Low Frequency Ionospheric Measurements

presented by
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Project Overview

- Seek to push analysis to finest scales possible to explore the full range of phenomena observable with the VLA

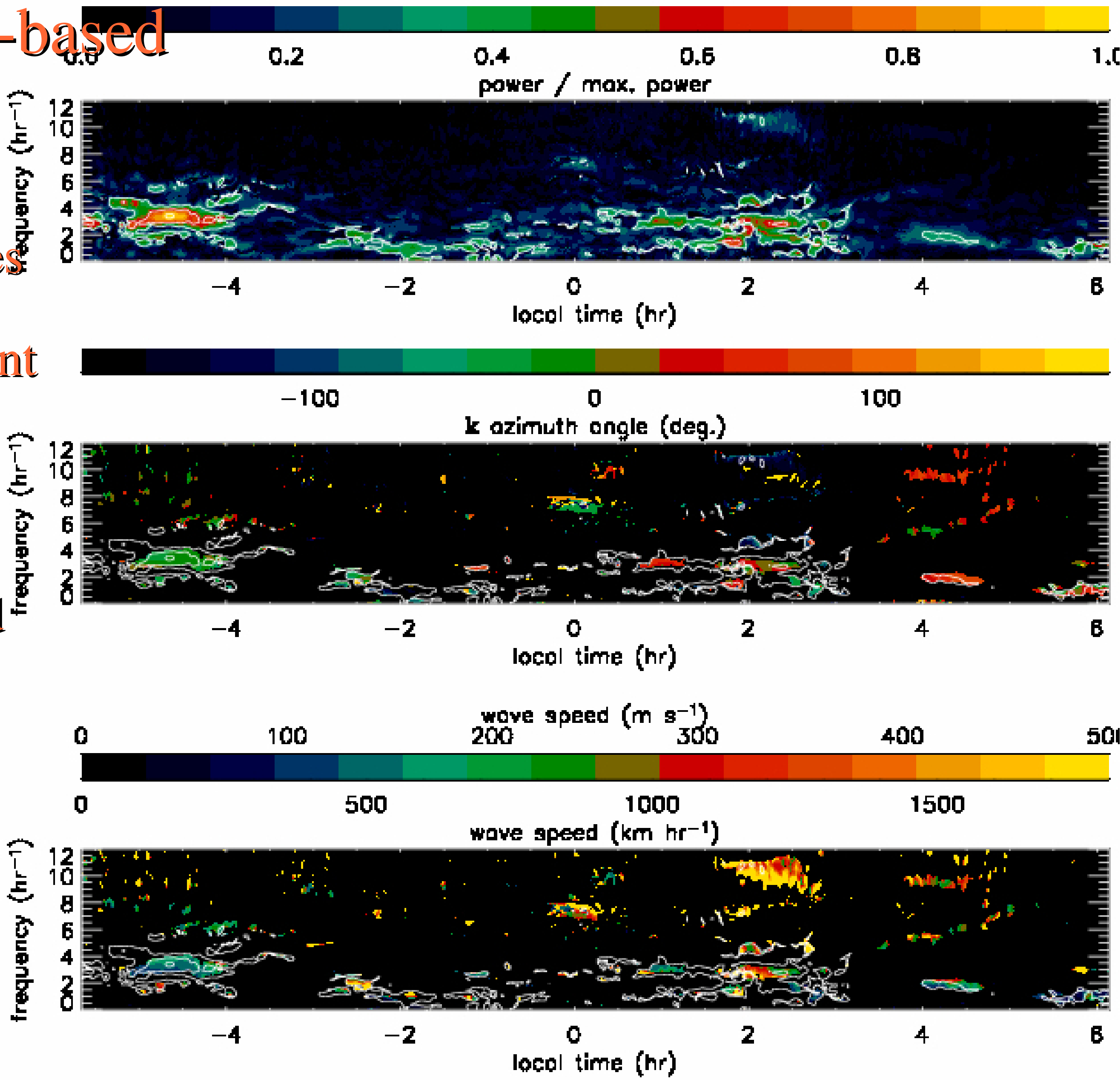
- With a bright source , VHF system can detect fluctuations smaller than 0.001 TECU (1 TECU = 10^{16} e^{-} m^{-2}), more than one order of magnitude more sensitive than GPS

- Have selected a 12-hour run on Cygnus A (Cyg A), one of the brightest radio sources in the sky (17,000 Jy at 74 MHz) from Aug. 2003 in A configuration to demonstrate what can be achieved with VLA VHF system

