# A Geophysical approach to assess Space Weather impacts on Earth

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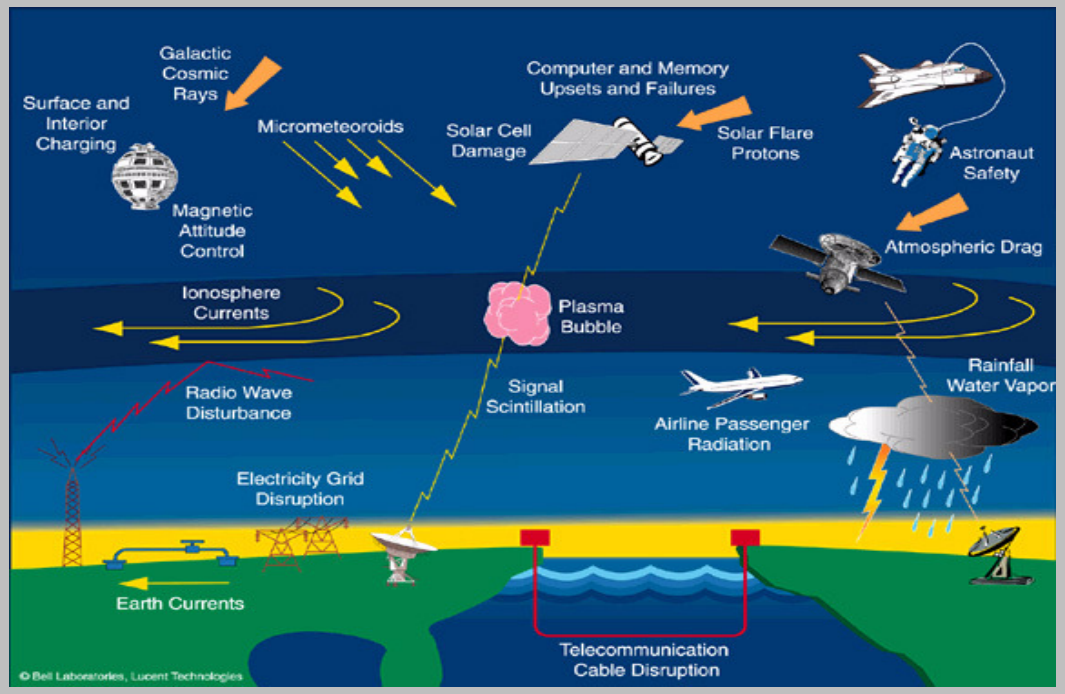
# Space Weather

The term "space weather" refers to conditions on the **Sun** and in the **solar wind**, **magnetosphere**, **ionosphere**, and **thermosphere** that can influence the performance and reliability of **space-borne** and **ground-based technological systems** and that can affect **human life or health**.




The underlying physics is not sufficiently well understood, and thus we do not have **appropriate warning tools** at hands. Further fundamental research is needed in order to finally understand the processes that tie our home planet to its parent star, the Sun.

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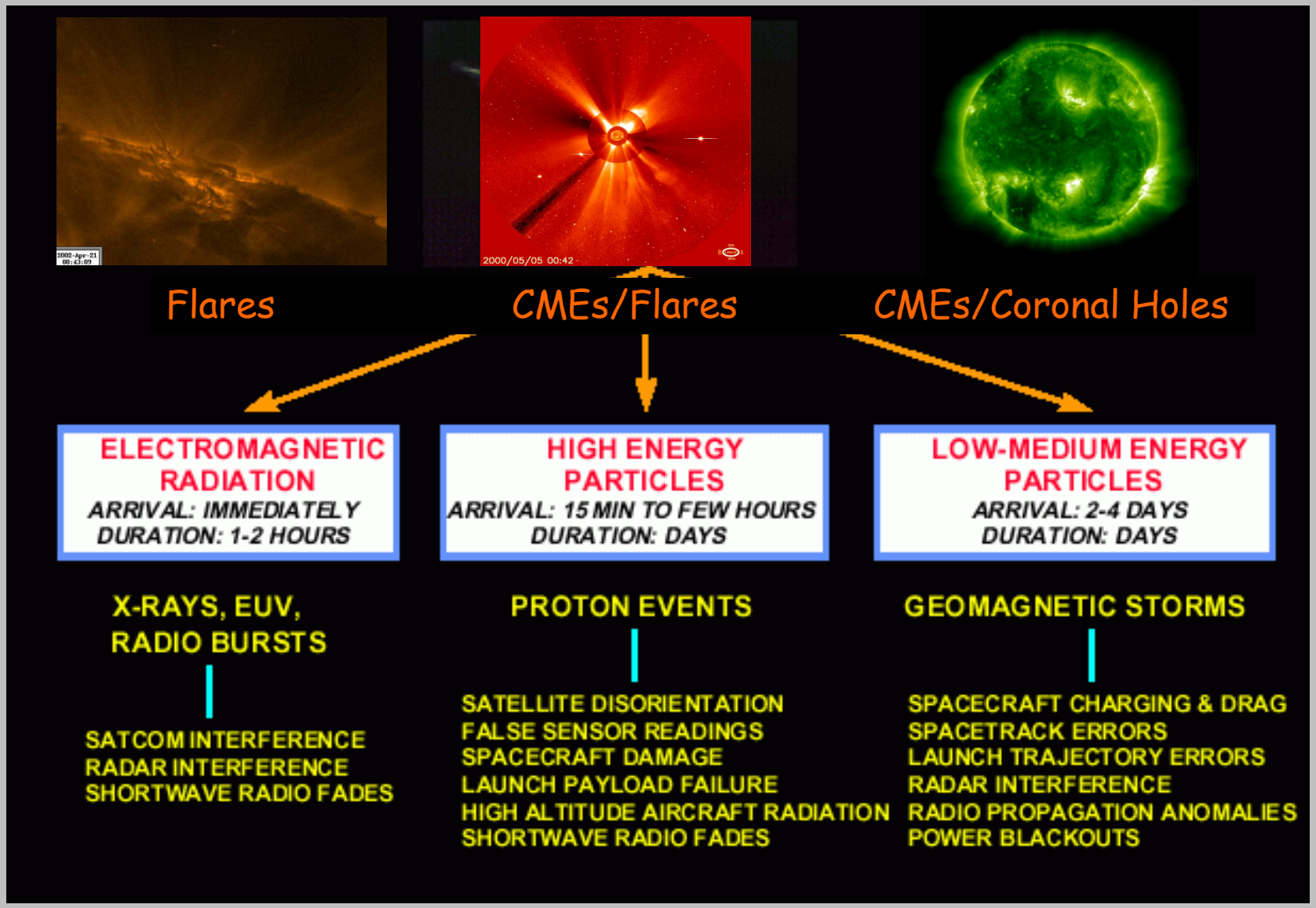
# Space Weather

