Grant awarded to this project was:

US$ 45,000 for Year 1;

US$ 35,750 for Year 2;

US$ 40,000 for Year 3:

Activity Undertaken

(1) Workshops: 1st workshop in Guangzhou, China, 2012; 2nd workshop in Raglan, New Zealand, 2013; 3rd workshop in Beijing, China, 2015.
(2) Theoretical framework development;
(3) UrbanCLIM platform development;

(4) Database development;
(5) Guangzhou case study;
(6) Applications in other projects.

Results

1. Workshops

The first workshop in Guangzhou set up the development framework and work plan of UrbanCLIM, and formed a community of practice (CoP) for UrbanCLIM;

The second workshop in New Zealand identified the gaps and challenges in the context of climate change urban adaptation including following key points: policy and legislation barriers and advances; climate change adaption practice in various urban sectors; Urban planning, decision making and climate change; emerging climate change science and methodological issues as they relate to adaptation practices; climate change vulnerability and risk assessment methodologies and tools.
The third open workshop in Beijing provided a venue for scientists and practitioners to discuss the emerging issues related to climate change adaptation where scientific, technical and practical challenges and solutions were equally important. This workshop reviewed: climate change risk assessment methodologies and tools; application of tools and solutions in adaptation practice; climate change information, communication and ethics for climate change services; climate change adaption practice in different sectors; Urban planning and decision making and climate change.

The discussion panel focused on (1) very high resolution RCM simulation on city scale extreme precipitation, potential applications, and future collaborations also was envisaged; (2) service solutions could be provided to urban policy makers, including data as a service, software as a service, within the ethics framework: integrity, transparency, humility, and collaboration.

2. Theoretical framework development

Given the open framework of UrbanCLIM and complex system nature of climate change and urban adaptation, appropriate theoretical frameworks are critical for communication, training and model development. These frameworks need to be broad enough to cover all the issue raised in climate change realm, including, adaptation, mitigation, risk assessment and governance, disaster risk reduction, sustainable development, science-policy interaction, and systemic science and methodology. Without proper understand of all these theoretical background, one can easily get lost in the complexity of climate change adaptation.

Therefore, UrbanCLIM adopted or further developed and applied these theoretical frameworks. This report includes:

Orderly Adaptation: emphasis on the integration of natural science and social science, and coordinated adaptation action at all scales and levels in order to achieve the best outcomes recognizing global system;

Socio-Ecological-System: the four subsystems in SES (natural, social, economic, institutional subsystems) define the boundary of a risk assessment and governance issue. In the SES realm, a risk in any of one subsystem links to other three subsystems, a risk assessment should not be isolated in one subsystem.

Integrated Risk Governance: Integrated risk governance places emphasis on risk within a larger context than risk management and seeks opportunities while dealing with the risks from a governance perspective. To achieve disaster risk reduction while building-up socio-economic capacity. Climate change adaptation is linked with Disaster Risk Reduction and Sustainable Development in the broader context of climate change.

System Science: System science is considered within the methodology of the whole UrbanCLIM platform including system dynamics and relates modelling approaches including technical methodology to building models in UrbanCLIM. All the interactions among the variables or parameter can be seen as the flow of information, energy and material. The system dynamics models thus attempts to simulate the system's potential behaviours.

3. UrbanCLIM platform development

The UrbanCLIM platform was built on the system dynamics simulation library with powerful simulation capabilities and great flexibility in simulation architecture, control, construction and integration. Built on Microsoft's industry standard .NET technology, UrbanCLIM also uses Windows Presentation Foundation (WPF) technology to implement a friendly, flexible and extensible GUI. The key functions of the UrbanCLIM platform includes:

- Modular design and standardized technologies to enable building on and linking to existing models and related applications;
- An open framework, allowing for multi-scale, multi-domain impact assessment, which can be customized case-by-case to suit each city;
- Integrated analysis tools to enable testing of adaptation and mitigation options against socio-economic drivers, likely impacts, and existing goals for sustainable development;
- Climate change uncertainty analysis building on GCM and RCM climate change scenarios;
- GIS interoperability;
- Visualization and further analysis options for the assessment of results;
- Integration of risk and cost-benefit analysis tools.

4. Database development

UrbanCLIM has, and will maintain, a comprehensive climate change assessment database which includes up-to-date IPCC AR5 GCMs, and CORDEX RCM data for historical data climate change scenarios, from monthly average of mean changes to subdaily extremes. These data have been adapted from SimCLIM and other international and national climate change related datasets directly or using various downscaling methodologies. UrbanCLIM will also be able to incorporate other emerging datasets. User defined scenario and empirical data also could be included into the UrbanCLIM database if users so desired. It is our expectation that the UrbanCLIM database would be organically grown by its user communities.

5. Guangzhou case study

A study on the urban anthropogenic heat flux over the Pearl River Delta of China was carried out by using WRF for dynamic downscaling. And the second component of this case study was to apply the PRDWUM model for water sector assessment. We calculated water intensities from annual socio-economic and water use data in Guangzhou. We find that the PRD managed to stabilize its absolute water use through significant improvements in industrial water use intensities, and early stabilisation of domestic water use intensities.

6. Applications in other projects

(1) Financing low-carbon, climate resilient urban infrastructure in Asia and the Pacific project (ADB funded) applied the City Climate Risk Profiler, which are tools and datasets driving the UrbanCLIM products and include: information of more than 20,000 cities and towns; climate related hazard and future projections, allowing city infrastructure relevant assessment; socio-economic and disaster risk data; GIS explorer within UrbanCLIM, basic GIS tools that are easy to use and install.

(2) Adapting to Climate Change in China (ACCC II) Project (funded by Swiss SDC) applied the extended UrbanCLIM platform for following tasks: provide guidance to provincial adaption planning for key areas; provide a tool kit to support mainstreaming provincial adaption planning; develop an Adaptation Planning Support and Risk Assessment System; train provincial researchers and policy makers; involve key institutions from national level to provincial level; provide comprehensive theoretical frameworks and practical tools for South-South knowledge sharing.

Relevance to the APN Goals, Science Agenda and to Policy Processes

The integrated tool includes a policy-making and planning module that has an interactive function for the urban policymakers to carry out risk, uncertainty and decision-making assessment (RUD); to provide support in each policymaking stage, including: identifying the problem and objectives; to establish risk tolerance and decision-making criteria; to identify and assess risks; to identify a range of A&M options with CBA, CEA; to appraise A&M options; to refine problems and criteria; to make decision, implement; and to monitor & evaluate. The participatory assessment and mediated modelling approaches were applied in this project to ensure that the tool was useful in policy making.

Self-evaluation

- Fulfilled the proposed tasks including, model development, dataset development and case study;
- Further development of UrbanCLIM with theoretical frameworks and real applications in projects are beyond the original project design.

Potential for further work

1) More applications of UrbanCLIM platform by seeking further funding and collaborations. UrbanCLIM software development is an expansive exercise that will need very high level understanding of the theoretical frameworks and programming technology, it can only be further developed through funded projects which allow dedicated staff time.

2) Further development of UrbanCLIM to Risk Informed Decision Support System (RIDS), extend UrbanCLIM to a more generic risk assessment and governance decision support system. Given the open framework of UrbanCLIM, it can be easily applied in environments beyond the urban sphere, and potentially all geographic risk governance realms. This move will provide more opportunities to promote the next generation of decision support systems.

3) Enlargement of UrbanCLIM community of practice, by promoting UrbanCLIM information online, and more promotion activities through new social media platforms.

4) Improvement of the usability of UrbanCLIM, including the model build experience and graphing; further development of the user guidance and related knowledge management tools.

Publications

Yinpeng Li, Peter Urich, Chonghua Yin, and Matthew Dooley: (2014) From Science to Adaptation and Mitigation Practice: UrbanCLIM: Towards an Extendable Decision Support System for Urban Planning, MAIRS Open Conference 2014, Beijing (Poster)

Yao Mingtian, Saskia Werners, Ronald Hutjes, LI Yinpeng, YIN Chonghua (2014) Model-based Sectoral Water Use Assessment in the Pearl River Delta, MAIRS Open Conference 2014, Beijing (Poster)

Junjie Zhan, 2014: Annual and diurnal variation of anthropogenic heat estimation in Guangzhou city, China and simulated regional impacts of anthropogenic heat release on climate, master degree thesis of Chengdu University of Information Technology& Institute of Atmospheric Physics, Chinese Academy of Sciences, pp50.

Acknowledgments

Great appreciation needs to be given to the MAIRS IPO for providing the UrbanCLIM team financial and in-kind support. And the ADB and Swiss SDC project teams which applied UrbanCLIM tools and datasets must be acknowledged for providing the opportunities to improve and further develop the platform.

Preface

The UrbanCLIM system was designed to provide robust support for three classes of users – developers, modellers and analysts/ urban policy makers. During past three implemental years, the UrbanCLIM project has seen the development of prototype software to a platform for applications in several projects. The platform UrbanCLIM has been further developed and generalized to a risk-informed decision support (RIDS) system, which includes theoretical frameworks, decision support guidance, climate change databases and model libraries. The community of practice has been developed and expended to more include collaborative institutes. This technical report depicts all aspects of UrbanCLIM development.

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1. Introduction

Urban areas concentrate populations, economic activities and built environments, thus increasing their risk to floods, heat waves, and other climate and weather hazards that climate change is expected to aggravate. There is an urgent need to develop robust and integrated climate change adaptation strategies for urban areas. The absence of an urban policy making support system that integrates with climate change risk and adaptation assessment is becoming a critical barrier for implementing sustainable climate change policy in Asia's rapidly growing urban centres. There is a need for a new decision support system that can integrate existing and future natural resource models into a common, collaborative, and flexible framework. Such a system will maintain modularity, reusability, and compatibility. The system will also recognize the fact that different categories of applications may require different levels of scientific detail and comprehensiveness, as driven by objectives, scale of application, and data constraints.

To help to realize such a system, this project proposes to develop a co-evolutionary urban climate change decision support tool (UrbanCLIM), to include the climate change impact and risk assessment functionality that can extend to the major sectors: climate related hazards resilience, water, transport, and health. The participatory assessment approach will be applied through working with urban policy makers and planners from targeted Asian cities.

2. Methodology

2.1 UrbanCLIM software development methodology

The UrbanCLIM platform was built on the system dynamics simulation library "Sage," from Highpoint Software Systems. Sage is a state of the art simulation engine, with powerful simulation capabilities and great flexibility in simulation architecture, control, construction and integration. Built on Microsoft's industry standard .NET technology, UrbanCLIM also uses Windows Presentation Foundation (WPF) technology to implement a friendly, flexible and extensible GUI.

The UrbanCLIM architecture was designed to provide robust support for three classes of users – Developers, Modellers and Analysts/Policy Makers. Developers are able to reach into the deepest software layers to extend existing, or build new, simulation, modelling and interactive capabilities that integrate seamlessly with (essentially becoming part of) the UrbanCLIM application. Modellers are able to use blocks and connectors, user interaction and model aggregation capabilities to create robust models, and Analysts and Policy Makers use simple and powerful analytical tools that smoothly integrate models and other decision making tools into a decision support engine for formulating practical approaches to real world challenges. Therefore, the UrbanCLIM core can act as a generic platform for many areas other than climate change by adding additional components.

The UrbanCLIM platform was designed to support layered applications. The central layer of the system provides the fundamental scientific understanding of climate change and related issues, the graphical user interface (GUI) and the model development environment. The interactive layer allows efficient and effective interaction between the model developer and end user. The policy making layer supports policy making processes by providing outputs in a variety of formats, such as graphs, maps, and technical information. UrbanCLIM supports a participatory assessment approach through users' dialogue with urban policy makers and planners from targeted cities.

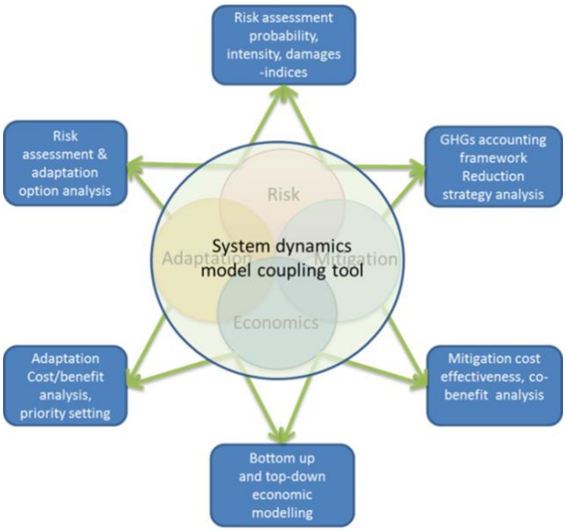

Figure 1: UrbanCLIM system dynamics methodologies

A unique advantage of applying a system dynamics approach is the ease with which one can extend and revise models as the domain is explored and questions arise. UrbanCLIM will allow in-flight alteration of models and their data and presentations, the use of a visual coupling tool for data conversion, and dynamic updating of workflows. A set of climate change impact models (flood, storm surge, heat waves and others as identified during the current project), economic models and multiple criteria decision analysis tools will be developed and incorporated into UrbanCLIM. The flexibility of the system will be augmented by establishing standard model and data libraries that provide the building blocks for a wide range of related applications.

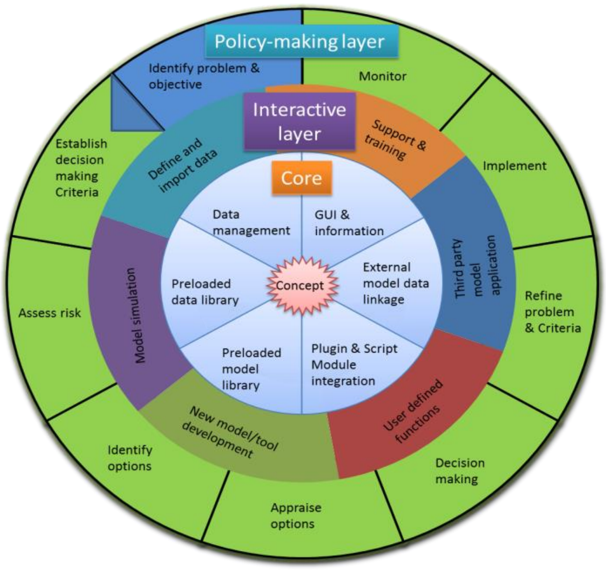

Figure 2: A layered architecture of UrbanCLIM and Risk Informed Decision Support (RIDS) system. One radiant concept; six core components; six interactive components; nine key stages of policy making process; each component can interact within the layer and between the layers

Table 1. The core components of the tool

Core 1: Data management	This tool allows the drag-and-drop function which means users can drag the customized data or models to the working window, and the data and model can work immediately after the drop (copy). Data management tools enable the import and export of the climate, land and socio-economic data, in time series (monthly, daily, hourly, sub-hourly) or spatial patterns (ARC-GIS grids, and polygon layers, for example). The site data manager, data import wizard, and data browser functions all permit the user to freely import site specific or gridded data into the system. An area browser allows users to view and edit all the data available in the system. Import & export link to other formats for third party software.
Core 2: Preloaded data	All the functions, data and models are linked to the climate change scenarios. This tool provides the basic climate change scenarios at the global level, and can also provide customized local scenarios according to the case study area and users' requirements. GCM data, RCM, SD data, historical observation data High level background GIS data, shapefiles, population, DEM, river basin, etc.
Core 3: Preloaded models	Models developed from previous work are preloaded into the system for application Generic models: such as, water balance model, extreme values analysis, drought index (SimCLIM modules) and others can be developed or linked Health impact model (need to be calibrated before application)
Core 4: Model integration tools	System dynamics approach. Dynamic-Link Library (DLL): new models or function can be developed as DLLs in a certain convention; they can then be dropped into the system and applied. Script: type in equations, simple models on screen and carry out the analysis
Core 5: **External model/ data linkage**	Provide data exchange protocol for the models and the tool can be linked to the toolkit.
Core 6: GUI & Information (Help)	Geographical information systems files: shape file, gridded file Graph: Excel, Access, database Note: user can type their notes and save to working items Help & Key message

Table 2. Interactive layer major functions

IL1: **Define and import data**	Data availability checking, define the baseline data, spatial resolution, master plan or projection future time line. Import the required data for model simulation: including: climatic, geophysical, socio-economic, geospatial data Geographical information systems files: shape file, gridded file Graph: Excel, Access, database
IL2: **Model simulation—output**	Parameter setting, run models, result checking, graphing, layout Parameter setting Climate scenario; socio-economic develop-scenario; adaption and/or mitigation option selection, input, cost estimate Economic analysis method (cost/benefit, cost effectiveness, co-benefit) Target setting Run models, result checking, graphing, layout
IL3: **New model/ tool development**	No suitable model is available in the model library, discuss with the related developer for new model development through in-depth research.
IL4: **Model coupling and development Tool**	**System Dynamics Methodology** Plugin DLL (screen shot), define functions through script functions Existing models can be re developed as DLL using a certain convention then plug into the tool for application. Simple equations/ relationship can be typed on the tool interface and to carry out analysis. ***One of the unique advantages of using system dynamics models to study public policy issues or problems is that they can easily be extended or revised to address additional questions as they arise.*** The tool allows users to register different models, input and output of the model, use a visual coupling tool for data conversion, define workflows, run workflows, and monitor workflows. The tool will deploy dynamic data conversion techniques for the user-created data mapping schemas using the provided visual tool.
IL5: **Link to third party models through linkage functions**	Complicated models or heavy computing consuming models which are not suitable to be directly run in the tool, a linkage function would perturb the model input data with climate change projection.

IL6: **Technical support and training**	It is essential for an appropriate application of the tools. The embedded complexity and uncertainty of climate change information may not be well understood without training or good technical support. Link to project feasibility study tools and finance instruments and guidance.

2.2 UrbanCLIM Community of Practice (CoP) strategies

UrbanCLIM platform development is one of the core values of the project. Another is the development of a Community of Practice – a diverse group of climate change modellers, analysts and decision makers. This CoP serves itself in two critical purposes – the first, directly, is the cross-pollination of ideas, techniques and technologies and the second, indirectly, is to guide the core development of the UrbanCLIM platform. More specifically, the UrbanCLIM CoP will:

- Promote science-based climate change practice;
- Promote climate change model and tool sharing through a community portal that leverages project management (e.g. SourceForge.net) and Wiki-like mechanisms;
- Provide a conduit for delivering software and information to its members;
- Invite participation and dialogue between inside and outside perspectives;
- Enable broad software development support for climate change adaptation and mitigation;
- Provide a web based forum new knowledge sharing;
- Present workshops on training and software development taking user feedback into consideration;
- Enable cross-functional collaboration in projects;
- Enhance public awareness of, and communication with, the CoP.

During the proof of concept stage, we have established relationships and communications among major players to enable further collaboration and development of model libraries, tools and application features. With individuals in the climate change research, software development, model development, urban planning and adaptation practitioner roles, these partners include elements of the following groups:

- Regional institutes from China, Korea, Japan, India, Vietnam, Philippines, Australia, and New Zealand;
- Research institutes and universities such as IAP, CAS, CSIRO, Yonsei, Ji'nan, Delhi, Nanjing, Waikato;

International Financial Institutions: ADB, WB;

International Climate Change Organizations: APN, MAIRS, CORDEX, CMIP, OCMIP, ALM;

Planning institutes: Guangzhou, Beijing, New Zealand, Australia, Vietnam, and Philippines;

Practitioners: RAMBOLL ENVIRON, AECOM, ARUP, CH2MHILL, and ESRI.

An in-depth implementation of UrbanCLIM will rely on this large scale collaboration to ensure that a wide range of needs are, or can be, met by the platform.

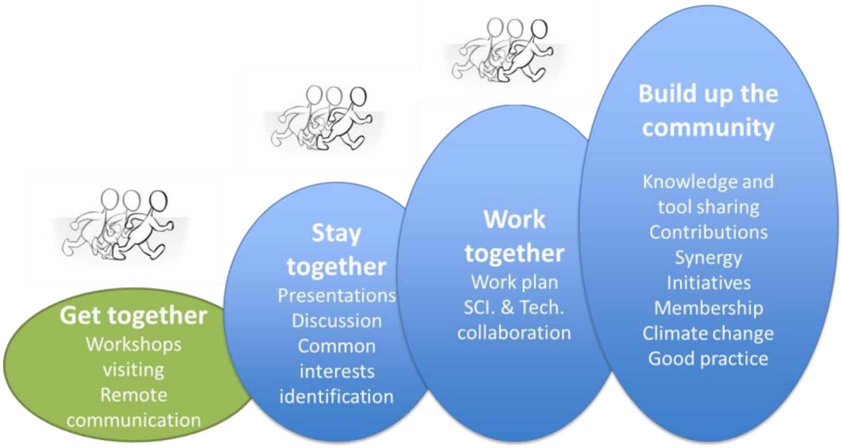

Figure 3: UrbanCLIM community of practice approaches

3. Results and Discussion

3.1 Workshops

3.1.1 Workshop in Guangzhou, China, 2012

A joint project workshop funded by Asia Pacific Network (APN) and Monsoon Asia Integrated Regional Study (MAIRS) 'Development of an integrated climate change impact assessment tool for urban policy makers (UrbanCLIM)', was held in Ji'nan University, Guangzhou, China, 29-31 October 2012.

This workshop was the first workshop of three in this three year APN project. More than 30 experts from 11 institutions shared their research and application experiences, including, the following Institutions: the International Global Change Institute (IGCI) New Zealand, MAIRS IPO, Institute of Atmospheric Physics (IAP, CAS); Nanjing University; Ji'nan University; Center for Water Resources Investigation and Planning, MONRE, Vietnam; USC-Water Resources Center Foundation Inc. Talamban, Cebu City, Philippines; Institute of Geography and Natural Resource (IGNRR, CAS); Centre of Urban Planning Research, Guangzhou Urban Planning & Design Survey Institute, Guangzhou (GZPI), China; State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology (SCSIO,CAS); Guangzhou Institute of Energy Conversion (GIEC, CAS); Southeast Asia START Regional Center, Chulalongkorn University, Thailand; Department of Geography, University of Delhi, India; Department of Atmospheric Sciences, Yonsei University, Korea.

The topics of the presentations covered the many areas around climate change risks and adaptation, including urban planning and governance, tools and modelling, Regional Climate Model comparison, water resources management, adaptation and mitigation synergy, coastal ocean environment, and freshwater lake environmental modelling. On the third day of the workshop, APN project leader Dr. Yinpeng Li, MAIRS IPO Dr Ai Likun, and key collaborators visited the Guangzhou Planning Institutes and gave a seminar to their planners in order to get a greater understanding on how UrbanCLIM could assist with planning practice. The action plan for the coming year was discussed and action items were decided.

Guangzhou workshop group photo

3.1.2 Workshop in Raglan, New Zealand, 2013

Workshop title: Climate Change and Urban Adaptation: Science and Practice: Exploring the Challenges

A workshop on Climate Change and Urban Adaptation: Science and Practice: Exploring the Challenges was held in Raglan, New Zealand, 9th - 11th Dec 2013. This workshop provided a unique venue for scientists and practitioners to discuss the emerging issues related to climate change and urban adaptation where scientific, technical and practical issues are equally valued. About 30 scientists and practioners from New Zealand, Australia, China, Thailand, and Vietnam attended. The workshop was supported by Asia Pacific Network for Global Change Research (APN), Monsoon Asia Integrated Regional Study (MAIRS), and International Global Change Institute (IGCI), through the project: 'Development of an Integrated Climate Change Impact Assessment Tool for Urban Policy-Makers (UrbanCLIM)'.

