Geomagnetic activity dependence and dawn-dusk asymmetry of thermospheric winds at high latitudes

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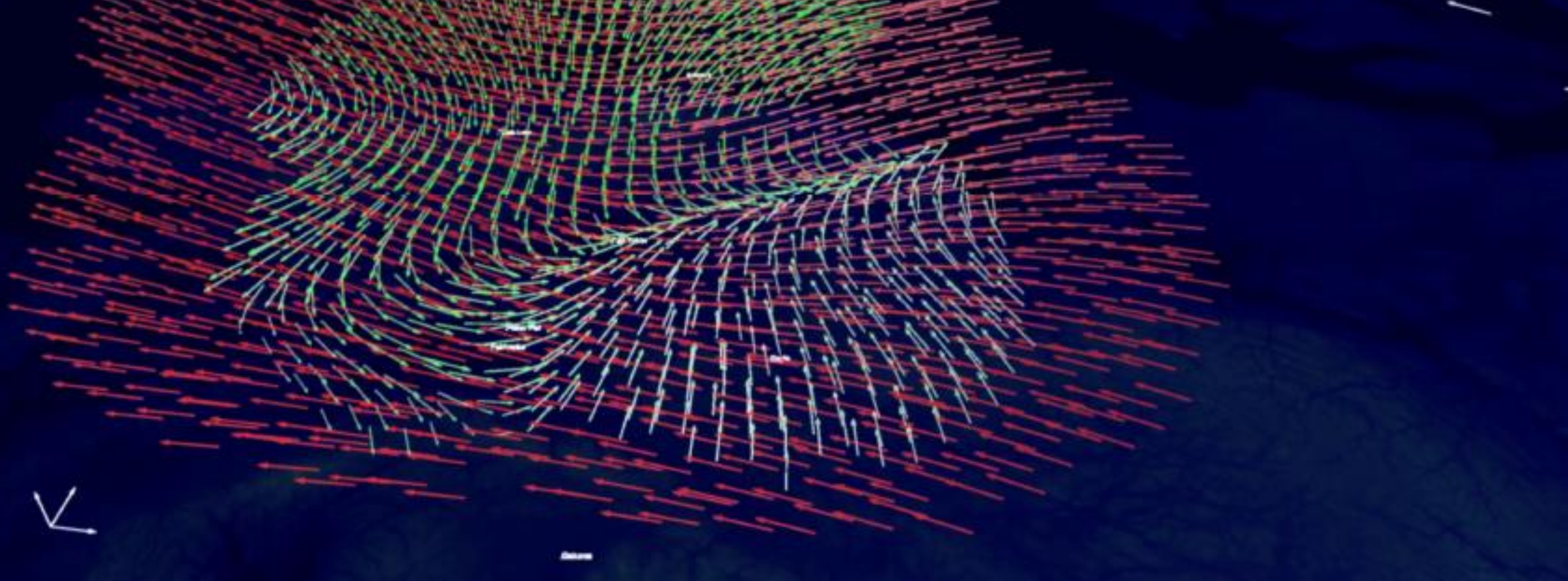
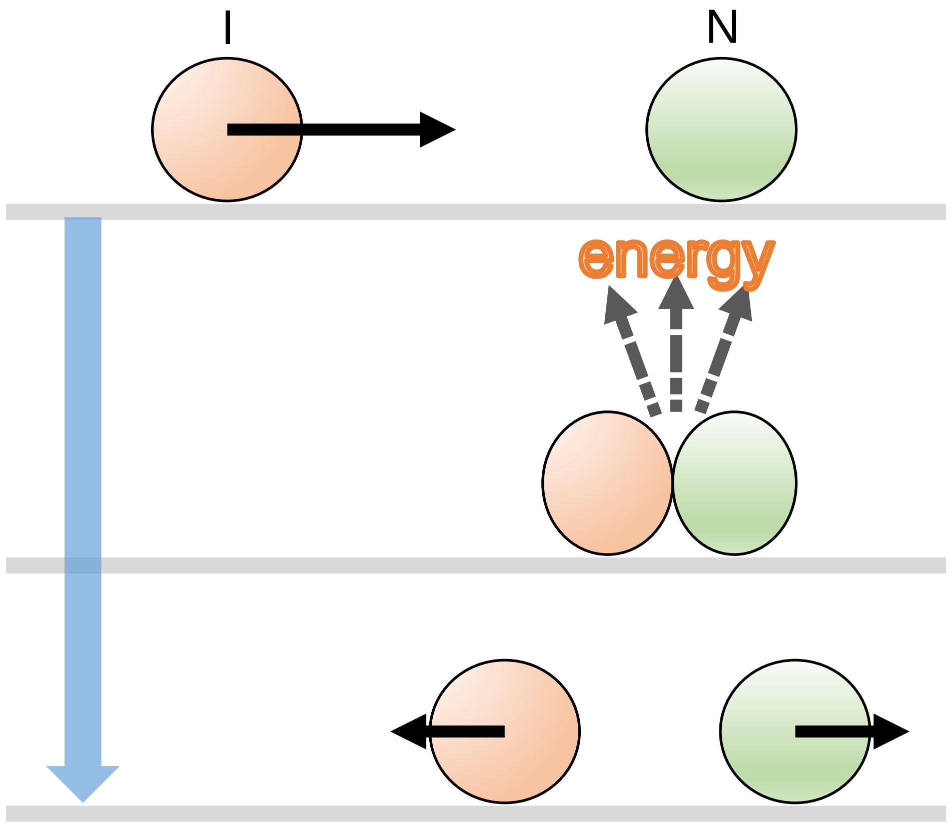


