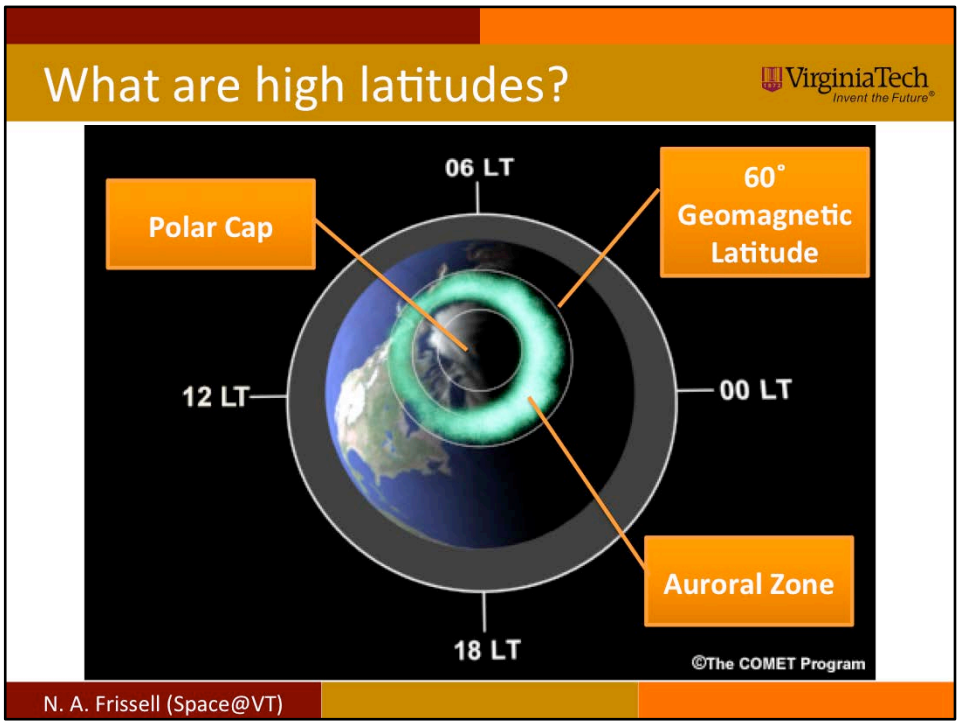
Tutorial on High Latitude Electrodynamics

Nathaniel A. Frissell
Virginia Tech SuperDARN Laboratory

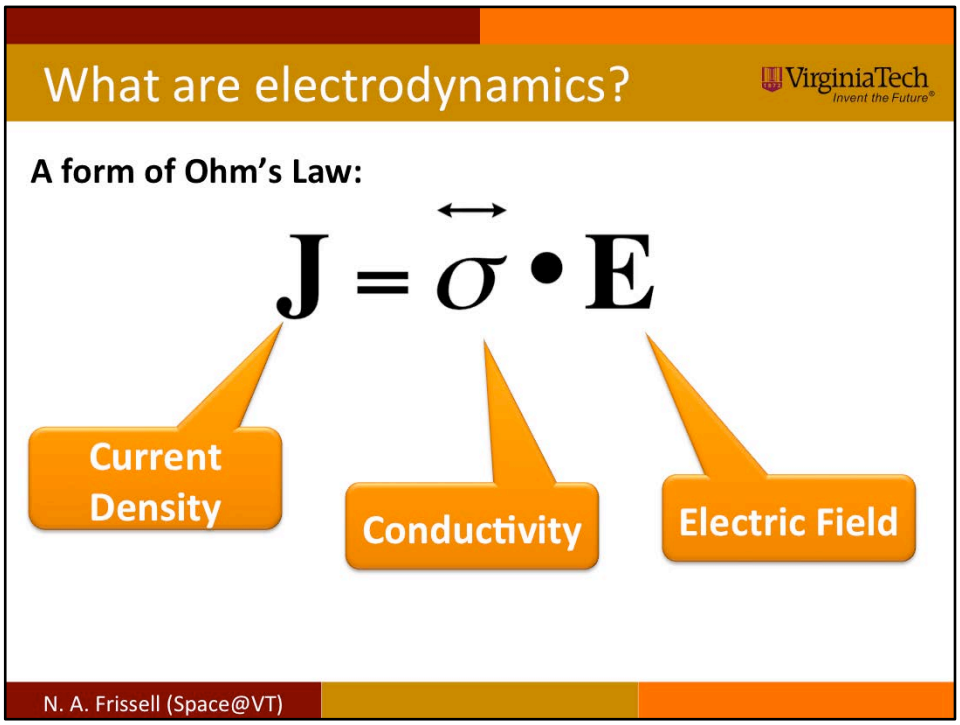
Outline

VirginiaTech
Invent the Future

1. Definition of High Latitude Electrodynamics
2. Generation of High Latitude Electric Fields
3. High Latitude Current Systems
    1. Pedersen Currents
    2. Hall Currents
    3. Field Aligned Currents
4. List of Measurement Techniques

