Identifying Correlations between Thermospheric Neutral Winds and Day-to-Day and Longitudinal Variability in Pre-Reversal Enhancement of Equatorial Zonal Electric Field

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Debating Mechanisms that Drive Pre-Reveral Enhancement

- Pre-reversal enhancement (PRE) is the enhanced zonal electric field at equatorial latitudes arising from the F-layer neutral wind dynamo that occurs during sunset
- Variabilities in the PRE have been linked to variabilities in other phenomena, including equatorial plasma bubbles and equatoral spead-F (Abdu 2019)
- Mechanisms that control its occurrence and predict its strength are still debated:
  - The Curl Free Mechanism (Eccles et al. 2015) proposes that the PRE is a result of magnetic field driving strong downward polarized electric fields
  - A study by Liu (2020) using WACCM-X simulations found that day-to-day variability in the PRE was largely controlled by E-region winds in mid-latitudes
  - Using GAIA simulations, Ghosh et al. (2020) found correlations in the F-region neutral winds with peak the PRE with correlation coefficient of 0.5 (approximately) at 19 solar local time (SLT).

We aim to leverage ICON data to test proposed mechanisms that drive the PRE and compare simulated correlations with in-situ and remote measurements.

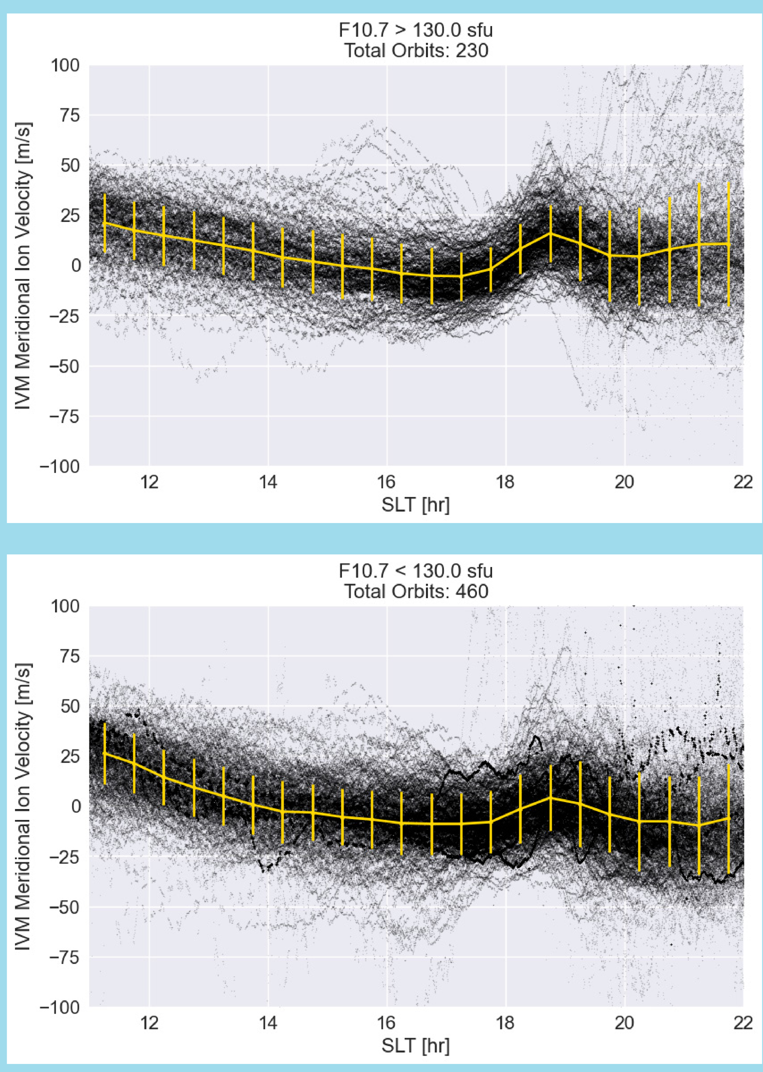


Fig. 1 *The PRE of plasma drifts around 19 SLT in 2022, measured by the IVM instrument on ICON. Stronger peaks in PRE are observed during periods of higher solar activity (top)*

