3

CLIMATE & ENVIRONMENTAL MODELLING PROGRAMME

The basic approach of CEMP is a fusion of innovation and sound mathematical modeling that can fill critical knowledge gaps and also enable real-life applications. The emphasis continues to be on understanding of the climate system and applications through multi-disciplinary modelling combining climate science with water, agriculture, health energy and sustainability in general.

CEMP uses a hierarchical modelling platform along with a spectrum of analysis and visualization tools. Most of the process models, with associated computer codes, are developed in-house. The CSIR climate observation and modelling network (COMoN) is a comprehensive data infrastructure. COMoN has been designed and developed by CEMP as a multi-application sustained network in a resource and effort sharing participation by multiple agencies.

CEMP has often adopted approaches that are unconventional but scientifically sound. After its cognitive network for monsoon forecasting, CEMP pioneered long-range, high-resolution forecasting of monsoon with novel methodology, such as a conceptual framework and methodology for advance dynamical forecasting of the date of onset of monsoon. CEMP has been communicating its experimental forecasts of monsoon to various agencies since 2003 for post-forecast evaluation.

Advance weather informatics, like forecasts of fog, can aid many sections of the society as well as strategic and industrial sectors. The dynamical fog forecasting model developed by CEMP was transferred to IMD for integration to the national weather services.

To complete the cycle from development to application, CEMP integrates effective outreach to its activities. An important outreach programme in weather informatics is in collaboration with Karnataka State Natural Disaster Monitoring Centre (KSNDMC). Forecasts generated using the novel methodology developed at CSIR-4PI are disseminated by KSNDMC for the benefit of the farmers. CEMP had been the first to develop an industrial interface in weather informatics.

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2.1 COMoN: Status and utilization

The CSIR Climate Observation and Modelling Network (COMoN) was established as a part of the CSIR Network Project Integrated Analysis for Impact, Mitigation and Sustainability (IAIMS : NWP-52). Through a synergy between a number of CSIR laboratories, IAF, DRDO, universities and state Govt, a network of 26 climate monitoring systems have been installed covering various parts of the country, from the Himalayas to coastal regions. COMoN is unique for its multi-application design.

The observations from COMoN has allowed to address diverse issues like

- Ground truthing of remotely-sensed soil moisture
- Data Optimality for meso-scale forecasting
- Model calibration for air pollution forecasting
- Identification of mechanism of fog over Delhi

Geographical Distribution of CSIR COMoN Towers

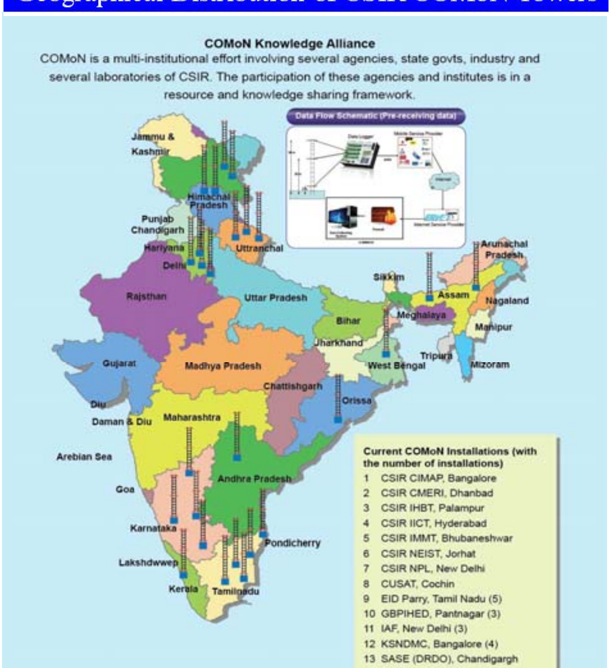

Figure 2.1

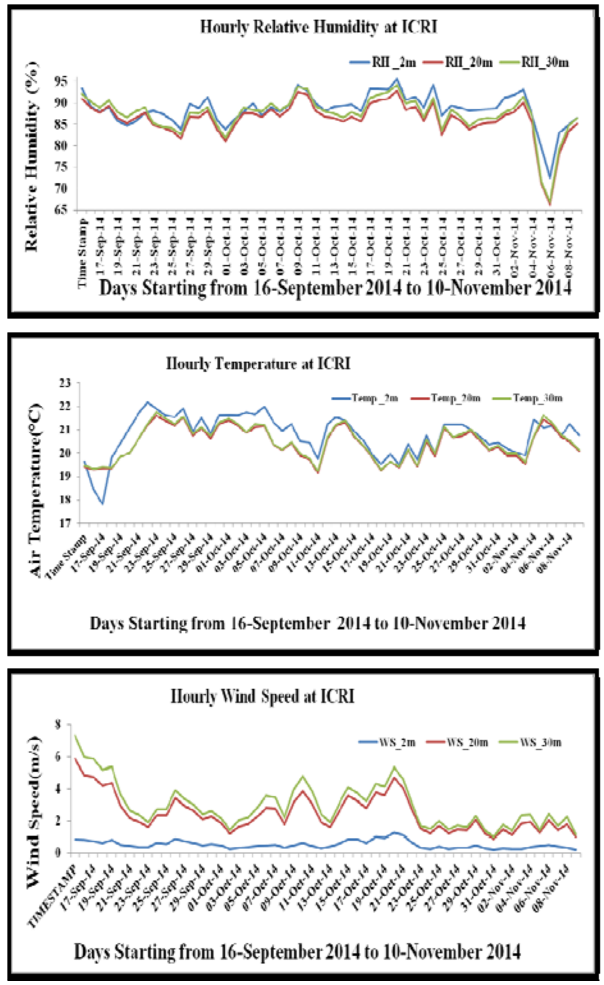

Figure 2.2 Hourly relative humidity, air temperature and wind speed at three levels during 16 September- 10 November, 2014 at COMoN Station at India Cardamom Research Institute, Myladampura

These results have passed through international per review, as evidenced by publications in high-impact SCI Publications.

COMoN provides an excellent opportunity for sustained, multi-sector R & D in monitoring and assessment in diverse areas like health, disaster, agriculture.

P Goswami and S Himesh

2.2 Panchayat-Level forecast over Karnataka: Fifth year of collaborative outreach

Weather informatics like rainfall advisories can enhance farmers' income and aid water and energy efficient agriculture. In a pioneering effort in the country, CSIR Centre for Mathematical Modelling and Computer Simulation (C-MMACS, repositioned 4PI) and Karnataka State Disaster Monitoring Centre (KSNDMC) have initiated rainfall forecasts at hobli-level (~ 10 Km) over Karnataka to. The Hobli-level rainfall forecast system over Karnataka is a culmination of collaboration between CSIR 4-PI and KSNDMC over more than a decade. Apart from other activities between the two organizations the hobli level meso scale rainfall forecasting activity started in 2010 and has now completed four years of rigorous testing, validation from the ground observations made from the telemetric rain gauge/weather monitoring network established by KSNDMC. However, given the tremendous spatial variability of rainfall, the forecasts need to be at still higher resolution. Based on a request from KSNDMC, forecasts at Gram Panchyat Level have been initiated in 2014. Results of Gram Panchyat Level forecast evaluation with KSNDMC rain gauge observation for the initial two months are presented. Comparison of number of hoblis where rainfall occurred for each day for the months of June and July with corresponding hoblis from morning and afternoon forecasts shows that forecast is reasonably skilful particularly for the month of July (Figure 2.3). The afternoon forecast is closer to observation compared to morning forecast. The forecast shows slight underprediction for the months of June compared to observation and in general majority of hoblis are with a bias within the range -3 to +3. The quality of forecasts is assessed by computing the correlation coefficient between forecasted and observed rainfall. A large number of hoblis with high values of correlation shows the agreement between forecasted and observed rainfall. We have also computed the root mean square errors in morning and afternoon forecasts by comparing with observed rainfall.

