From the music of the Spheres to Space Weather: how can we protect our space assets?

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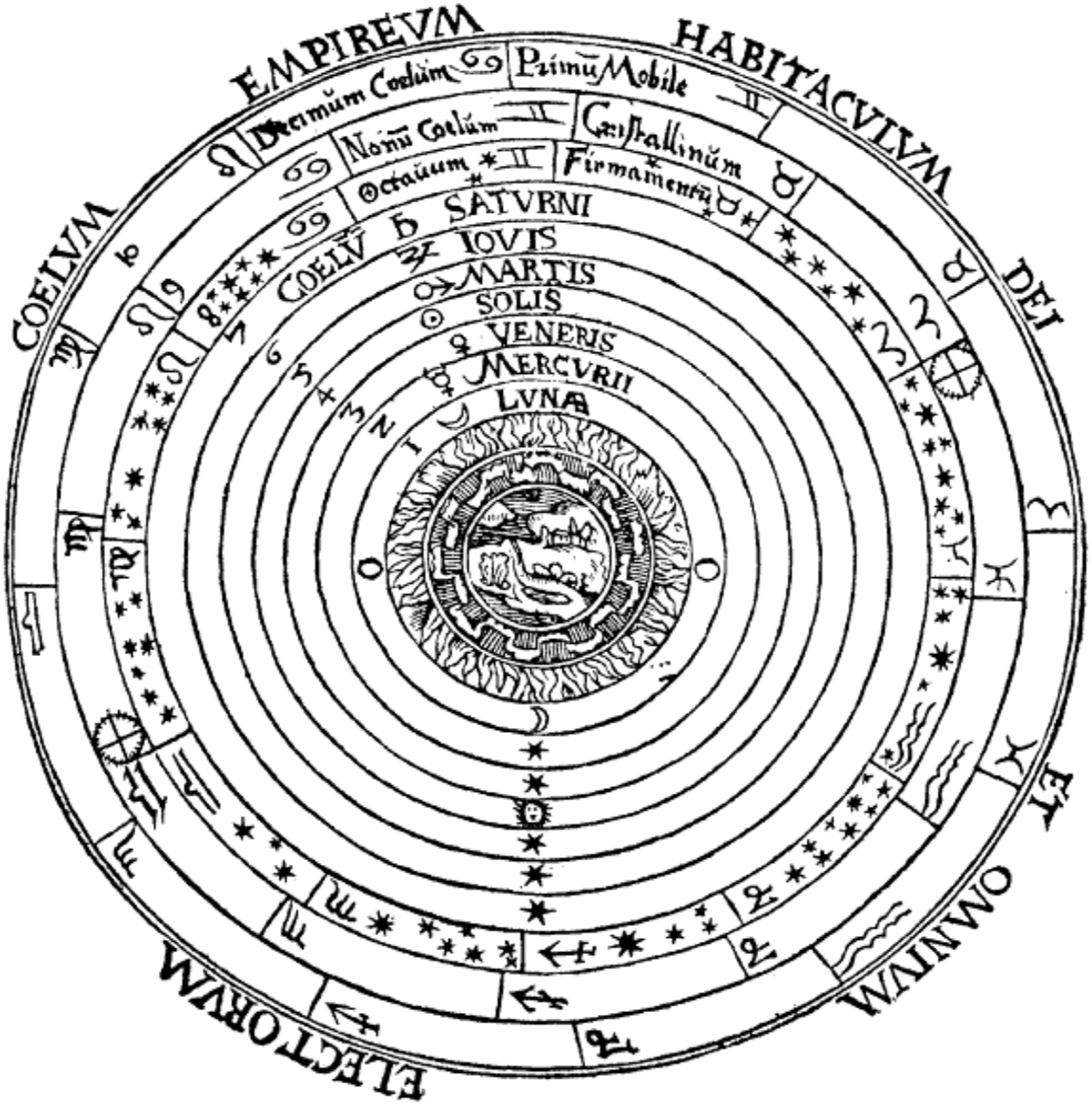
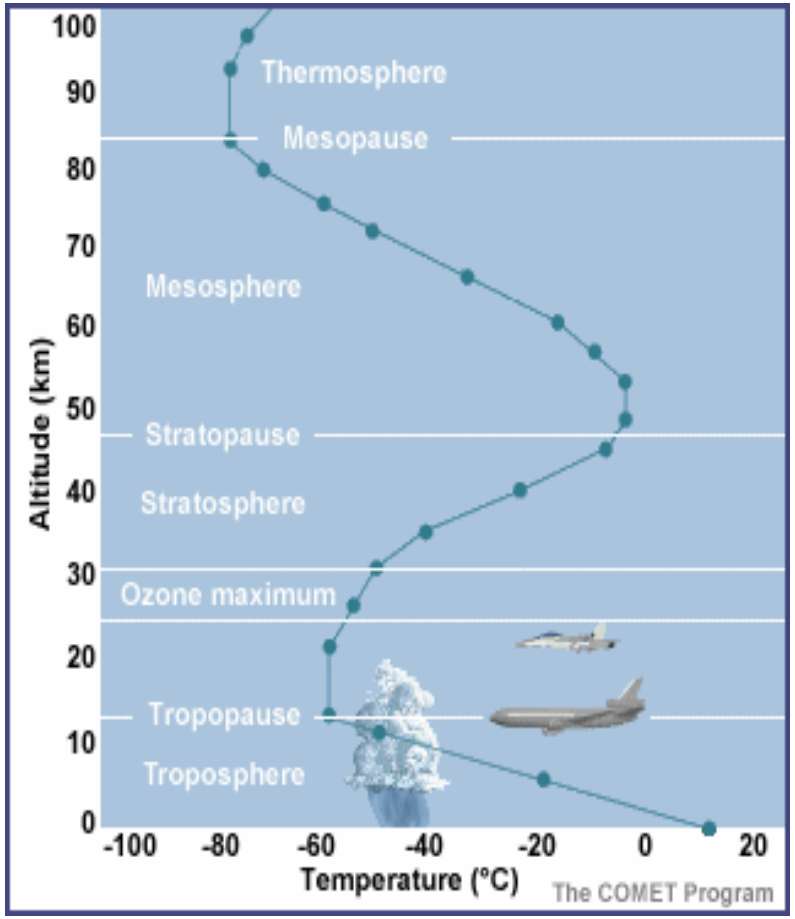
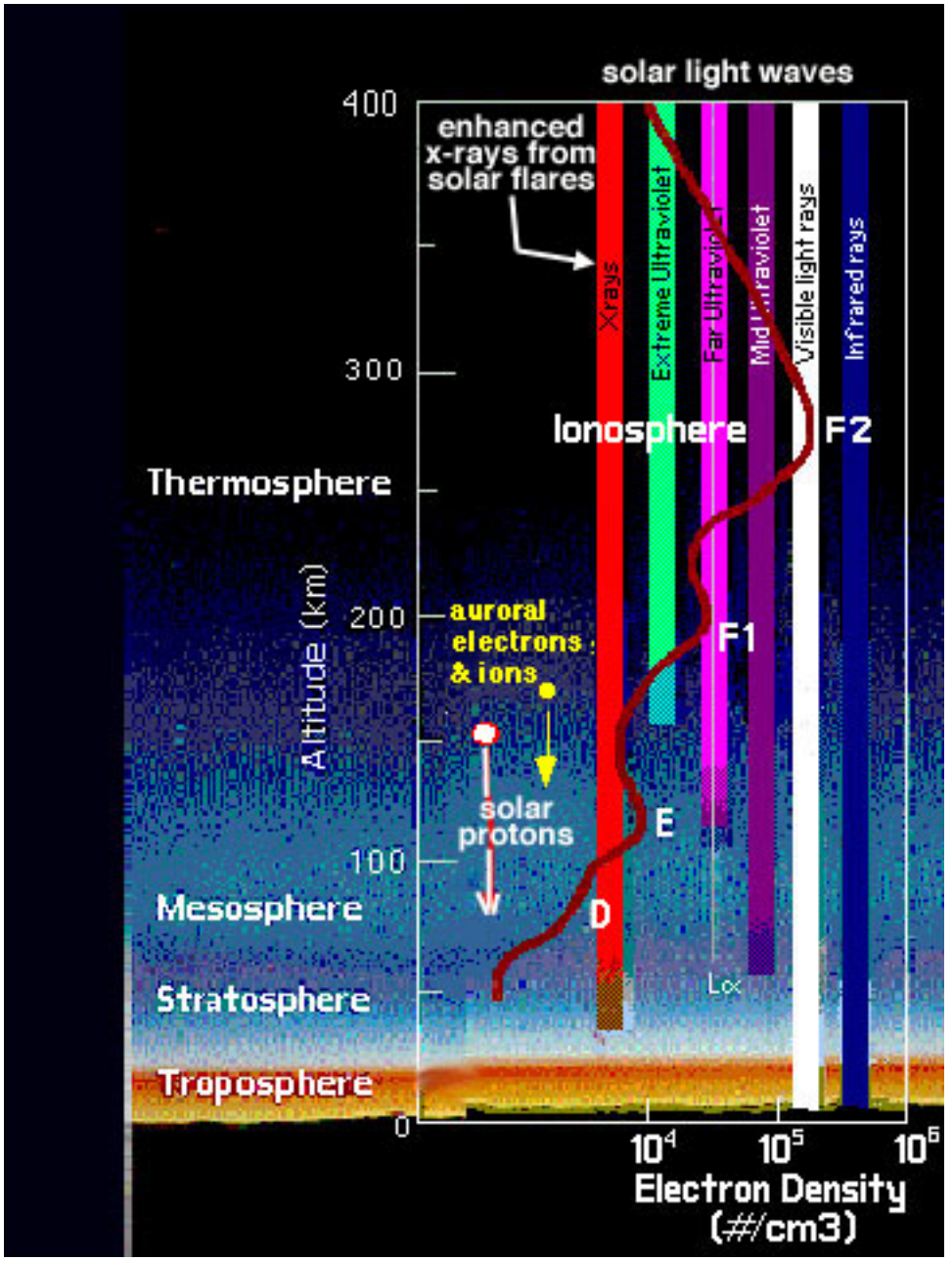
Spheres in geocentric philosophy



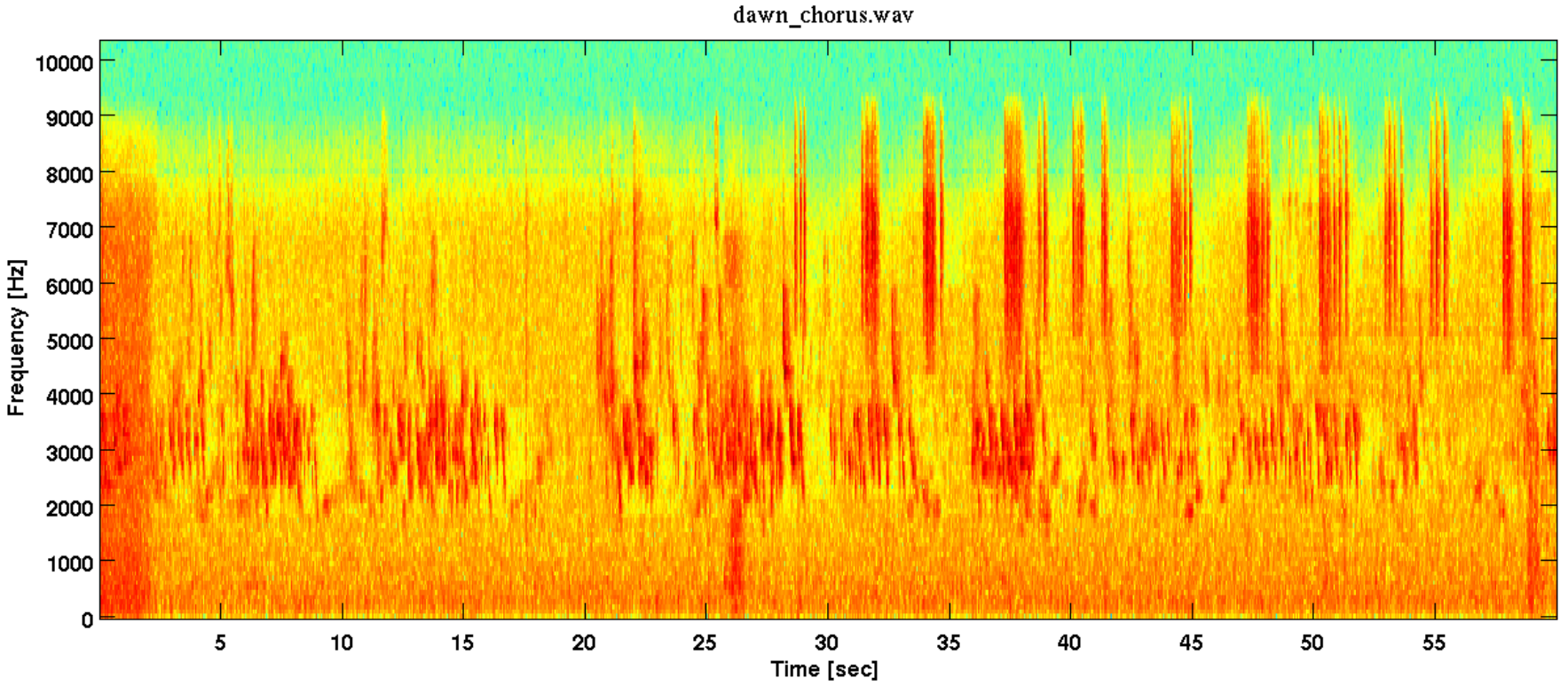
Spheres in modern science



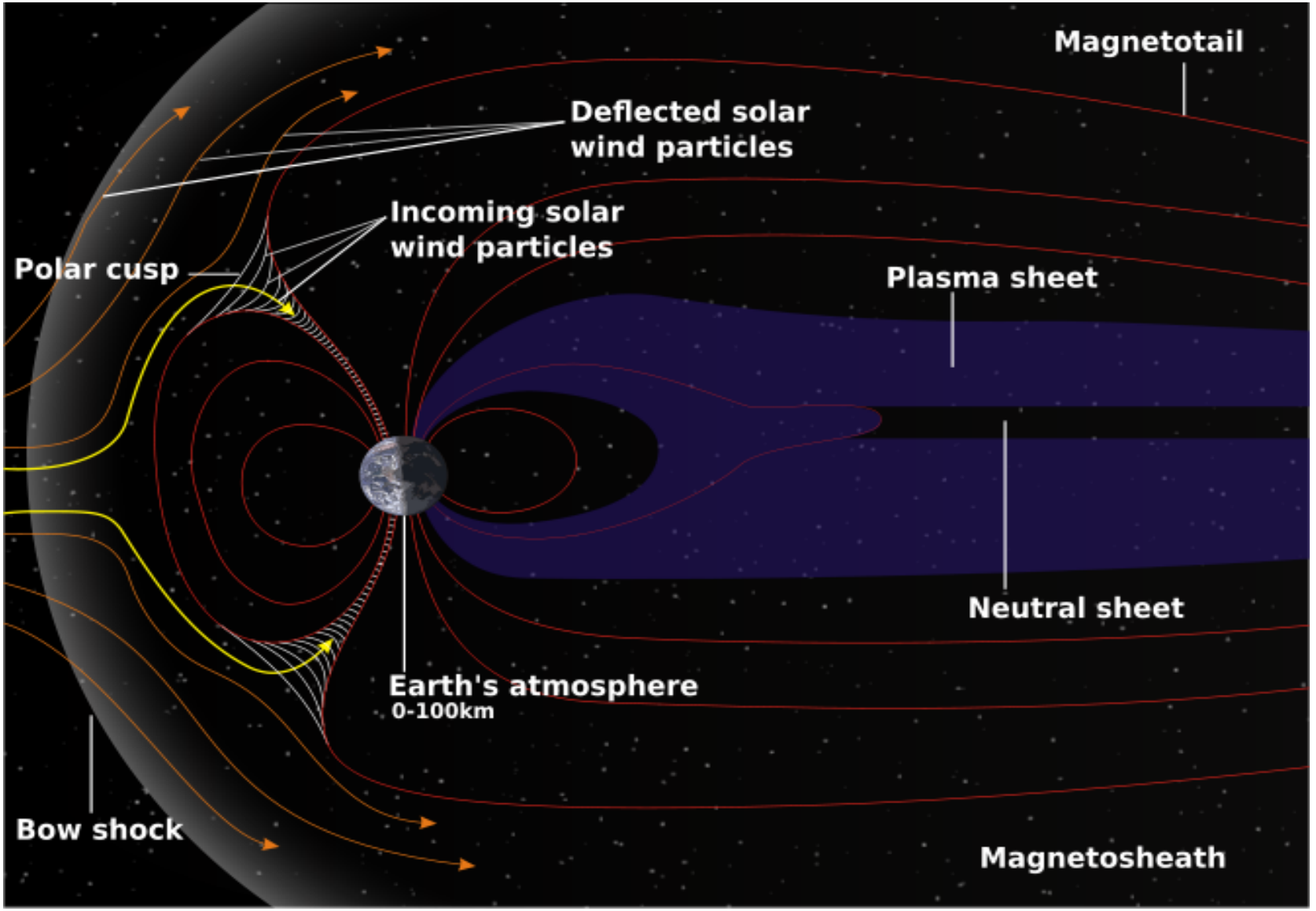


Music of the spheres

Music of the spheres



Magnetosphere



A tale of two magnetosphere - why is it important?