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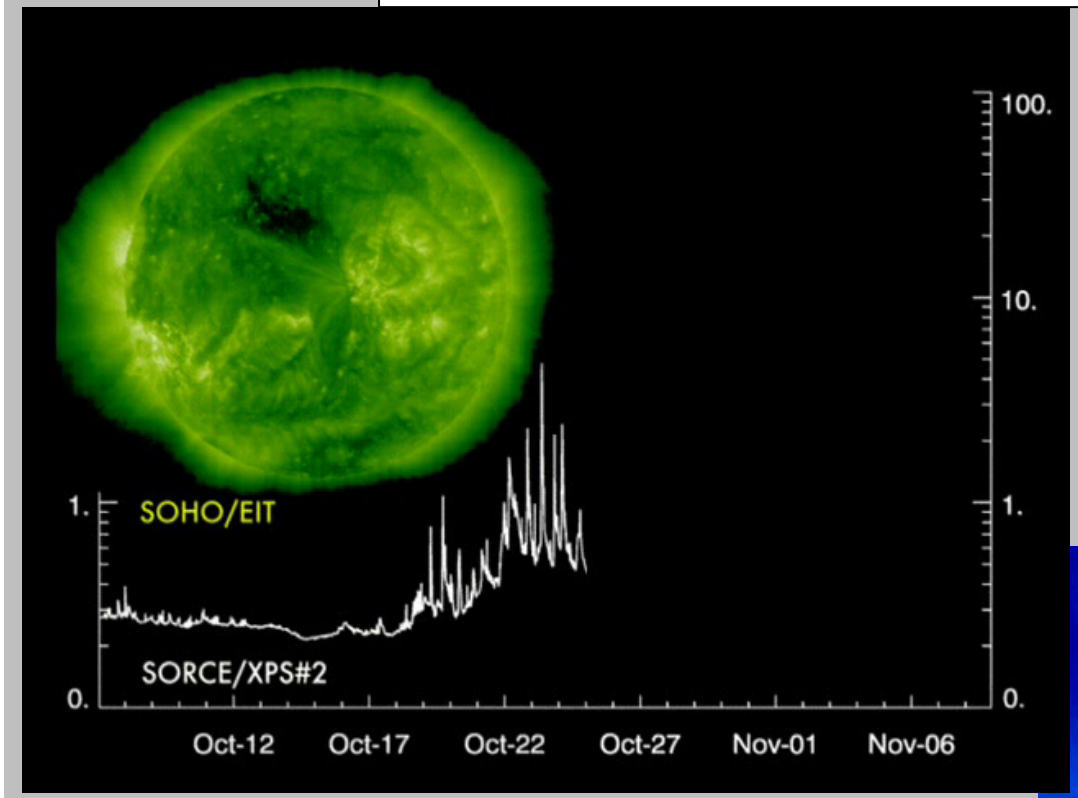
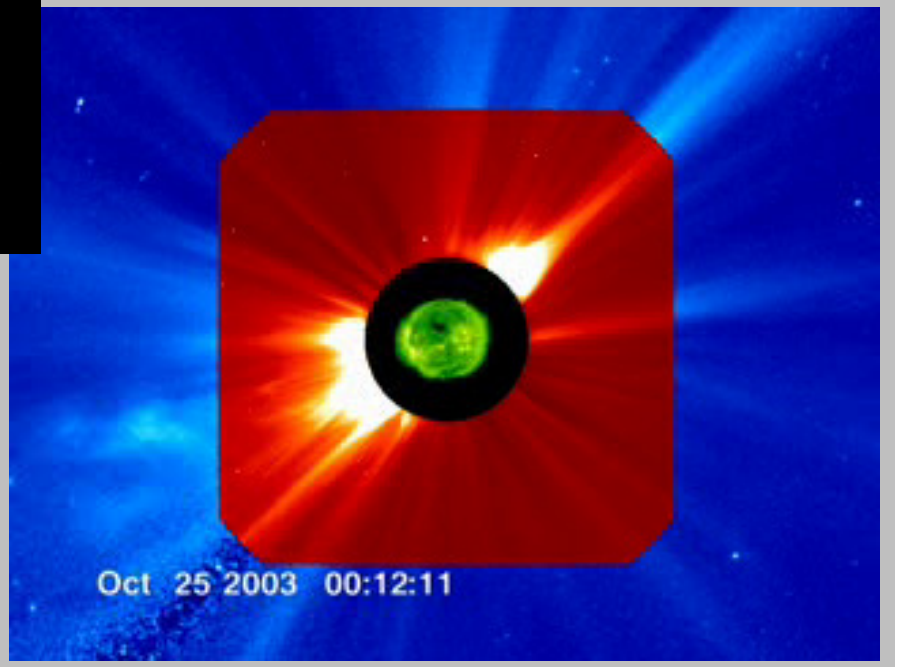
# Space Weather: causes




Coronal Mass Ejection (CME)

1 AU = 150 $10^6$ km ~ 110 solar Ø

Arrival time at 1 AU ~ 1.5 – 4 days




← 07/10/2003 to 09/11/2003 →

CMEs are fundamental for predictions on Space Weather conditions

# Space Weather: growing demand on SW products

Our society is much more dependent on technology than ever before.

