Agrometeorological Advisory to assist the farmers in meeting the challenges of extreme weather events

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सार – भारतीय अर्थव्यवस्था में योगदान देने वाले विभिन्न क्षेत्रों के लिए हाल ही में मौसम की चरम घटनाओं का घटना बड़ी चिंता का विषय रहा है। अन्य क्षेत्रों के अलावा, कृषि क्षेत्र मौसम की चरम घटनाओं से बुरी तरह प्रभावित हुआ है। मौसम और जलवायु की सूचना फसलों की हानि को कम करने में महत्वपूर्ण भूमिका निभाते हैं। भारत मौसम विज्ञान विभाग अत्याधुनिक उपकरणों और प्रौद्योगिकी का उपयोग करके कृषि समुदाय के लिए मौसम की चरम घटनाओं का मॉनिटरन करके और सूचना को पहले से ही उपलब्ध करा कर महत्वपूर्ण सेवा प्रदान कर रहा है और इस प्रकार किसानों को होने वाले बड़े नुकसान से बचाने में मदद कर रहा है। समुचित फसल तथा स्थान विशिष्ट कृषि मौसम परामर्शिकाएँ तैयार करने के लिए उपग्रह से प्राप्त सूचनाओं का भी उपयोग किया जाता है। लोक निजी साझेदारी के तहत आज देश में बड़ी संख्या में किसानों को कम समय के भीतर मौसम पूर्वानुमान और परामर्शिकाएँ भेजना संभव हो पाया है। इस प्रकार फसलों की पैदावार को बढ़ा कर कृषकों की आर्थिक स्थिति को सुधारना संभव हो पाया है।

ABSTRACT. In recent past extreme weather events are causing great concern in different sectors contributing to the Indian economy. Among other, agricultural sectors are badly affected by the extreme weather events. Weather and climate information play a great role in minimizing the loss of crops. India Meteorological Department is doing yeomen's service by providing advance information including monitoring of the extreme weather events along with the proper advisories to the farming community by using state of art instruments & technology through efficient delivering mechanism of the information and ultimately help the farmers from incurring great loss. Satellite information is also used for preparation of the accurate crop and location specific Agromet Advisories. Under Public Private Partnership, today it is possible to send the weather forecast and advisories within short time to large number of farmers in the country before the occurrence of extreme weather events and ultimately possible to improve the economic condition of small and marginal farmers by increasing the productivity of crops.

Keywords – Extreme weather events, Agrometeorological advisories, Weather forecast, Dissemination, Feedback, Awareness programmes

1. Introduction

Global food security is under constant threat from weather and climate extremes and will face further challenges from variable weather and climate change. Around the globe, extreme weather is wreaking havoc on increasingly vulnerable communities. There were series of unprecedented extreme events occurred in 2010 particularly in Pakistan, China and Russian Federation. March 2013 was exceptionally cold over most of Europe and was the second coldest March in UK since 1910. Same is true for India particularly since last 10 years. Extreme weather and climate events in different countries often cause major economic and human losses. Historical records of climate extremes are no longer reliable predictors of future droughts because of climate change. Therefore, agricultural, water and energy manager are facing increasing uncertainty in providing the basic services they depend on. Scientists are faced with the challenges of communicating scientifically robust information, quantifying their risks to human induced climate change, and evaluating the prospects for early warning of such events in a changing climate (WMO Meteoworld, 2013). All these are now being addressed under the research programme on extreme events by the World Research Programme initiated by World Meteorological Organisation.

The challenges that agriculture is facing in India are ever increasing. First, agriculture is highly dependent on weather and subject to its variability. Second, the possible impacts of climatic variability and climate change leading to extreme weather events pose major challenges. Finally, the sustainability of intensive agriculture using current technologies is being questioned within the context of the global climate change debate. Long-term changes and the increasing frequency of extreme weather events are likely to have adverse impacts on the agricultural sector. India

being mainly an agricultural country, the economy and further its growth purely depends on the vagaries of the weather and in particular the extreme weather events.

Extreme weather includes very high (and low) temperatures, very heavy rainfall (and snowfall in cold climates), hot and cold wind and very high wind speeds. By definition, extreme weather events occur only rarely and they are noticeable because they are so different from the usual weather and climate and because they are associated with adverse impacts on humans, infrastructure and ecosystems. In many cases, the most severe impacts are felt when several extreme events occur together. Examples include: (*i*) the impacts on agriculture of a combination of drought and a heat wave; (*ii*) high bushfire danger weather, which can be a combination of high temperature, low humidity, high wind and drought. The major extreme weather events related to agriculture are tropical cyclones, floods, heavy rain and landslides, cold waves, fog, snow storms, heat waves, hailstorms, thunderstorms and dust storms, drought and failure of rains. Occurrence of natural disasters such as floods and droughts could lead to crop failures, food insecurity, famine, loss of property and life, mass migration, and negative national economic growth. Due to recent advances in science and technology, it is now possible to forecast the occurrence of extreme events and the nature of devastation that they may cause with greater degree of accuracy and with longer lead time (Sivakumar *et al.*, 2005). Urban and non-urban pairs showed disparate changes for temperature and wind related extremes (generally more increases in temperature-related extremes, and more decreases in wind-related extremes in urban as compared to non-urban stations), and hence, appear to be counter to overall hypothesis that large scale climate drivers dominate changes in climate extremes (Mishra *et al.*, 2015). In a large country like India which is experiencing occurrence of different kinds of extreme events every year, the weather aberrations may be nullified to a large extent by suitable adoptive measures disseminated through Agromet Advisory Services (AAS) to the farming community (Chattopadhyay and Lal, 2007; Rathore *et al.*, 2009; Chattopadhyay and Rathore, 2013; Rathore *et al.*, 2013). In the present paper it has been showed that how the National Meteorological Services like India Meteorological Department in collaboration with other organisations has geared up its activities to face the challenges of such extreme events, particularly in providing the services to the farmers in the country.