Density variations in *Plasmasphere*

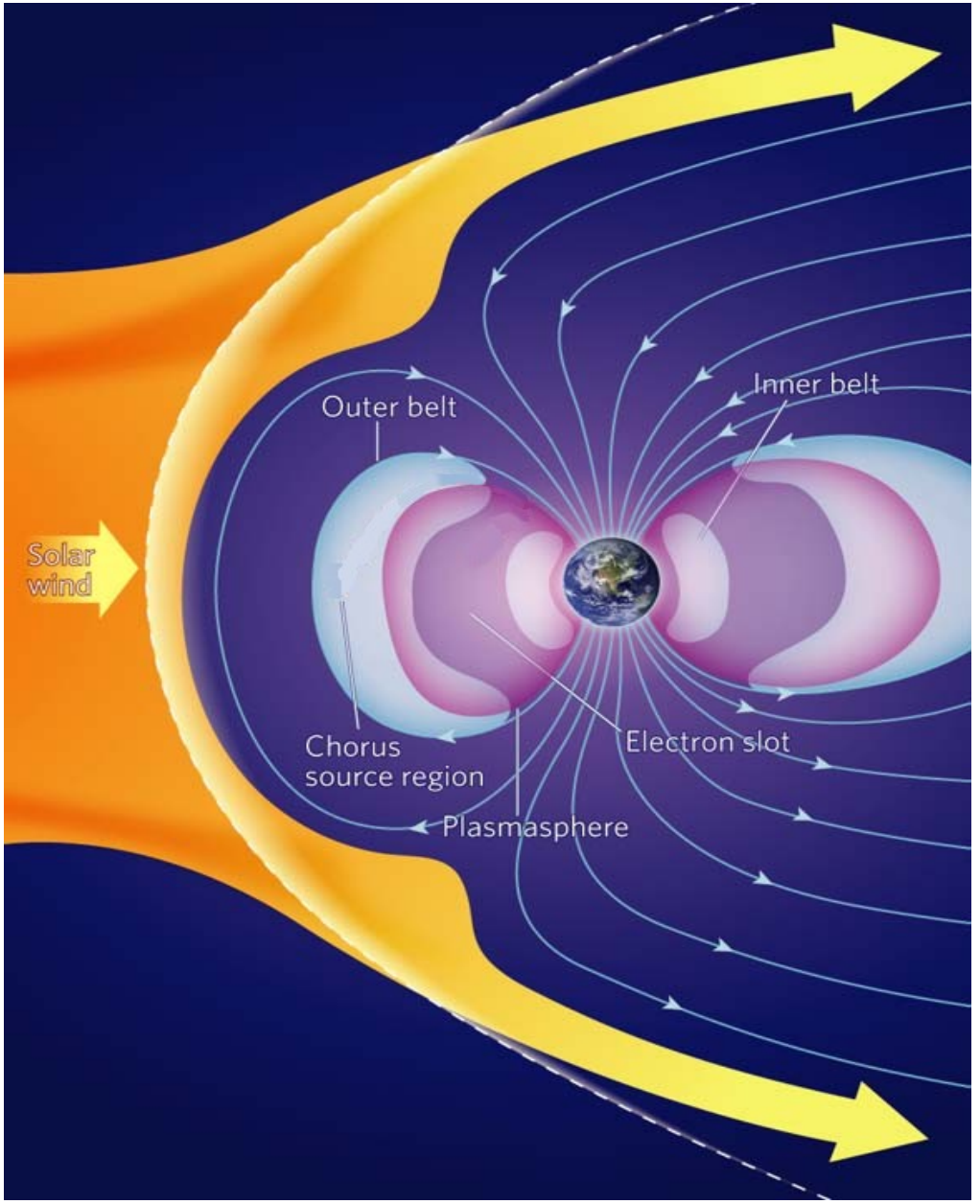
=> wave-particle interaction with *Radiation Belts*' particles =>

acceleration and precipitation

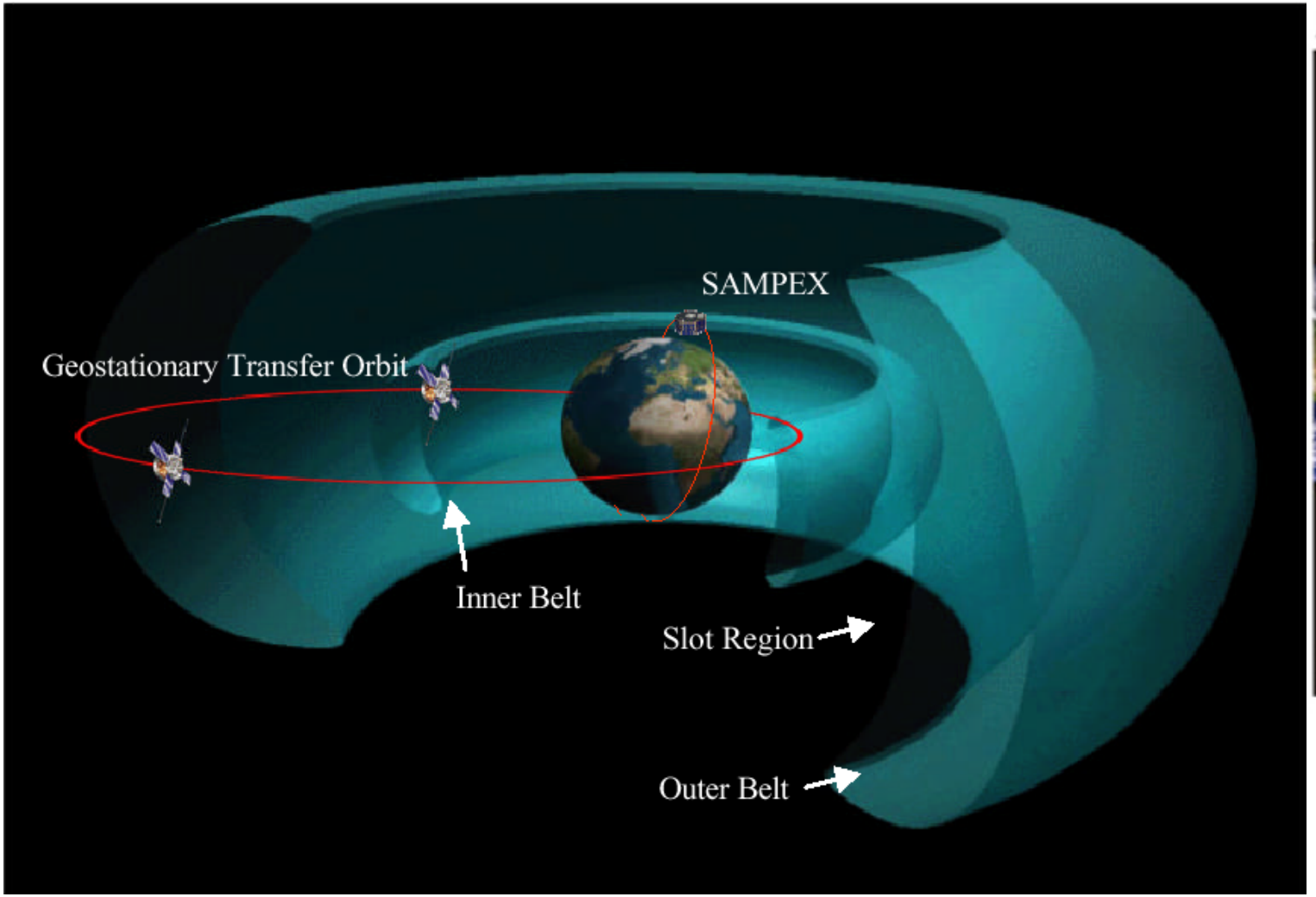
of high (relativistic) energy

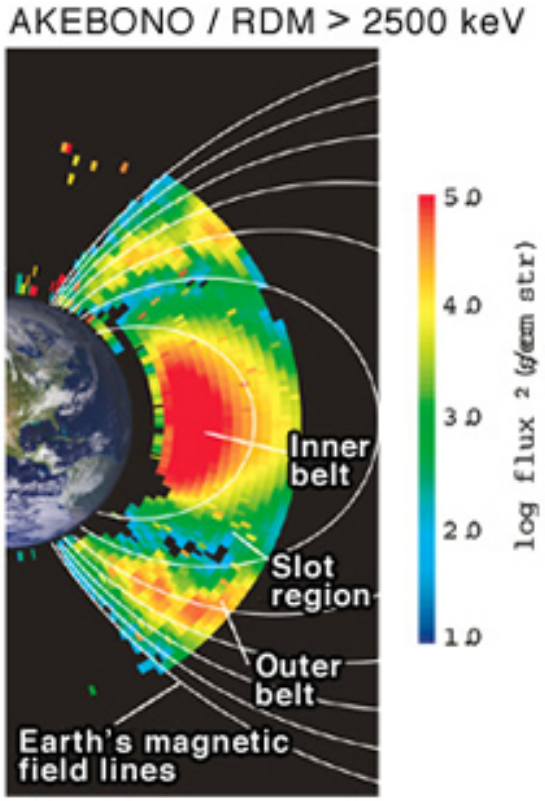
particles =>

- damage of satellites' solar cell and electronics
- energy transfer into the neutral atmosphere



A tale of two magnetospheres:
the HOT: Radiation Belts



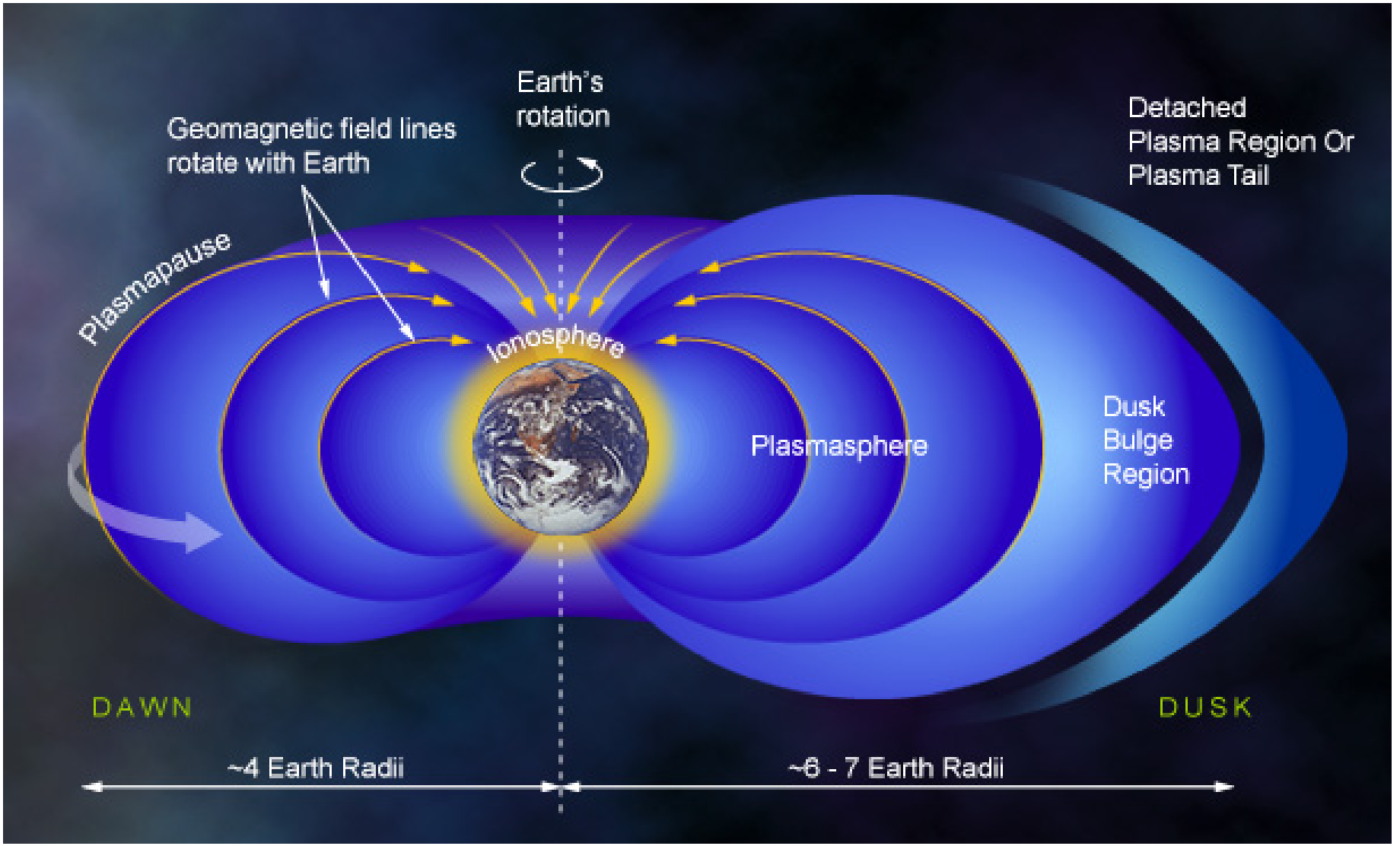


A tale of two magnetospheres: the HOT: Radiation Belts

- T~ 0.1-10 MeV (elektronok) ~ 10-100 MeV (protonok)
- Fluxus ~-10000/cm^2/s

- whistler mode wave amplifcation/generation (hiss and chorus)
- acceleration of charged particles to relativistic energy (10MeV electrons)
- precipitation of high energy charged particles

A tale of two magnetospheres
the COLD: Plasmasphere



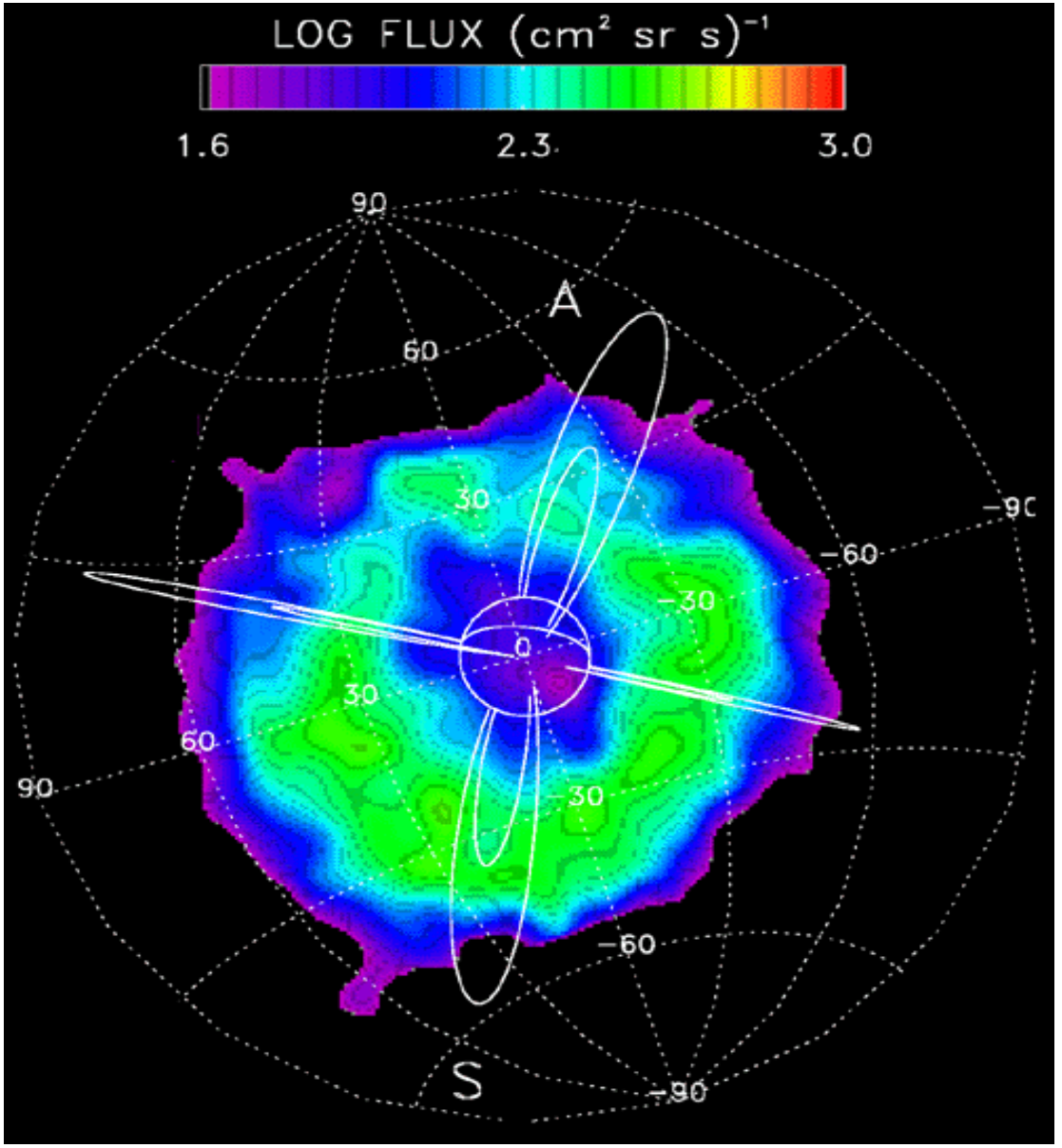
A tale of two magnetospheres
the COLD: Plasmasphere

- T~ 1 eV
- N~100-10000/cm^3

  - Wave propagation (phase and group velocity, wave-impedance)
  - propagation path

*A tale of ~~two~~ **three** magnetospheres*

the WARM : Ring Current



ENA image
on IMAGE

*A tale of ~~two~~ **three** magnetospheres*

the WARM : Ring Current

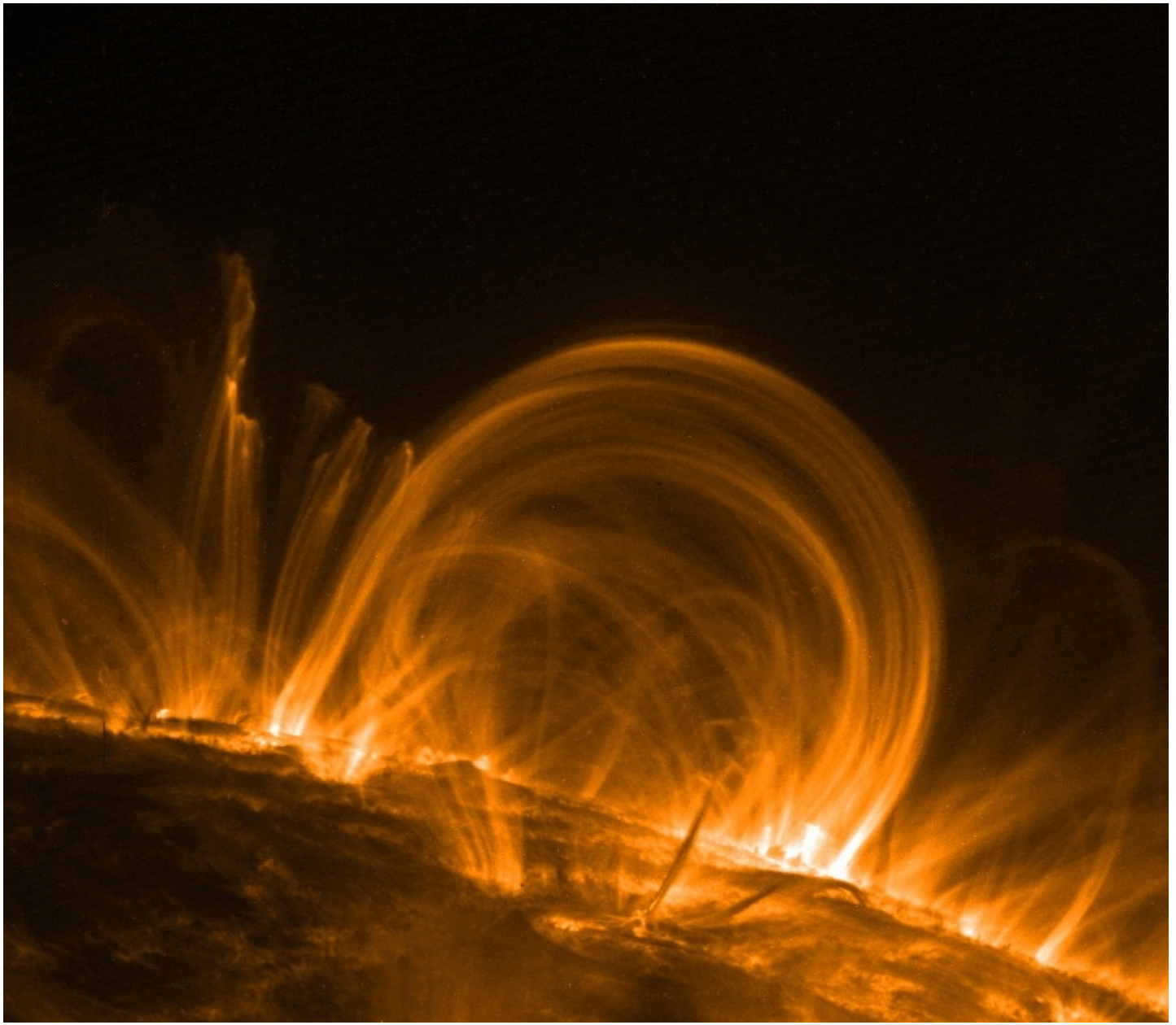
T~ 10 keV (electrons) ~ 200 keV (protons)

