ECE ILLINOIS

Mesospheric Wind Estimation with the Jicamarca MST Radar

Kiwook Lee[1], Erhan Kudeki[1], Pablo M. Reyes[1], Gerald Lehmacher[2], and Marco Milla[3]

[1]University of Illinois at Urbana-Champaign, Illinois, USA

[2]Clemson University, South Carolina, USA

[3]Jicamarca Radio Observatory, Lima, Peru

Motivation

Doppler shifts of the detected returns from Jicamarca MST radar occasionally show dual peaked spectra, one from the mainlobe and the other from the effective sidelobe. One simple approach to extract mainlobe peak is by selecting the peak with higher power. However, this approach has limitation because the power returns are proportional to electron density fluctuation at each height, and mainlobe beam and sidelobe beam are viewing different heights at a given time. To avoid such errors, we have implemented a clustering based algorithm to recognize the mainlobe component of the dual peaked spectra.

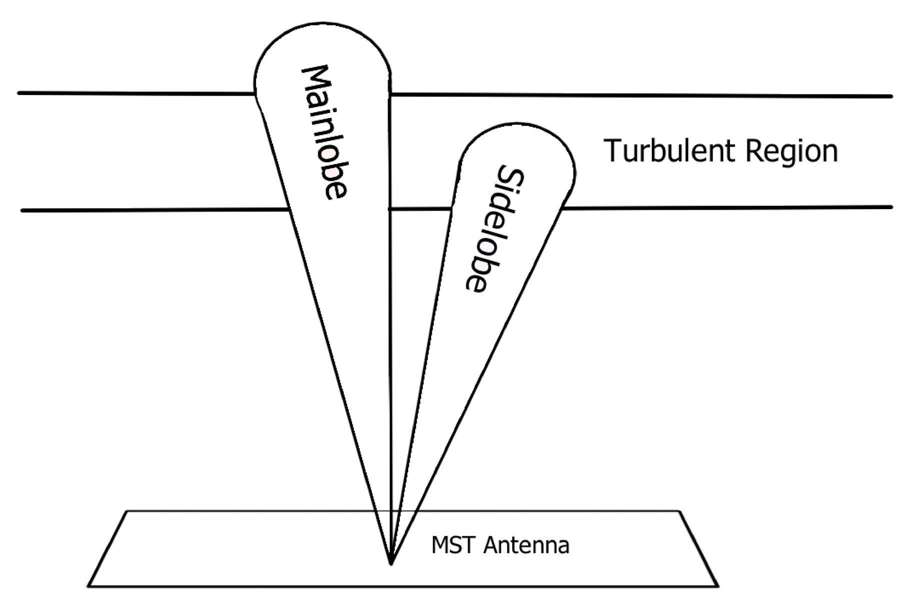

Figure 1. This is one instance where a sidelobe beam receives stronger returned pulses because it is looking at a lower height, which happens be more turbulent than the height mainlobe beam is viewing.

Background

- Four antenna beams (pointing to east, west, south, and zenith) of Jicamarca MST radar are used to detect the scattered pulse returns from mesospheric turbulence layers.
- Vector wind velocities are calculated from Doppler spectra of returned pulses.

$$\textit{beam vector} = \Theta = \begin{bmatrix} \Theta_{x,0} & \Theta_{y,0} & \Theta_{z,0} \\ \Theta_{x,1} & \Theta_{y,1} & \Theta_{z,1} \\ \Theta_{x,2} & \Theta_{y,2} & \Theta_{z,2} \\ \Theta_{x,3} & \Theta_{y,3} & \Theta_{z,3} \end{bmatrix}$$

$$\textit{wind vector} = \Omega = [u \;\; v \;\; w]^T$$

$$\Theta\Omega = V$$

$$\Omega = (\Theta^T\Theta)^{-1}\Theta^T V$$

- However, sidelobe contamination causes occasional dual peaked spectra, which is solved by using a clustering algorithm to extract a mainlobe peak along with a power comparison method.

