Space Weather

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Objective of the Presentation:

Enhance awareness of space weather and why you should care

Definition of Space Weather:

The conditions on the sun, in space, and in our upper atmosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.

Weather on Earth

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What's this Space Weather Thing?

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Weather on Earth

- Precipitation
- Light Displays
- Power of Nature
- Societal Danger

Weather in Space?

Weather in Space?

- Precipitation
- Light Displays
- Power of Nature
- Societal Danger

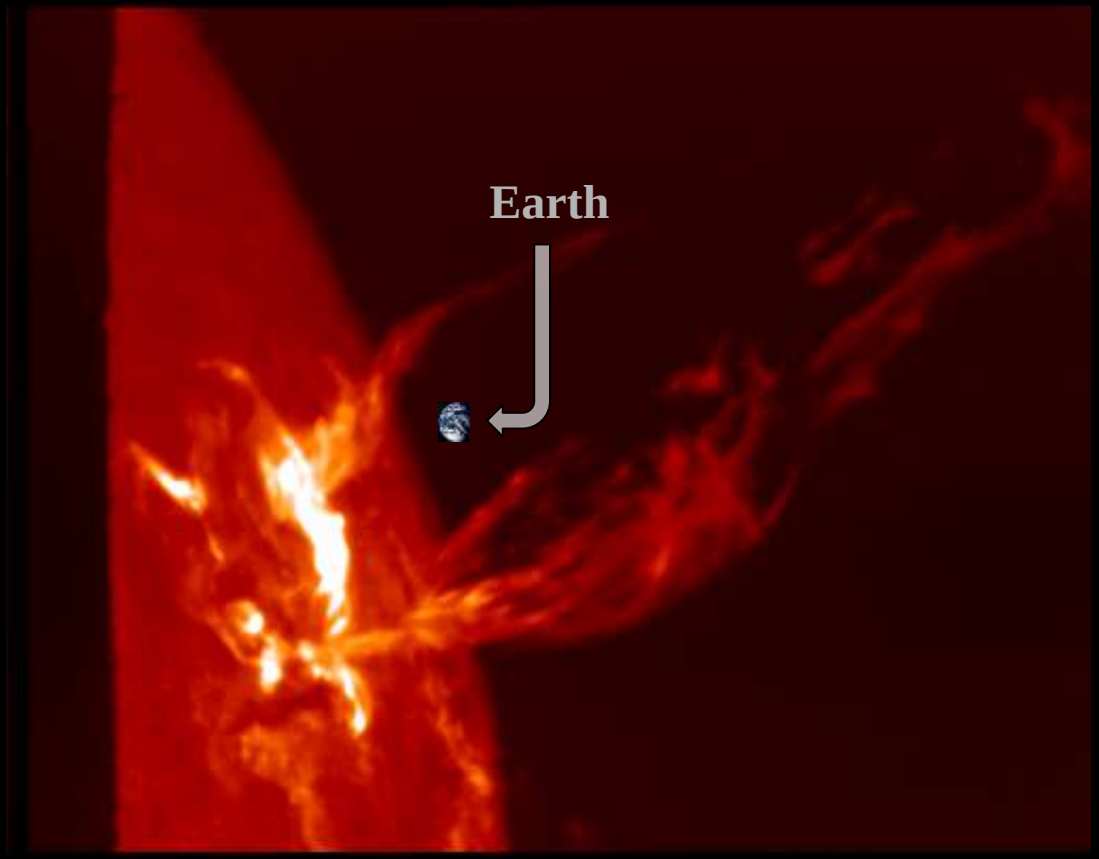
Shock and Awe?

Start at the Sun

Flare or Coronal Mass Ejection:

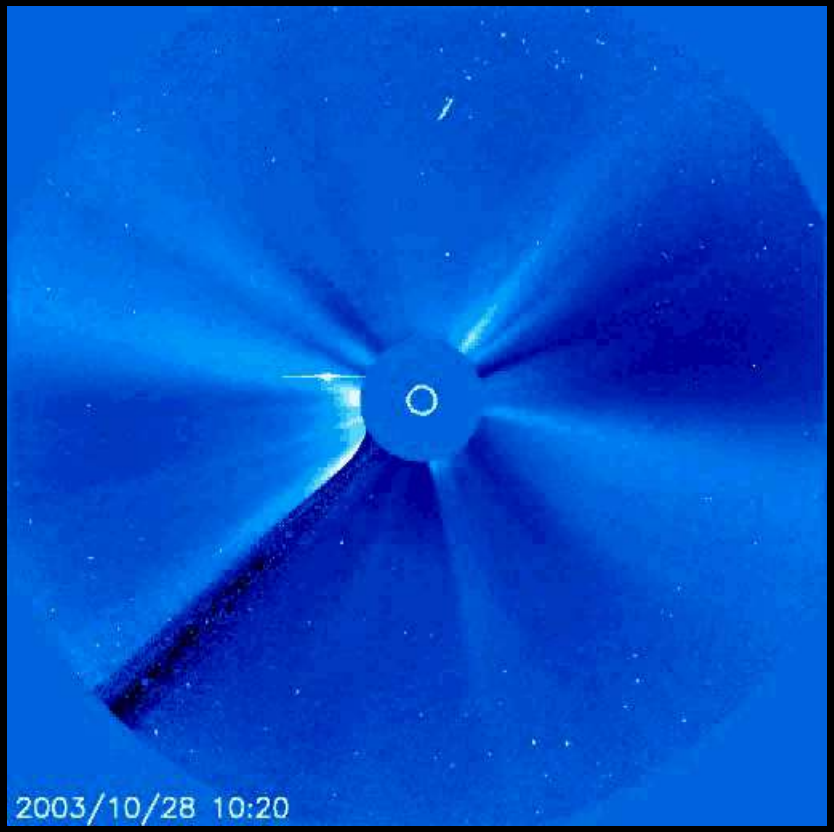
Violent release of as much a billion tons of matter.

Can be equivalent of 40 billion Hiroshima-sized atomic bombs.

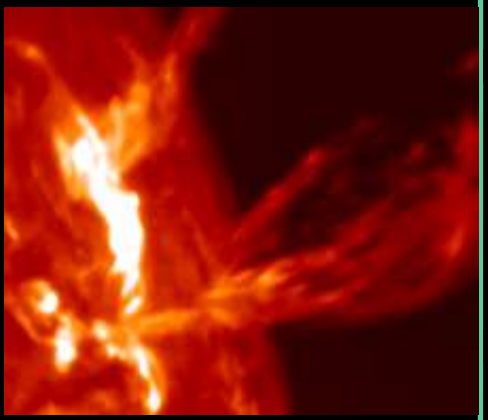


Weather at the Sun or Elsewhere Means There are Events

- What do you see?
- Near the Sun?
- Far from the Sun?



