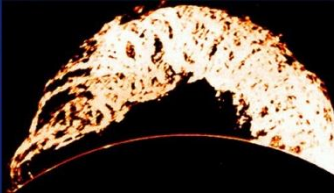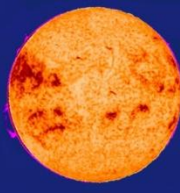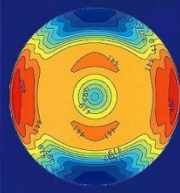# Properties of Electromagnetic Energy and Momentum Transfer Between the Magnetosphere and Upper Atmosphere

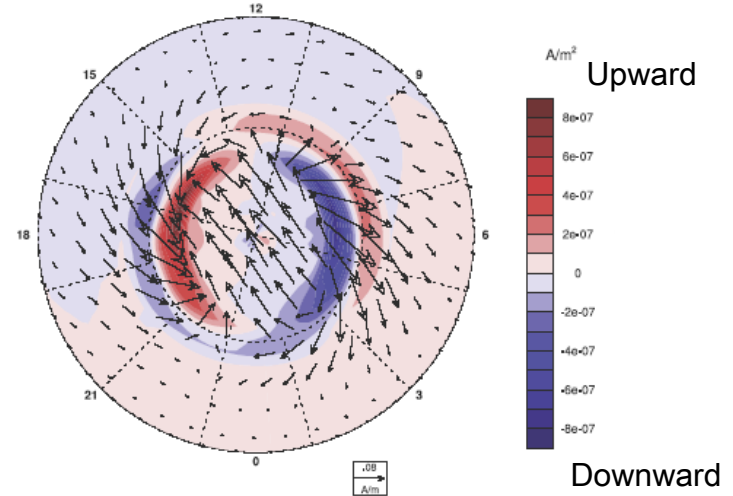Art Richmond and Astrid Maute
NCAR High Altitude Observatory

- Electromagnetic energy transfer on large and small scales

- Wind acceleration by Maxwell stress and feedback on plasma convection
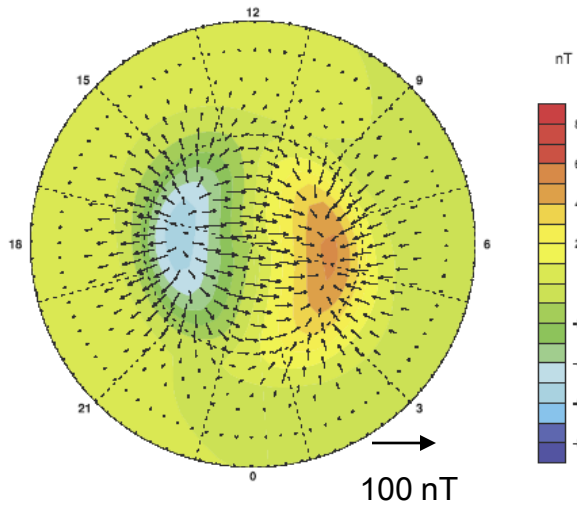
Electric Potential