The most rapidly growing sector of the communication market is satellite based:

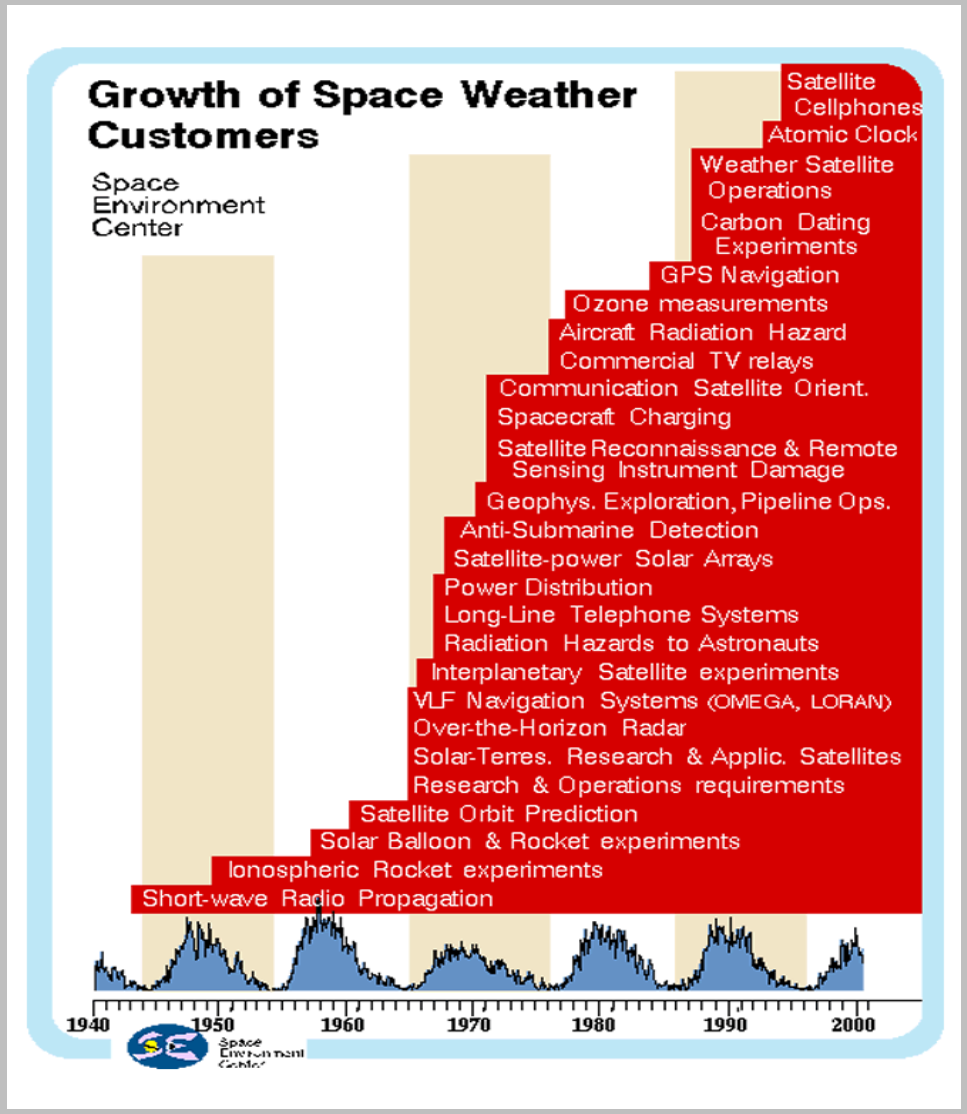
- broadcast TV/Radio
- long-distance telephone service, cell phones, pagers
- internet, finance transactions

Change in technology:

- more sensitive payloads
- high performance components
- lightweight and low cost

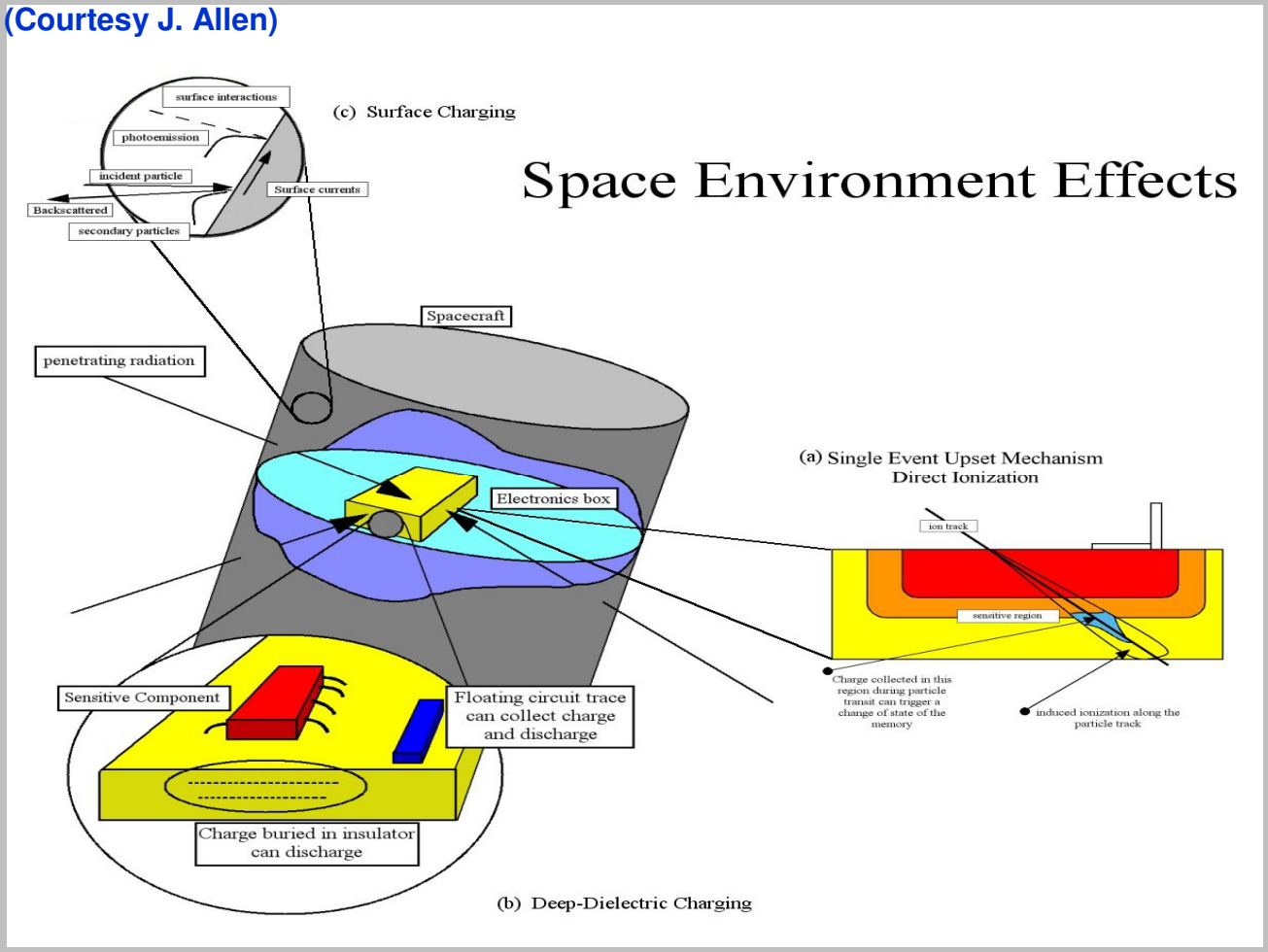
Humans in space:

