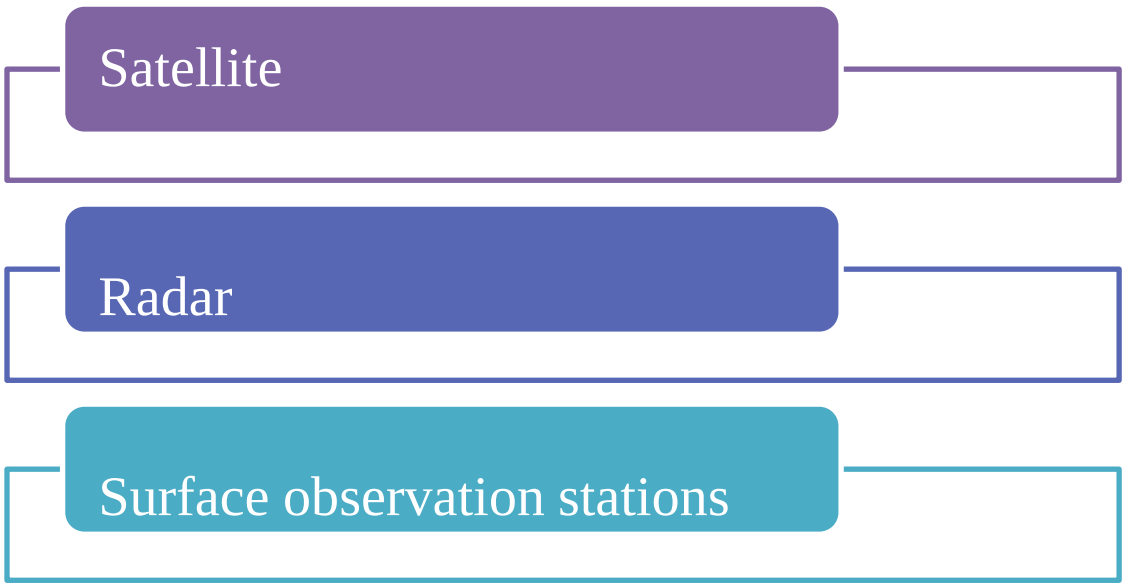
A Journey Towards Better Predictions

Weather and climate has fascinated human race from times immemorial. For carrying out day to day activities like hunting, farming, travelling man needed to know the weather that lies ahead. So they devised methods like animal behavior, plant behavior, state of physical objects like soil wind, sun to predict future weather. Science brought more definite ways of predicting weather, but the science that used the entire atmosphere as a laboratory has always grappled with uncertainty.

Over the year the world has experimented with observations of current weather parameters like sunshine, rain, moisture, mathematical models through which these observations are passed to predict the future rainfall, sunshine and fog. India's weather prediction had for long been taking a beating from common people but has shown remarkable improvement – thanks to the relentless efforts of scientists working on it in institutions at different corners of the country. As the entire country looks up to these network of institutions for prediction of monsoon, a phenomenon that fascinates poets and farmers alike, let us take a look at what led to India's weather prediction's journey from despise to cheers.

Observation Systems



Augmenting Observations: The data that initiates the journey

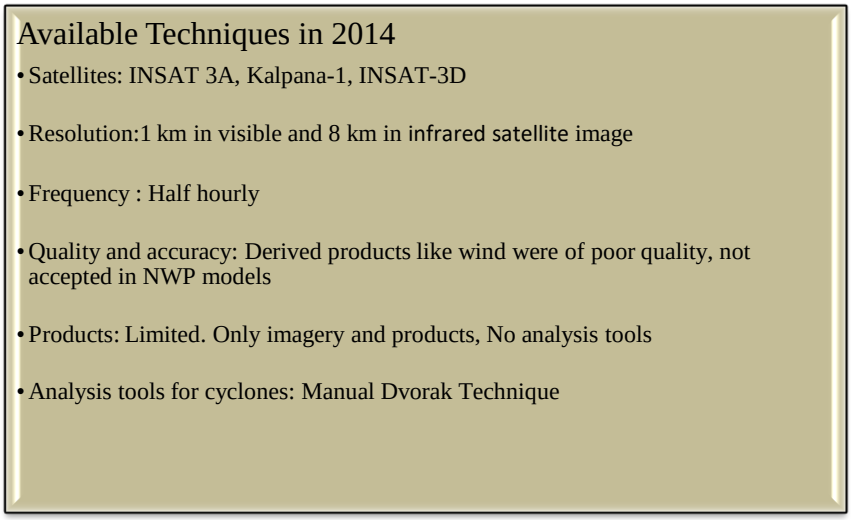
Improvement of observation through Satellites