The participants included climate science researchers, climate service providers, consulting practitioners, representatives of local government, government policy makers, legislative experts, adaptation project practitioners and evaluators. Challenges, lessons learnt, and new opportunities for climate change adaptation action in different countries were discussed in great depth during and after the workshop. Through this workshop the experts from different backgrounds formed a community of practice (CoP) for climate change adaptation.

The themes of the presentations covered:

- The importance and gaps in climate change information and communication for adaptation
- Policy and legislation barriers and advances

- Climate change adaption practice in various urban sectors
- Urban planning, decision making and climate change
- Emerging climate change science and methodological issues as they relate to adaptation practices, especially for 1-10 year predictions
- Climate change vulnerability and risk assessment methodologies and tools

Over the third day of the workshop, a project work plan was discussed among the key collaborators of the APN project UrbanCLIM team. Planning was informed by past progress that shall inform future software development, evolution of data libraries and case studies. Collaborative opportunities and ideas also thoroughly explored. After the workshop some the attendees also visited the IGCI office in Hamilton for more discussions on collaboration.

The workshop participants understood very clearly that effective collaboration through the development of an adaptation community of practice (CoP) will be critical to achieving 'best practice' in adaptation (See figure 4). This figure illustrates the key elements in climate change practice: (1) Scientist group, including pure and application climatological and meteorological research shall provide the observations, modelling and theory of climate change which are the foundation of climate change adaptation. This group's products include large sets of climate related data, methodologies and tools for that require further analysis for efficient application. (2) Practioners and Facilitator group, including the consultancy firms and individual practitioners, who focus on implementing adaptation projects and translating the climate change information to stakeholder accessible formats including documentation for local governments, and national and international agencies. (3) Government Policy Makers and international agencies group, the funding dispensers and outcome receivers. (4) Boundary crossers, or climate change service providers, because the perceived intellectual distance between scientists, practioners and policy makers there exist a number of gaps between the scientific community and organisations and individuals operating in the practice realm. There is a need for a group of people who can understand and communicate among and between these groups, which should include practical yet scientifically robust data services and practical tool development. The barriers among different groups could be filled through the efforts of a CoP approach.

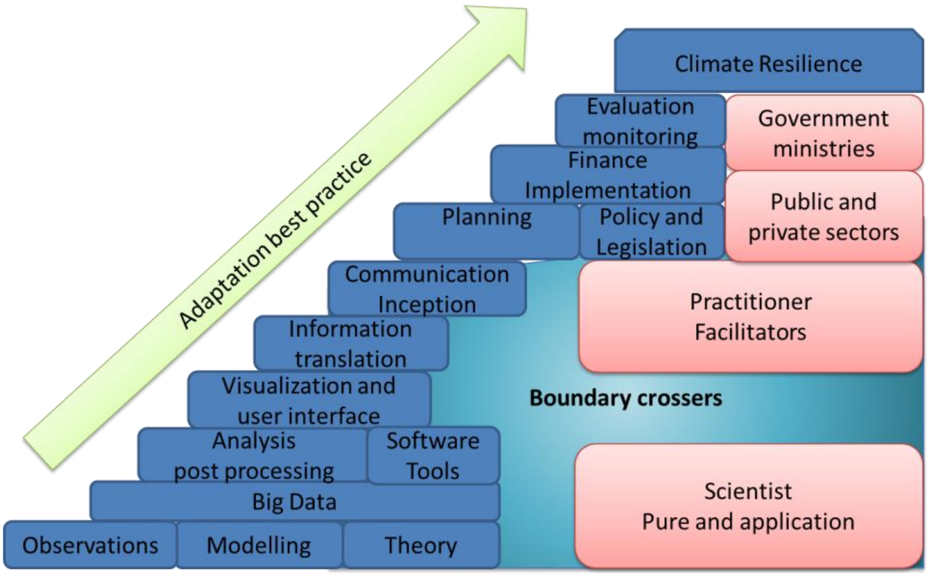

Figure 4: Climate change adaptation best practice community: opportunities and challenges

Raglan workshop group photo

3.1.3 Workshop in Beijing, China, 2015

Workshop Title: Open Workshop on City Climate Resilience Sciences and Services: Challenges and Solutions

Cities are dynamic and complex. There is no universal solution that can be applied to every city in any country. Adaptable, responsive, and innovative solutions that differ from one place to another enable cities to emerge in various guises and recognize the variation and dynamism of cities. Most urban cities in Asia are struggling to meet their infrastructure needs; maintain or provide adequate service delivery; and upgrade city systems to keep pace with the rate of change, urbanization, and population gain. Increased vulnerability—as a result of climate change and exposure to disaster events—shapes the development needs of urban areas; meanwhile mitigation pressure provides opportunities for low carbon development. This is the time to face the challenges, provide solution for cities.

Supported by Asia Pacific Network for Global Change Research (APN), Monsoon Asia Integrated Regional Study (MAIRS), and International Global Change Institute (IGCI), New Zealand and Key Laboratory of Regional Climate-Environment for Temperate East Asia (RCE TEA), the workshop was held in RCE-TEA, Institute of Atmospheric Physics, CAS, Beijing, China, on the13rd November 2015. This open workshop provided a venue for scientists and practitioners to discuss the emerging issues related to climate change adaptation where scientific, technical and practical challenges and solutions are equally important. This open workshop composited with presentations, panel discussions, and project workshop for APN funded project: *'Development of an Integrated Climate Change Impact Assessment Tool for Urban Policy-Makers'*.

Beside the scientist from mentioned support institutes, scientists from NOAA, Chinese Meteorological Administration, and Beijing Normal University attended the workshop as well.

The presentation and discussion topics including:

- Emerging climate change science and methodological issues as they relate to city resilience services
- Climate change risk assessment methodologies and tools
- Application of tools and solutions in adaptation practice
- Climate change information, communication and ethics for climate change services
- Climate change adaption practice in different sectors
- Urban planning and decision making and climate change

The discussion panel focused on (1) very high resolution RCM simulation on city scale extreme precipitation, potential applications, and future collaborations also was envisaged;

(2) Service solutions could be provided to urban policy makers, including data as a service, software as a service, within the ethics framework: Integrity, transparency, humility, and collaboration.

Beijing workshop group photo

3.2 UrbanCLIM Theoretical Framework Development

During the implementation of UrbanCLIM project and other related applications, we found out that in order to get stakeholders to understand and put the UrbanCLIM models and database into context, many concepts and theory frameworks have to be developed or adopted. Adaptation actions are carried out all over the world in different scales, from small community to whole nation planning, and different sectors, different politic regimes, financial situation, culture background. There is no one frameworks which can suit all circumstances. However, UrbanCLIM team is aiming to put adaptation into larger picture of understanding, and provide theoretical guidance for the purpose of mainstreaming and to avoid maladaptation adaptation. In this session the major theories could be applied in UrbanCLIM will be described.

3.2.1 Orderly Adaptation

As it is related to economic development, how to act against global warming is not a pure scientific issue. At present, many countries have started to facilitate clean energy technology development and utilization and take effective actions to reduce emissions, which become a kind of force to support the United Nations to hold the climate change conference in Bali and Copenhagen. The conferences are the signals of awareness of most of the national governments on the importance of taking coordinated actions against climate change (Ye and Dong 2010).

However, even from the scientific viewpoint, the academic community has not given a clear solution on how to act against global warming up to now. Economic interests-driven mankind’s large-scale and chaotic productive activities since Industrial Revolution have emitted a large number of greenhouse gases into atmosphere which has introduced global warming. This is an example that demonstrates how a large-scale disorderly human activity in history affected global climate system. Global warming has had a great impact on both human society and the natural environment. Today we are potentially facing another wave of disorderly human activity, which is a large variety of actions against climate change that each country taken itself under the name of protection of its national interests. Obviously, all countries try to make full usage of positive impacts and reduce or eliminate negative impacts of global warming. However, no country is isolated, and economic development of each country must have linked to other countries and regions.

Climate and environment are similar to economics, whose changes will affect other countries and regions too. Thus, it is hard to know that the consequences of the currently popular way that each country makes its own policy and takes its own action are whether leading a greater damage to the interests of the whole humanity or not.

To avoid the possible adverse influence introduced by a new wave of the disorderly human activities, it is beneficial globally to initiate coordinated research on the orderly human activity to cope with global climate change. Here, we put forward a proposal to build a framework that helps the world to take orderly action against climate change.

We need to take human society as an integral part of the earth system, and to implement this component into current earth system models. At present, a lot of ongoing national and international scientific programs have been implemented to understand the impact of human activity on climate change and the possible influence of climate change on the environment and economy, which have been partly reflected in the IPCC Assessment Reports.

In future, the descriptions of human activities in earth system model need to be further improved, and various virtual experiments needed to be conducted to quantitatively assess economic losses/benefits of each country under the course of human action against climate change. The model research should be organized and coordinated by the relevant international organizations, such as IPCC or WMO.

Adaptation actions will be expected to provide several best options based on which the human's actions against climate change can obtain the totally maximum benefits for the whole world through a comparative analysis of outputs of all experiments. After an integrated consideration, discussion and negotiation, the international organization can recommend one of the best, which is actually the ideal plan on how to take orderly human activity against climate change.

For some countries, the implementation of the orderly human activity against climate change may cause some losses of their economic benefits, which expose a problem related to national benefits. In such case, the implementation of these actions should be organized by authoritative international institutions, such as the United Nations.

If some countries have to endure a loss of their benefits due to the orderly human activity against climate change, the other countries should give them compensation, e.g., through an international funding sponsored by the United Nations' organization.

Till now the international society has been lack of comprehensive and effective measures regarding human actions against climate change, therefore, it is urgently needed that the scientists and the other communities associated with climate change immediately take coordinated research on the orderly human activity plan and by which to enhance policy makers to reach climate change agreement and take actions against climate change.

Mainstreaming of climate change adaptation

Action that addresses the interlinked challenges of disaster risk, sustainable development and climate change is a core priority given that 90% of recorded major disasters caused by natural hazards from 1995 to 2015 were linked to climate and weather including floods, storms, heatwaves and droughts.

UNISDR is focused on achieving stronger recognition of disaster risk reduction and climate change adaptation as essential elements of climate risk management and sustainable development.

UNISDR's efforts ensured that the links between disaster risk management and climate change adaptation were elaborated during the decisions taken around loss and damage at the November, 2013, COP19 (Climate Change Conference of the Parties) in Warsaw, Poland. Governments adopted the Warsaw International Mechanism on Loss and Damage associated with Climate Change Impacts with a focus on developing countries that are particularly vulnerable to the adverse effects of climate change. One of its stated functions is to enhance knowledge and understanding of comprehensive risk management approaches.

UNISDR (2015) Coherence and mutual reinforcement between the Sendai Framework for Disaster Risk Reduction 2015-2030 and international agreements for development and climate action.

Link mechanisms for monitoring and reporting of linked goals and indicators

- Align targets and indicators across agreements. Allow for a systematic monitoring of the contribution of disaster risk reduction to sustainable development through agreeing to disaster risk reduction-related indicators across the SDG targets aligned to indicators to be established through the Open-ended Intergovernmental Working Group on indicators and terminology for disaster risk reduction.

- The formulation of any adaptation or resilience related goal considered at the 21st Conference of the Parties (COP) in Paris should build on alignment with goals agreed in the Sendai Framework for Disaster Risk Reduction. Sendai targets related to early warning systems and risk assessment and management have particular relevance.
- Call for harmonized national reporting systems. To reduce the burden to countries reporting on international agendas, encourage harmonization in the design of the new generation of reporting tools and national reports to the UNFCCC, and the SDG reporting mechanisms. These should be complemented by commitments to measure risk systematically and strengthen existing national and global risk monitoring systems.
- Promote and prioritize programmes and partnership that yield multiple benefits for sustainable development, disaster risk reduction, financing for development, climate action and urban development. Build on established partnerships established for disaster risk reduction and voluntary commitments made to implementation of the Sendai Framework for Disaster Risk Reduction.

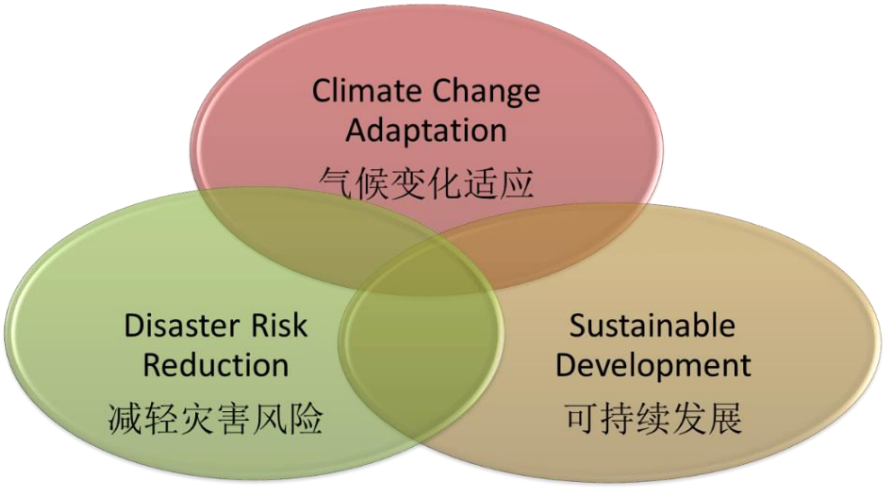

Figure 5: The overlapping nature of climate change adaptation, disaster risk reduction and sustainable development need coordinated actions of these three realms.

Science and policy interface

A group of decision support people have to commitment to advance science that is use-inspired as well as fundamental, and to provide information that can be used to inform decisions, conduct assessments, and support education and training. This requires sustaining two-way communication about what constitutes useful and scientifically valid knowledge across the boundary that separates users of scientific information from those who produce it. Sustaining interactions with stakeholders at the interface of science and policy is a challenge.

Science-Policy Interaction

Bridging the gap between policy and science is an issue which has triggered intensive debates over many years. No simple recipes have emerged. Policy makers often complain about a lack of policy relevant research results and scientists often complain about the ignorance of policy makers of their policy relevant research results. Some major causes of poor science-policy interaction and is intended as a help to avoid obvious pitfalls in particular science-policy interaction related to environmental and societal issues.

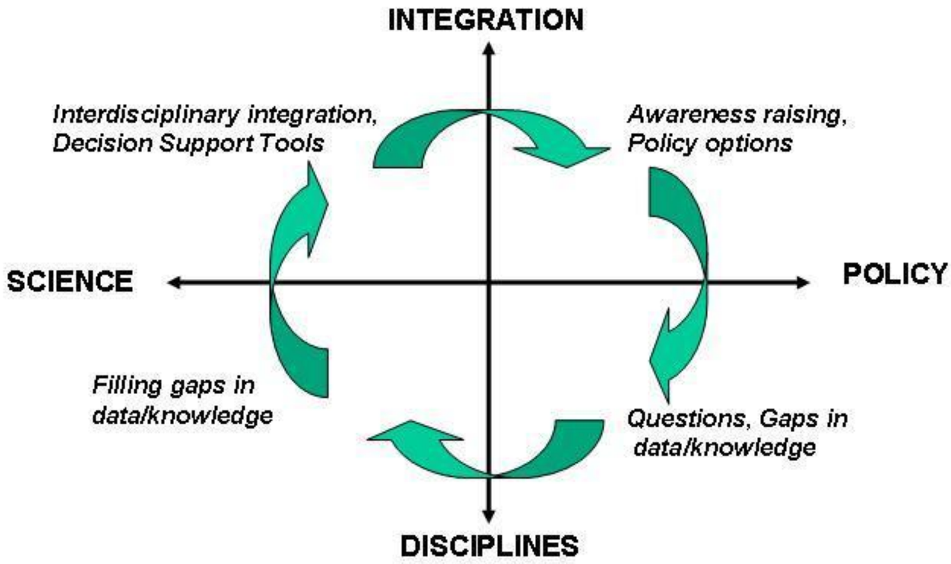

Figure 6: The Knowledge Cycle: an idealistic conceptual model of Science-Policy Interaction(online material).

The knowledge cycle

The knowledge cycle depicted in the figure provides an appealing model for science-policy interaction. The simplest interpretation of the picture is: science delivers facts and figures on which policy can build and policy formulates demands for lacking knowledge. However, reality is more complex, for several reasons.

The role of science is often seen as providing hard facts and figures. However, facts and figures produced by science generally refer to specific temporally and geographically bounded situations, which seldom match the situations of practical interest. Situations of policy interest often lay in future and are subject to more interactions of greater complexity and to different (often loosely defined) boundary conditions. Results of relevance for policy require extrapolation or generalization, relying on assumptions or models. But generally science does not provide a complete and unique set of validated assumptions and models. The science input to policy is therefore cursed with uncertainty and arbitrariness, especially in situations where underlying (natural, social) processes are not well understood. Science is an evolutionary (and at times even revolutionary) process, often with competing explanations for why things are as they are. Science-based policymaking may even become an illusion in cases of strongly conflicting scientific opinions and frequently changing insight and forecasts.

A second important reason for failure of the knowledge cycle are the different time scales at which science and policy progress: **the knowledge cycle does not fit the policy cycle**. Policy generally moves faster than science. Ongoing research produces new scientific evidence while policy decisions had to be taken already on the basis of earlier preliminary insight and forecasts. New theory, concepts, and empirical “facts” may emerge, pointing to opposite conclusions. This may frustrate the policy process and undermine the willingness of policymakers to listen to scientists and to invest in research.

Conflicts between science and policy may also arise from different perceptions regarding the weight of scientific evidence in policy decisions. Policymakers base their judgments not only on scientific evidence but also on their own experience (tacit knowledge) or on information provided by non scientific stakeholders. Such knowledge may be considered by technical experts as scientifically invalid. Disputes often already originate from different views on how a policy problem should be defined.

Effective science-policy interaction

The integration of new scientific information into policy is greatly facilitated for policies developed according to the principles of adaptive management. These principles emphasize uncertainty, the existence of multiple competing hypotheses, collective learning and incremental change. Adaptive management therefore can more easily cope with the continuing flow of new information produced by ongoing research. Adaptive management is also an appropriate strategy for learning what works and why, so that we can apply the lessons in the course of policy implementation.

Intermediaries between science and policy, individuals who can link the worlds of science and management and translate the concerns of one to members of the other, can be very helpful to streamline science-intensive policy processes. They are sometimes called “science brokers” or “boundary spanners”. Their efforts are generally aimed at evaluating, formulating, or altering management policy. They can also moderate cross-disciplinary working groups involving scientists and policymakers, to build a genuinely informed understanding of each other’s views and interests.

Clark and Meidinger mention several other important preconditions to successfully integrating science and policy:

- clarity of objectives, processes, and desired outcomes;
- clarity of roles and responsibilities of scientists, policymakers, and the public;
- quality control through open peer and public review;
- effective communication and involvement of stakeholders throughout the process.

The climate debate on the causes and impacts of global warming is an illustration of difficult science-policy interaction related to uncertainty and arbitrariness. The assessment process established by the Intergovernmental Panel on Climate Change provides an example of how to deal with this problem. Key characteristics of scientific international assessments, such as IPCC, are:

- they are demand driven, with involvement in the assessment process of the full range of decision-makers who would implement the potential responses;
- they are designed as an open, transparent, representative and legitimate process, with well defined principles and procedures;
- they involve experts from all relevant stakeholder groups in the scoping, preparation, peer-review, and outreach/communication;
- the process incorporates institutional as well as local and indigenous knowledge whenever appropriate;
- results and analyses are technically accurate;
- conclusions are policy-relevant but not policy-prescriptive;
- conclusions are evidence-based and not value-laden, i.e. they are devoid of ideological concepts and value-systems, recognizing that the assessment conclusions will be used within in a range of different value-systems;
- they cover risk assessment and management;
- they present different points of view;
- they quantify, or at least qualify, the uncertainties involved.

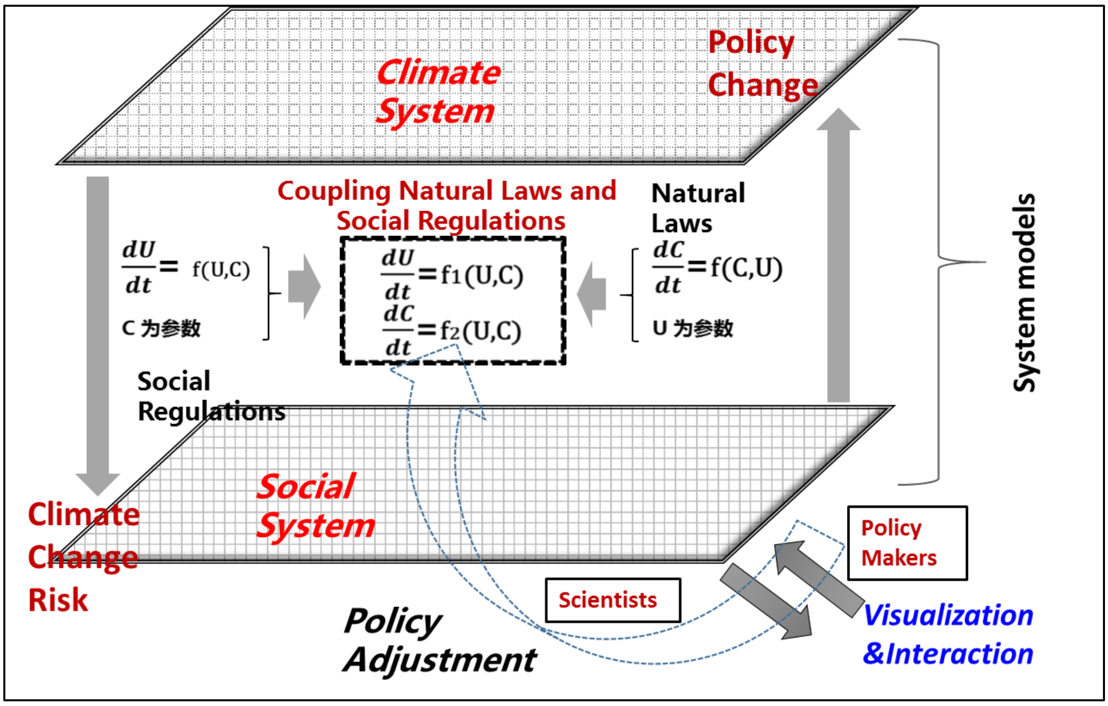

Figure 7: Modelling concept framework of Orderly adaptation, the interaction between climate system and socio-economic system need to be two coupled through system models, and the scientific information of climate change risks and opportunitiesneed to be communicated effectively with policy maker the visualization and interaction.

3.2.2 Integrated Risk Governance Framework

Risk is an uncertain (generally adverse) consequence of an event or activity with respect to something that human value. Risks are often accompanied by opportunities.

Systemic risks are embedded in the larger context of societal, financial and economic consequences and are at the intersection between natural events, economic, social and technological developments and policy-driven actions. Such risks are not confined to national borders; they cannot be managed through the actions of a single sector; they require robust governance approach if they are to be adequately managed. The governance of systemic risks requires cohesion between countries and the inclusion within the process of governments, industry, academia and civil society.

Governance refers to the actions, processes, traditions and institutions by which authority is exercised and decisions are taken and implemented.

- Risk governance deals with the identification, assessment, management and communication of risks in a broad context.
- It includes the totality of actors, rules, conventions, processes and mechanisms and is concerned with how relevant risk information is collected, analysed and communicated, and how management decisions are taken.
- It applies the principles of good governance that include transparency, effectiveness and efficiency, accountability, strategic focus, sustainability, equity and fairness, respect for the rule of law and the need for the chosen solution to be politically and legally feasible as well as ethically and publicly acceptable.