- more and longer manned missions



# Space Weather: effects

(Courtesy J. Allen)




**Single Event Upset (SEU)**

→ high energy protons or heavier ions

Component destruction

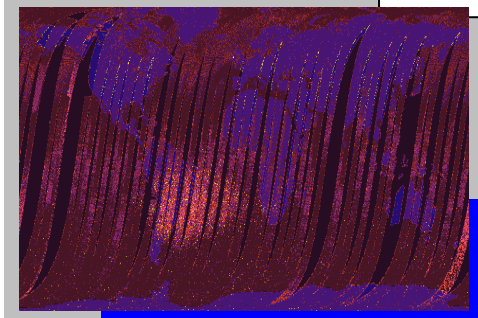
**Deep Charging** (bulk charging) → relativistic electrons (≥ 1~2 MeV) penetrate and accumulate

Dangerous discharges

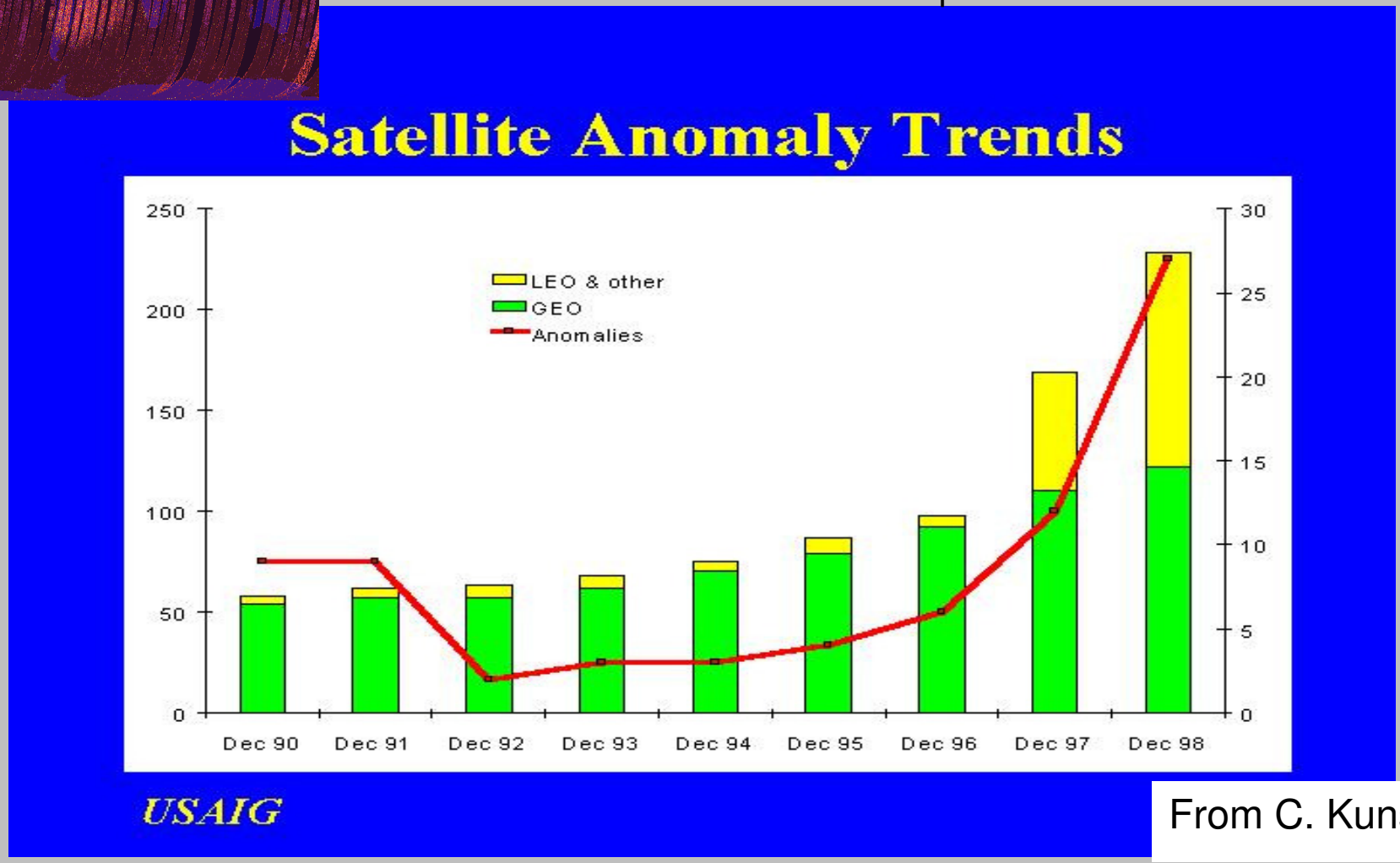
**Surface Charging** when differential voltages → thermal electrons (~10-15 Kev),

changes in reference voltages that trigger circuits (Phantom Commands), or generate destructive electrostatic discharges.

