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Combating Effect of Climate Change on Indian Agriculture through Smart Weather Forecasting and ICT Application

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Abstract: India, located in south central Asia, has great economic dependence on agriculture. A likely impact of climate change on agricultural productivity is causing great concern to the scientists and planners in the country. Weather forecasting at different spatial and temporal scales would be significant tool for adaption in agriculture under future climate change scenario. In the present paper, detailed elaboration has been made how the state-of-art technologies of weather forecasting including the climate projections can be taken as a tool to reduce the negative impacts of climate change and climatic variability. Also for combating the climate change issues, the adaptation requires effective and timely delivery and exchange of all supporting mechanism and meteorological information. Information and Communication Technologies (ICT) can also play a great role to disseminate the information. Efforts were also made to show the active role of on-going and proposed ICTs for adaptation in agriculture to climate change.

Keywords: Climate change; Variability; Weather forecasting; Information and Communication Technology.

Introduction

According to the IPCC Fourth Assessment report (2007), natural systems around the world are being affected by regional climate changes, particularly temperature increases and increase in temperature are very likely to be the result of anthropogenic emissions of greenhouse gases. In some weather events such as heat waves, storms and droughts that can have large impacts are likely to become more frequent and widespread in the future and in some cases, it may be more intense. In general, the impacts of climate change are expected to be broadly negative including reduced water availability, damage to crops and increased potential for diseases, especially those transmitted by insect vectors. Also in the IPCC report, it is concluded that intense tropical cyclone activity is likely to increase through the 21st century. Thus, it is reasonable to expect extreme events to occur more often in the future. Besides, there is extensive evidence that recent warming is strongly affecting terrestrial biological systems, including such changes as earlier timing of spring events (e.g. leaf unfolding, bird migration and egg laying; and shifts in ranges of plant and animal species).

India is more prone to numerous natural hazards, including cyclones, floods, droughts and landslides. Almost 85% of India's area is vulnerable to one or multiple hazard. Of the 28 states and seven union territories, 22 are disaster-prone. It is vulnerable to wind storms spawned in the Bay of Bengal and the Arabian

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Sea, earthquakes caused by active crustal movement in the Himalayan mountains, floods brought by monsoons, and droughts in the country's arid and semi-arid areas (Anonymous, 2013). Climate change may further aggravate these challenges.

In the recent decades, various extreme weather events occur in the country. The year 1998 was the warmest and declared as the weather-related disaster year. In India, Uttar Pradesh, Bihar, West Bengal, Orissa and Andhra Pradesh are the states that experienced summer heat waves. India experienced severe cold wave from December 2002 to January 2003. A huge crop loss was noticed in several states of the country due to floods in kharif, 2007. The years 2009 and 2012 proved drought years in the country. Also 2010 was one of the warmest year. Failure of September rains in Andhra Pradesh occurred in 2011. 43% rainfall deficiency was observed in the month of June in 2014. There is an urgent need to address climate change implications and to provide practical guidance for adaptation and mitigation at the local level and its dissemination to the different users. These measures will help minimize potential disaster losses due to climate variability and extreme weather events that have immediate implications.

In the present paper, elaborate discussion has been made on the projection of climate change in India and how the country is prepared to face the challenges by generation of improved forecasting at different scales as means of adaptation and also communication to the users, particularly in agriculture fronts.

Projections of Climate Change in India

Using a number of climate models, different scenarios have been generated for the future climate change in India. It has been projected that average surface temperature will increase by 2-4°C during 2050s, with marginal changes in monsoon rain in monsoon months (JJAS) and large changes of rainfall during non-monsoon months. The number of rainy days are set to decrease by more than 15 and the intensity of rains is likely to increase by 1-4 mm/day. Increase in frequency and intensity of cyclonic storms is projected. The hydrological cycle is predicted to become more intense, with higher annual average rainfall as well increased drought (Bhattacharya, 2006). Figure 1 shows rainfall projections at different seasons. According to Lal et al. (2001), an annual mean area-averaged surface warming