- n~10-100/cm^3

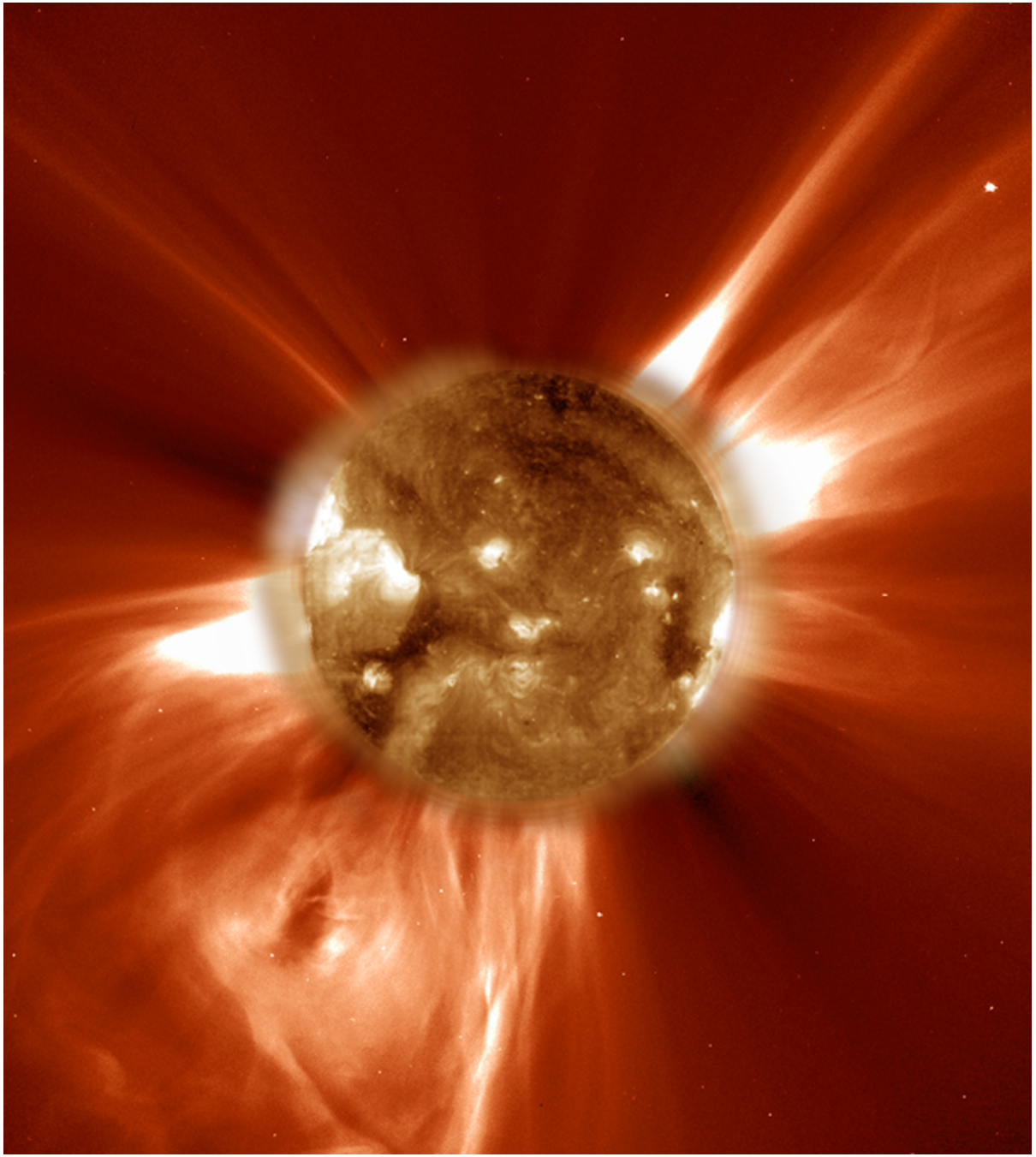
- The fluctuation of magnetic field during geomagnetic storms is caused by the variation of ring current

