ICON
Ionospheric Connection Explorer

Regulation of ionospheric plasma velocities by thermospheric winds

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ICON's Science Objective – Understand the source of ionospheric variability

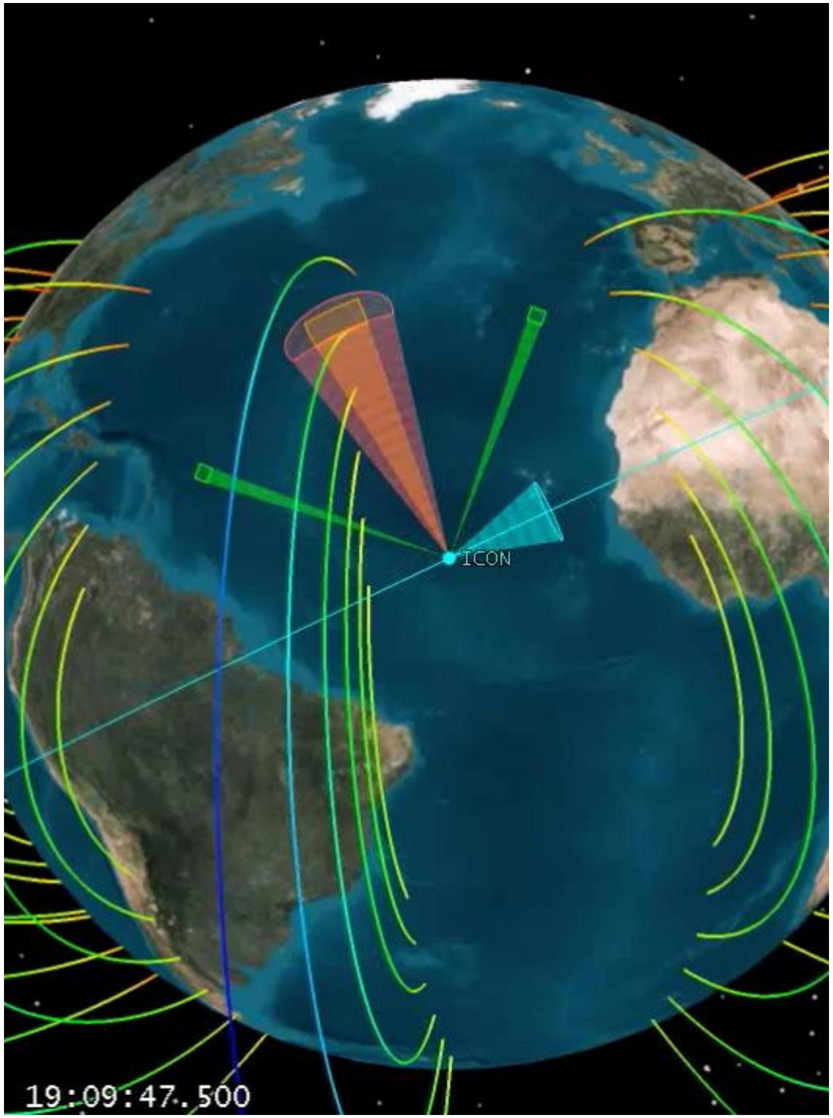
The Ionospheric wind dynamo is an influential driver the motion of the plasma as it develops during the daytime.

- How is it related to the overall flow of plasma in the system? To answer this, ICON measures both:

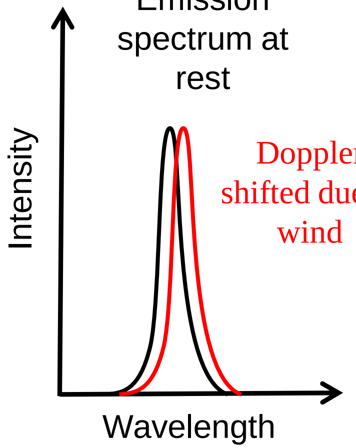
Neutral winds that carry the energy and momentum that drives the dynamo, and

The plasma velocity distribution, as it responds to the dynamo and other drivers.

This study focuses on the winds associated with vertical plasma drift at the equator near noon.