Risk accompanies change. It is a permanent and important part of life and the willingness and capacity to take and accept risk is crucial for achieving economic development and introducing new technologies. Many risks, and in particular those arising from emerging technologies, are accompanied by potential benefits and opportunities.

The challenge of better risk governance lies here: to enable societies to benefit from change while minimising the negative consequences of the associated risks.

IRGC's risk governance framework is a comprehensive approach to help understand, analyse and manage important risk issues for which there are deficits in risk governance structures and processes. The framework comprises five linked phases:

1) Pre-assessment
2) Appraisal
3) Characterisation and evaluation
4) Management
5) Communication

These interlinked phases, which are summarized in the following pages, together provide a means to gain a thorough understanding of a risk and to develop options for dealing with it.

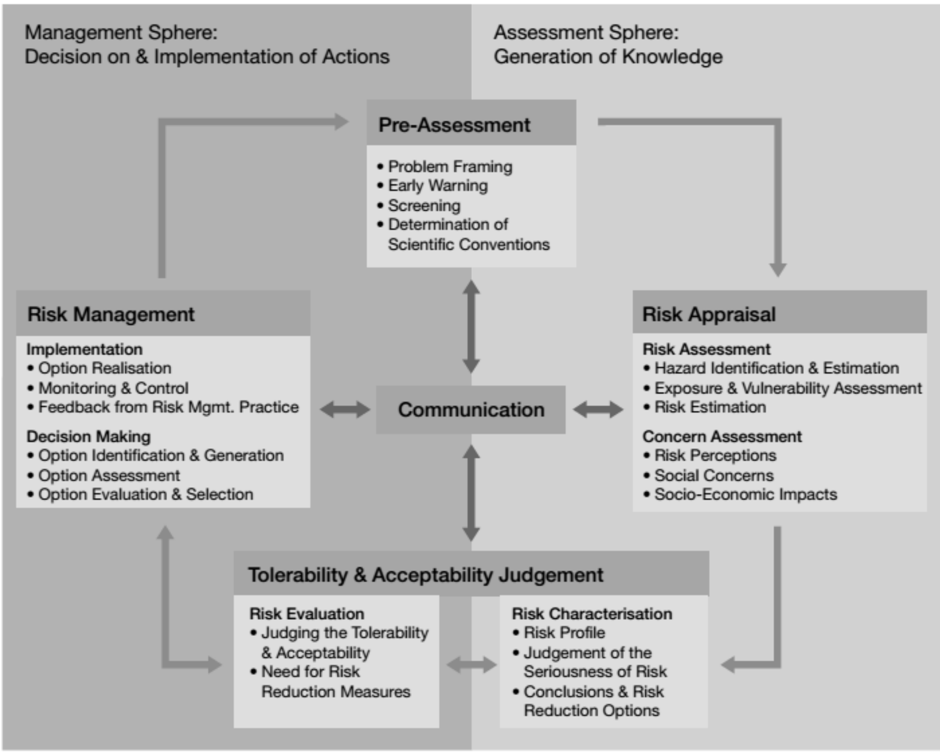

Figure 8: Integrated risk governance framework (Adopted from Integrated Risk Governance Council, 2006)

Pre-assessment

The purpose of the **pre-assessment phase** is to capture both the **variety of issues that stakeholders and society may associate with a certain risk as well as existing indicators, routines, and conventions that may prematurely narrow down, or act as a**

filter for, what is going to be addressed as risk. What counts as a risk may be different for different groups of actors.

(1) The first step of pre-assessment, risk framing, therefore places particular importance on the need for all interested parties to share a common understanding of the risk issue(s) being addressed or, otherwise, to raise awareness amongst those parties of the differences in what is perceived as a risk. For a common understanding to be achieved, actors need both to agree with the underlying goal of the activity or event generating the risk and be willing to accept the risk's foreseeable implications on that very goal.
(2) A second step of the pre-assessment phase, early warning and monitoring, establishes whether signals of the risk exist that would indicate its realisation. This step also investigates the institutional means in place for monitoring the environment for such early warning signals.
(3) The third step, pre-screening, takes up and looks into the widespread practice of conducting preliminary probes into hazards or risks and, based on prioritisation schemes and existing models for dealing with risk, of assigning a risk to pre-defined assessment and management 'routes'.
(4) The fourth and final step of pre-assessment selects major assumptions, conventions and procedural rules for assessing the risk as well as the emotions associated with it.

Risk appraisal

The objective of the **risk appraisal** phase is to provide the knowledge base for the societal decision on whether or not a risk should be taken and, if so, how the risk can possibly be reduced or contained. Risk appraisal thus comprises a scientific assessment of both the risk and of questions that stakeholders may have concerning its social and economic implications.

The first component of risk appraisal, risk assessment, seeks to link a potential source of harm, a hazard, with likely consequences, specifying probabilities of occurrence for the latter. Depending on the source of a risk and the organisational culture of the community dealing with it, many different ways exist for structuring risk assessment. Despite such diversity, three core steps can be identified. These are: the identification and, if possible, estimation of the hazard, an assessment of related exposure and/or vulnerability and an estimation of the consequent risk. The latter step – risk estimation – aggregates the results of the first two steps and states, for each conceivable degree of severity of the consequence(s), a probability of occurrence. Confirming the results of risk assessments can be extremely difficult, in particular when cause-effect relationships are hard to establish, when they are instable due to variations in both causes and effects and when effects are both scarce and difficult to understand. Depending on the achievable state and quality of knowledge, risk assessment is thus confronted with three major challenges that can best be summarised using the risk categories outlined above – 'complexity', 'uncertainty' and 'ambiguity'.

For a successful outcome to the risk process and, indeed, overall risk governance, it is crucial that the implications of these challenges are made transparent at the conclusion of risk assessment and throughout all subsequent phases.

Equally important to understanding the physical attributes of the risk is detailed knowledge of stakeholders' concerns and questions – emotions, hopes, fears, apprehensions – about the risk as well as likely social consequences, economic implications and political responses. The second component of risk appraisal, concern assessment, thus complements the results from risk assessment with insights from risk perception studies and interdisciplinary analyses of the risk's (secondary) social and economic implications.

Risk Judgement

The most controversial phase of handling risk, risk characterisation and evaluation, aims at judging a risk's acceptability and/or tolerability. A risk deemed 'acceptable' is usually limited in terms of negative consequences so that it is taken on without risk reduction or mitigation measures being envisaged. A risk deemed 'tolerable' links undertaking an activity – which is considered worthwhile for the value added or benefit it provides – with specific measures to diminish and limit the likely adverse consequences.

This judgement is informed by two distinct but closely related efforts to gather and compile the necessary knowledge which, in the case of tolerability, must additionally support an initial understanding of required risk reduction and mitigation measures. While risk characterisation compiles scientific evidence based on the results from the risk appraisal phase, risk evaluation assesses broader value-based issues that also influence the judgement. Such issues, which include questions such as the choice of technology, societal needs requiring a given risk agent to be present and the potential for substitution as well as for compensation, reach beyond the risk itself and into the realm of policy-making and societal balancing of risks and benefits.

Risk management

The risk management phase designs and implements the actions and remedies required to tackle risks with an aim to avoid, reduce, transfer or retain them. Risk management thereby relies on a sequence of six steps which facilitates systematic decision-making. To start with, and based on a reconsideration of the knowledge gained in the risk appraisal phase and while judging the acceptability and/or tolerability of a given risk, a range of potential risk management options is identified. The options are then assessed with regard to such criteria such as effectiveness, efficiency, minimisation of external side effects, sustainability etc. These assessment results are next complemented by a value judgement on the relative weight of each of the assessment criteria, allowing an evaluation of the risk management options. This evaluation supports the next step in which one (or more) of the of risk management options is selected, normally after consideration of possible trade-offs that need to be made between a number of second-best options. The final two steps include the implementation of the selected options and the periodic monitoring and review of their performance.

Based on the dominant characteristic of each of the four risk categories ('simple', 'complexity', 'uncertainty', 'ambiguity') it is possible to identify specific safety principles and, consequently, design a targeted risk management strategy (see Table I). 'Simple' risk problems can be managed using a 'routine-based' strategy which draws on traditional decision-making instruments, best practice as well as time-tested trial-and-error. For 'complex' and 'uncertain' risk problems it is helpful to distinguish the strategies required to deal with a risk agent from those directed at the risk-absorbing system: complex risks are thus usefully addressed on the basis of 'risk-informed' and 'robustness-focussed' strategies, while uncertain risks are better managed using 'precaution-based' and 'resilience-focussed' strategies.

Whereas the former strategies aim at accessing and acting on the best available scientific expertise and at reducing a system's vulnerability to known hazards and threats by improving its buffer capacity, the latter strategies pursue the goal of applying a precautionary approach in order to ensure the reversibility of critical decisions and of increasing a system's coping capacity to the point where it can withstand surprises. Finally, for 'ambiguous' risk problems the appropriate strategy consists of a 'discourse-based' strategy which seeks to create tolerance and mutual understanding of conflicting views and values with a view to eventually reconciling them.

Risk communication

The remaining element of the risk process is risk communication, which is of major importance throughout the entire risk handling chain. Not only should risk communication enable stakeholders and civil society to understand the rationale of the results and decisions from the risk appraisal and risk management phases when they are not formally part of the process, but it should also help them to make informed choices about risk, balancing factual knowledge about risk with personal interests, concerns, beliefs and resources, when they are themselves involved in risk-related decision-making. Effective risk communication consequently fosters tolerance for conflicting viewpoints and provides the basis for their resolution, and creates trust in the institutional means for assessing and managing risk and related concerns.

Eventually, risk communication can have a major impact on how well society is prepared to cope with risk and react to crises and disasters. Risk communication has to perform these functions both for the experts involved in the overall risk process – requiring the exchange of information between risk assessors and managers, between scientists and policy makers, between academic disciplines and across institutional barriers – and for the 'outside world' of those affected by the process.

In fact, communication is an essential factor for successful risk governance as well as for many climate change adaptation situations. This holds for two sets of reasons. On the one hand, the heterogeneity of actors at various scales makes it essential to communicate in order to create and maintain action capacity. On the other hand, the variety of agencies and publics that heat risk governance has to address requires flexible forms of communication in order to get heard and understood.

One might call the first aspect **internal communication** (within the actor network), while the second one refers to **external communication** with those institutions and groups that provide necessary information or are addressed as potential users. While it might be impossible to institutionalize these two strands in a separate organization, it is indispensable that all actors involved in the governance network should be aware of the necessity to get the communication side right.

Stakeholder involvement

IRGC has broadened the concept of risk assessment by adding the parallel activity of concern assessment – the consideration of individual, organisational and societal perceptions of and concerns about the consequences of risk. Both are relevant inputs to risk evaluation and risk management.

In addition, it provides guidance on how best to implement the idea of inclusive governance. Inclusive governance is based on the assumption that all stakeholders have something to contribute to the process of risk governance and that their inclusion improves the final decisions rather than impedes the decision-making process or compromises the quality of scientific input.

Very few risk governance models currently include procedures or guidance for how, or when, to involve the concerns of stakeholders – particularly the general public.

IRGC recommends that decision makers consider using the dominant characteristic of a risk as the basis for deciding on the appropriate level of stakeholder involvement in the process.

Whilst simple risks may require little consultation on the nature of the risk itself because of their routine nature (although consultation may be needed on the choice of the most effective method of control), highly complex and uncertain risks may benefit from wider dialogue amongst, respectively, a broader base of people with expert knowledge or all directly affected stakeholders. Risks with high levels of ambiguity are those for which wider stakeholder consultation is recommended, not least as means of trying to reconcile the various framings that different stakeholders may have when interpreting a risk or evaluating the options for its management.

For example, the organisational capacity of an organisation or system (the capability of key actors in the risk governance process to fulfil their roles) and the political cultures (the governmental and regulatory 'styles' that define particular institutions or countries) are important in determining governance processes. Also important are the risk culture, which impacts on the level of risk tolerance (or risk aversion), and the degree of trust in the institutions responsible for risk governance.

Wider Governance Issues: Organisational Capacity and Regulatory Styles

The wider governance issues pertinent to the context of a risk and the overall risk process, when different countries or, indeed, risk communities, may pursue for dealing with risk. The discussion of these wider issues begins with an assessment of the very notion of 'risk governance' which builds on the observation that collective decisions about risks are the outcome of a 'mosaic' of interactions between governmental or administrative actors, science communities, corporate actors and actors from civil society at large, many of the interactions taking place and relevant to only individual parts of the overall process. The interplay of these actors has various dimensions, including public participation, stakeholder involvement and the formal (horizontal and vertical) structures within which it occurs. Organisational prerequisites for effective risk governance, which are at the crossroads of the formal responsibilities of actors and their capability and authority to successfully fulfil their roles, and makes a very short case for risk education. The organisational prerequisites are summarised under the term 'institutional and organisational capacity' and include both intellectual and material 'assets', 'skills' and as well as the framework of relations, or 'capabilities', required to make use of the former two. **The discussion of wider risk governance issues concludes with a reflection on the role of political culture and a proposal for a typology of different regulatory regimes or governmental styles**

Principles and indicators of integrated risk governance (OECD, 2015)

Since one cannot improve what cannot be measured, it is proposed to build consensus across a range of stakeholders and the ultimate beneficiaries on a set of factual and perception-based indicators that can help assess whether the framework conditions are in place for the 12 Principles to be effectively implemented in practice. In the more medium-term, such indicators could also seek to assess the effectiveness of governance instruments in place to address each of the Principles.

These Principles apply to all levels of government. They are clustered around three categories:

(1) **Effectiveness** of climate change governance relates to the contribution of governance to define clear sustainable water policy goals and targets at different

levels of government, to implement those policy goals, and to meet expected objectives or targets.

(2) **Efficiency** of climate change governance relates to the contribution of governance to maximise the benefits of sustainable water management and welfare at the least cost to society.

(3) **Trust and Engagement** in climate change governance relate to the contribution of governance to building public confidence and ensuring inclusiveness of stakeholders through democratic legitimacy and fairness for society at large.

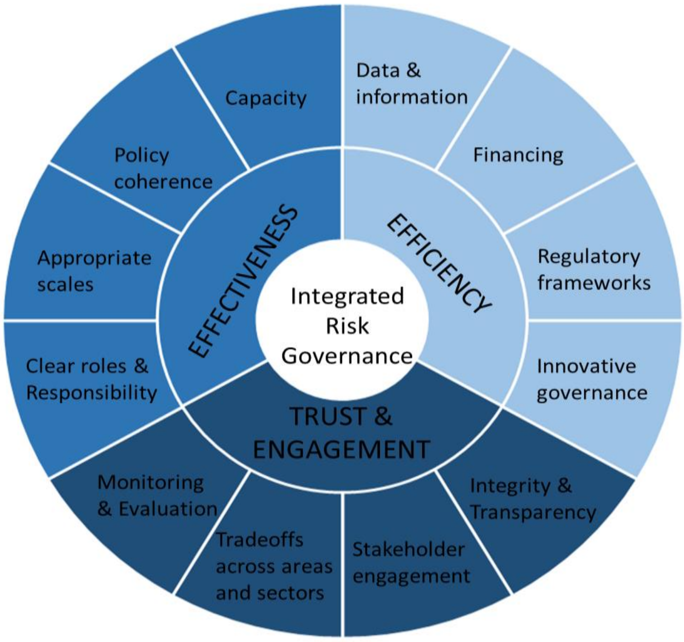

Figure 9: Climate change integrated risk governance performance components (modified based on OECD 2015)

3.2.3 Socio-Ecological-System

Longstanding approaches to solving ecological and social problems are often insufficient to address complex, highly interactive challenges facing our world today. Climate change, species loss, non-point source pollution, and technological and population pressures on scarce resources are all examples of problems that arise in social-ecological systems (SES). SESs are systems that involve both natural/ecological and human/social components that interact to affect system dynamics. Such challenges have led to calls for increasing attention to how societies organize governance and institutions. As an integral component of governance, institutions are of particular interest. Our ability to purposefully change institutions to enhance adaptive governance requires better understanding of how politics, science, and other factors affect institutional change.

A socio-ecological system can be defined as:

- A coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;
- A system that is defined at several spatial, temporal, and organisational scales, which may be hierarchically linked;

- A set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and
- A perpetually dynamic, complex system with continuous adaptation.

The concept of socio-ecological systems is to emphasise the integrated concept of humans in nature and to stress that the delineation between social systems and ecological systems is artificial and arbitrary. Whilst resilience has somewhat different meaning in social and ecological context, the SES approach holds that social and ecological systems are linked through feedback mechanisms, and that both display resilience and complexity.

Studying SESs from a complex system perspective is a fast-growing interdisciplinary field which can be viewed as an attempt to link different disciplines into a new body of knowledge that can be applied to solve some of the most serious environmental problems today. Management processes in the complex systems can be improved by making them adaptive and flexible, able to deal with uncertainty and surprise, and by building capacity to adapt to change. SESs are both complex and adaptive, meaning that they require continuous testing, learning about, and developing knowledge and understanding in order to cope with change and uncertainty.

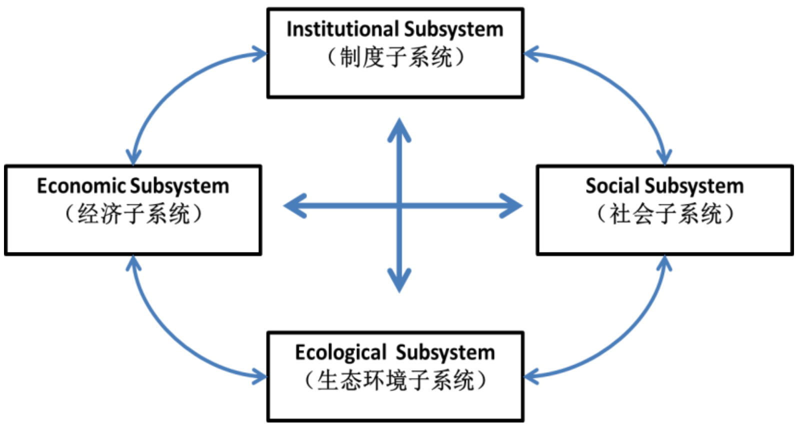

Figure 10: Socio-Ecological System framework four subsystems (social subsystem, economic system, institutional subsystem, ecological system (natural subsystem)) and their interactions are the ideal research topics of sustainability science; they are also the research objectives of integrated risk governance。

SES is a typical large complex system, complex systems differs from a simple system in that it has a number of attributes that cannot be observed in simple systems, such as nonlinearity, uncertainty, emergence, scale, and self-organisation.

- **Nonlinearity**: Nonlinearity is related to fundamental uncertainty. It generates path dependency, which refers to local rules of interaction that change as the system evolves and develops. A consequence of path dependency is the existence of multiple basins of attraction in ecosystem development and the potential for threshold behaviour and qualitative shifts in system dynamics under changing environmental influences.

- **Emergence**: Emergence is the appearance of behaviour that could not be anticipated from knowledge of the parts of the system alone.

- **Scale**: Scale is important when dealing with complex systems. In a complex system many subsystems can be distinguished; and since many complex systems are hierarchic, each subsystem is nested in a larger subsystem etc. Phenomena at each level of the scale tend to have their own emergent properties, and different levels may be coupled through feedback relationships. Therefore, complex systems should always be analysed or managed simultaneously at different scales.
- **Self-organisation**: Self organisation is one of the defining properties of complex systems. The basic idea is that open systems will reorganise at critical points of instability. The self-organisation principle, operationalised through feedback mechanisms, applies to many biological systems, social systems and even to mixture of simple chemicals. High speed computers and nonlinear mathematical techniques help simulate self-organisation by yielding complex results and yet strangely ordered effects. The direction of self-organisation will depend on such things as the system's history; it is path dependent and difficult to predict.

Box 1: Climate change risk assessment excerpts (King et al. 2015)

The greatest risks of climate change arise when thresholds are crossed: what had been gradual becomes sudden; what had been inconvenient becomes intolerable. The greatest reductions in risk will be won in the same way. Gradual, incremental measures will not be enough: we must seek out non-linear, discontinuous, transformational change.

Political leadership can and should be a source of non-linear change. It can move a government from inaction to action, and a society from apathy to engagement. With existing technology, there is already the opportunity for political leadership to dramatically change the trajectory of any country's emissions in the short term.

Technological innovation is a natural source of non-linear change. New technologies can emerge slowly, but then displace old ones rapidly and suddenly when some invisible threshold is crossed. We need to accelerate this pace of change, and bring forward those thresholds, in all the technologies that are needed to win the battle.

In finance, small changes in the rules of the game can produce large changes in results. The right adjustments to regulations and incentives will dramatically alter the flow of money, sending more of it in a direction that serves our long-term economic interests.

The power of non-linear change is not reserved to political leaders, technologists and markets. Social change can also be discontinuous, unpredictable, and dramatic. The battle against slavery (or colonialism) may have taken a century, but when change finally came, it came quickly.

The risks of climate change are amplified by feedbacks: rising temperatures melt ice; sea stripped of ice takes in more heat; and the temperatures rise faster. To win this battle, we must set up our own cycles of positive feedback. Political interventions must change market sentiment, so that the market sends more investment into clean energy technologies, so that this accelerates technological progress, so that new political interventions become possible.

Characteristic of Socio-Ecological System

Resilience is the capacity of a complex system to remain within a regime in the face of external perturbations and/or internal change. When a complex system is forced beyond the boundaries of a regime, i.e., a regime shift, the new regime is typically characterized by a new set of structures and processes. An adaptive cycle describes the processes of development and decay in a system, and captures the dynamic character of structures and processes in complex systems.

A **panarchy** is a nested set of adaptive cycles. Panarchy differs from hierarchy in that conditions can arise that trigger “bottom-up,” i.e., cross-scale cascading, change in the system. Because of this subtle, but critical difference, the panarchy model does a better job of capturing the dynamics of complex systems, e.g., “surprise.” Further, levels in a panarchy are not static states, but rather adaptive cycles that are interconnected to other adaptive cycles in the panarchy. Each cycle operates over a discrete range of scale in both time and space and is connected to adjacent levels (adaptive cycles). Adaptive cycles do not exist in isolation. Because adaptive cycles operate over specific ranges of scale, a system’s resilience is dependent upon the interactions between structure and dynamics at multiple scales. Panarchy was developed to specifically address issues of scale, as well as cross-scale dynamics.

3.2.4 System Science and System Dynamics

Systems science is an interdisciplinary field that studies the nature of systems—from simple to complex—in nature, society, and science itself. The field aims to develop interdisciplinary foundations that are applicable in a variety of areas, such as engineering, biology, medicine, and social sciences.

Systems science covers formal sciences such as complex systems, cybernetics, dynamical systems theory, and systems theory, and applications in the field of the natural and social sciences and engineering, such as control theory, operations research, social systems theory, systems biology, systems dynamics, human factors, systems ecology, systems engineering and systems psychology. Themes commonly stressed in system science are (a) holistic view, (b) interaction between a system and its embedding environment, and (c) complex (often subtle) trajectories of dynamic behavior that sometimes are stable (and thus reinforcing), while at various 'boundary conditions' can become wildly unstable (and thus destructive). Concerns about Earth-scale biosphere/geosphere dynamics is an example of the nature of problems to which systems science seeks to contribute meaningful insights.

System dynamics models

System dynamics is a methodology and mathematical modeling technique to frame, understand, and discuss complex issues and problems. Originally developed in the 1950s to help corporate managers improve their understanding of industrial processes, SD is currently being used throughout the public and private sector for policy analysis and design.

SD models solve the problem of simultaneity (mutual causation) by updating all variables in small time increments with positive and negative feedbacks and time delays structuring the interactions and control. The best known SD model is probably the 1972 The Limits to

Growth. This model forecast that exponential growth would lead to economic collapse during the 21st century under a wide variety of growth scenarios.

