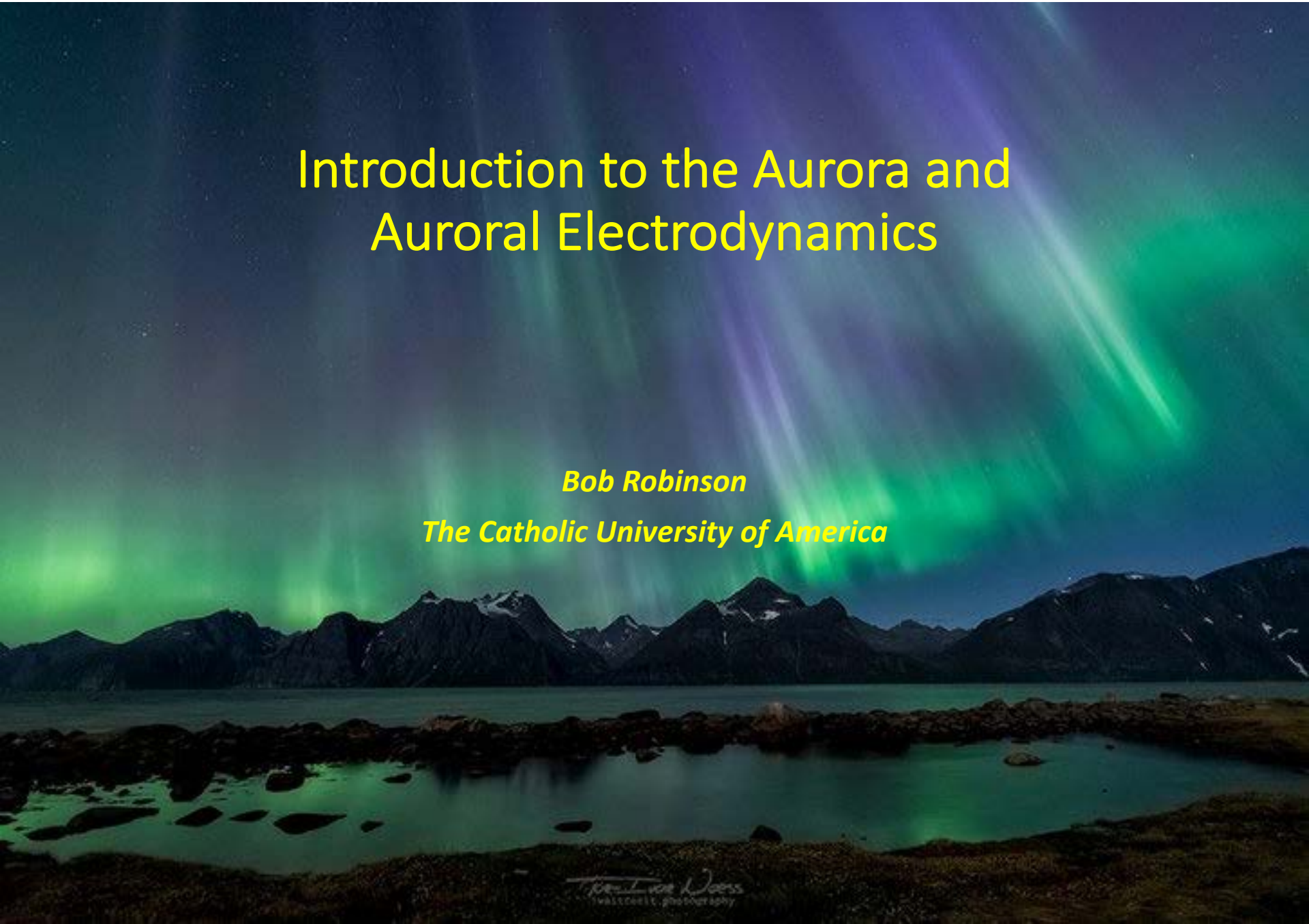
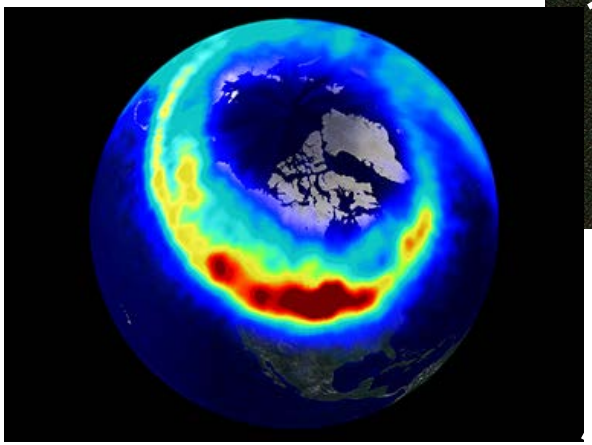


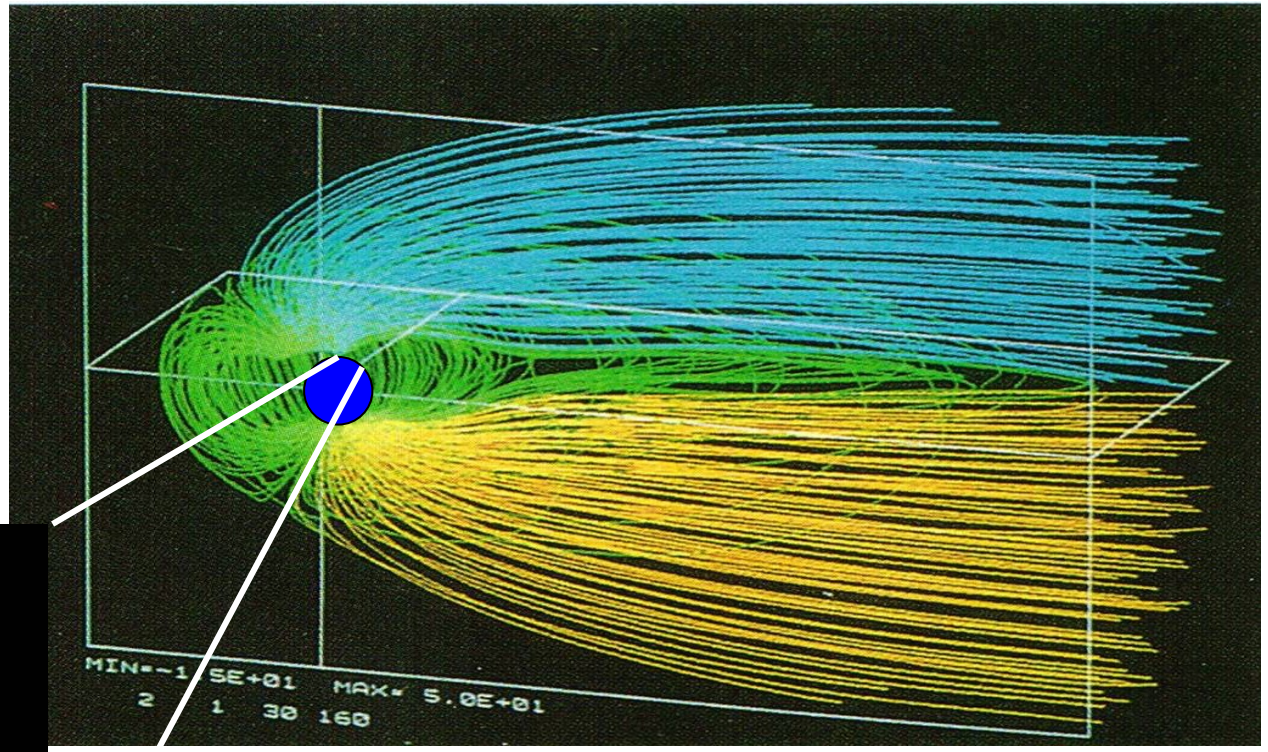
Introduction to the Aurora and Auroral Electrodynamics