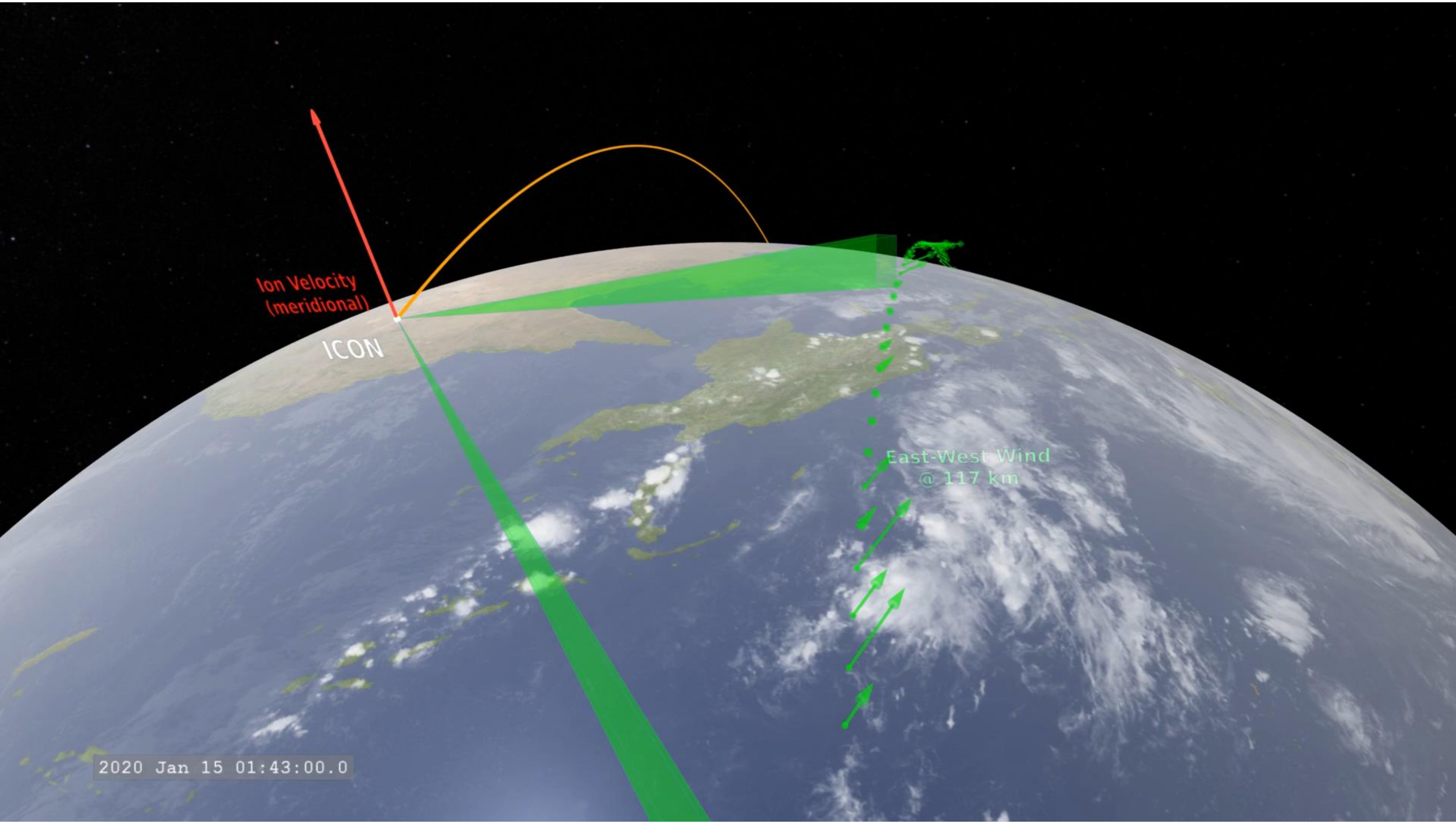


MIGHTI Science Target is Visible Emission of Atomic Oxygen

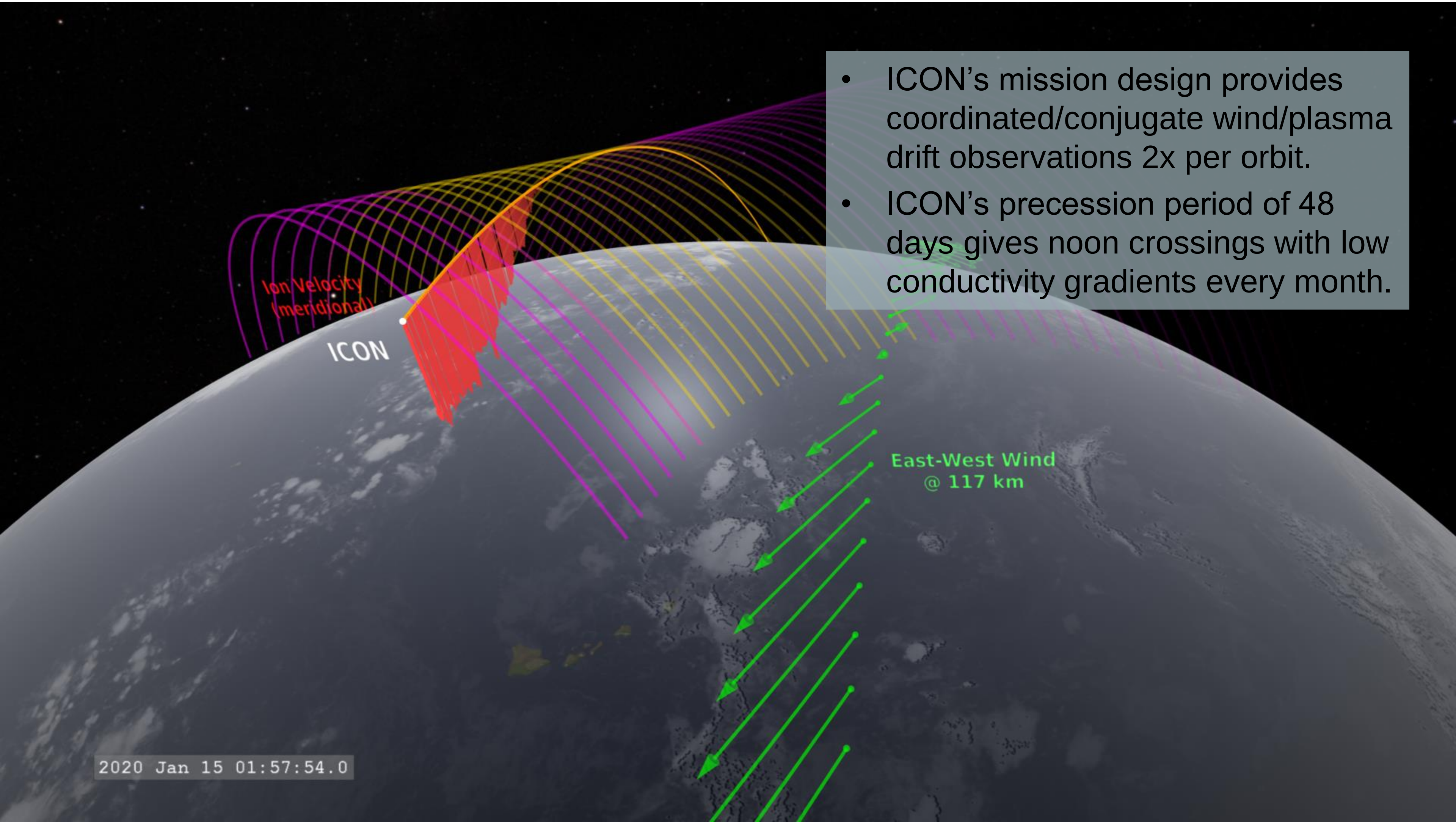


- MIGHTI implements a pair of Michelson Interferometers to retrieve Doppler shifts of light at dominant emission wavelengths of atomic oxygen (OI)
- Doppler shift is a proxy for bulk atmospheric motion