System dynamics is an aspect of systems theory as a method to understand the dynamic behavior of complex systems. The basis of the method is the recognition that the structure of any system, the many circular, interlocking, sometimes time-delayed relationships among its components, is often just as important in determining its behavior as the individual components themselves. Examples are chaos theory and social dynamics. It is also claimed that because there are often properties-of-the-whole which cannot be found among the properties-of-the-elements, in some cases the behavior of the whole cannot be explained in terms of the behavior of the parts.

Therefore, policy might be more effective if geared towards i) improving the resilience of the system and decreasing its vulnerabilities; ii) avoiding (promoting) dangerous (positive) tipping points, and iii) identifying the key actors in a network that can promote changes in the system.

Complexity methods and methodologies can help take into account the complex features of the systems under analysis.

1. **Modeling is a good strategy to obtain better understanding of how a system works, and one which allows incorporating the complex features of the system.** Modeling can help identify the important players in the system under analysis (agents), their different characteristics (heterogeneity), their interrelations (interconnectedness), and how these components together give rise to complex and sometimes unexpected behavior. Examples of such modeling techniques are cellular automata and agent-based modeling. Heemskerk and colleagues collect a clarifying sequence of modeling definitions:

Box 2: What is model?

A model is an abstraction or simplification of reality (Furtado et al.2015). Scientists often use models to explore systems and processes they cannot directly manipulate. Models can be more or less quantitative, deterministic, abstract, and empirical. They help define questions and concepts more precisely, generate hypotheses, assist in testing these hypotheses, and generate predictions. Model building consists of determining system parts, choosing the relationships of interest between these parts, specifying the mechanisms by which the parts interact, identifying missing information, and exploring the behavior of the model. The model building process can be as enlightening as the model itself, because it reveals what we know and what we don't know about the connections and causalities in the systems under study. Thus modeling can both suggest what might be fruitful paths of study and help pursue those paths.

2. **Modeling permits simulating scenarios as a decision-support tool to inform policy making.** Models work as platforms for so-called in silico experiments, by means of which different policy options can be computationally simulated and "cheaply" tested.

3. Modeling stimulates a forward-looking, prospective view of policy, by allowing scenario building and testing. Models can enable prognosis that are less based solely on probabilities but that include essential interactions at various scales and with various agents' interests considered. Policymakers can thus work with spaces of scenarios and realms of probabilities that occur given known rupture points.

4. Models can be continuously improved, as more knowledge is gained about the system. Models can also be simple and provide general insights, or specific to help tackle a particular problem.

5. Models are a means of communicating one's ideas and theories and can work as a "meeting point" for collaborative work among interdisciplinary teams. "Models not only help formulate questions, clarify system boundaries, and identify gaps in existing data, but also reveal the thoughts and assumptions of fellow scientists" (Heemskerk, Wilson and Pavao Zuckerman, 2003).

6. The notion of multiple models contributes to the understanding of social phenomena in particular and of public policies in general because it is based on the richness of diversity, difference and dissimilarities (Page, 2007). As Page (2007) argues, no single model can independently cover comprehensively the intricacies of some phenomena, especially those of subjective nature, complex ones. He also states that models section the analysis with specific parameters, be it from the theoretical, methodological or procedural point of view. Thus, the diversity of models implies a larger coverage of possible scenarios that are more keen to envelope unexpected sequences, unlikely important events, unique tipping points.

Data are a valuable resource for policy making and complexity methods give insights into how to use them to the best extent.

- Data can help visualize, describe and identify features of the system to be better explored. Social network analysis, for instance, relies on the visual representation of networks to convey complex information.
- Data mining, machine learning, network analysis and other association studies can provide insights into the functioning of the system.
- Data can help validate and improve models.

Finally, knowledge can be viewed as a feedback process, "an endless cycle of proud proposing and disdainful doubting" (Mitchell, 2011, p. 295). Modeling provides a way to structure this process and to improve the understanding of the system one wants to impact. The cycle of data analysis, modeling, validation, simulation, implementation, data analysis, re-modeling and so on might be the "strange loop" that can provide decision support for tackling complex problems through public policy. If not a certain, determined path to be tread on, complex systems may illuminate the key pathways to policy-makers, clarifying what is likely to happen given choices of sets of paths, after so much has been travelled on.

3.2.5 Decision Support Processes and Decision Support Systems

The support tool need to in align with the process by providing useable and understandable, useful information and knowledge to help policy maker and planners. This is critical for the research knowledge can be justified and incorporated to decision making or planning process. Therefore in each stage of the decision making and planning related information and tool should be provided to the users.

Stage one: Provide help, key information or template for stage one: Identifying the problem and objectives; Highlight some of the key characteristics of A&M as a decision problem; A checklist of things to consider in identifying the scope and overarching objectives of A&M;

Stage two: Establish your risk tolerance and decision-making criteria; Highlight the major approaches to climate risk assessment; Highlight the major approaches to A&M decision-making and their advantages and disadvantages. Provide risk assessment and scenarios analysis tools for: **Stage three**: Identify and assess your risks; **Stage four**: Identify a range of A&M options with CBA, CEA; **Stage five**: Appraise you're A&M options; **Stage seven**: Refine problem and criteria

Help on reporting and evaluation for **Stage six**: Make decision; **Stage eight**: Implement; **Stage night**: Monitor & evaluation (Figure 11)

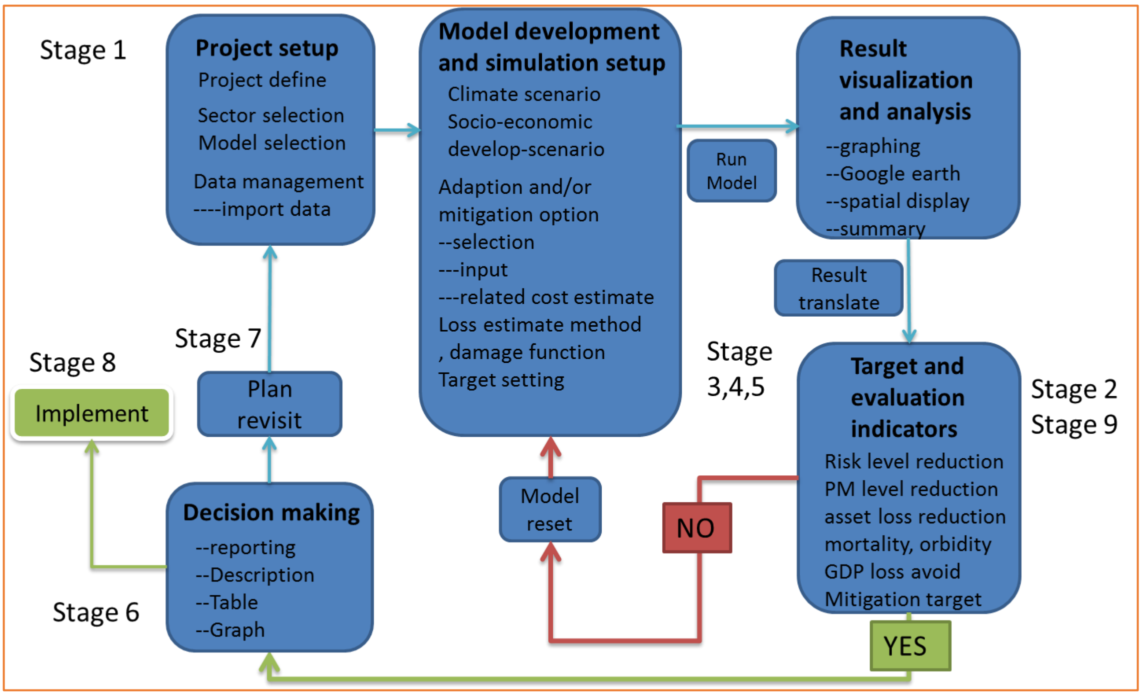

Figure 11: Flowchart link to policy making procedure and UrbanCLIM support function

Beyond the software itself, the system also could provide the opportunities to carry out mediated modelling. Mediated Modelling (MM) works with stakeholder groups to combines the best of 'participatory and consensus based approaches to decision-making' with the most appropriate modelling approaches. This also will be discussed in the stakeholder engagement section.

3.2.6 Risk Informed Decision Framework (RIDF) Planning Process

The RIDF has been developed to integrate risk and decision science methods (and detailed risk tradeoff analysis) into the USACE 6-step planning process (USACE 2009).The RIDF draws on risk analysis techniques to characterize and assess the uncertainties that complicate the decision and to provide for a comprehensive look at competing performance criteria under various future scenario conditions. These include uncertainties in the economic and environmental conditions that will influence the outcome of a decision as well as the stochastic nature of storm surge events. The purpose is to help planners characterize the critical uncertainties most important to the choice among plans and to identify robust risk reduction strategies, which are decision alternatives that perform relatively well across a wide range of future conditions.

The features of RIDF:

- Accounts for the consequences of low-probability storms including expected property damages, population at risk, and regional economic impacts.
- Helps decision makers adjust their decisions to account for a lack of knowledge regarding the economic and environmental conditions that will influence plan performance.
- Provides for a better understanding of tradeoffs and remaining risks among competing areas of interests and project outputs.

What are the Advantages of RIDF?

The RIDF has several advantages.

The framework engages stakeholders and decision makers in a process of issue identification and priority setting to formally establish project goals. The process helps decision makers to:

- Identify and reveal hidden agendas
- Identify, acknowledge and, when possible, fill data gaps that, if filled, could influence decisions;
- Objectives are expressed in the form of a multi-attribute utility function that:
- Gives objectives that are difficult to monetize the same consideration as monetary objectives, enabling environmental and social decision objectives to receive equal consideration with economic objectives.
- Allows decision makers to make explicit tradeoffs between objectives because progress on one objective can be used to compensate for lack of progress on another objective.

Outputs and plan performance and evaluation scoring allow for equal consideration of stakeholder preferences, as well as cost efficiencies, project effectiveness in reducing risk and future funding requirements necessary for plan implementation.

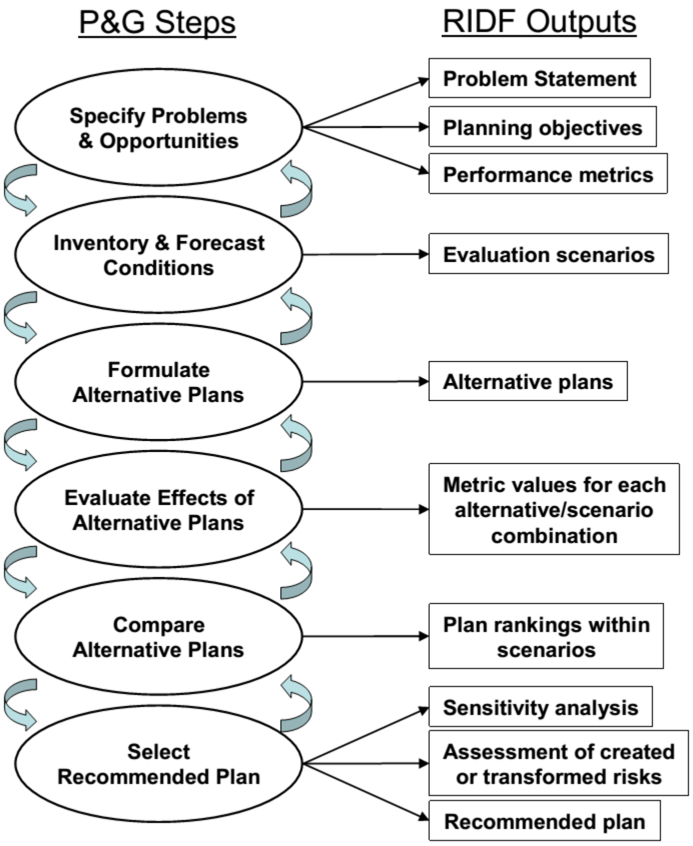

Figure 12: Risk-Informed Decision Framework

(1) **Specify Problems and Opportunities**:

Frame the decision by developing a problem statement and identifying the spatial and temporal boundaries of analysis (i.e. planning area and planning units).

Establish planning objectives and choose outcome measures of performance, or metrics, which reflect progress toward achieving the planning objectives.

(2) **Inventory and Forecast Conditions**:

Select models of physical and economic systems or other appropriate tools to simulate decision outcomes in terms of the selected performance metrics. Identify important sources of uncertainty in physical and economic models.

(3) **Formulate Alternative Plans**:

Formulate decision alternatives by identifying potential measures for flood risk reduction, pre-screening poor performing measures, and formulating an array of alternatives planning unit from remaining measures.

(4) **Evaluate Effects of Alternative Plans**:

Model the outcome measures of performance for each alternative and each scenario.

(5) **Compare Alternative Plans**:

- Obtain weights on metrics from the decision makers and/or stakeholder groups.
- Calculate multi-attribute utility and implement the stakeholder preference analysis for each alternative and scenario.

- Identify consistently dominating plans in each planning unit based on the multi-attribute utility values.
- Develop alternative ranking of plans based on assessment of evaluation criteria addressing other decision objectives viewed as important to decision makers.
- Conduct an indexed scoring of alternatives based on the MCDA results and alternative plan rankings.
- Identify the final array of alternatives for each planning unit and prepare detailed tradeoffs analysis of plan performance and outputs for these alternatives.
- Apply secondary evaluation criteria and sensitivity analysis (e.g., varying levels of participation in nonstructural measures and analysis of alternatives under degraded coastal conditions).
- Screen out plans that are consistently dominated.

(6) **Select a Recommended Plan**:

- Develop strategies for combining top performing alternatives in each planning unit to create comprehensive plans.
- Develop conclusions and findings based on the above analyses.

3.2.7 Adaptation as Risk Management

Adaptation to climate change can be seen as an issue of climate risk management for certain circumstance, such as industries or enterprise where ISO31000:2009 is well accepted. ISO 31000:2009 definition of risk, as being: “The effect of uncertainty on business objectives”, and risk is calculated as the product of the likelihood of a climate-related event, and the consequences. Risk can have both negative and positive consequences, which in this guidebook are referred to as threats and opportunities, respectively. All organisations, be they in the public or private sector, will have business plans and objectives, some of which may be affected by, or sensitive to climate impacts.

Business objectives are taken to mean the values, goals, and targets that any organisation may have or desire to obtain. These objectives can be analysed as to the effect that climate and other relevant factors e.g. socio-economic and socio-political, may have on their successful achievement.

A risk management framework provides a means within which to systematically analyse these risks, understand how they are generated as a result of the interaction of climate and non-climate factors, what the negative and positive consequences may be, and how we may be able to intervene to reduce threats and make the most of any opportunities. The risk management framework as applied to adaptation is shown schematically in figure C. Stages 3 and 5 of this process is where the main focus of this guidebook is placed.

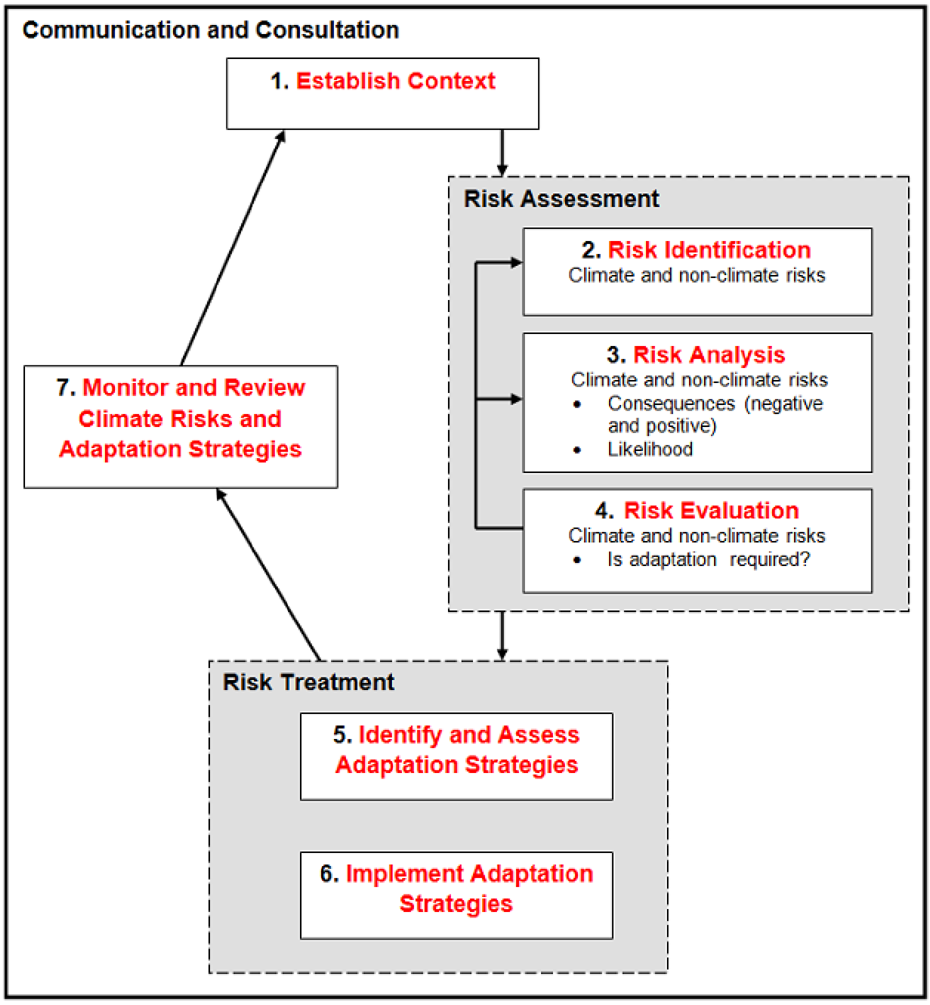

Figure 13: A schematic of adaptation as a process of risk management, showing the various stages involved in the risk management process and their interactions, as applied to climate change adaptation. The risk management process may not proceed in a linear process from step 1 through 7, and in practice steps 3 and 5 may be performed in combination. Source: Adapted from ISO 31000:2009.

Communication and consultation

Effective communication and wide ranging consultation is a continuous aspect and integral part of the whole risk management framework. This means formulating appropriate questions that relate to key business objectives, knowing what these objectives are, and being able to identify a wide range of risks that might impact upon these objectives. Furthermore, when developing causal models of how risk is generated, one needs to be able to call upon all relevant expertise that may exist both within and outside an organisation, in order to have the best possible chance of developing sound system understanding. The same is true when considering potential adaptation strategies, and seeking to implement them, as stakeholder buy-in will almost certainly be necessary. So an effective communication strategy that involves and actively seeks stakeholder participation from the outset is advisable, though this will depend on the specific context of a given adaptation problem. Also, it is crucial that the results of any analyses in relation to adaptation planning are carefully documented and communicated to all relevant parties. Moreover, the implications of any analyses need to be appropriately discussed, the various sources of uncertainty acknowledged, and the level of confidence associated with any analysis reported. In doing so, the actual meaning and implications of the analysis for informing adaptation decision making should be made clear.

Establish the context

Establishing the proper and relevant context for the risk management process is central to the overall success of the process. Stated simply, unless the right questions - properly framed and scoped - are being asked, the value and effectiveness of the later analytical stages will be undermined, and the likelihood of successful risk treatment and adaptation reduced, and may possibly increase the potential for maladaptation.

Important questions to ask when establishing the context, is first of all to determine what is the aim of the exercise, would you simply like to get a feel for how your organisation may be affected by changes in climate in order to raise awareness of climate change, or do you have a specific question or risk, which you know is sensitive to changes in climate. In other words, depending on the complexity of the question or level of detail that may be involved, a number of questions will be important to answer at this stage, these might include:

(1) What is the risk or risks that we would like to analyse?
(2) Who or what is at risk? Specify the business objectives.
(3) What are we actually trying to find out? Or what is the aim of the exercise? Do you need an exact answer e.g. risk will increase or decrease by 15% in 30 years' time, or would simply obtaining a feel for the direction of travel e.g. will the risk increase or decrease in the future, suffice to motivate action? The answer to this question will inform the selection of a suitable method or tool to use to carry out the analysis.
(4) What is an appropriate method for answering the aim of the exercise, given the available resources for the analysis? Are we making things too complicated? How will the consequences and likelihood be measured or assessed?
(5) What are the key climate and non-climate factors relevant to a given risk?
(6) Over what kind of time horizon do we want to consider the risks? This will depend on the planning horizon and decision lead time, and scope for flexibility in adaptation. For example, for a large infrastructure project e.g. a new energy plant or bridge, relevant risks may be analysed over the next century.
(7) What are the risk criteria? What level of risk is deemed acceptable, or at what level of risk would we take action to treat the risks? What is our attitude to risk?
(8) What are our options for treating the risk(s)?
(9) Do we need to involve internal and external stakeholders? Who are the relevant stakeholders? This is a critical question to ask, as it should help ensure that the best possible chance is given to understanding the full scope of the problem that is being addressed, and that the issues that are important to stakeholders are made known and considered.
(10) How do these climate risks fit in with or relate to other business priorities or activities?

Having established the context all involved parties (or actors) should be able to answer the question why they are setting out on the task of risk management, and what they are trying to achieve. Irrespective of the motivation for risk management, it cannot be emphasised enough how crucial this stage in the overall process is.

Risk assessment

All risk assessment needs some kind of causal model that links the changes in climate and non-climate factors to the way in which risks are generated (Fenton & Neil 2012). These models can vary from conceptual to numerical models. Risk assessment consists of three stages, whereby risks are identified, analysed, and evaluated. These three stages are described below.

Risk identification

The first stage of the risk assessment phase is that of risk identification, which consists of finding, identifying and describing risks. This stage involves identifying risk sources, areas of impacts, and their causes and potential consequences. This stage should also include consideration of any possible knock on effects or dependencies between risks and consequences, as this will be of importance later when considering risk treatment and adaptation options. Key to this phase is being able to develop or identify causal relationships between risk sources and consequences.

Risk identification could involve a comprehensive assessment of all climate risks that an organisation faces, or it could be identifying key risk sources that are relevant to one specific risk, which would go towards developing a causal model, or help in the selection of a causal model, to help analyse the risks. It may not be possible to identify all risk sources and consequences however. Nevertheless, it is important that this process is as comprehensive as possible, for each particular adaptation problem. Clearly, communication and consultation with relevant stakeholders will be of major importance in this stage.

This stage of the risk assessment can use a range of different methods to generate this information, including organisational experience of business activities where threats and opportunities that could change in magnitude and/or frequency under climate change are garnered via interviews, workshops, or surveys. Analysis of observations of past climate and weather events and company records that led to a given risk, also offers a potentially powerful source of information. Literature reviews, meta-analyses and professional and industry body literature, summarising the kind of impacts that may be likely in a given sector, could form the basis of a preliminary stage of risk identification.

Risk analysis

Having identified risks, the next stage is to generate information upon which the various risks can be analysed and understood. This involves considering the causes and sources of risk, determining their negative and positive consequences, and their likelihood. The combination of the consequences and likelihood determines the level or significance of the risk e.g. high, medium, low. It is generally a good idea to employ a range of different methods for generating the kind of information needed for analysing consequences and likelihood of events.

A number of methods of varying complexity exist, upon which the information needed for risk analysis can be generated, and these are described in detail in chapter 4. The sophistication of the approach taken will depend upon a number of factors, including the size and nature of the risk(s) or adaptation problem, the available resources, expertise, availability of information and data. It may, for example, make sense to adopt a tiered approach to risk analysis, whereby a preliminary risk screening step is performed, leading to a more rapid analysis of the risks, which may then lead to further allocation of resources to permit more detailed investigation of the more significant risks (consistent with the risk criteria), identified on the basis of the risk screening. The available methods range from qualitative analysis of existing information e.g. a survey of available scientific literature on possible changes in climate, and advice from professional bodies, to fully quantitative analysis based on climate impact modelling (where suitable and applicable models exist).