2. Role of weather/climate in minimising the loss of crops under extreme climate events

Weather and climate play an important role in agricultural production. It has a profound influence on crop growth, development and yields; on the incidence of pests and diseases; on water needs; and on fertilizer requirements. Accurate information on extreme meteorological parameters has great potential for increasing output to the farmers. This information is also useful for modification of crop environment, protection from frost, strong wind and also irrigation scheduling leading to efficient water management and drought preparedness (Das, 2012). Weather aberrations may cause physical damage to crops and soil erosion. Climate information services will be one of the tools to meet the challenges of the future particularly with reference to extreme events. The provision of need based climate information to farmers can support the management of agricultural resources (land, water and genetic resources). Better understanding of the climate in a location provides opportunities to design various measures to reduce its impacts on natural resources. In India a combination of traditional and more innovative technological approaches are being used to manage drought risk. Technological drought management (*e.g.*, development and use of drought tolerant cultivars, shifting cropping seasons in agriculture, and flood and drought control techniques in water management) is combined with model-based seasonal and annual to decadal forecasts. Model results are then translated into an early warning in order to take appropriate drought protection measures.

India Meteorological Department (IMD), Ministry of Earth Sciences (MoES) is operating Gramin Krishi Mausam Seva (GKMS) project at district level in India, which represents a small step towards agriculture management in rhythm with weather and climate variability leading to weather proofing for farm production. In order to minimize the adverse impact of malevolent weather, GKMS scheme provides a very special kind of inputs to the farmer as advisories that can make a tremendous difference to the agriculture production. The primary role of combating the negative impact of extreme events under the Agromet Advisory Services is to find out the basic requirement to generate ways and means of adjusting crop cultivation plans/practices depending on the time of occurrence of the extreme events. From June 2008, IMD started issuing quantitative district-level forecasts five days ahead of a weather event. The parameters include rainfall, temperature, wind speed and direction, relative humidity and cloudiness. Under this project, Agromet Field Units (AMFUs) are preparing district level Agromet Advisories for the farmers in the country. A wide variety of channels and modes are used to disseminate climate and agromet information to the farmers, with conventional mass media continuing to play the primary role. Farmers are using these advisories for sowing and transplantation of crops, fertilizer application, predictions regarding pests and
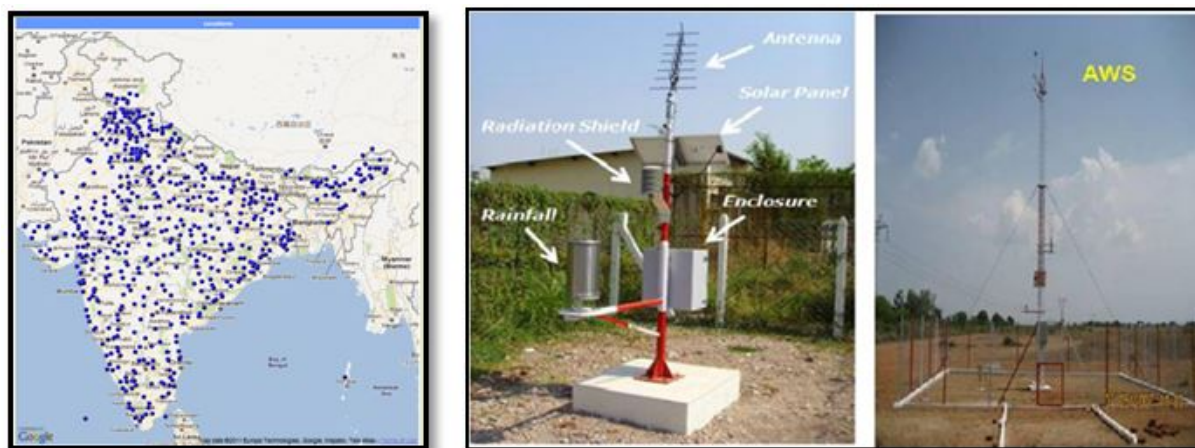
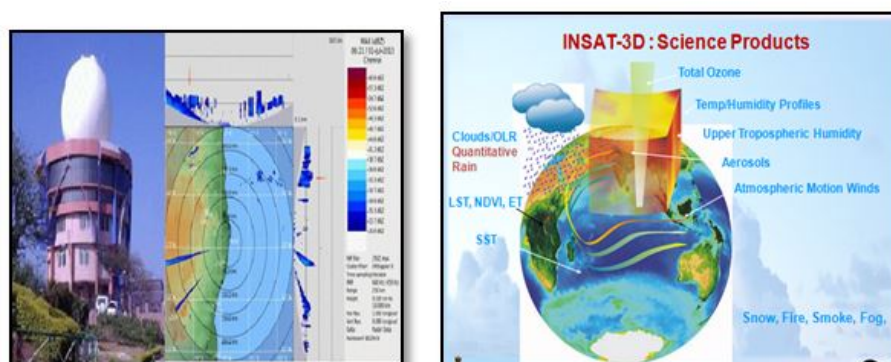**Fig. 1(a).** Network of observatories in India

Fig. 1(b). Tools used in the network

diseases and measures to control them, weeding/thinning, irrigation (quantities and timing) and harvest of crops.

3. Data, products & Tools used for generating advisories under extreme events

IMD is having different kinds of network of observatories in India to monitor and assess the extreme events 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. Figs. 1 (a&b) show the Weather Observational network in India.

