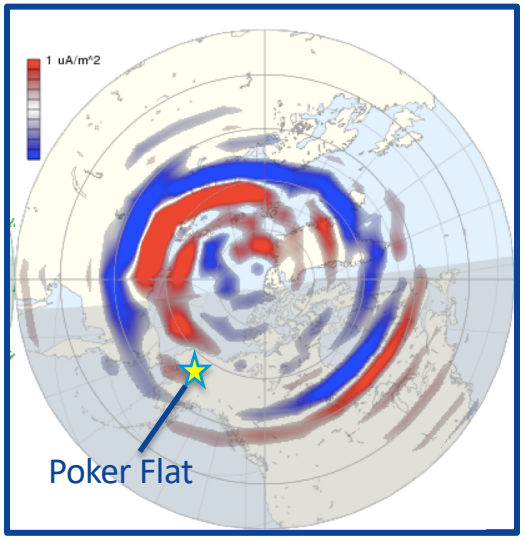
Space Weather?: Impulsive Energy Transfer During Geomagnetic Storms (Session 6: Advances in space weather research and modeling)

Lawrence Zanetti, National Oceanic and Atmospheric Administration (larry.zanetti@noaa.gov)
Robert Robinson, The Catholic University of America
Elsayed Talaat, National Oceanic and Atmospheric Administration

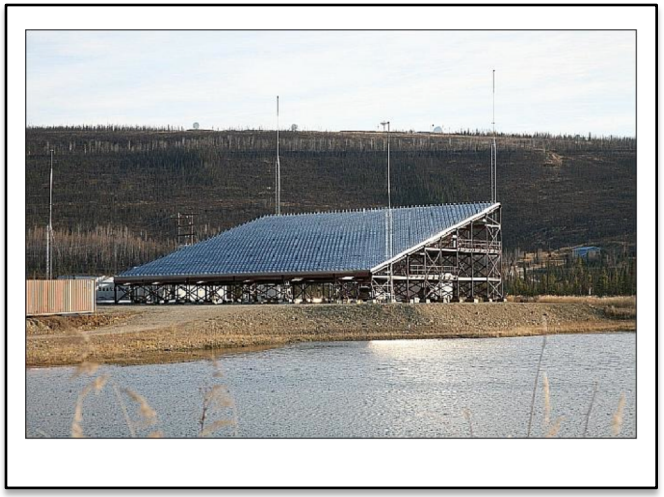
American Meteorological Society 99th Annual Meeting
8 January, 2019

