Forecasting extreme weather events

Shailesh Nayak
Earth System Science Organization
New Delhi

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Extreme Weather

- Extreme weather and climate events, interacting with vulnerable human and natural systems, can lead to disasters, especially in absence of responsive social system.
- Accurate and timely forecast of heavy rains, tropical cyclones, storm surges, thunder storms, hail storms, cloud burst, heat and cold waves, etc. are required to respond effectively to such events.
- Continuous improvement in observations, development of assimilation and modelling systems, understanding of various physical processes and building capacity to improve forecast have been undertaken.
Numerical Weather Prediction System

Global Observations
- SURFACE from land stations
- SHIP
- BUOY
- Upper Air RSRW/PIBAL
- Aircraft
- Satellite High Resolution Satellite Obsn Internet (FTP)
- Internet (FTP) ~600mb/dy
- RTH, IMD
- GTS ~20 Gb/dy

Data Reception
- NKN
- 24x7
- ISRO (MT) proposed dedicated link
- Observation quality checks & monitoring 4 times a day for 00,06,12,18 UTC

Global Data Assimilation
- Global Analysis Initial state
- Global Forecast Model 10 day FCST
- Global Model (22 Km resolution) once in a day for 00 UTC

Forecast Models
- Meso-scale Data Assimilation & Model
- Statistical Interpolation Model (location specific FCST)
- Visualisation

Users
- NKN
- NESDIS
- EUMETSAT
- Input ~9GB
Global observations of atmosphere, ocean, land surface, cryosphere, along with satellite and aircraft observations are processed at in real time for their further utilisation in the numerical weather prediction system. Large increase in assimilation of observations has been accomplished.

<table>
<thead>
<tr>
<th>Type of Observations</th>
<th>Avg. No. of Reports/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Surface</td>
<td>48,000</td>
</tr>
<tr>
<td>Ship</td>
<td>11,000</td>
</tr>
<tr>
<td>Buoy</td>
<td>44,000</td>
</tr>
<tr>
<td>Upper-air Sonde</td>
<td>1,500</td>
</tr>
<tr>
<td>Aircraft</td>
<td>4,20,000</td>
</tr>
<tr>
<td>Satellite Wind</td>
<td>7,00,000</td>
</tr>
<tr>
<td>Satellite Radiance</td>
<td>2,00,000,000</td>
</tr>
</tbody>
</table>
### Verification of Global Model Forecasts

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ECMWF</th>
<th>NCEP</th>
<th>NCMRWF</th>
<th>UKMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 hPa AC (Anomaly Correlation) of Geopotential Height Northern Hemisphere (Day 5)</td>
<td>0.91</td>
<td>0.89</td>
<td>0.89</td>
<td>0.91</td>
</tr>
<tr>
<td>500 hPa AC of Geopotential Height, Southern Hemisphere (Day 5)</td>
<td>0.86</td>
<td>0.83</td>
<td>0.82</td>
<td>0.84</td>
</tr>
<tr>
<td>850 hPa Wind RMSE Global Tropics (Day 3) m/s</td>
<td>2.79</td>
<td>3.01</td>
<td>3.01</td>
<td>3.12</td>
</tr>
<tr>
<td>200 hPa Wind RMSE Global Tropics (Day 3) m/s</td>
<td>6.71</td>
<td>7.63</td>
<td>7.77</td>
<td>7.18</td>
</tr>
</tbody>
</table>

**Graphs:**
- **850 hPa Winds SEP 2012**
- **RMSEV**

**Legend for bar graph:**
- NCMRWF
- UKMO
- ECMWF
- NCEP

**Graphs details:**
- The bar graph shows RMSE values for different forecast days.
- The line graph indicates RMSE values over a period from Jan-05 to Sep-12.
Forecasting Weather