VERY LOW IONIZATION RATE

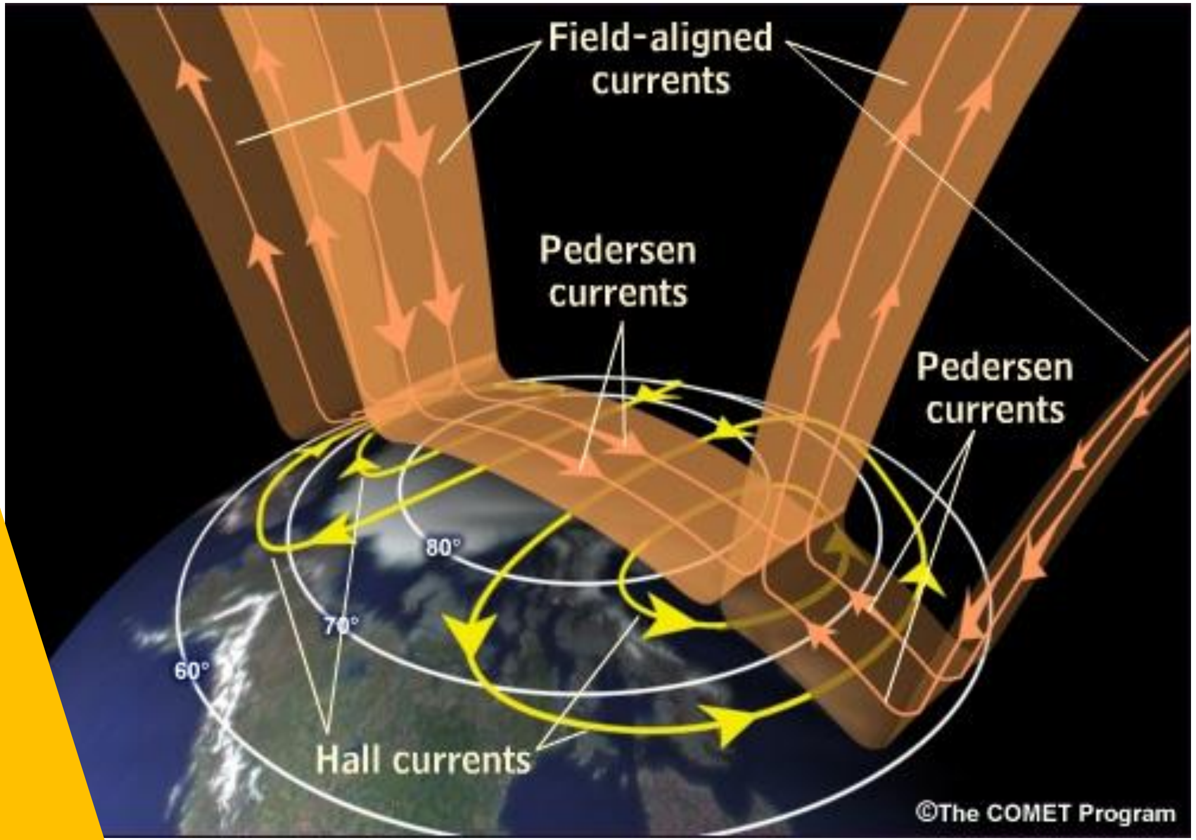
Particle collisions

particle COLLISIONS
between NEUTRALS
and IONS



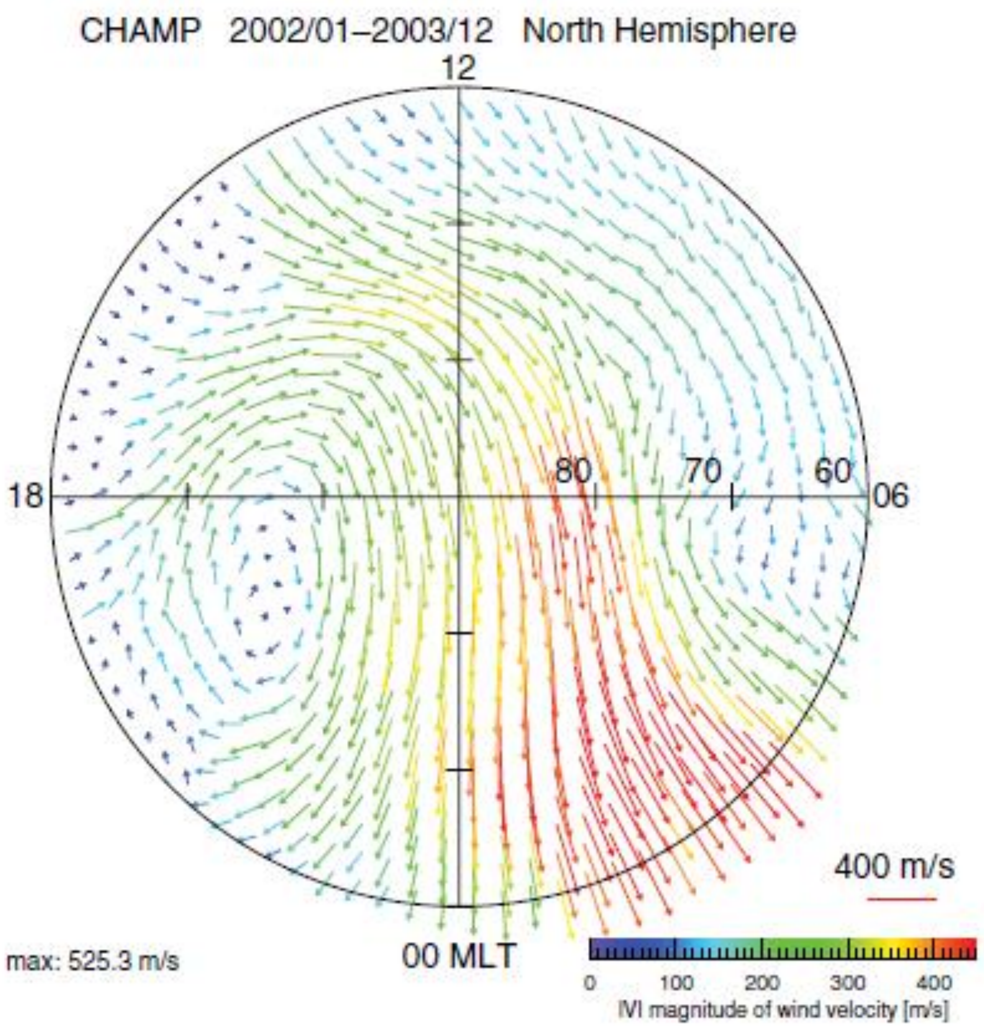
Ion drag & Joule heating

ENERGY CONVERSION



Ionospheric plasma kinetic energy is converted to kinetic energy of the thermospheric neutrals (ion drag) and thermal energy of the neutrals (Joule heating).

Thermospheric wind pattern (at F-region altitude)



Förster+, AGU Monograph, 2017

Dominant dusk cell

Return plasma flows in dusk drag the thermosphere westward.

Clear anti-sunward flow

