RADAR INPUTS

TC MONITORING & PREDICTION

B. Arul Malar Kannan
Scientist
ba.kannan@imd.gov.in

Discussion with WMO-ESCAP-II meet
Predictability – Novelty – Vagaries
swirling moist air mass
Resembling a coiled snake

Role Mechanism: CISK

\[ P = f (\zeta + 5) (S_z + 3)^{-1} E \left( \partial \theta_e / \partial p + 5 \right) (RH-40)/30 \]

Threshold 73 \times 10^{-8} \text{ Cal}^\circ \text{Ksec}^{-1} \text{Cm}^{-3}

Nomenclature

<table>
<thead>
<tr>
<th>Wind</th>
<th>Wind Speed</th>
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<tr>
<td>Low</td>
<td>&lt; 17kt</td>
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<tr>
<td>Depression</td>
<td>17kt – 27kt</td>
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<tr>
<td>Deep depression</td>
<td>28kt – 33kt</td>
</tr>
<tr>
<td>Cyclonic storm</td>
<td>34kt – 47kt</td>
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<tr>
<td>Severe cyclonic storm</td>
<td>48kt – 63kt</td>
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<td>Very severe cyclonic storm</td>
<td>64kt – 90kt</td>
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<tr>
<td>Extremely severe cyclonic storm</td>
<td>91kt – 119kt</td>
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<tr>
<td>Super cyclonic storm</td>
<td>120kt and more</td>
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</table>

Wind

- Low: < 17kt
- Depression: 17kt – 27kt
- Deep depression: 28kt – 33kt
- Cyclonic storm: 34kt – 47kt
- Severe cyclonic storm: 48kt – 63kt
- Very severe cyclonic storm: 64kt – 90kt
- Extremely severe cyclonic storm: 91kt – 119kt
- Super cyclonic storm: 120kt and more

Transition from very strong winds to light winds at the outer edge
OBSERVED by Radar

- System pattern/features
  - Shape
  - Cloud cover and type
  - Spread
  - Orientation
  - Intensity

- System Parameters
  - Location
  - Centre
  - Eye (dia. & features)
  - RMR, RMW

- System Tendency & Movement

- Other Relevant Derived info.
  - Wind Fields
  - RF
  - Turbulence
Radar observed Cyclone features

S. Ragavan, 1985 WMO 26, composite of many observed systems
Radar observed Cyclone features

The Radial Measured Wind has the following convention in accordance to frequency red shift:

- Incoming wind: Blue [Cool colours -ve]
- Outgoing Wind: Red [Warm colours +ve]

If an Anti-clock-wise rotational vortex [Cyclonic - in the northern Hemisphere] is to the south-east of the radar the upper D has to be with cool coloured and the lower D with warm colours.
Movement prediction

- Squall line indicator
- Squall line movement (Gust front, Bright band)
- Automated track
- Playback & extrapolate
Cyclone movement
Probable movement
Center identifying

- Meighen’s method
- Logarithmic spiral
- Velocity doublet
- Zero isotach line
- Animated Sequence

• Intense TC's shall be even without an eye (Weatherford and Gray 1988).
• Cyclone too close - partial eye is observed - sub-refraction (Raghavan etal 1980)
• The farther side is not usually seen - ray attenuation
• Eye of intense TC tends to be circular, Ellipses/polygons/irregular shapes are common (Lewis and Hawkins 1982, Muramatsu 1986).
• The eye shape varies with time and also rotate around center.
• Eye distorted due to radar observational limitations, and rotation may be spurious.
Meighen's method yields a different center position and a different eye size. Fixes obtained by his method gives smoother track.
Fixing of centre

Logarithmic spiral of CS reveals the system centre through spiral fit

Each organized spiral may have a different center

Cross angle is considered to be reflecting the intensity and organization of the system

\[ r = Ae^{\theta \tan \alpha} \]

System intensification – eye reveals

During eye formation the inner most SCS has cross angle zero
Radar Cyclone center: 13.6325°N  81.4065°E
Center Log spiral and Meighen’s
Wind Analysis
Fixing of centre
WIND FIELD

Blaze of Origin:

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<tr>
<th>Name</th>
<th>Date</th>
<th>Time (UTC)</th>
<th>Latitude</th>
<th>Longitude</th>
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CROSSED COAST NEAR TO NAGCHILPATNA ROUND MID-NIGHT ON DECEMBER 15

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<td>/</td>
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<td>D</td>
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An axisymmetric vortex can ideally be considered to be a modified Rankine Vortex (Rankine 1901).

