High-frequency Radar observations of vertical velocity in the tropical UTLS over Kochi, India

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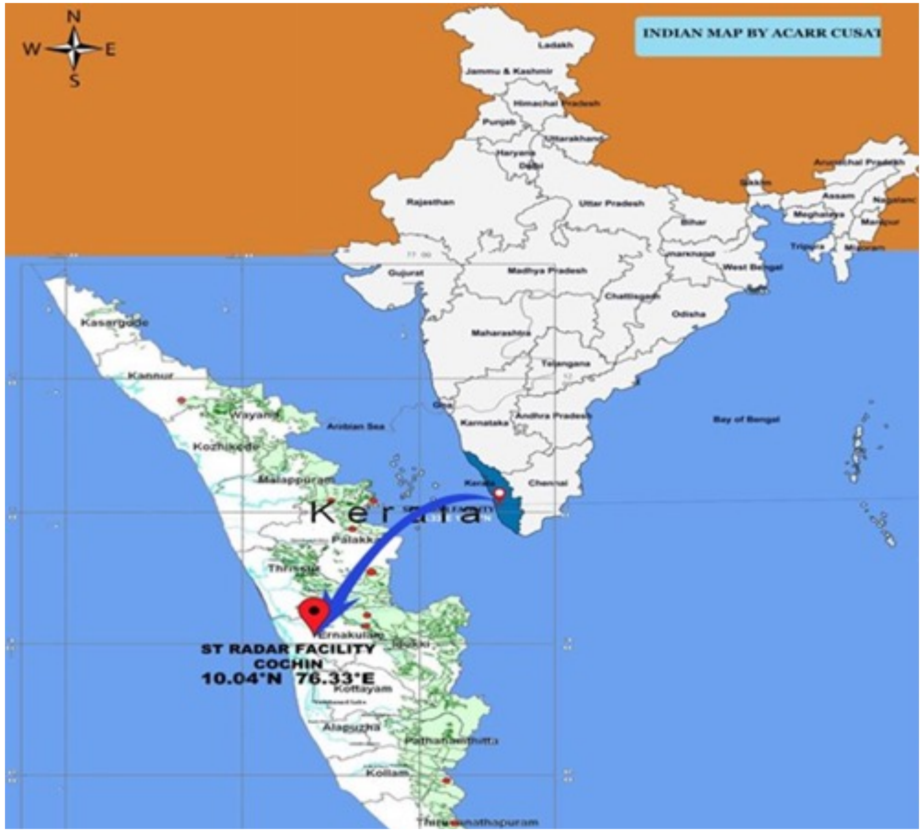
Outline

- Wind profiler radar at Cochin-An introduction
- IGW using ACARR radar- Previous study
- High frequency measurement of vertical velocity

About the 205 MHz radar at ACARR

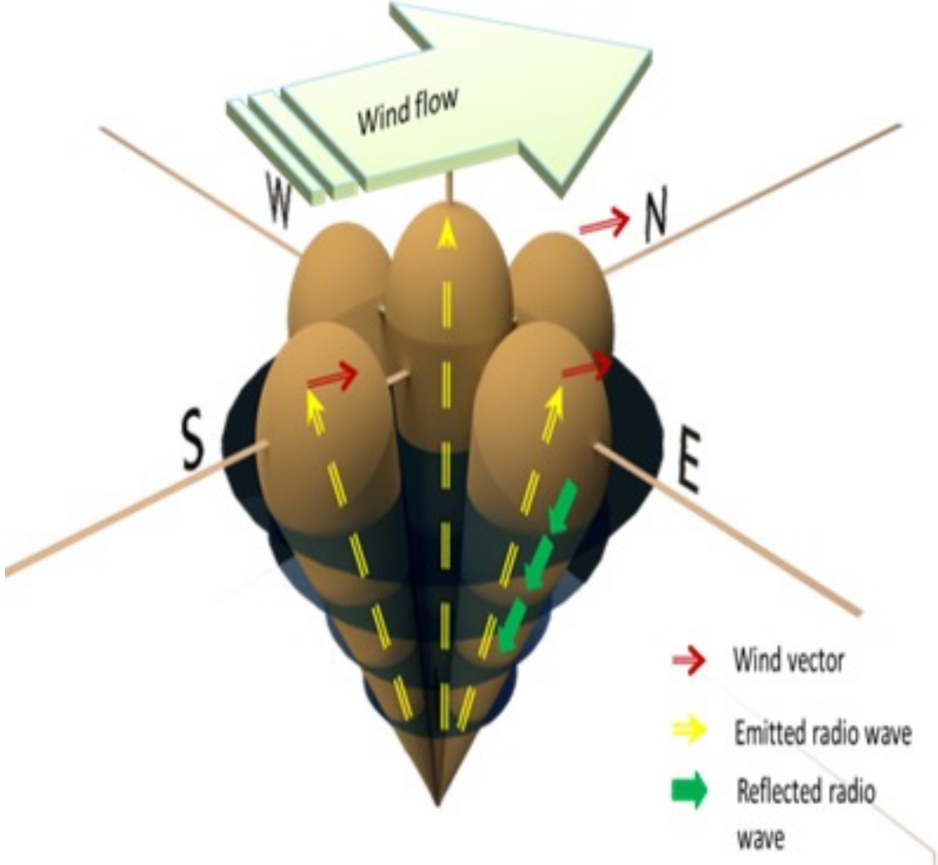


Location

Aerial View

205 MHz radar

- Vertically pulsed Doppler radar
- Analyze the backscattered signals to determine the velocity of air along the beams (Bragg scattering)
- Measure wind in high temporal and spatial resolution