Bob Robinson

The Catholic University of America

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





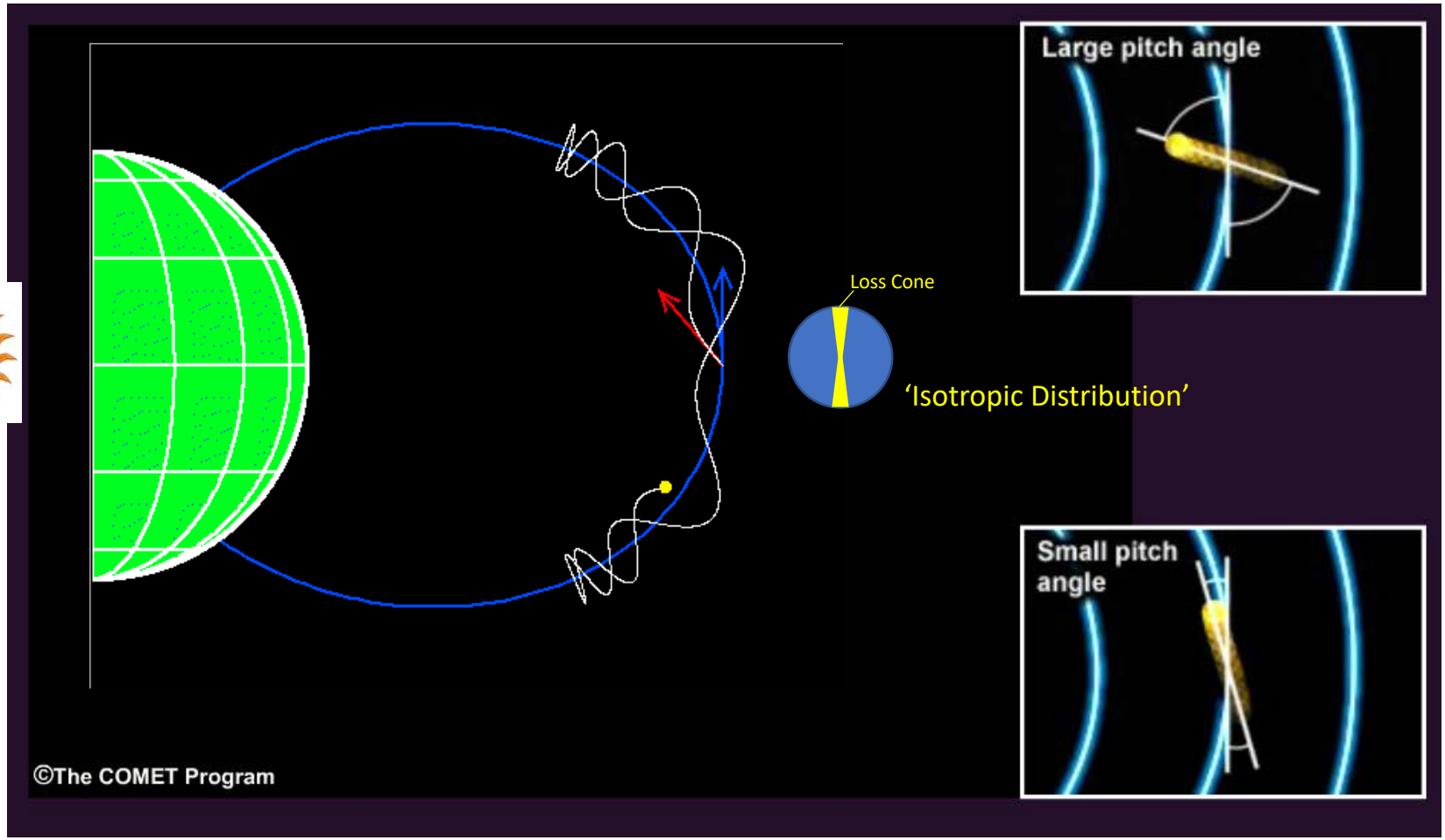
The magnetosphere is threaded by magnetic fields, which very quickly and efficiently transfer information along the length of the field lines

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



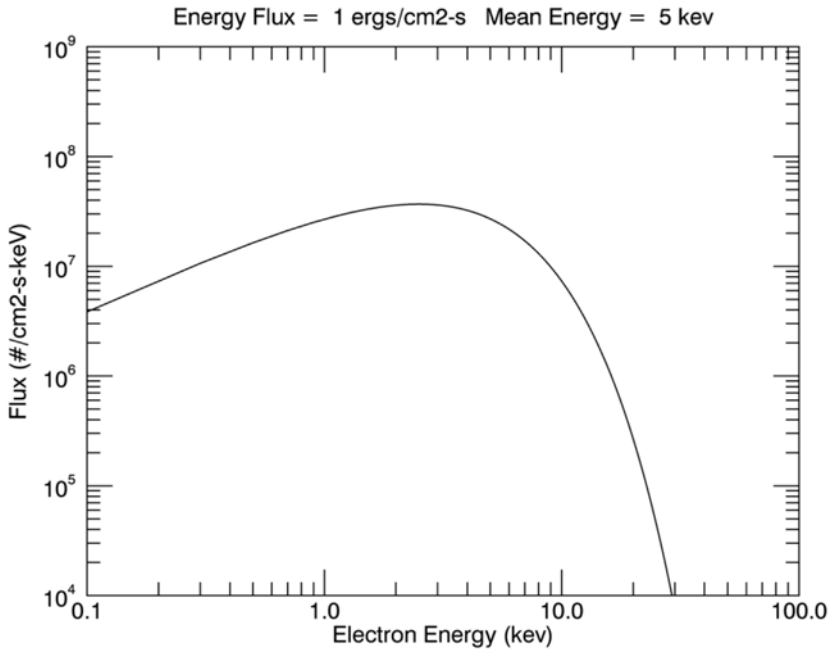
Auroral electrons (to first approximation) are characterized by a Maxwell-Boltzmann distribution