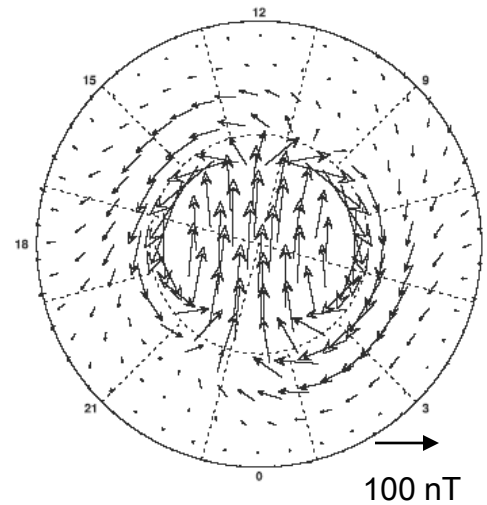Northern hemisphere
June solstice, 17 UT

[kV]
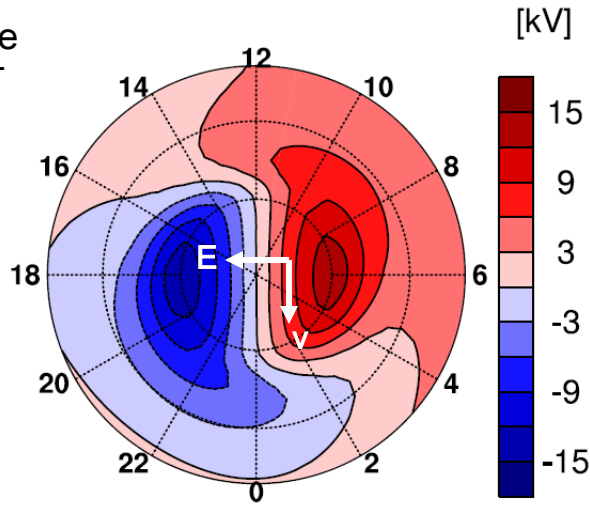
Ionospheric and
Field-Aligned Current

A/m²
Upward
Downward

Poloidal Magnetic
Perturbation Field, 400 km

nT

100 nT

Toroidal Magnetic
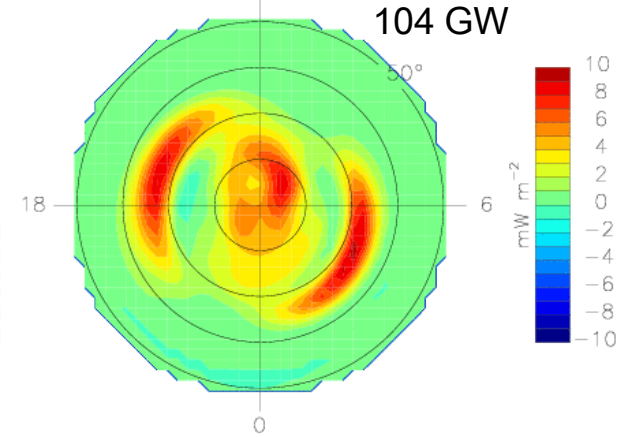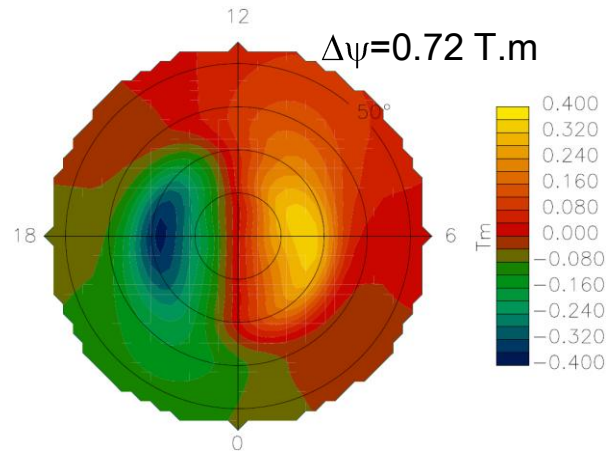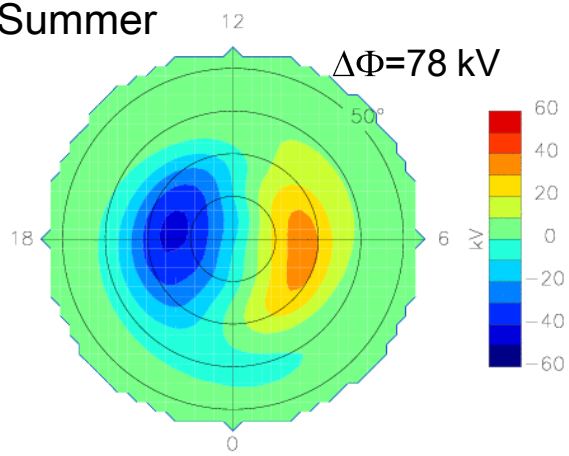Perturbation Field, 400 km