- Will use techniques developed here on other similar datasets

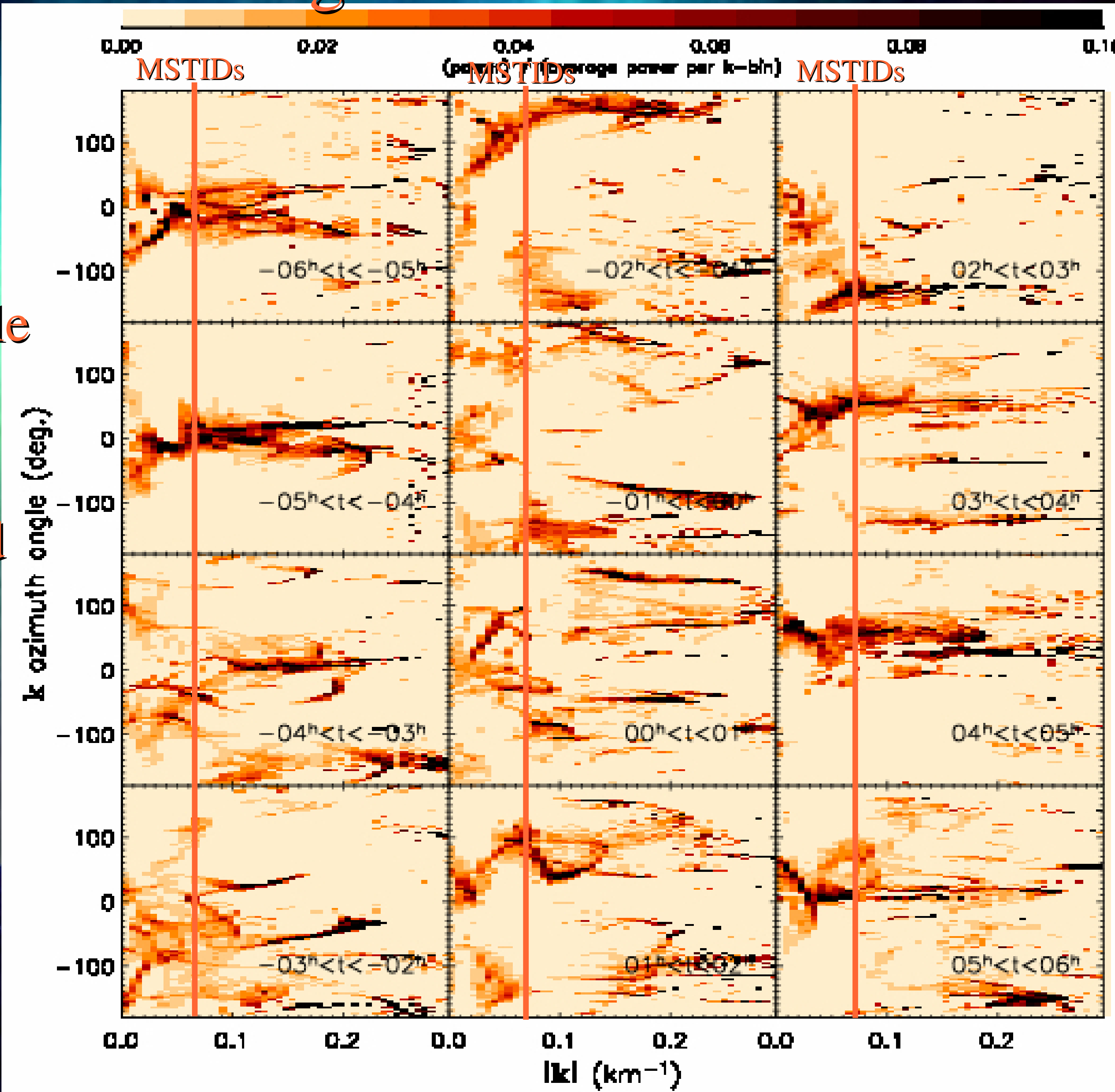
Polynomial-based

* ✳ Detected several instances of low-period waves, consistent with medium-scale TIDs (MSTIDs): periods of 10 min. to 1 hr and speeds between 180 and 1,080 km hr^{-1}
* ✳ Seen here directed NE, N, or NW