Electrodynamic Forcing of the Lower Atmosphere on the Ionosphere



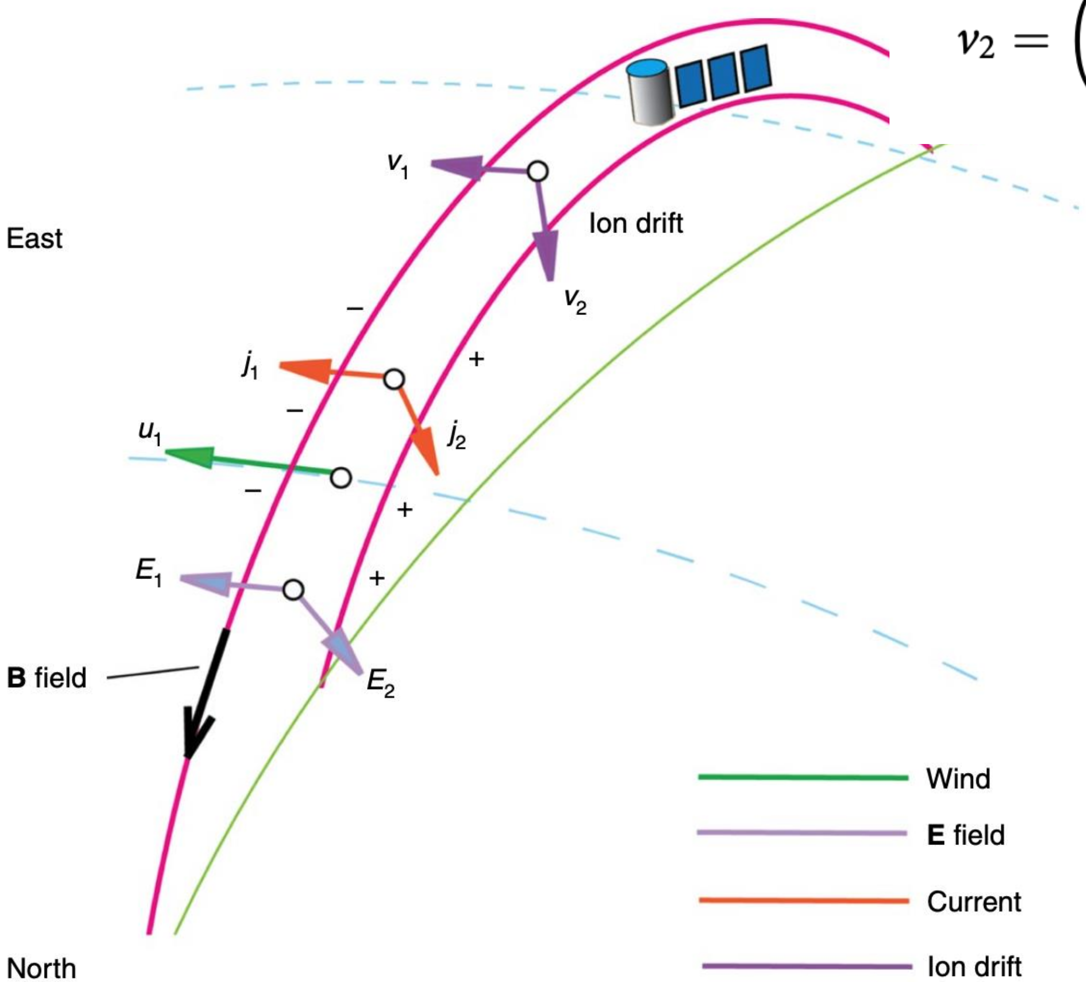
Electrodynamic Forcing of the Lower Atmosphere on the Ionosphere



- ICON's mission design provides coordinated/conjugate wind/plasma drift observations 2x per orbit.
- ICON's precession period of 48 days gives noon crossings with low conductivity gradients every month.