Technical specifications of 205 MHz radar

Parameters	Specification
Frequency	205 MHz
Bandwidth	5 MHz
Type of system	Active Phased Array with TRM
Antenna element	Three Element Yagi-Uda antenna
Height coverage	315 m to 20 km
Range gates	1024 (Programmable)
Modes of operation	Doppler Beam Swinging / Spaced Antenna Method
Height resolution	~45 m up to 6 km and 150 or 300 m up to 20 km
Beam width _	~3˚
Off-Zenith Angle	Selectable from 0˚ to 30˚ in steps of 1˚
Azimuth angle	0˚ to 360˚ with 1˚ resolution
Pulse width	0.3 to 76.8 µs
Modulation	Binary Phase Shift Keying (BPSK) coded compression
Code	Complementary Code/ Barker Code
Baud	0.3 to 4.8 ms in steps of 0.3 ms

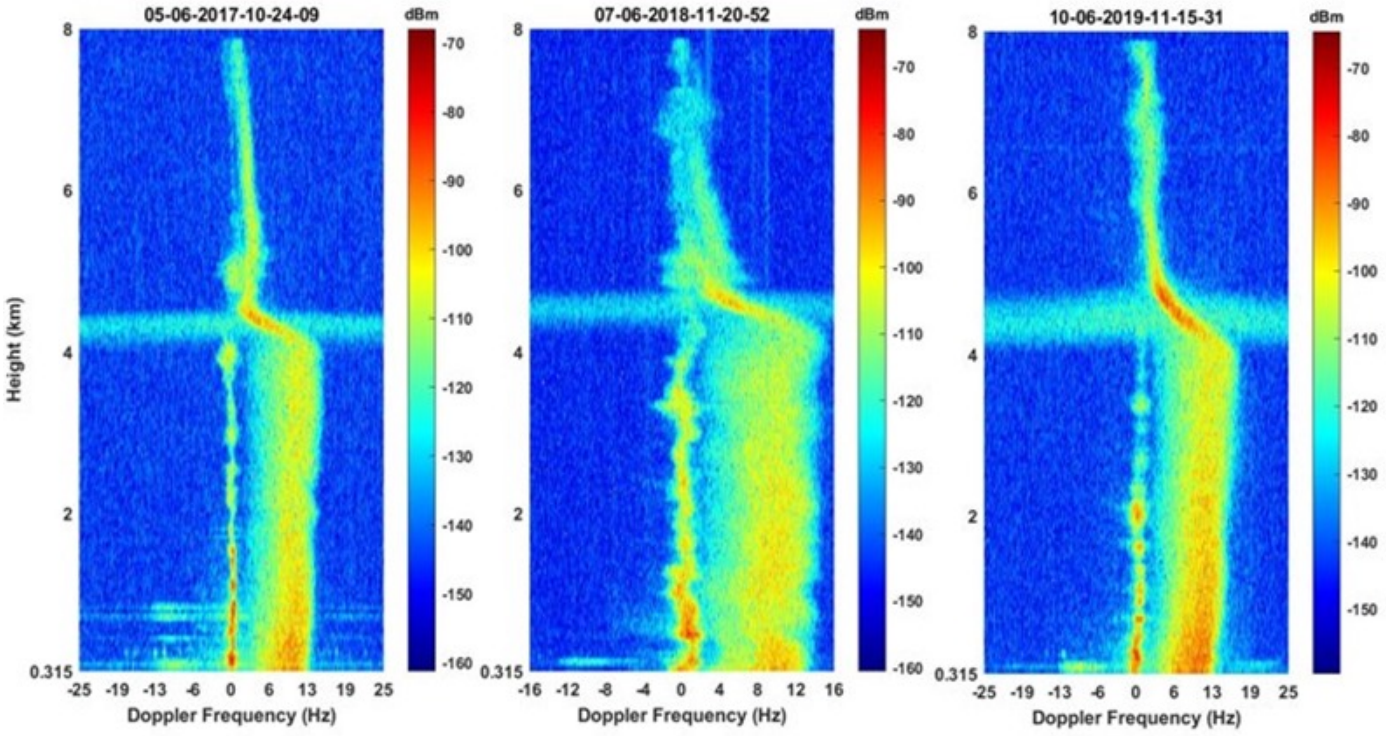
Technical specifications of 205 MHz radar

Parameters	Specification
Pulse Repetition Frequency (PRF)	100 Hz to 16 kHz Selectable
TR Module transmit peak power	500 W (typical per element)
Duty ratio	up to 15% (Max)
Peak power aperture product	~1.6×10^8 Wm^2
Radar system sensitivity	-165 dBm
Dynamic range	70 dB(min)
Master reference oscillator	Rubidium oscillator
Type of receiver	Direct band with sampling
Type of signal processor	FFT based frequency domain