• High resolution (25-km) global models, especially GFS and UKMO, demonstrate high skill up to 5 days in advance.
• GEFS (based on GFS) Ensemble Forecasts (80 Km) based on 20 members. 15 members forecast rainfall excess of 16 cm/day. Crucial input for forecasters.
• GEFS Forecast Probabilities: Forecast probabilities for 5-10 cm/day rain for the event to occur 5 days in advance.
• WRF (27, 9 and 3 km) Rainfall Regional Forecast, 3 days in advance.
• Local forecasts are based on the output of models and synoptic conditions (pressure, wind, rainfall), satellite and radar data, 3 days in advance.
• The accuracy is quantified using Correlation and Probability of Detection (POD).
• City-specific Weather forecasting.
• Nowcasting: 3 hour advance forecast using satellite (V, IR radiance), radar, etc. data.
• 24 hour advance forecast using model. CFS and UKMO models are used.
• 117 towns are being covered.
Customized Services

- Special forecasts including Hourly nowcasts of weather conditions for the smooth conduct of Amarnath Yatra, Char Dham, etc. have been provided. SMSs are sent to all stakeholders.

- Location specific seven days Forecast for Maha Kumbh-2013 issued uninterruptedly for 56 days, the entire period of Maha kumbh.
Forecasting Extreme Rainfall: Uttarakhand

NCUM: RAINFALL & WIND (600 hPa) VALID FOR 00Z18Jun2013

(a) OBS(IMD) RF & ANA WIND  (b) DAY-1 FCST  (c) DAY-3 FCST

(d) DAY-5 FCST  (e) DAY-7 FCST

Legend:
- Blue: T574
- Red: NCUM
- Yellow: UKMO

Correlation Coefficient:
- 1.0
- 0.8
- 0.6
- 0.4
- 0.2
- 0.0

Day-1  Day-2  Day-3  Day-4  Day-5
Forecasting Heavy Rainfall: Uttarakhand

Regional Forecast: Rain/thundershowers occur would occur at many places over Himachal Pradesh and Uttarakhand during next 48 hours.

Local Forecast: Rain/thundershowers in Joshimath, Badrinath, Kedarnath, Yamontri and Gangotri.

Char dham Yatra advised to be postponed by three days.
INSAT images of satellite Kalpana, showing stream of cloud from Uttarakhand rainfall region to central Eurasia.

- Recent studies suggested a physical link between monsoon intense convection over NW India and melting of Arctic Sea Ice. The pathway is through Central Eurasia by means of large scale atmospheric waves which transport heat anomalies to Arctic (Krishnamurti et al. 2013).

- An International Project under the Belmont Forum has been planned to study ‘Polar regions and Monsoon.’ The scoping Workshop has been organized in Goa in October, 2013.
Forecasting Heavy Rainfall: Gujarat

- Low pressure area associated with upper air cyclonic circulation extending up to mid-tropospheric level.
Operational Cyclone Forecast

- 4 day track forecast. Skill Improvement for 72, 48, 24 h for track: 50, 40 and 35 % in last five years.
- Ratio of severe storms to total storms over north Indian ocean has shown an increasing trend. Prediction of associated rainfall, wind velocity, surge and inundation.
- Improved observational system (Buoys, satellite, Radar and AWS), better understanding of structure of convective clouds, formation of eye and spiral rainbands for improving numerical models and forecast of associated Rainfall. Ocean-atmosphere interactions for intensity forecast.
Track forecast error (km)

Trend in improvement in track forecast (km/Year) during 2003-12

- 12 hr- ~ 50 km
- 24 hr- ~70 km

Average during last five (2008-12)

- 24 hr- 133 km,
- 48 hr-254 km
- 72 hr- 376 km

12 hr forecast error (km)
- Linear
- Multi-year

24 hr forecast error (km)
- Linear
- Multi-year

36 hr forecast error (km)
- Linear
- Multi-year

48 hr forecast error (km)
- Linear
- Multi-year

60 hr forecast error (km)
- Linear
- Multi-year

72 hr forecast error (km)
- Linear
- Multi-year

Linear (12 hr forecast error(km))

