Statistical Characteristics of Convective Clouds over the Western Ghats Derived from X-band Radar Observations

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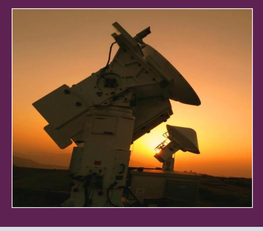

Background, Data, and Methodology

Orographic precipitation over Western Ghats (~6000 mm annual): Despite one of the largest rainfall areas of the SW monsoon, observations on convection lifecycle are lacking.

Few ground-based studies: [e.g. Konwar et al (2014); Deshpande et al (2015), Das et al (2017), Kalapureddy et al (2017)]

But most studies confined to long-term satellite data: [e.g. Romatschke and Houze, 2011, S. Kumar et al., 2014; Shiege et al 2016; Kumar and Bhat 2016]

Satellite lack time-continuous aspects of convection: formation, growth, duration, movement.

Number of questions remain unanswered:

Where does convection initiate in the Western Ghats?
What is the average size of convective clouds?
What are their propagation aspects, average lifetime, vertical structure and diurnal cycle?

Continuous X-band radar observations (pertaining to small-scale convective state) at Mandhardev would provide the best test bed to study these questions.

TITAN cell-tracking algorithm is used to identify, track convective storm (Dixon & Wiener 1993). "Storm (or cell)" is a 3D contiguous region in space with reflectivity > 35 dBZ at 2 km altitude above the surface, and volume exceeds 15 km³. A storm must last for a minimum of two successive radar scans (>24 min).

Cell Occurrences & Large Scale features

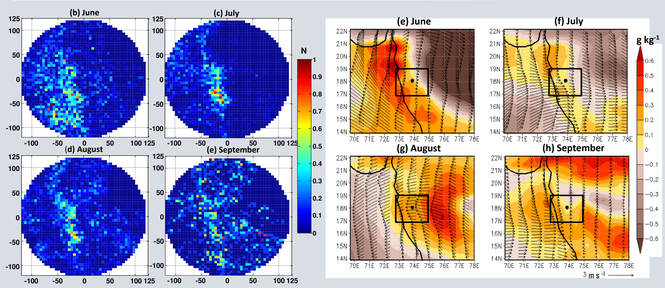

Figure 1 : Month wise variation in Storm Occurrence (a-d) and anomalies of surface Specific Humidity. and Wind (e-h).

Spatial distribution of storms influenced by anomalies of surface specific humidity and wind fields

Convective Depth and Intensity

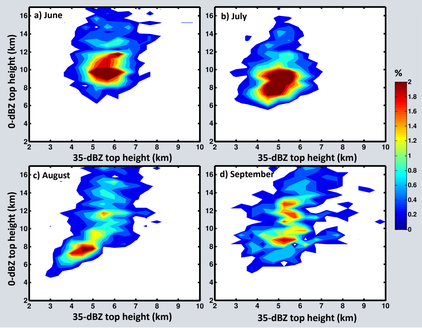

Figure 2 : Relative frequency distribution of convective cells as a function of 0 dBZ and 35 dBZ top heights for each months of monsoon 2014.

0 dBZ Top : Depth of Storm

35 dBZ Top : Intensity of Storm

For wide range of 0dBZ Tops, height attained by 35 dBZ is maximum 7km. June corresponds to the period with deep storms having intense internal structures.

Spatial Distribution of Convective Cell Properties

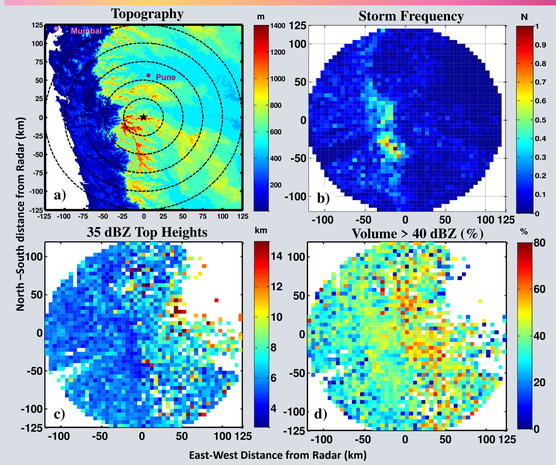

Figure 3: a)Topography around IITM X band radar b) Storm Occurrence Frequency c) Storm Top Heights d) Percentage volume of Storms with reflectivity > 40 dBZ

IITM's X-band (precipitation) and Ka-band(cloud) Doppler radars are deployed at Mandhardev (1.3Km AMSL) on the windward side of the Western Ghats

Increased storm frequency over the Windward slopes of mountains compared to coastal and Lee sides highlights orographic influence on storm activity

Shallow storms (<6 km) on windward slopes and deep cells (>7km) dominates the Lee side. Systems over lee side deeper.

Intense storms with higher volumes of cells exceeding 40 dBZ on Leeward sides, less intense storms with lesser cell volumes exceeding 40 dBZ on windward side

Effect of Underlying surface on Convective Cell Onset

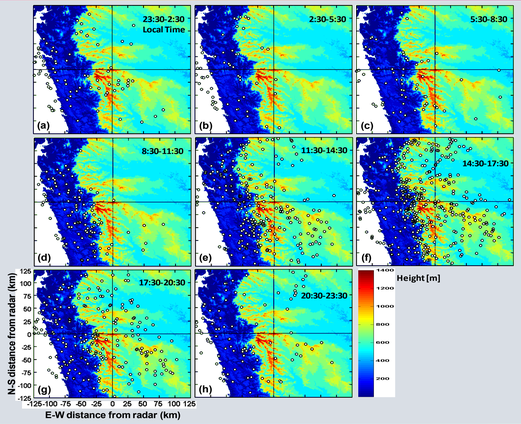

Figure 4: Temporal variation of Convective Cell Onset w.r.t. Underlying topography during JJAS 2014.