Regardless of the approach taken to generate the information upon which consequence and likelihood is determined, it is important that all analyses provide statements on and consideration of the sources of uncertainty, together with any caveats associated with the methods used to generate the information, and thus the level of confidence that may be associated with the analysis of consequences and likelihood. Assigning a level of confidence is also sometimes referred to as a certainty assessment (WBGU 1998).

In order to provide a systematic way of summarising, comparing and prioritising risks, the results of a risk analysis are often classified according to an ordinal scale e.g. a value from 1-5, or low, medium, high, and is presented in the form of a heat-map and/or a risk profile. A typical example of a heat-map is shown in figure

These heat maps provide a useful way in which to summarise risks, but the decision of whether or not a given risk needs treating is not simply based on these heat maps or risk profiles, but rather a process of evaluation of what the implications of the risk analysis are, and how the determined level of risk aligns with an organisation's risk attitude.

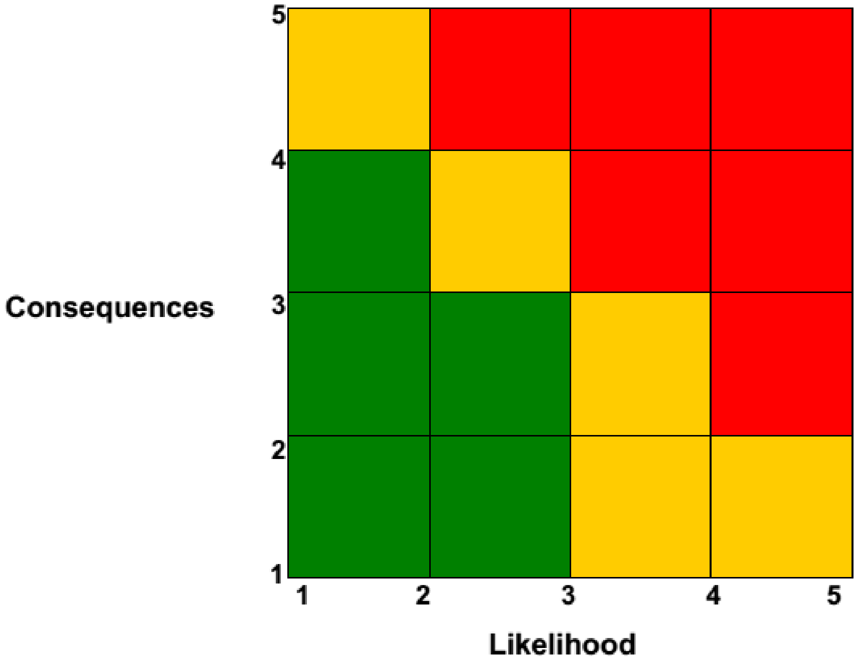

Figure 14: An example of a typical heat map, on which the ratings for likelihood and consequences for a given risk or risks could be plotted.

Risks appearing in red grid squares would theoretically represent the immediate need for risk treatment, amber squares those where more information or a better understanding of the generation of risk is required, and should be monitored for risk treatment, and green grid squares risks which do not require treatment (adaptation), but should nevertheless be monitored.

Risk evaluation

Having analysed risks, the next stage is to evaluate what, if any, action is required, or in other words, do we need to adapt? Do I need to take action, and how soon might I need to do so? This decision will most likely not be taken solely on the basis of the risk analysis, but will also likely depend on how the risks relate to other priorities within an organisation, its legal and regulatory requirements, and available resources for taking action. The results of the risk analysis will simply inform the decision making process within an organisation.

The **evaluation stage informs the risk treatment stage, and the evaluation involves comparing the results of the risk analysis and the level of risk, against the risk or decision criteria determined at the outset of the process when establishing the context for the risk management process.** Whether these risks are evaluated as being significant however, is not simply a combination of the two components, whereby high consequences and likelihood means a large or significant risk. For example, on the basis of a risk analysis a particular event may be assigned a low likelihood, but have very significant consequences if it did happen. An organisation may decide that this risk is too great for them to bear, given their risk attitude, and decide to treat it, or at least to explore ways in which it could be treated.

This point serves to highlight that the results of an analysis need to be carefully analysed, interpreted and evaluated. Indeed, the results of a risk analysis can be used to make a decision that more information is needed, and that more research or resources should be devoted to the priority risks, and may even lead to different questions being asked. It is also possible that the results of a risk analysis lead to the identification of new risks (Lempert 2012).

Risk treatment

Having evaluated whether and which risks need treating, risk treatment consists of a two stage process of identifying and assessing adaptation options, and then implementing the selected option(s). We focus here on the first two aspects of the first stage of risk treatment, identifying and assessing adaptation options. We provide no detailed discussion of the various issues involved in the implementation of adaptation strategies, as there is still a lot of knowledge and experience that needs to be gained in understanding factors which enable organisations to make progress in actively implementing adaptation strategies.

Detailed consideration of implementation issues is not, however, the focus of this guidebook, and it is also the case that the process of carrying out a risk assessment can itself provide, or at least initiate, this process of social learning, almost as a by-product.

Identifying adaptation strategies

Having determined the risks that need treating, possibilities for reducing threats and seizing any opportunities that climate change may present, involves being able to identify feasible adaptation strategies. The identification of possible strategies or actions can proceed according to consulting generic or existing strategies which have been researched as possible suitable candidates, and these can be found relatively easily in various sources on the web. However, it is the case that a lot of the identified adaptation strategies are simply possibilities, the question of how realistic, effective or desirable they are needs to be investigated within the specific context of a given organisations' risks, attitude to risk, availability of resources, and so on. In practice, it may also be the case that having undertaken a risk assessment, there emerge some very clear practical actions that could be implemented relatively simply.

Adaptation strategies for treating risks can be classified according to their mode of operation.

These include (adapted from the ISO 31000:2009):

- Avoiding the risk entirely by ceasing certain operations e.g. relocating a factory or distribution centre.
- Taking or increasing the risk to pursue an opportunity.
- Removing the risk source.
- Reducing the likelihood and/or consequences e.g. building more water storage capacity, or public awareness campaigns to use water more conservatively.

- Transferring the risk e.g. through an insurance policy.
- Do nothing i.e. based on the results of an analysis a decision may be made that a given risk can be accepted.

Assessing adaptation strategies

Having identified a candidate list of feasible adaptation strategies, the task then is to be able to have some kind of rational basis for choosing between the different options. There are various methods which may be used to do this, depending on the kind of adaptation strategy that is sought, and possibly constraining factors such as organisational culture and fitting in with existing methods and practices.

Choosing between different adaptation strategies can be determined according to their relative performance against various criteria e.g. cost, efficacy, equity, stakeholder acceptance. It is also important to state that adequate consideration should be given to the possible knock-on effects that a given strategy may have, such that the potential for maladaptation can be highlighted or detected, and thus avoided.

In order to be able to assess the performance of the different adaptation strategies, we need to be able to link the action of the strategy to the functioning of a given system. This clearly needs to be built into the development of the causal models, be they qualitative or quantitative.

Regardless of the method used to ultimately choose between adaptation strategies, it is very important that the various options should be assessed over as wide a range of possible futures as possible (determined by climate and non-climate factors).

It is also important to acknowledge that while adaptation strategies may be able to reduce the risk of certain events, they may not be able to eliminate the risks entirely, and as such, plans should be made for dealing with any residual risk.

Again, it should also be clear that deciding which strategies to implement will almost inevitably be determined by more informal considerations relating to the general business decision context and competing priorities.

Implement adaptation options

Having determined the strategy or strategies deemed to be most or more desirable, these options then need to be implemented. It may well be the case that a range of different actions are considered and implemented, and this is generally thought to be good practice.

This may be combined with a particular approach to adaptation known as adaptation pathways, whereby, different strategies can be implemented, based on the performance of existing ones, and in the light of new information, and system learning. In other words, as is deemed necessary to obtain an acceptable level of risk.

Monitor and review climate risks and adaptation strategies

After implementation of adaptation strategies it is important that systems are either already in place, or put in place, which will allow for the measuring and monitoring of their performance.

It is also important that the various risks identified are monitored and periodically reviewed, either in the light of new information, changes in key factors that determine the functioning of a given system, or as part of a periodic organisational risk management review.

Models and uncertainty in risk assessment

Increasing the chances for successful adaptation requires a sound understanding of how a given system functions, in response to the key driving variables (climate and non-climate) which may generate a risk for an organisation. This system understanding needs to be represented in the form of a causal model which establishes the relationships and interrelationships between these variables, and how risks are generated, and thus how we may intervene with well-chosen adaptation actions to minimise threats and maximise opportunities (Fenton & Neil 2012).

Box 3: Incremental and transformational adaptation (experts from IPCC WGII 2014 Chapter 20)

Climate change calls for new approaches to sustainable development that take into account complex interactions between climate and social and ecological systems. Climate-resilient pathways are development trajectories that combine adaptation and mitigation to realize the goal of sustainable development. They can be seen as iterative, continually evolving processes for managing change within complex systems.

If the magnitude and rate of climate change is kept minimal or moderate, incremental adaptation may be a sufficient response to consequences in many locations and contexts. However, in cases where vulnerability is currently high, transformational adaptation may be needed to respond to changes in climate and climate variability. In the absence of ambitious mitigation efforts, the impacts of climate change can be expected to increase dramatically from the second half of the 21st century onward. In this case, transformational adaptation may be required in advance of disruptive impacts to reduce risks and vulnerabilities.

This distinction between incremental and transformational adaptation is important: incremental adaptation can be considered extensions of actions and behaviors that already are in place to reduce losses or enhance benefits associated with climate change, often where the goal is to maintain the essence and integrity of an existing system or process at a given scale. Transformational adaptation, in contrast, includes actions that change the fundamental attributes of a system in response to actual or expected impacts of climate change. These may involve adaptations at a larger scale or greater intensity than previously experienced; adaptations that are new to a region or system; or adaptations that transform places or lead to a shift in the location of activities. Such transformations are expected to occur when the rate and magnitude of climate change threatens to overwhelm the resilience of existing systems, or when vulnerability is high.

3.2.8 System Dynamics Model

Purpose of the Model

The first step of the modeling process, deciding on the model purpose, is a two part decision. Deciding on the model purpose means focusing on a problem and narrowing down the model's audience. By deciding on the model's purpose, a modeller makes the later choices of both components and structure feasible.

A system dynamics model is built to understand a system of forces that have created a “problem” and continue to sustain it. To have a meaningful model, there must be some underlying problem in a system that creates a need for additional knowledge and understanding of the system. The goal of the conceptualization stage is to arrive at a rough conceptual model capable of addressing the relevant problem in a system.

After choosing what problem area to focus on, a modeller must gather relevant data and further define the focus of the model. Relevant data for a system dynamicist consists not only of measured statistical data, but also operating knowledge from people familiar with the system being analyzed. The modeller should also consider a model’s primary audience.

If the model’s structure and behavior cannot be understood by its audience, or if it does not answer questions interesting to the audience, then the model is rendered useless. The first step in creating a meaningful model from available data is defining the purpose of a model while keeping in mind the model’s audience.

The model purpose should mention some type of action or behavior over time that the model will analyze. Coming to an agreement on the purpose of the model is essential. Without a clear and strictly defined purpose it is very difficult to decide which components of the system are important. Another concern of experienced modelers is whether it is worthwhile to build the model as defined. A very abstract purpose, such as “I am building this model about the environment to understand how it works,” is likely to result in a waste of time. Such a model would probably include too many components and be too complex for any practical analysis.

The purpose of a model usually falls into one of the following categories:

- to clarify knowledge and understanding of the system
- to discover policies that will improve system behavior
- to capture mental models and serve as a communication and unifying medium.

System Dynamics (SD) is a powerful scientific methodology for simulating complex systems and to observe and test their dynamic behaviour. SD can be viewed as the ‘quantification’ of casual loop models. The System Dynamics Society define SD as *“A methodology for studying and managing complex feedback systems. Feedback refers to the situation where X affecting Y and Y in turn affecting X perhaps through a chain of causes and effects. Only the study of the whole system as a feedback system will lead to correct results.” (www.systemdynamics.org)*

System dynamics is interdisciplinary in nature as its scientific roots, namely, nonlinear dynamics and feedback concepts can be found in mathematics, physics, and engineering. As SD deals with human behaviour as well as bio-physical systems, it also draws on cognitive and social psychology, economics, and other social sciences.

Stock & Flow Concepts

System dynamics modelling is based on the Stock and Flow concepts. These concepts are mathematical parallels of integration and derivation respectively. In other words, Stock represents accumulation while Flow denotes the *change* in the level (state) of a variable. Examples of stocks are CO_2 levels in atmosphere, amount of nitrate in soil, population, level of confidence, etc. Examples of flows are emissions, absorptions, births/deaths, production, etc. As flows represent change over time, they are measured and expressed as per unit of time, such as rain fall per day, birth per year, production per week, etc. SD models are constructed and run in specialised computer software (the commercial ones include iThink, Vensim, and Powersim).

Developing a simulation model

Once an S-F model is developed it can be simulated. The first step of simulation is to populate the model with data. In SD models, the data can be quantitative or qualitative and it can come from a variety of sources including scientific and statistical data bases, observations, interviews, expert knowledge, historical records, publications, survey responses, media reports, and so on. In the absence of any known data, the relationship between variables can be hypothesised and incorporated into the model in the form of "graphical functions". After the data is entered into the model, the model can be run. This stage involves using specialised computer packages mentioned earlier. The results of these runs or experiments can be shown in sophisticated graphical or tabular forms.

Validating the model

Before a model can be used for decision making or policy analysis, the modellers and stakeholders must have sufficient confidence in the 'soundness and usefulness' of the model. However, *"There is no single test which serves to 'validate' a system dynamics model. Rather, confidence in a dynamic simulation model accumulates gradually as the model passes more tests and as new points of correspondence between the model and empirical reality are identified."* Confidence in a SD model is generated through 'validation'.

3.3 Development UrbanCLIM Platform

3.3.1 Feature and User Experiences

The UrbanCLIM platform was built on the system dynamics simulation library "Sage," from Highpoint Software Systems. Sage is a state of the art simulation engine, with powerful simulation capabilities and great flexibility in simulation architecture, control, construction and integration. Built on Microsoft's industry standard .NET technology, UrbanCLIM also uses Windows Presentation Foundation (WPF) technology to implement a friendly, flexible and extensible GUI. The key functions of the UrbanCLIM platform includes:

- Modular design and standardized technologies to enable building on and linking to existing models and related applications;
- An open framework, allowing for multi-scale, multi-domain impact assessment, which can be customized case-by-case to suit each city;
- Integrated analysis tools to enable testing of adaptation and mitigation options against socio-economic drivers, likely impacts, and existing goals for sustainable development;
- Climate change uncertainty analysis building on GCM and RCM climate change scenarios;
- GIS interoperability;
- Visualization and further analysis options for the assessment of results;
- Integration of risk and cost-benefit analysis tools.

User experiences

Knowledge Base Navigator: A featured navigator tool presents case studies in conjunction with plain-language documentation to enhance understanding of the climate change background and implications of the case study.

Model Construction and Execution: Users can drag blocks from categorized libraries on a palette to a canvas, then configure and link those blocks together according to the model workflow. Running the model (with pause/resume and abort options) enables the user to quickly verify the correctness of the model, and arrive at analytical results.

Model Personalization: Users can add a personal logo to the canvas and embed documentation in the logo block, and can also change the look of custom function blocks.

Visualization Tools: GIS and the WPF chart control can be embedded in a model, enabling the user to easily produce high quality visualizations of model outputs.

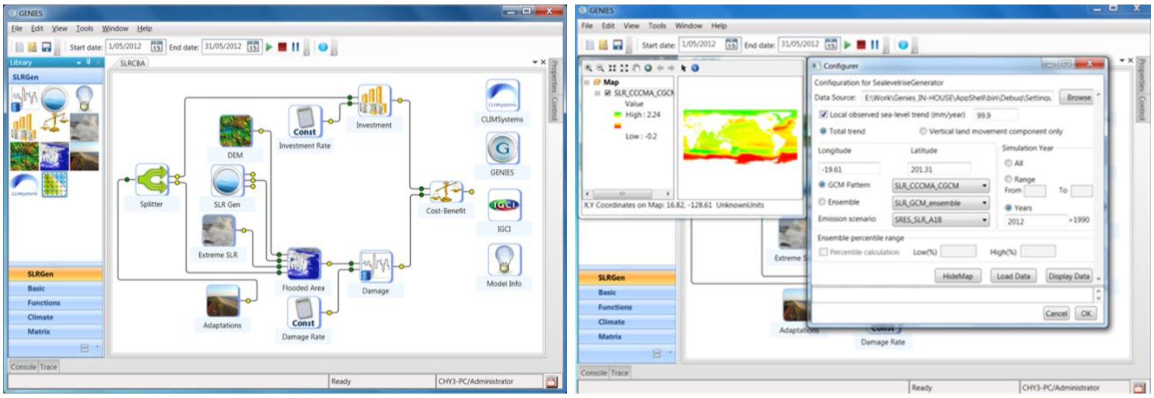

Figure 16a: UrbanCLIM screenshots for sea level rise adaptation cost/benefit analysis model

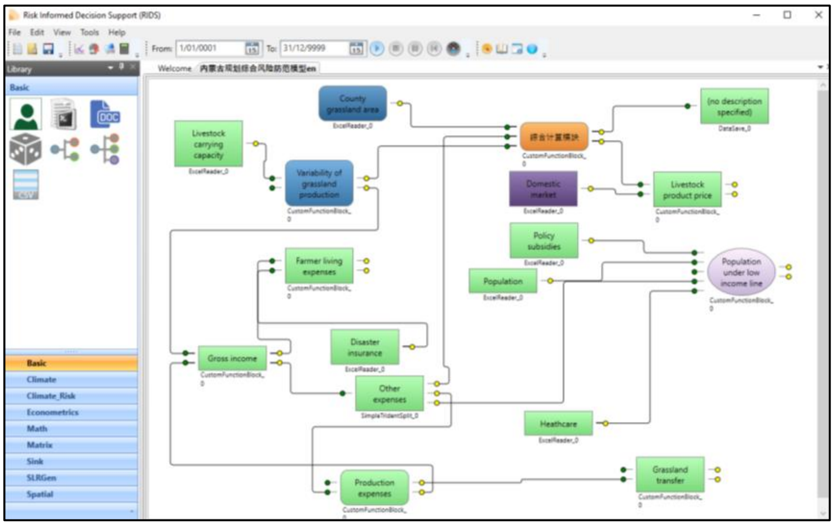

Figure 16b: UrbanCLIM/RIDS screen shot of Inner Mongolia climate change adaptation and farmer livelihood modelling

Box 4: FAQ for UrbanCLIM

How does UrbanCLIM link with other models and tools?
Via dynamic link libraries, OpenMI, sidecar executables, data exchange, or recoding.
How can UrbanCLIM handle complicated cross sector systems and multiple issues?
Start from simple, hide the complexity behind a hierarchical model structure, external model data linkages.
How can the models and studies built by one user be transferred to another user?
The models and studies can be exported as a standalone package, and then shared with others.
How can users contribute to UrbanCLIM?
Workshop, ideas, models, criticism, project applications.
How will UrbanCLIM be maintained and updated?
UrbanCLIM will develop model, data and knowledge contributions through the CoP. UrbanCLIM will be part of Risk Informed Decision Support (RIDS) system managed by International Global Change Institute (IGCI), more information can be found: http://www.igci.org.nz/rids/
When can UrbanCLIM be released to public users?
The CoP group can start to test and contribute to UrbanCLIM development and improvement through contact development team in IGCI.

3.3.2 The Building Up of UrbanCLIM Database

UrbanCLIM has, and will maintain, a comprehensive climate change assessment database which includes up-to-date IPCC GCM, and RCM data for climate change scenarios. These data have been adapted from SimCLIM and other international and national climate change related datasets directly or using various downscaling methodologies. UrbanCLIM will also be able to incorporate other emerging datasets. User defined scenario and empirical data also could be included into the UrbanCLIM database if users so desired. It is our expectation that the UrbanCLIM database would be organically grown by its user communities. From a technology perspective, we are considering basing a central repository on an open source system called 'Subversion." Integrated into UrbanCLIM, it would enable people to use the data, models and tools from the central repository, but also to non-destructively overlay that content with their own local variants for exploratory, transient or what-if analysis. This allows the users to control data such that an "official study" must use sanctioned models and data, while giving individual organizations the freedom to use their own where appropriate.

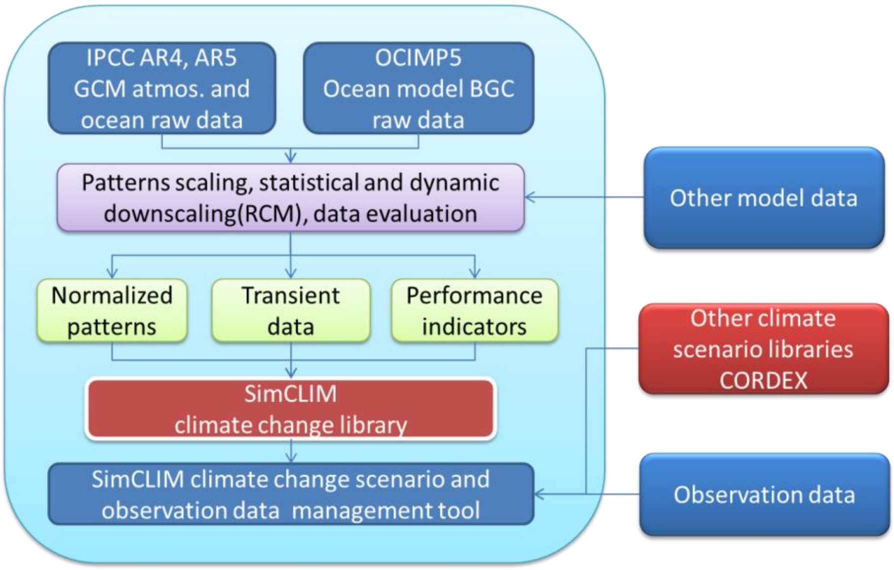

Figure 17: UrbanCLIM data library strategy

3.3.2.1 CMIP5 database based on SimCLIM

Global Baseline Climatology

The original data populating SimCLIM 2013 represented by global baseline climatology of different variables were obtained from various publicly accessible data sources. The data sources were selected based on our best knowledge, concerning the quality of the data. A ***bilinear interpolation*** method was applied to interpolate the data from their original resolution to 0.5°*0.5° degrees.

Temperature

Mean, maximum and minimum temperatures for the land area are extracted from the CRU_ts3.20 (1981-2010) dataset with a spatial resolution of 0.5°. You can check the details on

http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__ACTIVITY_3ec0d1c6-4616-11e2-89a3-00163e251233

Mean temperature data for the ocean area were derived from NASA reanalysis data (http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl), and the diurnal temperature range were calculated from multiple GCMs, then maximum and minimum temperatures were derived.

Precipitation

Land precipitation: CRU_ts3.20 with a spatial resolution of 0.5°degrees (1981-2010).

Ocean precipitation is from Xie Arkin (1981-2002), plus GPCP (2003-2010) (1.0°).

Wind speed

In order to get a more accurate baseline and global coverage, SimCLIM global wind speed baseline is a monthly climatology combined with three different datasets, then interpolated to a 0.5°*0.5° latitude and longitude grid.