# Space Weather: effects

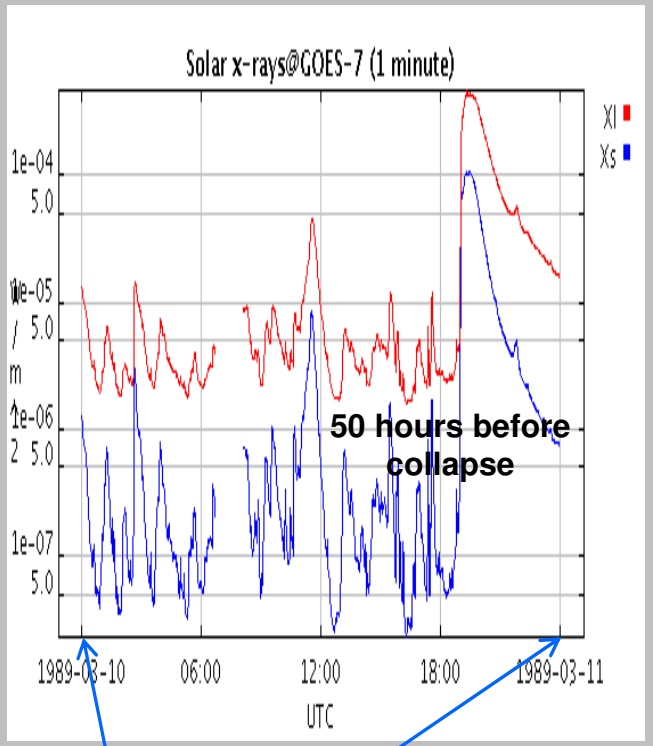


The number of reported anomalies increases with the number of satellites. But situation can be worst since many anomalies may not be reported

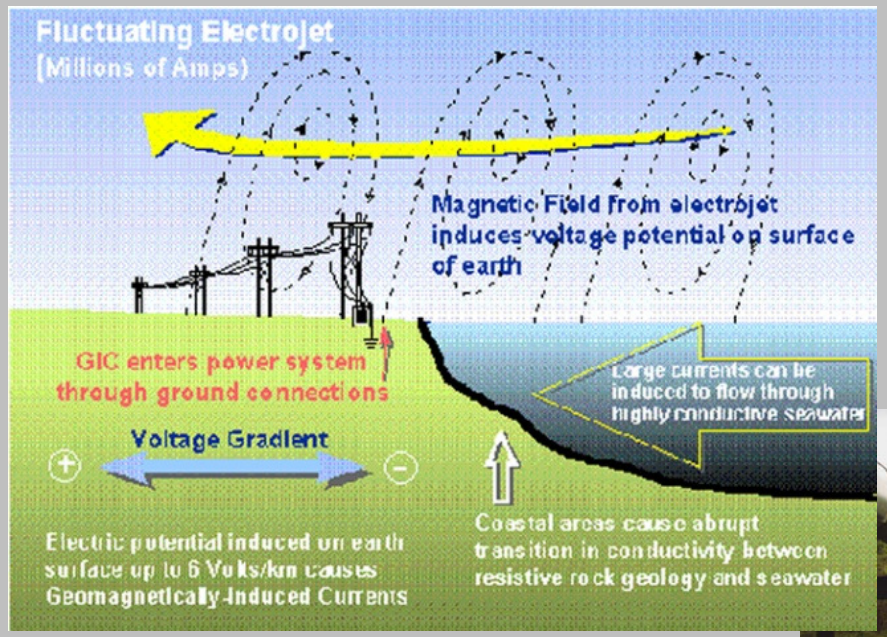


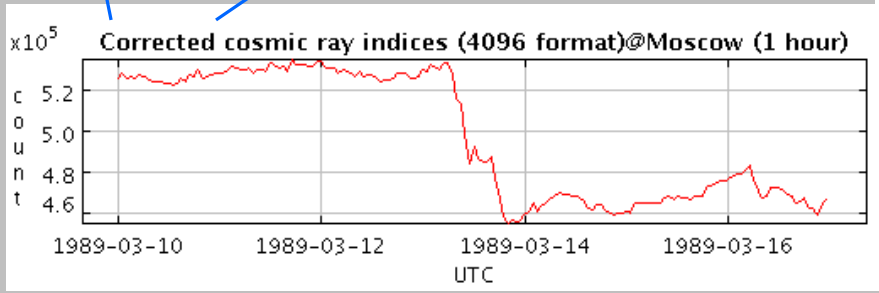

From C. Kunstadter

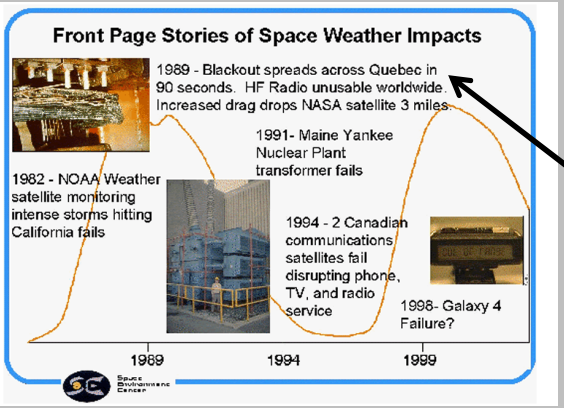
# Space Weather: effects




## GICs




**System collapse in few seconds after huge voltage oscillations: loss of > 20 000 MW**

# ISWI (Former IHY)

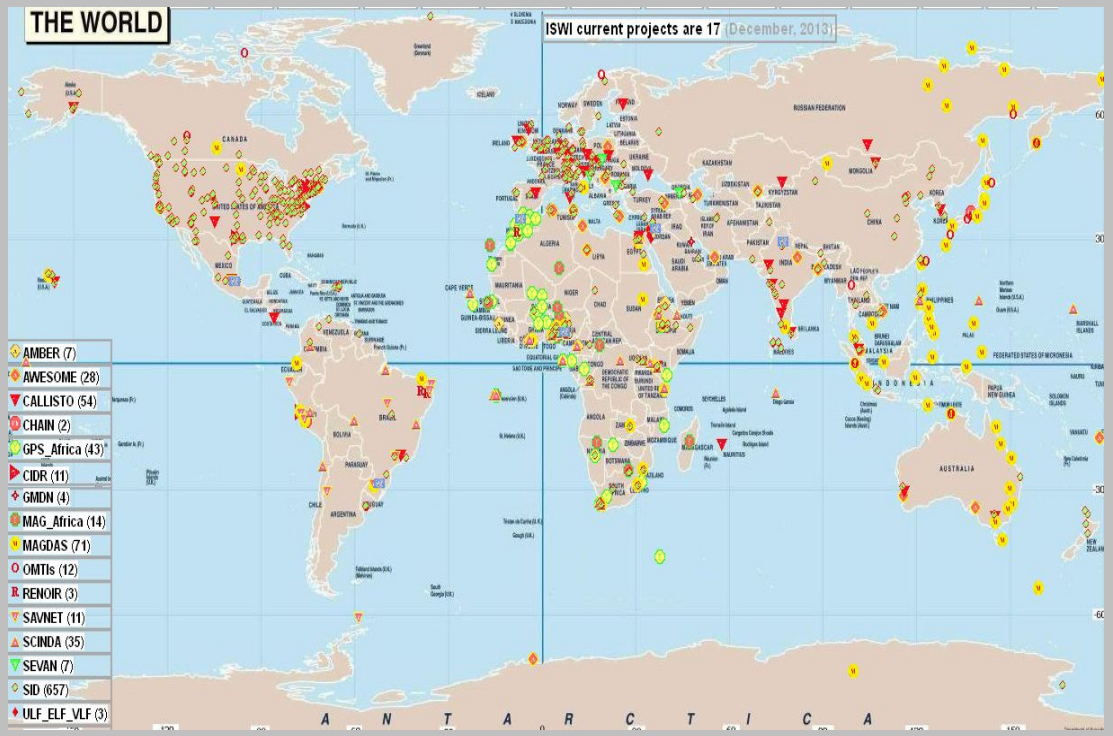
**ISWI is a program of international cooperation** to advance the space weather science by a combination of instrument deployment, analysis and interpretation of space weather data from the deployed instruments in conjunction with space data, and communicate the results to the public and students.

