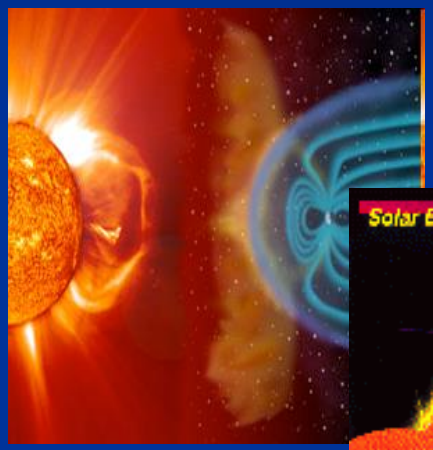
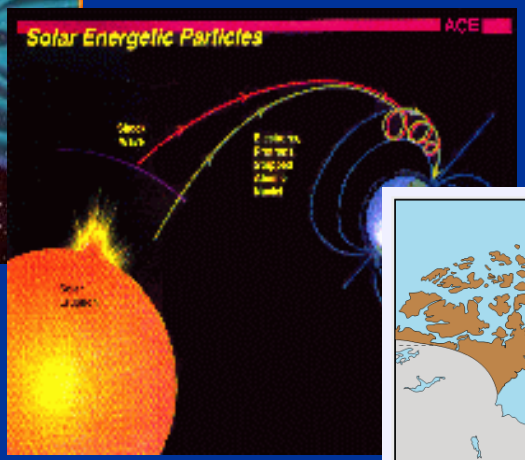
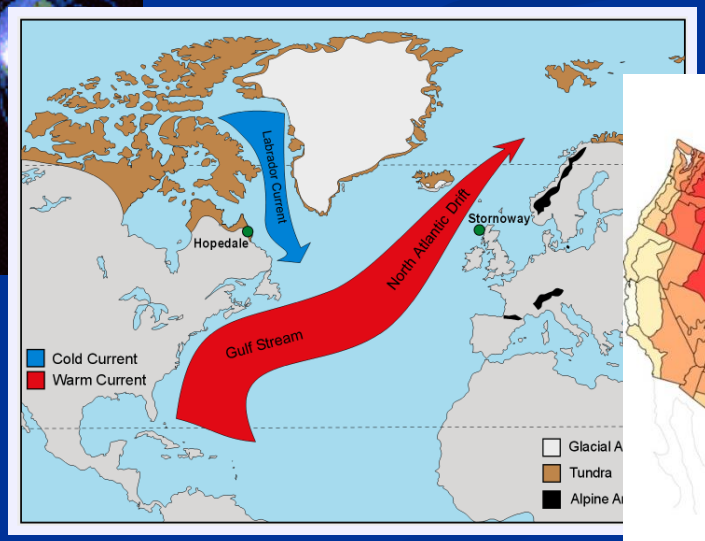
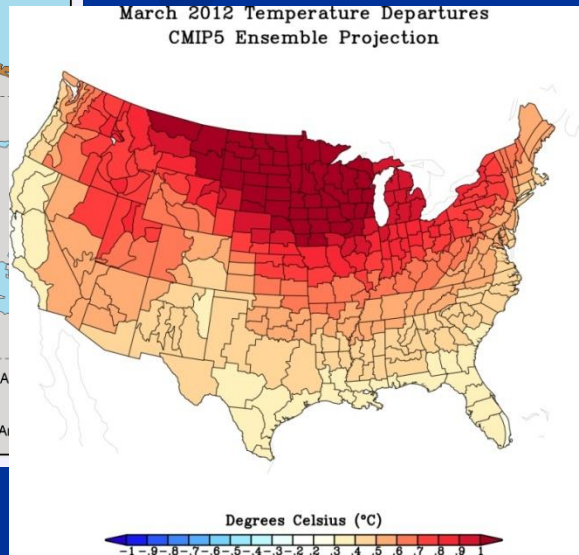
Correlation between CME-related strong geomagnetic storms, SEP and Earth's surface Temperature in north-east USA: 1997-2015

Menesidou, S. , G. Anagnostopoulos, D. Eythomiadis,
A. Koufogiannidis, E. Pavlos, G. Pavlos,
Space Research Laboratory
Demokritos University of Thrace









12th Conference of Hel.A.S
Thessaloniki, 28.6 – 2.7.2015

OUTLINE

1. Introduction: Sun, Weather, and Climate

2. March 2012 CME extreme events

- Rainfall in Greece
- Globally Meteorological Extreme records.
- Historical heat wave in USA

5. March 2015 CME

from…. **-9°** C to… **22°** C

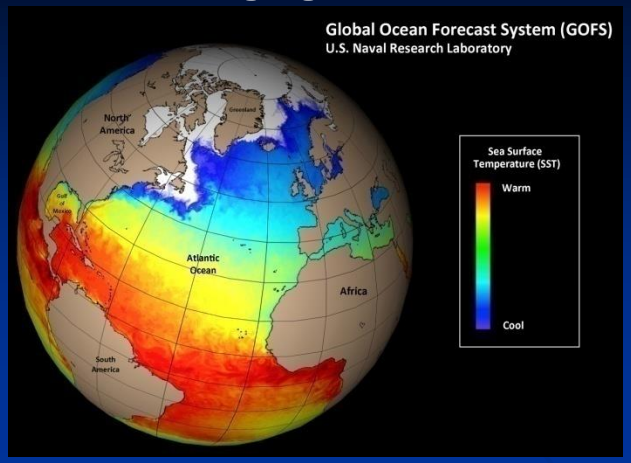
3. Major CMEs-Temperature increases (Wisconsin):

A statistical study (ACE s/c era: 1997- today)

6. Conclusions. Short term SEP effects to weather

2. S.M.CL-r research: social applications

- **Separate natural – anthropogenic influences.**



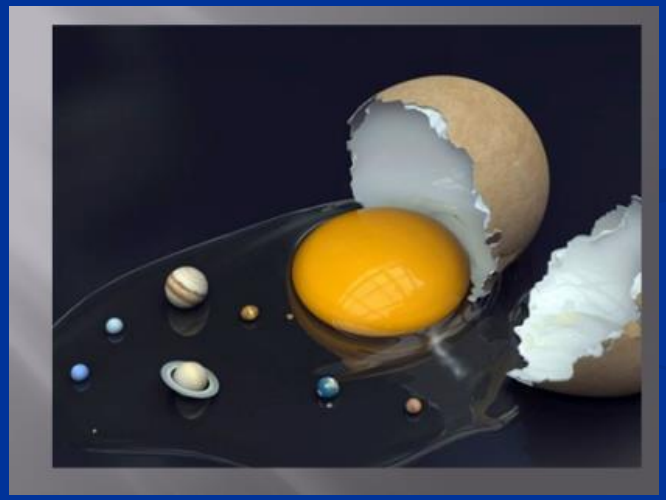
- **Improve Climate changes - predictions**

Understand / predict Extreme weather events: protect People' food / health / life

Physical Phenomenon/ Parameter	Height	Time Delay From Flare / SSC	Number of Events	Authors
ΔP >0	500mb≈ 5km	**< 24 hours (SF)**	53 Flares	Schuurmans (1965)
ΔP >0	500mb ≈ 5km	**<6 hours (SF)**	81 Flares (≥2 +)	Schuurmans & Oort (1969)
ΔBe^{7}, ΔP^{32} > 0	2.96km / Zugspitze	**2nd day (SF)** **(Max V_{sw} / Ap)**	≥ 2	Schuurmans & Oort (1969)
∇P (S-N)	Earth's surface	**2-3 days / SSC**		Mustel (1972)
∇P (S-N)	Earth's surface	**3 days / SSC**	14 cases/ 20 years	Sidorenkov (1974)
Clouds		**SEP, Aurorae**		Roberts (1975)

1. Current research

- **Sun-Magnetosphere- Climate relationships research is a topic of increasing interest in the last 20 years.**



- *Review by Grey et al. (2010) : ~350 references (1995-2010)*

Emphasis on Solar cycle Climate trends

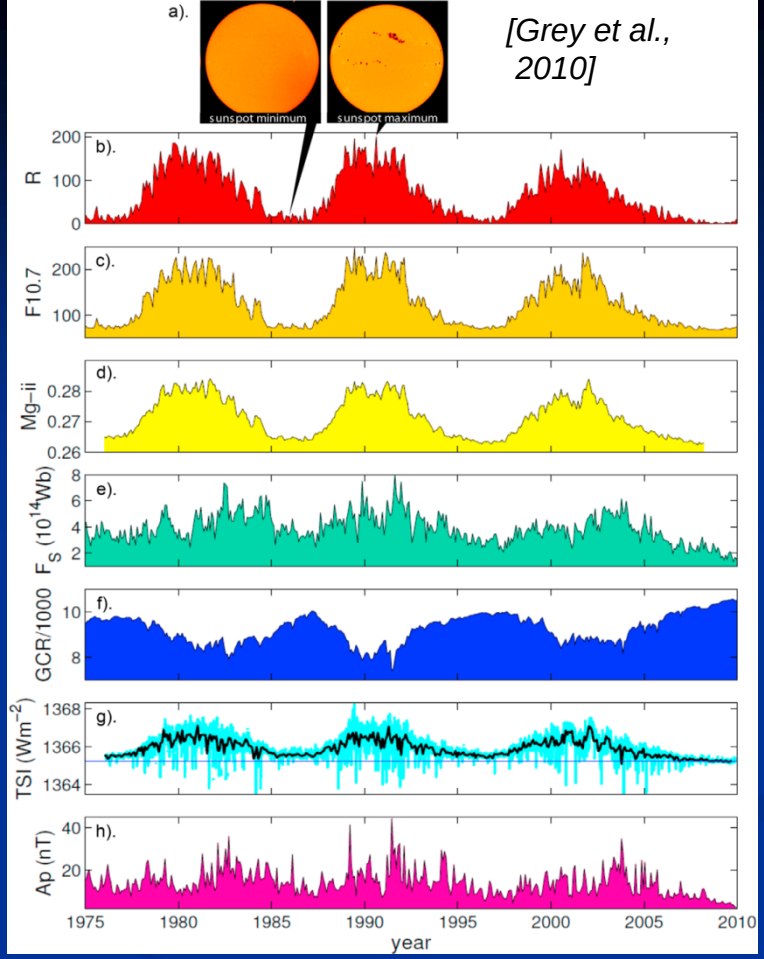
- ✓ solar irradiance
- ✓ open solar B-field flux
- ✓ Geomagnetic Activity
- ✓ cloudy (cosmic ray)
- ✓ Stratospheric changes
- ✓ Sea S. Temperature

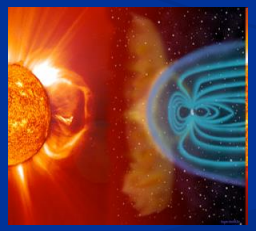
  (~4 years delay)
- ✓ Polar temperatures & winds

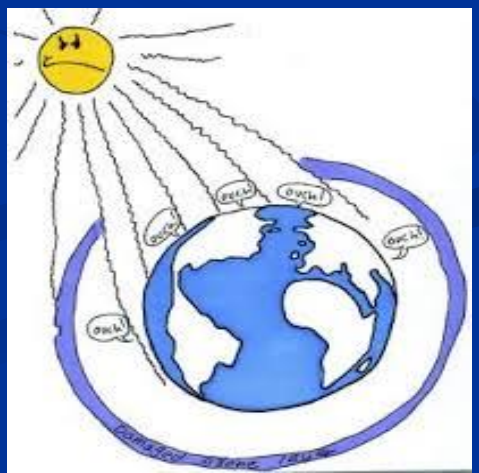
  [Grey et al., 2010 & references therein]
- ✓ Quasi- biennial oscillation

  [Labitzke, 1987; Labitzke and van Loon, 1988;

  Labitzke et al., 2006].







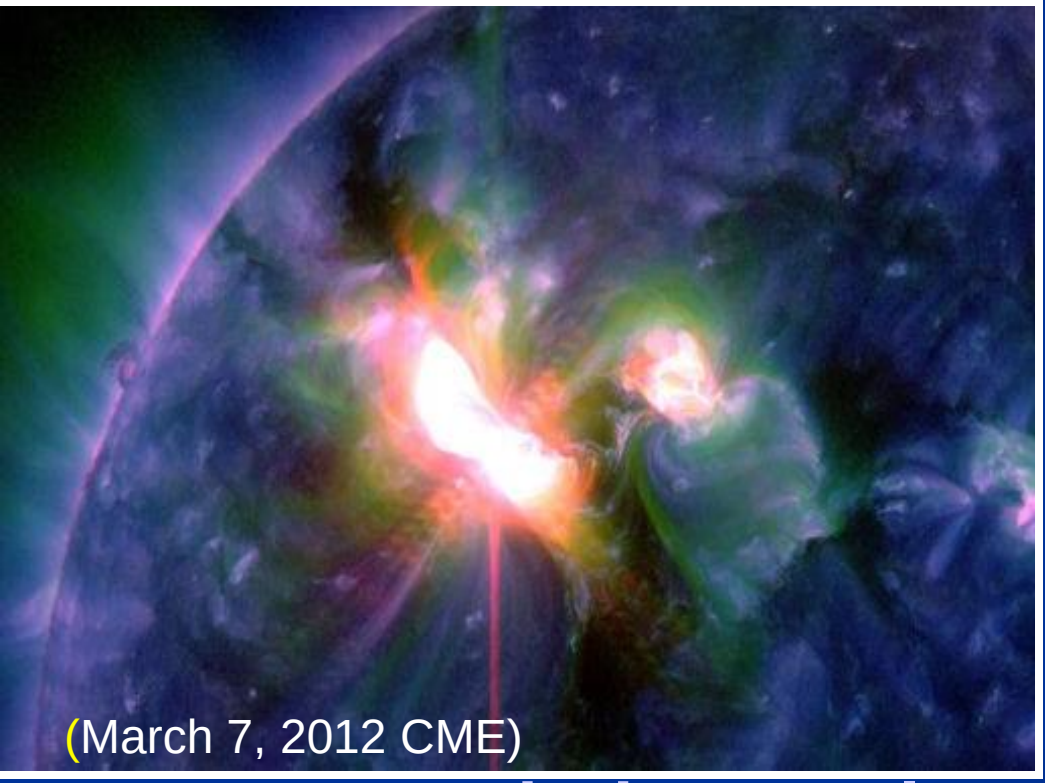
Recent studies:

"**…energetic particle forcing driving dynamical changes in the atmosphere …**in the form of **electron and proton precipitation…"** *are important and that* **…** *(were found to be)* **as intense as** those arising from the known solar irradi**ance** variations".

Seppala and Clilverd (2014)

Clilverd et al. (2015 and references therein)

The results of this presentation have been gained because of a case study… on superstorm of March 7, 2012



Participating Universities and Research Centers

Aristotle University of Thessaloniki (AUTH)
National Observatory of Athens (NOA)
National and Kapodistrian University of Athens (NKUA)
Academy of Athens (AOA)
University of Ioannina (UOI)
Democritus University of Thrace (DUTH)

European Union
European Social Fund

OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION & RELIGIOUS AFFAIRS
MANAGING AUTHORITY

NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND

Co-financed by Greece and the European Union

(http://proteus.space.noa.gr/~hnswrn)

Second Biggest Flare Of the Solar Cycle

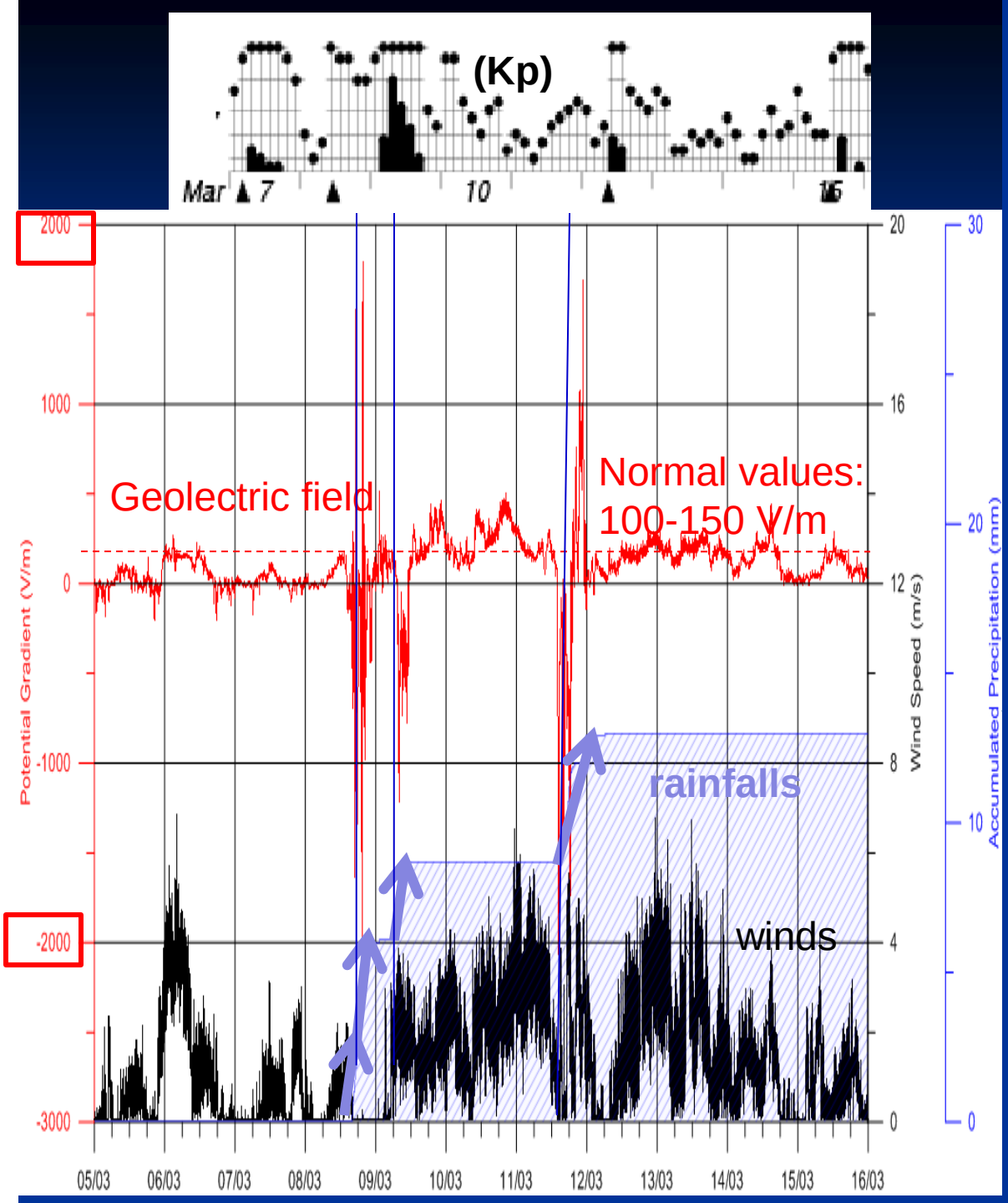
(NASA SDO) http://www.nasa.gov/mission_pages/sdo/news/solar-activity.htm

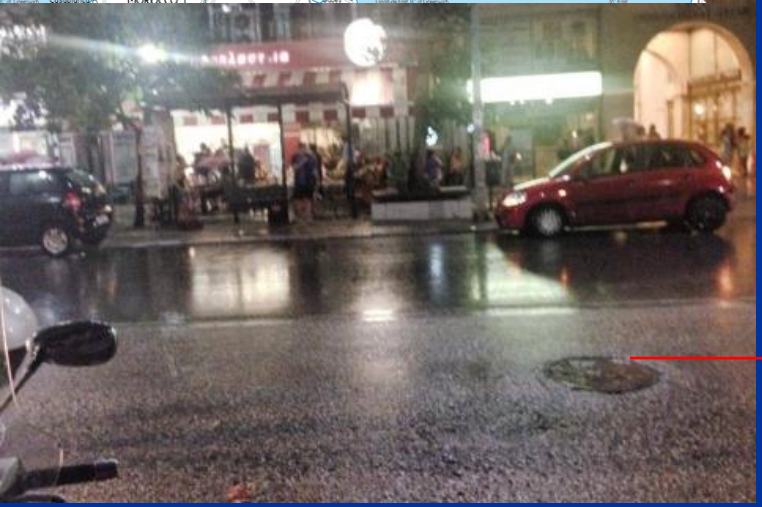
Collaboration with Dep. of Environmental Eng. /DUTH:
Correlation of
Geomagnetic activity (Kp),

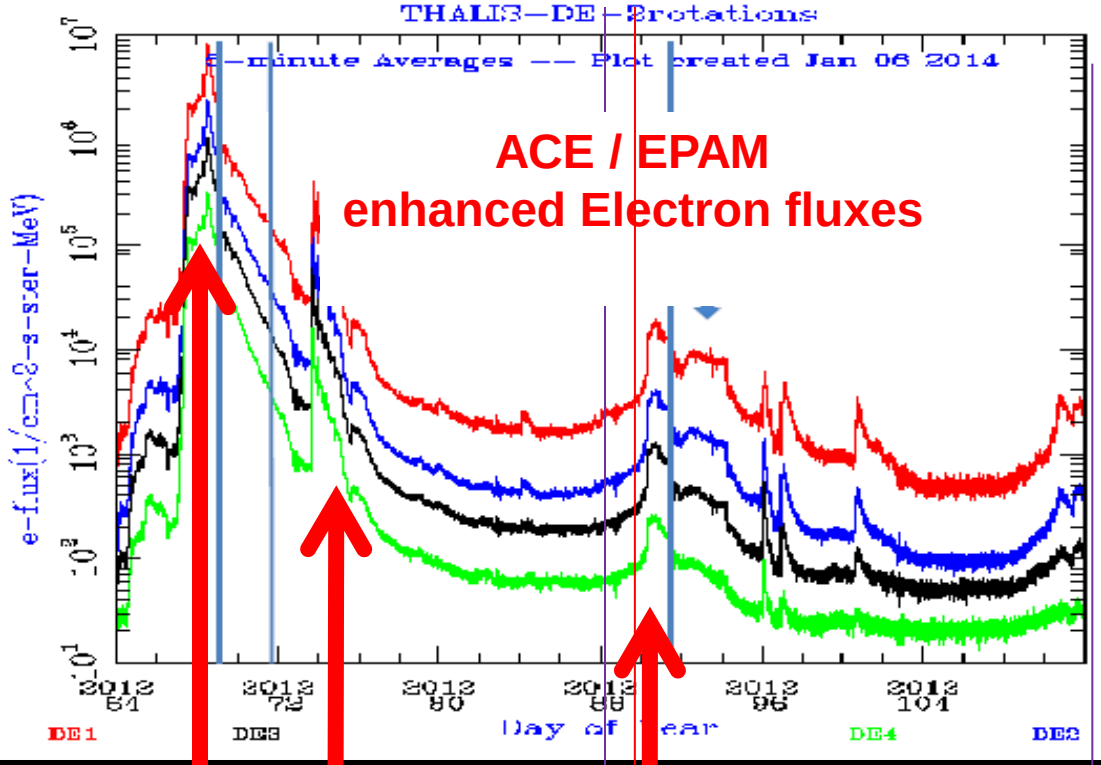
fluctuating geolectric field (~1500 V/m),

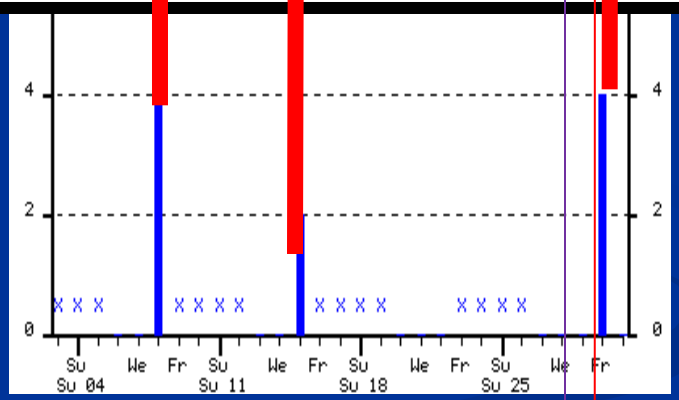
rainfalls

and strong winds









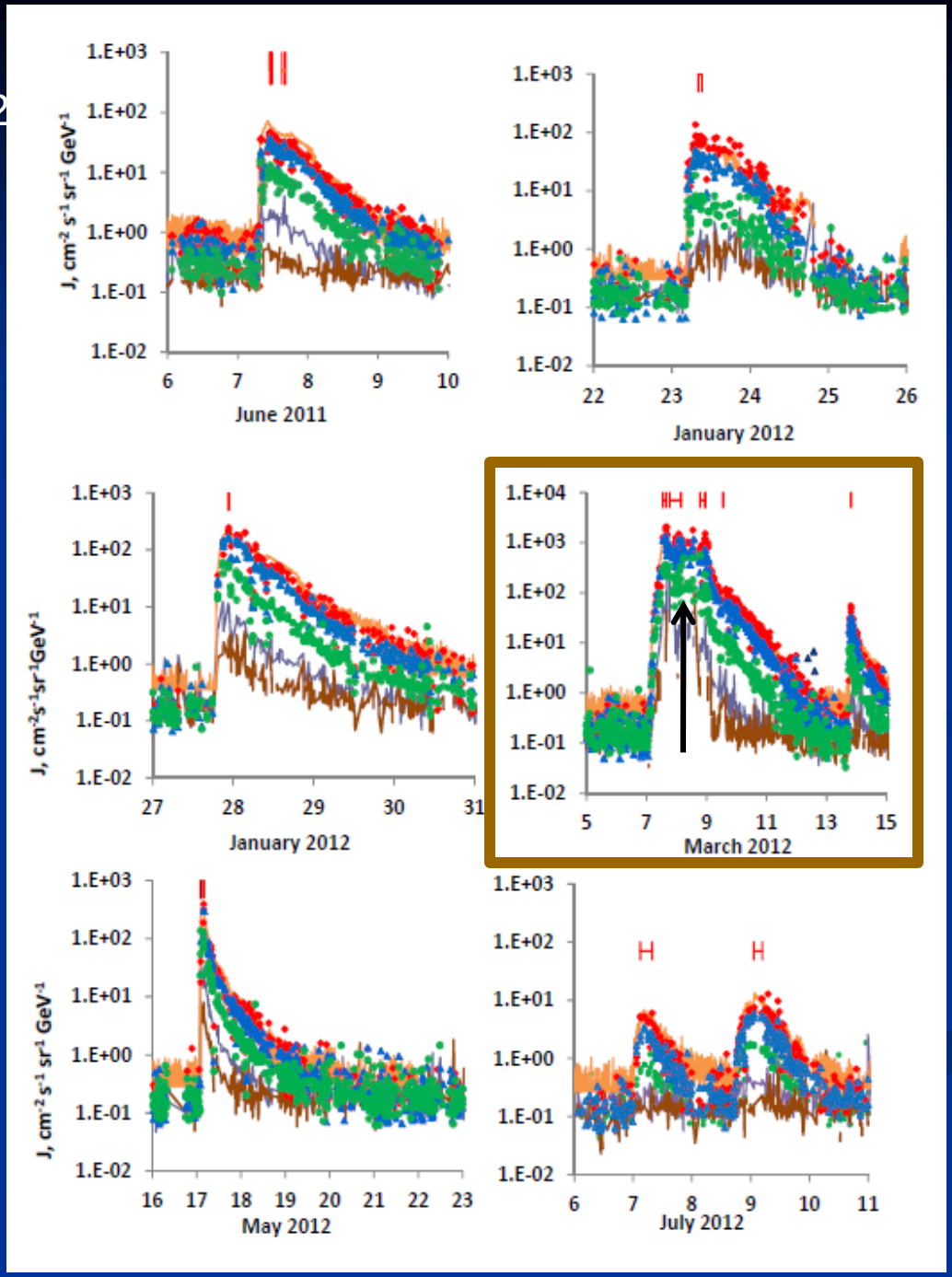
Rainfall in Alexandroupoli / North Greece on days of SEP

PAMELA Intensity-time profiles of SEP events recorded in 2011-2012 in comparison with 0.1 GeV intensity from GOES 13 (orange line).