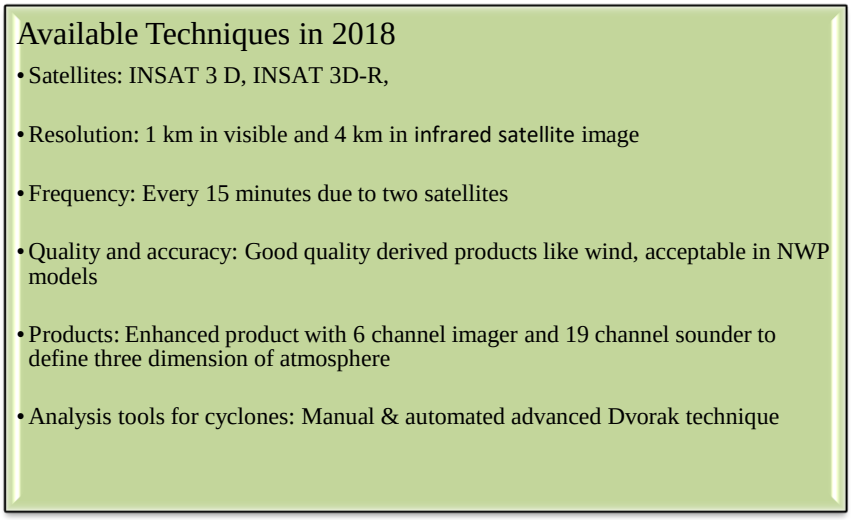
How does satellite helps in weather prediction?

Satellites scan the earth using different wave lengths known as channels. Current INSAT geostationary meteorological satellites have three channel imager with the following channels:

i) Visible wavelengths (0.55 0.75 um, reflected solar radiation).

ii) IR (thermal infrared, 10.5 12.5 um).