AMPERE Measurements of Field-Aligned Currents



+

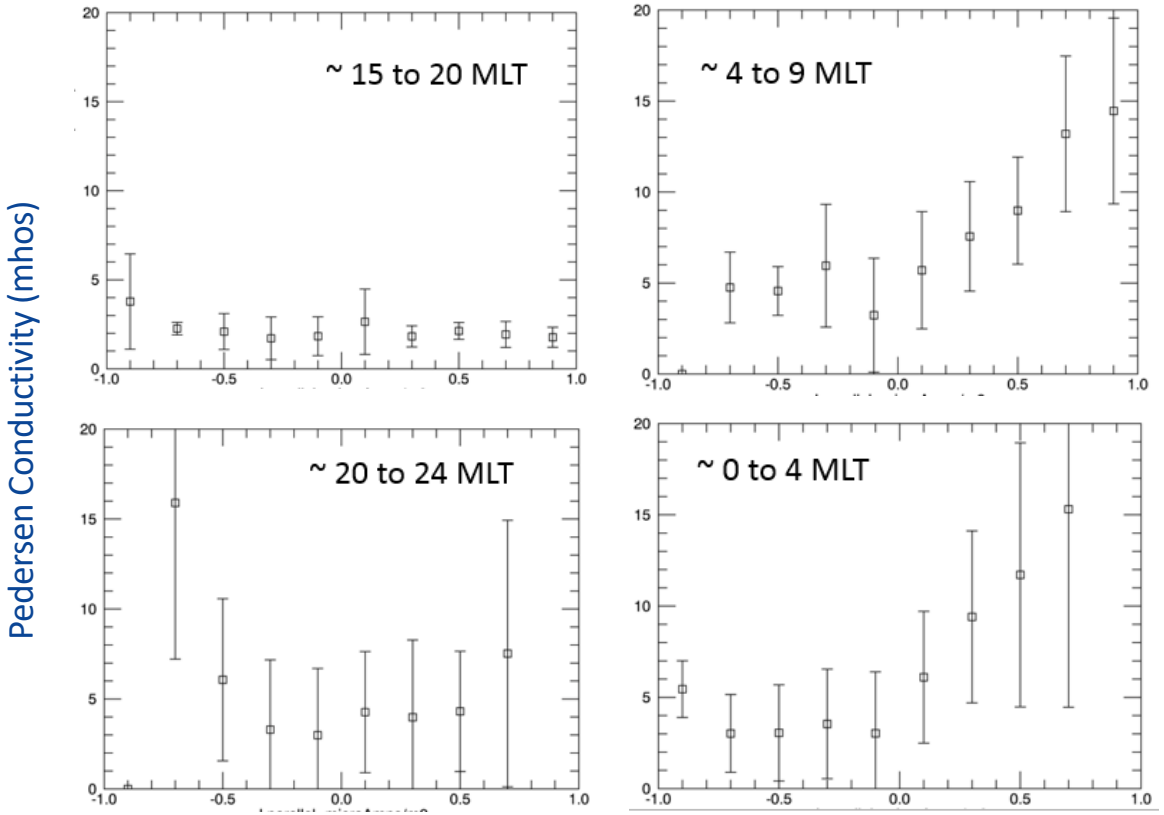
Poker Flat Incoherent Scatter Radar measurements of ionospheric electron densities



Measurements every 10 minutes
18 geomagnetically active days

2592 simultaneous and coincident measurements of height-integrated ionosphere conductivities and field-aligned currents

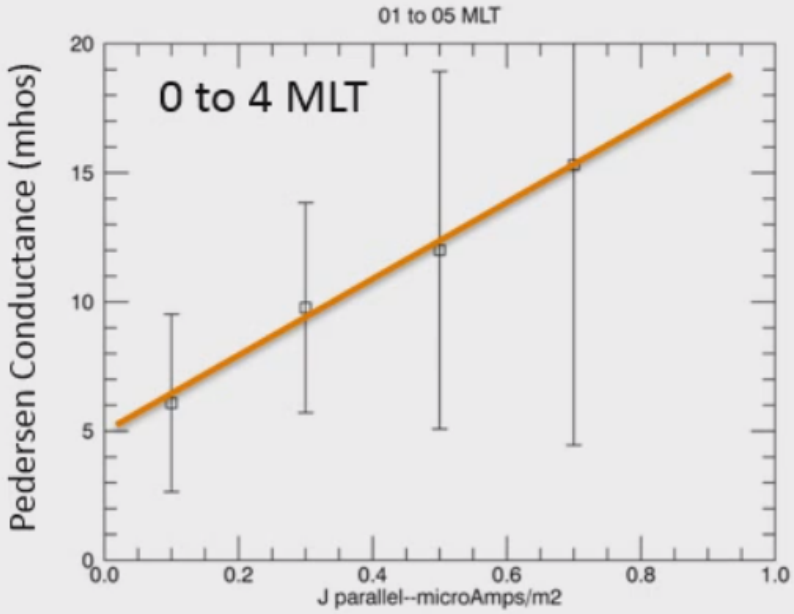
Field-Aligned Currents vs. Pedersen Conductance

