Final Report to:
Asia-Pacific Network for Global Change Research

Analysis of Climate Change Simulations of Southeast Asia

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Final Report

Analysis of Climate Change Simulations of Southeast Asia

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Introduction and Background

CSIRO Atmospheric Research has carried out large climate simulations for Southeast Asian Regional Committee for START (SARCS) using the Divisional of Atmospheric Research Limited Area Model (DARLAM) at 44 km resolution. These were for a domain 93°E to 152°E and 25°S to 22°N for:

a) 1990 (an El Nino year), nesting within analyses from the European Centre for Medium Range Weather Forecasts (ECMWF);
b) 10 years for present CO_2 conditions nesting within the CSIRO transient atmosphere-ocean general circulation model (GCM);
c) 10 years nesting in the GCM for CO_2 conditions 50 years from now;
d) 10 years nesting in the GCM for CO_2 conditions 100 years from now.

Full model output was saved 12-hourly, and surface fields 3-hourly. Most features of the tropical climate system were captured in the simulations.

The present APN project was a 5-week workshop in Melbourne, starting 10 January 2000. The aim of the workshop was to assist climate scientists of the region to understand and make good use of the output from the SARCS simulations. Fifteen scientists were invited to participate. Melbourne was chosen as the venue to facilitate access to the large data sets and computing facilities, with ready provision and application of the analysis and graphics tools used at CSIRO. Valuable discussions were expected between the participants and between CSIRO staff. It was intended that the visiting scientists should become well equipped to carry out further analyses on return to their own countries.

During the workshop, the objectives included:

- analysing the SARCS climate-change simulations in detail for Indonesia, Malaysia, Philippines, Singapore, Vietnam, and a Pacific Island State;
- examining rainfall and temperature changes, expected 50 and 100 years from the present;
- examining rainfall variability within 10-year periods for selected places for
    - present conditions,
    - 50 years from now,
    - 100 years from now;
- examining the modelled variability, and relating it to ENSO effects;
- examining diurnal and seasonal characteristics within the simulations, and comparing with observations;
- comparing aspects of the simulations nested within analyses for both an El Nino and La Nina period, and relate to observed climate data and, where possible, agricultural production. To aid this objective, extra simulations were performed prior to the workshop for 1982 (El Nino) and 1988 (La Nina).

Outline of activities conducted

An extended lecture was given each morning on a topic relevant to climate change simulations or their analysis, as follows:

1. "Introduction to the workshop" J. McGregor, J. Katzfey and K. Nguyen
2. "Regional climate modelling and SARCS" J. Katzfey
3. "Use of statistics in climate research" K. Walsh
4. "Perspectives on global climate modelling" H. Gordon
5. "Tropical cyclones: structure and variability" K. Walsh
6. "The Southeast Asian Monsoon" R. Suppiah
7. "Seasonal predictability in the Australian Region" I. Smith
8. "Model intercomparisons: results from AMIP II" M. Dix
9. "Regional intercomparison of GCM results" P. Whetton
10. "Convective parameterizations" J. Katzfey
11. "ENSO and climate variability" R. Allan
12. "Observations and simulated changes in extreme temperatures and rainfall" K. Hennessy
13. "Climate change modelling" M. Dix
14. "Climate change detection and attribution: IPCC the Third Assessment Report" D. Karoly
15. "Comparison of different sensors for fire assessment in tropical rainforests" F. Siegertry
16. "Dynamical formulation of models" J. McGregor
17. "Coastal modelling and impacts for climate change" K. McInnes
18. "Description of a soil/canopy scheme in DARLAM" E. Kowalczyk
19. "Meeting supply and demand: reconciling climate model output with impact needs" R. Jones
20. "The Air Pollution Model (TAPM)" P. Hurley
21. "Aerosols" J. Jensen and M. Keywood
22. "New grid formulations" J. McGregor

Each afternoon, intensive tutorials were given to instruct the participants, for both Unix computers and PCs:

- how to access the output files of the CSIRO SARCS simulations;
- proficiency in manipulating netcdf files;
- proficiency with the Grads and Gnuplot computer graphics packages.

Each day the participants worked on their projects (one project per country) analysing selected aspects of the simulations, with ongoing guidance from the workshop tutors.

During the workshop the participants gave three short presentations on their projects covering: (a) background, (b) preliminary results, (c) concluding results. The final presentations were of a high standard, providing interesting and varied approaches. The participants demonstrated a great increase in their computer and analysis skills over the period, and also produced short written reports.