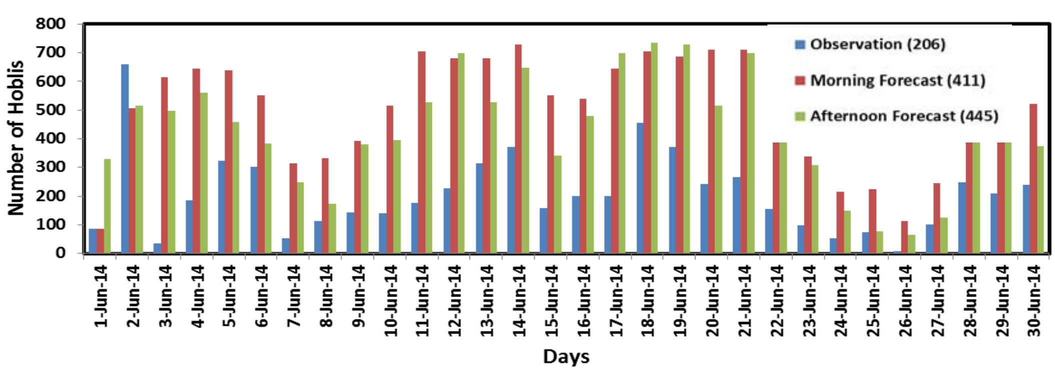

Figure 2.3 Comparison of number of hoblis where rainfall is observed (>1 mm) for the months of June with corresponding hoblis from Morning and Afternoon Forecasts.

Majority of hoblis (more than 500) in RMSE category < 10 mm clearly indicates good forecast skill and as seen earlier afternoon forecast is more skilful compared to morning forecast.

V Rakesh and P Goswami

2.3 Long-range high resolution Forecasting of monsoon 2014

Enhancement of scope and skill in monsoon forecasting skill remains a national priority and a major scientific challenge; in spite of decades of efforts by the world scientific community, the skill of monsoon forecasts at user relevant scales remain poor. CSIR-4PI has taken up this challenge with advanced and innovative mathematical modeling and algorithms.

Date of onset of monsoon

The date of onset of monsoon (DOM) with the first sustained and significant rainfall over Kerala signifies the arrival of the main agricultural season in India. Thus, accurate and advance prediction of DOM can help agricultural planning like preparation of land and sowing schedule.

Table 2.1 Performance of CSIR-4PI Experimental Forecasts of Monsoon Onset

Year	Forecast	Announced	Error
2007	May 26	May 28	+2
2008	May 28	May 31	+3
2009	May 23	May 23	0
2010	May 29	May 31	+2
2011	May 29	June 03	+5
2012	June 05	June 05	0
2013	June 01	May 31	1
2014	**June 07**	**June 07**	**0**
Average Error			**1.6 Days**

Although forecasting of day to day variability of rainfall beyond a few days remains a major challenge, we have argued that large transitions like the onset of monsoon should have a high signal-to-noise ratio and should be predictable.

Following methodologies developed at CSIR-4PI , the forecast of date of onset was issued in April, 2014; it matched with the date of onset announced **by IMD (June 07, 2014).**

It is worth mentioning that in the eight years of advance forecasting of Date of Onset (Table 2.1) there had been only one year (20) with large error (~5 days; the average error (~2.2 days) is well below the natural variability (~6 days).

Regional category Forecasts

Following its standard procedure, CSIR-4PI issued its experimental forecasts in early April, 2014.

Table 2.2 Categories for different regions from CSIR-4PI forecast and Observation

Region	Extent	June-August		June		July		August		% of Agreement
		CM	IMD	CM	IMD	CM	IMD	CM	IMD	
All-India	Continental land	N	N	D	D	D	N	N	N	75
North-India	(72-84 °E, 24-30 °N)	N	D	D	D	N	D	N	D	25
South India	(75-78°E, 8-12°N)	N	N	N	D	N	N	N	E	50
Central India	(72-84°E, 20-28°N)	D	D	D	D	D	N	N	D	50
North-east India	(92-96°E, 24-30°N)	N	N	D	D	E	D	N	N	75
North-west India	(68-75°E, 24-30°N)	E	D	D	D	N	N	E	D	50

Table 2.2 represents a comparison of the category forecast and observation both at monthly and seasonal scale for the different regions over India.

As there are still not many forecasts with detailed spatio-temporal variability as provided in CSIR-4PI forecasts, a direct comparison of forecasts is not possible; however, there is good agreement with observations (IMD) over several regions Table 2.2.

K C Gouda and P Goswami

2.4 Climate change assessment over India: Impact on economy

A major challenge for planning and adaptation is identification of reliable projection. A critical aspect of climate change that has received relatively less attention is the impact on the economy. India's economy strongly dependent on agriculture and allied sectors. However impact of climate change over India on its economy is less explored. Perhaps the biggest challenge in creating an accurate and quantitative knowledge base for assessing and developing adaptation strategies is the uncertainties in the climate projections.

The 20th century climate simulations from CMIP3 for the period 1951-2000 and the historical experiment simulations from CMIP5 for the period 1951-2005 are validated against observations and selected models are used for creating future scenarios. The All Model Ensemble (AME) includes 36-model simulations from CMIP5 and 24 simulations from CMIP3. The Event Based Ensemble (EBE) is based on the ability to simulate the observed pattern of extremes (monsoon) events for the period 1951-2012 within an acceptability condition of maximum of ±25% (Figure 2.4 b, c) differences between the observed and the simulated monsoon categories .In the present case, three categories are defined in terms of departures (R_a) in all Indian summer monsoon rainfall (ISMR) from long-period mean: deficient (<= -10%), normal (-10<&>10%) and excess (>=10%). Based on the criteria, the EBE consists of 5 models from CMIP5 and 6 models from CMIP3 from the total simulations. The reliability of the EBE projections is also evident from the fact that

