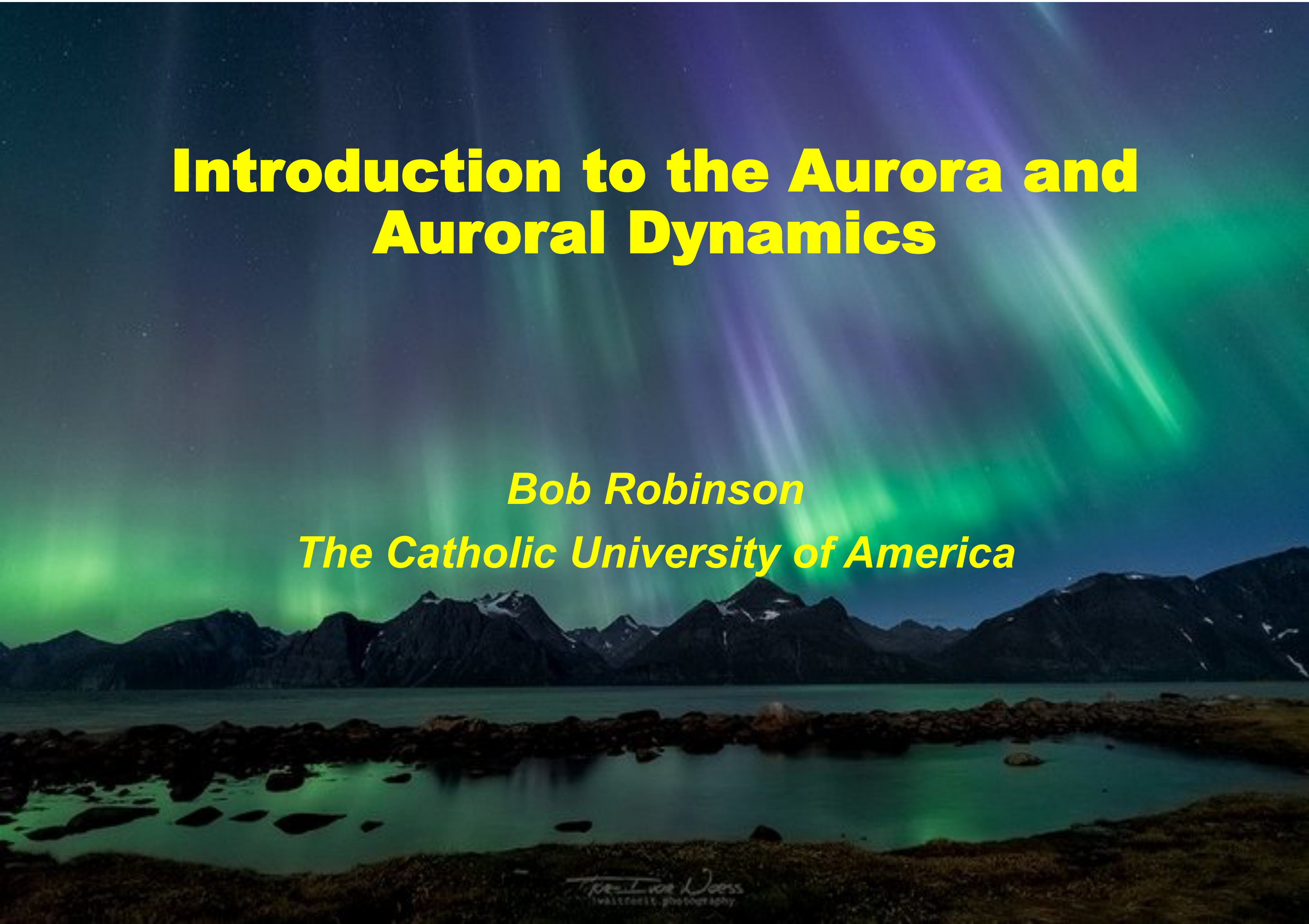


Introduction to the Aurora and Auroral Dynamics

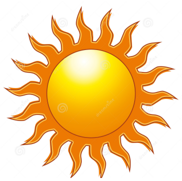
Bob Robinson

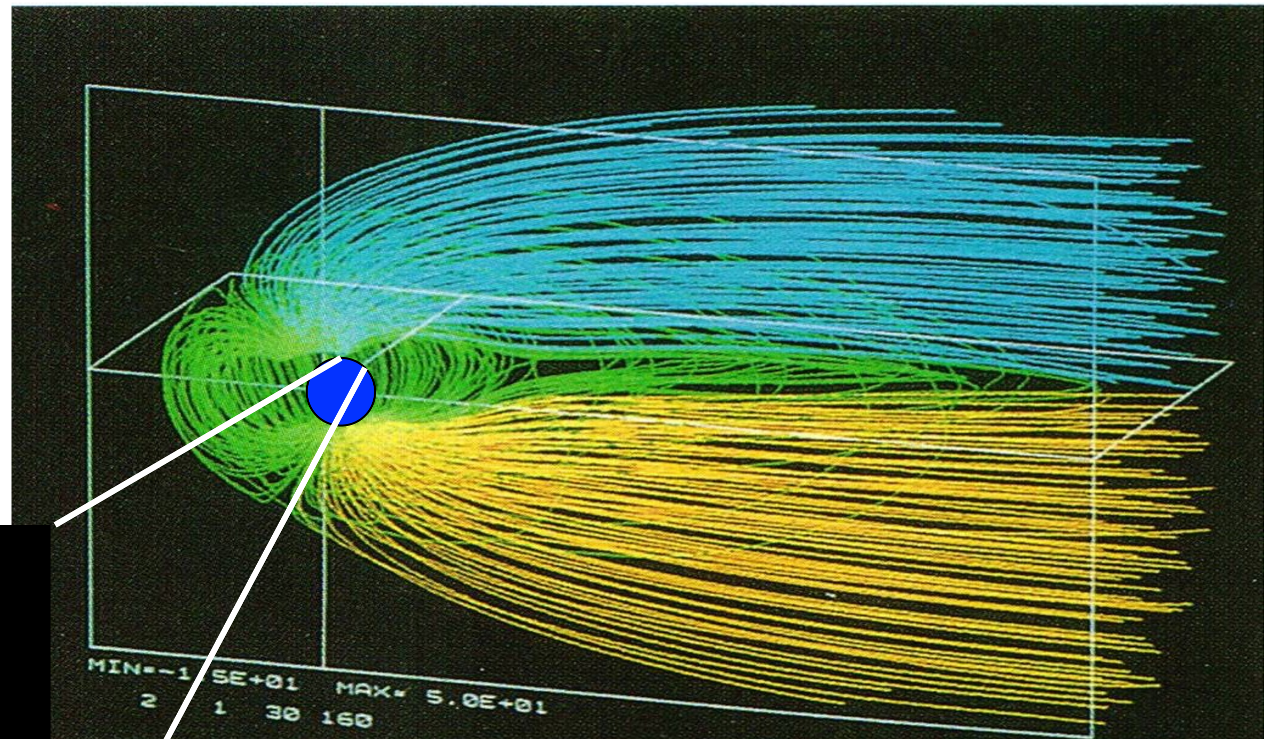
The Catholic University of America

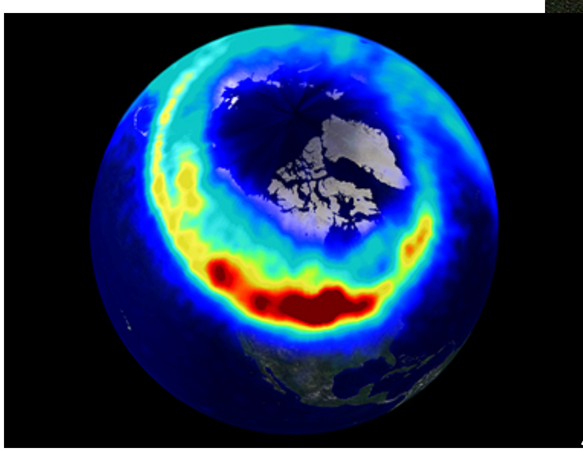
Why the aurora is important to space weather?

- The aurora is a source of energy input to the atmosphere.
- The aurora changes the ionospheric electrical conductance, which modifies currents that couple the ionosphere to the magnetosphere.
- The aurora produces disturbances to ionospheric electron density that disrupt communication, navigation, and surveillance (radar) systems.
- The aurora contains information about the processes that take place as a result of solar wind forcing and magnetospheric processes.
- The aurora is the ultimate check on our understanding of space weather effects on geospace.