100 nT

IMF B_z = -5 nT, B_y = 0
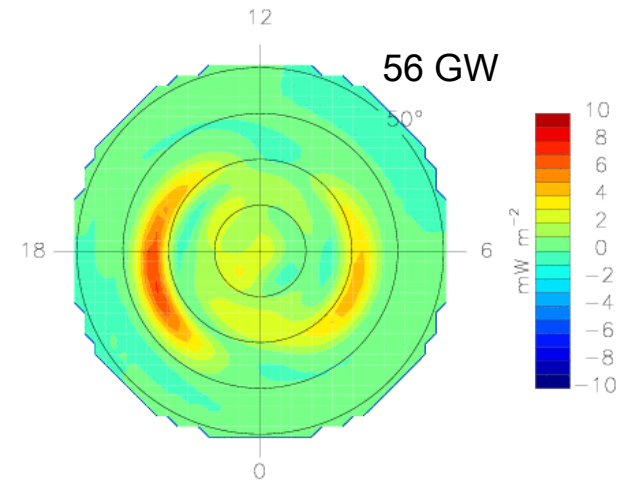
Electric Potential
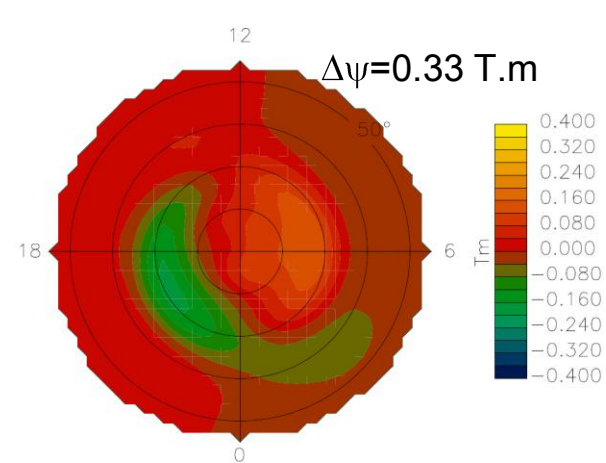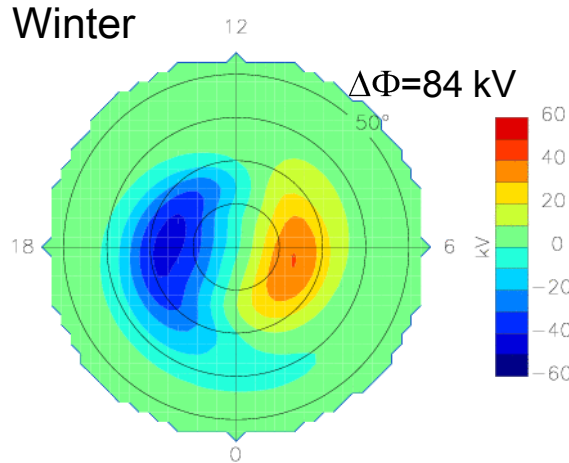
Magnetic Stream Function

$$\frac{\overline{\mathbf{E}} \times \overline{\delta\mathbf{B}}}{\mu_0} \cdot \mathbf{b}$$

Summer

$\Delta\Phi$=78 kV

$\Delta\psi$=0.72 T.m

104 GW

$\Delta\psi/(\mu_0\Delta\Phi)$ = 7.4 S

Winter

$\Delta\Phi$=84 kV

$\Delta\psi$=0.33 T.m

56 GW

$\Delta\psi/(\mu_0\Delta\Phi)$ = 3.1 S

(a) DE2/IDM and Weimer

Along-track Electric Field [mV/m]

DE-2 observations

Weimer (2001)
empirical model

latitude [deg]

Matsuo and Richmond (2008)