Special forecasts issued are: tropical cyclone (North Indian Ocean) track, intensity, structure changes and landfall process (wind and gust, rainfall and storm surge); heavy rain and strong winds triggered by tropical cyclones, SW and NE monsoon, troughs and Inter Tropical Convergence Zone (ITCZ) migration and orography; thunderstorms and hail associated with severe convection; extreme hot and cold conditions and frost. Different types of forecast at different scales issued by IMD even for extreme events and ultimately for generating advisories for the farmers are as follows:

3.1. *Medium range weather forecast*

IMD is issuing quantitative district level (646 districts) weather forecast up to 5 days and the products comprise of quantitative forecasts for 7 weather parameters *viz.*, rainfall, maximum temperature, minimum temperatures, wind speed, wind direction, relative humidity and cloudiness. This weather forecast is generally valid for a period of 5 days and 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
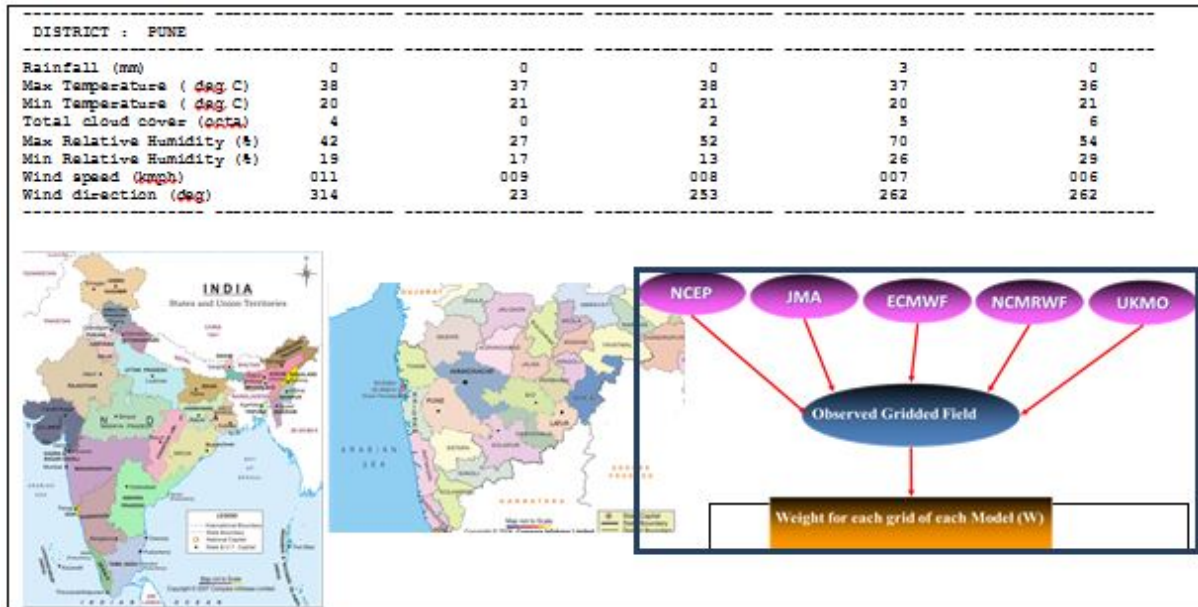
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 DISTRICT :  PUNE
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 Rainfall (mm)               0               0               0               3               0
 Max Temperature ( deg C)   38              37              38              37              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
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Fig. 2. Generation of district level weather forecast (DLWF)
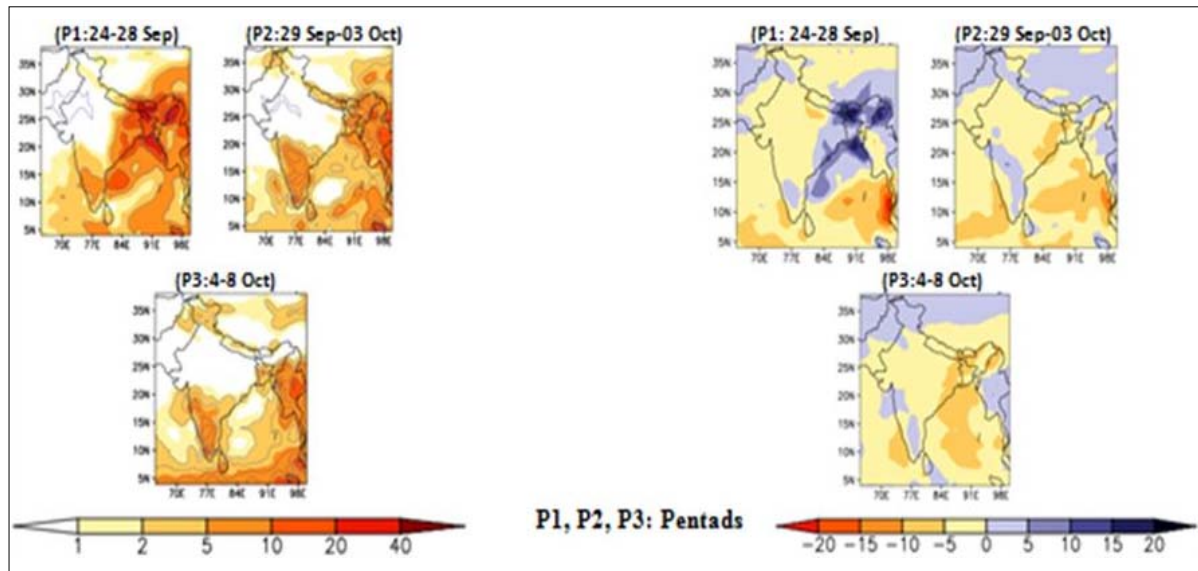
Fig. 3. The Extended range forecast issued by IITM for the period of 24 September to 8 October, 2014 (Rainfall in mm)

Weather Forecasting (NCMRWF) and the U K Met Office (UKMO). Fig. 2 shows the generation of district level weather forecast (DLWF).