Anti-sunward thermospheric flow is dominant along the ionospheric plasma flow in the polar cap.

Unclear dawn cell

Signature of the return plasma flow (eastward flow) cannot be clearly seen in dawn.

Scientific objectives

What is geomagnetic activity dependence of the thermospheric wind at high latitude?

- Statistical analysis of the FPI wind (630 nm) in Tromsø, Norway (69.6N, 19.2E in geographic & 66.7N in geomagnetic coordinate)
- Separating measurements with SME

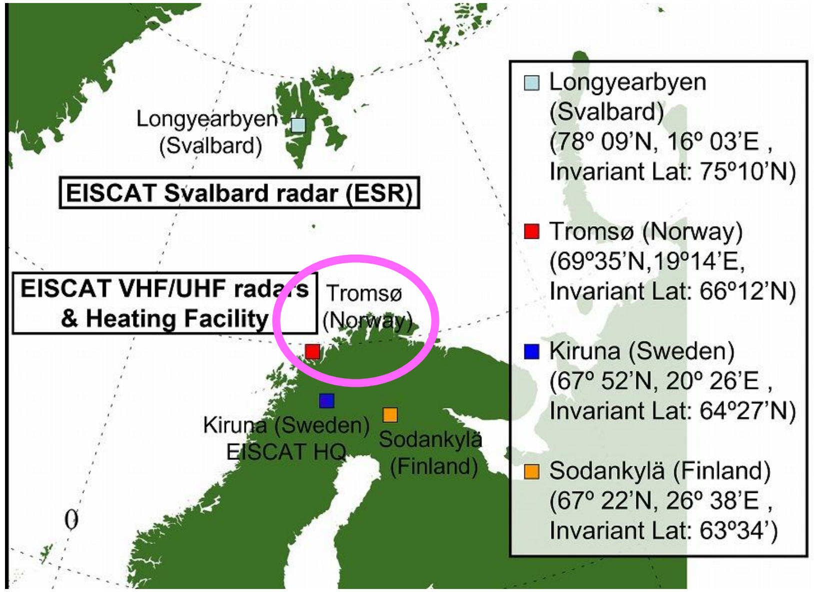
Does ion drag affect the dawn-dusk asymmetry in the wind pattern?