The root of all *good* and *evil*

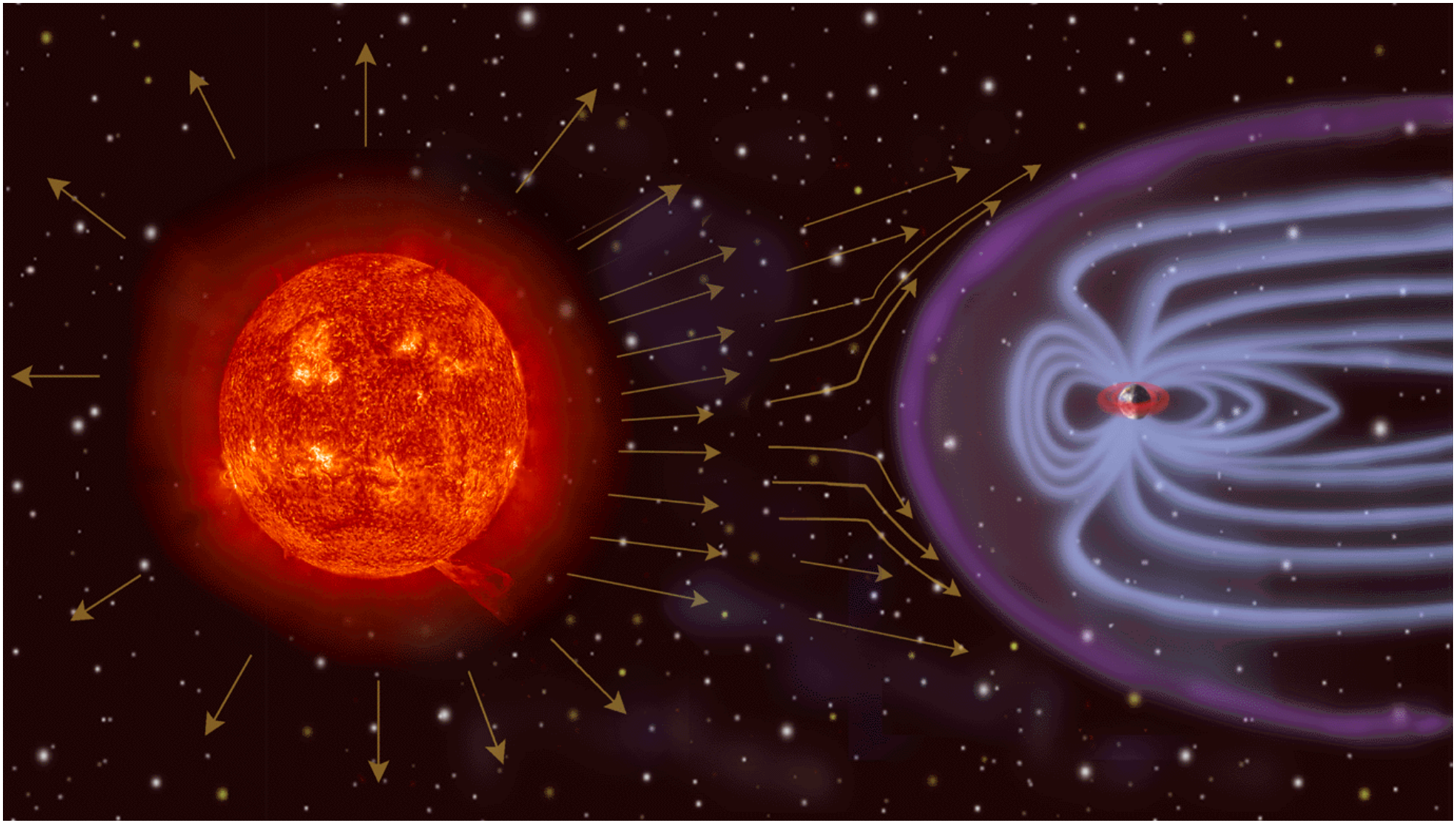
The root of all *good* and *evil*



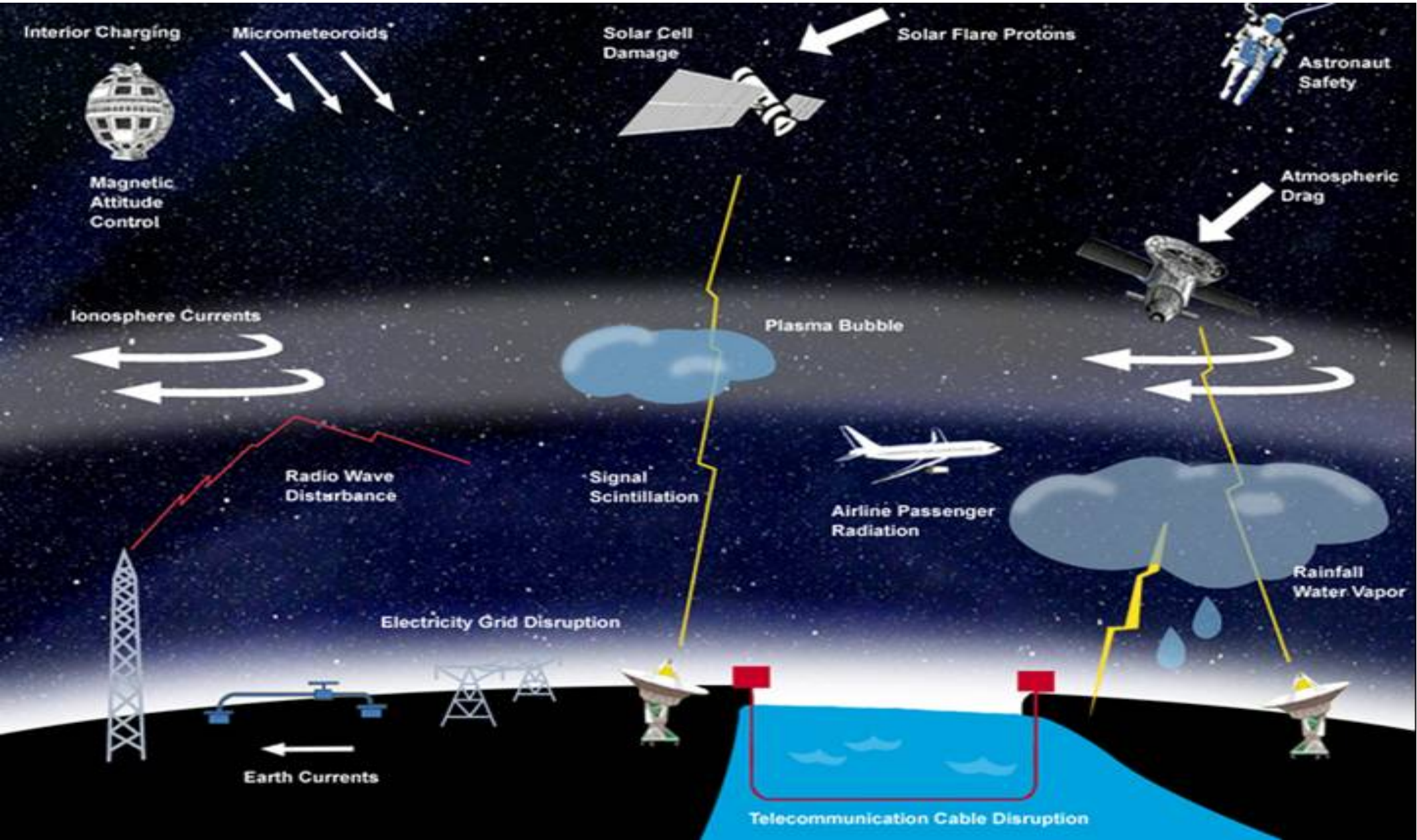
The root of all *good* and *evil*



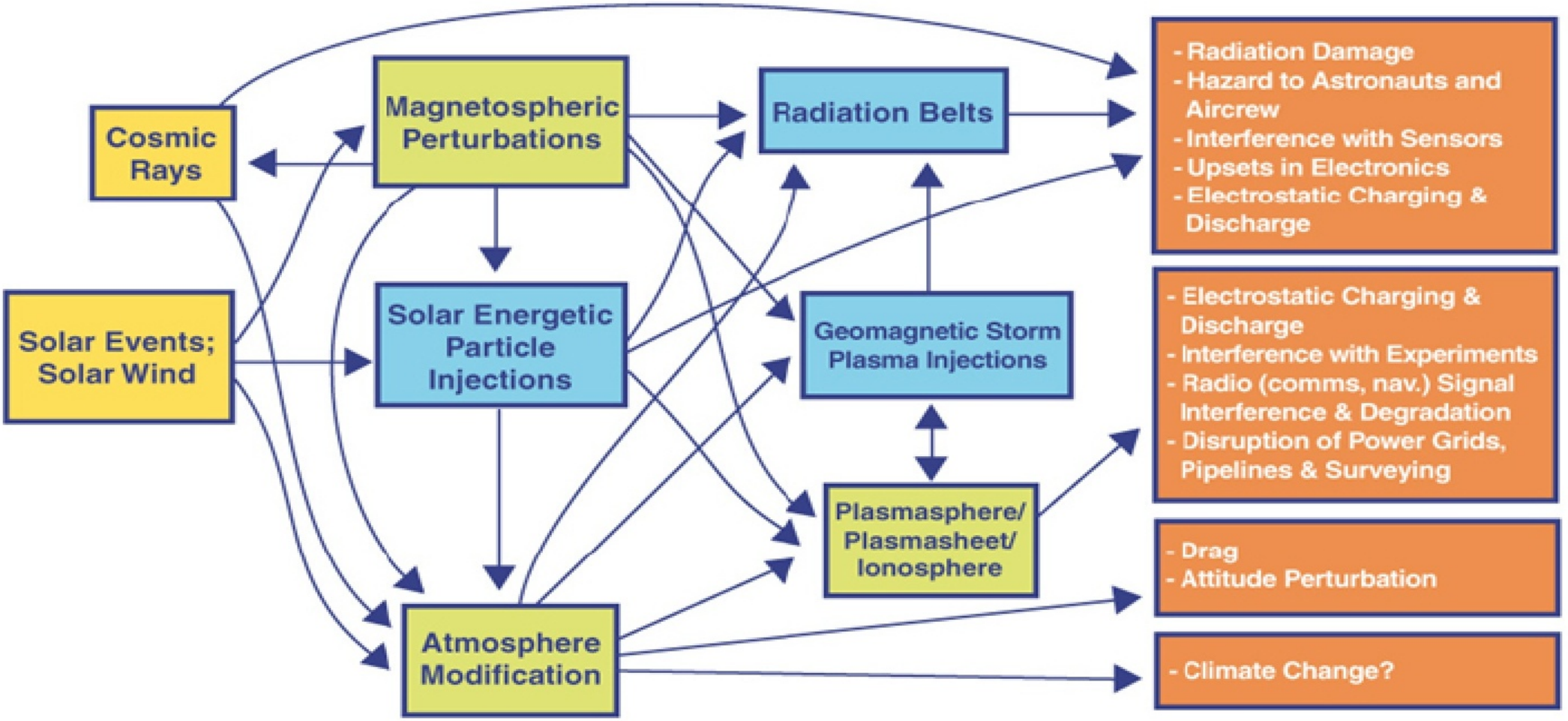
Space Weather



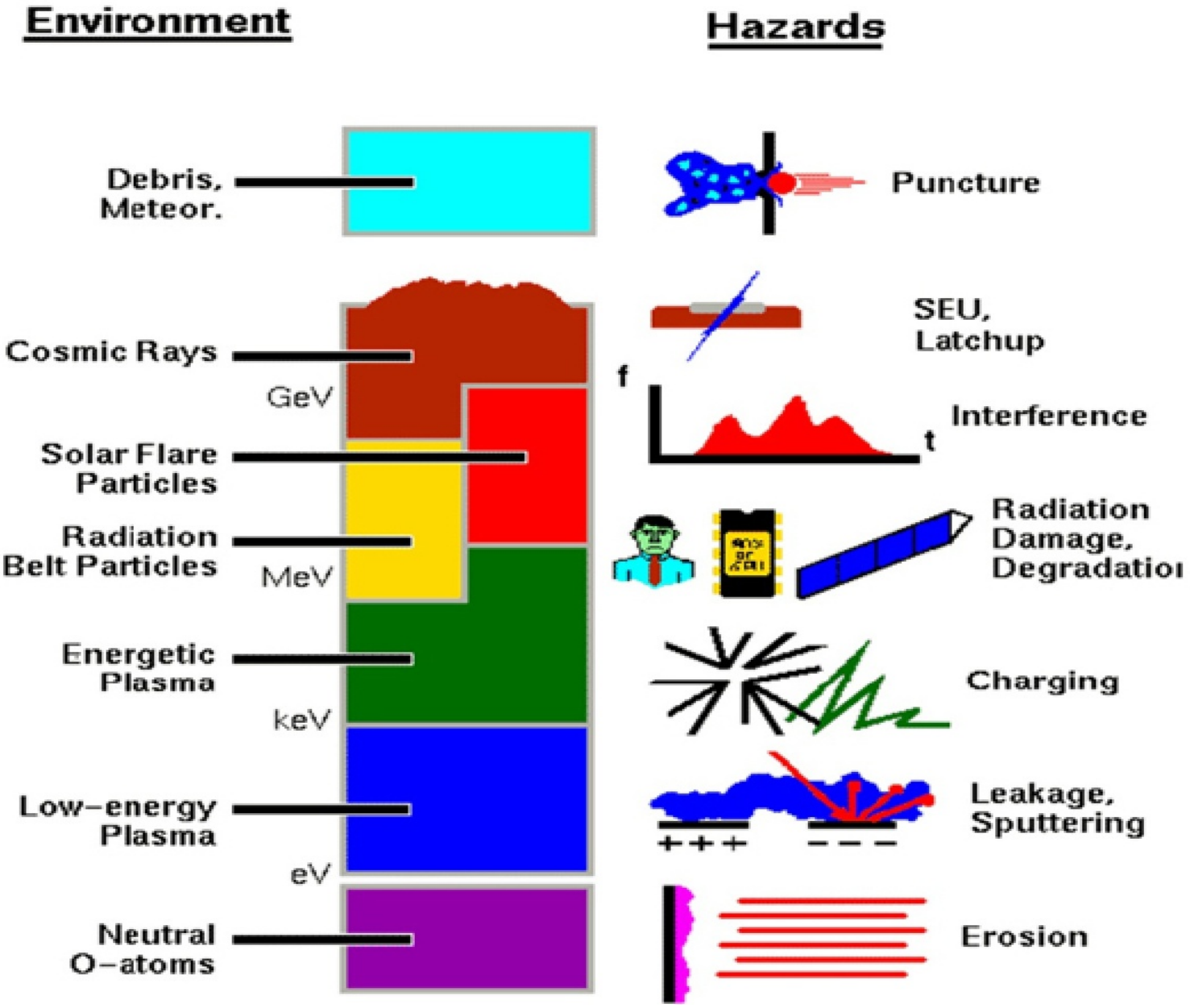
Space Weather



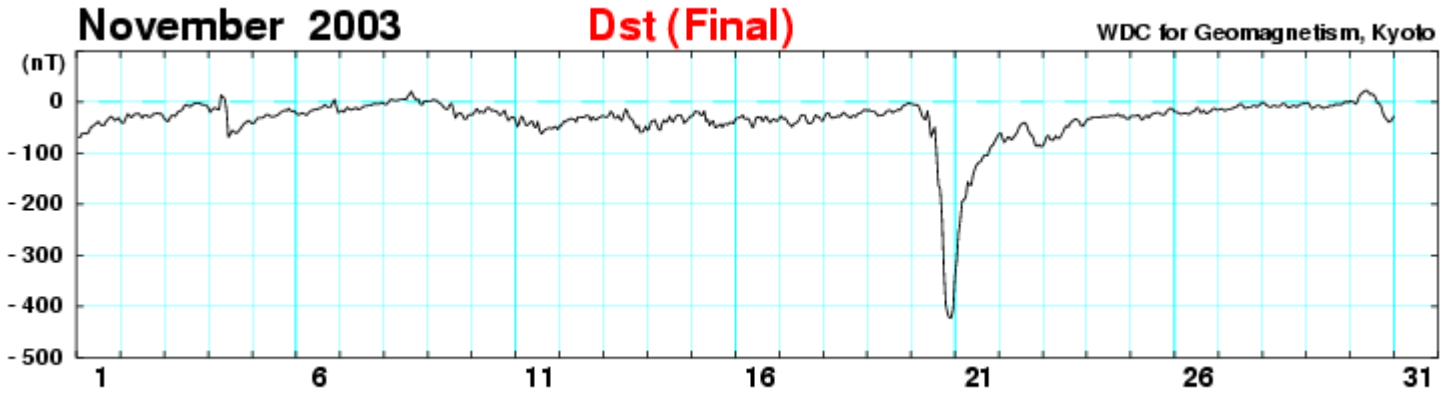
Space Weather: *effects*



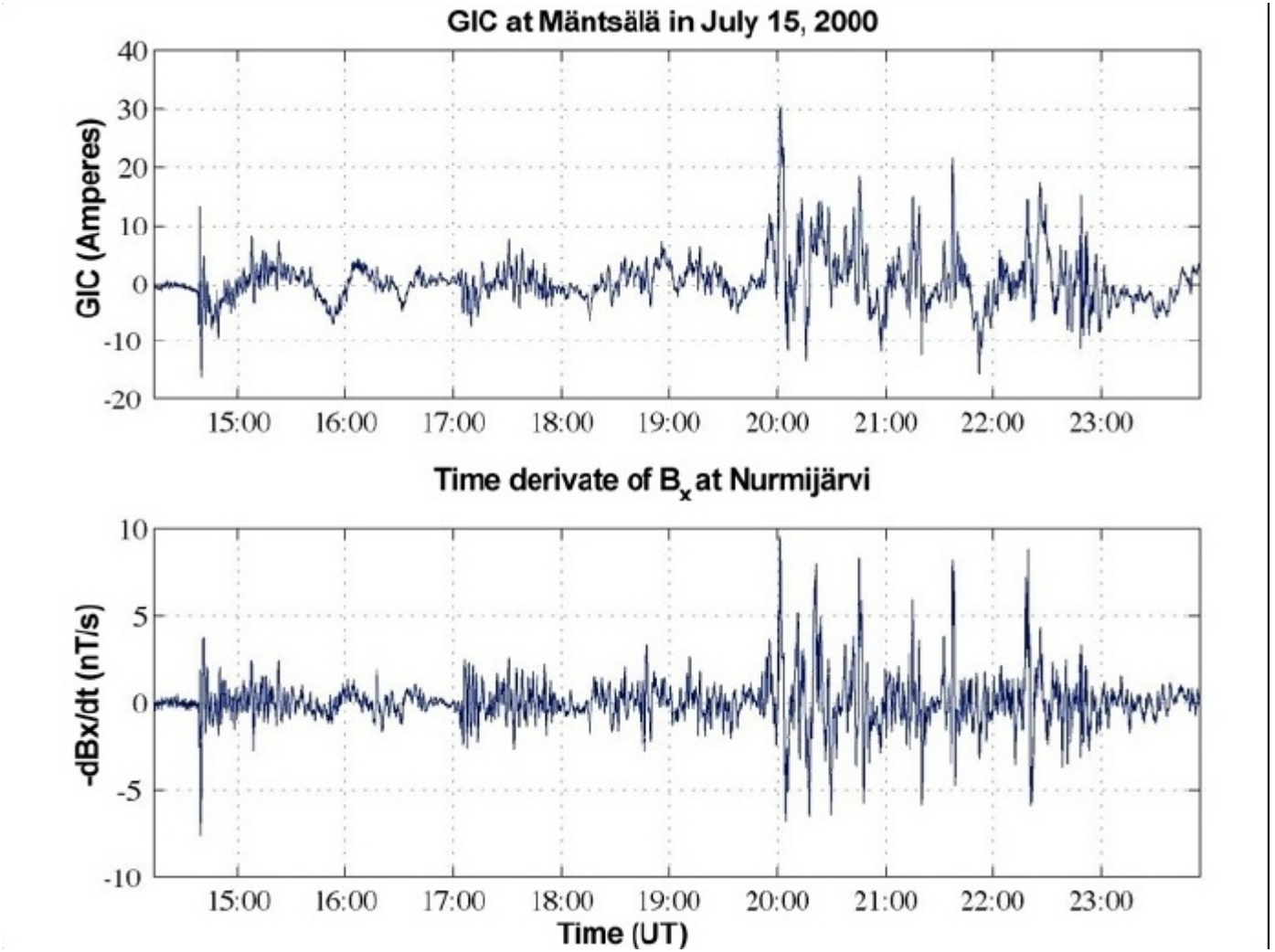
Space Weather: *effects*



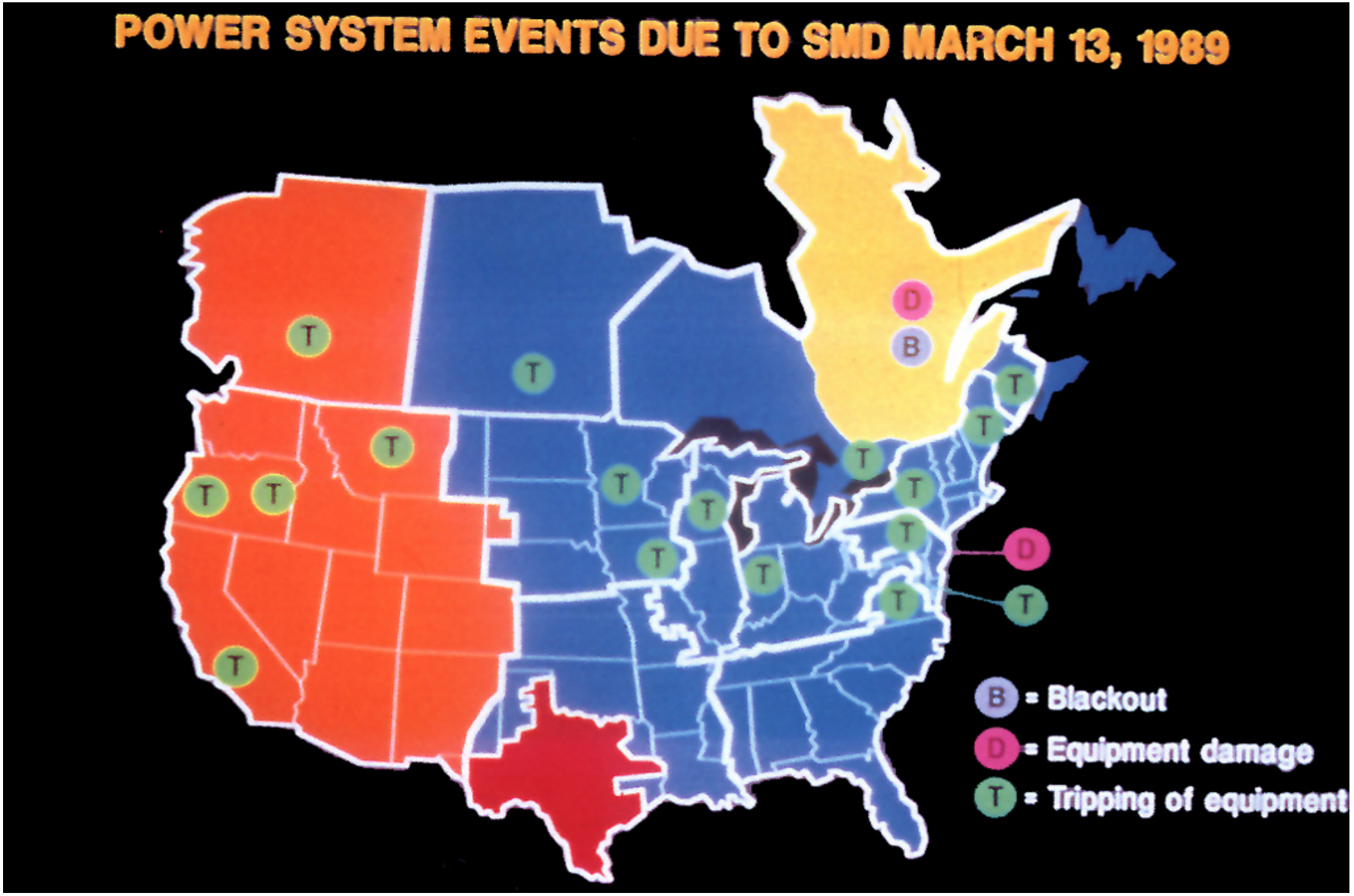
Magnetic storms



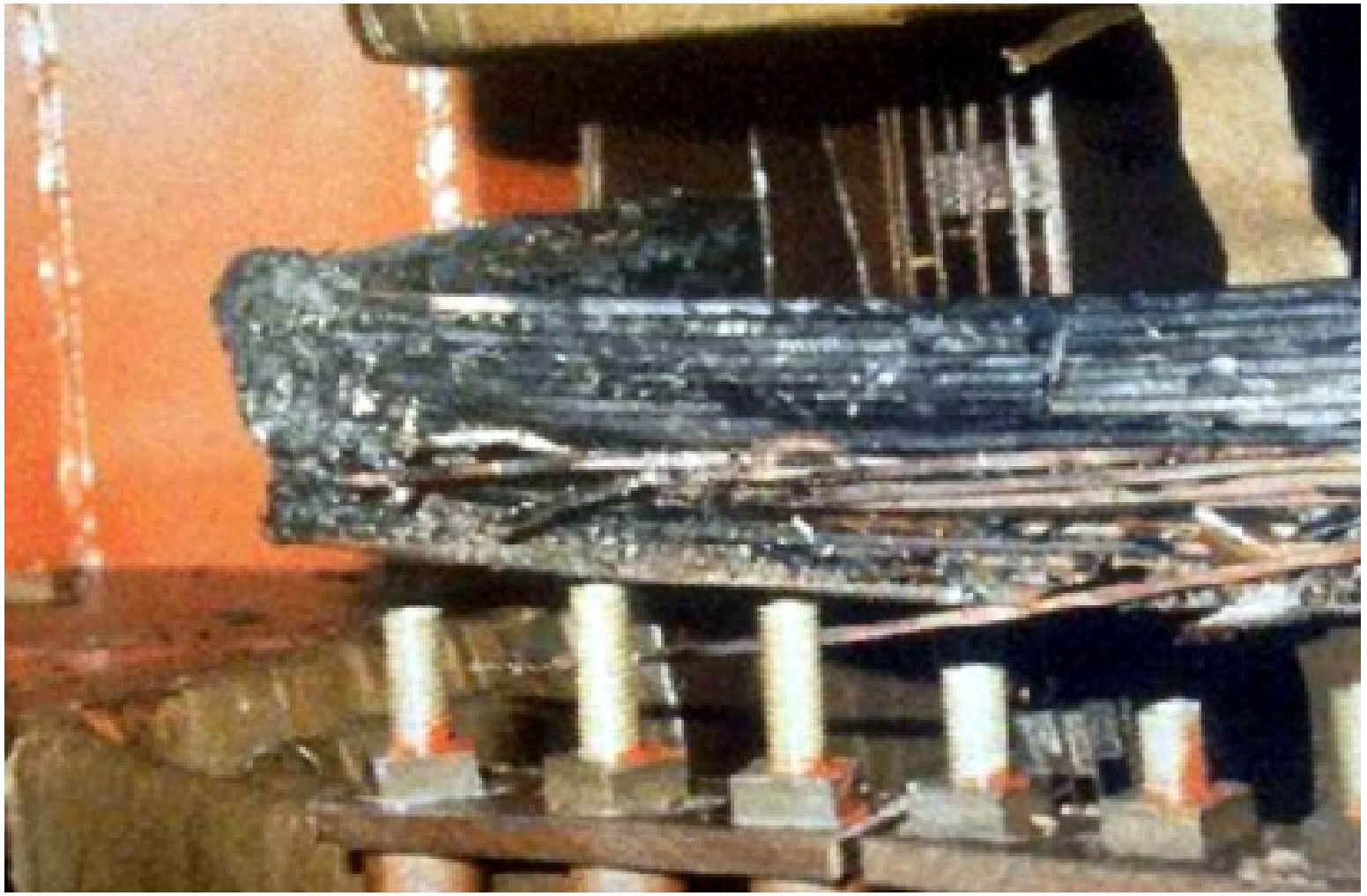
Magnetic storms: the effects



Magnetic storms: the effects



Magnetic storms: the effects



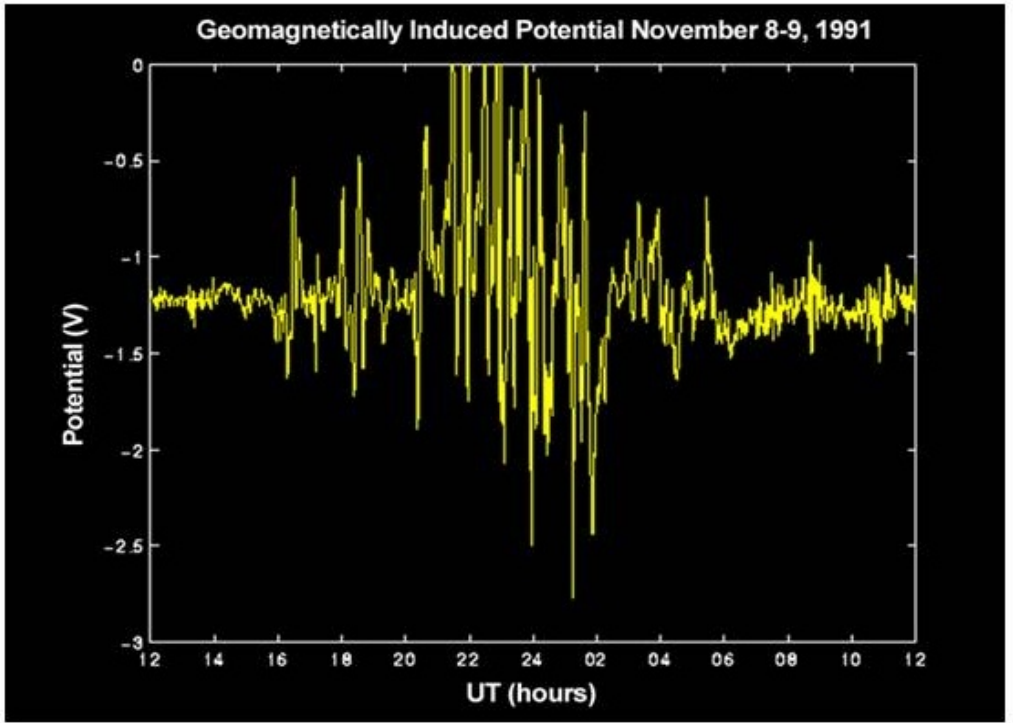
Magnetic storms: the effects

Meltdown of a transformer in South Africa due to the Halloween storm in October – November 2003.

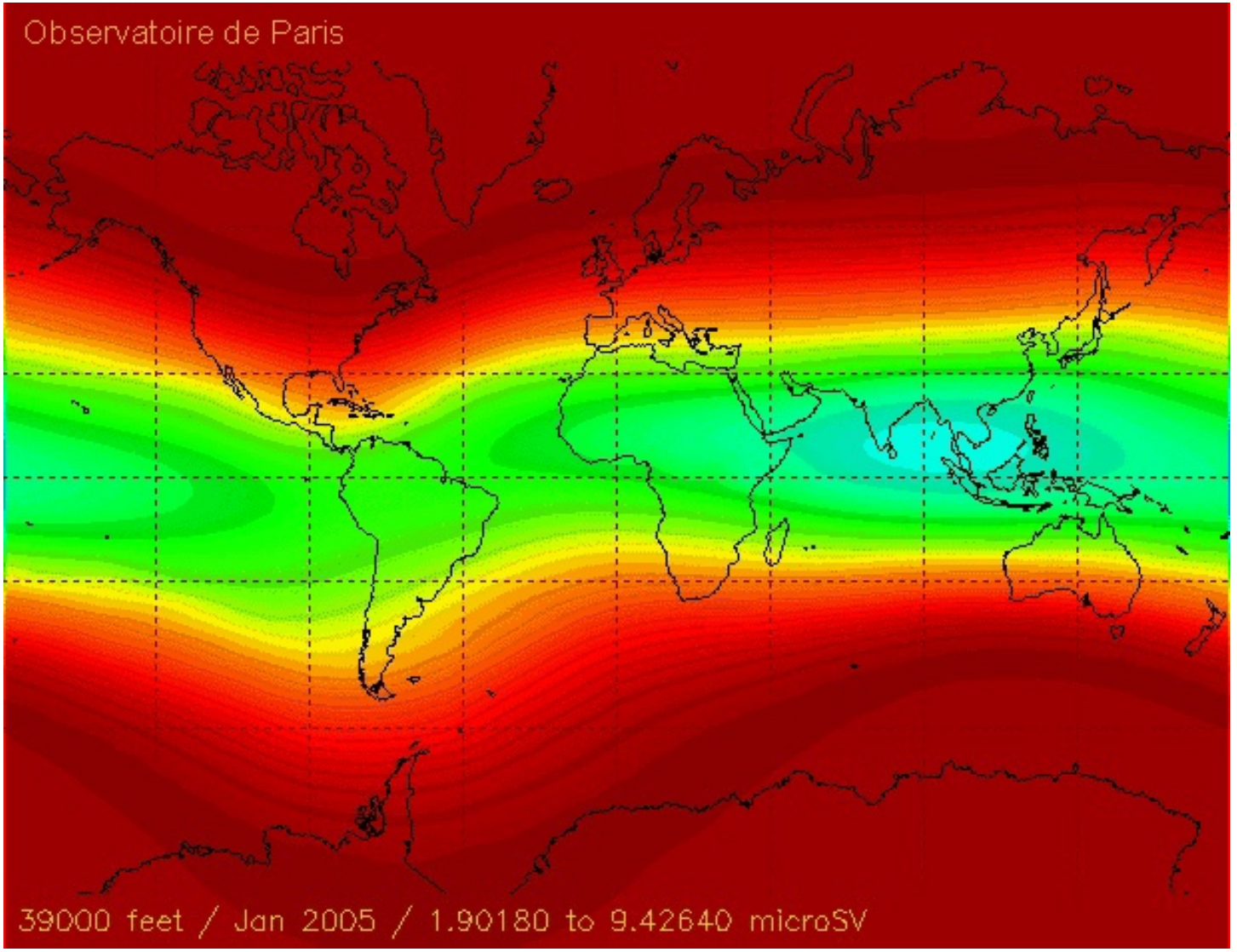
Magnetic storms: the effects

In 2006 oil was flowing out from the Alaska pipeline. Additional corrosion due to GIC's may have contributed to this accident. Here: Alaska pipeline near Fairbanks.