Predicting ionospheric drifts from lower thermospheric winds

NASA ICON Ionospheric Connection Explorer



$$v_2 = \left(\frac{\Sigma_H}{\Sigma_C} U_1^H + \frac{\Sigma_P}{\Sigma_C} U_2^P + \frac{\Sigma_H^2}{\Sigma_C \Sigma_P} U_2^H - \frac{\Sigma_H}{\Sigma_C} U_1^P \right)$$

1,2 = zonal, meridional

H, P = Hall, Pedersen

Decoder #1: U_1^H Is line integrated zonal wind weighted by the Hall conductivity

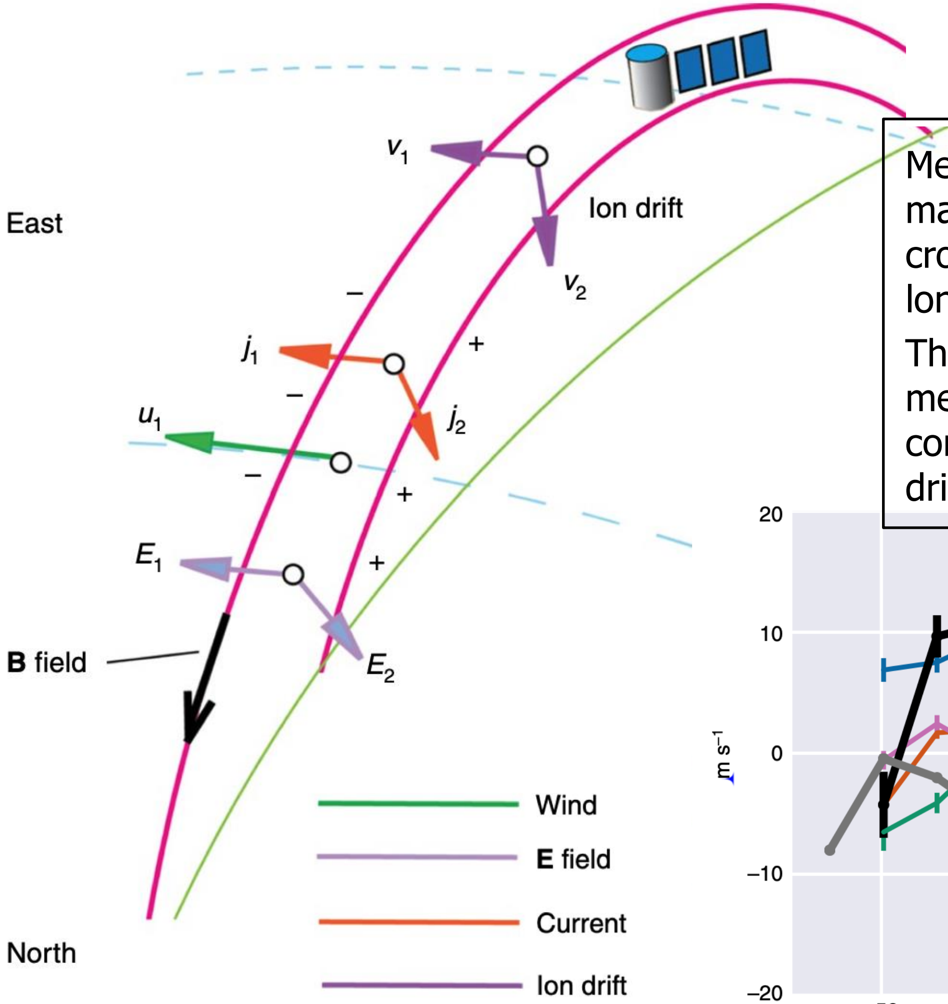
$$U_1^H = \frac{\int \sigma_H u_1 \, ds}{\int \sigma_H \, ds}$$

Decoder #2 Σ_C Is the Cowling conductance

$$\Sigma_C = \frac{\Sigma_H^2}{\Sigma_P} + \Sigma_P$$

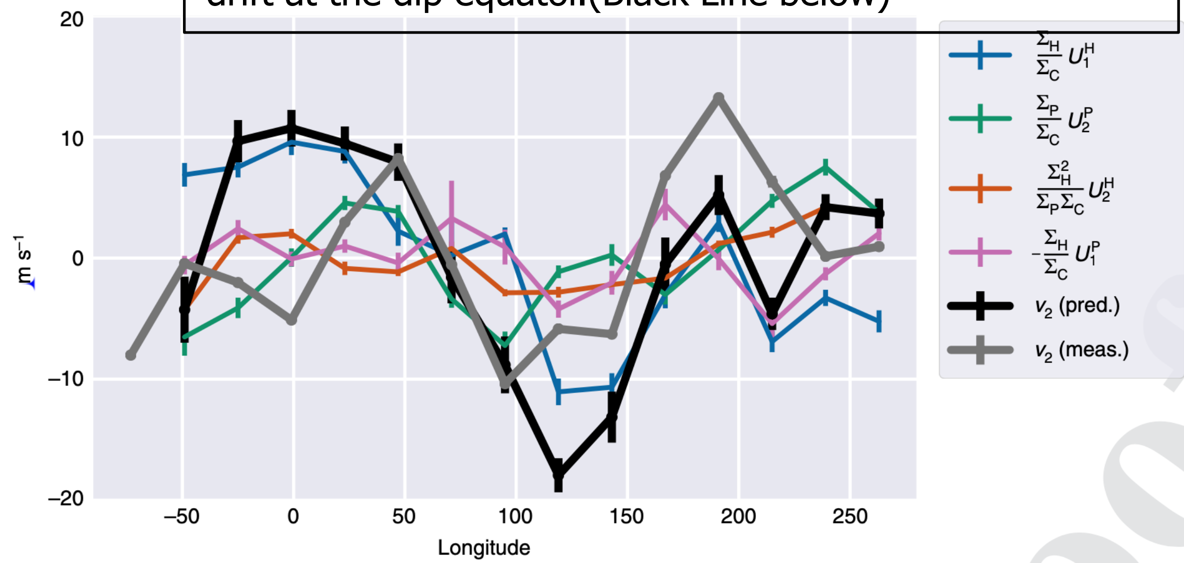
Predicting ionospheric drifts from lower thermospheric winds