Time Scale for Solar Effects at Earth



~10 min

8 Minutes

Mins to hours

X-RAYS

Unimpeded

Radio Waves

10s Mins

Mins to a Day

Impeded

High Energy Particles

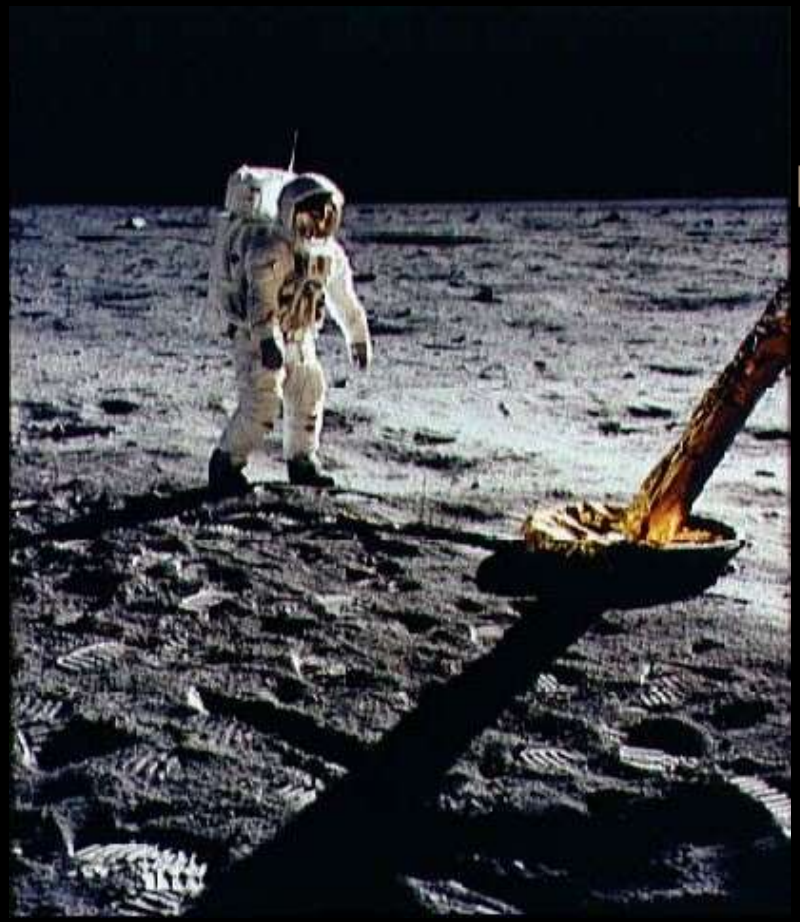
Few Days

Indirect

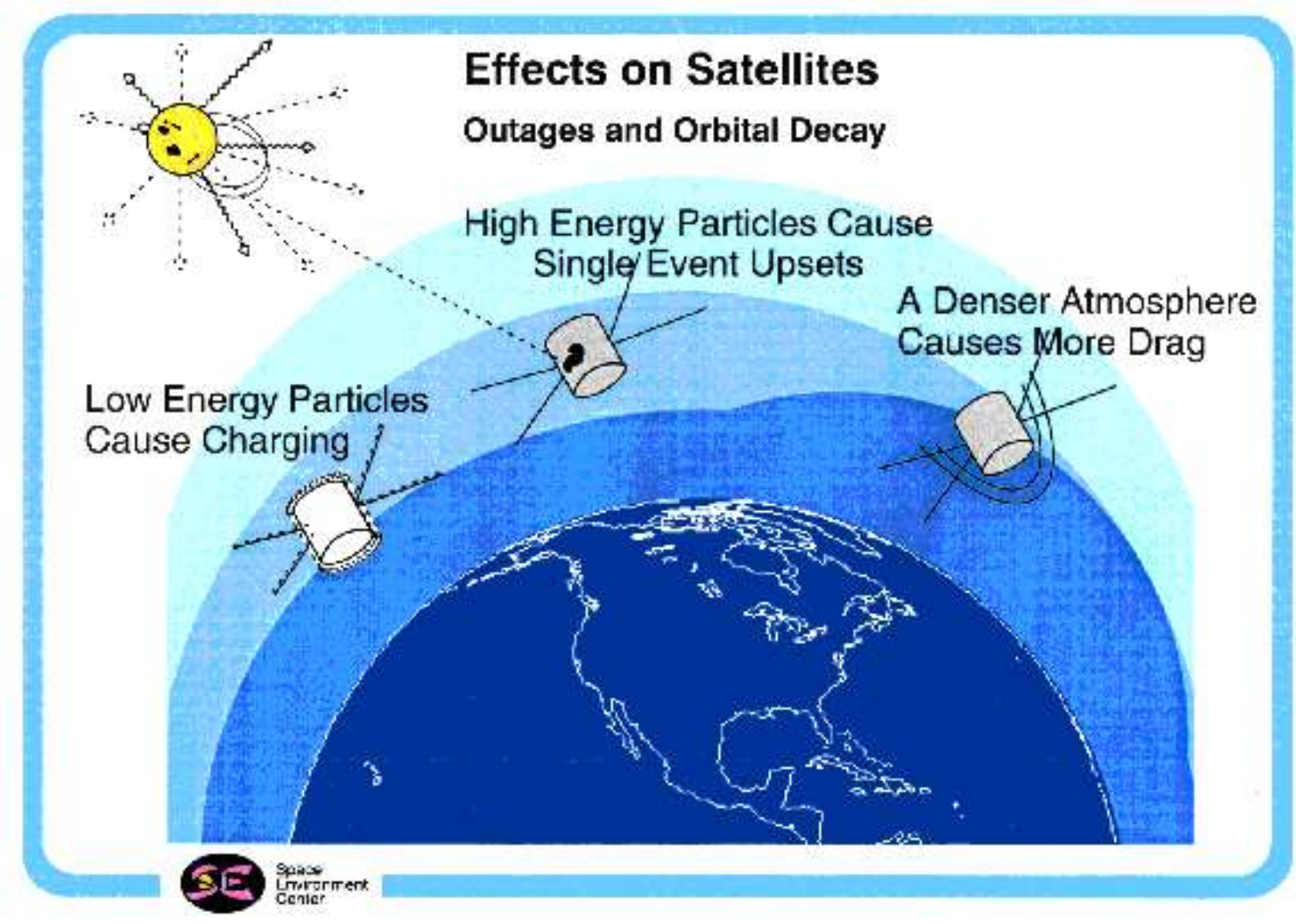
Days

Solar Wind Blast

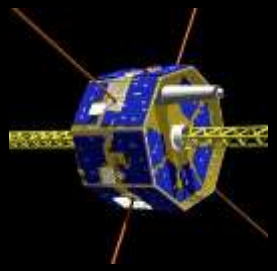
Hazards to Humans in Space



Satellite Hazards



Risks for Electronics



- In space single event upsets (SEUs) cause satellite control errors, risking damage or loss
- In aircraft SEUs cause upsets of about 1 per 200 hours of operation measured on a Boeing 777 autopilot: (designed for 1:1 million); pacemakers have been used to measure SEUs in commercial aircraft

- On the ground SEUs are thought to have caused power loses in German high-speed trains in the 1990's from cosmic radiation.

