Accumulated Rainfall Variability over Different Geographical Regions

Based on GPCP Monthly Accumulated Rainfall (Jan 1979 to Oct-2015)

• Indian Region
• Europe Region
• Russian Region
• USA East Coast
GPCP Accumulated Rainfall (mm); USA East Coast Region (29N-49N, 84W-64W)
Hail occurrences during a hundred years
Diurnal variation of Hail storms in India

Monthly distribution of Hail storms in India
Observed annual mean temperature over India

All India annual mean temperature anomaly (1901-2016)
All India Monsoon Rainfall as well as all India June, July, August and September rainfall do not show any significant trend.

However, significant trends and major shifts in rainfall pattern are being noticed in smaller spatial scale.
Trends in the monsoon season rainfall for the 36 meteorological sub-divisions of India for the period 1901-2010
Low & Moderate events

Heavy events (>10cm)

V. Heavy events (>15cm)

Source: Goswami et al., Science, Dec., 2006
ML: Monsoon low
MTC: Mid-tropospheric cyclone
C: Cyclone
TS: Thunderstorm
OV: Onset Vortex

Location and Normal movement of weather System in India

- Western Disturbance
- Fog
- Off-shore vortices
- Easterly wave

Map shows the location and movement of different weather systems in India, including locations such as Jodhpur, Bhopal, Jabalpur, Darjeeling, Begampet (Hyderabad), Tiruchchirappalli, and Trivandrum.
Frequency of Heavy Rainfall Events
June to September

Heavy Rainfall Events

HEAVY RF > 10 CM
NUMBER OF HEAVY RAINFALL (10 TO 15cm) EVENTS JUN-SEPT (1901-2009)

Very HEAVY RF > 15 CM
NUMBER OF EXTREME RAINFALL(>=15cm) EVENTS JUN-SEPT (1901-2009)

Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
Rapid Emissions Reductions (RCP 2.6)
Continued Emissions Increases (RCP 8.5)
High Resolution regional climate simulations for

1. Understanding Regional Climate Process
2. Improving climate models
3. Capacity Building
4. Providing evaluated high resolution regional climate projections for land-regions worldwide
5. Linking climate modelling better with regional impact, adaptation and vulnerability assessment
Coordinated Regional Climate Downscaling Experiment (CORDEX):
The CORDEX vision is to advance and coordinate the science and application of regional climate downscaling through global partnerships

CORDEX South Asia Co-ordination @ CCCR, IITM, Pune

• Development of multi-model ensemble projections of high resolution (50km) regional climate change scenarios for South Asia
  • Generation of regional climate projections at CCCR-IITM
    • Downscaled 6 CMIP5 AOGCMs using ICTP RegCM4 regional climate model for historical period 1951-2005, and for two future scenarios (RCP4.5 and RCP8.5) for the period 2006-2099
      http://cccr.tropmet.res.in/home/cordexsa_datasets.jsp
  • Co-ordination with partner institutions for multi-model ensemble projections – SMHI, CSC, IAES, CSIRO, ICTP...

• Development of an Earth System Grid Federation (ESGF) data node at CCCR-IITM for CORDEX South Asia
  • Archival, Management, Dissemination of CORDEX South Asia data
  • Published ~2 TB of IITM-RegCM4 outputs on CCCR-IITM ESGF data node after quality assurance as per CORDEX archival specifications.

• Summary of 17 CORDEX South Asia datasets available on ESGF (~20 TB)
  • IITM-RegCM4: Hist (6); RCP8.5 (6); RCP4.5 (6)
  • SMHI-RCA4: Hist (10); RCP8.5 (10); RCP4.5 (10); RCP2.6 (5)
  • CSC-REMO2009: Hist (1); RCP8.5 (1); RCP4.5 (1); RCP2.6 (1)

• CCCR-IITM developing a global high resolution (27km) atmospheric version of the IITM Earth System Model

• CORDEX South Asia Point of Contact (PoC): Dr. R. Krishnan, Executive Director, CCCR, IITM
• CORDEX Science Advisory Team (SAT) member: Dr. J. Sanjay, Scientist, CCCR, IITM

