# Impact of interhemispheric winds on equatorial plasma drift : Comparison between global simulations and ICON Observations

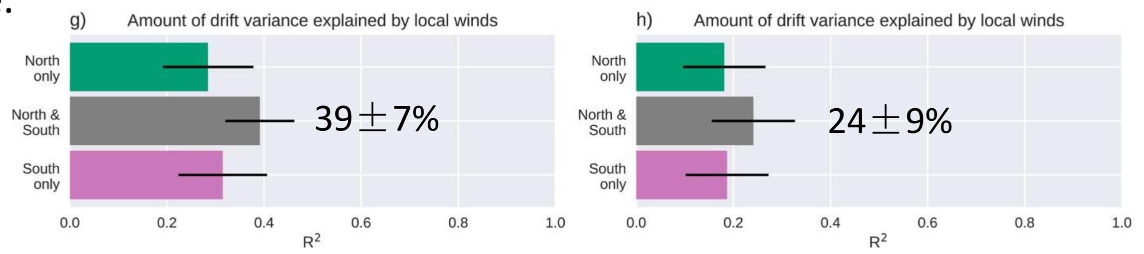
Minjing Li[1], Yue Deng[1], Brian Harding[2], Joseph D Huba[3],
University of Texas at Arlington[1], University of California, Berkeley[2], Syntek Technologies Inc[3]

Email: mxl9483@mavs.uta.edu

COUP-5

## Introduction & Motivation

- Short-term ionospheric variability, often linked to transient mesoscale forcings, remains poorly understood due to limited simultaneous observations of equatorial plasma drift and neutral wind drivers.
- Harding et al. (2024), using 149 pairs of ICON maneuvers, showed that conjugate neutral winds explain 39±7% of the day-to-day variability in vertical plasma drift and 24±9% of the variability in zonal drift.
- Due to the limited sample size of 149, contributions from other factors are difficult to evaluate.




[Harding et al. 2024]

## Methodology

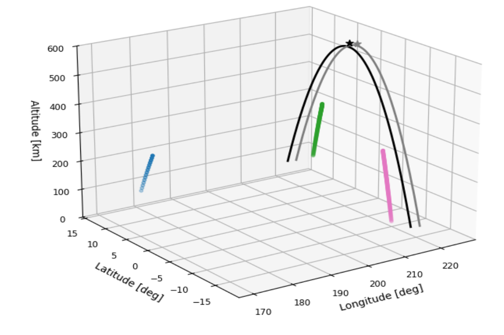


Fig. 1. Schematic of ICON observations in conjugate and normal modes, showing wind measurement offsets from precise conjugacy.

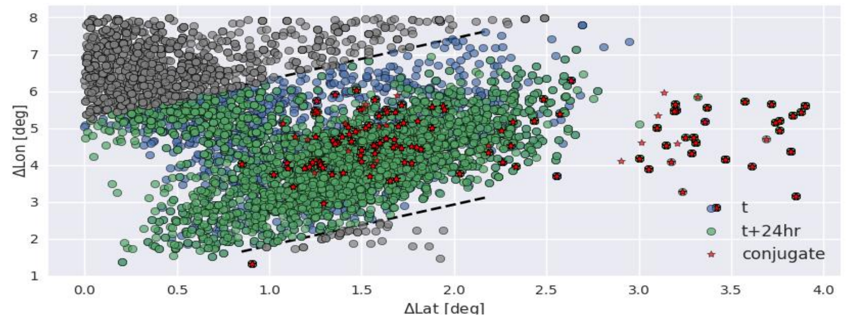



Fig. 2. Offset of MIGHTI wind measurements from precise conjugacy at 160 km altitude when ICON crossed the magnetic equator (Dec 2019 – Nov 2022).

### Normal mode data selection

- The offset with spatial differences Δlat < $5^0$ and Δlon < $8^0$ are retained. As shown in Fig. 2, gray dots are excluded based on these criteria.
- Data pairs with 23–25 hr time differences are selected for D2D analysis.
- A total of 1919 valid samples are identified, more than the 148 available from conjugate-mode data

### GITM-SAMI3 setup

- Dates: Mar. 20th, June 22nd, Sep 22nd, Dec 22nd; Conditions: $F107$=75, Kp=2
- Wind perturbation (~±50 m/s) added to the background wind at ±$15^0$ mlat & $110^0$W mlon, in the lower E-region, from 1220 to 1350 LT (duration: 1.5 hr)