The aurora allows us to ‘see’ the magnetosphere and observe geospace processes







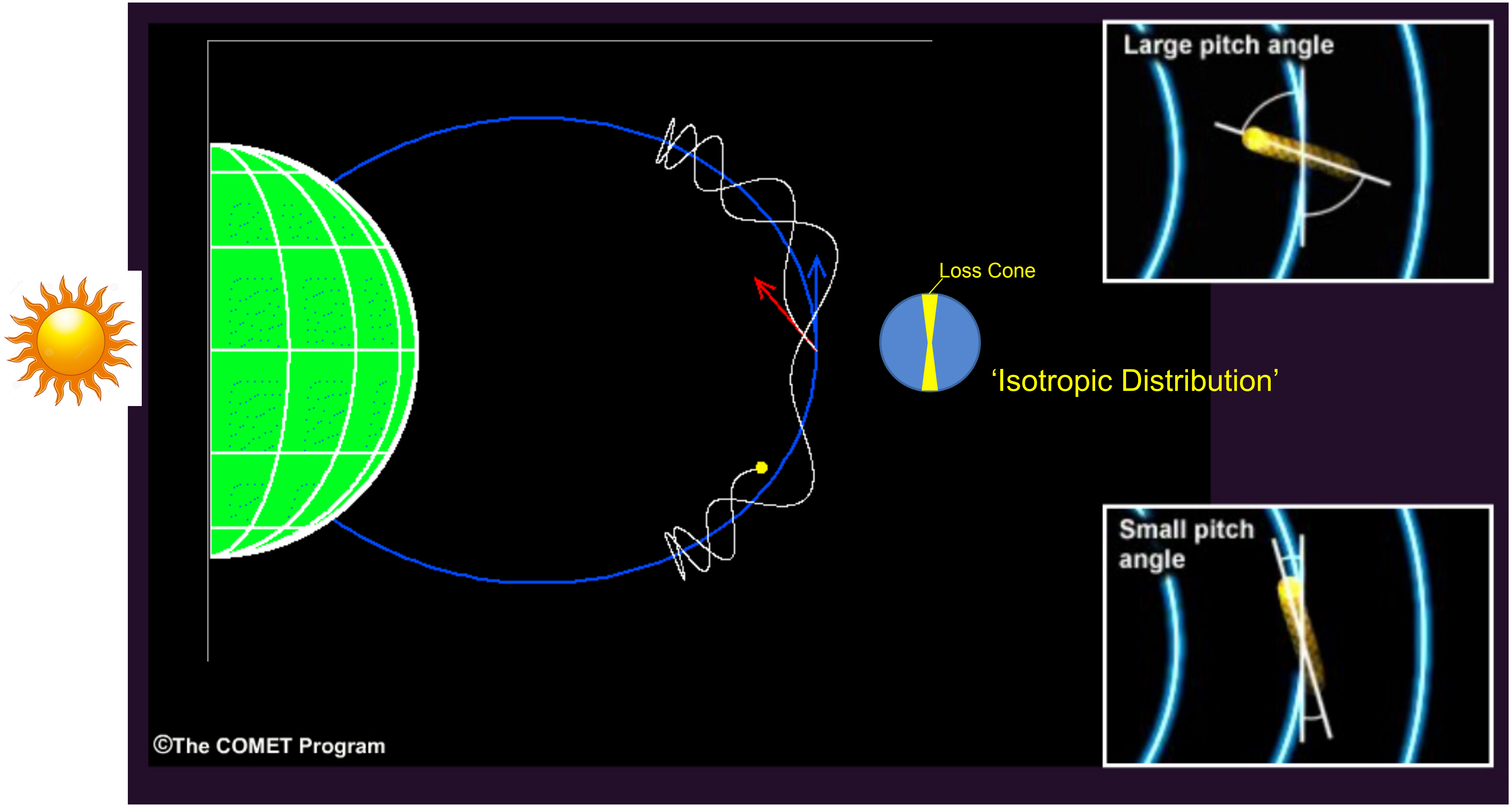
The magnetosphere is threaded by magnetic fields, which very quickly and efficiently transfer information along the length of the field lines

Decoding the Aurora

What can the properties of the aurora tell us about the magnetosphere, the geospace system, and space weather?

- Ionospheric effects
  - Light
  - Electron Density
- Motion
- Electrical Properties
- Morphology

Magnetospheric Origin of Auroral Particles



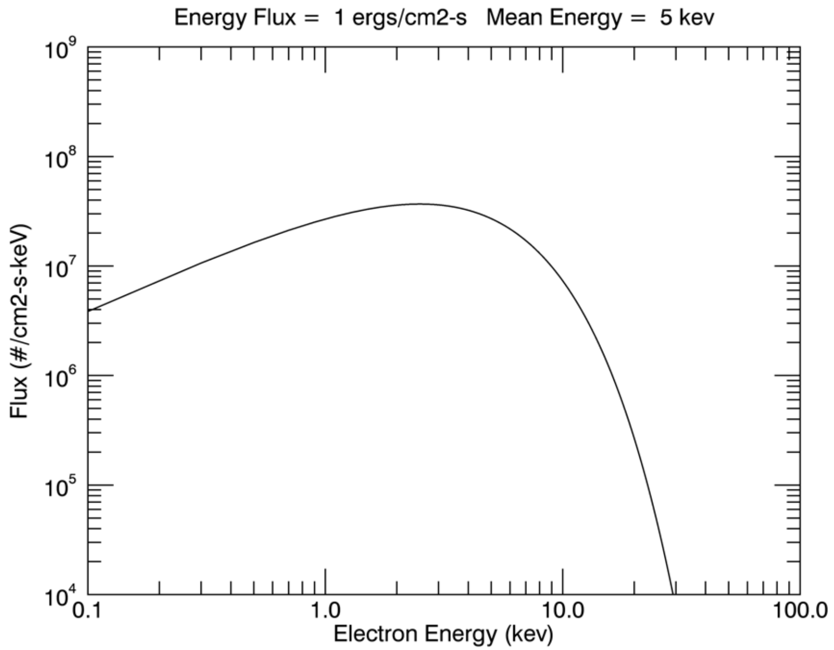
Auroral electrons (to first approximation) are characterized by a Maxwell-Boltzmann distribution

$$f(v) = n\left(\frac{m}{2\pi kT}\right)^{\frac{3}{2}} \exp\left(-\frac{mv^2}{2kT}\right)$$

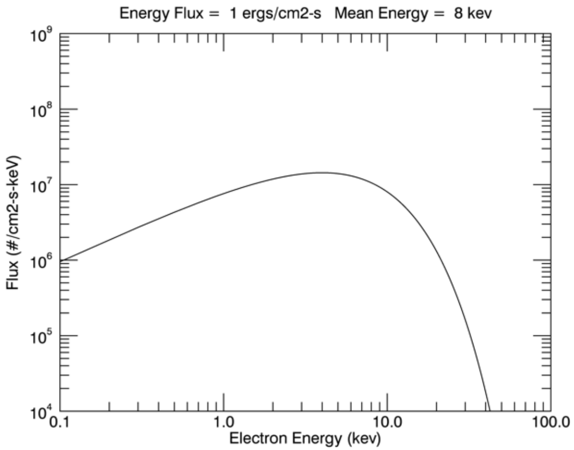
$$F(E) = \frac{2E}{m^2} n \left(\frac{m}{2\pi kT}\right)^{3/2} \exp\left(-E/kT\right)$$

$$F(E) = \frac{\Phi_E}{(\bar{E})^3} \exp\left(-2E/\bar{E}\right)$$

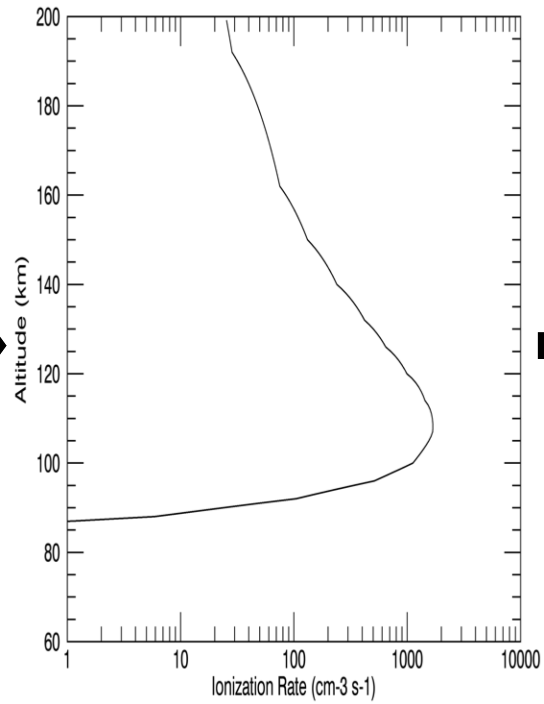
where Φ_E is the total energy flux and
kT is the temperature and
E is the mean energy (= 2*kT)