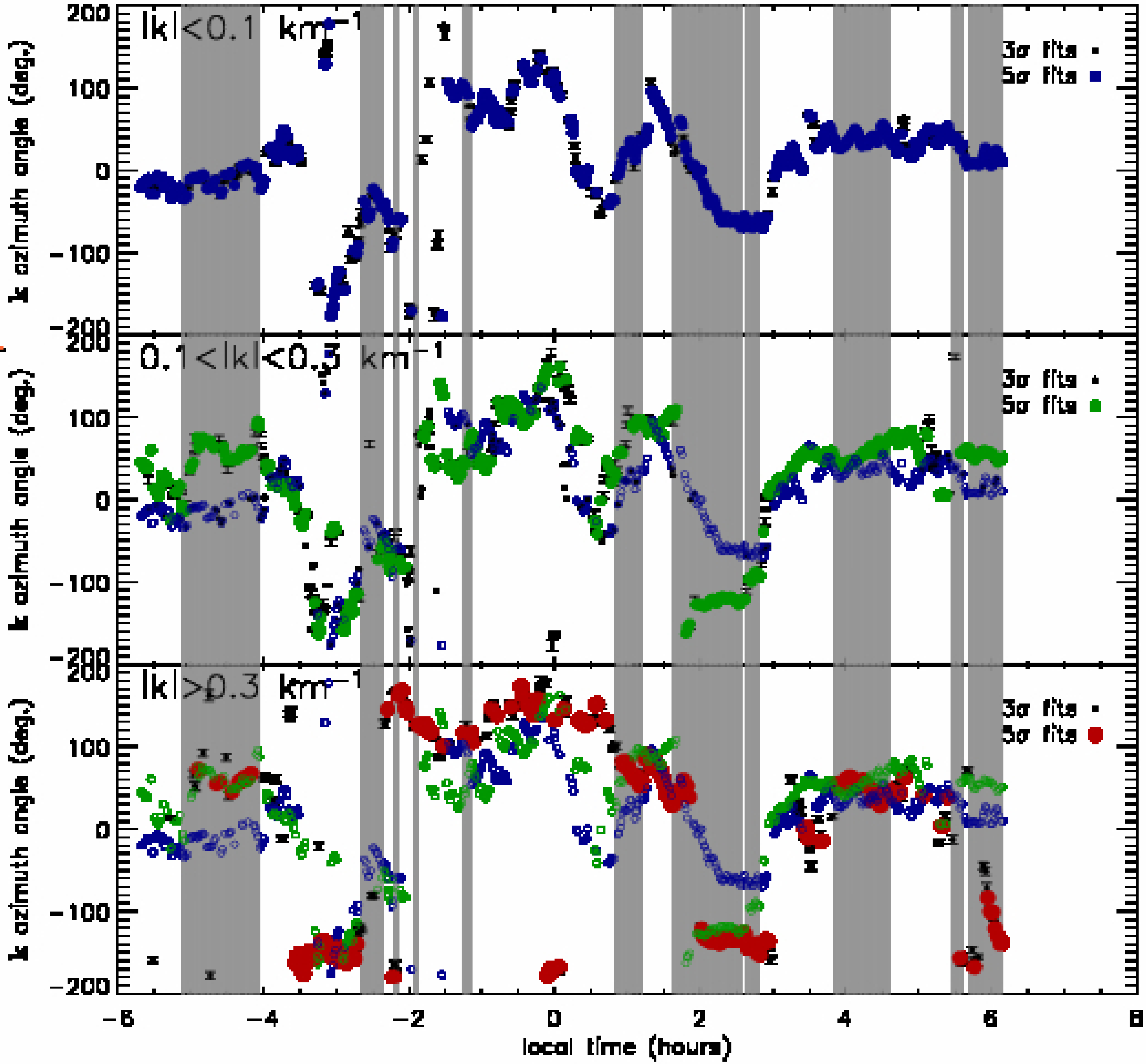
Azimuth Angle Distributions

- Power as function of wavenumber, k, and azimuth angle reveal many smaller scale waves, often at similar times and directions as MSTIDs



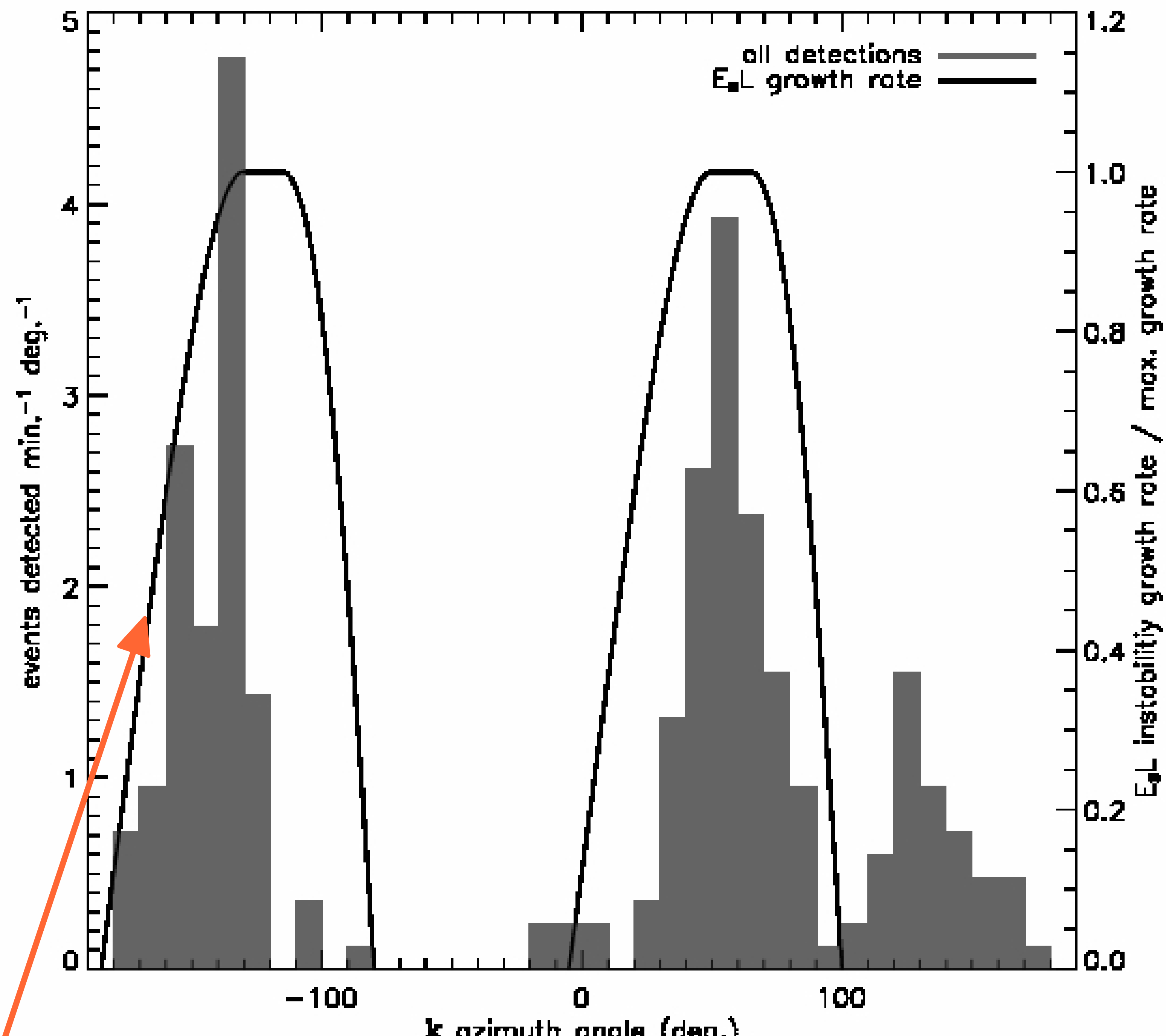
Arm-based - cont.