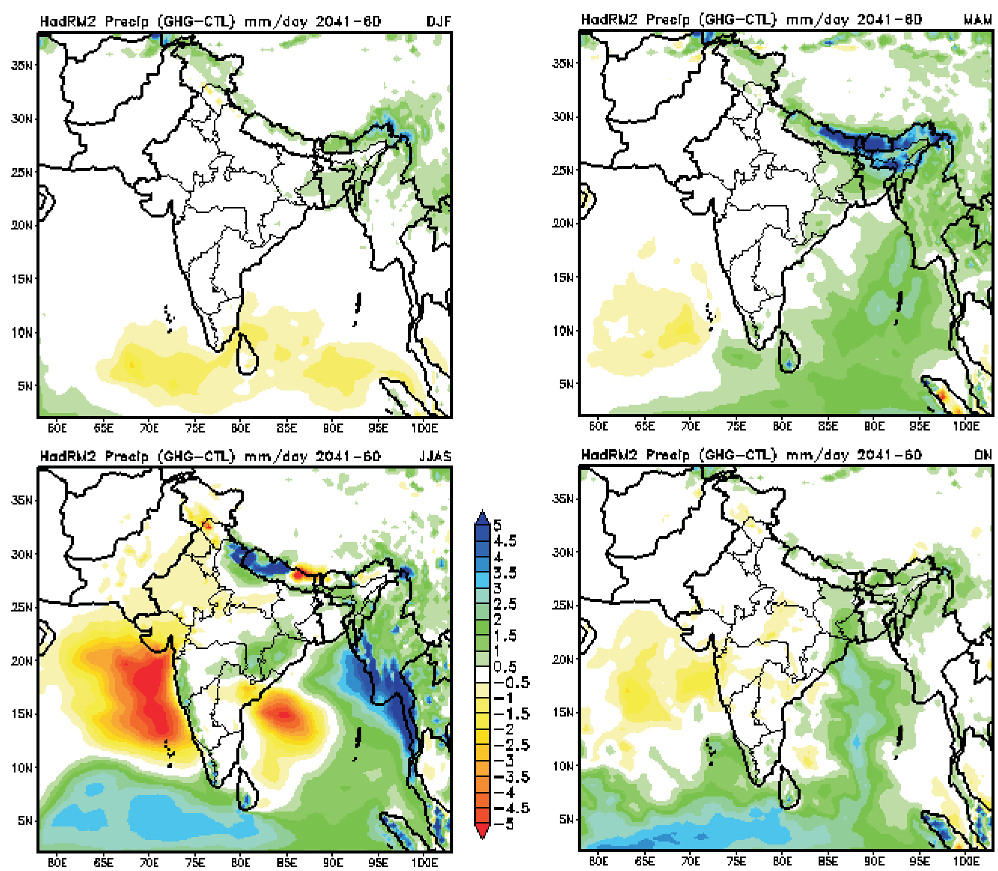


Figure 1: Rainfall projections at different seasons. (*Source:* Bhattacharya, 2006)

over the Indian subcontinent will range between 3.5 and 5.6°C over the region by 2080. These projections show more warming in winter season over summer monsoon. The spatial distribution of surface warming suggests a mean annual rise in surface temperatures in north India by 3°C or more by 2050. In case of rainfall, a marginal increase of 7 to 10 per cent in annual rainfall is projected over the subcontinent by the year 2080. However, the study suggests a fall in rainfall by 5 to 25% in winter while it would be 10 to 15% increase in summer monsoon rainfall over the country.

Although the effects of climate change from anthropogenic forcing on the use of water resources in the world remain difficult to project, anticipated climate change combined with other drivers of change is likely to intensify current agricultural water management challenges in India. Higher temperatures and more frequent drought are expected to reduce water availability, hydropower potential, and in general, crop productivity. The effects of population growth and increasing water demand, which are often but not always coupled, are likely to be a more significant source of water stress than climate change when considering changes to mean precipitation and runoff. Increasing temperatures in all regions are expected to increase evaporative demand, which would tend to increase the amount of water required to achieve a given level of plant production if crop phenology and management are to be held constant.

Weather Forecasting as a Tool Used for Adaptation in Agriculture in India

Under the changing climate, accurate weather forecasts not only helps the farmers protect themselves against natural factors but they can also benefit significantly as long as they are aware of the actions they can take to leverage of good weather patterns. It is no exaggeration to describe the advances made over the past half century as revolutionary. Operational forecasting today uses guidance from a wide range of models. The forecasts of monsoon in intra-seasonal (up to three weeks and monthly) and seasonal (JJAS; seasonal average) scales are very crucial for agriculture purpose. The agriculture sectors like farmers are very much benefited if accurate outlook of monsoon conditions are provided to them in the extended range. The forecast of active/break cycle of monsoon, commonly known as the Extended Range Forecasts (ERF) or forecast of monsoon up to around three weeks is of great importance for agricultural planning (sowing, harvesting, etc.), which can enable tactical adjustments to the strategic decisions that are made based on the longer-lead seasonal forecasts, and also will help in timely review of the ongoing monsoon conditions for providing outlooks to farmers. Forecasts of precipitation on this intermediate time-scale are critical for the optimization of planting and harvesting.

