ICMEs as drivers of Sun-Earth coupling and Space Weather initiatives of LAMP in Argentina

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In collaboration with Demoulin P., Janvier M., Masías-Mesa J.J., Medina S., Carbalo H., López V., Niemela-Celada A.E., Asorey H., & LAGO Collaboration (www.lagoproject.net)

International Space Weather Initiative Workshop
ICTP, 20–24 May 2019

Road map:

- ICMEs: as forcing geo-space activity
- ICMEs: Shielding of GCRs
- LAMP Space Weather initiatives in Argentina
- Other operative initiatives in the region

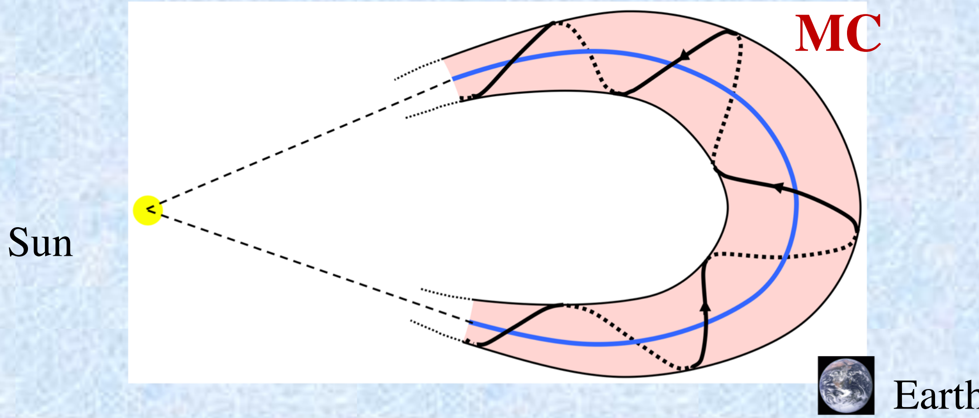
$V_x(t)$ & $B_s(t)$ near Earth are determined
by (i) solar initial condition and (ii) **IP evolution**

Then, two ICME/MC with same initial conditions can arrive Earth with **different $V_x(t)$ & $B_s(t)$** profiles

What are the most relevant physical mechanisms in the IP evolution?
(interaction w ambient, erosion, …)
How much affect each one?

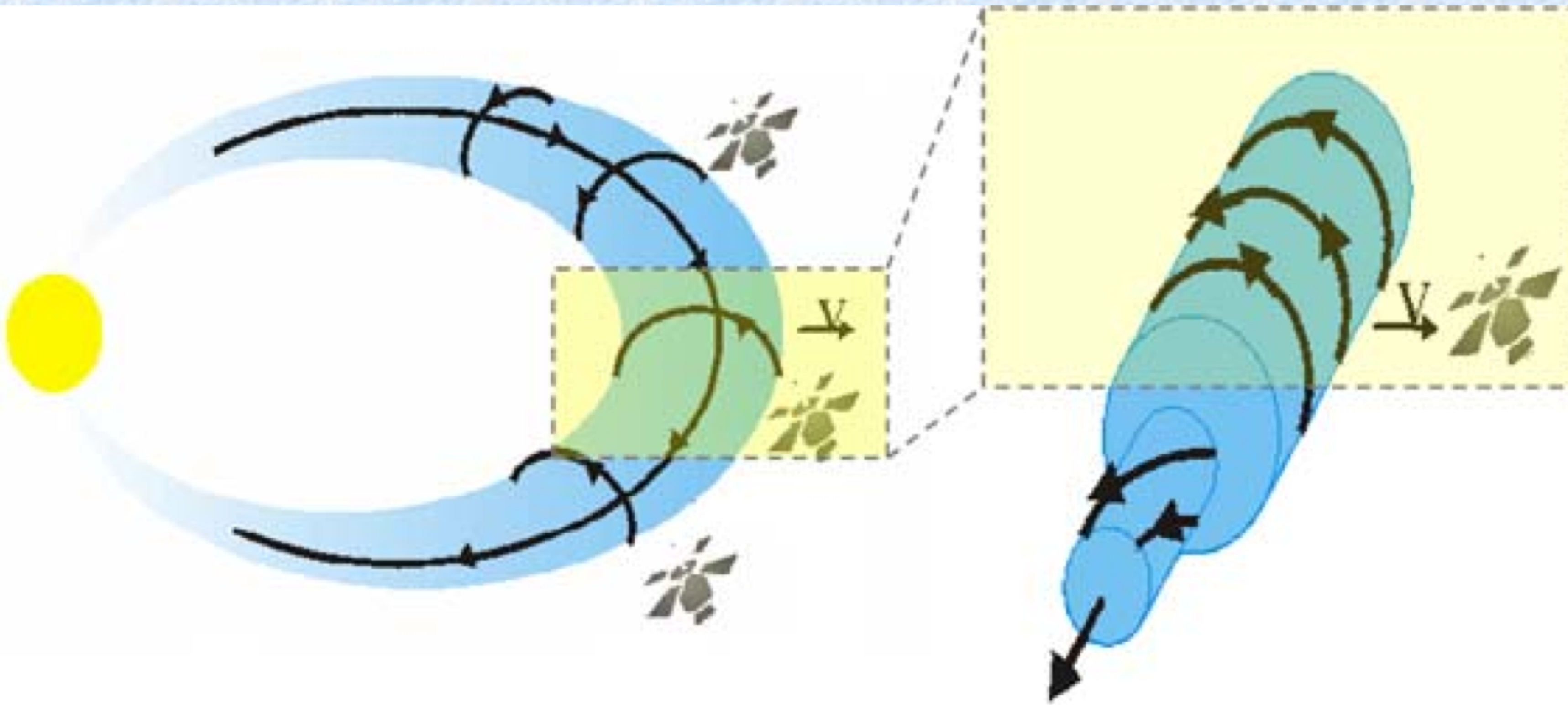
We focus now on one of the main IP aspects of ICMEs, which affect their geo-effectiveness while they are propagating from Sun to Earth:

- Erosion due to magnetic reconnection
- Typical 3D global shape in the heliosphere
- Typical time profile observed at IP near Earth

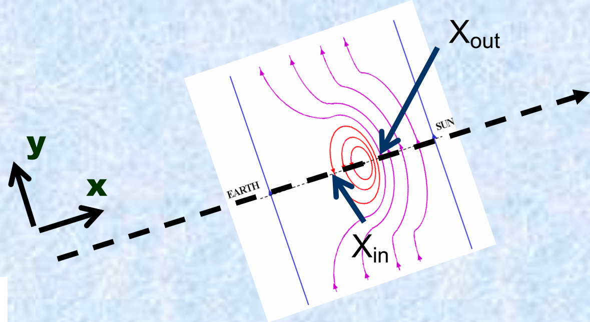


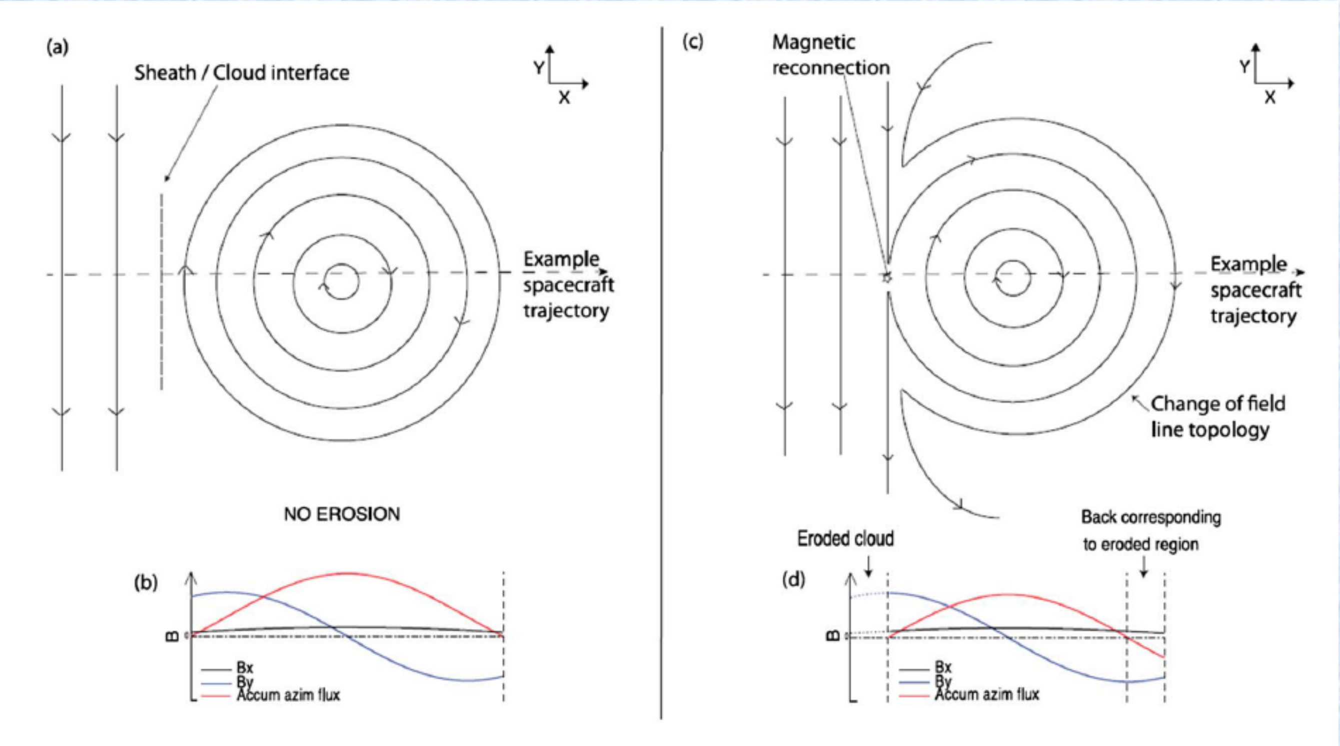
Note that the Earth/MC relative size is not real !
Thus, knowledge of details of the MC structure are importante to determine how geoeffective will be