$$v_2 = \left(\frac{\Sigma_H}{\Sigma_C} U_1^H + \frac{\Sigma_P}{\Sigma_C} U_2^P + \frac{\Sigma_H^2}{\Sigma_C \Sigma_P} U_2^H - \frac{\Sigma_H}{\Sigma_C} U_1^P \right)$$



Measurements of the vertical drift at the dip equator are made around the planet for ~ 1 week near a noon crossing, and average vertical drift is determined vs longitude.

The predicted vertical drift is calculated from wind measurements on the conjugate field line,and components combine to determine a predicted vertical drift at the dip equator.(Black Line below)



Calculation of Ionospheric Current

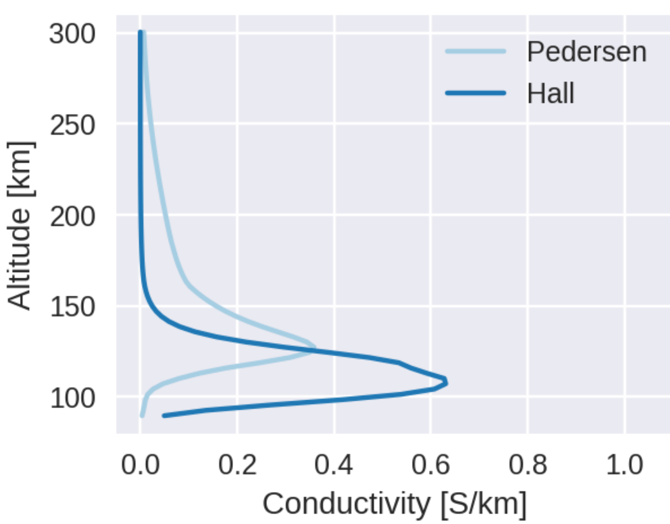
Ohm's Law in the ionosphere

$$\bar{j} = \underline{\sigma} \cdot \left(\bar{E} + \bar{u} \times \bar{B} \right)$$

where

$$\sigma = \begin{pmatrix} \sigma_P & -\sigma_H & 0 \\ \sigma_H & \sigma_P & 0 \\ 0 & 0 & \sigma_0 \end{pmatrix}$$

and



$$\nabla \cdot \mathbf{j} = 0 \qquad \int_S^N \nabla \cdot \mathbf{j}\, dx_3 = 0$$

Integrating yields

$$\frac{\partial J_1}{\partial x_1} + \frac{\partial J_2}{\partial x_2} + j_3^S - j_3^N = 0$$

Three assumptions follow:

1) Earth provides an insulator, not current, at footpoints.
2) There is no net current flow in the meridonal direction
3) Zonal conductivity gradients are small so $\frac{\partial J_1}{\partial x_1}$ ~0.

The brief derivation in the paper leads to the equation used.