- Arm- and polynomial-based agree when MSTIDs detected
- Intermediate- and small-scale classes seem to be part of same class of waves (speeds similar as well)
- Detected with MSTIDs, but often in different directions



Small-scale Wave Directions

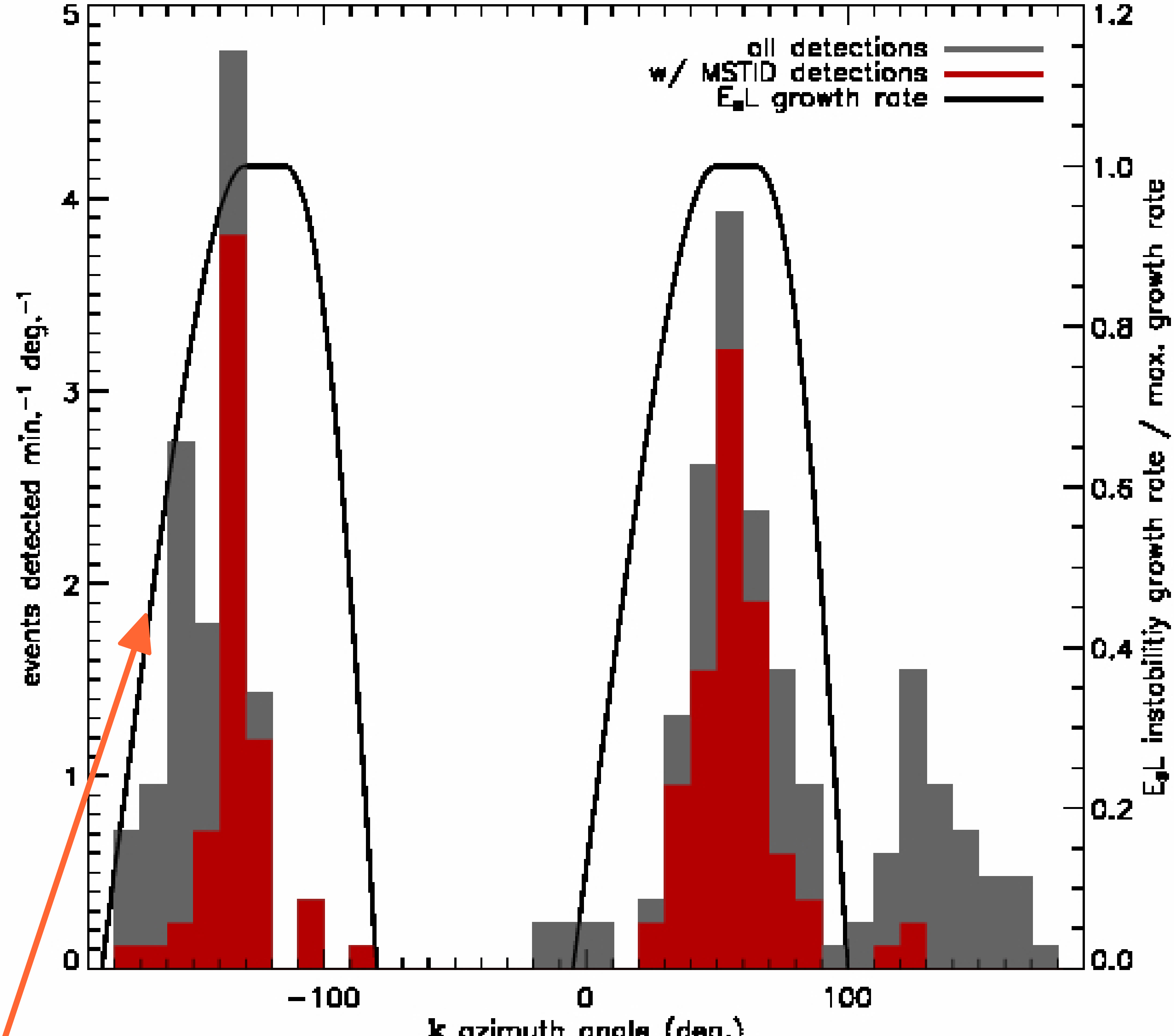
- Small-scale wave directions distributed in three groups
- Two have almost same wave-front orientations (i.e., directions ~180° apart), consistent with requirements of E_s-layer instability



from Cosgrove and Tsunoda (2002)