Data

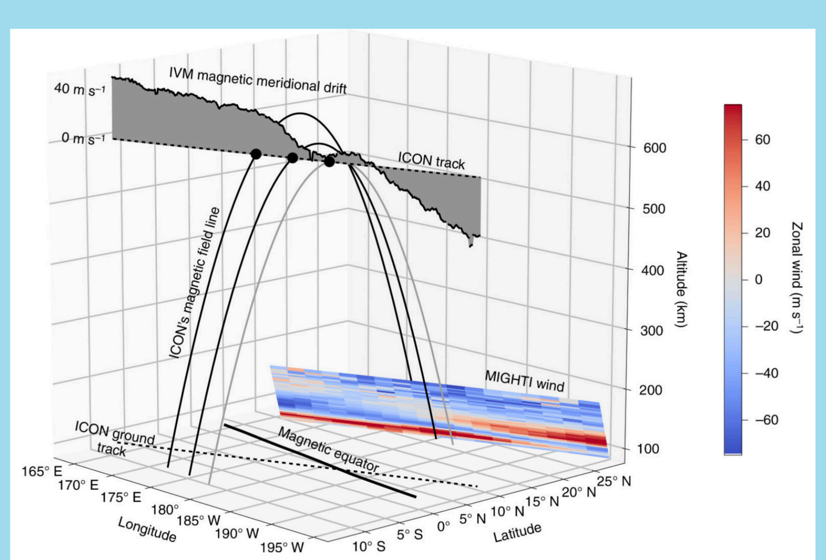
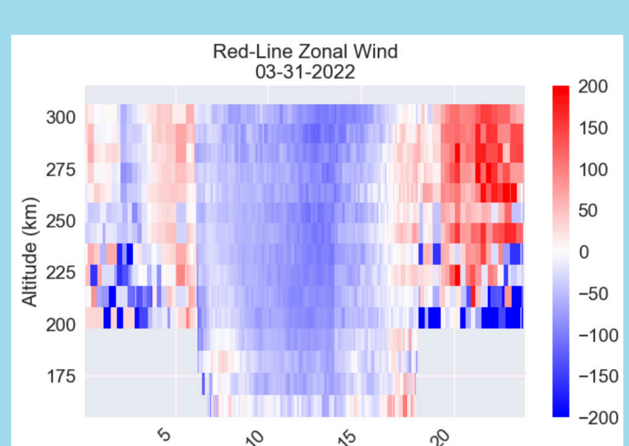


Fig. 2 *Diagram showing how ICON supports simultaneous observations of lower thermospheric winds and ionospheric plasma velocities (Immel et al 2021)*

For this analysis, we use level 2 data from the Ionospheric Connection Explorer (ICON) mission's Ion Velocity Meter (IVM) and Michelson Interferometer for Global High-resolution Thermospheric Imaging (MIGHTI).

- MIGHTI observes neutral winds remotely at altitudes of 90-300 km using red (630.0 nm) and green (557.7 nm) airglow emissions
- IVM measures the ion drift velocity in-situ



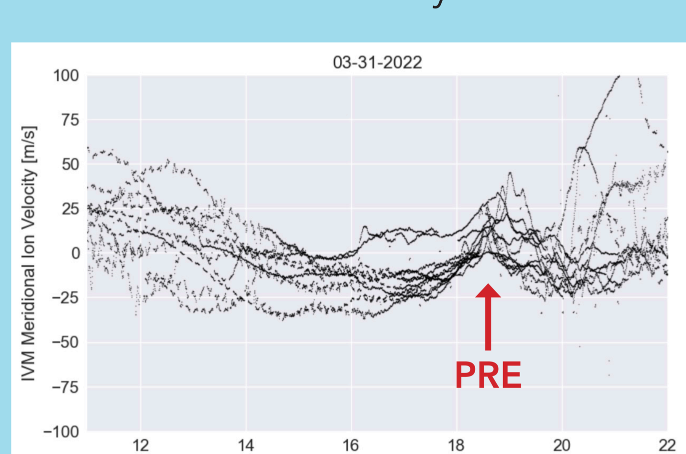


Fig. 3 (left) *MIGHTI red-line zonal neutral wind measurements taken on March 1, 2022*
Fig. 4 (right) *IVM meridional plasma drift measurements taken on March 1, 2022*

Methods

- We select ICON data sampled between 17.5-19.5 SLT, where the solar zenith angle is ~98 degrees within 5 degrees of magnetic equator.
- We constrain our analysis to data from 2022, to capture the highest solar activity during the ICON mission period.
- To isolate longitudinal variability, we identify changes in MIGHTI neutral winds and IVM plasma drifts between 203 pairs of consecutive orbits.
- To isolate day-to-day variability, we identify changes in MIGHTI neutral winds and IVM plasma drifts between 100 pairs of orbits at nearly the same longitude, where the times of crossing the magnetic equator are separated by ~1 day (24-24.15 hrs).