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

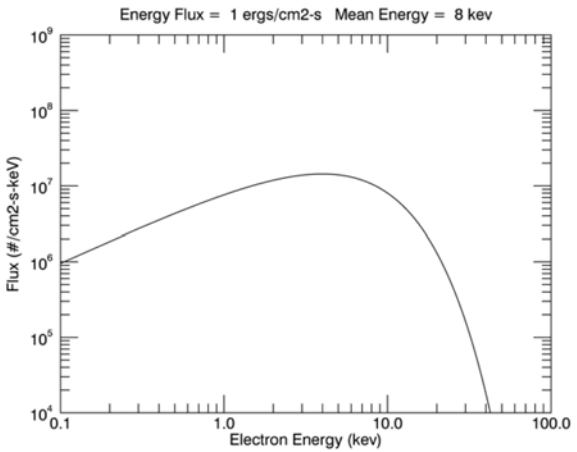
$$F(E) = \frac{2E}{m^2} n\left(\frac{m}{2\pi kT}\right)^{3/2} \exp\left(-E/kT\right)$$

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

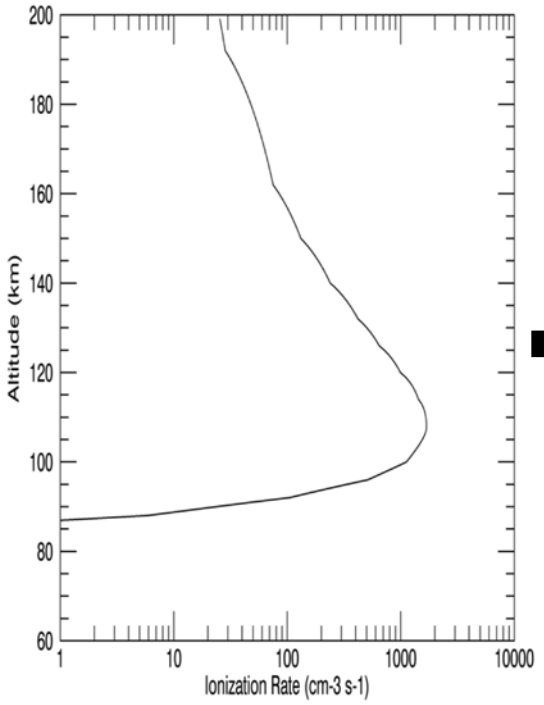
where Φ_E is the total energy flux and
kT is the temperature and
E is the mean energy (= 2*kT)



