
Seminars on Space Weather
Panamá 2018

**Observation and forecasts
systems.**

Sistemas de observación y predicción.



Dr. J. E. R. Costa by

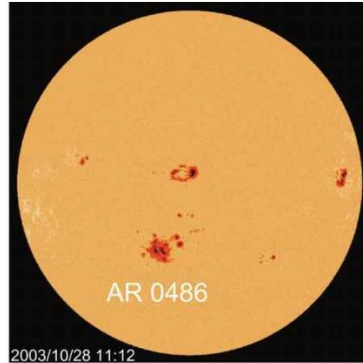


Co-authored by Dr. Clezio Denardin

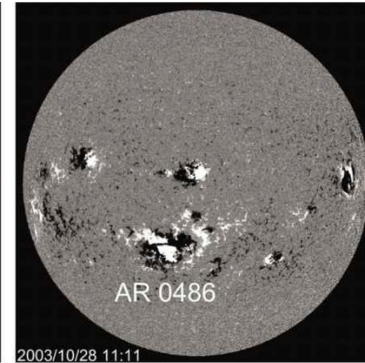
The Halloween Event (Oct 28-29, 2003)

This is an extreme event that impacted Earth recently!

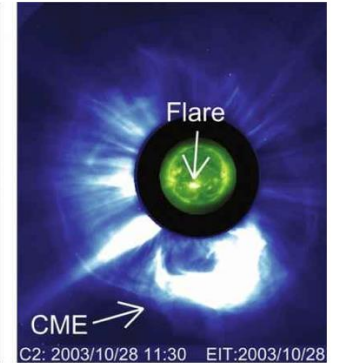
- Very soon after the flare and CME the society took actions to safeguard the technological systems.
- Two super intense geomagnetic storm was produced



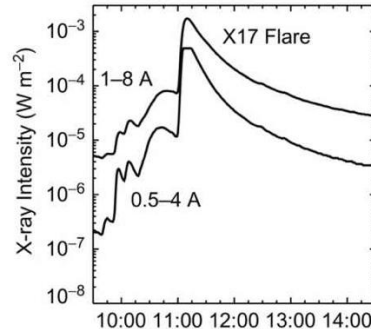
(A)



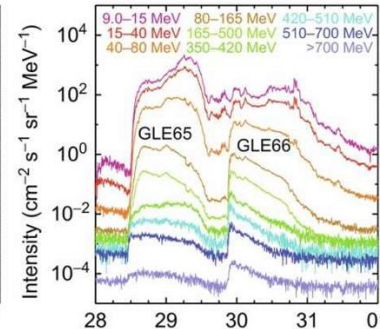
(B)



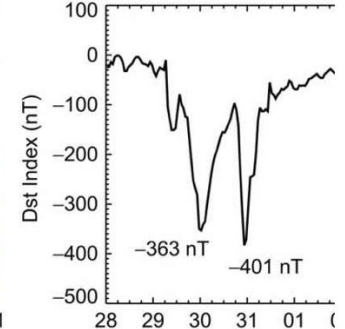
(C)



(D) Start time (2003/10/28 09:30)



(E) Start time (2003/10/28 00:00)



(F) Start time (2003/10/28 00:00)

What is observed/monitored?

The physical and phenomenological state of the natural space environment, including the Sun and the interplanetary and planetary environments.

Magnetized plasma

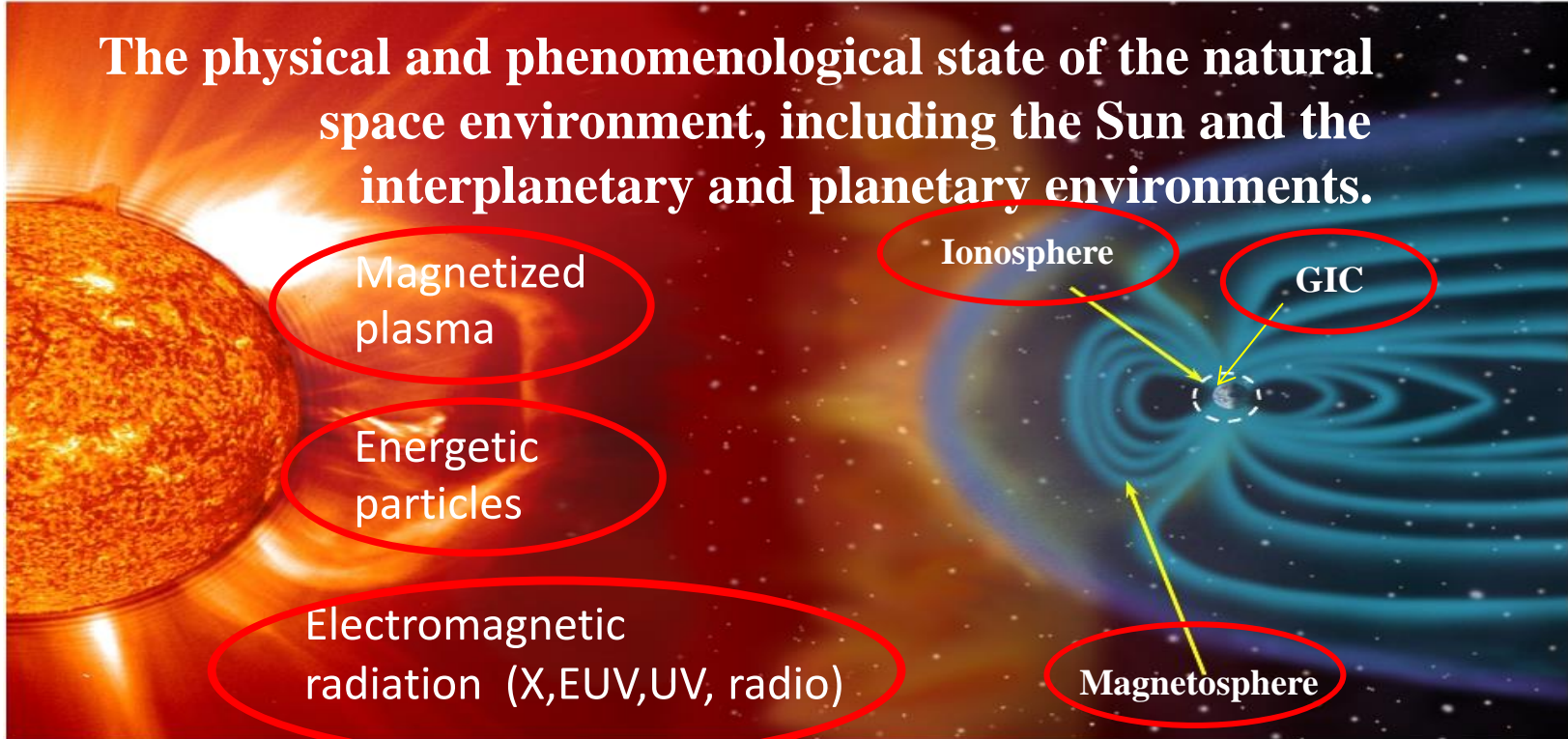
Energetic particles

Electromagnetic radiation (X,EUV,UV, radio)

Ionosphere

GIC

Magnetosphere



Observations and Numerical Modeling



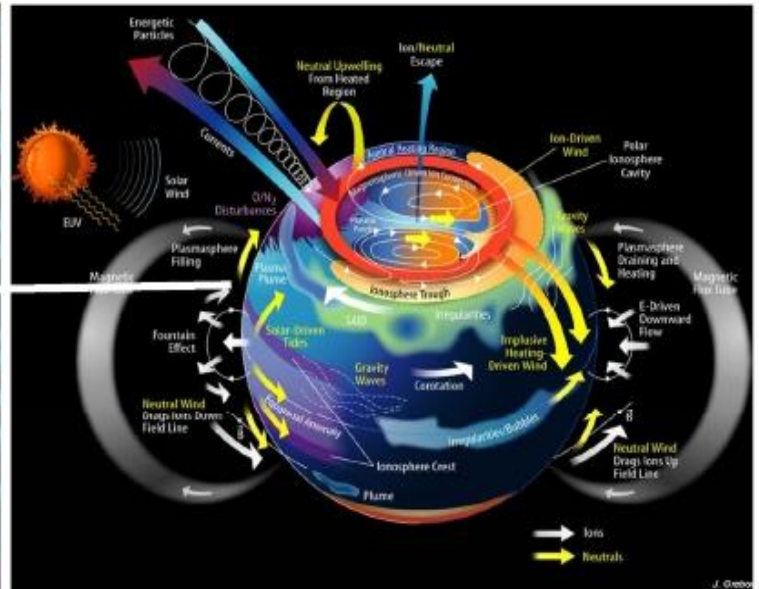
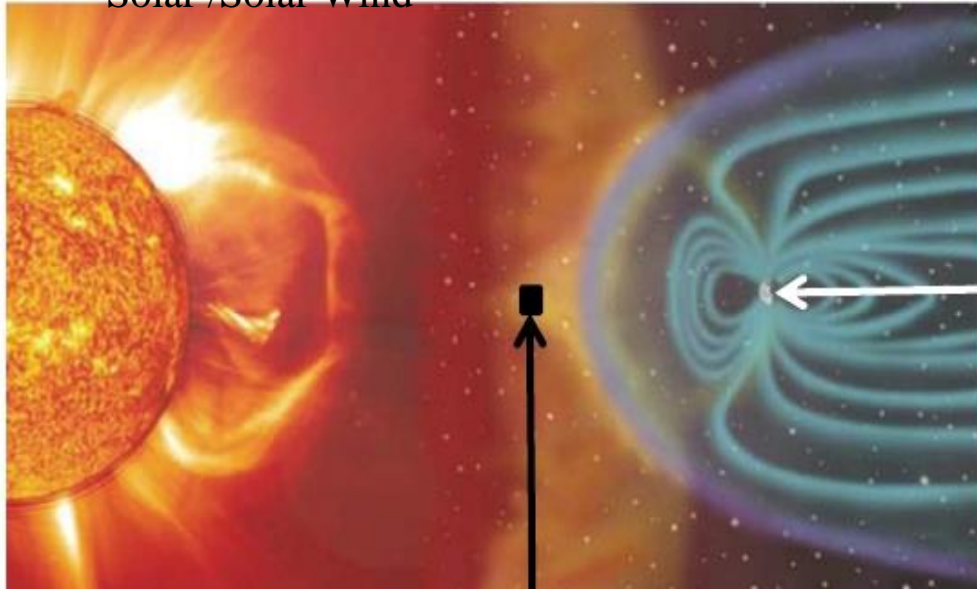
COMMUNITY
 COORDINATED
 MODELING
 CENTER

CCMC - <https://ccmc.gsfc.nasa.gov>

Magnetosphere/
 Ionosphere

Atmosphere/
 Ionosphere

Solar /Solar Wind



L1 Satellite Location – DSCOVR

TECHNOLOGY SECTORS - FEED BACK

- **Aviation**

- Disruption of communication and radiation risk
- Next generation air traffic management systems will rely on GNSS



- **GNSS**

- Degradation of accuracy or availability
- Strong growth in applications – surveying, drilling, precision agriculture, navigation, aviation



- **Electric Utilities**

- Potential for significant disruption of service with short-term and long-term consequences



- **Space Systems**

- Degradation or loss of satellite capabilities
- Disruption of launch scheduling