Range-aliased echoes may confuse the center-finding algorithm.

Simulation is for idealised vortex. Generally vortex asymmetric and eye wall incomplete. Localised shear zone confuses while looking for the couplet.
PPI(V) & VVP

File: 200706190530430.png
Type: PPI(V)
Range: 30.0 km

File: 200706190530476.png
Type: VVP
Range: 30.0 km

19.06.2007
05:30:34

CHENNAI
Scan R: 250 km
Scan Res: 0.50 km
Disp R: 30 km
Disp Res: 0.150 km
PW: Short
PRF: 600 / 450
AS: 8.50 deg/s
TS: 39
RS: 2
CC: Doppler 0
SQI: 0.35
CSR: 15.0 dB
LDG: 2.0 dB
AZ: 0.0-359.0
EL: 0.0 deg

CDR Chennai
WIND ANALYSIS
Phailin (Oct 2013)
Eye wall height about 13 km, eye seen at around 490 km
Doppler Velocities
Wind Analysis

RADAR versus CIRCULATION

ROTATION

CONVERGENCE

DIVERGENCE

INDIA METEOROLOGICAL DEPARTMENT
Assymetric Vortex - Movement
Fixing of centre
CENTRE VARIATIONS

Satellite (VIS) – Radar Overlay

भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT
CENTRE VARIATIONS

Satellite (VIS) – Radar Overlay

08:25:28 Z
29 DEC 2011
TENDENCY
Useful Products (PCAPPI)
Useful Products (VVP)
Limitations & overcoming

- Type of Radar
- Anomalous propagation
- Signal interference
- Clutter mitigation
- Atmospheric Attenuation
- Earth curvature
- Nyquist Velocity & (Doppler) dilemma
- Beam width resolutions
TYPE OF RADAR Sensitivity Issues

- With increased interaction/ influence of atmosphere at higher frequencies, sensitivity increases provided all other factors are identical (Power transmitted, beam width, scattering mechanism etc.)

**Sensitivity of radar bands in decreasing trend:**

- W, V, Ka, K, Ku, X, C, S, L

Study at Darwin: A Radar System Designed for Validation of Cloud Resolving Models Pavlos Kollias, Atmospheric Science Division, Brookhaven National Laboratory
Radar limitations and overcoming - INTERFERENCE & Propagation

1. Ground Clutter
2. Sea Clutter
3. Anomalous Propagation
4. Folding
5. Rail-Interference
   a. Weather Signal from Cloud
PROPAGATION

\[ \phi_h^2 - \phi_0^2 = -2h/R_e \] with \( R_e = kR \) where \( k = \left[ 1 + \frac{R}{n_0 dh} \right]^{-1} \)

<table>
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<th>( K )</th>
<th>RI gradient</th>
<th>Total Ray curvature</th>
<th>Virtual earth</th>
<th>Atmospheric refraction</th>
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<td>( dN/dh &gt; 0 )</td>
<td>Moves up</td>
<td>More Convex</td>
<td>Sub refraction</td>
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<td>1</td>
<td>( dN/dh = 0 )</td>
<td>Moves up</td>
<td>Actual</td>
<td>Sub refraction</td>
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<td>&gt;1</td>
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<td>Moves up/down</td>
<td>Convex/flat/concave</td>
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<td>0 &gt; dN/dh &gt; -39</td>
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<td>-39</td>
<td>Moves up</td>
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<td>Normal refraction</td>
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<td>Moves down</td>
<td>Less convex</td>
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<tr>
<td>-157</td>
<td>Moves down</td>
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<td>&lt;-157</td>
<td>Down</td>
<td>Concave</td>
<td>Super refraction (Ducting)</td>
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</table>

\[ h = \sqrt{r^2 + R_e^2 + 2rR_e \sin \phi - R_e^2 + H_0} \]
(also \( h = \sin \phi + r^2/2R_e + h_o \))

\[ R_{\text{horizon}} = \sqrt{2R_e h_t} + \sqrt{2R_e h_r} \]
Radar Limitations and Overcoming Curvature

\[ h = \sqrt{r^2 + (kR)^2 + 2rkR \sin \theta} - kR + H_0 \]
Curvature Effects center