In order to prepare good forecast at different temporal and spatial scale, IMD is having different kinds of network of observatories in India to monitor and assess the weather which are Conventional Observational Network, Automatic Weather Stations (AWS), Buoy/ Ship Observations, Cyclone Detection Radars, Doppler Weather Radars and Satellites observations. Satellite and radar observations are very crucial for monitoring and assessment of hazards, especially Himalayan region and North Indian Ocean. Figure 2 shows weather observational network like Automatic Weather Stations (AWS) /Agro AWS, Storm Detection Radars, Doppler Weather Radars in the country.

Depending on the time-scale, forecast can be classified in to following four categories viz.

(a) Short range – Up to three days
(b) Medium range (about 4 to 7 days in tropics; although it is up to 10 days over mid latitude)
(c) Extended range or intra-seasonal (Beyond seven days up to a month)
(d) Long range or seasonal (one season)

Short Range Weather Forecast (SRF)

SRF is covering a period from immediate future to three days. Short Range Forecast is needed for general public, agricultural sector, aviation and navigation sectors, fisheries operations, construction business, transportation, defense services, mountaineering and tourism, energy sector etc. The elements include rainfall, temperature, thunderstorm, dust storm, clouds, cyclonic storms (their courses and stages), heavy rainfall warnings, frost warning, squall warning, heat waves, cold waves etc. Techniques used for SRF are: Synoptic methods, Statistical methods, and Numerical weather prediction. Synoptic Methods are being used in India and many other countries with fair degree of satisfaction for SRF despite its limitations.This method uses synoptic charts of various levels, climatology, and persistence and analogue factors as its tools. Discussion about the terminology of SRF used in IMD, such as isolated, few places, many places, most places etc. This includes nowcasting also which is a forecast issued for 0-12 hrs. duration.

In view of the recent improvement in monitoring and forecasting due to introduction of digital and image

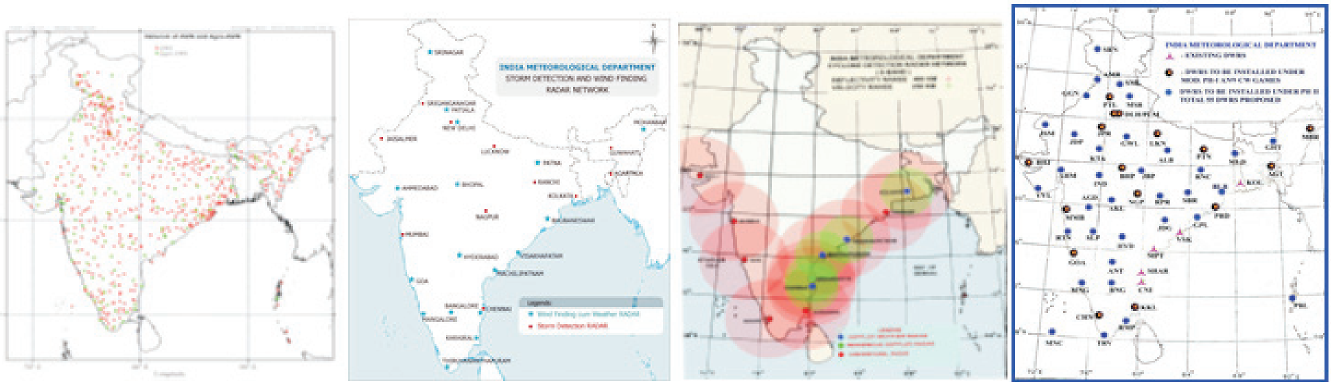


Figure 2: Weather observational network in India. (*Source:* IMD)

information at 10 minutes interval from a network of 14 doppler weather radars, a dense automatic weather station (AWS) network, half hourly satellite observations from Kalpana and INSAT-3D satellites, better analytical tools in synergy system at forecaster's workstation, availability of mesoscale models and computational and communication capabilities, IMD has implemented nowcasting of thunderstorms, squalls and hailstorms. Nowcasting in India has been benefited from major developments in observational meteorology and computer-based interactive data processing and display systems in IMD. The nowcast alerts are based on doppler radar data and are issued few hours before the event and thus would be very useful to alert the farming community about the occurrence of the adverse weather. Figure 3 shows the network of nowcast stations of IMD across India.