1981 September 26
1030-1055 UT

Field-Aligned Poynting Flux, IMF B_z = -5 nT, B_y = 0

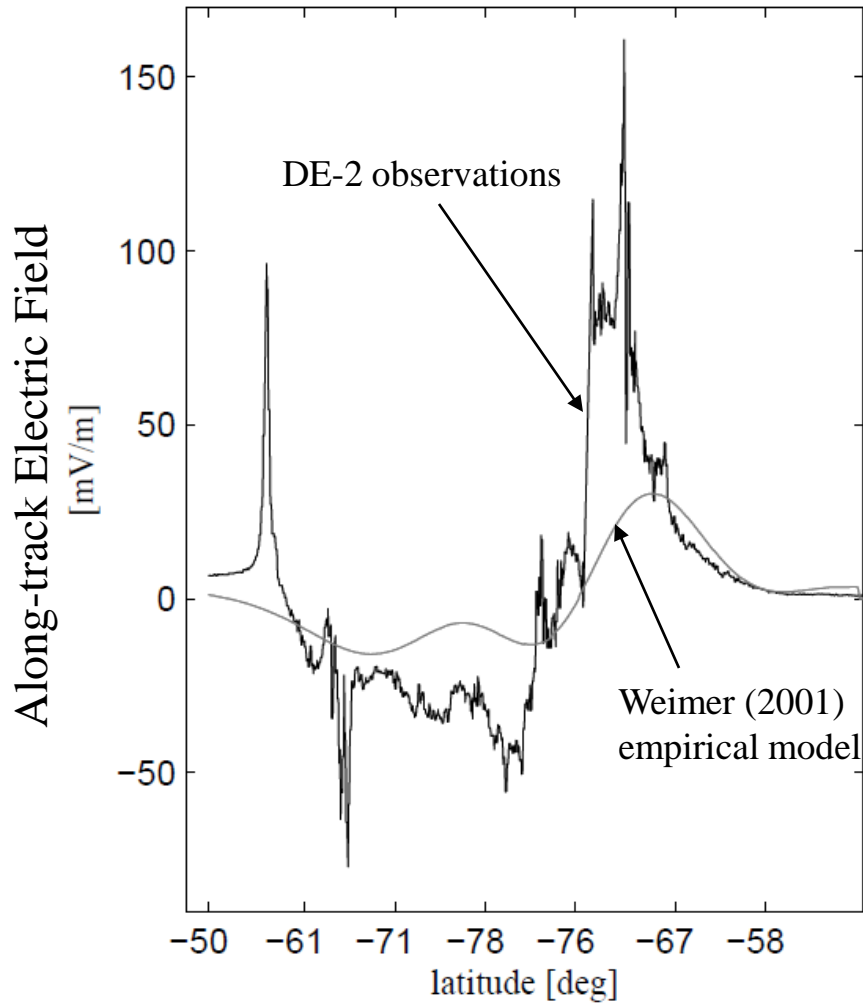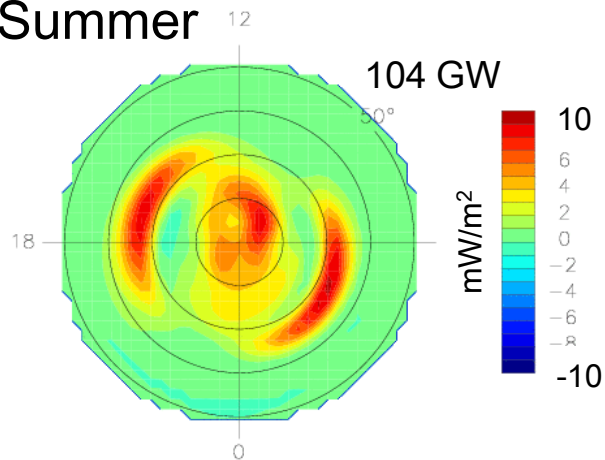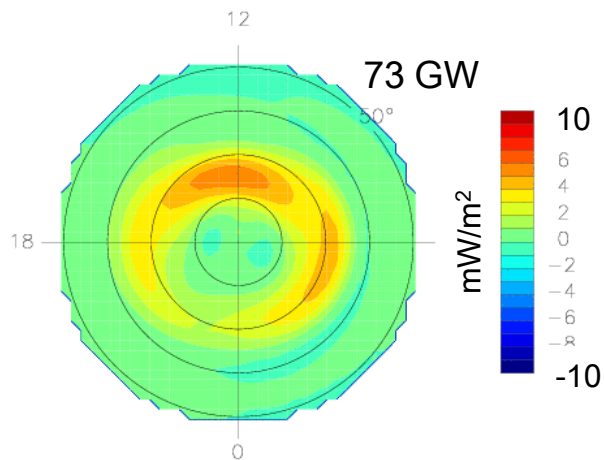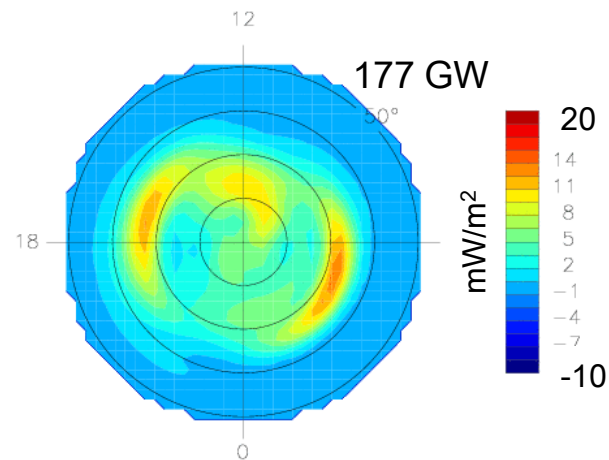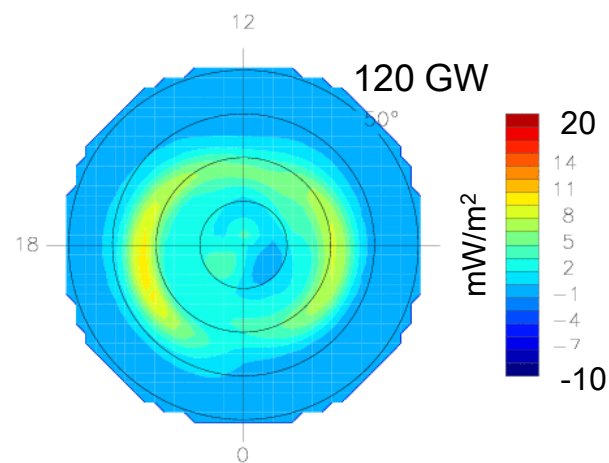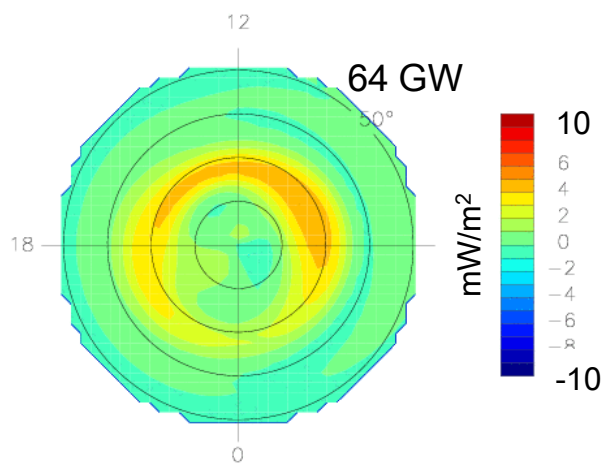$$\frac{\overline{\mathbf{E} \times \overline{\delta \mathbf{B}}}}{\mu_0} \cdot \mathbf{b}$$