Highlights of the ACARR Radar

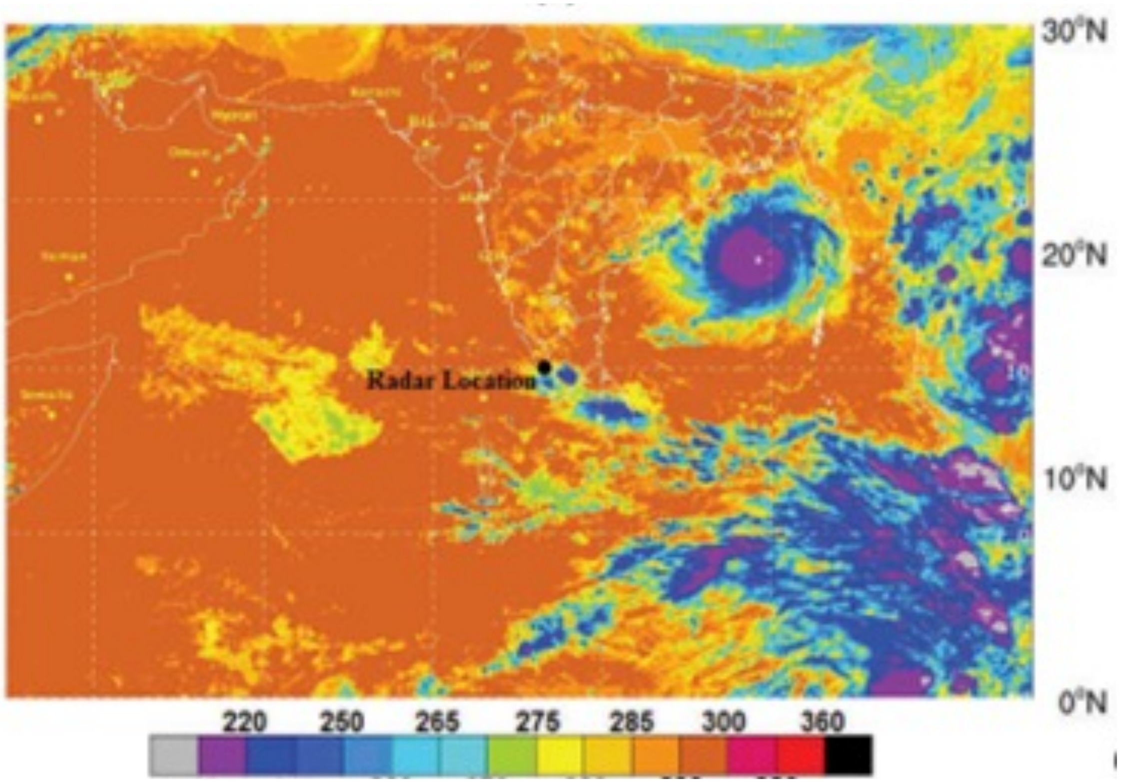
- Same height coverage with less power aperture product as compared to 40-50 MHz radar.
- Effect of galactic noise is less in 205 MHz radar as compared to 50 MHz.
- More height coverage as compared to 400 MHz radar.

Highlights of the ACARR Radar



Doppler power spectra during rainy conditions

IGW studies using the Radar



- 205 MHz ST radar data from 22-27th October 2016 has been used for the study.
- An intensified deep depression, Cyclone Kyant developed in the Bay of Bengal on 25th October 2016.

Reference: Ajil Kottayil, Karathazhiyath Satheesan, Kesavapillai Mohankumar, Sivan Chandran & Titu Samson (2018) An investigation into the characteristics of inertia gravity waves in the upper troposphere/lower stratosphere using a 205 MHz wind profiling radar, Remote Sensing Letters, 9:3, 284-293, DOI: 10.1080/2150704X.2017.1418991

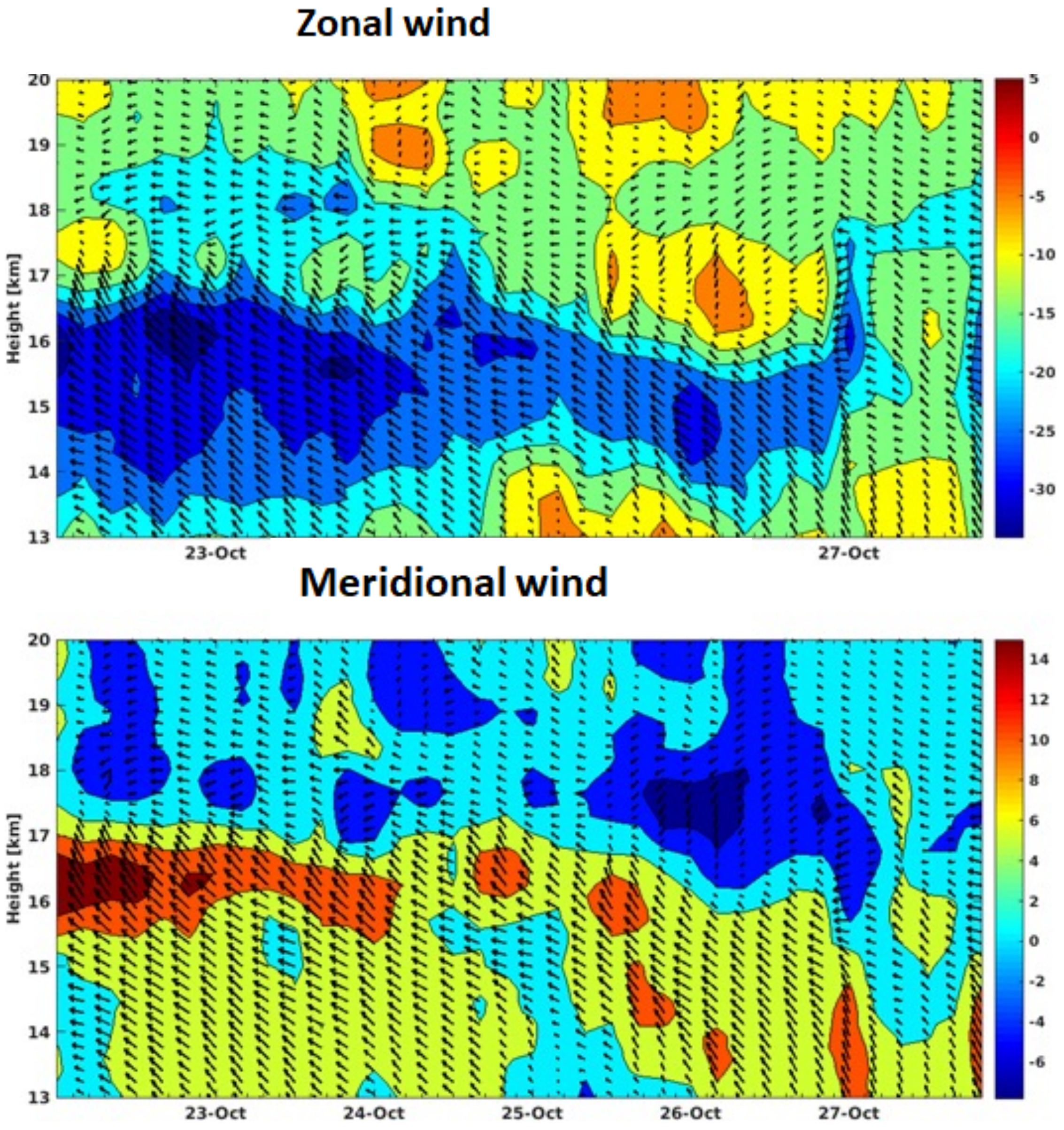
IGW studies contd....