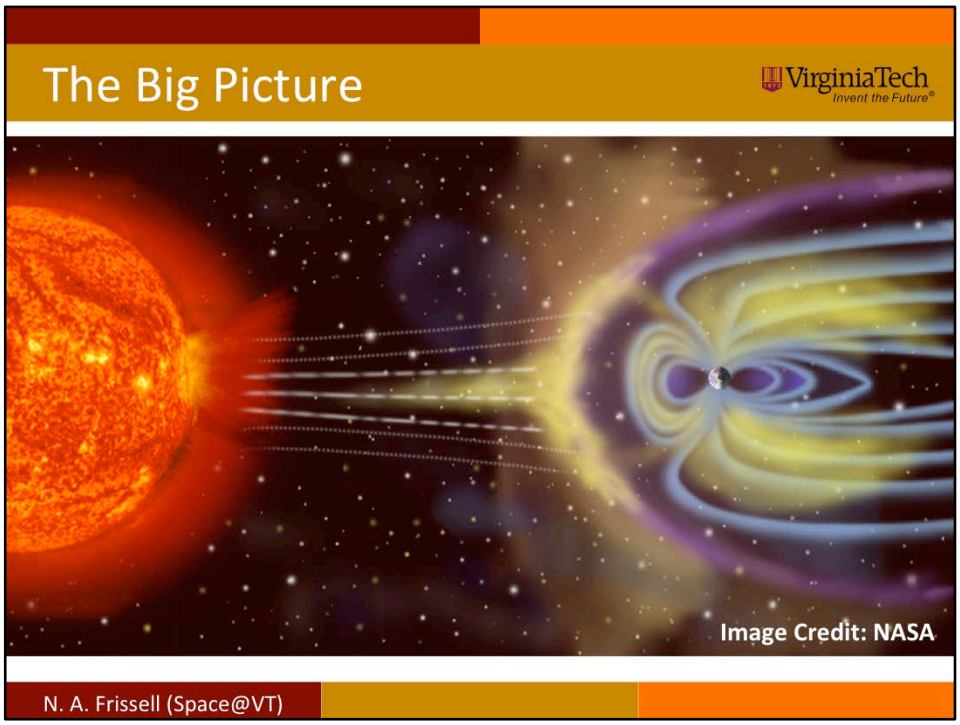


In space physics, we define high latitudes as those regions including and poleward of the auroral zone.
In this talk, we are especially interested in the E region ionosphere (90 – 120 km).



In electrodynamics, we study changing electric fields, currents, and conductivities. Here we look at one form of of Ohm's law.

We are going to look at conductivities and electric fields in the high-latitude ionosphere in order to learn something about the current systems that you can find there.