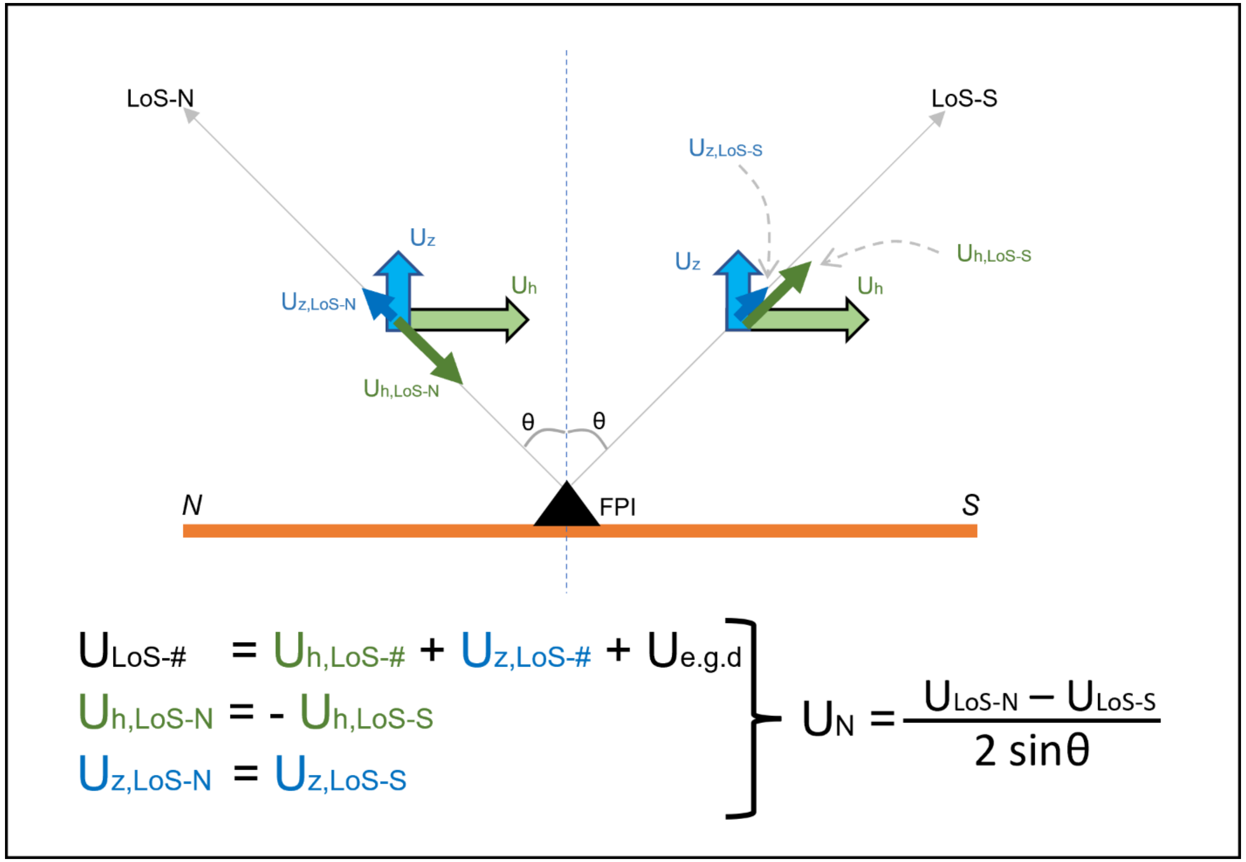
- The geostrophic force (Coriolis & centrifugal forces) is a strong candidate, but how about the ion drag?
- Estimate a quiet-time wind pattern from statistical analysis with SME, then derive wind deviations from the quiet-time wind pattern

Dataset

Fabry-Perot interferometer (FPI)

- located at the Tromsø EISCAT radar site
- 630 nm (peak ~ 240 km)
- 2009.Jan – 2017.Sep
- clear sky condition
- "4 oblique directions + vertical" provides the wind vector.



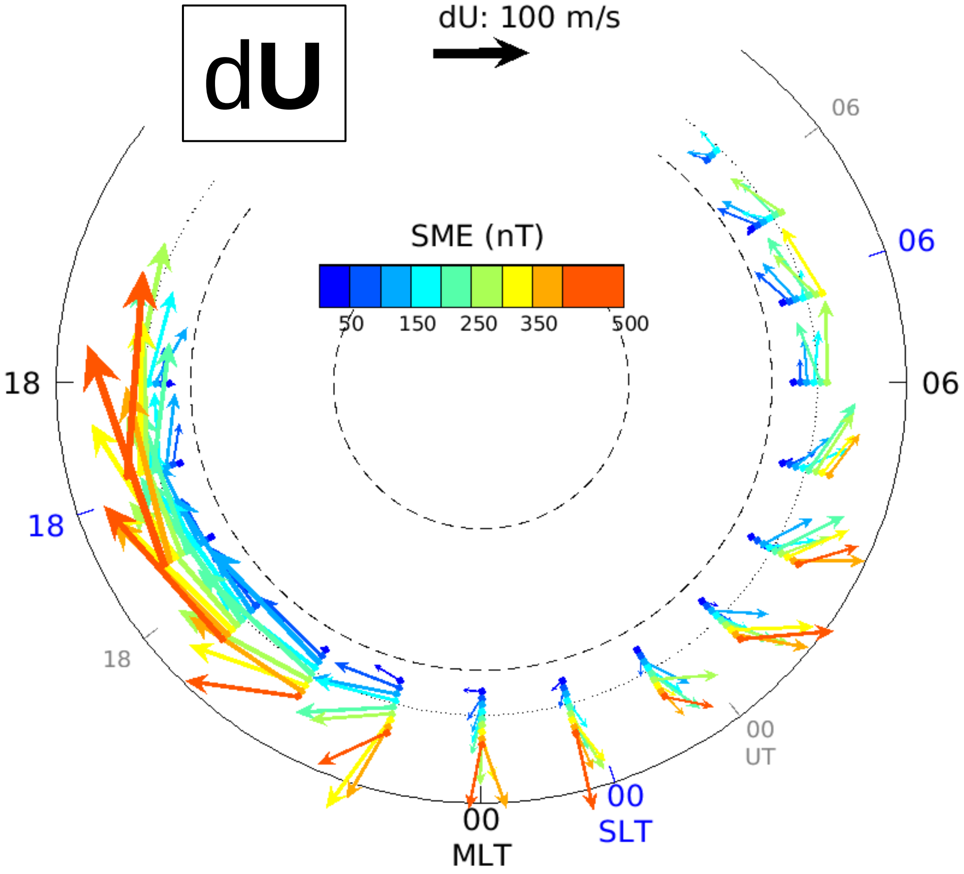


dU: SME dependence

Magnitude of dU is **larger in dusk than dawn**, which is like typical ionospheric plasma convection.

Cell-like pattern can be seen even at lower SME level.