Medium Range Weather Forecast

India Meteorological Department (IMD) is issuing quantitative district level (646 districts) weather forecast up to five days and the products comprise quantitative forecasts for seven weather parameters viz., rainfall, maximum temperature, minimum temperature, wind speed, wind direction, relative humidity and cloudiness in the country. This weather forecast is generally valid for a period of five days and is prepared using the models like National Centers for Environmental Prediction (NCEP), the Japan Meteorological Agency (JMA), the European Centre for Medium-Range Weather Forecasts (ECMWF), National Centre for Medium Range Weather Forecasting (NCMRWF) and the UK Met Office (UKMO). Figure 4 shows the generation of district level weather forecast (DLWF).

Extended Range Weather Forecast

IMD in collaboration with IITM, Pune started to use the same in Agromet Advisory bulletins particularly in forecasting of long dry spells and heavy rain on fortnightly basis. Higher resolution models could be useful in the Extended Range Forecast (ERF) of extreme events and the formation of cyclonic systems. However,

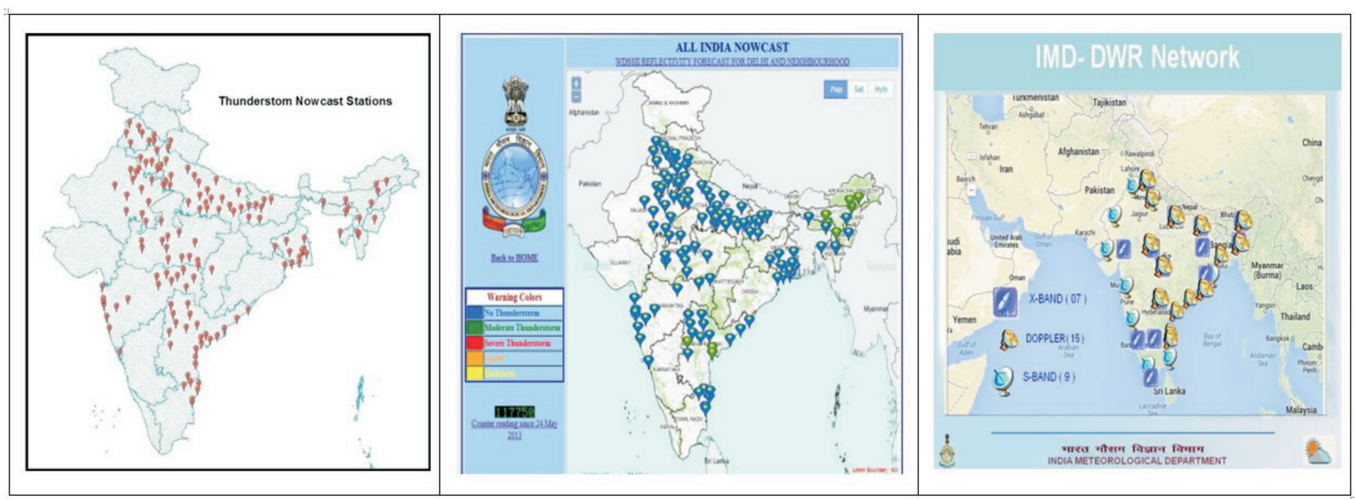
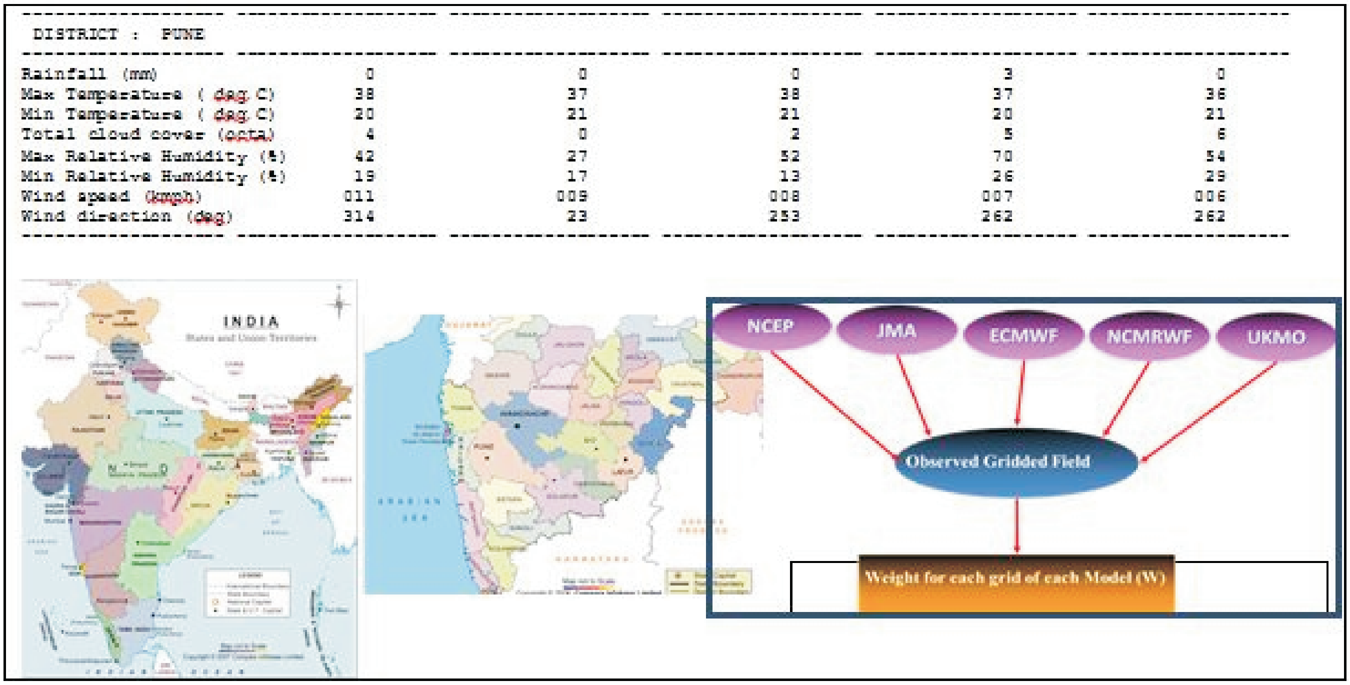