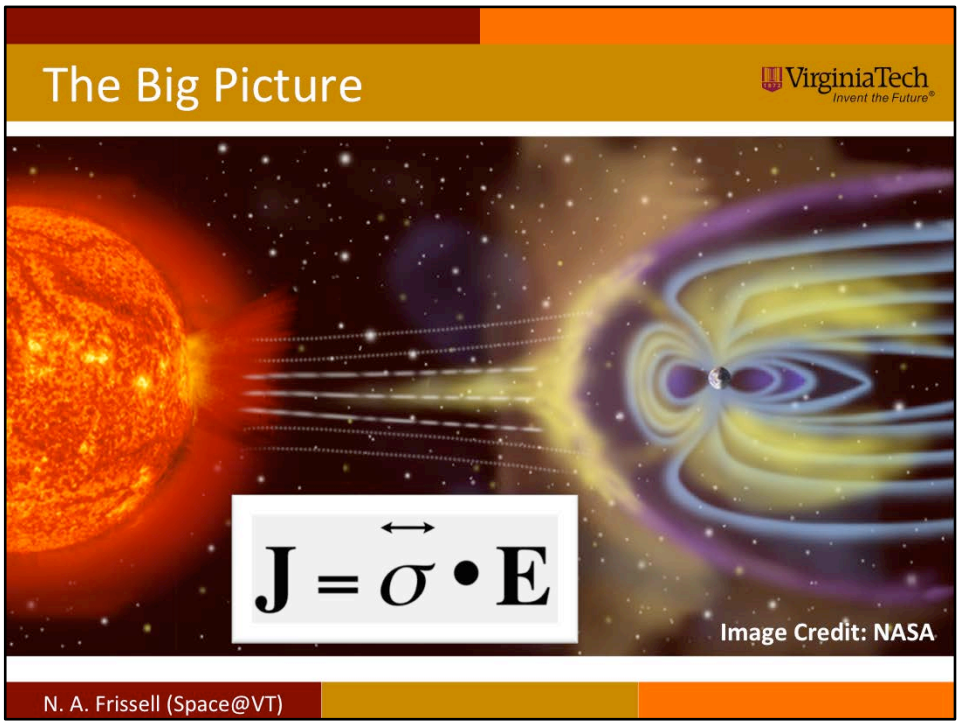


Sun

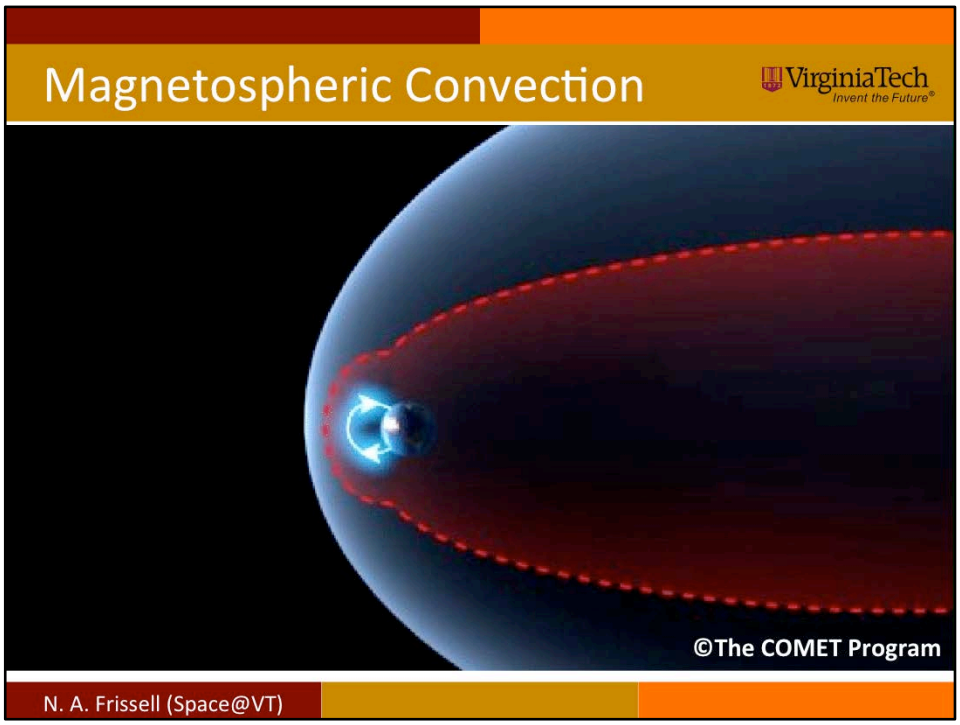
1. UV Radiation
2. SW Electrons and Ions
3. IMF for Energy Coupling

Earth

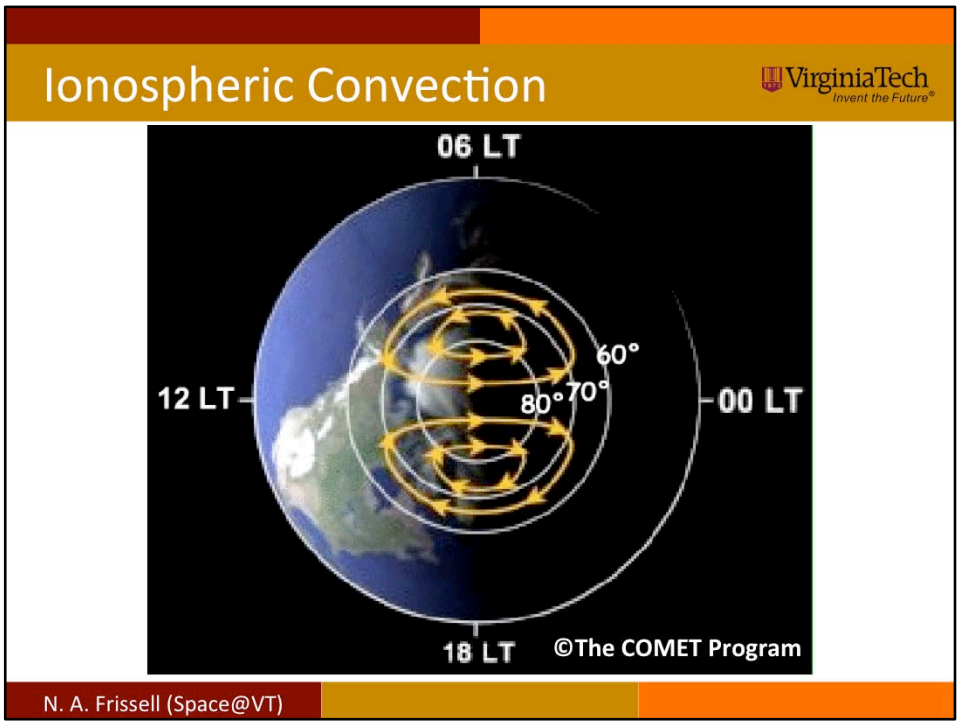
1. Internal Magnetic Field - Magnetosphere
2. Neutral Atmosphere