Auroral Energy Deposition



Auroral Electron Energy Distribution

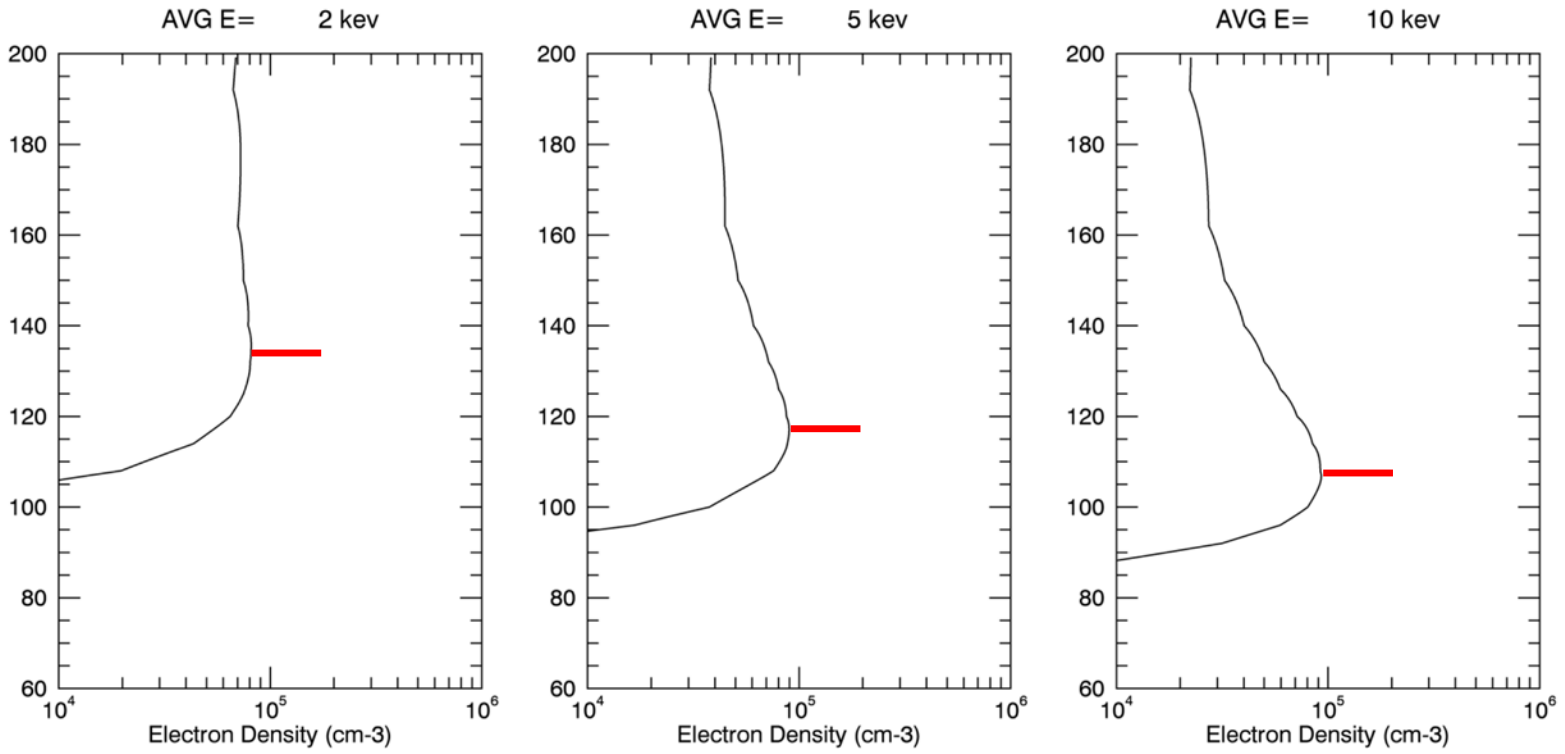


Energy Deposition Profile

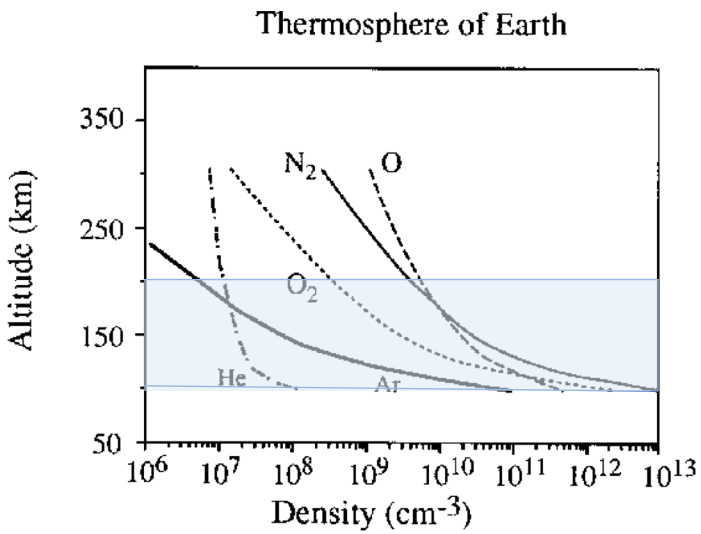
Electron Density

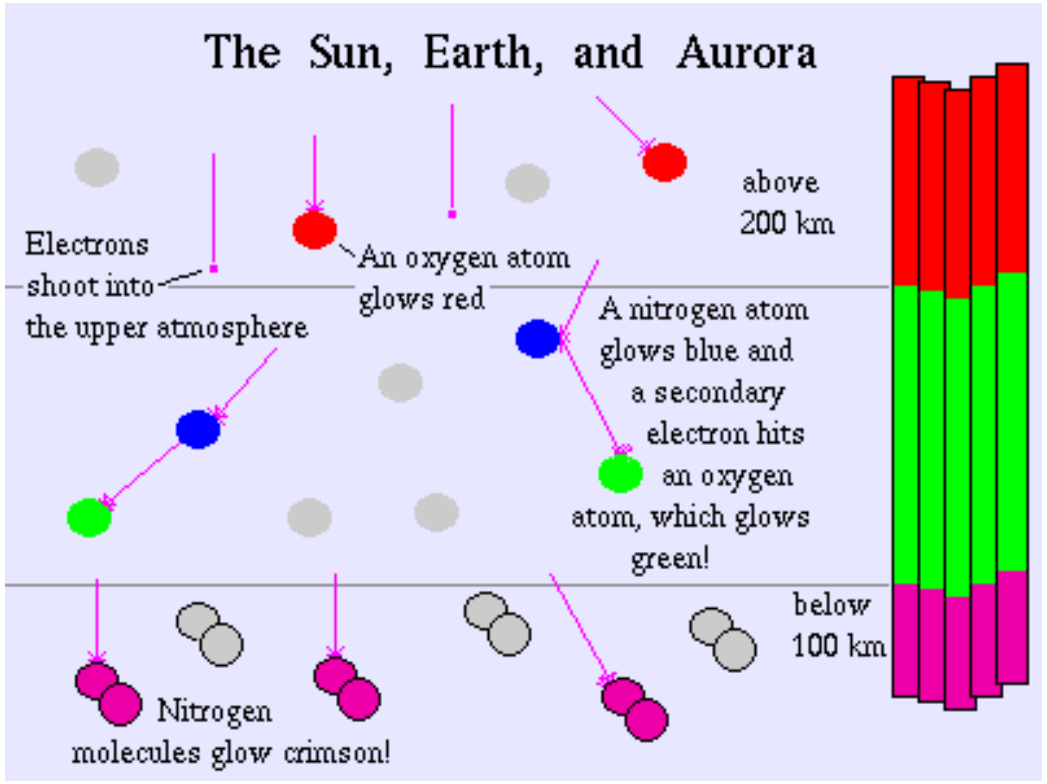
Luminosity

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.

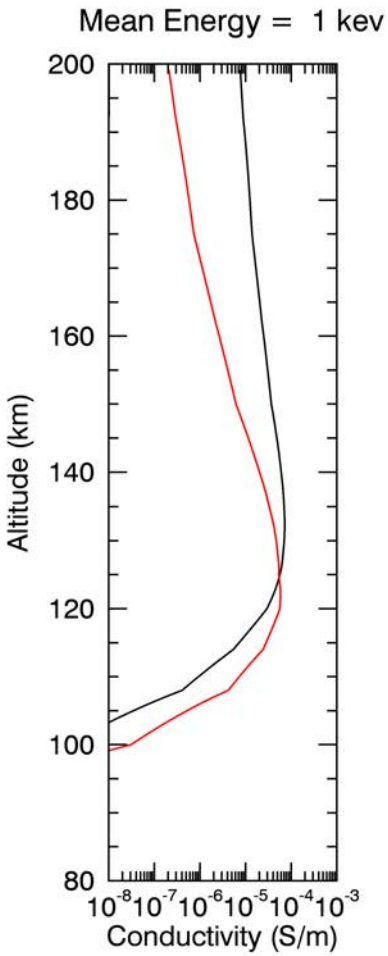




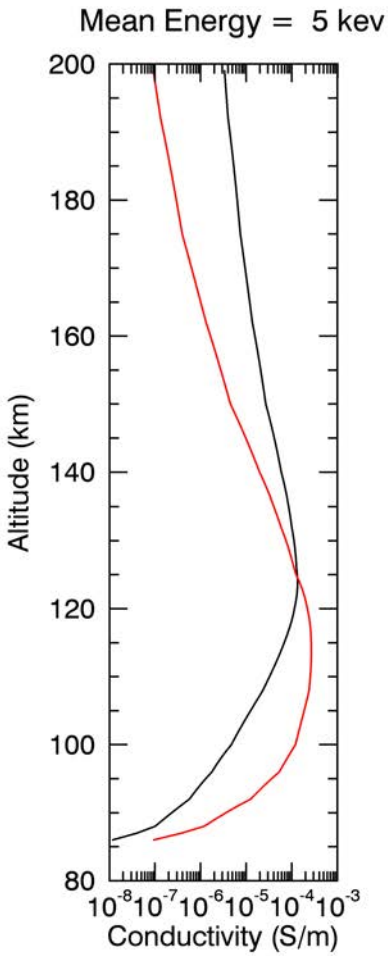
Auroral color tells us about the energy of the precipitating particles producing the light

Ionospheric Conductivity Profiles

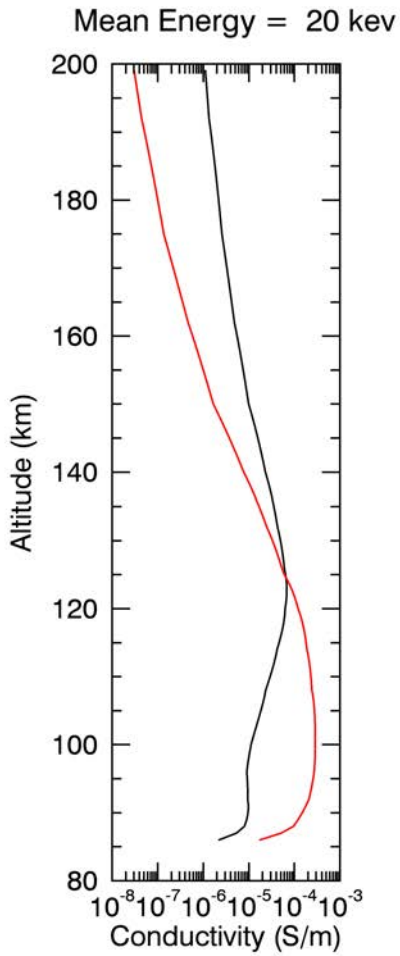
$\Sigma_P = 2.7\ mhos$
$\Sigma_H = 1.4\ mhos$