Cylindrical good approximation for local slide

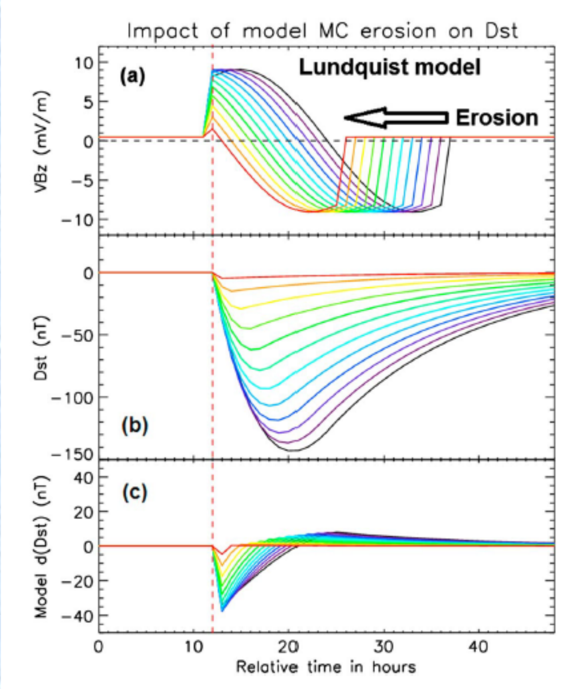


How much erosion from Sun to 1 AU can affect the geoeffectiveness





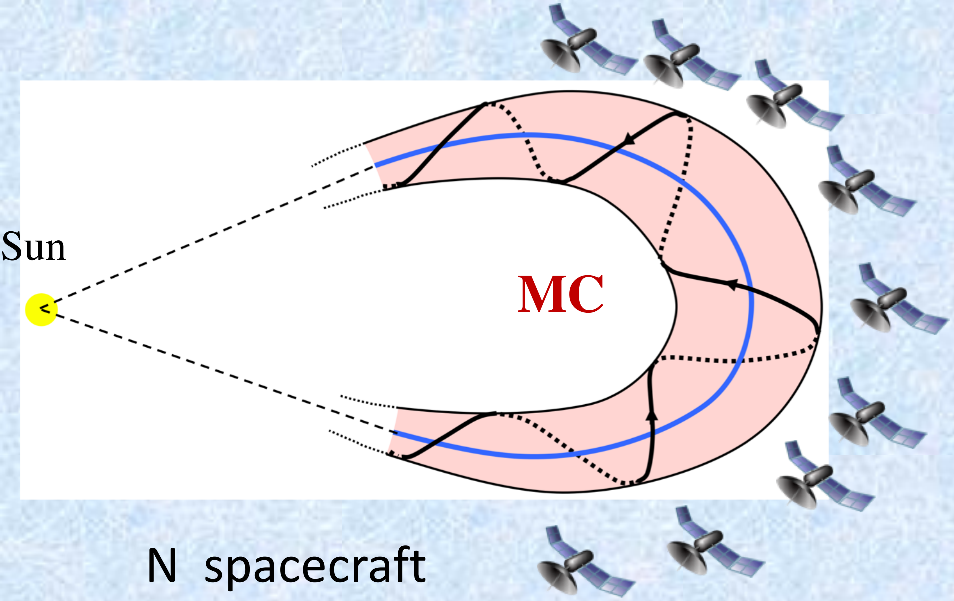
[Dasso+ 2006, Lavraud+ 2014 Ruffenach+ 2015]



Numerical estimations for one eroded case provide a reduction of the Dst peak around 30%

Eroded case 30% weaker than if no erosion had occurred

It is possible to get the global 3D shape from a model, compared with statistical observations of a single MC crossed by multiple spacecrafts



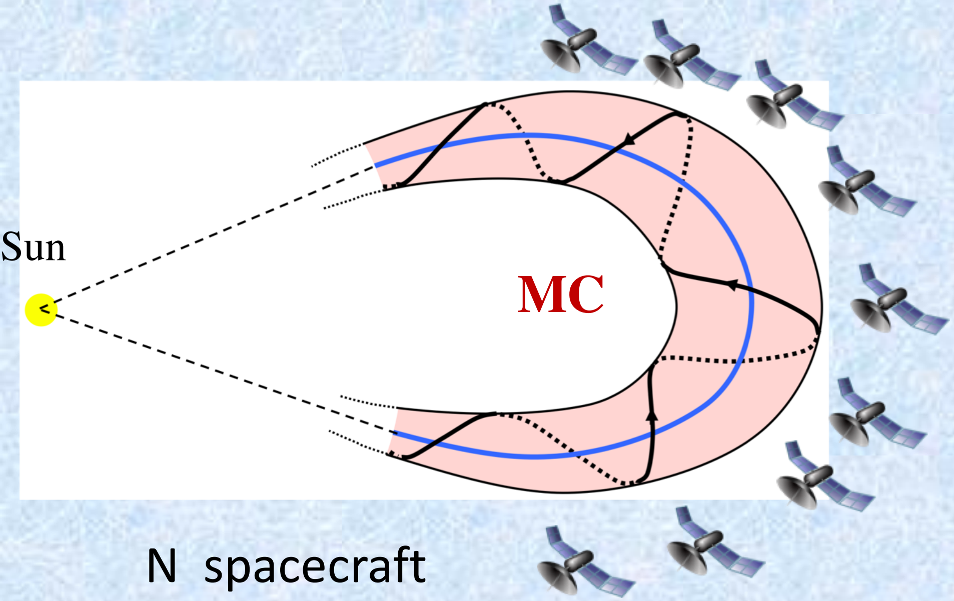
N spacecraft

N × 

May be interplanetary cubesats in the near future?

It is possible to get the global 3D shape from a model, compared with statistical observations of a single MC crossed by multiple spacecrafts

At the moment, one single spacecraft, but for many events observed at different places



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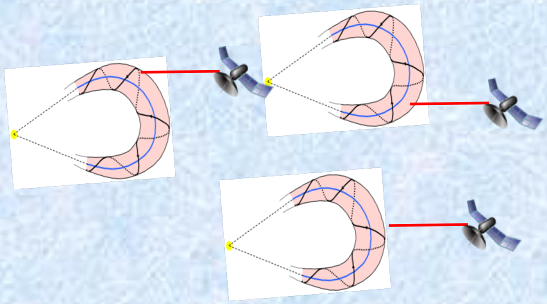