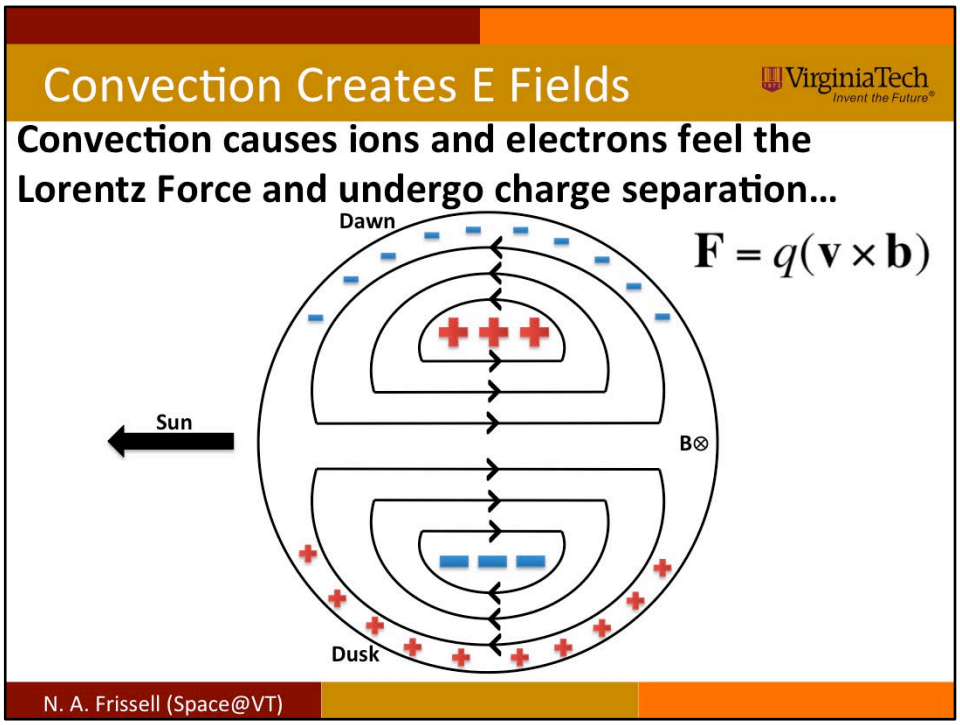
Start by looking at convection… a process that generates E.



