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C. Cid, Y. Cerrato, E. Saiz, A. Guerrero, J. Palacios

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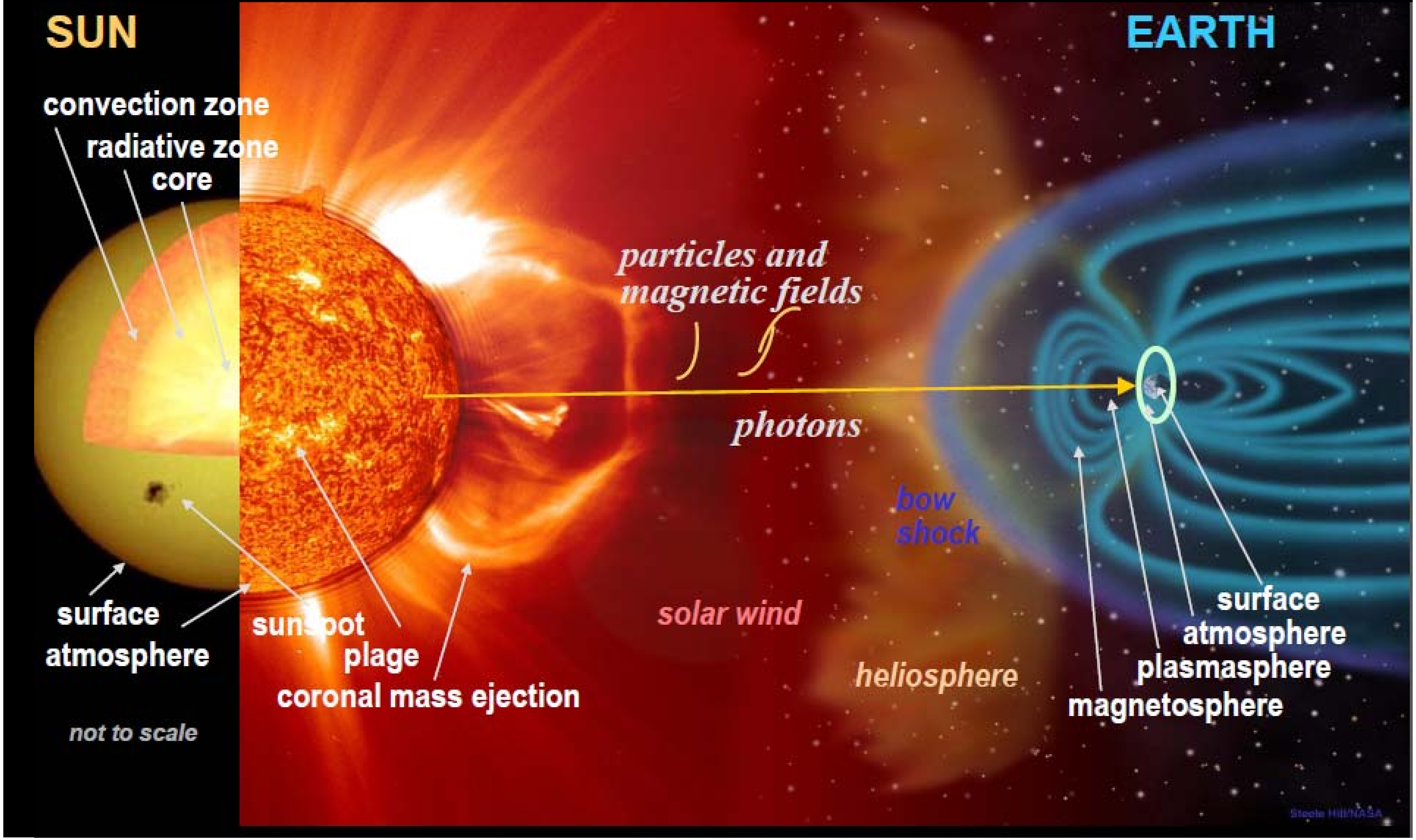
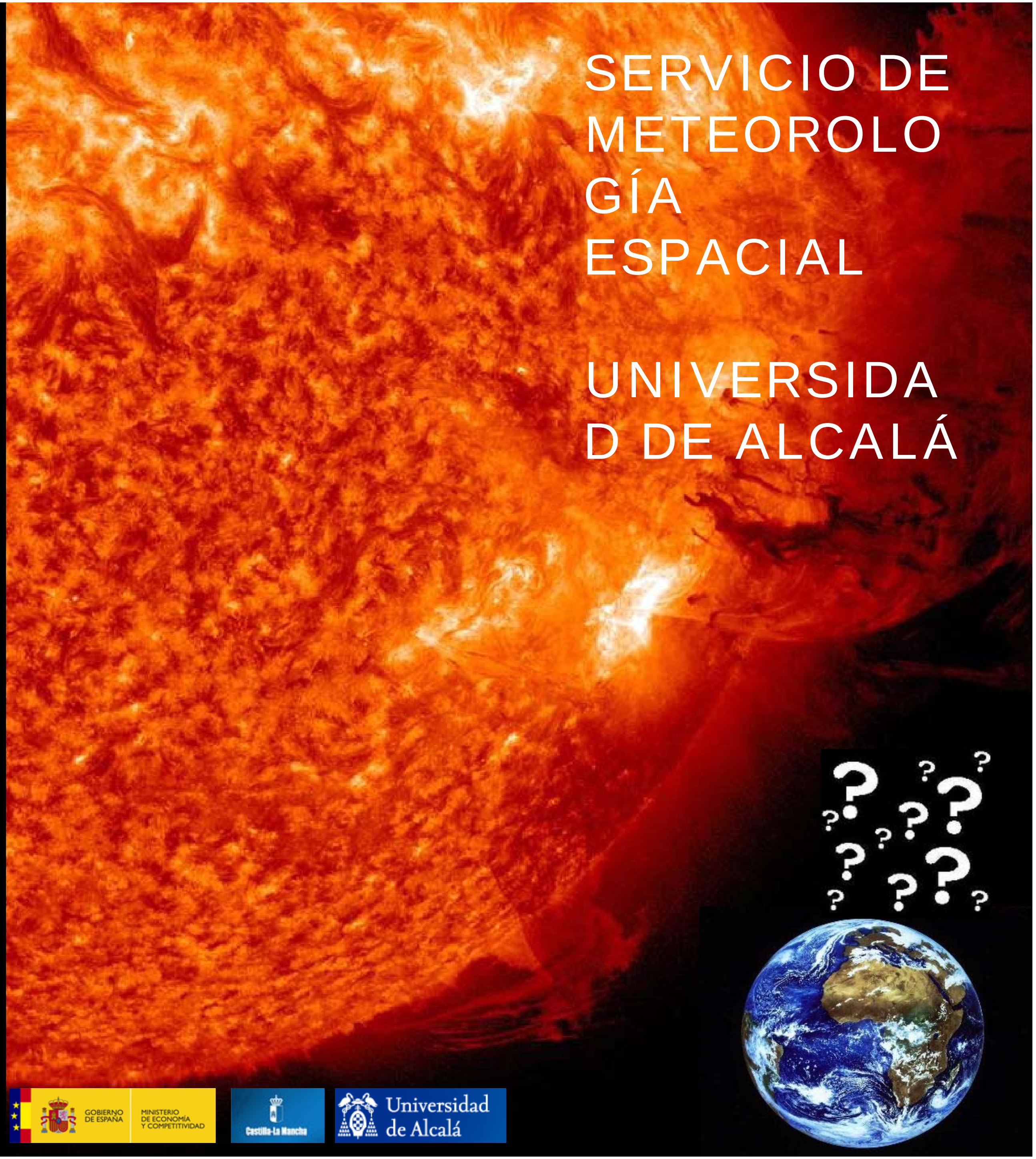
El escenario: la cadena Sol-Tierra





SERVICIO DE METEOROLOGÍA ESPACIAL

UNIVERSIDAD DE ALCALÁ

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Ann. Geophys., 26, 3989–3998, 2008
www.ann-geophys.net/26/3989/2008/

Annales Geophysicae

Forecasting intense geomagnetic activity using interplanetary magnetic field data

E. Saiz, C. Cid, and Y. Cerrato

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Abstract. Southward interplanetary magnetic fields are considered traces of geoeffectiveness since they are a main agent of magnetic reconnection of solar wind and magnetosphere. The first part of this work revises the ability to forecast intense geomagnetic activity using different procedures available in the literature. The study shows that current methods do not succeed in making confident predictions. This fact led us to develop a new forecasting procedure, which provides trustworthy results in predicting large variations of D_{st} index over a sample of 10 years of observations and is based on the value B_z only. The proposed forecasting method appears as a worthy tool for space weather purposes because it is not affected by the lack of solar wind plasma data, which usually occurs during severe geomagnetic activity. Moreover, the results obtained guide us to provide a new interpretation of the physical mechanisms involved in the interaction between the solar wind and the magnetosphere using Faraday's law.

