Impact forecasting & Risk based warnings for Tropical Cyclones making landfall along the Indian coasts

Sunitha Devi. S
s.sunitha@imd.gov.in

IBF workshop: 30\textsuperscript{th} Aug. 2021

India Meteorological Department
Mausam Bhavan, Lodi Road, New Delhi-110 003.
Outline

- Introduction
- Cyclone hazards
- Typical images of cyclone damage
- Impacts by
  - Strong winds
  - Heavy rains
  - Storm Surge

On Socio-economic front

- Present practice – examples
- Recent developments – from Static to Dynamic
- Summary & future plan
Cyclones Warning Services

- IMD is mandated to monitor and issue warnings regarding tropical cyclones over the north Indian ocean for the country.

- International Responsibility:
  - IMD also acts as RSMC to provide tropical cyclone advisories to 13 countries under WMO/ESCAP Panel (Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka, Thailand, Yemen, UAE, Saudi Arabia, Qatar, Iran).
  - Acts a Tropical Cyclone Advisory Centre (TCAC) to provide cyclone advisories to Asia Pacific countries for civil aviation
  - Provides support for Global maritime Distress Support System (GMDSS) over the north Indian Ocean.
Potential Impact upon Landfall of a Tropical Cyclone

- Effect of local Tides
- Effect of local Coastal Configuration
- Low Atmospheric Pressure in the Centre
- Wind
- Rain
- Storm Surge
- Flooding

Loss of Human Life: Injuries

Damage to structures & Continent

Damage to onshore & offshore installations

Erosion of Beaches

Flooding of Low-Lying Coastal Areas

Loss of Soil Fertility from Saline Intrusion

Land Subsidence

Contamination of Domestic Water Supply

Loss of Communications & Power

Destruction of Vegetation, Crops, Livestock

Damage to Shipping & Fishing Facilities

Damage to onshore & offshore installations
Cyclone Mitigation Measures

- Reduction of cyclone disasters depends on several factors including:
  - hazard analysis,
  - vulnerability analysis,
  - preparedness & planning,
  - early warning and mitigation.

- The early warning is a major component as evident from a survey conducted for the south Asian region.

- The early warning component includes:
  - skill in monitoring and prediction of cyclone,
  - effective warning products generation and dissemination,
  - coordination with emergency response units
  - the public perception about the credibility of the official predictions and warnings.
Cyclone Hazard Prone Districts
- Frequency of cyclone
- Frequency of severe cyclone
- Probable maximum Precipitation
- Wind strength
- Storm surge

About 4-5 cyclones develop over NIO, 2-3 become severe

Mohapatra 2015
Aftermath of ESCS FANI – 3rd May 2019... Bhubaneswar
West Bengal: Ferry services have been suspended at Bichali Ghat in Kolkata.
1. Impacts of Cyclone - winds

- Damage to infrastructure (installations, dwellings), communication lines, Trees.
- Gusts – short, but rapid bursts in wind speed – main cause of damage
- Squalls – Longer period of strong wind speed – associated with the array of thunderstorms in the spiral band – cause uprooting of trees & associated damage
2. Impacts of Cyclone - Torrential rains & inland Flooding

- Unabated rains cause flash floods
- Rainwater on top of Storm Surge could aggravate the impacts
- Serious problem for people who become shelterless
- Cause large scale soil erosion & weakening of embankments
3. Impacts of Cyclone – Storm Surge

- Sea water inundates low lying areas of coastal regions, drowning human beings & livestock
- Causes erosion of beaches & embankments
- Destroys vegetation, reduces soil fertility.
Present practice - Examples
### Impact Based Forecast