Wind speed for ocean

The blended sea winds contain globally gridded, high resolution ocean surface vector winds and wind stresses on a global 0.25° grid, and multiple time resolutions of 6-hourly, daily, monthly, and 11-year (1995-2005) climatological monthlies (http://www.ncdc.noaa.gov/oa/rsad/air-sea/seawinds.html).

Wind speed for land area

We describe the construction of a 10 minute latitude/longitude data set of mean monthly surface climate over global land areas, excluding Antarctica (New et al., 2002)

Wind speed for polar area

Monthly and annual averaged values for a 10-year period (July 1983 - June 1993).
http://power.larc.nasa.gov/cgi-bin/cgiwrap/solar/global.cgi?email=global@larc.nasa.gov

Wind Speed At 50 m Above The Surface Of The Earth (m/s)

Solar radiation

The data set contains monthly average global fields of eleven shortwave (SW) surface radiative parameters derived with the shortwave algorithm of the NASA World Climate Research Programme/Global Energy and Water-Cycle Experiment (WCRP/GEWEX) Surface Radiation Budget (SRB) Project.

The SimCLIM 2013 baseline uses all Sky Surface Downward Flux (RSDS in GCM variable name convention) monthly averages of 1984 to 2006.

Acknowledgments: These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center. For detailed data descriptions please refer to the readme file of the original dataset (http://eosweb.larc.nasa.gov/PRODOCS/srb/table_srb.html).

Relative humidity

Relative data were derived from NASA reanalysis monthly assimilated state on pressure data 1981 to 2000, (http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl), with original resolution 0.8° .

Other variables

Other variables such as Sea Surface Temperature (SST) can be transformed and inserted into SimCLIM 2013 data sets on demand.

Global GCM Climate Change Projection Data

For SimCLIM 2013 CLIMsystems follows the IPCC Fifth Assessment Report. As the CMIP5 datasets under different emission scenarios (Table 1) for IPCC AR5 are publicly available. SimCLIM 2013 is supported by this data. In general, these data are produced and maintained by their respective research institutes. Moreover, these data have different spatial resolutions (Table 2). For convenience of analyses, all data were processed by a ***pattern scaling*** method, and then were regridded to a common 720*360 grid (0.5°*0.5°) using a ***bilinear interpolation*** method.

Emission Scenarios for IPCC AR5

The GCM data in SimCLIM is from CIMP5 which is also the data source for IPCC AR5 climate change projections. For more information on CMIP5 please visit: http://cmip-pcmdi.llnl.gov/cmip5/ guide_to_cmip5.html.

The Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its Fifth Assessment Report (AR5). The four RCPs, RCP2.6, RCP4.5, RCP6.0, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 (of 2.6, 4.5, 6.0, and 8.5 W/m2, respectively) (Table 1).

Table 3. Overview of representative concentration pathways (RCPs) (van Vuuren *et al.* 2011; Moss *et al.* 2010; Rojeli *et al*. 2012)

Description[a]		CO_2 Equivalent	SRES Equivalent	Publication – IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m2 in 2100.	**1370**	**A1FI**	**Raiahi *et al.* 2007 – MESSAGE**
RCP6.0	Stabilization without overshoot pathway to 6 W/m2 at 2100	**850**	**B2**	**Fujino *et al*.; Hijioka *et al*. 2008 – AIM**
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m2 2100	**650**	**B1**	**Clark *et al.* 2006; Smith and Wigley 2006; Wise *et al*. 2009 – GCAM**
RCP2.6	Peak in radiative forcing at ~ 3 W/m2 before 2100 and decline	**490**	**None**	**van Vuuren *et al*., 2007; van Vuuren *et al*. 2006 - IMAGE**

[a] Approximate radiative forcing levels were defined as ±5% of the stated level in W/m_2 relative to pre-industrial levels. Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents.

Brief GCM Description

GCM data were retrieved from the Earth System Grid (ESG) data portal for CMIP5 (Table 2). The main improvements in CMIP5 include (a) the addition of interactive ocean and land carbon cycles of varying degrees of complexity, (b) more comprehensive modelling of the indirect effect of aerosols, and (c) the use of time-evolving volcanic and solar forcing in most models (e.g., Taylor et al., 2012). The CMIP5 models generally have higher horizontal and vertical resolution (median resolution180*96L39) compared to the CMIP3 (median resolution 128*64L24).

Table 4. CMIP5 GCMs used in SimCLIM 2013

	Model	Country	Spatial resolution for atmospheric variable (longitude*latitude)	Spatial resolution for ocean variable (longitude*latitude)
1	ACCESS1.3	Australia	192*145	360*300
2	ACCESS1.0	Australia	192*145	360*300
3	BCC-CSM1-1	China	128*64	360*232
4	BCC-CSM1-1-m	China	320*160	360*232
5	BNU-ESM	China	128*64	
6	CanESM2	Canada	128*64	256*192
7	CCSM4	USA	288*192	320*384
8	CESM1-BGC	USA	288*192	320*384

9	CESM1-CAM5	USA	288*192	320*384
10	CMCC-CM	Italy	480*240	182*149
11	CMCC-CMS	Italy	192*96	182*149
12	CNRM-CM5	France	256*128	362*292
13	CSIRO-Mk3-6-0	Australia	192*96	192*189
14	EC-EARTH	Netherlands	320*160	362*292
15	FGOALS-g2	China	128*60	360*196
16	FGOALS-s2	China	128*108	360*196
17	GFDL-CM3	USA	144*90	360*200
18	GFDL-ESM2G	USA	144*90	360*210
19	GFDL-ESM2M	USA	144*90	360*200
20	GISS-E2-H	USA	144*90	144*90
21	GISS-E2-H-CC	USA	144*90	144*90
22	GISS-E2-R	USA	144*90	288*180
23	GISS-E2-R-CC	USA	144*90	288*180
24	HADCM3	UK	96*73	96*73
25	HadGEM2-AO	UK	192*145	360*216
26	HadGEM2-CC	UK	192*145	360*216
27	HadGEM2-ES	UK	192*145	360*216
28	INMCM4	Russia	180*120	360*340
29	IPSL-CM5A-LR	France	96*96	182*149
30	IPSL-CM5A-MR	France	144*142	182*149
31	IPSL-CM5B-LR	France	96*96	182*149
32	MIROC4H	Japan	640*320	1280*912
33	MIROC5	Japan	256*128	256*224
34	MIROC-ESM	Japan	128*64	256*192
35	MIROC-ESM-CHEM	Japan	128*64	256*192
36	MPI-ESM-LR	Germany	192*96	256*220
37	MPI-ESM-MR	Norway	192*96	802*404
38	MRI-CGCM3	Japan	320*160	360*368
39	NorESM1-M	Norway	144*96	320*384
40	NorESM1-ME	Norway	144*96	320*384

Data processing methodology – Pattern scaling

Pattern scaling is based on the theory that, firstly, a simple climate model can accurately represent the global responses of a GCM, even when the response is non-linear (Raper et al. 2001), and secondly, a wide range of climatic variables represented by a GCM are a linear function of the global annual mean temperature change represented by the same GCM at different spatial and/or temporal scales (Mitchell, 2003, Whetton et al. 2005). Pattern-scaling does not seem to be a very large source of error in constructing regional climate projections for extreme scenarios (Ruosteenoja, et al. 2007), however, in applying pattern-scaling, two fundamental sources of error related to its underlying theory need to be addressed: 1) Nonlinearity error: the local responses of climate variables, precipitation in particular, may not be inherently linear functions of the global mean temperature change; and 2) Noise due to the internal variability of the GCM. Based on the pattern scaling theory, for a given GCM, the linear response change pattern of a climate variable to global mean temperature change represented by the GCM, should be obtained from any one of its GHG emission simulation outputs. Pattern scaling may be described as follows: for a given climate variable *V*, its anomaly ΔV^* for a particular grid cell (*i*), month (*j*) and year or period (*y*) under an representative concentration pathway RCP 4.5:

$$\Delta V^*_{yij} = \Delta T_y \cdot \Delta V'_{ij} \tag{1}$$

ΔT being the annual global mean temperature change.

The local change pattern value ($\Delta V'_{ij}$) was calculated from the GCM simulation anomaly (ΔV_{yij}) using linear least squares regression, that is, the slope of the fitted linear line.

$$\Delta V'_{ij} = \frac{\sum_{y=1}^{m} \Delta T_y \cdot \Delta V_{yij}}{\sum_{y=1}^{m} (\Delta T_y)^2} \tag{2}$$

where *m* is the number of future sample periods used, from 2006-2100, 19 periods in total. The average of 5 years represents a period.

The RCP4.5 runs were used for generating the patterns for the SimCLIM 2013 default pattern dataset, regarding the compatibility with IPCC (2013), other patterns generated from other RCP runs are also available on request. The global patterns are in 0.5° latitude * longitude grids interpolated from GCM original resolution, using a bilinear interpolation method.

Global pattern for other variable, include wind, solar radiation, relative humidity, sea surface temperature, all use the same methodology. See table 2 for the list of GCMs used in SimCLIM 2013 monthly precipitation and temperature patterns.

Mean sea level rise generator methodology

Global-mean sea-level rise scenarios are readily available and are regularly updated by the IPCC. To date, most coastal impact and adaptation assessments have ignored regional variations in sea-level scenarios, largely due to a lack of technical guidance and access to the necessary data in a usable form. This has been rectified by the publishing of the IPCC Report in 2011 that includes sea level rise outputs generated using the SimCLIM modelling system (Nicholls et al., 2011). Nevertheless, regional and local assessments would benefit from considering the components of sea-level change on a more individual basis, since the uncertainty for sea-level change during the 21st century at any site is very likely to be larger than the global-mean scenarios suggest.

The regional pattern of thermal expansion under RCP forcing can be approximated using a pattern-scaling method similar to that previously applied for other climate variables (e.g. Santer *et al.*, 1990; Carter *et al.*, 2001). In applying the pattern-scaling method to sea level, "standardised" (or "normalised") patterns of regional thermal expansion change, as produced by coupled AOGCMs, are derived by dividing the average spatial pattern of change for a future period (e.g. 2081-2100) by the corresponding global-mean value of thermal expansion for the same period. The resulting standardised sea-level pattern is thereby expressed per unit of global-mean thermal expansion. The pattern-scaling approach has been formalised within an integrated assessment modelling system called SimCLIM 2013.

We employed the following equation to calculate the normalised sea surface elevation patterns, (or sea surface height above the geoid, ZOS), termed *DZOS (unit: cm/cm ∆GSLR)*:

$$DZOS_{ij} = \{(ZOS_{ij2090} - ZOS_{ij1995}) + \Delta GSLR\ \} / \Delta GSLR$$

Where,

$\Delta GSLR$ is the global mean annual sea level change due to thermal expansion

$$\Delta GSLR = ZOSTOGA_{2090} - ZOSTOGA_{1995}$$

Where,

ZOSTOGA is the global mean thermosteric sea level change

i, j denote the latitude and longitude position;

2090 is the average of 2080-2100; 1995 is the average of 1986-2005.

Twenty four GCM (RCP45) runs, which have both local *ZOS* and *ZOSTOGA* data, are used in SimCLIM 2013.

For the local land movement component, we input a value for the local sea-level trend. If the trend in relative sea-level change from vertical land movement is known (i.e. from the SONEL database), we can simply enter the value (in mm/yr) which is added to the future projection. Often, however, only the total undifferentiated trend is known (as estimated, for example, from tide-gauge data). This total trend cannot simply be added onto the future projection because it would “double-count” the effect that global warming has already had on observed sea-level rise and would therefore inflate the future projected rise. A process for extracting a vertical land movement trend from tidal data can be applied to replace or supplement (cross check) SONEL data.

Availabilities of GCM variables

SimCLIM 2013 can display climate change information either for a single GCM or ensemble of multiple GCMs. However, each GCM might provide different data depending on the climate variable i.e. not every GCM possesses the same number or type of climate variables. For convenience, the availability of GCM variables is summarized in table 3. Please keep in mind that only the corresponding variables used for the baseline period are extracted from GCM archives. These variables includes Temp – Temperature (including mean, minimum and maximum), Precip – Precipitation, SolRad – Solar Radiation, RelHum – Relative Humidity, Wind – Wind Speed, and SLR – Sea Level Rise.

Table 5: Availability of GCM variables in the SimCLIM 2013 global data package

	Model	Temp	Precip	SolRad	RelHum	Wind	SLR
1	ACCESS1.3	Yes	Yes	Yes	Yes	Yes	
2	ACCESS1.0	Yes	Yes	Yes	Yes	Yes	
3	BCC-CSM1-1	Yes	Yes		Yes	Yes	Yes
4	BCC-CSM1-1-m	Yes	Yes		Yes		Yes
5	BNU-ESM	Yes	Yes				
6	CanESM2	Yes	Yes	Yes	Yes	Yes	Yes
7	CCSM4	Yes	Yes	Yes	Yes		Yes
8	CESM1-BGC	Yes	Yes	Yes	Yes		
9	CESM1-CAM5	Yes	Yes	Yes	Yes		
10	CMCC-CM	Yes	Yes	Yes		Yes	Yes

11	CMCC-CMS	Yes	Yes	Yes		Yes	Yes
12	CNRM-CM5	Yes	Yes	Yes		Yes	Yes
13	CSIRO-Mk3-6-0	Yes	Yes	Yes	Yes	Yes	Yes
14	EC-EARTH	Yes	Yes			Yes	
15	FGOALS-g2	Yes	Yes				
16	FGOALS-s2	Yes	Yes				
17	GFDL-CM3	Yes	Yes	Yes	Yes	Yes	Yes
18	GFDL-ESM2G	Yes	Yes	Yes	Yes	Yes	Yes
19	GFDL-ESM2M	Yes	Yes	Yes	Yes	Yes	Yes
20	GISS-E2-H	Yes	Yes	Yes	Yes	Yes	
21	GISS-E2-H-CC	Yes	Yes	Yes	Yes	Yes	
22	GISS-E2-R	Yes	Yes	Yes	Yes	Yes	
23	GISS-E2-R-CC	Yes	Yes	Yes	Yes	Yes	
24	HADCM3	Yes	Yes	Yes	Yes	Yes	
25	HadGEM2-AO	Yes	Yes	Yes		Yes	
26	HadGEM2-CC	Yes	Yes	Yes	Yes	Yes	Yes
27	HadGEM2-ES	Yes	Yes	Yes	Yes	Yes	Yes
28	INMCM4	Yes	Yes	Yes	Yes	Yes	Yes
29	IPSL-CM5A-LR	Yes	Yes	Yes	Yes	Yes	
30	IPSL-CM5A-MR	Yes	Yes	Yes	Yes	Yes	
31	IPSL-CM5B-LR	Yes	Yes	Yes	Yes	Yes	
32	MIROC4H	Yes	Yes	Yes	Yes		
33	MIROC5	Yes	Yes	Yes	Yes	Yes	Yes
34	MIROC-ESM	Yes	Yes	Yes	Yes	Yes	Yes
35	MIROC-ESM-CHEM	Yes	Yes	Yes	Yes	Yes	Yes
36	MPI-ESM-LR	Yes	Yes	Yes		Yes	Yes
37	MPI-ESM-MR	Yes	Yes	Yes		Yes	Yes
38	MRI-CGCM3	Yes	Yes	Yes	Yes	Yes	Yes
39	NorESM1-M	Yes	Yes			Yes	Yes
40	NorESM1-ME	Yes	Yes				Yes

Regional spatial data customization

An area whose spatial scale is smaller than the global scale is defined as a region/study area in SimCLIM 2013. The most commonly used region is the country. Sometimes, a region can be drilled down into for smaller areas such as the Upper Mekong River Basin versus the Lower Mekong River Basin. A regional data source and spatial resolution is typically derived through discussion between the SimCLIM 2013 end user and the development team at CLIMsystems. This consultation is conducted to provide the best data package to the end user. Generally, the smaller the region, the higher the spatial resolution.

For a specific region (country or area), producing regional climate dataset depends on the availability of baseline and future climate change projection data from local agencies. *The principle is that CLIMsystems will adopt local data as much as possible*, and then fill data gaps using publicly available data using the most appropriate interpolation method to generate an appropriate spatial resolution is required.

If there are datasets produced by national/local agencies, whenever possible or through the request of end users CLIMsystems will adopt local data for application in SimCLIM 2013. For the USA, CLIMsystems has adopted PRISM data for the baseline and BCSD generated by BLM and then post-processed by CLIMsystems for climate change patterns which represent one source of publicly available data for the USA.

If there are datasets for baseline period for a region, but no climate change projection data, CLIMsystems uses the pattern scaling method to produce the change patterns, then interpolates the data to a pre-defined resolution.

Extreme precipitation patterns

In SimCLIM 2013, site data are mainly managed at the daily scale and mainly used to study the changes in the frequency and intensity of extreme events. Combined with GCM future climate change scenarios, the data can be extended to investigate extreme events under a changing climate. Due to the availability of daily data, only the 22 GCMs in the CMIP5 archive were analysed for extreme precipitation change patterns, using the average change patterns of RCP4.5 and RCP8.5 scenarios runs (Table 4). Detailed data processing methodology please refer to Li et al. (2011)

Table 6: GCM list for 3 hourly extreme precipitation change patterns

No	**Name**	**No**	**Name**
1	ACCESS1-3	**12**	INMCM4
2	CANESM2	**13**	IPSL-CM5A-LR
3	CCSM4	**14**	IPSL-CM5A-MR
4	CESM1-BGC	**15**	IPSL-CM5B-LR
5	CMCC-CM	**16**	MIROC5
6	CMCC-CMS	**17**	MIROC-ESM
7	CNRM-CM5	**18**	MIROC-ESM-CHEM
8	CSIRO-MK-3-6	**19**	MPI-ESM-LR
9	GFDL-ESM2G	**20**	MPI-ESM-MR
10	GFDL-ESM2M	**21**	MRI-CGCM3
11	HADGEM2-ES	**22**	NorESM1-M

3.3.2.2 RMIP3 data was processed in to SimCLIM/UrbanCLIM format.

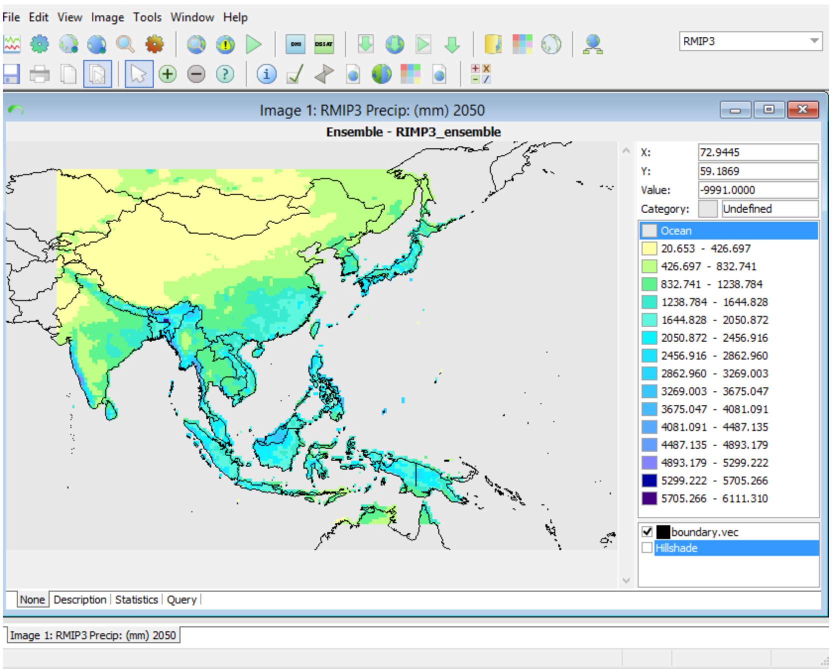

Figure 18: SimCLIM screenshot for RMIP3 data

Table 7: RMIP3 project models and data availability

	Model	Group	Country
1	CCAM	CSIRO	Australia
2	CCAM-60KM	CSIRO	Australia
3	NIED-RAMS	NIED	Japan
4	MRI_RCM	MRI	Japan
5	ReGCM3	CMA	China
6	GRIMs	YSU	Korea
7	iRCM	IU	USA
8	WRF	NJU	China
9	WRF_SN	NJU	China
10	WRF_RRTM	NJU	China
11	SNU RCM	SNU	Korea
12	ReGCM3	NJU	China

3.4 UrbanCLIM Model Library Development Strategies

3.4.1 Steps of Building System Dynamics Models in UrbanCLIM

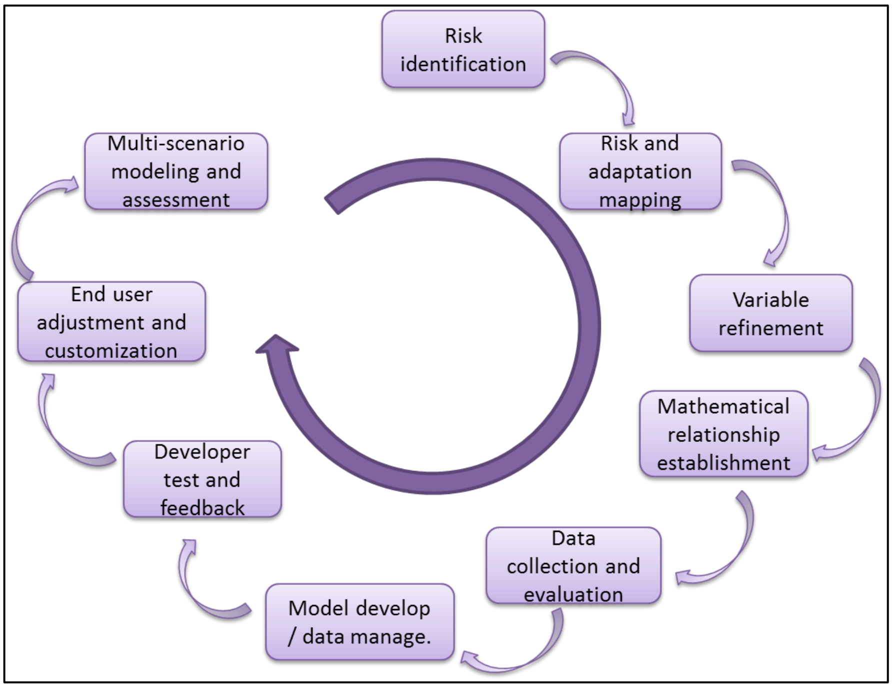

Figure 19: Steps for building system dynamics model in UrbanCLIM platform

Step 1: Risk identification

The objective of this step is to create a broad list of climate change risks that might affect your organization's ability to achieve its goals.

What is "Risk identification"?

This is the process of generating a broad list of reasonably foreseeable ways that climate change stressors could keep your organization from achieving its goals. It is important to consider all potential risks during the risk identification step. If risks are not identified in this step, they will not be analyzed and evaluated in the steps that follow.

Risk identification is normally carried with expert group discussion and brainstorming: experts are the experienced researchers and managers and officers coming from different sectors, their expertise should cover, social, ecology, climate, and institution aspects. The understanding of the real risk situation is very important.

Methods for identifying risks

Identifying risks is the first and perhaps the most important step in the risk management process. If there is a failure to identify any particular risk then other steps in the risk management cannot be implemented for that risk.

It is important to realise that an organisation's exposure to risk may be constantly changing. For example, at the time that a risk audit takes place, an organisation may not have any sponsorship contracts. The risk audit may therefore not uncover any risks associated with sponsorship because at the time none were apparent. However some months later after risk management policies and procedures have been documented, the organisation is successful in obtaining a major sponsor and key personnel have not adequately considered risks.