Keywords. Interplanetary physics (Interplanetary magnetic fields) – Magnetospheric physics (Solar wind-magnetosphere interactions; Storms and substorms)

1 Introduction

Several studies have shown that coronal mass injections (CMEs) are the most geoeffective solar phenomena (Brueckner et al., 1998; Cane et al., 2000; Gopalswamy et al., 2000, 2005; Wang et al., 2002; Webb et al., 2000; Zhang et al., 2003). However, forecasting geomagnetic activity from solar observations has become a difficult task nowadays, and the main efforts in this field have been dedicated to the interplanetary causes such as magnetic clouds, shocks, co-rotating interaction regions, etc. (Cid et al., 2004; Echer et al., 2005; Huttunen et al., 2002; Gonzalez et al., 2007; Gosling et al., 1991; Richardson et al., 2002, 2006; Zhang et al., 20
On the other hand, the time (less than 2 h) for forewarn
of events using L1 measurements is not enough to iden
these interplanetary events before the onset of a geomagn
storm. Due to this fact, forecasts using interplanetary m
surements have been made without knowing in advance
kind of magnetic structure related to these observations.

Several authors have pointed out the high probability
intense storms being triggered during the southward in
planetary magnetic field (IMF) passage (see as examp
Kokubun et al., 1977; Tsurutani, 2001; Huttunen et
2002). Gonzalez and Tsurutani (1987) found that duskw
interplanetary electric fields greater than 5 mV/m over
riods lasting for at least 3 h were related to intense sto
($D_{st} \leq -100$ nT). Tsurutani and Gonzalez (1995) found
the above mentioned condition was approximately equival
to $B_z \leq -10$ nT lasting for at least 3 h. Zhang et al. (20
also studied interplanetary causes of intense geomagn
storms at different stages of the solar cycle, and their res
agreed with previously mentioned work, except that time
terval was reduced in the case of solar minimum to 2.5 h.

The D_{st} index, which is a measurement of geomagn
disturbance at terrestrial surface, is a proxy of the enhan
ment of the storm-time ring current. However, the D_{st} p
value is not the only magnitude that should be conside
in quantifying geoeffectiveness. The effects of signific
variations in this index are at least as important as very
values of it. Burton et al. (1975) developed a model for
variations, taking into account the energy balance of the r
current. After a correction of dynamic pressure effects,
corrected D_{st} (D^*_{st}) temporal variation is obtained as a c
bination of a source term ($Q(t)$, called injection functi
and a loss term proportional to its own D_{st} index

$$\frac{dD^*_{st}}{dt} = Q(t) - \frac{D^*_{st}}{\tau}$$

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Hyperbolic decay of the Dst Index during the recovery phase of intense geomagnetic storms

J. Aguado,[1] C. Cid,[1] E. Saiz,[1] and Y. Cerrato[1]

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[1] What one commonly considers for reproducing the recovery phase of magnetosphere, as seen by the Dst index, is exponential function. However, the magnetosphere recovers faster in the first hours than in the late recovery phase. The early steepness followed by the late smoothness in the magnetospheric response is a feature that leads to the proposal of a hyperbolic decay function to reproduce the recovery phase instead of the exponential function. A superposed epoch analysis of recovery phases of intense storms from 1963 to 2003 was performed, categorizing the storms by their intensity into five subsets. The hyperbolic decay function reproduces experimental data better than what the exponential function does for any subset of storms, which indicates a nonlinear coupling between *d*Dst/*dt* and Dst. Moreover, this kind of mathematical function, where the degree of reduction of the Dst index depends on time, allows for explaining different lifetimes of the physical mechanisms involved in the recovery phase and provides new insights for the modeling of the Dst index.

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1. Introduction

[2] As a result of the solar wind-magnetosphere coupling, there is energy transfer into the inner magnetosphere. Plasma sheet ions were thought for many years to be energized and trapped on closed drift paths producing a symmetric ring current around the Earth. The strength of the ground disturbance produced by the gyration and drift of these ions was quantified by the hourly Dst index [*Sugiura and Kamei*, 1991], calculated by averaging horizontal magnetic deviations observed at four low-latitude stations. This index was considered a measure of the ring current intensity reporting on the total energy of ring current particles through the Dessler-Parker-Sckopke (DSP) relation [*Dessler and Parker*, 1959; *Sckopke*, 1966].

[3] Looking at the Dst index, the main feature of a geomagnetic storm is a depression, corresponding to the main phase of the storm, lasting between approximately 3 and 12 h, which is followed by a slower recovery during which Dst increases back toward zero over hours to tens of hours (recovery phase) because of the ring current decay. The minimum value reached by Dst index corresponds to the peak value and it is considered a magnitude of the intensity of the storm, so a storm is considered intense if the Dst peak value reaches at least −100 nT [*Gonzalez et al.*, 1994].

[4] At present the ring current is considered the dominant contributor to the Dst index, although it is influenced by other current systems such as the magnetopause, magnetotail, and induced Earth currents. However, the idea of a symmetric ring current remains only for the late recovery phase. As energetic ions from the plasma sheet are convected deep into the dipolar regions under the action of enhanced convection electric field, an intense asymmetric ring current (partial ring current) develops. The injection model, first proposed by *DeForest and McIlwain* [1971], predicted that the ring current was asymmetric only as long as injection continues, that is, in the main phase of the storm. However, it is now understood that the partial ring current far exceeds the symmetric ring current throughout the entire main phase and into the very early recovery phase of moderate and intense geomagnetic storms. Several papers have considered this issue from a theoretical point of view [e.g., *Takahashi et al.*, 1990; *Ebihara and Ejiri*, 1998, 2000; *Jordanova et al.*, 1998; *Liemohn et al.*, 1999, 2001; *Kozyra et al.*, 2002; *Kozyra and Liemohn*, 2003; *Liemohn and Kozyra*, 2005] and from an observational one [e.g., *Greenspan and Hamilton*, 2000; *Jorgensen et al.*, 2001; *Mitchell et al.*, 2001; *Pollock et al.*, 2001; *Søraas et al.*, 2002, 2003]. The asymmetric ring current is a consequence of the energetic injected ions which move on open drift paths once through the inner magnetosphere before they pass through dayside magnetopause [*Liemohn et al.*, 1999, 2001; *Kozyra et al.*, 2002; *Daglis and Kozyra*, 2002; *Fok et al.*, 2003; *Burch*, 2005; *Kalegaev et al.*, 2008]. As the early recovery phase of the storm begins, the convection electric field weakens. This decrease turns open drift paths into closed ones forming the symmetric ring current. At the end of the early recovery phase, ~80–90% of the remaining ring current energy is trapped in closed drift paths [*Daglis and Kozyra*, 2002]; a major symmetric ring current