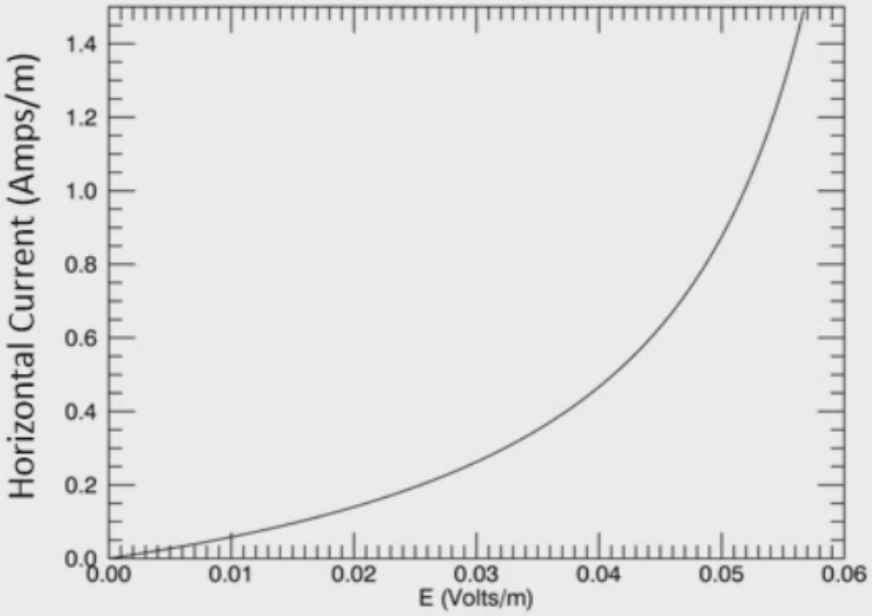


Robinson, et al., to be submitted 2019, draft available

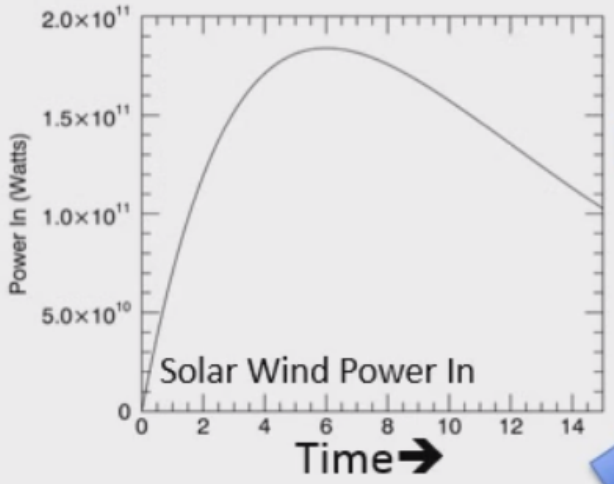
Variation of conductance with field-aligned current causes runaway current conditions

- The ionosphere-magnetosphere current system is a variable resistance circuit.
- Electrical devices in which the resistivity decreases with increasing current are subject to runaway current conditions.
- As the current grows, the resistivity decreases, allowing more current to flow.
- With no mechanism to control the current, the voltage discharges rapidly, and the current drops.
- The current-voltage diagram for this type of circuit has the current becoming infinite at some value of the voltage.