<table>
<thead>
<tr>
<th>MSW (knot)/kmph</th>
<th>Impact</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>28-33 (51–62)</td>
<td>• Some breaches in Kutcha road due to flooding.</td>
<td>Fishermen advised not to venture into the open seas.</td>
</tr>
<tr>
<td></td>
<td>• Minor damage to loose/unsecured structures/kutcha embankments.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Minor damage to banana trees/coastal agriculture/ripe paddy crops due to salt spray.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Very rough seas. Sea waves about 4-6 m high.</td>
<td></td>
</tr>
<tr>
<td>34-49 (63-91)</td>
<td>• Major damage to thatched huts/kutcha roads. Minor damage to Pucca roads.</td>
<td>Total suspension of fishing operations.</td>
</tr>
<tr>
<td></td>
<td>• Minor damage to power/communication lines due to breaking of branches.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Some damage to paddy crops/banana/papaya trees/orchards</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High to very high sea waves( 6-9 m)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Sea water inundation in low lying areas after erosion of Kutcha embankments.</td>
<td></td>
</tr>
</tbody>
</table>
# EXPECTED DAMAGE AND SUGGESTED ACTION

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Damage expected</th>
<th>Action Suggested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deep Depression</strong></td>
<td>Minor damage to loose and unsecured structures.</td>
<td>Fishermen advised not to venture into the open seas.</td>
</tr>
<tr>
<td>50 – 61 kmph (28-33 knots)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cyclonic Storm</strong></td>
<td>Damage to thatched huts. Breaking of tree branches causing minor damage to power and communication lines</td>
<td>Total suspension of fishing operations</td>
</tr>
<tr>
<td>62 – 87 kmph (34-47 knots)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Severe Cyclonic Storm</strong></td>
<td>Extensive damage to thatched roofs and huts. Minor damage to power and communication lines due to uprooting of large avenue trees. Flooding of escape routes.</td>
<td>Total suspension of fishing operations. Coastal hutment dwellers to be moved to safer places. People in affected areas to remain indoors.</td>
</tr>
<tr>
<td>88-117 kmph (48-63 knots)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## EXPECTED DAMAGE AND SUGGESTED ACTION

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Damage expected</th>
<th>Action Suggested</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Extremely Severe Cyclonic Storm</strong> 167-221 kmph (90-119 knots)</td>
<td>Extensive damage to kutcha houses. Some damage to old buildings. Large-scale disruption of power and communication lines. Disruption of rail and road traffic due to extensive flooding. Potential threat from flying debris.</td>
<td>Total suspension of fishing operations. Extensive evacuation from coastal areas. Diversion or suspension of rail and road traffic. People in affected areas to remain indoors.</td>
</tr>
<tr>
<td><strong>Super Cyclonic Storm</strong> 222 kmph and more (120 knots and more)</td>
<td>Extensive structural damage to residential and industrial buildings. Total disruption of communication and power supply. Extensive damage to bridges causing large-scale disruption of rail and road traffic. Large-scale flooding and inundation of Sea water. Air full of flying debris.</td>
<td>Total suspension of fishing operations. Large-scale evacuation of coastal population. Total suspension of rail and road traffic in vulnerable areas. People in affected areas to remain indoors.</td>
</tr>
</tbody>
</table>
Different colour codes as mentioned below are being used since post monsoon season of 2006 for the different stages of the cyclone warning bulletins as desired by the National Disaster Management.

<table>
<thead>
<tr>
<th>Stage of warning</th>
<th>Colour code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclone Alert</td>
<td>Yellow</td>
</tr>
<tr>
<td>Cyclone Warning</td>
<td>Orange</td>
</tr>
<tr>
<td>Post landfall out look</td>
<td>Red</td>
</tr>
</tbody>
</table>
Why we need to further improve and re-orient the impact based weather forecasts in case of Cyclones -

- Experience of Tropical Cyclone, Titli
- Good quality forecasts from IMD
- 77 people died in Odisha due to landslides and floods
  - Disaster managers and people expected the wind and rainfall – they did not expect the land slide and flood in south interior Odisha
Impact forecasting from Static to Dynamic...
Impact-based Forecasting

An illustration on how weather information can be translated to response actions

- Relevant information from weather data is extracted and placed into the situation context to produce impact estimations;
- With potential impact information available, response scenarios can be set-up

Source: Baode Chen and Xu Tang (2014) Translating weather forecasts into impact-relevant information
Key Essentials for Impact based Forecasting
Translating hazard information into impact scenarios

- Hazard
- Exposure
- Vulnerability
- Impact/Risk

Value at Risk

Statistical - census and survey data

GIS/Geospatial – Infrastructure, settlements, land use..