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0148-0227/10/2009JA014658

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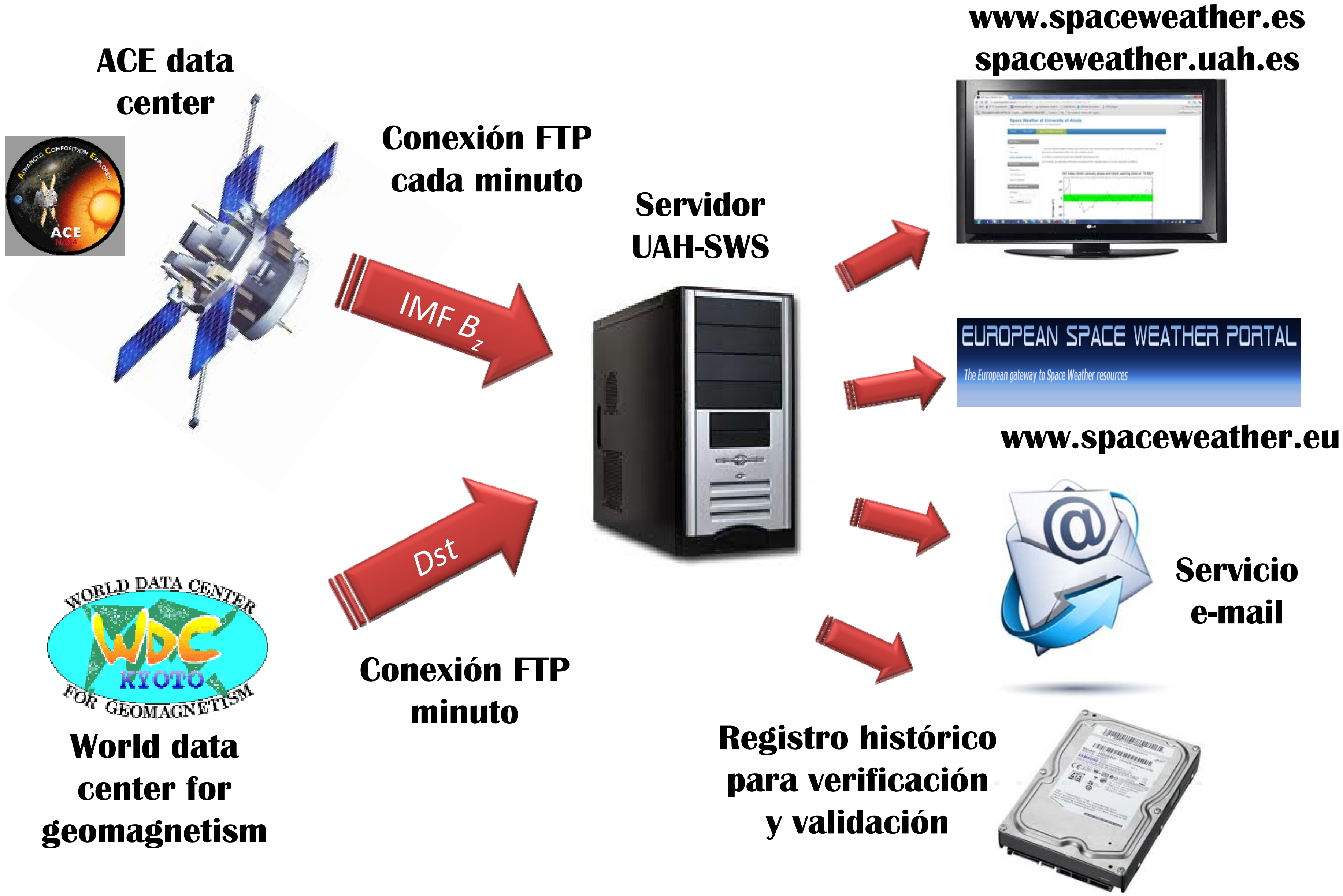
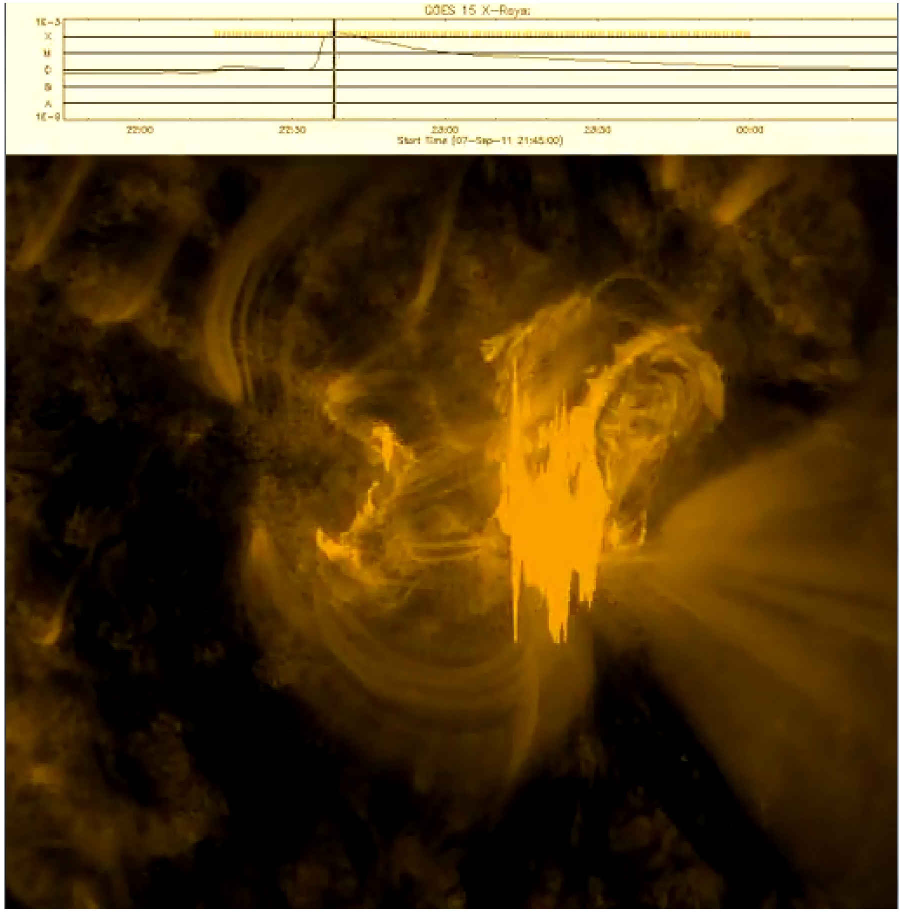
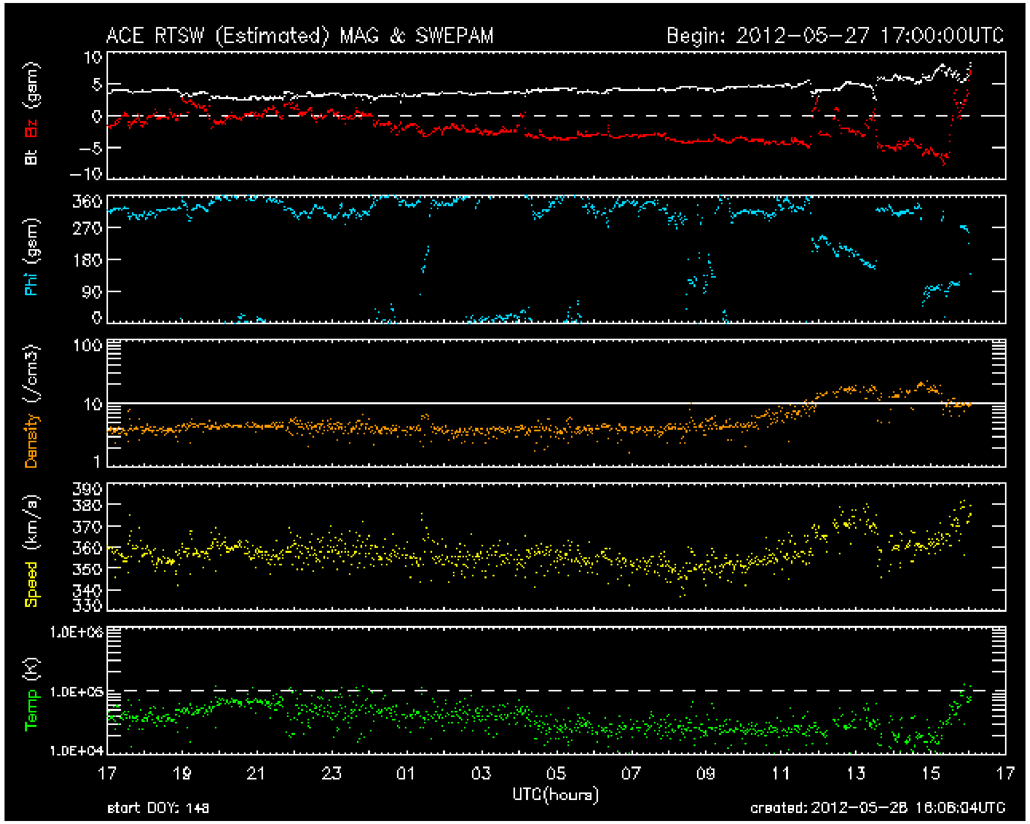
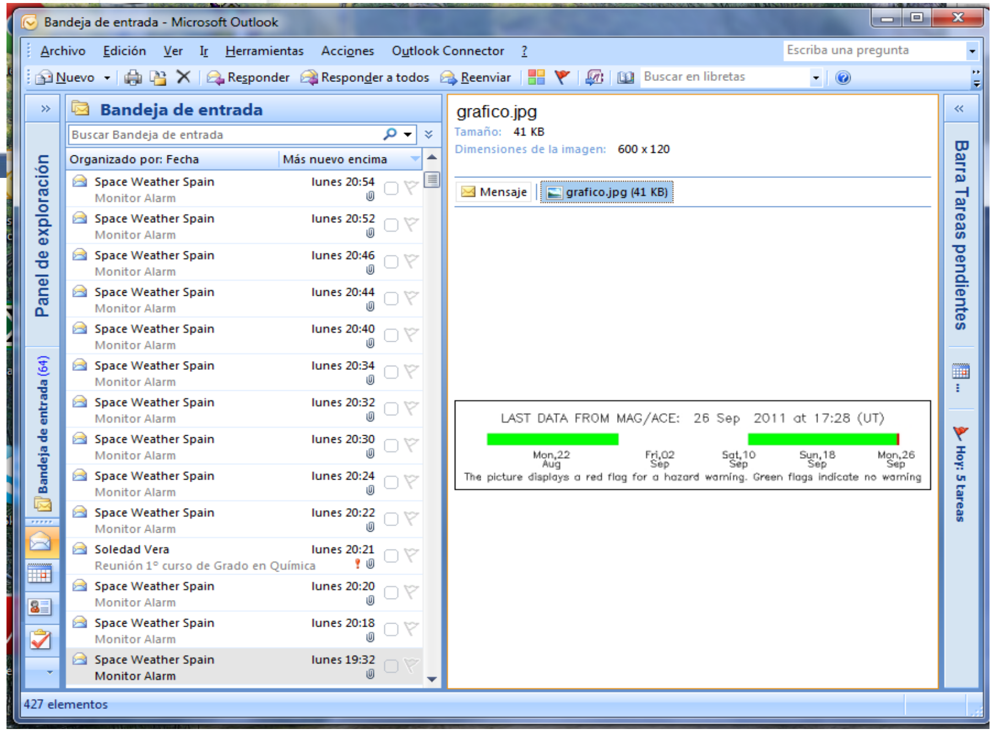