Small-scale Wave Directions

- ✳ Small-scale wave directions distributed in three groups
- ✳ Two have almost same wave-front orientations (i.e., directions 180° apart), consistent with requirements of E_s-layer instability
- ✳ Better agreement for those coincident w/ MSTIDs



from Cosgrove and Tsunoda (2002)

Small-scale Waves and E-F Coupled Instability

MSTIDs aligned NW-SE:

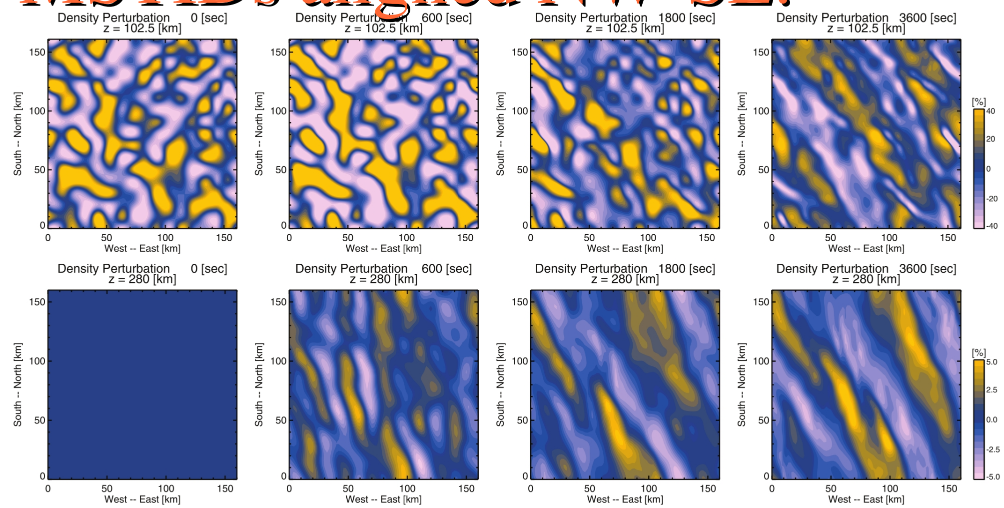


Figure 11. Plasma density perturbation at altitudes of (top) 102.5 and (bottom) 280 km at $t = 0$, 600, 1800, and 3600 s in case RP1. The top images are shifted along the meridional direction so that the same coordinate points are connected by **B**.

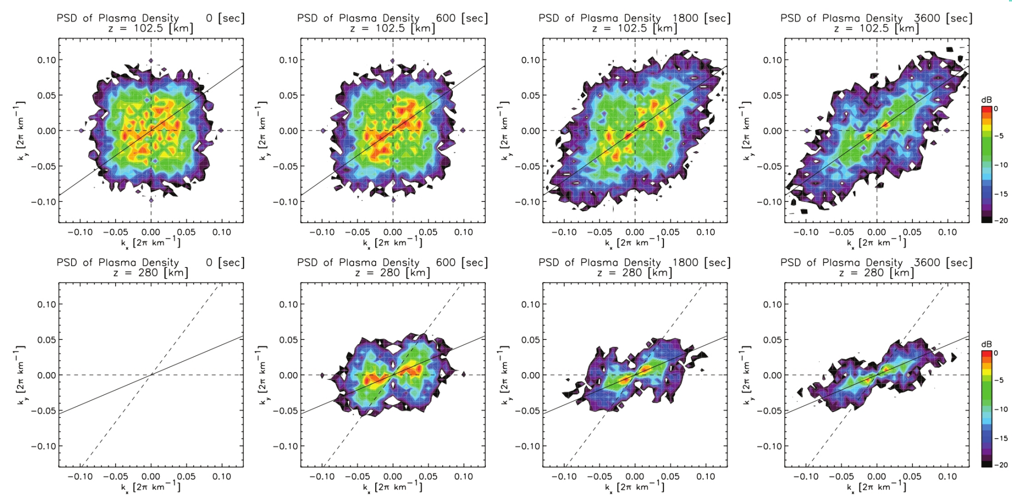


Figure 12. Power spectral density of each image in Figure 11 in the wave vector domain. Each image is symmetric about the origin and normalized by the spectral peak. The solid lines in the top (bottom) row represent the direction of γ_E^{max} (γ_P^{max}). The dotted lines represent the marginal stability direction where $\gamma_E = 0$ and $\gamma_P = 0$.

