USE OF SATELLITE DATA AND PRODUCTS FOR MONITORING AND PREDICTION OF THUNDERSTORMS AND TROPICAL CYCLONES

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Weather Systems affecting India

ML: Monsoon low
MTC: Mid-tropospheric cyclone
C: Cyclone
TS: Thunderstorm
OV: Onset Vortex

Easterly wave

AOMSUC – 10, 2-7 December, 2019 – Melbourne, Australia
Seasons

Winter
• January-February
• Western Disturbances, Snowfall, Fog

Pre-Monsoon
• March-April-May
• Thunderstorms, Lightning, Cyclones

Monsoon
• June-July-August-September
• Rainfall, Floods, landslides

Post-Monsoon
• October-November-December
• North-East Monsoon, Cyclones
Very Severe Cyclonic Storm Bulbul
Very Severe Cyclonic Storm Bulbul

- Death: 14 people in India, 12 people in Bangladesh
- Loss of Rs 23,811 crore in devastation
- Affected around 35 lakh people
- Power department: loss of Rs 597 crore
- 14,89,924 hectare of agricultural land have been damaged
Global Annual Occurrence of Tropical cyclones
Tropical Cyclones Monitoring Centres

member countries of RSMC New Delhi: India, Bangladesh, Myanmar, Pakistan, Sri Lanka, Thailand, Maldives, Oman, UAE,
## Classification of Low Pressure Systems

<table>
<thead>
<tr>
<th>Low Pressure System</th>
<th>Abbreviation</th>
<th>Wind Speed Associated (Knots)</th>
<th>T.No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Marked Low</td>
<td>WML</td>
<td>&lt; 17</td>
<td>1.0</td>
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<tr>
<td>Depression</td>
<td>D</td>
<td>17-27</td>
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</tr>
<tr>
<td>Deep Depression</td>
<td>DD</td>
<td>28-33</td>
<td>2.0</td>
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<tr>
<td>Cyclonic Storm</td>
<td>CS</td>
<td>34-47</td>
<td>2.5, 3.0</td>
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<tr>
<td>Severe Cyclonic Storm</td>
<td>SCS</td>
<td>48-63</td>
<td>3.5</td>
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<tr>
<td>Very Severe Cyclonic Storm</td>
<td>VSCS</td>
<td>64-89</td>
<td>4.0, 4.5</td>
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<tr>
<td>Extremely Severe Cyclonic Storm</td>
<td>ESCS</td>
<td>91-119</td>
<td>5.0, 5.5, 6.0</td>
</tr>
<tr>
<td>Super Cyclonic Storm</td>
<td>SuCS</td>
<td>≥120</td>
<td>&gt;6.5</td>
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</table>
## Global annual frequency of tropical cyclones

<table>
<thead>
<tr>
<th>S.No.-</th>
<th>Basin</th>
<th>Seasonal period</th>
<th>Average annual frequency of TCs</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(MWS ≥ 34 knots)</td>
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<tr>
<td>1</td>
<td>Atlantic</td>
<td>June-November</td>
<td>9.7</td>
</tr>
<tr>
<td>2</td>
<td>Northeast Pacific</td>
<td>May-November</td>
<td>16.5</td>
</tr>
<tr>
<td>3</td>
<td>Northwest Pacific</td>
<td>April – January</td>
<td>25.7</td>
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<tr>
<td>4</td>
<td>North Indian</td>
<td>April-December</td>
<td>5.4</td>
</tr>
<tr>
<td>5</td>
<td>Southwest Indian</td>
<td>October-May</td>
<td>10.4</td>
</tr>
<tr>
<td>6</td>
<td>Australian Southeast Indian</td>
<td>October-May</td>
<td>6.9</td>
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<tr>
<td>7</td>
<td>Australian Southwest Pacific</td>
<td>October-May</td>
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<tr>
<td></td>
<td><strong>Global</strong></td>
<td></td>
<td><strong>83.7</strong></td>
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</tbody>
</table>
Satellite based monitoring