- The upper-level wind during the campaign period was south-easterly, showing its maximum value at 16 km.

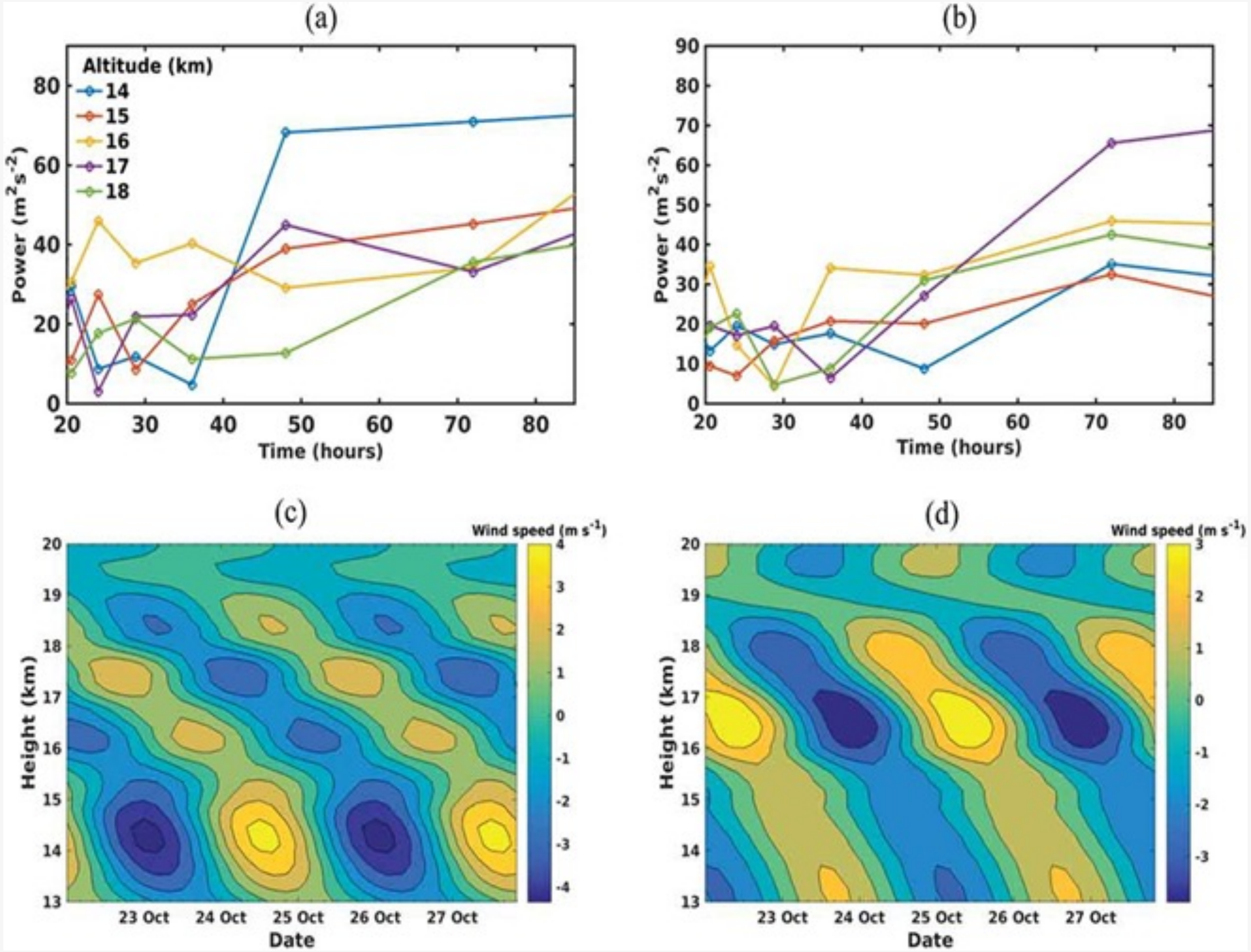
- The inertial period at the radar location is calculated from the equation below.

$$T_{\text{inertial}} = 2\pi/f = 2\pi/(2\Omega \sin\phi)$$

= 68.64 hours (2.86days).



IGW studies contd..