$$\frac{\overline{\mathbf{E'} \times \delta \mathbf{B'}}}{\mu_0} \cdot \mathbf{b}$$

$$\overline{\mathbf{S}} \cdot \mathbf{b}$$

Summer

104 GW

73 GW

177 GW

Winter

56 GW

64 GW

120 GW
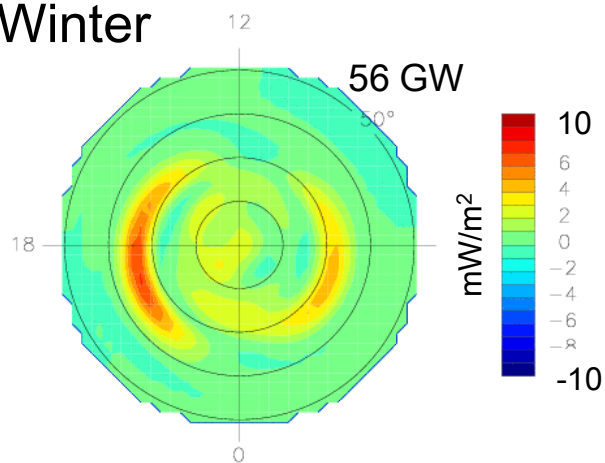
Southern Hemisphere, Summer

WINDII Observations
Pedersen−Weighted Neutral Wind

$\overline{B}_y = -3.2$ nT $\overline{B}_y = 3.2$ nT $\overline{B}_z = -2.0$ nT $\overline{B}_z = 2.0$ nT