Figure 3: The network of nowcast stations in India. (*Source:* IMD)



DISTRICT : PUNE

Rainfall (mm)	0	0	0	3	0
Max Temperature (deg C)	38	37	38	37	36
Min Temperature (deg C)	20	21	21	20	21
Total cloud cover (octa)	4	0	2	5	6
Max Relative Humidity (%)	42	27	52	70	54
Min Relative Humidity (%)	19	17	13	26	29
Wind speed (kmph)	011	009	008	007	006
Wind direction (deg)	314	23	253	262	262

Figure 4: Generation of District Level Weather Forecast (DLWF). (*Source:* IMD)

they need to be improved in order to predict the tele-connection patterns realistically (Susmitha et al., 2014). Figure 5 shows the Extended Range Forecast issued by IITM for the period of 24 September to 8 October 2014.

Long Range Weather Forecast (LRF)

The forecast for the South-West monsoon rainfall is issued in April and June. Figure 6 shows the Operational Long Range Forecast issued for South West monsoon rainfall. From 2007, a new statistical forecasting system is used, which is based on the ensemble technique involving eight predictors. In the ensemble method, all possible models based on all the combination of predictors are considered. Thus, for April (June) forecast, with 5 (6) predictors, 31 (63) different models were developed. Out of all the possible models, ensemble mean of the best few models were selected based on their skill in predicting monsoon rainfall