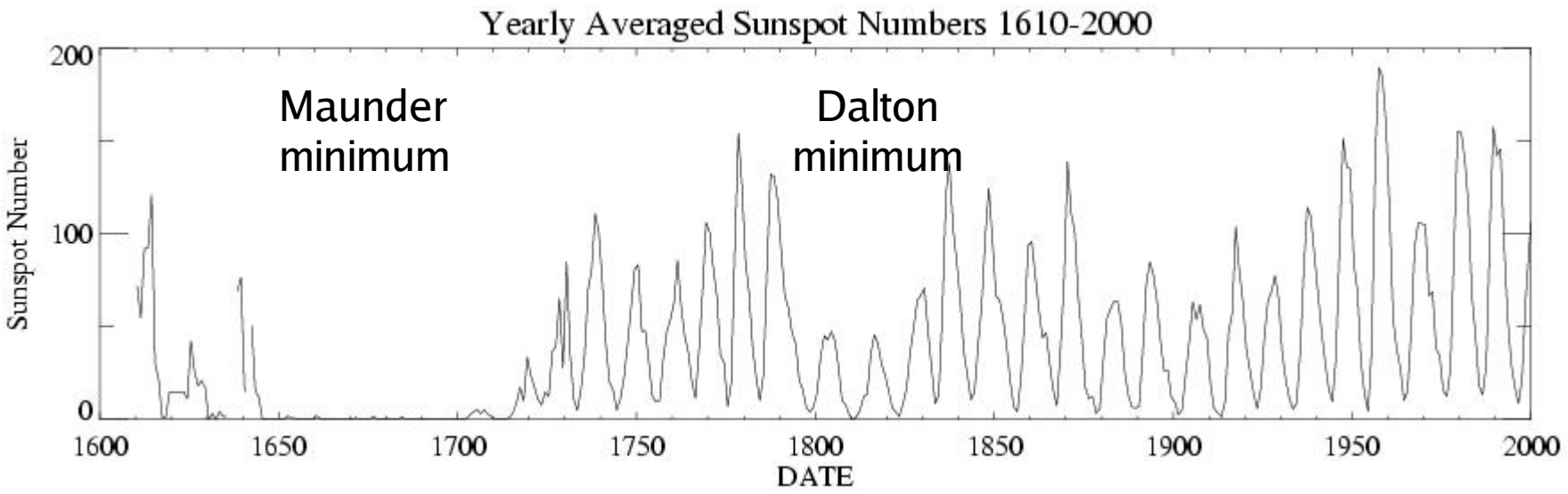
Swedish pipeline data.



Space Weather effects on biosphere



Space Weather effects on biosphere



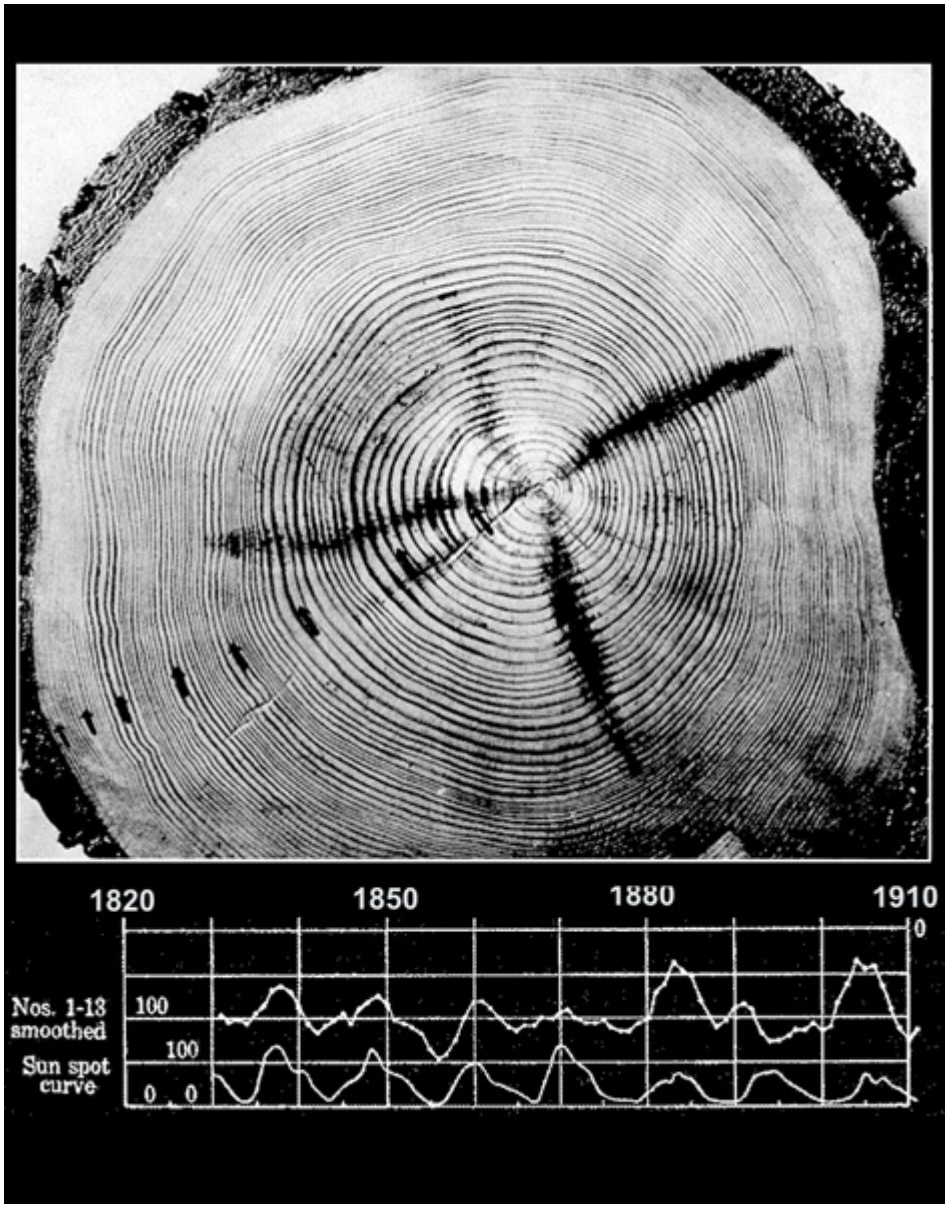
Space Weather effects on biosphere/climate

The Hunters in the Snow by Pieter Brueghel the Elder, 1565

Space Weather effects on biosphere/climate

View of River Thames in Winter (1660) by Aert can der Neer (1603-1677)

Space Weather effects on biosphere



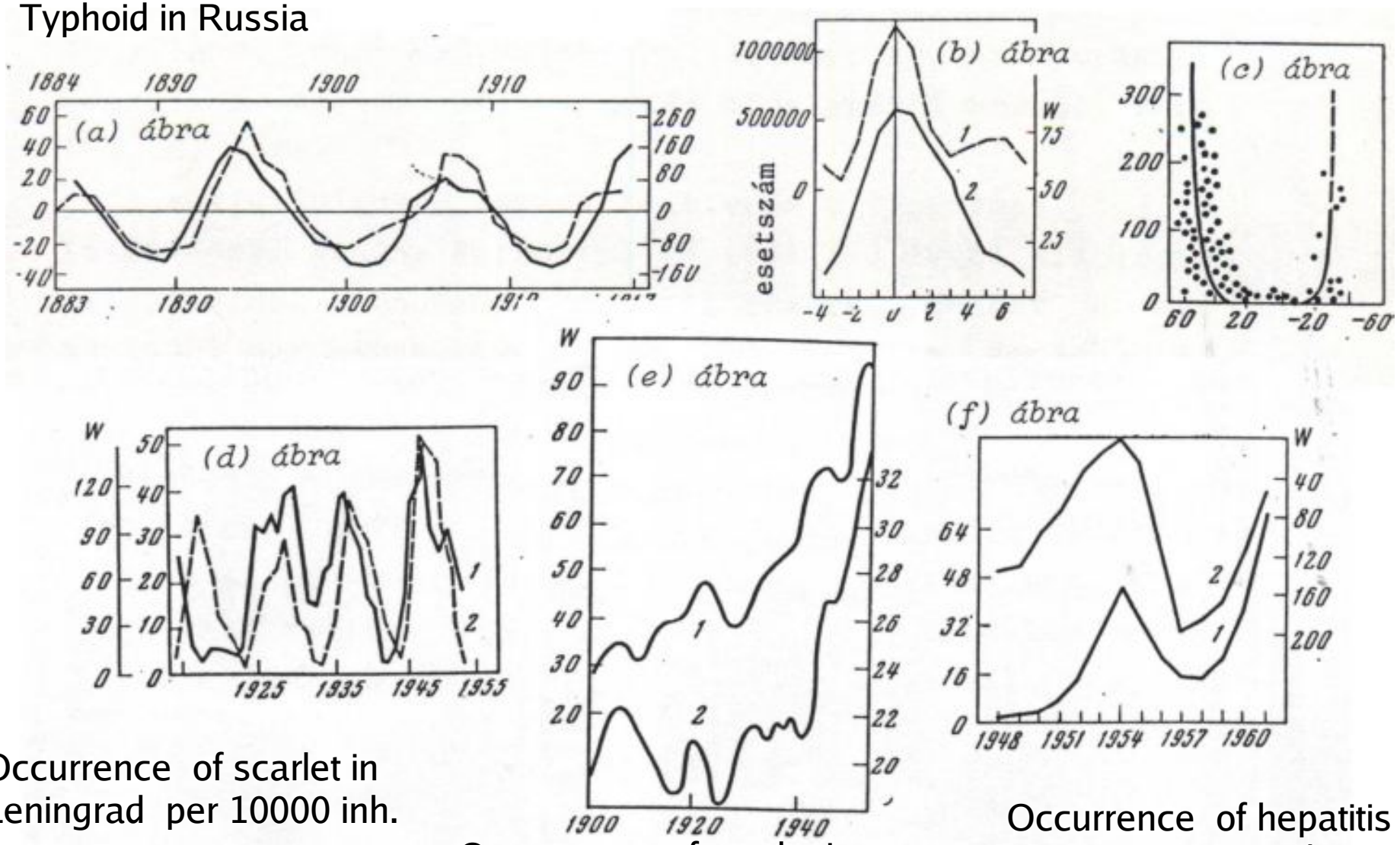
Space Weather effects on biosphere

2 = Sunspot or Wolf number

People died in cholera in Russia (1823-1923)

Occurrence of scarlet vs. latitude per 10000 inh.

Typhoid in Russia



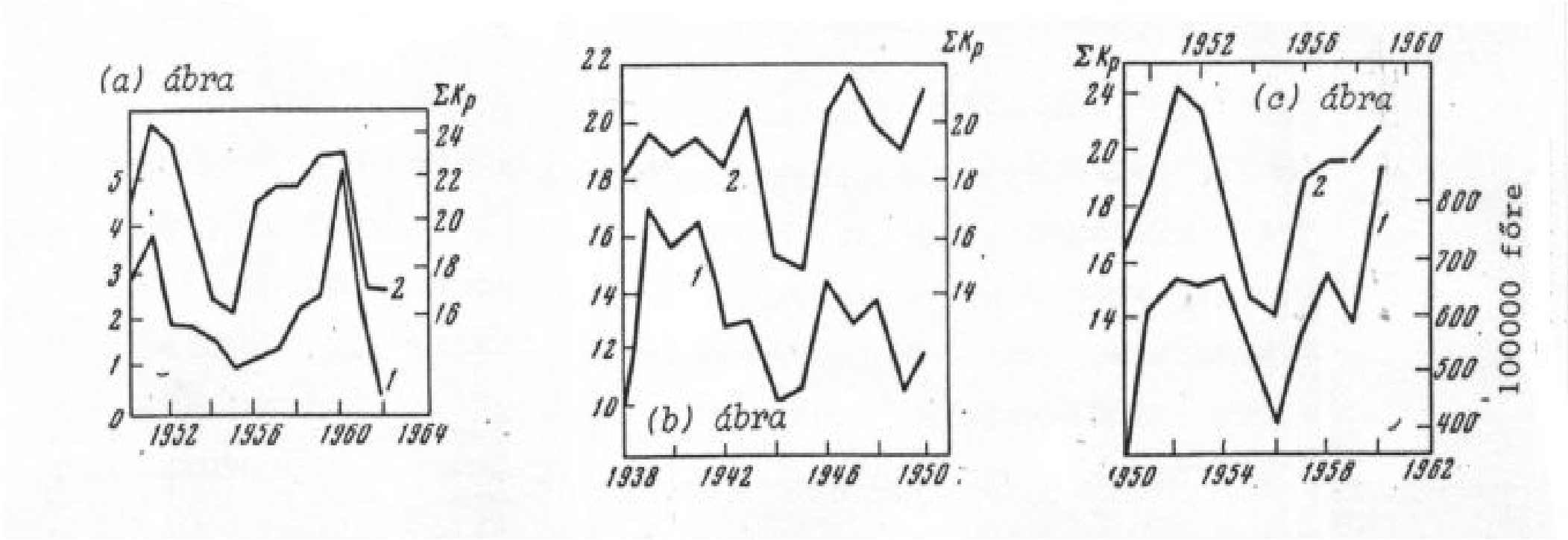
Occurrence of scarlet in Leningrad per 10000 inh.

Occurrence of scarlet in Sovietunion per 10000 inh.

Occurrence of hepatitis in USA per 10000 inh.

Space Weather effects on biosphere

2 = Kp index

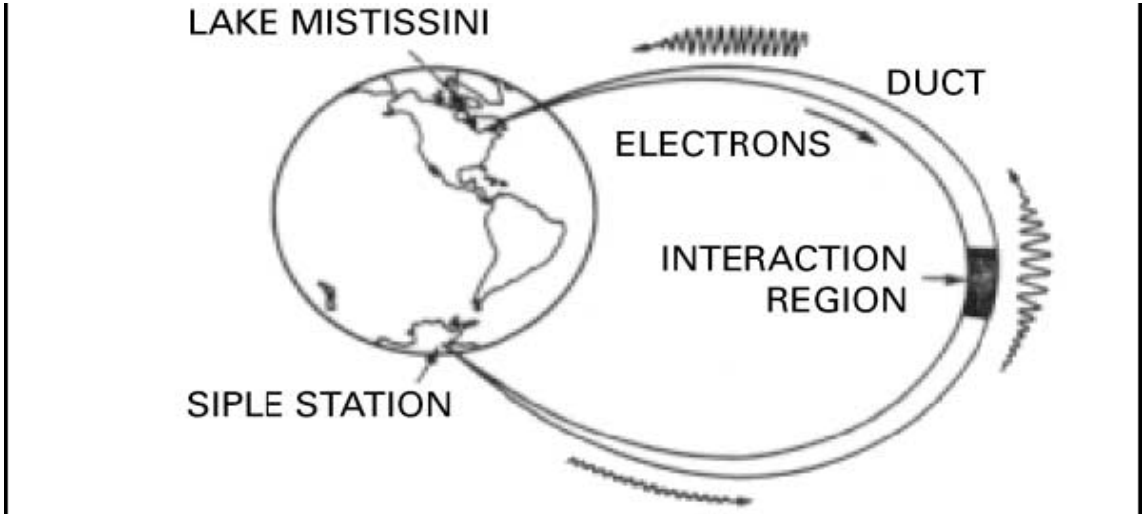


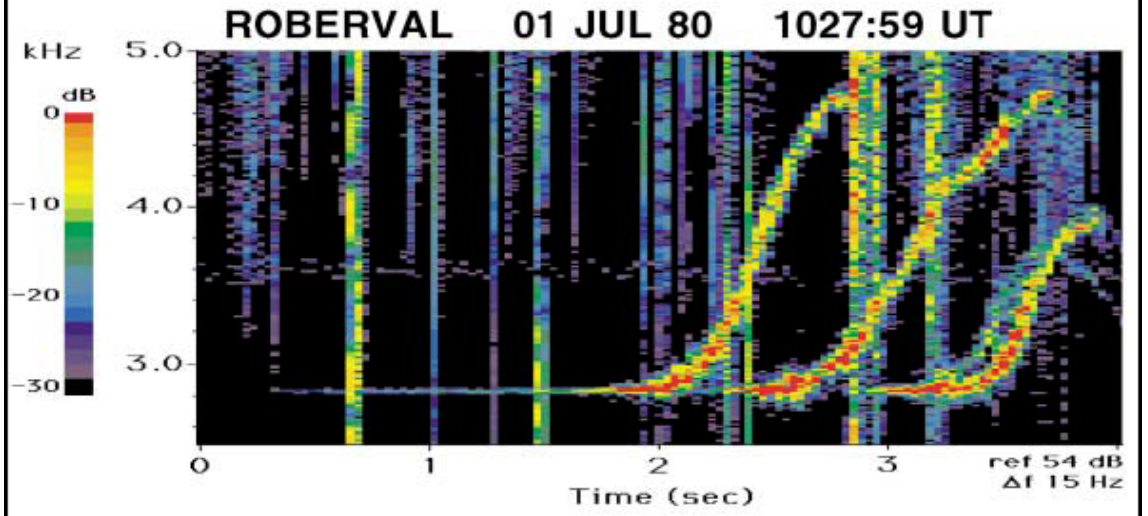
Occurrence of paralysis in Japan per 10000 inh.

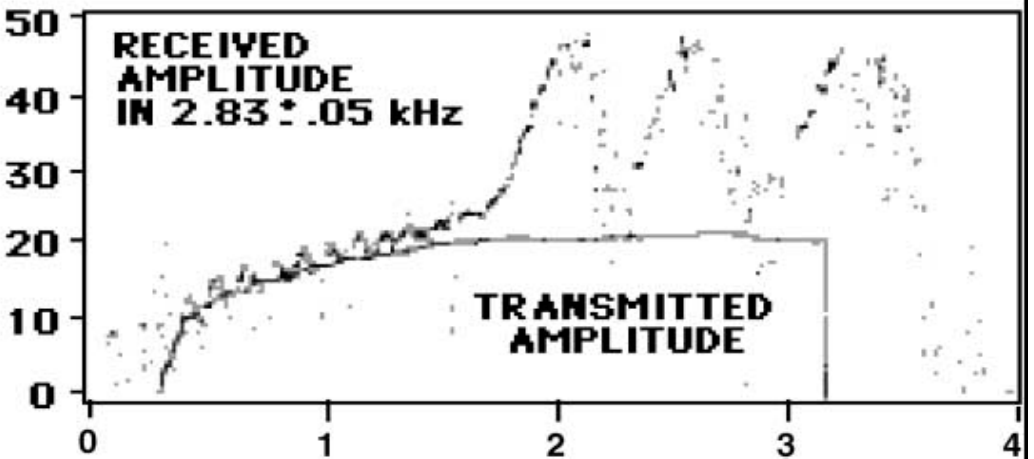
Occurrence of dysentery in world per 10000 inh.

Occurrence of tetanus in Australia per 10000 inh.