GOES 15 X-Rays
22:00
22:30
23:00
23:30
00:00
Start Time (07-Sep-11 21:45:00)

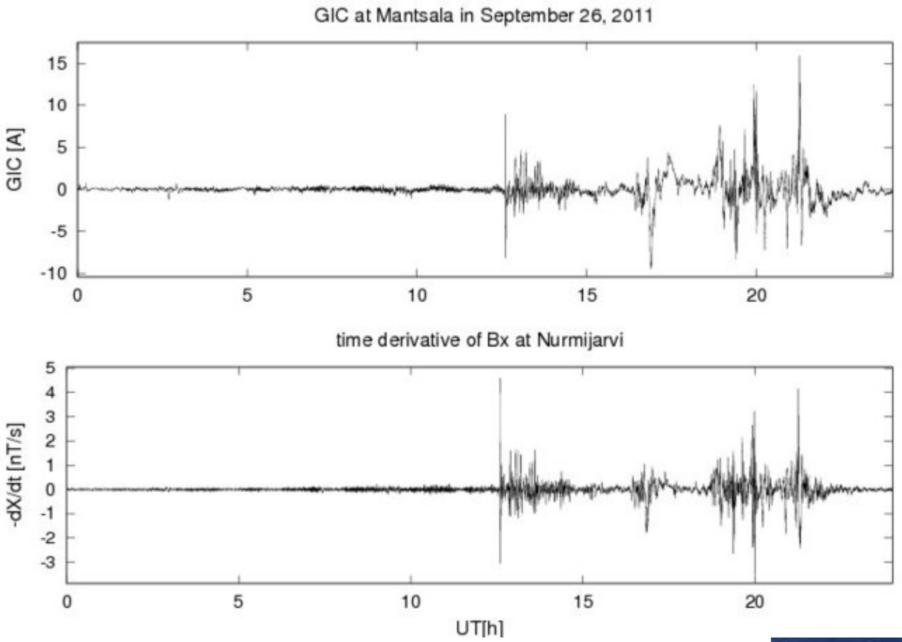

ACE RTSW (Estimated) MAG & SWEPAM
Begin: 2012-05-27 17:00:00UTC
Bt Bz (gsm)
Phi (gsm)
Density (/cm3)
Speed (km/s)
Temp (K)
UTC(hours)
start DOY: 148
created: 2012-05-28 16:08:04UTC

La primera alerta del monitor

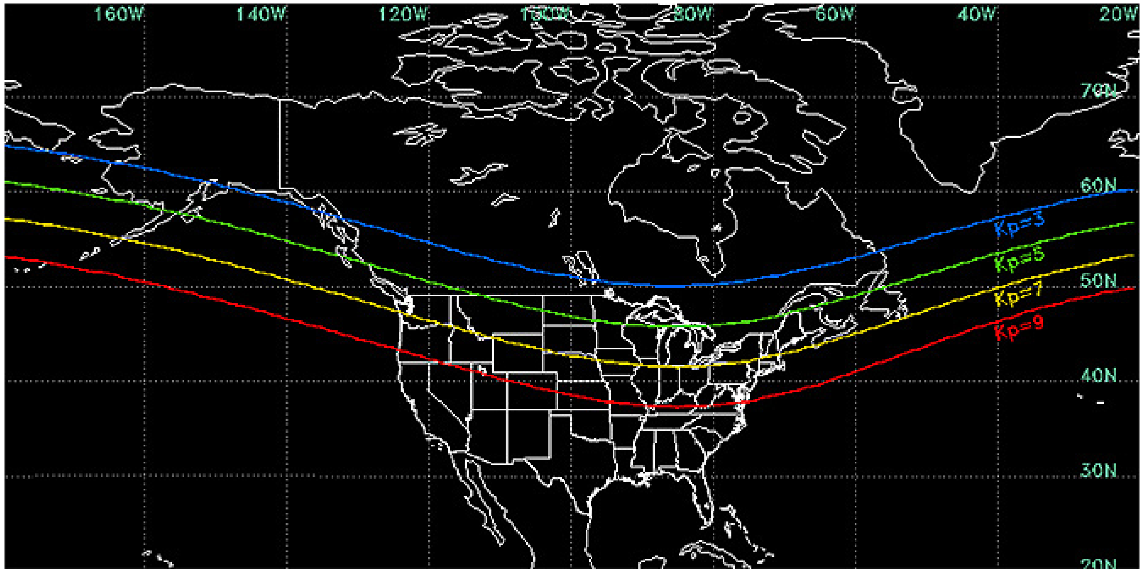
26 Septiembre 2011, 13:25 UT



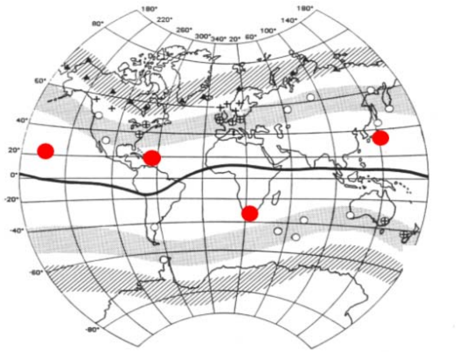
Los efectos en tierra

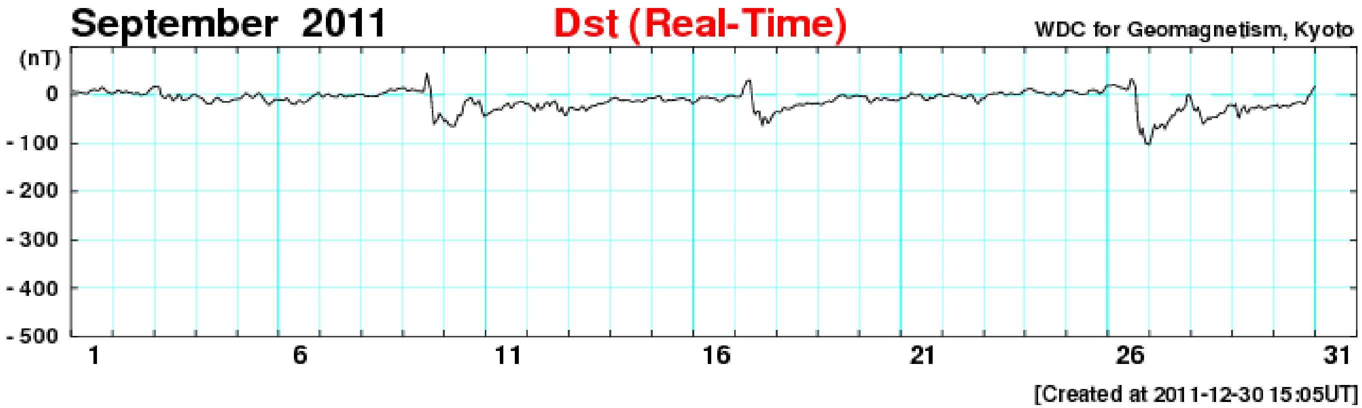


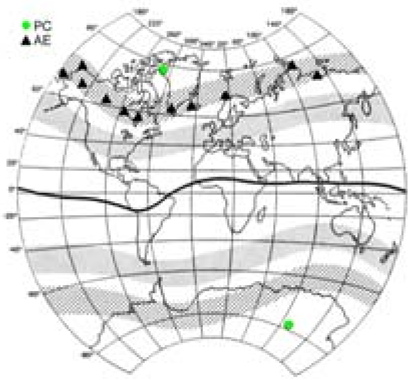
“Acababa de anochecer y comenzamos a ver columnas verticales de luz en el cielo. El color verde estaba por todas partes, pero también había muchas zonas de color rojo” (Travis Novitsky, Minnesota, USA)