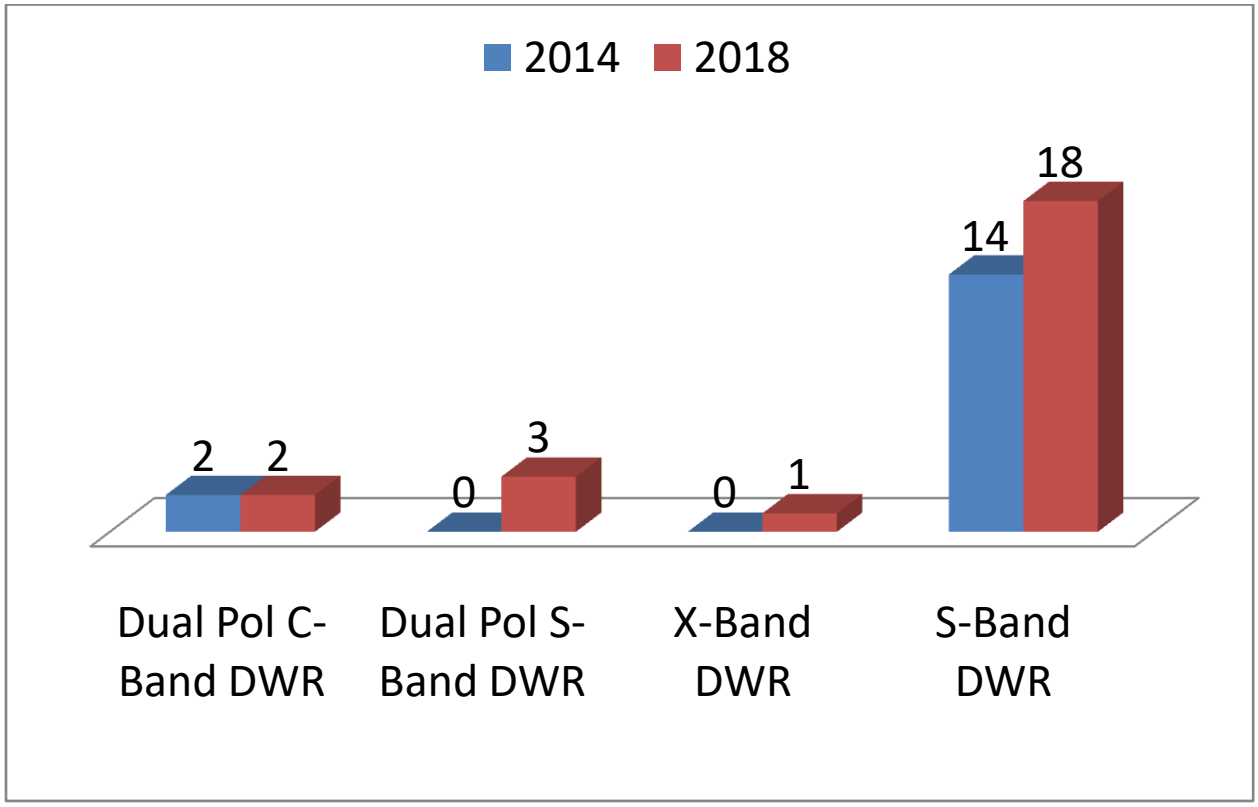


- Kalpana-1 carried a three channel Very High-Resolution Radiometer
- It's resolution is 2 km in the visible band and 8 km in thermal infrared and water vapor bands.
- Used for hydro meteorological data collection from land and river basins.
- INSAT-3DR carried 6-channel Imager and a 19 –channel Sounder payloads.
- First time sounder payload has been put up on an Indian satellite