PAMELA :

0.102 GeV	(red rhombs)
0.121-0.144 GeV	(blue triangles)
0.169-0.235	(green circles)
0.276-0.378 GeV	(grey line)
0.440-0.592 GeV	**(brown line)**

The March 2012 SEP events is characterized by a three orders of magnitudes high energy (~0.6 GeV) proton flux Increase



[PDF] The Historic March 2012 Heat Wave:A Meteorological ...

www.crh.noaa.gov/.../NWS-March%20Hea... ▾ Μετάφραση αυτής της σελίδας

1 Μαρ 201

northwest

NEWS
News, features & press releases

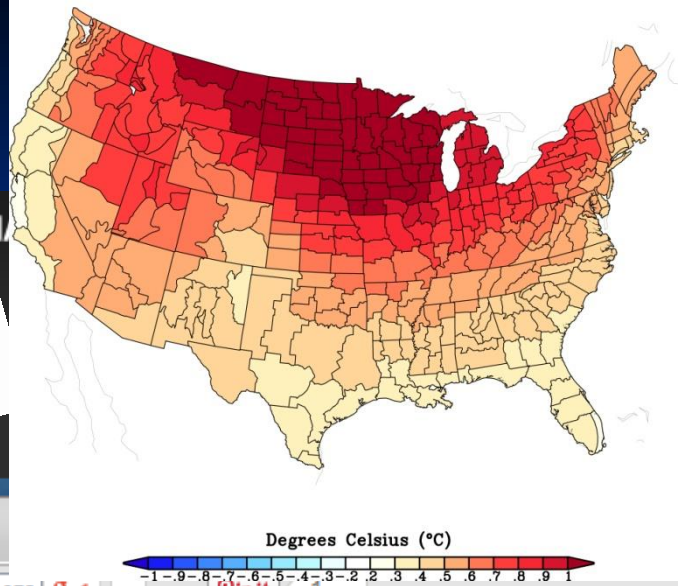
MISSIONS
Current

Historic March 2012 Heat Wave: A Meteorological Retrospective

Samantha Borth, Valparaiso University '12
Richard Castro, NWS Chicago
Kevin Birk, NWS Chicago

Media Resources

March 2012 Temperature Departures
CMIP5 Ensemble Projection



Text Size + − Tweet 42 Μου αρέσει! 372 +1 9 Pin it 1

NASA Measures Impact of Huge Solar Flare on Earth's Atmosphere 03.23.12

A key NASA instrument that can directly measure the impact of solar events on the Earth's upper atmosphere has weighed in on the huge flare that impacted Earth last week.

The flare was considered one of the largest solar events in years even though its impact on the power grid and communications was minimal due to the angle it hit Earth.

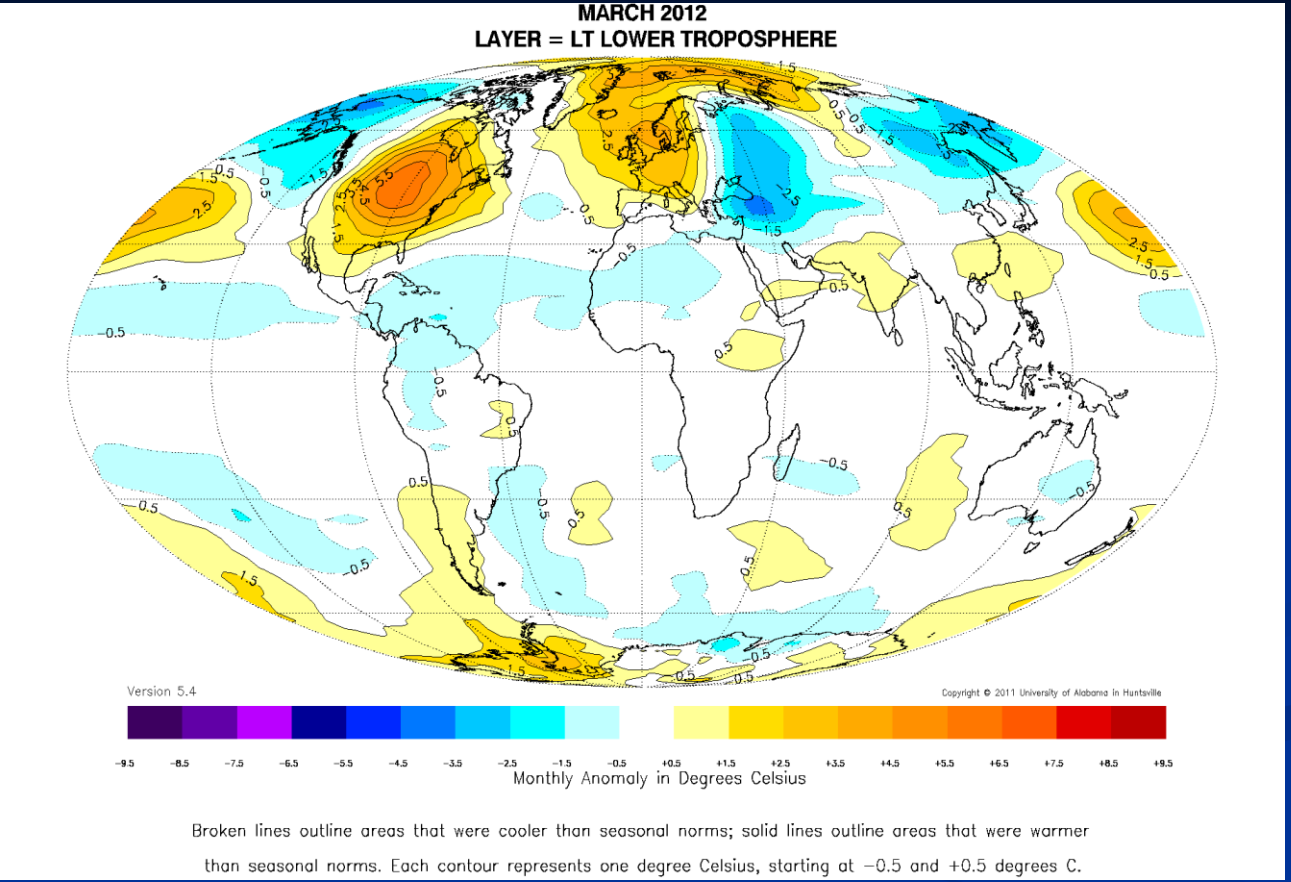
s direct interaction with the upper mosphere was measured by NASA's BER (Sounding of the Atmosphere using adband Emission Radiometry) nstrument orbiting on the TIMED (Thermosphere, Ionosphere, Mesosphere,

Atmospheric Chemistry and Physics Discussions

Will climate change increase ozone depletion from low-energy-electron precipitation?

..., P. Jöckel[1,2], M. Dameris[2], and P. J. Crutzen[1]

Temperature anomalies

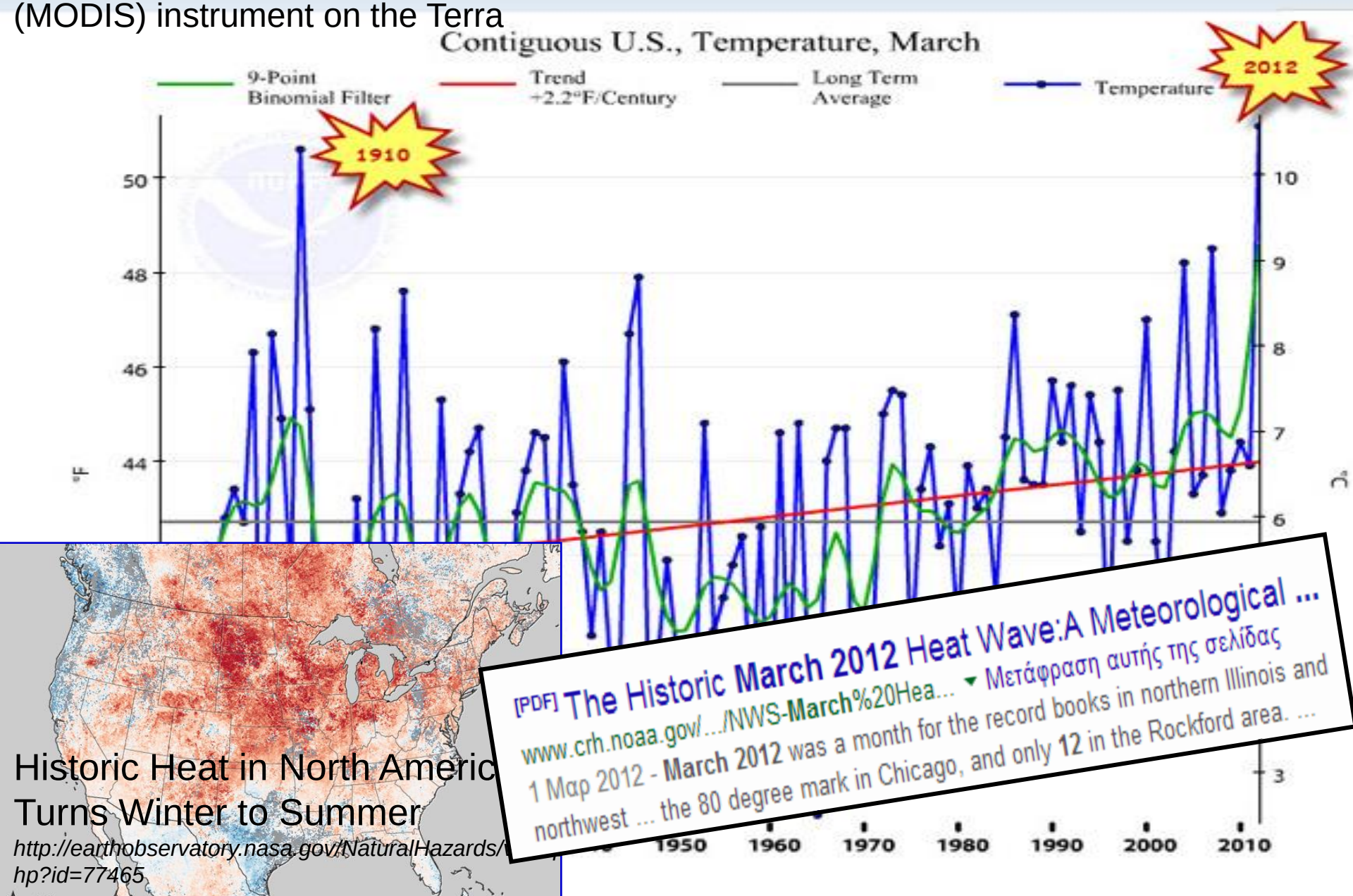


The March map of **temperature anomalies** shows that **warmer-than-average** temperatures occurred all over the globe: across the contiguous United States, Canada, Mexico, southern South America, the United Kingdom, Scandinavia, northern Russia, and parts of southeastern Asia.

NOAA: March 2012 the Warmest on Record

by Chris Dolce, weather.com Meteorologist

(MODIS) instrument on the Terra



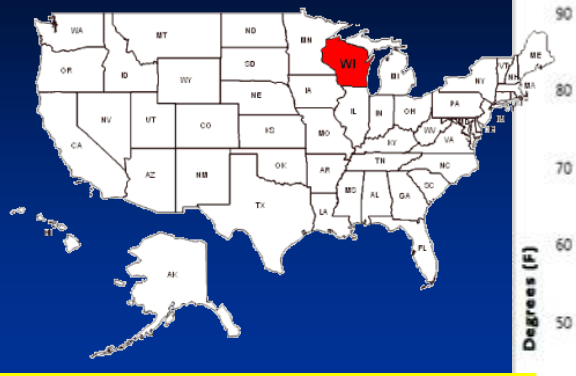
[PDF] The Historic March 2012 Heat Wave:A Meteorological ...

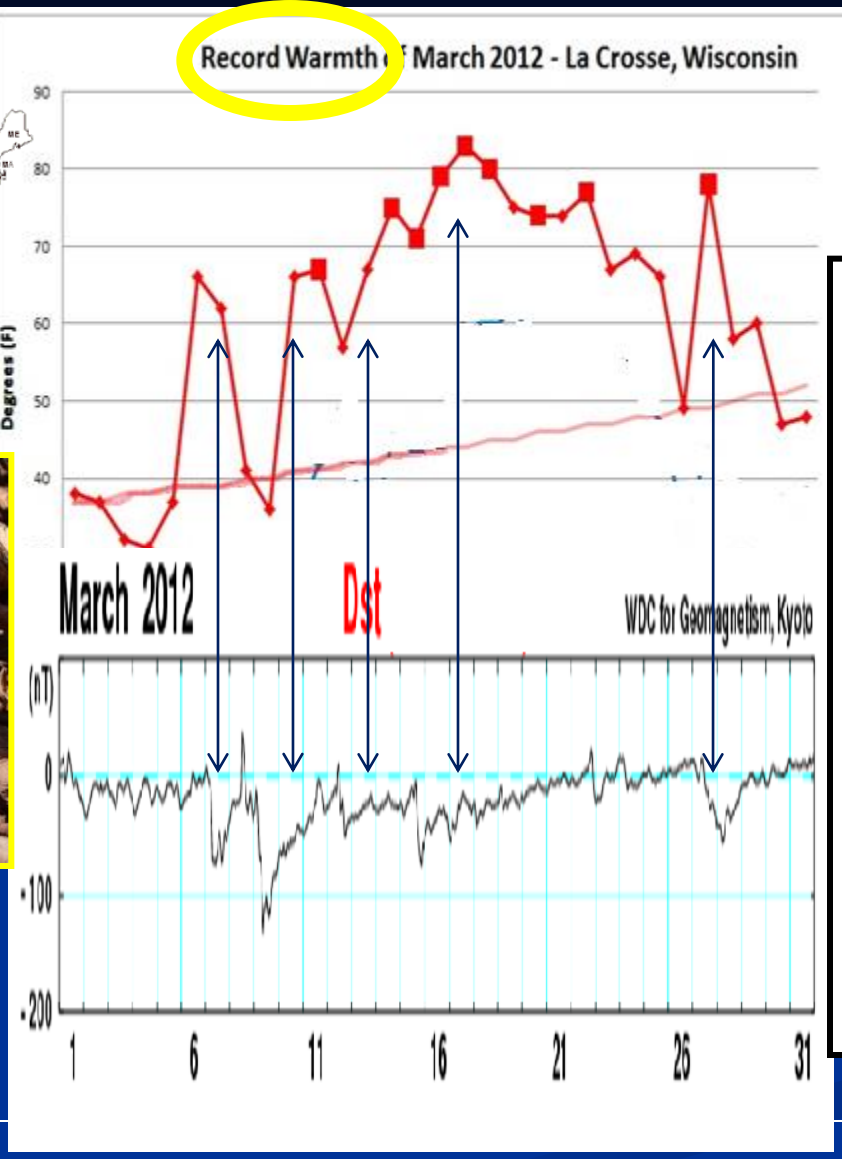
www.crh.noaa.gov/.../NWS-March%20Hea... ▾ Μετάφραση αυτής της σελίδας

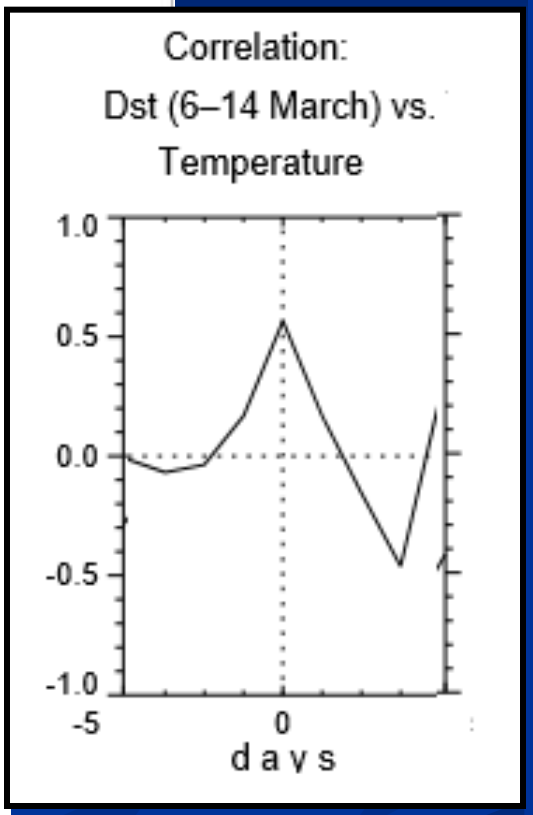
1 Μαρ 2012 - March 2012 was a month for the record books in northern Illinois and northwest ... the 80 degree mark in Chicago, and only 12 in the Rockford area. ...

Historic Heat in North Americ
Turns Winter to Summer

http://earthobservatory.nasa.gov/NaturalHazards/
hp?id=77465







Correlation between geomagnetic index Dst – Temperature

12-23 March

Was this extreme March 2012 U.S. heatwave event anticipated?

"A black swan most probably was observed in March 2012 (lest we forget 1910)…. **Our current estimate of the impact of GHG forcing is that it likely contributed on the order of 5% to 10% of the magnitude of the heat wave during 12-23 March… But there is always the randomness".**

The question: Randmness or a correlation between space & atmospheric extreme events?

http://www.esrl.noaa.gov/psd/csi/events/2012/marchheatwave/anticipation.html

Britain set for two-week heatwave | Daily Mail Online
www.dailymail.co.uk/.../Britain-set-week-h... ▾ Μετάφραση αυτής της σελίδας
Britain is heading for a sizzling two-week **heatwave** with temperatures set to soar into the nineties, ... Friday, Jun 26th **2015** 11PM 65°F 2AM 69°F 5-Day Forecast ..... **March** 4, 2014: Teresa Giudice and Joe Giudice, who starred in the reality ...

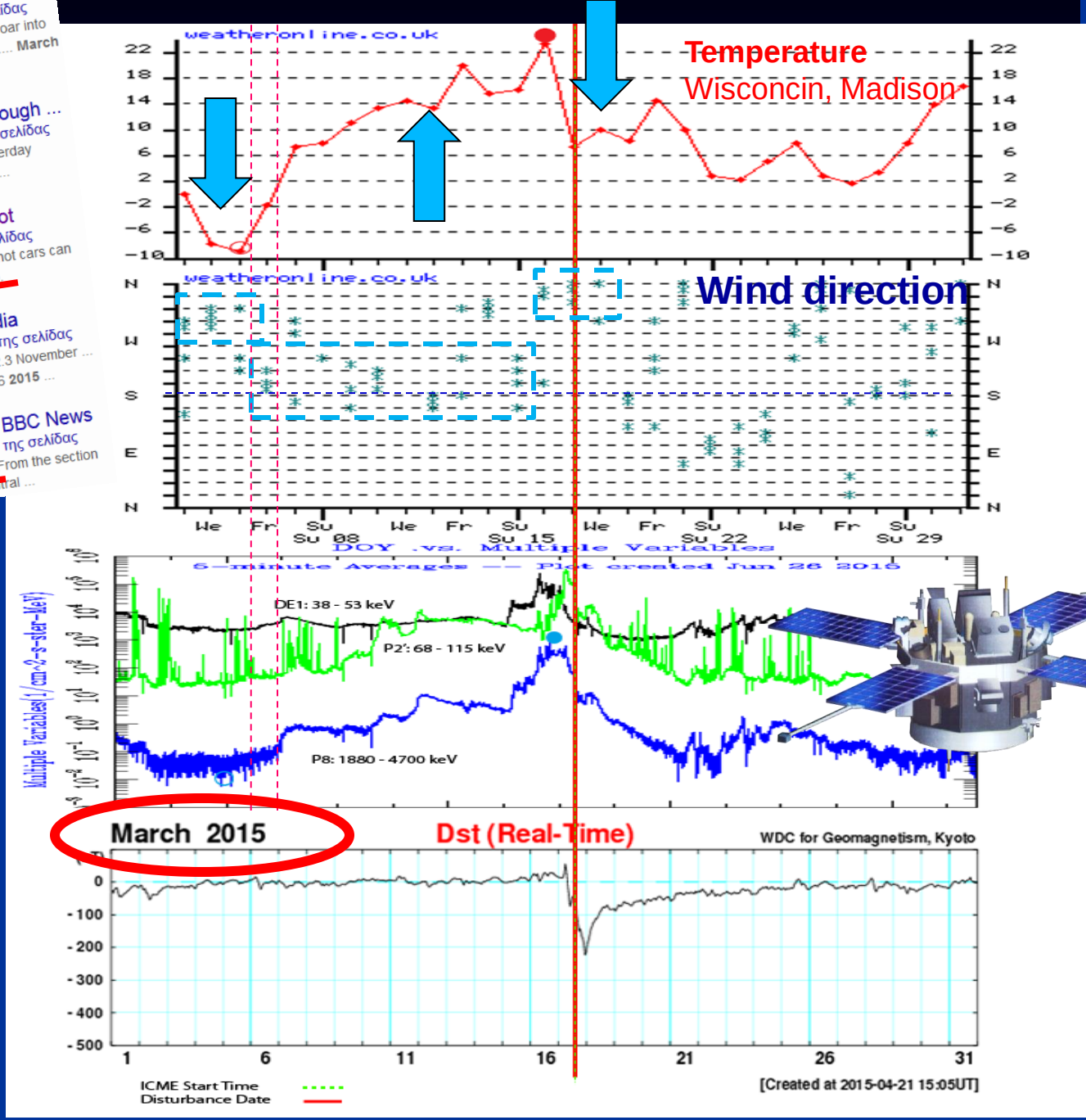
Queensland heatwave: Parts of the state sweltering through ...
www.abc.net.au/.../**2015**...**march**.../633161... ▾ Μετάφραση αυτής της σελίδας
18 Μαρ 2015 - BoM said one outback western Queensland community yesterday recorded the hottest day this late in **March** in the state's history and there ...

Heat Wave - 2015 News and Articles - Why Is It So Hot
www.livescience.com/topics/**heat-wave**/ ▾ Μετάφραση αυτής της σελίδας
As a **heat wave** grips the I-95 corridor this week, researchers warn how hot cars can get, posing .... Last month was the **March** warmest on record since 1895.

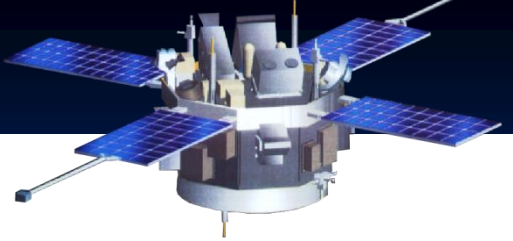
Climate of Adelaide - Wikipedia, the free encyclopedia
https://en.wikipedia.org/.../Climate_of_Ade... ▾ Μετάφραση αυτής της σελίδας
2.1 **March** 2008 **heatwave**; 2.2 January–February 2009 **heatwave**; 2.3 November ... **heatwave**; 2.5 Autumn 2014: Warmest Adelaide autumn on record; 2.6 **2015** ...

Australia sees record-breaking March heat-wave - BBC News
www.bbc.co.uk/.../world-australia-320281... ▾ Μετάφραση αυτής της σελίδας
Australia sees record-breaking March **heat-wave**. **24 March 2015**. From the section Australia. Birdsville Hotel in central west Queensland Birdsville in central ...

