Daytime Thermospheric Disturbance Winds, Transients, and Transport

Lily Oglesby[1], Thomas J. Immel[2], Brian J. Harding[2], Romina Nikoukar[3]

[1]Department of Astrophysics, University of California, Berkeley [2]Space Sciences Laboratory, University of California, Berkeley [3]Applied Physics Laboratory, Johns Hopkins University

1. Motivation

Background - The Ionosphere and Geomagnetic Storms:

During solar storms and coronal mass ejections, tremendous amounts of plasma are ejected into space. The plasma induces a magnetic field that may be in the opposite direction to the magnetic field on Earth. The interaction between these magnetic fields drive energy into the ionosphere, allowing for ion outflow, and can change wind speeds and directions in the ionosphere.[1]

Motivation - Importance:

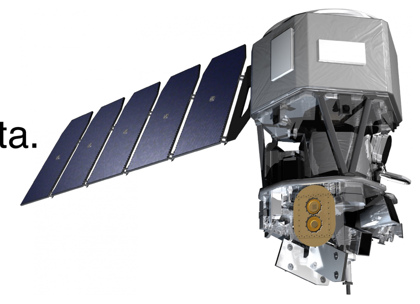
Geomagnetic storms affect technology, both ground and air. As the solar max comes, there will be more storms which affect our technology, so detection is vital.

Motivation - Contribution:

Much research[2] has characterized storms in the F – region (upper part of the atmosphere), but there is little work on storms and their effects in the E – region[3]. This work can better characterize interaction between the upper atmosphere and geomagnetic storms.

Objective:

Effects of small to moderate geomagnetic storms during ICON's mission are evident in the data.



We will quantify storm effects including:

- Establishing departures from baseline winds (zonal and meridional)
- Evaluating altitude distribution of storm effects

Storm effects are easily identifiable in F – region meridional winds. Do they extend down to the E – region and affect the ionospheric wind dynamo there?

[1] Rees, David. "Observations and modelling of ionospheric and thermospheric disturbances during major geomagnetic storms: A review." *Journal of Atmospheric and Terrestrial Physics* 57.12 (1995): 1433-1457.
[2] Fejer, Bela G., et al. "Average daytime F region disturbance neutral winds measured by UARS: Initial results." Geophysical Research Letters 27.13 (2000): 1859-1862.
[3] Zhang, S. P., & Shepherd, G. G. (2000, July). Neutral winds in the lower thermosphere observed by WINDII during the April 4-5th, 1993 storm. Geophys. Res. Lett., 27 (13), 1855-1858. doi: 10.1029/2000GL000034238

2. Data and Methods

Ionospheric Connection Explorer (ICON):

We utilize meridional and zonal wind data from ICON instrument MIGHTI.

Methods:

Geomagnetic storms increase standard deviation of wind speed, so taking the standard deviation of the wind speed will allow for storm detection as seen in Figure 1.