3.2. *Extended range weather forecast*

Under the "National Monsoon Mission" Project of Govt. of India, Indian Institute of Tropical Meteorology (IITM) has adopted Climate Forecast System (CFS) coupled model from NCEP for seasonal and extended range prediction of Indian summer monsoon on Indo-US collaborative mode. At present multi-model ensemble (MME) forecast has been prepared using the CFS (T126 & T382) and GFSbc (T126 & T382). Fig. 3 shows the Extended Range Forecast issued by IITM for the period of 24 September to 8 October, 2014.
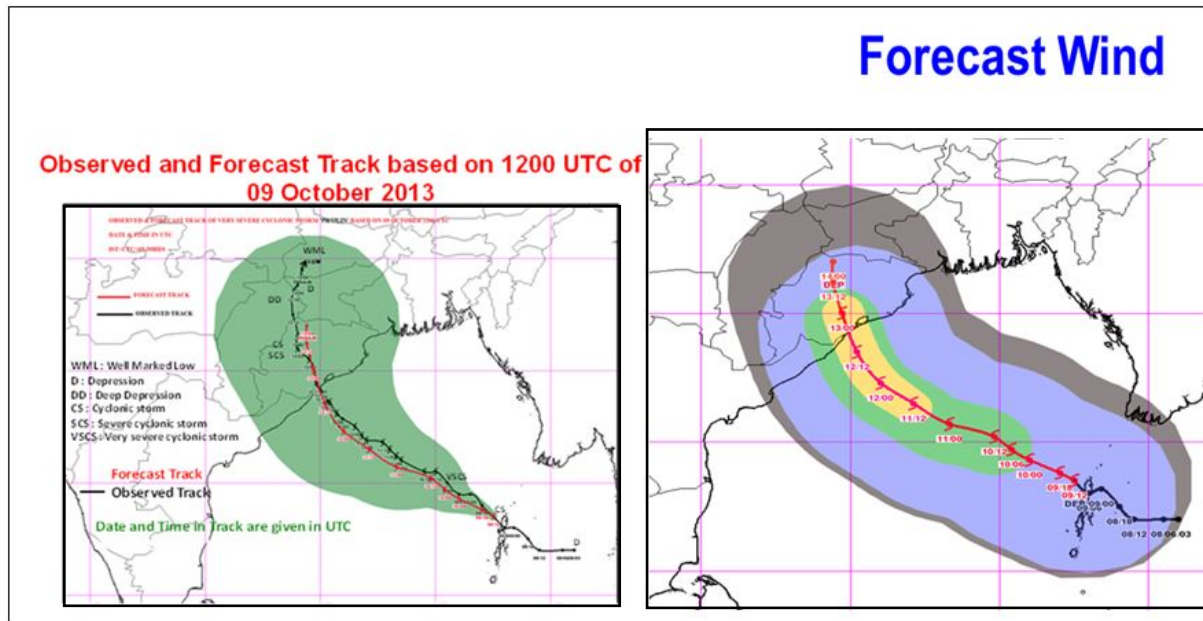
Fig. 4. The observed and forecast track of cyclone 'PHAILIN' based on 1200 UTC of 9 October, 2013

IMD in Collaboration with IITM, Pune started to use the same in Agromet Advisory bulletin 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, they need to be improved in order to predict the tele connection patterns realistically (Joseph Susmitha *et al.*, 2014).

3.3. *Cyclone forecast*

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. Fig. 4 shows the observed and forecast track of cyclone 'PHAILIN' based on 1200 UTC of 9 October, 2013.

3.4. *Nowcast*

In view of the recent improvement in monitoring and forecasting due to introduction of digital and image 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. These nowcasts are primarily made by forecasters at various Meteorological Centres (MCs) and Regional Meteorological Centres (RMCs) of India Meteorological Department. Therefore, automatic dissemination of warnings for disastrous weather events like severe thunderstorms, hail, squalls etc. to all mobile users of that particular area, for which warning is issued, through SMS alerts is being initiated. These nowcast alerts are based on Doppler data and are issued few hours
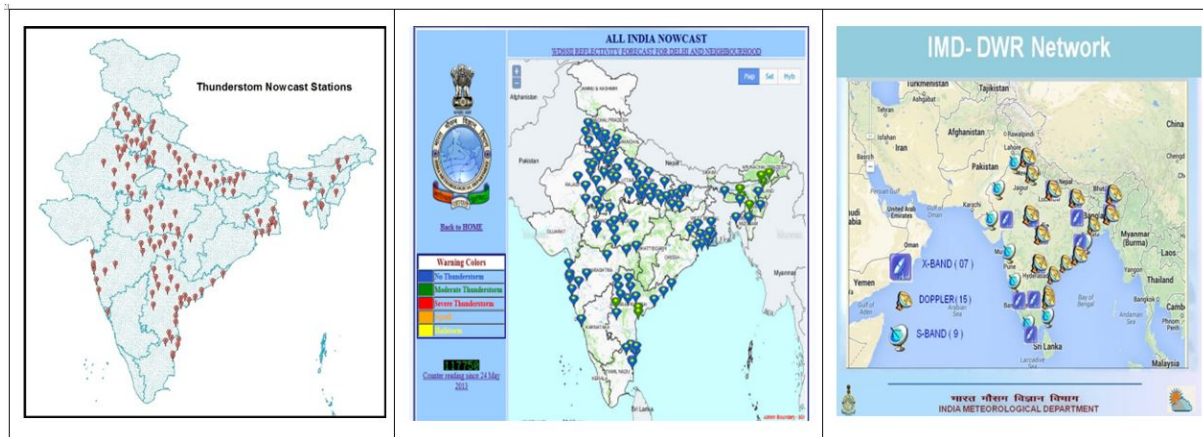
Fig. 5. The network of Nowcast stations of IMD across India

before the event and thus would be very useful to alert the farming community about the occurrence of the adverse weather. Fig. 5 shows the network of nowcast stations of IMD across India.