Auroral Energy Deposition



Auroral Electron Energy Distribution

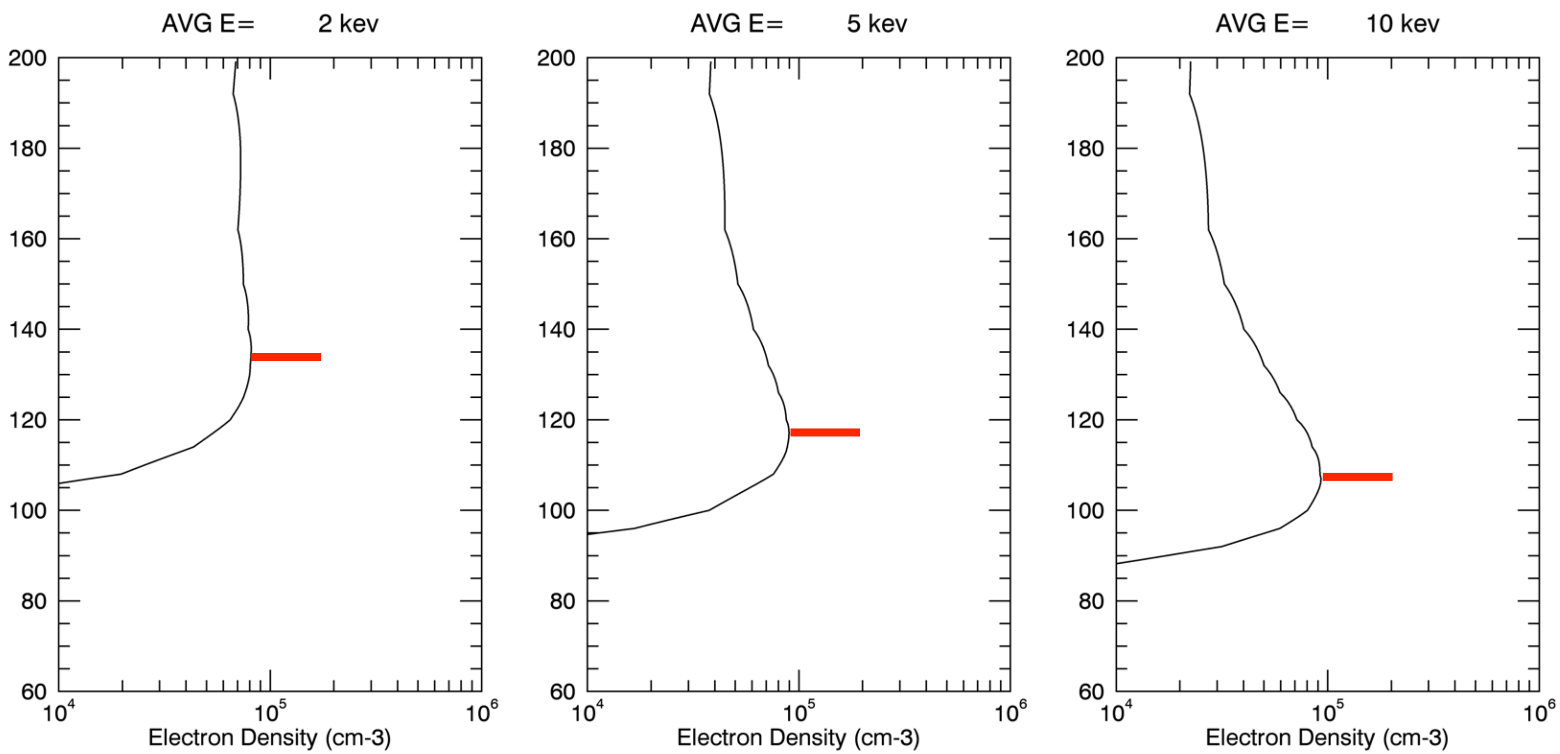


Energy Deposition Profile

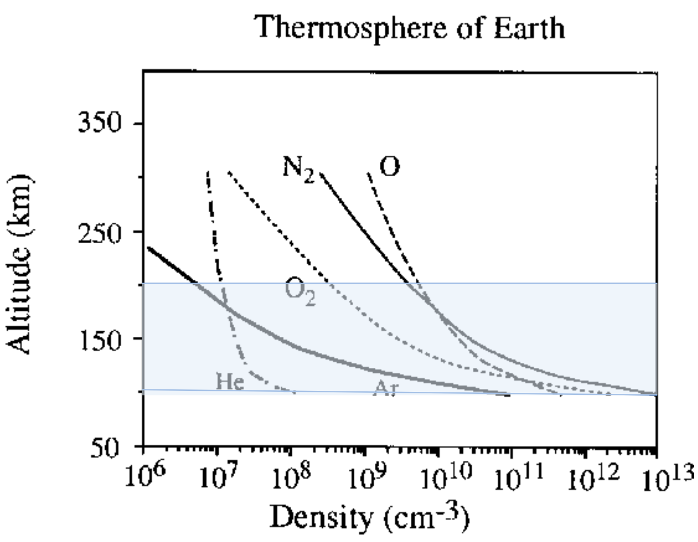
Electron Density

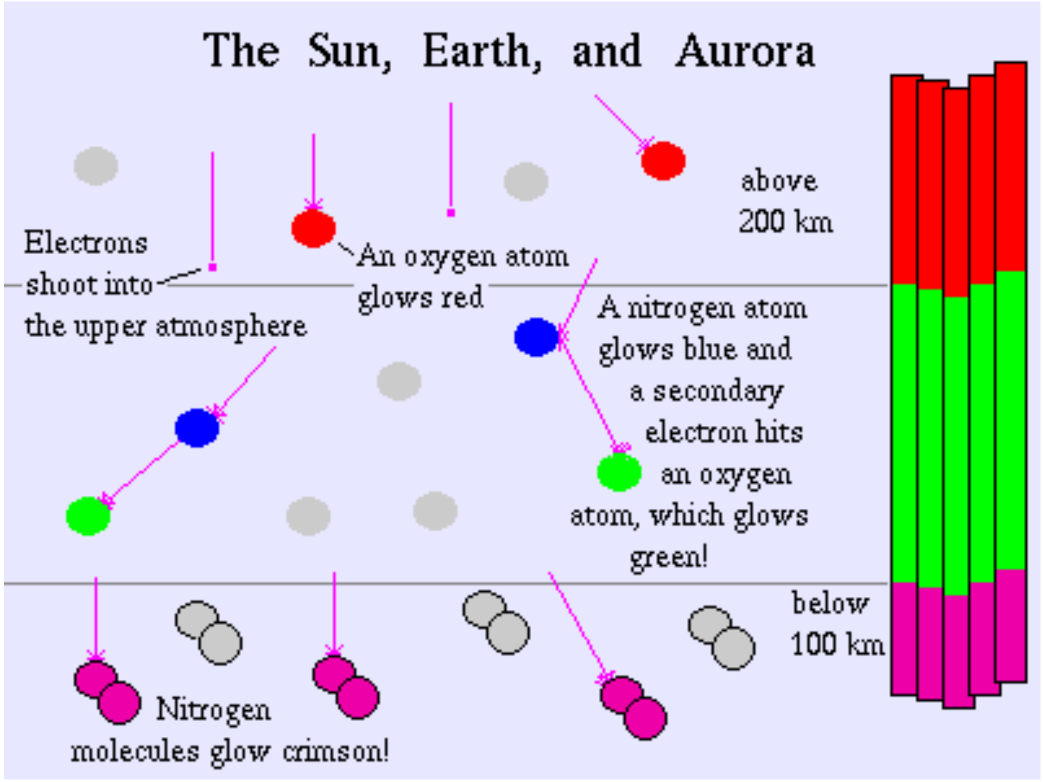
Luminosity

The energy flux and mean energy of the precipitation determine the peak electron density and the altitude of the peak



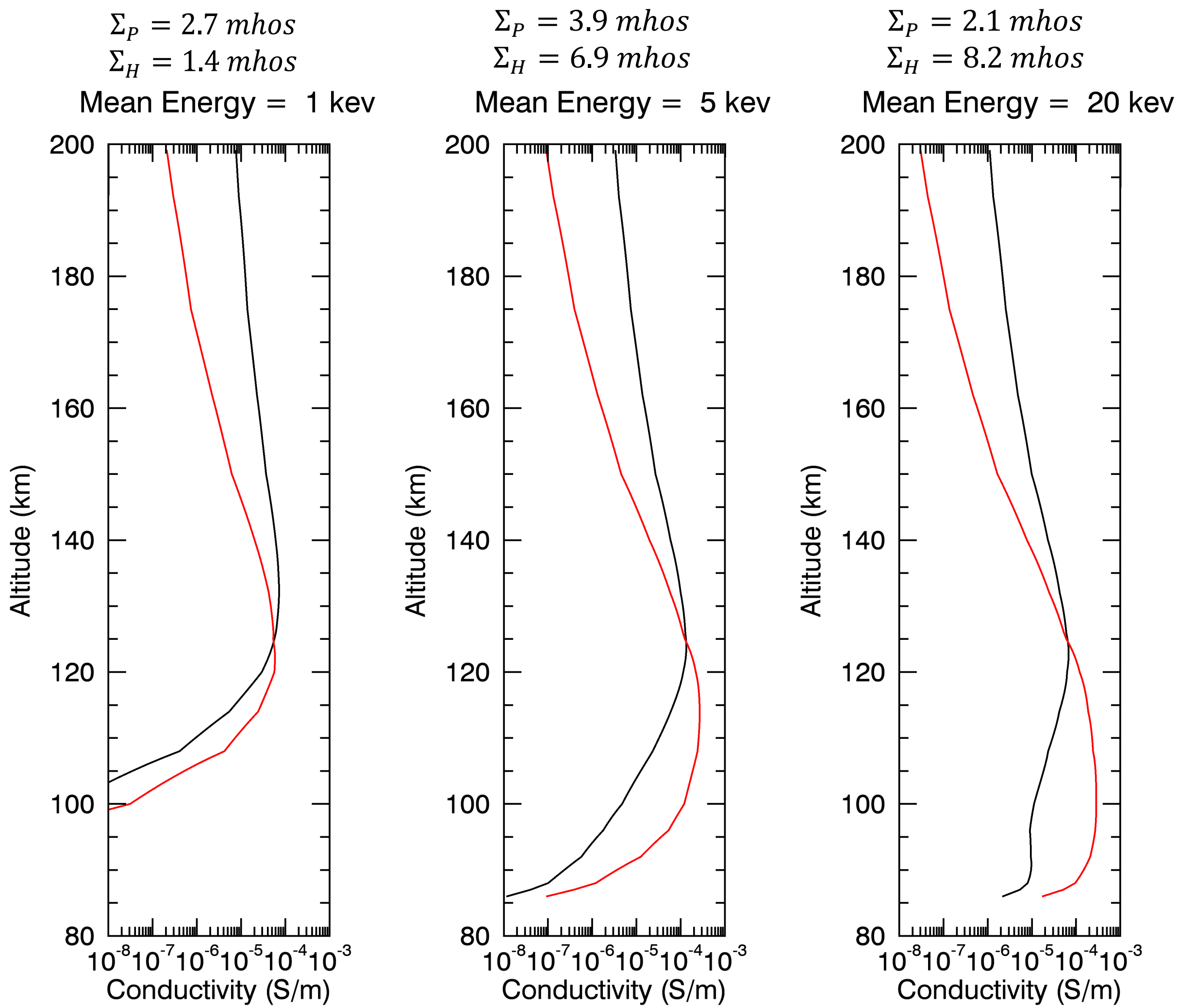
The color of the aurora tells us about the type and energy of the precipitating particles that cause it.