Designing SW capabilities

User Needs

Understanding the risks and the actions to be taken

Targeted Services

Develop usable capabilities from basic science knowledge

Observing infrastructure

Distributed space-based and ground based

Global Coordination

Consistent, accurate message

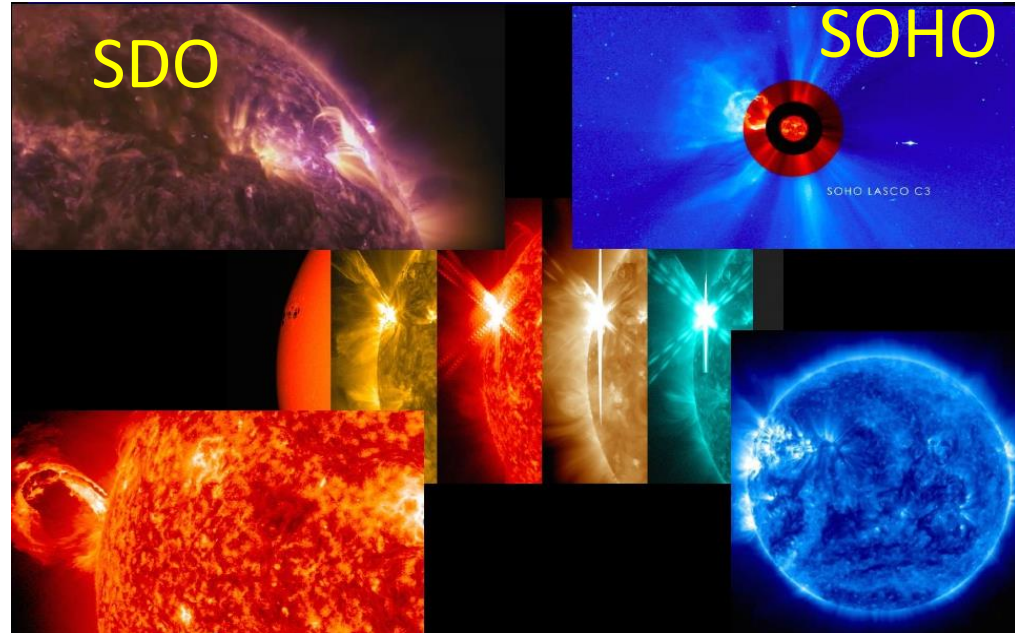
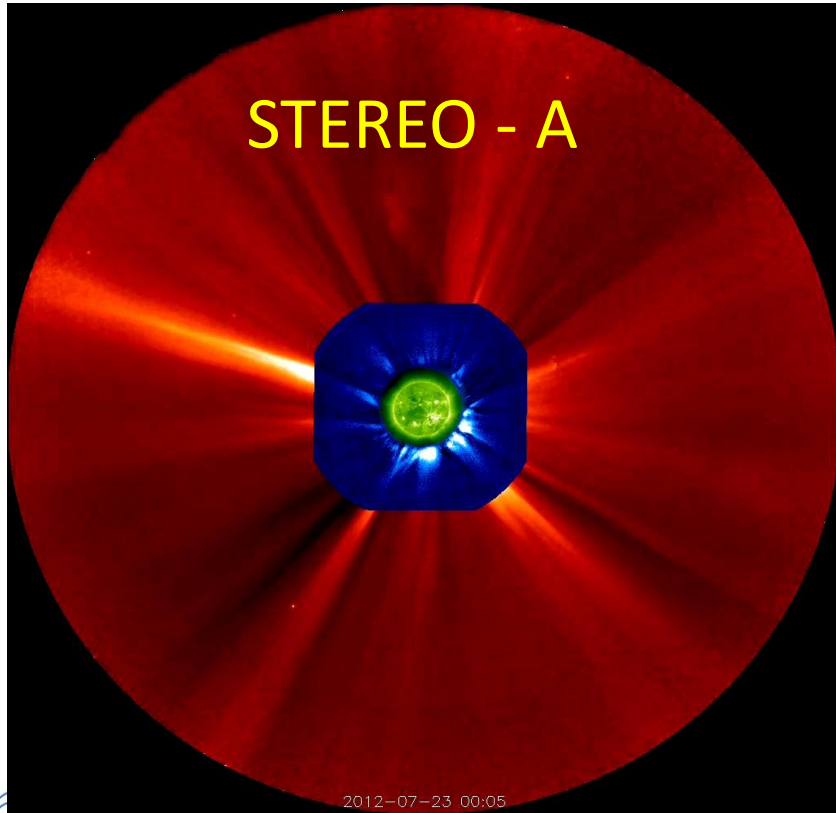
Observation from the Space



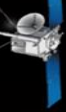
Space Weather Portfolio

- NASA/NOAA and ESA research satellites, such as DSCVR, SOHO (with ESA), STEREO, and SDO, designed for scientific studies have provided over the past decade or more critical measurements essential for specifying and forecasting the space environment system, including the outward propagation of eruptive solar events and solar wind conditions upstream from Earth.
- Also, a growing literature has documented the need to provide a long-term strategy for monitoring in space, and elucidated the large number of space weather effects.

Space based – short wavelengths



STEREO



STEREO



Heliophysics Research Missions with Real- time Space Weather Utility

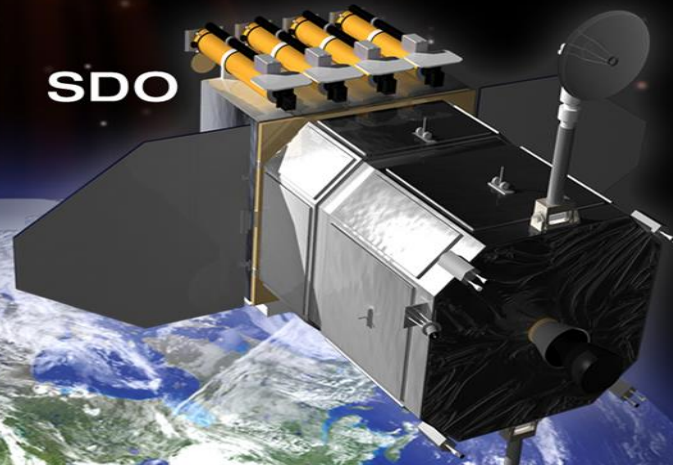
DSCOVR



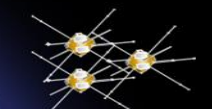
SOHO



SDO



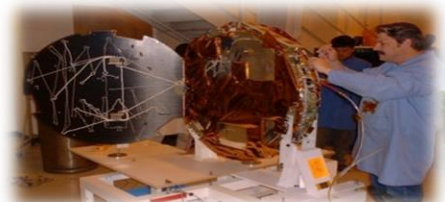
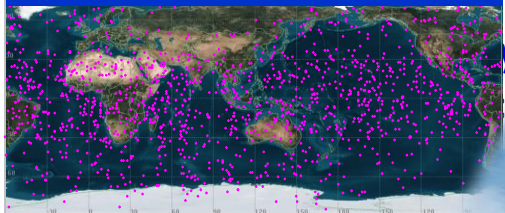
RBSP



EMBRACE - Two Missions in Satellites

EMBRACE antenna for **COSMIC 2** satellite constellation with **NOAA** to measure electron content profiles by measuring radio occultation of GNSS - 2018.

COSMIC 2 Occultation – 3 Hrs Coverage



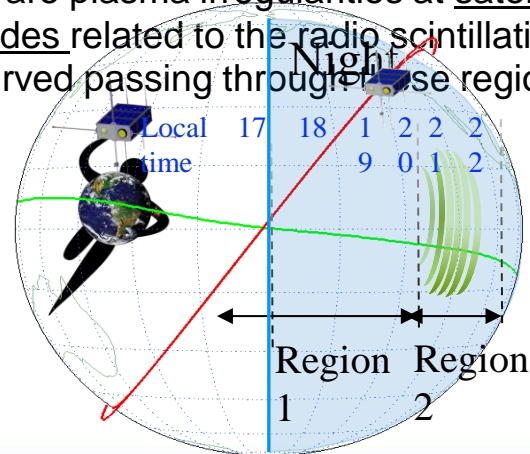
Downlink constructed
by EMBRACE
for COSMIC 2 mission

SPORT The **S**cintillation **P**rediction **O**bservations
Research **T**ask – 2019

NASA – ITA – INPE Mission

Science Goals

1. What is the state of the ionosphere that gives rise to the growth of plasma bubbles that extend into and above the F-peak at different longitudes?
2. How are plasma irregularities at satellite altitudes related to the radio scintillations observed passing through these regions?





OSCAR

Observing Systems Capability Analysis and Review Tool

[Home](#) |
 [Observation Requirements](#) |
 [Space-based Capabilities](#) |
 [Surface-based Capabilities](#) |

[Overview](#) |
 [Variables](#) |
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Application: Space Weather

Details

Name	Space Weather
Description	Space weather is a discipline which aims at observing, understanding and predicting the state of the Sun, of the interplanetary and planetary environments, their disturbances, and the potential impacts of these disturbances on biological and technological systems. http://www.wmo.int/pages/prog/www/OSY/SOG/SoG-SW.pdf
Corresponding Institution	WMO-ISES
Contact Person	Terrance Onsager terry.onsager@noaa.gov

Variables measured in this Application Area

Subdomain	Variables
Basic atmospheric	Atmospheric temperature Wind (horizontal) Atmospheric density
	Geomagnetic field
Solid Earth and magnetic field	
Ionospheric disturbances	foEs foF2 h'F hmF2 Ionospheric plasma velocity Ionospheric Radio Absorption Spread F Ionospheric Scintillation Ionospheric Vertical Total Electron Content (VTEC)
	Energetic particles and solar wind
	Cosmic ray neutron flux Interplanetary magnetic field Proton differential directional flux Solar wind density Solar wind temperature Solar wind velocity Radiation Dose Rate Electron differential directional flux Heavy ion angular flux energy and mass spectrum
Solar monitoring	Solar EUV flux Heliospheric image Solar Ca II-K image Solar EUV image Solar H-alpha image Solar magnetic field Solar radio flux Solar white light image Solar X-ray image Solar coronagraphic image Solar X-ray flux



OSCAR database (WMO) for solar obs.

Coronagraphs, EUV images

Radiation: X ray fluxes

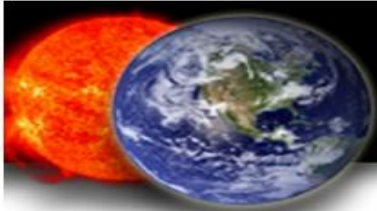
Coronagraphs, EUV images

Magnetometer, EUV images

Instrument	NRT?	Sorting	Satellite	Orbit	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
EIT		3	SOHO		X	X	X	X	X	X	X	X	X	X	X	X
SEM (SOHO)		3	SOHO		X	X	X	X	X	X	X	X	X	X	X	X
LASCO		5	SOHO		X	X	X	X	X	X	X	X	X	X	X	X
MDI		5	SOHO		X	X	X	X	X	X	X	X	X	X	X	X
SEM/XRS-EUV ①	Yes	2	GOES-15	135°W				X	X	X	X	X	X	X	X	X
SXI ①	Yes	2	GOES-15	135°W				X	X	X	X	X	X	X	X	X
SEM/XRS-EUV ①	Yes	2	GOES-14	105°W			X	X	X	X	X	X	X	X	X	X
SXI ①	Yes	2	GOES-14	105°W			X	X	X	X	X	X	X	X	X	X
EXIS		2	GOES-16	75.2°W											X	X
SUVI		3	GOES-16	75.2°W										X	X	X
SEM/XRS-EUV ①	Yes	2	GOES-13	60°W	X	X	X	X	X	X	X	X	X	X	X	X
SXI ①	Yes	2	GOES-13	60°W	X	X	X	X	X	X	X	X	X	X	X	X
GGAK-E/DIR-E	Yes	2	Electro-L N2	76°E										X	X	X
SXM		2	FY-2G	105°E									X	X	X	X
SXM		2	FY-2F	112°E						X	X	X	X	X	X	X
SECCHI/EUVI ①		3	STEREO (2 sats)	23.44 °	X	X	X	X	X	X	X	X	X	X	X	X
SECCHI/COR-1 ①		5	STEREO (2 sats)	23.44 °	X	X	X	X	X	X	X	X	X	X	X	X
SECCHI/COR-2 ①		5	STEREO (2 sats)	23.44 °	X	X	X	X	X	X	X	X	X	X	X	X
SECCHI/HI-1 ①		5	STEREO (2 sats)	23.44 °	X	X	X	X	X	X	X	X	X	X	X	X
SECCHI/HI-2 ①		5	STEREO (2 sats)	23.44 °	X	X	X	X	X	X	X	X	X	X	X	X
AIA		3	SDO	28.9 °				X	X	X	X	X	X	X	X	X
HMI		5	SDO	28.9 °				X	X	X	X	X	X	X	X	X
RHESSI		1	RHESSI	38 °	X	X	X	X	X	X	X	X	X	X	X	X
XFO ①		2	SORCE	48 °	X	X	X	X	X	X	X	X	X	X	X	X
SEE		2	TIMED ①	74 °	X	X	X	X	X	X	X	X	X	X	X	X
XRT		2	Solar-B (Hinode)	06:00 asc	X	X	X	X	X	X	X	X	X	X	X	X
SWAP		3	PROBA-2 ①	06:00 asc			X	X	X	X	X	X	X	X	X	X
LYRA		3	PROBA-2 ①	06:00 asc			X	X	X	X	X	X	X	X	X	X
IRIS (IRIS)		4	IRIS	06:00 asc							X	X	X	X	X	X
SOT		5	Solar-B (Hinode)	06:00 asc	X	X	X	X	X	X	X	X	X	X	X	X

Observation from the Ground





Challenge for WMO Members – Transition of Data from Research to Operations

Networks of Ground-Based Data UN International Space Weather Initiative



Distributed Space-Based Assets International Living With a Star



More than 25 Space Agencies

Challenges:

- Utilizing existing research data for space weather services
- Real time access
- Maintaining long-term continuity of key measurements

Instruments

The EMBRACE program runs many advanced-sites over the Country with different instruments such as: Radiometers, Ionosondes, Magnetometers, Imagers, VHF radar, GNSS data, GIC and Muon sensors.