$\Sigma_P = 3.9\ mhos$
$\Sigma_H = 6.9\ mhos$



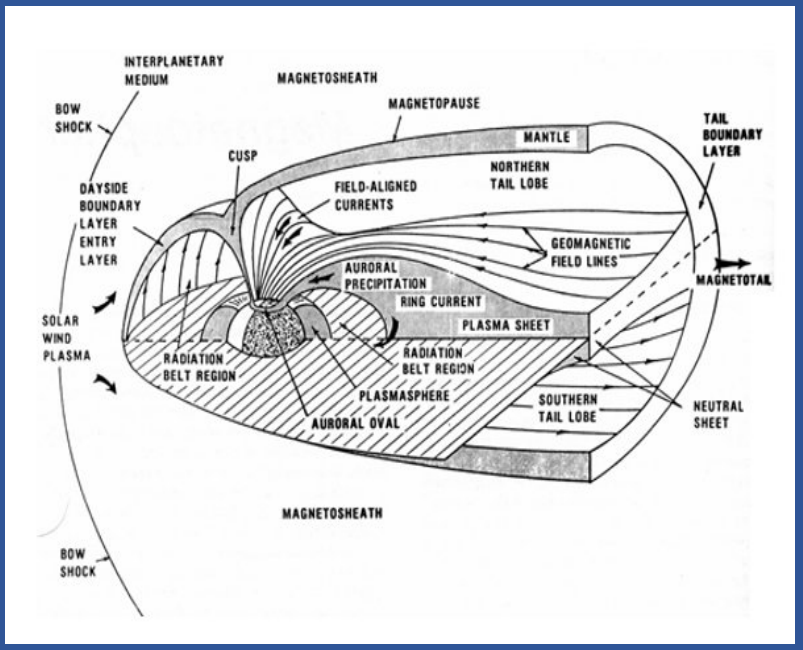
$\Sigma_P = 2.1\ mhos$
$\Sigma_H = 8.2\ mhos$

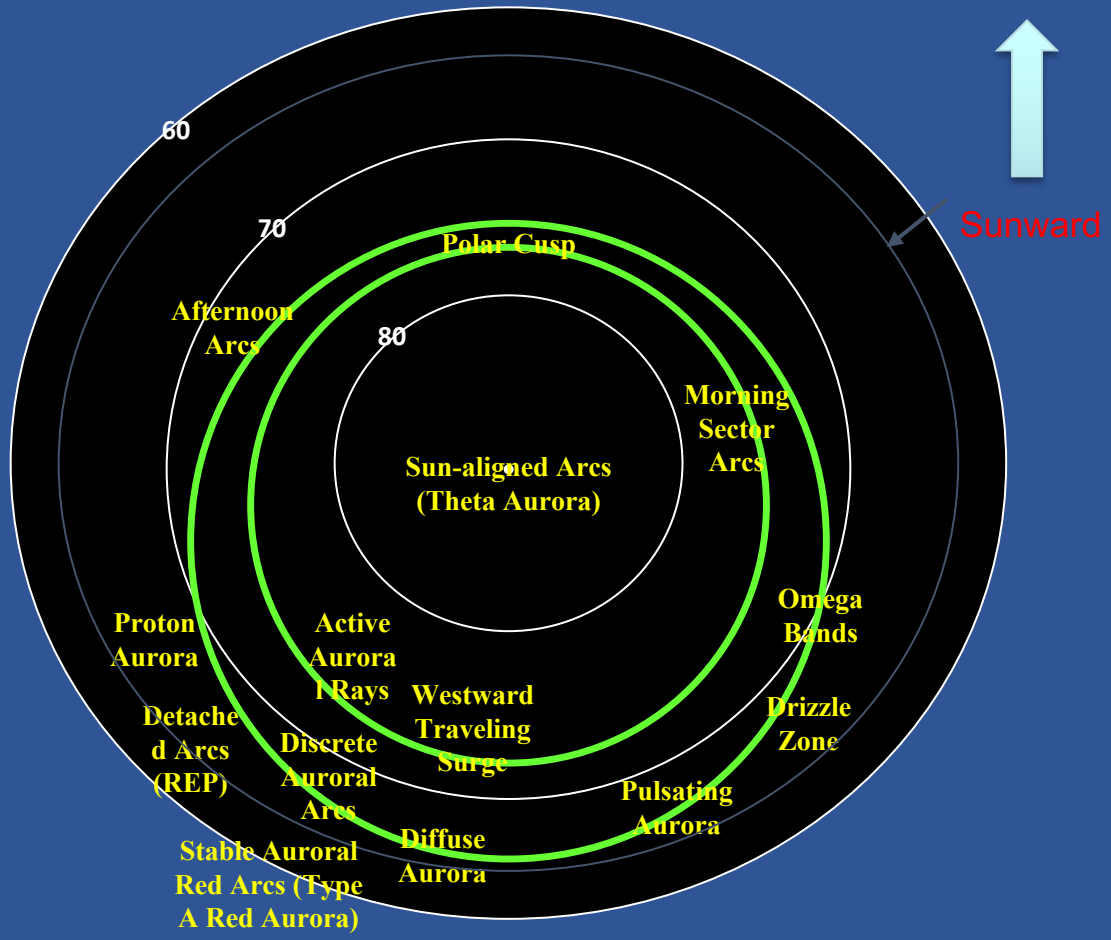


Two-Parameter Specification of Aurorally-Related Properties

- 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 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

A solution based on field-aligned currents

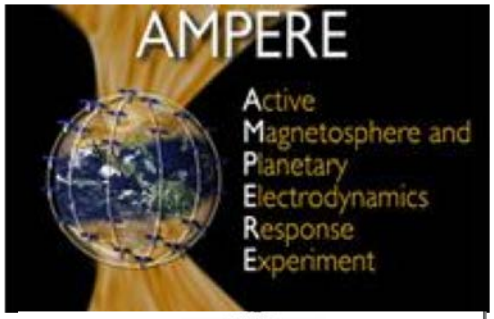
$$\bar{J} = \Sigma_P \bar{E} - \Sigma_H (\bar{E} \times \bar{B})/|B|$$

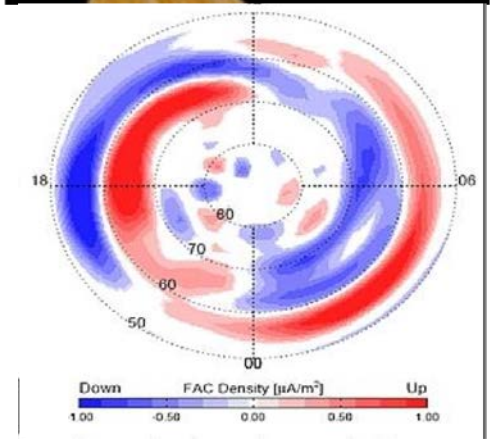
From current continuity:

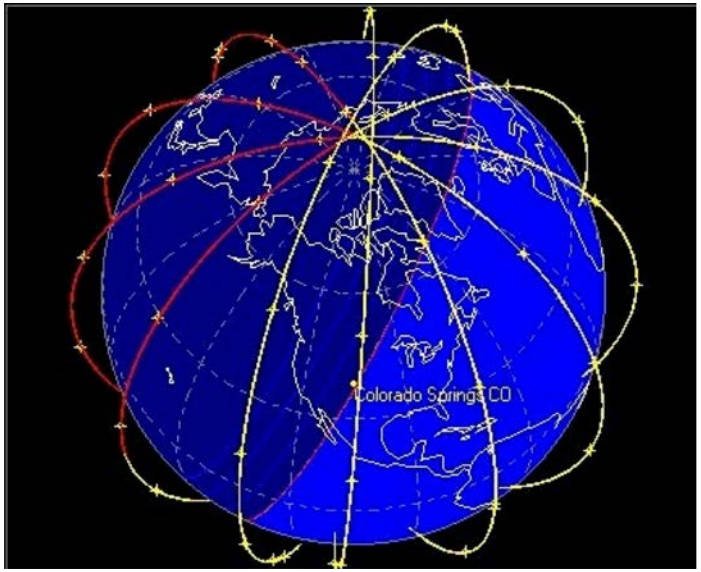
$$\nabla \cdot \bar{J} = 0$$

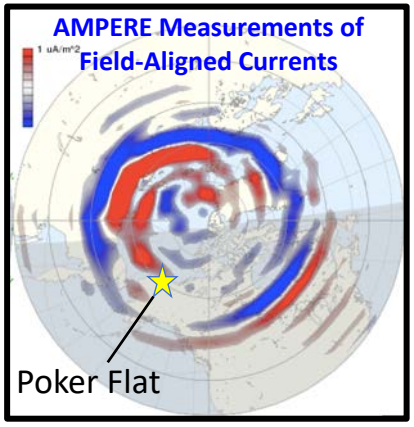
$$J_{\parallel} = \nabla \cdot J_{\perp}$$

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









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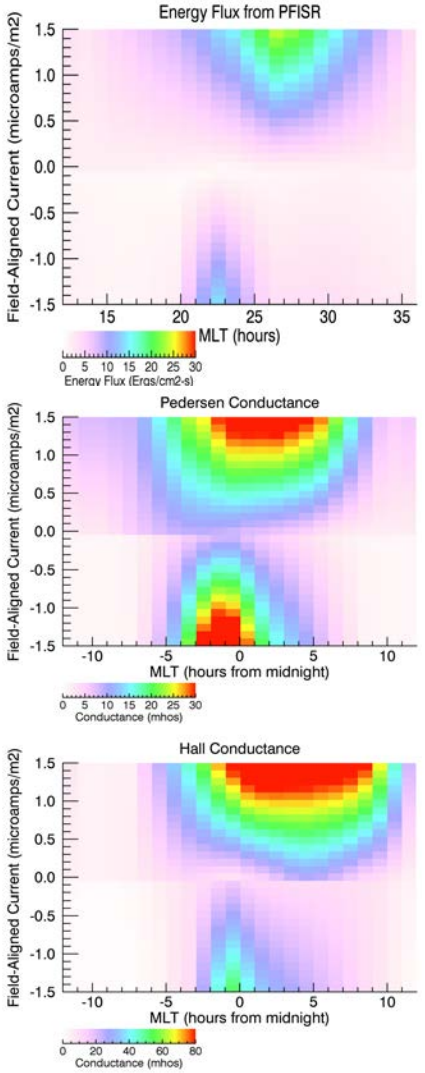
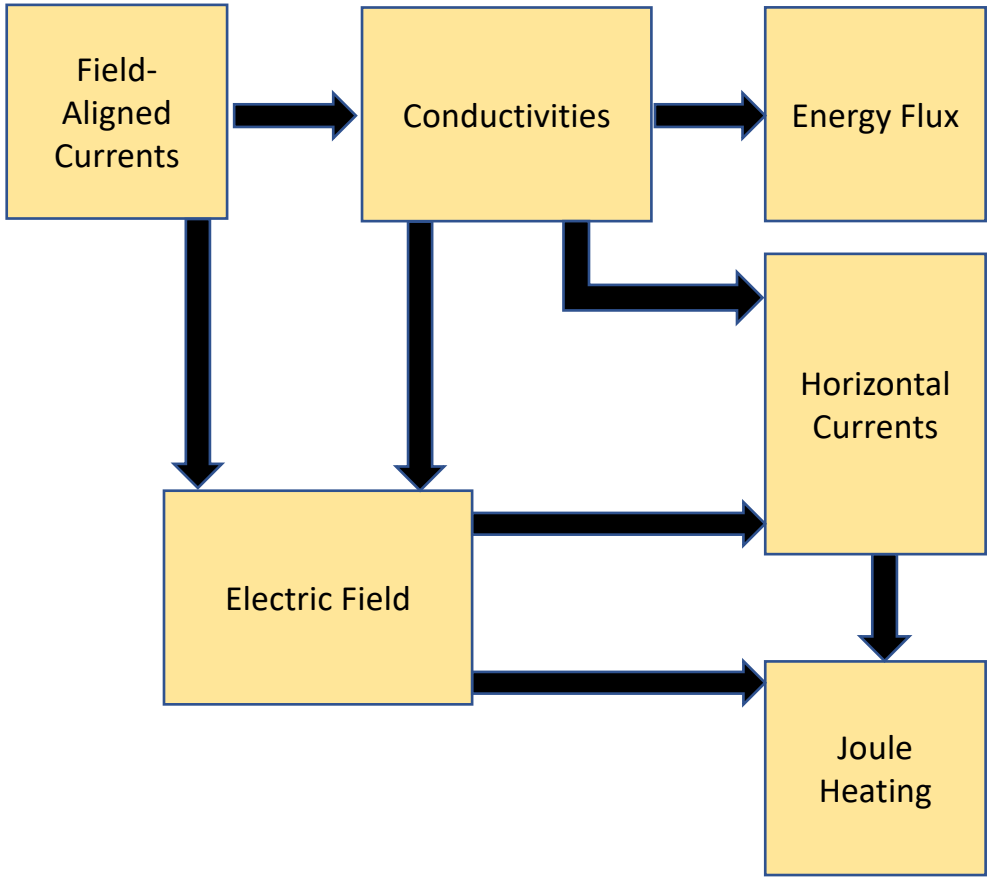
Poker Flat Incoherent Scatter Radar measurements of ionospheric electron densities

By statistically relating AMPERE field-aligned currents to conductivities measured by the Poker Flat Incoherent Scatter Radar , we can self-consistently calculate electric fields, currents, and Joule heating globally every two minutes.