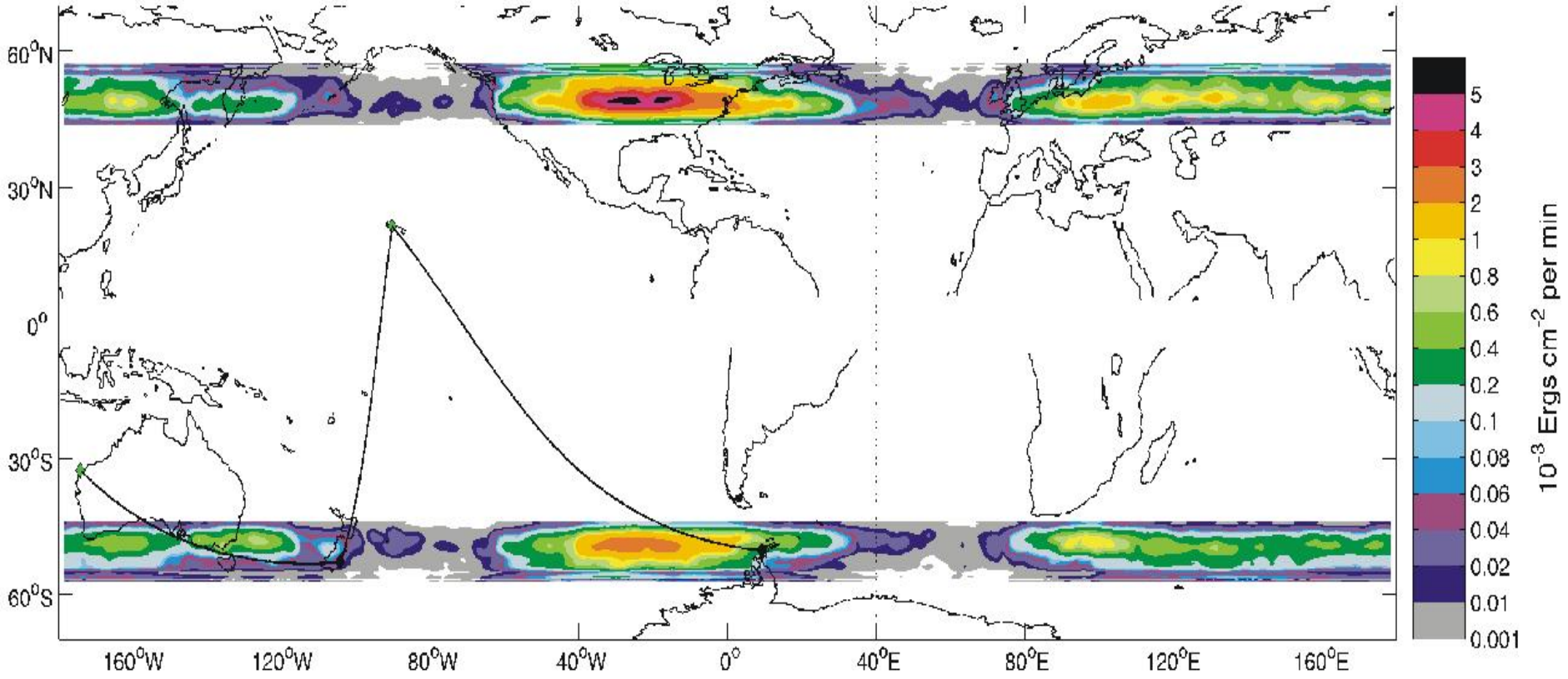
Wave-particle interaction-



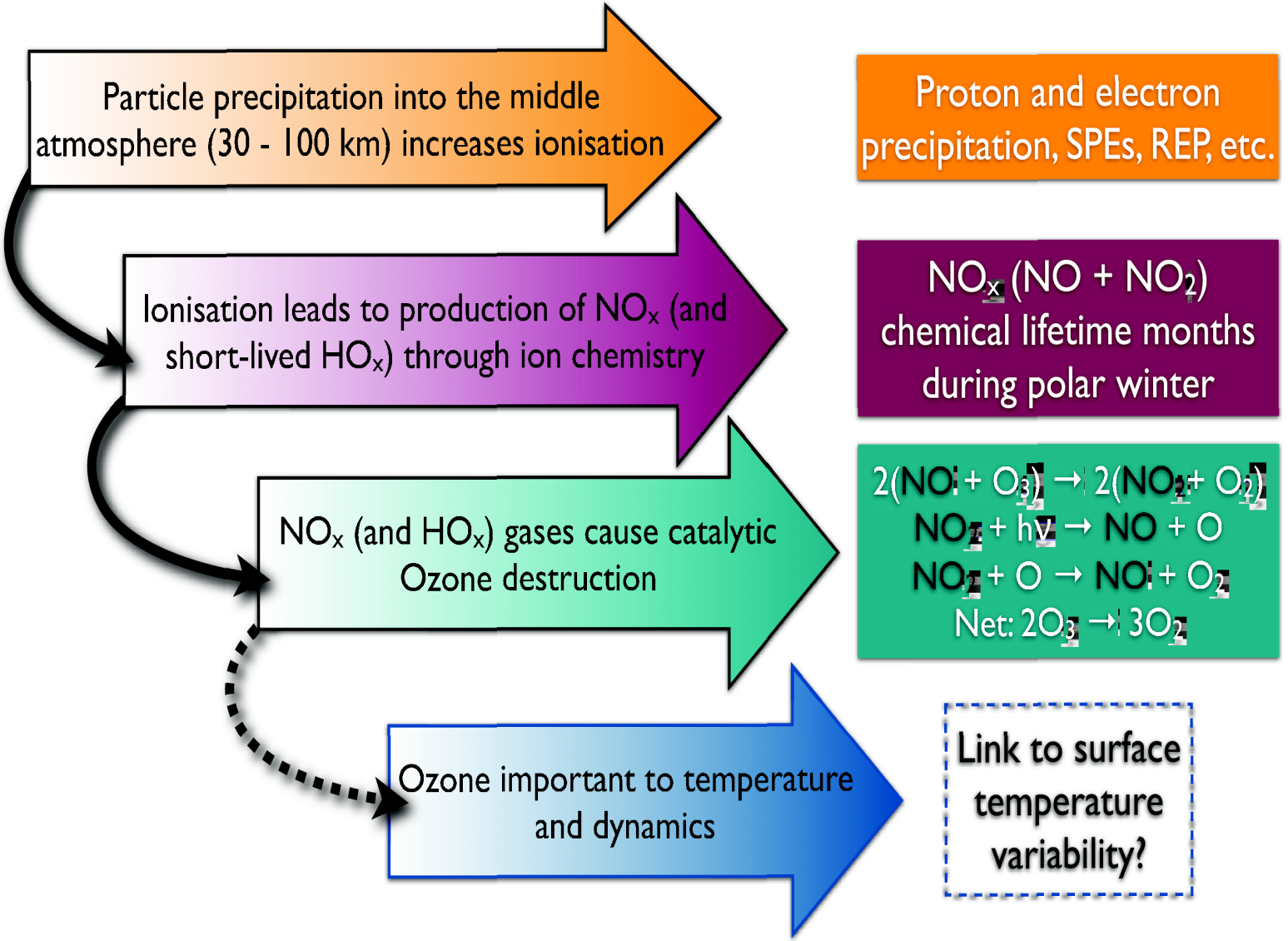




Wave-particle interaction-precipitating energy

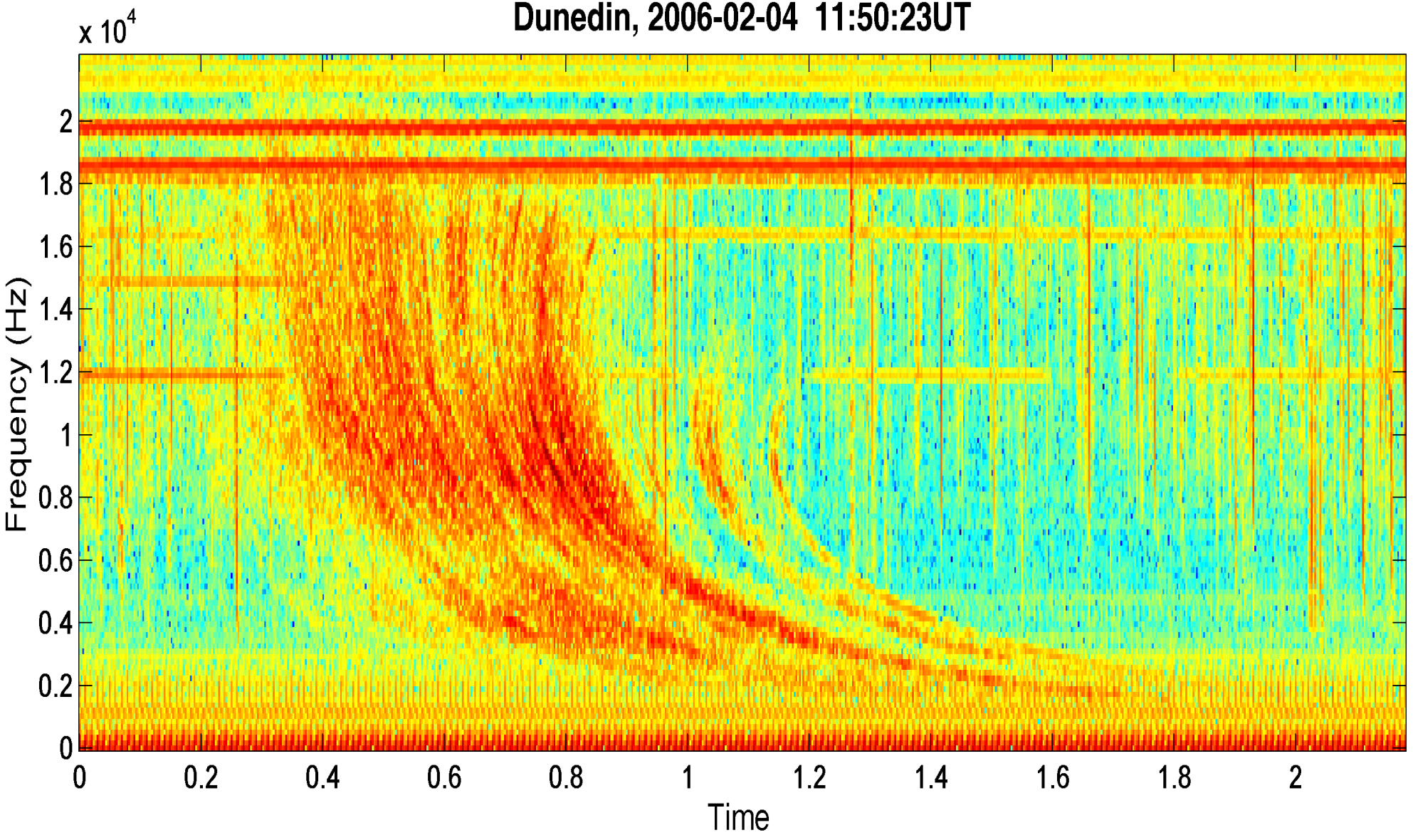


Energetic particle precipitation and the atmosphere



Music of the spheres - again

Music of the spheres
How does it look like?



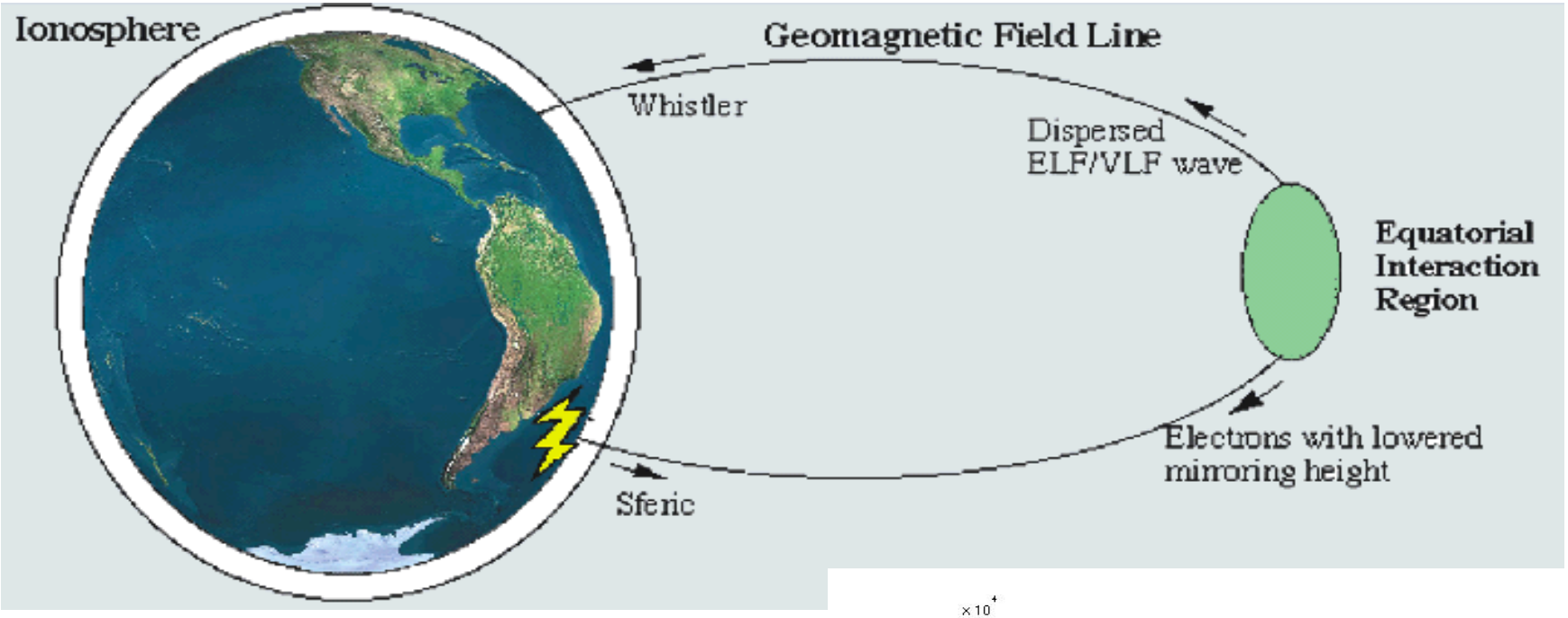
A brief history

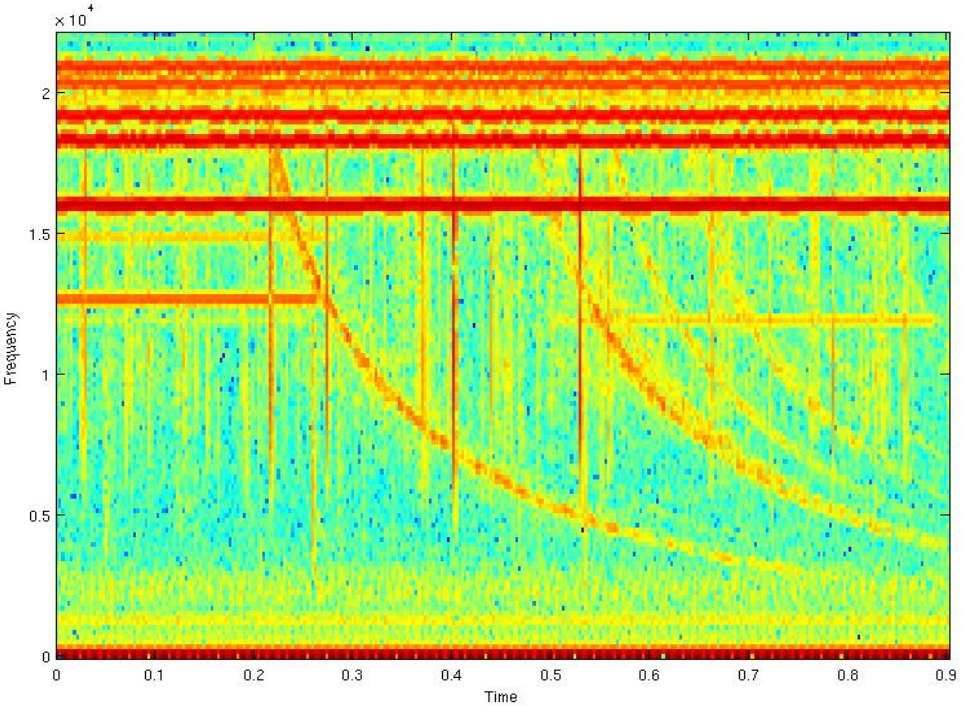
- 1886 Sonnblick High Altitude Observatory, Austria (cf. Hertz experiment, 1887): whistling noise on 22km long telephone line

A brief history II.

- Barkhausen, WWI: spy on enemy communications – or 'heard the grenades fly'
- 1953 L. R. O. Storey: origin and propagation of whistlers, *plasmasphere, short* and *long* whistlers
- 1956 R. Helliwell: *nose whistlers*
- 1963 D. Carpenter *plasmapause*

Origin of *whistlers*





What are the *whistlers* good for?

1. ***Nose*** frequency
2. ***Dispersion***

From ***1.*** + ***2.*** => where & what

Where did it travel in *plasmasphere*

What was the *plasma density* there

Traditional whistler analyses

- Both steps of analyses require continuous human assistance :

  - selecting whistler traces

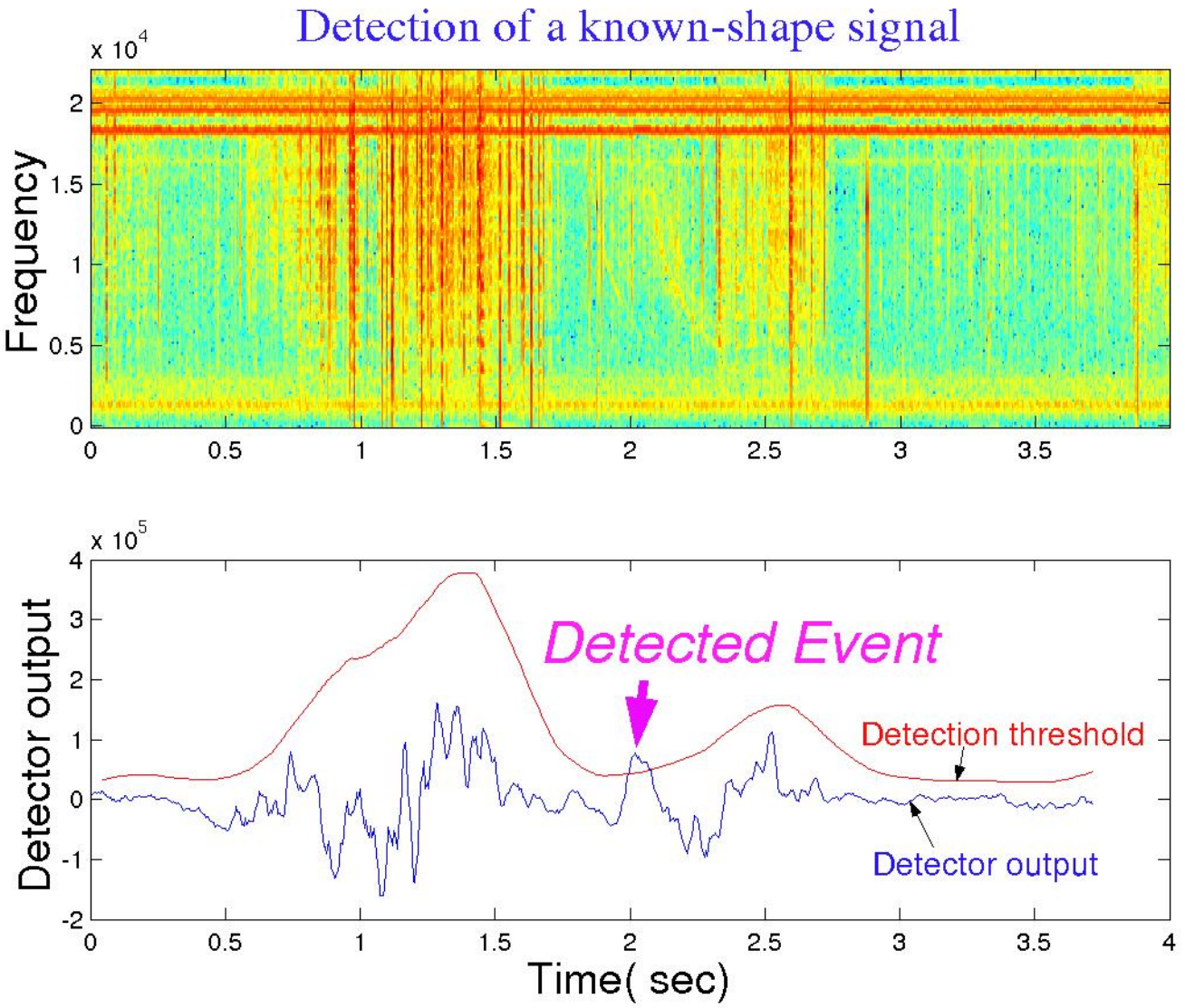
  - scaling the traces

- Both are tiresome – complete analysis of 1 hour recordings usually requires a day or more→ no one can make non-stop recording – thus it never becomes a standard application and was never used in *Space Weather*