### Comparison Between Normal Mode and Conjugate Mode Results

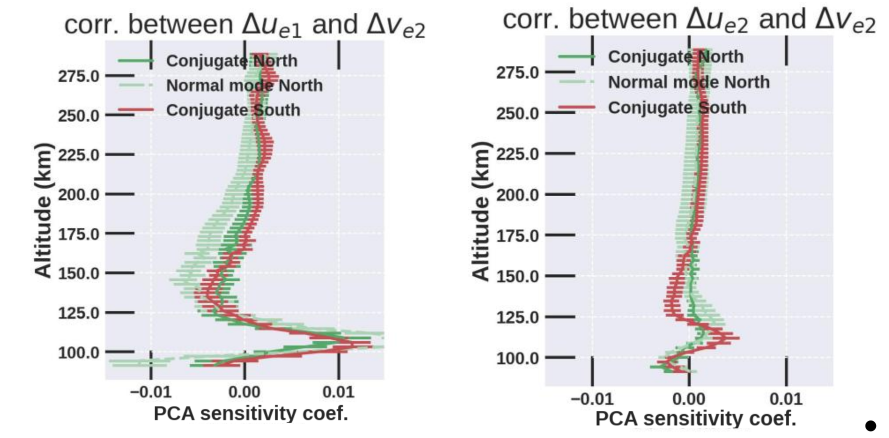



Fig. 3. Regression-derived coefficients across altitudes, representing the sensitivity of plasma drift variability to winds at different altitudes in the magnetic zonal and meridional directions.

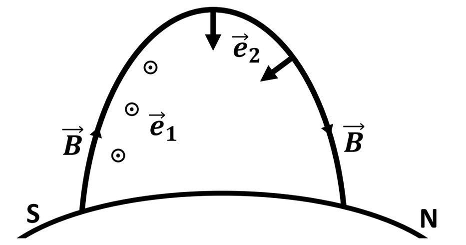



Fig. 4: Schematic illustrating the direction of $\boldsymbol{e}_2$ (magnetic meridional downward) and $\boldsymbol{e}_1$ (magnetic zonal)

- The overall altitude profile shape is generally consistent with that of the northern conjugate data. This supports using normal mode data to expand the dataset and enable more detailed analyses.