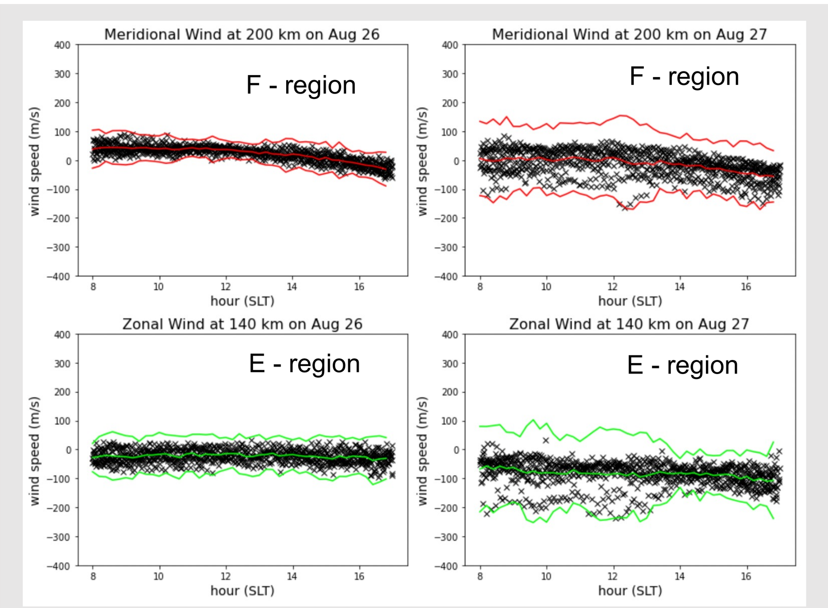
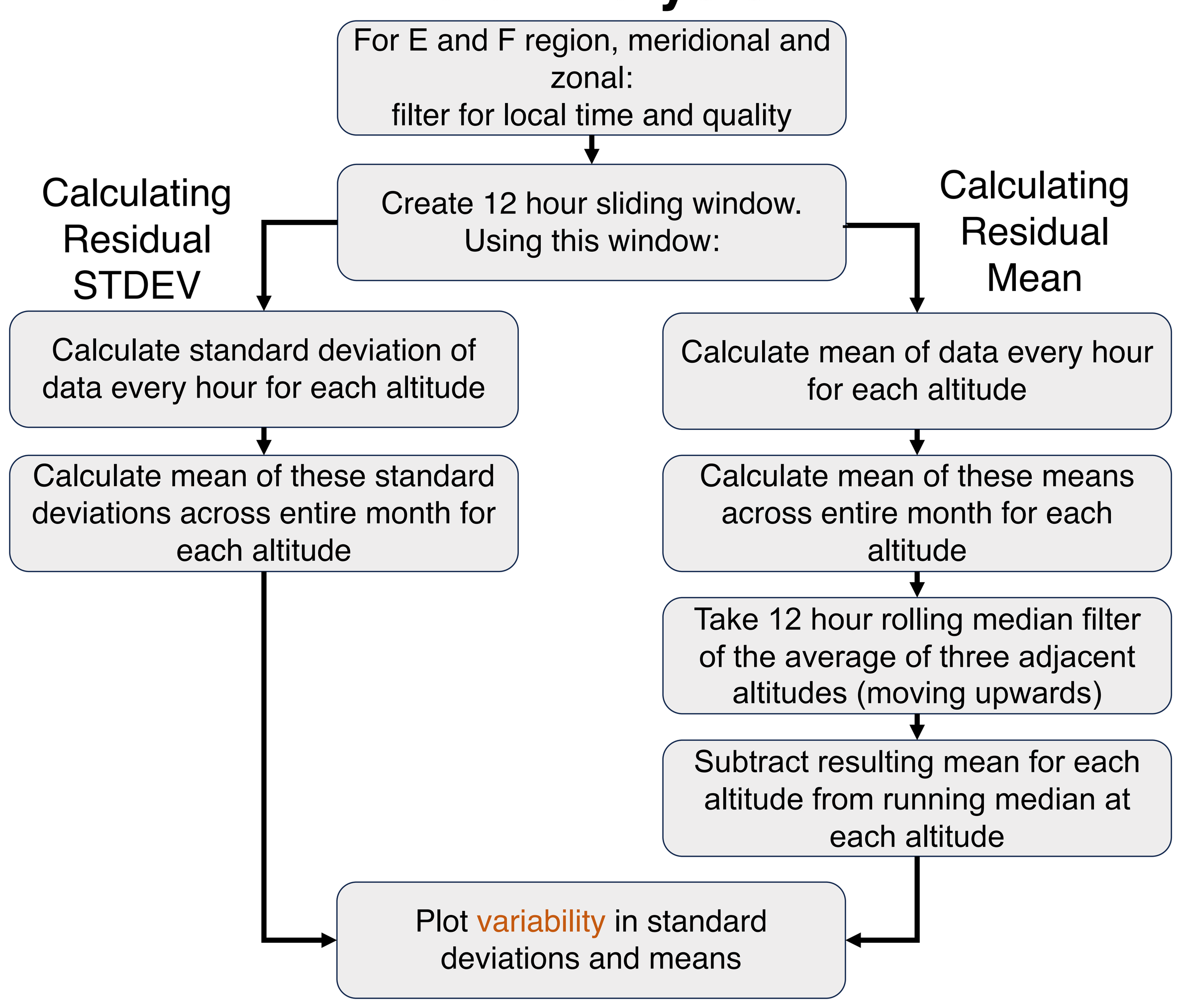


Fig 1: Mean and 3 sigma range on measurements, in 1-hour local time bins for regular day (left side) vs storm day (right side). E- and F-region altitudes selected for plots. Standard deviation is variable at high and low altitudes, while the mean is stable.