Table 8: The following table presents some of the many methods for identifying risks:

Questionnaire	Distributing a questionnaire to staff and volunteers about their observations of risks and knowledge of risk management procedures. There is every chance that people within the organisation are aware of a risk that has not been previously identified in any risk management audit. The risk management questionnaire may serve to prompt memories of specific events or encourage people to voice their opinion on perceived risks.
Organisation's Records	Reviewing the following organisation documents may yield information about risks exposures. However, this aspect of risk auditing may be time intensive. • Minutes of committee meetings • Event management plans and report • Policy documents • Contracts for facilities • Sponsorship proposals • Resource agreements with government funding providers
Flowcharting	• A worthwhile risk identification strategy is to create flow charts for the organisation and delivery of programs, events and

	services provided by the organisation. • The benefit of a flowchart to the risk identification process is that it identifies possible ways in which basic processes in sport and recreation management can be interrupted. • Any interruption to the provision of events, programs and services is a potential for loss.
Professional Expertise	Organisations may consider using risk management consultants with expertise to identify virtually any risk exposure. However the services of such consultants may be available only at a significant cost.
On-Site Investigations	On-site investigations provide opportunities for face-to-face discussions with organisation personnel. Such discussions may lead to a better understanding of the extent of risks arising when events and activities do not go as planned. On-site investigations may also shed light on the frequency with which such undesirable events occur.

Step 2: Risk and adaptation mapping

This step is to find out the relationships and linkage among the risk (and potential options) factors, in order to map out the structure of socio-ecological system. In this step SES framework need to be applied. The identified risks need to be put into the SES context, to consider the inter-dependency of the four subsystems.

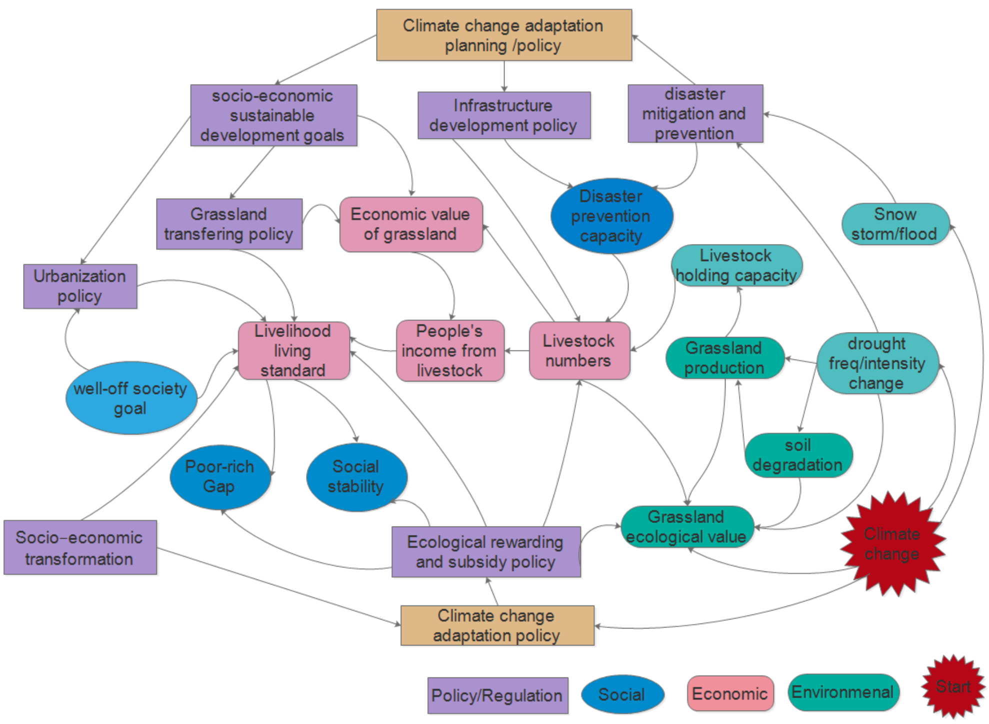

Figure 20: Risk and adaptation mapping of Inner Mongolia people's livelihood and grassland under climate change. Different shape and colour of the text box represent the subsystems variables belonging to.

Step 3: Variable refinement

This step is to select the most important variables and the data availability of these variables also needs to be considered. Try to reduce the number of variable; otherwise the model could be complicated. Key order parameter selection is also in this step.

Step 4: Mathematical relationship establishment

The mathematical equations between variable need to be identified from literature, or developed using existing data. The relationship among multiple variables could be one very complicated as a sub-model. So mathematical capacity normal is critical for building a system dynamics model in this case is in UrbanCLIM or RIDS platform.

Step 5: Data collection and evaluation

According to selected variables and equations, related data need to be collected and evaluation. Whether the data is available normally decides which variable should be included in the model. The data could be statistical data, time series data, GIS data, or ranking or rating data (such as, 1-5 in rating),

Step 6: Model development and data management

Use the available mathematical equations, and data to build the model. In this step, a lot of thinking is needed, because the model needs to be built in most simple and logical but robust way. It is a process of programming. The user can learn from the software manuals, however the most efficient way is to work with modellers who familiar with the software and programming language.

Step 7: Developer test and feedback

This step is to run the model and test performance of the model. It normally needs many times of testing and modification in order to get the expected results. And the developer needs to demonstrate the model the end users, seeking for the opinions on the model, then modify or improve the model accordingly.

Step 8: End-user adjustment and customization

After get the model running smoothly, end-users can start to adjust the model in order to have better understanding of the model, and eventually customize the model to what they like, including skin colour, graph type, logo, etc.

Step 9: Multi-scenario simulation and assessment

The final step is to carry out real simulation and show the scenario to related stakeholders, they could be policy makers or peer-researchers.

And all the steps in model building also are a process of capacity building on risk assessment, risk management, and integrated risk governance. So this process could be iterative for many times

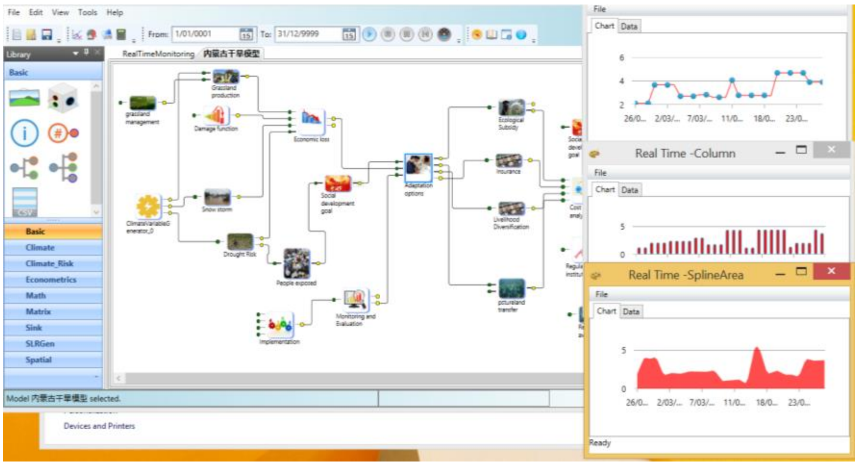

Figure 21: A screen shot of UrbanCLIM model and simulation result visualization and real time monitoring

3.4.2 UrbanCLIM Model Library Development Strategies

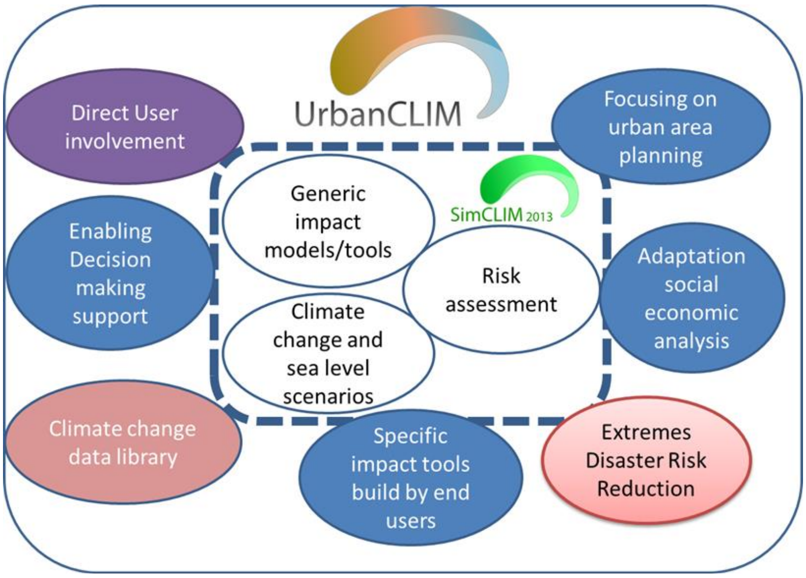

Figure 22: UrbanCLIM model library development strategies

To help realize a publicly accessible and broadly useful library, this project proposes to cooperatively develop an extended urban climate change decision support model library, potentially to include models tailored to climate change impact and risk assessment for the other major analytical sectors: climate related hazards resilience, water, transport, and health. We would involve urban policy makers and planners from targeted Asian cities as a part of this cooperative approach. Many models have already been created for these sectors, although most of them are standalone, or too specific for broader use. Through the UrbanCLIM Community of Practice, these models and tools can be enhanced and integrated into a standard platform, enabling robust knowledge and technology sharing and transfer.

During the proof of concept stage, a number of climate change analyses, decision support tools and models have been identified and prioritized for strategic integration into the UrbanCLIM platform.

Some models and tools have been demonstrated to our stakeholders in China and Vietnam, including a climate change scenario generator, a sea level rise scenario generator, a sea level rise impact model including damage and cost-benefit analysis model, and a decision tree and multiple criteria decision analysis tool. A number of existing models also were identified which can be integrated with UrbanCLIM, including extreme event analysis, heat stress modelling, and water resources management tools.

3.4.3 UrbanCLIM Navigator Building

The UrbanCLIM navigator presents models and studies in an informational setting. Each model and study is presented alongside documentation that explains its use, applicability, limitations, and genesis. A user can dynamically create a new study or project, add documentation and models, and optionally export it for general use, including importing it into a community knowledge base.

The UrbanCLIM navigator is intended to:

- Enable decision makers and planners to be more productive, more comprehensive and more correct in a shorter period of time by providing a friendly browser-like environment that speeds the learning curve.
- Provide a common repository for data, models and tools, thereby encouraging active cross-pollination of disparate knowledge, reuse of appropriate models and leveraging of analytical tools across a range of analytical domains.

During the proof of concept stage, we have built up an illustrative set of models and documentation in the UrbanCLIM knowledge base, including documentation and models for the case study cities, Guangzhou, China and Rach Gia, Vietnam. These documents and models should be viewed -- as is the UrbanCLIM tool itself -- as a proof-of concept, and as an impetus for further discussion as to the utility of such a knowledge management approach.

3.5 Guangzhou Case Study

3.5.1 Guangzhou Case Study Dynamic Downscaling

The urban anthropogenic heat flux simulated by WRF over Pearl River Delta of China.
The version 3.5 of WRF model was used to simulate the anthropogenic heat flux in city clusters of PRD. This model has 28 vertical layers in atmosphere, 50hPa for top layer height. The Lambert Conformal Conic projection was used and the center point is located in Guangzhou of 23ºN, 113ºE. The integration time begins at 00:00 of Nov. 15th 2010 to 00:00 of Dec. 31st 2011, and the first half month was taken as spinup. The whole year of 2011 was analyzed over the city clusters of PRD. Four domains were nested with spatial resolution of 1km, 3km, 9km and 27km (Figure 23).

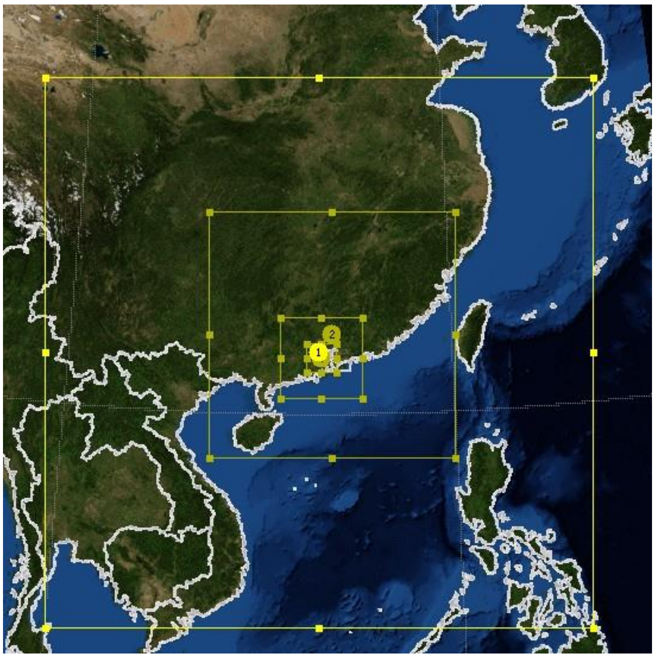

Figure 23: Four nested domains in Pearl River Delta (PRD) of China using the WRF model.

Table 1. The numerical experiments used for control run (CTR) and sensitivity run (SI)

Cases	Urban canopy	Anthropogenic heat release
CTR	No	No
SI	Yes	Yes

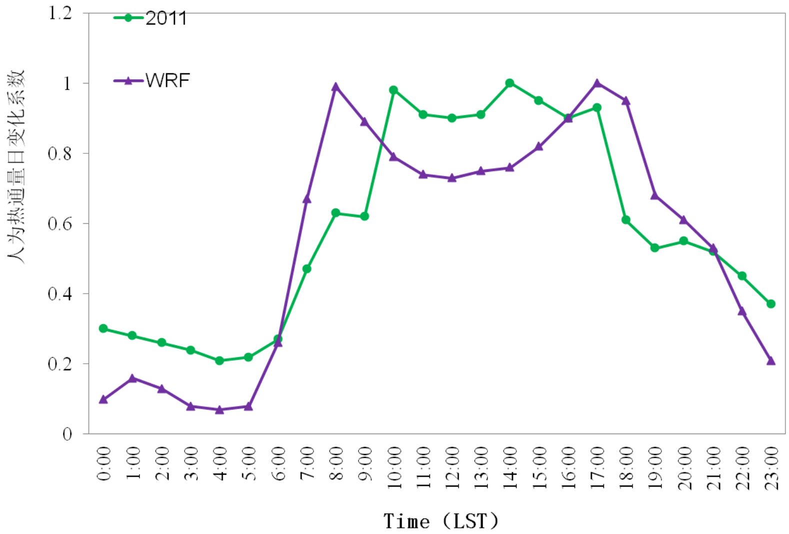

Figure 24: The diurnal variation anthropogenic heat coefficient of original WRF and calibrated value in 2011.

The default diurnal variation coefficient of original WRF is the blue line in Figure 24, whereas the calibrated value used in this modeling is the green line based on the Statistic Almanac of Guangzhou. The timing difference of peaks can be attributed to the difference in life style of USA and China.

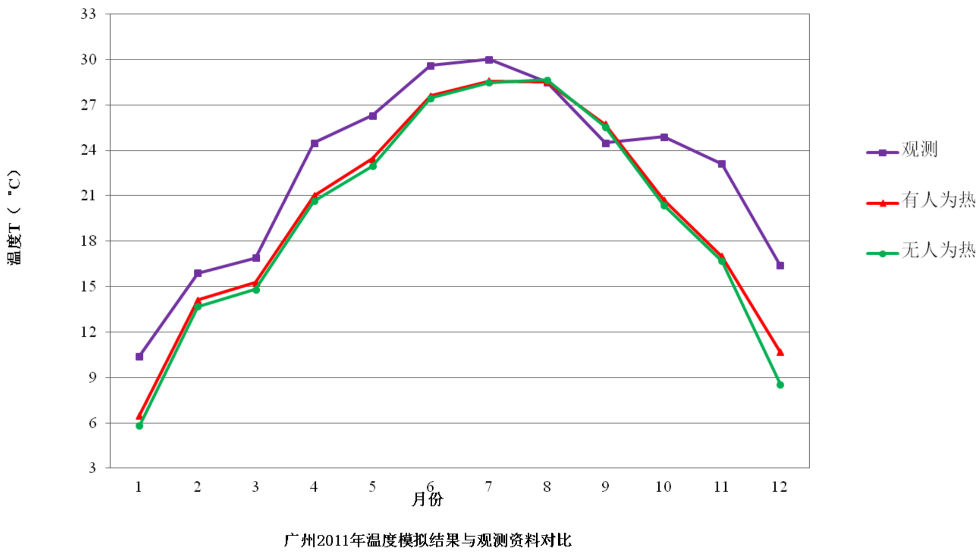

Figure 25: The simulated and observed surface air temperature of Guangzhou in 2011, units: ºC. The blue curve is observation, the green curve is the simulation without anthropogenic heat flux, and the red line is the simulation with anthropogenic heat flux.

Figure 25 shows the improvement of surface air temperature (SAT) simulation in Guangzhou by adding the calibrated anthropogenic heat flux into WRF model. Compared to the observed SAT, the incorporation of anthropogenic heat flux leads to the average SAT increase of 0.46ºC. The maximum increase of 2.1ºC occurs in January, while the lowest enhancement of 0.1ºC in December.

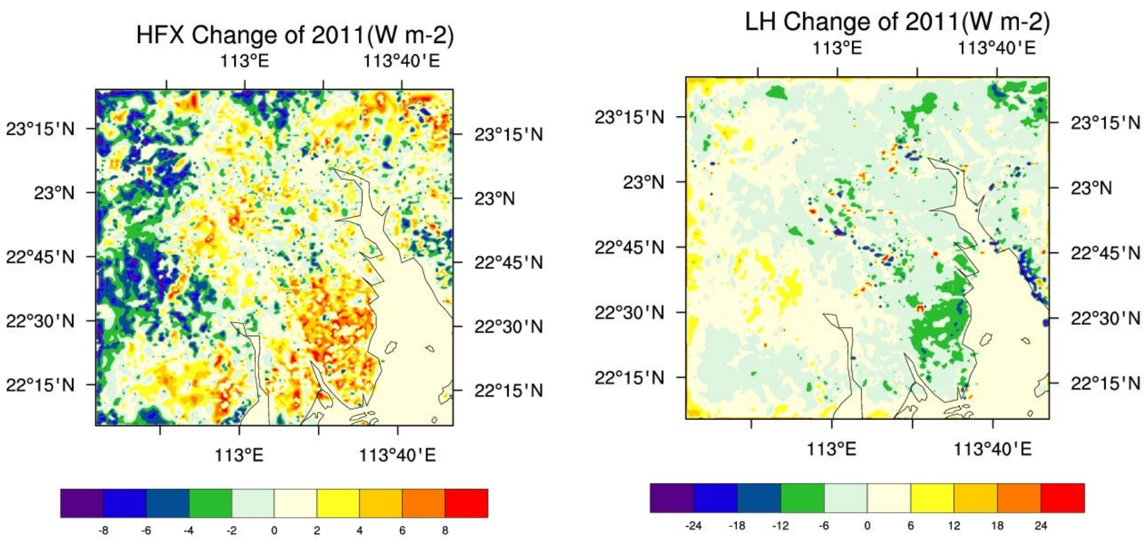

Figure 26: The difference of surface heat flux in PRD (SI minus CTR) in 2011.

Figure 26 presents the overall enhanced surface sensible heat flux over PRD by add the anthropogenic heat flux. The latent heat flux generally declines along the city clusters of

PRD, especially in the leeward of south PRD.

The original coefficient of anthropogenic heat flux in default WRF needs to be calibrated in PRD. By adding the adjusted coefficient of anthropogenic heat flux, the simulated surface air temperature in Guangzhou has been improved, especially in winter. The improvement is attributed to the enhanced surface sensible heat flux in the city clusters in PRD of China.

3.5.2 Model-based Sectoral Water Use Assessment in the Pearl River Delta

The Pearl River Basin is characterized by a monsoon climate with an extremely uneven spatial and temporal distribution of rainfall. Frequent droughts in the upstream, combined with salt intrusion in the delta has caused severe water shortage events in the Pearl River Delta (PRD) since 2004. Assessing and managing water use is crucial for supporting sustainable oriented river basin management and regional development. The first consistent and comprehensive assessment of sectoral water use in the Pearl River Delta (PRD) was performed.

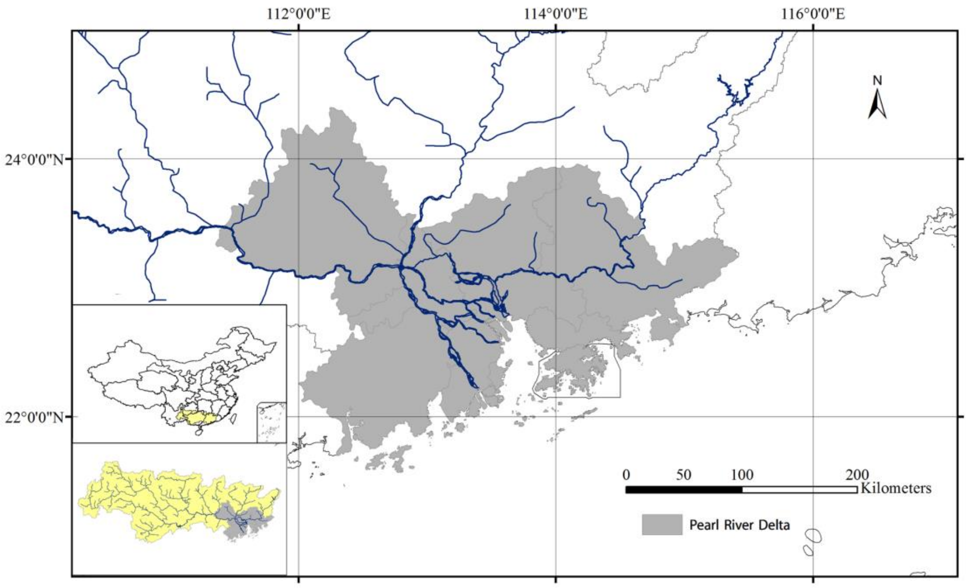

Figure 27: The Pearl River Delta. Map at the lower-left corner is location of the delta area in the whole Pearl River Basin. Above is where the Pearl River Basin is allocated in China.

Objective
•Identify the influence of past, present and future urbanization processes on the spatial and temporal patterns of water use in the Pearl River Delta.
•Assess the role of present climate variability and its future changes on the spatio-temporal patterns of water uses in the urbanizing Pearl River Delta.