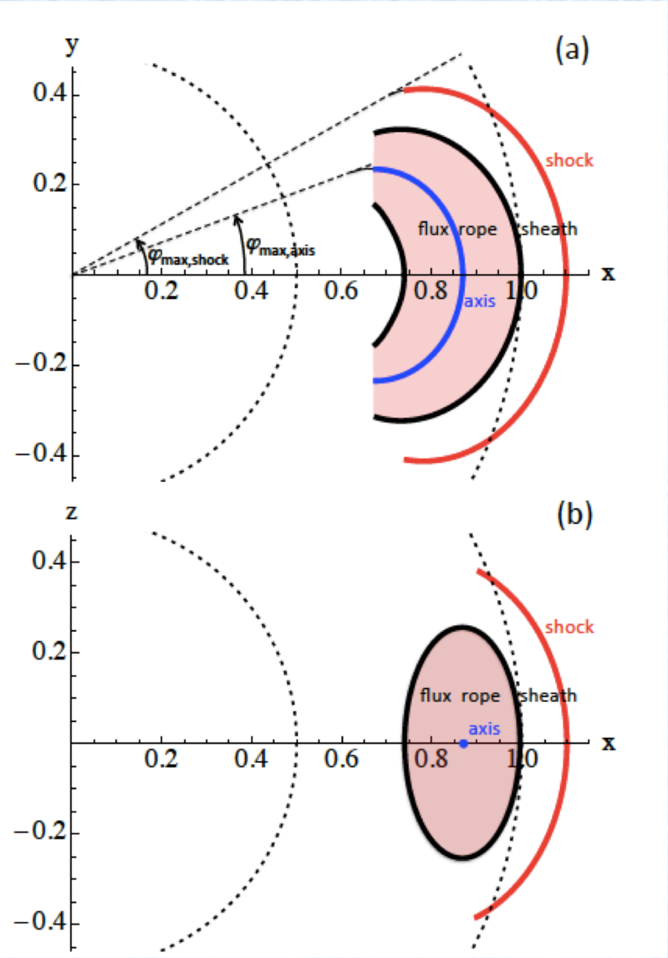
Crossing a statistically significant # of events => large variety of crossing at different locations (along the flux rope). For similar sample of MCs, equivalent to the scenario of the left

[Janvier+ 2013, 2014]

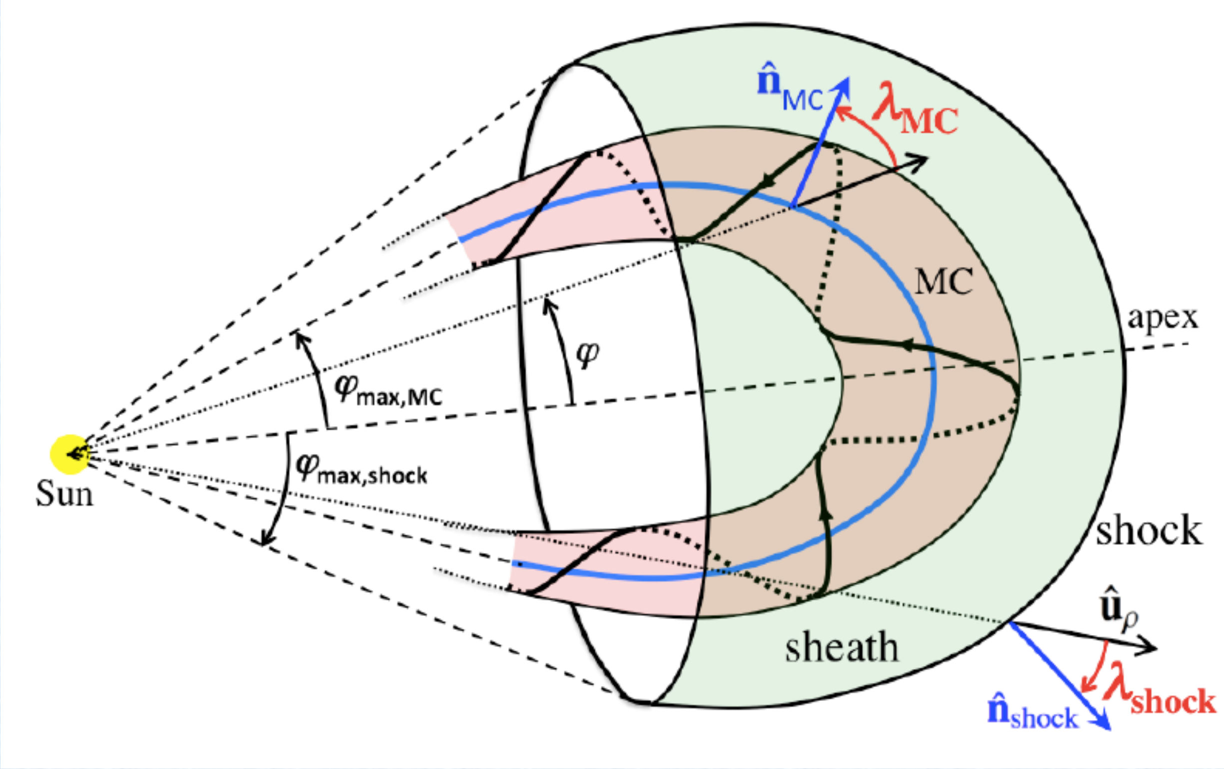
Then, from assuming a free geometrical model, and comparison with observations => a typical shape can be deduced

First quantitative cartoon for typical flux rope and driven shock, based on statistical analysis

Same procedure for the shape of the 3D surface of the shock wave: elliptical shape (symmetry axis along Sun-apex) [Janvier+ 2015]



[Demoulin+, A&A, 2016]



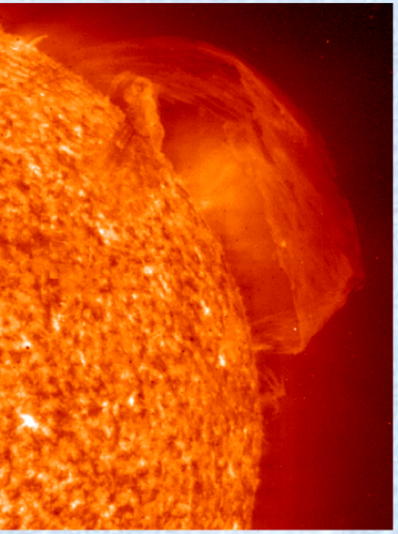
When an ICME strongly interacts with non-stationary solar wind or for ICME-ICME interaction, the evolution is not smooth and strong deviations are expected on the 3D shape and on the geo-effectiveness [Dasso+ JGR 2009]

Key solar wind properties for the Sun-Earth coupling and space weather forecasting

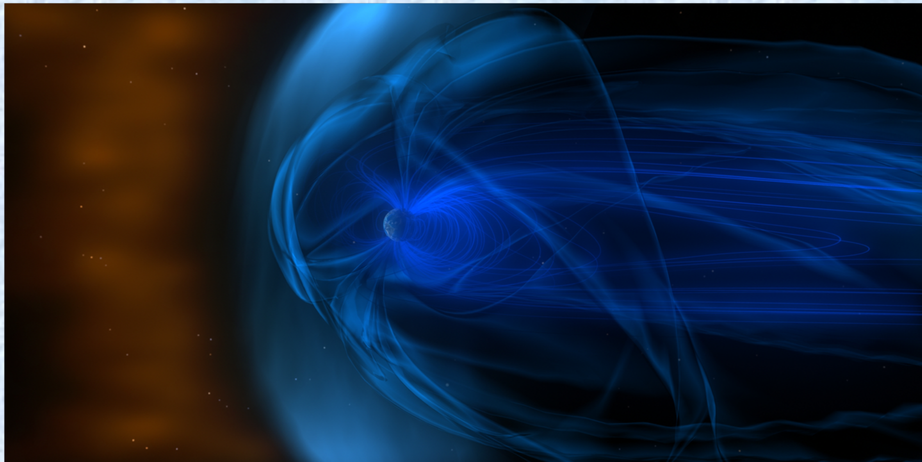
- interplanetary magnetic field
- solar wind speed
- solar wind density
- level of turbulence, etc

interplanetary magnetic field + solar wind speed → dawn-dusk electric field

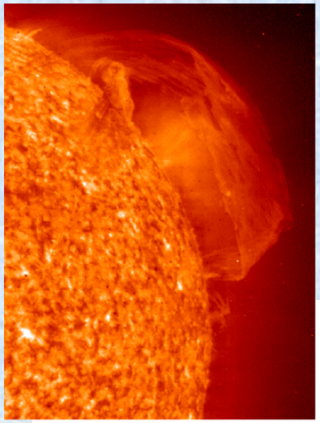
solar wind speed + solar wind density → dynamic pressure