SPECM



Radio Monitor
Spectrometer
.4-18 GHz

CALLIST

O



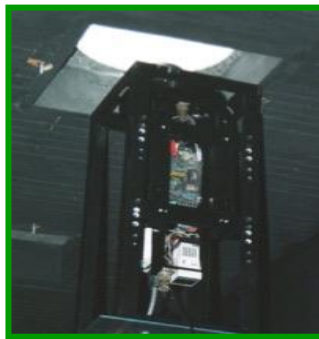
BDA Solar Array

Solar radio imaging 1.2-1.7GHz



Iono
sondes

Photometers All Sky



Magnetometers



GNSS



Muon Detector
Shinshu University



EMBRACE/INPE observatories



Networks in Latin America

- The networks of sensors today in Latin America is mostly driven by science. They are now being used by SW operations through cooperation with existing projects.
- We have now in Latin America two Regional Warning Center (Brazil and Mexico) and we are talking to Argentina to organize their AWC (associate).
- Gaps in the network are being used for planning the investment of EMBRACE program or through international initiatives.
- I will present some conclusions and offer suggestions to overcome some of the main difficulties.

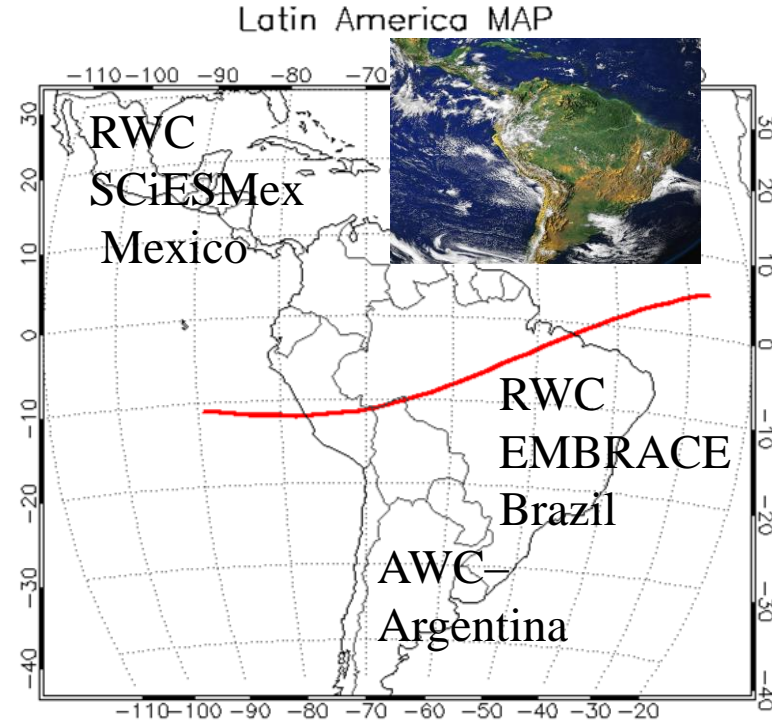


TABLE 1. Summary of the Scientific Networks/Facilities, operating in Latin America

Group	Name(Acronym)	Origin (Year)	Objective of Investigation (Primary Objective)	Current Status (FO, PO, NO*)
Atm.	Embrace GlowNet Airglow imagers	1998	Gravity Waves (85 km) and Plasma Bubbles (260 km) footprints signature and propagations	PO
Atm.	AAS	1998	Airglow in mesopause region	FO
Atm.	SARINET	1999	D-Region density variations and solar flares related effects	FO
Atm.	SAVNET	2006	D-Region (daytime) and E-Region (nighttime) density variations and solar flares related effects	FO
Atm.	NDMC	1998	Mesopause region and changing climate	FO
Atm.	RIOM-SMN	2012	Absorption in ionosphere	PO
Atm.	Schumann station	2014	Schumann resonance frequencies	FO
Atm.	Embrace DigiNet Ionosondes	1990	Bottom-side ionospheric profile measurements and upper-side ionospheric profile theoretical extrapolations, Maximum Usable Frequency from oblique HF ionospheric reflections	PO
Atm.	RBMC GNSS sensors	1996	Total ionized atmosphere content and positioning for several purposes like geodynamics studies of the South American plate	FO
Atm.	Calibra Magnetometers	2012	Total ionized atmosphere content and positioning for several purposes like topographical and geodetic surveys, land management and offshore operations	PO
Mag.	Embrace MagNet	2011	Geomagnetic field variations and geomagnetic storm detections	PO

Magnetometers

Mag.	Intermagnet in Mexico	2002	Geomagnetic field (absolute, variations), to	PO
Mag.	Intermagnet in Argentina	1991	geomagnetic storm detections, long term secular changes and contribute to IGRF	FO
Mag.	SMN-LAS	1961	Geomagnetic Storms. South American Magnetic Anomaly.	FO

Cosmic Rays

I. M.	GMDN in Brazil	2006	Cosmic ray, ICMEs trough Forbush decrease	FO
I. M.	SciCRT-GMDN in Mexico	2014	Cosmic ray, ICMEs trough Forbush decrease	FO
I. M.	LAGO	2011	Cosmic ray, ICMEs trough Forbush decrease	PO
I. M.	Auger - Low energy modes	2005	Cosmic ray, ICMEs trough Forbush decrease	FO
I. M.	Cosmic Ray Observatory	1999	Cosmic ray, ICMEs trough Forbush decrease	FO

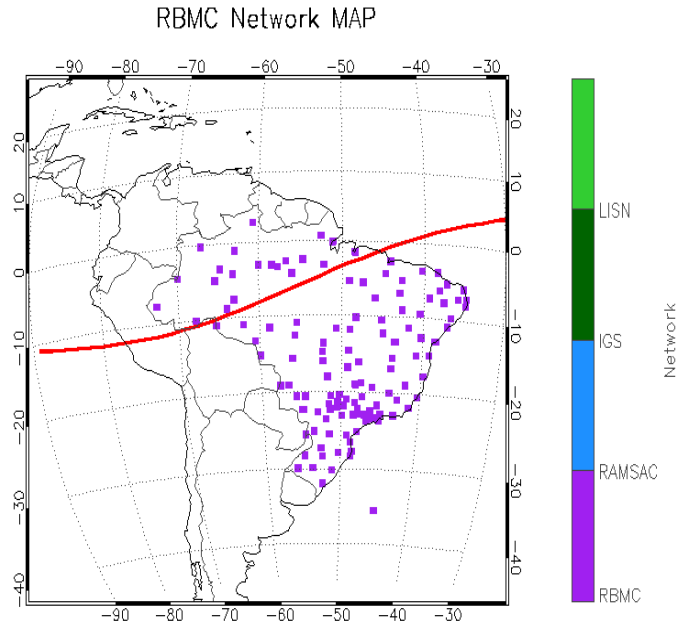
Interplanetary Scintillation

Sun	Solar Submillimeter Telescope	1999	Active region	FO
Sun	Callisto-MEXART	2015	Solar radio burst	FO
Sun	Solar Neutron Telescope Network	2004	Solar energetic particles	FO
Sun	Itapetinga Radio	1974	Galactic and extra-galactic studies, solar physics specially the solar continuous emission and transition region monitoring	FO
Sun	Brazilian Decimetric Array	2004	Galactic and extra-galactic studies, high resolution solar physics	PO
Sun	Northeast Radio Space Observatory	1993	Geodetic studies as well as galactic and extra-galactic studies.	FO

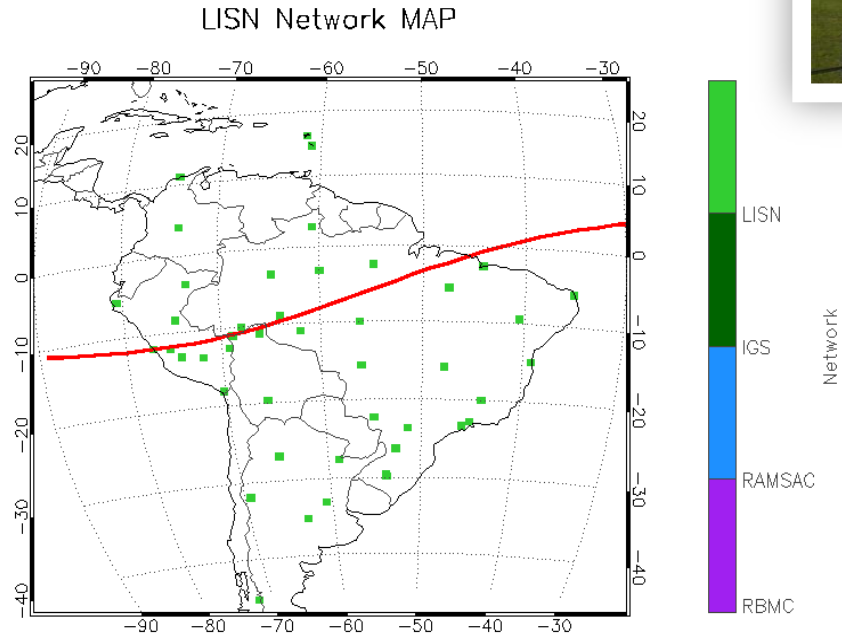
Solar observatories

* FO = Fully operational, PO = Partially Operational, NO = Not Operational

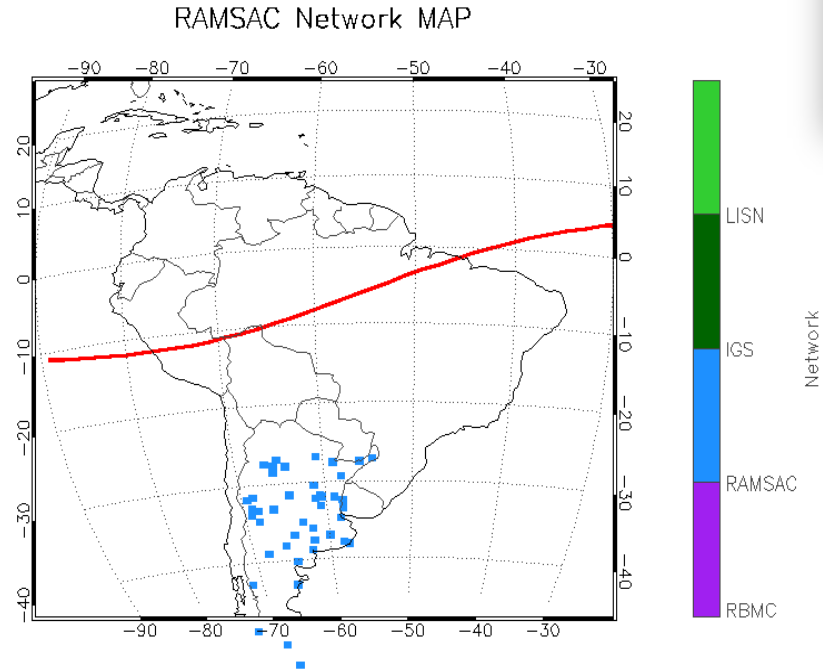
- The EMBRACE program does not own all the instruments used to complete the South America TEC map (now being extended to Latin America).
- A successful program of national and international cooperation was set to grant a denser GNSS network.
- In this example the Brazilian RBMC net.



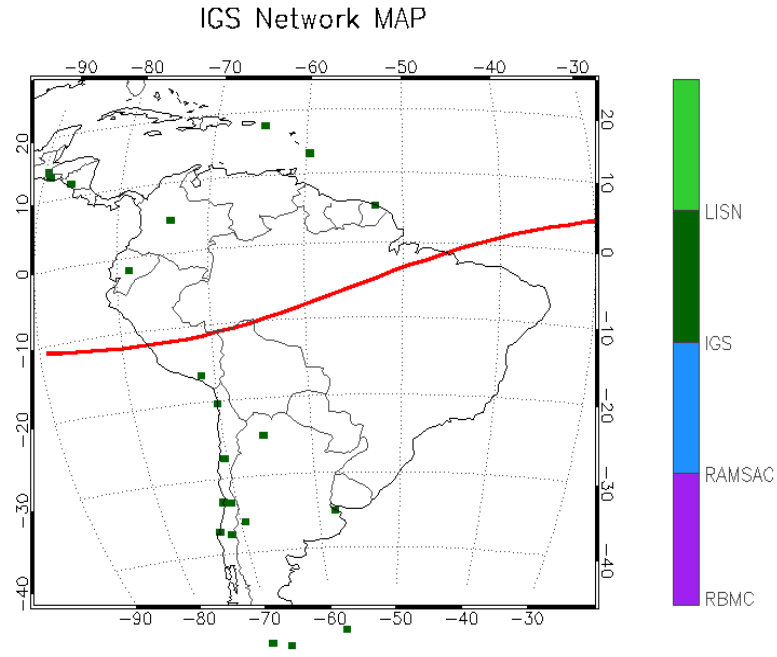
GNSS Network for determinations of TEC Net: LISN – Boston College, USA