ESGF Data Node @ CCCR-IITM
http://cccr.tropmet.res.in/home/esgf_node.jsp
Multi-Hazard Vulnerability
Numerical Weather Prediction (NWP) Modeling: Backbone for Forecasting and Warning Services

Models in 2017:
- Ensemble Pred. Tools: GEFS, UMEPS
- Global Models: GFS(T1534), Unified Model
- Regional Models: WRF, HWRF
- Nowcasting Tools: (WDSSII, ARPS Model)

Warnings Activities

By 2019:
- 12 km Global Model Ensemble prediction system
- 1-3 km Regional multi-model prediction system
- Ocean-atmosphere coupled severe weather pred. systems
- Parametric models and Expert systems – severe weather Warning up to 5-7 days, Forecast outlook up to 10-15 days
Improvement in weather forecast & warning Services

2006
• High Performance Computing Systems
  resolution of global NWP models of 35 km & regional model of 27 km.
• Validity of forecasts of 2 days and spatial resolution of meteorological subdivision.

2017
• Increased resolution of global NWP models to 12 km & regional 9 & 3 km.
• Improved capabilities for predicting high impact weather events.
• Increase in validity of forecasts 7 days and at district level. Block-wise expt. forecasts for selected blocks also introduced.
• Specialized services were introduced for Power & health sectors.
• Dedicated forecast for Pilgrimage for Shri Amarnathji Yatra, Mata Vaishno Devi, Hemkund sahib, Char Dham etc.
• Improvement in seasonal forecast of southwest monsoon season rainfall and introduction of monthly forecasts for rainfall and temperature anomalies.

2018-20
• Further improvement in forecasting skills & warning by introduction of Probablistic high resolution (12Km) Global Ensemble Weather Forecasting System (GEFS).
• Web based Forecasting system for all forecasting offices
2006
• State level Agromet Advisory from 25 state units
• No SMS services

2016
• District level advisories through 130 Agromet Field Units (AMFUs) to all 636 agricultural districts.
• Presently around 2.41 Crores farmers are directly benefitted by this service being provided through SMS.
• Regular agrometeorological information twice a day and at increased frequency is being provided through DD Kisan launched specifically by the government for benefit of the farmers.

By 2018-20
Setting up functional District Agro-meteorological field Units (DAMU) in all 660 districts.
• Improved services with additional climate & soil information for rainfed agriculture and irrigated agriculture zones of the country at block level.
Severe Weather Forecast & Warnings skills

Noticeable improvements achieved in Skills of Heavy Rainfall Forecast (False Alarm Rate reduced from 46% to 11% & Probability of Detection increased from 49% to 67% from 2002-12 to 2013-15)

Lead time of warnings increased from 3 to 5 days in respect of Rainfall, heat wave, cold wave.

Introduced new Forecast bulletin Terminology

Target for 2019: Improvement of accuracy and skill by 20% up to 7 days
IMD acts as WMO recognized Regional Centre to provide cyclone advisories to all countries in north Indian Ocean region.

Noteworthy improvement in track and intensity forecast of the tropical cyclones (24 hour forecast error in track prediction reduced from 137 km to 97 km and Landfall error from 101 Km to 56 Km during 2007-11 to 2012-16).

Probabilistic genesis Forecast up to 3 days and Track and intensity forecast up to 5 days in text and graphics

Target for 2024: Reduction in error and Improvement of skill by 20% up to 7 days
City specific forecasts

Introduced Thunderstorm /Now cast for cities covered under DWRs for 206 cities.

Introduction of Highway Forecast

Increase in city forecast from around 30 in 2006 to 324 in 2016.

Target for 2024: 600 cities and improvement in accuracy and skill by 20%
IMD : GFS MODEL (12 Km) 850 hPa WIND (kt) & RAINFALL (mm) FORECAST (24 HR)

based on 00 UTC of 21-07-2017 valid for 03 UTC of 22-07-2017

(Background does not depict political boundary)
HYDROLOGICAL SERVICES

• **2016**: Preparation of Rainfall Statistics; daily, weekly & monthly. Commended by the President of India.
• Provides real-time rainfall information by means of GIS based rainfall products.