A Simple Model of Magnetosphere-Ionosphere Energy Transfer

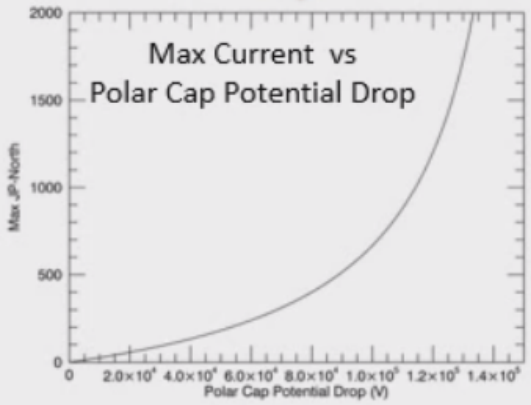


+

-

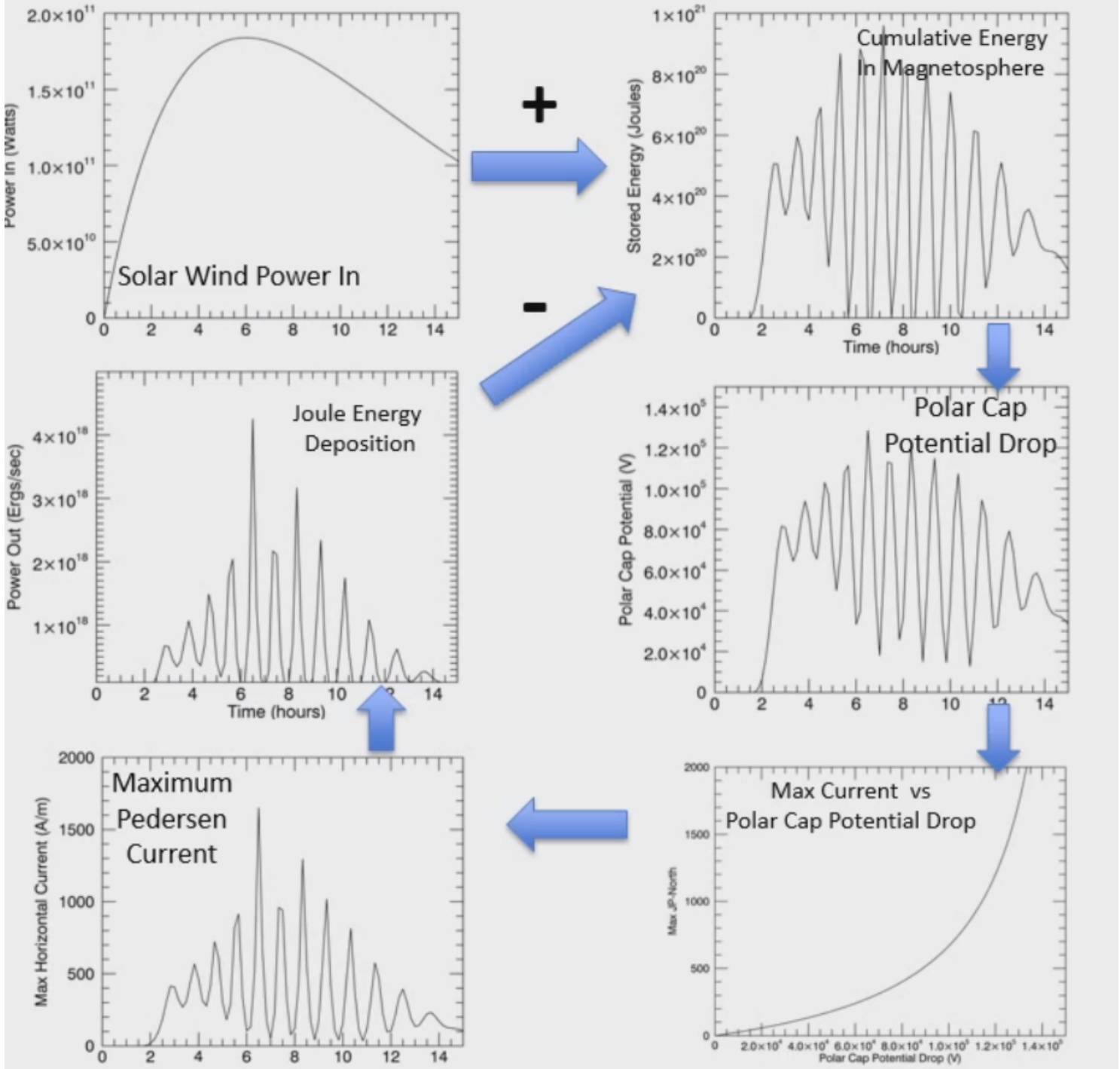
Cumulative Energy In Magnetosphere

Polar Cap Potential Drop