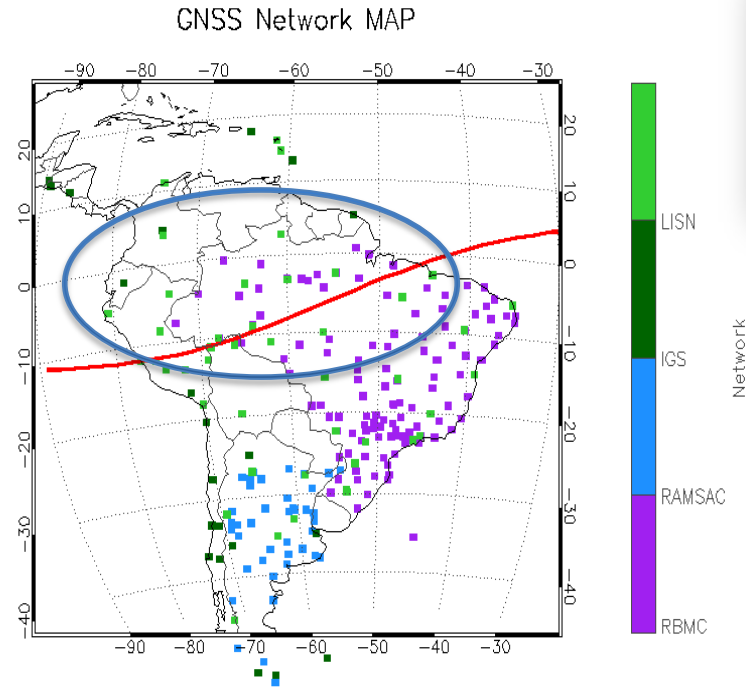
GNSS Network for determinations of TEC Net: RAMSAC - Argentina



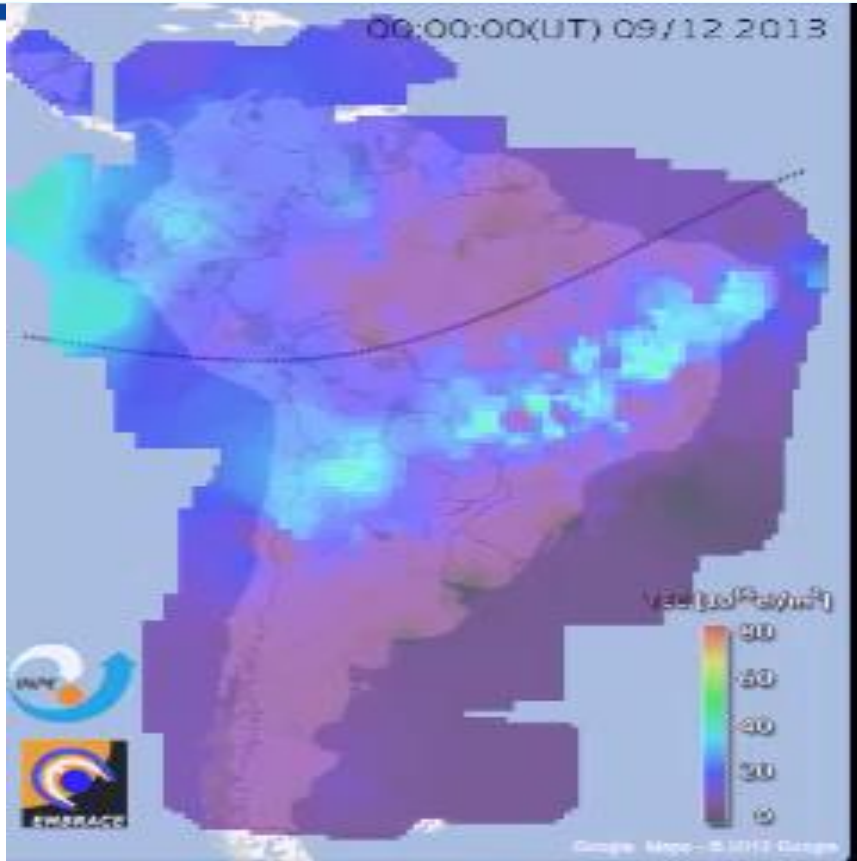
GNSS Network for determinations of TEC Net: IGS - International



- Even including all sensors it is still a **low density array**.
- Mainly in the North of Amazon region and some neighbors countries .
- This map does not include Central America.

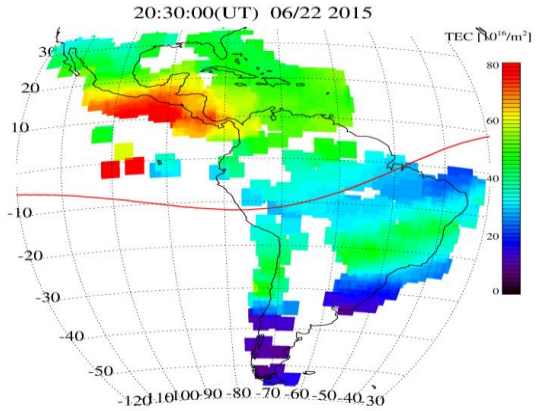
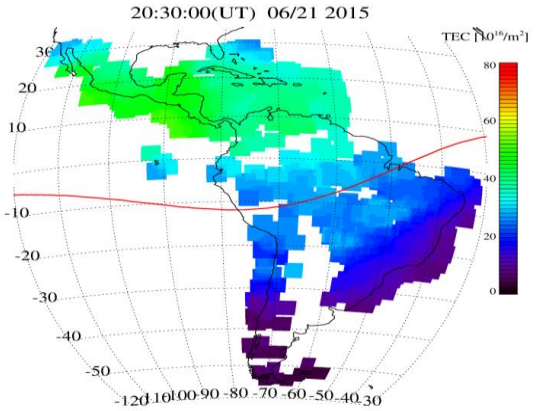
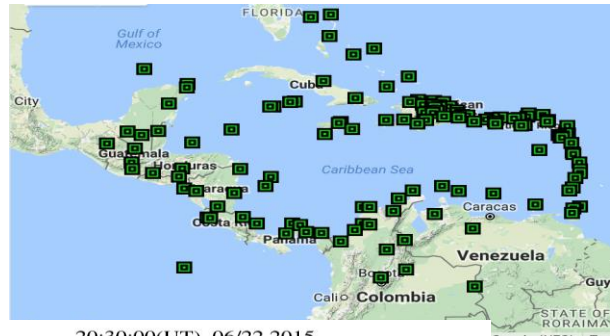


TEC Map over South America



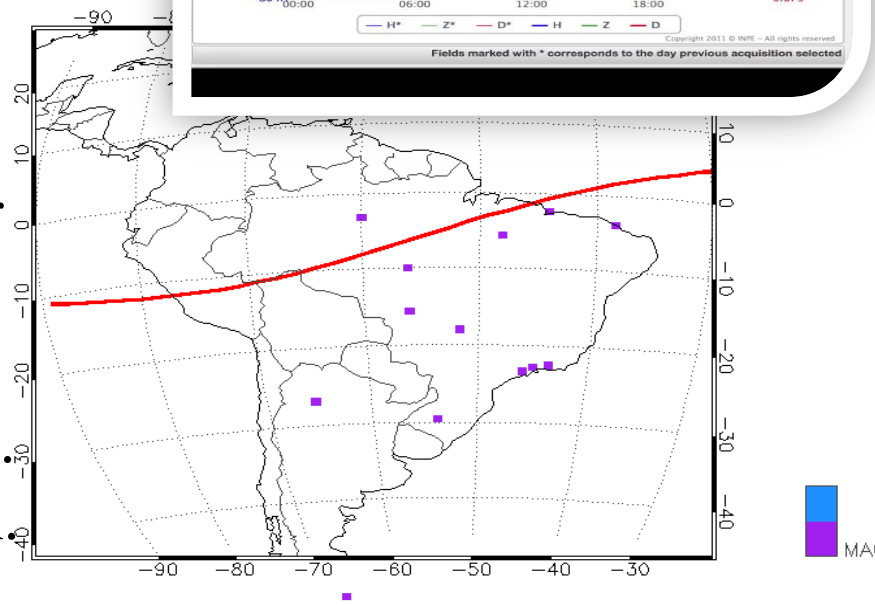
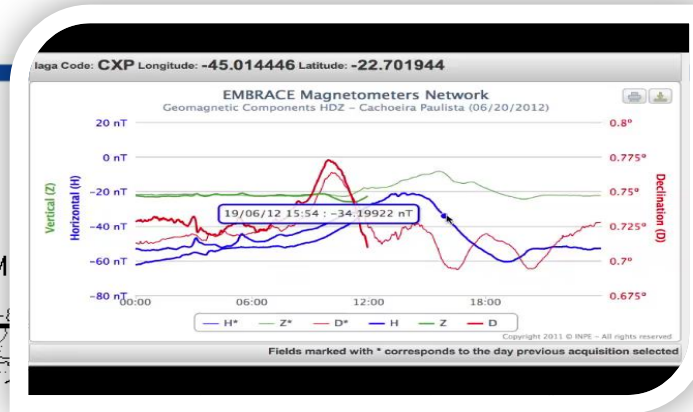
GNSS Network for determinations of TEC Net: TLALOCNet-Mexico and COCONet-Central America

- The network is now being extended to whole Latin America including these two Networks.
- The gaps can be seen in the TEC maps.



Magnetometer Network Net: EMBRACE

- A low density network
- Although the magnetometers are cross-calibrated some of them are noisy due to electrical devices near.
- As the Magnetic Equator has moved to the West there is no magnetometer under the Equatorial Electro Jet.
- EEJ may amplifies the geomagnetic variations that give origin to the GIC.
- Need to have more focus on research.

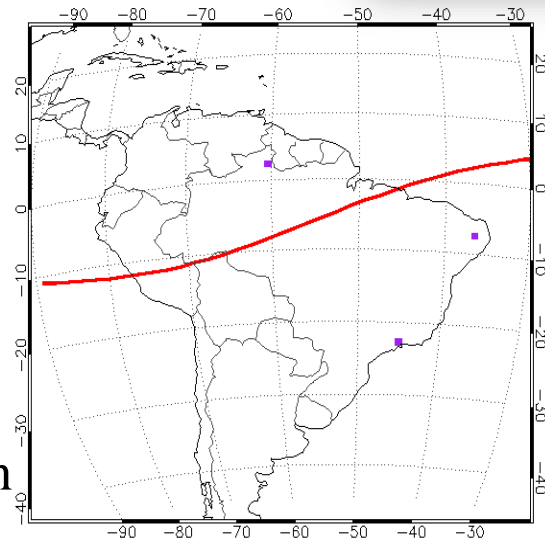


Airglow Network. Net: EMBRACE

- **Low density network.**
- Very important for the plasma bubble monitoring.
- Suffers from adequate sites without light pollution, clear sky and infrastructure.
- Need investment in F-P interferometer to understand better the plasma irregularity called plasma bubble.
- Two F-P were acquired to measure thermospheric winds and temperature (EMBRACE).
- Initial discussion with **Dr. Qian Wu -NCAR** (2 FPI) to be part of a North_South network.
- Initial discussion with **Dra. Hsieh, Syau-Yun** (John Hopkins) (4 All-Sky) to be deployed in Brazil