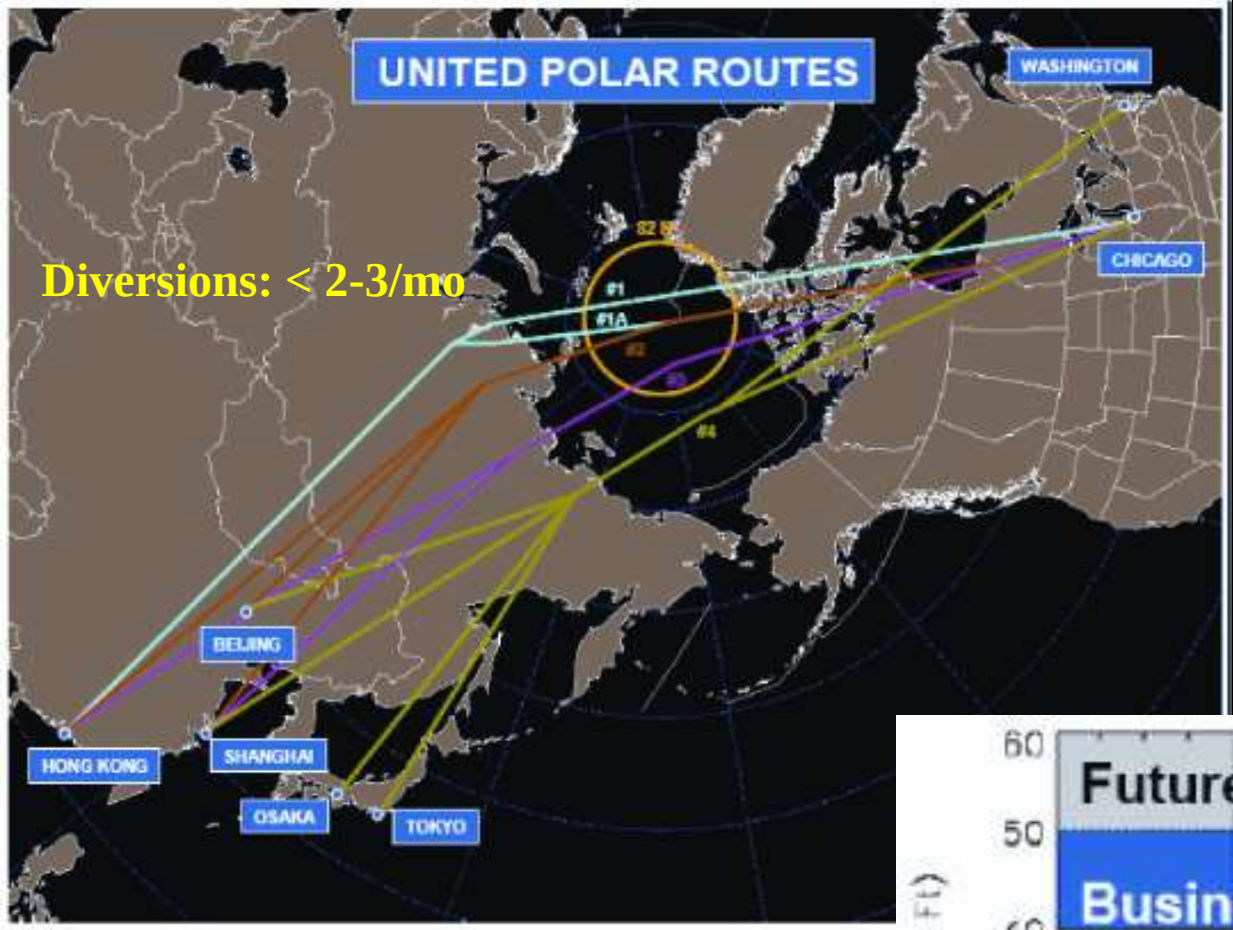
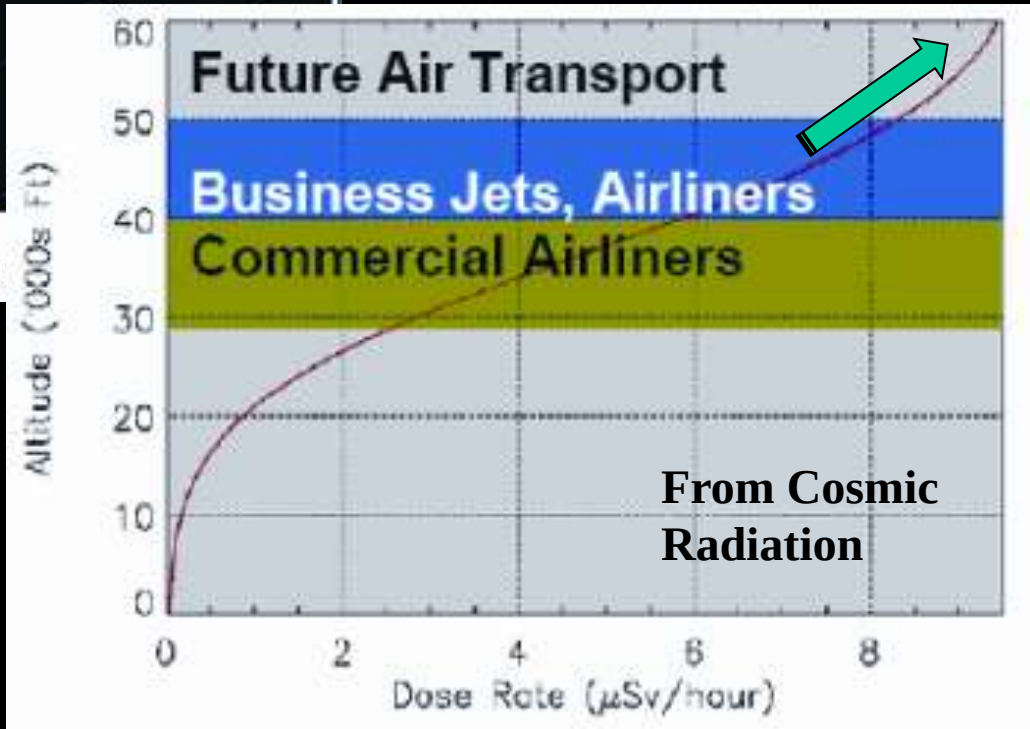


Figure 1. Polar Routes used by United Airlines (source:

Transpolar Flights and cosmic radiation risks are increasing



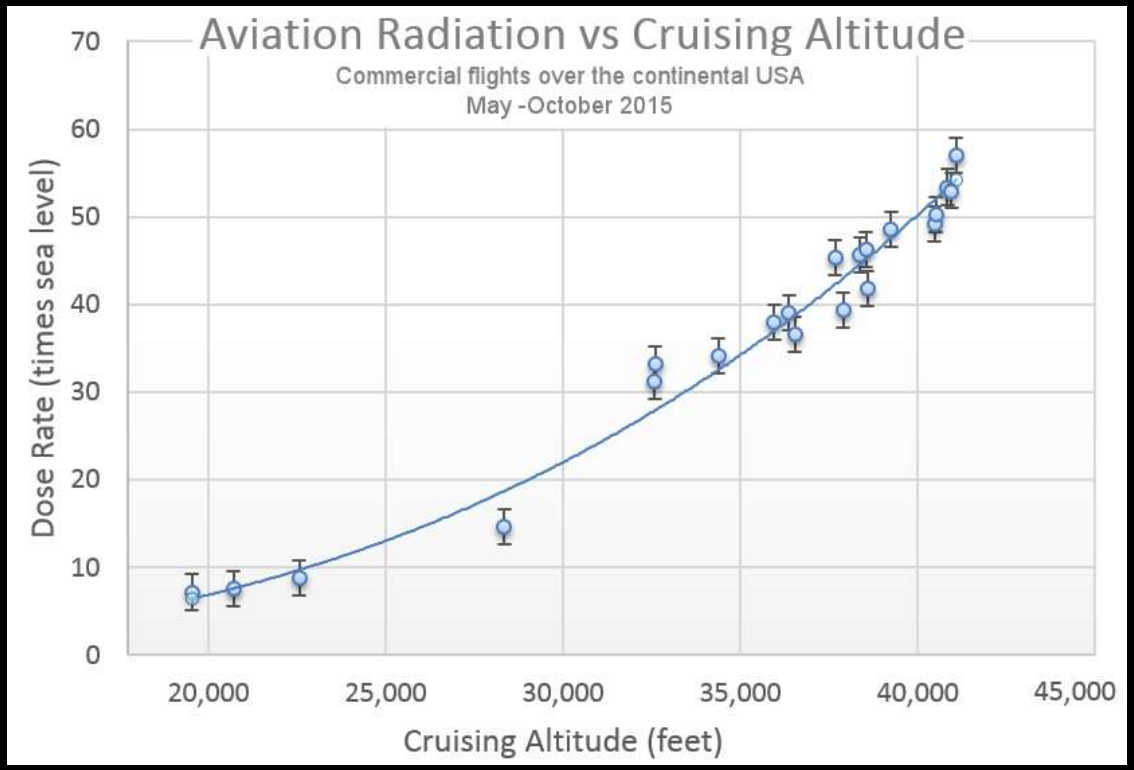
From the American Meteorological Society & SolarMetrics Policy Workshop Report March 2007

Max permissible mean dose rate limit: 7.5 mSv/hour

Spaceweather.com and the Students of Earth to Sky Calculus

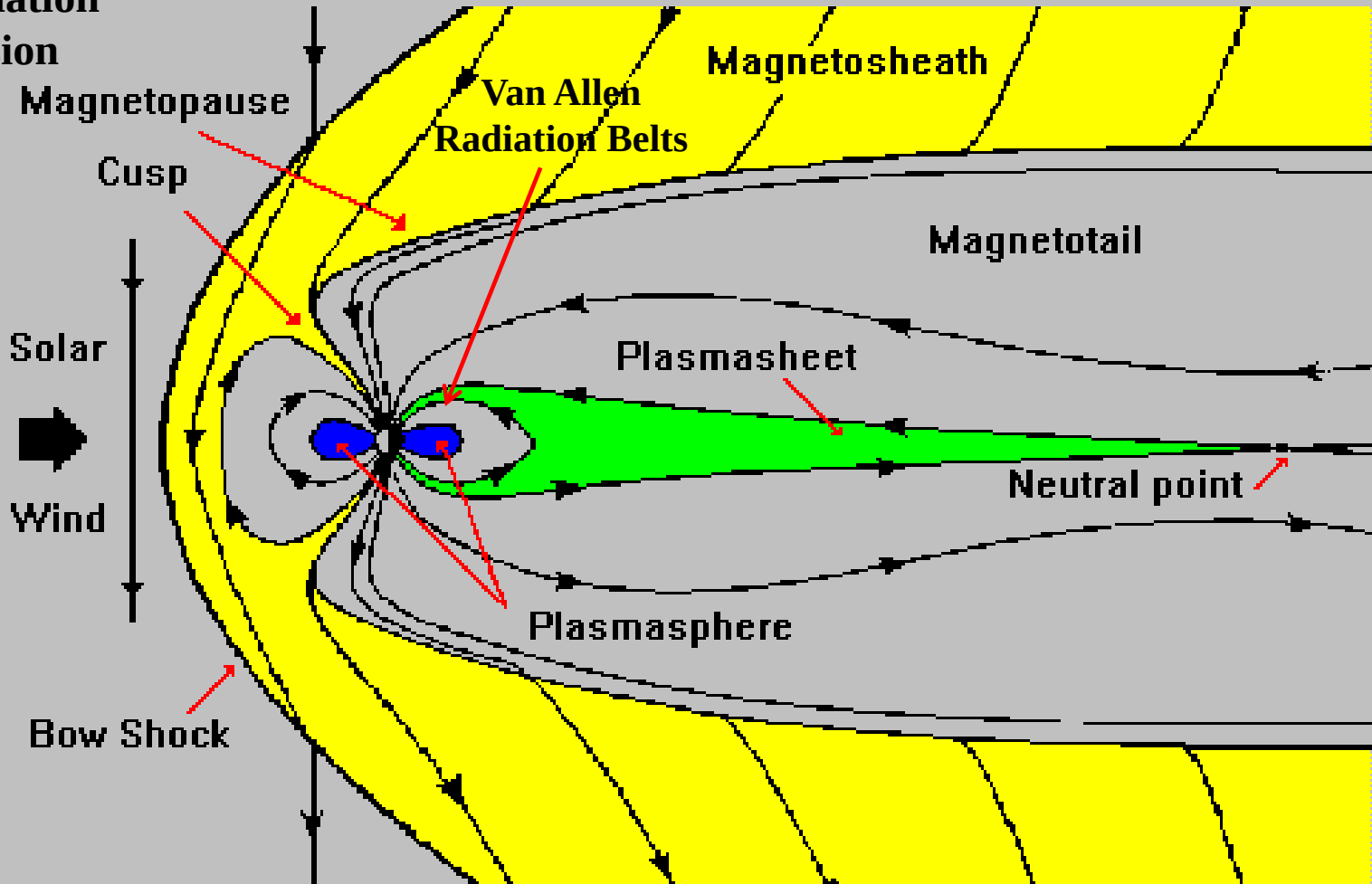
May to October 2015 this group has been bringing their cosmic radiation detectors on commercial aircraft. This chart summarizes their results from inside the airplane on 18 flights in the continental USA.

Cosmic radiation comes from outside the solar system. High solar activity reduces how much reaches Earth, low solar activity like that now coming allow more to reach Earth. Stay tuned for continued reporting in future months…