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



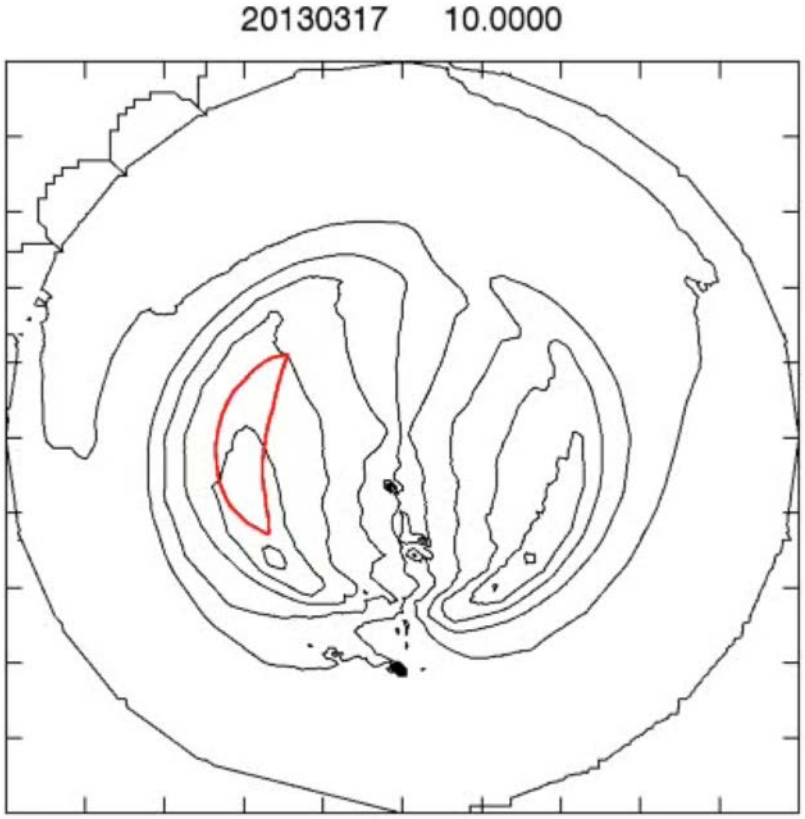
Calculation of Auroral Electrodynamic Parameters