Under the joint initiative by Indian Space Research Organization (ISRO), Indian Council of Agricultural Research (ICAR), India Meteorological Department, National Centre for Medium Range Weather Forecasting (NCMRWF), Noida, Mahalanobis National Crop Forecasting Centre (MNCFC), New Delhi under DAC (Department Agriculture and Cooperation) has started preparation different satellite based agromet product to generate   more accurate crop and location specific advisories The ISRO centers include Space Applications Centre, Ahmedabad, National Remote Sensing Centre, Hyderabad, ISRO HQ, Bangalore, Indian Institute of Remote Sensing, Dehradun, and ICAR. The ICAR centers include National Centre for Integrated Pest Management, New Delhi, Indian Agricultural Research Institute, New Delhi.

4. Nature of impacts of extreme events in agriculture and corresponding agromet advisories issued to the farmers

All the extreme events are impacting negatively on farming in India. Preparedness messages and education on how to apply forecast information from National Meteorological and Hydrological Services (NMHS) to decision making are focussing on three objectives: action oriented, consistent messaging of the expected risk and reaching out to the farmers in more meaningful ways. The followings are some major extreme events and the agromet advisories issued to the farmers to take appropriate measures in such events.

4.1. *Drought / dry spell*

Drought is widely recognised as a slow creeping natural hazard that occurs as a consequence of natural climatic variability. In recent years, concern has grown worldwide that drought may be increasing in frequency and severity given the changing climatic condition. Though drought cannot be stopped happening, but the knowledge and the experience should be put in place to adopt the measures that mitigate their impacts. Due to uncertainty of rains during the drought conditions, farmers sometimes make several attempts at sowing of seeds leading to a drastic reduction in seed reserves, ultimately neither sufficient for planting nor for consumption. Also roots of the plants get very less water while at the same time more is being transpired by the leaves. As a consequence, the water budget within the body of a plant loses balance and lead to water deficit. Water deficit during the growing period of the crops distorted the development and results in the reduction of crop yield.

Several drought products are being used to monitor drought. Aridity anomaly index has been used to monitor the incidence, spread, intensification and recession of drought. With the help of aridity anomalies, crop stress conditions in various parts of the country are monitored during the monsoon season. These anomalies are used for crop planning and in the early warning system during drought / desertification. The Standardized Precipitation Index (SPI) (Guttman, 1999; Guhathakurta *et al.*, 2011) and Normalised Difference Vegetation Index (NDVI) (Bhattacharya *et al.*, 2008)   are also used along with rainfall departure from normal for monitoring status of rainfall situation. Depending on SPI values categories of rainfall situation and ultimately drought condition for a particular period is determined. Different agromet
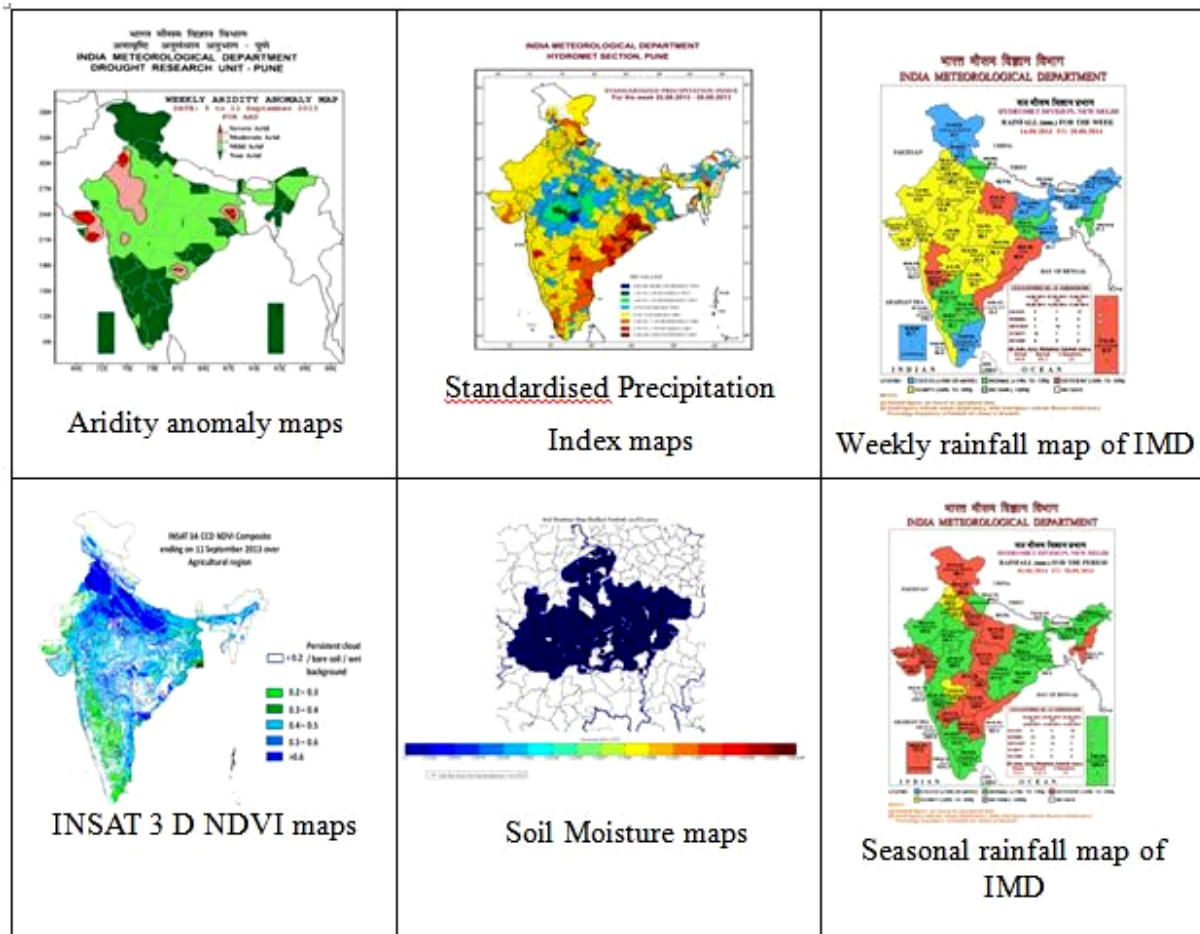
Fig. 6. Different agromet products used for monitoring drought / dry spell