Auroral color tells us about the energy of the precipitating particles producing the light

Ionospheric Conductivity Profiles



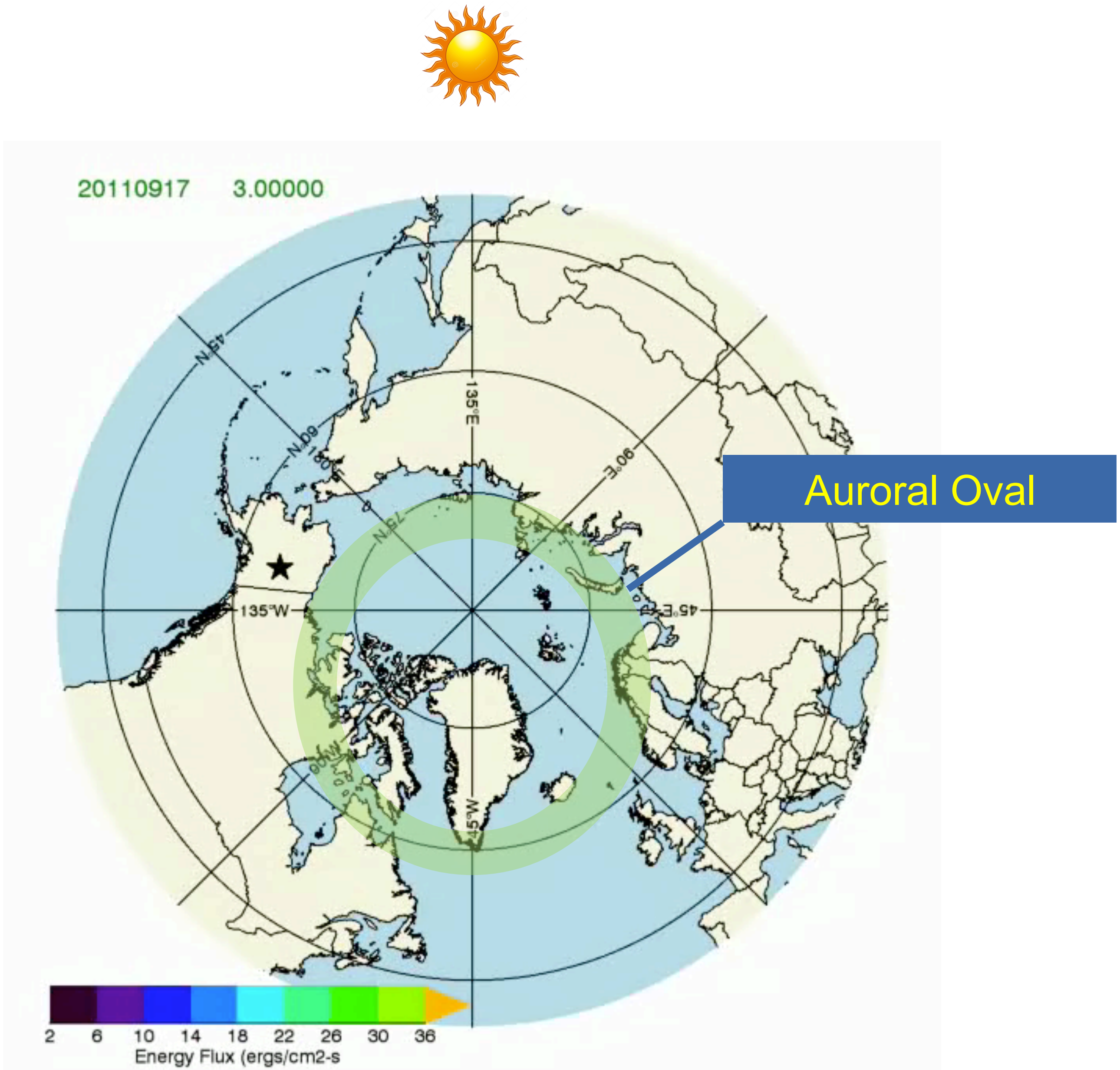
Two-Parameter Specification of Aurorally-Related Properties

- Magnetospheric: electron number density and temperature
- Auroral: Average energy and flux of electron precipitation
- Ionospheric: total electron density and height of the E-region peak
- Thermospheric: integrated light emission and ratio of two emissions with different altitude dependences
- Electrodynamic: Hall and Pedersen conductance

Auroral Motions

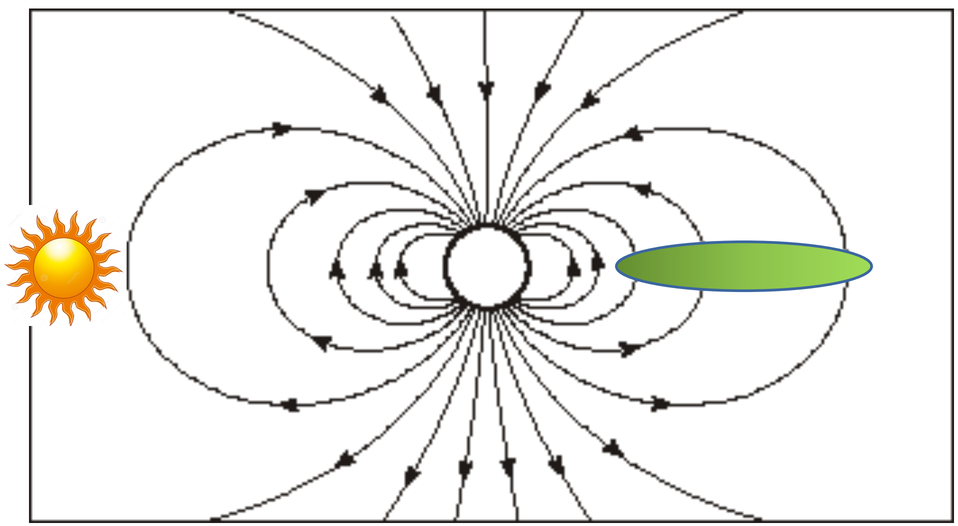
- Apparent motion due to Earth rotation
- Apparent motion due to dynamics of the auroral acceleration region
- Apparent motion due to changing magnetic fields

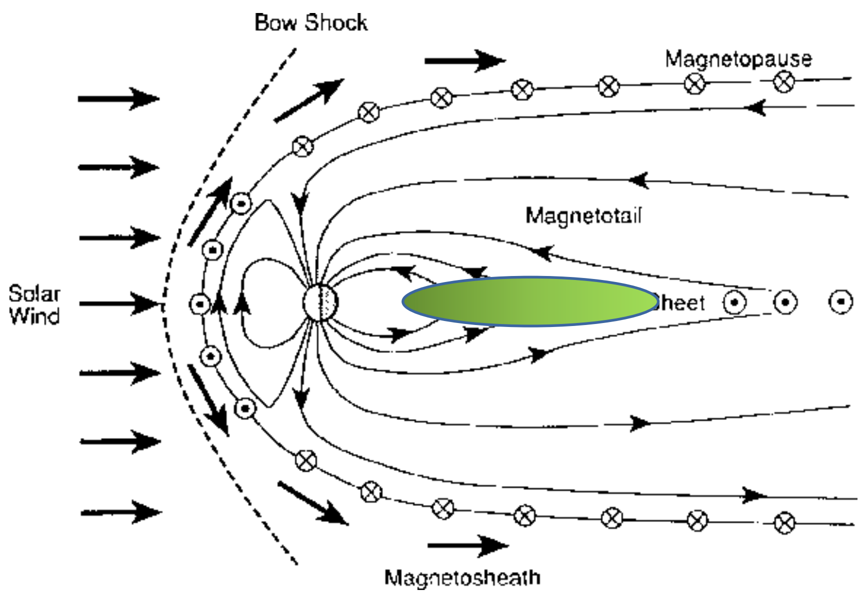
Motion due to Earth's Rotation

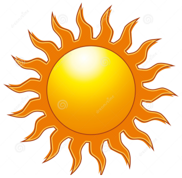


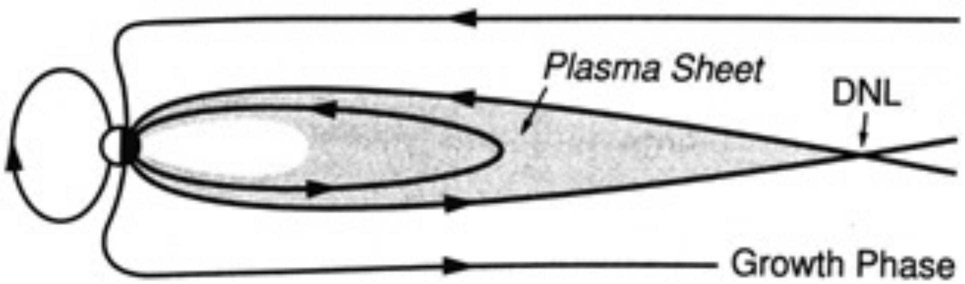
Motion due to dynamics of auroral particles