During the final two weeks participants were also given the opportunity to carry out one-month regional climate simulations for their own country using DARLAM.

Outcomes/Products

a) A 5-week workshop was carried out, successfully accomplishing all the intended objectives.
b) The 15 participants sponsored by APN were trained in the analysis of large data sets produced by regional climate simulations.
c) Three CD-ROMs were produced by CSIRO for the workshop. These contain monthly climatologies of all the prescribed simulations. All participants have been given copies of the CD-ROMs for use on return to their own countries.
d) The participants brought a selection of station data, and learned how to compare them with the archived model grid-point data.
e) Most participants learned how to run DARLAM for a 1-month simulation over their own country on a 44 x 44 x 18 grid and to examine graphically the output.
f) A very high resolution (10 km) 12-month simulation was performed over Samoa.
g) It was found that the DARLAM simulations for SARCS over Southeast Asia generally represent well the present-day climate for the region, with regard to rainfall and maximum/minimum temperatures. These results and others were described in the following presentations for the different countries (summaries are provided in the Appendix).
    - "Climate change modelling simulation for Cambodia" Pak Sokharavuth and Sum Thy
    - "Primary investigation and some initial climatic applications of the CSIRO model for Vietnam" Hoang Minh Hien
    - "Results of the DARLAM climatological simulations over Fiji: is there a signal for climate change over this region?" Nilesh Kumar
    - "Climatological model simulations for small islands (Samoa): 10-km resolution nesting the DARLAM model in a GCM" Sagato Tuiafiso
    - "Comparisons of the model with observations for Indonesia" Mezak A. Ratag, Bambang Siswanto and Eddy Suaydhi
    - "DARLAM climate change simulations: rainfall analysis for the Philippine region" Felicidad Villareal
    - "Changes in wind patterns for the next 50 years over the area 5°S - 20°N and 95°E - 150°E " Zabani B. Md. Zuki
    - "Verification of DARLAM by comparing rainfall using observed and measured data with special emphasis on topographic effects " Kasis Inape
    - "Verification of precipitation simulated by DARLAM for Southeast Asia" Hu Yihong
    - "Comparison of various AOGCM runs for the Southeast Asian region with observations" Suruchi Bhadwal
    - "Comparison of climate model data and observational data for Thailand" Dararat Disbunchong, Anuchit Ratanasuwan and Wira Smalhe

Future directions/follow-up work

- The participants have been encouraged to continue their analyses by making use of the CD-ROMs on their own PCs.
- Future collaborations and projects -
  - a number of participants wish to use DARLAM for climate research within their own institutions;
  - Vietnam, Cambodia, Laos and Australia are formulating a regional climate modelling proposal for submission to APN later this year;
  - the present-day rainfall patterns from the Samoa run are very encouraging, and it is hoped to extend significantly the duration of this simulation.
- The contacts formed between the participants will be very valuable in future climate change activities.
- In the near future it is planned to combine the country reports into a single technical report.

Appendix. Summaries of the country presentations

The participants all produced written reports of their projects. The following summaries are lightly edited extracts from those reports. More complete scientific details of the projects will be provided in a future CSIRO technical paper.

Climate change modelling simulation for Cambodia

Pak Sokharavuth and Sum Thy

We have compared the model data set and the observations for some stations in Cambodia. There are seven stations operating in Cambodia today: Pochentong, Siemreap, Sihanoukville, Battam Bang, Kompong Cham, Svay Rieng, and Kampot. In the project, we have chosen the years 1982 and 1988. In addition, we also compared the temperatures at Pochentong station from the simulations (control, 50-year and 100-year) with the observations during the year 1981 to 1990.

Comparing the maximum and minimum temperatures at Pochentong station for 1982, we found that the maximum temperatures from the observations and the model are generally very similar, but differ slightly from January to March. The observations increase slightly from 30°C in January to 34°C in March, while the model decreases slightly from 37°C in January to 35°C in March. However, the minimum temperatures are very similar.

We have also done a comparison in 1988 of two stations: Pochentong and Kampong Cham. We find that maximum temperatures in the model are quite different from the observations. In addition, the minimum temperature was slightly different (N.B. it was subsequently realised that the 1988 simulation had incorrect nesting data).

Finally, we have compared maximum and minimum temperatures of the 10-year control with 10 years of observations at Pochentong station. We also examined the 50-year and 100-year maximum and minimum temperatures. We found that the maximum temperatures in the model control run and the observations are quite similar, except in April. In this month, the observations show higher temperatures, while the model shows lower temperatures. The model has quite similar minimum temperatures to the observations, although the model temperatures are lower then the observations for the whole period.