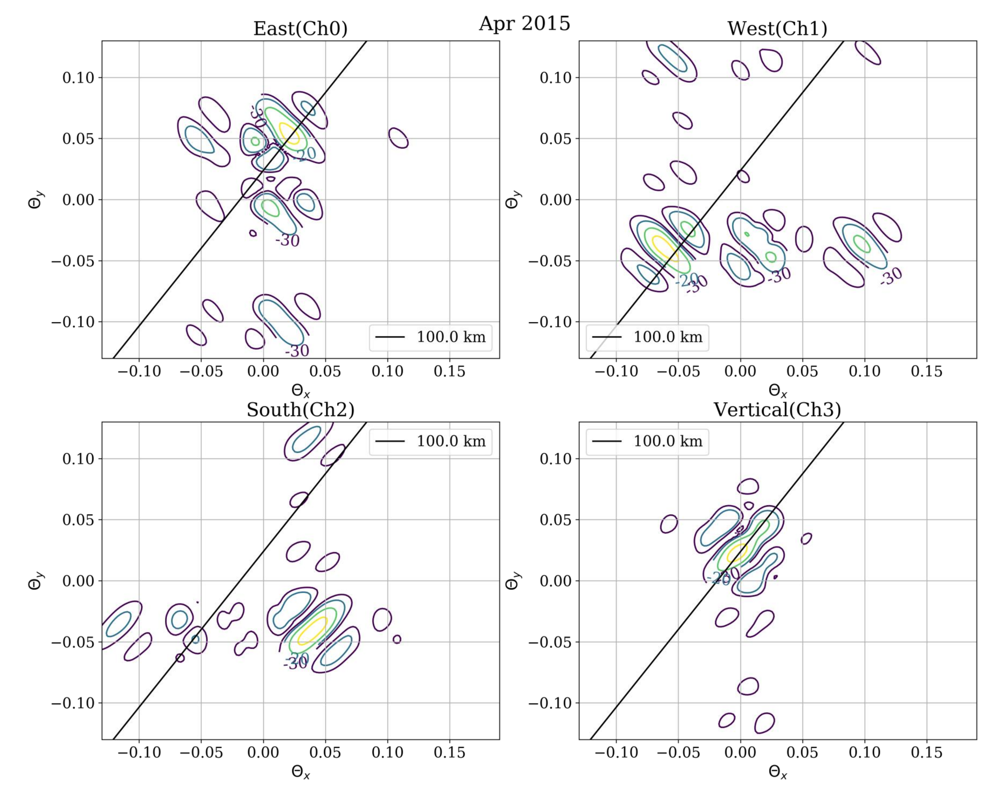

Figure 2. Antenna beam pattern of Jicamarca MST radar, 2015. Each subplot illustrates a beam pattern of one direction, where yellow contour is -3 dB, green contour is -8 dB, and black line is earth's magnetic field.

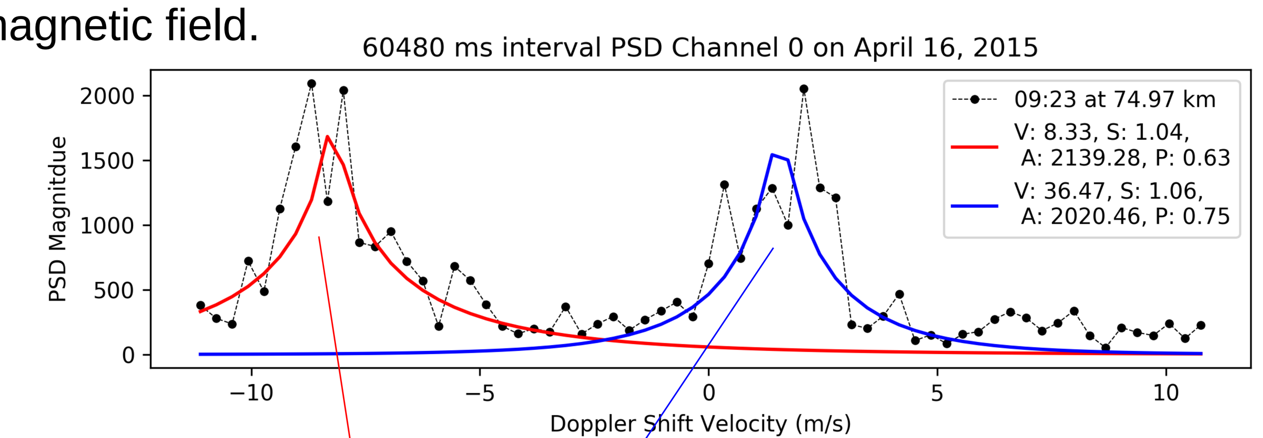

Figure 3. Fitted power spectral density of returned pulses at 9:23, 74.97 km, on April 16, 2015. Red line was selected as mainlobe peak, and blue line as sidelobe peak from power comparison