## Results

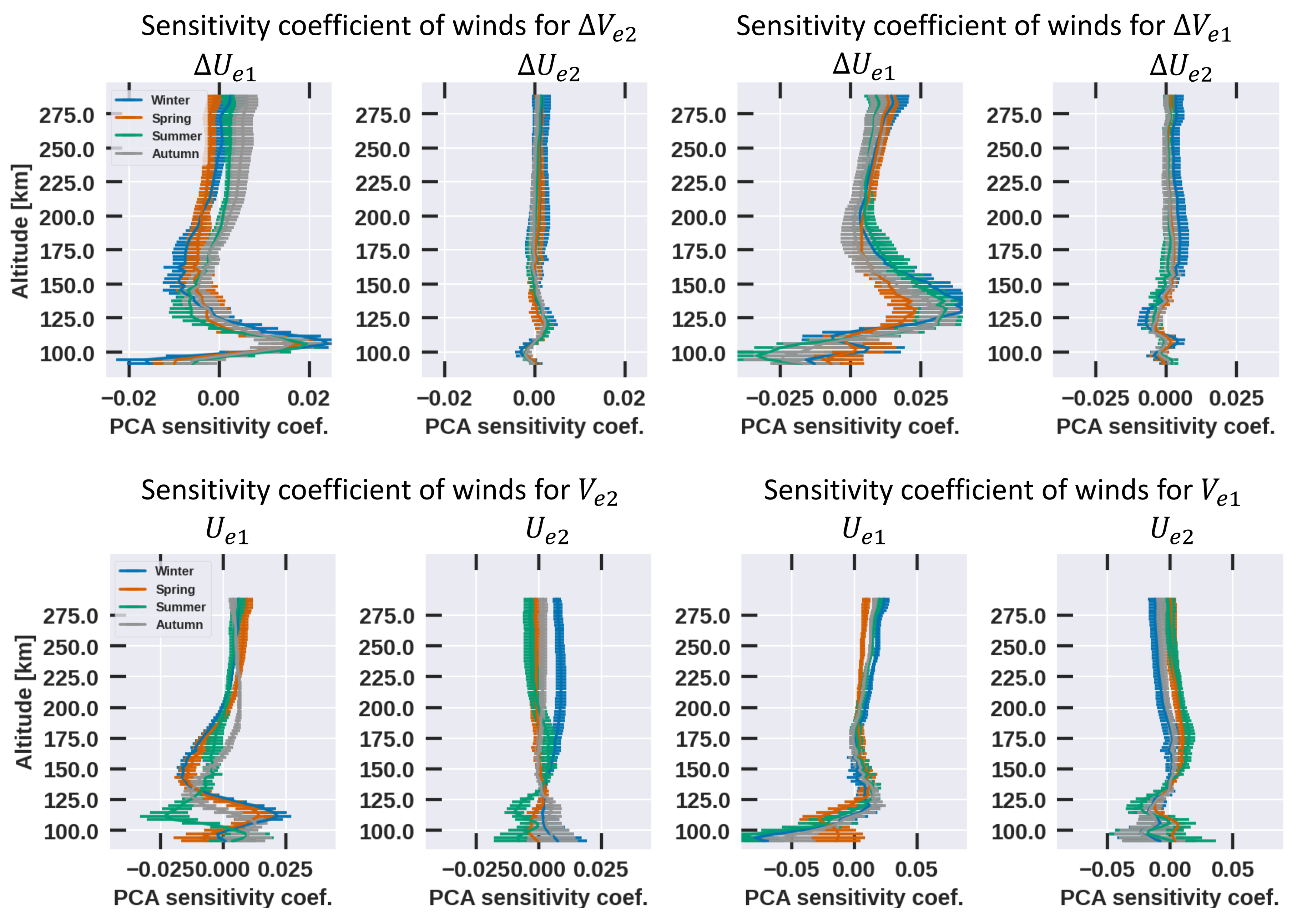



Fig. 5. (Top) Regression-derived coefficients showing how variability in meridional plasma drift (left) responds to wind variations at different altitudes. The right panel shows the same for zonal plasma drift. Colors indicate seasons. (Bottom) Same, but for direct wind-drift relation rather than day-to-day variability.

### Altitude-Dependent Wind Influence on Plasma Drifts by Season

(Seasonal subsets are projected onto principal components derived from the full dataset, enabling consistent coefficient comparisons across seasons.)

- Drift sensitivity to winds across altitude shows more consistent seasonal patterns for day-to-day variations, in contrast to direct wind–drift.

- Across all seasons, $\Delta U_{e1}$ exhibits a strong influence near 106 km in the $\Delta V_{e2}$ regression and near 135 km in the $\Delta V_{e1}$ regression.
- Wind forcing explains most drift variability in summer but least in winter. Large winter coef. result from minimal variance

- In the summer season, an opposite trend is observed at lower E-region altitudes.

### Correlation of FLI currents driven by winds and electric fields

To investigate the total contribution of winds to plasma drift along the field line, we compute field-line integrated currents instead of using determination coefficients, thereby avoiding the influence of large seasonal differences in variance when studying seasonal effects.

### Geomagnetic activity

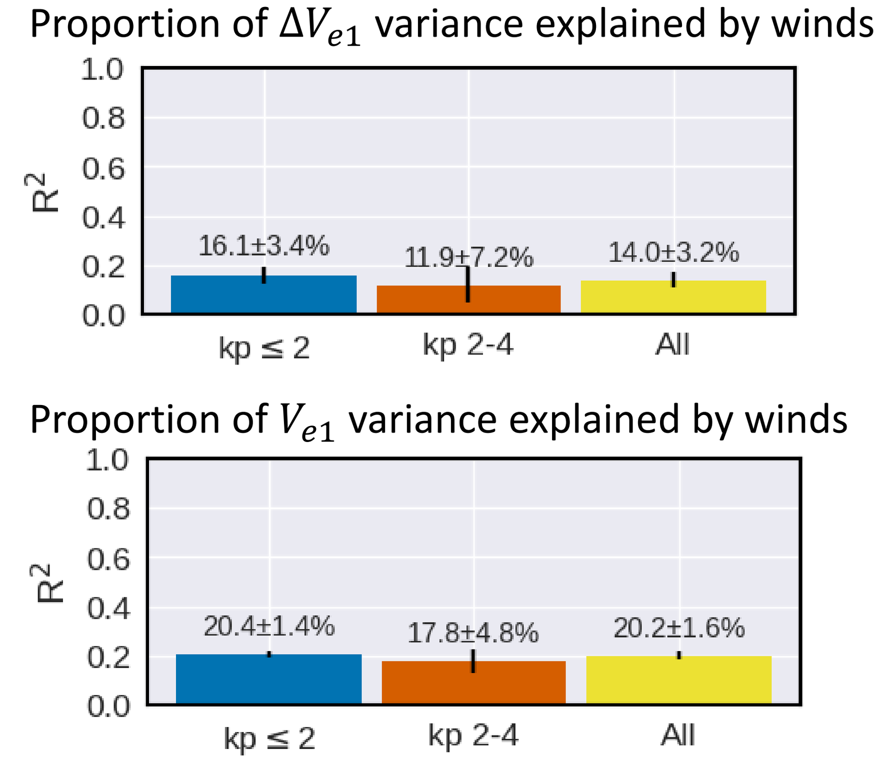



Fig. 7. Comparison of determination coefficients (R²) across two Kp categories, representing the proportion of drift variance explained by winds.