200 m/s
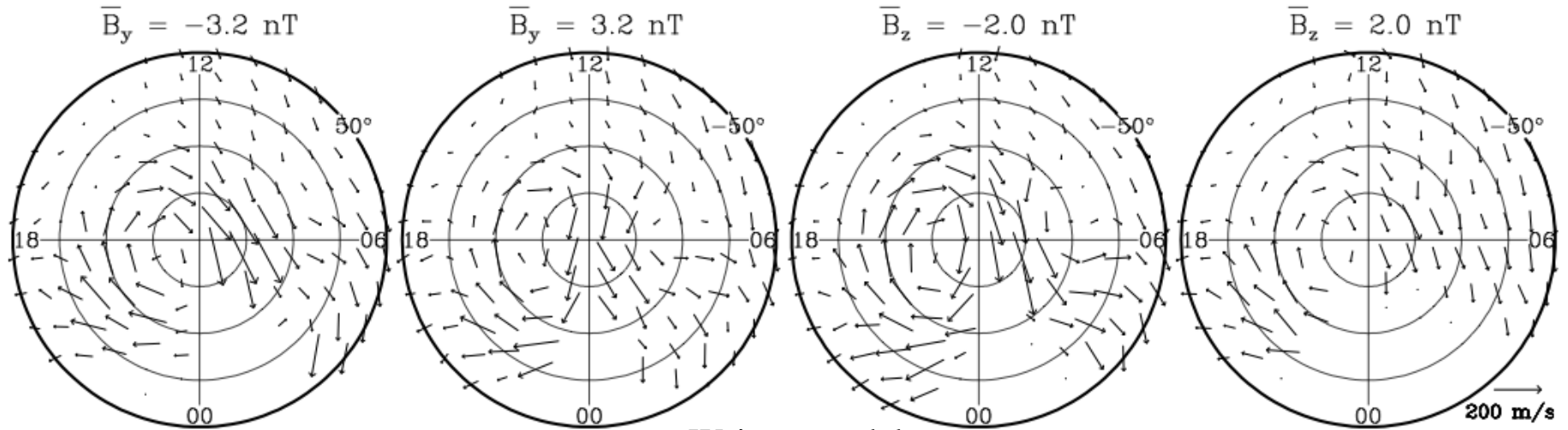
Weimer model
Convection Velocity