MSTIDs aligned N-S:

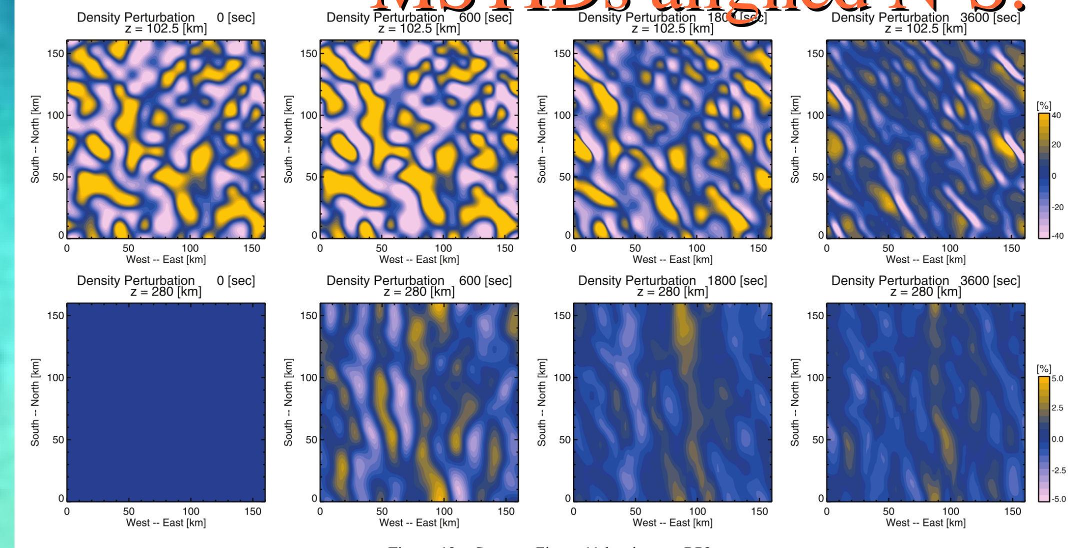
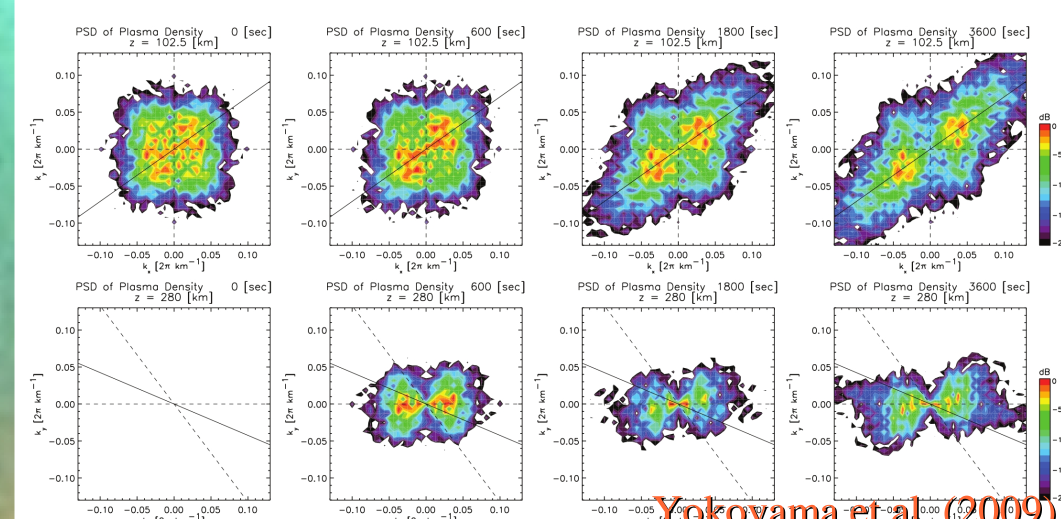


Figure 13. Same as Figure 11 but in case RP2.