The Pearl River Delta regional Water Use Model (PRDWUM)
In order to improve our understanding of the driving forces of the water use trends occurred in the PRD, we used a regional water use model which links reported water use records with documented socio-economic data. These data have been documented more consistently and in greater detail for a longer period. For each of the 9 cities, PRDWUM assesses freshwater use of four sectors, namely domestic (urban and rural separated, DOMU and DOMR), manufacturing industry (MAN), thermal electricity industry (ELE), and irrigation

(IRR). Overall, water use in every sector is expressed as a function of its driving forces and water use intensity of various water usage processes. In general, the total water use is assessed as:

$$\boldsymbol{W_{Total}} = \boldsymbol{\Sigma\, W_i} = \boldsymbol{\Sigma(I_i \times F_i)} \quad (1)$$

where W is volume of water use, I_i is the water use intensity of sector i, and F_i is the driving forces. The water use intensity I_i can be subject to structural and technological changes, as described later.

a. Domestic (PRDWUM-DOM)

In the domestic sector, municipal water use may be simulated as a function of multiple variables that may affect water use, including water price, number of cars, occupants, rooms, incomes and other household characteristics. More recently, efforts have been made to explore the influence of block water price, income and household composition on residential consumption. Data availability in the PRD is not sufficient to feed such data intensive models on household levels. PRDWUM-DOM borrows concepts from the global water use model WaterGAP2 and using calibrated parameters for each of the nine cities. The overall domestic water use is expressed as a product of per capita water use intensity and population in the area. Urban and rural water uses are separated into two sub-sectors since the observed state and trends of the two strongly differed during study period. The rural domestic water use (DOMR) module computes household water use only. For urban domestic water uses (DOMU) the public water uses (construction and service industry) are included.

b. Manufacturing Industry (PRDWUM-MAN)

We adopt a simple approach where manufacturing water use is computed as a product of the manufacturing water use intensity (I_{MAN}) and the IVA. I_{MAN} is affected by multiple factors such as economic growth, manufacturing composition, and technological improvements. Technological improvements are difficult to be assessed due to data limitation and great diversity of technology acceptance between different manufacturers. Xiong compared several factors affecting the industrial water use of Shaanxi Province northeast in China, and built a multi-linear regression forecast model. Inspired by his work, we propose a non-linear regression model to compute the manufacturing water use intensity as a function of per capita GDP and manufacture composition:

$$\ln(\boldsymbol{I_{MAN}}) = \boldsymbol{b_0} + \boldsymbol{b_1} \times \ln(\boldsymbol{GDP_{ca}}) + \boldsymbol{b_2} \times \ln(\boldsymbol{R_{HL}}) \quad (2)$$

where GDP_{ca} is the annual per capita GDP, R_{HL} is the production ratio between heavy and light industry. Table 2 shows the curve parameters (b_0, b_1, b_2) calibrated for each of the nine cities based on change of the historical water uses.

c. Thermal Electricity Industry (PRDWUM-ELE)

Water used by the thermal electricity industry in each of the nine cities is computed by multiplying their electricity production with provincial average water use intensity, I_{ELE}. The estimated I_{ELE} ranges from 60-100 m^3/MWh during the study period. An average of 82m^3/MWh is used in the PRDWUM. The present study assumes that all the electricity production in the PRD is produced by (fossil fuel or nuclear) thermal power plants. Not all cooling systems need fresh water though. Sea water utilized for cooling purposes in the PRD is subtracted from the model result. However the PRD-specific data about sea water utilization are being reported only since 2008. The average fraction of sea water utilization of Guangdong province from 2008 to 2010, about 67%, is applied to the rest of the study period to the PRD.

d. Irrigation (PRDWUM-IRR)

PRDWUM-IRR computes the consumptive irrigation water use as the amount of water required by each crop to be able to evapotranspirate at the optimal rate under the given climate conditions. Crop specific consumptive water use intensity I_c is computed following the FAO-56 approach based on 10-days intervals. Irrigation water withdrawal is then estimated with a local irrigation efficiency of 0.6.

Daily meteorological data are gathered from 8 measurement stations in the area. Cultivation areas of 19 crops are collected for each of the nine cities. For other crops the FAO suggested global average values are adopted. Vegetable, fruits and alfalfa are assumed to be grown all year around. Crop factors for these plants remain constant through the year.

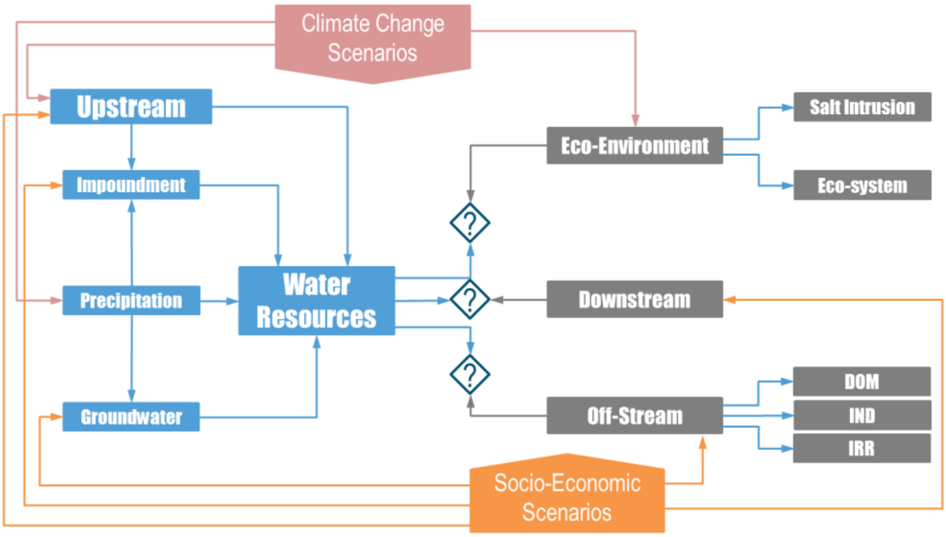

Figure 28: A flowchart for PRD water sector assessment model

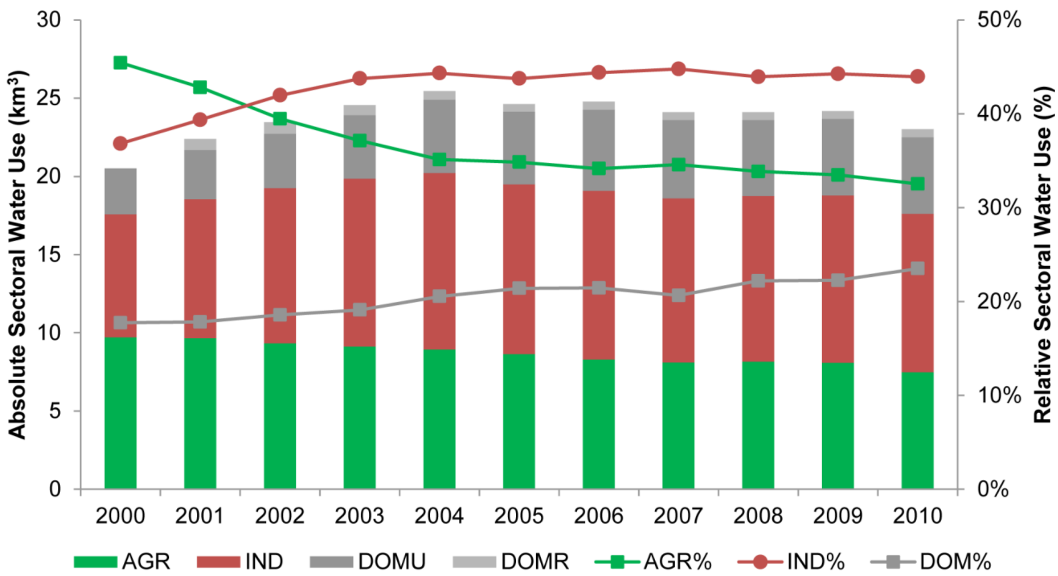

Figure 29: Sectoral water use of the PRD. Absolute (bars, left axis) and relative (lines, right axis) sectoral water use of agriculture, industry and domestic water use of the PRD reported by Guangdong Water Resource Bulletin.

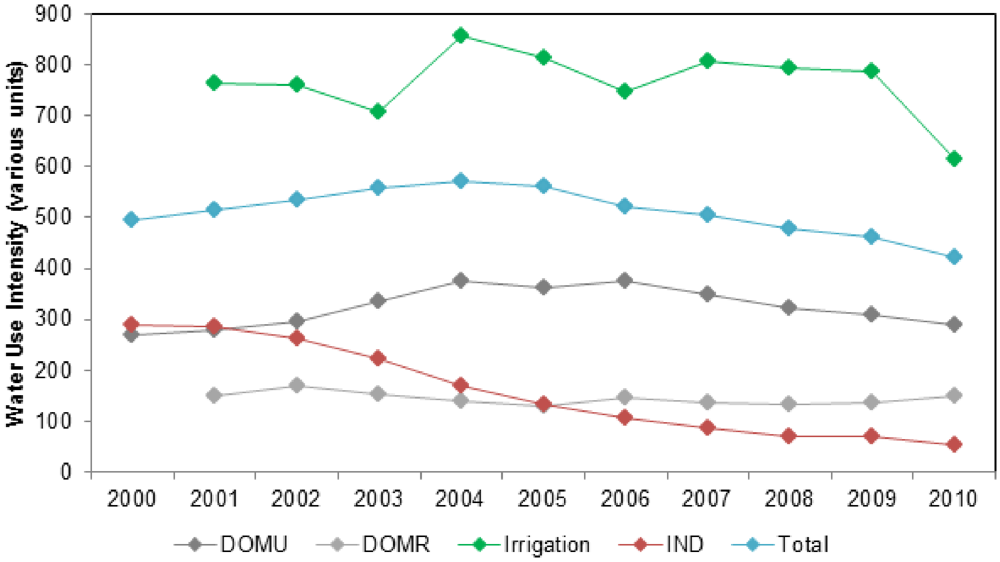

Figure 30: Water use intensity in the PRD. Values shown are in the units of litres/person-day for DOMU and DOMR, m3/104 Yuan IVA for IND, m3/MU for IRR, and m3/person-year for the Total water use intensity (Total) respectively.

3.6 Applications in other projects

3.6.1 Financing low-carbon, climate resilient urban infrastructure in Asia and the Pacific (ADB TA-8865 REG)

Background

The Asia Pacific region contains some of the world's major economic powerhouses. The region is also fast becoming a major driver of greenhouse gas emissions worldwide, and at the same time is increasingly exposed to the risks of climate change. However, significant opportunities exist to develop low-carbon and climate resilient cities. In many cases infrastructure and urban developments that have not yet been locked-in or are still in the early stages of planning and implementation which represents a major opportunity to shape the nature of this future development in the region in a low carbon and resilient fashion. It is also recognised that much of the required development and infrastructure in small and medium sized cities in particular is yet to be built so there are significant opportunities for low carbon and climate resilient approaches from the outset. As the IPCC Fifth Assessment Report has highlighted large scale mitigation achievements will need to be attained through systemic and cross sector approaches, identifying these system and cross sector opportunities in cities will need to be a focus of this project.

However, it is also recognised that developing countries require massive additional investment to transition to a low-carbon and climate-resilient development path. Carbon mitigation in developing countries could cost $140 billion–$175 billion per year during 2010–2030. Adaptation costs for developing countries in Asia and the Pacific from 2010 to 2050 are estimated at $40 billion per year.

Main objectives of this project

(1) **Selected "archetype" cities**. To building a picture of the investment needs will focus either on archetype cities or agglomerations that are representative of a larger group of cities in Asia and the Pacific. In this regard six selected "archetype" cities will be analysed, through a master plan-level assessment of current and projected infrastructure needs by 2030.
(2) **Quantify the infrastructure financing needs of selected cities**. The team assembled for this project, consisting of both international and national specialists, will quantify the infrastructure financing needs of selected cities, including filling existing infrastructure gaps and projected infrastructure needs, using investment in low-carbon infrastructure where feasible and climate-resilient infrastructure in all cases.
(3) **Identify appropriate financing mechanisms**: The TA will identify appropriate financing mechanisms and structures that will be needed to support the implementation of the identified infrastructure. There will be a focus on those cities that have demonstrated willingness to explore low-carbon and climate-resilient infrastructure alternatives and the project will identify opportunities and preferred approaches to finance for low-carbon and climate-resilient development using a range of identified financial sources, mechanisms and structures.

Tool will be applied for this project:

City Climate Risk Profiler, a tool of UrbanCLIM series of products.

- Information of more than 20,000 cities and towns
- Climate related hazard and future projections, allowing city infrastructure relevant assessment;
- Socio-economic and disaster risk data
- GIS explorer, light GIS tool easy to use and install

The dataset could be applied for different sectors:

- Transport
- Energy
- Water
- Waste
- Communications
- Social infrastructure (health, education etc.)
- Other

City climate risk profile indicators:

- Sea level rise
- Extreme heat events
- Extreme precipitation events
- Cyclones
- Fire/bushfires
- Storms
- Flooding
- Other

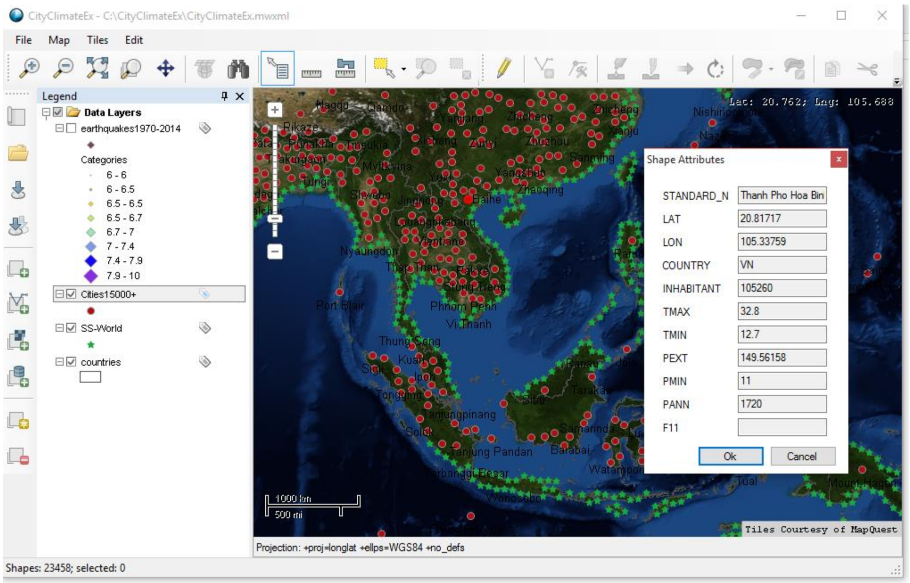

Figure 31: A screen shot of City Climate Profiler in UrbanCLIM platform

3.6.2 Adapting to Climate Change in China (ACCC II) Project

Projection introduction

Adapting to Climate Change in China Phase II (ACCC II) project is coordinated by China Nation Development and Reform Commission (NDRC), and co-funded by the Swiss Agency for Development and Cooperation (SDC). In the next three years, the Development and Reform Commissions in each province will work with ACCC to incorporate climate change adaptation into the formulation of national and provincial policy plans, support the formulation and implementation of comprehensive provincial adaption plans for key areas, and share this experience with other developing countries. This project established a state-level project management office, and coordinates domestic and international technical support experts. The initial case studies provinces include: Guizhou, Jiangxi, Inner Mongolia, Ningxia and Jilin. Each province will focus on the specific key climate change challenges. Experts from a wide disciplinary spread are involved in the project, including: adaptation, risk assessment, integrated risk governance, economic, social science, system science and meteorological science.

The institutions involved include: Development Research Centre of the State Council, Chinese Academy of Sciences, China Meteorological Administration, Beijing Normal University, Renmin University of China, International Food Policy Research Institute, UKCIP, Intasave, CLIMsystems, SwissRe, and top institutes from each of the pilot provinces.

Key objectives of the project:

- Provide guidance to provincial adaption planning for key areas
- Provide tool kit to support mainstreaming provincial adaption planning
- Develop an Adaptation Planning Support and Risk Assessment System
- Train provincial researchers and policy makers
- Involve key institutions from national level to provincial level
- Provide comprehensive theoretical framework and practical tools for South-South knowledge sharing

Theoretical Framework:

- Orderly adaptation;
- Socio-Ecological System;
- Integrated Risk Governance;
- System Science;
- Integrating climate change adaptation, disaster prevention and mitigation and sustainable development are indispensable

System Dynamics Simulation Platform UrbanCLIM

- Combining, refining, and integrating the methodologies and theories of planning process and risk management into an advanced information technology;
- Using system simulation approach gives IT the soul;
- Improve planning efficiency and present results through advanced visualization techniques.

4. Conclusions

4.1 Workshops

The first workshop in Guangzhou set up the development framework and work plan of UrbanCLIM, and form a community of practice (CoP) for UrbanCLIM;

The second workshop in New Zealand identified the gaps and challenges in the context of climate change urban adaptation including following key points: Policy and legislation barriers and advances; Climate change adaption practice in various urban sectors; Urban planning, decision making and climate change; Emerging climate change science and methodological issues as they relate to adaptation practices; Climate change vulnerability and risk assessment methodologies and tools.
Third open workshop in Beijing provided a venue for scientists and practitioners to discuss the emerging issues related to climate change adaptation where scientific, technical and practical challenges and solutions are equally important. This workshop reviewed: Climate change risk assessment methodologies and tools; Application of tools and solutions in adaptation practice; Climate change information, communication and ethics for climate change services; Climate change adaption practice in different sectors; Urban planning and decision making and climate change.

The discussion panel focused on (1) very high resolution RCM simulation on city scale extreme precipitation, potential applications, and future collaborations also was envisaged; (2) Service solutions could be provided to urban policy makers, including data as a service, software as a service, within the ethics framework: Integrity, transparency, humility, and collaboration.

4.2 Theoretical framework development

Given the open framework of UrbanCLIM and complex system nature of climate change and urban adaptation, proper theoretical frameworks are critical for communication, training and model development. These frameworks need to be broad enough to cover all the issue raised in climate change realm, including, adaption, mitigation, risk assessment and governance, disaster risk reduction, sustainable development, science-policy interaction, system science. Without proper understand of all these theoretical background, one can easily get lost in the mist of complexity of climate change adaptation.

Therefore, UrbanCLIM adopted or further developed and applied these theoretical frameworks. This report depicted:

Orderly Adaptation: emphasis on the integration of natural science and social science, and coordinated adaptation action at all scales and levels in order to achieve the best outcomes at global system;

Socio-Ecological-System: the four subsystems in SES (natural, social, economic, institutional subsystems) define the boundary of a risk assessment and governance issue. In the SES realm, a risk in any of one subsystem links to other three subsystems, a risk assessment should not be isolated in one subsystem.

Integrated Risk Governance: Integrated risk governance emphasis on put risk into a larger context than risk management, seek opportunities while dealing with the risks from governance perspective. To achieve disaster risk reduction while build up the socio-economic capacity. Climate change adaptation need to link with Disaster Risk Reduction and Sustainable Development in a broader context of climate change.

System Science: system science in the thinking methodology of whole UrbanCLIM platform and system dynamics and related modelling approaches are the technical methodology for building model in UrbanCLIM. All the interactions among the variables or parameter can be seen as the flow of information, energy and material. The system dynamics models are to simulate the system behaviours.

4.3 UrbanCLIM platform development

The UrbanCLIM platform was built on the system dynamics simulation library with powerful simulation capabilities and great flexibility in simulation architecture, control, construction and integration. Built on Microsoft's industry standard .NET technology, UrbanCLIM also uses Windows Presentation Foundation (WPF) technology to implement a friendly, flexible and extensible GUI. The key functions of the UrbanCLIM platform includes:

- Modular design and standardized technologies to enable building on and linking to existing models and related applications;
- An open framework, allowing for multi-scale, multi-domain impact assessment, which can be customized case-by-case to suit each city;
- Integrated analysis tools to enable testing of adaptation and mitigation options against socio-economic drivers, likely impacts, and existing goals for sustainable development;
- Climate change uncertainty analysis building on GCM and RCM climate change scenarios;
- GIS interoperability;
- Visualization and further analysis options for the assessment of results;
- Integration of risk and cost-benefit analysis tools.

4.4 Database development

UrbanCLIM has, and will maintain, a comprehensive climate change assessment database which includes up-to-date IPCC AR5 GCMs, and CORDEX RCM data for historical data climate change scenarios, from monthly average of mean changes to subdaily extremes. These data have been adapted from SimCLIM and other international and national climate change related datasets directly or using various downscaling methodologies. UrbanCLIM will also be able to incorporate other emerging datasets. User defined scenario and empirical data also could be included into the UrbanCLIM database if users so desired. It is our expectation that the UrbanCLIM database would be organically grown by its user communities.

4.5 Guangzhou case study

A study on the urban anthropogenic heat flux over Pearl River Delta of China was carried by using WRF for dynamic downscaling. And the second component of this case study was to apply PRDWUM model for water sector assessment. We calculate water intensities from annual socio-economic and water use data in Guangzhou. We find that the PRD managed to stabilize its absolute water use by significant improvements in industrial water use intensities, and early stabilisation of domestic water use intensities.

4.6 Other applications

(1) Financing low-carbon, climate resilient urban infrastructure in Asia and the Pacific project (ADB funded) applied City Climate Risk Profiler, which are tools and datasets of UrbanCLIM products: Information of more than 20,000 cities and towns; Climate related hazard and future projections, allowing city infrastructure relevant assessment; Socio-economic and disaster risk data; GIS explorer within UrbanCLIM, light GIS tool easy to use and install.

(2) Adapting to Climate Change in China (ACCC II) Project (funded by Swiss SDC) applied the extended UrbanCLIM platform for following tasks: Provide guidance to provincial adaption planning for key areas; Provide tool kit to support mainstreaming provincial adaption planning; Develop an Adaptation Planning Support and Risk Assessment System; Train provincial researchers and policy makers; Involve key institutions from national level to provincial level; Provide comprehensive theoretical framework and practical tools for South-South knowledge sharing

5. Future Directions

I. More applications of UrbanCLIM platform by seeking further user feedback, funding and collaborations. UrbanCLIM software development is an expansive exercise which need very high level understand of the theoretical frameworks and programming technology and the ability to gain vital feedback on user experience. This only can be further developed through funded projects which allow dedicated staff time.

II. Further development of UrbanCLIM to Risk Informed Decision Support System (RIDS), extend UrbanCLIM to a more generic risk assessment and governance decision support system. Given the open framework of UrbanCLIM, it can be logically applied to the area beyond urban area, and potentially all risk governance realm. This move will provide more opportunities to promote the next generation of decision support system.

III. Enlargement of UrbanCLIM community of practice, by promote UrbanCLIM information online, and more promotion activities through new medias

IV. Improvement of the usability of UrbanCLIM, including the model build experience and graphing; further development of the user guidance and related knowledge management tools.

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Appendix

Conferences/Symposia/Workshops

Please find all the appendices for workshops in separated files

Appendix 1 Guangzhou workshop agenda

Appendix 2 Guangzhou workshop participant list

Appendix 3 Guangzhou workshop photos

Appendix 4 Guangzhou workshop presentations

Appendix 5 Raglan workshop agenda

Appendix 6 Raglan workshop participant list

Appendix 7 Raglan workshop photos

Appendix 8 Raglan workshop presentations

Appendix 9 Beijing workshop agenda

Appendix 10 Beijing workshop participant list

Appendix 11 Beijing workshop photos

Appendix 12 Beijing workshop presentations

Funding sources outside the APN

This project received financial and in-kind support from following entities or projects:

1) Monsoon Asia Integrated Regional Study (MAIRS), IPO provided financial and in kind support.
2) Key Laboratory of Regional Climate-Environment for Temperate East Asia (RCE-TEA), IAP, Chinese Academy of Sciences
3) Financing low-carbon, climate resilient urban infrastructure in Asia and the Pacific project (funded by ADB)
4) Adapting to Climate Change in China (ACCC II) Project (funded by Swiss SDC)

List of Young Scientists

Mingtian Yao: *PhD candidate,* Wageningen University and Research Centre (WUR), Netherlands. He worked on Guangzhou case study of this project using the Pearl River Delta regional Water Use Model (PRDWUM).

Meng Wang: PhD, the University of Waikato, New Zealand. She worked on the database development of this project.

Glossary of Terms

Include list of acronyms and abbreviations

In the Appendix section, the report may also include:

- *Actual data or access to data used in the study*

- *Abstracts, Power Point Slides of conference/symposia/workshop presentations*
- *Conference/symposium/workshop reports*

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2. By e-mail and addressed to Dr. Stevenson (lastevenson@apn-gcr.org) and Dyota Condrorini (dcondrorini@apn-gcr.org).

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