- High Energy Solar **proton** impact
- Amount of protons
- **History** of SEP
- (not only the Flare / Kp)
- South **warm air flow**

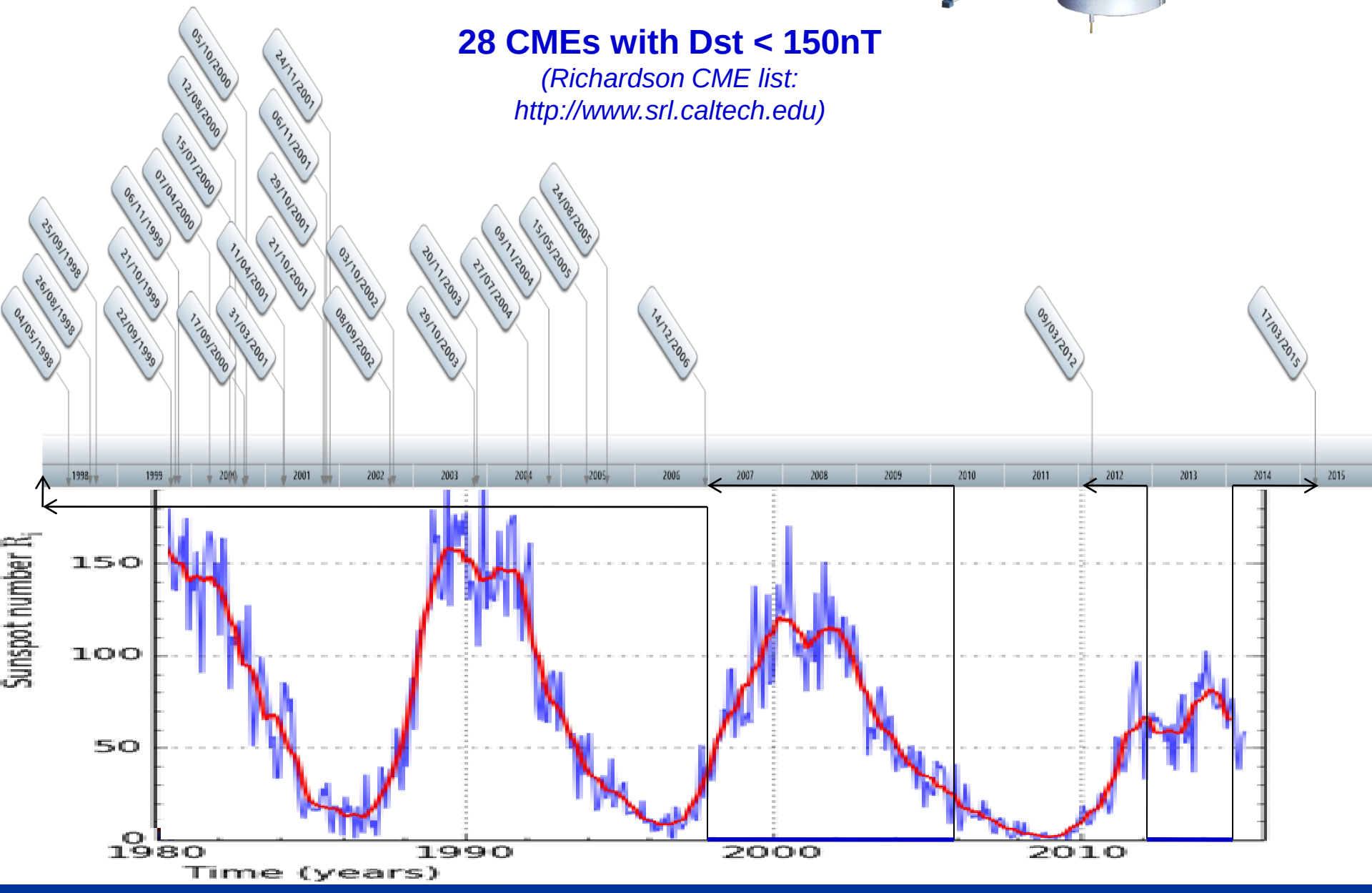


ACE era (1997 – today)



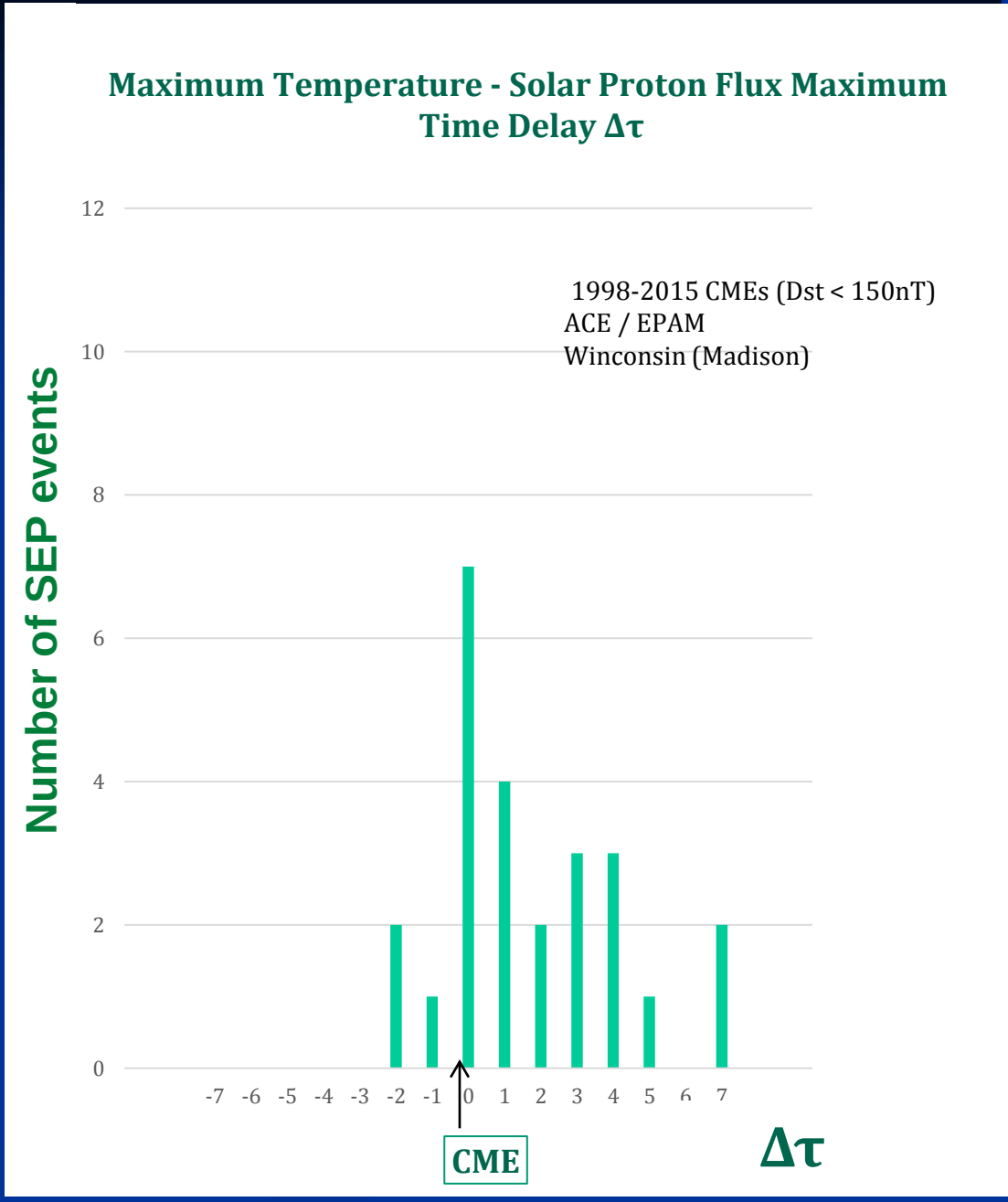
28 CMEs with Dst < 150nT

(Richardson CME list:
http://www.srl.caltech.edu)



Most SEP show ΔT ≥ 0:

Maximum S. Temperature coincides with or follow Solar Proton Flux Maximum (daily averages)



Winter times are preferable

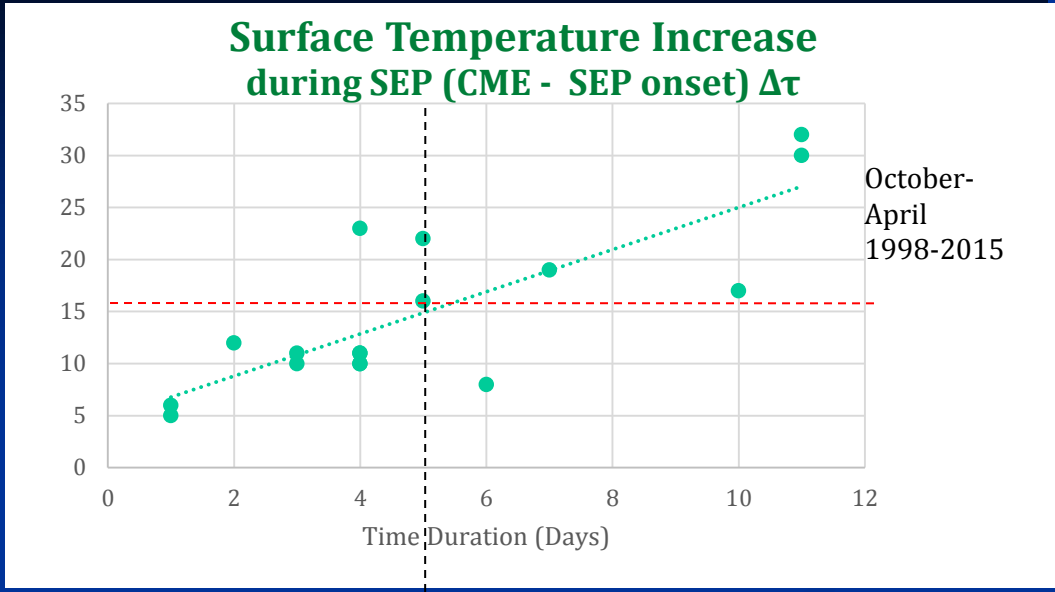
for very large

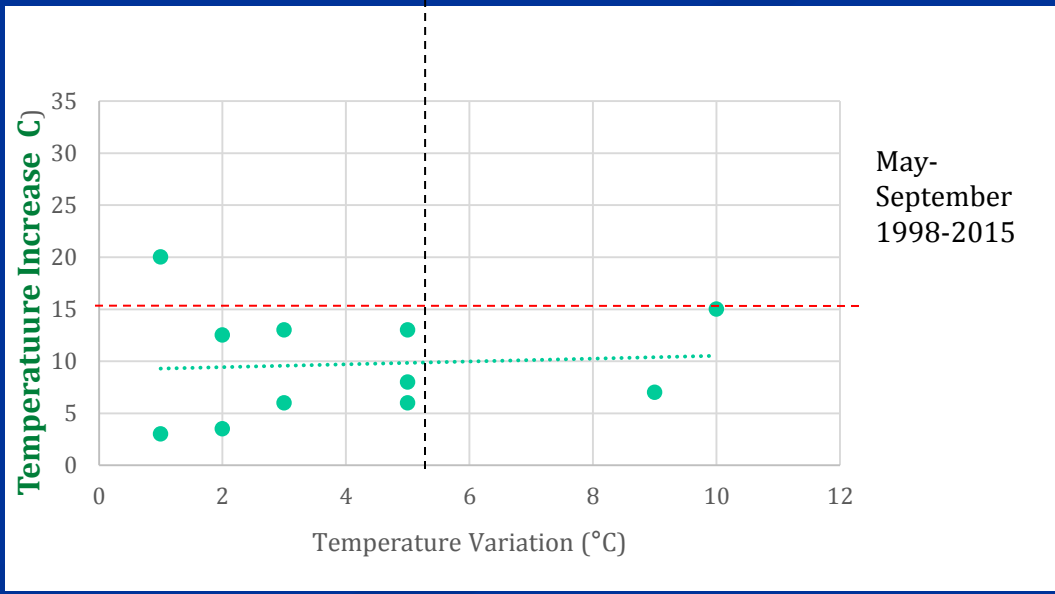
Temperature increases

within ~ 5 days or more (<10)

from SEP onset

(i.e. March 2012, 2015 heatwaves)



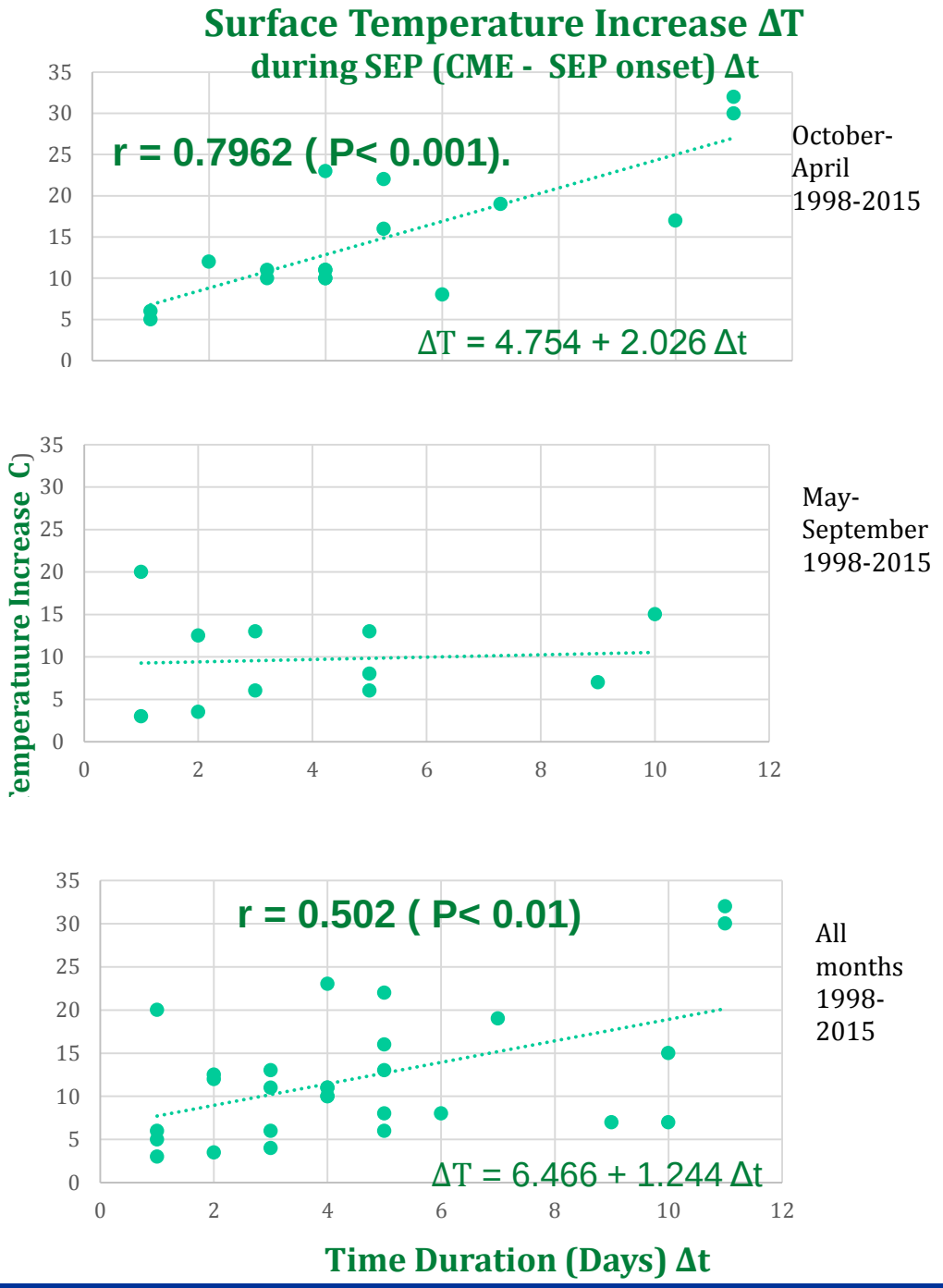


Surface Temperature Increase ΔT
during SEP (CME - SEP onset) Δt

Very strong / significant Correlation
r = 0.7962, P< 0.001),
ΔT/Δt = 2^0C/day
(Oct. – April)

NO significant Correlation
(May – Sep.)

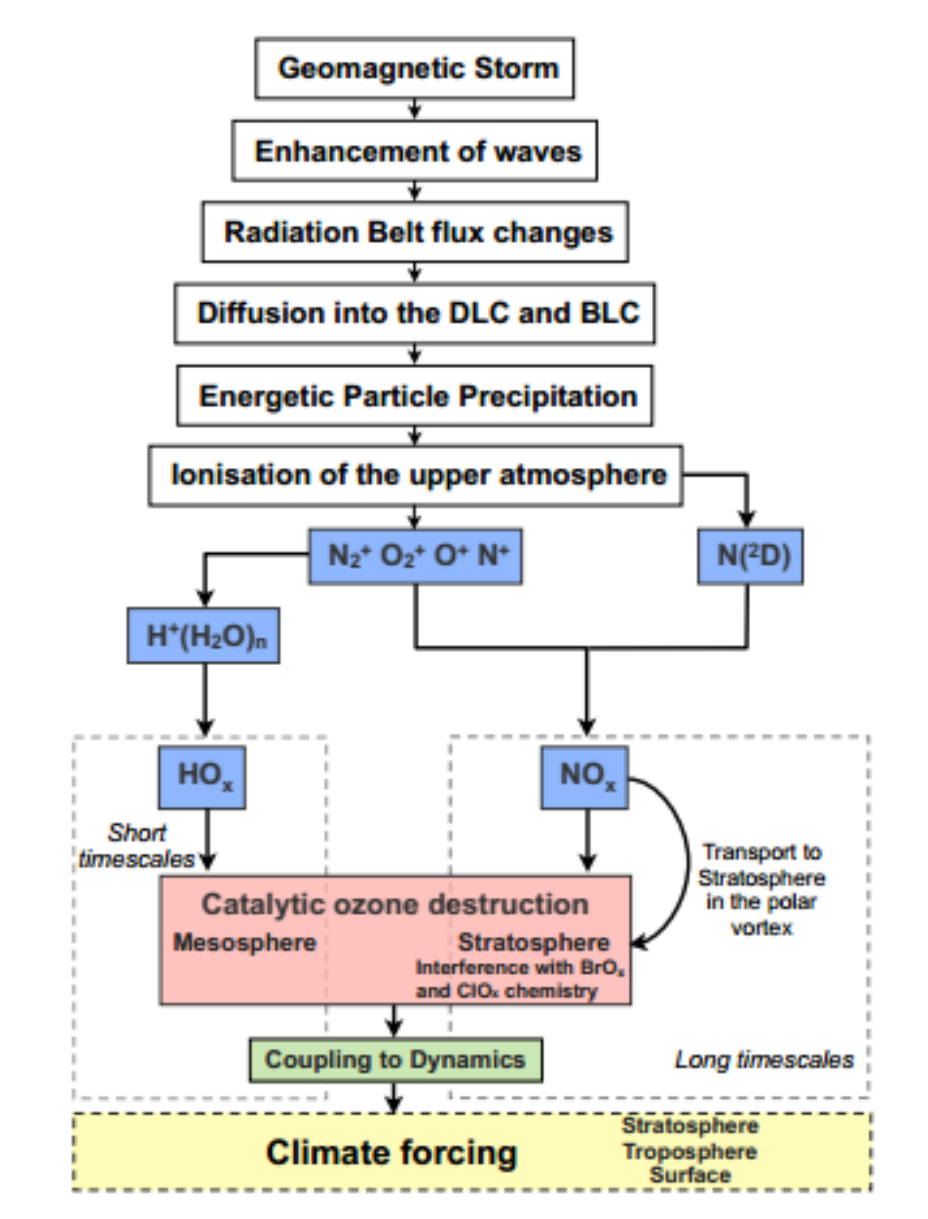
Strong / significant Correlation
(r = 0.502, P< 0.01
(All months)

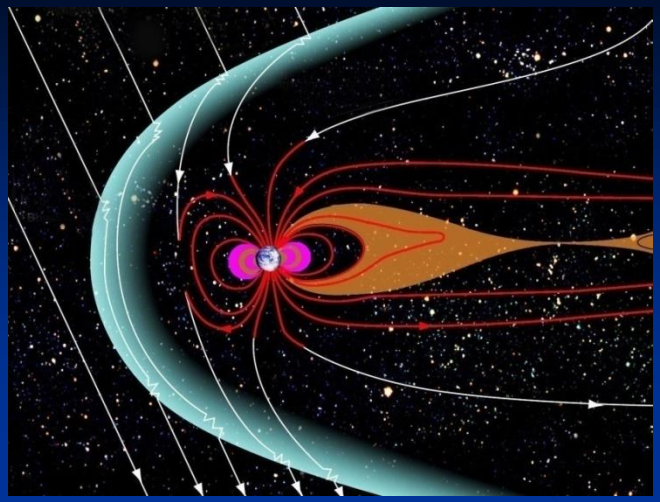


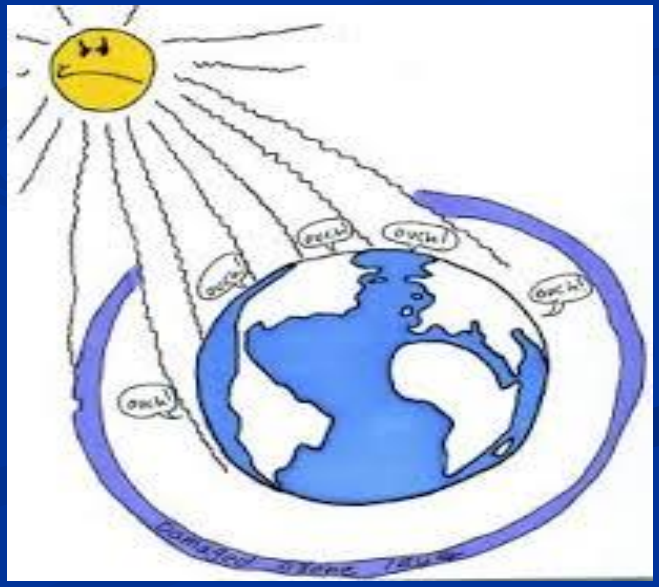
Possible Mechanisms:

1. SEP – NAO
2. SEP - Large stratospheric / tropospheric pressure gradient – downward air flow
3. SEP- Ionization – aerosol particles – cloud condensation
4. SEP- Ionization- Variation in global electric circuit
5. Ozon related chemical / energy changes

   but even more


Geomagnetic Storm
Enhancement of waves
Radiation Belt flux changes
Diffusion into the DLC and BLC
Energetic Particle Precipitation
Ionisation of the upper atmosphere
N_2^+ O_2^+ O^+ N^+
$N(^2D)$
$H^+(H_2O)_n$
HO_x
NO_x
Short timescales
Transport to Stratosphere in the polar vortex
Catalytic ozone destruction
Mesosphere
Stratosphere
Interference with BrO_x and ClO_x chemistry
Coupling to Dynamics
Long timescales
Climate forcing
Stratosphere
Troposphere
Surface





Possible Mechanisms: 1. SEP – NAO

The Historic March 2012 Heat Wave: *A Meteorological Retrospective*

Samantha Borth, *Valparaiso University '12*
Richard Castro, *NWS Chicago*
Kevin Birk, *NWS Chicago*

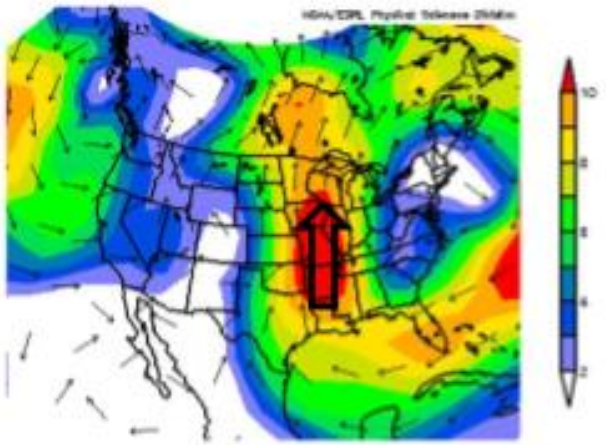
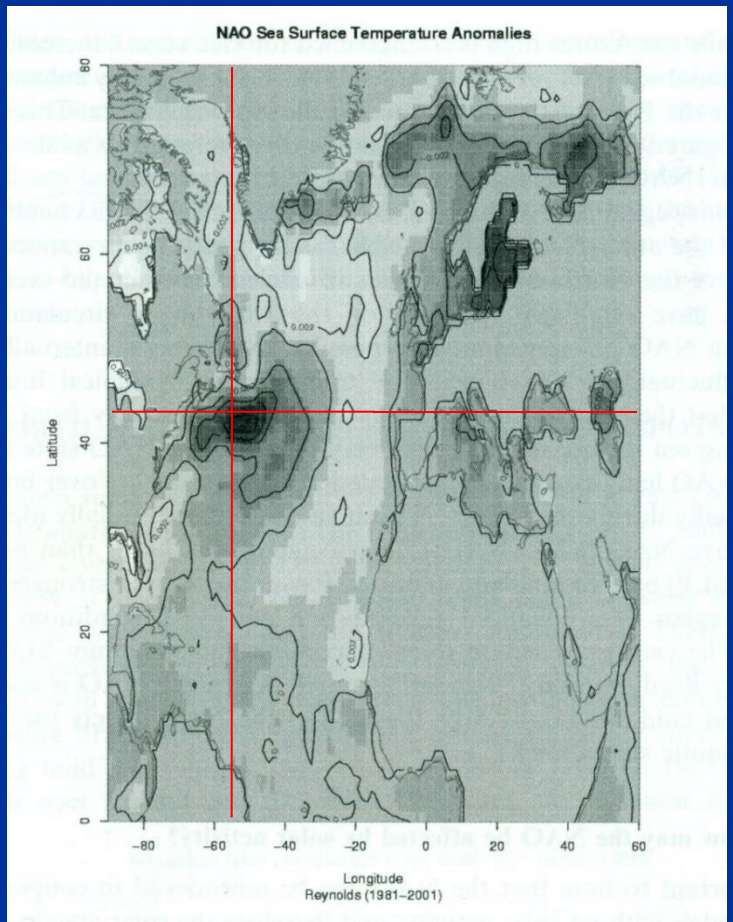
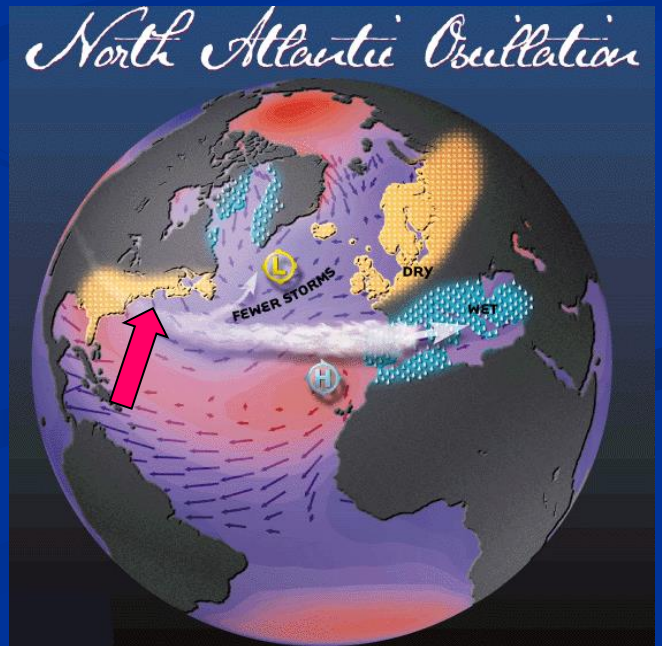
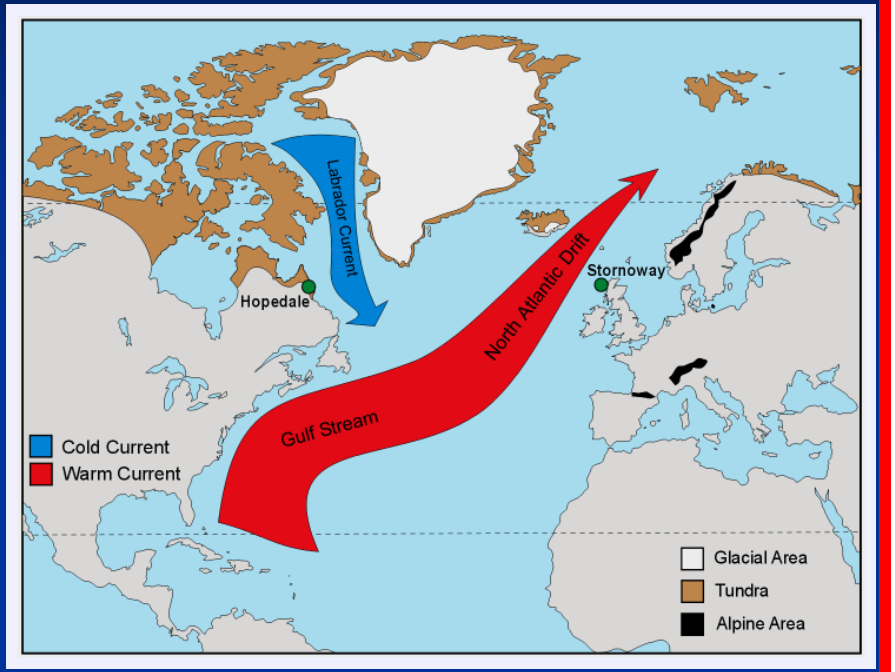
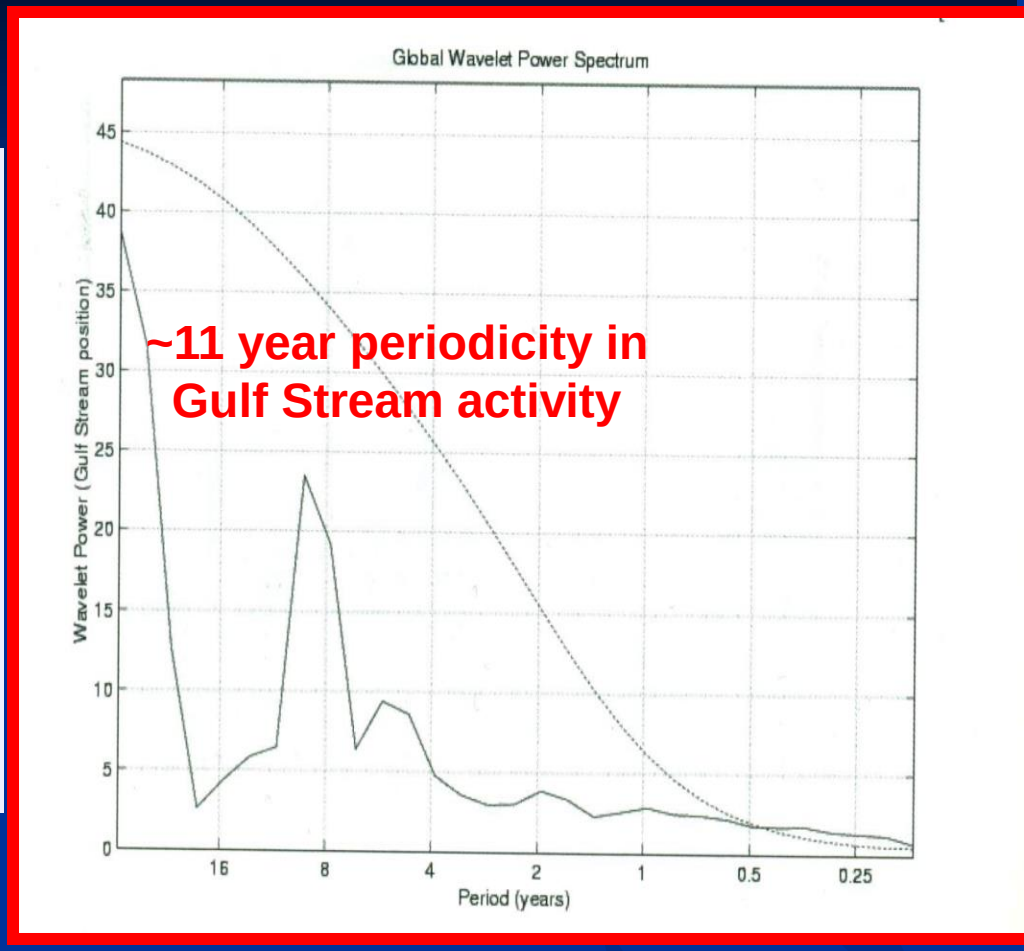


Figure 2.3 indicates the average 850 mb wind vector anomaly throughout the period of the heat wave. The arrow indicates the placement of the southerly low level jet.