Automatic Whistler Detector and Analyzer (AWDA) System

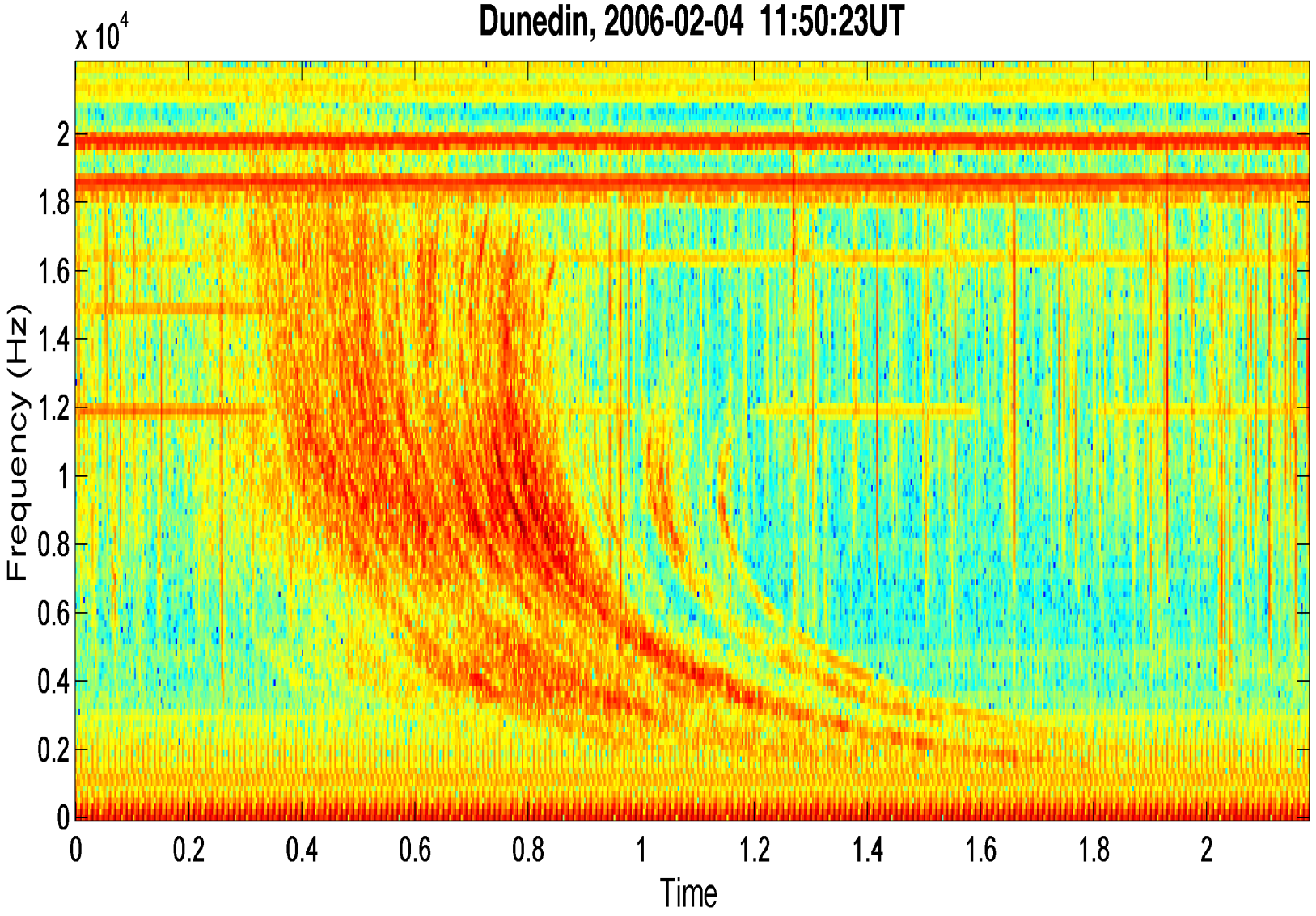
- Both steps of analysis are automatic:
  - detection of whistler traces
  - scaling of traces
- It can run non-stop with minimal human control

Automatic Whistler Detector

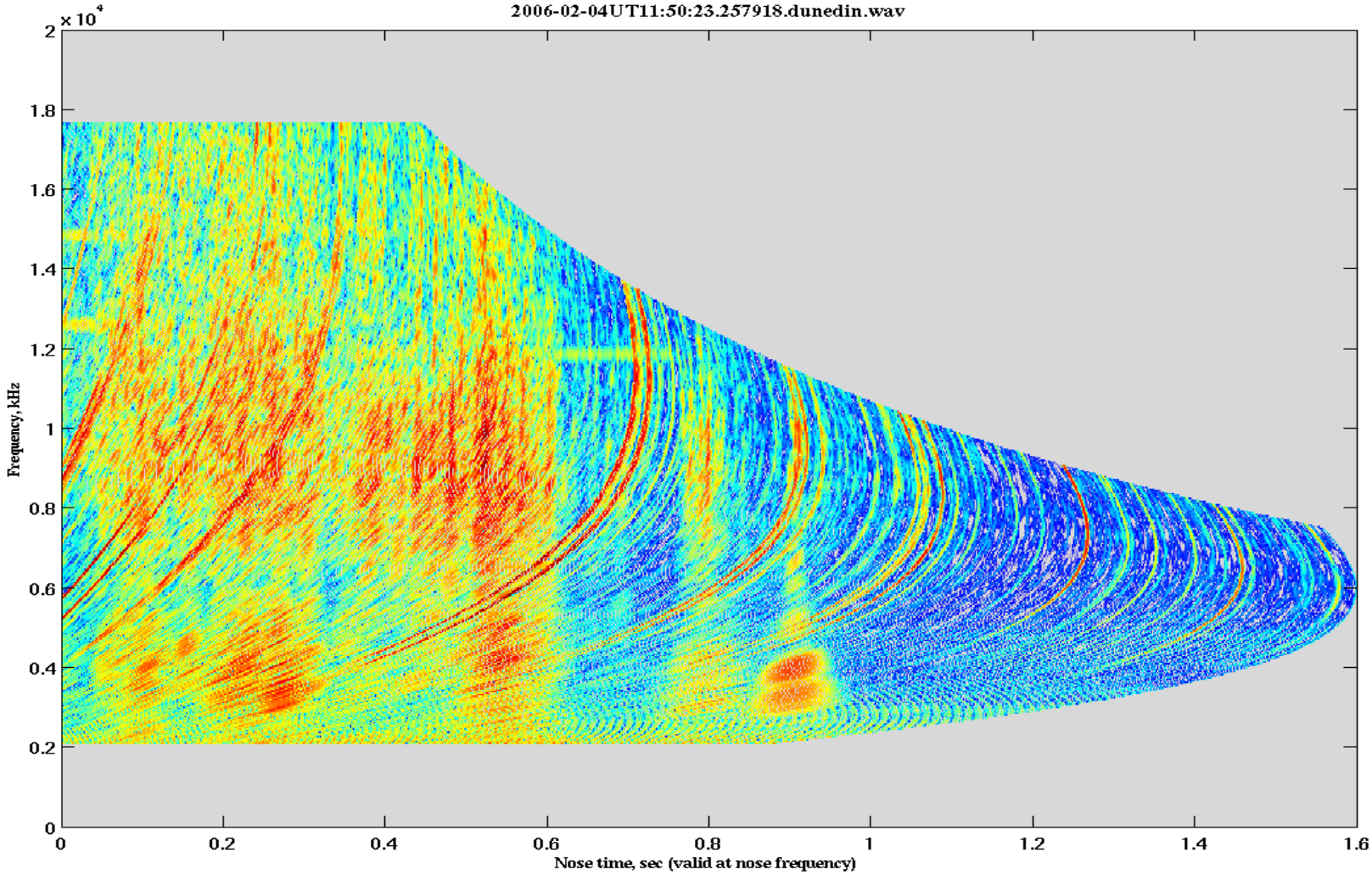


Virtual whistler trace transformation (VTT)

(Lichtenberger, JGR, 2009):



Virtual whistler trace transformation (VTT) – it can be applied to the spectrogram matrix and not to individual *(f-t)* pairs!



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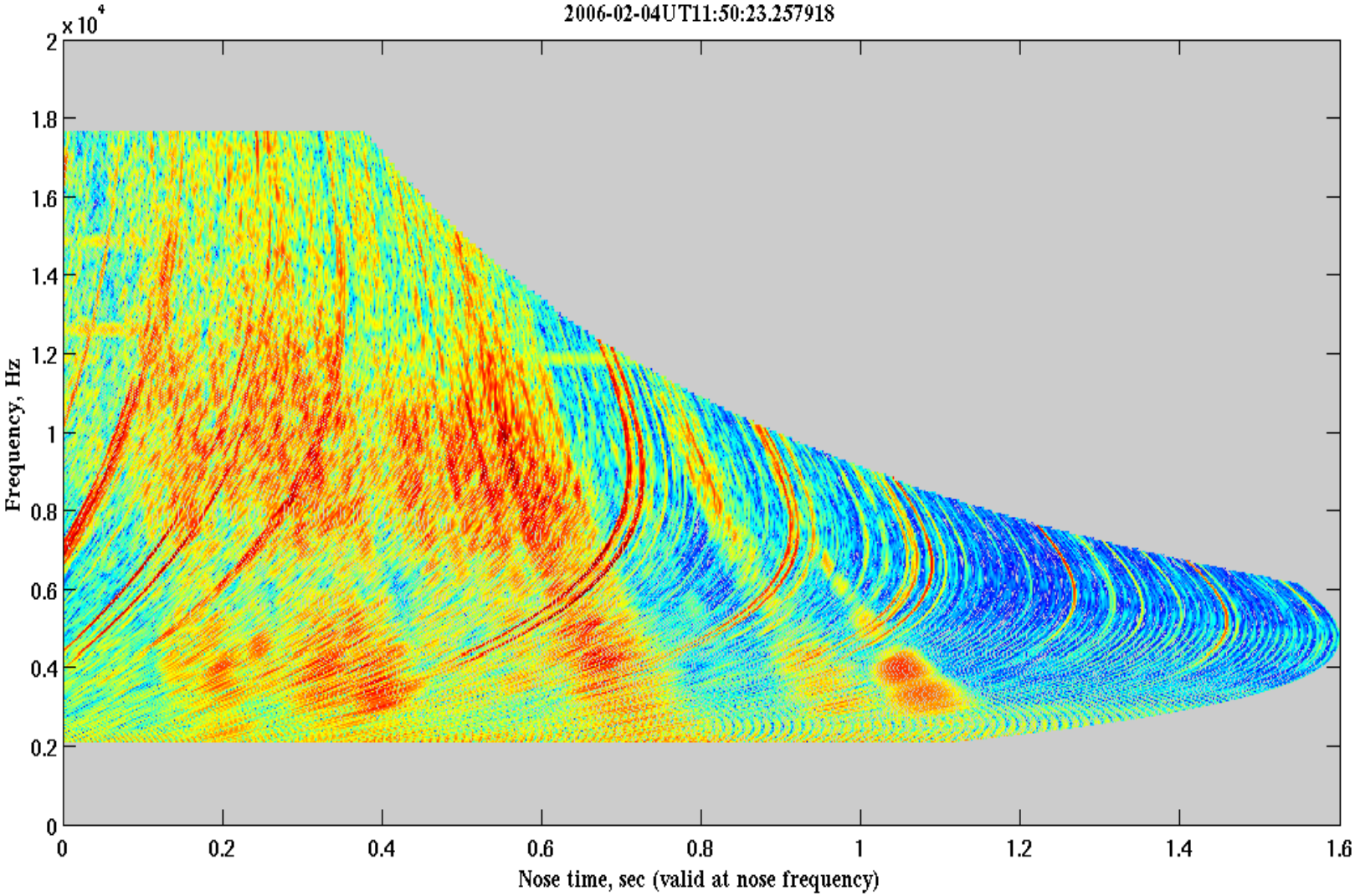


Automatic Whistler Detector and Analyzer (AWDA) system [Lichtenberger et al., *JGR*, 2008]:

Whistlers are searched in the broad-band VLF signal without human interaction

Automatic whistler analyses yields plasma and propagation parameters → electron density distribution → *Space Weather*

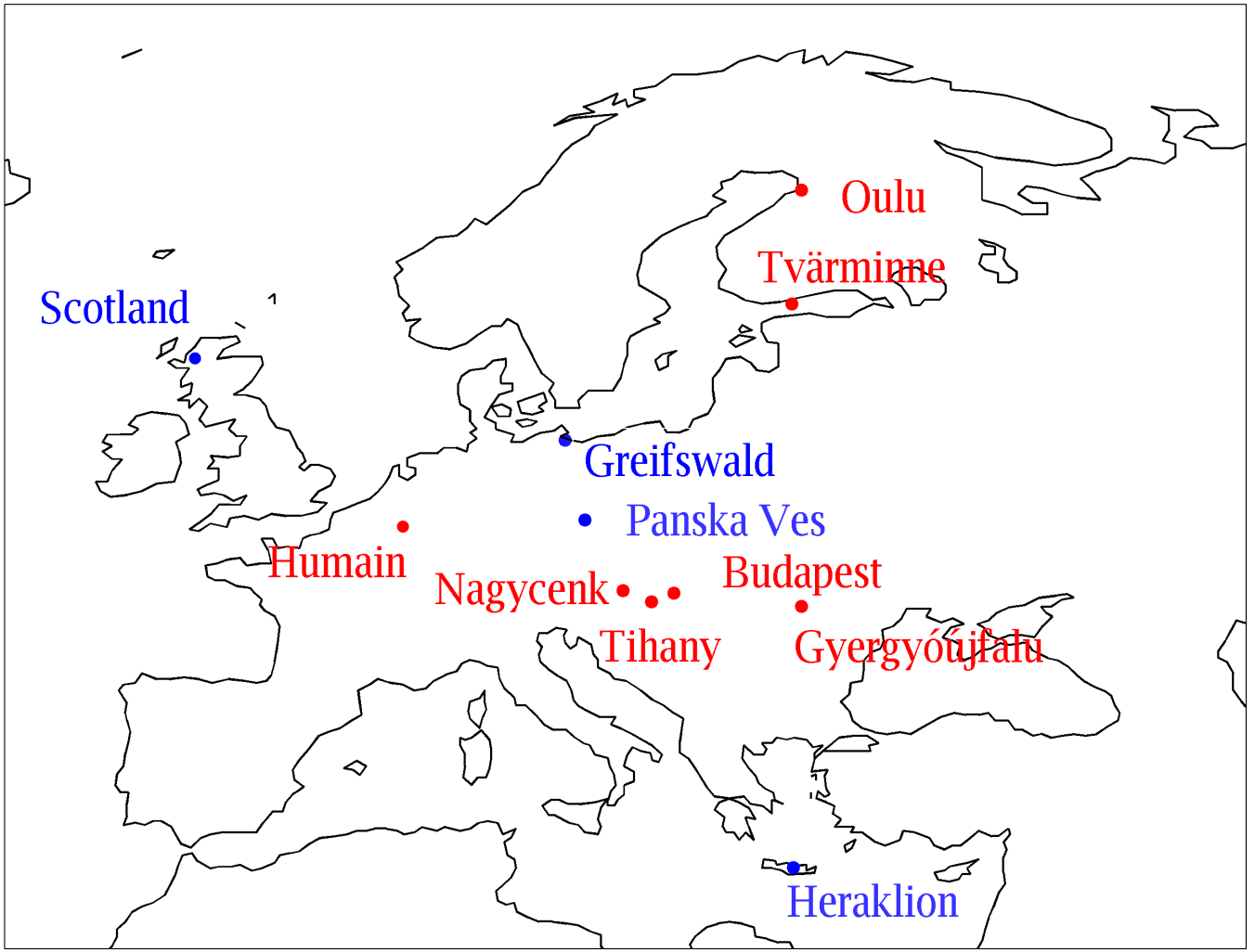
AWDANet

Extending network of AWDA systems covering low-, mid- and high (magnetic) latitudes since 2002 including conjugate locations

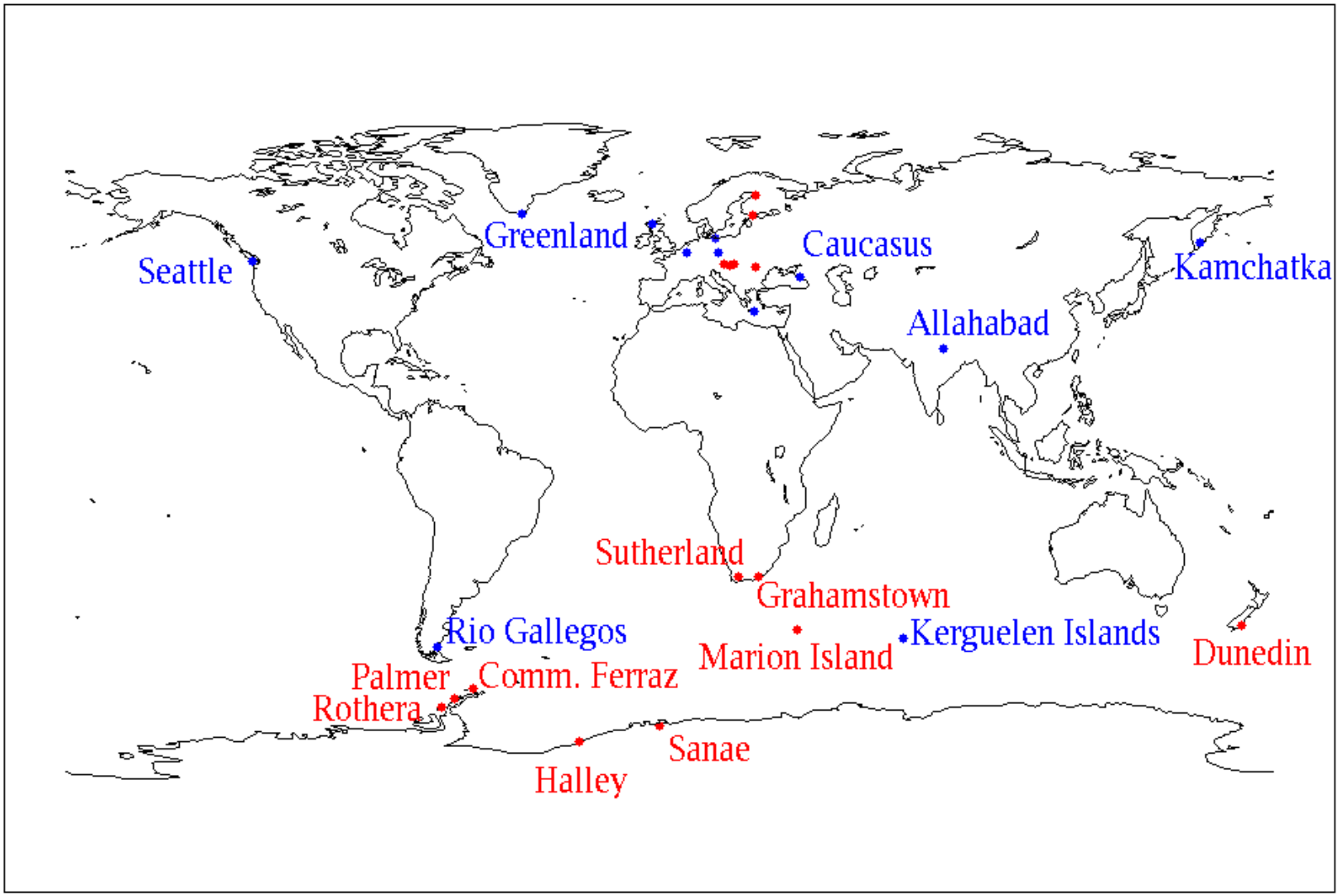
~50 000-10 000 000 (!) traces/year/station