Data Analysis:



3. Results

Choice of Residual

We Compare meridional (north/south) winds in upper atmosphere to zonal (east/west) winds in lower atmosphere because geomagnetic storms transport wind from high latitudes to lower latitudes. Air going south turns perpendicular due to the Coriolis effect. We are looking for a negative change in the east/west winds in the lower ionosphere.

We use averaged standard deviation of north/south winds to indicate magnitude of wind speed. We use residuals to the mean for east/west winds to determine directionality of wind speeds.

Figures 2, 3, and 4 compare meridional winds to zonal winds to determine whether storms detected in meridional winds are also detected in zonal winds.

Comparison of May 2021 Storms – Data:

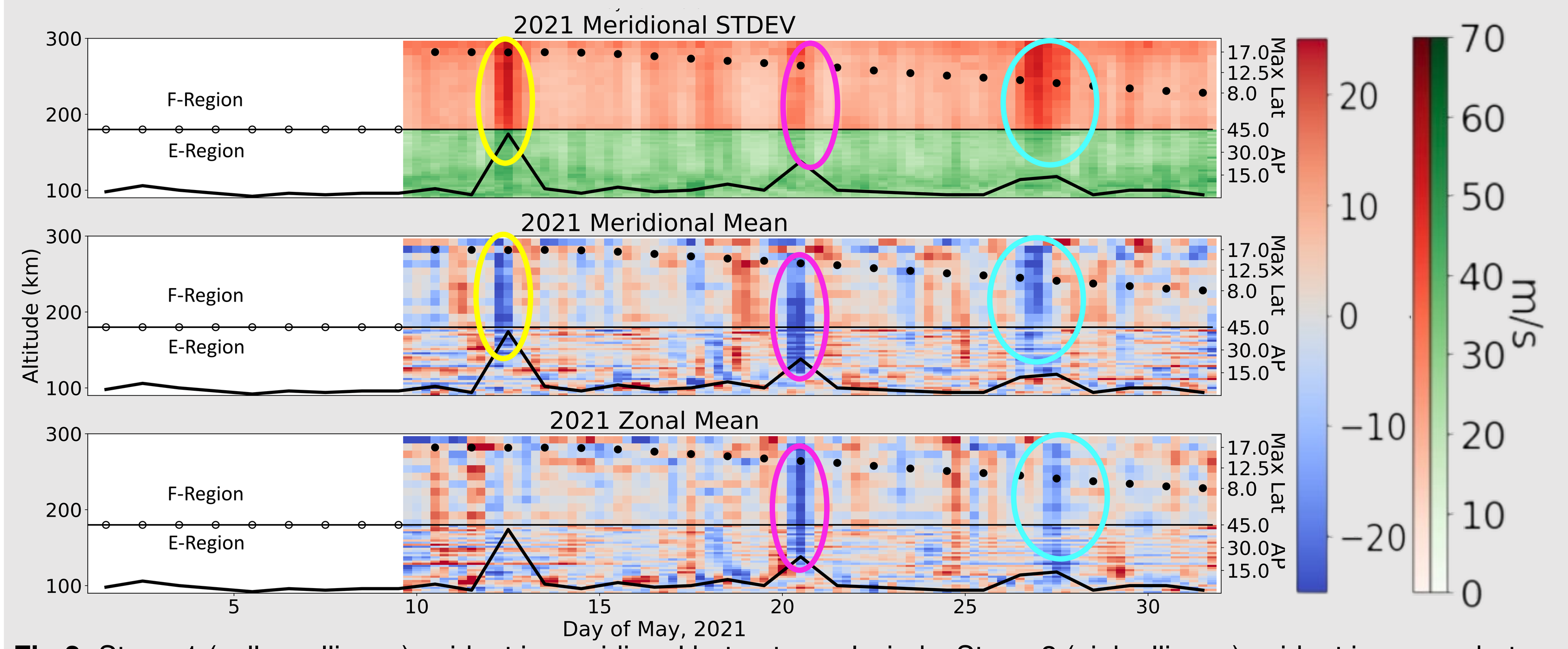


Fig 2: Storm 1 (yellow ellipses) evident in meridional but not zonal winds. Storm 2 (pink ellipses) evident in means but weak in standard deviation. Storm 3 (neon blue ellipses) evident in all three plots, with a delay in the zonal mean. Black dots represent maximum latitude at which measurements for that day were taken.