Due to the lack of human resources and equipment in Cambodia, we would like to ask CSIRO and APN to support Cambodia in both funding training and equipment, in order to enable Cambodia to run model simulations, and to catch up at the international level.

Primary investigation and some initial climatic applications of the CSIRO model for Vietnam

Hoang Minh Hien

The DARLAM model is a regional climatic model and Vietnam is located near the border of the selected area for DARLAM, so the test of its output for the current climate is a necessary and important step. For the APN Workshop, printed listing of some climatic data was brought for 16 stations from different regions of Vietnam. The data are for monthly temperature and monthly rainfall only (for the period 1961 to 1998). All of the available stations are inland. During the workshop, the monthly climatic average values were not available.

Primary tests were made for:

- specific years 1982, 1988 and 1990
- specific stations in northern, middle and southern regions of Vietnam
- monthly temperature and monthly rainfall.

- The primary comparison test showed that the agreement of DARLAM outputs with monthly temperature is better than that with the monthly rainfall
- For some stations the modelled temperature is higher than the observed temperature
- The agreement at the southern stations, which are closer to the centre of the selected area than northern stations, is no better than that at the northern stations
- In general the model has captured the seasonal trend and the peaks of monthly temperature and monthly rainfall in the year
- It is important that the model grid point selected for the comparison with a climatic station be over land.

The Vietnam territory is quite narrow (in some places the width is only 50-60 km) and long (from 8°N to 23°N. The climate is very different for different regions of Vietnam. In northern Vietnam there are four seasons, whilst in southern Vietnam there are only two seasons (wet and dry). Most of the available climatic stations are located in the coastal zone. An improved type of comparison could probably be made by testing the climatic regions of Vietnam for at least three different classes: mountain, plain and coastal regions. If possible the number of stations should be increased to provide climatic data for every region.

Short studies were also made regarding "ENSO impacts in Vietnam" and "50-year and 100-year climatic predictions".

Results of the DARLAM climatological simulations over Fiji: is there a signal for climate change over this region?

Nilesh Kumar

In the present study, results from a 125-km, 140-year simulation of the CSIRO DARLAM model are compared to observations in Fiji, in order to check the performance of the model over Fiji. The model works well over the Fiji region and is able to pick out ENSO effects well. There seems to be enough evidence to suggest that the climate of Fiji has changed over the last 60 years and continues to do so. Both maximum and minimum temperatures have risen in the last 58 years. Towards the end of the millennium, rainfall has taken a downward trend.

Modelled maximum and minimum temperatures also show a steady increase with time. Screen temperature is likely to show a 0.8°C increase by 2030. On the other hand, rainfall generated by the model was fairly stable on the long time scale, and does not show any marked change in the rainfall pattern over the next 30 years.

Correlation coefficients between the observed and modelled data for temperatures and rainfall were calculated using 5-year running means. The correlation coefficients were 0.53, 0.80 and 0.95 for maximum temperature, minimum temperature and rainfall, respectively. This result may be fortuitous, considering that the model was not using observed sea surface temperatures or analysed atmospheric fields.

Comparing monthly averages of maximum temperature, minimum temperature and rainfall over 39 years of observations gives striking similarity with the model. Seasonal variations in rainfall are well picked up by the model. Similarly, there is a good seasonal correlation for sea surface temperature and screen temperature. There is one point to be noted though, that the sea surface temperature is greater than the screen temperature. This is mainly because a sea point has been chosen for the data from the model, as there is no model land point near Fiji. At a resolution of 125 km, this was the best choice for comparing the performance of the model with observations.

Spectral energy was also calculated for the time series of temperature and rainfall. Annual and inter-seasonal variations (signals) are omitted from the series by using a 12-month filter. The model is able to pick out the ENSO events quite well, through the distinct high energy peaks at 3- and 5-year periods.

Climatological model simulations for small islands (Samoa): 10-km resolution nesting the DARLAM model in a GCM

Sagato Tuiafiso

The regional climate modelling simulations for the Southeast Asia region using DARLAM reproduce many of the present climate features. For a large land mass, the 44-km resolution will be no problem, but for small land areas such as small islands in the Pacific, climate prediction needs to be taken with caution.