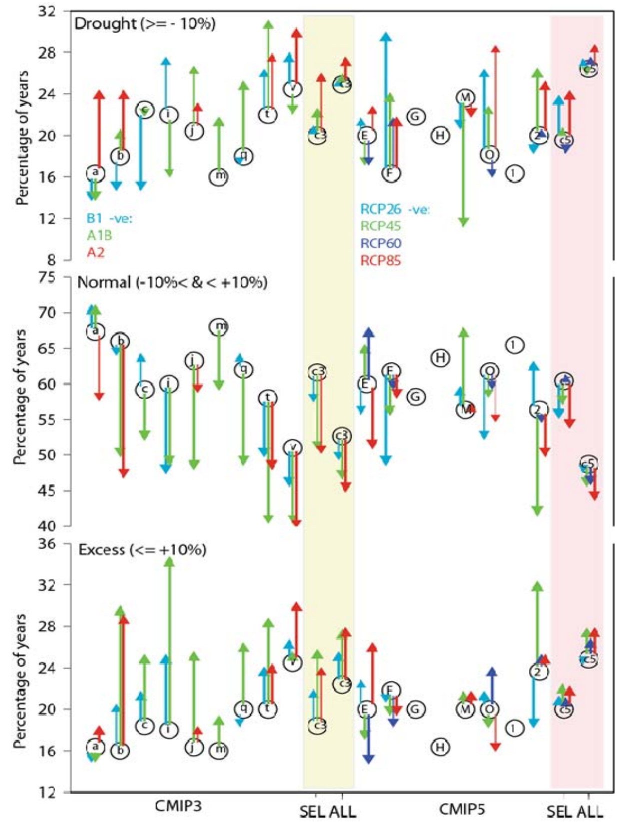

Figure 2.4 Distribution of climate projections for Indian summer monsoon rainfall under different climate scenarios by the individual climate models, which constitute the event based ensemble (EBE) from both CMIP3 and CMIP5.

most of the individual models (Figure 2.4) in this ensemble projected the same sign of change with different magnitudes; also each simulation is individually comparable to the corresponding ensemble average.

These results shows that while a definite reliability can not be assigned to future climate projections carefully developed and evaluated methodologies can be adopted to minimize uncertainties for decision support.

K V Ramesh, K B Shafeer, Alfred Jhony and P Goswami

2.5 Simulation of heavy rainfall events over Indian region

Extreme rainfall events (ERE) contribute a significant component of the Indian summer monsoon rainfall. Thus an important requirement for regional climate simulations is to attain desirable quality and reliability in simulating the extreme rainfall events. While the global circulation model (GCM) with coarse resolution are not preferred for simulation of extreme events, it is expected that the global domain in a GCM would allow better representation of scale interactions, resulting in adequate skill in simulating localized events in spite of lower resolution. At the same time, a GCM with skill in simulation of extreme events will provide a more reliable tool for seamless prediction. The present work provides an assessment of a GCM for simulating 40 ERE that occurred over India during 1998–2013. It is found that, expectedly, the GCM forecasts underestimate the observed (TRMM) rainfall in most cases, but not always. Somewhat surprisingly, the forecasts of location are quite accurate in spite of low resolution (~50 km). An interesting result is that the highest skill of the forecasts is realized at 48 h lead rather than at 24 or 96 h lead. Diagnostics of dynamical fields like convergence shows that the forecasts can capture contrasting features on pre-event, event and post-event days. The forecast configuration used is similar to one that has been used for long-range monsoon forecasting and tropical cyclones in earlier studies; the present results on ERE forecasting, therefore, provide an indication for the potential application of the model for seamless prediction.

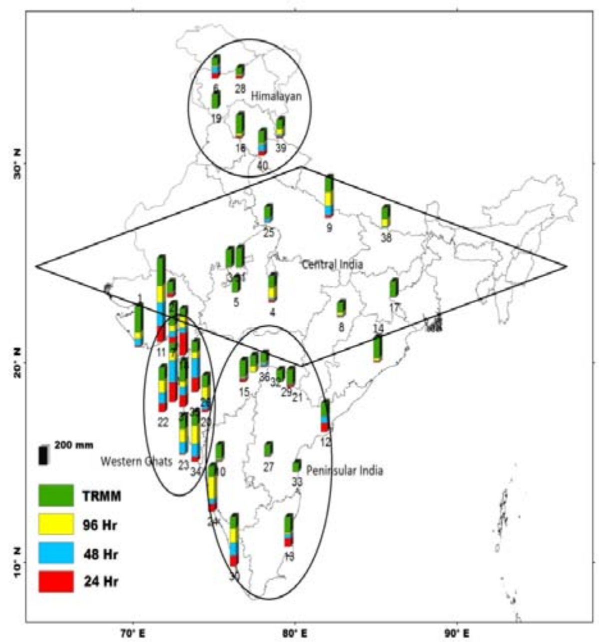

Figure 2.5 Distribution of the forty Extreme Rainfall Events over the four regions considered for regional analysis shown schematically. The bars represent the maximum daily rainfall over a 2°x2° box around the observed location simulated by GCM at 3 forecast leads (24Hr, 48Hr and 96Hr) and the observed daily rainfall on that event day from TRMM.

The extreme rainfall events impact diverse sectors like agriculture, energy, public health and tourism.

The present results show that it is feasible to use a properly calibrated GCM configuration to forecast ERE about 48 hours in advance. Combined with subsequent networking through radar and GIS, such forecasts can provide valuable inputs for pro-active disaster management.

Work is currently under progress to calibrate and validate the GCM for forecasting ERE over other locations and at larger loads.

P Goswami and B Kantha Rao
Climate Dynamics, 2014

2.6 Model configuration for predicting cyclone over Indian Ocean

With rapid enhancement in computing, there is need for evaluation of strategies for tropical cyclone simulations. Although limited area models (LAM) with their high resolutions appear to be the first choice to simulate tropical cyclones with their convective nature, our results show that an atmospheric General Circulation Model (GCM), even with relatively coarser resolution, provides a better candi LAM and GCM for tropical cyclone forecasting. While this conclusion cannot be claimed to be valid for any pair of GCM and LAM, our results provide the basis for such a forecasting strategy.

In actual application, it is possible to improve skill further through techniques like objective debiasing and assimilation of observations. However, such improvement is expected for both LAM and GCM; thus our basic conclusion regarding comparative performance is likely to remain unchanged.

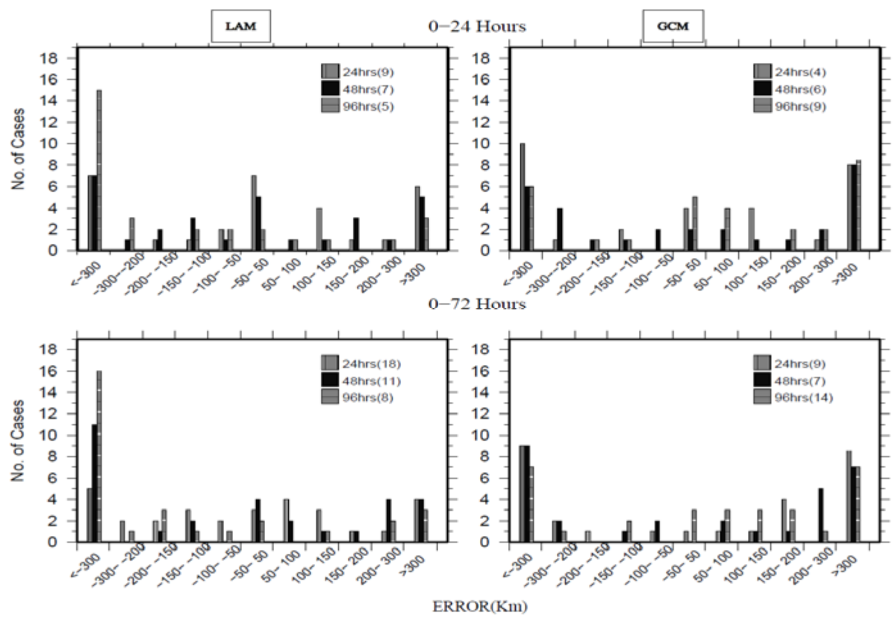

Figure 2.6 Histogram of errors in simulated track for different lead hours for LAM and GCM. The number in the bracket represents the number of cases with error between (top) -100 to +100 km and (bottom) -200 to +200 km.

date, especially at longer (>24-hour) leads. Considered for all the categories and for the moderate cyclones, the 96-hour lead forecasts with GCM are superior to those with LAM; for the severe cyclones, they are comparable. On the other hand, for 24-hour forecast lead, the LAM forecasts are superior to those with GCM for the severe cyclones. It is thus possible to conceive a strategy combining both

With growing computing power, it is now possible to carry out simulations with GCM at sufficiently high resolutions for a applications. At the sametime, there is need for a seamless forecast flatform; a GCM provides a natural candidate for such seamless forecasting.