- The data is available at a higher resolution comparison to earlier satellites
- Geophysical products from these satellites are more accurate and of higher resolution.
- Imager provides images at every 15-minute interval
- Sounder provides information at every 30-minute interval

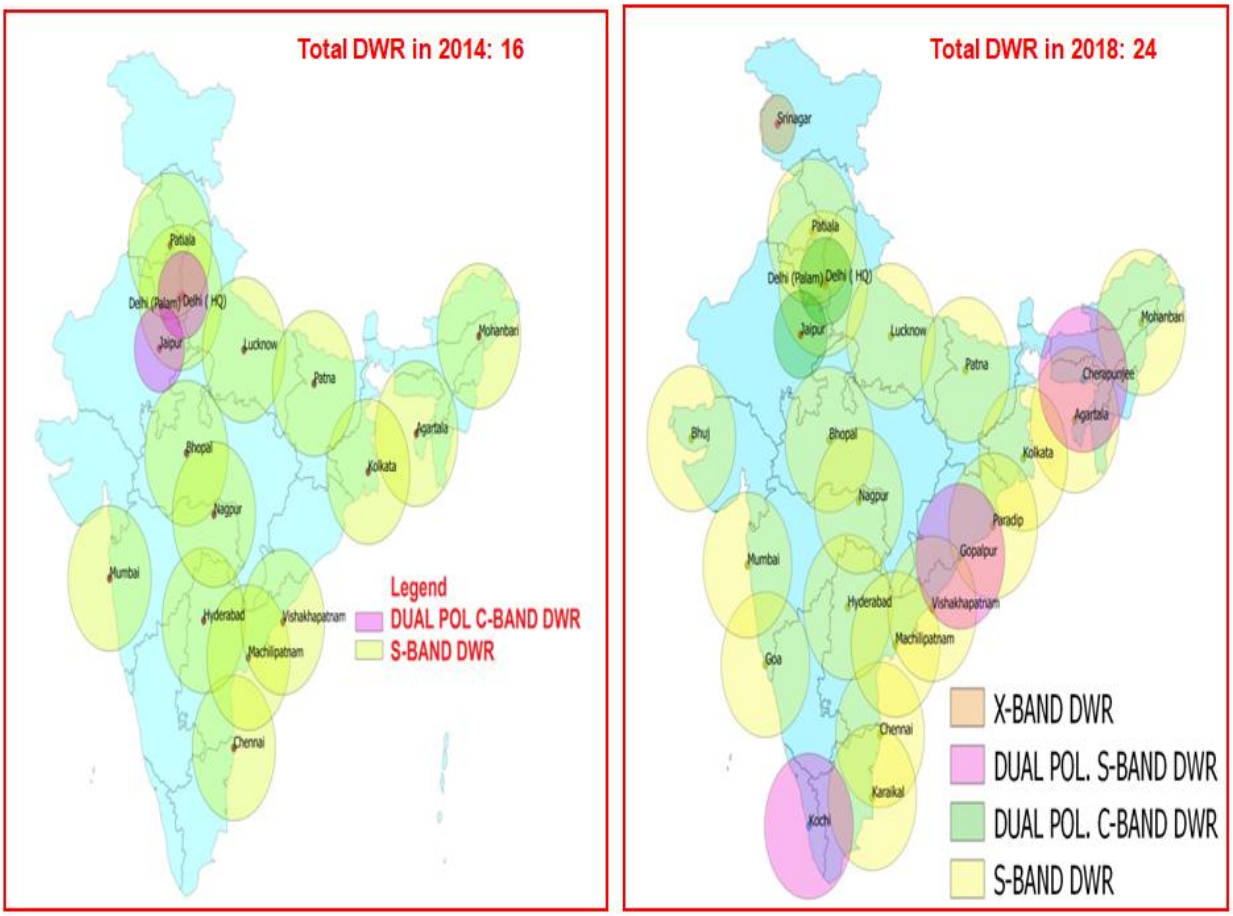
Improvement of observation through Radar