200 m/s
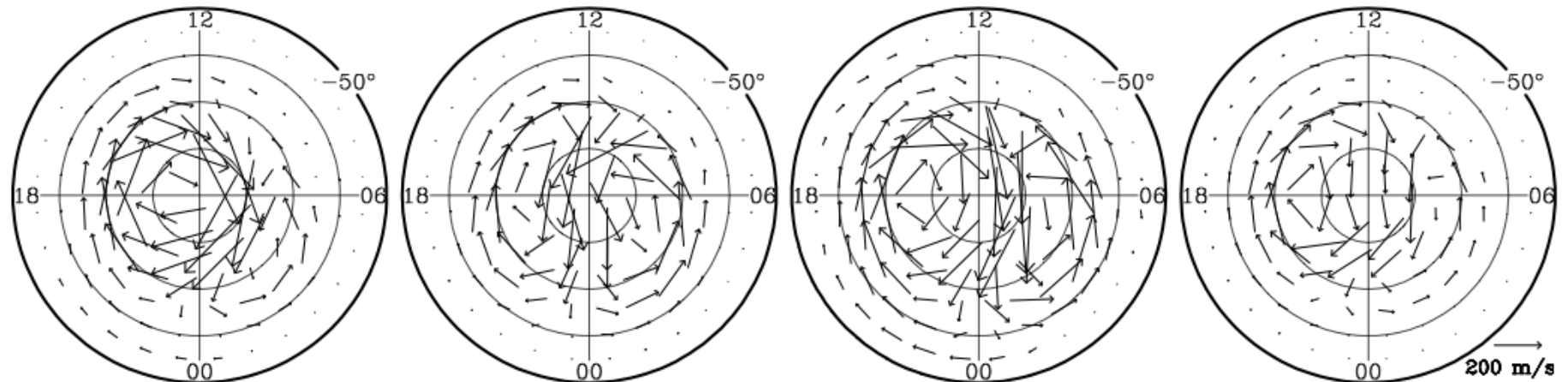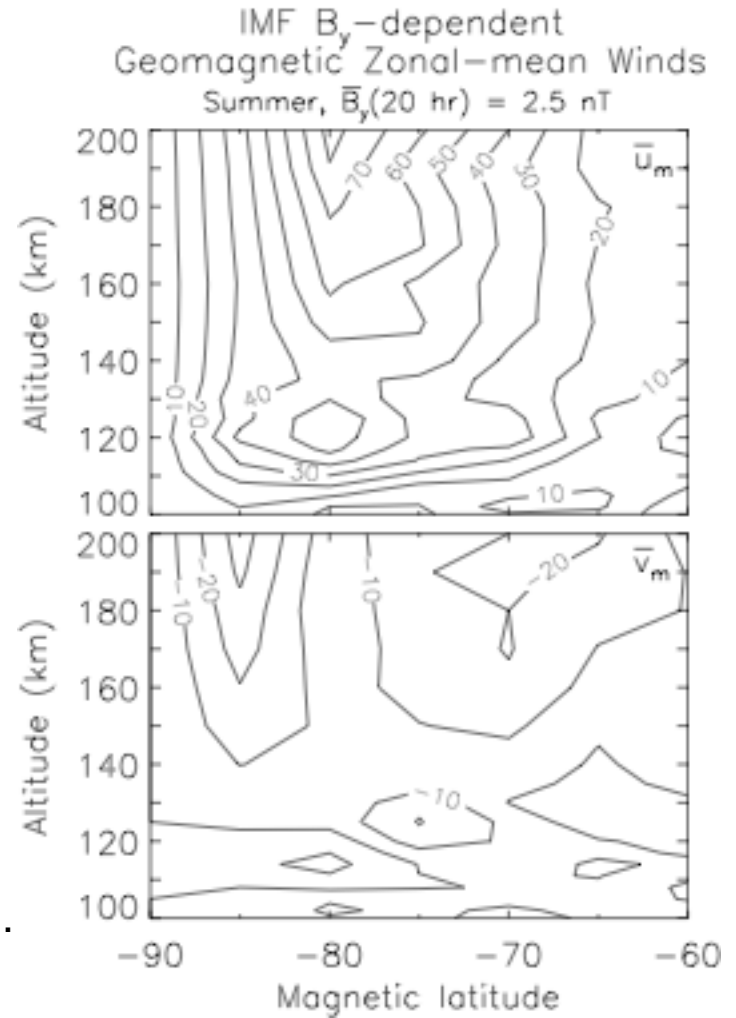
Zonal Mean Eastward Magnetic
Perturbation Above Ionosphere
(Summer, IMF B_y = 2.5 nT)
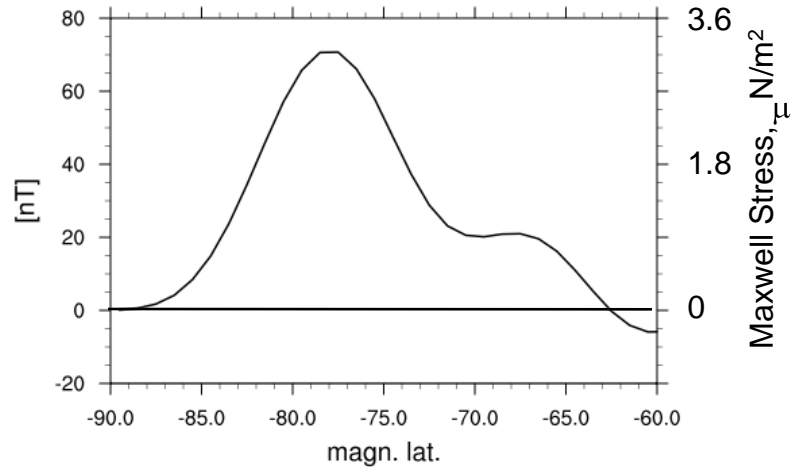
Atmospheric mass ~ 10^{-3} kg/m^2 above 110 km

2×10^{-6} N/m^2 causes 2×10^{-3} m/s^2 acceleration,
which produces 40 m/s wind after 2×10^4 s (~ 6 hours).

IMF B_y-dependent
Geomagnetic Zonal-mean Winds
Summer, $\bar{B}_y$(20 hr) = 2.5 nT

Richmond et al. [2003]

Some Questions

- What are the distributions of energy and momentum flux during dynamic conditions?

- How are small-scale convection velocities related to ionospheric conductivity structures in the E and F regions?

- What is the dynamic response of winds to changing convection on different temporal and spatial scales?

- How does the magnetosphere respond to the winds?