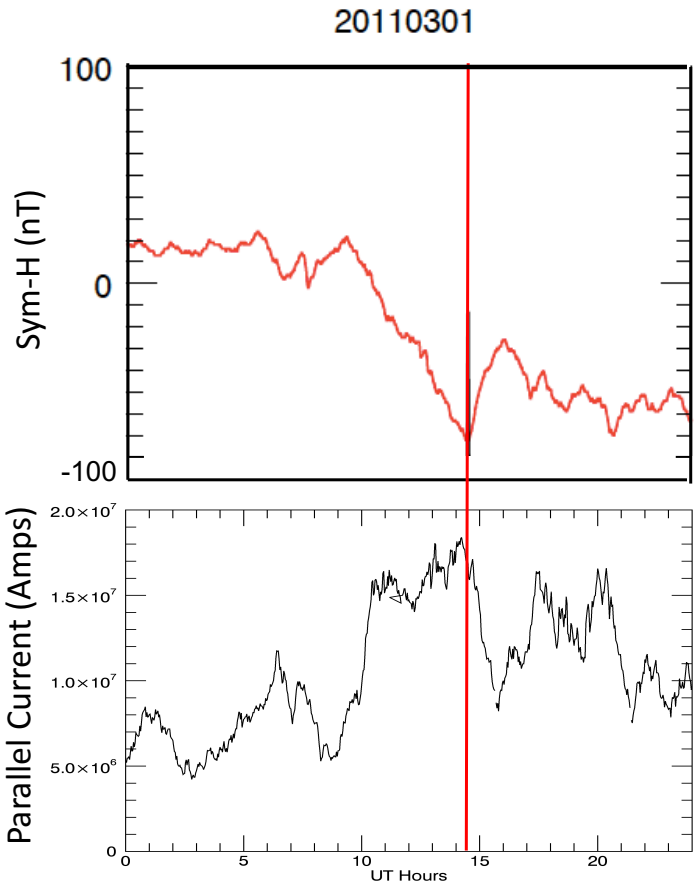


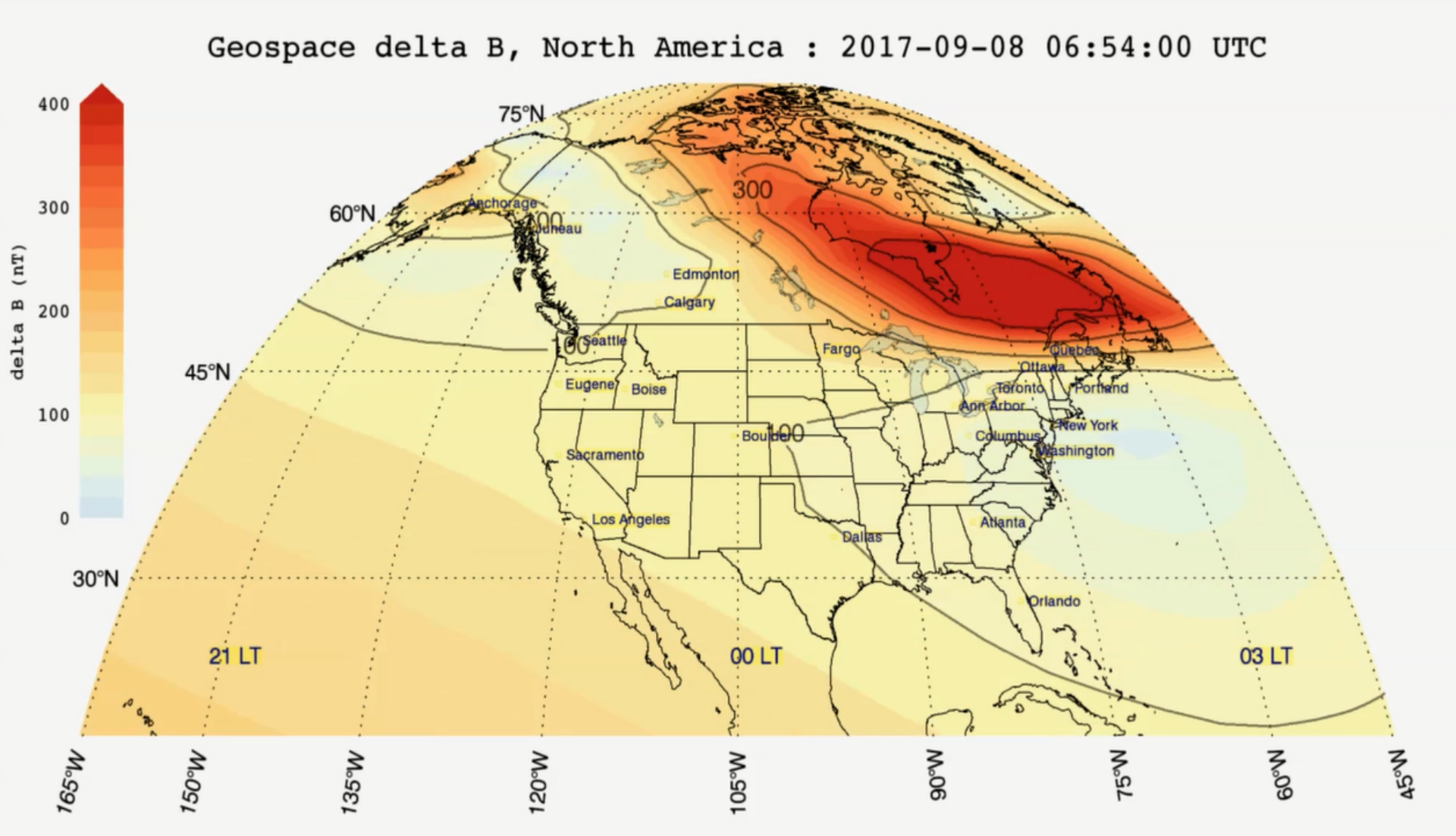