Linear (24 hr forecast error (km))
Operational Cyclone Forecast

Mean landfall point forecast error (km)

Average (2008-12)
- 24 hr: 91 km
- 48 hr: 96 km
- 72 hr: 135 km

Absolute error(kt) of maximum sustained surface wind forecast
Impact of OSCAT Winds on the Assessment of the Thane Cyclone
Assimilation of Meghatropique – Saphir (183 GHz, water vapour) Data for Neelam Cyclone
The Hydrodynamic model ADCIRC (ADVANCED CIRCULATION) is being used for the prediction of surges and associated inland inundation. ADCIRC makes use of triangular (irregular) gridded mesh for the computations. Bathymetry, topography, astronomical tides and wind stress are the input to the model. Output of the model includes sea surface elevation, depth averaged currents and inundation depth.
Climate Change and Extreme Weather

- A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events, and can result in unprecedented extreme weather and climate events.

- In a warming climate, frequency of intense rainfall events, heat waves are likely to increase over south Asia (IPCC report (AR6) 27 Sept, 2018).
Increase in Heavy Rainfall ( > 15 cm) Events
Along with the increase in annual temperatures, frequency of heat waves over India has increased.

**Top:** Days with Heat waves over the country during pre-monsoon season

**Bottom:** Days with Severe Heat waves over the country during pre-monsoon season
Climate Products

Warm Days

Cold Nights

January, 2013

Percentage of days when Max Temp More than 90th percentile

Percentage of days when Min Temp less than 10th percentile
Climate Products

Standardized Precipitation Index (SPI) is an index for monitoring rainfall situation.
Cumulative SPI indicates the cumulative effect of rainfall deficit or excess over a region. Orange and red colours indicate accumulated rainfall deficiency.
Himalayan Meteorology

- Augmentation, strengthening and integration of network of all the observations
- Develop customized high resolution NWP models
- Develop capabilities for
  - accurate forecasting of severe weather events over targeted smaller areas (selective valley sectors)
  - special forecasts (Highway, Expeditions, Pilgrimage, tourism, Agriculture, Horticulture, etc.)
  - now-casting (Pilgrimage routes Amarnath Yatra and Kailash-Manasarovar, etc.)
Observations from INSAT 3D Sounder (V, IR, temperature, humidity profiles)

INSAT-3D Sounder Radiances (mW/m²/sr/cm⁻¹)
10 August 2013 0331UTC
Cloud Physics Lab has been set up at Mahabaleshwar to study microphysical characteristics of aerosols and clouds and associated environmental conditions.

- Understanding of interaction of aerosols and clouds and rainfall process.
- Development of microphysical parameterization scheme for numerical weather prediction models
Predicting Extreme Weather

• Sustaining and integrating observations
  – Cost effective technologies to monitor pre-conditions and evolution of extreme events, which will sustain in extreme weather and climate conditions

• Multi-tiered prediction strategy
  – Probabilistic advisories based on Global Ensemble prediction system (5-7 days in advance)
  – Watch based on regional high resolution model predictions with data assimilation (1-3 days in advance)
  – Now casting based on high resolution models and assimilation of Doppler Weather Radar Data (up to 6 hours)
Concluding Remarks

- Improvement in Forecast depends on
  - Augmenting in observation systems to record vital signs of earth system which includes radar and satellites (Himalayan Meteorology, INSAT 3D, Aircraft, Modernization Phase II),
  - Understanding of earth system processes (Cloud Physics, Changing Water Cycle, Ocean-air interaction, ice-sea-air interaction),
  - Development of improved models and assimilation techniques (Monsoon Mission, Extreme Weather modeling),
  - Augmenting High Performance Computing,
  - Recruitment of appropriate manpower on a sustained basis (Advanced Training School in Earth System Science).
THANK YOU