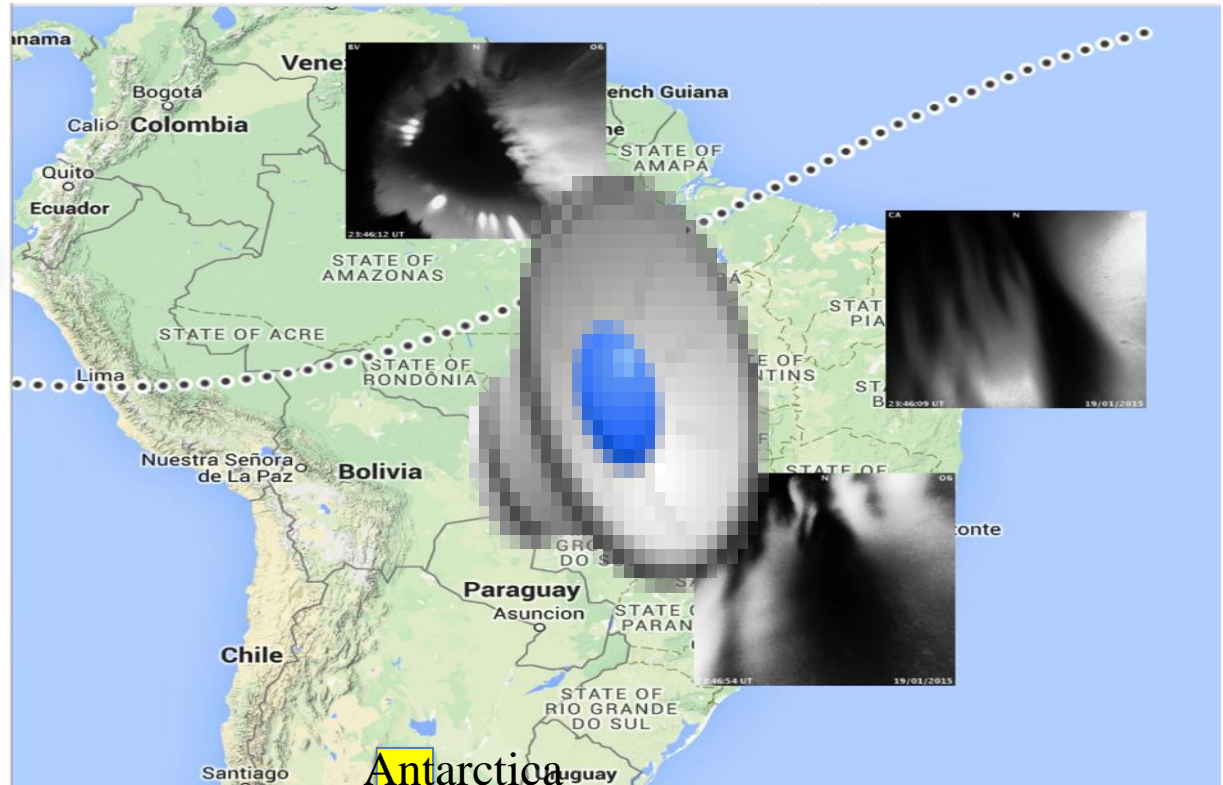
All Sky Network Map



The photometers Network



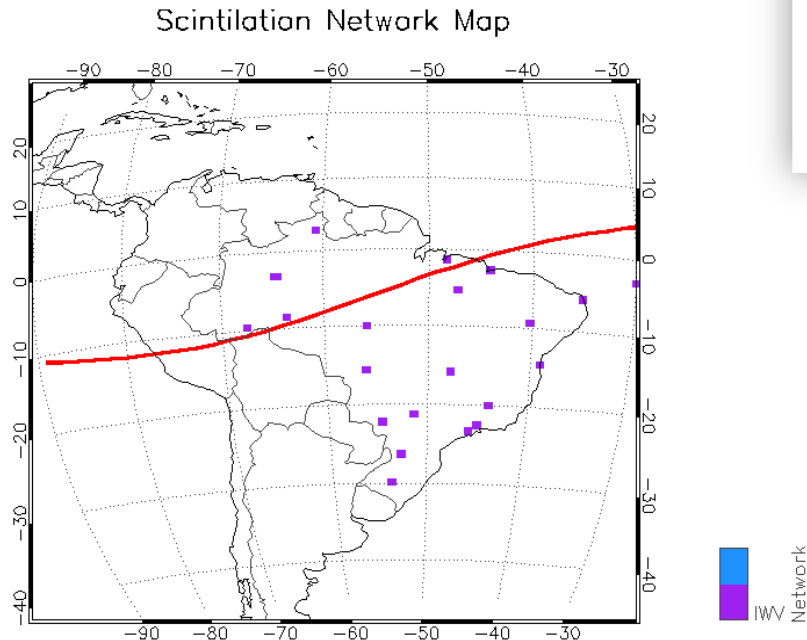
Installed in Antarctica



Antarctica

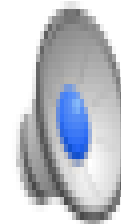
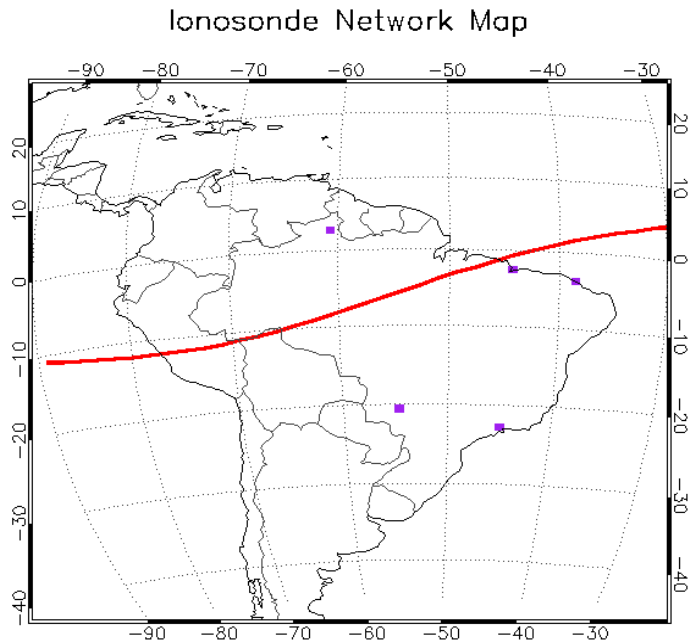


- **Low density network.**
- Very important for monitoring disturbance in radio wave propagation (index S4, others).
- The full network suffers from old GNSS receivers without capability to measure scintillations.



Ionosonde Network. Net: EMBRACE

- **Low density network.**
- Need Ionosondes at the crest of the anomaly.
- Lack of local technical/scientific training to stimulate the partnership in planned strategic sites.



SCiESMEX-Mexico

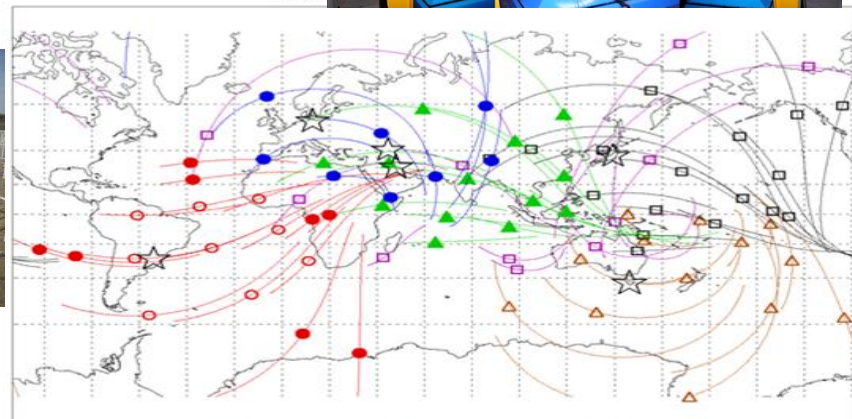
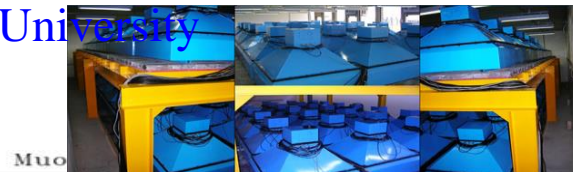
A radiotelescope MEXART, an array of 4096 dipoles operating at 140 MHz to track solar wind large-scale disturbances using the interplanetary scintillation technique.



Source: Mejia-Ambriz et.al, Solar Phys (2010) 265: 309–320

EMBACE-Brazil

A muon detector part of the Global Muon Detector Network –GMDN
 Shinshu University

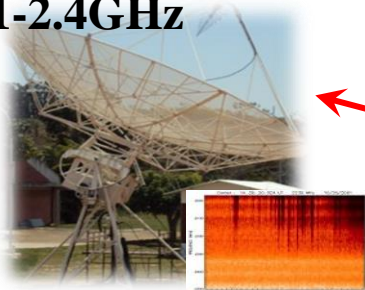


□ Nagoya △ Hobart ○ SaoMartinho (● extended)
 □ Aragats ▲ Kuwait ● Greifswald

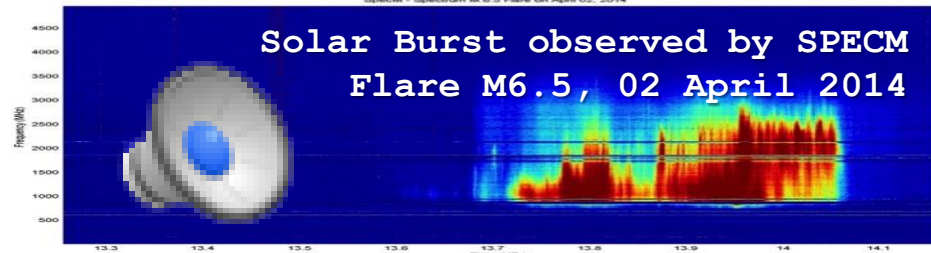
1) Nagoya, Japan; 2) Hobart, Australia; 3) City of Kuwait, Kuwait;
 4) São Martinho da Serra, Brazil

Solar Monitors - Network

BSS – Solar Spectrometer
 1-2.4GHz

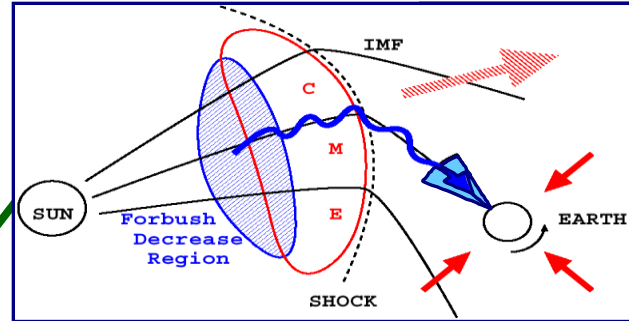


BDA – Solar Interferometer

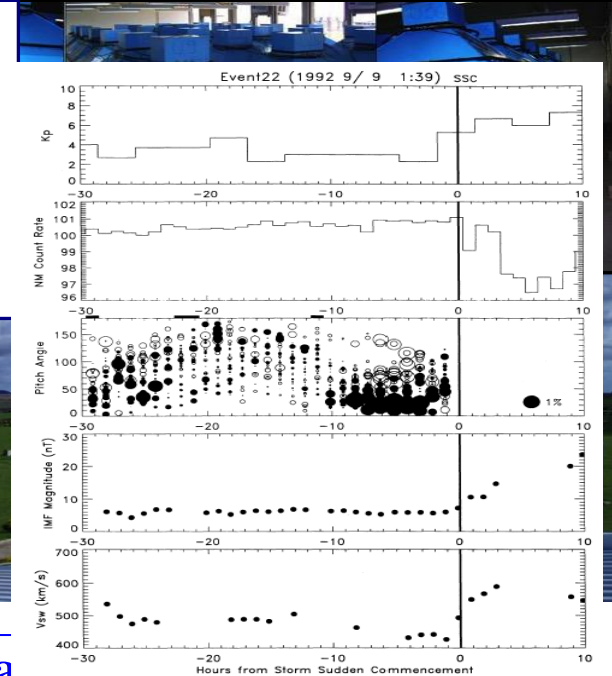


Cosmic ray monitoring by Muon detector

Magnetic storm 6-8 hours ahead



São Martinho da Serra
Santa Maria (S29, W53)







Munakata et al, JGR.2000

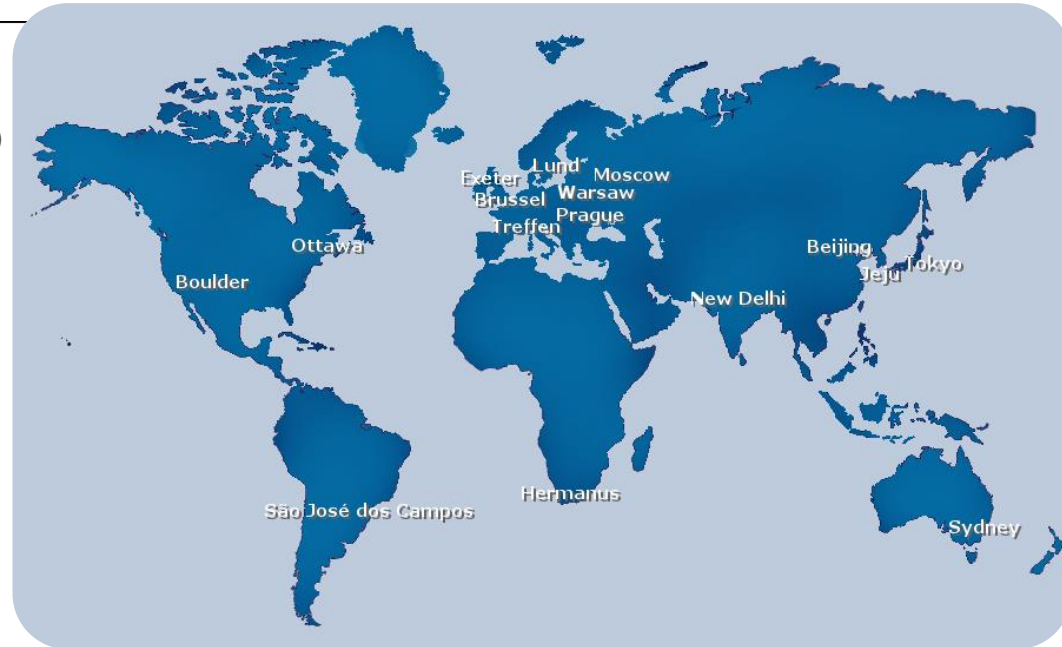
Risk Management



EMBRACE

ISES (RWC members)

<ul style="list-style-type: none"> •  SWS (Australia) •  KSO (Austria) •  SIDC (Belgium) •  EMBRACE (Brazil) •  CSWFC (Canada) •  SEPC (China) •  SAPC (China) •  IAP (Czech Republic) •  NPL (India) •  SWIFtS (Indonesia) 	<ul style="list-style-type: none"> •  NICT (Japan) •  KSWC (Republic of Korea) •  SCiESMEX (Mexico) •  SRC (Poland) •  IAG (Russia) •  SANSa (South Africa) •  LSWC (Sweden) •  MOSWOC (UK) •  SWPC (USA)
---	---



16 Regional Warning Centers
 4 Associate Warning Centers
 1 Collaborative Expert Center

Space Weather Risks are Recognized - National Mitigation Plans are being Developed

South Korea:

- Space Weather included in National Risk Profile
- Roles and responsibilities of agencies and ministries defined



Korea Space Weather Center

United Kingdom:

National Register Recognizes
Space Weather Risks



CabinetOffice

National Risk
Register of
Civil Emergencies

2012 edition

Space Weather Risks are Recognized

- U.S. National Strategy and Action Plan released October, 2015
- Developed by the Space Weather Operations, Research, and Mitigation Task Force
- Addresses benchmarks, response, data, research, modeling, and operations
- Mandates basic and targeted research
- National and international actions



Space Weather Risks are Recognized

- Addresses observing needs for:
 - Long lead-time forecasts
 - Alerts of hazardous conditions
 - Event climatology
 - Model validation
 - Scientific research
- Observing domains:
 - Ionosphere
 - Thermosphere
 - Geomagnetic
 - Energetic Particles
 - Solar and Interplanetary

Statement of Guidance

Space Weather Observations

STATEMENT OF GUIDANCE FOR SPACE WEATHER OBSERVATIONS

(Point of contact: Terence Chugger, NOAA, USA)
(First version, approved by the ITCSSG-7, 11 May 2012)

1. Introduction and Overview of Recommendations

This document contains the first Statement of Guidance and Gap Analysis conducted by the WMO Inter-Programme Coordination Team on Space Weather (ICTSW). This initial effort did not undertake to catalog all existing observations. Rather, the emphasis was placed on documenting the areas identified as most important for: 1. maintaining services in cases where the long-term continuity of observations is in doubt; 2. improving existing services, either through increased spatial coverage, improved timeliness or improved accuracy; and 3. enabling new services. This effort has not included a comprehensive documentation of customer requirements. Nonetheless, the recommendations are based on knowledge of space weather customers, whose needs can vary considerably from one region to another, and on the adequacy of existing and planned observations for current or future products.