File: 2008042812570540.ppz
Type: PPI(Z)
Range: 600.0 km

28.04.2008
12:57:05

dBZ
- 46.7 - 50.0+
- 43.3 - 46.7
- 40.0 - 43.3
- 36.7 - 40.0
- 33.3 - 36.7
- 30.0 - 33.3
- 26.7 - 30.0
- 23.3 - 26.7
- 20.0 - 23.3
- 16.7 - 20.0
- 13.3 - 16.7
- 10.0 - 13.3
- 6.7 - 10.0
- 3.3 - 6.7
- 0.0 - 3.3

CHENNAI
Scan R : 600 km
Scan Res: 1.00 km
Disp R : 600 km
Disp Res: 3.000 km
PW : Long
PRF: 250 / 0
AS : 6.00 deg/s
TS : 41
RS : 1
CC : Doppler 10
SQI: 0.15
CSR: 15.0 dB
LOG: 3.0 dB
AZ : 0.0-359.0
EL : -0.2 deg

CDR Chennai
Attenuation Artifacts
Rayleigh scatter Radars Attenuation in clear air

10x difference in attenuation between Ku-Ka (favorable DWR- if beams matched)
Radar limitation overcoming FOLDING (RANGE)

\[ R_u = \frac{c}{2 \times \text{PRF}} \]

Range folded  actual
Radar limitation overcoming
FOLDING (VELOCITY)

\[ V_N = \frac{\lambda}{4 \text{ PRF}} \]

Velocity folded  actual

[Diagram showing radar outputs and mathematical relationship]
(i) DWR Chennai operational wavelength is 10.4348cm: The requirement is to get range as well as velocity till around 475km. To attain this unambiguous range of 475 the PRFh is 315Hz. Using Maximum unfolding through Dual PRF (ie 4:5) the PRF combination PRFh:PRFl :: 315:252 has been arrived.

This would give an unambiguous velocity of 32.87m/s. As this ratio of PRF has lot of jitters, IIR clutter filtering has been kept off as would lead to losing of good valid signature, further signal qualifiers of SQI reduced to 0.1, LOG 1.5. Further the scan angles have been chosen to be -0.4, 0.2 & 1 degree that the volume resolves upto 15km height. Beam height diagram placed
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NIVAR – Abnormal Features

Multiple Eye....[Earlier reported Mukherjee etal June 1976]
Cyclone Morphology

MIMIC: Morphed Integrated Microwave Imagery at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) (MIMIC)

MIMIC: A New Approach to Visualizing Satellite Microwave Imagery of Tropical Cyclones

Unlike conventional microwave imagery that is updated frequently, MIMIC imagery acknowledges the limitations of available data and generates an enhanced view of the storm's structure and development. Specifically, the time variability of the storm's structure allows visualization of historical changes. In tropical cyclone applications, the MIMIC imagery can provide unique insights into the evolution of a storm.
HWSR - Wind plot of Cuddalore (Between 2020-11-25 18:30:00 and 2020-11-25 19:30:00)

Max Wind

3 Min Wind

1 Min Wind

AWS - Wind & Pressure plot of Puducherry (Between 2020-11-25 19:15:00 and 2020-11-25 21:00:00)
This material is provided as a part of the Training/discussion, and not for public distribution or commercial use.

Most of the imageries incorporated, are owned by India Meteorological Department, GoI for use of those images, prior permission of IMD shall be obtained.

Credits to:
1. India Meteorological Department (IMD), MoES, Government of India
2. BMI (COX bazar data of SIDR)
3. COMET training module
4. NOAA, NASA
5. Web resources
Of course, my beloved family too... that silently toils at the background in keeping my spirits alive

Books for a better understanding of weather radars & its applications:
7. Radar for Meteorologists by Ronald E. Rinehart, Rinehart Publications, USA
8. Polarimetric Doppler weather radar - Bringi & Chandrasekar, Cam. UP, USA
9. Doppler Radar and Weather Observations-Doviak and Zrnic, Academic Pr,