MEETING REPORT

Weather and climate informatics for proactive healthcare*

A large fraction of the world's population, especially people in the lower economic strata and away from proper healthcare facilities, suffer from disease-related cost, anxiety, loss of working hours and vulnerability. However, response to many diseases like malaria is still mostly reactive, based on general schedule or post-outbreak decision. Although measures like insecticide-impregnated mosquito nets are being tried, the conventional reactive healthcare has certain drawbacks that cannot be conceptually removed at present. An obvious drawback of reactive healthcare is that the disease, and the associated treatment, imply stress, trauma and economic loss for the patient and the family. The lag between manifestation and recovery can imply enhanced susceptibility to other diseases through reduced immunity. On the other hand, proactive, preventive measures could significantly reduce disease burden and drug load. The basic premise for proactive healthcare is that susceptibility and likely onset of some diseases can be foreseen (predicted), and proactive measures can be taken for prevention. While in the case of many diseases such proactive prevention is still a distant dream, certain diseases may be more amenable to proactive control. In particular, diseases that depend directly or indirectly on weather variables may be proactively controlled based on prior knowledge of weather variables.

Weather can affect health directly (temperature and extreme weather-related illness and death) and indirectly, such as through air pollution-related disorders, water- and food-borne diseases, disease vector and others. Thus advance and accurate forecasts of the weather variables can be applied to proactively reduce disease threats, for example, through larval sanitation. For the case of malaria, the disease vectors can survive only at particular temperature ranges; the vector genesis locations thus vary, making a general prevention schedule less effective. The changes in the weather patterns due to climate change can then provide long-term scenarios of vulnerability and adaptation options. The challenge is to convert such weather forecasts to disease forecasts.

A workshop was recently held to identify available components, map expertise and strengths, and plan an integrated platform for proactive healthcare; the sessions were thus focused on discussions around selected topics. Scientists from CSIR C-MMACS (CSIR-4PI), Bengaluru; the University of Liverpool, England; several R&D organizations and State Departments participated in the workshop.

Emphasizing the growing role of modelling and data-intensive research aided by high-performance computing, Shyam Shetty (CSIR-4PI) in his inaugural speech noted that new applications like proactive healthcare put additional conceptual and resource demands on accuracy, precision as well as the scope of validation of the forecasts. Noting that such novel methodology cannot be developed without effective synergy, Andy P. Morse (University of Liverpool, UK) in his introduction to INDRASS, emphasized the successful two-way knowledge sharing between C-MMACS and the University of Liverpool to undertake challenging problems. An important result from the collaboration presented by Morse was skill in seasonal forecasting of malaria load over India; these results showed that proactive policy planning for managing malaria was possible with technology and skill now available.

P. Goswami (CSIR C-MMACS, Bengaluru) in his overview of the workshop, stressed upon the growing observation, modelling and forecasting capabilities in the country to address the difficult but important goal of proactive healthcare. He highlighted some of the advances in mathematical modelling of malaria and acute respiratory disorder validated over India that make forecast-based proactive control conceptually possible. Goswami highlighted several other works worldwide, including at C-MMACS, that have shown the appreciable roles of weather and climate in disease dynamics.

Several participants stressed upon important aspects related to modelling of diseases. With specific reference to flaviviruses that are a common cause of arboviral disease globally and that include dengue virus (DENV) and Japanese encephalitis virus (JEV), Lance Turtle (University of Liverpool, UK) drew attention to the fact that although in a simplistic modelling scenario the hosts are either immune or susceptible, more sophisticated and detailed modelling is necessary because in reality the situation is generally more complex, with the actual order of viral infection playing a role in determining clinical phenotype. Turtle pointed out that while this was well known for DENV (which is really four different viruses), it might be true for JEV as well. Taking such immune interference effects into account, though challenging, could improve the accuracy of disease models.

Healthcare necessarily involves socio-economic issues, and a comprehensive and applicable platform for pro-active healthcare must include such factors. U. S. N. Murty (CSIR-Indian Institute of Chemical Technology, Hyderabad) highlighted the importance of socio-economic inequalities in risk factors for vector borne diseases with examples from a case study on filariasis. He also pointed out that although the importance of social factors in the etiology of diseases is becoming increasingly clear, there is need for model-based and data-based studies in several areas.

It was clear from the presentations and the discussions that several steps and actions have been initiated in the country for disease prevention. For example, reduction of mosquito larvae can automatically reduce the population of the adult (biting) mosquitoes. S. K. Ghosh (National Institute of Malaria Research (NIMR), Bengaluru) outlined the methodology of larval source management in mitigating

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climate challenge in vector control. He emphasized, however, that proactive vector control methods would add an extra dimension in healthcare and, in particular, in reducing residual transmission due to random sources that are not covered by fixed-site control. Balakrishnan (National Centre for Disease Control (ICMR), Bengaluru) shared information on the Integrated Disease Surveillance Project (IDSP) launched in November 2004. Highlighting IDSP's primary objective, he outlined the major components as integration and decentralization of surveillance, capability building and use of information technology. He pointed out that many diseases, like tick-borne diseases, are indirectly affected by weather (such as through flooding); forecast-based disease control would add tremendous value to early detection, control and response.