Maximum Pedersen Current

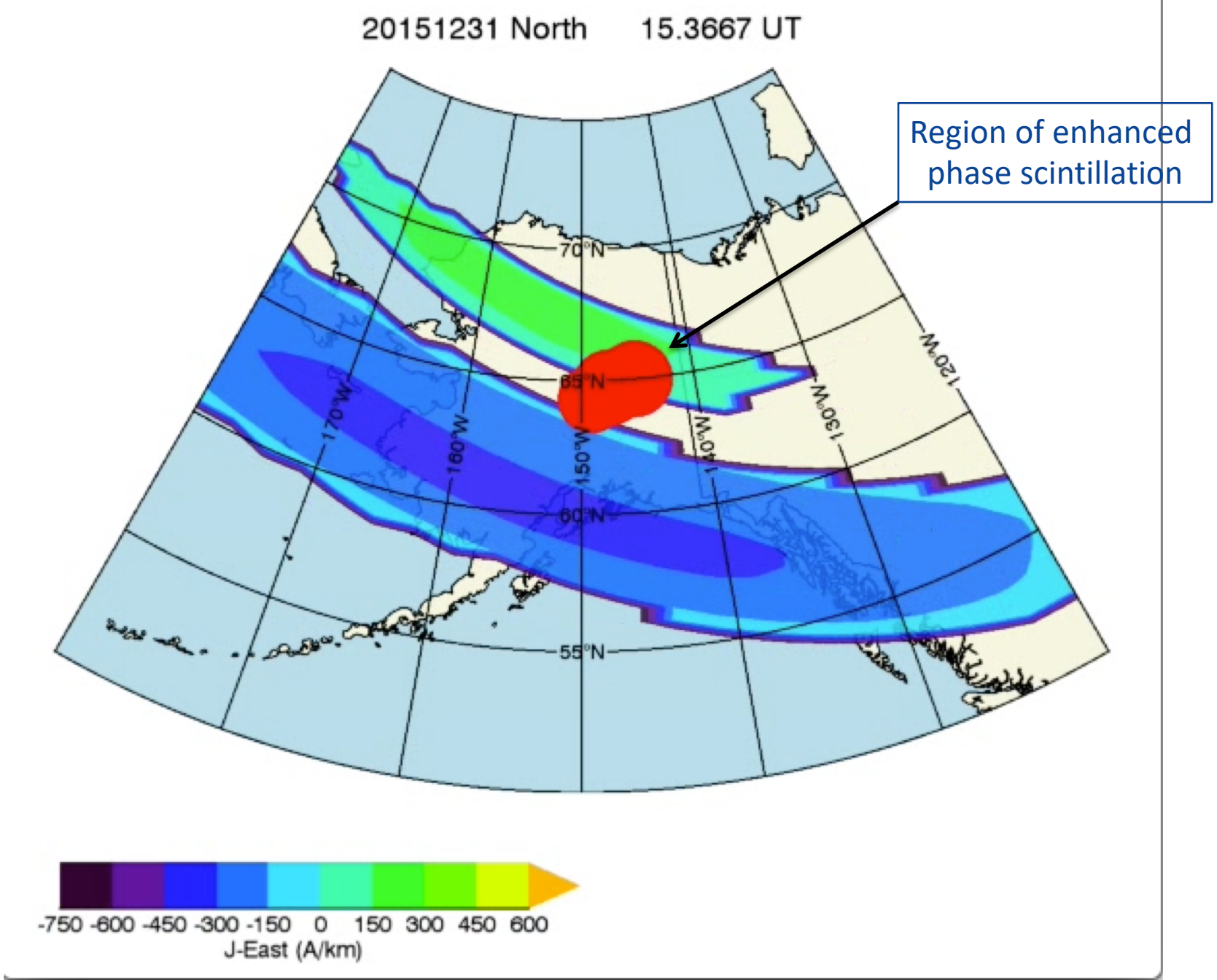
Joule Energy Deposition (Power Out)