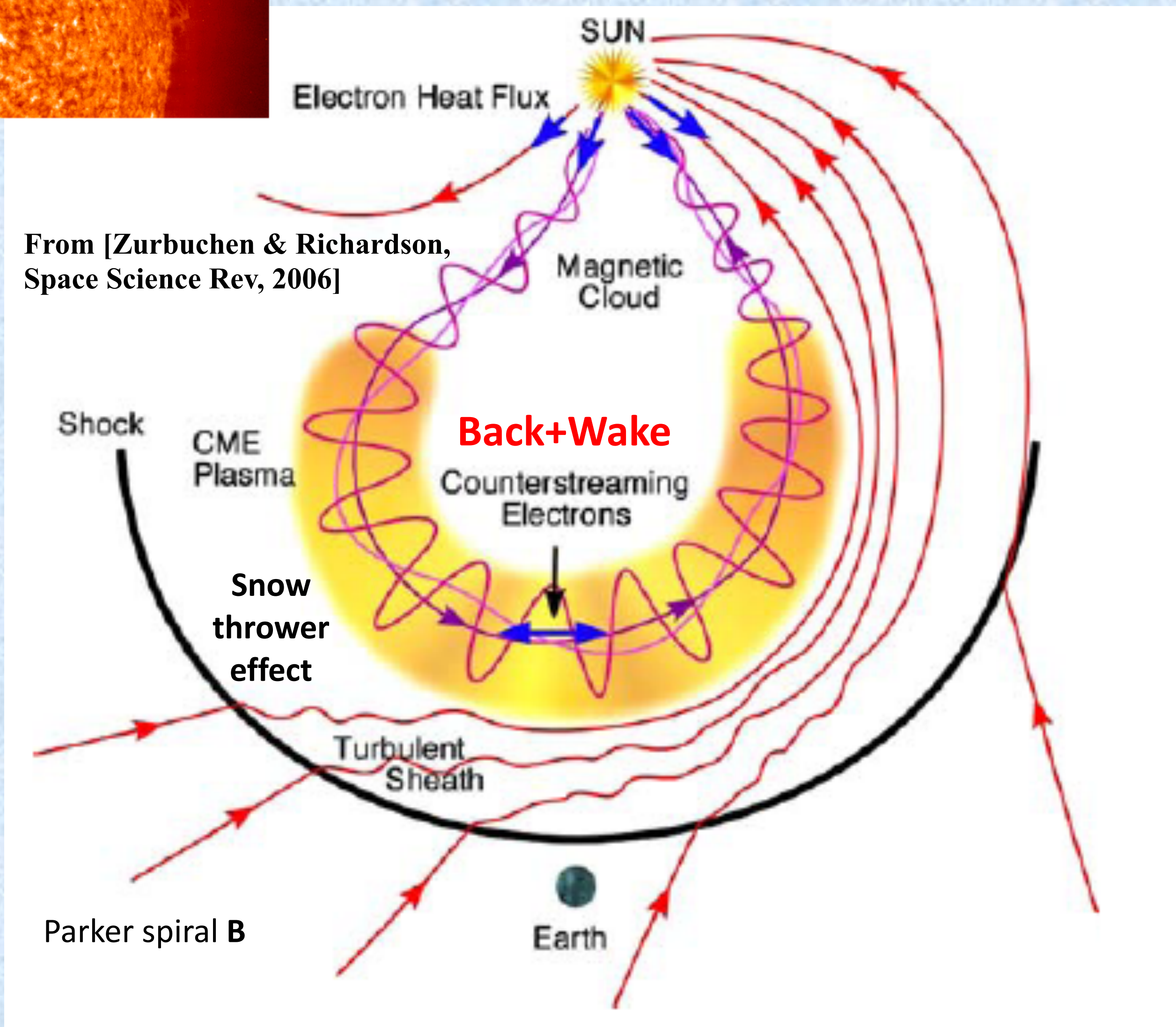


ICMEs are IP transients, that change drastically the interplanetary plasma and magnetic properties near Earth

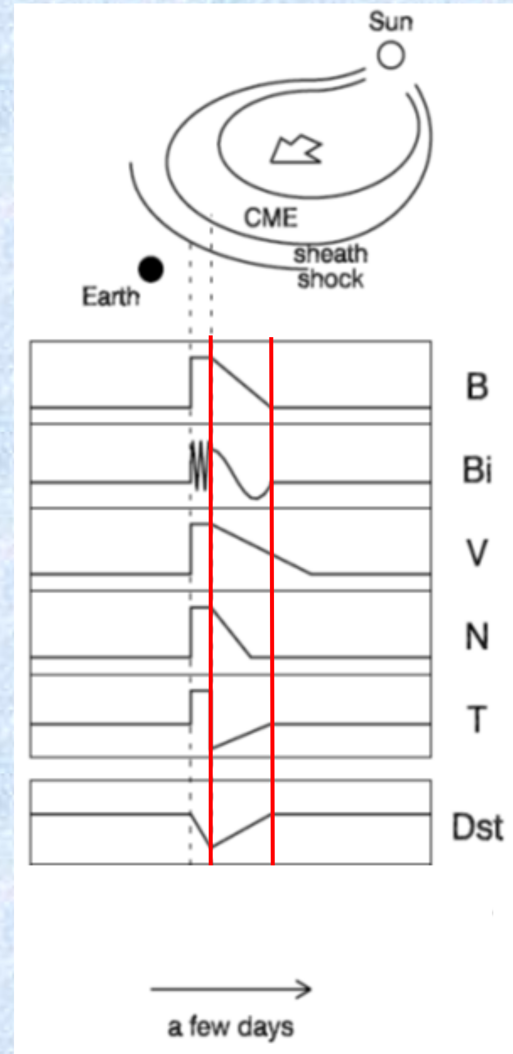


Four key substructures inside an ICME: shock, sheath, ejecta and back-wake





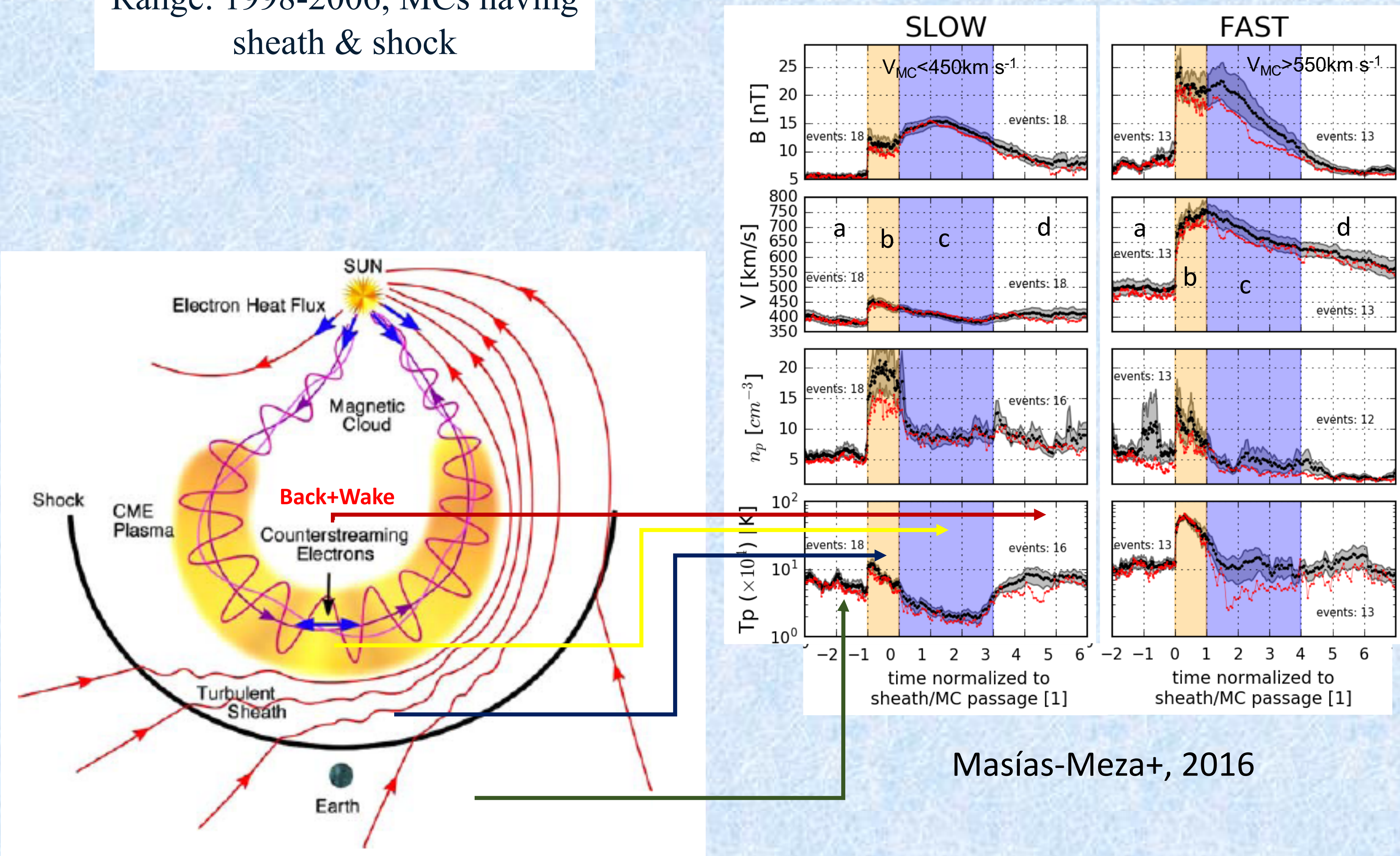
From [Zurbuchen & Richardson, Space Science Rev, 2006]