**INSAT-3DR**
- 74°
- 30 mins Scan
- 6 Channel Imager + 19 Channel Sounder

**INSAT-3D**
- 82°
- 30 mins Scan
- 6 Channel Imager + 19 Channel Sounder

**METEOSAT-8**
- 41.5°
- 10 mins
- 12 Channel Imager

**METEOSAT-8**
- 41.5°
- 10 mins
- 12 Channel Imager

**METOP A, B, C**
- Scatsat-1

**Microwave**
- SSMI
- SSMIS
- GPM
- AMSU

**Visible**

**Enhanced**

**IR**

**Scatterometer**

**Microwave**
Satellite based techniques

Vernon Dvorak (circa: late 1970s).

Locate System

Estimate Intensity

Data T No.

Model Expected T No.

Pattern adjusted Model T No.

Pattern recognition

Choose best estimate

Apply constraints

T No.

Final Intensity
Limitations

➢ Dependence on IR at Night
➢ Lack of Enough ASCAT observations
➢ Lack of Enough Microwave passes
➢ Subjectivity Involved
➢ Limited Success of ADT
➢ No Validation against Aircraft Observations over Indian Ocean
ASCAT imagery for Hikaa
Fani Cyclone Microwave imagery
Rapid Scan Animation
Microwave based study of Cyclones

The difference in location of centres based on estimates of Navy, NRL using microwave imageries and estimates of satellite Meteorology Division satellites is higher (more than 100 Kms) when intensity is T1.0 or T1.5. It gradually decreases with increase in intensity of the CD. Average difference in centres estimated by Satellite Meteorology Division of IMD and SSD NOAA based on various microwave imageries varies from 17 Kms. to 91 Kms.

There is also difference in location of centre of CDs by SSD, NOAA and Navy,NRL. The average difference is 72 Km.
MCS Associated with TCs

IR images

CTT contours of TCs
MCS Associated with TCs

• The process of cyclogenesis involves the clusters getting organized and coming closer to each other, resulting in decrease in distance between centre of TC and the clusters.

• There is increase in average distance of clusters from the centre of TC with respect to increase in intensity up to T2.5–T3.5. After that distance decreases with increase in intensity as the cloud pattern changes to the CDO or eye pattern.

• The convective clusters rotate anticlockwise around the centre of vortex during the life cycle of TC. However, it gets disrupted when there is interaction of TC with the land surface.

• Distance between the clusters remains almost same during genesis and growing phase, and it gradually decreases during mature phase of TC.

• The area of convective clusters increases from genesis phase till the intensity reaches T3.0. Thereafter, it decreases gradually with increase in intensity.
### Advances in Cyclone Forecasting: Track forecast skill (%)

#### Average during last five years (2014-18)
- **12 hr**: 54.8%
- **24 hr**: 58.2%
- **36 hr**: 67.9%
- **48 hr**: 70.3%
- **60 hr**: 72.6%
- **72 hr**: 74.1%

#### Improvement in skill from 2009-13 to 2014-18
- **12 hr**: 24%
- **24 hr**: 22%
- **36 hr**: 24%
- **48 hr**: 18%
- **60 hr**: 15%
- **72 hr**: 12%

### Annual Track Forecast Skill (%)

![Annual Track Forecast Skill Graph](image)

### (b) Track Forecast Skill (%)

![Track Forecast Skill Bar Chart](image)
**Advances in Cyclone Forecasting:**

**Improvement in Landfall Point forecast**

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<th>Lead</th>
<th>Error</th>
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<tr>
<td>12 hr</td>
<td>26.5 km</td>
<td>24 hr</td>
<td>46.6 km</td>
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<tr>
<td>36 hr</td>
<td>44.1 km</td>
<td>48 hr</td>
<td>69.7 km</td>
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<tr>
<td>60 hr</td>
<td>88.9 km</td>
<td>72 hr</td>
<td>104.3 km</td>
</tr>
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**Reduction in Landfall point forecast error from 2009-13 to 2014-18:**