Eastward acceleration signature of the wind by the dawn-side ion drag was found in dU. *New results!*



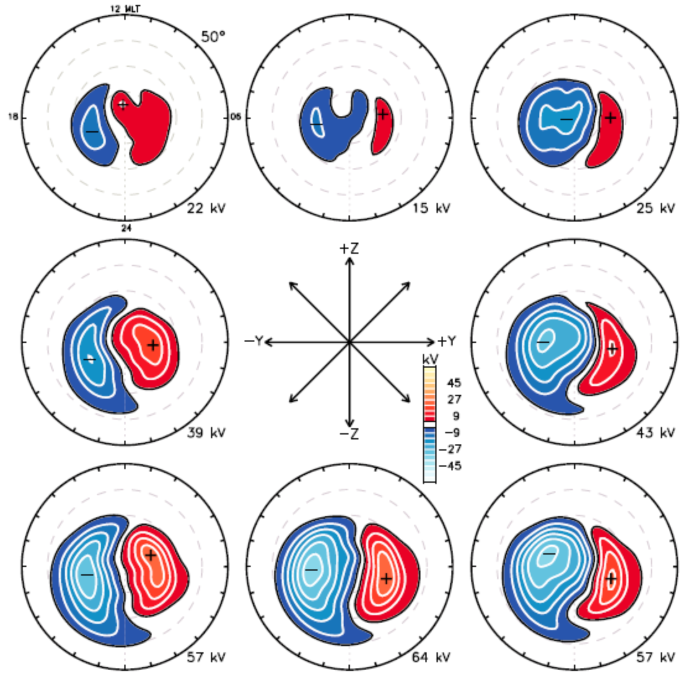
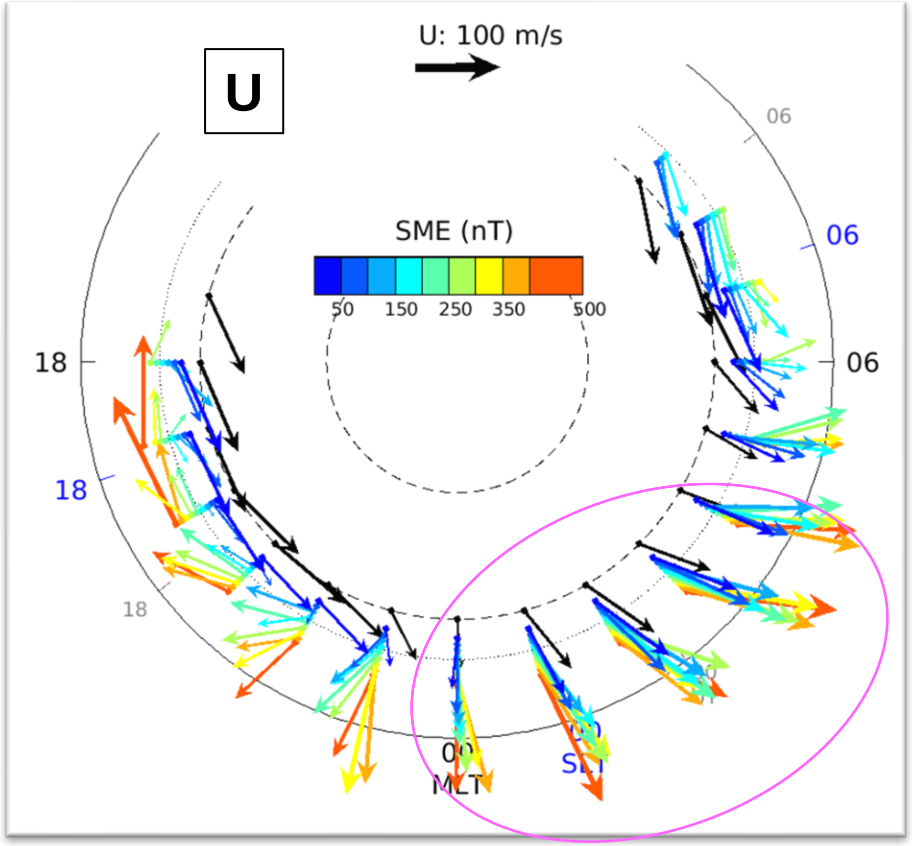
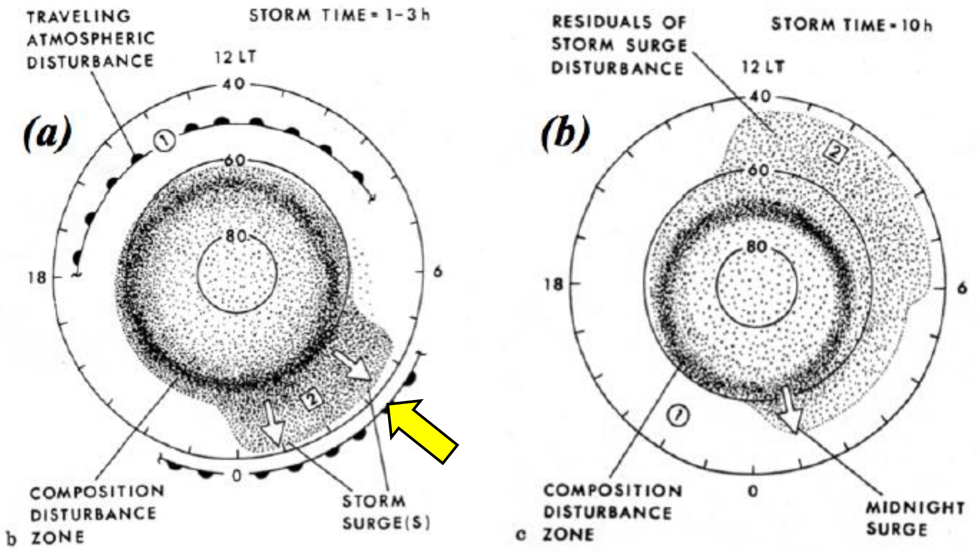


Figure 5. Statistical convection patterns sorted by interplanetary magnetic field clock angle for $1.6 \leq E_{SW} < 2.1$ mV/m and neutral dipole tilt. Electrostatic potential is indicated by color according to the scale near the center of the figure, and equipotential contours are plotted at 6-kV intervals beginning at ±3 kV. The patterns are rotated so that noon (12 magnetic local time, MLT) is at the top with dawn (06 MLT) on the right and dusk (18 MLT) on the left. All plots have a low-latitude boundary of 50° magnetic latitude. The locations of the potential maxima (plus signs) and minima (minus signs) are marked, and the cross-polar cap potential difference is given at the bottom right of each panel.