G N Mahapatra and P Goswami

2.7 Impact of data assimilation on high-resolution rainfall forecasts

Advances in assimilation of observations can provide key inputs for improvement in forecast skill, especially at short range. However, there are many issues that need in-depth exploration. In limited area models (LAM) that are generally used for short-range forecasting, the impact of data assimilation is likely to depend on the background state through lateral boundary forcing; this may introduce certain seasonality in the impact of data assimilation on rainfall forecasts. It is also likely that the impact of data assimilation on forecasts will have certain spatial variability. Similarly, the impact of data assimilation may also depend on the category (intensity) of rainfall. These aspects for rainfall forecasts at high resolution were examined using a LAM (An advanced version of Weather Research and Forecasting Model). We have carried out twin simulations with and without data assimilation; the simulations without data assimilation are used as the benchmark. Analysis of simulations for 40 sample days distributed over the years 2012–2014 over Karnataka was carried out to estimate impact of data assimilation. The results showed strong seasonality and location dependence in impact of data assimilation. Our results also show that improvement due to data assimilation is higher/lower for lower/higher rainfall categories.

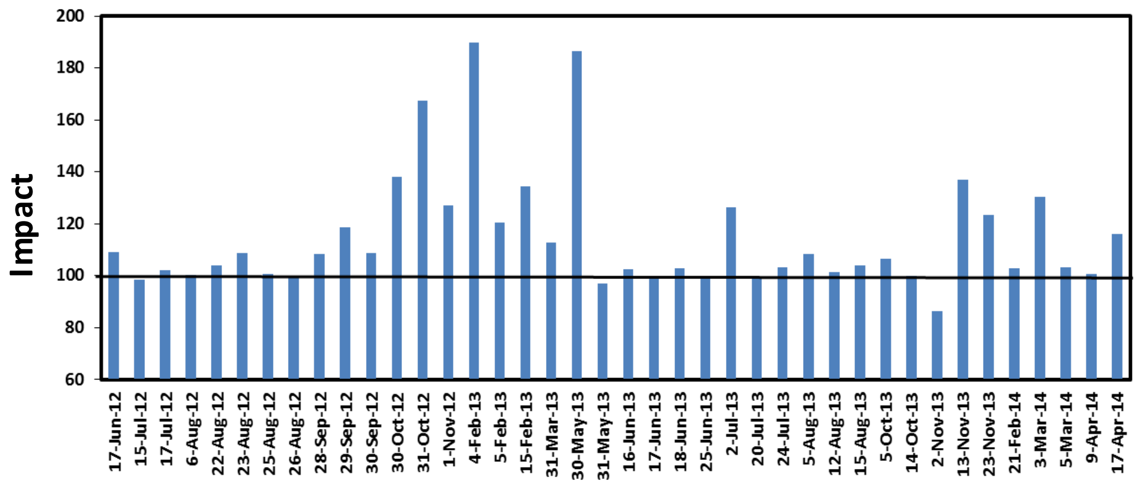

Figure 2.7 Impact index (in %; defined as the ratio of number of hoblis over Karnataka with impact ratio >1 to that having values <1) against different cases computed by validating forecasted daily rainfall with rain-gauge observations.

Assimilation of data is one of the key elements in a forecast cycle; even small improvements in the assimilation methodology can have significant impact of forecast skill. The results have important implications in design of observation system and assessment of impact of forecasts.

V Rakesh and P Goswami
J Geophys. Res. Atmos., 2015

2.8 Comparison of soil moisture of COMoN and remote sensing (ASCAT)

Accurate soil moisture data, critical for many applications such as agriculture and estimation of ground water, is limited worldwide and particularly over India. A long-term sustained soil moisture observation at four vertical levels (5, 15, 50, and 100 cm) is now available at several locations over India under a multi-institutional effort Climate Observations and Modeling Network (COMoN) led by CSIR, India. At the same time, a high resolution (0.1° × 0.1°) daily (moving 5-day mean) surface relative soil moisture data set has now become available from the Advanced Scatterometer (ASCAT). However, there is a need to compare remotely sensed data and in situ observations to ensure consistency and quantify uncertainties. This is particularly true for India characterized by diverse climatic zones. We have carried out a comparative analysis of gridded ASCAT soil moisture data and in situ COMoN station data over six locations during the period 2010–2013. at daily, weekly, monthly, and seasonal timescales. Analyses show that (Figure 2.8) the two data sets are generally consistent, although there are seasonalities in the agreement; the correlation coefficient is higher for the wet season (summer, autumn), and moderate for dry season (winter, spring). The correlation coefficients range from 0.73 to 0.91 (above 99% significance level). The results quantify the reliability and robustness of ASCAT soil moisture over different climatic regions in India and also identify certain differences between the two data sets from different observation platforms.

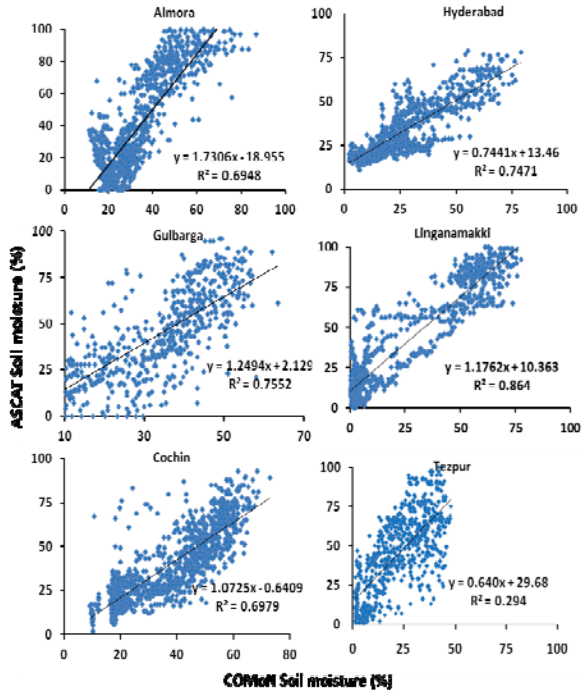

Figure 2.8 Scatter plot of soil moisture from ASCAT and COMoN, x-axis represents the COMoN while y-axis represents the ASCAT.