Comparison of May 2021 Storms – TIEGCM:

The TIEGCM model defines tidal perturbations in the meridional and zonal winds based off MIGHTI observations. We have sampled the model at the MIGHTI sampling locations to create a synthetic dataset, which we can compare with the real dataset. This dataset was subject to the same analysis as the data.

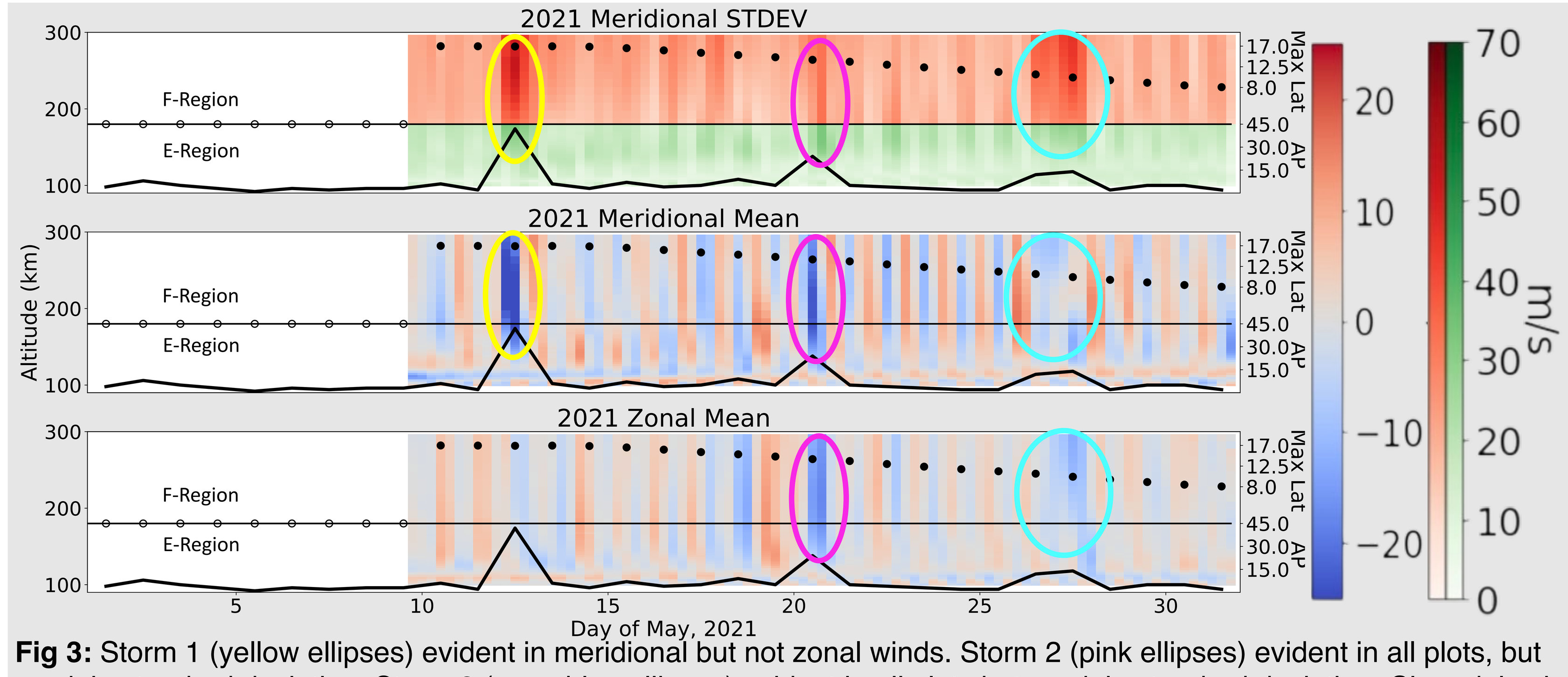


Fig 3: Storm 1 (yellow ellipses) evident in meridional but not zonal winds. Storm 2 (pink ellipses) evident in all plots, but weak in standard deviation. Storm 3 (neon blue ellipses) evident in all plots but weak in standard deviation. Clear delay in storm between red and green line.