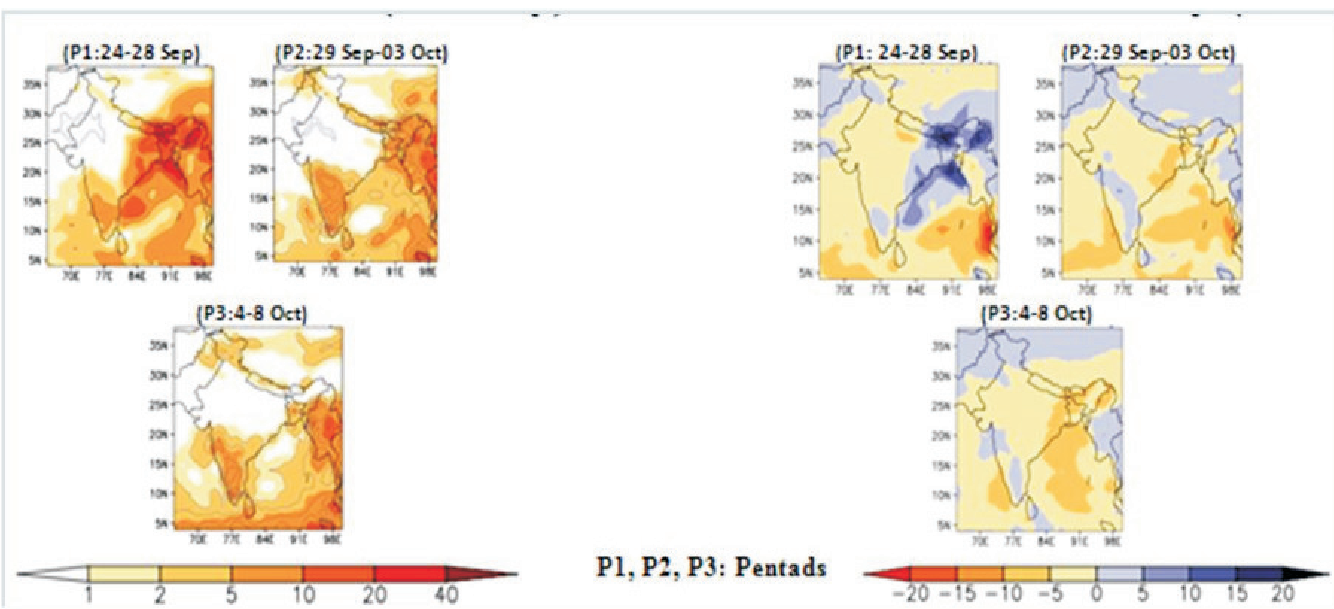


Figure 5: The extended range forecast issued by IITM for the period of 24 September to 8 October 2014 (rainfall in mm). (*Source:* IITM)

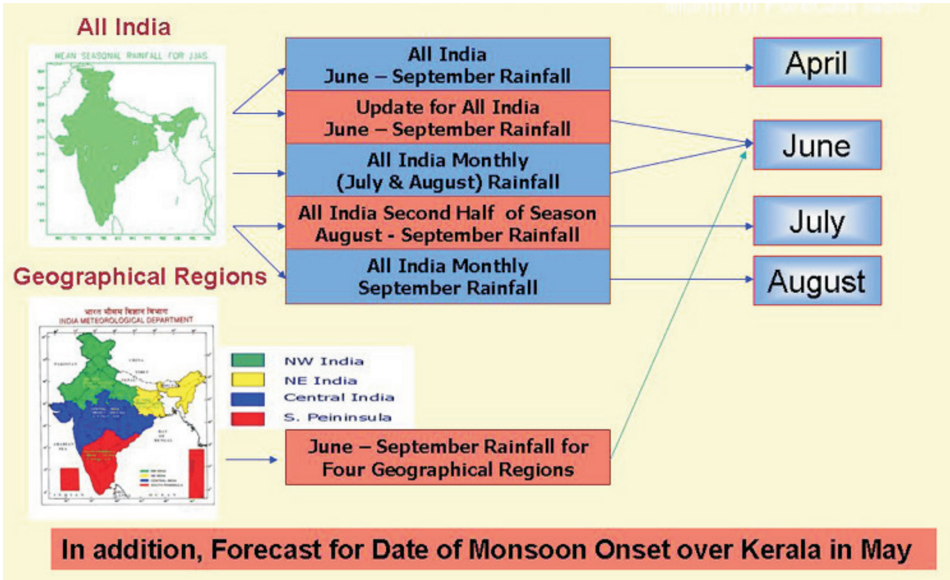


Figure 6: Operational long range forecast issued for South West monsoon rainfall. (*Source:* IMD)

during a common period. The weights are proportional to the multiple correlation coefficients of the models during the training period. For developing the models, two different statistical techniques namely, Multiple Regression (MR) and Projection Pursuit Regression (PPR) were considered.

National Climate Centre also prepares an extended range forecast for the onset of southwest monsoon rainfall over Kerala. This forecast was first issued in 2005. The forecast is issued based on indigenously developed statistical model with six predictors. In addition, IMD prepares operational long range forecasts for the Winter Precipitation (Jan to March) over Northwest India and Northeast Monsoon rainfall (October to December) over South Peninsula. For this purpose, separate statistical models have been developed.