A warm engine **Gulf Stream during Solar Max**

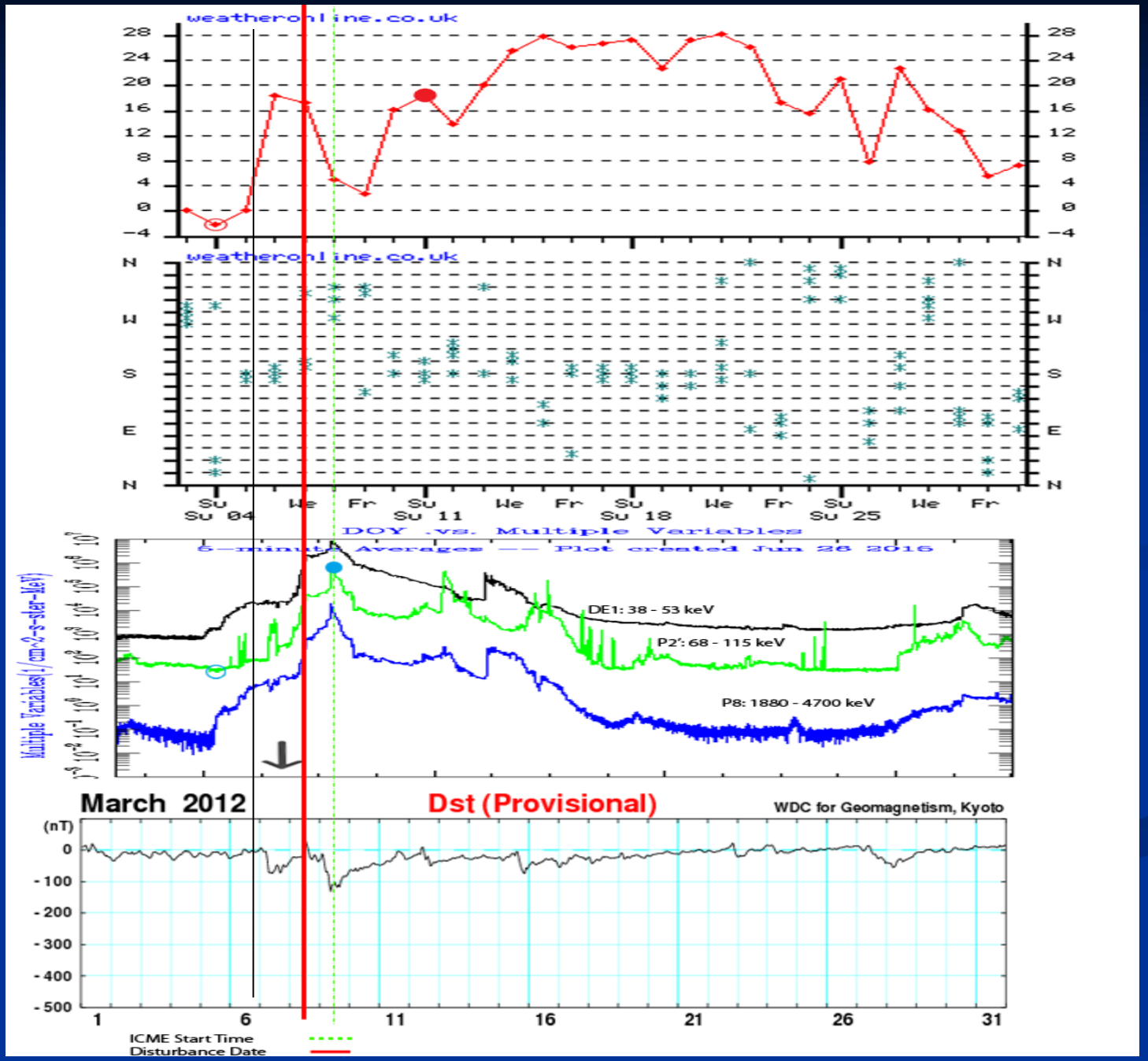
our study may support:

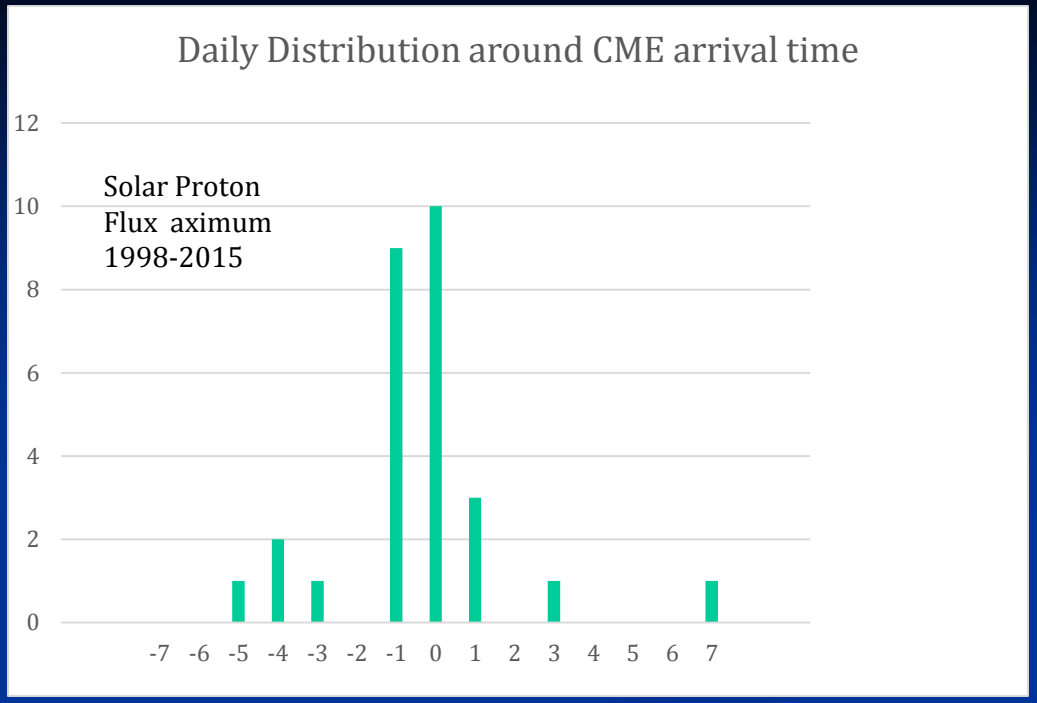
SEP impact on Gulf Stream

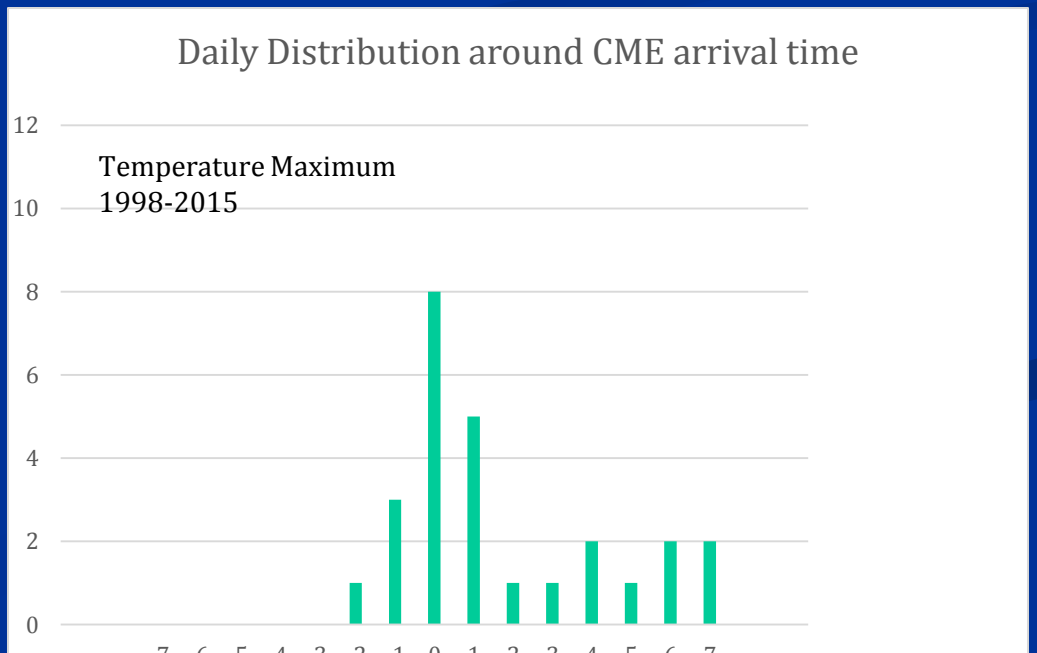
...in order to be able to reliably model the response (of meteorological data) from geomagnetic sources we also need better understanding of the different particle sources: This provides a challenge to the scientific community working on solar-terrestrial physics

Seppala et al., JGR, 2009

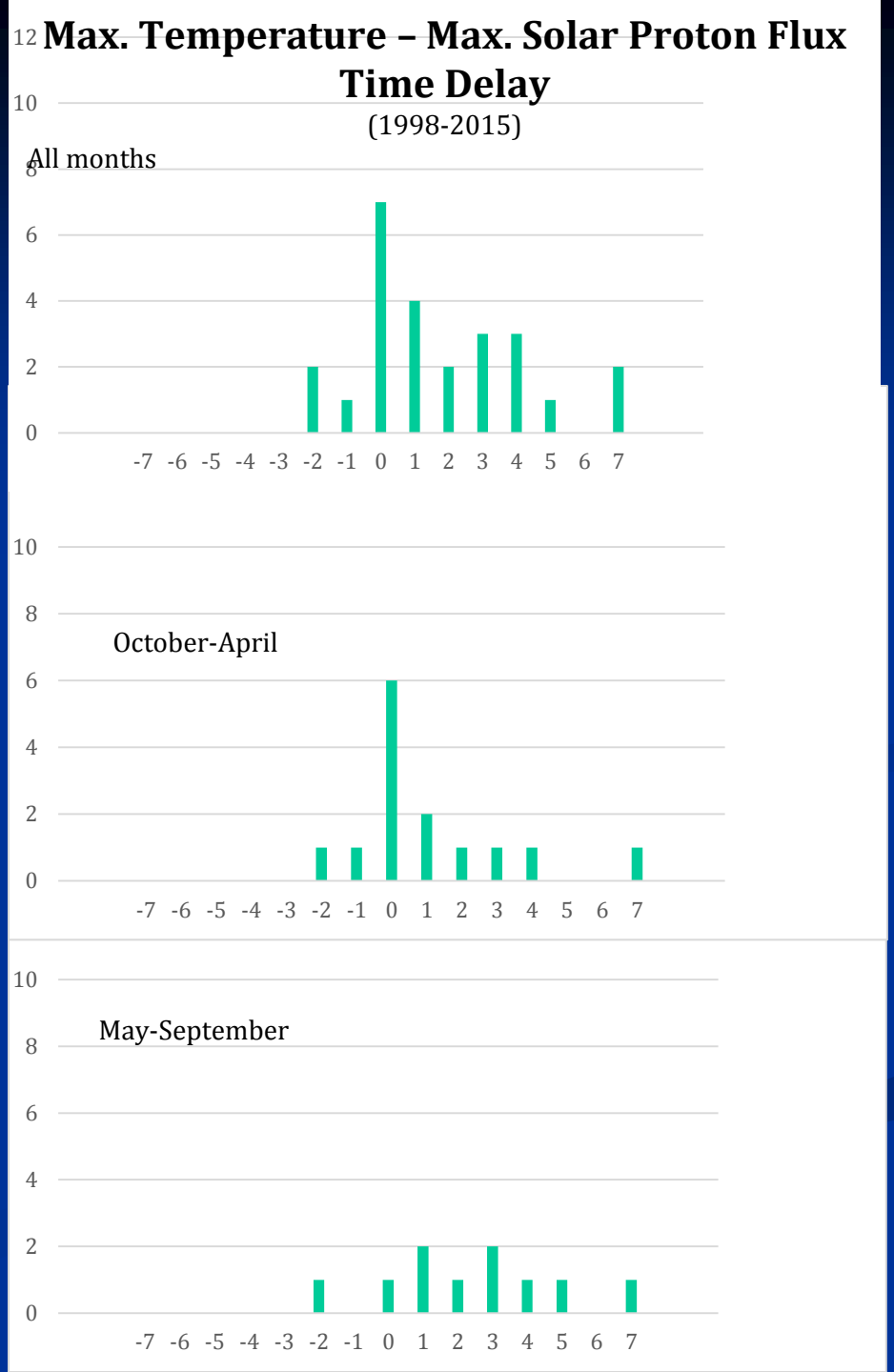
Thank you for your attention


weatheronline.co.uk
28
24
20
16
12
8
4
0
-4
N
W
S
E
Su 04
We
Fr
Su 11
Su 18
Su 25
DOY .vs. Multiple Variables
5-minute Averages --- Plot created Jun 26 2016
Multiple Variables(1/cm^2-s-ster-MeV)
DE1: 38 - 53 keV
P2': 68 - 115 keV
P8: 1880 - 4700 keV
March 2012
Dst (Provisional)
WDC for Geomagnetism, Kyoto
(nT)
0
-100
-200
-300
-400
-500
1
6
11
16
21
26
31
ICME Start Time
Disturbance Date


Daily Distribution around CME arrival time
Solar Proton
Flux aximum
1998-2015
12
10
8
6
4
2
0
-7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7


Daily Distribution around CME arrival time
Temperature Maximum
1998-2015
12
10
8
6
4
2
0

Distribution around CME arrival time



D. GENERAL CONCLUSION-1

The great CME / superstorm of March 2012 was followed by

A FAST (few hours) response TROPOSPHERE - MAGNETOSPHERE

A sequence of physical events (GREECE)

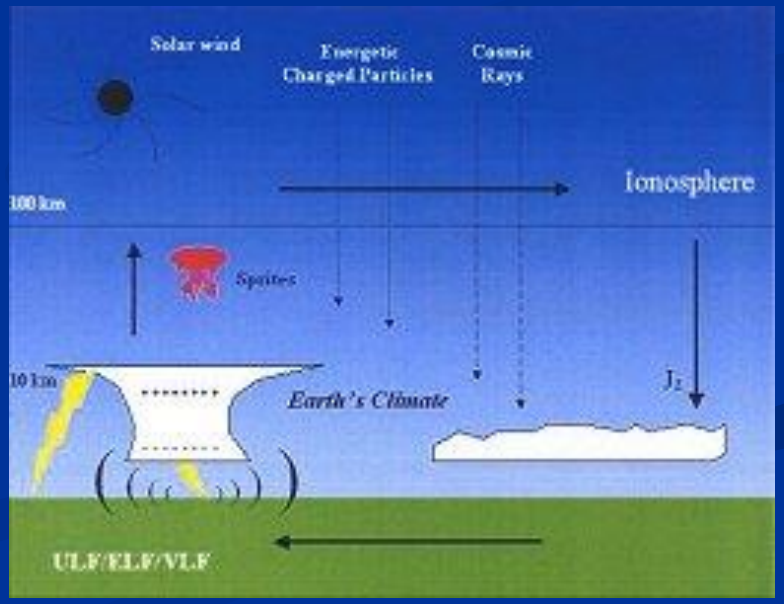
Probably suggests that radiation

belt electron precipitation

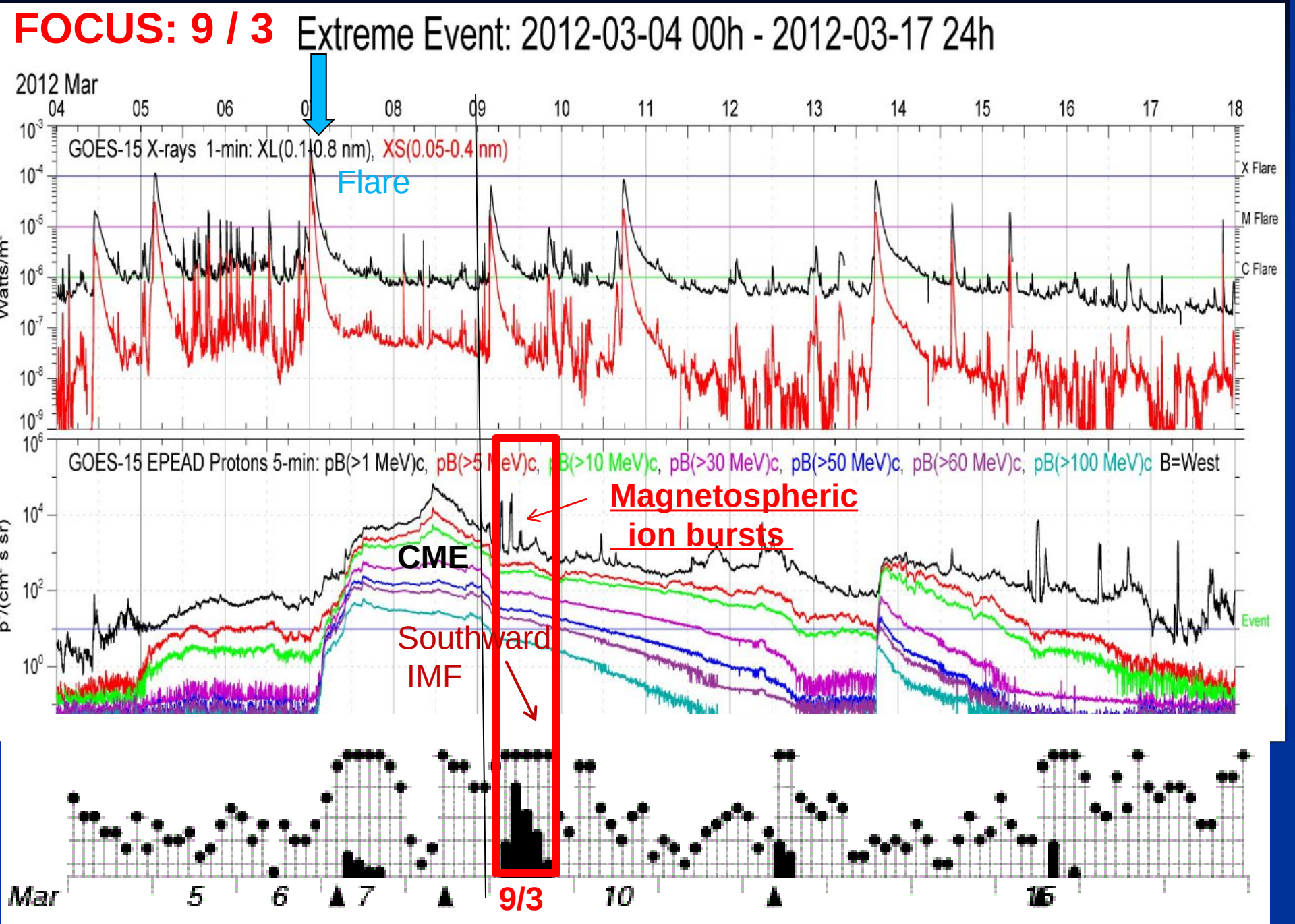
into the middle latitude atmosphere

may create an excess ionization

under special S.M.Cl conditions



B. CASE STUDY: MARCH 2012 EXTREME EVENTS / GREECE

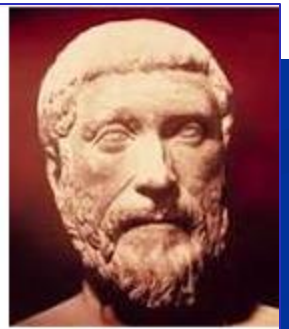


4. CORRELATION OF SPACE – METEOROLOGICAL EVENTS

Already in ancient Greece, around 400 B.C., Meton observed sunspots (*Hoyt and Schatten*, 1997). After twenty years of solar studies he came to the conclusion that high solar activity, i.e. high number of sunspots, is associated with wet weather in Greece. Today the observations of Meton could have been associated with the changes of the North Atlantic Oscillation (NAO) (*Hurrell et al.*, 2003).

Μέτων ο Αθηναίος

Ο Μέτωνας ήταν Έλληνας μαθηματικός, αστρονόμος, γεωμέτρης και μηχανικός ο οποίος έζησε στην Αθήνα τον 5ο π.Χ. αιώνα.