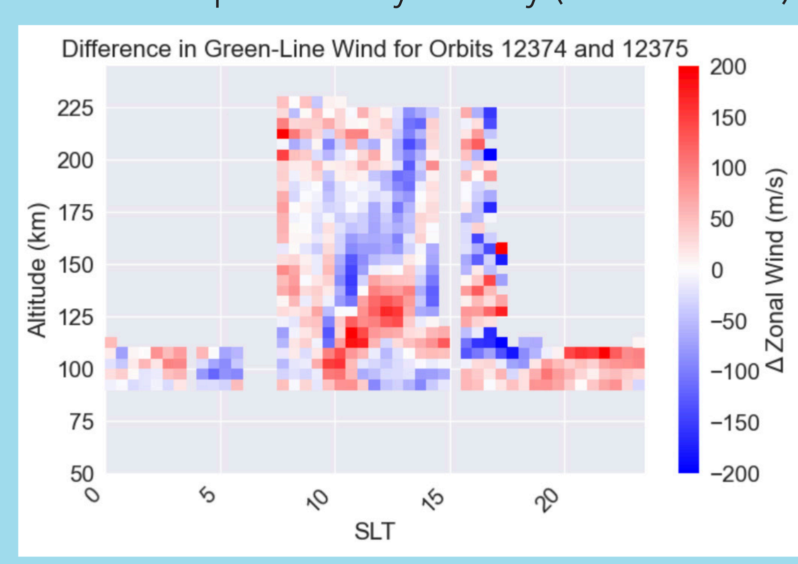


Fig. 5 *Differences in MIGHTI green-line (557.7 nm) neutral wind measurements between orbits 12374 and 12375*

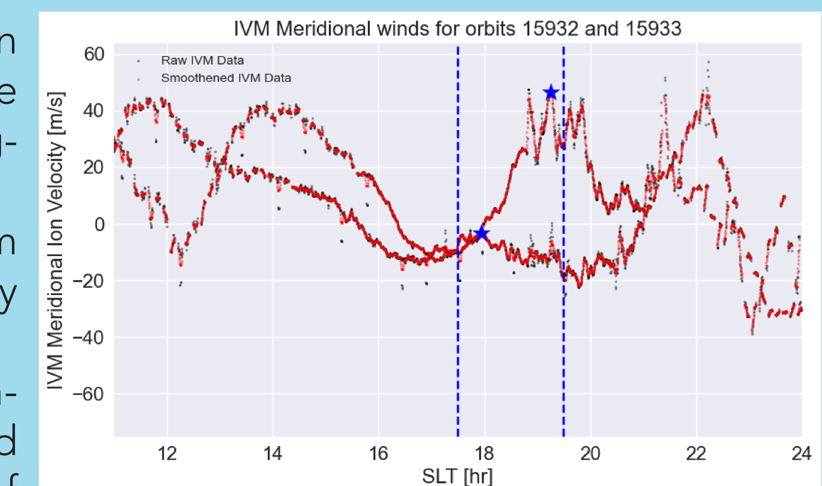


Fig. 6 *IVM plasma drift velocity measurements for orbits 15932 and 15933. We apply a rolling mean filter to smoothen the data. Peak plasma drifts between 17.5-19.5 SLT marked with blue stars.*

- For each orbit, we define the peak PRE strength as the maximum IVM plasma drift velocity measured by ICON IVM for that orbit between 17.5-19.5 LT.
- We bin MIGHTI neutral wind data into 0.25 hr SLT bins.
- To test whether changes in the PRE strength are associated with changes in neutral winds, for each pair of orbits, we compare differences in the peak PRE with differences in zonal neutral wind measurements with measurements taken at each altitude and SLT bin. We then calculate the Pearson correlation coefficient between differences in PRE strength and neutral winds.

Findings: Weak Correlations Between Zonal Neutral Winds and Meridional Plasma Drifts for Orbits Separated by 1 Day

- The top plot shows correlations between differences in peak PRE and differences zonal red-line (630 nm) neutral winds for different altitudes and solar local times.
- The bottom plot shows correlations between differences in peak PRE and differences zonal green-line (557.7 nm) neutral winds for different altitudes and solar local times.
- We find small correlations (≤0.3) between day-to-day variabilities in PRE strength and neutral winds