Special weather forecast in relation to extreme weather like cyclone, cold wave, heat wave, frost, hailstorms etc. is also issued to the farmers. These forecasts are normally issued for planting, applying agricultural, chemical crop protection, forestry

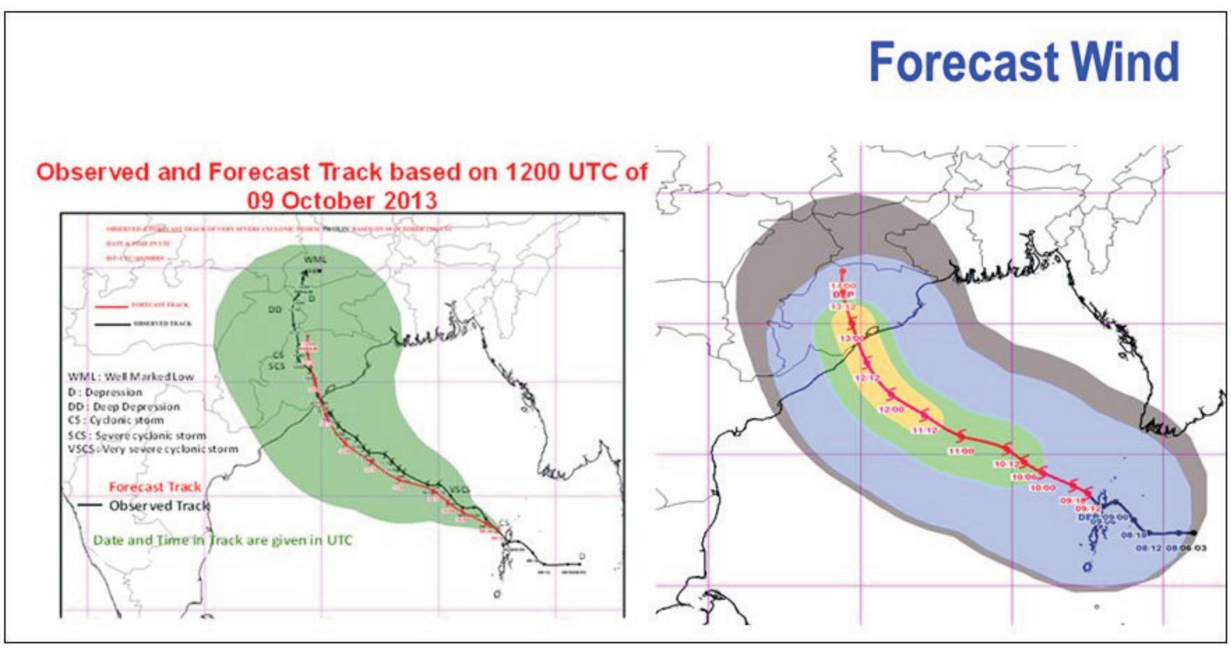


Figure 7: The observed and forecast track of cyclone 'Phailin' based on 1200 UTC of 9 October 2013. (*Source:* IMD)

operations as well as for serving other weather related agricultural elements associated with the crop and its location.

Cyclone warnings are issued to State Government officials in four stages. The first stage warning is issued 72 hours in advance as “Pre Cyclone Watch” containing early warning about the development of a cyclonic disturbance in the north Indian Ocean, its likely intensification into a tropical cyclone and the coastal belt likely to experience adverse weather. The Second Stage warning known as “Cyclone Alert” is issued at least 48 hours in advance of the expected commencement of adverse weather over the coastal areas. The third stage warning known as “Cyclone Warning” is issued at least 24 hours in advance of the expected commencement of adverse weather over the coastal areas and landfall point is forecast at this stage. The fourth stage of warning known as “Post Landfall Outlook” is issued by the concerned Area Cyclone Warning Centres (ACWCs)/Cyclone Warning Centres (CWCs) of IMD and Cyclone Warning Division (CWD) at IMD, New Delhi at least 12 hours in advance of expected time of landfall. Figure 7 shows the observed and forecast track of cyclone ‘Phailin’ based on 1200 UTC of 9 October 2013.

Role of ICT in Adapting Climate Change

Accurate weather forecasts not only help farmers protect themselves against natural factors but they can also benefit significantly as long as they are aware of the actions they can take to leverage of good weather patterns. Weather information is also an input for developing risk mitigation tools such as index insurance products for farmers. Access to regular and reliable weather information is very poor in most developing countries. With limited external information, farmers rely on historical weather patterns for farming but the growing unpredictability in weather systems due to climate change has increased the risk for farmers. Short-term weather patterns can also be significantly different within small geographic areas, especially in tropical zones. Providing granular information for these micro-climate systems is an important element of effective weather information. Multiple stakeholders in the agriculture ecosystem use weather information. Climatic conditions and seasonal forecasts help farmers in planning for the upcoming season to maximize productivity based on expected weather patterns.