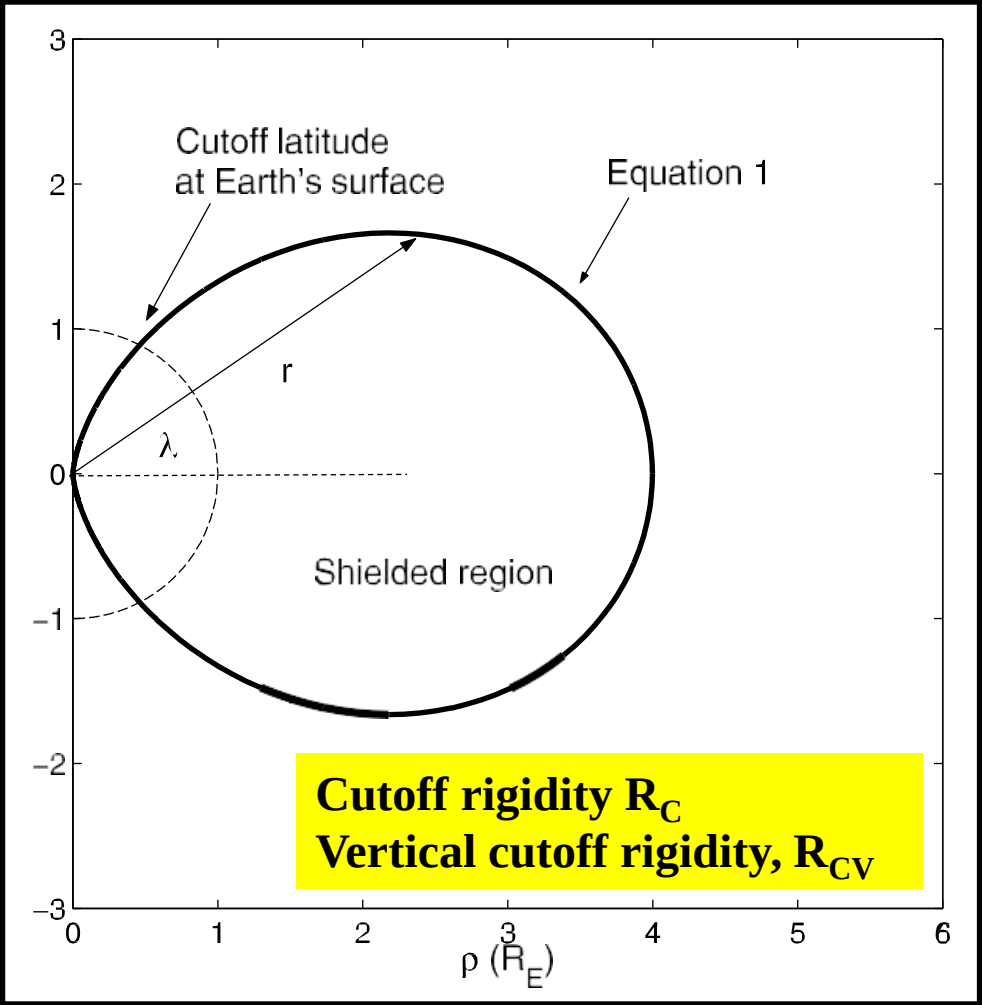


Earth's Magnetic Environment
"The Magnetosphere"

Precipitation
Electric Currents
Ionospheric scintillation
10MW radio emission
Radiation



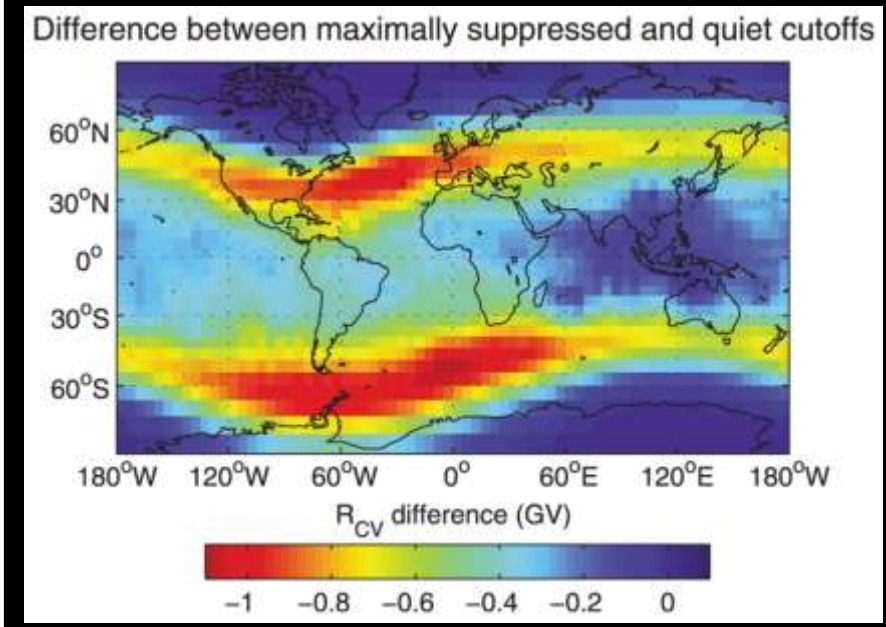
Rigidity R = Bρ = p/q
B = magnetic field strength
ρ = gyroradius
p = particle momentum
q = particle charge
Stormer, (1955) Oxford Univ. Press, London