products used for monitoring drought / dry spell have been presented in Fig. 6.

Under the dry spell / drought like situation, farmers are getting information through AAS of IMD regarding contingency crop planning like cultivation of medium / short duration crop varieties, mulching etc.

4.1.1. *Extreme cold*

Long-time extreme cold weather combined with other meteorological phenomena results in loss of winter and fruit crops and vineyards due to frost injury. The main agrometeorological factor influencing frost damage in crops including plant injury at the depth of plant roots is low soil temperature. Long and intensive cooling causes complete devastation of crops. Cold waves and frost warnings are issued by the regional and state forecasting offices of IMD to enable the farmers to adopt timely protective measures for the crops like potato in northern region, grapes in Maharashtra etc. To protect from cold injury, irrigation is important for standing crops as adequate soil moisture keeps the soil comparatively warm and saves it from cold and also smoke arrangement should be made around the fields. In such situations farmers are getting advice to irrigate crops to protect from frost and also to arrange smoke around the fields and to cover the crop necessarily by green net *e.g.*, nursery vegetables, paddy, papaya etc. to save the crops from the ground frost. Likewise the advisories are being issued at district level keeping in mind the crop growing area and also for livestock and poultry. Grapes could suffer cracks due to the extreme cold conditions in the traditional belt of the crop in Nasik region of Maharashtra. If mercury drops to 4.4 °C, farmers are advised to (*i*) arrange for smoking around the field and apply light irrigation to the crop and (*ii*) spray fresh water to the bunches.

4.2. *Heat waves*

High temperature results in the desiccation of the plants and disturbs the balance between photosynthesis

Fig. 7. Crop damage due to hailstorms in Maharashtra
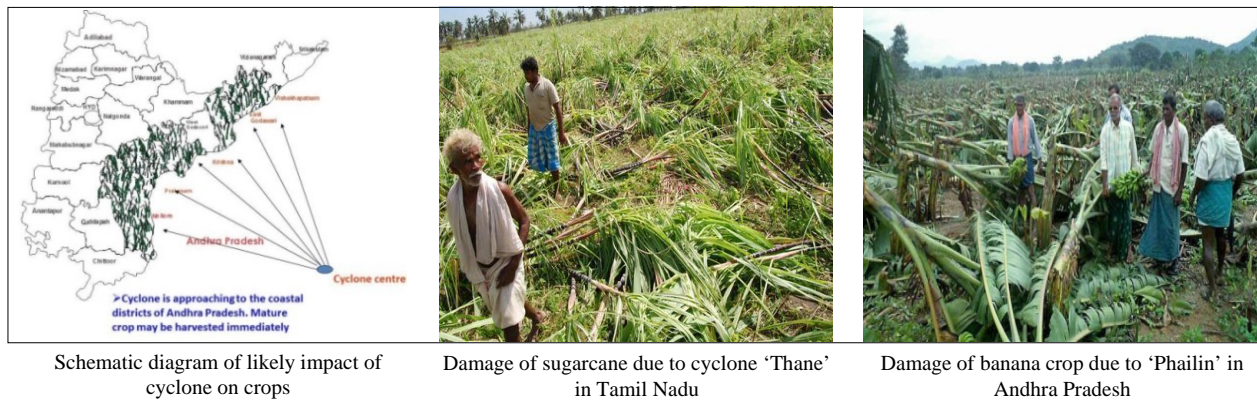
Schematic diagram of likely impact of
cyclone on crops

Damage of sugarcane due to cyclone 'Thane'
in Tamil Nadu

Damage of banana crop due to 'Phailin' in
Andhra Pradesh

Fig. 8. Damages caused by the recent cyclones

and respiration. Also during the period of heat waves, the extreme high temperatures together with higher vapour pressure deficit can generate intense evaportranspiration. The harmful effects of excessive temperatures are usually aggravated by lack of available moisture. When normal maximum temperature of a station is more than 40 °C, farmers are getting advice to apply frequent irrigations to the crops, mulches to maintain high moisture status in the soil and spraying of antitranspirants on crops.

4.3. *Hailstorms, thunderstorms and dust storms*

The arid regions of India are characterised by frequent and strong winds which are partly due to considerable convection during the day time. The usually sparse vegetation is not capable of slowing down the air movement, so the dust and sand storms occurred frequently in the regions. Also, as winter season proceeds towards spring, the temperature rises initially in the southern parts of India giving rise to thunderstorms and squally weather which are hazardous in nature. The hailstorm frequencies are higher in the Assam valley

followed by hills of Uttarakhand. Recently Marathwada, Vidarbha, Northern Maharashtra and parts of Western Maharashtra experienced the unprecedented hail storms and unseasonal rainfall. Because of this, there was a great damage of standing *rabi* crops in Maharashtra (Fig. 7). Under such situation, advisories are issued both during pre and post hailstorm occurrence.