Real time operation is in *experimental* phase

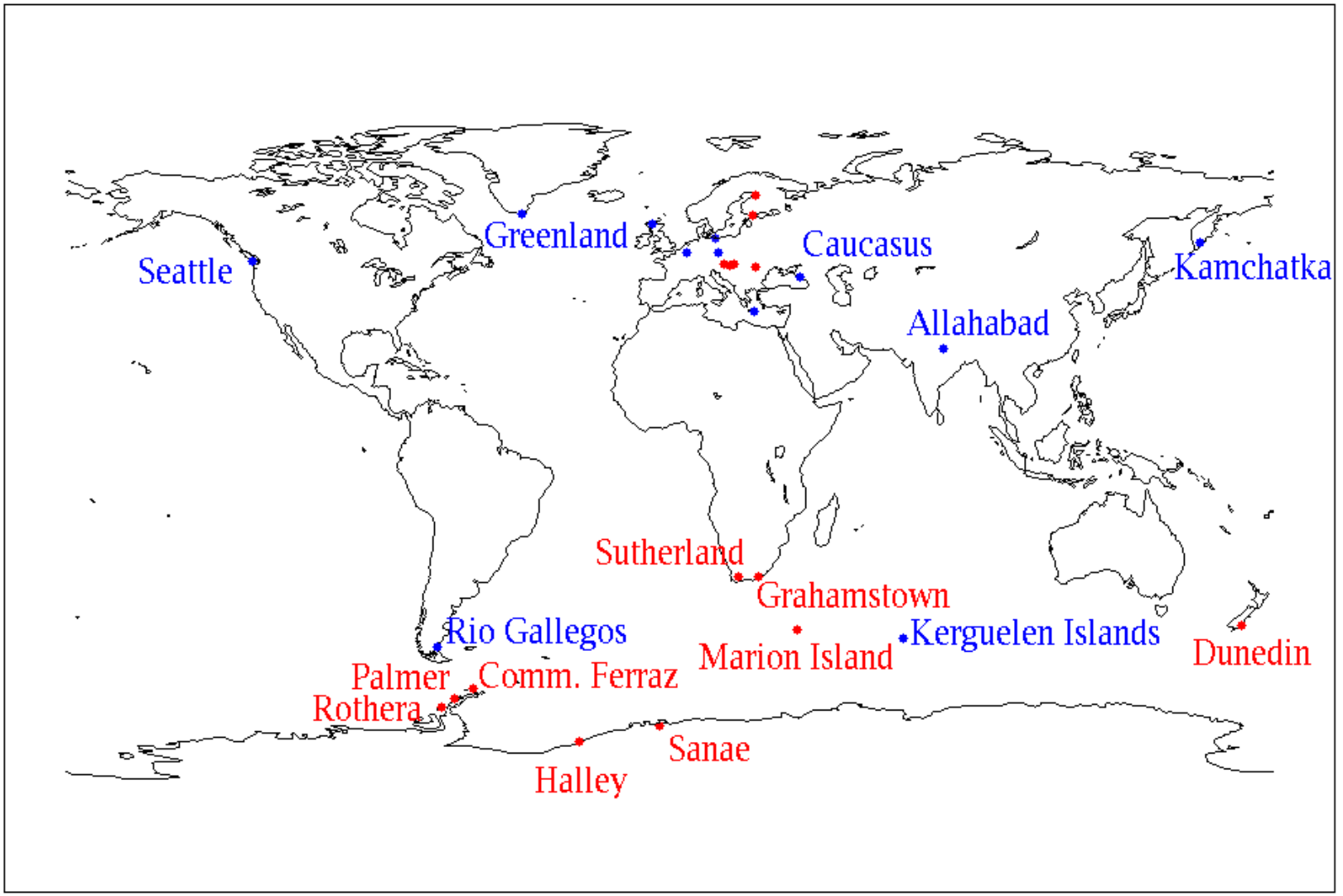
AWDANet -Europe



AWDANet - World

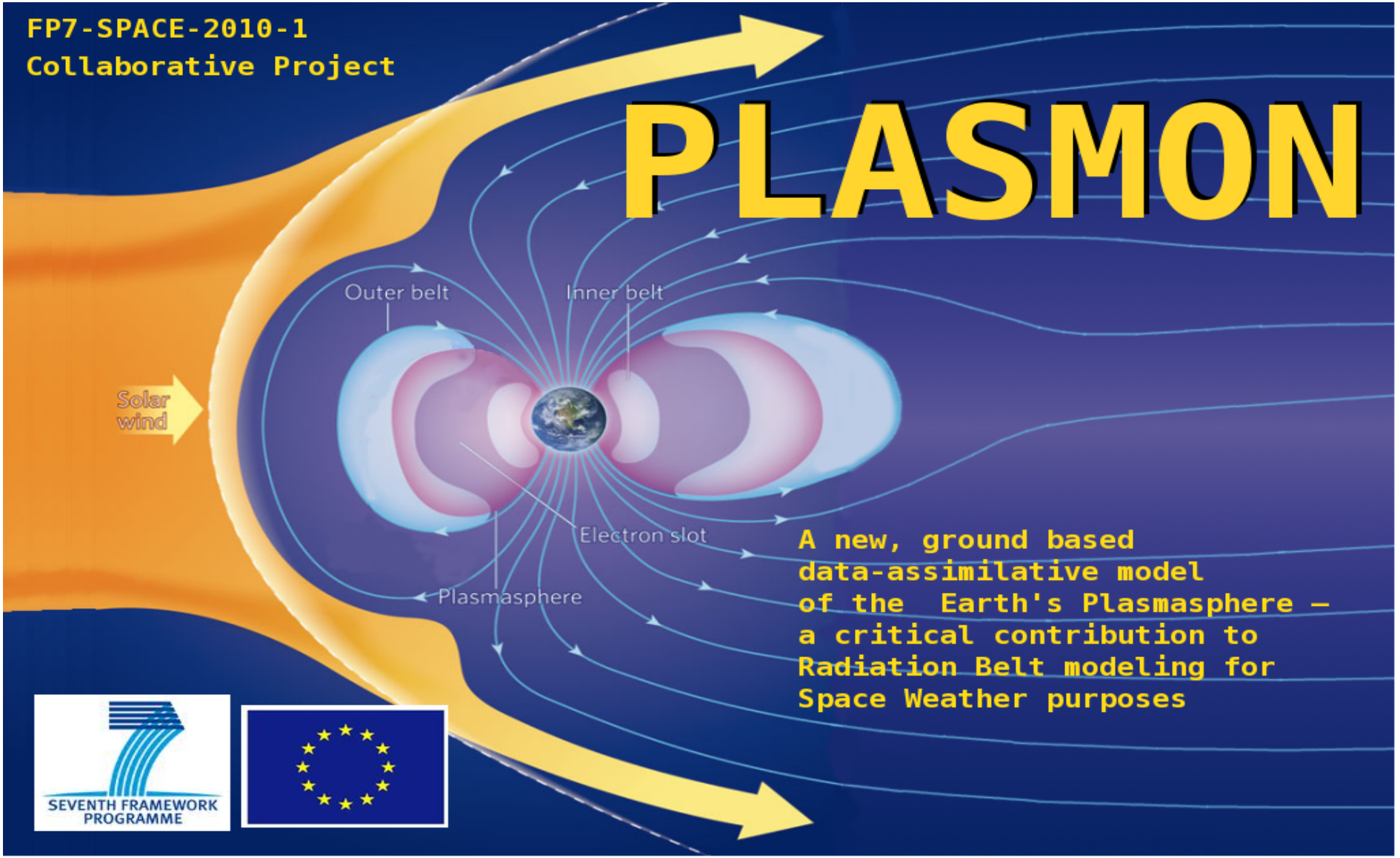


AWDANet - World



FP7-SPACE-2010-1
Collaborative Project

PLASMON



A new, ground based data-assimilative model of the Earth's Plasmasphere – a critical contribution to Radiation Belt modeling for Space Weather purposes

SEVENTH FRAMEWORK PROGRAMME

UNIVERSITAS BUDAPESTINENSIS DE ROLANDO EÖTVÖS NOMINATA

http://plasmon.elte.hu

Participants

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Eötvös University	János Lichtenberger	Hungary
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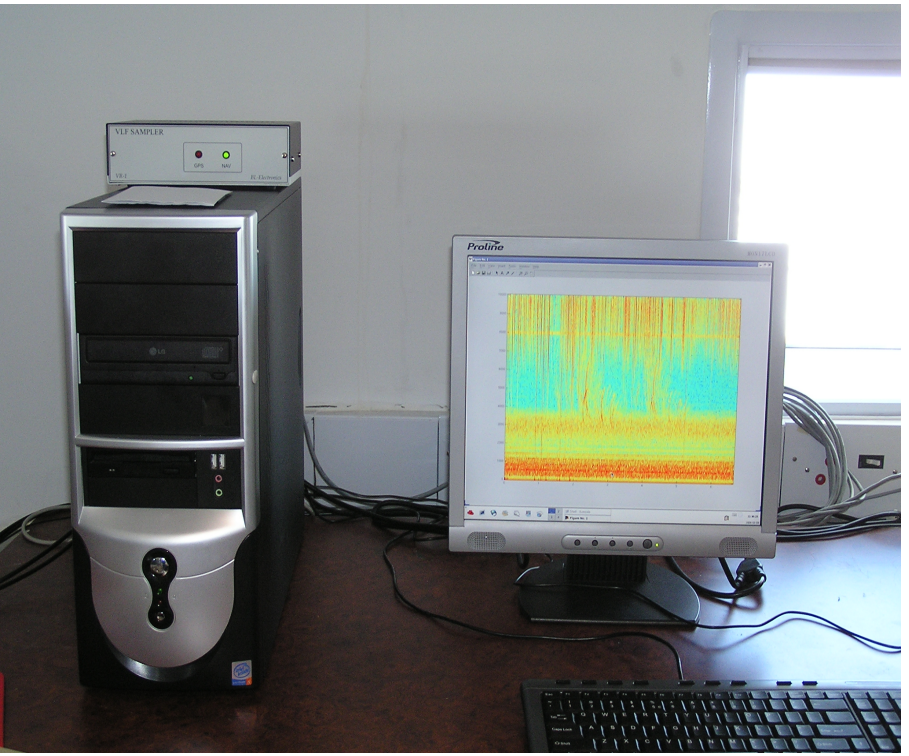
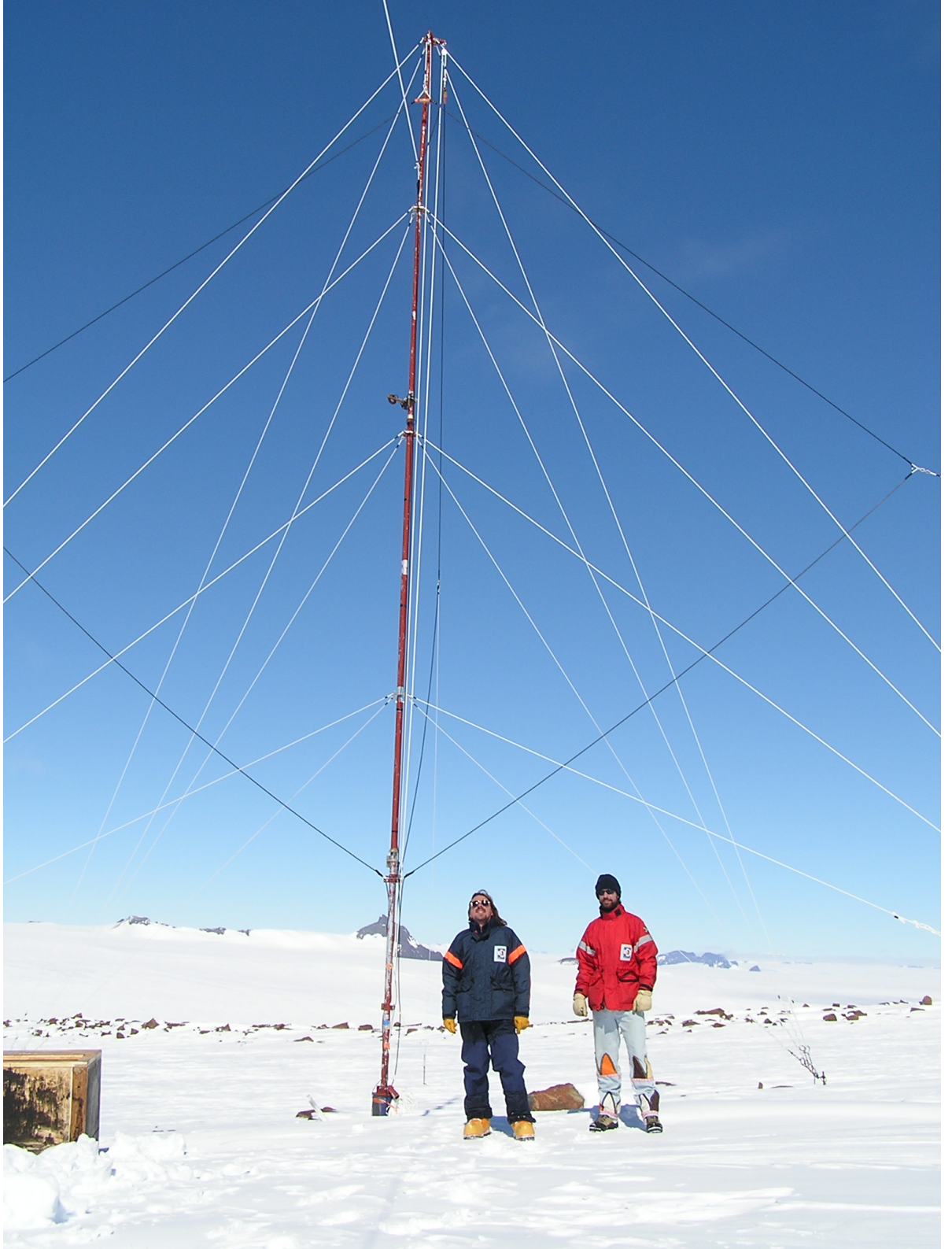
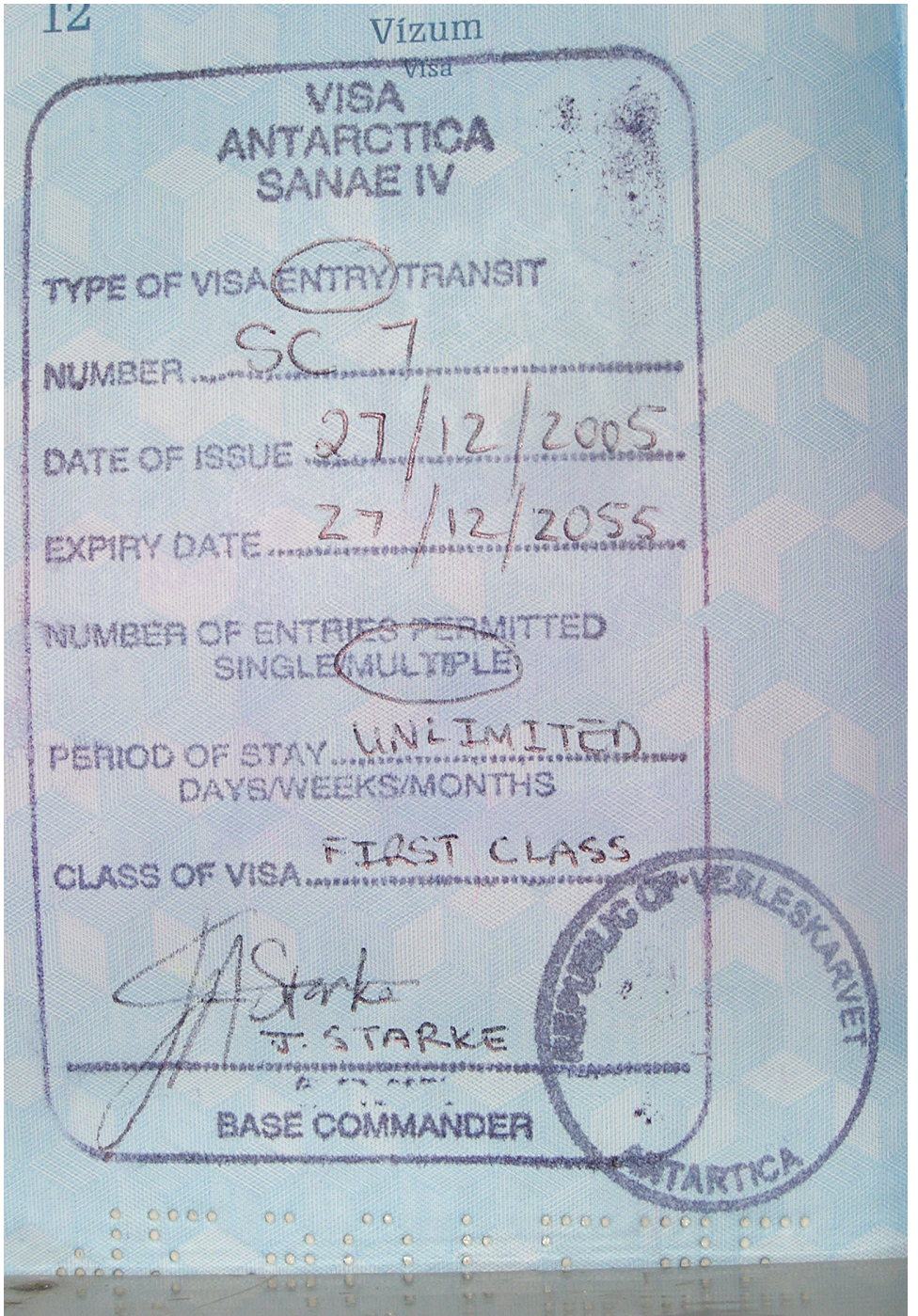
Eötvös Loránd Geophysical Institute	Balázs Heilig	Hungary
University of L'Aquila	Massimo Vellante	Italy
Sodankyla Geophysical Observatory	Jyrki Manninen	Finland
University of Otago	Craig Rodger	New Zealand
Hermanus Magnetic Observatory	Andrew Collier	South Africa
New Mexico Institute of Mining and Technology	Anders Jorgensen	USA
Institute of Geophysics, Polish Academy of Sciences	Jan Reda	Poland
University of Washington	Robert Holzworth	USA
Los Alamos National Laboratory	Reiner Friedel	USA

The *AWDANet* station – the first *stand-alone* Hungarian space experiment in Antarctica





The first *gulyás* in *Antarctica* - and the prize for it



SANAE, Antarctica, the advent of twelfth-night, 2006