Influence of Solar Activity Cycles on Earth's Climate

ISAC

ESA ITT AO/1-4618/NL/AR

F. Boberg, H. Lundstedt, and P. Wintoft
Swedish Institute of Space Physics

Ion-pair production rates due to solar protons

1, Nov. 2, 1969;

2, August 4, 1972, 1500- 1600 UT;

3, August 4, 1972, 1508 UT;

4, August 4, 1972, 2200 UT;

5, September 29, 1961) galactic cosmic rays

6, ssmin; 7, ssmax;

8. precipitating electrons,

1,Zmuda and Potemra (1972); 2, Kohl et al. (1973) and Bazilevskaya et al. (1973);

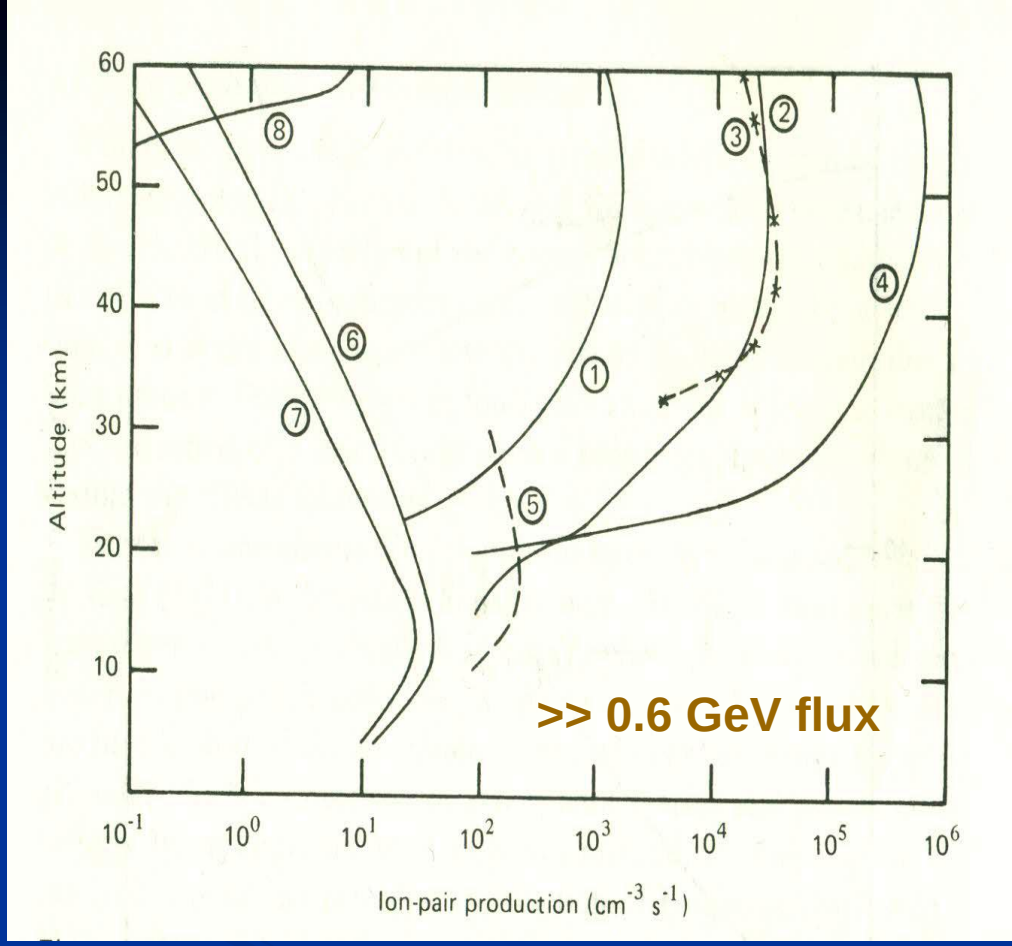
3, Reagan and Watt (1976);

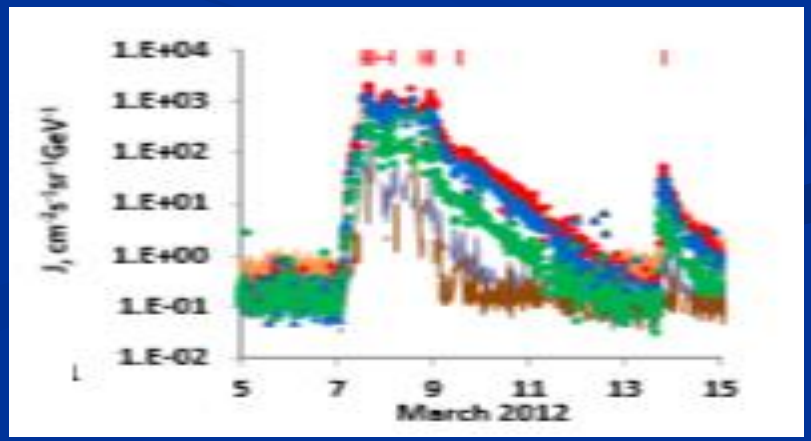
4, Kohl et al. (1973);

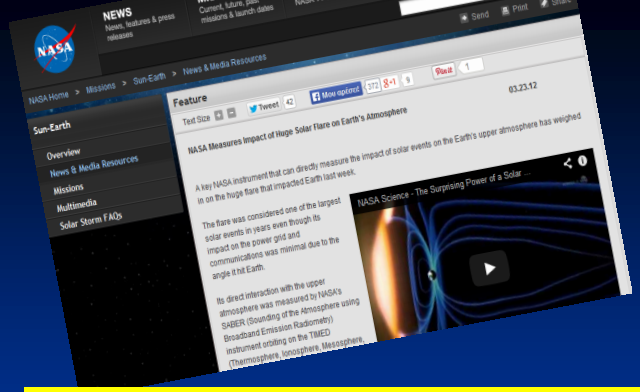
5,Bryant et al. (1962);

6,7 Webber (1962);

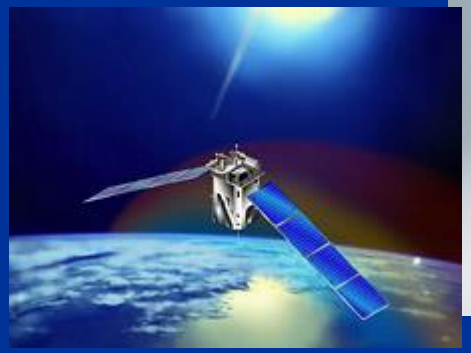
8, Larsen et al. (1976)

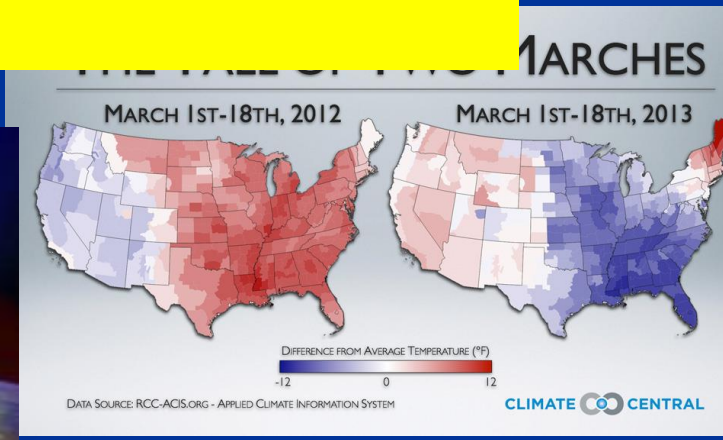






Space weather a good tool to understand unexplained so far extreme meteorological phenomena



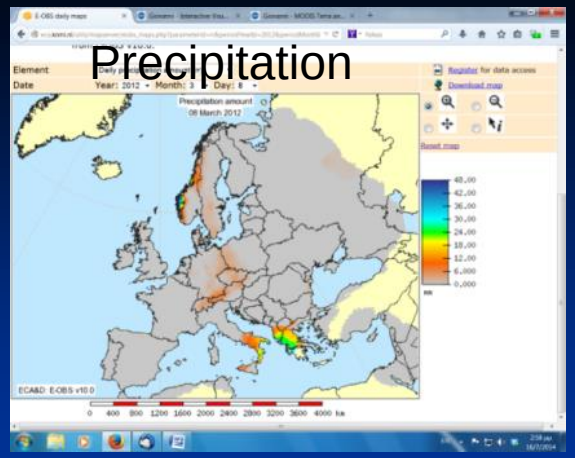


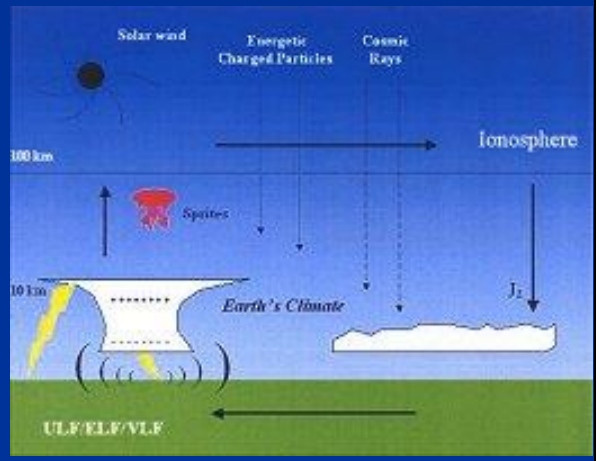
Conclusions

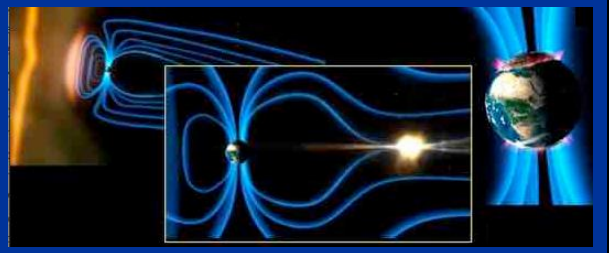
Comparison of SEP events with Temperature in Wisconsin related with CME induced great (Dst ≤150nT) storms

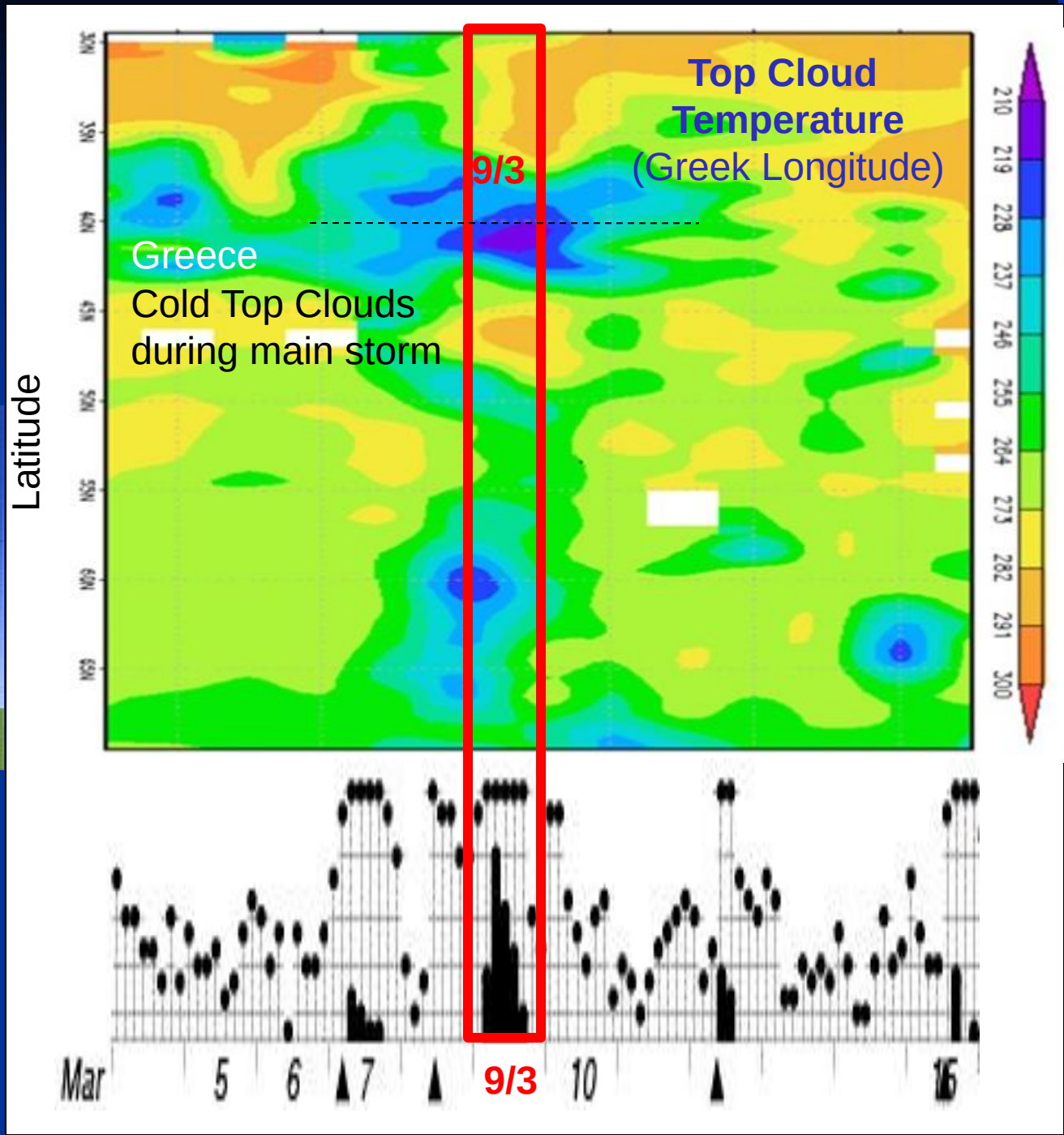
Main Results

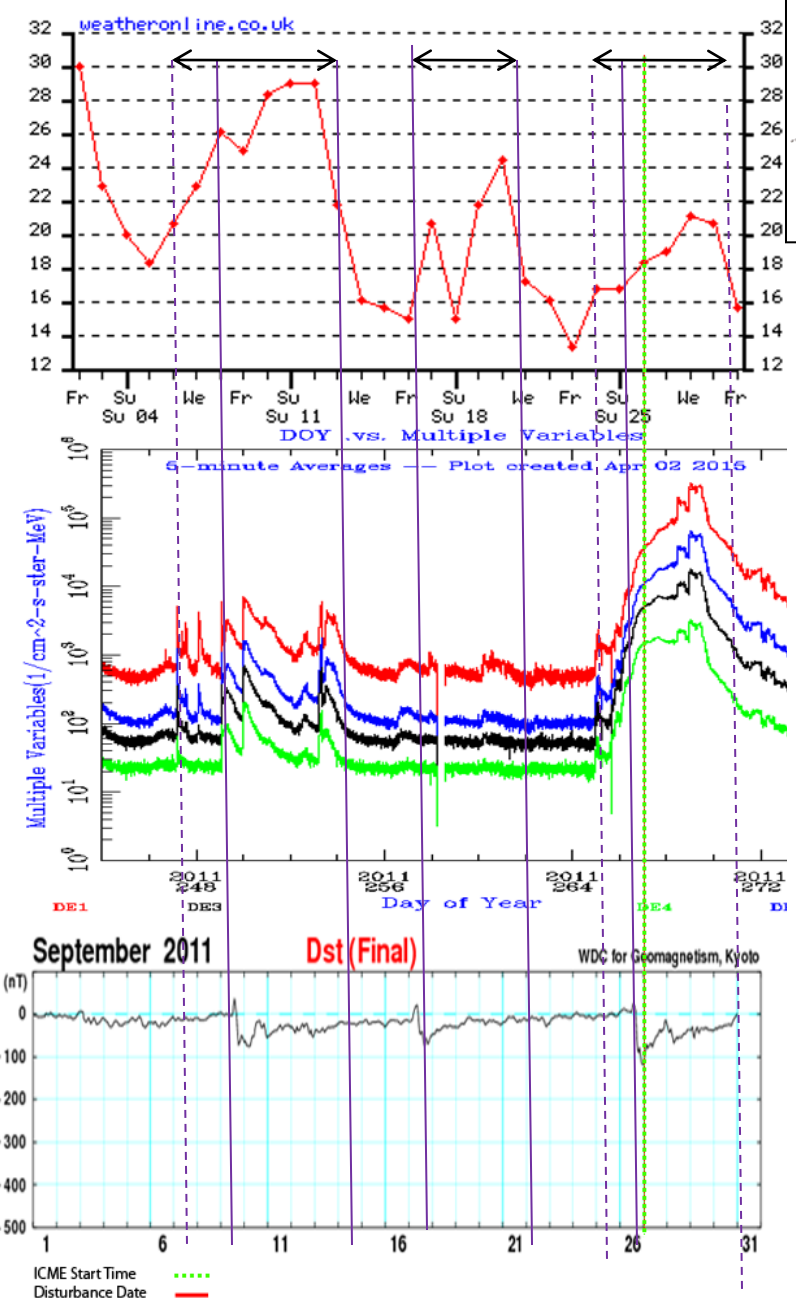
1. SEP enhanced flux duration is linearly correlated with temperature increases (ΔT/day ≈) before CMEs.
2. Most of T_{Max} values were recorded close to the CME (day): within a time internal [ø-7day, 0+7day],16 cases with T_{Max} (over a total of 26) were recorder within the internal [ø-1, ø+1 d].
4. The Temperature increase is related with the Gulf Stream (warm air streams from south/tropical latitudes).
3. Geomagnetic activity contributes to Temperature increases.
5. Rainfall, winds, cold clouds and extreme variation of geoelectric field were recorded in Greece in the correlation with Kp changes in Greece during the March 2012 CME.
6. Larger Temperature increases were observed between October-April than May-September: 7/15 versus 1/11 cases with $\Delta T/15^{o}$ C .

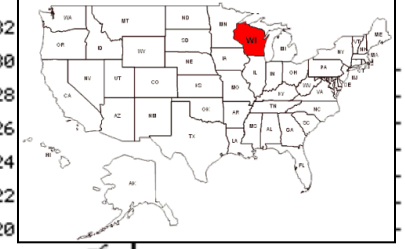

Precipitation

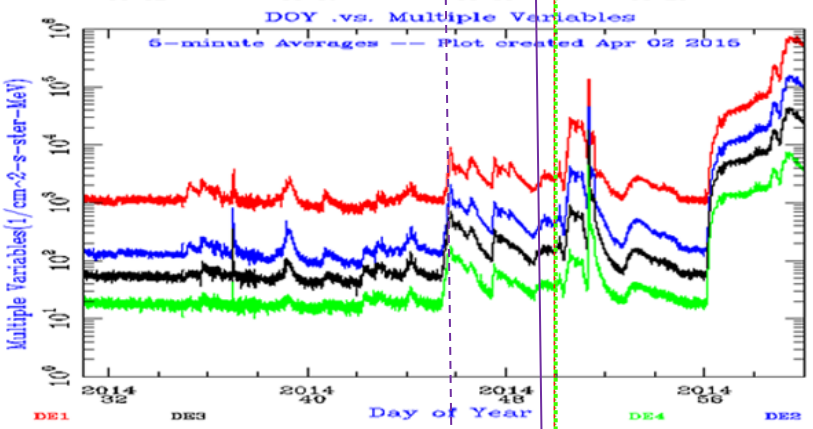

Solar wind
Energetic Charged Particles
Cosmic Rays
Ionosphere
100 km
Sprites
10 km
Earth's Climate
ULF/ELF/VLF

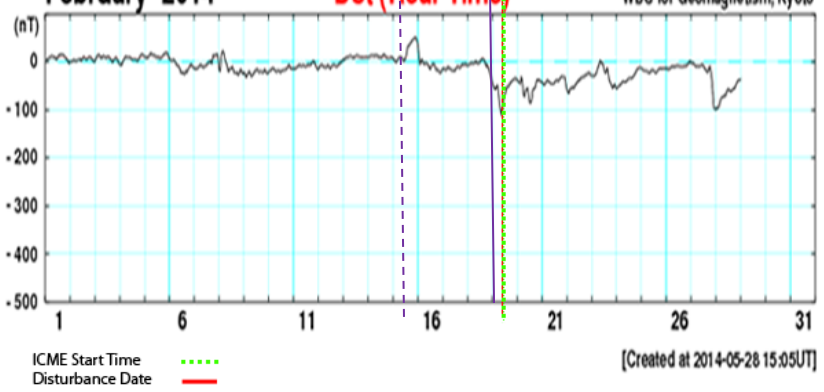



Top Cloud Temperature
(Greek Longitude)
9/3
Greece
Cold Top Clouds
during main storm
Latitude
32N
35N
40N
45N
50N
55N
60N
65N
210
219
228
237
246
255
264
273
282
291
300
Mar
5
6
7
9/3
10
15









Several big (Dst<-100nt) storms between 1998 – 2015 show S.M.CL-r

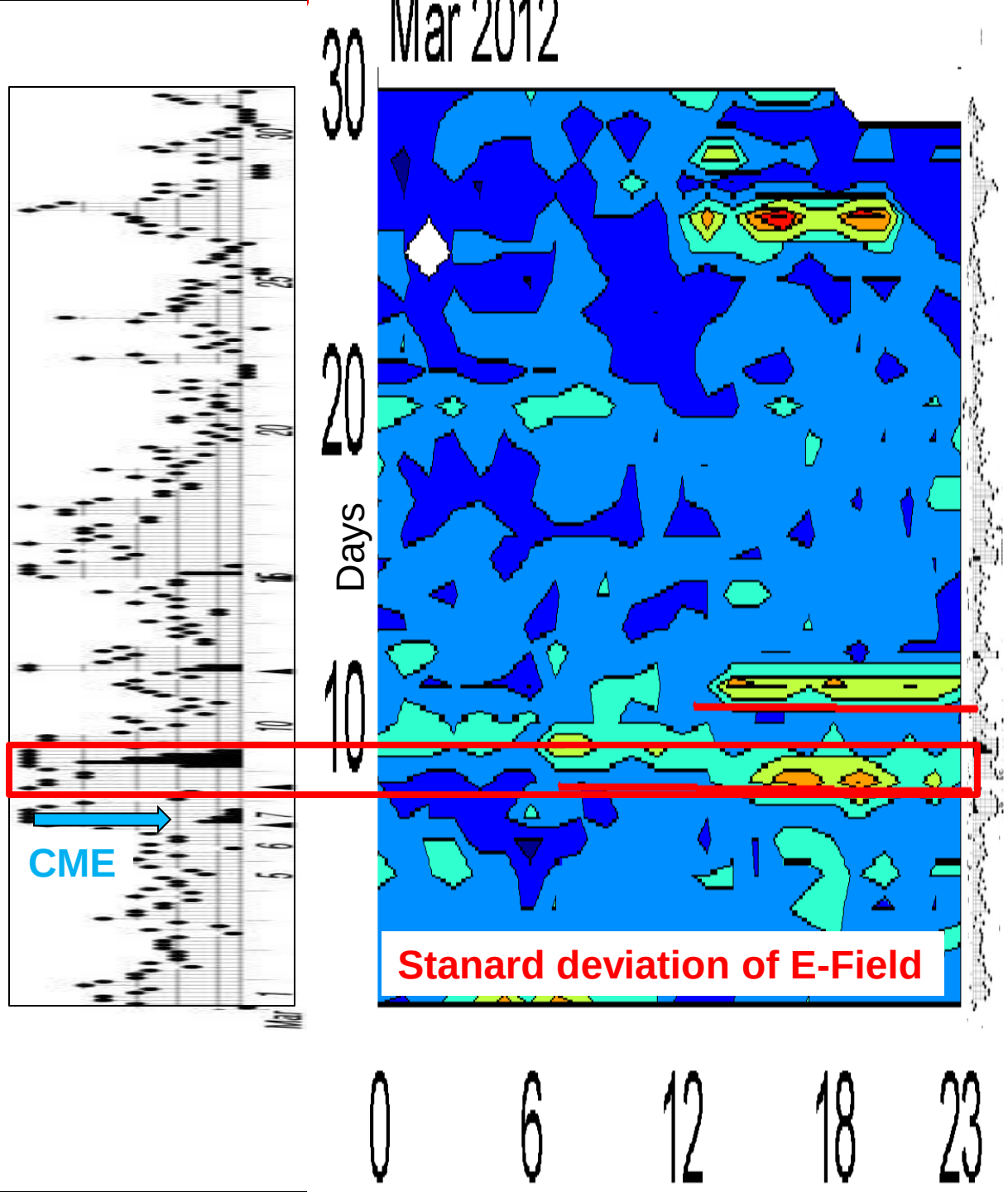
…and a collaboration Dep. of Enviromental Engineering (Pr. K. Kourtidis)..

first correlation

- ❑ CME
- ❑ Magnetospheric activity
- ❑ Geolectric field disturbances

the days after the CME

(8-9.3.2012)



March 2012- GENERAL CONCLUSIONS

FAST MAGNETOSPHERE - TROPOSPHERE RELATED PROCESSES (GRECE: ~4 hours; N.E. USA: < 1 day)

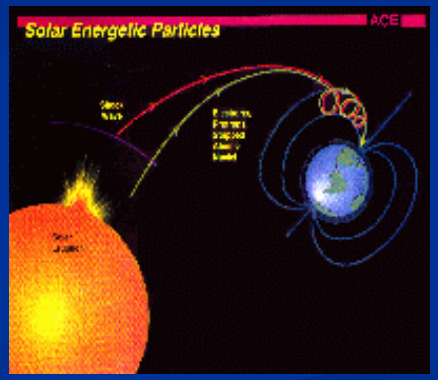
- **Geomagnetic Storm (Kp, Dst) rainfall in Greece / heat wave in N.E. USA correlation**

- **Correlation between Temperature variations in USA – Greece with ~3 days delay**

- **Highly disturbed / variable in direction geoelectric field during rainfall in Greece and close relation with magnetospheric particle precipitation >>> may suggest strong contribution of cloudy ionization to the rainfalls**
  [Markson, 1981; Tinsley et al., 1989; Tinsley, 2000; Markson and Muir, 1980, Harrison and Usoskin, 2010]; Chalmers, 1967; Gunn, 1965; Zhou and Tinsley, 2007;. Nicoll and Harrison, 2009; Bennett and Harrison, 2009].