What a Doppler Weather Radar (DWR) does?

Radar is acronym for Radio Detection and Ranging. It uses electromagnetic waves in microwave region to intensity of moving and nonmoving targets.

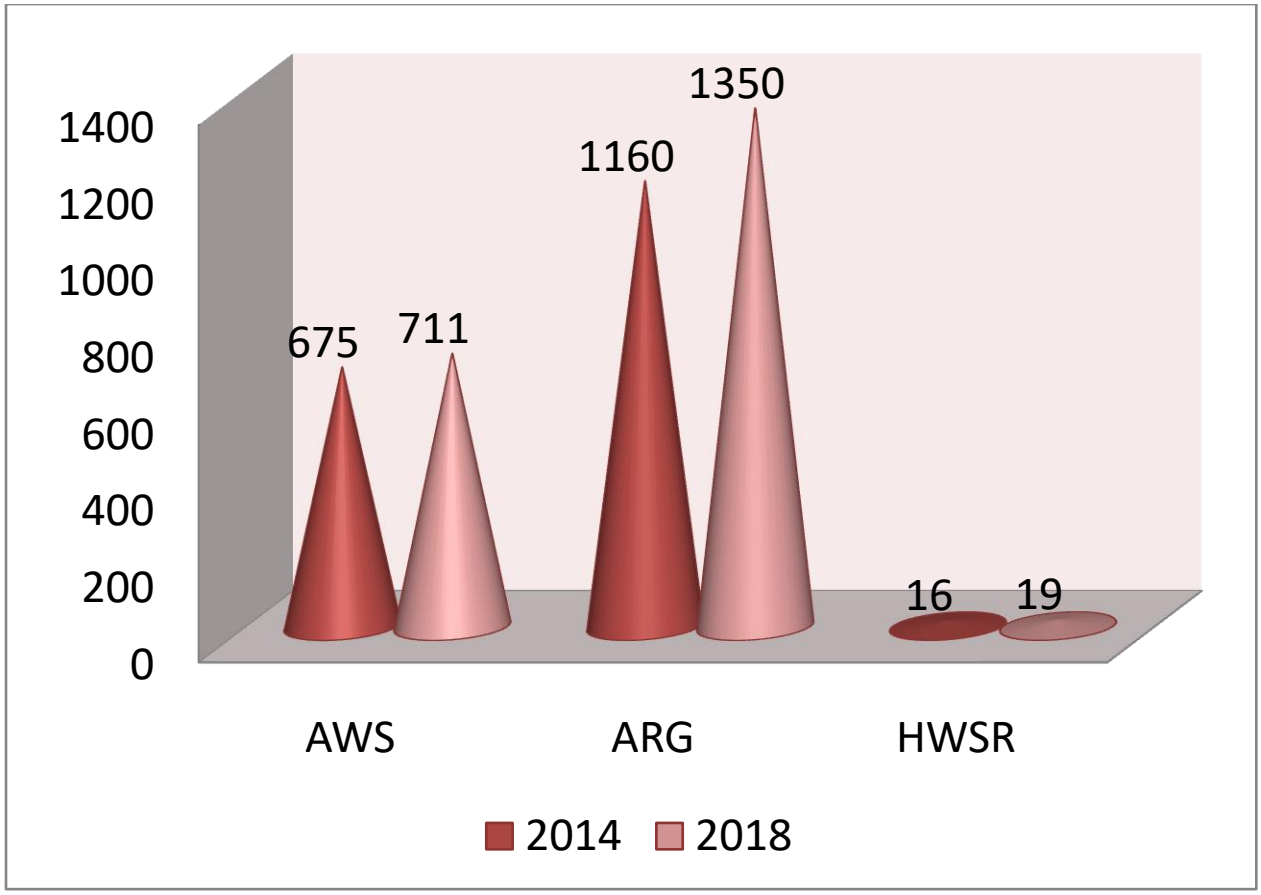


- DWR provides advance information, enhancing the lead-time.
- The conventional radars are only able to track and predict cyclones
- There has been enhancement of DWR network from 16 in 2014 to 24 in 2018
- The DWR provides detailed information on storm's internal wind flow and structure
- The X, S and C are operating band of frequency for DWR's.