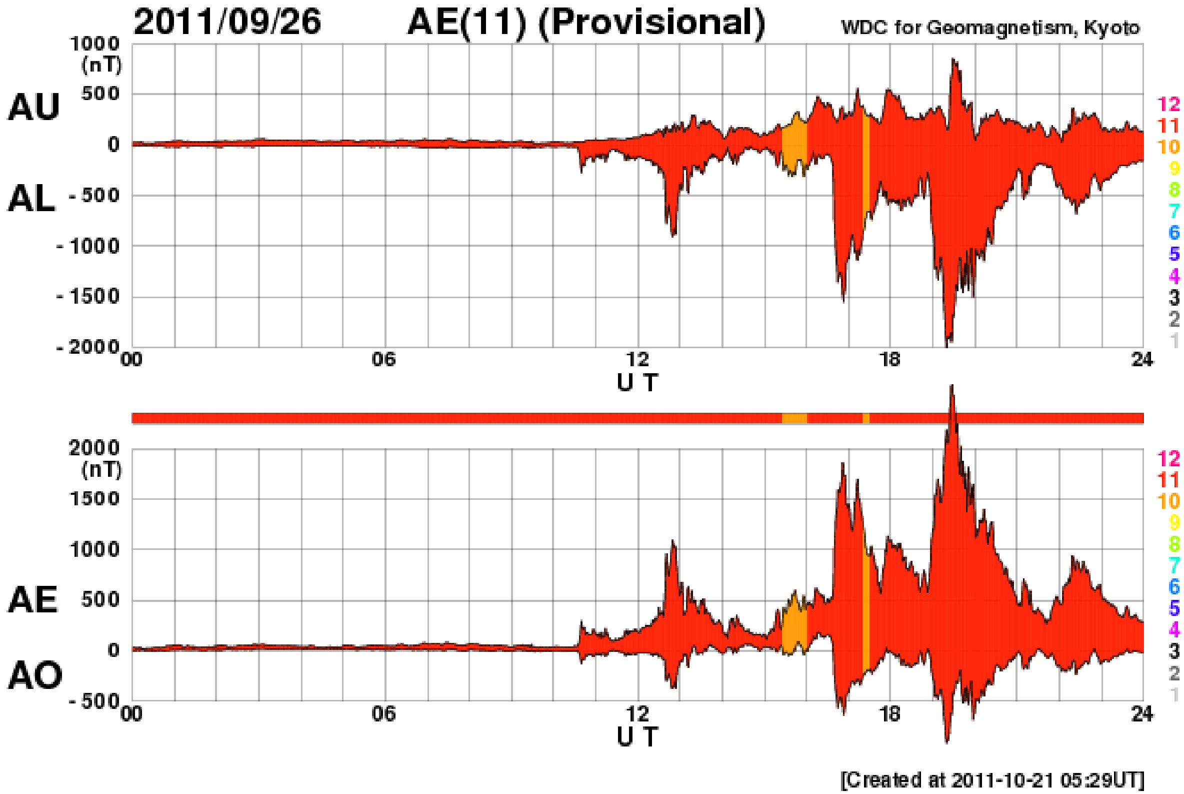


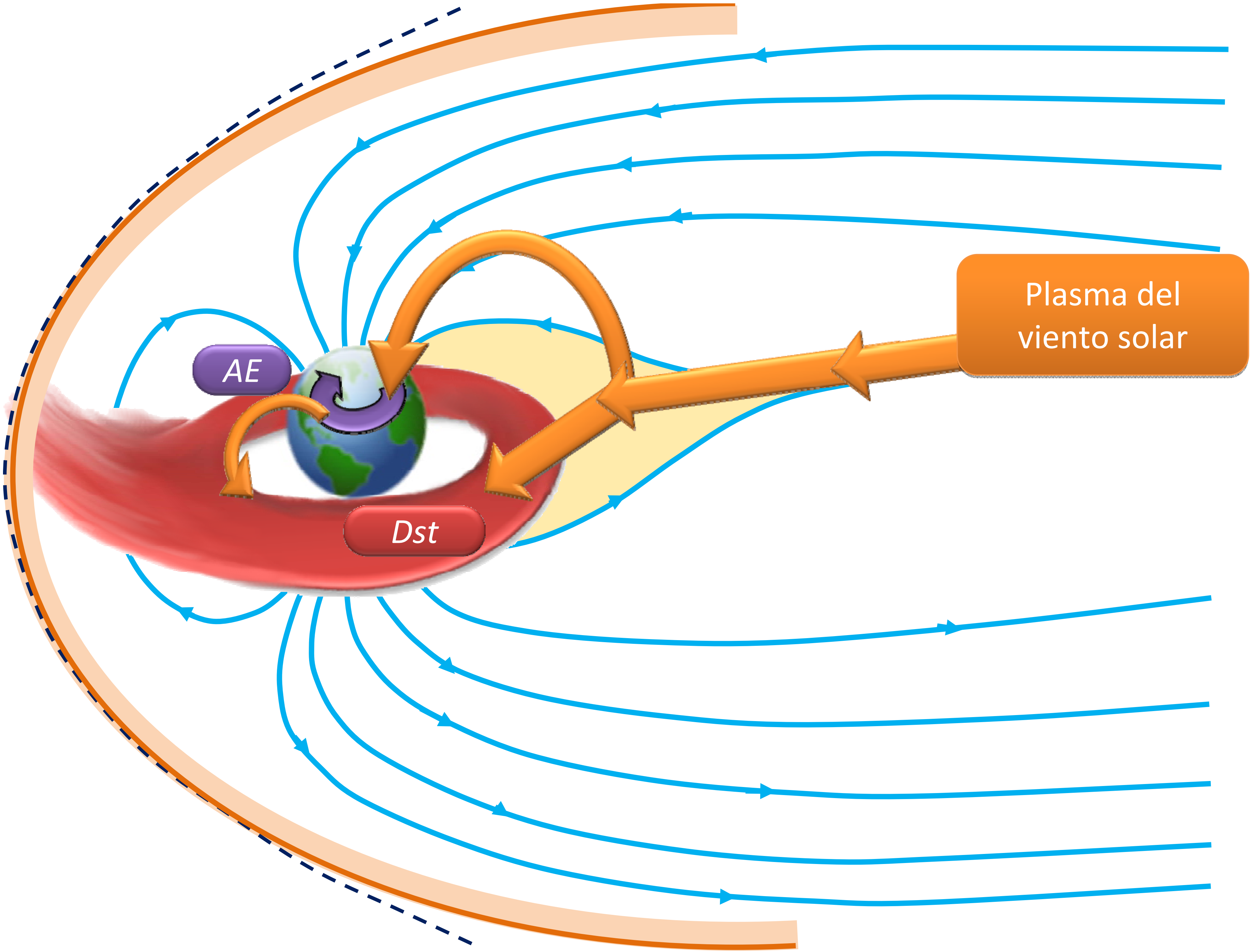
La perturbación en tierra



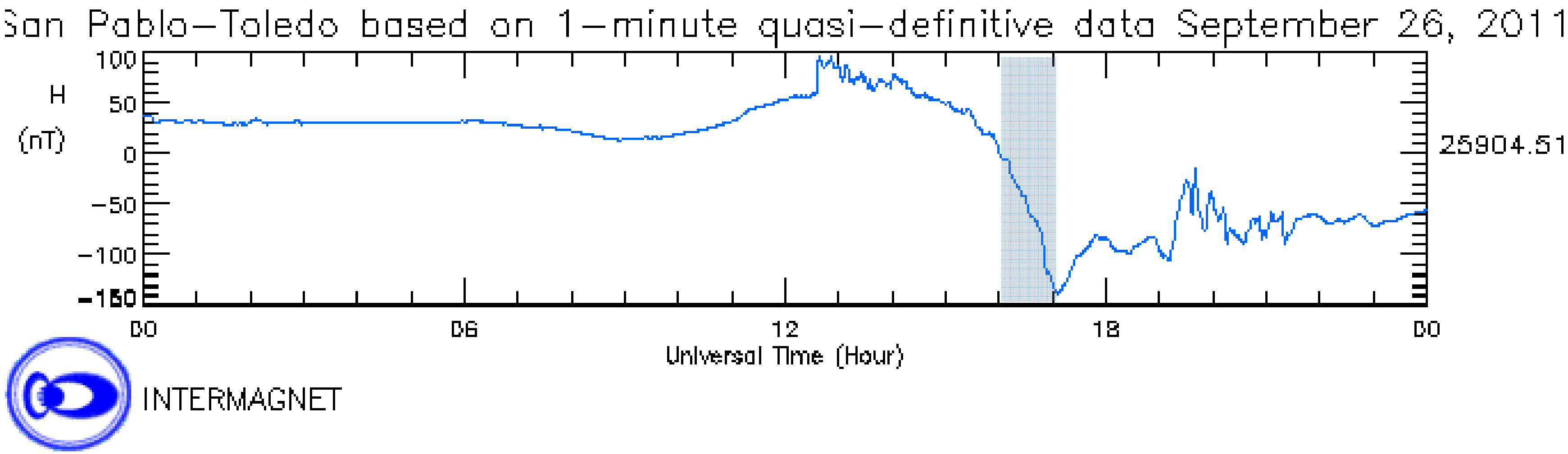







Plasma del viento solar
AE
Dst

La perturbación en España



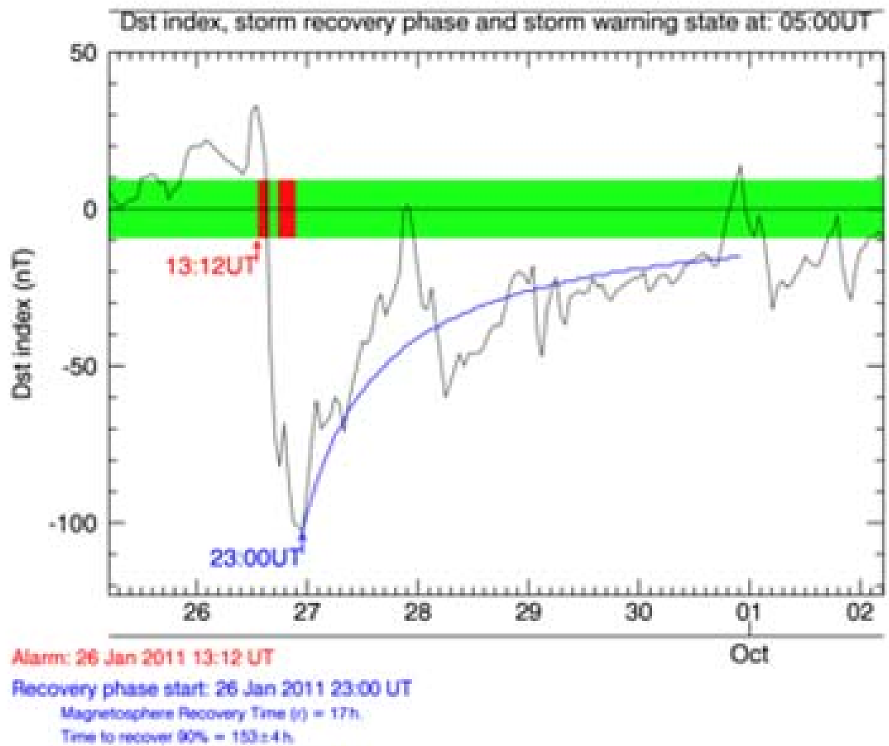
26 Septiembre 2011, 13:25 UT

Dst(16 UT)= +3 nT, Dst(17 UT)= -53 nT ⟹ ΔDst=56 nT en 1 hora

