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CONFERENCE REPORT

Simulation modeling and climate change: issues and challenges

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The importance of climate has increased with the realization that climate change is not restricted to the Holocene or Pleistocene era but is a reality in a time scale that has affected present human civilization. Particularly extreme climatic events emphasize the importance of climate to society and demonstrate associated vulnerabilities. Anthropogenic impacts on the Earth system are mostly studied by computing key climatic processes through mathematical models. During recent decades, climate models, crop simulation models, hydrology models, and other sectorial models have been developed and used extensively to study the climate change and its impacts band being used to make appropriate management decisions by professionals, stakeholders, and policy makers/administrator/decision makers. It is expected that with the increased use of computers, improved skill, and good data sets, the use of simulation models by professionals as well as policy and decision makers will increase during the coming decades.

However, forecasting future climate associates considerable uncertainties. With uncertainties in the basic science of climate and in its predictions, the understanding of possible future climatic impacts also becomes ambiguous. Such an ambiguity initiates the necessity of using simulation models, which are used to investigate the response of a climate system subjected to specific stresses. In order to assess the current status of dynamic simulation modeling in India, a national workshop on "Simulation Modeling and Climate Change: Issues and Challenges" was organized by Dr. RK Mall, Institute of Environment and Sustainable Development (IESD), Banaras Hindu University (BHU) in collaboration with Department of Science and Technology (DST), Government of India on April 21, 2014 (Fig. 1). The workshop was aimed at understanding the present status of dynamic simulation modeling, problems that are being faced by different professionals as well as policy and decision makers due to uncertainties in climate projection, lack of capacity and capability of different stakeholders in studying impact assessment. The entire proceedings of the workshop were divided in four sessions including climate change scenarios: *climate modeling*; *impact assessment—water resource modeling*; *impact assessment—agriculture, health and other sectors*; *and conclusively panel discussions.* Eminent scientists and climate researchers from different distinguished institutional bodies attended the workshop and shared their perspective views, most notably from the Ministry of Earth Science (MoES), Govt. of India; DST, Govt. of India; Indian Institute of Technology (IIT), New Delhi; Indian Institute of Technology (IIT), Bhubaneswar; Indian Institute of Technology (IIT), Roorkee; Indian Institute of Remote Sensing (IIRS), Dehradun; India Meteorological Department (IMD), New Delhi; National Institute of Hydrology (NIH), Roorkee; Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad; National Centre for Medium Range Weather Forecasting (NCMRWF), Noida; Jawaharlal Nehru University (JNU), Delhi; Physical Research Laboratory (PRL), Ahmedabad; Institute of Environment and Sustainable Development (IESD), Banaras Hindu University; and other central and state universities/laboratories/institutions.

The first session of the workshop was chaired by *Prof. UC Mohanty* from IIT, Bhubaneswar, a renowned climate scientist

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Fig. 1 The first session of the national workshop on *Simulation Modeling and Climate Change*: *Issues and Challenges*, April 21, 2014

who stressed upon climate adaptation strategies as observed impacts of climate change are widespread and consequential. He emphasized that a fraction of total inhabitants of climate-sensitive area should be trained accordingly so that the adaptation knowledge may be dissipated down to the larger community. *Prof. SK Dash* from IIT, Delhi, highlighted the uncertainties and challenges associated with climate models with special emphasis to Indian context. He connected the climate-regulated social issues by emphasizing repercussions of land use change of a particular area to a regional temperature profile. Additionally, Prof. Dash stressed on the prediction of climate extremes from the climate models so that the model helps to develop appropriate preparedness policies. In continuation, *Dr. Jagbir Singh*, a scientist from NCMRWF, also stressed on better representation of cloud dynamics in climate model so that extreme climate events may be modeled better with a higher level of accuracy. He also focused on climate change adaptation and preparedness so that climate change adaptation may be transmitted from a phase of social awareness to the construction of actual strategies and plans in societies. His specific emphasis was on gaps in climate data and, therefore, stressed on developing efficient manpower in the local level which was consequently well supported by *Dr. S C Bhan*, Director of IMD. According Dr. Bhan, cities in developing countries are burdened with excessive population growth, escalating adaptation needs, and substantial development deficits created by a shortage of financial and human resources and other associated factors, and therefore, human resource development is the best strategy to cope up with climate change. He emphasized on developing and adapting to certain practices viz. agricultural and socioeconomical practices at grass-root level taking into account climate model uncertainties so that both climate change adaptation and mitigation may be integrated for sustainable development. Dr. Sunil Singh of PRL, Ahmedabad, mentioned that the credibility of a climate simulation model is lacking in India mainly because most of the simulation models were developed and validated in temperate countries. Therefore, in order to accurately simulate mean state and seasonal cycles of tropical climate, climate scientists in India should put emphasis on developing indigenous simulation model considering explicitly regional impacts of tropospheric aerosol, improved physical process descriptions, black carbon-climate chemistry, location-specific environmental factors, and land use planning. Conclusively, the first session ends with specific recommendations like the following:

1. Accurate prediction of climate extremes from the climate models so that it helps to develop appropriate preparedness policies
2. Human resource development to perform ground-level data collections and modeling at a regional scale
3. Identification of climate data gap for climate modeling
4. Conducting long-term field experiments to understand fundamental climate processes

Climate change is projected to be a powerful stressor on Earth's water resources which motivated the *second session of the workshop* to specifically focus on "Impact Assessment: Water Resource Modeling." The session was chaired by *Prof. S.K. Tripathi*, IIT, Roorkee, who emphasized the need for incorporation of climate impact assessment of water resource and its subsequent management for subsurface and surface water models. The lead talk of *Dr. RD Singh*, Director of NIH, Roorkee, was focused on the objectives of National Water Mission (MoWR 2011) in the background of the National Action Plan on Climate Change (NAPCC 2008). Dr. Singh emphasized the fact that the impact of changing land use pattern is more drastic over the hydrological cycle as compared to climate change, and therefore, inclusion of changing land use pattern in ensemble modeling will provide better model performance. Such model outputs will also be more effective for climate impact adaptation studies. Dr. Singh recommended downscaling the outputs of basins and subbasins of the country through ensemble modeling to achieve more reliable forecasting of climate change impact on water resources. In an identical opinion, *Dr. N J Raju*, JNU, Delhi, concluded that land use changes are dominating factors, which are pushing the water resources to the brink of existence. Thus, there is an urgent need of scientifically sound integration of climate, land use, and water models so that proper forecasting of climatic impacts on water resources may be achieved with minimum uncertainties. Adding on to the above discussion, Dr. RK Mall, IESD-BHU, has reported that a study has been initiated by the Ministry of Water Resources, Government of India, to study the impact of climate change on the water resources in Ganga River basin in India, for which several institutions of India have been participating and are going to use hydrology models, Geographic Information System (GIS), and ground and satellite data. *Dr. P K*

Champati Ray, Head and Sc'SG" of IIRS, Dehradun, emphasized on developing location-specific indigenous models capable of simulating country-specific climatic pattern and its associated impacts. Such an endeavor, to his opinion, calls for the real-time field database generation and collaborative execution of research projects. Additionally, he stressed on the inclusion of natural phenomenon viz. landslides, mass wasting, mountain tectonics, and climate dynamics in the simulation models especially in the context of the Himalayan regions. This was further substantiated by Dr. Raju in terms of inclusion of snowfall pattern and small springs into such models. Conclusively, Dr. Singh emphasized on the need of appropriate legislative body which may be held responsible for creating mass awareness and management of climate-induced water scarcity of the country. The broad thrust areas that came out from the discussion of the session II are as follows:

1. Simulation of climate change impact may be approached better by ensemble modeling compared to a single model.
2. Land use changes are the major driving agent for the water resources compared to climatic threats.
3. Downscaling model outputs to basin or subbasin level is still to be worked out.
4. Location-specific indigenous model for simulating country-specific climatic impact is essential.
5. Policy-level stability through establishing independent regulative bodies