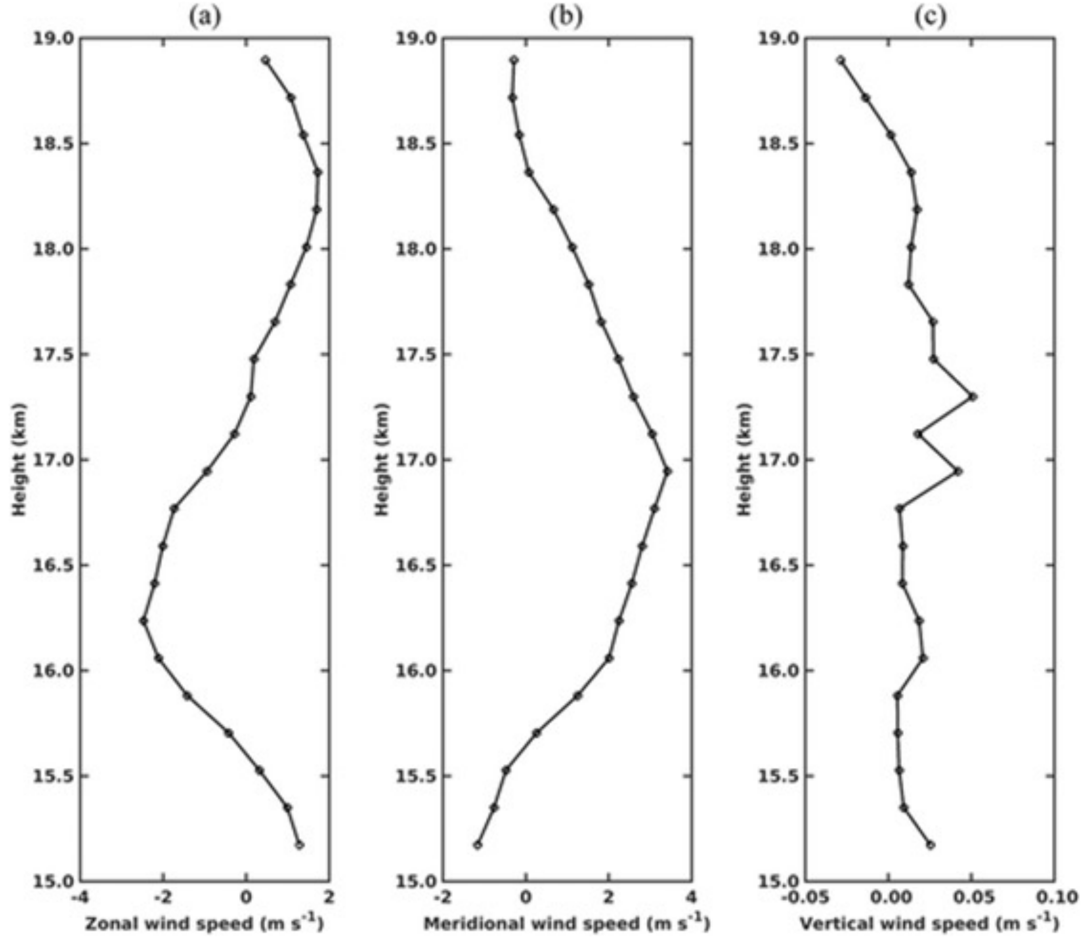


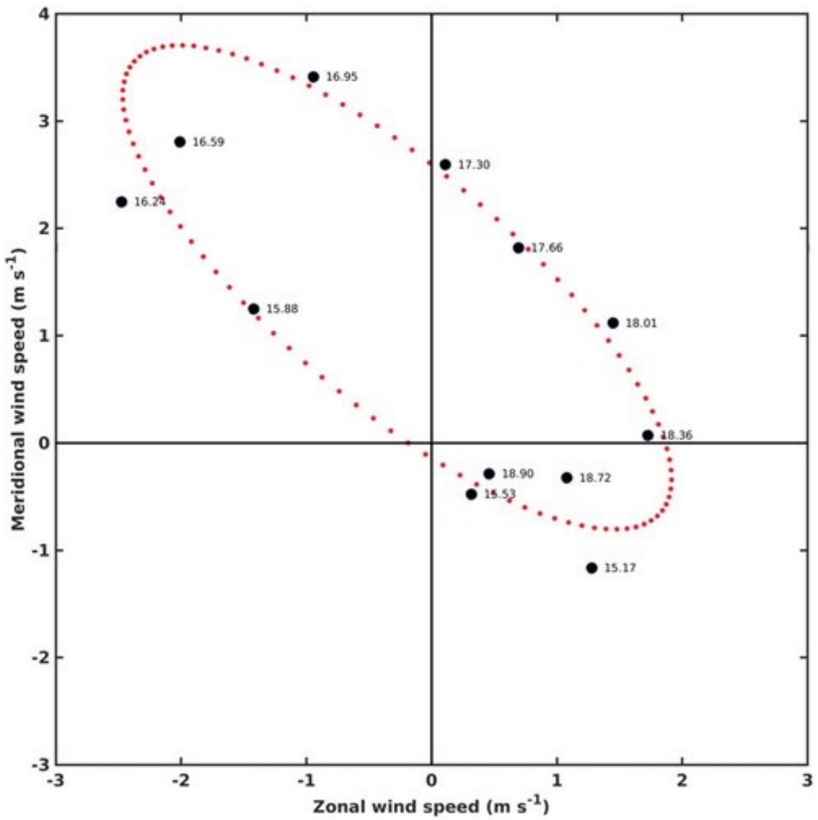
Zonal wind

Meridional wind

- The wave signatures and their time-height dependence are much more pronounced in fig (c) and (d).
- The figure shows the time series of leading frequency component in the wind data.
- There is a distinct downward propagation of the phases in both zonal and meridional winds with a periodicity of around 3 days.

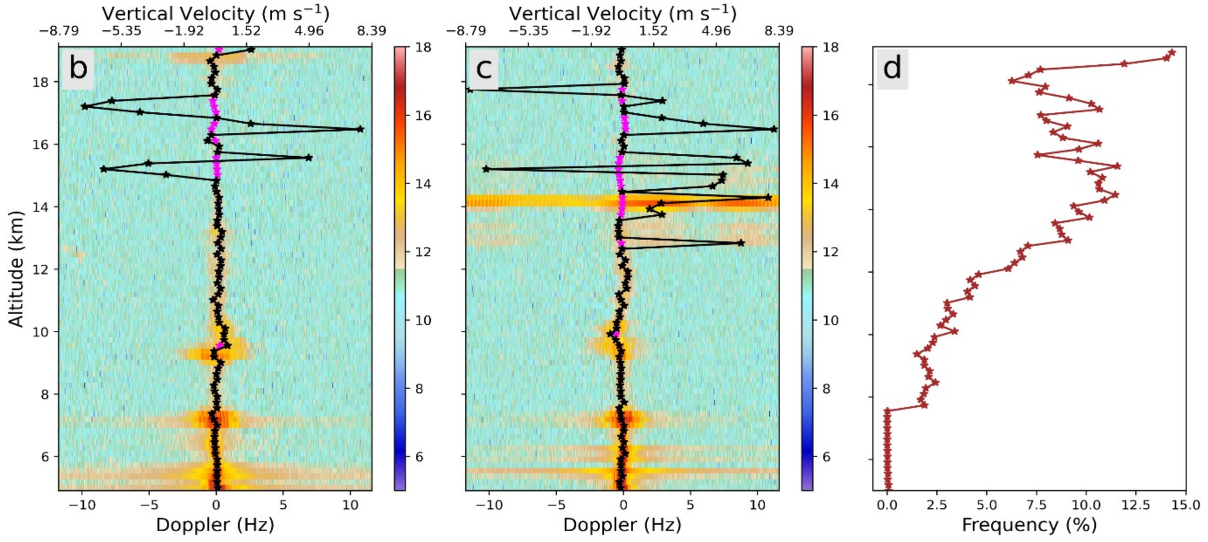
Perturbation of
a) Zonal b) Meridional c) vertical wind speed