27 sept 00 UT: Dst min = -117 nT

Valor H mínimo San Pablo-Toledo (~ 17 UT) ~ -150 nT

La imagen del UAH-SWS ha mejorado desde entonces



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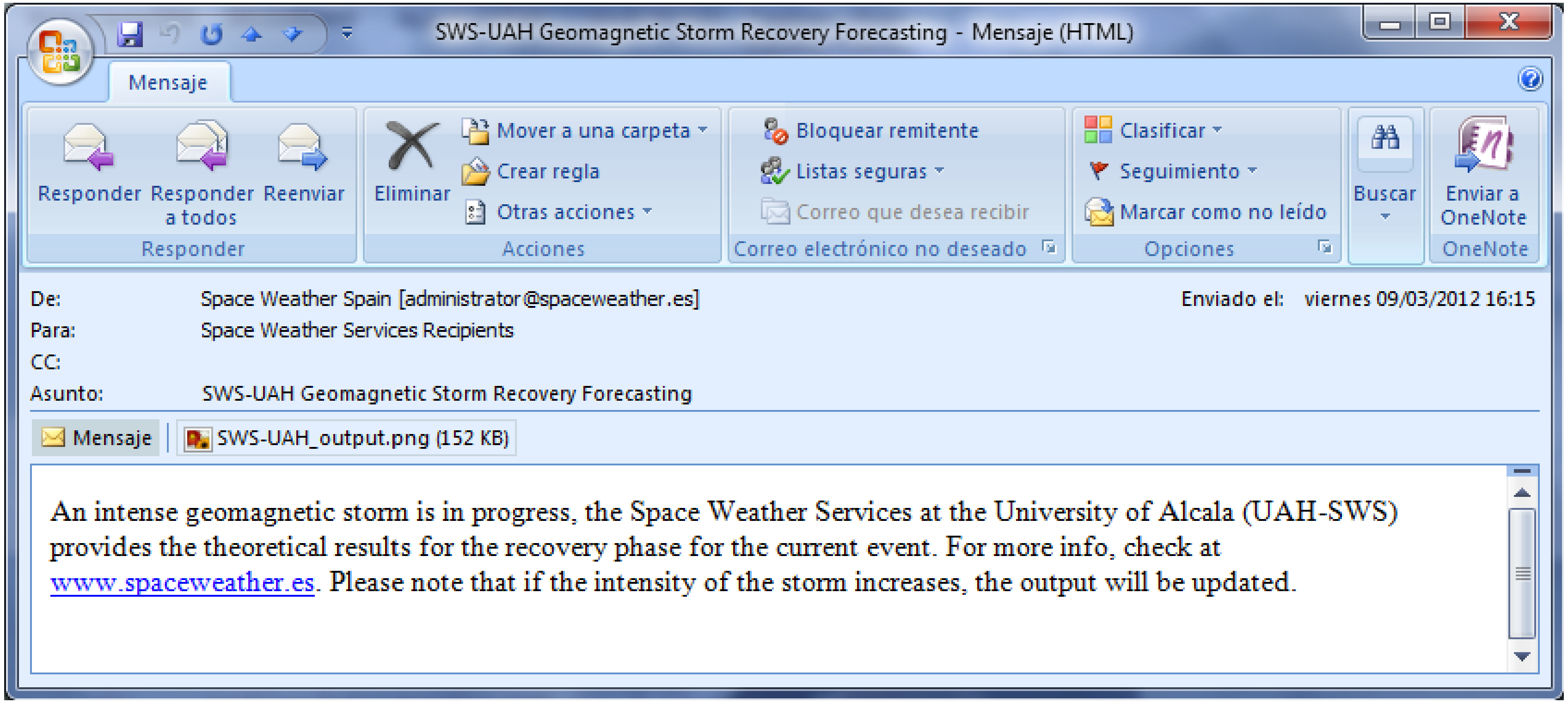
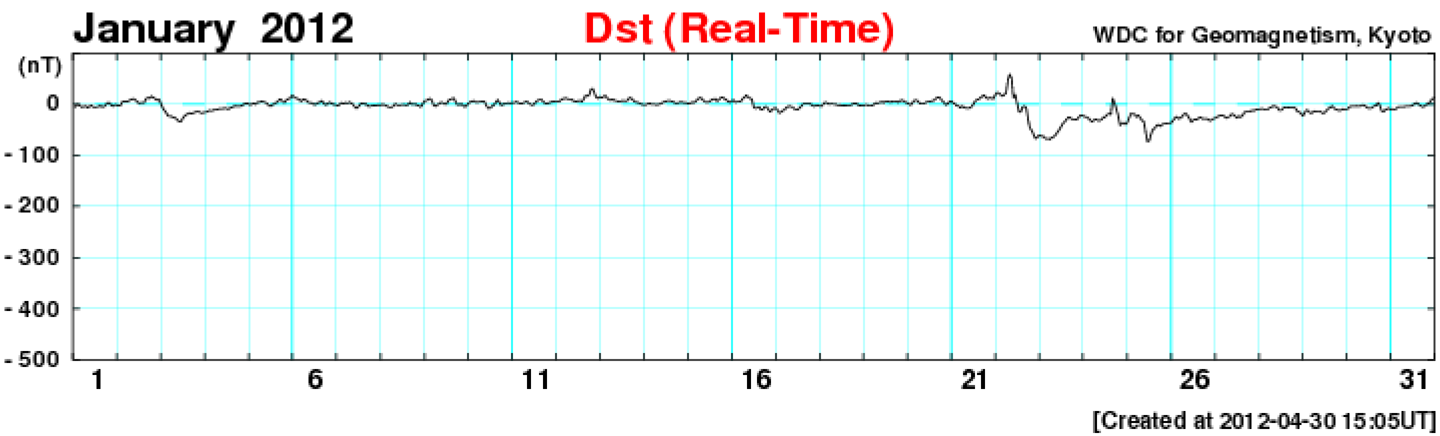
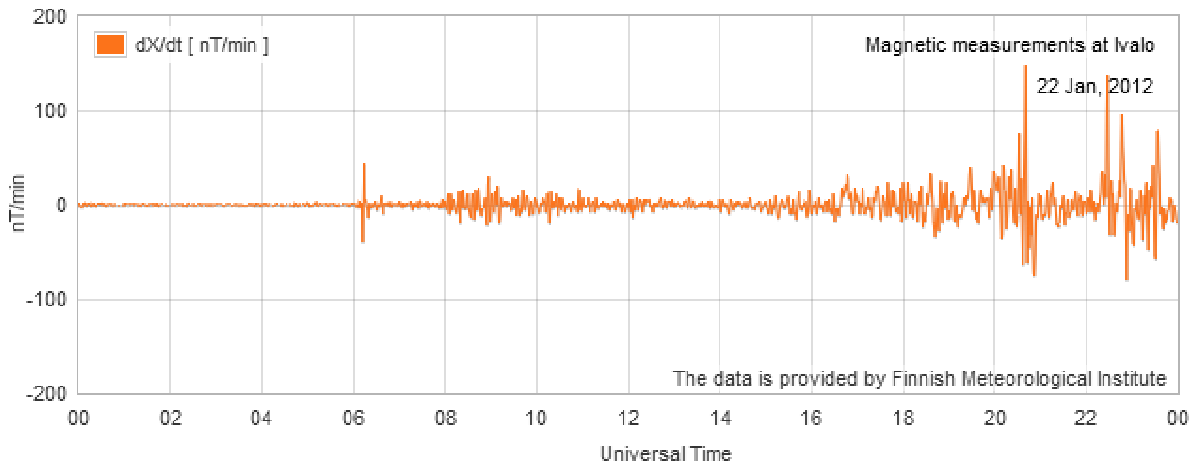