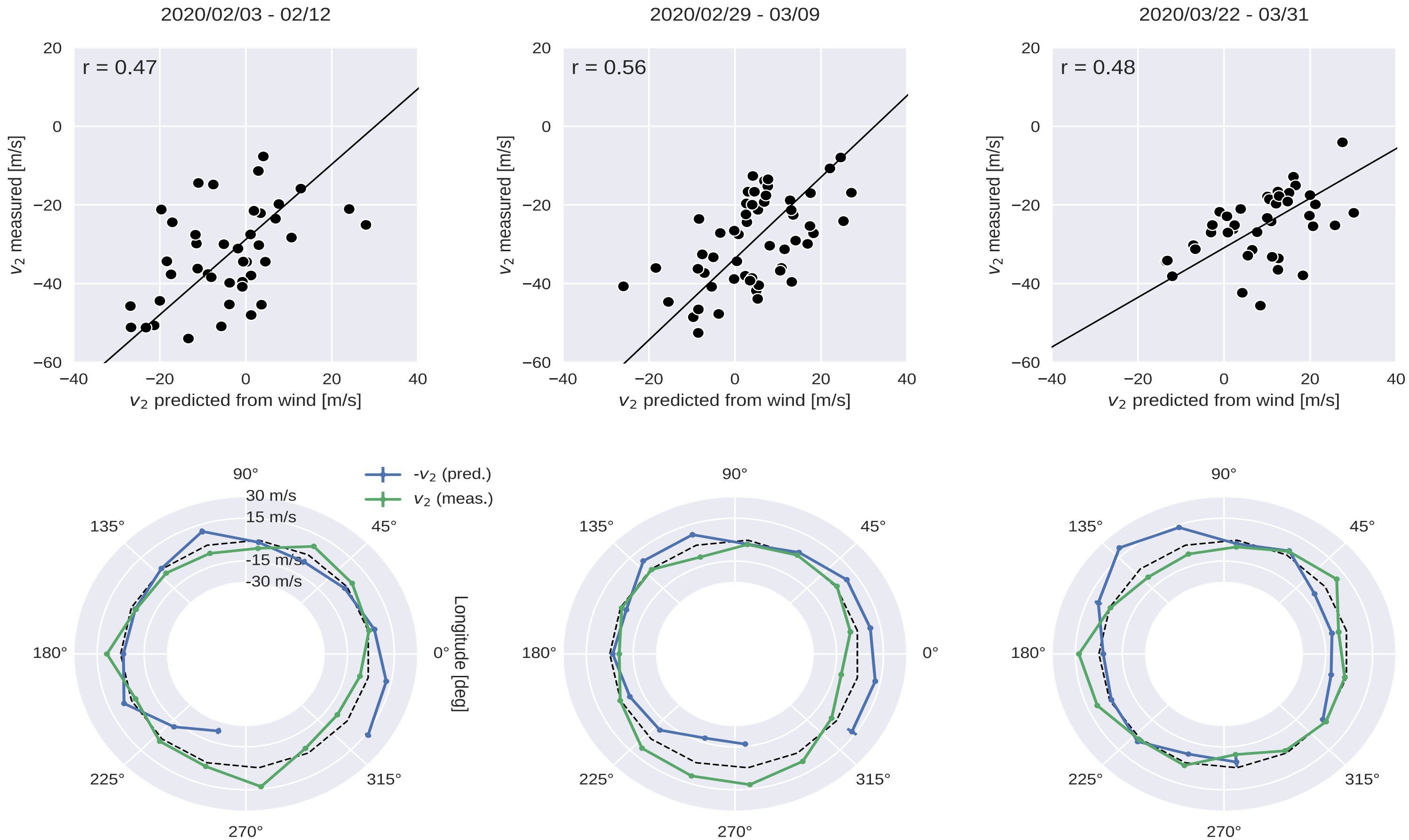
$$v_2 = \left(\frac{\Sigma_H}{\Sigma_C} U_1^H + \frac{\Sigma_P}{\Sigma_C} U_2^P + \frac{\Sigma_H^2}{\Sigma_C \Sigma_P} U_2^H - \frac{\Sigma_H}{\Sigma_C} U_1^P \right) + C_{ext}$$

A fourth assumption is that any external forcing is also constant (Cext) over the period of noon-crossing

Predicted vs. Measured Drift 12-14 LT

Noon crossings are spaced by the precession of the orbit.

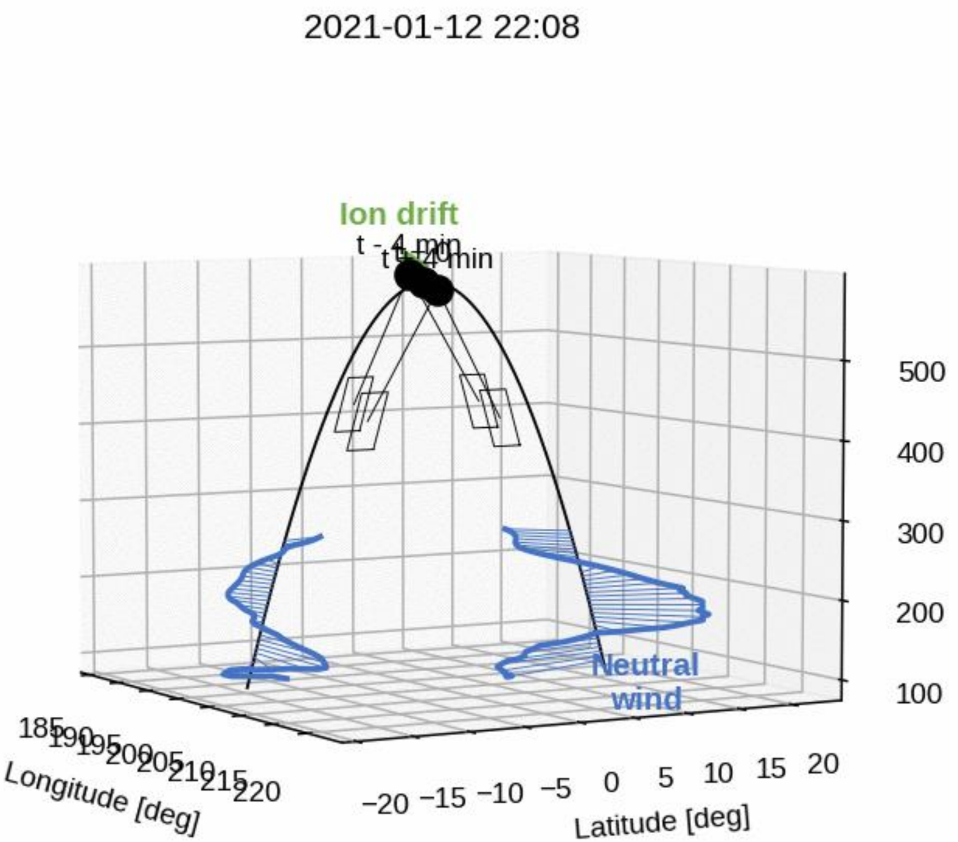
Observed and predicted drifts for 3 noon crossings are shown below