Work is now under progress to develop algorithms for synthesizing station soil mixture data from COMoN with gridded soil mixture data from ASCAT for a spatially homogeneous data set. Such a homogeneous soil moisture data set will have applications in several sectors like agriculture (moisture adequacy), water resources (ground water modeling) and vulnerability (landslides)

K R Bhimala and P Goswami

2.9 Forecast model for daily CO concentration over Delhi

Advance and accurate forecasts of air pollutant concentrations have many applications at different scales, from traffic planning to health advisories. However, such models need to incorporate local factors and must be validated against local observations for applicability. Dynamical models of species concentration driven by meteorological fields provide a promising avenue for pollution forecasts and control.

ous local sources like vehicular emission, domestic appliances and industrial sources; large-scale factors like advection are incorporated through the meteorological fields. Together with our earlier results, the present work adds to the robustness and enhanced scope of dynamical forecast of air pollution.

For all the three years as well as their average, the number of days in different concentrations bins are very similar (figure 2.9) forecasts based as fields from MM5 and those based on NCEP Reanalysis (used as benchmark).

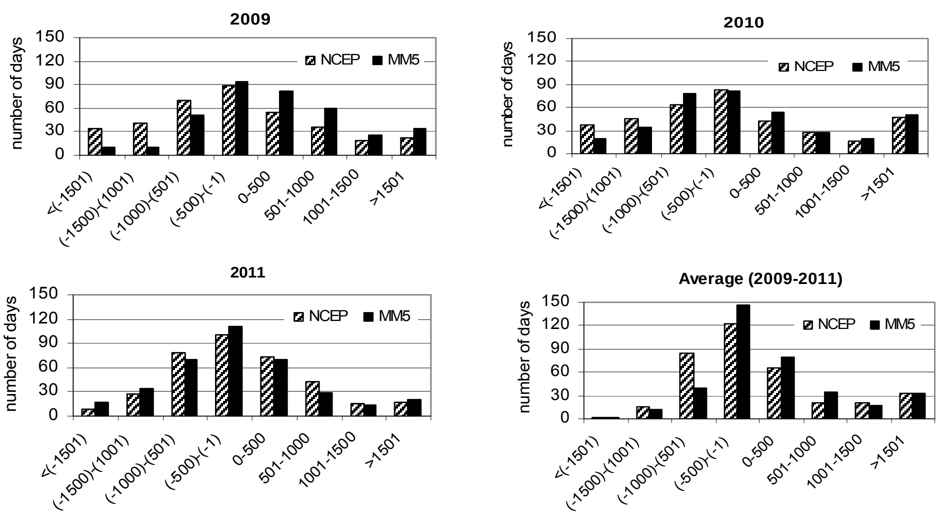

Figure 2.9 Histogram of errors showing the number of days in different error bins (observed-simulated) for the duration 2009-2011. The simulations with NCEP are based on area-averaged daily fields from NCEP Reanalysis for the day of the forecast and meso-scale (MM5) model. The observed concentration data is from CPCB.

It has been shown earlier that a dynamical model successfully simulates, in forecast mode, the observed (CPCB, India) daily concentrations of SPM, RSPM, SO2 and NO2 over Delhi. The present work shows that the model skill is also significant in predicting CO. We have used a meso-scale atmospheric model (MM5) to generate the meteorological forecasts that drive the species consentration model. The species concentration model incorporates vari-

The air pollution model calibrated and validated for Delhi and other urban air basins can be also applied to assess and design traffic in terms of parameters like road width and time to reduce air pollution..

Jurismita Baruah and P Goswami

2.10 Prevention of malaria through pro-active vector sanitation

Response to outbreaks of malaria is still mostly re-active, based on general schedule or post-outbreak decision. However, abundance of the mosquito vector that leads to outbreaks of malaria can vary significantly depending upon the environmental conditions, making a general schedule less effective. Further, exposure of the [incidental] human host to bites also determines the intensity of the epidemic. Identification of potential sites and time of vector genesis can, therefore, enable proactive vector sanitation and reduction of encounters between mosquito and human through exposure advisories. Validated quantitative relations between weather variables and malaria vector, along with recent advances in meteorological monitoring and mesoscale weather forecasting, integrating other critical components like GIS and communication now make such a platform feasible. A forecast model for vector (mosquito) genesis was developed at CSIR-4PI based on a mathematical model driven by the meteorological variables incorporating factors related to transmission and socio-economics. The model was calibrated and validated over Arunachal Pradesh and subsequently, over all the 28 states of India. A feasibility analysis as well as a proof of concept was explored using the malaria model, driven by the meteorological fields. The meteorological forecasts were generated using an atmospheric meso-scale model (WRF) calibrated over India. Experimental forecasts of vector genesis, hosted on the institution's web page for limited period showed (Figure 2.10) the general quality and consistence of the forecasts. Such an approach and methodology would lead to a paradigm shift through ensuring wellness rather than treatment; the applicability of the approach to some other diseases is discussed.

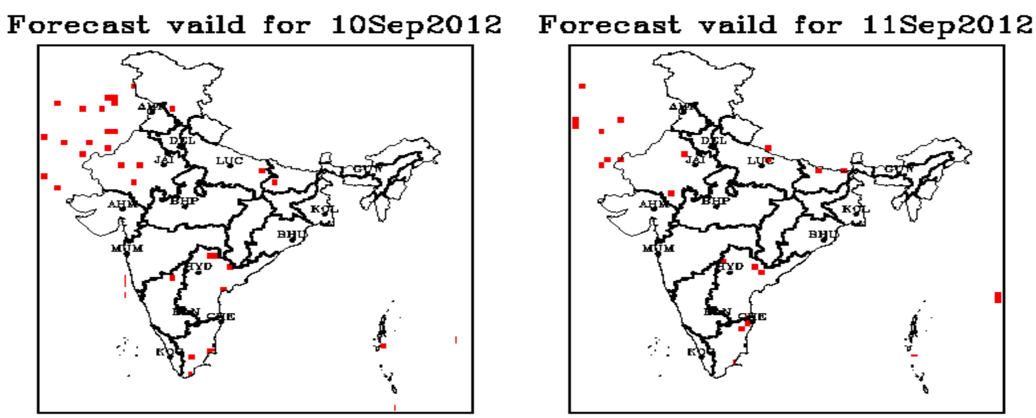

Figure 2.10 Spatial distribution of locations of vector genesis based on forecasts from the malaria model with meteorological fields derived from atmospheric meso-scale forecast.

It is worth emphasizing that the atmospheric forecast configuration applied is essentially the same that has been applied for generating Panchayat-level rainfall forecasting over Karnataka for the past five years.

Thus an integrated forecast platform can be developed for multiple applications.

P Goswami
Current Science, 2015

2.11 Virtual water trade and time scales for loss of water sustainability

A comparative regional analysis, Assessment and policy design for sustainability in primary resources like arable land and water need to adopt long-term perspective; even small but persistent effects like net export of water may influence sustainability through irreversible losses.