Pre hailstorm advisory : Before the hailstorm, farmers are advised to give mechanical support to the crops. Harvest the matured crops and keep in a safe place.

Post hailstorm advisory : After the hailstorm also give the mechanical support to the crops and collect the dropped fruits and destroy the same.

4.4. *Cyclone*

Cyclone events are also affecting crops in the cyclone prone regions. Horticultural crops show mechanical damage due to strong winds blown during the cyclone. Specific advisories on harvesting, salt spray in
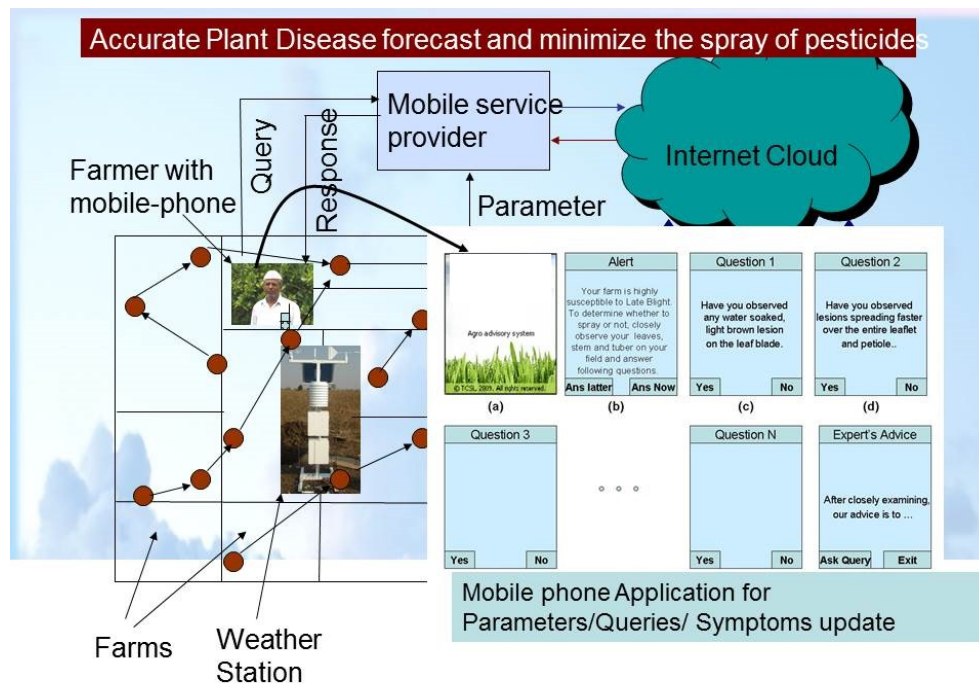
Fig. 9. Mode of dissemination of information on weather alerts and agromet advisories using mobile phone

coastal region are given during the cyclone period. Recent cyclones like 'NILAM', THANE", 'HUDHUD' and 'NILOFAR' caused great damages of agriculture in the country (Fig. 8).

Pre cyclone advisory : When the cyclone is approaching, farmers are getting pre cyclone warning that the cyclone is approaching and heavy rains are expected and they are subsequently advised to harvest the matured crops and keep the harvested produces in a safe place.

Post cyclone advisory : After the event is over, farmers are advised to drain out excess water from the standing crop fields and carry out propping of sugarcane, banana plants (to keep them erect) and thus, to minimize the damage.

4.5. *Intense rainfall and floods*

Very intense rainfall and floods can damage the different crops in the fields. Flooding can create anaerobic soil conditions that can have significant impact on vegetation. Chemical reactions in anaerobic soils also lead to a reduction in nitrate and the formation of nitrogen gas. This de-nitrification can be a significant cause of loss of plant vigour and growth following flooding. Along with this, heavy rainfall causes soil erosion, disruption to critical agricultural activities, water logging, increased

moisture stress and attack of pests and diseases on the crops. Excess rainfall always causes water logging / runoff. In such cases farmers are getting advice to postpone fertilizer application and inter culturing due to excess rainfall.

5. Dissemination of weather and agrometeorological information and awareness among the farming community for extreme weather events

Information such as severe weather warnings potential to cause crop damage must be received by the farmers in ways they expect *i.e.*, using technology with which they are familiar. Agromet advisories prepared under GKMS project are disseminated to the farmers regularly and also in case of extreme weather through Short Message Service (SMS) messaging and Interactive Voice Response Technology (IVR). In a public-private partnership (PPP) arrangement, AMFUs are preparing and sending district AAS bulletins twice weekly to private companies including IFFCO Kisan Sanchar Limited (IKSL), NOKIA, Reuter Market Light (RML), Handygo, Mahindra Samriddhi comprising of weather forecasts and advisories on extreme events along with crop, pest, disease, seed and fertilizer information all over the country. AMFUs are also uploading the agromet advisories in the form of SMS in regional languages in Kisan Portal started by Ministry of Agriculture, Govt. of
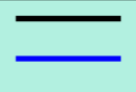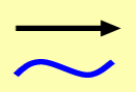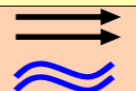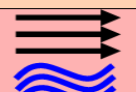
Fig. 10. Weather Alerts as SMS textused for the fisherman in Lake Victoria in Africa

India and their respective web sites of Universities or National Institutes. Presently 8.5 million farmers are taking benefits of dissemination service of IMD for the farming communities. Information delivered on mobile phone contributes to a multi-source delivery system, building on more traditional sources such as television broadcast, the Internet and All India Radios and community Radios.