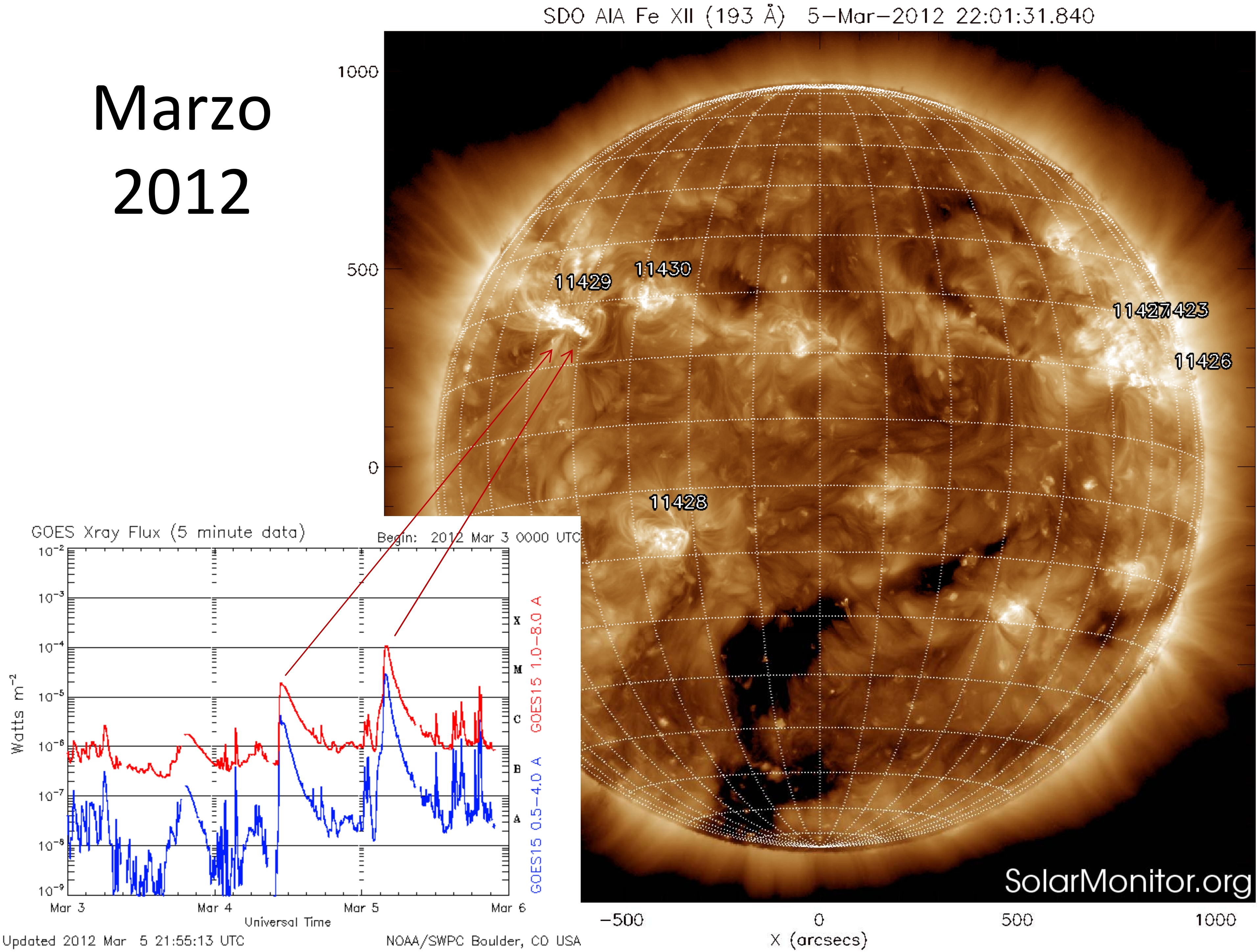
22 de enero de 2012: falsa alerta



Alerta: 22 Enero 2011 ➡ **ΔDst=37 nT en 1 hora**

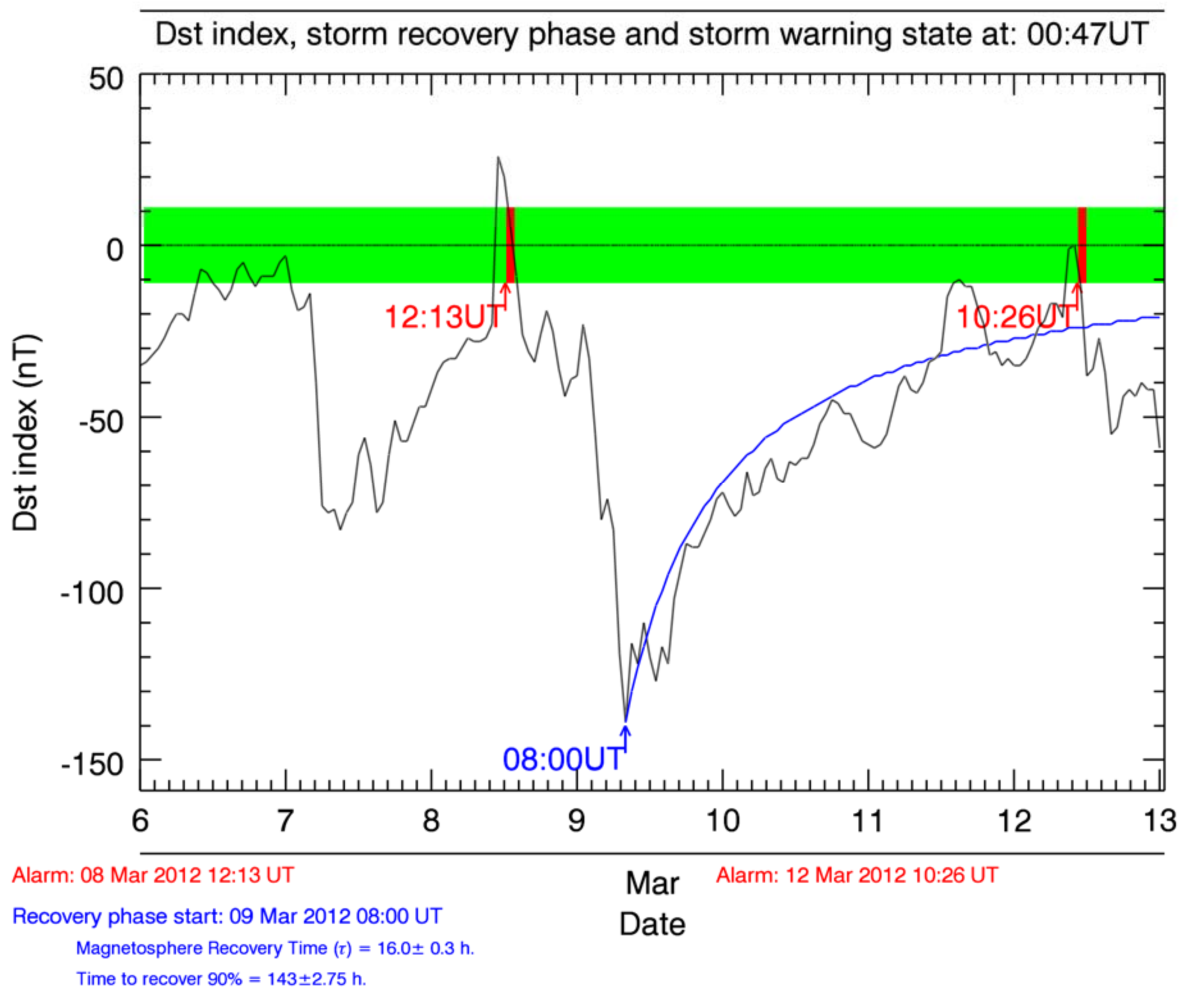


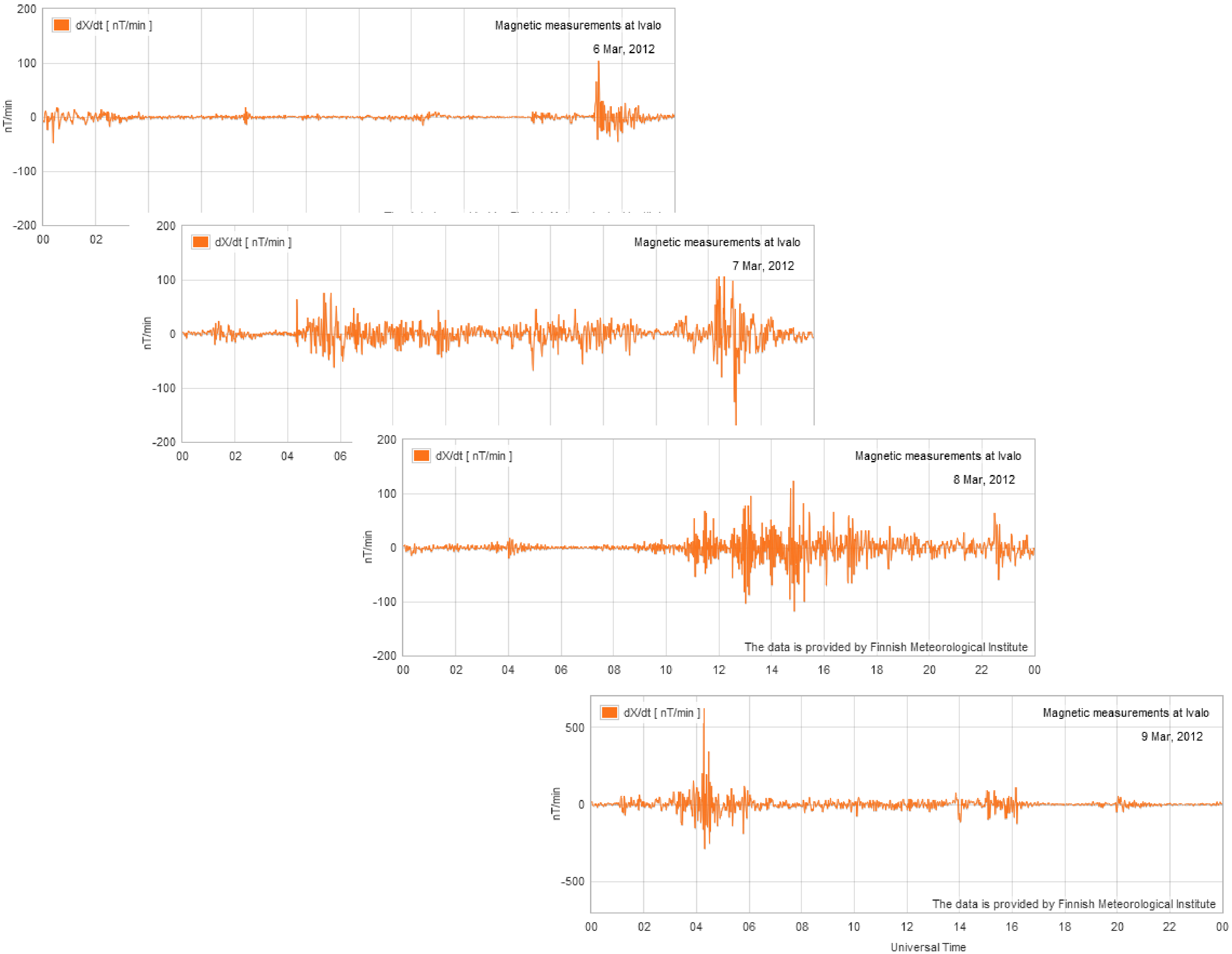
Marzo 2012



SDO AIA Fe XII (193 Å) 5-Mar-2012 22:01:31.840
1000
500
0
11429
11430
11427
11423
11426
11428
SolarMonitor.org
-500
0
500
1000
X (arcsecs)
GOES Xray Flux (5 minute data)
Begin: 2012 Mar 3 0000 UTC
Watts m-2
X
M
C
B
A
GOES15 1.0–8.0 A
GOES15 0.5–4.0 A
Mar 3
Mar 4
Mar 5
Mar 6
Universal Time
Updated 2012 Mar 5 21:55:13 UTC
NOAA/SWPC Boulder, CO USA

Alerta del 8 de marzo de 2012




dX/dt [nT/min]
Magnetic measurements at Ivalo
6 Mar, 2012
nT/min
200
100
0
-100
-200
00
02
dX/dt [nT/min]
Magnetic measurements at Ivalo
7 Mar, 2012
nT/min
200
100
0
-100
-200
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02
04
06
dX/dt [nT/min]
Magnetic measurements at Ivalo
8 Mar, 2012
nT/min
200
100
0
-100
-200
The data is provided by Finnish Meteorological Institute
00
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14
16
18
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22
00
dX/dt [nT/min]
Magnetic measurements at Ivalo
9 Mar, 2012
nT/min
500
0
-500
The data is provided by Finnish Meteorological Institute
00
02
04
06
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12
14
16
18
20
22
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Universal Time

Conclusiones

- Los efectos de la actividad solar son muy diversos y afectan a diferentes sectores, por lo que resulta fundamental conocer el escenario real de la interacción entre la actividad solar y el entorno terrestre antes de exponer situaciones alarmistas, a menudo erróneas.
- La Universidad de Alcalá dispone actualmente del único servicio en España para alertar de posibles alteraciones en el campo magnético de la superficie terrestre.
- Tras el proceso de verificación realizado durante el presente ciclo solar, el servicio ha mostrado su capacidad para competir a nivel mundial.

Gracias por su atención