An important but mostly overlooked process is the virtual trade of water. The term virtual trade has been used in various contexts in case of water; here we refer to the transfer of water embedded in exported/imported grains and other agricultural products. While the water used in production is reusable in general, the water embedded in exported grains and agricultural products is irrecoverable. Although it may be a slow process, a net export of embedded water can reduce a nation's water sustainability. With growing consumption, this virtual water trade has become an important element in the water sustainability of a nation. We estimate and contrast the virtual (embedded) water trades of two populous nations, India and China, to present certain quantitative measures and time scales. Estimates show that export of embedded water alone can lead to loss of water sustainability. With the current rate of net export of water (embedded) in the end products, India is poised to lose its entire available water in less than 1000 years; much shorter time scales are implied in terms of water for production. The two cases contrast and exemplify sustainable and non-sustainable virtual water trade in a long term perspective. It is noteworthy that while India's recent trade balance in virtual water is negative (export/

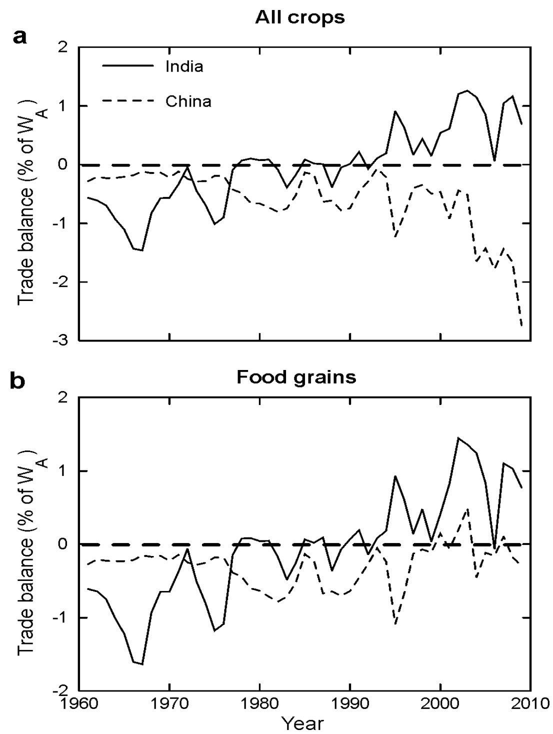

Figure 2.11 Trade balance in terms of total water involved in production as percentage of water available for all crops (a) and food grains (b) for India (solid line) and China (dash line).

import), China has maintained a positive trade balance in virtual water water essentially since 1960. At the same time, China possesses a much larger water resource than that of India.

It is important therefore, to evolve an export/import policy for agricultural products so that there is a zero or positive (more import) balance in virtual water trade. Such policies can take into account type of agricultural products as well as countries to trade with for net import through virtual water.

P Goswami and Shivnarain Nishad
Nature Scientific Reports, 2014

2.12 Towards seasonal forecasting of malaria in India

Outlook of disease burdens can help advance planning and preparedness. For diseases like malaria that depend on vector (mosquito) population, weather conditions play a decisive role. Thus seasonal disease outlooks are possible through disease model driven by seasonal forecasts. A 30-year hindcast of the climatic suitability for malaria transmission in India was explored using meteorological variables from a state of the art seasonal forecast model to drive a process-based, dynamic disease model. The spatial distribution and seasonal cycles of temperature and precipitation from the forecast model were compared to three observationally-based meteorological datasets. These time series are then used to drive the disease model, producing a simulated forecast of malaria and three synthetic malaria time series that are qualitatively compared to contemporary and pre-intervention malaria estimates. The area under the Relative Operator Characteristic (ROC) curve is calculated as a quantitative metric of forecast skill, comparing the forecast to themeteorologically-driven synthetic malaria time series.

The forecast shows probabilistic skill in predicting the spatial distribution of *Plasmodium falciparum* incidence when compared to the simulated meteorologically- driven malaria time series, particularly where modelled incidence shows high seasonal and interannual variability such as in Orissa, West Bengal, and Jharkhand (North-east India), and Gujarat, Rajastan, Madhya Pradesh and Maharashtra (North-west India). Focusing on these two regions, the malaria forecast is able to distinguish between years of

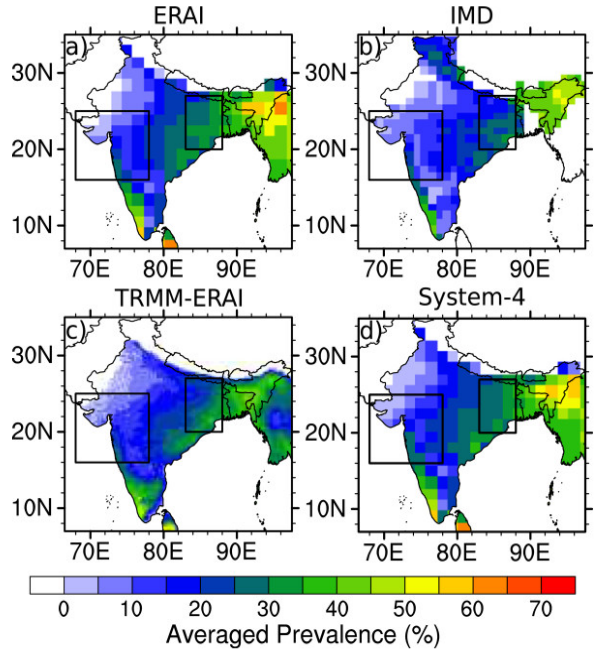

Figure 2.12 Annual average malaria prevalence (%). Output is shown from the Liverpool Malaria Model (LMM) driven by a) ERAI (1981–2010), b) IMD (1981-2002), c) TRMM precipitation and ERAI temperature (TRMM-ERAI, 1998–2010) and d) the System-4 forecast (1981–2010) .The two boxes enclose the regions of interest in Northwest and Northeast India.

"high", "above average" and "low" malaria incidence in the peak malaria transmission seasons, with more than 70% sensitivity and a statistically significant area under the ROC curve. These results are encouraging given that the three month forecast lead time used is well in excess of the target for early warning systems adopted by the World Health Organization. This approach could form the basis of an operational system to identify the probability of regional malaria epidemics, allowing advanced and targeted allocation of resources for combatting malaria in India.

J M Lauderdale, C Caminade, A E Heath, A E Jones, D A MacLeod, K C Gouda,U S N Murty, P Goswami, S R Mutheneni, A P Morse
Malaria Journal, 2014

2.13 Forecast model for capsule rot of small cardamom: A CSIR-ICRI synergy

Small cardamom is an economically important spice crop. However, cardamom is susceptible to several diseases that significantly reduce yield. Proactive prevention of these diseases based on advance warning can enhance the efficiency of disease control and reduce environmental load of pesticides. Many of these diseases are governed by weather variables (for example, through control of fungal growth). This work presents a disease (capsule rot of cardamom) forecast model based on a set of meteorological variables. While no single weather variable provides successful simulation, an optimal combination of weather variables provides sufficient skill for advance warning of the disease.

CSIR-4PI and Indian Cardamom Research Institute (ICRI) had initiated a collaboration to develop and validate forecast model for capsule rot of small cardamam. A forecast model was developed at CSIR-4PI which was then validated with data provided by ICRI.