Samoa was struck by moderate to severe drought during the 1982-1983 and 1997-1998 El Ninos. After studying the relationship of the Southern Oscillation Index with data from a single rainfall station, I was convinced that the 1997-1998 water shortage could have been less severe if the public had been aware of past events. It was found that the Mulinuu Rainfall corresponded well with the SOI. The lack of proper climate information for the island necessitates that this case study be carried through after the workshop.

Since Samoa was not seen on the 44-km resolution SARCS simulation of DARLAM, a 10-km resolution run was produced, the first of its kind. A test run for one January showed some very attractive results. July was chosen as the second month, which also gave results similar to the mean observed data. A few changes were made with parameter values for the vegetation cover and the soil type for the Samoa model. The sandy soil was changed to loamy soil and the vegetation changed. These changes improved the model output for the single July run. The modelled year showed promising results. There was a low value for model rainfall for the initial January, probably due to an initial response of the model while settling down. High rainfall for July might be due to incorrect soil moisture or temperature, or orographic effects.

Comparisons of the model with observations for Indonesia

Mezak A. Ratag, Bambang Siswanto and Eddy Suaydhi

1) *Rainfall and temperature*
In this study, a comparison was made of the precipitation and maximum temperatures for 23 selected cities throughout the various regions of Indonesia with the SARCS RCM output. The data from the 10-year control simulation at the nearest land grid-point to the observations were used for the comparisons. In general, it was found that the annual cycle of precipitation was captured by the model simulations, especially for the middle part of Indonesia.

2) *Annual cycle of wind profiles*
Data from a number of stations with radiosondes (and a few with wind profilers) were compared with the monthly means from the nearest model grid point of the 10-year control SARCS RCM simulation. Although, the comparison was reasonable in general terms, the timing was not always correct (such as regarding changes in direction of meridional flow), especially in the upper troposphere.

3) *Wavelet analysis of precipitation over Indonesia*
Ten years of monthly data from the 10-year control run, as well as the two climate change runs, were analysed for selected cities in Indonesia using wavelet transforms and compared with observational data. The analyses showed annual and biannual peaks in precipitation. The annual peak in the model was much stronger than in the observations; the biannual peak for the model was rather weak.

DARLAM climate change simulations: rainfall analysis for the Philippine region

Felicidad Villareal

Analysing the results for 16 different synoptic stations in the Philippines, the following conclusions were generated:

1) The control run of DARLAM has simulated fairly well the climatology of the different stations, except that heavy precipitation episodes were not well captured. The prevailing winds (northeast and southwest monsoons) corresponded well to the real climate of the Philippines. To further analyse this, Hoevmoller diagrams along 120°E and 125°E were produced and verified against stations lying near to those longitudes. The 120°E diagram showed a maximum rainfall rate centred about the month of August. This was verified against climatological data of the Iba synoptic station (120°E, 15.3°N), which has a

maximum rainfall of about 1000 mm during the month of August. The 125°E diagram showed maximum rainfall for this longitude during November-December. This was verified against the historical data of Virac (124.2°E, 13.6°N), which has maximum rainfall during the November-December.

2) Generally, the analysis persistently showed that there will be an increase of rainfall 50 and 100 years from the present during the northeast monsoon season (November through February) for all stations above 12.5°N latitude. Consequently, a deficient rainfall was expected during southwest monsoon season (June through September). For stations below 12.5°N, there was a strong indication of a rainfall surplus throughout the year. There was little difference between the 50-year and 100-year monthly rainfall simulations observed for stations. However, quantification of these amounts was not included in this study.
3) Further analysis is therefore recommended, with the objective of achieving more realistic results. Likewise, it is also recommended to stratify the study by season (the southwest and northeast monsoon seasons).

Changes in wind patterns for the next 50 years over the area 5°S - 20°N and 95°E - 150°E

Zabani B. Md. Zuki

The aim was to observe any change in the wind flow pattern and the location of the monsoon trough over the area between 5°S to 20°N and 95°E to 150°E for the next 50 years. The area was chosen because it is in the DARLAM model domain and the weather in Malaysia is greatly influenced by the wind flow and the location of this monsoon trough, particularly during the northeasterly monsoon. Monthly comparisons of the wind flow pattern for the control and 50-year data sets were carried out.

Conclusions

1) There is a change in the wind flow pattern during the June, July, August (southwest monsoon) and September months over certain areas. There is an indication of greater penetration of westerly flow over the Western Pacific in these months.
2) The trough line is shifted northward in the months of June, July, (possibly August) and September in the 50-year data set, compared to the control.
3) An explanation was not found to relate this change of the wind flow pattern to the temperature increases.
4) There is no significant change in the simulated wind flow pattern over Malaysia.