The following is the format of SMS in the cyclone HUDHUD in English and regional language:

English	Due to HUDHUD Cyclone rainfall would occur at most places with heavy to very heavy rainfall at a few places over Srikakulam from 11th October Onwards. • Harvest the crops maize, groundnut and pulses immediately and arrange for propping in sugarcane and banana crops.
Telugu	హుదుద్రుఫానుప్రభావంవల్లజిల్లాలలోభారీనుండిఅతి భారీవర్షాలుకొన్నిచటుల తారీకునుంచికురిసేఅవకాశంఉన్నది .కనుకకోతకువచ్చినమొక్కజొన్న, పేరుసెనగమరియుఅపరాలపంటలనువెంటనేకోసిజా గ్రత్తచేసుకోవలెను .చెరకుమరియుఅరటితోటలుపడిపోకుండానిలగాట్టు కోవలెను.

Mobile communications technology has become the world's most common way of transmitting voice, data,

and services, and no technology has ever spread faster. Based on this technology, mobile applications can improve advance warning of weather risks, pests and other environmental risks and provide timely, locally relevant information on how to respond to these. The mode of dissemination of information on weather alerts and agromet advisories using mobile phone has been illustrated in Fig. 9.

Weather Alerts as SMS text like: severity (isolated, widespread, severe, heavy, moderate, strong, poor, clear, calm); validity (03, 06, 12 hours); name of the hazard (strong wind, heavy thunderstorm, high waves); date and advice information (such as No alert, Be aware, Be prepared, Take action) can be given to the users. This technology is being used for the fisherman in Lake Victoria in Africa (Fig. 10). Such technology is being used jointly by IMD and Indian National Centre for Ocean Information Services (INCOIS).

Along with the dissemination, to make farmers more self-reliant in dealing with extreme weather and climate issues that affect agricultural production, the Farmer Awareness Programmes have been arranged in different districts at 104 locations in the country. In order to improve the linkages with the AAS system and to develop a local (village) level rain measuring network, five rain gauges made of plastic are also distributed to a group of progressive farmers selected by AMFU during the meeting. These farmers are then trained to record and report the rainfall observations to the relevant AMFUs, which in turn communicate it to IMD.

6. Feedbacks from the farmers

For improvement of agromet advisory services, collection of feedback plays an important role. Feedback

mechanism developed under GKMS by participating in kisan melas, field visit and personnel contact and interaction with farmers from different States. Mechanisms are being developed to get on-line feedback from the famers through mobile phones.   Recently feedback has been collected for the farmers of Srikakulam, East Godavari, Vishakhapattanam and Vijayanagram districts of Andhra Pradesh on the services provided during pre and post of cyclone HUDHUD crossed Andhrea Pradesh. Some of the examples are cited here. (*i*) A. Gouramma, farmer from Srikakulam district of Andhra Pradesh informed that the Cyclone alert messages was extremely useful as he received 4-5 days before advancement of HUDHUD Cyclone in his areas. Accordingly he harvested his paddy crop in advance. (*ii*) A Chinnamma, farmer from Srikakulam district of Andhra Pradesh was very satisfied with Cyclone alert & corresponding Agromet Advisories. He also conveyed these messages to his friends & relatives and ultimately full community was benefited. (*iii*) A Y A Yashwanth, Farmer from Ambhugw village of Adilabad district of Andhra Pradesh was happy with the alert messages and utilized the information for managing his cattle. He also shared these messages with his friends and villagers. He was very thankful for accurate cyclone alerts and it's timely dissemination to the farmers.

7.   Summary and conclusion

The potential for catastrophic damage and loss of crops in India due to the extreme events is enormous. Due to the substantial improvements in observational network *i.e.*, automatic weather stations, doppler radar, satellite and numerical weather prediction models, today it is possible to forecast the extreme weather events well in advance for taking appropriate measure. India Meteorological Department in collaboration with other organisations is providing the best services to the farmers in the country. Through the network of Agromet Field Units located at State Agricultural Universities, ICAR institutes and IITs, weather forecast are being translated into appropriate advisories before and after the occurrences of extreme weather events. Besides, the great challenges of communication the crop and location specific advisories to the unreached and unprivileged farmers in the villages is possible by sending the agromet advisories through SMS under public private partnership mode. It is also tried to send the required messages by sending alerts through mobiles even to the fishermen venturing into the sea. Effective feedback mechanism has been established to provide need based services to farmer before the incidence of the extreme weather events. Every year, a number of Farmer Awareness Programmes are conducted to aware and availing of the Agromet Advisory Services. Though useful services are being provided to the farmers through the Agromet Advisory Services during the extreme events by using the latest state of art technology, there is an urgent need for a better understanding of the changing climate patterns and how they affect extreme weather events. The thrust areas of for management of extreme events through Agromet Advisory Services include:

- Improvement in scientific understanding.

- Improvement in monitoring and prediction of disastrous weather like heavy rain/snowfall over data sparse Himalayan region and adjoining plains and cyclonic disturbances over north Indian Ocean using land/Ocean and space based tools.

- Improvement in nowcast of meso-scale disastrous events like thunderstorm, hailstorm and tornado.

- Improvement in space based telecommunication measures.

- Active initiation of Forecast Demonstration Projects on Cyclone, Thunderstorm, Fog and heavy rain during monsoon due to Continental Tropical Convergence Zone (CTCZ).

- Development of suitable adaptation and mitigation measures to minimize the effect of extreme weather in agriculture.

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