The *third session* on "Impact Assessment: Agriculture, Health and other Sectors" was chaired by *Prof. RP Singh*, Director of IAS-BHU. Prof. Singh especially focused on the specific model requirements for improved predictions of rainfall so that farmers may well develop strategies for enhanced water use efficiency. *Dr. VUM Rao*, CRIDA, Hyderabad, substantiated Prof. RP Singh's opinion and suggested that the climate modelers must opt for rigorous multi-model ensemble techniques and crop-specific information to assess future crop productivity. Additionally, high-resolution low-uncertainty projections on a daily time scale would lead to higher compatibility with crop models. Conclusively, development of integrated system simulation model framed to serve the purpose of crop water economy and generation of real-time block-level weather data was also emphasized. Supporting Dr. Rao's views, Prof. RP Singh also highlighted the greater need of reliable model projections than that of tolerant crop variety development so that farmers may well be informed for appropriate practices. Additionally, *Prof. D R Reddy*, Director of Extension, Acharya NG Ranga Agricultural University, Hyderabad, emphasized on specific management of the different varieties of crop under different climatic conditions. Application of remote sensing and GIS techniques were also felt essential for the development of gridded data to validate the model projections. Overall, this session explored the scope simulation models as powerful tools when adopted with an interdisciplinary approach to backup the decision making of the farmers as well as that of the policy makers. The specific recommendations of the sessions were as follows:

1. The biophysical and socioeconomic determinant of the crop productivity should be included in the simulation model.
2. Projection on extreme weather events at finer resolutions
3. Integrated system simulation model with special emphasis on crop water economy
4. Use of gridded data for validation
5. Location-specific data downscaling based on time and space

The *concluding session* was specifically aimed for panel discussions to identify gaps and priority areas to derive possible future strategies. *Prof. UC Mohanty* emphasized on the need for appropriate adaptation strategies in the sectors like health, agriculture, water, and ecosystem, keeping in mind risk assessment at the marginal and deeper levels of the society. To supplement the adaptation strategies of such kind, he suggested that the simulation models must be observation oriented, capable of assisting research and development on the use of climate change projection. Dr. RD Singh recommended that basin-scale water resource modeling should be processed through spatiotemporally downscaling, and downscaled output should be linked to decision support system. Additionally, an allocation scenario on the basis of climate change impact for every sector must also be developed. He finally pointed out the need of filling up the knowledge gaps between scientists and stakeholders and effective information transfer to the end-users. *Dr. Vyas Pandey*, Head of Anand Agricultural University, Gujrat, raised an urgency of downscaled Taluka-level daily weather forecast availability up to 30–45 days along with its integration to GIS/remote sensing. Dr. P K Champati Ray reinforced the scope of remote sensing in data processing, which was an addition to what Dr. Pandey had said. Greenhouse gas observation network formulation was another thought-provoking opinion from Dr. VUM Rao. In addition to this, *Prof. AS Raghubanshi*, Director of IESD-BHU, emphasized on the development of data repository and on the requirement of reliability and validity in meta-data.

While the workshop provided an opportunity for graduate students and young researchers to learn from experts from India in the field of simulation modeling and climate change, it also paved the way for the following recommendations:

1. Accurate prediction of climate extremes in the simulation models and projection at finer resolutions so that it helps to develop appropriate preparedness policies

2. Human resource development to perform ground-level data collections and modeling in a regional scale
3. Conducting long-term field experiments to understand fundamental climate processes
4. Land use changes are the major driving agent for the water resources compared to climatic threats.
5. Basin-scale water modeling should be processed through spatiotemporally downscaling.
6. Location-specific indigenous model for simulating country-specific climatic impact is essential.
7. Biophysical and socioeconomic determinant of the crop productivity should be included in the simulation model.
8. Data repository development and meta-data reliability assurance
9. Knowledge gaps should be filled, and information must be reached in intact form by the end-users in time.
10. Creation of a Department of Atmospheric and Ocean Sciences at IESD-BHU for specially addressing masters/doctoral students on climate change issues

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