Verification of DARLAM by comparing rainfall using observed and measured data with special emphasis on topographic effects

Kasis Inape

PNG is one of the most rugged and most difficult countries to model reasonably well. The project consists of two phases. Phase 1 compares the modelled rainfall data with the observations for high altitude (highland) stations, while Phase 2 deals with the rainfall for the low lying (coastal) regions.

Phase 1 (high altitude stations)

- For 1982, which was an El Nino year, the model incorrectly represented the rainfall (e.g. too much rainfall in June-July-August for Mendi).

- For 1990, the basic seasonality of precipitation was captured well for most cases, although the rainfall was still somewhat excessive.
- For longer climatological records, the model did reasonably well for both the seasonality and precipitation. However, the model still, generally, over-estimated the rainfall.

Phase 2 (coastal stations)

- For 1982, the model incorrectly represented the rainfall (e.g. too much rainfall for Daru)
- For 1990, even though the basic seasonality of precipitation was captured for all stations, the model still over-estimated the rainfall.

Conclusions

- For both years, the model over-estimated the rainfall, regardless of whether it was an El Nino or La Nina year
- Generally, for the longer (10-year) climatological simulation, the model did very well. This may be due to "averaging effects".
- Since the model over-estimated the rainfall for most of the selected stations for the two different phases, it can be concluded that the model did not fully take into consideration the topographic effects, which are vital for a country like PNG.

Verification of precipitation simulated by DARLAM for Southeast Asia

Hu Yihong

After an initial study of observational data, 18 stations were selected to examine rainfall variation during El Nino (1982), La Nina (1988) and a normal year (1990). Monthly data from 10 to 100 years for each station were also averaged to obtain climatological data.

Data from four stations over Borneo, two stations over Sulawesi and three stations over Sumatra and Java were examined. Over Borneo and Sulawesi, it was found that rainfall is significantly below normal in the El Nino year and above normal in the La Nina year. In Sumatra and Java, however, rainfall variations between the El Nino and La Nina year are not obvious. Elsewhere, rainfall for three stations (Dagupan, Tacolban and Zamboanga) of the Philippines are sensitive to whether it is an El Nino or La Nina year. Rainfall in Singapore and Kuala Lumpur also increased very much in 1988 and decreased in 1982. In 1988, rainfall of Playku, which is located on the east coastline of Vietnam, increased tremendously, five to ten times above normal. Rainfall for Udon (northern Thailand), Prachnap Khirikhan (west of the Gulf of Thailand) and Kota Bharu (north Malaysia) did not vary between 1982, 1988 and 1990.

Monthly precipitation simulated by DARLAM is extracted over the nearest land point to each observation station. Mean error, RMS error and correlation coefficients are calculated by comparing the observational data and the DARLAM simulations. For most of the 18 stations, the bias between the observed and simulated rainfall is small for 1990, but relatively large in 1988. Correlation coefficients are also low for 1988, being less than 0.5 for most of the 18 stations (N.B. it was subsequently realised that the 1988 simulation had used incorrect nesting data).

DARLAM generally captures the monthly and seasonal variations of rainfall over the region. However, DARLAM tends to overestimate rainfall in the El Nino year and underestimate rainfall in the La Nina year. To further investigate the performance of DARLAM, the region is divided into four areas: 1) Thailand, Vietnam, Cambodia and Lao; 2) West Malaysia, Singapore, Sumatra and Java; 3) Borneo and Sulawesi; 4) Philippines. Mean error, RMS error and correlation coefficient for the above four areas and the whole region were calculated. DARLAM performs well over Areas 1 and 2 for 1982, and over Areas 1 and 4 for 1990. Precipitation simulated by DARLAM for 1988 is not realistic, for the reasons mentioned above.

In summary the evaluation of DARLAM simulations for 1982, 1988 and 1990 shows that DARLAM, a regional climate model, is able to simulate monthly and seasonal changes of rainfall for the tropics and sub-tropics. Based on the results of this report, DARLAM performs better over the northern part of Southeast Asia. However, the quantitative precipitation prediction by the regional climate model still needs to be improved.

More cases should be studied with good quality observational data before drawing consolidated conclusions. More sophisticated methods such as pattern correlation could be used to investigate the model response to El Nino and La Nina.