In addition to the work of the ICTSW, this effort benefited greatly from the participation of numerous colleagues. These colleagues who contributed directly to the analysis of space weather observing systems and to the text include: Marilyn Freeman (British Antarctic Survey), Alex Chandler (University of Bath), Chris Davis (University of Reading), Jeff Love (United States Geological Survey), Greg Blesedter (National Oceanic and Atmospheric Administration) and Tim Fuller-Rowell (University of Colorado).

Vulnerability to space weather is increasing as we become more reliant on advanced technology. Active navigation and communication, drilling, mining and agriculture, electric power grid reliability – these critical activities can be impacted by space weather anywhere on the globe. Our economy, security and environmental stewardship interests now extend well above the atmosphere into space. We increasingly rely on satellite-based navigation and timing systems for transportation, commodities and financial services. Satellite communication is now a critical element of our global flow of information, supporting disaster preparedness, emergency response and broad economic growth. Our electric power grids are becoming more heavily loaded and interconnected, which increases their vulnerability to space weather. Although the direct effects of space weather are typically felt at the industry and infrastructure levels and may not be obvious to the average citizen, we are all impacted.

Actions are being taken today by industries and governments around the globe. For example, the International Civil Aviation Organization (ICAO) is updating requirements for space weather services to protect against communication outages, navigation errors and radiation risks. Electric power distribution is adjusted during space storms to avoid grid disruption. Conditions impacting satellite-based navigation systems are monitored and back-up measures are taken during high-impact events. Government emergency management agencies are developing procedures to manage the unique risks of space weather, including impacts that could simultaneously disrupt critical infrastructures in multiple countries and in widely separated regions on the globe. It is among the aims of ICTSW to provide guidance on observation capabilities needed to support such services.

To-day, services relying on operational and research observing assets can help all WMO Members to monitor disturbances and to warn of upcoming storms. The space environment, however, is vastly undersampled. Significant gaps in our observing capabilities limit our ability to provide a comprehensive characterization of the important physical parameters, and limit the accuracy of our predictive models. Existing ground-based and space-based assets have not all been integrated into a coordinated observing network. These include a number of Global Navigation Satellites

Inter Programme Coordination team on Space Weather

<http://www.wmo.int/pages/prog/www/OSY/SOG/SoG-SW.doc>

Communication with Users



Communicating through scales



SPACE WEATHER PREDICTION CENTER
 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Sunday, July 8, 2018

HOME ABOUT SPACE WEATHER PRODUCTS AND DATA DASHBOARDS MEDIA AND RESOURCES SUBSCRIBE ANNUAL MEETING FEEDBACK

Search

SPACE WEATHER CONDITIONS on NOAA Scales

24-Hour Observed Maximums			Latest Observed			Predicted 2018-07-08 UTC				
R	S	G	R	S	G	R1-R2	1%	S1 or greater	1%	G
none	none	none	none	none	none	R3-R5	1%		none	

EMBRACE
 ESTUDO E MONITORAMENTO BRASILEIRO DO CLIMA ESPACIAL
 INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

Home Embrace Products Bulletin Indices and Data Workshops Glossary Data Contact

Day's last			Day's max			Latest event		
GOES	MAG	UNAVAILABLE	GOES	MAG	UNAVAILABLE	GOES	MAG	UNAVAILABLE
R0	G0	S0	R0	G0	S0	R2	G1	S0



Daily Forecasts (1-3 day):

- Solar flares **R-scale**
- Solar energetic particles **S-scale**
- Geomagnetic activity **G-scale**
- 10.7 cm radio flux **daily flux**

Event-Driven Warnings and Alerts:

- Warnings: geomagnetic storms, proton events
- Alerts: solar flare, proton event, geomagnetic storm, electron event, solar radio burst

Numerical Models:

- **WSA-Enlil** – background solar wind and CMEs (**wind velocity, density, ..**)
- Relativistic Electron Forecast Model (**density time profile**)
- D-Region Absorption Product (**maximum frequency absorption**)
- U.S. Total Electron Content (**TEC map over US**)
- Ovation Aurora Model (**Aurora observation and prediction**)

RWC Brazil: Some Highlights

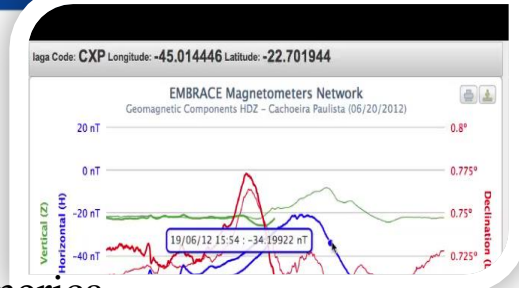
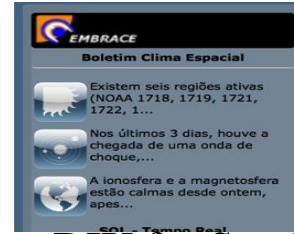
Daily Bulletins

Easy data handling

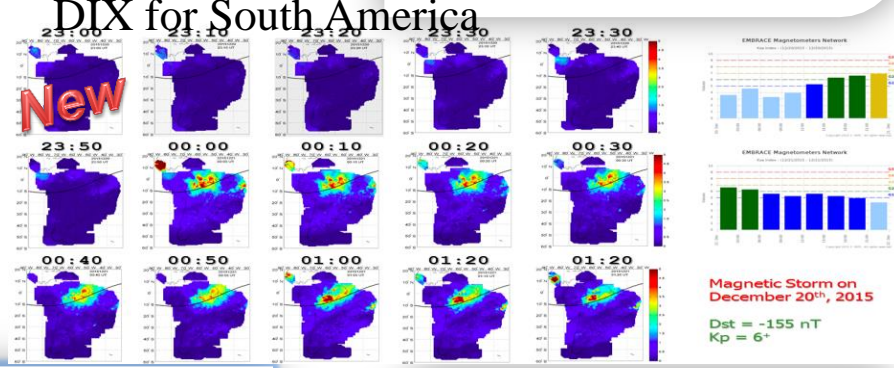
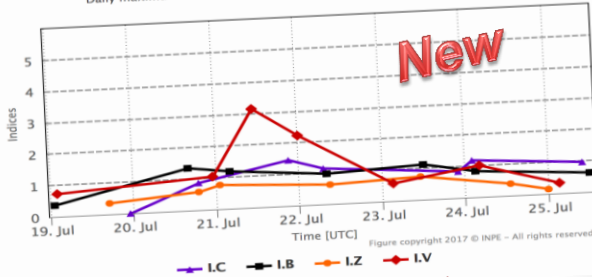
New indices are provided to classify the interplanetary measurements in simple scales based on a rate of occurrence to facilitate the end user information.

The geomagnetic storm alert is based on a regional K index for South America (KSA).

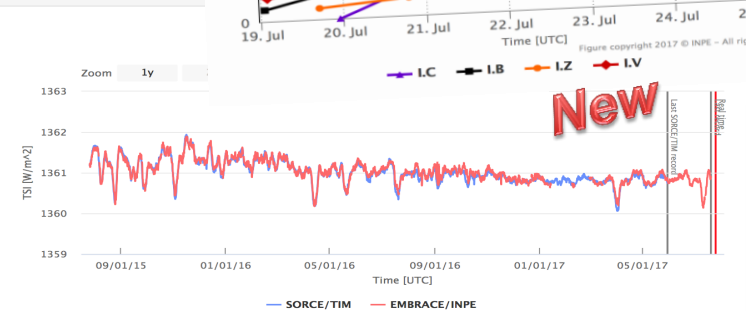
The ionosphere disturbance index (DIX) is being develop to be a primary product in **EMBRACE** cita



DIX for South America
 Summary of the Interplanetary Medium Indices
 Daily maximum - most recent between 19 Jul, 2017 and 25 Jul, 2017



Total Solar Irradiance (TSI) chart



Geomag alerter by KSA



GOES burst alerter



Total Solar Irradiance prediction

NOAA Space Weather Scales

Category		Effect	Physical	Average Frequency
Geomagnetic Storms				
G 5	Extreme	<p><u>Power systems</u>: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage.</p> <p><u>Spacecraft operations</u>: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites.</p> <p><u>Other systems</u>: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**</p>	Kp=9 determined every 3 hours	Number of storm events when Kp level was met; (number of storm days) 4 per cycle (4 days per cycle)
G 4	Severe	<p><u>Power systems</u>: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid.</p> <p><u>Spacecraft operations</u>: may experience surface charging and tracking problems, corrections may be needed for orientation problems.</p> <p><u>Other systems</u>: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**</p>	Kp=8	100 per cycle (60 days per cycle)

**For more information on geomagnetic storms and their effects, visit the NOAA Space Weather Prediction Center website at www.swpc.noaa.gov/aurora.

NOAA Space Weather Scales

For specific locations around the globe, use geographic latitude to determine fluxy sightings (see www.spc.ncep.noaa.gov/cawm04/)

Solar Radiation Storms

Flux level of \geq 10 MeV particles (ions)*	Number of events when flux level was met**
---	--

			Flux level of \geq 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	<p><u>Biological:</u> unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. ***</p> <p><u>Satellite operations:</u> satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible.</p> <p><u>Other systems:</u> complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.</p>	10^5	Fewer than 1 per cycle
S 4	Severe	<p><u>Biological:</u> unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. ***</p> <p><u>Satellite operations:</u> may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded.</p> <p><u>Other systems:</u> blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.</p>	10^4	3 per cycle

NOAA Space Weather Scales

Radio Blackouts

GOES X-ray
peak brightness

Number of events when
flux level was met;

R 5	Extreme	<p><u>HF Radio:</u> Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector.</p> <p><u>Navigation:</u> Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.</p>	X20 (2×10^{-3})	Fewer than 1 per cycle
R 4	Severe	<p><u>HF Radio:</u> HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time.</p> <p><u>Navigation:</u> Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.</p>	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	<p><u>HF Radio:</u> Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth.</p> <p><u>Navigation:</u> Low-frequency navigation signals degraded for about an hour.</p>	X1 (10^{-4})	175 per cycle (140 days per cycle)

Indices of the interplanetary medium

Indices

I.B – Interplanetary

Magnetic field
Intensification

I.Z – Pure southward
component of
magnetic field

I.V – Persistent
increasing of the Solar
Wind Speed

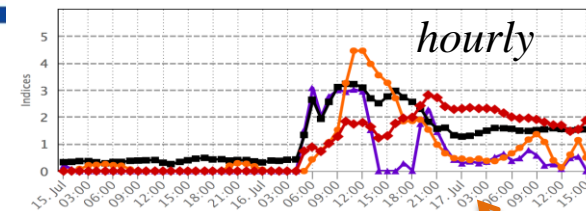
I.C - Magnetopause

The IM indices were created based in the rate of occurrence to describe better the space weather daily or hourly conditions in the interplanetary medium close to the Earth. They are signatures of the solar wind speed, magnetic configuration and its effects on the magnetopause

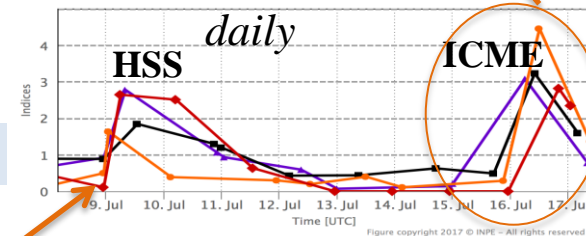
Indices I.B, I.Z, I.V, I.C	Level	Typical Occurrence
5	Extreme	one day every two years
4	Severe	one day every six months
3	Strong	one day every month
2	Moderate	one day every fortnight
1	Minor	one day every week
0	Absent	one day every 1.5 days