Kataoka and Miyoshi, 2006

Superposed Epoch Analysis: Splitting samples by velocity (best 'order-parameter')

-ACE: MAG and SWEPAM, Range: 1998-2006, MCs having sheath & shock



Masías-Meza+, 2016

Effects of IP conditions on transport of GCRs, on short and large time scales (i.e., Forbush and solar cycle modulation)

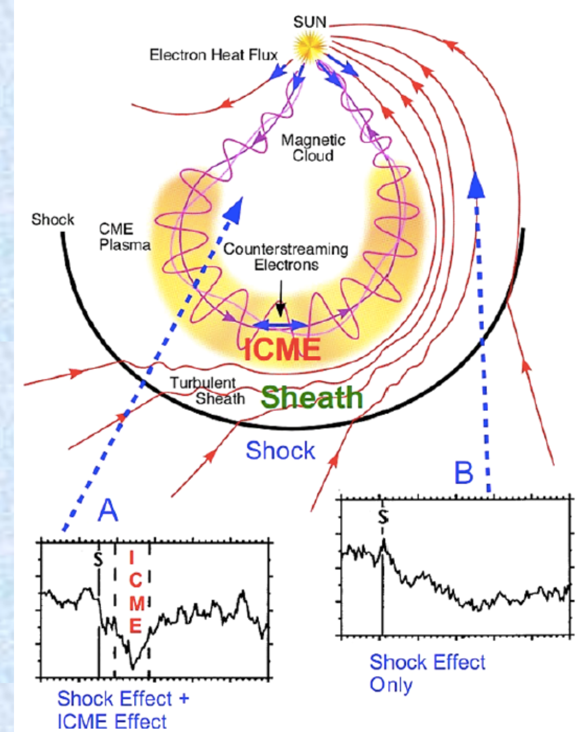
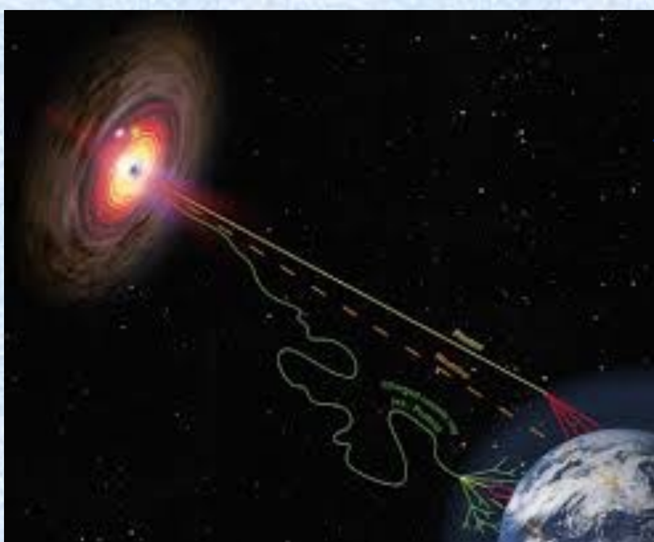
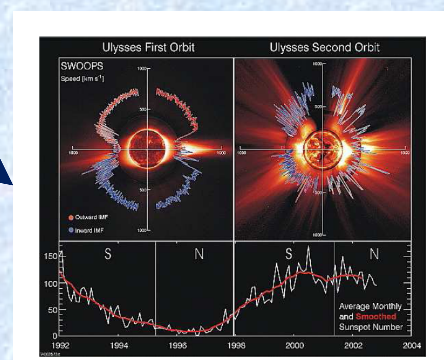
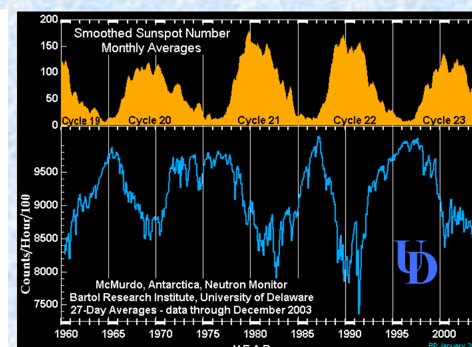


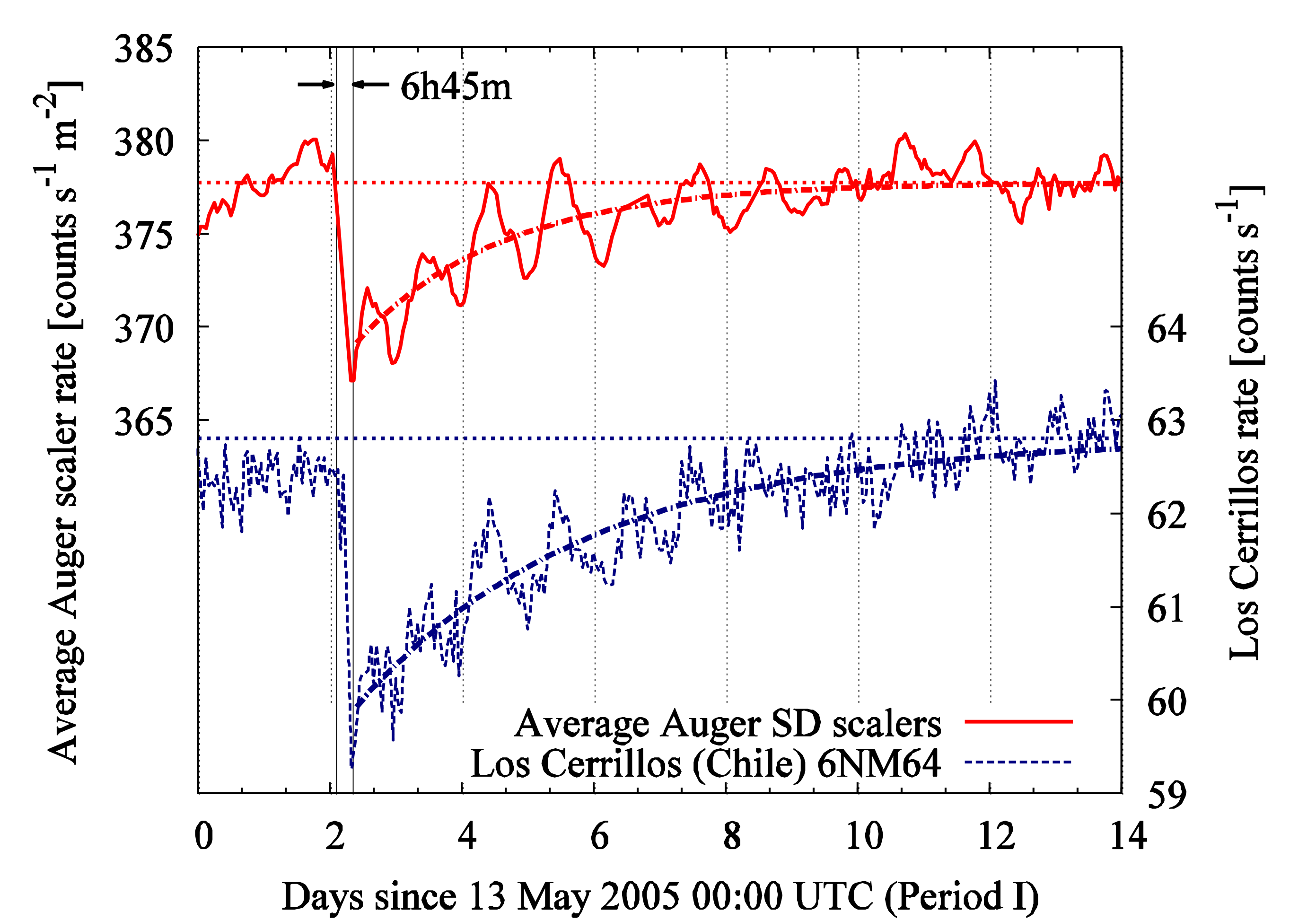
Figure from Richardson & Cane [2011]







• Comparison of a Forbush Decrease observed with a typical Neutron Monitor (NM, blue dashed) and with a Water Cherenkov radiation Detector (WCD, red solid).
• Forbush event: May 15th, 2005, NM is from Los Cerrillos (Chile). WCD is from the Pierre Auger Observatory.
• FD-NM peak was ~ 7% & FD-WCD peak was ~ 3%
• Similar daily variations in the flux are seen at both observatories.
• **WCDs can discriminate different energy channels in secondaries.**