Thomas & Shepherd, JGR Space Physics, 2018

U: Equatorward surge from midnight to dawn





Prölss, 1993

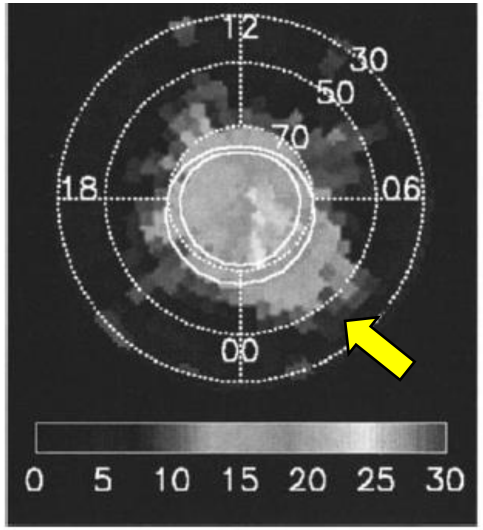
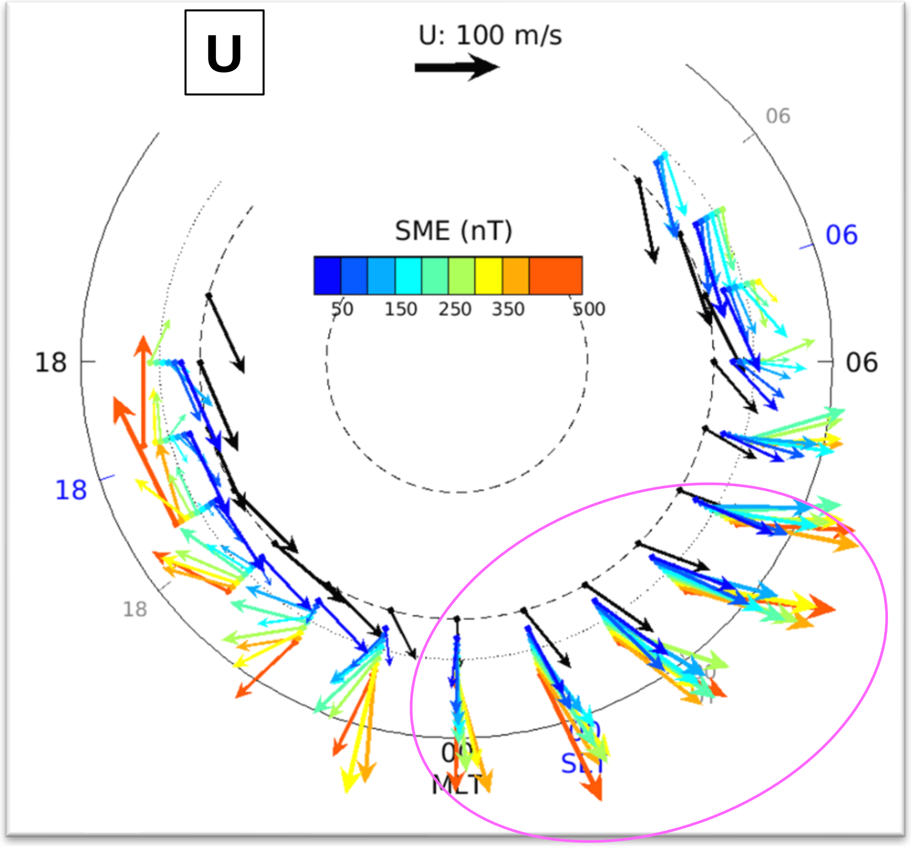


Figure 3. Polar Maps of Vertical Wind Standard Deviation, $\sigma(V_z)$, in m s^{-1} plotted with bins of 0.5 h LMT and 5^0 invariant latitude. Top panel: Southern hemisphere; lower panel: Northern hemisphere. These maps use orthographic projections centered on the geomagnetic poles.