Cartographic, Geological, Hydro-meteorological..

Geospatial Data – Vector and Raster

Source: Modified from Francis Ghesquiere, The Word Bank
NDMA has developed web based Dynamic Composite Risk Atlas & DSS (Web-DCRA/DSS) tool utilising-

- IMD’s cyclone track & displays it with COU & wind distribution
- Surge heights at river mouth locations, IMD observed and forecast rainfall data, CWC water level and discharge data to generate flood depth
- HWRF wind data to project wind speed distribution at various infrastructure elements to generate cyclonic wind risk assessment
- Surge water levels (INCOIS) & velocity data to generate inundation & associated velocity at infrastructure
- Flood hazard data to project inundation due to floods at buildings

- Runs risk assessment model to estimate affected population & potential damage to infrastructure from wind, surge and flood
This tool helps in generating the impact scenario, State wise as well as District, Village & tehsil wise on various coastal infra-structure exposures upto 10 m elevation including:

- Residential, Industrial & Commercial buildings
- Fire Stations
- Police Stations
- Cyclone shelters
- Educational institutions
- Airports & Runways
- Bridges
- Railway Stations
- Railway lines
- Roads
- Sea ports
- Agricultural land
- Power & Communication lines
- Drinking & waste water
- Power plants
- Oil & gas lines

<table>
<thead>
<tr>
<th>Exposure Type</th>
<th>Exposure (INR Lakhs)</th>
<th>Wind Loss (INR Lakhs)</th>
<th>Flood Loss (INR Lakhs)</th>
<th>Surge Loss (INR Lakhs)</th>
<th>Combined Loss (INR Lakhs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>12,87,089.37</td>
<td>1,88,705.79</td>
<td>30.83</td>
<td>0.00</td>
<td>1,88,705.79</td>
</tr>
<tr>
<td>Building</td>
<td>6,74,28,691.78</td>
<td>2,312.38</td>
<td>39,346.65</td>
<td>3,203.62</td>
<td>39,544.52</td>
</tr>
<tr>
<td>Essential Facilities</td>
<td>26,86,776.16</td>
<td>21.98</td>
<td>9,857.62</td>
<td>268.37</td>
<td>9,861.30</td>
</tr>
<tr>
<td>Transportation</td>
<td>1,05,24,200.23</td>
<td>30.34</td>
<td>83,645.51</td>
<td>243.73</td>
<td>83,645.87</td>
</tr>
<tr>
<td>Utilities</td>
<td>31,41,562.72</td>
<td>14.84</td>
<td>173.81</td>
<td>700.88</td>
<td>722.26</td>
</tr>
</tbody>
</table>
This helps in generating the likely impact scenario by assessing the Risk via evaluating the Hazard, vulnerability & exposure conditions in the Cyclone prone districts.

It aids in conveying advisories through web as well as Mobile App based services in local languages.

This would enhance our capability to respond to cyclones manifold, provided an efficient & quality database updating is carried out.
Summary & Future Plans

- India Meteorological Department at present provides the potential impacts associated with Cyclonic Storms based on the Historical records.

- National Centre for Coastal Research (NCCR), had developed a ‘cyclone impact index’ by creating a weighted overlay analysis of forecast precipitation & winds associated with a cyclone – overlaid with the Population data to provide a Ranking and finally the ‘Risk map’.

- IMD plans to switch over into Dynamic impact based forecasts making use of the Web DCRA-DSS tool from the ensuing Cyclone Season.
In the 50 years since Cyclone Bhola & 20 years since the Odisha Super Cyclone, the accuracy of weather forecasts has improved dramatically.

Today’s five-day cyclone forecast is as good as a three-day forecast was 20 years ago.

But the way we communicate their risks and impacts needs further improvement.

Attempts are on with other relevant stakeholders & user agencies to provide the impact based forecasts & also to develop Standard Operating Procedures as per the user requirement towards building resilience.