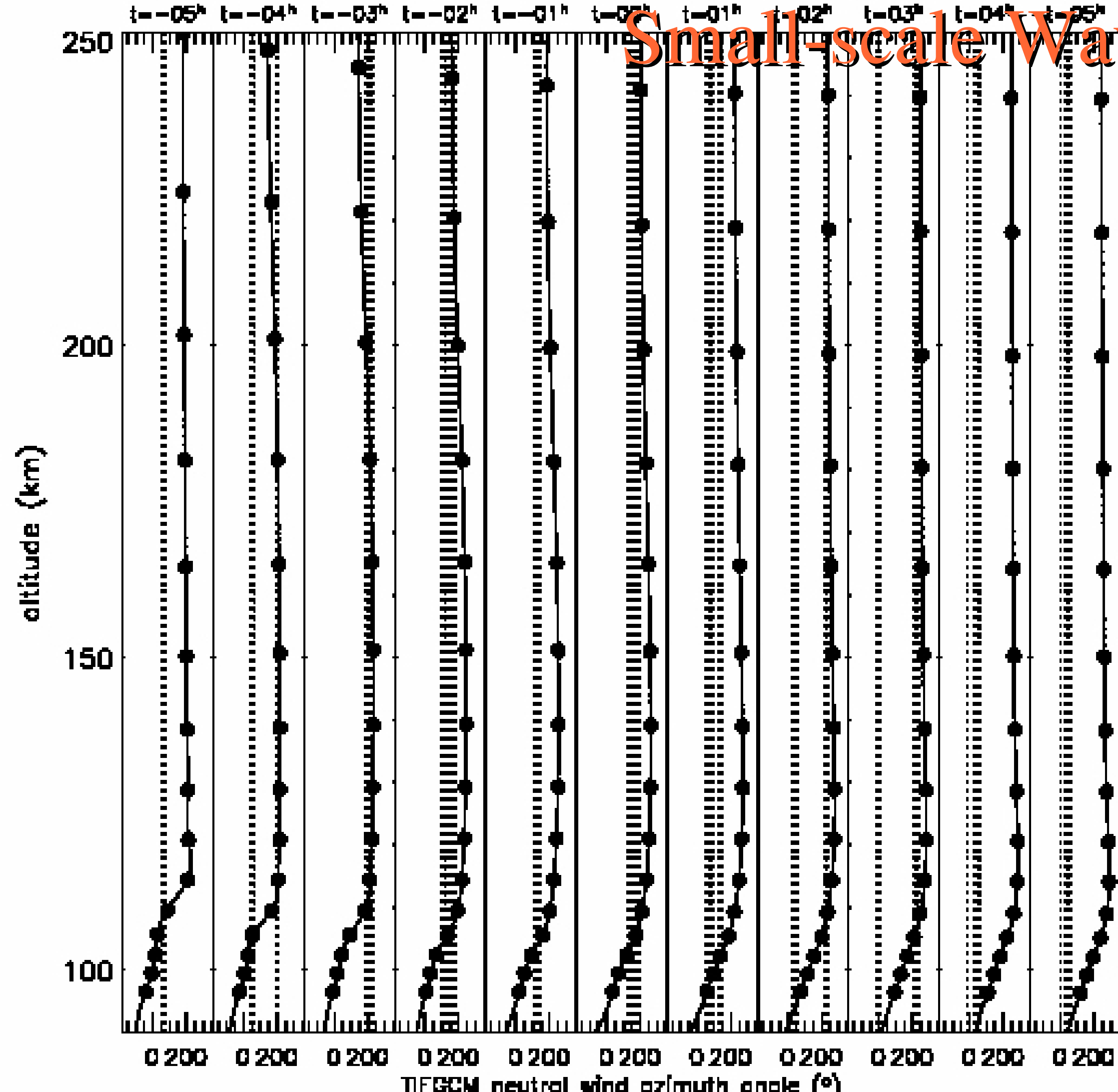


Yokoyama et al. (2009)

Figure 14. Same as Figure 12 but in case RP2.

✷ Small-scale waves coincident w/ MSTIDs consistent with predictions of simulations of E-F coupled instability

Small-scale Waves and QP-Echoes



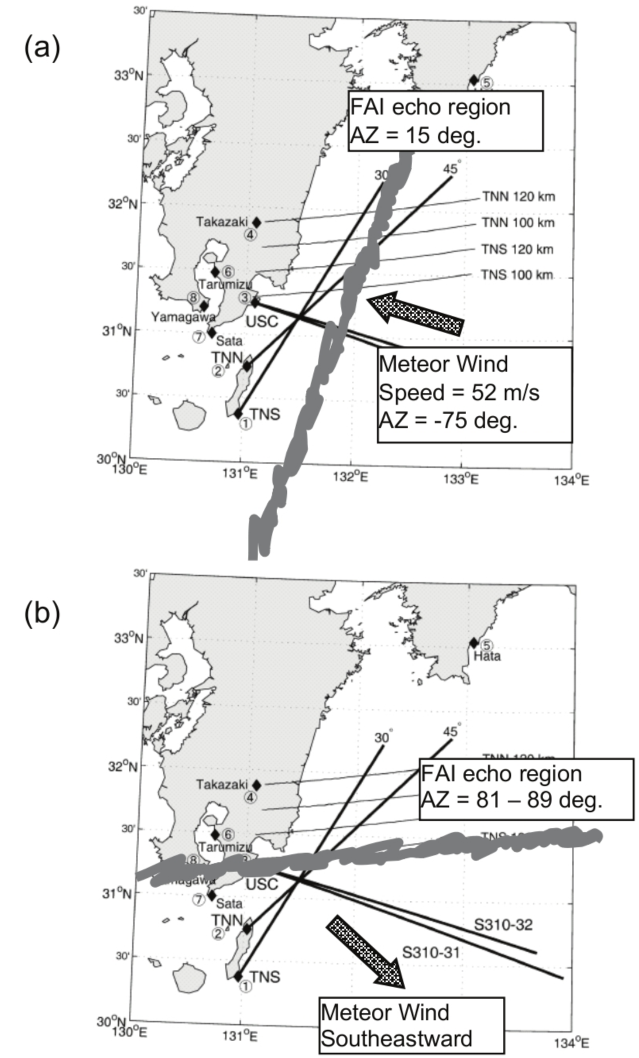


Fig. 5. Alignment of QP echo structures determined from two radar experiments from the TNN and TNS sites. Thick arrows indicate direction of neutral winds. Panel **(a)** shows results during the rocket experiment on 3 August 2002, while panel **(b)** shows the typical structure found from the entire radar observation period (based on Saito et al., 2005).