A major challenge in proactive healthcare is the changes in the weather patterns due to a changing climate; these changes imply altered vulnerability to vector-borne diseases. R. C. Dhiman (ICMR, New Delhi) highlighted the potential effects of climate variability and climate change on vector-borne diseases in India. He noted that while rainfall was used for early warning of malaria way back in 1923, the recent advances offered new and exciting possibilities. In view of changing climatic conditions, urbanization and lifestyle, diseases like dengue are emerging threats; development of tools for early warning of malaria and dengue is the need of hour to negate the adverse impact of climate change. For example, seasonal forecasts of expected mosquito (malarial load) can significantly aid proactive planning and optimize application of pesticides like DDT.

It was noted, however, that dynamical forecasting and climate simulations have seen tremendous progress in the last few decades. K. V. Ramesh (CSIR C-MMACS) outlined some preliminary results on future projections of malaria vulnerability in India based on projections from IPCC CMIP5 simulations over India. He also showed the dependence of the projections on the choice of the climate projections, and highlighted the challenge involved in assessing reliability of such projections. A. P. Morse presented several results to demonstrate that the forecasting technology has made enough progress to start outreach with decision makers and health planners to move towards operational use of such forecasts. He outlined the structure of the Liverpool Malaria Model (LMM) and how it is driven by climate model datasets and showed that high levels of skill of the magnitude of the seasonal malaria outbreaks could be achieved for lead times of 3 months for northeast and northwest India. Morse also highlighted several avenues of improvement, such as inclusion of non-climate factors to drive the malaria model. K. C. Gouda (CSIR C-MMACS) demonstrated the usefulness of seasonal forecasting of malaria and other disease loads and outlined feasibility of such seasonal forecasting with application of the C-MMACS global circulation model in predicting malaria parameters like incidence, prevalence, number of mosquito, etc. a season in advance over India. V. Rakesh (CSIR C-MMACS) emphasized the need for region-specific approach and incorporation of location-specific features like drainage, and the useful role customized weather information like sunshine hours, solar radiation and soil moisture can play in disease control. He also outlined some of the results on high-resolution weather forecasting from the C-MMACS platform generated in operational setting over Karnataka.

Weather has direct effects on health, and the analysis by G. N. Mohapatra (CSIR C-MMACS) showed the weather conditions associated with heat waves in Odisha. His analysis brought out certain regions and periods of vulnerability to heat waves in India, and identified certain variables. The presentation by Juri Baruah showed that acute respiratory disorders (ARD) in Delhi are primarily associated with cold days, and hence may be predictable. These analyses also emphasized the need for both carefully designed observations and high-resolution forecasts for proactive measures. The meeting noted that the network of multi-level meteorological profilers, established by CSIR through its Climate Observation and Modelling Network (COMoN), can be a critical component for such proactive healthcare programmes.

Careful analyses are also needed to identify the drivers of diseases. There are puzzling cases of malaria even in the absence of favourable conditions in terms of the known meteorological variables. The results outlined by Kantha Rao showed that soil moisture can play an important role in malaria dynamics, especially over regions where rainfall is low. Facilities like COMoN can provide critical inputs for such studies.

Following the presentations and topic-specific discussions, the panel discussion was aimed at a synthesis and identification of definite actions points and a roadmap. The panel noted that while early attempts at disease prediction were subsequently discontinued, advent of new technologies and expertise makes a fresh attempt at proactive healthcare platform (PHP) desirable and feasible. In particular, a weather-based proactive healthcare programme can be developed to address multiple issues like: (a) Disease prevention (control before occurrence); (b) Targeted, precision application/measures; (c) Sufficient lead time for planning and operation; (d) Single platform for a spectrum of diseases (malaria, dengue, JE, heat stroke, ARD); (e) Reduced drug load and insecticide load; (f) Reduced anxiety, reduction in loss of schooling hours for treatment; (g) Climate resilience: long-term outlook for planning, adaptation and preparedness.

The panel noted that effective proactive healthcare should include and integrate:

- Identification of weather (climate) drivers for diseases from observations.
- Customized and validated weather/climate–disease interface models.
- Identification of optimum set of variables (weather, disease, environmental).
- Forecast configuration for disease/vector prediction at seasonal-to-daily scales.
- Reliable climate projections for vulnerability and risk analysis.
- Identification and modelling of socio-economic drivers of diseases.
- Modelling and inclusion of immunity, migration and transmission.
- Effective outreach mechanism: Information and Communication Technology solutions with GIS and dissemination network.