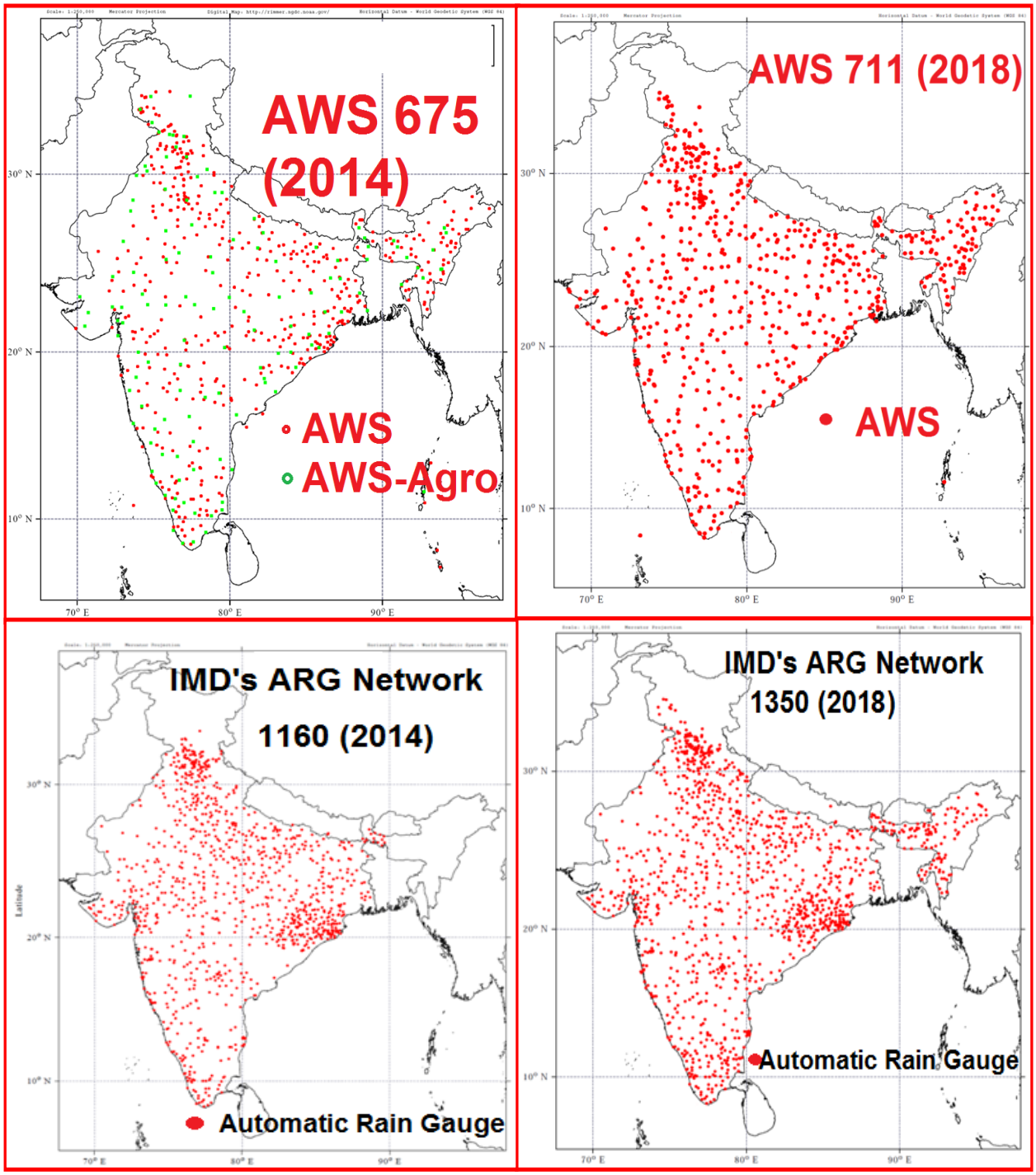


Numbers of Radars in 2014 and 2018 at various geographical regions of India

Improvement of observation through Surface observation stations



- As on 2018, IMD has a network of 711 Automatic weather stations (AWS), 1350 Automatic rain gauges (ARG) & 19 High whirl speed recorder (HWSR) against 675 AWS, 1160 ARG & 16 HWSR.
- At 200 surface meteorological observatories, mercury barometers have been replaced with digital standard barometers during 2015 – 2018.


AWS 675 (2014)
AWS
AWS-Agro
AWS 711 (2018)
AWS
IMD's ARG Network 1160 (2014)
Automatic Rain Gauge
IMD's ARG Network 1350 (2018)
Automatic Rain Gauge
30° N
20° N
10° N
70° E
80° E
90° E
Latitude

Participating Institutions in weather prediction

Times	Department Name	Mandate	Significance
1	Indian Meteorology Department	To take meteorological observations, warn against adverse weather phenomenon and to provide all meteorological based information	Consists of essential centers and divisions responsible for weather prediction and statistical data.
2	Upper Air Instruments Division	To facilitate and coordinate for all technical aspects in the field of upper air instrumentation	Consisting of hydrogen factory and laboratories. Comprise of radiosonde, pilot balloon observatories and radar systems.
3	Surface Instrument Division	To manufacture, calibrate, maintain and supply surface observation instruments	Comprise of AWS and ARG networks for near real time forecasting.
4	Agriculture Metrology Division	To minimize the impact of adverse weather on crops and to make use of crop-weather relationships to boost agricultural production	Comprise of the centre for research programmes in agricultural meteorology
5	Regional Meteorological Centre's	To take meteorological observations and to provide current and forecast meteorological information	Consist of the six regional centers across India.
6	Meteorological Centre's	To render quick and better meteorological services to the Indian States	Consists of seventeen centers across India states.
7	Cyclone Warning Centre	To provide information about cyclones using satellites, radars and other devices	Consists of coastal bulletin, fisherman warning and monsoon prediction systems
8	Indian Institute of Tropical Meteorology	To further the advancement of Research in Ocean-Atmosphere by undertaking relevant scientific programmes and collaborate with other research institutes.	Consists of Governing Council, constituted by the Government of India to oversee the policies and related issues.
9	National Centre for Medium Range Weather Forecasting	To ensure maximum data assimilation following global standards to provide optimum model analysis fields in real time	Consists of council to provide research opportunities in Numerical Weather Prediction, Diagnostic Studies, Crop Weather Modeling and Computer Science
10	CoE in Climate Modelling, IIT Delhi	To develop an India centric climate model to address certain pressing issues of climate change in India, and to educate manpower in numerical modeling of the Earth system and climate	Consists of researchers to perform the required upgrades to an existing climate model and build a better model for the Indian region through improved physical and computational implementations

Prediction Models

Numerical Weather Prediction (NWP) refers to the simulation and prediction of the atmosphere with a computer model, whereas Weather Research Forecasting (WRF) is a set of software for prediction. Objectives of NWP model is to improve the accuracy, reliability and range of weather forecasts via:

- Better understanding of atmospheric processes and their representation in numerical model.
- Assimilation of data from all available platforms including satellites/radars.
- Use of ensemble and multi-model ensemble techniques.

Coupled climate models:

A dynamical prediction system was set up based on two state-of-the-art coupled climate models. It generates reliable dynamical model predictions in short to medium range (up to 10 days), extended range (up to 20 days) and seasonal (up to one season) for monsoon prediction.