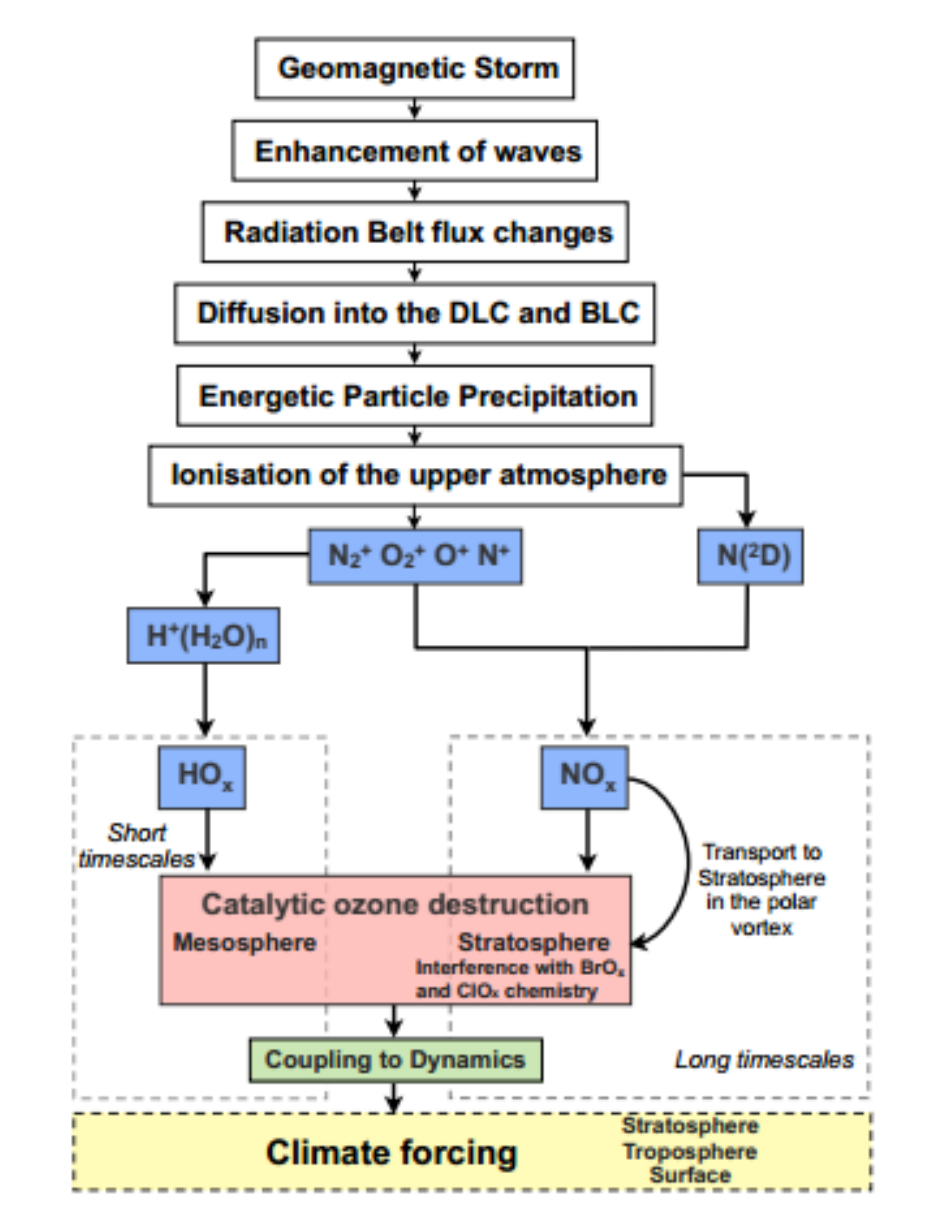
- **Strong correlation of surface Temperature to Geomagnetic activity for >20 days in N.E. USA, the presence of positive NOA index also suggest a fast interaction between electron precipitation, +NOA, air masses steaming from Mexico Golf, high pressure / temperatures**

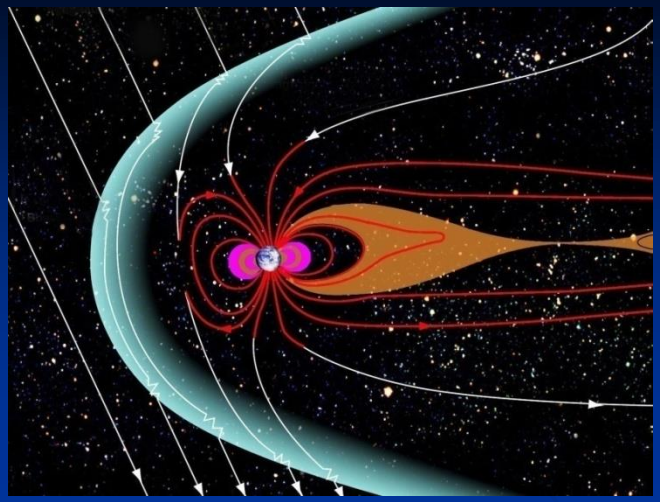
- **Extreme HIGH INTENSITY/ENERGY ambient SOLAR particle population may contribute to the extreme March 2012 events .**

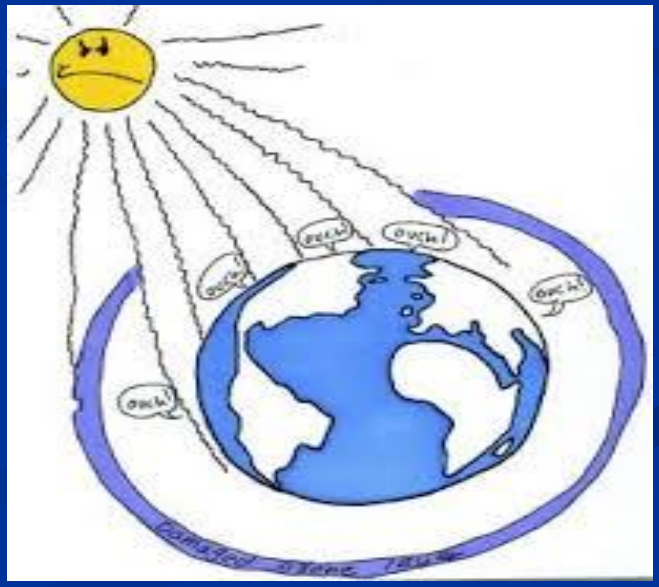


- **The warm 2011-2012 winter as well as other factors (NAO, AO, MJE) may also contributed to the extreme heat wave phenomenon in N.E. USA** (*Samantha Borth, Richard Castro, Kevin BirkThe Historic March 2012 Heat Wave: A Meteorological Retrospective*)

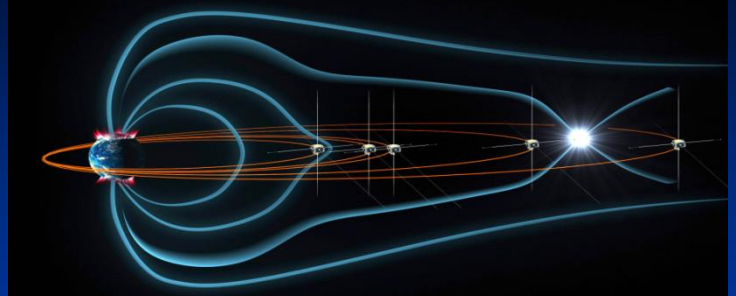
-

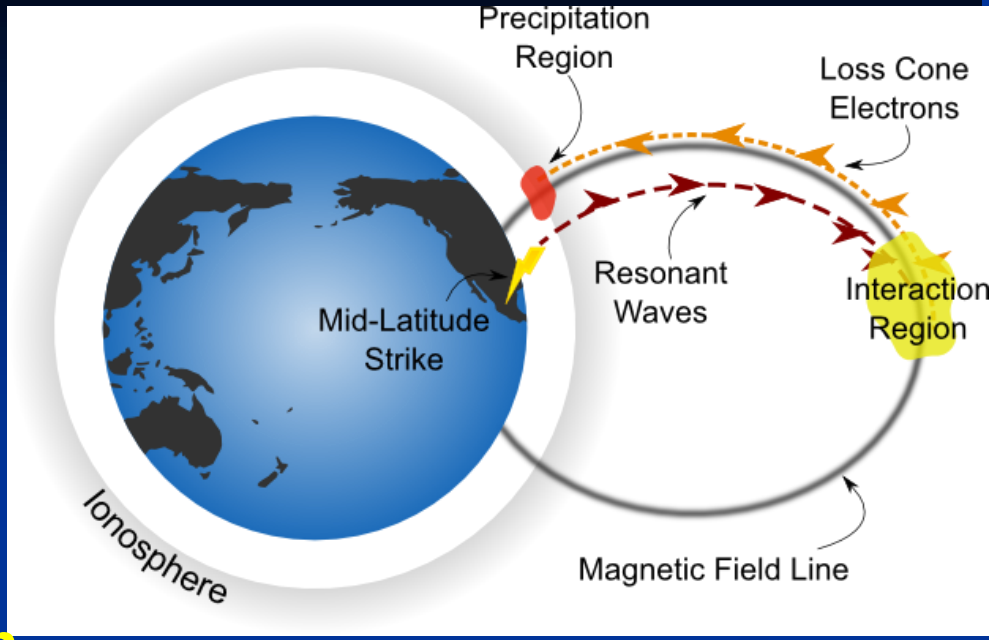

Geomagnetic Storm
Enhancement of waves
Radiation Belt flux changes
Diffusion into the DLC and BLC
Energetic Particle Precipitation
Ionisation of the upper atmosphere
N_2^+ O_2^+ O^+ N^+
$N(^2D)$
$H^+(H_2O)_n$
HO_x
NO_x
Short timescales
Transport to Stratosphere in the polar vortex
Catalytic ozone destruction
Mesosphere
Stratosphere
Interference with BrO_x and ClO_x chemistry
Coupling to Dynamics
Long timescales
Climate forcing
Stratosphere
Troposphere
Surface



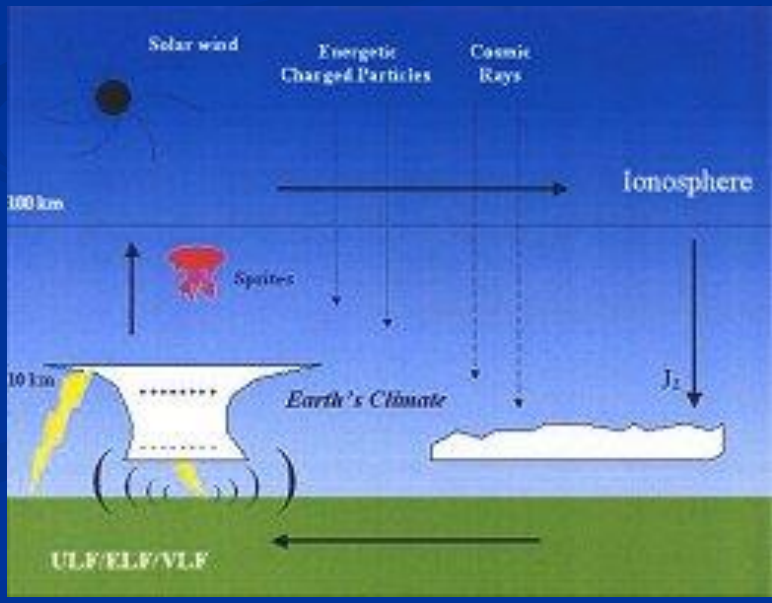


2st mechanism

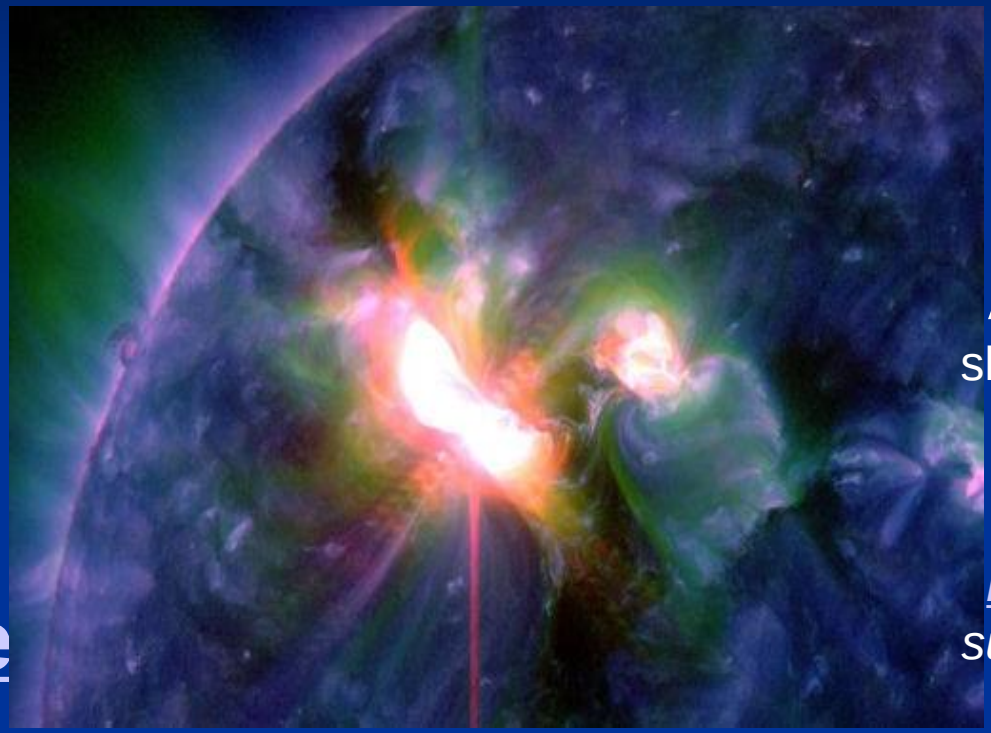




- **Wave-particle interaction processes in the radiation belts scatter energetic electrons into the middle latitude atmosphere and create direct excess ionization**



Thales



An aurora on March 8, 2012 shimmering over snow-covered mountains in Faskrudsfjordur, Iceland. (*Image courtesy of Jónína*

NASA news

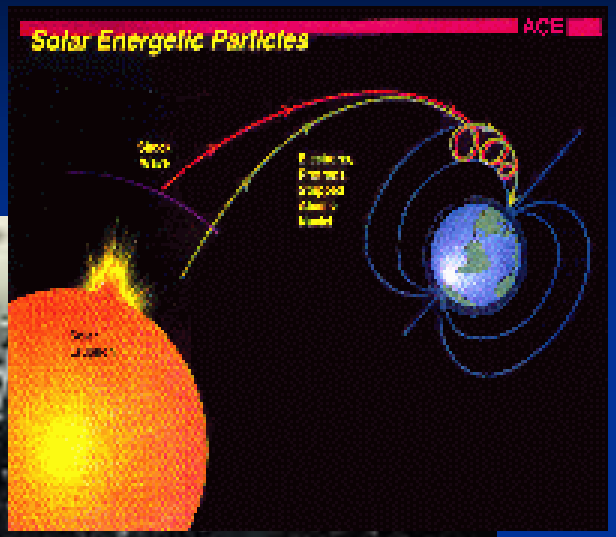
http://www.nasa.gov/mission_pages/sunearth/news/News030712-X5-4.html

e

s/sdo/ne

Correlation between Extreme Space and Atmospheric variations

March 2012 superstorm

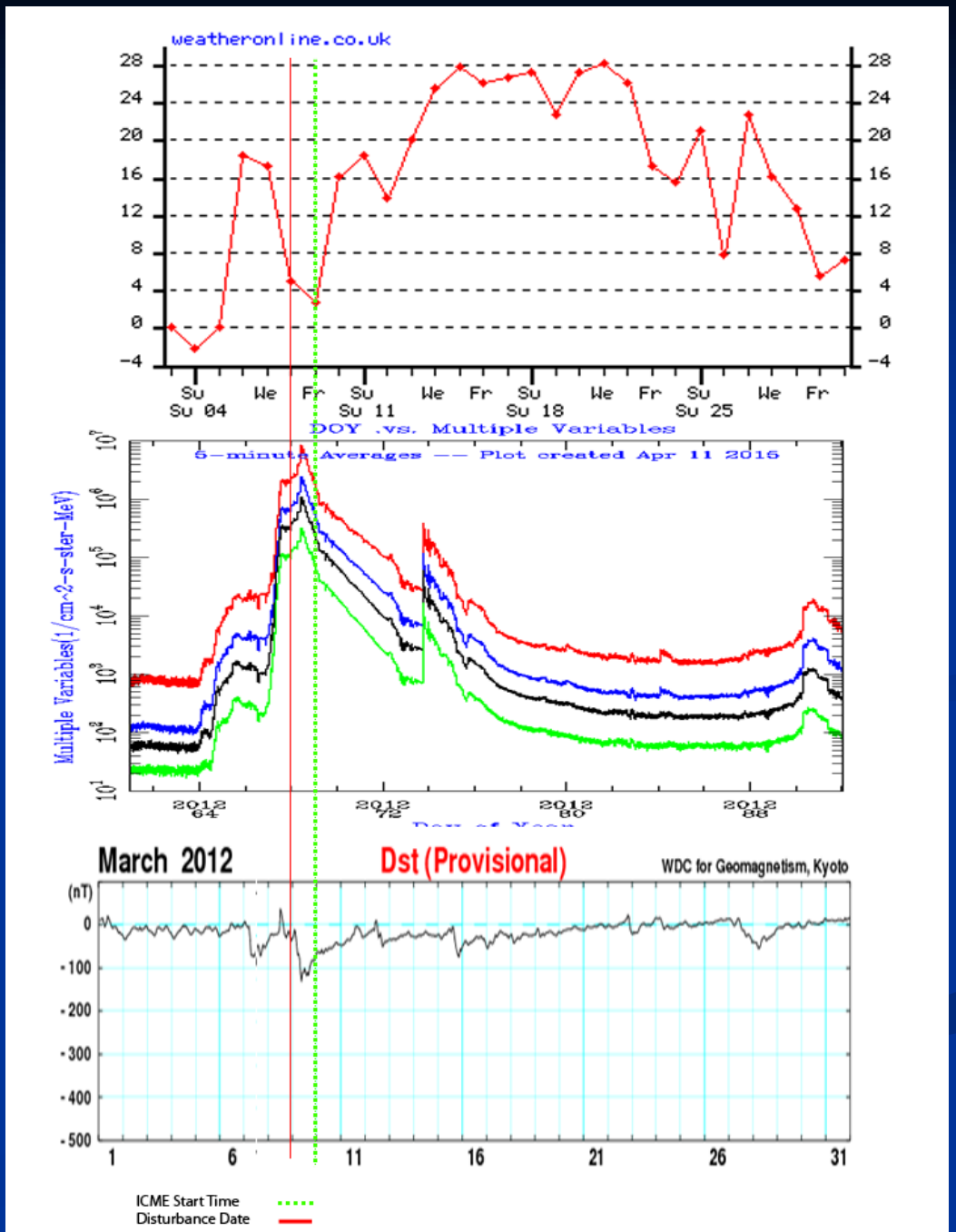


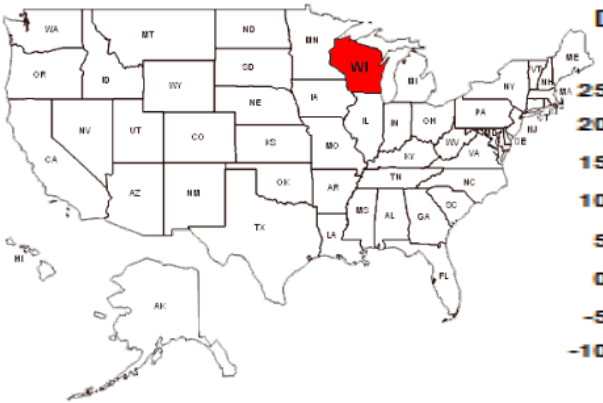
5. Discussion & Conclusions

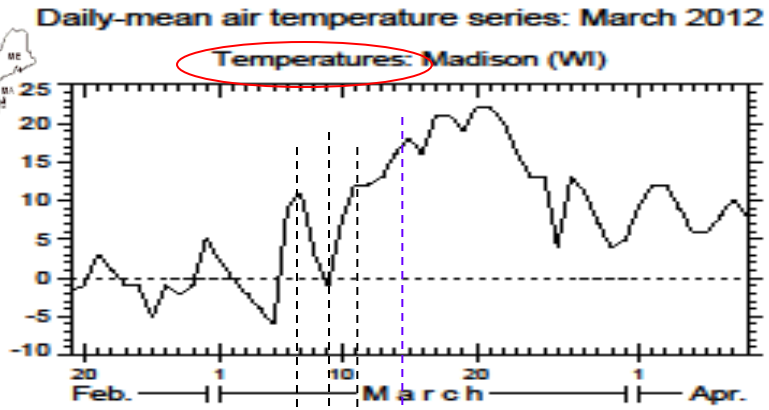
FUTURE WORK

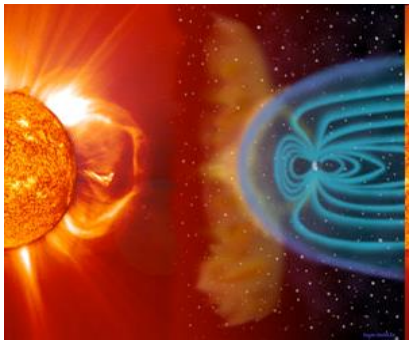
Greek wet weather /NE USA Temperatures response to CMEs :statistical studies

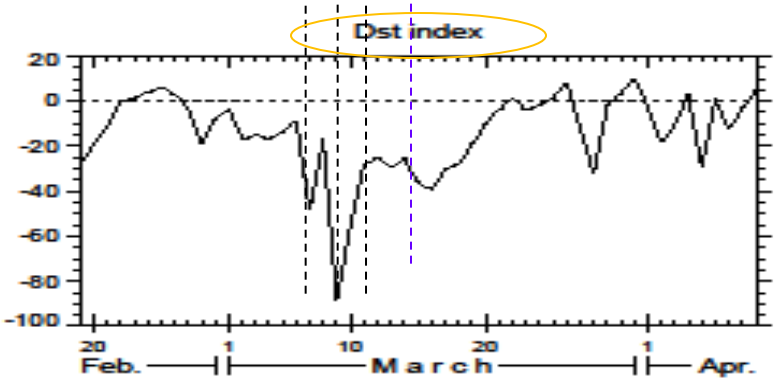
Study of the nature of FAST climate responses to CMEs.

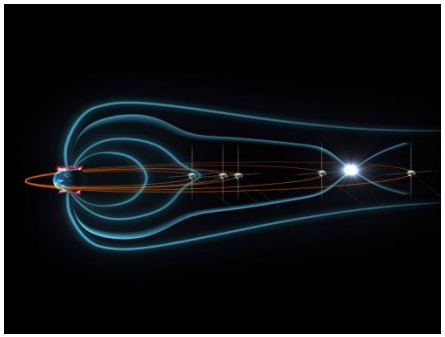

weatheronline.co.uk
28
24
20
16
12
8
4
0
-4
Su
Su 04
We
Fr
Su
Su 11
We
Fr
Su
Su 18
We
Fr
Su
Su 25
We
Fr
DOY .vs. Multiple Variables
5-minute Averages -- Plot created Apr 11 2016
Multiple Variables(1/cm^2-s-ster-MeV)
2012
64
2012
72
2012
80
2012
88
March 2012
Dst (Provisional)
WDC for Geomagnetism, Kyoto
(nT)
0
-100
-200
-300
-400
-500
1
6
11
16
21
26
31
ICME Start Time
Disturbance Date

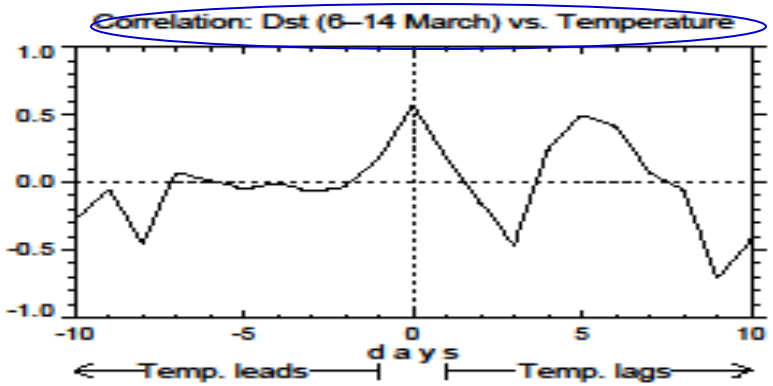

WA
MT
ND
MN
OR
ID
SD
WI
WY
NE
IA
IL
MI
NV
UT
CO
KS
MO
IN
OH
PA
NY
VT
NH
ME
CA
AZ
NM
OK
AR
KY
WV
VA
TN
NC
SC
GA
AL
MS
LA
TX
FL
HI
AK


Daily-mean air temperature series: March 2012
Temperatures: Madison (WI)
25
20
15
10
5
0
-5
-10
20
Feb.
1
10
20
March
1
Apr.



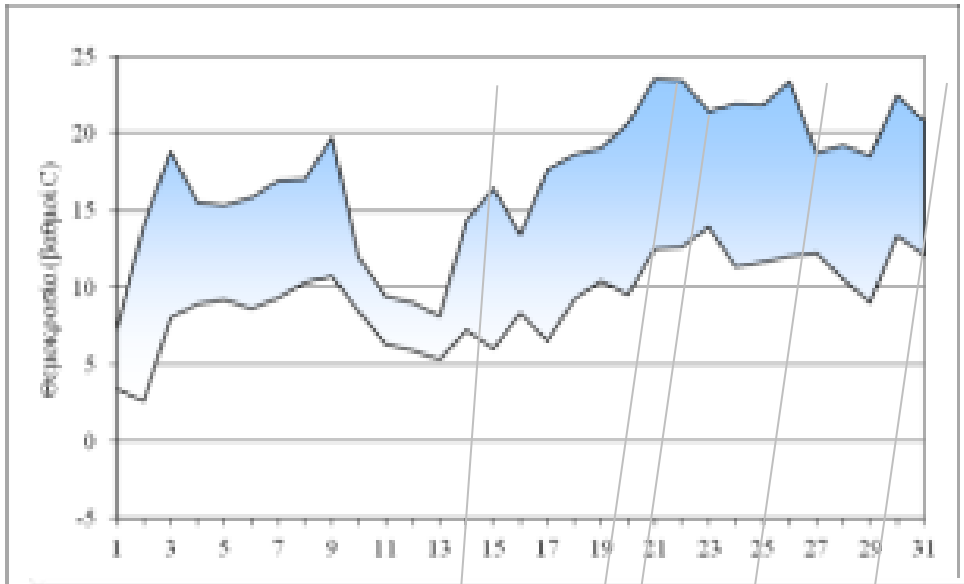

Dst index
20
0
-20
-40
-60
-80
-100
20
Feb.
1
10
20
March
1
Apr.