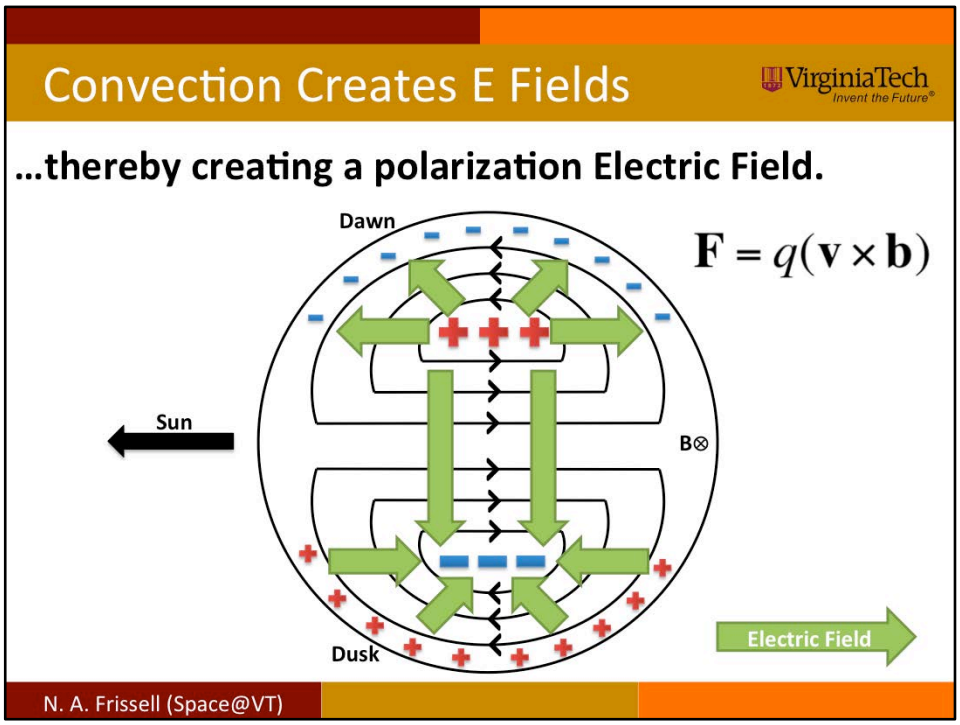
DRIVES Ionospheric Convection



These streamlines represent the motion of the footprints of the magnetospheric convection AND the motion of the plasma. In the ionospheric region, the ions and electrons of the plasma are pulled along by the motion of the field lines.



Vortical convection separates the electrons from the ions, and creates a polarization electric field which points to negative charges.



Vortical convection separates the electrons from the ions, and creates a polarization electric field which points to negative charges.

Ionospheric Conductivities

VirginiaTech Invent the Future

- In the ionosphere, the conductivity is a tensor.

$$\mathbf{J} = \overleftrightarrow{\sigma} \bullet \mathbf{E} \qquad \overleftrightarrow{\sigma} = \begin{bmatrix} \sigma_p & -\sigma_H & 0 \\ \sigma_H & \sigma_p & 0 \\ 0 & 0 & \sigma_{\parallel} \end{bmatrix}$$

- Often, it is much easier to order the currents in terms of magnetic field direction:

$$\mathbf{J} = \sigma_p \mathbf{E}_{\perp} + \sigma_H \mathbf{B} \times \mathbf{E}_{\perp} + \sigma_{\parallel} E_{\parallel} \mathbf{B}$$

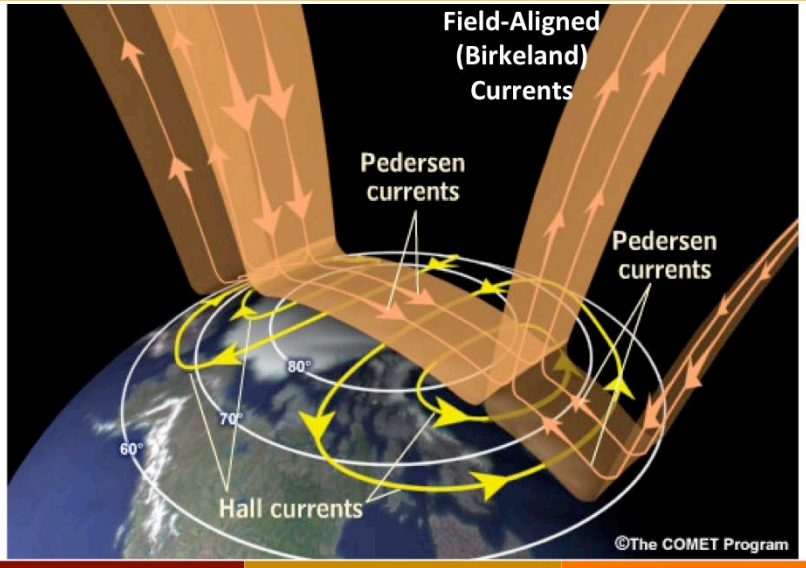
(Pedersen Current) (Hall Current) (Field Aligned/Birkeland Current)

N. A. Frissell (Space@VT)

Conductivity is a tensor… the conductivity does not behave the same in all directions. Contrast to block of copper.
It is easiest to look at the conductivities and currents when they are organized relative to magnetic field direction.