15 Instrumental Arrays

- heliospheric, solar, ionospheric, atmospheric physics
- deployed in 122 countries

11 Training schools since 2010 (ISWI)

Societal impacts workshop




During ~ 10 years IHY + ISWI → outstanding results → effort needs to continue

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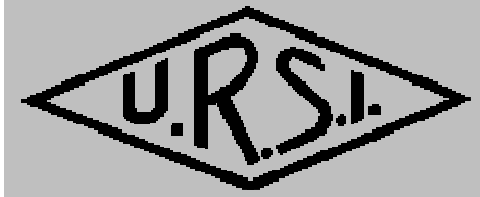


Union Radio Scientifique Internationale
Past President: François Lefeuvre



Scientific Committee on Solar-Terrestrial Physics
President: Nat. Gopalswamy


Coordinated at Centro de Radioastronomia e Astrofísica Mackenzie
Escola de Engenharia
Universidade Presbiteriana Mackenzie, São Paulo, SP, Brazil

The main objective was to incentivize the development on a long-term basis of a **regional centre** for the use of Geophysics as a new approach for **Natural Disaster prevention**, and to assess the **impacts of Space Weather conditions** on the Earth's environment and technological systems. Since radio communications and observations are important to assess geophysical hazards, the former objective implies a natural collaborative activity between Latin-American scientists involved in radio and geophysical sciences.

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# ICSU/URSI-SCOSTEP: Main achievements

- Foster new collaborations with scientists and institutions within (10 countries) and outside South America (7 countries)

  Brazil; Peru; Argentina; Mexico; Ecuador; Colombia ;
  Chile ; Paraguay ; Uruguay ;Venezuela

- Definition of thematic working groups – WG reports

- Instrumental facilities upgrade/extension

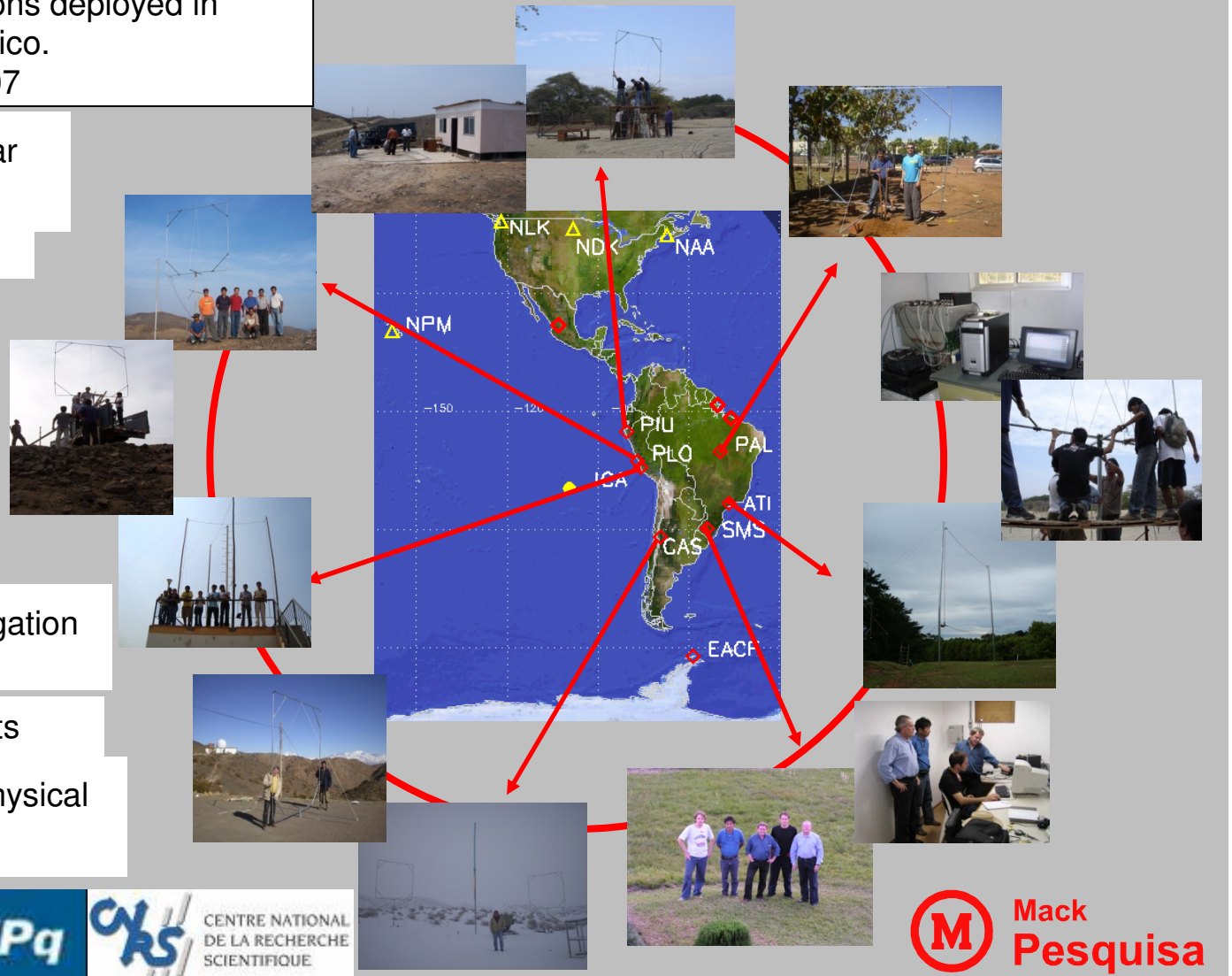
- Development of **skills and human resources**