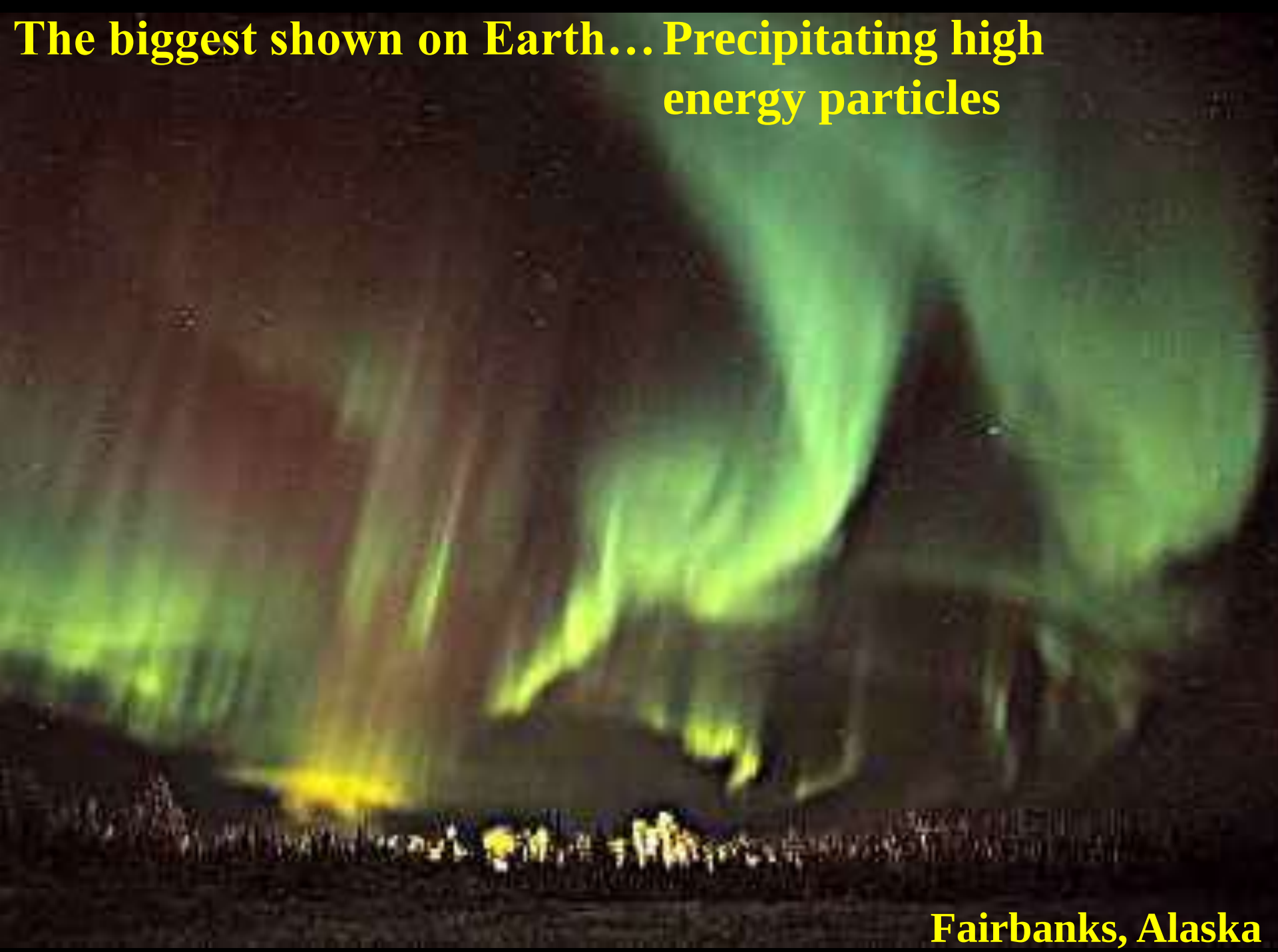


For a simple dipole:

$$r = \sqrt{\frac{M}{R}} \frac{cos^2\lambda}{\sqrt{(1 + kcos^3\lambda)}}$$

r = radial distance from dipole center
M = dipole moment
R = rigidity
k = sine of angle α
α = angle off Nadir in meridian plane
λ = magnetic latitude
Kress et al. (2010), *Space Weather*, 8, S05001, doi:10.1029/2009SW000488

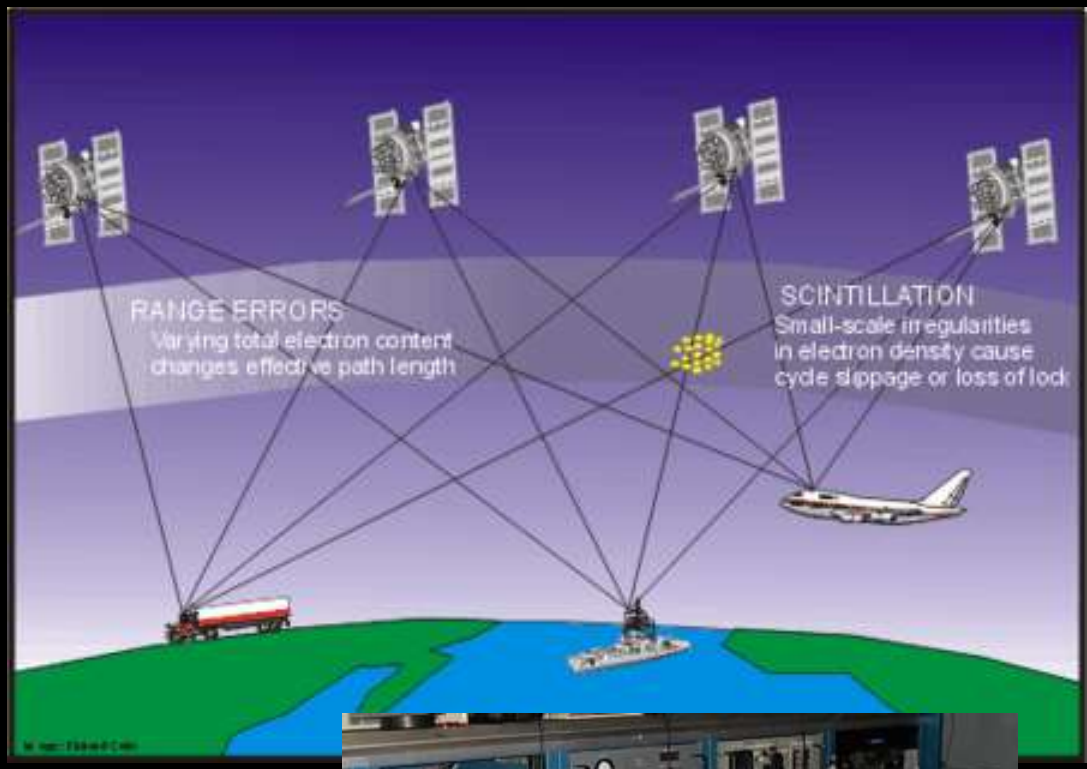



The biggest shown on Earth… Precipitating high energy particles
Fairbanks, Alaska

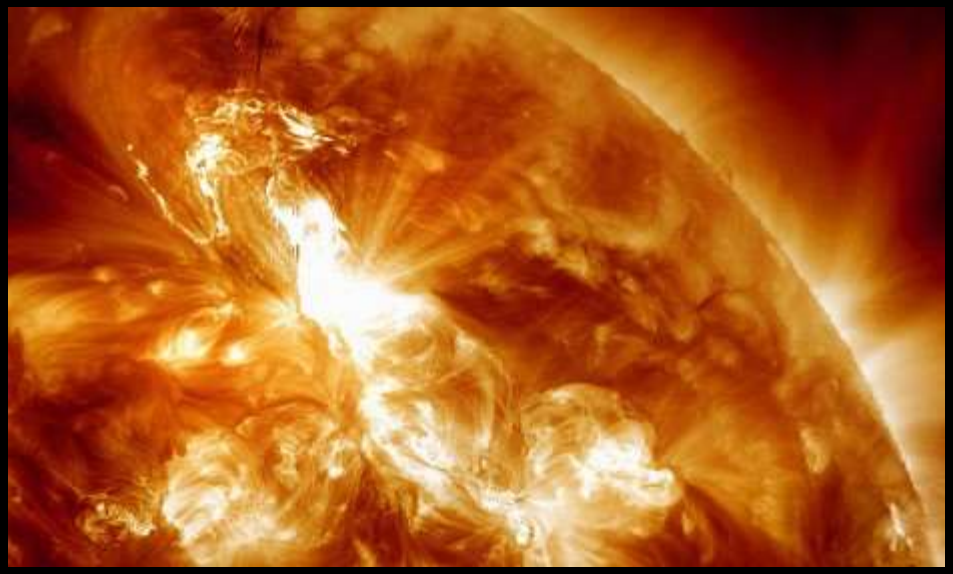
Disruption of:

HF Communication

Navigation

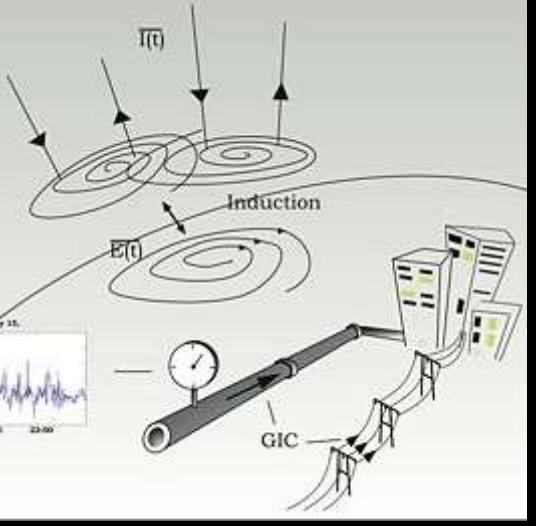


‘Solar storm’ grounds Swedish air traffic

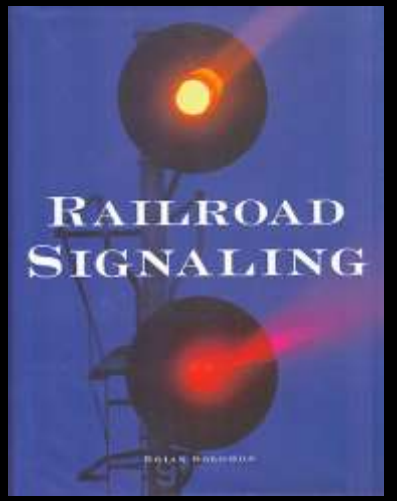


Reported in the December 1, 2015 issue of “The Local Europe AB” an English version of Sweden’s news:

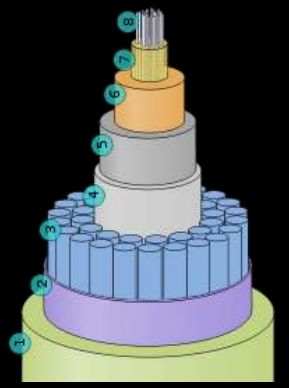
Planes were grounded at some of Sweden's busiest airports on Wednesday afternoon because of a "solar storm" interfering with air traffic control radar systems, authorities said.



Ground Induced Currents (GIC)



- Railroads:
  - Sweden in 1982, railway signals failed to switch correctly
  - Norway in 2000, 19 lives were lost



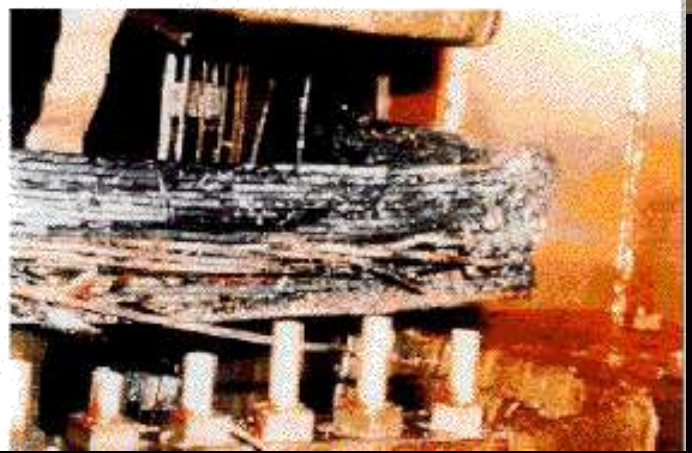
- Deep Sea Cables:
  - Space Weather can generate hundreds to thousands of volts