Current Systems

VirginiaTech
Invent the Future®

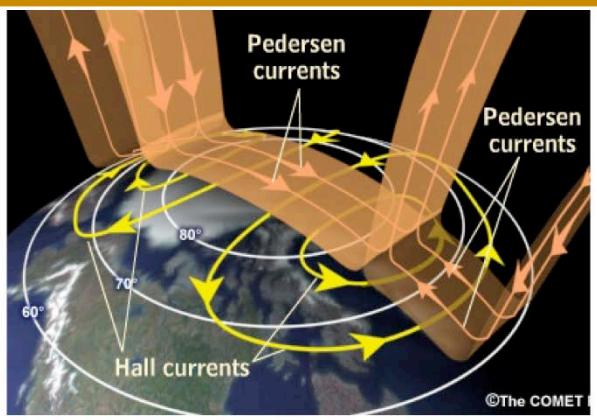


N. A. Frissell (Space@VT)

Pedersen Currents

VirginiaTech
Invent the Future

$$\mathbf{J}_p = \sigma_p \mathbf{E}_\perp$$



- Flows in the direction of the electric field that is perpendicular to the magnetic field.
- Created by the acceleration of ions and electrons after a collision (Feels **F**=*q***E**).

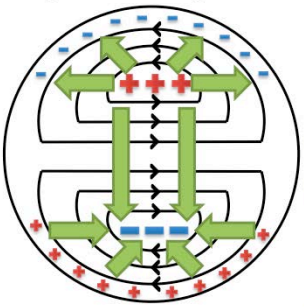
N. A. Frissell (Space@VT)

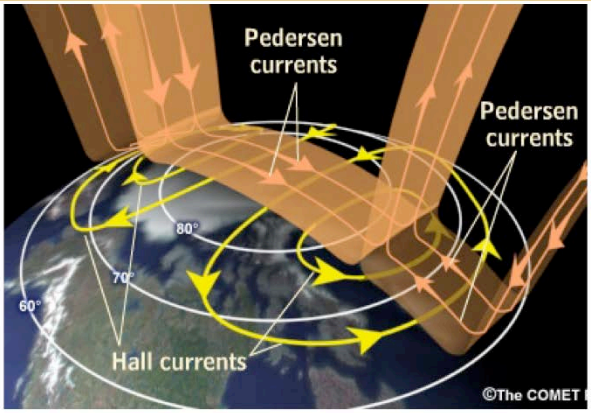
Pedersen currents are strongest near 125 km altitude.

Pedersen Currents

VirginiaTech
Invent the Future

$$\mathbf{J}_p = \sigma_p \mathbf{E}_\perp$$



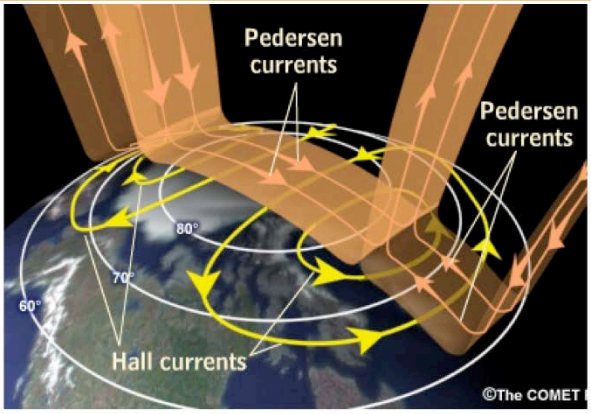


- Flows in the direction of the electric field that is perpendicular to the magnetic field.
- Created by the acceleration of ions and electrons after a collision (Feels **F**=*q***E**).

Hall Currents

VirginiaTech
Invent the Future

$$\mathbf{J}_H = \sigma_H \mathbf{B} \times \mathbf{E}_\perp$$



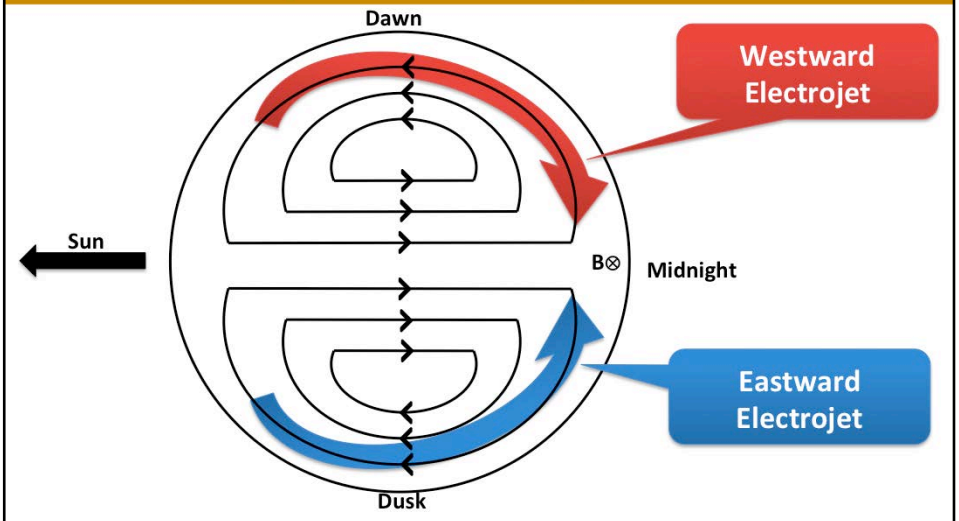
- Flows perpendicular to both electric and magnetic fields in the opposite direction of the plasma flow.
- Created by uneven response to the **E** x **B** drift. (Ions are big, collide with neutrals, therefore go slower than electrons.)