The district-wise and river basin-wise rainfall statistics is helpful to farmers for their agricultural activities and flood forecast/water management.

2016
• Quantitative precipitation forecast (QPF) to CWC for flood forecast purposes increased from 125 to 146 river sub-basins.
• QPF increased from 5 day to 7 days from flood season 2015.
• Sub catchment wise QPF from NWP models- GFS for 7 days in addition to WRF, MME for 3 days
• QPF for 4 new catchments Jhelum, Pennar, Torsa, Sankosh which involves 12 sub catchments.

2006
• Conventional Quantitative precipitation forecast (QPF) to CWC for flood forecast purposes for 125 river basins

By 2019: Develop a State-of-the-Art Hydrological Information System and Flood Warning Support for all the Major River Basins of the Country.
• Monitor the three dimensional variability of regional hydrological cycle and assess its expected changes and impacts in the future.
• Preparation of Rainfall Statistics; daily, weekly & monthly. Commended by the President of India.
• Provides real-time rainfall information by means of GIS based rainfall products.

District-wise and river basin-wise rainfall statistics is helpful to farmers for their agricultural activities and water management.
SWFDP – Bay of Bengal

- Bangladesh
- India
- Maldives
- Myanmar
- Sri Lanka
- Thailand
- Bhutan
- Nepal
- Afghanistan
- Pakistan

Severe Weather from TCs, severe thunderstorms and monsoon:
Heavy precipitation, Strong winds
Large waves / swell, Storm Surge

Improved severe weather forecasting, warning services to disaster management (PWS) and other sectoral applications
Activities Critical for Coastal Areas

- Observing Systems for Atmospheric and Oceanic Science & Services – multi-scale networks over Land (Doppler Weather Radars; Automatic Weather Stations/Rain Gauges; High Wind Speed Recorders etc.), Sea (moored and drifting buoys, Argo Floats, ADCP and Current Moorings etc.), in-situ airborne & ship borne platforms and Satellite Based systems (INSAT, Kalpana, OCEANSAT, Megha Tropique, NOAA, EUMETSAT etc.) for real time data transmission and reception

- 24X7 system of severe weather surveillance and forecasting (continuously scaling up) - Cyclones; Tsunami and Storm Surges; other severe weather systems; River basin scale meteorological support for CWCs river flood warning system

- Continuously monitoring the pattern of sea level changes all along the Indian coastline with established 26 tide gauges.

- Vulnerability of the Coastal Zones – [3-Dimensional Geographical Information System (3D GIS) maps for the entire coastal stretch; mosaic with other available topographic and thematic high resolution maps at 1:100000; 1:25000; 1:5000 scale; shoreline change maps at 1:25000 scale] for effective emergency response, risk reduction, sustainable shoreline management and natural resource management

- Climate services information products viz. spatial monthly scale anomalies of rainfall and temperature; minimum/maximum temperature; standardized Precipitation Index (SPI) etc. along with severe weather events.
Future Plans for Coastal Areas

• Building multi-scale & multi-sensor networks for Long-term measurements of various environmental/terrestrial/marine/bio-geochemical/GHGs variables at large/regional/local/eco-system scales to capture vital signatures of the earth system response to climate variability and change

• Comprehensive multi-institutional Program for Changing Water Cycle; thermal expansion of Bay of Bengal and Arabian Sea; Sea Level Changes & coastal zone impacts; Engineering and Technical Solutions for Structural Safety of Coastal Investments

• Build Earth System Model (ESM) to treat comprehensively the coupling of various sub-systems (ocean-atmosphere; land-atmosphere; cryosphere-atmosphere; biogeochemical cycles over ocean and land; aerosols-GHGs-clouds-precipitation etc.) to improve our predictions of weather, climate, hazards, locate new living as well as non-living resources.

• Expanding services in support of four key climate-sensitive sectors, including agriculture, water, health and climate and disaster risk management for rendering customized services for societal, environmental or economic benefits

• Accelerating initiatives related to Capacity Building – for regular induction of skilled and specialized manpower
Thanks !