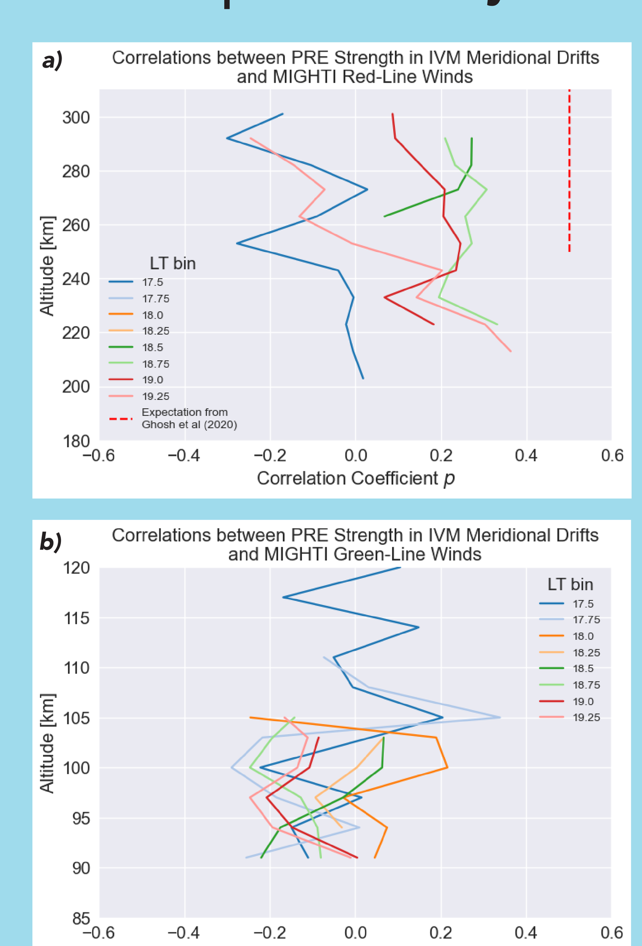


Fig. 7 *Correlations between differences in measurements of PRE strength and **(a)** red-line and **(b)** green-line neutral winds between orbits separated by one day for varying altitude and SLT bins.*

Findings: Weak Correlations Between Zonal Neutral Winds and Meridional Plasma Drifts for Consecutive Orbits

- The top plot shows correlations between differences in peak PRE and differences zonal red-line (630 nm) neutral winds for different altitudes and solar local times.
- The bottom plot shows correlations between differences in peak PRE and differences zonal green-line (557.7 nm) neutral winds for different altitudes and solar local times.
- We find small correlations (≤0.25) between longtudinal variabilities in PRE strength and neutral winds.

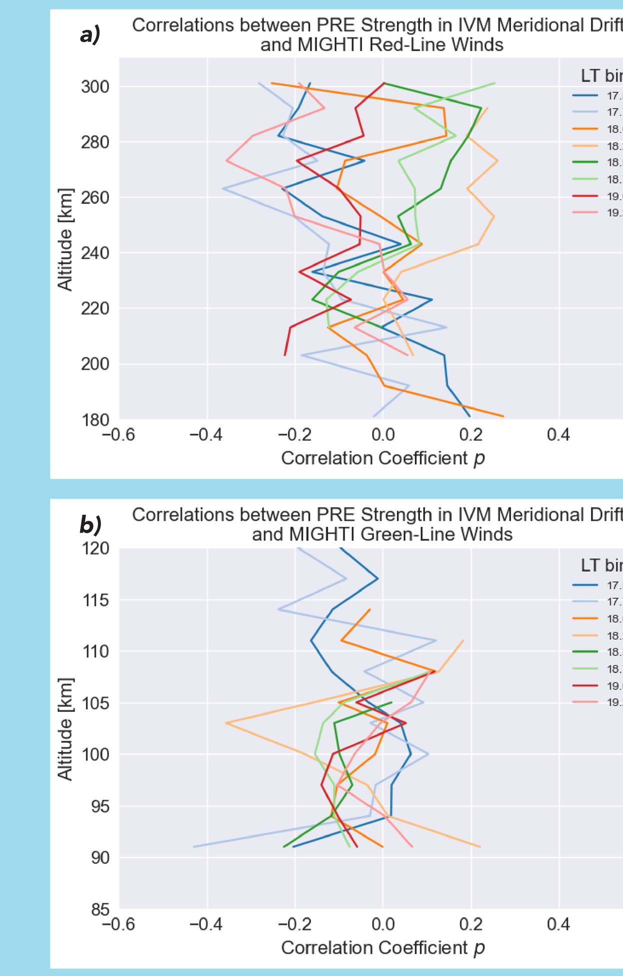


Fig. 8 *Correlations between differences in measurements of PRE strength and **(a)** red-line and **(b)** green-line neutral winds between consecutive orbits for varying altitude and SLT bins.*

Summary and Next Steps

- We do not find high correlations between day-to-day and longitudinal variabilities in peak PRE strength and eastward neutral winds in ICON measurements.
- These results disagree with results using simulated data from GAIA models (Ghosh et al 2020).
  - This discrepancy may arise due to ICON measuring neutral winds at different magnetic apex latitudes further from the magnetic equator.
- Ongoing work
  - Using a principal component regression model to predict zonal neutral winds for altitudes and local times where there is limited data
  - Comparing results using ICON in-situ and remote data with results using WACCM-X simulations that sample ICON data

References and Acknowledgements

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