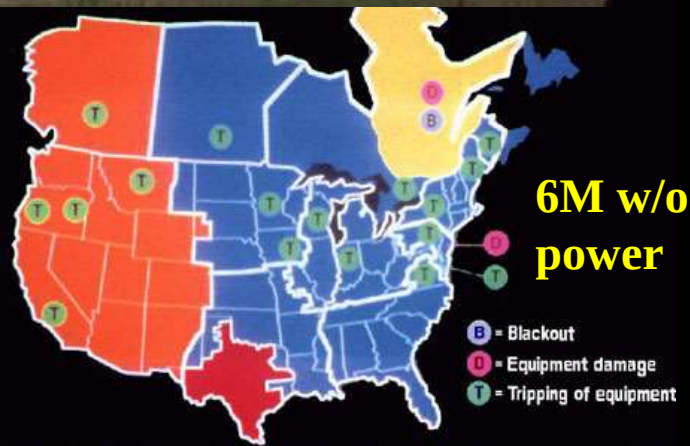
Pipeline Corrosion

Electrical Power Disruption Due to Induced Electric Currents

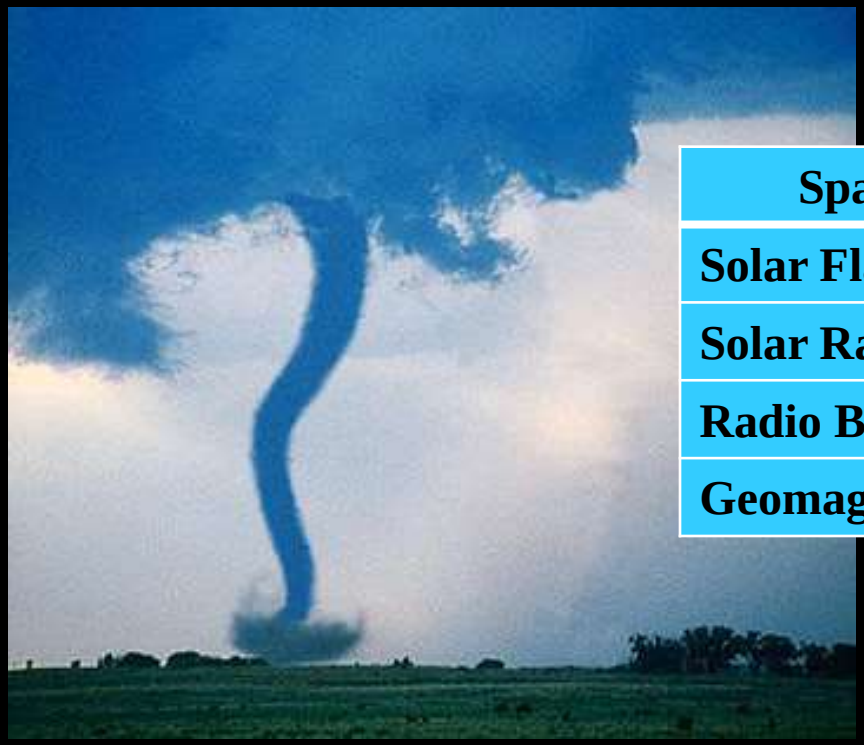
PJM Public Service
Step Up Transformer

Severe internal damage caused by the space storm of 13 March, 1989





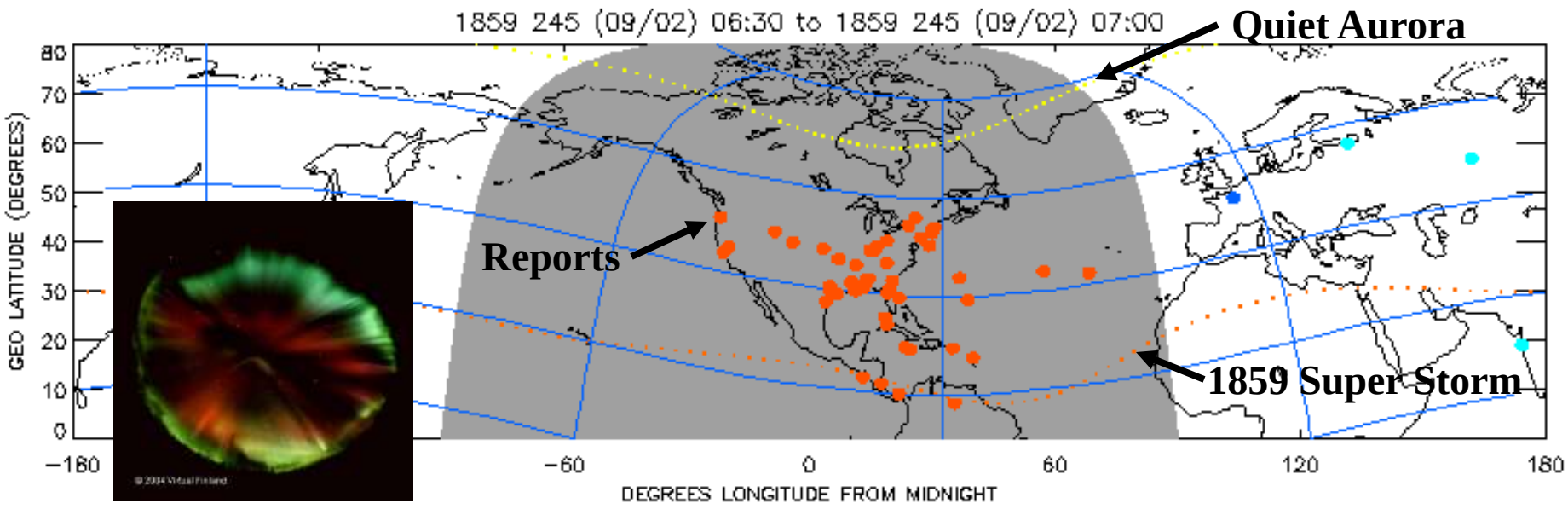
Atmospheric storms are measured. Space storms are too.



Space Storm	Minor → Extreme
Solar Flares	B → C → M → X
Solar Radiation	S1 → S5
Radio Blackouts	R1 → R5
Geomagnetic Storms	G1 → G5

September 2, 1859 Event

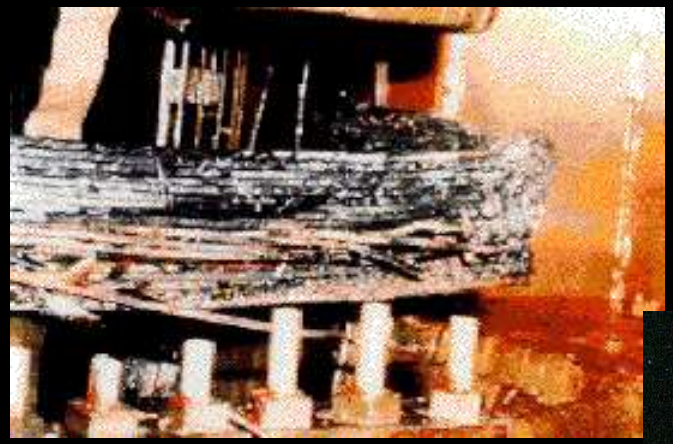
3X recent storm strength / 1/3 strongest ever



- Messenger (deck log: Lat. 49º) "we witnessed the most magnificent display of the aurora boreales (sic) imaginable … the whole firmament was a blaze of Crimson shooting up from all points of the compass but the most splendid from the South W. I have not the language to describe it"

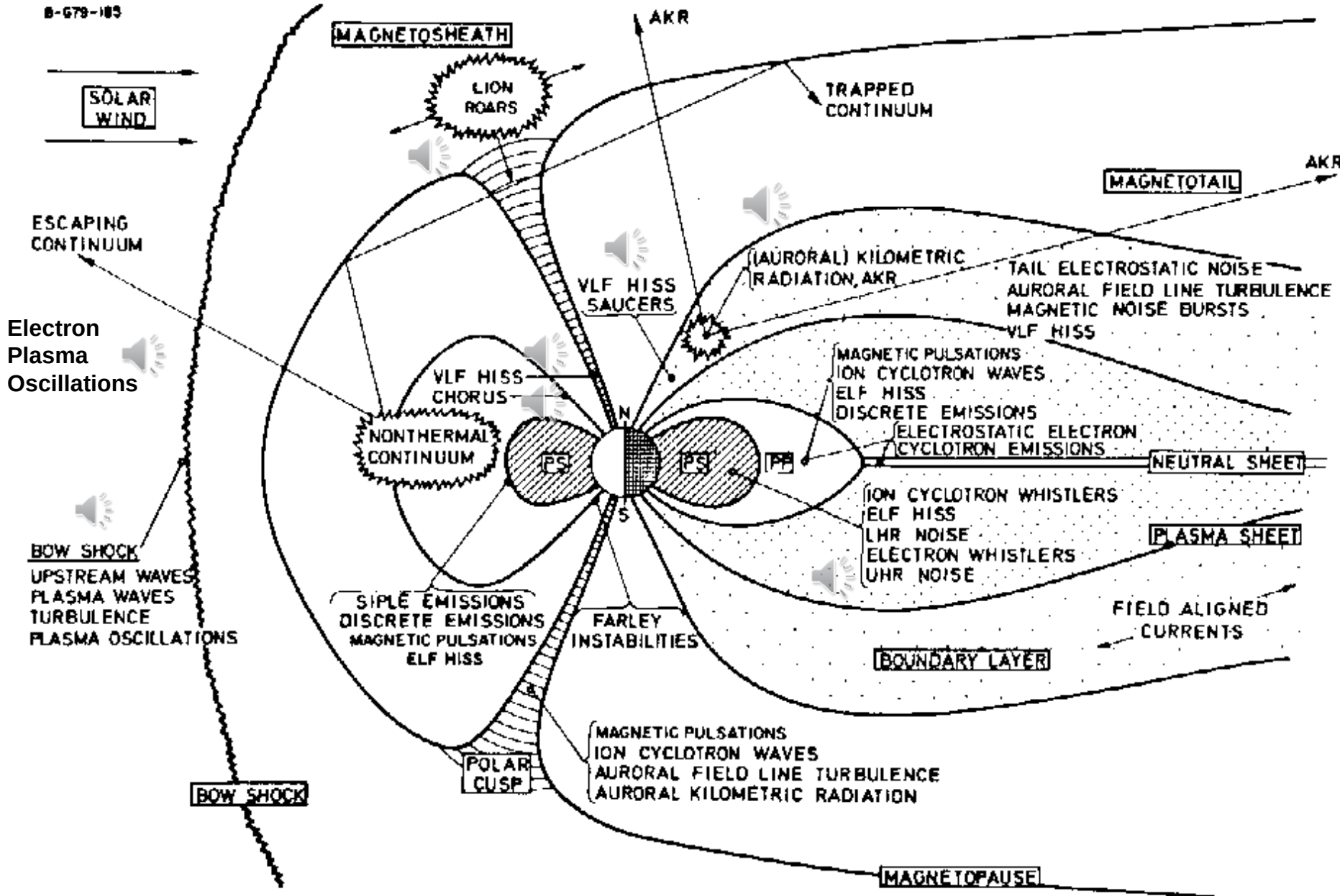
Courtesy James L. Green, NASA/GSFC

Weather in Space



- Precipitation
- Light Displays
- Power of Nature
- Societal Danger

Shock and Awe



Recordings from U. Iowa Professor Donald Gurnett