The panel also noted that the proposed PHP could lead to several important and measurable outputs like:

- Reduction in the number of malaria (blood sample-positive) cases.
- Reduction in the number of hospital admissions.

- Reduction in the amount of insecticides applied.

It was noted that such a platform for proactive healthcare is implementable with current technology, with the important components tested and calibrated for a given region. The country now has the required expertise, as evidenced by high-impact publications as well as its successful operational outreach programmes. The panel recommended that a national programme on proactive healthcare based on weather and climate informatics should be initiated through a multi-agency research synergy and effective outreach. As the various components improve through sustained and active R&D, the effectiveness of such a programme can gradually grow.

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MEETING REPORT

Atmosphere–ocean interactions in the Indo-Pacific basin and their impact on Asian climate*

The regular and extreme weather and climate events in the Indo-Pacific basin, namely the southwest and northeast monsoons, the El-Niño Southern Oscillation (ENSO), and the cyclones/typhoons, often evolve together and profoundly influence Asian as well as global climate. There are many aspects of these events that are still neither well understood over seasonal time scales nor over the longer period of global climate change. In practical terms, they are often not well forecast.

The workshop covering these aspects of Asian climate, meteorology and oceanography brought together scientists from India, Japan, Malaysia, Sri Lanka, Vietnam, UK and USA. New results were presented based on the extensive data that are now available over the Indian Ocean. Improved computational models developed at the large international research and forecasting centres explain the systematic features of the seasonal and multi-year climatic oscillations; notably the South and East Asian monsoons, and the influences of ENSO extending from the Pacific to the eastern side of the Indian Ocean. However other perturbations, such as the Equatorial Indian Ocean Oscillation (EQUINOO), also need to be analysed in order to explain the variations of the monsoon rains over South Asia. Trends in sea surface temperature also affect seasons in South East Asia.

The technical sessions consisted of 19 invited talks, poster session and a panel discussion. In the first session on Indian Ocean Dipole (IOD), ENSO and EQUINOO, Sulochana Gadgil (India) said that EQUINOO and ENSO together explain all major Indian drought years. She suggested that understanding the physics of EQUINOO and improving its prediction be one of the foci of research of the Asian Network on Climate Science and Technology (ANCST) as it has important implications for prediction of the interannual variation of the Asian monsoon. Kentaro Ando (Japan) reviewed recent and planned international observational programmes in the Indian Ocean and on-going studies of IOD and air–sea interaction in the Eastern Indian Ocean. The data in the eastern and southern Indian Ocean are comprehensive, but there are gaps in the northwestern Indian Ocean owing to activities of pirates. N. Saji (Japan) discussed the observed and modelled teleconnections along the Equatorial Waveguide during IOD–ENSO interactions, focusing on the 2006 El-Niño event which models failed to predict. He suggested that IOD dynamics plays a significant role in the evolution of these events. Lareef Zubair (Sri Lanka/USA) showed how ENSO, IOD, EQUINOO and Madden-Julian Oscillation (MJO) influence the climate of islands in equatorial Indian Ocean. Kunio Yoneyama (Japan) presented new results from a recent field campaign on MJO in Indian Ocean named CINDY/DYNAMO. The inter tropical convergence zone (ITCZ) in the southern hemisphere may initiate convection during MJO. C. Gnanaseelan (India) discussed a tropical Indian Ocean (TIO) mode of subsurface temperature variability in observations and climate models. Coupled air–sea models qualitatively represent this mode of variability and their seasonal evolution, but not their duration.

Jun Matsumoto (Japan) in introducing the theme of extreme weather and climate, described the influence of ENSO and MJO on heavy rainfalls in Central Vietnam. Heavy rainfalls in Central Vietnam are observed more frequently when MJO activity is pronounced in the equatorial eastern Maritime Continent, and in La Niña years. M. Rajeevan (India) noted that extreme precipitation events over India show an increasing trend in recent years but there is a multi-decadal variation that needs to be accounted for. The frequency and extent of severe heat waves have increased over India. Recent modelling initiatives suggest a possibility of useful forewarnings of severe weather events with adequate lead time. S. Kumarenthiran (Malaysia) said that cold air surges from the Siberian high pressure system cause abundant rainfall over the northeastern states of Peninsula Malaysia and the western part of Sarawak. Therefore understanding and advance prediction of cold surges are vital in providing early warnings for disaster preparedness. Dato Samah (Malaysia) noted that changes in the Antarctic can have large influence on ocean circulation system and global climate as Southern Ocean connects all the global oceans.

*A report on the International Workshop held at Divecha Centre for Climate Change, Indian Institute of Science, Bengaluru, India, during 23–24 November 2014 and organized by Divecha Centre for Climate Change (www.dccc.iisc.ernet.in), and the Asian Network on Climate Science and Technology (www.ancst.org), (based in Malaysia).