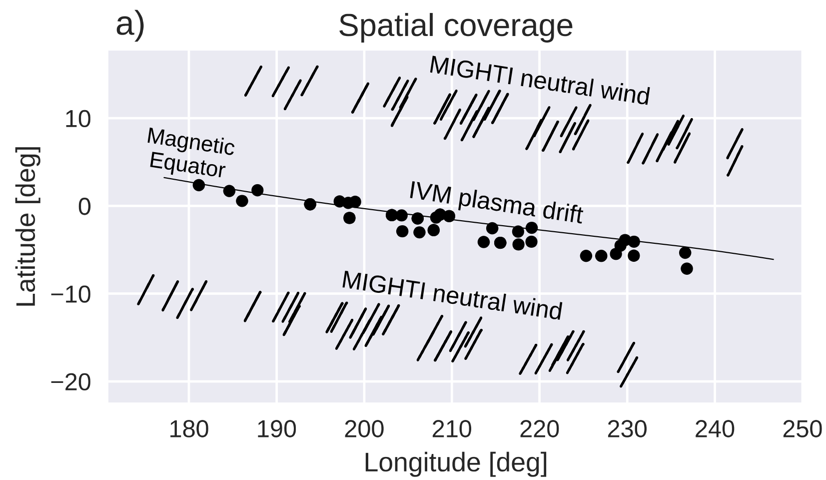


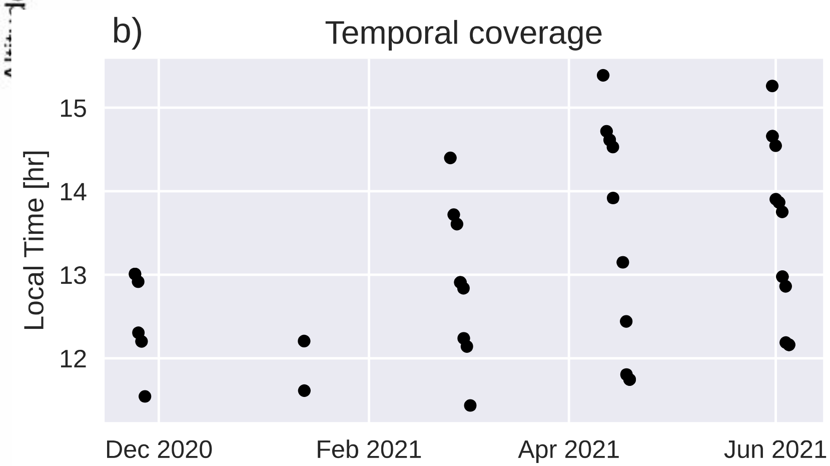
Correlations around 0.5 using data only from the northern ½ of the field line.

Conjugate maneuver coverage

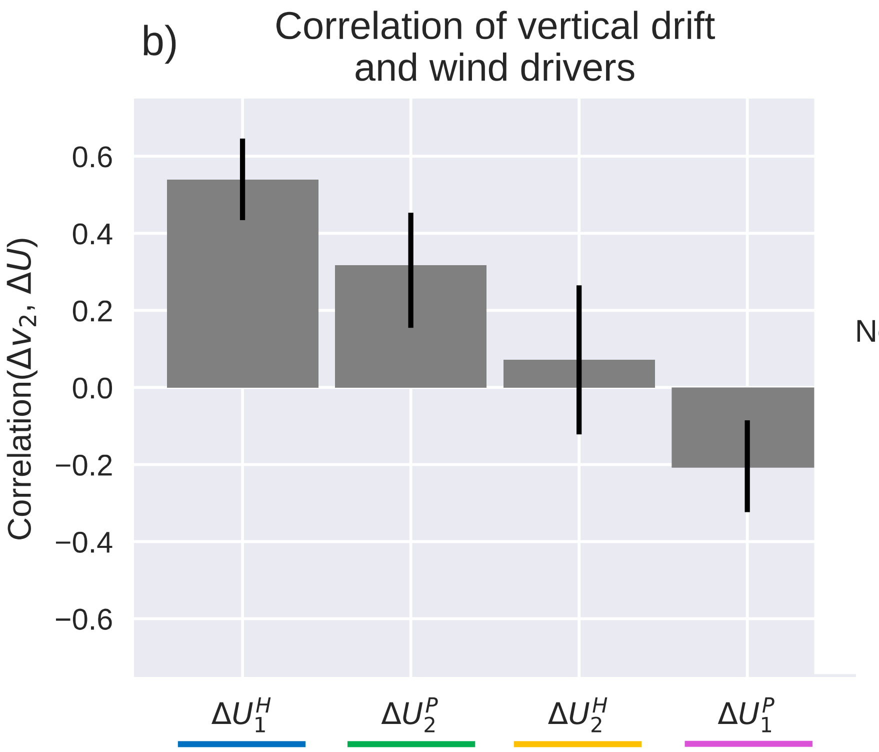
•Observational geometry during ICON's "conjugate maneuver"