✴ Remaining SE- and SW- directed small-scale waves more consistent with previously studied QP echoes which appear more heavily influenced by neutral wind

Summary and Future Work

- ✳ Cyg A dataset demonstrates that unique dynamic range of VLA (and now EVLA) VHF system may provide crucial information regarding E-F layer interaction

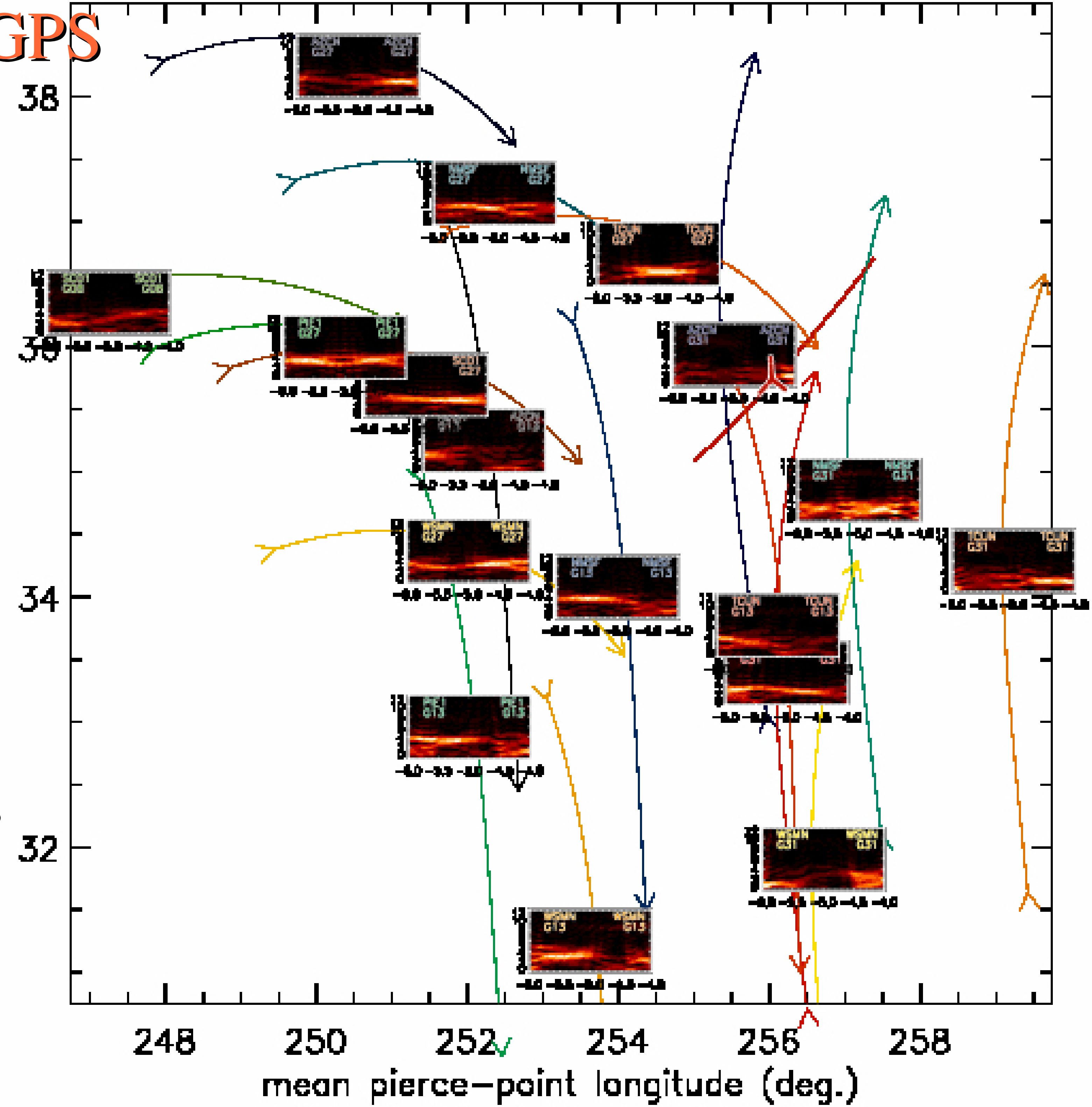
- ✳ Crucial to activities requiring high precision GPS positions as MSTIDs can increase uncertainty to higher than ~10 cm

- ✳ Have a list of six additional VHF datasets with similar long (>1 hr) scans of Cyg A and other bright sources (Cas A, Virgo A, etc.) at different times of day and year with which we will repeat this analysis

- ✳ Will also explore techniques such as field-based calibration which measure ionospheric fluctuations over the entire VLA field of view (15^{o} at 74 MHz) to see how sensitive they are to small- and large-scale fluctuations and to try and constrain vertical locations of detected disturbances

Concurrent GPS

- ✴ Only 6 dual-frequency GPS receivers in NM available during observations
- ✴ See similar MSTIDs during same time periods, giving partial validation
- ✴ Spacing between receivers (>100 km) too large to track individual waves



Concurrent GPS - cont.

- Pierce-point speeds comparable with MSTIDs – can use Doppler shift to search for statistical detection of preferred MSTID direction, if there is one
- Results consistent with VLA data