The simulations of monthly disease incidences for the two years of 2008 and 2010 show good correspondence with observations, with correlation coefficient between observations and simulations significant in each case (Figure 2.13). However, there are over predictions in the months of September-December; although these errors in the predictions for the winter months are generally below thresholds to effect decisions, they need further improvement and attraction feature of the forecasts is their

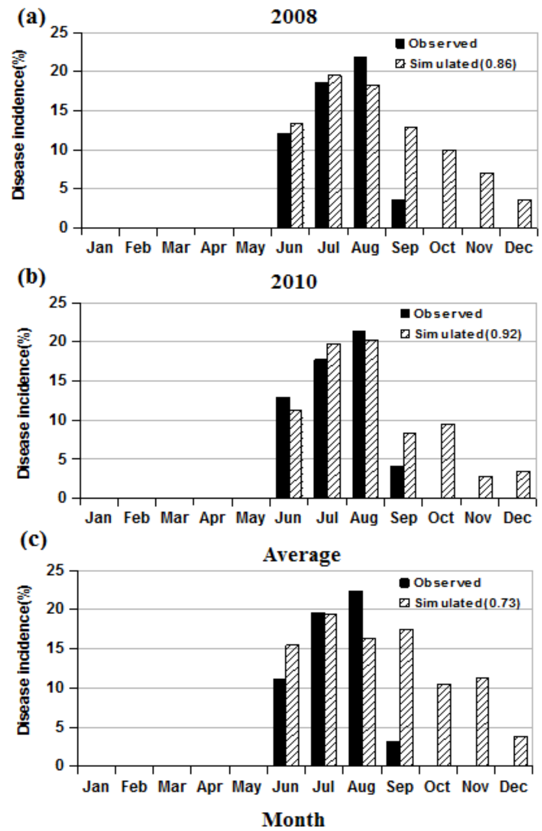

Figure 2.13 Observed and simulated values of disease occurrence with the forecast model for (a) 2008 (b) 2010 and (c) average.

ability to capture the abrupt but appreciable disease onset.

There is need for further calibration and validation of the model, especially at daily scale; the establishment of multi-level weather profiler at ICRI under The CSIR Climate Observation and Modelling Network (COMoN) provides an opportunity for such development. At the same time, the model is being extended to other weather driven crop diseases like castor botryties and alter maria leaf blight in sunflower.

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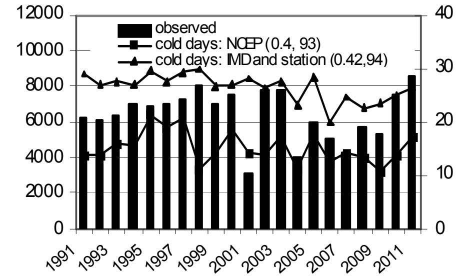
Current Science, 2014

2.14 Quantification of relative roles of drivers of acute respiratory diseases

Several thousands of people, including children, suffer from acute respiratory disease (ARD) every year worldwide. Pro-active planning and mitigation for these diseases require identification of the major drivers in a location-specific manner. While the importance of air pollutants in ARD has been extensively studied and emphasized, the role of weather variables has been less explored. With Delhi with its large population and pollution as a test case, we have examined the relative roles of air pollution and weather (cold days) in ARD.

Data from both National Centers for Environmental Prediction (NCEP) and The CSIR Climate Observation and Modelling Network (COMoN) and Indian Meteorological Department (IMD) were used to identify days with temperature below a thresholds (Cold Days). Pollution (Respiratory Particulate Matter) concentrations were adopted from the public-domain data from the Central Pollutions Control Board (CPCB, India). The ARD deaths were considered both in terms of actual numbers and as % of (annual) pollution. The data for the period 1991-2011 showed complex inter annual variabilty in the number of cold days as well as the number of ARD deaths.

It was found that both the number of cold days and air pollution play important roles in ARD load; however, the number of cold days emerges as the major driver. These conclusions are consistent with analyses for several other states in India. The robust



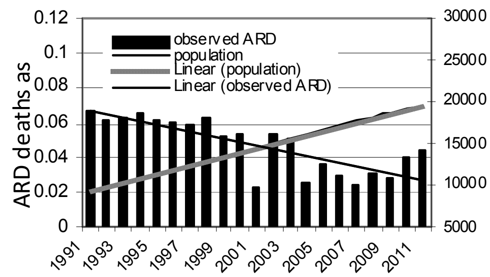


Figure 2.14 Number of ARD deaths reported during 1991-2011 with (a) percentage of cold days (20^0C) and (b) ARD deaths as percentage of population and annual population. The corresponding observed ARD deaths have been adopted from Government of NCT of Delhi. The first number in bracket in the top panel represents the correlation coefficients between number of deaths from observations and percentage of cold days, with the significance level (second number).

association between ARD load and cold days provides basis for estimating and predicting ARD load through dynamical model, as well as impact of climate change. In particular, high-resolution forecasts from atmospheric meso-scale models can be used to generate and issue advisories for vulnerable locations. Such measures can reduce disease incidences leading to improvement in healthcare and quality of living.

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Nature Scientific Reports 2014

2.15 Integrated disaster assessment and modelling over the Himalayan region

An important but missing aspect of vulnerability analysis is a multi-scale approach. While events like earthquakes have large disaster potential, they are relatively rare, with long return periods. On the oth-erhand, episodes of extreme rainfall events are quite frequent, with considerable demage potential.

Further, extreme rainfall can also act as triggers for landslide events. Finally, vulnerability critically depends upon the socio-economics of the region.

The changing climate combined with socio-economic transformations introduces new vulnerability in many regions. Of particular importance is the Himalayan region characterized by high seismicity, as well as extreme rainfall events; growing socio-economic activities in this region in the recent years have made it vulnerable to a wide spectrum of natural events. However, a comprehensive and integrated assessment of vulnerability of this region in the changing socio-climatic conditions is missing, as most analyses tend to focus on one or the other event (scale).

An important but missing aspect of vulnerability analysis is a multi-scale approach. While events like earthquakes have large disaster potential, they are relatively rare, with long return periods. On the other hand, episodes of extreme rainfall events are quite frequent, with considerable damage potential.

Further, extreme rainfall can also act as triggers for landslide events. Finally, vulnerability critically depends upon the socio-economics of the region.

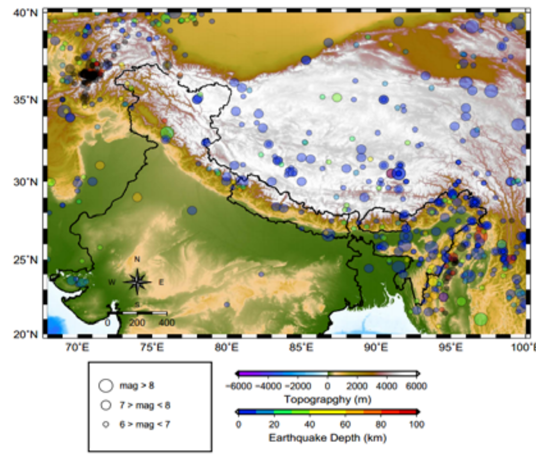

Figure 2.15 Digital elevation map of the Himlalaya-Tibetan region representing location of epicenter of historical earthquakes (circles) with magnitude greater than 6.0 up to December 2011. Colour scale and diameter of the circles indicates depth and magnitudes respectively. Background: Shuttle Radar Topography Mission (SRTM) elevation map.

An integrated analysis of vulnerability of this region, in the form of a quantified vulnerability index, to geological as well as a class of meteorological events was developed. The vulnerability index was then superposed on socio-economic backdrop. It was found that the combined analysis brings out aspects not revealed by any isolated analysis.

The present work is a part of the inter-disciplinary (inter-Group) effort to develop an integrated Disaster Assessment and Modelling (IDAM) for pro-active disaster management through assessment, forecasting and projections. IDAM is being developed as a multi-application utility to strategic as well as social sections.