The clockwise rotation with height corresponds to upward transportation energy with downward phase

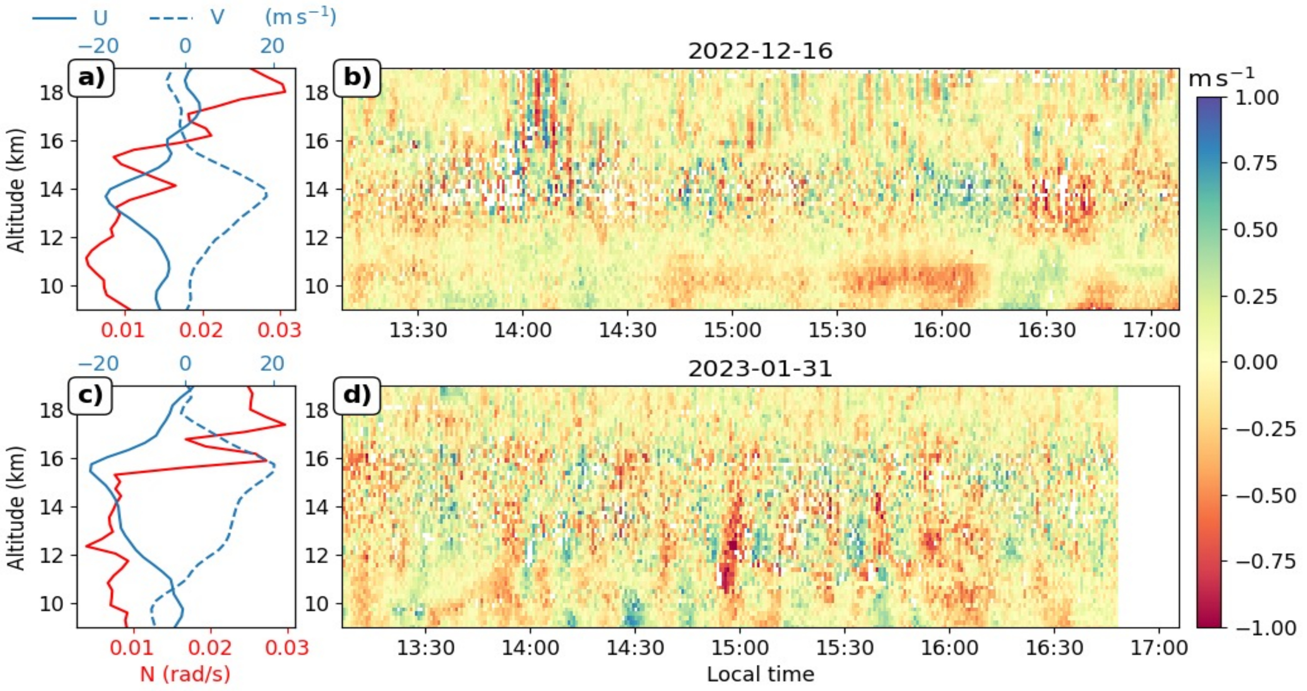
High frequency radar observation at UTLS



(b, c) Doppler power spectra of vertical beam obtained on 2 March, 2023. (d) Percentage of outliers detected and are replaced by interpolation at different altitudes during the measurement period.

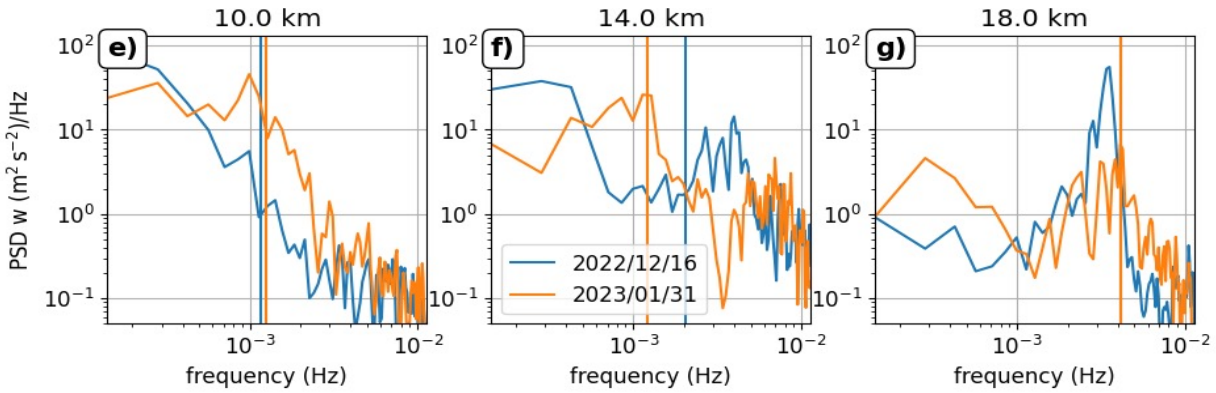
- ACARR radar is operated in zenith mode and the vertical velocity measurements are generated for every 44 s continuously for 4 hours, between 12--16 hours local time from 14, Dec 2023 to 11, April 2024 .
- 63 days of measurements are used
- Raw radar measurements are processed Doppler power spectrum is quality controlled for outliers