Motion due to changing magnetic fields

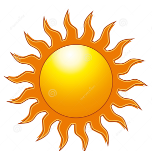


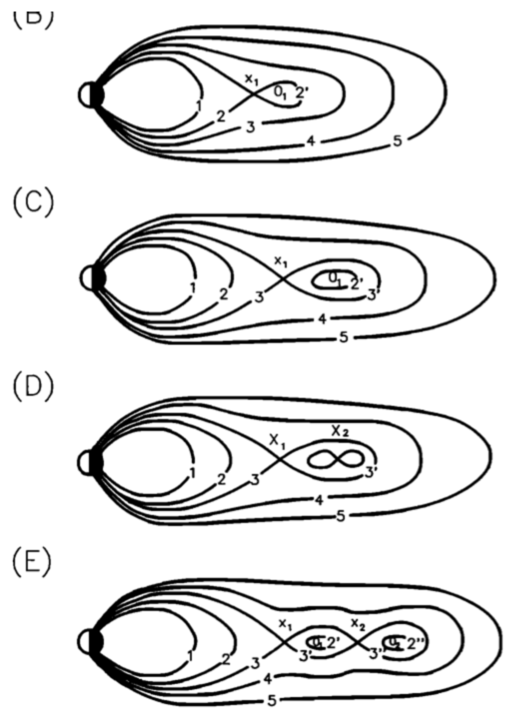




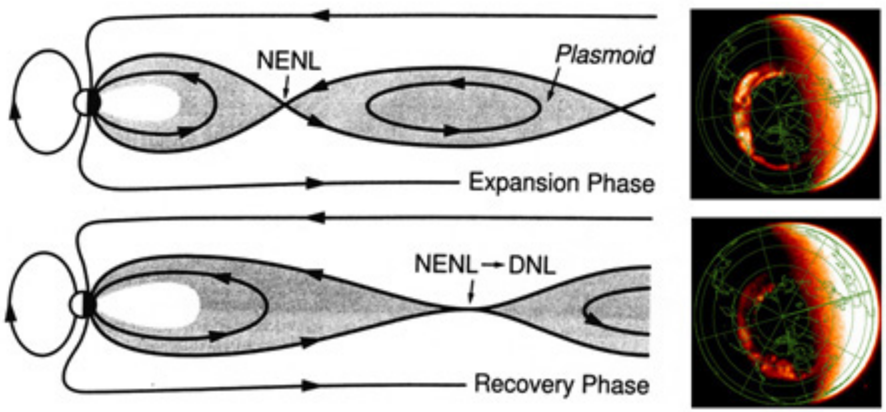

Plasma Sheet
DNL
Growth Phase

Observing the structure of the magnetotail from Earth

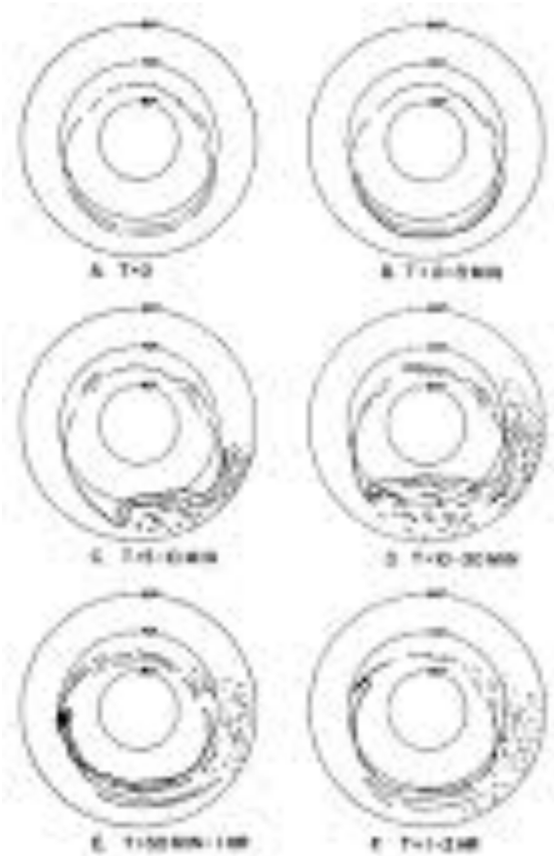


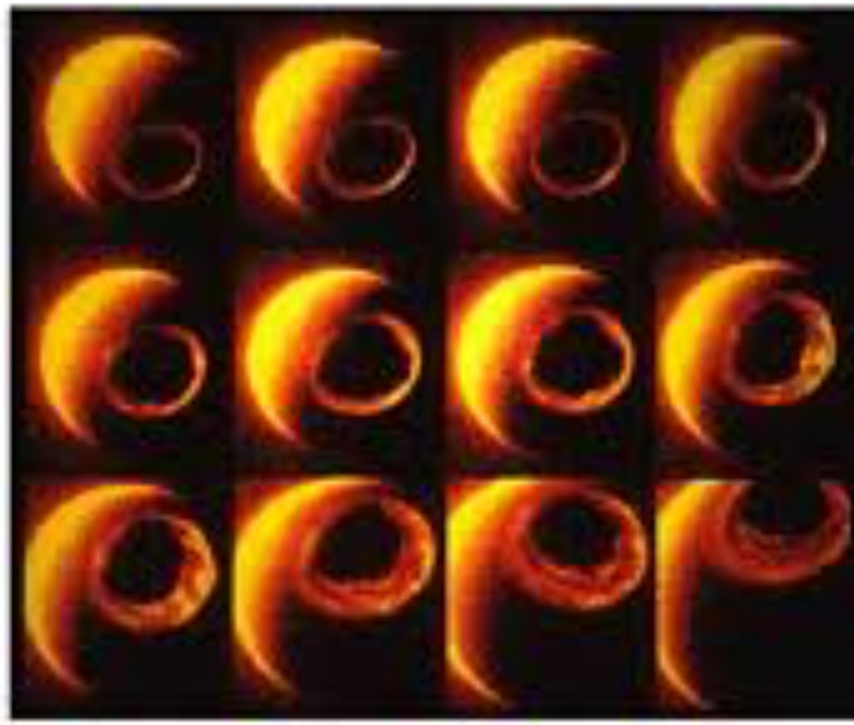


Auroral Breakup

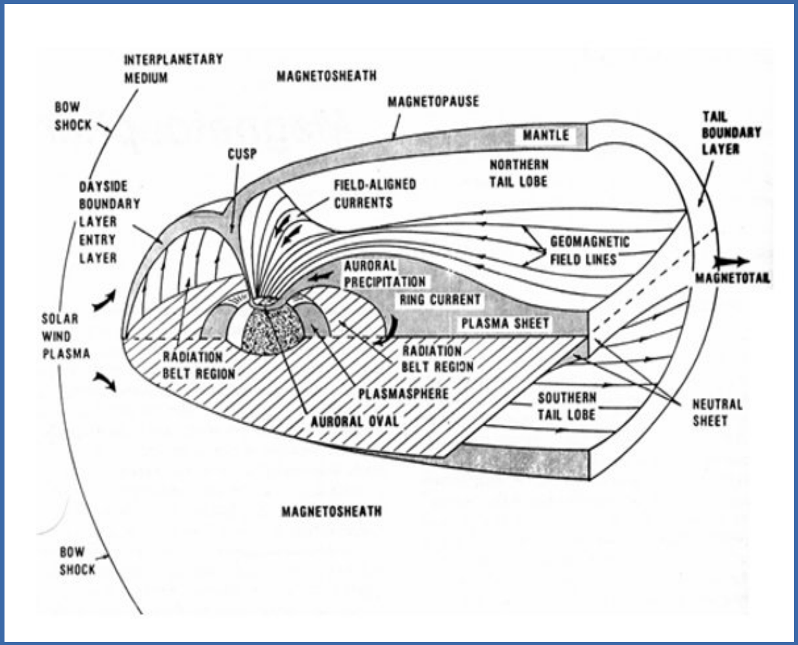


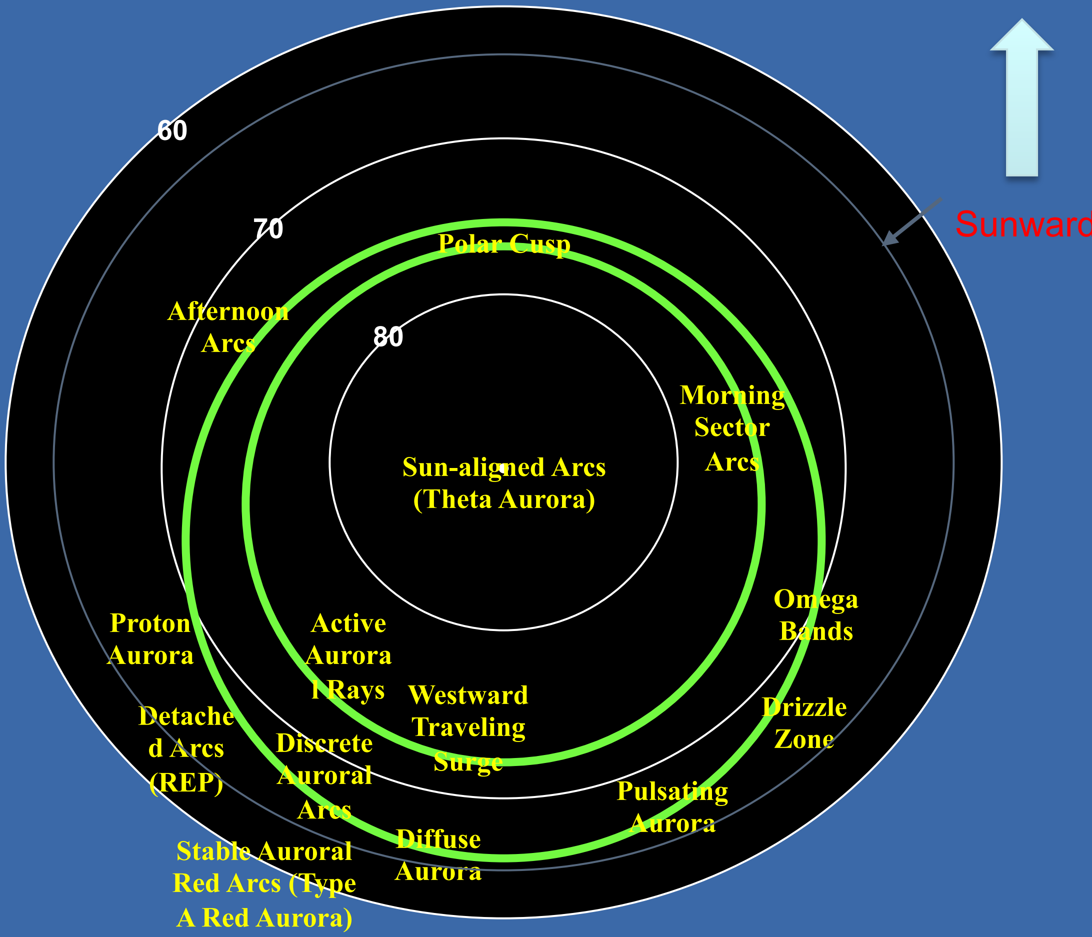
Auroral Substorm Dynamics Seen from Space





Auroral morphology and how it relates to the magnetosphere





Auroral Electrical Properties

Ohm's Law: $V = IR$

In the ionosphere: $\bar{J} = \tilde{\Sigma}\,\bar{\mathrm{E}}$

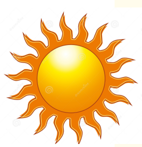
where $\tilde{\Sigma}$ is the tensor, height-integrated conductivity.

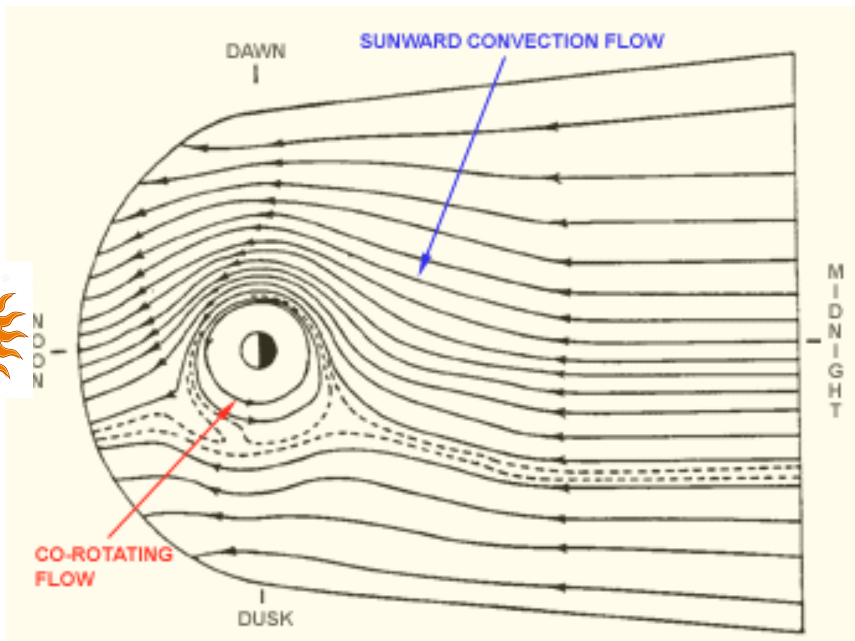
$$\bar{J} = \begin{bmatrix} \Sigma_{\mathrm{P}} & -\Sigma_{\mathrm{H}} \\ \Sigma_{\mathrm{H}} & \Sigma_{\mathrm{P}} \end{bmatrix} \bar{E}$$

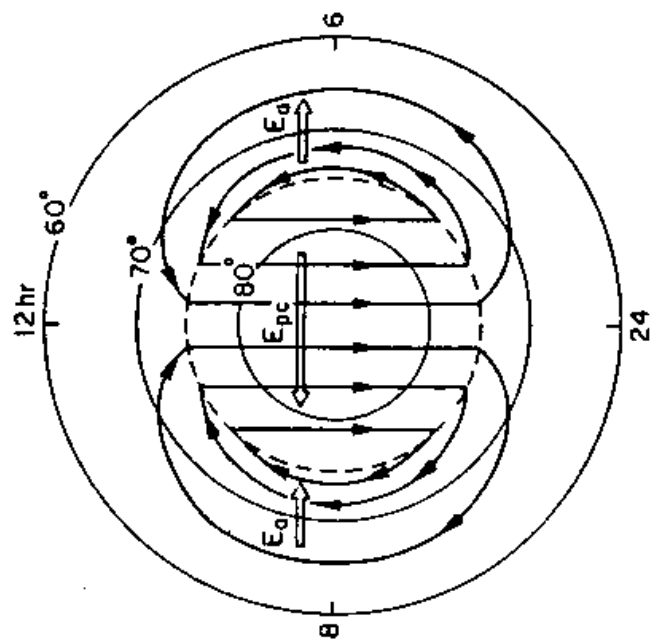
$$\bar{J} = \Sigma_P \bar{E} - \Sigma_H (\bar{E} \times \bar{B}) / |B|$$

Electric fields, conductivities, and currents are needed for a complete specification of auroral electrodynamics