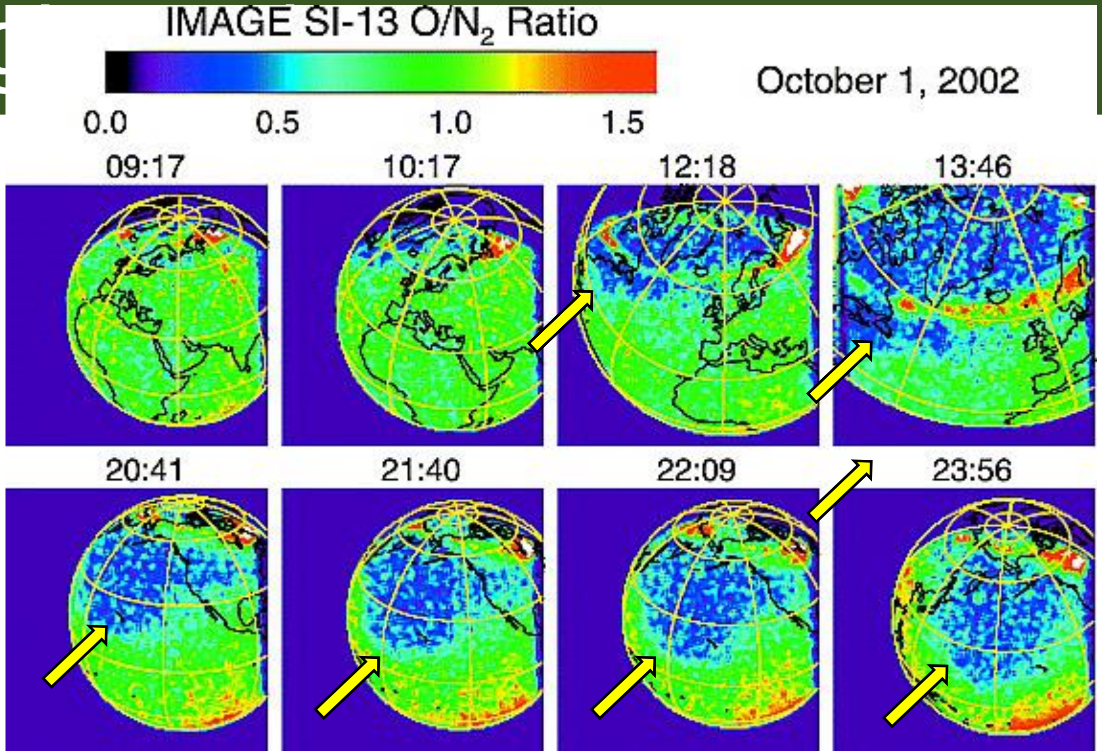
Innis+, GRL, 2001.

- westward turning in dusk with SME increase
- clear dusk cell but unclear dawn cell
- equatorward flows from midnight to dawn increasing magnitude with SME

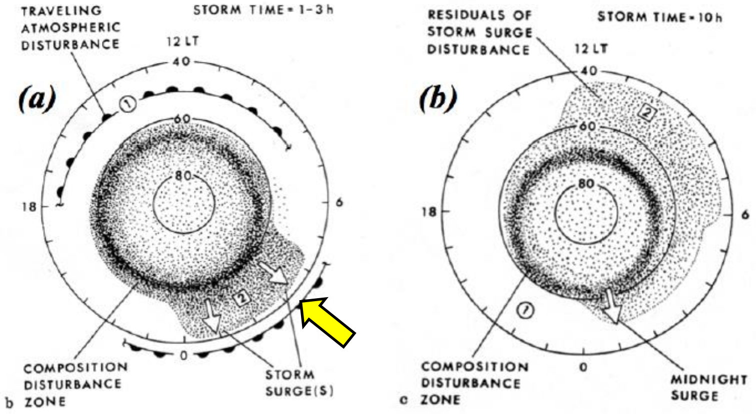
U: Equatorward surge from midnig



- westward turning in dusk with SME increase
- clear dusk cell but unclear dawn cell
- equatorward flows from midnight to dawn increasing magnitude with SME
  - transport disturbed air to mid/low latitudes, generating ionospheric disturbances



Zhang+ JGR, 2004



Prölss, 1993

Summary & Conclusions

Thermospheric winds measured with the FPI in Tromsø, Norway in winter months for approximately 9 years (2009 January to 2017 September) were statistically analyzed by grouping data into several SME bins from 30 to 500 nT. Hourly mean values under SME ≤ 40 nT were defined as geomagnetic quiet-time wind in this study. Wind deviations or dU were derived by subtracting the quiet-time wind from the measurements.

New results!

- **dU: eastward wind acceleration at dawn by the ion drag**

  This is the first study to our knowledge to report a dawn-dusk asymmetry in the thermospheric wind acceleration as well as the eastward wind acceleration at dawn by the ion drag.

- **dU: larger westward values at dusk and smaller eastward values at dawn**

  The dU pattern is characterized by larger westward values at dusk and smaller eastward values at dawn. One of the reasons to produce asymmetry in the magnitude is likely the dawn-dusk asymmetry of the ionospheric plasma convection.

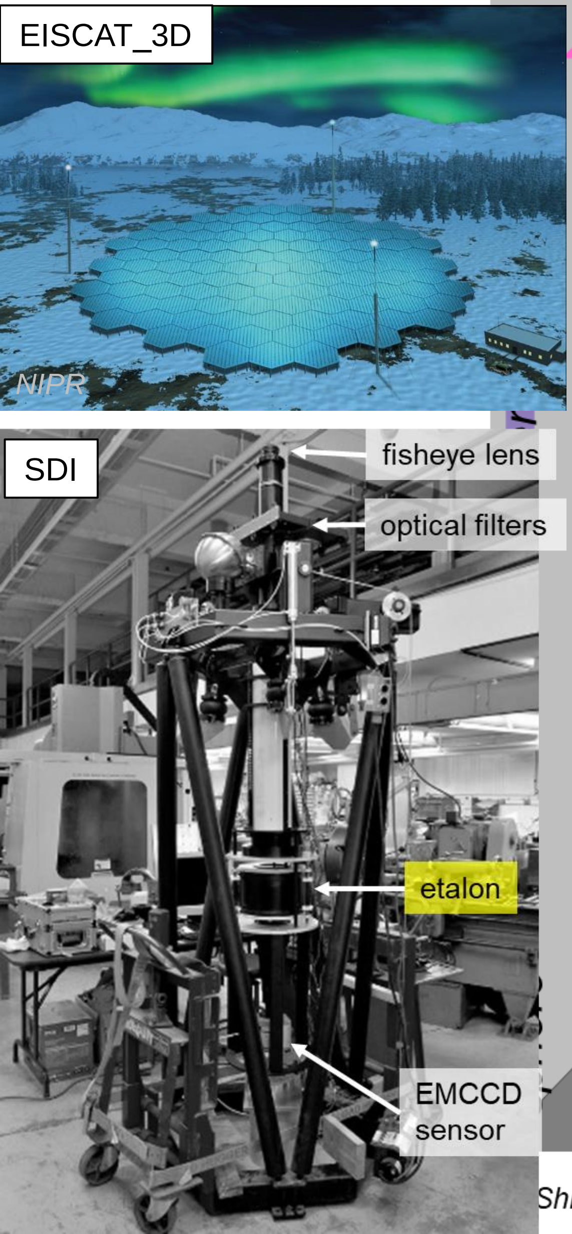
- **U: deviate toward the ionospheric plasma flow even with a small activity**