Evidence of trapped GW in the tropical UTLS



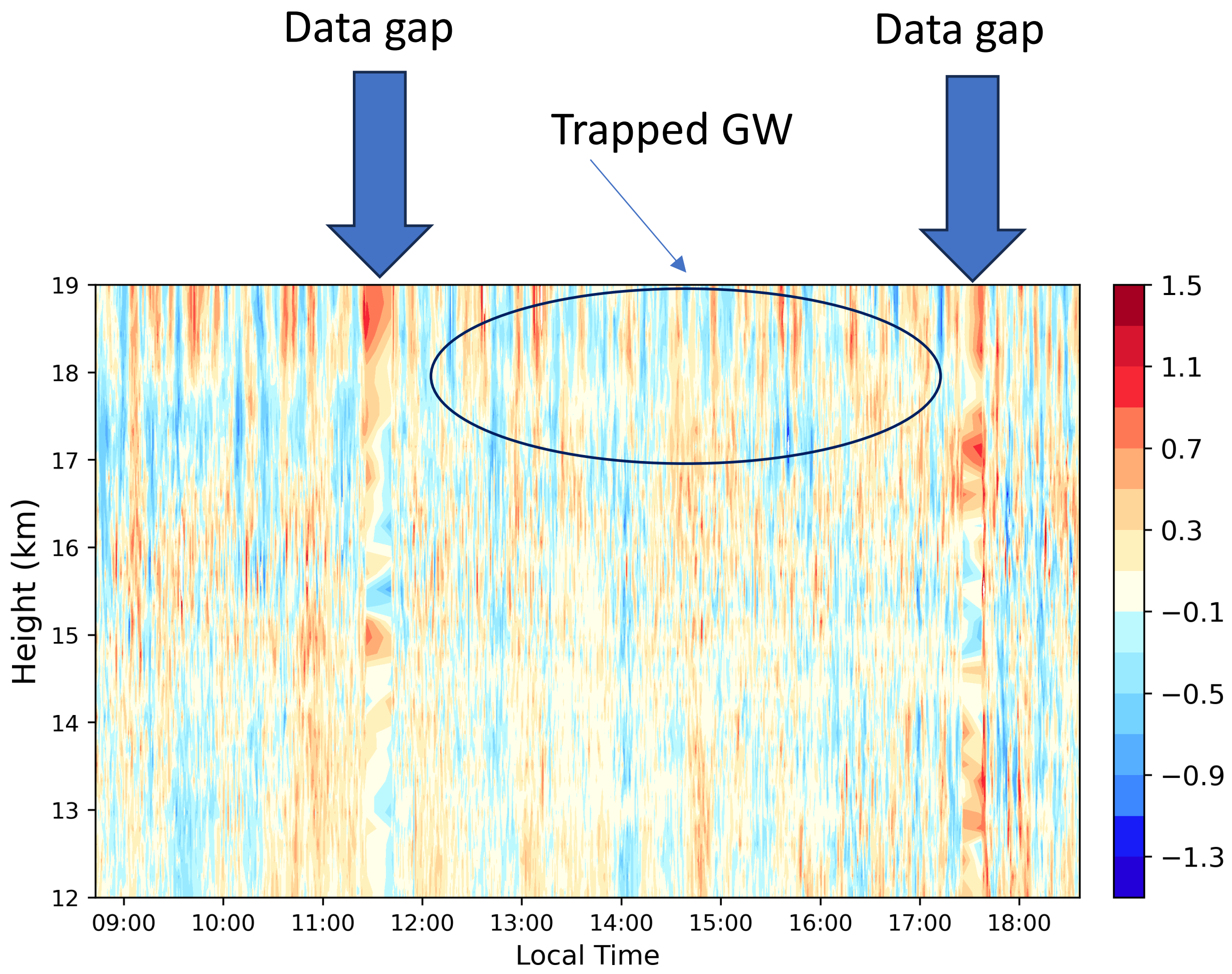
- Variability in the troposphere (below 14 km) is of longer period (tens of minutes) than in the TTL and lower stratosphere (periods of a few minutes)
- Intermittent pulse of vertically oriented phase line in the UTLS
- ERA5 indicates little shear (no KHi)
- Frequency near Brunt-Väisälä -> likely trapped gravity waves

ERA5 wind and Brunt-Vaisala frequency profiles and (b, d) ACARR vertical velocity, negative (positive) values indicate ascending (descending) motions . (e,f,g) Corresponding periodograms of vertical velocity at 10, 14 and 18 km altitude.