- 12 hr: 32%,
- 24 hr: 38%
- 36 hr: 53%
- 48 hr: 29%
- 60 hr: -6%
- 72 hr: 15%

**Annual Average Landfall Point Error (km)**

![Graph showing annual average landfall point error](image)

**Comparative Average Landfall Point Error (km)**

![Bar chart comparing average landfall point error](image)
Thunderstorm over Delhi

(Traffic jam on a Delhi road after the storm)
Severe Thunderstorm over Bihar on 21 April, 2015
Example
Example

Hyderabad
6 May 2016
Lightning

Animation (last 9 hours)

Still Image (Latest 15 minutes)

[Images of maps showing lightning activity]

Lightning Products

- Lightning Animation
  - Animation | KML
  - RealTime | RealTime-15mins | RealTime-30mins
  - Previous Day

- Real Time Amplitude
  - Total | C-C | C-G

- Real Time Count
  - Total | C-C | C-G

- Last 3-hours Amplitude
  - Total | C-C | C-G

- Last 3-hours Count
  - Total | C-C | C-G

- LMI Based Lightning
  - Real Time Count | Last 3-hours Count

AOMSUC – 10, 2-7 December, 2019 – Melbourne, Australia
Radar + Lightning + Satellite on single platform
Advantages:
- Available Day and Night
- Dust Displacement monitoring at high temporal resolution.
- Allows for detection of water vapour boundaries in the lower troposphere.
  (Pinkish-DRY) (Blue – (Moist) air mass )

Limitations:
- Height or concentration of dust can not be determined
- Visibility also can not be ascertained

1. Dust
2. Dense convective Clouds
3. Thin Cirrus Clouds
4. Thick mid-level (Alto / nimbo-stratus) clouds – Yellow

AOMSUC – 10, 2-7 December, 2019 – Melbourne, Australia
Satellite based nowcasting
Rapidly Developing thunderstorm
Nowcasting products generated using NWC-SA
✓ an algorithm for tracking and forecasting radiative and morphological characteristics of *Mesoscale Convective Systems*” (MCSs)
✓ through their entire life cycles using geostationary satellite thermal channel information (10.8 µm).
The main steps of the algorithm are the following:

✓ A cloud cluster detection method based on a size and temperature threshold
✓ A statistical module to identify morphological and radiative parameter of each MCS
✓ A tracking technique based on MCS overlapping areas between successive images
✓ A forecast module based on MCS evolution in previous time steps

There are different studies based on identification of MCS:

➢ Maddox (1980)
➢ Torres (2003)
➢ Vila (2005)

AOMSUC – 10, 2-7 December, 2019 – Melbourne, Australia
Overall Validation Result

3 hour fcst

(a) AAE of forecast of minimum CTBT of Cloud Cluster

(b) RMSE of minimum CTBT

(a) AAE in prediction of the size of the cell

(b) RMSE in prediction of the Size of the Cell

Actual TIR1 Image
Appreciation from Government of West Bengal and Government of Bangladesh for cyclone BULBUL forecast
THANK YOU
Fani Cyclone Microwave imagery
**MCS Associated with TCs**

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<th>Characteristic</th>
<th>Threshold</th>
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<tr>
<td><strong>Size of MCC</strong></td>
<td>A: Cold cloud shield with continuously low IR temperature ≤ -30°C must have an area ≥ 100000 km$^2$</td>
</tr>
<tr>
<td><strong>Initiation of MCC</strong></td>
<td>Size and intensity definitions (A and B) are satisfied. Initiation for MCCs occurred when the IR convective cloud shields reached minimum initiation size of 10000 km$^2$</td>
</tr>
<tr>
<td><strong>Development of MCC</strong></td>
<td>Size definitions A and B must be met for a period ≥ 6h</td>
</tr>
<tr>
<td><strong>Life Duration of MCC</strong></td>
<td>Time in hours from the initiation stage of an MCC to its dissipation or termination stage.</td>
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**MCS Associated with TCs**

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