N. A. Frissell (Space@VT)

Hall Currents are strongest near 105 km altitude.

Electrojets (Hall Currents)

VirginiaTech
Invent the Future

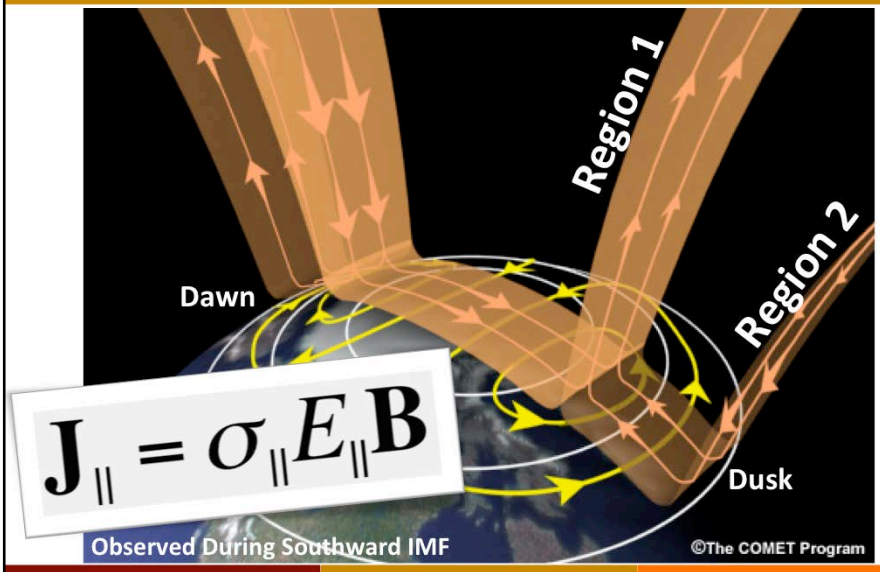


Also, auroral precipitation enhances conductivity and creates the "Auroral Electrojet."

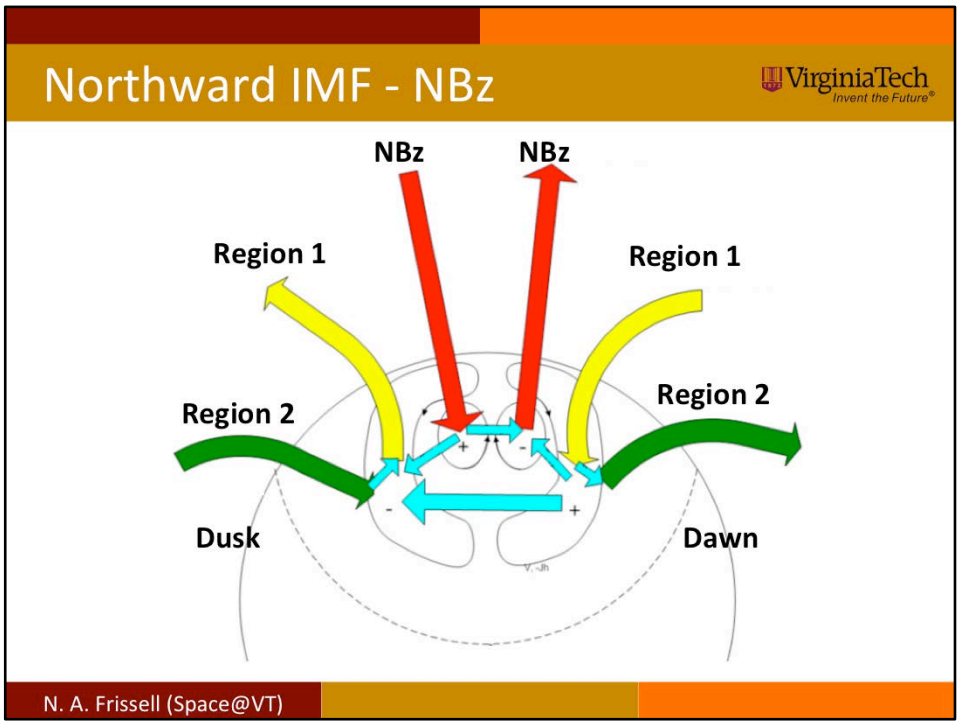
N. A. Frissell (Space@VT)