Comparison of May 2021 Storms – NOHME:

The NOHME model is the same as the TIEGCM but excludes tidal forcing at the lower atmosphere boundary. Looking at the NOHME model may reveal if diurnal tides are obscuring the strength of storm effects. This dataset was subject to the same analysis as the data.

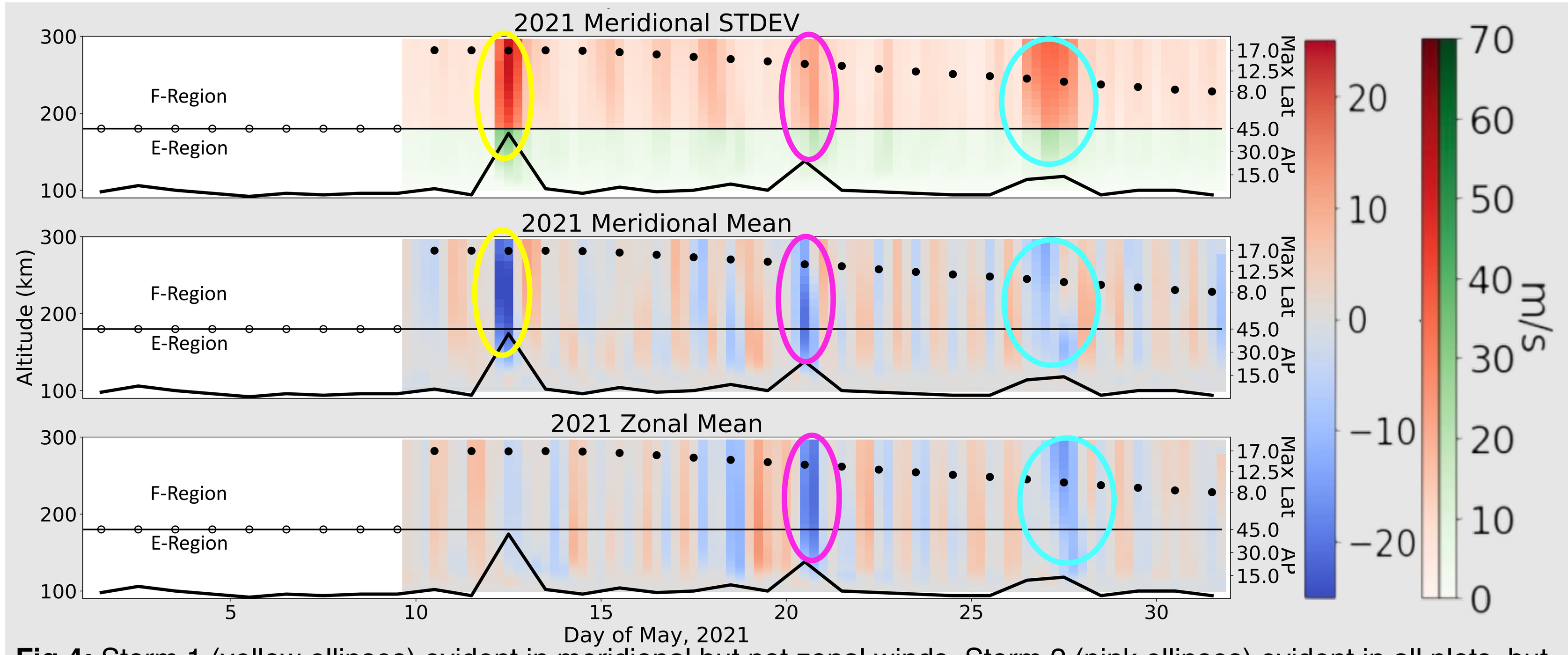


Fig 4: Storm 1 (yellow ellipses) evident in meridional but not zonal winds. Storm 2 (pink ellipses) evident in all plots, but weak in standard deviation. Storm 3 (neon blue ellipses) evident in all plots but weak in standard deviation. Clear delay in storm between red and green line.