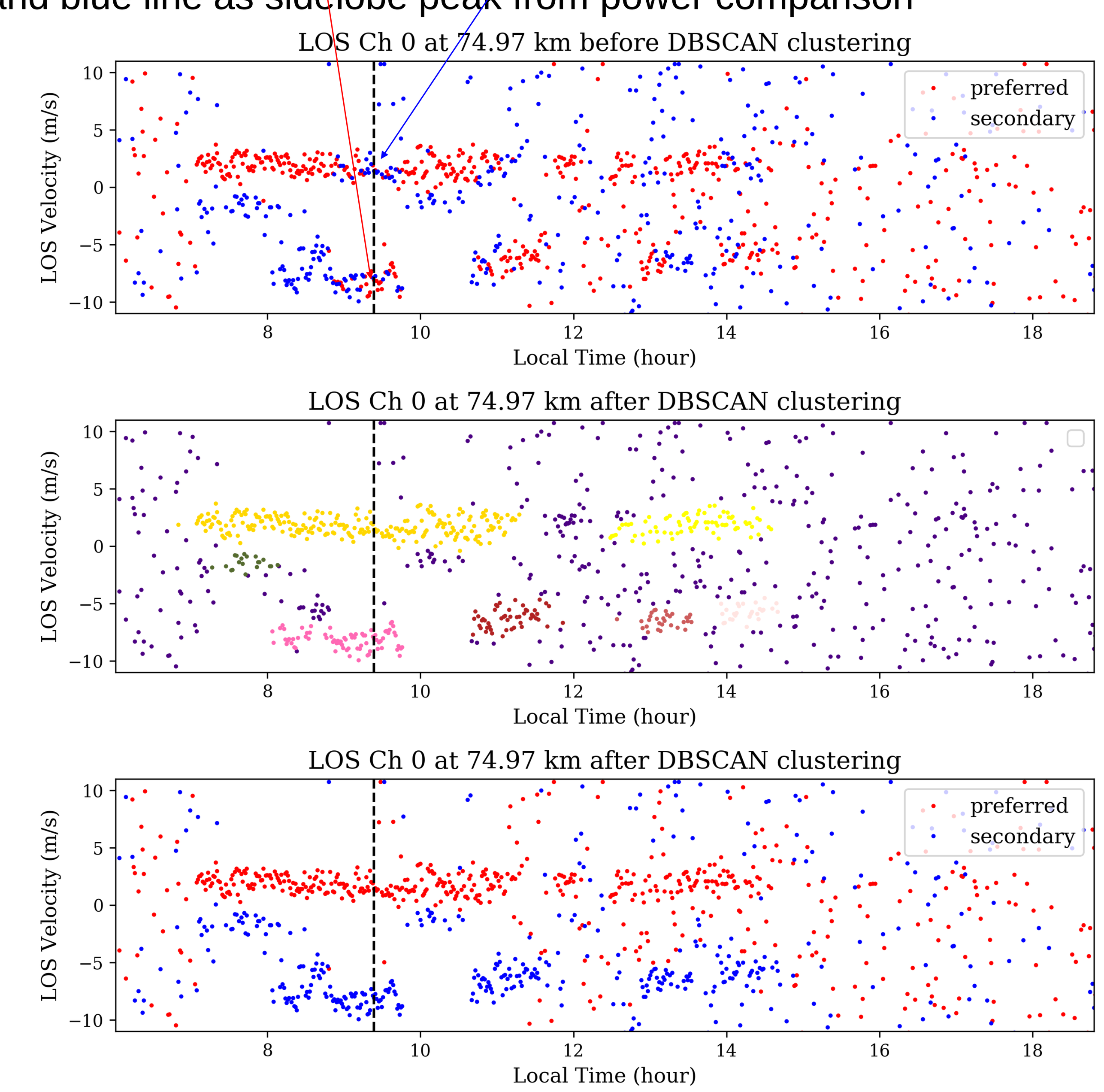

Figure 4. Initial classification of mainlobe and sidelobe peak by power comparison method (top). Clustering into smaller groups by a clustering algorithm called DBSCAN (middle). Final classification (bottom).