Comparison of various AOGCM runs for the Southeast Asian region with observations

Suruchi Bhadwal

The only tools currently available to simulate the response of the global climate system are GCMs; these are able to represent various physical processes between the atmosphere, ocean and land. Results of some coupled GCMs are made available by the Data Distribution Centre (DDC) – a shared operation between the Climatic Research Unit (CRU) in the United Kingdom and Deutsches Klimarechenzentrum (DKRZ) in Germany.

Results are extracted from transient, warm-start, GCM simulations including control, greenhouse gas (GHG) and GHG + sulphate aerosol forcings. These GCMs depict global climate using a grid with horizontal resolution 250-600 km, with 9-20 vertical layers and 30 layers in the ocean. The resolution is thus quite coarse. In this report, an attempt has been made to study the simulations of various coupled GCMs, in particular the Canadian Climate Centre Model (CCCMa), Geophysical Fluid Dynamics Laboratory (GFDL), CSIRO9 and Max Planck Institute (MPI). The focus of the study has been for Southeast Asia within latitudes 20°N to 10°S, and longitudes 95°E to 155°E, including Thailand, Laos, Kampuchea, Vietnam, Malaysia, Singapore, Indonesia and the Philippines.

In the observational 100-year records, the temperatures have remained below average until the middle of the century. An increase in temperature of 0.2 to 0.3°C has been observed in the last 20 years or so. Looking at individual model runs, the GCMs give a fair picture of gradual increases in temperature initially, with rapid increases in temperature in the latter half of the 21st century. Looking at the various model runs from a period of 1958-2056, the GFDL run is observed to simulate relatively lower screen temperatures for the Southeast Asian region.

In addition to the changes in temperature, many other associated fields such as precipitation are expected to change. Projections from the various GCM runs show an increase in precipitation in the initial years, but a decrease in precipitation in the latter half of the century for the Southeast Asian region.

There are many uncertainties in the future projections of climate change by the various GCMs. These include future greenhouse gas emissions and concentrations, non-linear feedbacks, sub-grid scale physical processes not parameterized properly, and inadequate horizontal and vertical resolution. Though the projections of the GCM runs might not give a representative range of climate change at the regional or local scales, they do suggest the possibility of future changes in climate.

Comparison of climate model data and observational data for Thailand

Dararat Disbunchong, Anuchit Ratanasuwan and Wira Smalhe

The climate in Thailand is characterised by seasonal weather patterns associated with the two monsoons and the occurrence of tropical cyclones in the two core areas of cyclogenesis (the northern Indian Ocean and the northwestern Pacific Ocean). The summer southwest monsoon influences the climate of the country from May to September and the winter northeast monsoon controls the climate from November to February. The monsoons bring substantial precipitation to most of the country.

As a result of the seasonal shifts in climate, a large part of the country is exposed to annual floods and droughts; climate change represents an additional stress. Projected climate changes in the region include strengthening of the monsoon circulation, increases in surface temperature and increases in the magnitude and frequency of extreme rainfall events. These changes could result in major impacts on the country in terms of hydrology, water resources, agriculture, forest and human settlements.

Climate change is related to the impact on forest areas in two ways. It determines the length and severity of the fire seasons and it determines the amount of forest fuel in an area. Although climate is an average of the weather, it is very useful to know the magnitude of extreme temperature and rainfall events. Fire management can make good use of climate data for an area, to determine fire occurrence over time. These can be used to prepare action plans and to provide warnings for anticipated extremes.

We selected to study the northern part of Thailand. Most of this area is mountainous and covered by forest. The main problem for this area is land use change (decrease of the forest area) caused by human activity and forest fires. We tried to relate changes in temperature and rainfall from the regional climate model data to the expected effect on forest fuels and forest fires.

Examining daily maximum temperatures in 1990 from Mae Sarieng station, it was found that the highest temperature from observational data was 40.6°C, occurring on 25 April, when the model temperature was 40.1°C. The highest temperature from the model data was 42.5°C, on 24 April. During 1990 the maximum temperature from the model in this area is higher than the observed station data by 1-2°C. The time variation of the maximum temperatures from the model follows the observations closely.

Maximum temperatures in April for 10 years (1988-1997) of observational data for Mae Sarieng station were compared against the various 10-year model data sets. The observations showed a decreasing trend during the 10 years, whilst there was no trend in any of the 10-year model data sets (nor should any trend be expected). The daily variability of the modelled maxima was similar to that of the observations. However, the average maximum temperature from the control simulation was several °C lower than the observations for this month.

Climate modelling is a very powerful tool to assist in management and planning, especially when linked with Remote Sensing and Geographic Information Systems.

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