•In order to identify the occurrence of cumulus convection and the processes that trigger or suppress it, the Convective cell onset is studied.

•Convective cell onset is defined as the first time occurrence of convective cell with reflectivity of 35 dBZ. Therefore, it can also be called as single newly-formed storm.

•An eastward progression of convective activity from upstream the barrier through windward slopes of mountains over to the lee side is observed.

• Cell onset times depend on the combination of local time and the underlying surface.

Cell Kinematics

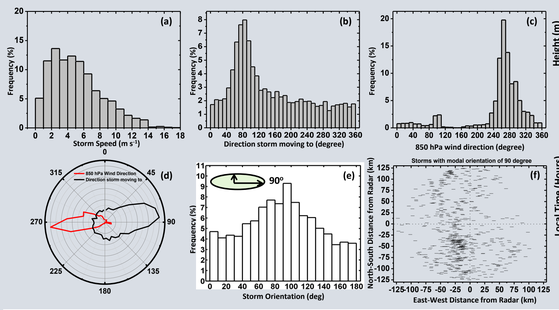

Figure 5: Frequency Distribution of a)speed b) storm direction c)wind direction at 850 hPa d) wind rose of storm and wind directions d) Storm orientation e) storms with modal orientation of 90 degree.

Slow Storms: 3-5 ms⁻¹; Storm move east-west; steered by large scale wind at 850 hPa; modal orientation of 90° parallel to Eat-West ridges, influence of ridge topography in aligning storms parallel to them.

Reduced Dimension Analysis

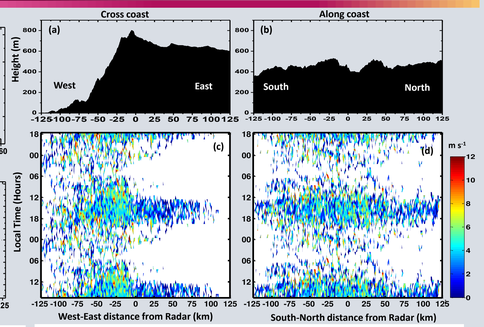

Figure 6: Topography along a) Cross coast and (b) along coast dimensions and Diurnal Hovmoller along c)cross coast and d)along coast dimensions.

Slopping pattern in cross coast direction : Systematic progression. Horizontal pattern in along coast direction : slow movement, unorganized convection

Frequency Distribution: Cell Properties

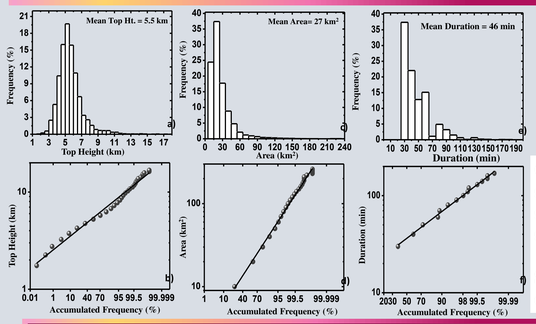

Fig 7: Frequency distribution of 35-dBZ Top Heights, Area and Storm Duration

Convection has shallow depth, sub-MCS nature, short lifetime

Storm properties obey Lognormality

Diurnal Variation of Cell Properties

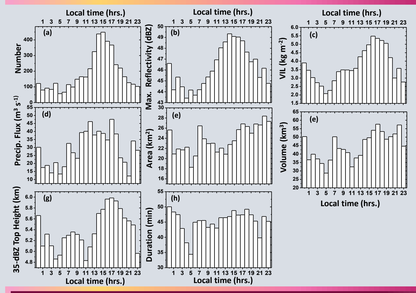

Figure 8: Diurnal evolution of storm Properties

Storms exhibit small nocturnal and strong afternoon maxima

Afternoon peak due to convective system over land & morning peak to those over ocean

Convective area peak delayed by several hours to that of precipitation.

Classification of Convective Cell Types

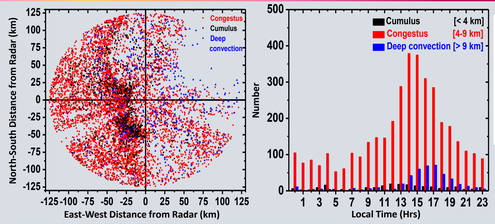

Figure 9:
a. Spatial distribution of Cell Types
b. Diurnal evolution of Cell Types

Congestus dominates. Cumulus and Congestus clusters along windward mountains. Deep convection on lee side. Lead-Lag relation of Congestus and deep > transition from shallow to deep (heating and moistening by Congestus important).

Summary

- **First–time view of time-continuous aspects of convection, with respect to complex topography.**
- **Increased frequency of cell initiation along upslope compared to coastal & lee side highlights orographic response to southwesterlies with superimposed diurnal cycle.**
- **Convection has shallow depth, sub-MCS nature, short lifetime, slow movement, east-west alignment.**
- **Cell properties follow log-normal dist. Storms steered by largescale flow at 850 hPa to move in east-west direction and orient along mountain ridges.**

Future Scope

- **Radar observed small-scale convective features are useful in validating CRMs.**
- **Vertical structure of convection during dry and wet spells will be studied.**
- **Combined Radar and Lighting data shall help linking convective storm intensity with microphysics & lightning production.**

Acknowledgements

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