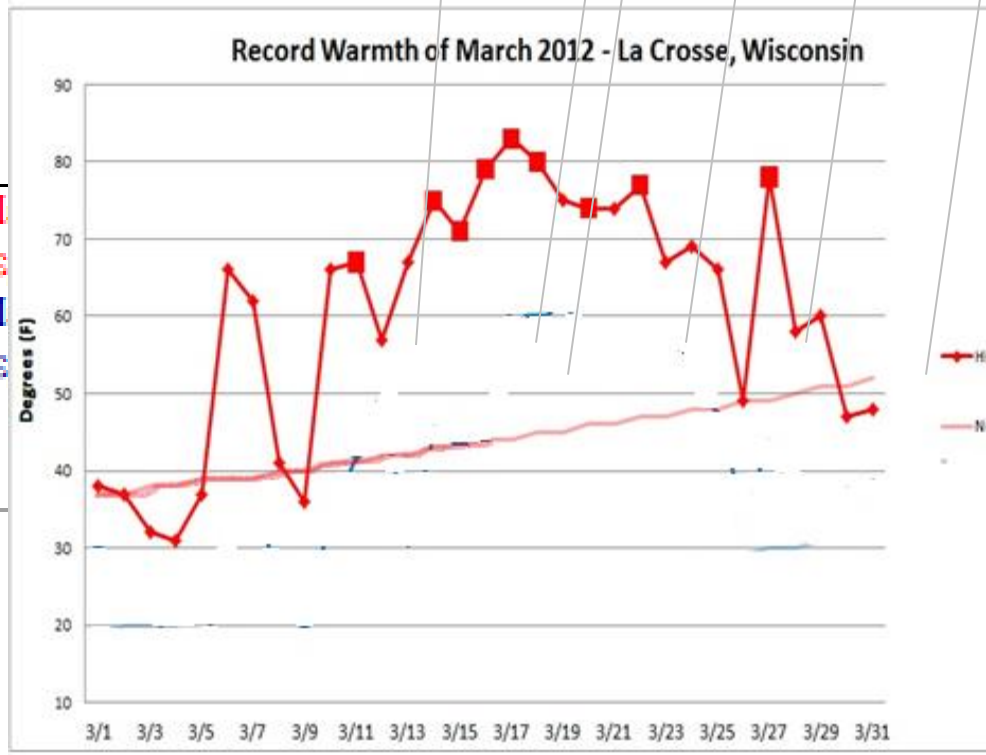



Correlation: Dst (6–14 March) vs. Temperature
1.0
0.5
0.0
-0.5
-1.0
-10
-5
0
5
10
days
Temp. leads
Temp. lags

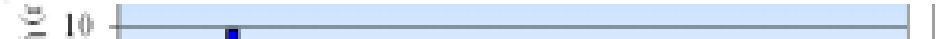

ΞΑΝΘΗ
XANTHI

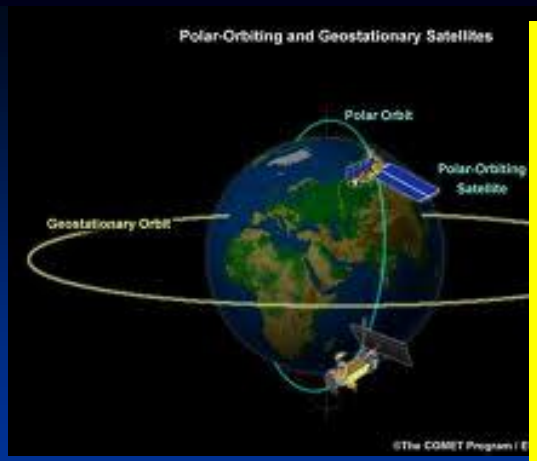

DEMOKRITOS


25
20
15
10
5
0
-5
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31


Record Warmth of March 2012 - La Crosse, Wisconsin
Degrees (F)
90
80
70
60
50
40
30
20
10
3/1 3/3 3/5 3/7 3/9 3/11 3/13 3/15 3/17 3/19 3/21 3/23 3/25 3/27 3/29 3/31

M
θε
M
θε

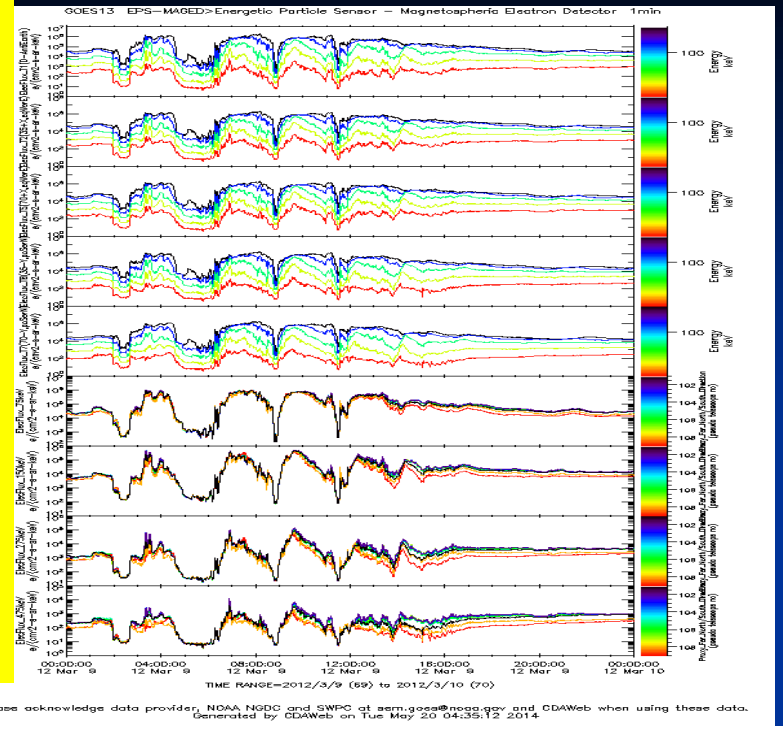

10

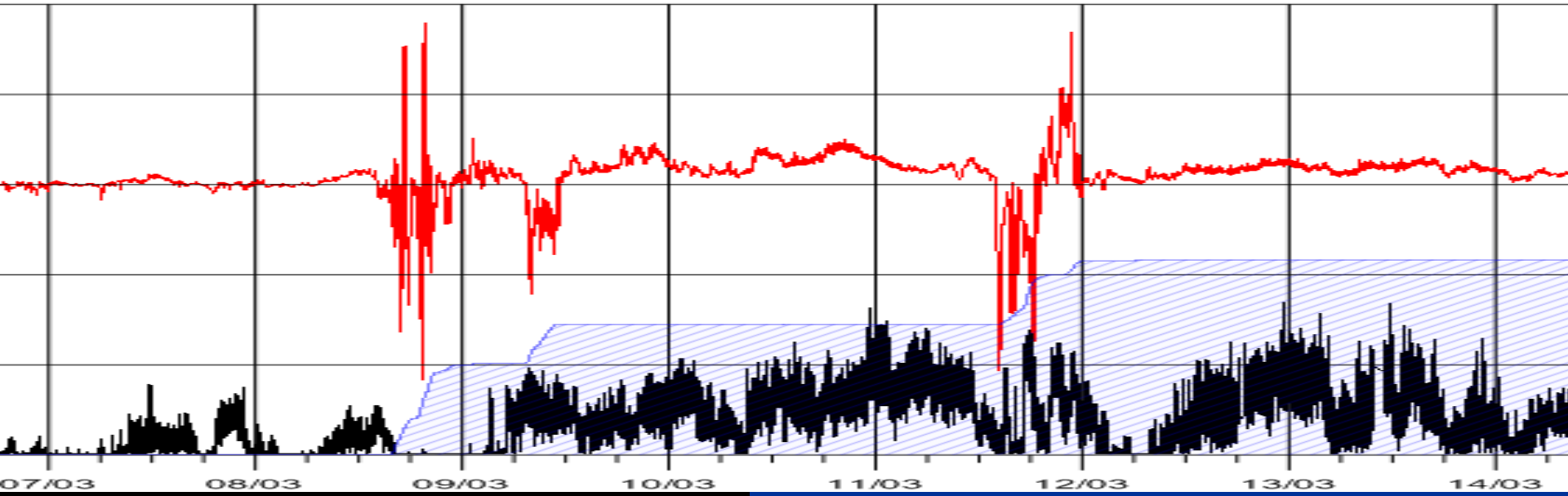


9.3.2012

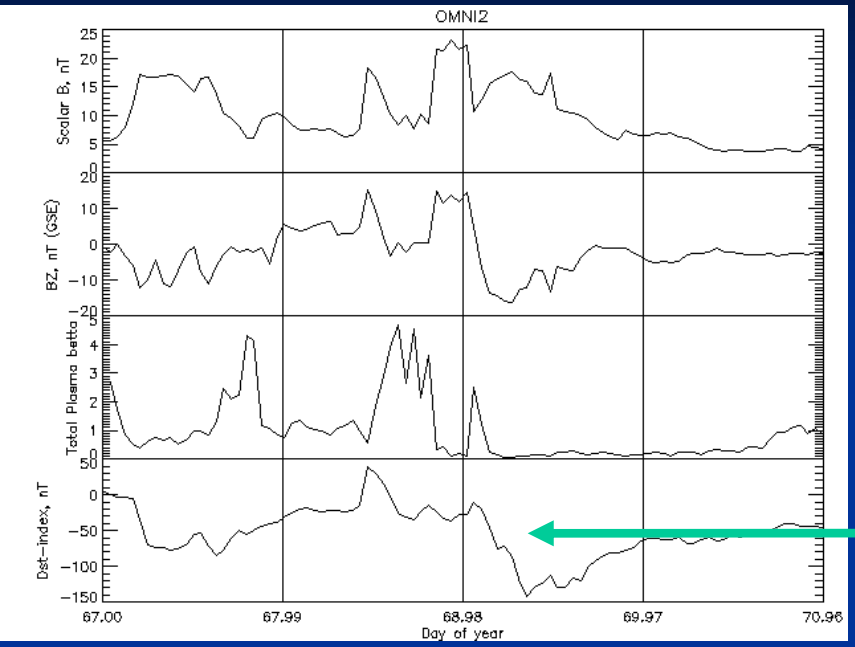
Strong Energetic particle injection events

observed by stationary s/c NOAA 13





7-8 March 2012: a “busy” period in the geospace



B

Bz

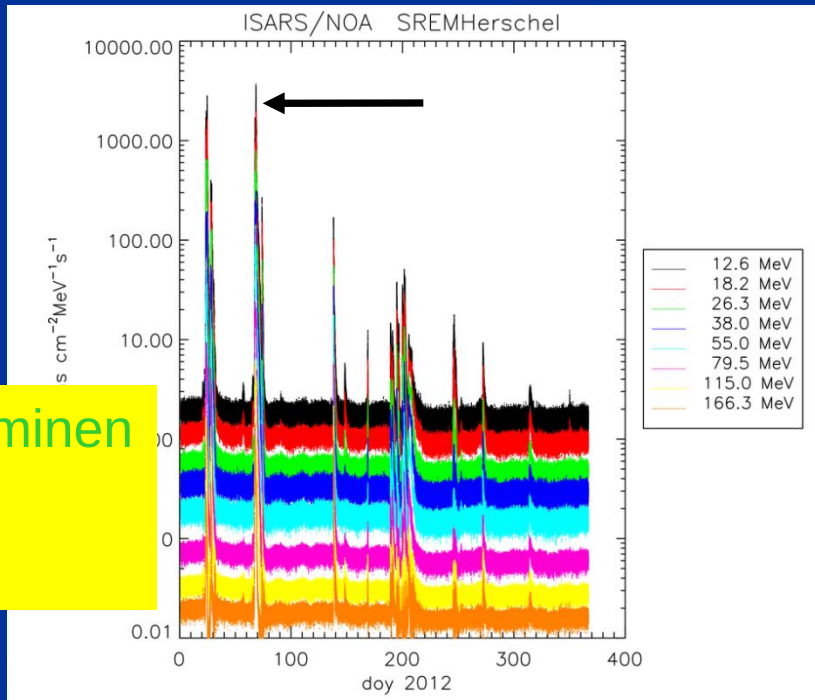
ICME

plasma beta

Dst

Intense geomagnetic storm

(min Dst ~ -150 nT; largest of cycle 24)



SREM: Daglis, Sandberg, Anastasiadis, Nieminen

Most intense proton event of 2012

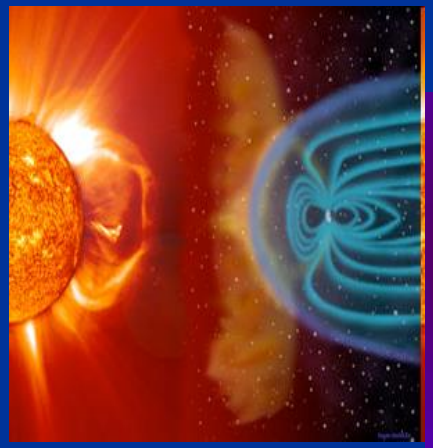
Correlation between Extreme Space - Atmospheric variations

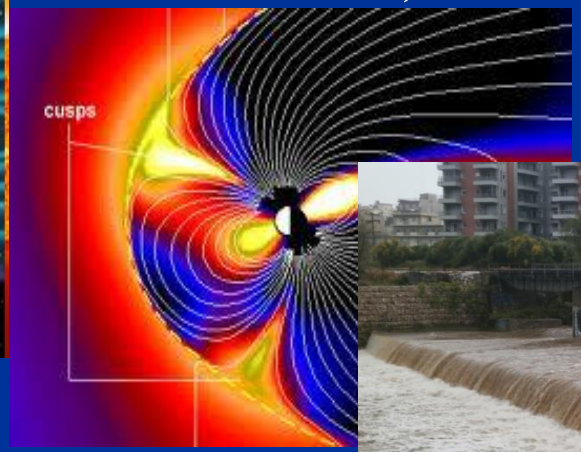
March 2012 superstorm

Anagnostopoulos G.

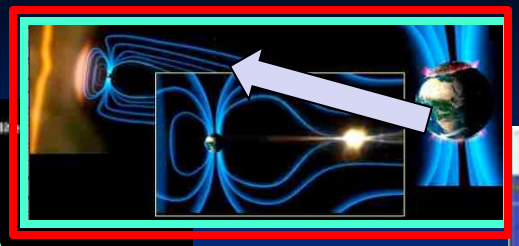
Contribution:

K. Kourtidis, N. Hatzigeorgiu, Efthymiadis)

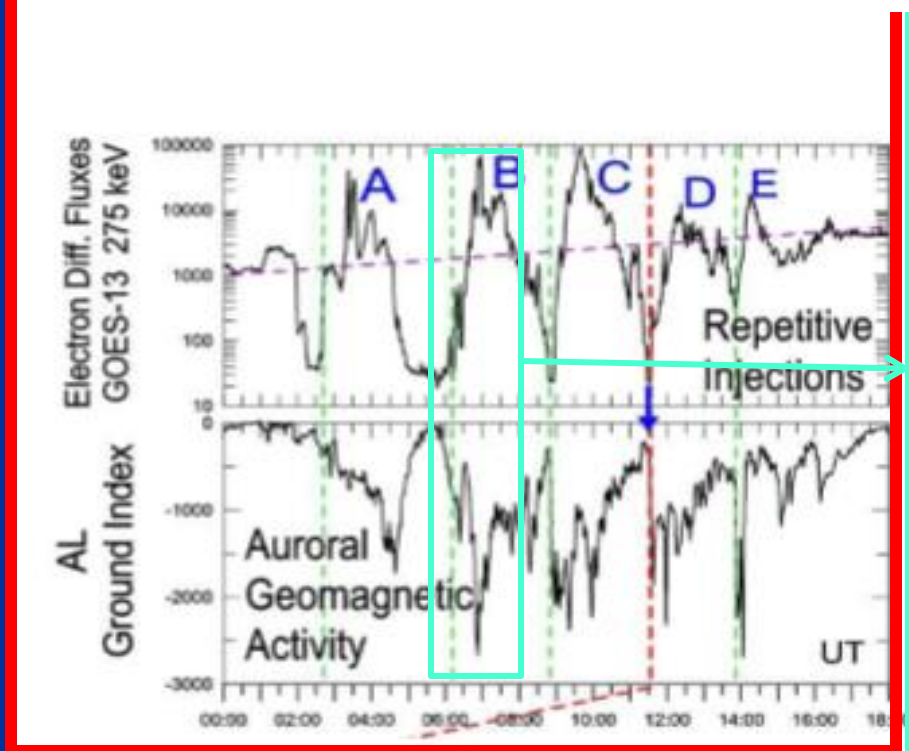




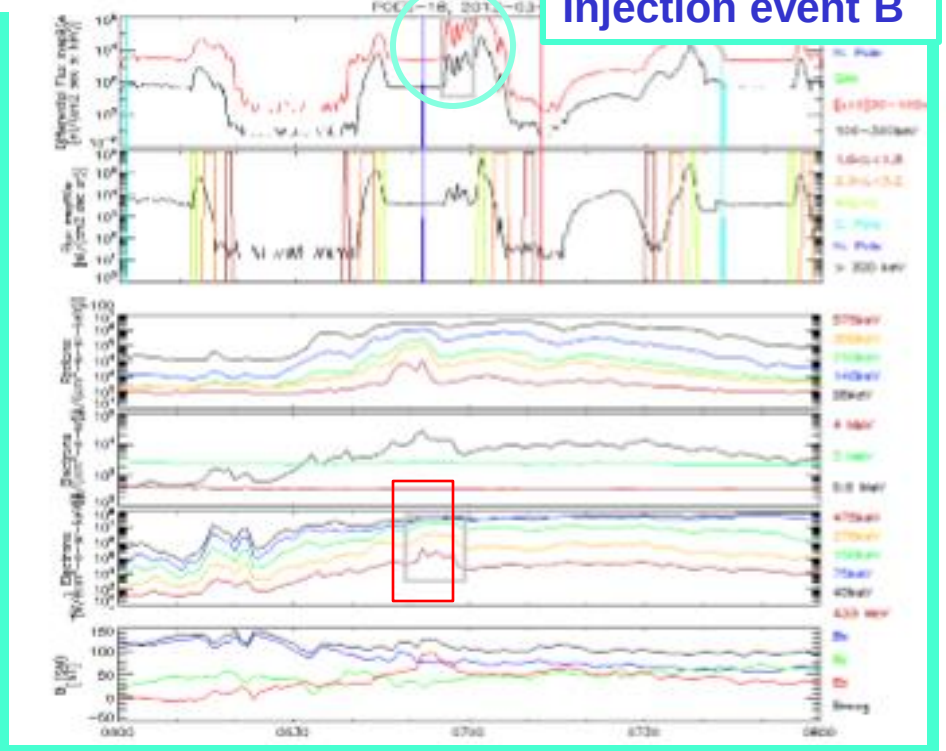
Magnetospheric e- injection / precipitation in Ionosphere



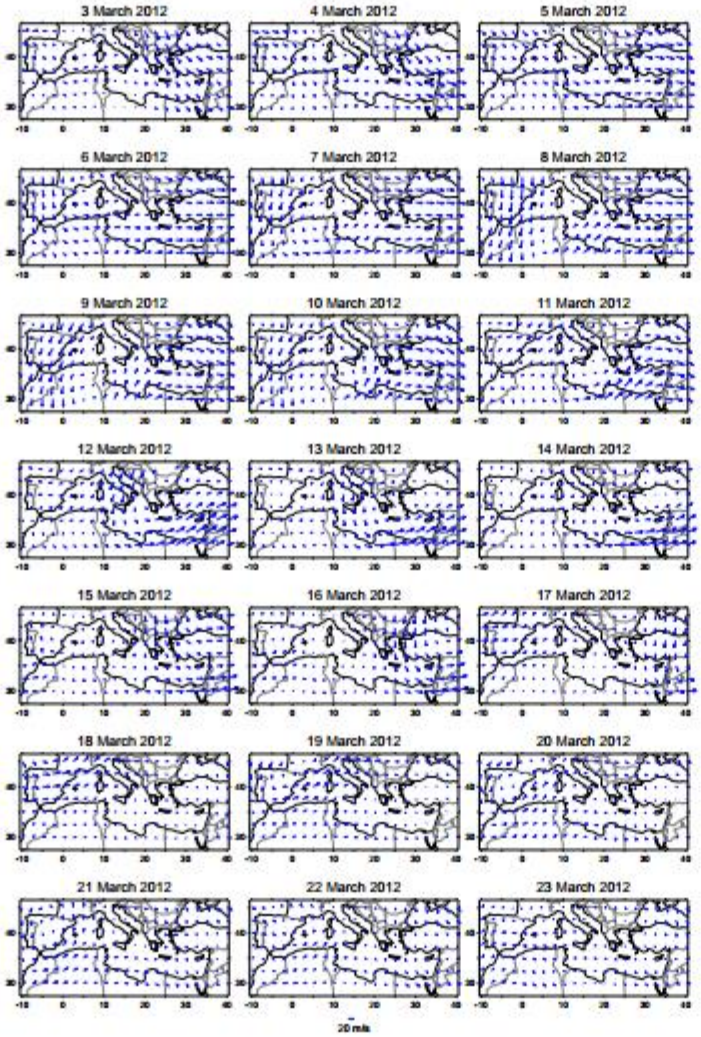
9.3.2012



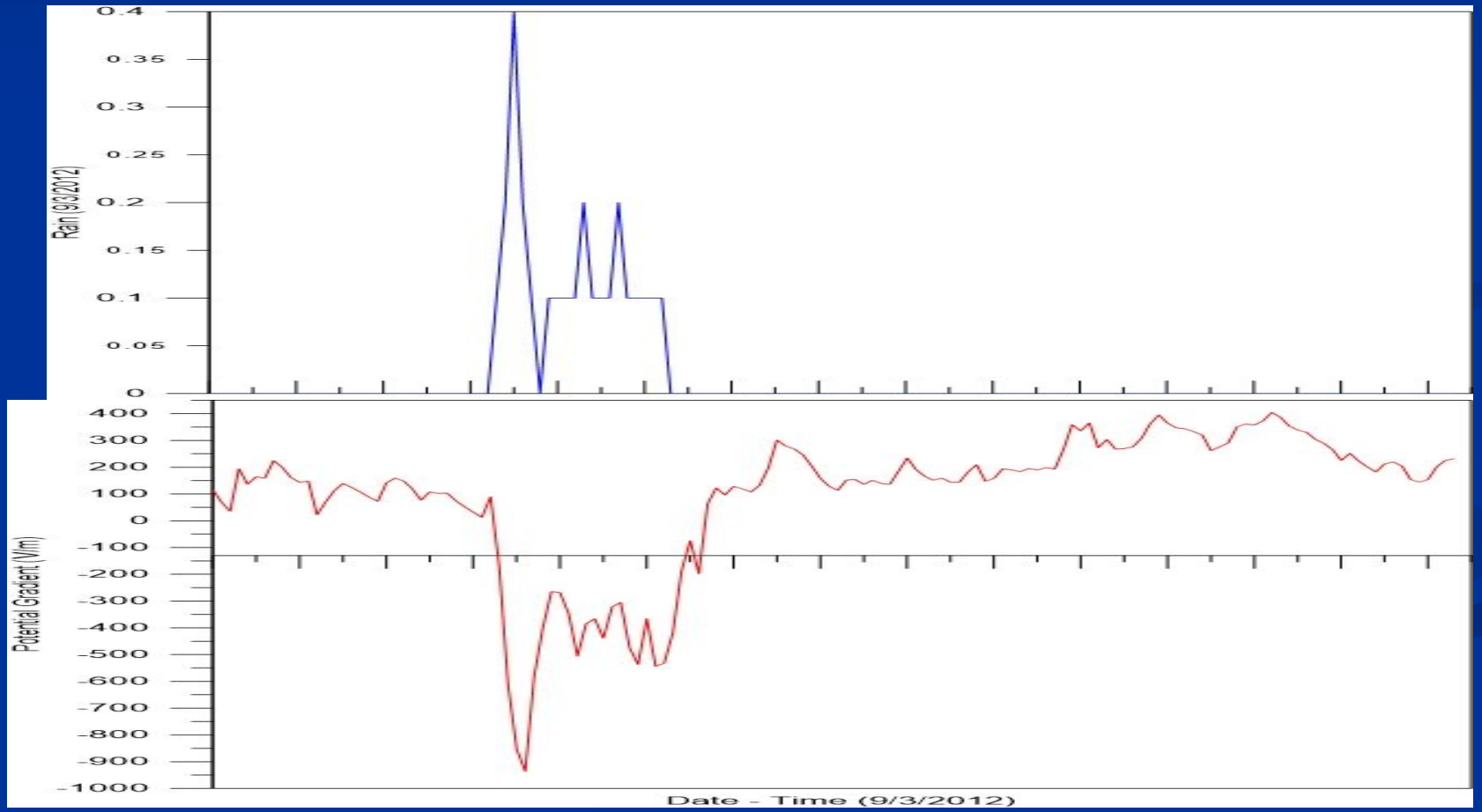
Injection event B

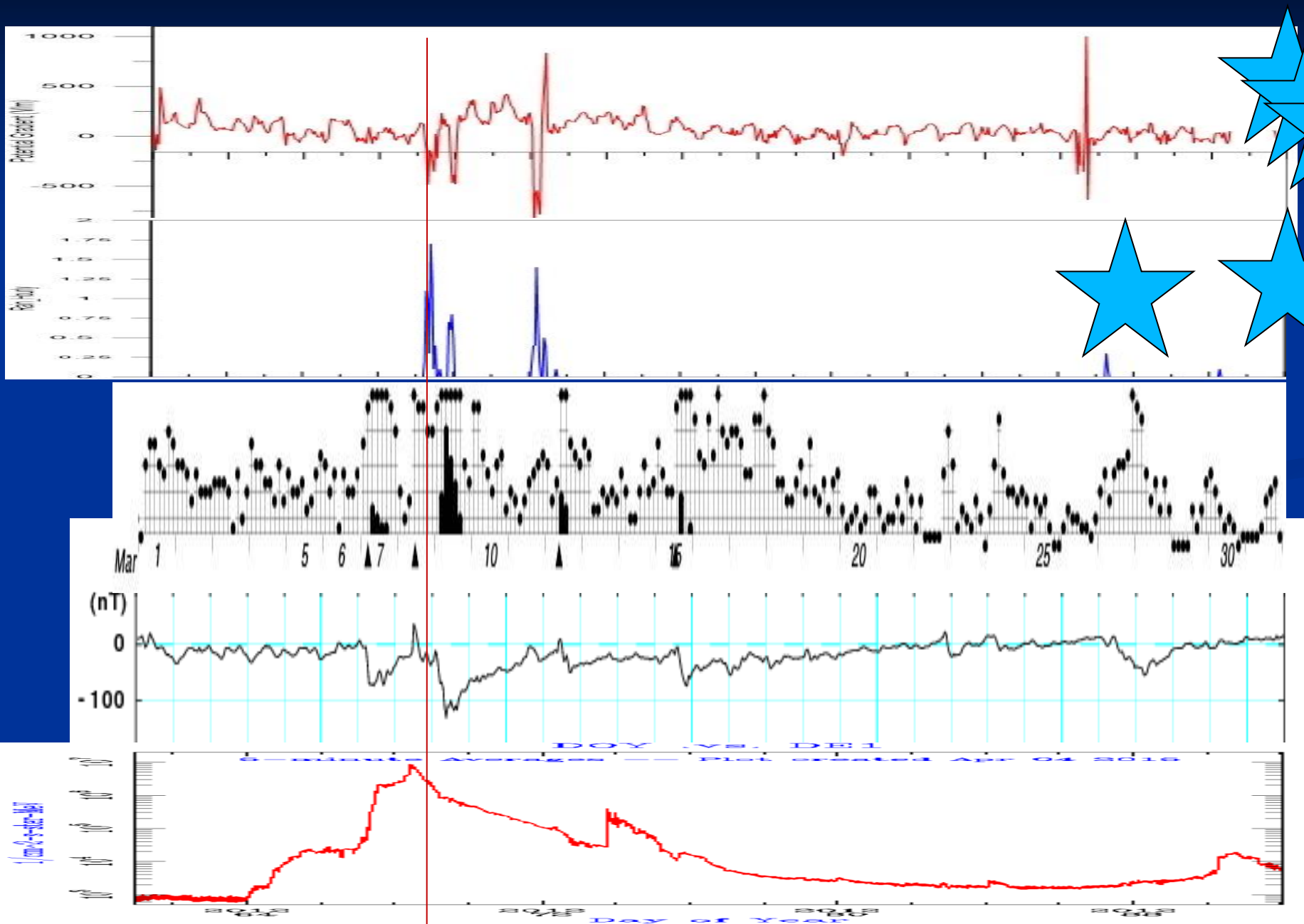


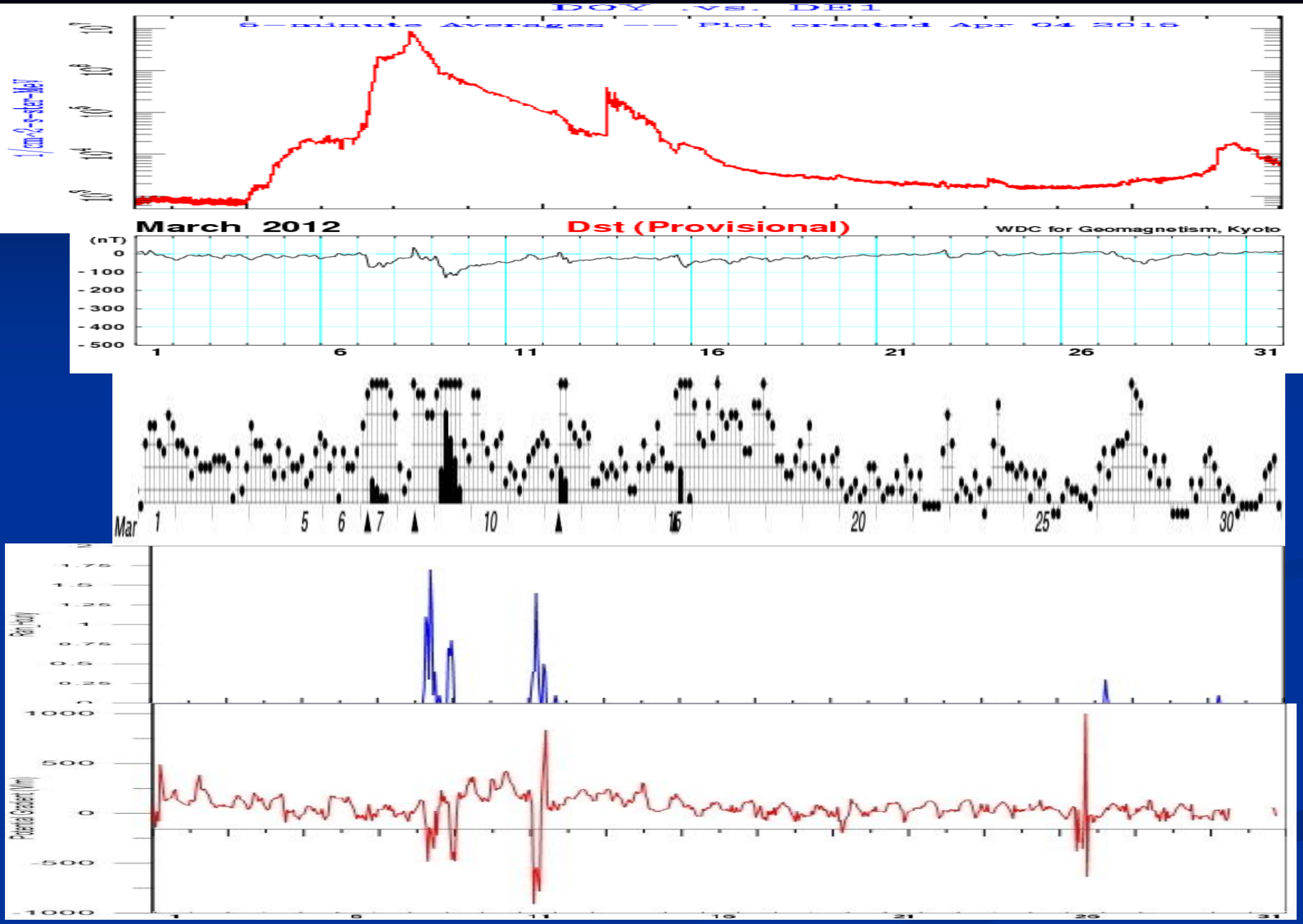
Wind field (500 hPa) over Mediterranean: March 2012