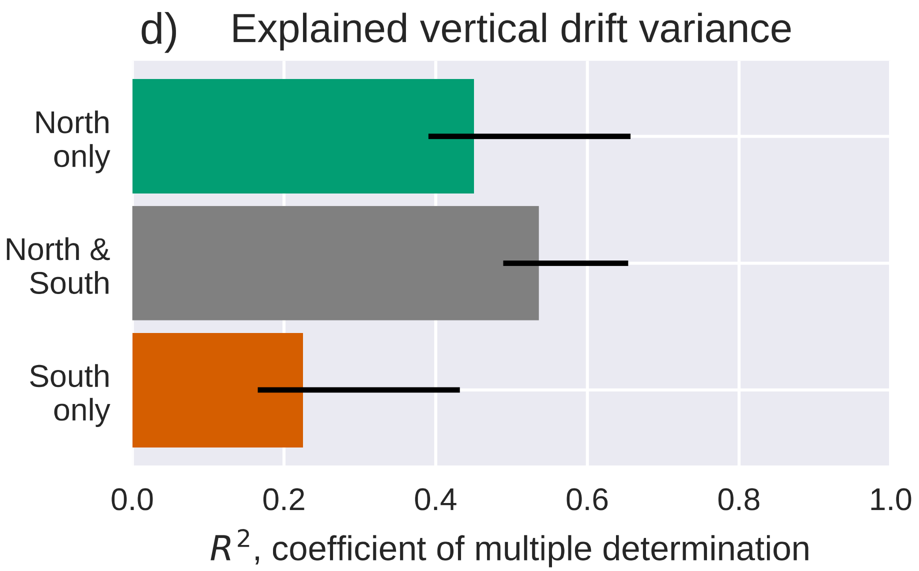






Inclusion of Southern Views 12-14 LT





50-66% of vertical drift variance is associated with *local* wind drivers

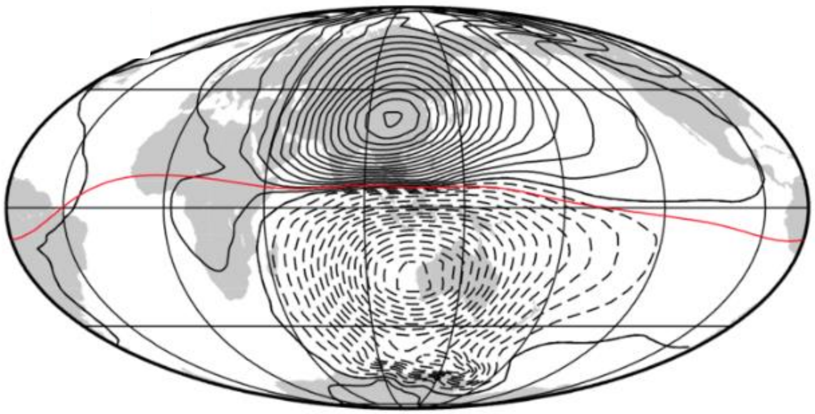
Accounting for errors in MIGHTI v04 winds suggests the true contribution is **~75%**
– to be confirmed after v05 of the MIGHTI dataset is available

Continued work in many areas is open

- Comparisons with Swarm to retrieve actual currents, like IVM retrieves actual drifts.
- Expanding to other local times and nighttime dynamo studies.
- Source and impact of wind shears in driving more rapid changes than just tides/planetary waves.

Comparing Winds and Plasma Motion

•Ionospheric Sq current system
•*Sabaka et al.* [2015]

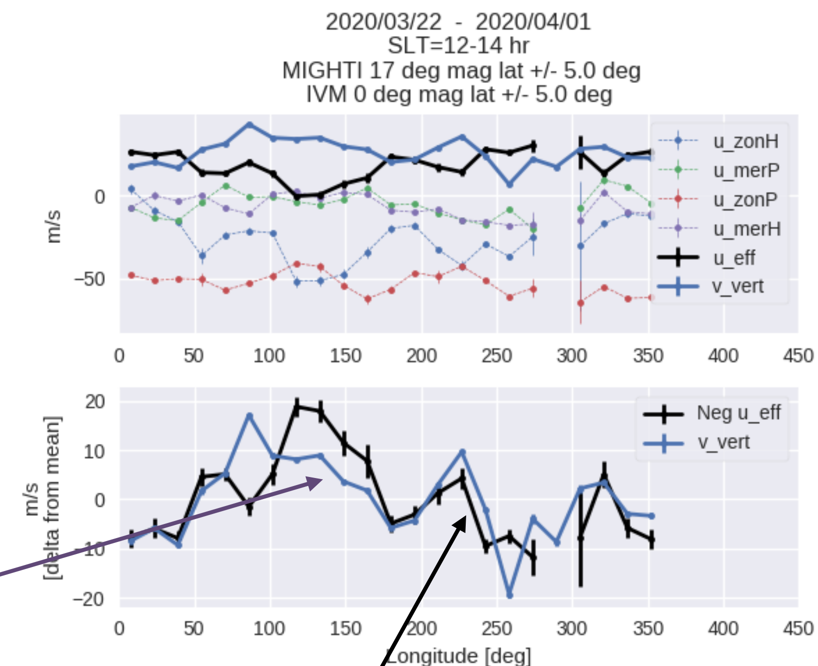


$$\bar{j} = \underline{\sigma} \cdot \left(\bar{E} + \bar{u} \times \bar{B} \right)$$

Performing field line integration of Ohm's law one can show:

$$v_2 = \left(\frac{\Sigma_H}{\Sigma_C} U_1^H + \frac{\Sigma_P}{\Sigma_C} U_2^P + \frac{\Sigma_H^2}{\Sigma_C \Sigma_P} U_2^H - \frac{\Sigma_H}{\Sigma_C} U_1^P \right) + C_{ext}$$

"Effective wind" includes all 4 wind-driven current terms



- **Near local noon**, meridional current is negligible
- → *Zonal current is constant*
- **Near equinox,** northern and southern conductances are similar
- **During quiet times**, the magnetosphere has little influence on low latitude electric fields

•**Topside ionospheric motion** reflects the **lower thermospheric wind drivers**, in terms of the longitudinal pattern, likely caused by non-migrating tides