# SAVNET

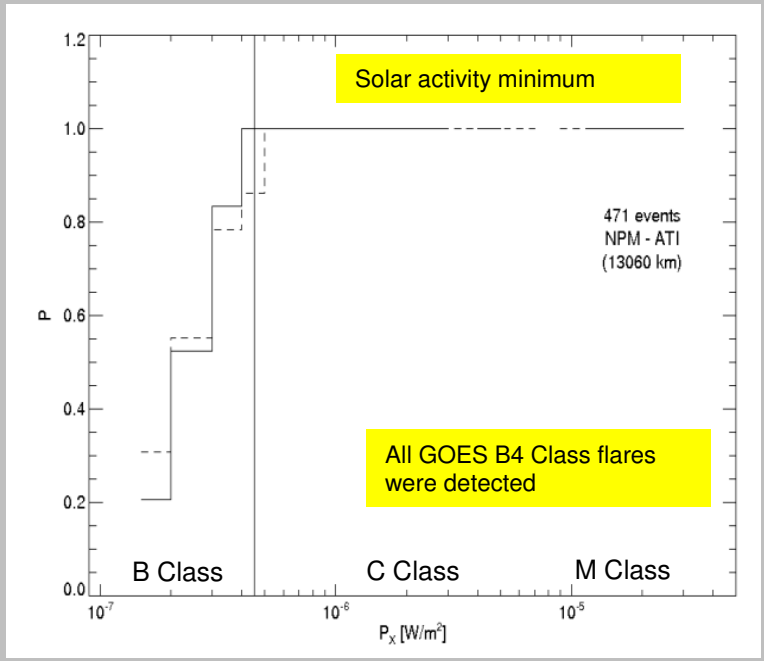
**CRAAM/EE**

11 VLF tracking receiver stations deployed in Brazil, Peru , Argentina e México.
6 years of operation since 2007

- Long-term and transient solar activity (Ly-$\alpha$ ; solar flares)
- D Region absorption models
- mesospheric disturbances (T, NO, $O_3$)
- Physics of the lower ionospheric (C/D) regions
- Atmos. Physics (TGFs)
- Subionospheric radio propagation modeling
- Search for seismic-EM effects
- Detection of Remote astrophysical objects

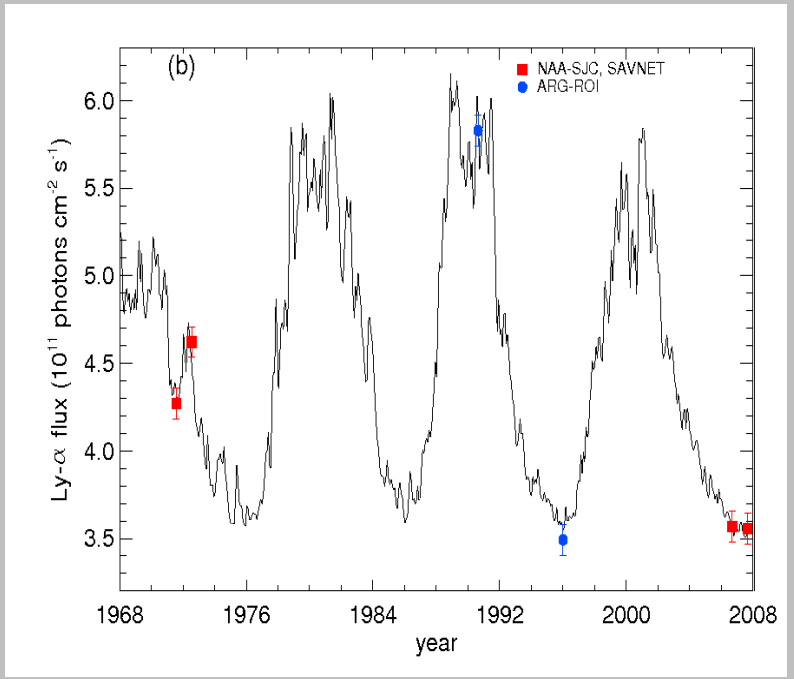


## Solar Flare Detection




For this period of solar activity, the lower detected solar flare B 2.7 → 2.7 $10^{-7}$ W/m$^2$ → all ≥ B 4 Class events are detected with 100 % probability. Smallest SXR flare detected so far → B1.8

## Ionospheric C-Region




Indirect monitoring of the Lyman-α solar radiation

The Lyman-α line is the strongest solar radiation, important for the energetic balance in the Earth atmosphere. It cannot be observed from the ground.

# The Embrace Network



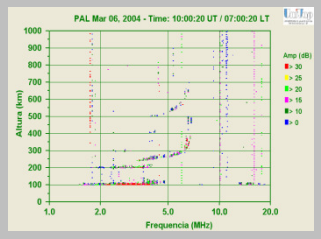
# The Embrace Network

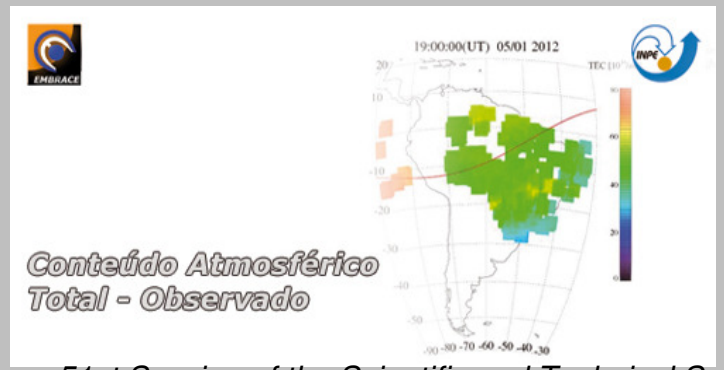

Users interested in diagnostics of Space Weather effects on different technological systems: GNSS, communication systems, geolocalization, energy distribution network, academic professionals

As a result many products are provided on real-time:

Not only but also


- Daily Space Weather activity bulletin
- TEC (Predicted values SUPIM)
- Ionosonde indices
  (f0F2, h'F, hmF2, MUF)