The operational statistical model

It helps in correctly predict the deficient monsoon rainfall. Accurate forecast of deficient monsoons has prompted the Government to initiate appropriate action to minimize related damage

NWP models		2014	2018
GFS (Deterministic)	Resolution	25km of Zooming	12km of zooming
	Forecast periods	Earlier it was 7 Days	Now it is 10 days
	Products for severe weather	-	• Cyclone, Heavy rain, Thunderstorm, • Fog, Cold wave, Heat wave,
GEFS (Ensemble member 20)	Resolution	-	25 km
	Forecast periods	-	Frequency is 8 days
	Products for severe weather	-	• Probability quantitative rainfall forecast. • Ensemble spread and mean forecast

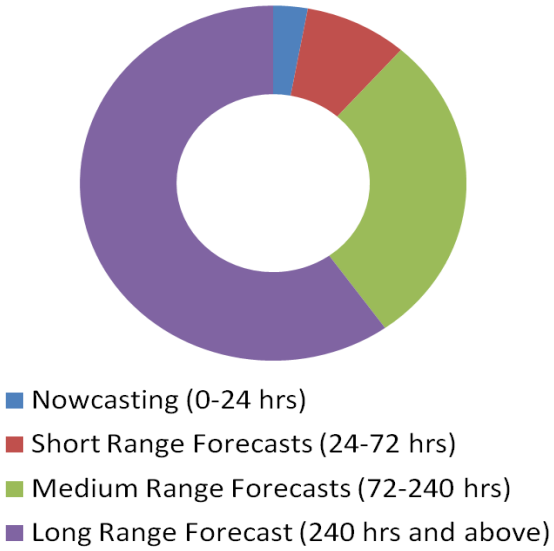
Improvement in Global NWP modeling

2013	2014-15	2016-2017
WRF-v3.4(27 km)	WRF-v3.4 double nests (upto 27 km and 9 km)	WRF-v3.6 (upto 9 km and 3 km)
WRFDA-v3.1 (upto 27km) Assimilation of conventional observations	WRFDA-v3.4 (upto 27 km) Assimilation of conventional and radar observations	WRFDA-v3.6 (upto 9 km) Assimilation of conventional and multiple radar observations

Improvement in Regional NWP modeling

The prediction skill of dynamic models has also improved considerably for Global Forecast system (GFS). Major achievements in global and regional modeling are represented.

Strategy for weather Predictions



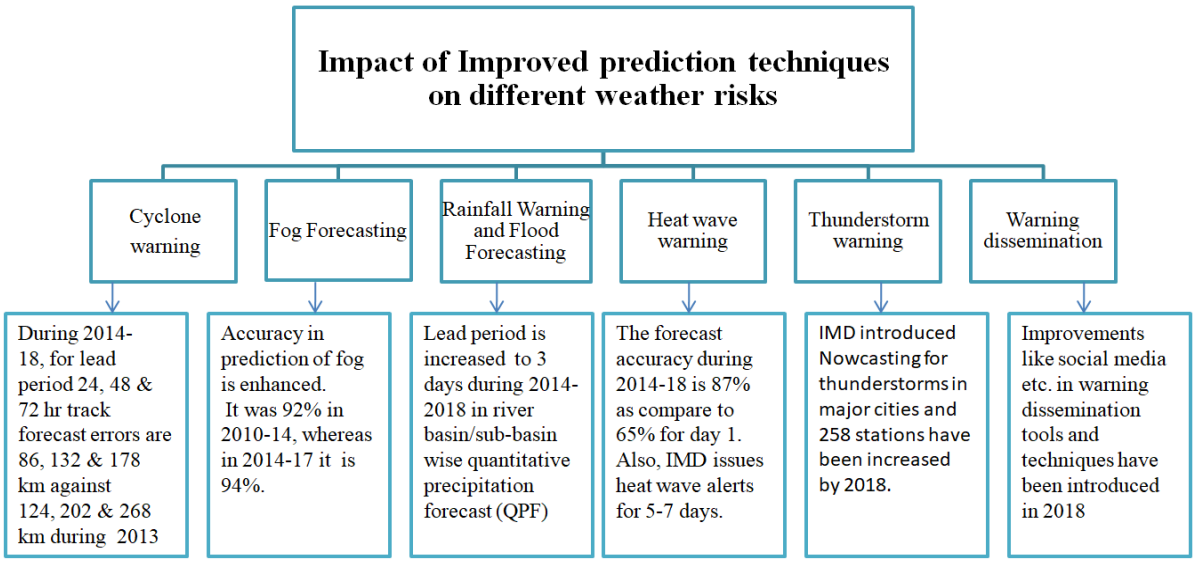
To monitor and provide warnings for severe weather phenomena alerts and prediction are issued for various lead time ranging:

Nowcasting : A short range forecast having a lead time /validity of less than 24 hrs

Short range forecasts : Forecasts having a lead time /validity period of 1 to 3 days

Medium range forecasts : Forecasts having a lead time /validity period of 4 to 10 days

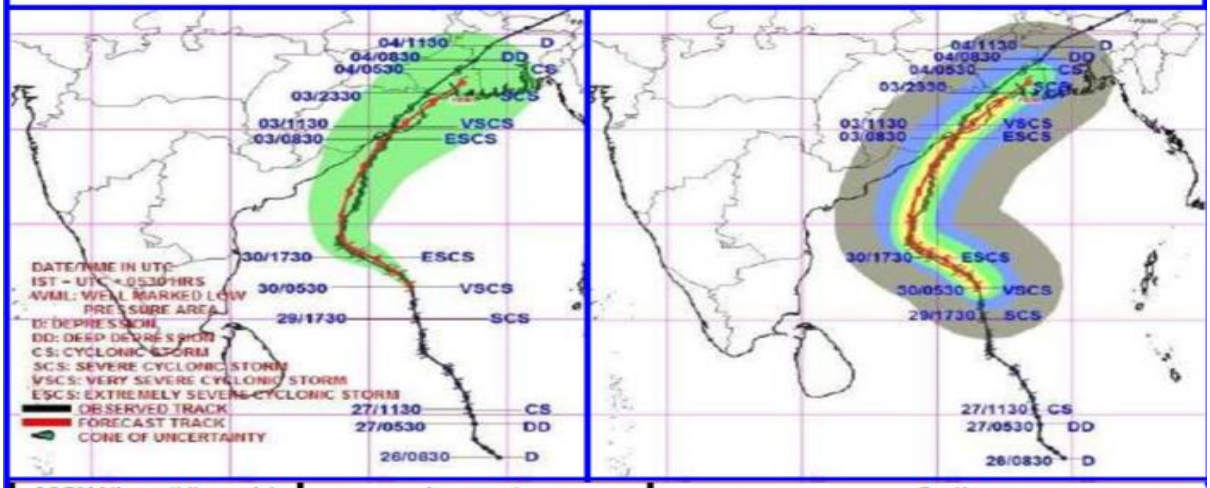
Long range/Extended Range forecasts : Forecasts having a lead time /validity period beyond 10 days



ESCS Fani: The Remarkable Prediction

- Rapid scanning of cyclone by INSAT-3DR was carried out during life cycle of Extremely Severe Cyclonic Storm (ESCS) FANI.
- The lightning data was superimposed on the satellite and radar image.
- The cyclone was continuously monitored and tracked by all the DWRs along the east coast
- Forecast was provided with latest data assimilation tools.
- IMD issued Extended Range Outlook giving 15 days probabilistic cyclogenesis forecast
- On 23rd April, it was predicted that the system would intensify into a cyclonic storm, while low pressure area formed on 25th April.
- Cone of uncertainty representing uncertainty in track was reduced by 20-30% for different lead periods due to reduction in track forecast errors during 2014- 18 as compared to that during 2009-13.

Observed Track and Forecast based on 0530 hrs IST of 30th April (72 hrs prior to landfall) with cone of uncertainty & wind distribution



MSW(knot)/kmph)	Impact	Action
28-33 /(51—62)	Very rough seas.	Total suspension of fishing operations
34-49/(63-91)	High to very high seas	Total suspension of fishing operations
50-63/(92-117)	Very High seas	Total suspension of fishing operations
≥ 64 (≥118)	Phenomenal	Total suspension of fishing operations

Excerpt of Appreciation from United Nations Office for Disaster Risk Reduction

The government's zero casualty policy for natural disasters and the near accuracy of the India Meteorological Department's early warning system have helped reduce the possibility of deaths from cyclone "FANI".