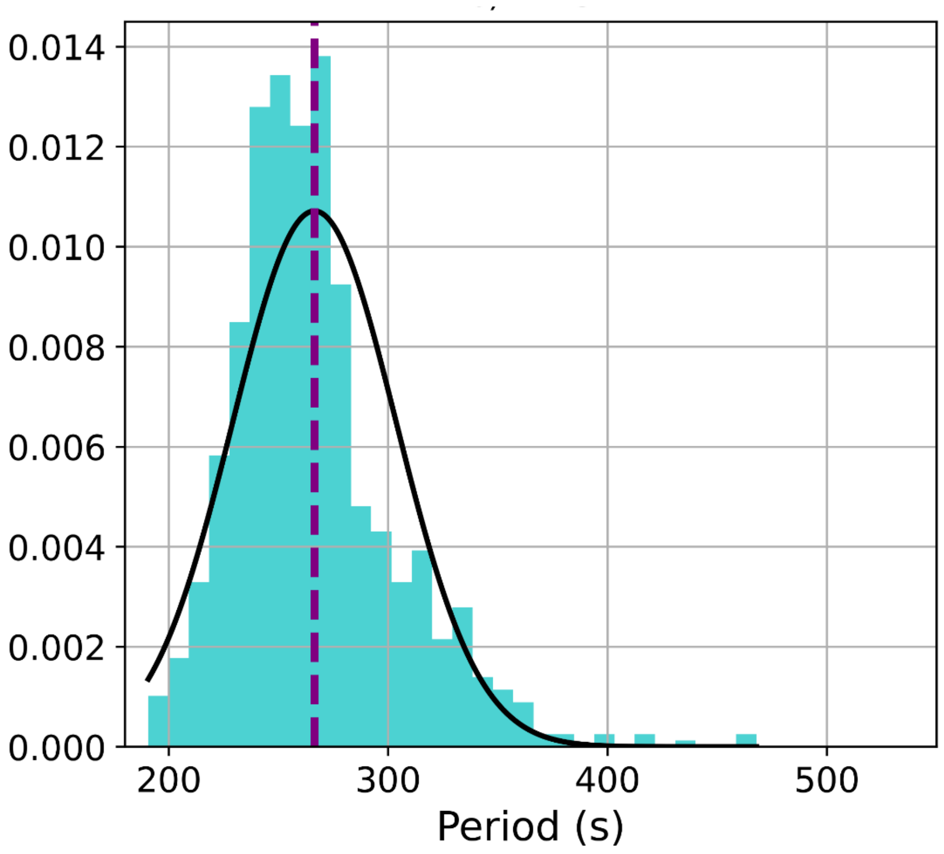


Kottayil et al., in prep.

Evidence of trapped GW at the UTLS

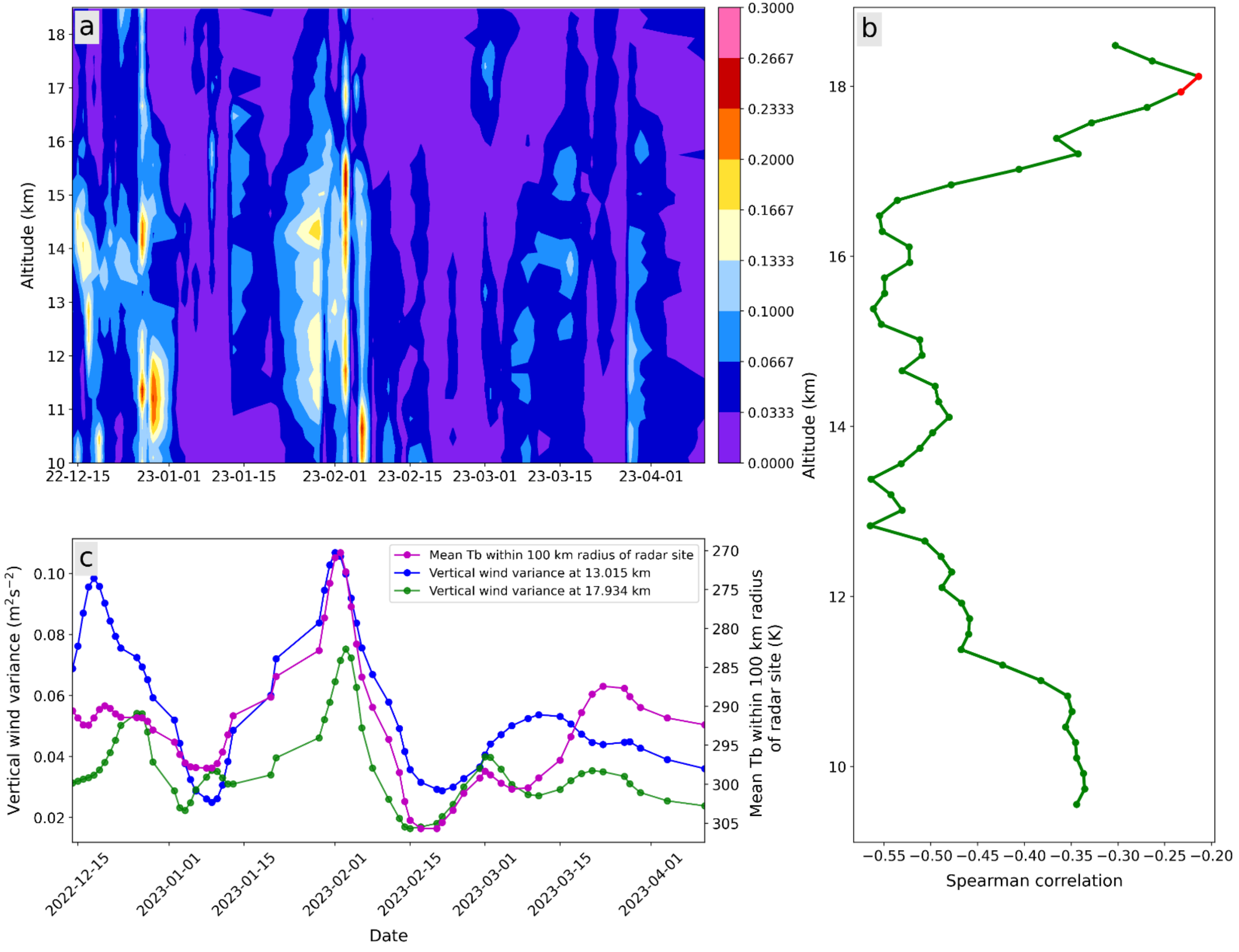


August 12, 2023



Theory: Various combination of Brunt Vaisala and Intrinsic frequency are favourable for ducted gravity waves in the UTLS

Convection and vertical velocity variance



a. Time evolution of the profiles vertical velocity variance
b. Spearman correlation between vertical velocity variance and mean IR window brightness temperature within 100 km around the radar location.
c. Time series of vertical velocity variance at 13 km and 17.9 km and mean 11 micro meter temperature within 100 km around the radar location.

Conclusions and Future work

- High frequency measurements of vertical velocity at the UTLS from ACARR radar at Kochi, India
- Frequent detection of trapped gravity waves in the UTLS
- Impact of convection on the vertical velocity variance
- Kottayil et al., to be submitted to GRL

Ongoing work in collab. with LMD Paris

- Contribution of trapped waves on vertical velocity variability at the UTLS
- Impact of trapped waves on chemical and micro-physical processes at the UTLS

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