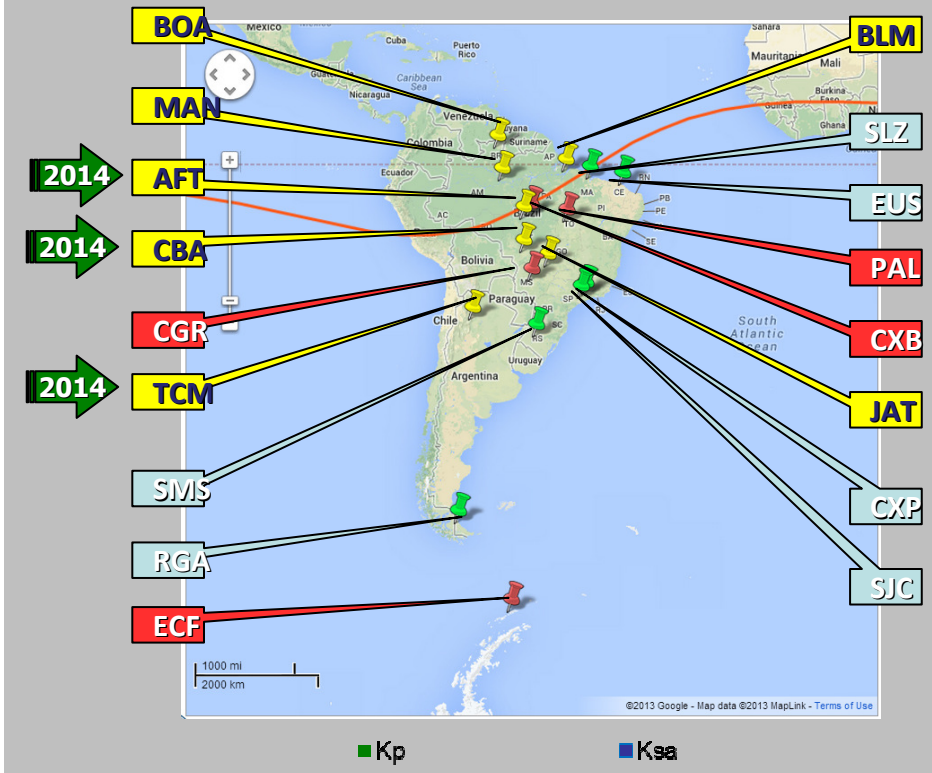


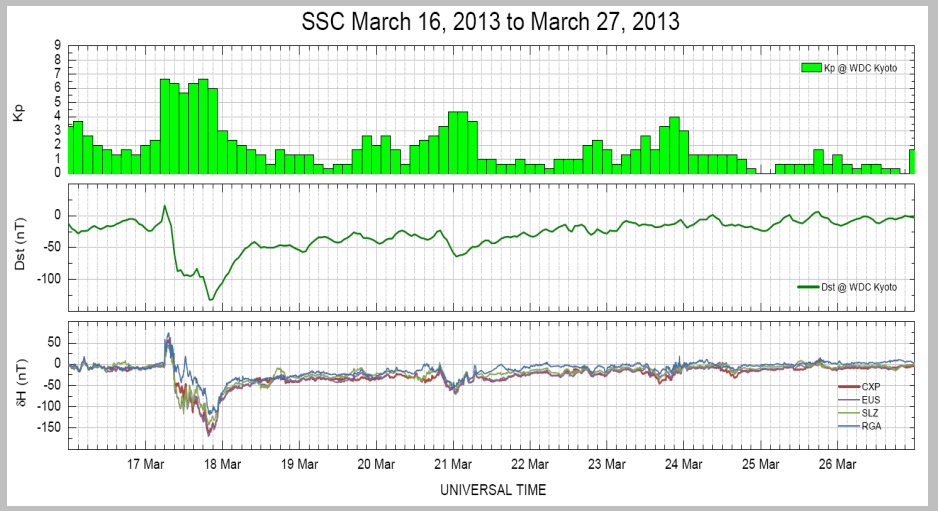



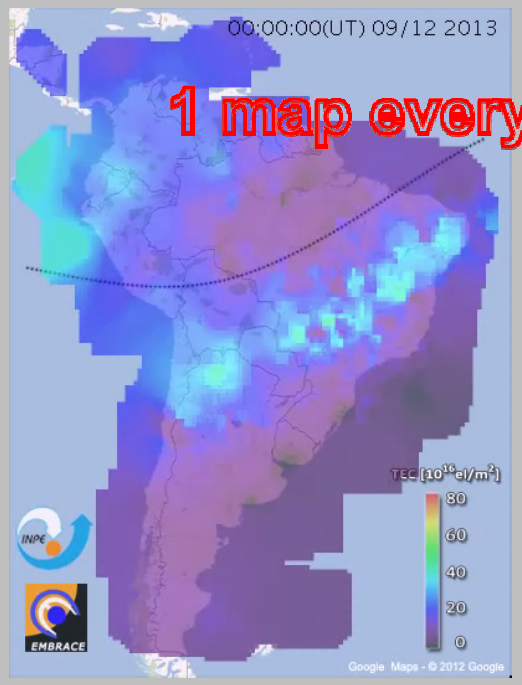

- Ionospheric plasma bubble activity index

- Magnetic indices

# The Embrace Network





MCT / INPE / CEA / DAE - IONO - Clezio Marcos De Nardin - clezio.denardin@.inpe.br

# CONCLUSIONS

Nowadays, almost everyone can feel the effects of the Space Weather dynamics → constantly growing dependency of our society on technology (ground and space)

A better understanding of the Space Weather dynamics needs efforts on the study of fundamental processes at the Sun (solar flares, CMEs, solar cycle variations etc …).

The lower ionosphere plasma is a medium very sensitive to external forcing: radiation, energetic particle fluxes, magnetic clouds. We can use it as a large sensor of external disturbances to monitor Space Weather effects. This is what actually does the VLF technique.

<u>Multidisciplinary science:</u>

Heliospheric, solar, magnetospheric, ionospheric, atmospheric physics →

- large international collaborations
- several Unions need to be involved and to participate (URSI, SCOSTEP, COSPAR, IAGA, …)
- put together and combine the data from the existing monitoring instrumental networks, extend the existing arrays and install new instrumental facilities (ISWI)
- modeling effort is needed for prediction of the Geo-Space Dynamics (ISWI)
- development of skills and human resources (ISWI)