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B Kantha Rao, Ashish

2.16 Simulation of a heavy rainfall event: Case study over Bengaluru

This study is about the meso-scale simulation, diagnostics and analysis of heavy rainfall event that occurred on 8th of October 2013 over Bengaluru, the capital city of Karnataka in India. The city normally receives good amount of rain during Northeast monsoon in addition to regular Southwest monsoon. One of the rain gauges out of 19 located in the city, recorded the highest total (24-hour accumulated) rainfall of 123 mm on the event day. The simulated results are based on high resolution (2-km) and time -ensemble simulations (3 initial conditions) using the 3-nested Weather Research and Forecast (WRFV3) model (Figure 2.16). Simulated rainfall was compared with Tropical Rainfall Measuring Mission (TRMM) and rain gauge data (Figure 2.17) and found be in be in good agreement with observation. The model was able to reproduce the entire lifecycle of the event with closely matching observation in terms of; time of initiation, time evolution (Figure 2.18), highest intensity, spatial distribution and location.

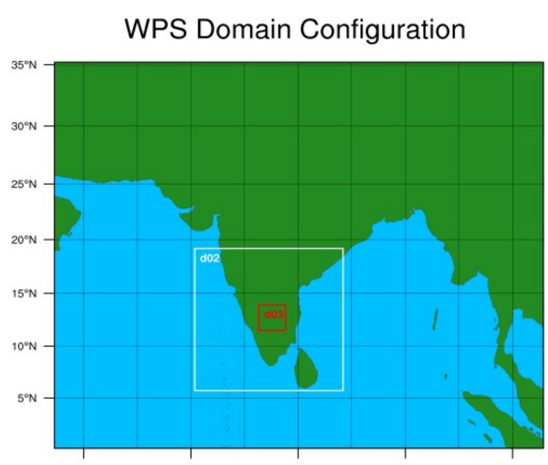

Figure 2.16 WRF Model Simulation Domain

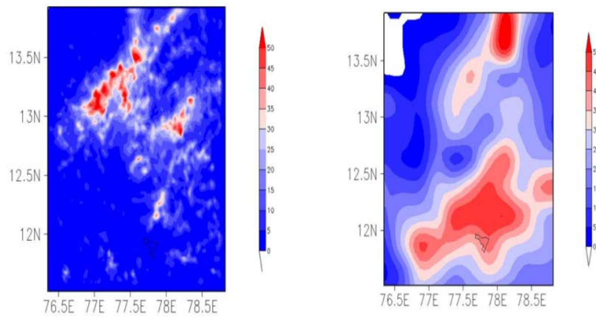

Figure 2.19 Spatial distribution of simulated rain (left) compared with TRMM data. Despite the discernable differences between the TRMM and model results, model captured the high intensity convective cells and overall pattern reasonably well.

The performance of the model in simulating this event was assessed in terms percentage error for intensity and location. The intensity error in terms of 24-hour accumulated maximum rain was found to be 19.3 %

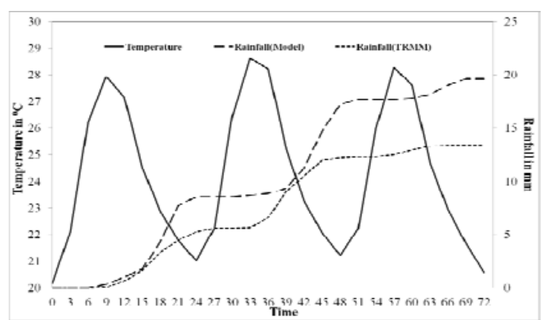

Figure 2.18 Time evolution of domain averaged (inner domain D3) simulated rainfall and surface temperature. It may be seen that the model successfully simulated the diurnal pattern of surface temperature. Time evolution of the simulated rain is seen to be in close agreement with TRMM data.

and 8 % with respect to TRMM (0.25°) and rain gauge (averaged over 6 rain gauges) observation respectively. The location error was found to be about 40 km (0.48°E, 0.15°N) and 10km (0.08°E, 0.05 °N) w.r.t TRMM and rain gauge respectively.

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2.17 Model configuration for fog forecasting

A popular strategy for forecasting fog is to drive a fog process model with meteorological forecasts from an atmospheric model. The best candidate for an atmospheric model to drive a fog forecasts at high spatial distribution is an atmospheric meso-scale model Several studies have employed this strategy for development and evaluation of fog fore-casts models. A critical question in adopting and calibrating such an atmospheric model is its ability to simulate the contrasts in the meteorological vari-ables for foggy and non-foggy days. It is expected that the meteorological fields will have different characteristics for foggy and non-foggy days. How-ever, due to the prevailing background conditions and local processes, the differences are likely to be site-specific and season-specific. The magnitudes of contrasts in different fields at different levels for foggy and non-foggy days indicate the precision and accuracy required in simulation of the meteorologi-cal fields for forecasting fog; smaller contrast in a field means that a model requires more accurate prediction of this field. Our results that T and RH have 1 degree and 5 % contrasts, respectively near the ground, imply an accuracy of at least 1 degree and 5% to skillfully predict fog with a NWP model. The objective of the present study is to carry out such a validation of an atmospheric meso-scale model (MM5) over a fog-prone metropolis (Delhi). While we consider validation of the forecasts of the variables themselves in terms of standard measures, the focus is on simulating and validating the ob-served contrast in the meteorological fields for foggy and non-foggy days. The observational analy-sis showed the contrasts in the meteorological fields to be present also in the upper levels; accordingly, the simulated contrasts were also examined against the corresponding observed values; independent data sets were used wherever possible (Figure 2.19).

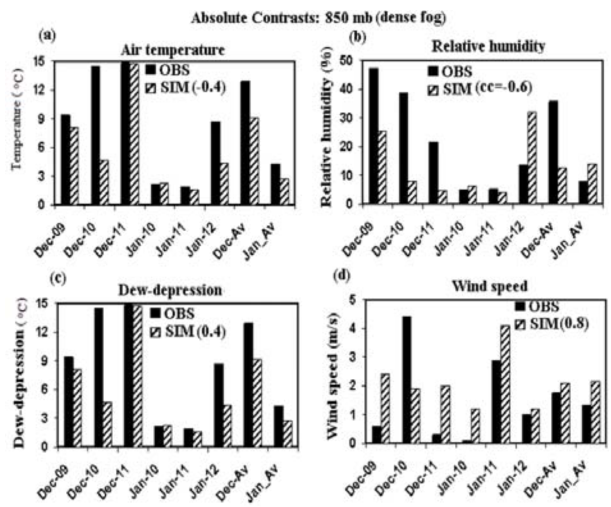

Figure 2.19 Monthly averages of observed (black bars) and simulated (shaded bars) absolute contrasts in (a) air temperature (°C), (b) relative humidity, (c) dew-depression and (d) wind speed between composites of non-foggy days and dense fog days at 850 mb. Observed mete-orological variable is adopted from radiosonde observa-tion at 00 UTC over Delhi Safdurjang airport for the months December and January through 2009-2012. Simu-lated variable is adopted from area averaged forecasts around Delhi from an atmospheric meso-scale model MM5 for the same period. The numbers in the bracket are the correlation coefficients between observed and simulated contrasts for each of the respective variable.

The contrasts for the different years also show ap-preciable differences; this inter annual variability is likely an indication (and possible measure) of varia-tions in the large-scale conditions from year to year, and their effect on fog occurrence over a location. Similarly, it is important to identify the critical val-ues and meteorological conditions for formations and dissipation of various types of fogs under differ-ent large-scale conditions.

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