From Pierre Auger Collaboration [Jinst, 2011]

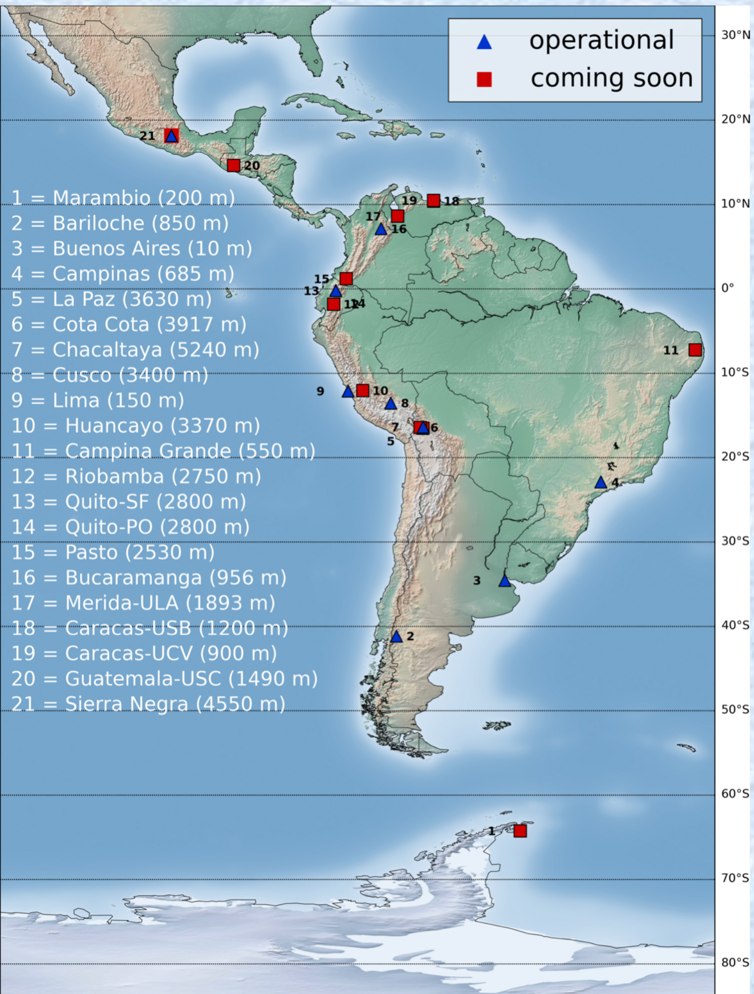
WCDs from the LAGO Collab have also observed FDs [e.g., Asorey+ICRC, 2016]

A LAGO node at Antarctic [Dasso+,ICRC, 2016]

LATIN AMERICAN GIANT OBSERVATORY (LAGO):

WWW.LAGOPROJECT.ORG

A LATIN AMERICAN ASTROPARTICLE NETWORK



Operative LAGO detectors will cover a geographical gap.

And also will provide energy resolution for:
- direct observations for secondary CRs
- modeled primary CRs

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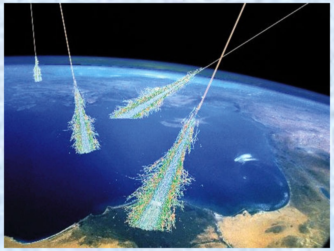
NEWRUS (NEW antarctic cosmic Rays detector to Use in Space weather)

An Space Weather laboratory was recently set up (las campaign) in the Argentine Antarctic Marambio base. Different instruments were installed: particle detector (NEWRUS), meteorological station, magnetometer, etc. NEWRUS forms part of a LAGO node [Water Cherenkov detector].

The Antarctic campaign was done in Jan-March, 2019. Participants of the campaign: Dasso S. (project PI), Gulisano A. (project co-PI), Aresno O. and Pereira M.



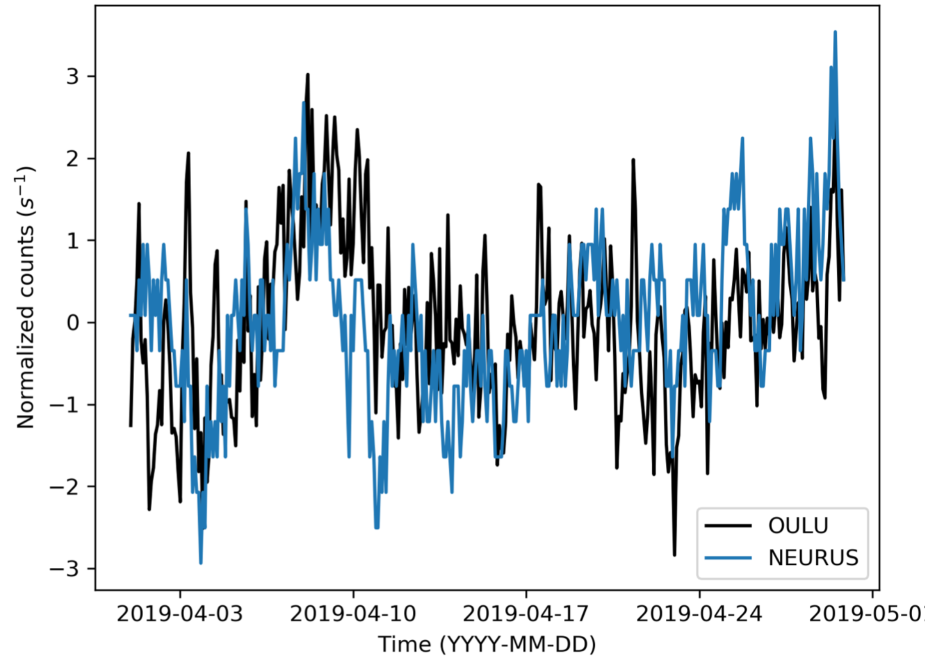
Comparison of Neurus during its first month of observations at Antarctic

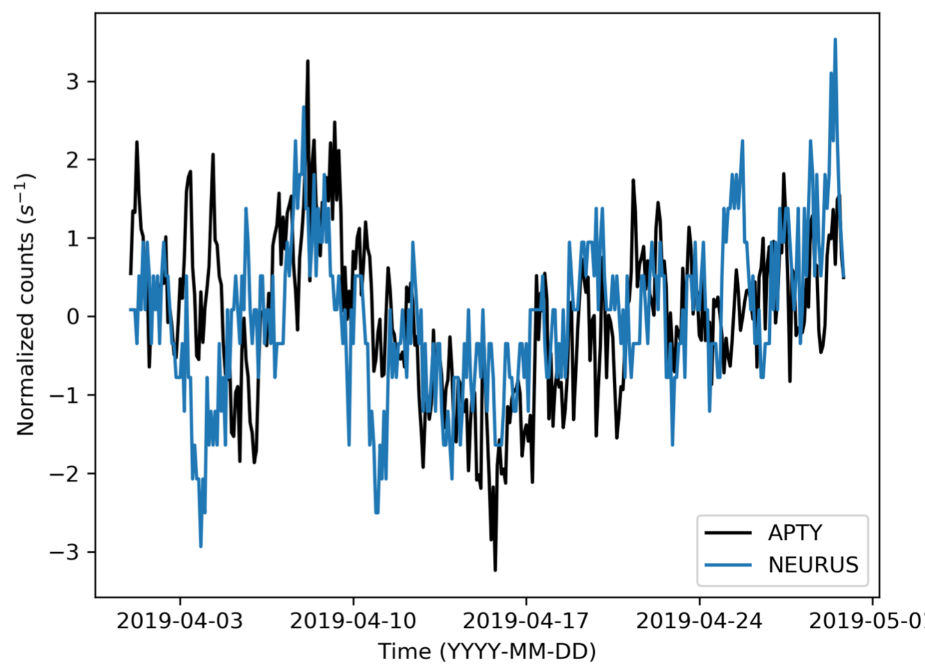
OULU	65.05587, 25.46792	
APTY	67.5704, 33.3935	
NEURUS	-64.23934, -56.62491	

Rc_{OULU} ~ 1 GV

Rc_{APTY} ~ 1 GV

Rc_{Neurus} ~ 2 GV





Real time data will be publicly available soon in internet, for operative as well as for scientific aims

Space Weather Initiatives

in Argentina

Three main milestones for Space Weather in Argentina

CNIE: Comisión Nacional de Investigaciones Espaciales

Linkage with NASA. Sandro Radicella was the first CNIE fellow abroad (NASA & Boulder), then returned to Argentina to share knowledge and know how learned, mainly on ionosphere

Strong development of upper atmosphere research at the National University of Tucumán (UNT).