<http://www2.inpe.br/climaespacial/portal/swd-home/>

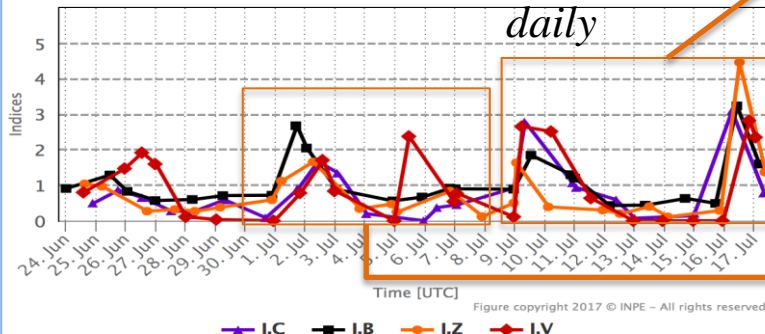
Summary of the Interplanetary Medium Indices
Hourly indices – most recent between 15 Jul, 2017 and 17 Jul, 2017



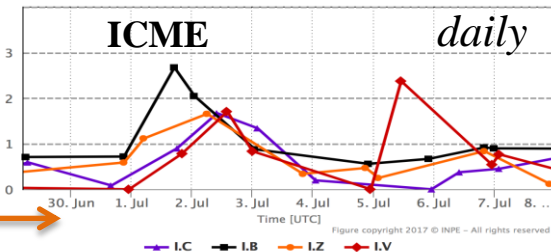
Summary of the Interplanetary Medium Indices
Daily maximum – most recent between 24 Jun, 2017 and 17 Jul, 2017



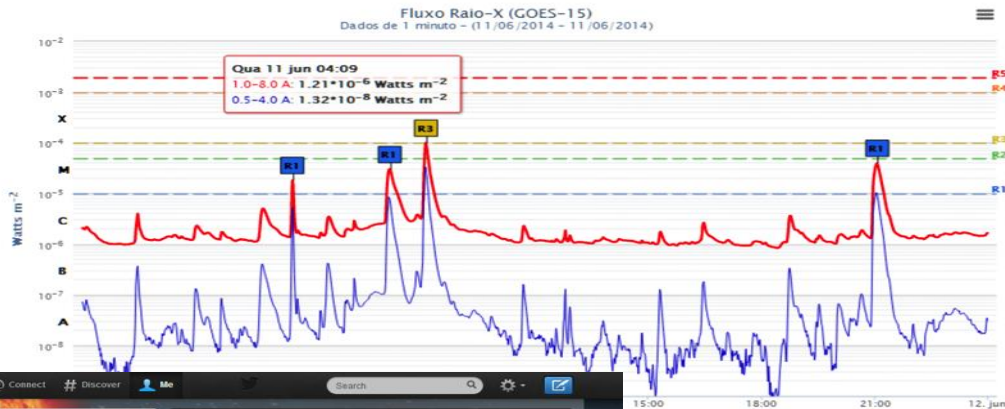
Summary of the Interplanetary Medium Indices
Daily maximum – most recent between 24 Jun, 2017 and 17 Jul, 2017



Summary of the Interplanetary Medium Indices
Daily maximum – most recent between 24 Jun, 2017 and 17 Jul, 2017



Flare Alerts



@climaespacial

CLASS_X

Clezio Marcos De Nardin,
 O sistema de monitoramento do EMBRACE detectou um evento CLASS_X através do instrumento GOES.

The monitoring system EMBRACE detected an CLASS_X event through the instrument GOES.

ALERTA RAI0-X GOES



O sistema de detecção de eventos EMBRACE verificou a existência de flare classe X com nível de severidade R3 ocorrido em 11-06-2014 às 09:06:00 UTC.

Effeto de Severidade R3:
 HF Radio: Grande área de blackout em comunicação em rádio HF; perda de rádio contatos por aproximadamente uma hora na região iluminada. Navegação: Navegação em baixa frequência degradada por aproximadamente uma hora.

X-RAY GOES ALERT



The event detection system EMBRACE verified the existence of flare class X with severity level R3 occurred in 06-11-2014 at 09:06:00 UTC.

Effect Severity R3
 HF Radio: Large area blackout in HF radio communication, loss of radio contact for about an hour in the illuminated region. Navigation: Navigation in low frequency degraded for about an hour.

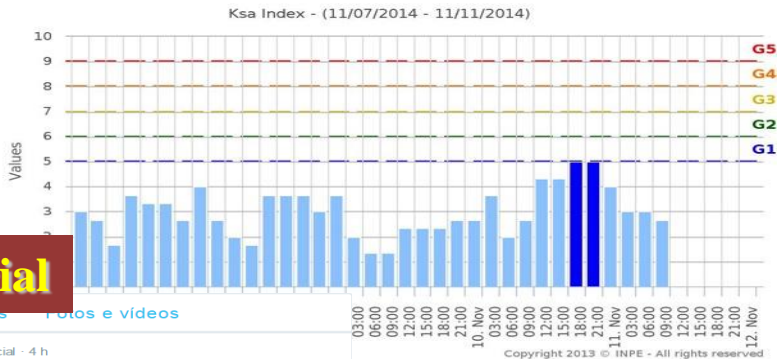
Esta é uma mensagem automática. Por favor não responda este email. Se precisar contactar-nos envie email para contato.embrace@inpe.br. This is an automated message. Please do not reply to this email. If you need to contact us please send email to contato.embrace@inpe.br.

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Magnetic Storm Alert

EMBRACE Magnetometers Network



@climaespacial

Tweets Tweets e respostas Fotos e Vídeos

Programa EMBRACE @climaespacial · 4 h
 [ALERT] Embrace/INPE detected a G1 level Magnetic Storm using the Ksa index. See details bit.ly/1o2QpUS #INPE #SpaceWeather

Programa EMBRACE @climaespacial · 4 h
 [ALERTA] Embrace/INPE detectou tempe índice Ksa. Detalhes em bit.ly/1v6aOcv.

Programa EMBRACE @climaespacial · 22 h
 Subtempestade geomag manhã de hoje eleva os i para 4+ e 1000 nT, respe

EMBRACE Magnetometers Network



Ksa - 10-11-2014 18:00:00

Clezio Marcos De Nardin,

O sistema de monitoramento do Embrace/INPE detectou uma tempestade magnética nível G1 no índice de perturbação magnético Sul-americano Ksa. Detalhes em <http://bit.ly/1v6aOcv>.

The Embrace/INPE monitoring system detected a G1 level Magnetic Storm using the South American disturbance index Ksa. See details <http://bit.ly/1o2QpUS>.

G1 (Fraco) - 5o



Evento ocorrido no período: 10/11/2014 18:00:00 a 10/11/2014 21:00:00

Efeito: Sistema elétrico: flutuações fracas na voltagem podem acontecer. Operação de satélite: possível impacto pequeno nas operações. Outros sistemas: animais migratórios são afetados neste nível e em níveis mais altos.

Medida: Kp = 5

Frequência Amostral: 1700 por ciclo (900 dias por ciclo)

G1 (Minor) - 5o



Event occurred in the period: 11/10/2014 18:00:00 to 11/10/2014 21:00:00

Effect: Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels.

Measure: Kp = 5

Average Frequency: 1700 per cycle (900 days per cycle)

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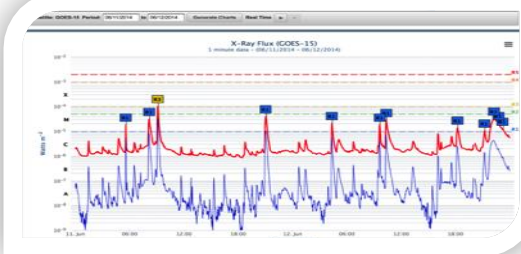
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RWC Brazil: Some Highlights

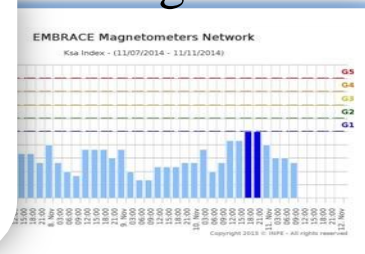
Daily Bulletins



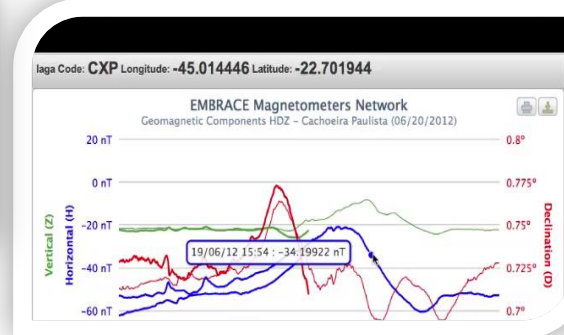
GOES burst



Geomag alerter

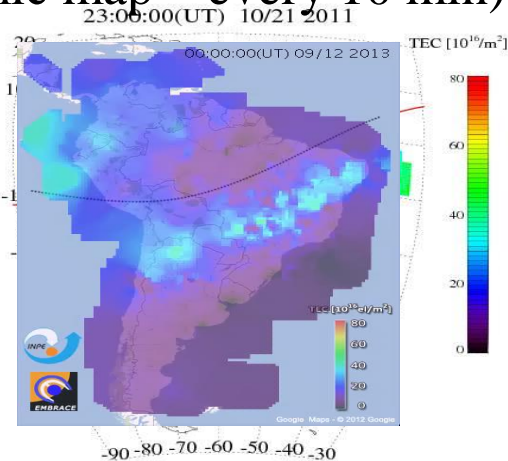


Easy data handling

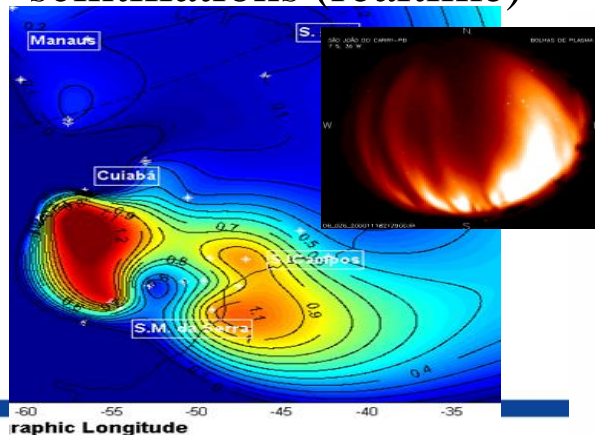


GPS TEC Map over South America

(dynamic map – every 10 min)

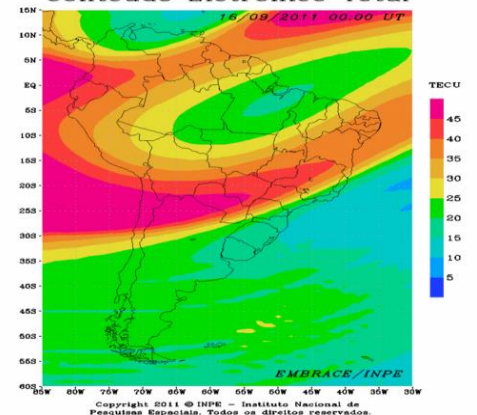


Plasma bubbles and scintillations (realtime)



Ionospheric model

(TEC 24 hours ahead)