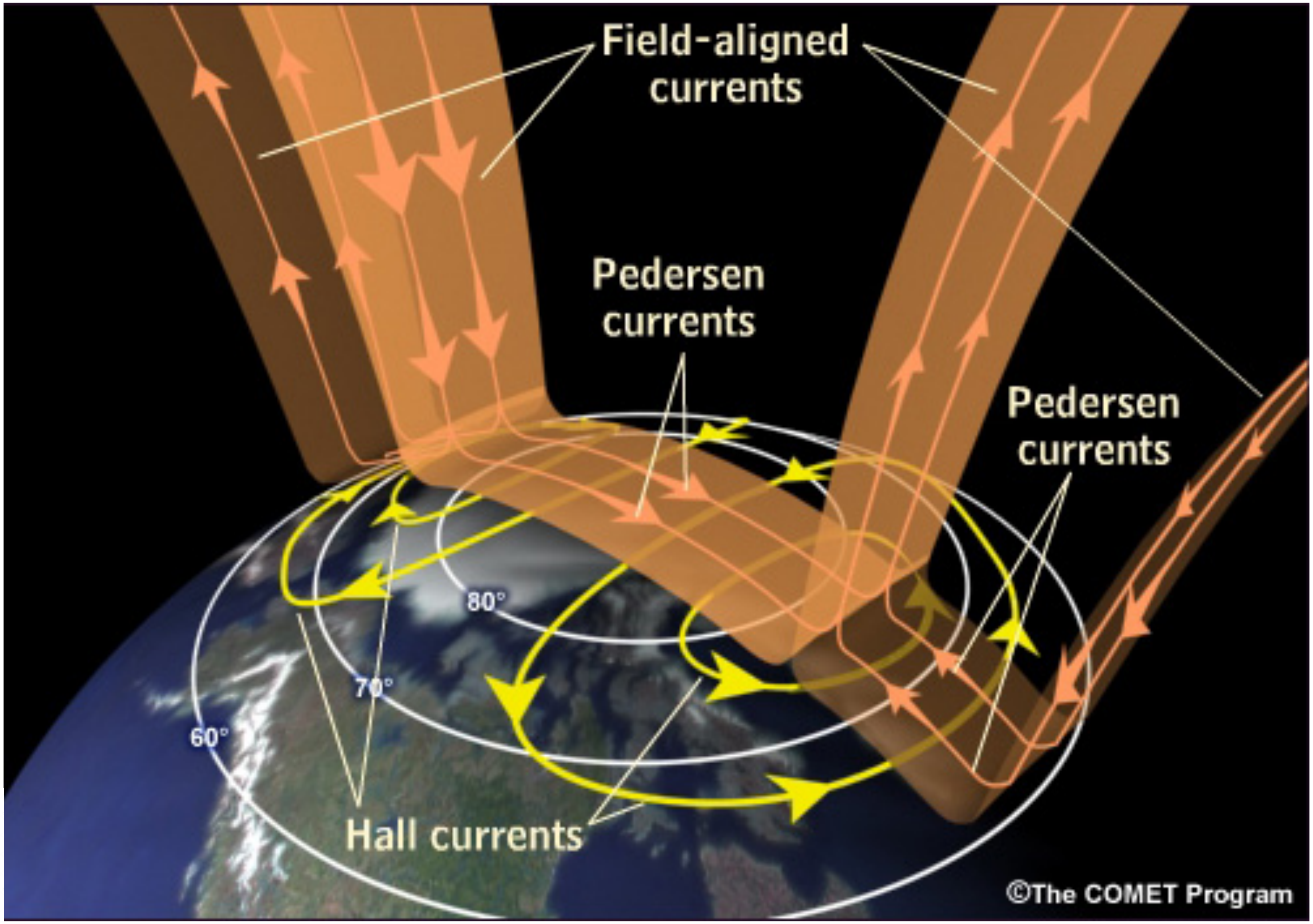
Electric fields and convection







Birkeland (Field-Aligned) Currents



A solution based on field-aligned currents

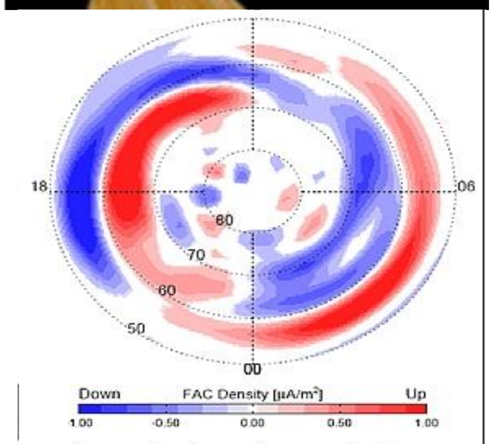
$$\bar{J} = \Sigma_P \bar{E} - \Sigma_H (\bar{E} \times \bar{B})/|B|$$

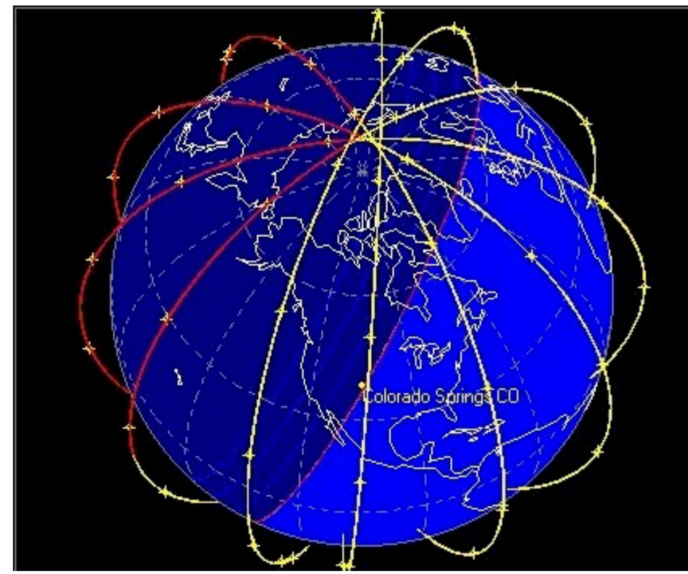
From current continuity:

$$\nabla \cdot \bar{J} = 0$$

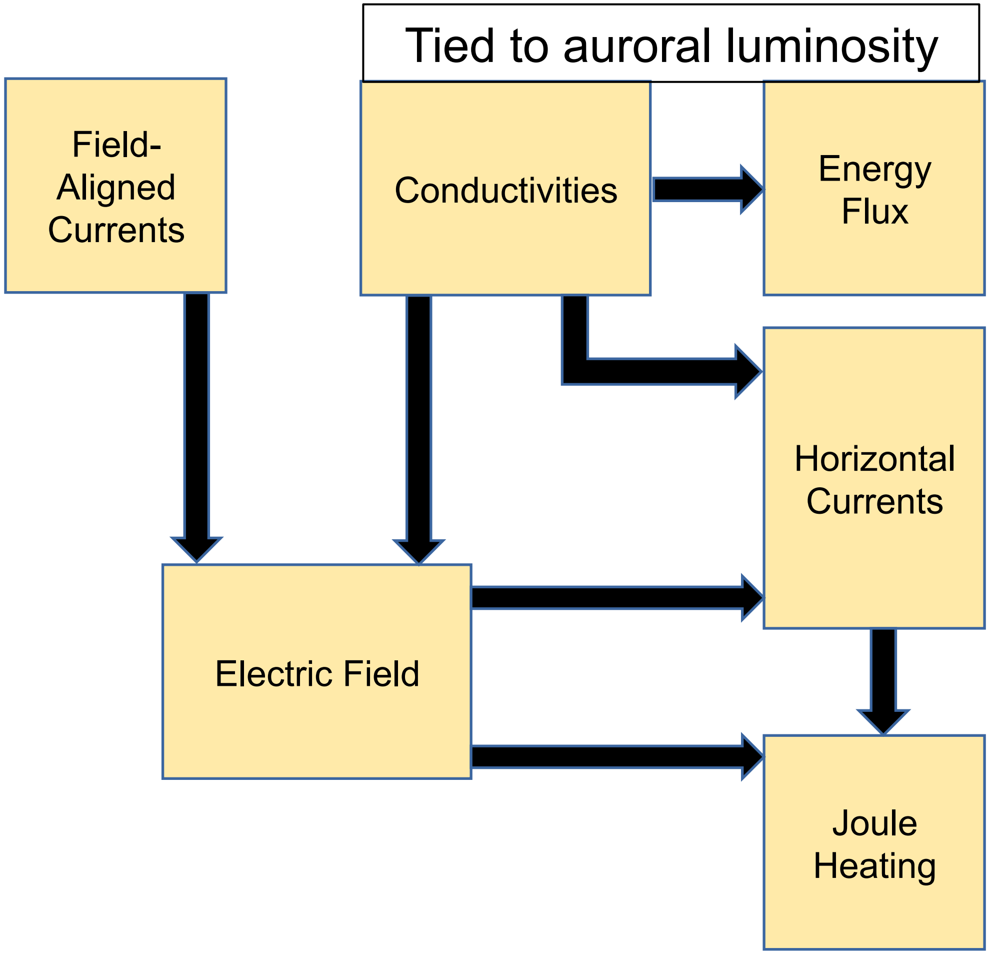
$$J_\parallel = \nabla \cdot J_\perp$$

$$J_\parallel = \nabla \cdot (\bar{\bar{\Sigma}} \bar{E})$$





Calculation of Auroral Electrodynamic Parameters

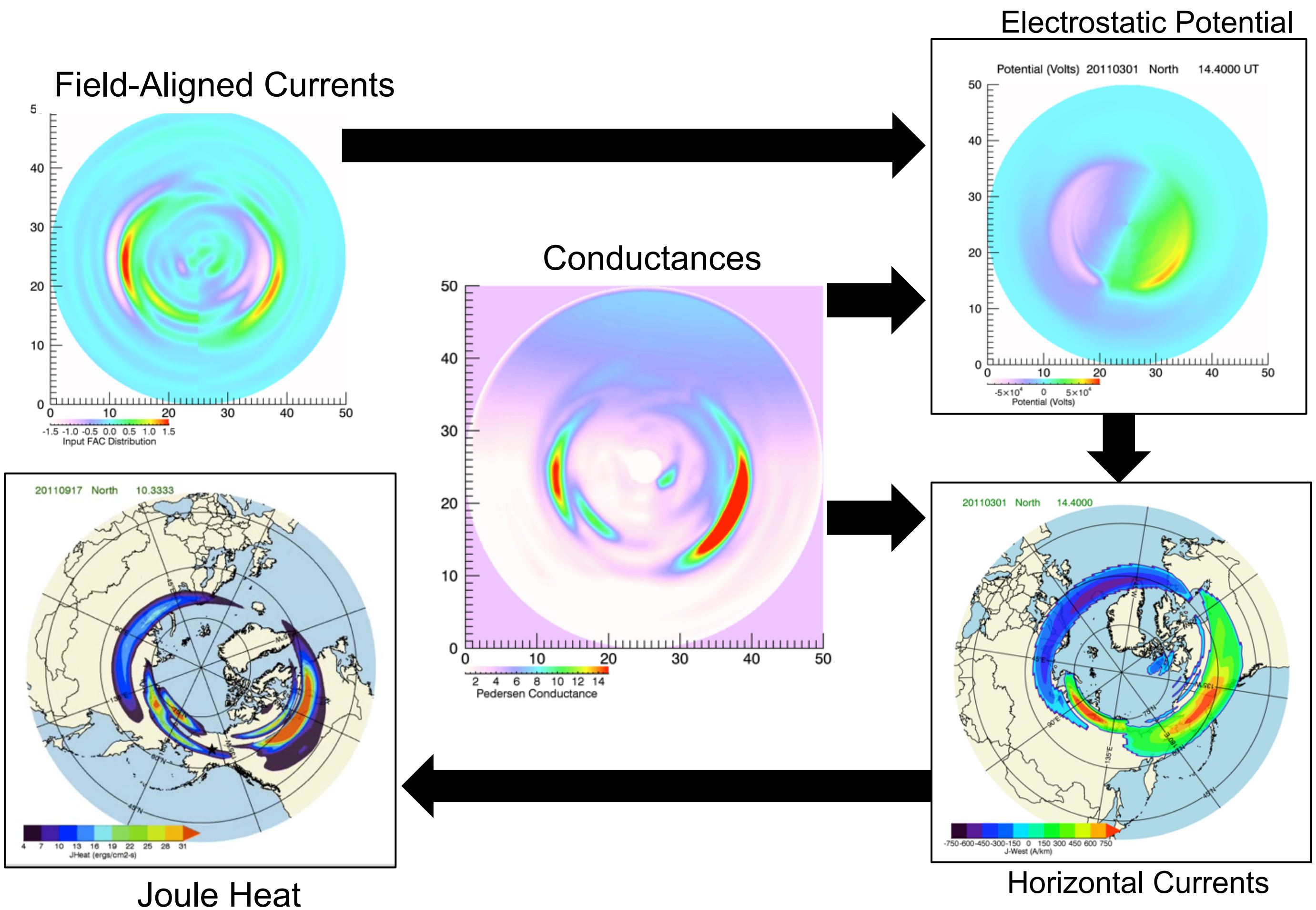


$$J_{\parallel} = \nabla \cdot (\bar{\bar{\Sigma}}\bar{E})$$

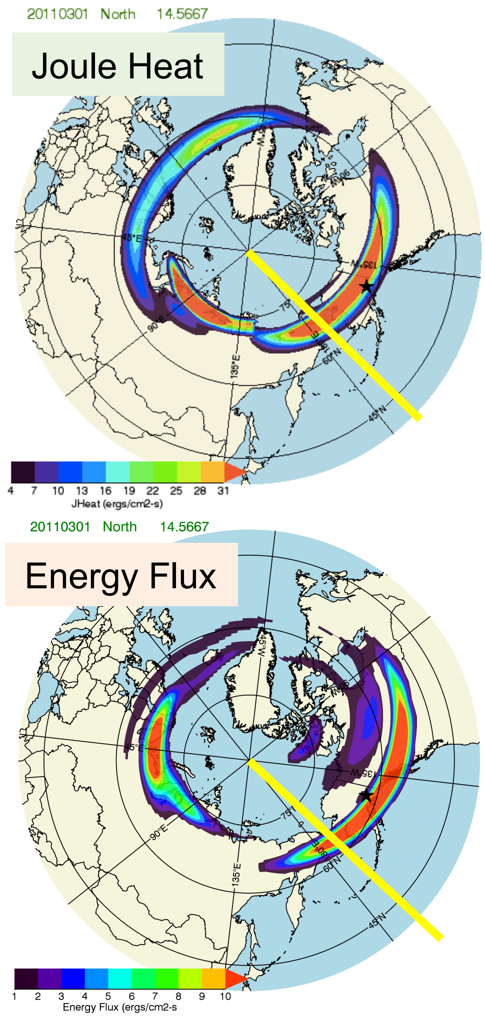
$$\bar{J} = \Sigma_P \bar{E} - \Sigma_H (\bar{E} \times \bar{B})/|B|$$

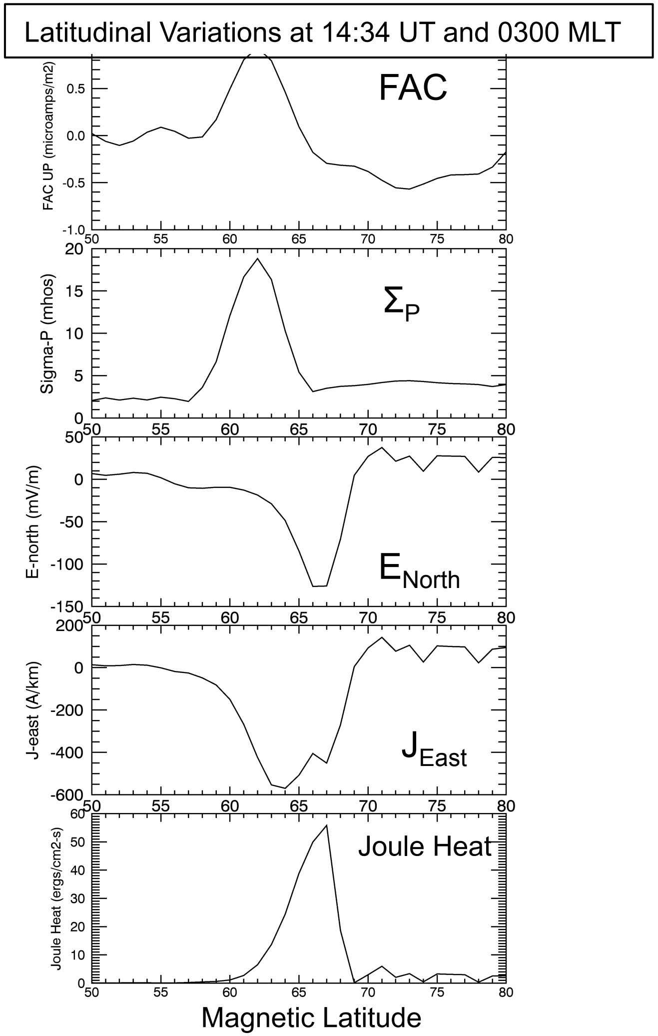
$$Joule\ Heat = \Sigma_P E^2$$

Calculation of Electric Fields, Horizontal Currents and Joule Heat from Field-Aligned Currents and Conductivities

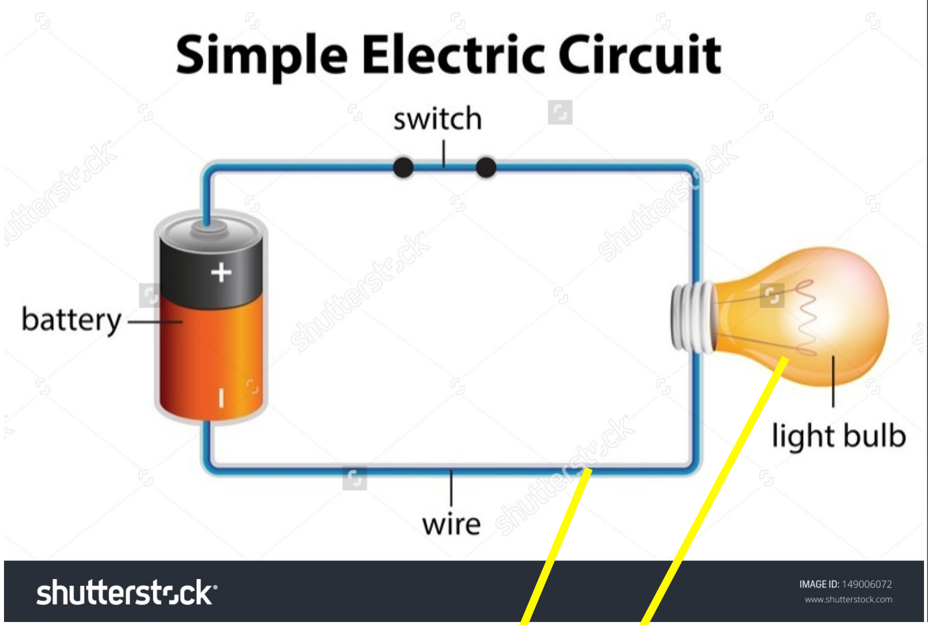


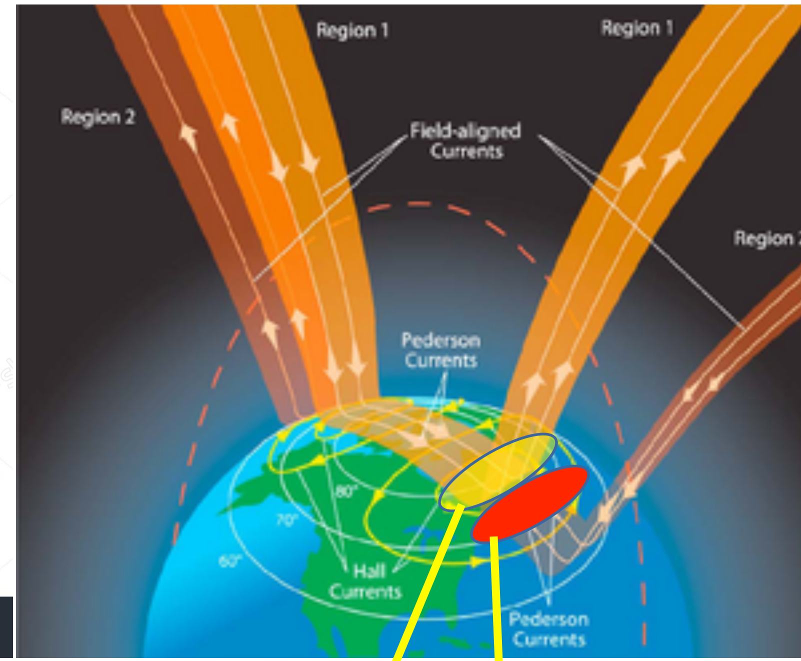
Greatest Auroral Power Dissipation Occurs Adjacent to the Aurora





Power Dissipated in Electrical Circuits





Low Resistance

High Resistance

Low Resistance

High Resistance

The Importance of Auroral Conductances

- Give information about the energy flux and average energy of precipitating electrons

- Can be combined with field-aligned currents to determine electric fields and convection

- Are used with electric fields to calculate currents and Joule heating

Summary

- Studying the aurora provides quantitative information about:
  - The type and energy distribution of the precipitating particles
  - The density and temperature of the magnetospheric plasma associated with the auroral particle precipitation
  - The spatial and temporal properties of magnetospheric domains to which the aurora is magnetically connected
  - The changes in the magnetospheric magnetic fields resulting from magnetosphere-solar wind coupling
  - The convective motion of magnetospheric plasma
  - Resistive heating of the ionosphere and thermosphere