Field-Aligned Currents

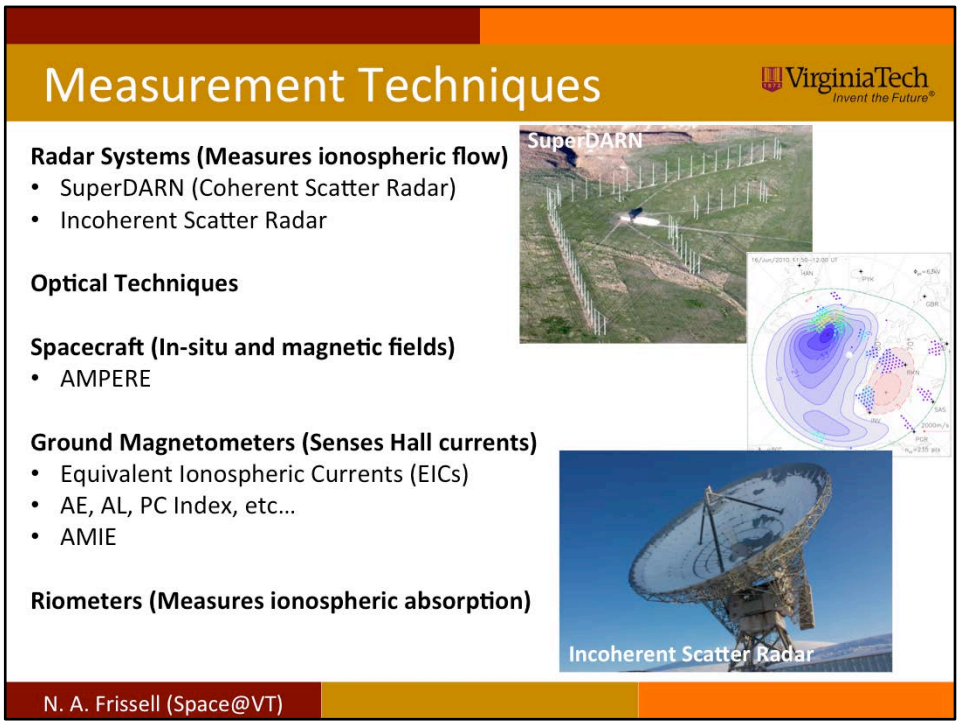
VirginiaTech
Invent the Future®



N. A. Frissell (Space@VT)



Currents flow along field lines. Pedersen currents are strongest near 125 km altitude. Hall Currents are strongest near 105 km altitude.



SuperDARN – Ionospheric Plasma Flow and Electric Potential (Connected with Ionospheric E-Fields and magnetic reconnection).

PC Index - The PC-index has been introduced by *Troshichev et al.* [1979, 1988] as an index for monitoring geomagnetic activity over the polar caps caused by changes in the interplanetary magnetic field (IMF) and solar wind.

AMIE - Assimilative Mapping of Ionospheric Electrodynamics

Acknowledgements

Special thanks to:

- (now Doctors) Betsy Mitchell and Rick Wilder.
- The Kivelson & Russell *Introduction to Space Physics* textbook.
- Oulu online space physics text (https://wiki.oulu.fi/display/SpaceWiki/Oulu+Space+Physics+Textbook)
- The COMET Program (for most images/videos)

The source of this material is the COMET® Website at http://meted.ucar.edu/ of the University Corporation for Atmospheric Research (UCAR), sponsored in part through cooperative agreement(s) with the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce (DOC). *©1997-2011 University Corporation for Atmospheric Research. All Rights Reserved.*

- The Virginia Tech SuperDARN Laboratory

Thank you!
Questions?

Recap of Outline:

1. Definition of High Latitude Electrodynamics
2. Generation of High Latitude Electric Fields
3. High Latitude Current Systems
    1. Pedersen Currents
    2. Hall Currents
    3. Field Aligned Currents
4. List of Measurement Techniques