1960

IAFE: Instituto de Astronomía y Física del Espacio, UBA-CONICET


Se Han Realizado Mediciones Sobre Ciertas Radiaciones Cósmicas en el Océano Atlántico

I A F E
CONICET
U B A

Ghielmetti-Roederer: strong development of magnetospheric and energetic particles research (UBA).

1969

CONAE: COmisión Nacional Aero Espacial (current Argentina Space Agency).

CONAE
COMISION NACIONAL DE ACTIVIDADES ESPACIALES

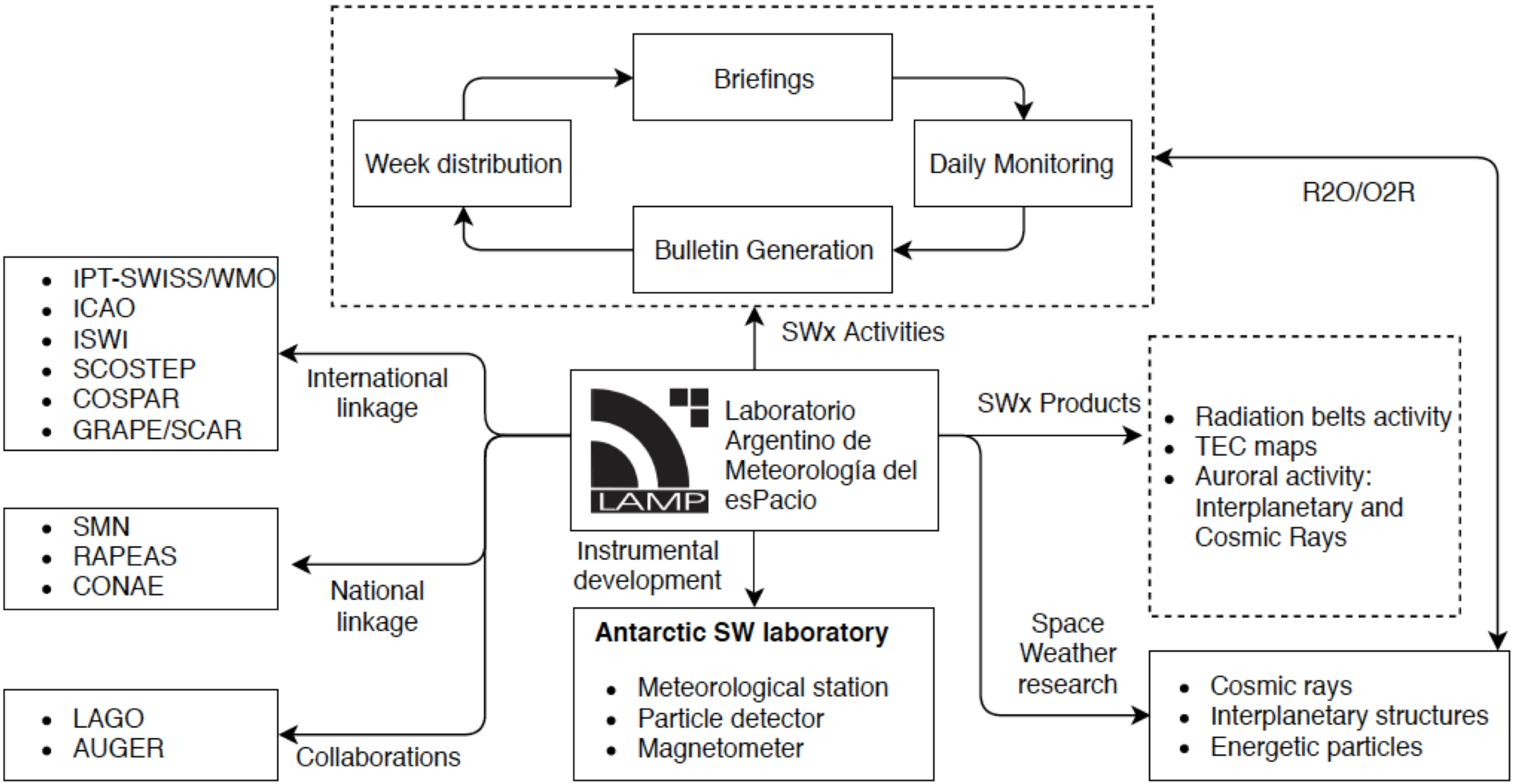
1991

Now

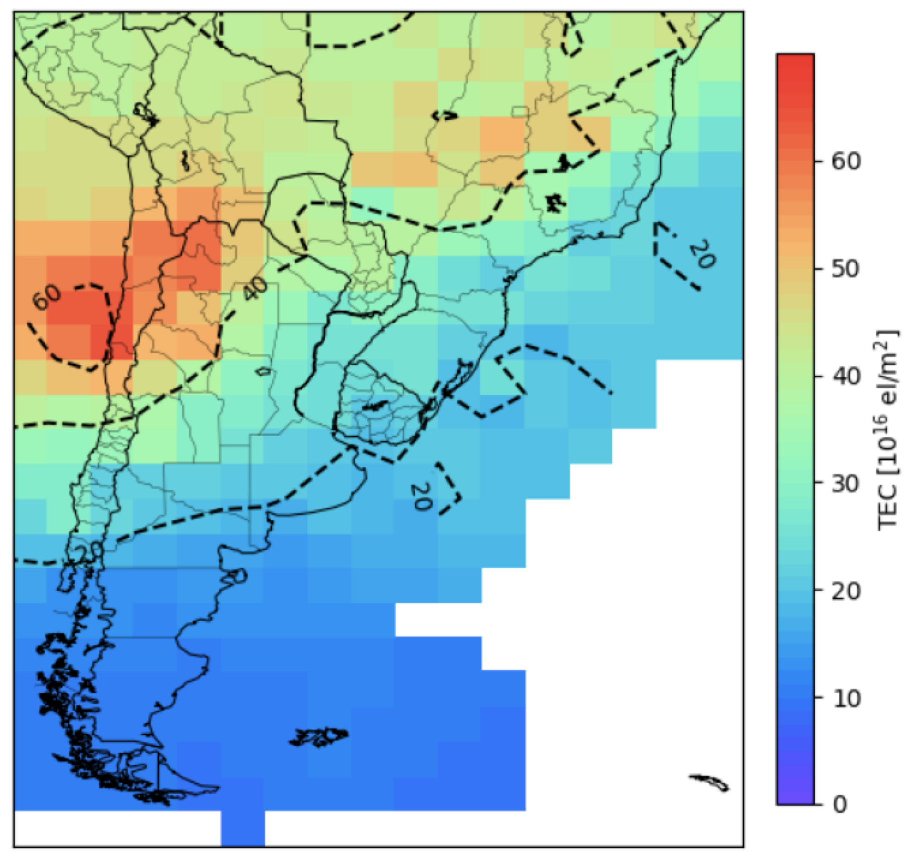
Nowadays, there are many groups from many Universities and Institutions working on Space Weather or on topics linked with: CAB, CONAE, CONICET, IAA, IAFE, UBA, UNLP, UNT, UTN, SMN, etc etc.

LAMP (Laboratorio Argentino de Meteorología del esPacio): Activities and Linkages

www.iafe.uba.ar/u/lamp



Example of one of the prototype-operative products offered in the LAMP website (VTEC over Argentina, using GPS-RAMSAC, developed in collaboration with EMBRACE-INPE): spaceweather.at.fcen.uba.ar



[Takahashi+, Space Weather AGU, 2016]

Structure of the weekly bulleting produced by LAMP from 2016

WEEKLY BULLETIN ON THE SPACE WEATHER CONDITIONS

Date: dd - dd/mm/yyyy
Observer.: Surname

SUN CONDITIONS

Active Regions	Total number of ARs; NOAA AR number (approximate latitude)
Coronal Holes	Total number of CHs; position and dimension expressed in %; dynamic (growing or reducing size); day of passage throw the center of the solar disk.
Solar Flares	Total number of solar flares (); #A(); #B(); #C(); #M(); #X(); Strongest event
Filaments/Prominences	Total number of filaments or prominences, position
Coronal Mass Ejections	Total number of CMEs, date of ejection, earth directed or not
Energetic Particles	Date of occurence of SPEs (coming soon: FDs, GLEs) and time duration

INTERPLANETARY MEDIUM CONDITIONS

Solar wind speed	Fluctuations, tendency, maximum value reached
South component of the Interplanetary magnetic field	periods with Bz<-5nT, long time duration or fluctuations
Interplanetary structures	Date, characteristics