Shorter real-time meteorological information of less than ten days and daily forecasts further help determine timing of various activities such as sowing, weeding, spraying and harvesting. Weather information can be especially impactful if combined with specific advice or tips on the actions that need to be taken by the farmers to address weather patterns. Real-time daily or 2-3 day forecasts can also help farmers make very practical decisions that can save them time and money or protect them from weather related damage. Some of the most common uses of ICT for disseminating agro-meteorological information include (Anonymous, 2012):

(i) Transmitting simple weather forecasts including seasonal, ten-day, or short-term forecasts that are daily or every few days.

(ii) Reminders or tips that are related to the actions that farmers can take in response to the expected weather conditions (e.g. sunshine tomorrow, spray fertilizer or pesticide for a given crop).

(iii) Warnings or alerts for disasters or extreme weather events. Extreme weather events such as storms and lightning are particularly prevalent in tropical climates and especially so in coastal areas where low-lying land is susceptible to frequent flooding due to inclement weather. Flood warnings are also important for farmers situated along major river systems.

ICT-based data collection also provides a mechanism to survey farmers to understand localized needs. Text surveys with simple yes/no responses or longer surveys completed through an intermediary on a smartphone platform can then be used to customize information to be relevant for specific micro-climate areas and the challenges farmers are facing based on their crops or farming practices. Along with this ICT can play a great role in climate change adaptation. Linking of successful ICT pilot projects can be donewith farmer field schools, farmer awareness programmes, farmers clubs which can provide weather forecast and agromet information to the farmers. This could also include those related to climate and building capacity on a wider scale to the farming communities. Such approaches enhance the understanding of farmers’ needs and improve the existing state of dissemination of agromet advisory services. There is a need of strengthening of ICTs in the country as well as in the world in terms of infrastructure and capacity building.

In India, IMD in collaboration with 127 Agromet Field Units and Krishi Vigyan Kendra has taken initiatives to disseminate agromet advisories at district and block level also, presently disseminating agromet advisories to 11.46 million farmers through SMS and

IVRS system under Public Private Partnership mode like Reuter Market Light, NOKIA-HCL, Reliance Foundation, Mahindra Samriddhi, NABARD, IFFCO Kisan Sanchar Limited and also through Kisan Portal launched by the Ministry of Agriculture. Figure 8 shows how ICT can be used for agriculture in different ways for the benefit of the farmers.

Conclusion

In the future, we would expect larger, longer more intense extreme events than that of the last few years. Weather and climate events continue to exact a toll on society despite the tremendous advances and investment in prediction science and operational forecasting over the past century. Weather related hazards including early/late onset of rainy seasons and chronic events such as drought and extended periods of extreme cold or heat, trigger and account for a great proportion of disaster losses. Improvements in availability of weather data through satellite data collection and the science of weather forecasting using increasingly sophisticated models will provide an opportunity to make a quantum leap in improving both the access and quality of information to farmers in almost any part of the world.

The challenge is to develop cost effective models that are able to deliver the information in a timely and understandable form at the level of granularity that is needed to make it actionable. A multi-stakeholder approach including public-private partnerships and civil society to coordinate efforts in facilitating efficient weather information systems may help support effectiveness. Climatic conditions and seasonal forecasts can help the farmers in planning for the upcoming season to maximize productivity based on expected weather patterns. Seasonal forecast can also be used to decide which crops to grow, seed varieties for planting, purchase seed and inputs and prepare their land accordingly. Shorter real-time meteorological information of less than ten days and daily forecasts further helps in determining timing of various activities such as sowing, weeding, spraying and harvesting.

Real-time daily or 2-3 day forecasts can also help farmers make very practical decisions that can save them time and money or protect them from weather related damage. For example, with the knowledge that rain is expected farmers can cover or move indoors crops that have been left outdoors for drying; or postpone spraying pesticide on their crops to another day and possibly save both the cost of washed off pesticide as well as the time and labour costs associated with the activity. Through ICT, it is possible to transmit simple weather forecasts including seasonal, ten-day, or short-term forecasts that are daily or every few days. Farmers can get reminders or tips that are related to the actions that they can take in response to the expected weather conditions (e.g. sunshine tomorrow, spray fertilizer or pesticide for a given crop). Warnings or

Figure 8: Use of ICT for agriculture in different ways.

alerts can also be given in case of floods, storms and lightning. ICT has the potential to become a strategic enabler of climate and weather information systems by not only providing a platform to scale the dissemination of information to the farmers at unprecedented levels but also do so at the level of localization and temporal specificity that is an important element of effective and actionable weather information.

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