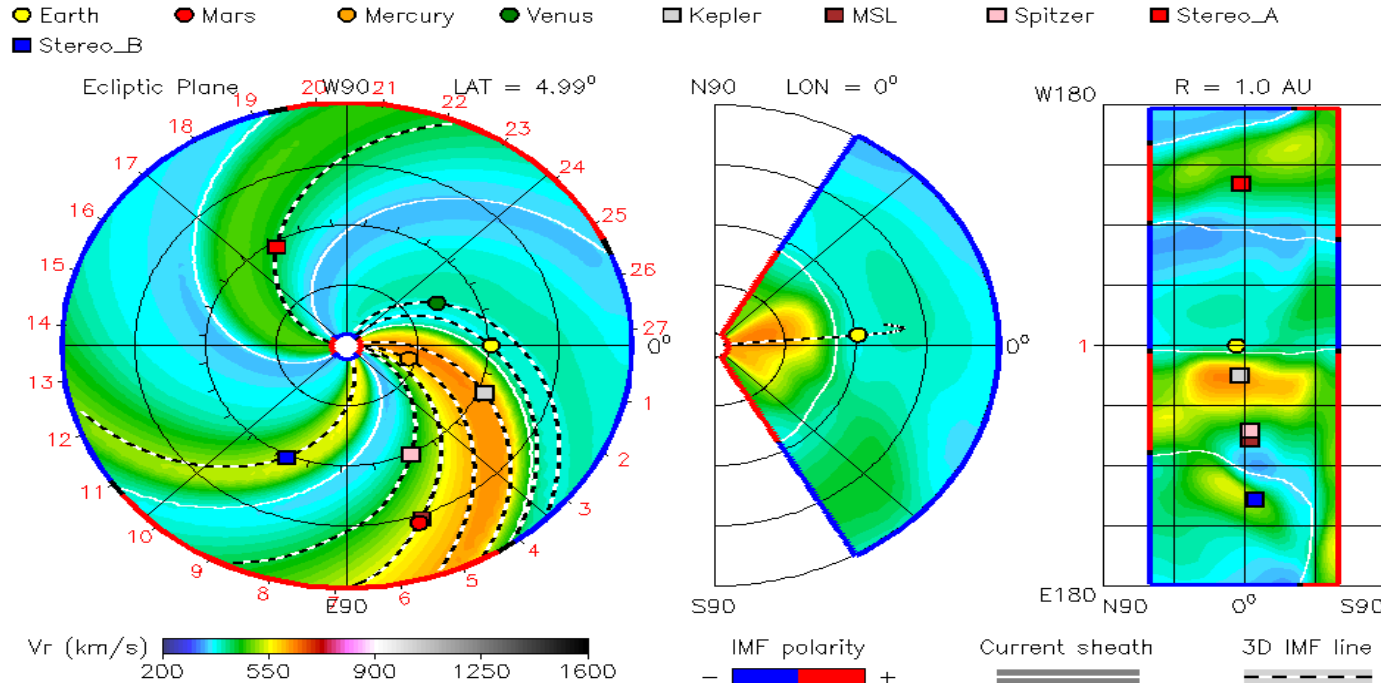
Modeling to Predict



WSA-ENLIL Model: Solar Wind Speed

2012-07-22T00:00

2012-07-22T00 +0.00 day



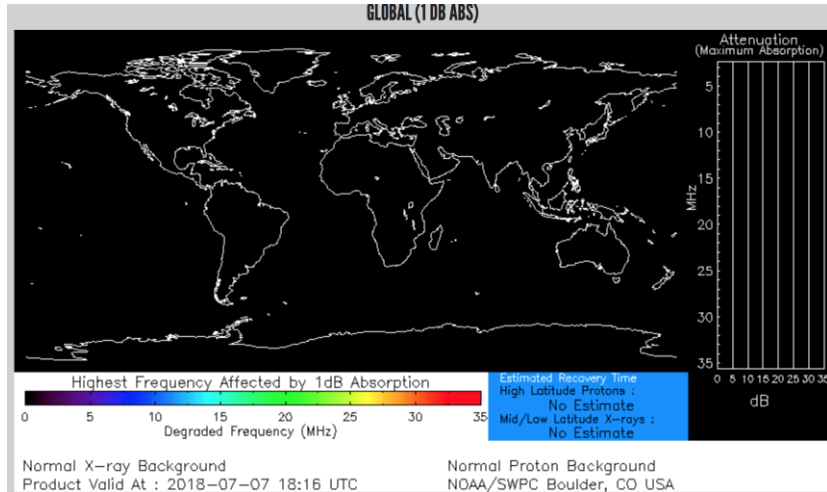
ENLIL-2.7 lowres-2126-a3b1f WSA_V2.2 GONG-2126

[comet/watp-sid/258x30x90x1.2126-a3b1f-16-mep1urn1ed-1.g03q5d2.gong-2012-07-2100](http://comet.watp-sid/258x30x90x1.2126-a3b1f-16-mep1urn1ed-1.g03q5d2.gong-2012-07-2100) 2012-07-23

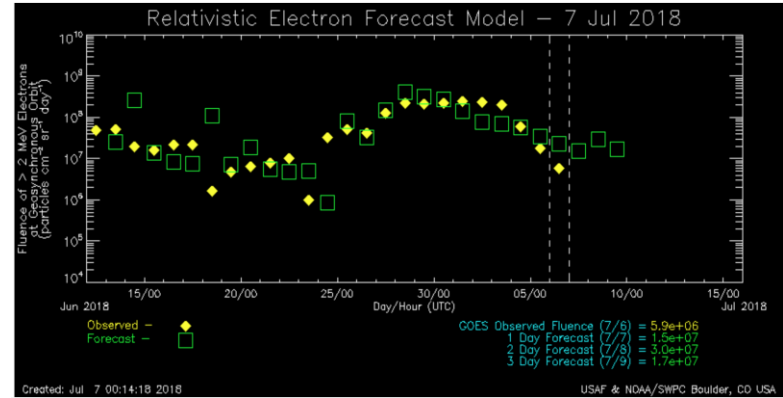


Some predicted products (SWPC)

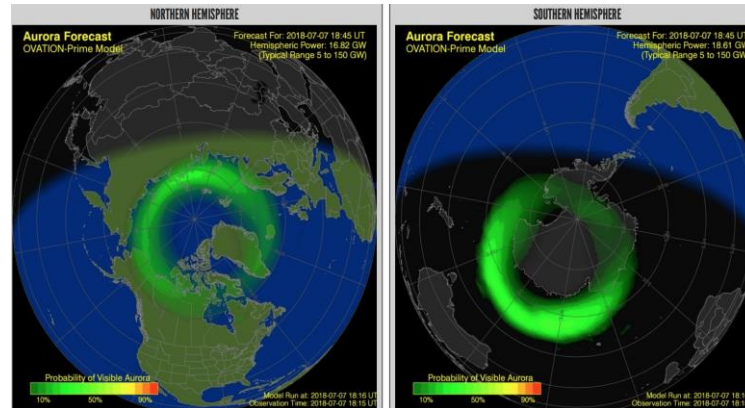
F-Region absorption



Relativistic electron forecast



Aurora oval prediction

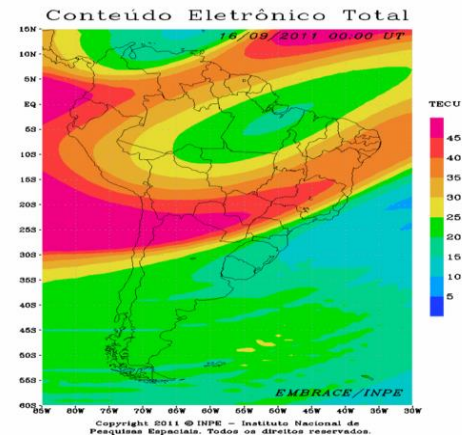
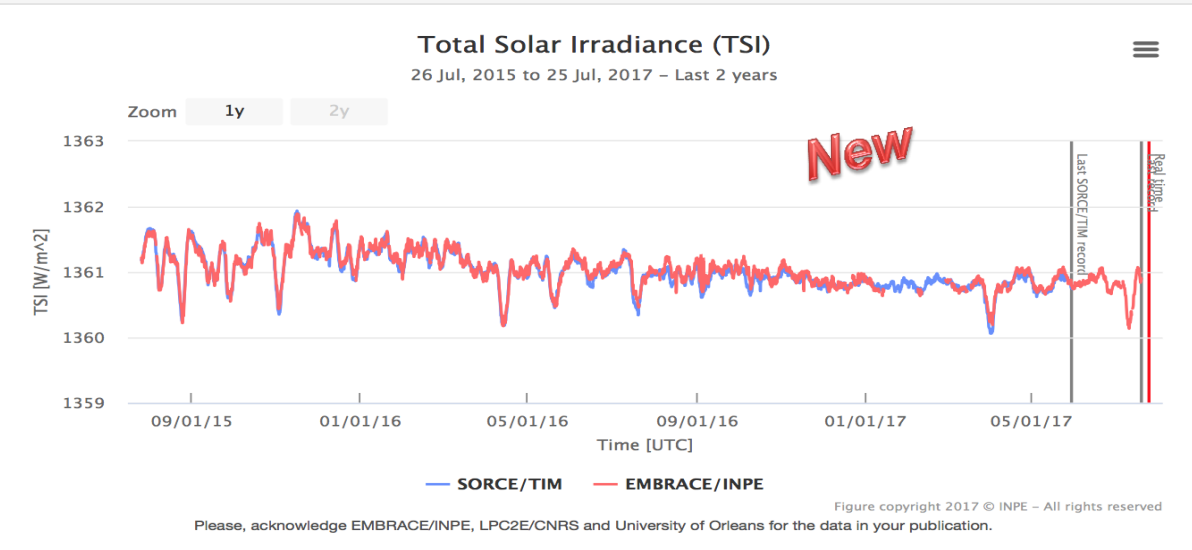


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The geomagnetic storm alert is based on a regional K index for South America (KSA).

The ionosphere disturbance index (DIX) is being developed to be a primary product in EMBRACE site.

Total Solar Irradiance (TSI) chart (Observed vs Estimated)

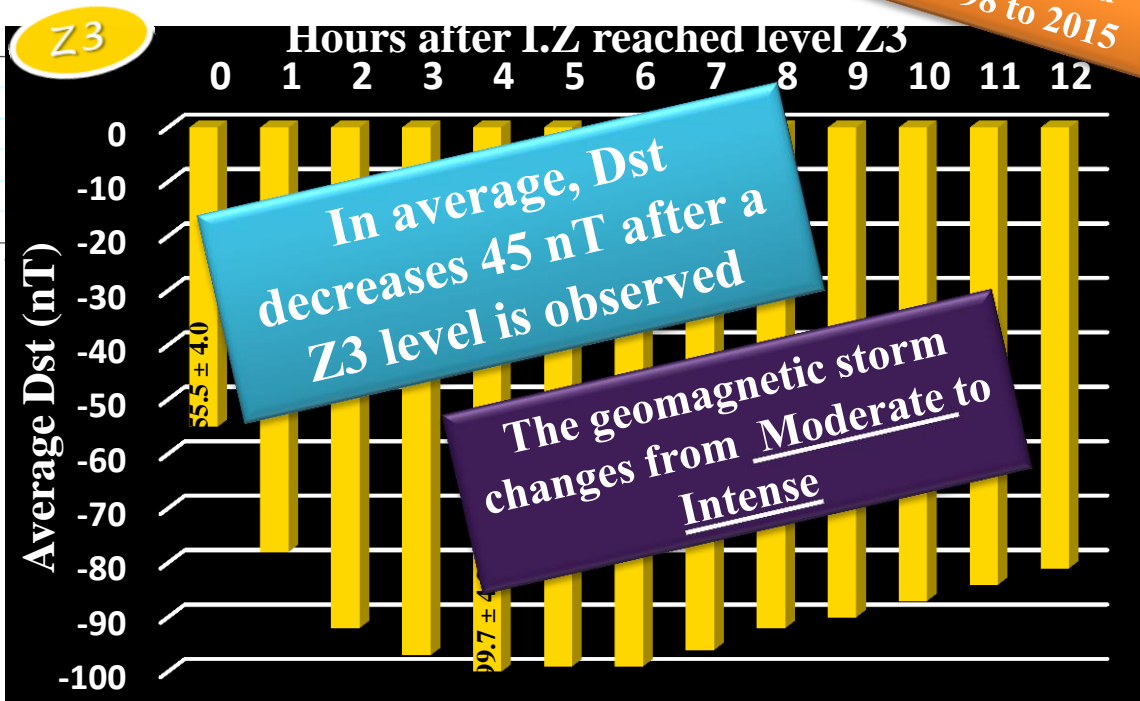
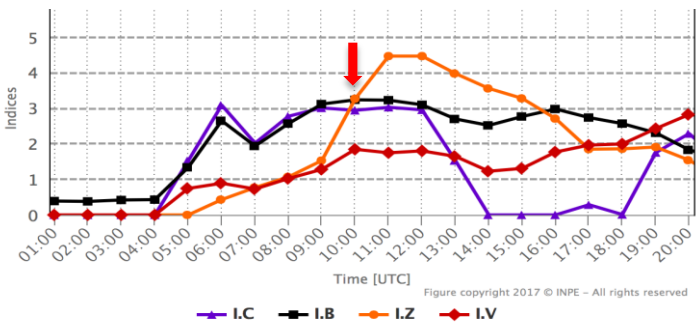
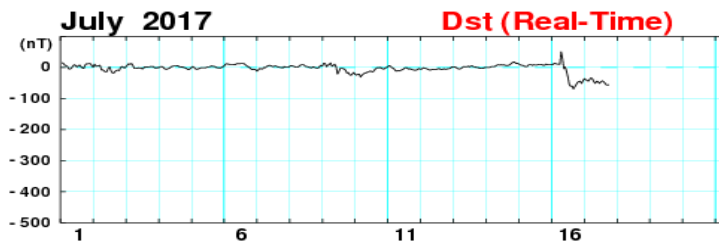


Ionospheric model SUPIM

Example: a practical use of I.Z. index

The interplanetary medium I.Z index presents a strong correlation with Dst index. From the period of 1998-2015 events observed it is noted that after I.Z reaches a level 3 the Dst will decrease 45 nT in average in four to six hours (Braga et al, 2017, in preparation).

Statistic of observed events in 1998 to 2015



Thank you
Gracias

<http://www.inpe.br/climaespacial>

joaquim.costa@inpe.br