WEEKLY BULLETIN ON THE SPACE WEATHER CONDITIONS

Date: dd - dd/mm/yyyy
Observer.: Surname

MAGNETOSPHERE CONDITIONS

Índice Kp	Date of maximum value, tendency
Índice DST	Date of maximum value, tendency
Índice Ksa	Date of maximum value, tendency
High energy electrons	Peak intensity and time duration

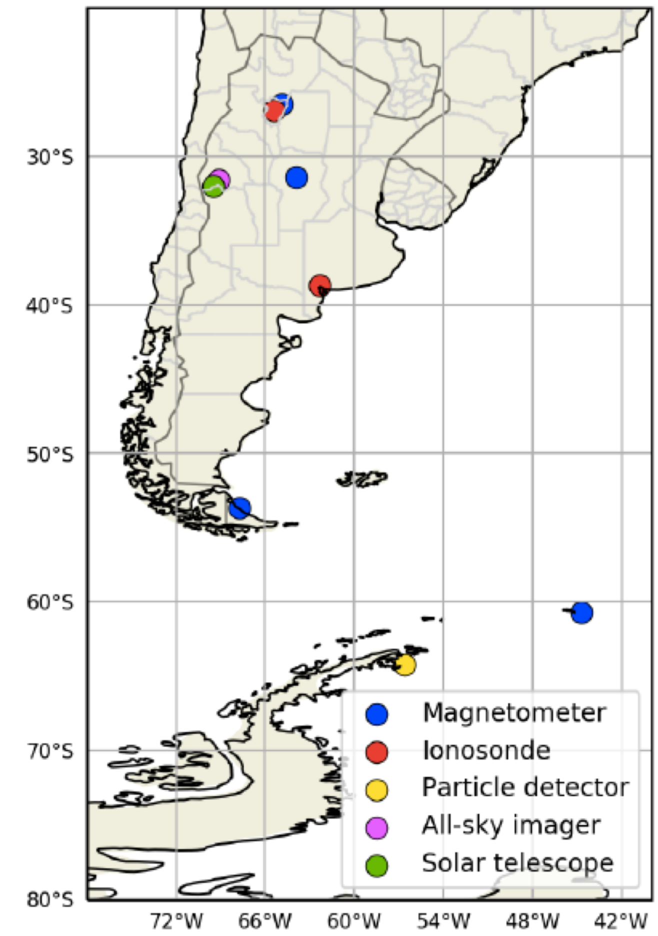
IONOSPHERE CONDITIONS

foF2	Descripción de la curva diaria
TEC	Máximo valor, región con máximo valor de TEC,

FORECAST (3 DAYS)

Solar wind	Solar wind evolution
Solar flares	Percentage of probability of occurrence for C, M and X solar flares
Geomagnetic storms	Expected Kp value (Geomagnetic storm level)
Solar radiation storms	Probability in percentage of occurrence
Radio blackouts	Probability in percentage of occurrence

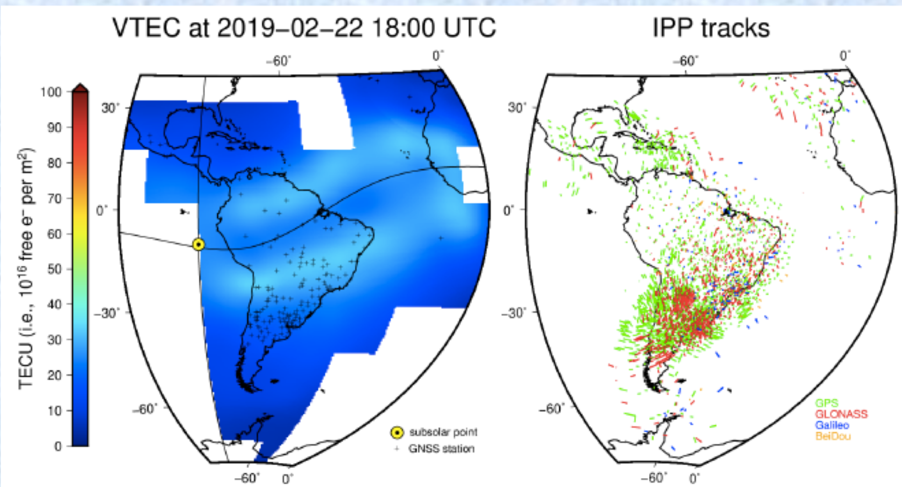
For constructing the bulletin, LAMP analyzes data from own products and instruments, and also public data offered by different institutions [global, regional and in Argentina]



Instrument	Location	Latitude	Longitude	Institution
Solar telescope	El Leoncito - San Juan	31.8S	69.3W	MPI/IAFE/OAFA
Particle detector	Marambio - Antarctic	64.2S	56.3W	LAMP/LAGO
Magnetometer	Pilar - Córdoba	31.4S	63.9W	SMN/INTERMAGNET
Magnetometer	Orcadas - Antarctic	60.7S	44.7W	SMN/INTERMAGNET
Magnetometer	Rio Grande - Tierra del Fuego	53.8S	67.8W	UNLP/EMBRACE
Magnetometer	S. M. Tucumán - Tucumán	26.8S	65.2W	UNT/EMBRACE
Magnetometer	San Martín Antarctic base	68.1S	67.1W	IAA
Magnetometer	Belgrano 2 Antarctic base	77.8S	24.5W	IAA
Ionosonde	S.M. Tucumán - Tucumán	26.9S	65.4W	UNT/INGV
Ionosonde	Bahia Blanca - Buenos Aires	38.7S	62.3W	UNT/INGV
All-sky imager	El Leoncito - San Juan	31.8S	69.3W	BU

More operative Space Weather initiatives in Argentina

- FACET-UNT: public real time data of (1) Ionospheric sounder, (2) Multistatic HF Doppler Radar, (3) Magnetometer, (4) Double Frequency GPS receiver & (5) Riometer single channel
- MAGGIA-UNLP: public real time VTEC



A recent product shown near real time VTEC maps on central/south America [using GPS, GLONASS, Galileo & BeiDou] was developed at the MAGGIA Lab, UNLP [Mendoza+, Space Weather AGU, 2019]

And coming soon:

- FACET-UNT: a new WCD-LAGO at Tucuman, a portal with more SWx operative products, program of SWx courses.
- IAA: 2 magnetometers already working at Antarctic will provide real time data
- SMN: 2 magnetometers already included in INTERMAGNET will provide real time data
- Etc etc etc ...

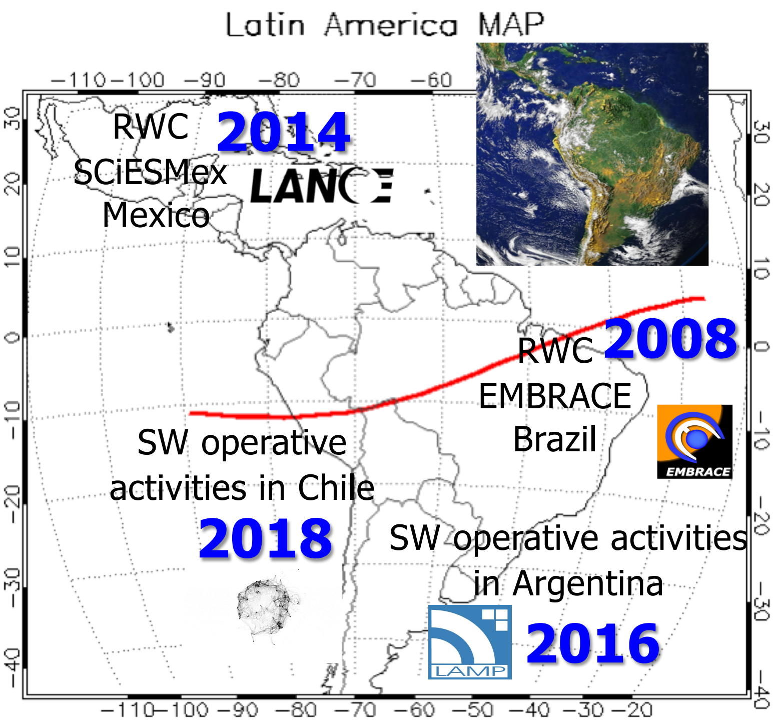
Laboratorio Argentino de Meteorología del esPacio
LAMP
EMBRACE
LABORATORIO DE CLIMA ESPACIAL CHILENO

Introduction

- 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.

- There is now in Latin America two Regional Warning Center (Brazil and Mexico), one Associate Warning Center in Argentina and a Space Weather service being constructed in Chile.

- Gaps in the network are being used for planning the investment f.ex. of EMBRACE program or through international initiatives.



presented by Joaquim E R Costa– joaquim.costa@inpe.br

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Courtesy [adapted] of Joaquim Costa [shown in 2019 SW-Boulder-WS]