Times of Max Wind Speeds in May 2021 at 192 km to determine delays

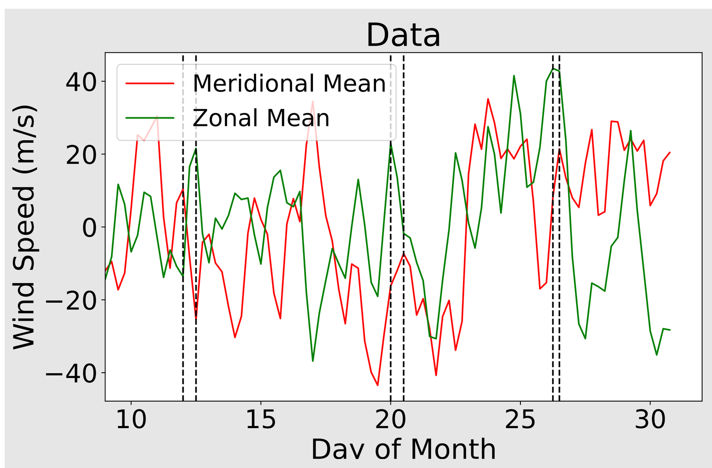


Fig 5: Storm 1: Half day delay in peaks. Storm 2: Half day delay in peaks. Storm 3: Zonal peaks before meridional

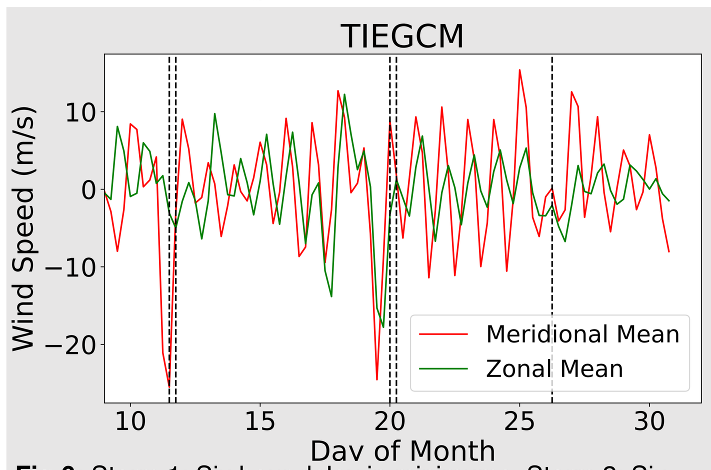


Fig 6: Storm 1: Six hour delay in minimums. Storm 2: Six hour delay in peaks. Storm 3: Maxes occur at same time, values are both negative.

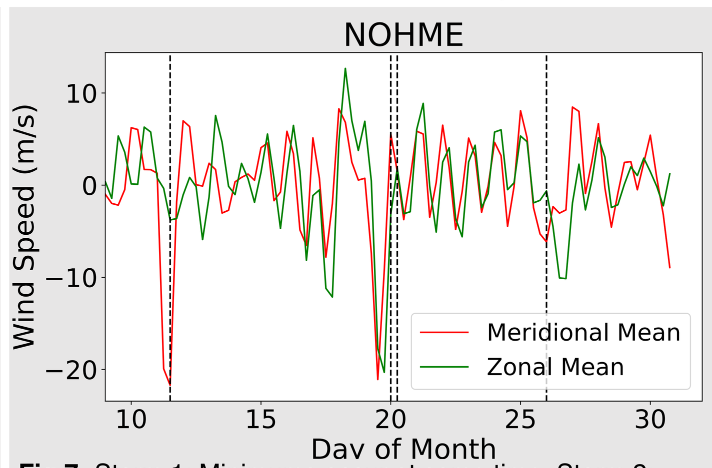


Fig 7: Storm 1: Minimums occur at same time. Storm 2: Maxes occur at same time as TIEGCM. Storm 3: Maxes occur at same time

4. Conclusions and Future Work

Conclusions:

- Not all storms are detected in Zonal means, implying not all storms are strong enough to affect the E – region disturbance dynamo.
- There is often a delay between peak wind speed of Meridional standard deviation and Zonal mean, implying it takes time for effects in the upper atmosphere to appear in the E – region.
- TIEGCM mostly agrees with data but there are some differences

Future Work:

- Analysis of all storms in data set, including delay in max wind speeds
- Further exploration of why magnitude of standard deviation of TIEGCM and NOHME differ

ICON is supported by NASA's Explorers Program through contracts NNG12FA45C and NNG12FA42I. ICON data are processed in the ICON Science Data Center at UCB and are available at https://icon.ssl.berkeley.edu/Data