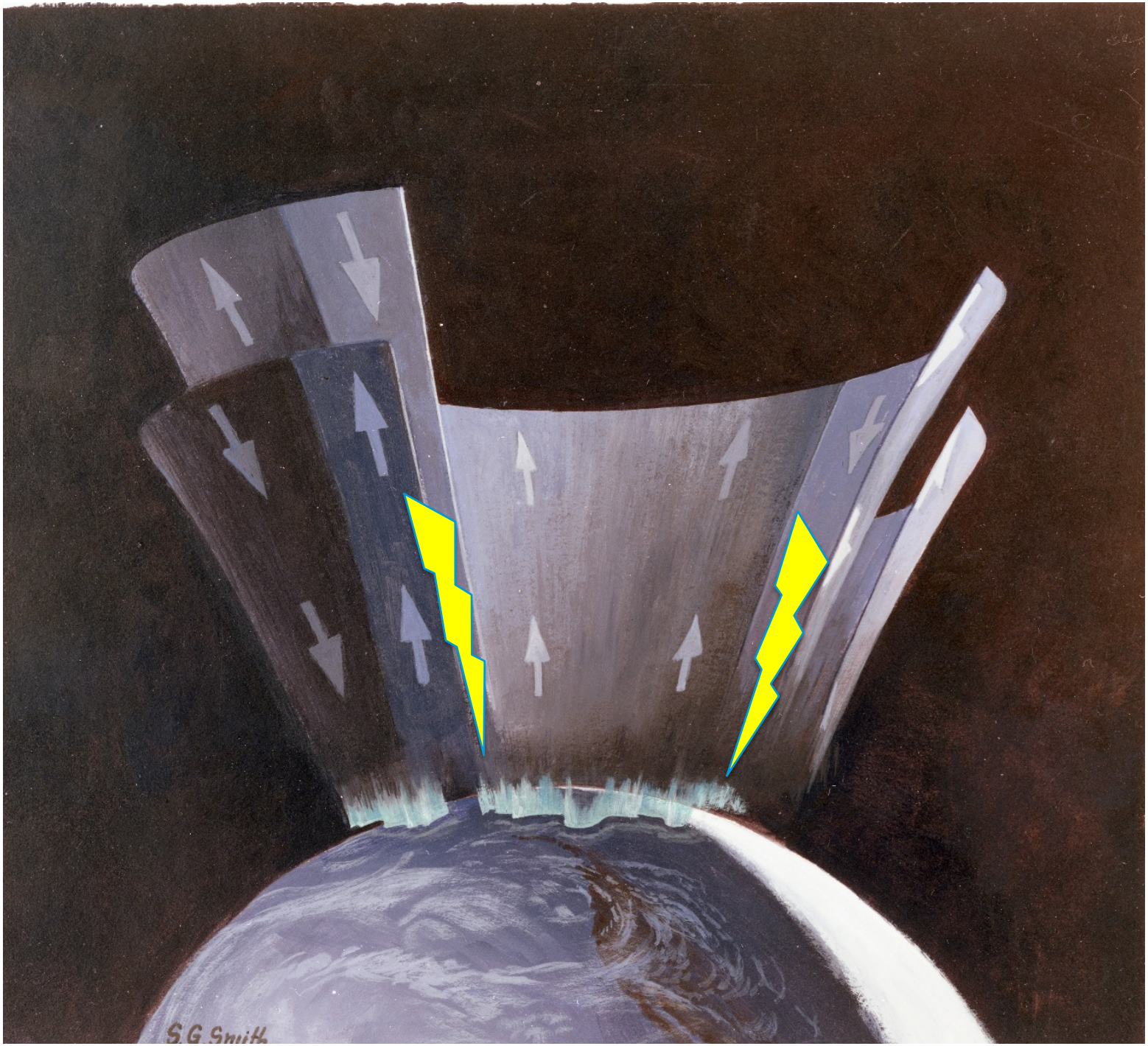

Solar Wind Power In
Power In (Watts)
+
Cumulative Energy
In Magnetosphere
Stored Energy (Joules)
Time (hours)
-
Joule Energy
Deposition
Power Out (Ergs/sec)
Time (hours)
Polar Cap
Potential Drop
Polar Cap Potential (V)
Maximum
Pedersen
Current
Max Horizontal Current (A/m)
Max Current vs
Polar Cap Potential Drop
Polar Cap Potential Drop (V)

Possible interpretation: Impulsive events could <u>cause</u> decrease in ring current energy due to intense discharge of electrical energy from magnetosphere to ionosphere.




Geospace delta B, North America : 2017-09-08 06:54:00 UTC
delta B (nT)
400
300
200
100
0
75°N
60°N
45°N
30°N
300
300
100
100
Anchorage
Juneau
Edmonton
Calgary
Seattle
Eugene
Boise
Fargo
Quebec
Ottawa
Toronto
Portland
Ann Arbor
New York
Columbus
Washington
Boulder
Sacramento
Los Angeles
Dallas
Atlanta
Orlando
21 LT
00 LT
03 LT
165°W
150°W
135°W
120°W
105°W
90°W
75°W
60°W
45°W
Space Weather Prediction Center
University of Michigan Geospace Model (SWMF)
File : 20170908T0451_20170908T065400


20151231 North 15.3667 UT
Region of enhanced phase scintillation
70°N
65°N
60°N
55°N
170°W
160°W
150°W
140°W
130°W
120°W
-750 -600 -450 -300 -150 0 150 300 450 600
J-East (A/km)


S.G. Smith

Thoughts

- Localized dipolarizations (substorms) occur throughout the magnetosphere during disturbed times
- It's not clear how the global forcing provided by the solar wind can lead to localized disturbances in the magnetosphere
- Localized disturbances may be controlled by the ionosphere due to the increased conductivity associated with increasing current (lightning effect)
- Space Weather?: Large ground dB/dt due to small scale and rapid timescale?

Summary

- High latitude ionospheric conductance model based on AMPERE field-aligned currents
- During geomagnetic storms, energy transfer from the magnetosphere to the ionosphere occurs via localized and impulsive Joule heating events lasting 1 to 4 hours
- In this model, the impulsive transfer of energy happens because of the enhancement of ionospheric conductivity with increasing upward field-aligned current (sort of – short circuit)
- Similar to lightning in that runaway current produces a rapid transfer of electrical energy from one part of the circuit to another