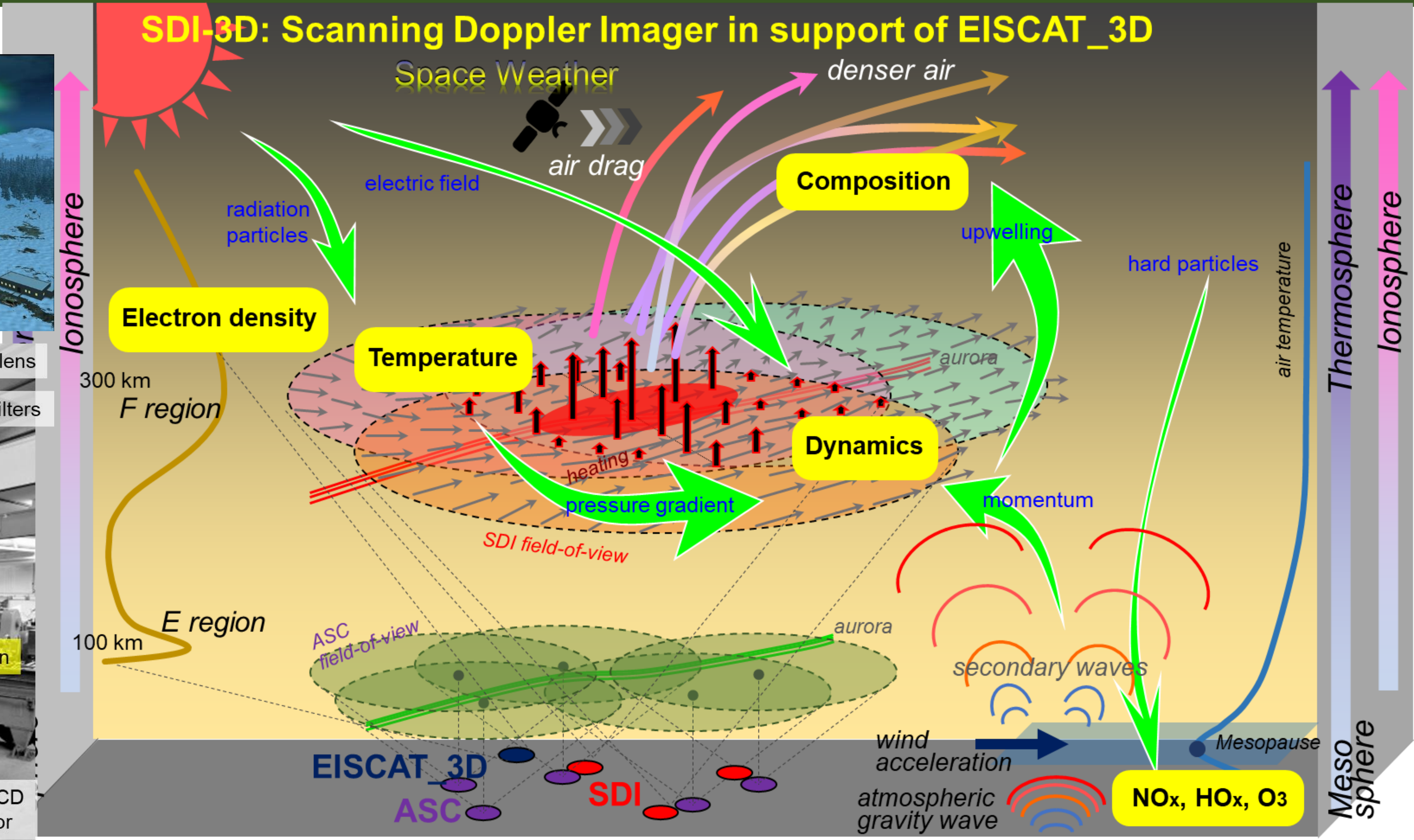
  The quiet-time wind pattern is dominated by the pressure gradient associated with solar radiation and the geostrophic force balance. However, because of ion drag, the wind pattern can deviate toward the ionospheric plasma flow even with a small increase (10 nT of SME) in the geomagnetic activity.

- **U: equatorward winds are dominant from midnight to dawn**

  From midnight to dawn, equatorward winds are dominant for all SME levels but slightly increase in magnitude and rotate eastward with the SME.

SDI-3D project: SDI operation will start in Oct.2023





Shin-ichiro Oyama