Results

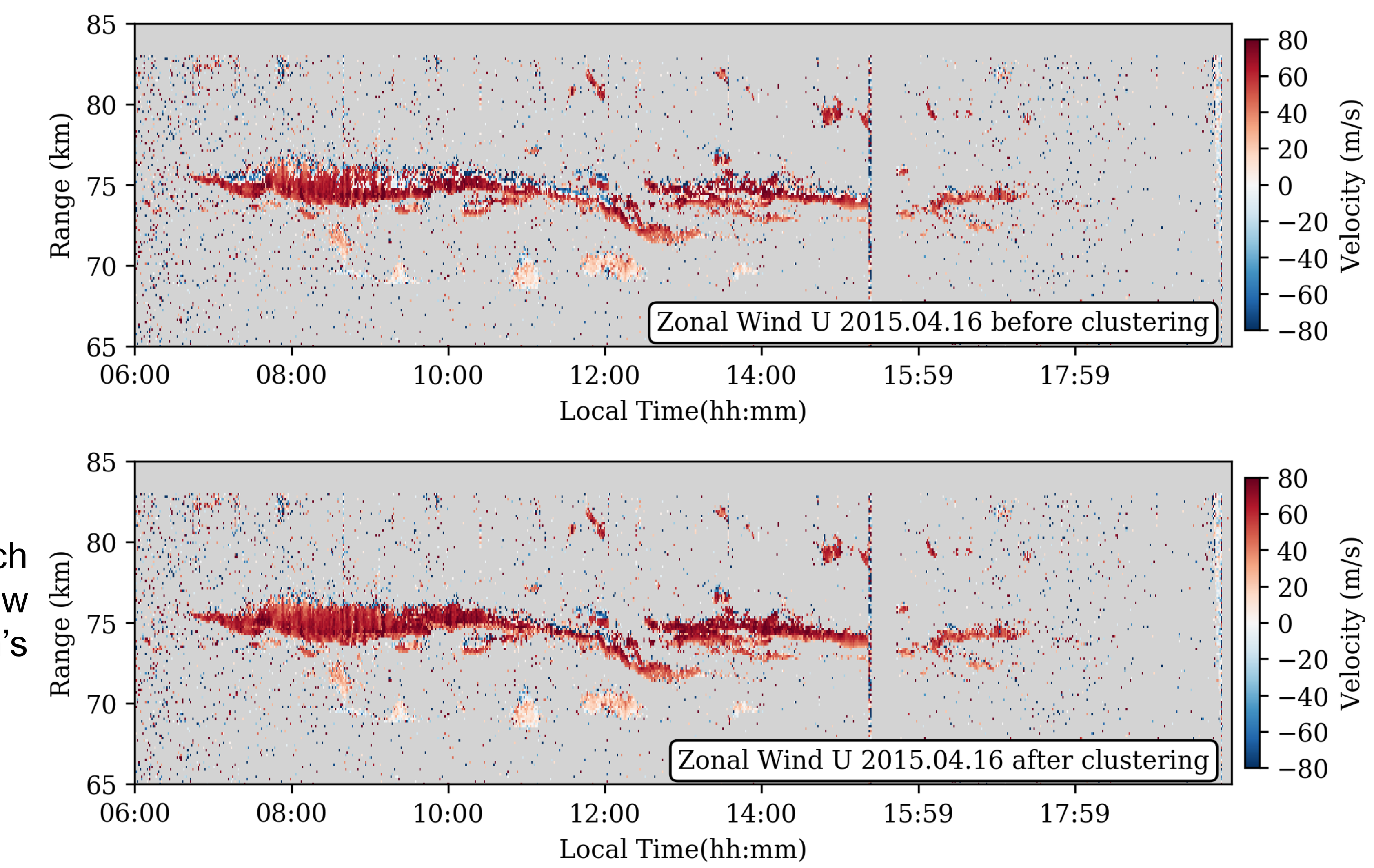

Figure 5. Zonal windmap in April 16, 2015. Upper turbulence layer of mesosphere has a sudden shift in wind velocities by sidelobe contamination (top), which are resolved using clustering algorithm (bottom)

Conclusion

- Vector wind velocities are calculated by mainlobe beam locations and Doppler shift velocities of the returned pulses.
- Occasional dual peaked spectra contaminate vector wind velocities by accidently using sidelobe beam location instead.
- Our clustering algorithm along with power comparison method is shown to improve the mesospheric wind estimation and potentially be applied to other MST radars with strong sidelobe beams.
- All of mesospheric windmaps in 2015 have small to large improvement from applying the clustering algorithm.