Proportion of selected Data by Kp Level (Dec 2019 – Nov 2022):

- Kp ≤ 2: 57.5%
- 2 < Kp ≤ 4: 41.2%
- Kp > 4: 1.2%

The contribution of winds to plasma drift shows minimal dependence on low-moderate geomagnetic activity.

**ICON Observation** | **GITM-SAMI3 Modeling**

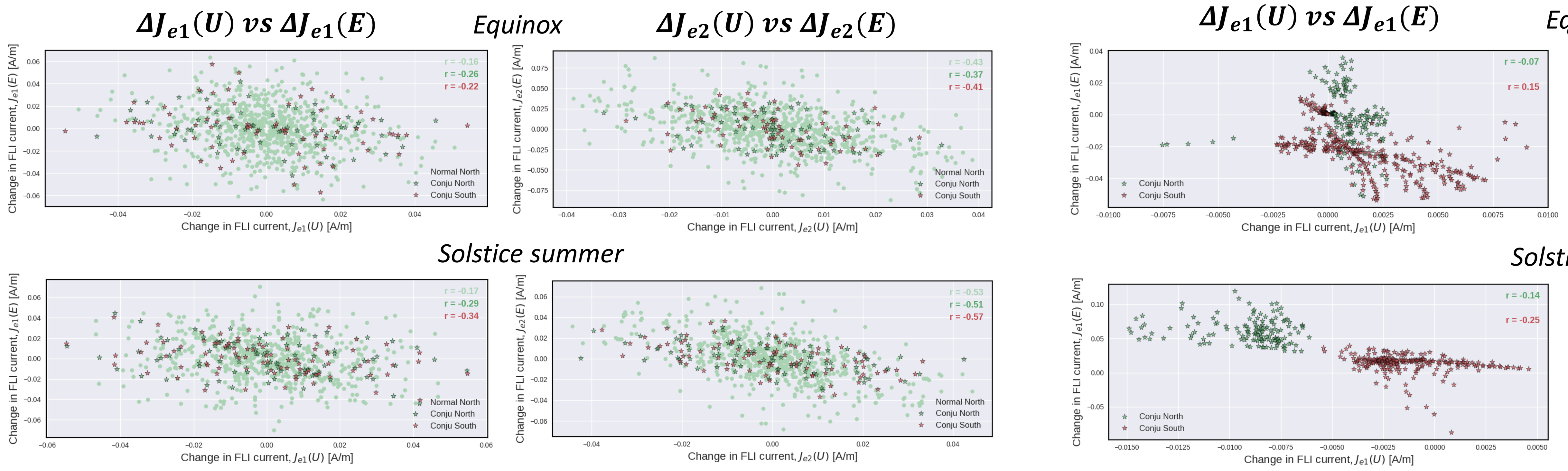



Fig. 6. Data–model comparison of day-to-day variations in FLI current driven by winds (x-axis) and electric fields (y-axis).

- Higher wind–E-field correlation in $\Delta J_{e2}$ than $\Delta J_{e1}$. A similar pattern is seen for $J$, with ~0.2 and ~0.1 higher correlations for $J_{e1}$ and $J_{e2}$, respectively (not shown).
- Wind-driven contributions stronger in the summer hemisphere than during equinox.
- Modeled coefficient magnitudes deviate from observations in both hemisphere and appear more scattered due to inclusion of outputs within a 1 hr window.
- The difference likely implies different drivers for day-to-day variations (observation) and concurrent responses (simulation).

## Summary

1. The seasonal pattern of wind-driven drift sensitivity remains fairly consistent across altitudes for day-to-day variability, but not for total wind–drift relationships, particularly during the solstice in the lower E-region.
2. In the summer hemisphere, ~30% of the electric field–driven current in the magnetic zonal direction and ~4% in the meridional (downward) direction are explained by winds, based on ICON observations. Correlations are higher during solstice than equinox.
3. During this time, the ICON observation period (Dec 2019 – Nov 2022) mostly falls within low to moderate geomagnetic activity. Wind–drift correlations across altitudes and total altitude-integrated wind contributions appear independent of geomagnetic activity.