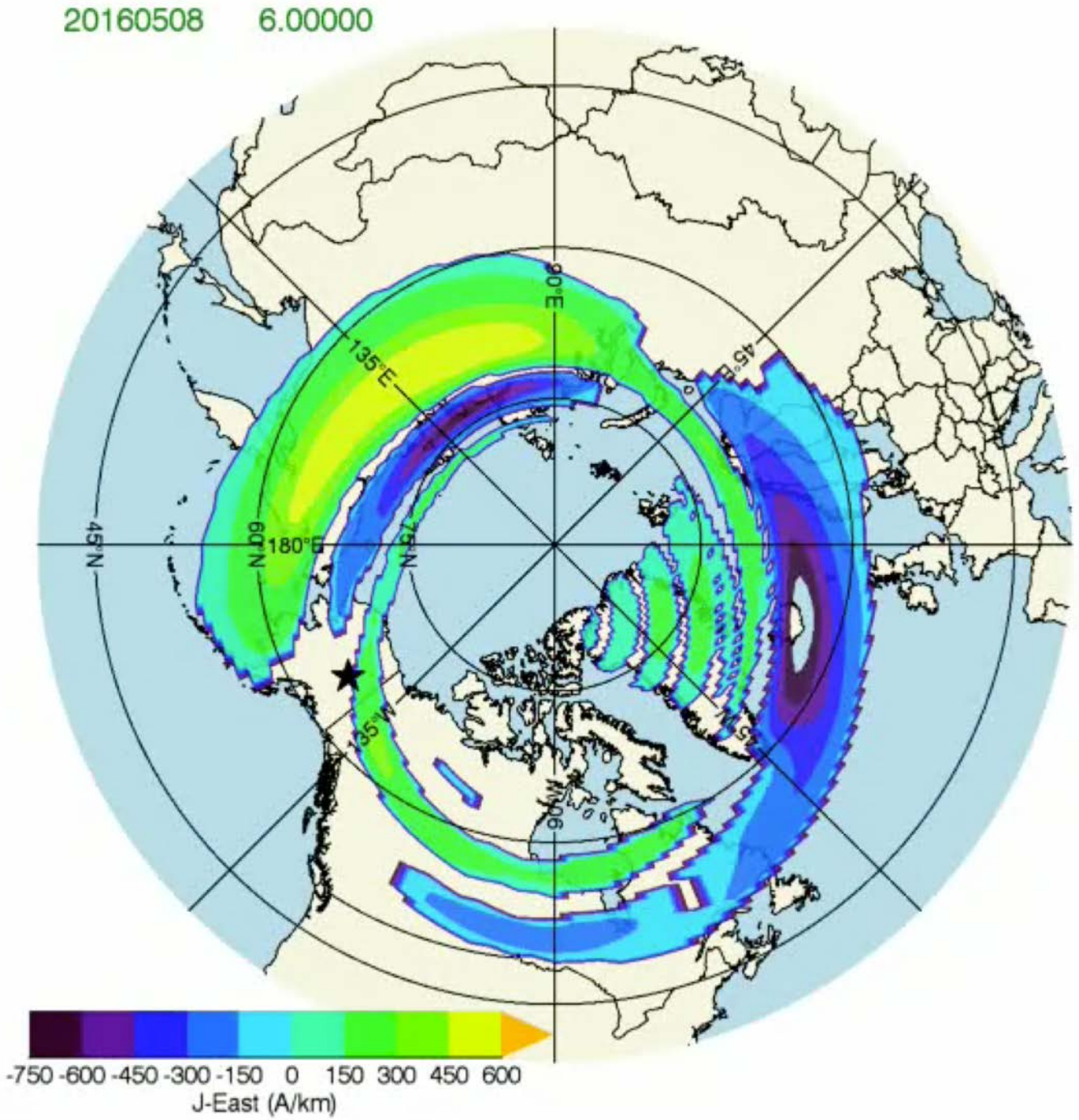


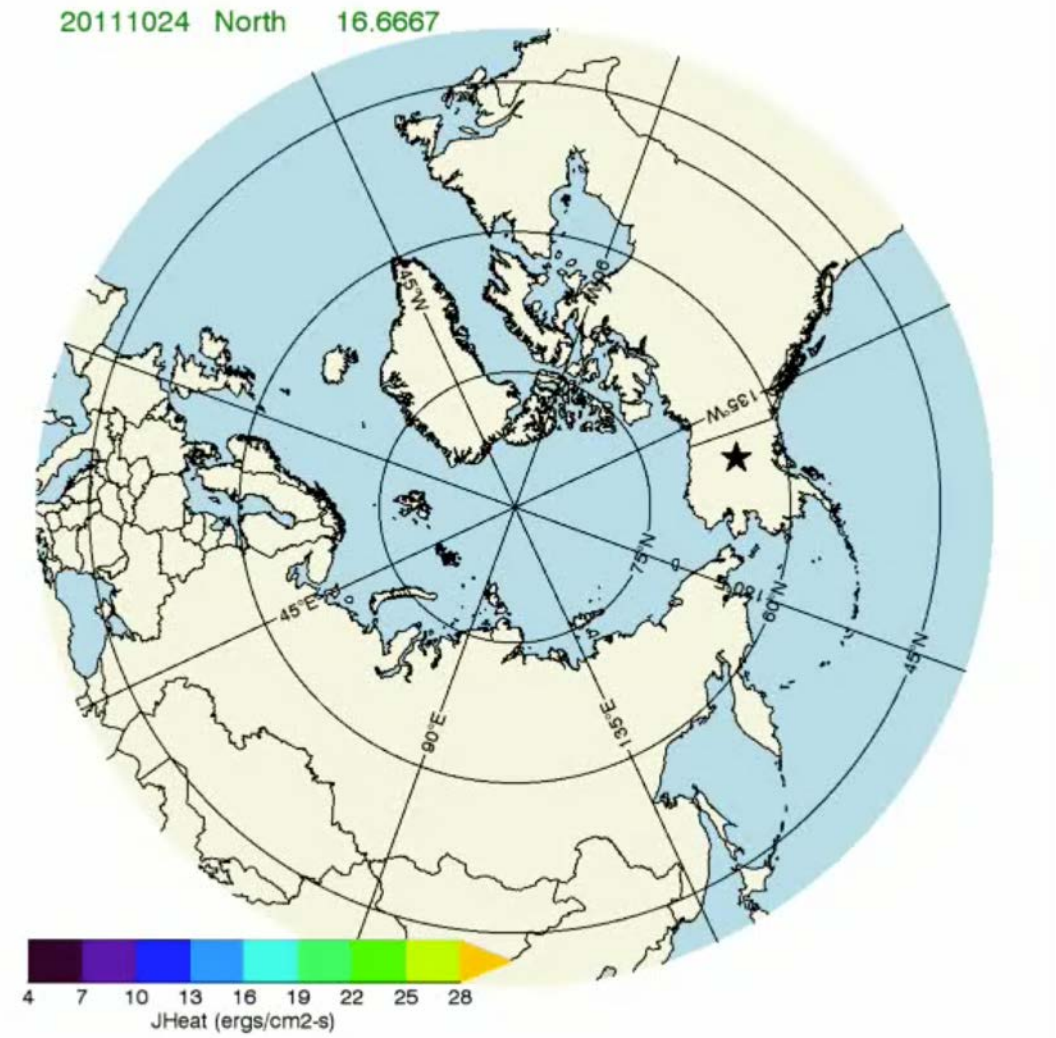
$$J_{\parallel} = \nabla \cdot (\bar{\bar{\Sigma}}\bar{E})$$

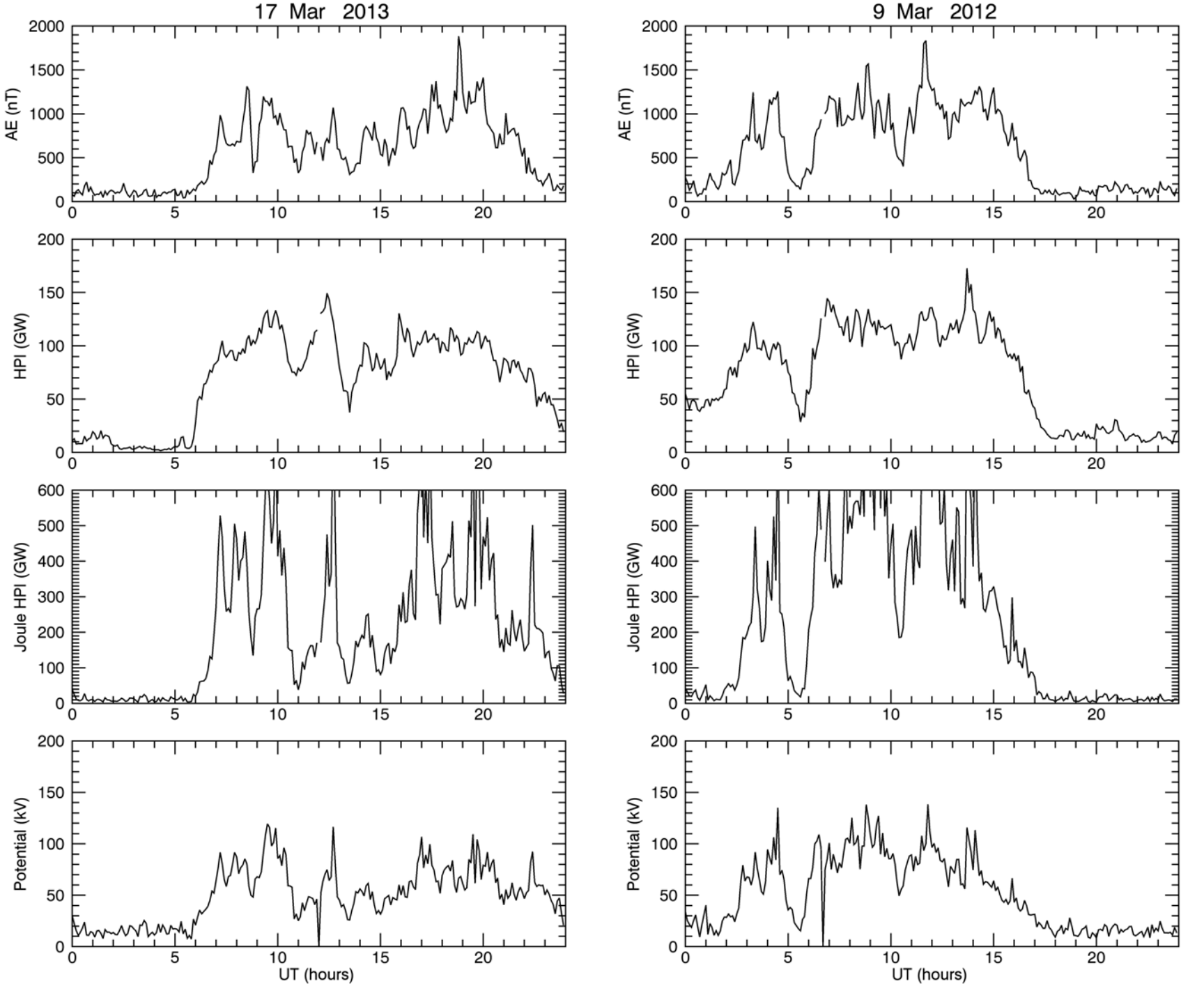
$$\bar{J} = \Sigma_P \bar{E} - \Sigma_H (\bar{E} \times \bar{B})/|B|$$

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


20130317 10.0000


20160508 6.00000
90°E
135°E
45°E
0
45°N
60°N
75°N
180°E
135°W
90°W
-750 -600 -450 -300 -150 0 150 300 450 600
J-East (A/km)


20111024 North 16.6667
45°W
90°W
135°W
45°E
90°E
135°E
180°
75°N
60°N
45°N
4 7 10 13 16 19 22 25 28
JHeat (ergs/cm2-s)


17 Mar 2013
9 Mar 2012
AE (nT)
HPI (GW)
Joule HPI (GW)
Potential (kV)
UT (hours)
UT (hours)

Summary

- Auroral luminosities and electron density profiles provide information about the spectral properties of the precipitating particles.
- Properties of the aurora can be related to properties of the magnetospheric plasma source populations.
- The different types of aurora can be related to magnetospheric plasma domains and the phases of geomagnetic storms.
- Specification of auroral field-aligned currents and conductivities provide the means to calculate electric fields, currents, and Joule (resistive) heating.
- Current observational and modeling capabilities provide the means to calculate electric fields, currents, and energy input from precipitation and Joule heating globally.