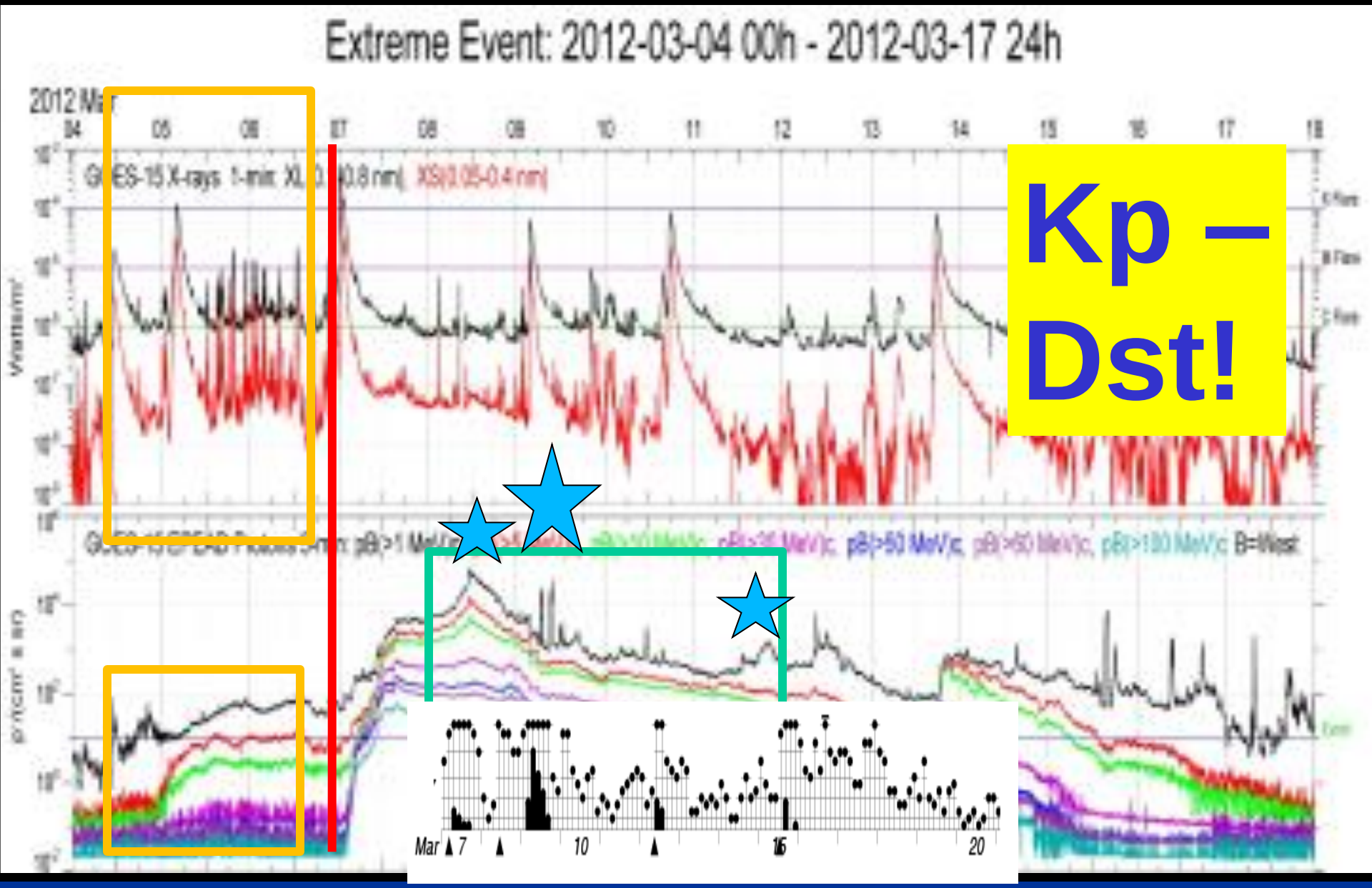



Rain (9/3/2012)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
WS (9/3/2012)
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Potential Gradient (V/m)
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
Date - Time (9/3/2012)

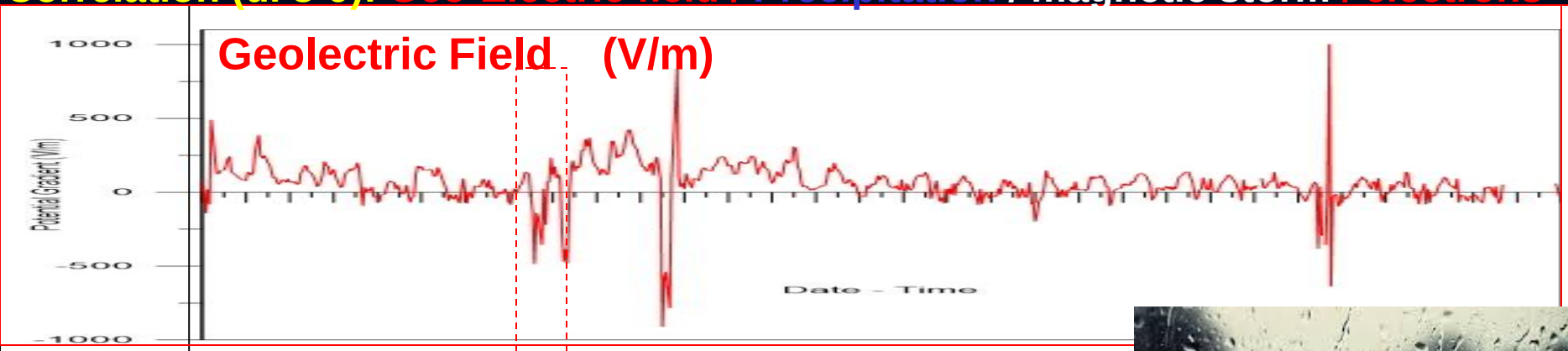

Rain (9/3/2012)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Potential Gradient (V/m)
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
Date - Time (9/3/2012)

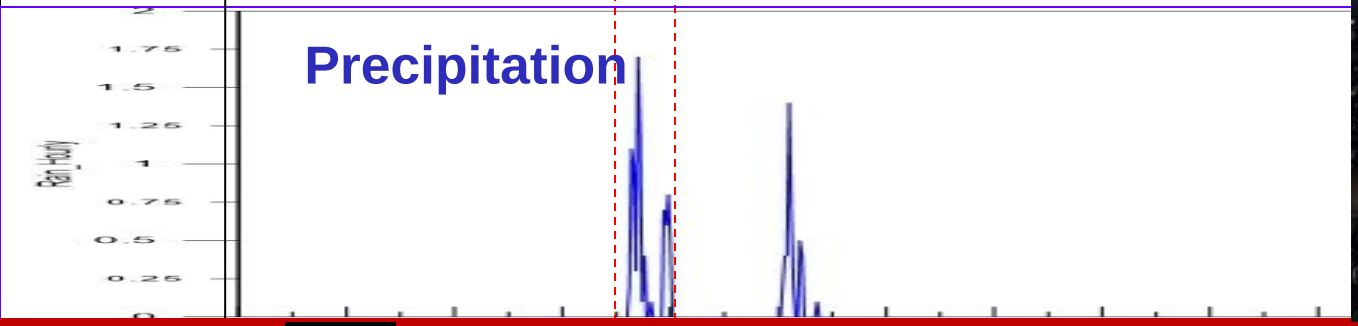

1000
500
0
-500
Potential Gradient (V/m)
Rain (in/hr)
Mar
1
5
6
7
10
15
20
25
30
(nT)
0
-100
DOY vs. DE1
6-minute Averages
Plot created Apr 04 2016
Day of Year

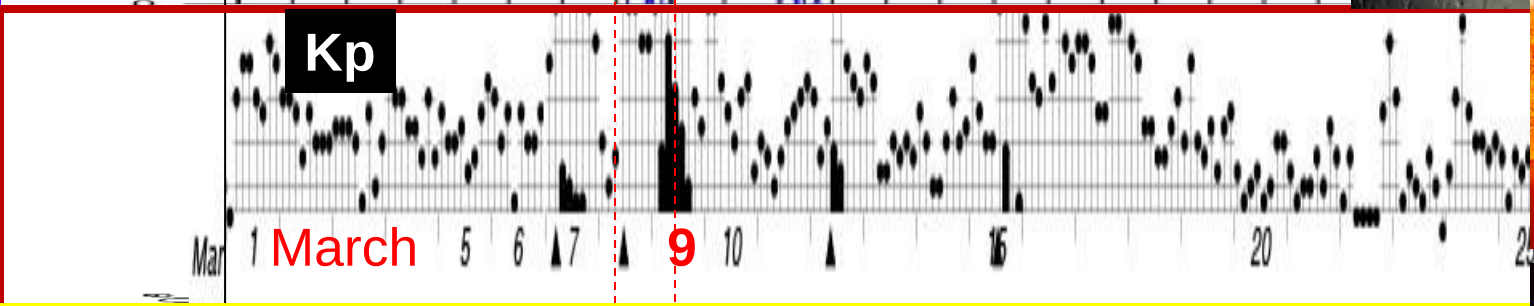

DOY .vs. DE1
5-minute Averages --- Plot created Apr 04 2016
March 2012
Dst (Provisional)
WDC for Geomagnetism, Kyoto
(nT)
0
-100
-200
-300
-400
-500
1
6
11
16
21
26
31
Mar
1
5
6
7
10
15
20
25
30
1000
500
0
-500
-1000

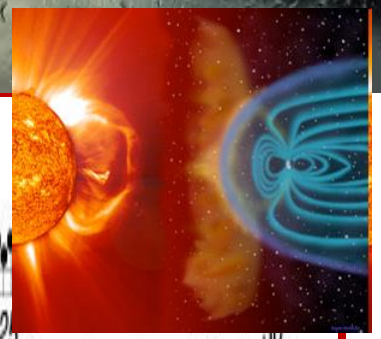

Extreme Event: 2012-03-04 00h - 2012-03-17 24h
Kp –
Dst!
Mar
7
10
15
20

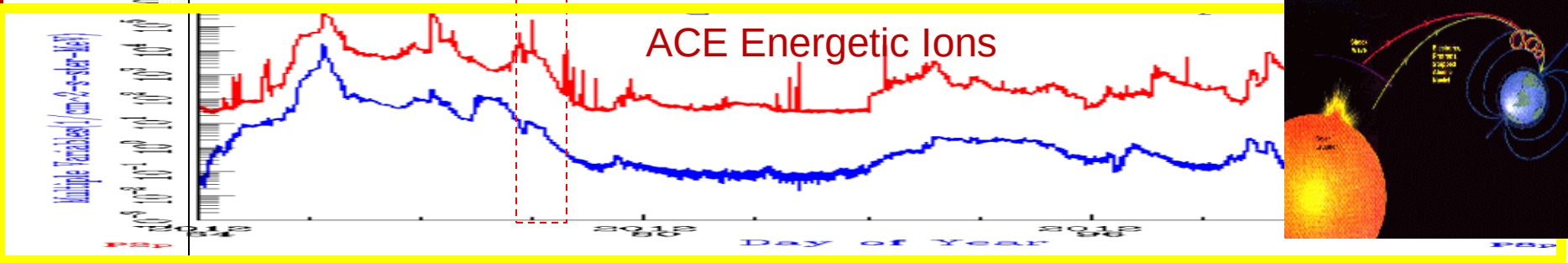
Correlation (d. 8-9): Geo-Electric field / Precipitation / magnetic storm / electrons











Μάρτης… γδάρτης – Βροχές, κρύο και κακοκαιρία σε όλη τη χώρα

GREECE, March 6-13, 2012 effects

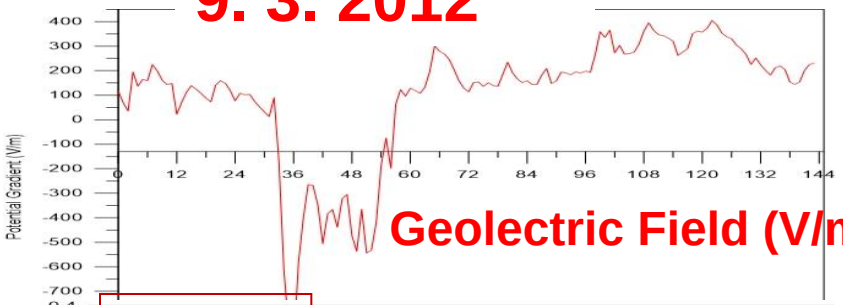
Πέμπτη, 6 Μαρτίου, 2014 07:59 πμ

Απαγορευτικό απόπλου λόγω κακοκαιρίας. Σήμερα 13 Μαρτίου

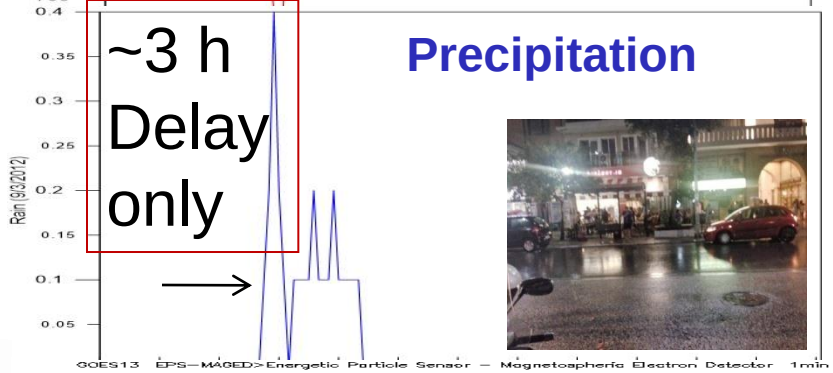
12/03/2012

Τοπικές βροχές και καταιγίδες θα σημειωθούν την Τρίτη 13 Μαρτίου σε ολόκληρη τη χώρα. Χιόνια θα πέσουν στα ορεινά και ημιορεινά. Οι άνεμοι θα πνέουν βόρειοι εντάσεως 8 με 9 Μποφόρ. Η θερμοκρασία θα κυμανθεί σε χαμηλά επίπεδα Στην Αττική θα σημειωθούν βροχοπτώσεις ενώ υπάρχει πιθανότητα να εκδηλωθούν καταιγίδες. Το πρωί θα χιονίσει στα γύρω ορεινά. Τα φαινόμενα

9. 3. 2012

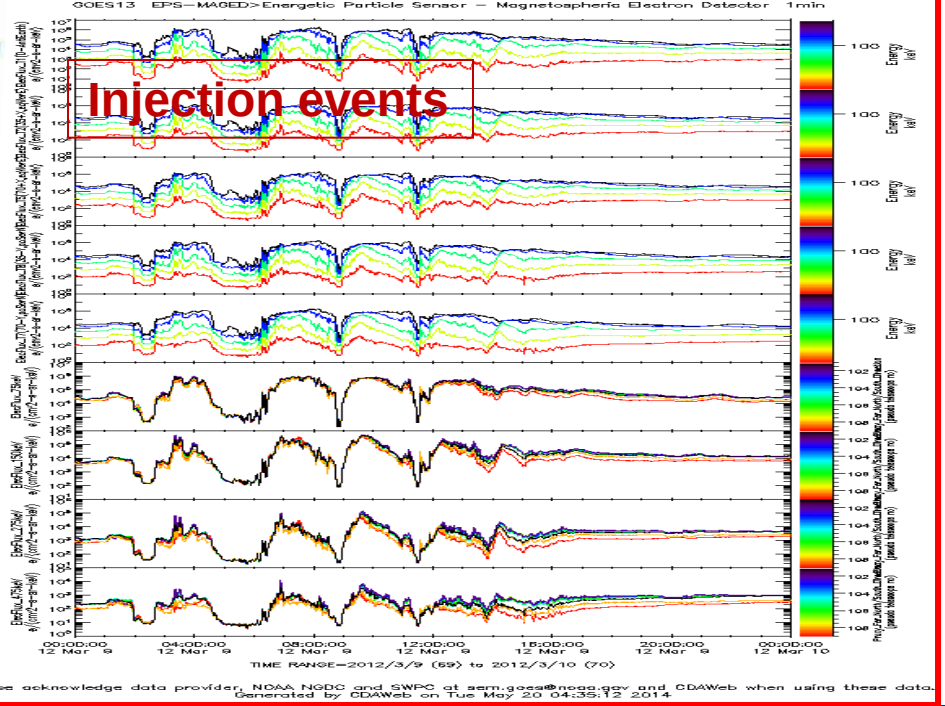


Geolectric Field (V/m)



~3 h Delay only

Precipitation



Inner R

Electron injection observed by NOAA 15 is related with electron bursts in the ionopsphere at very high latitudes ($7 < L < 20$)

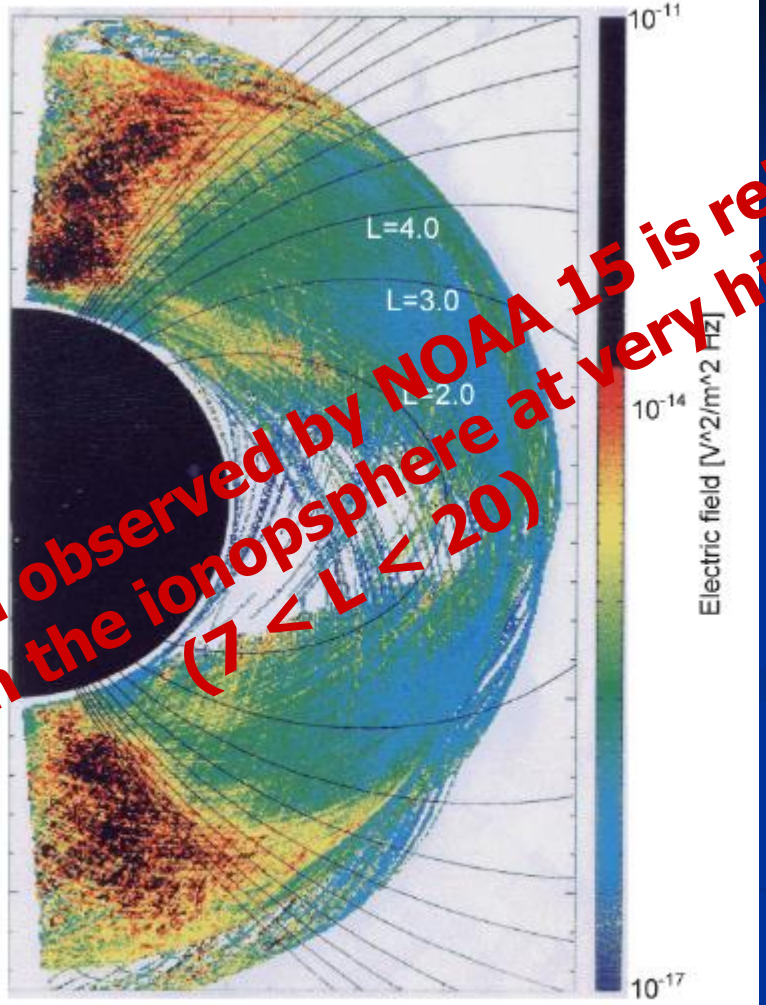
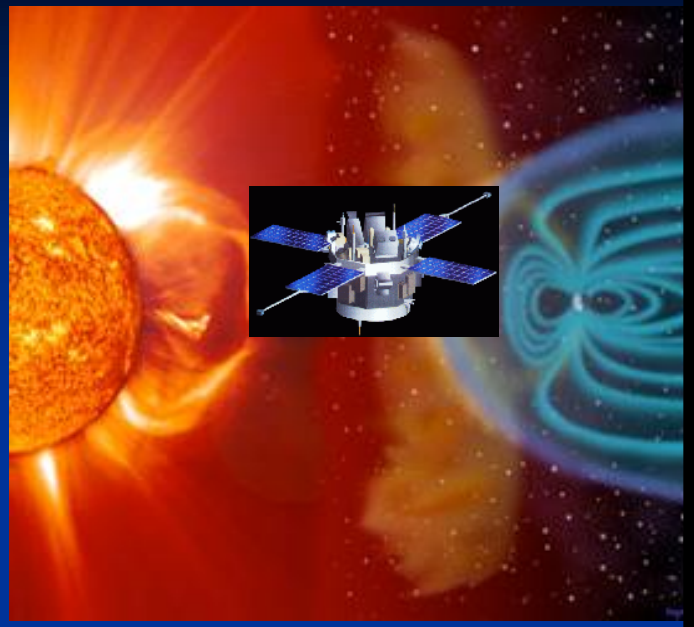
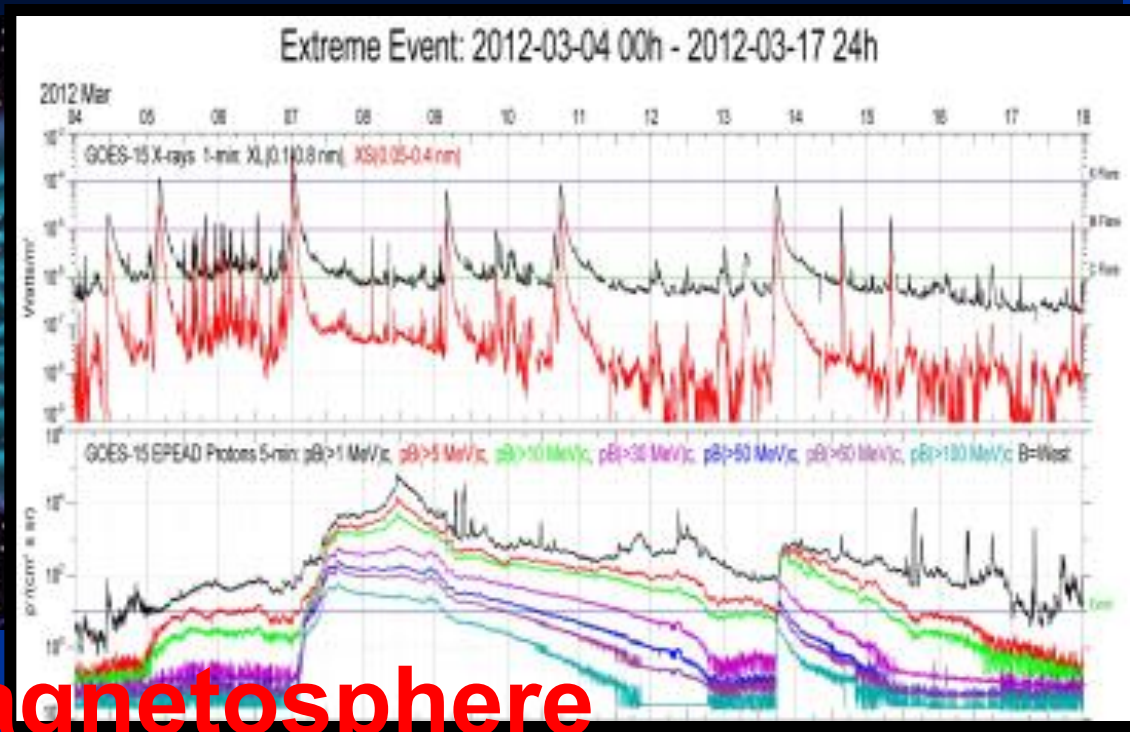


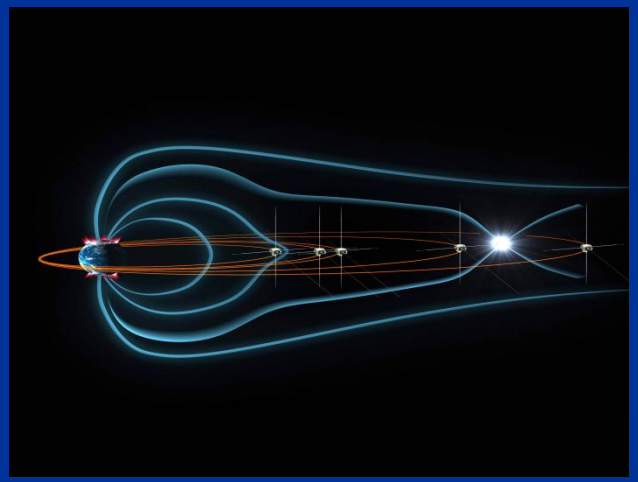
Fig. 7. Latitudinal distribution of the averaged electric field spectral intensity in the frequency range from 24 to 34 kHz during the period from 1989 to 1995 (courtesy of Kobayashi, 1997).

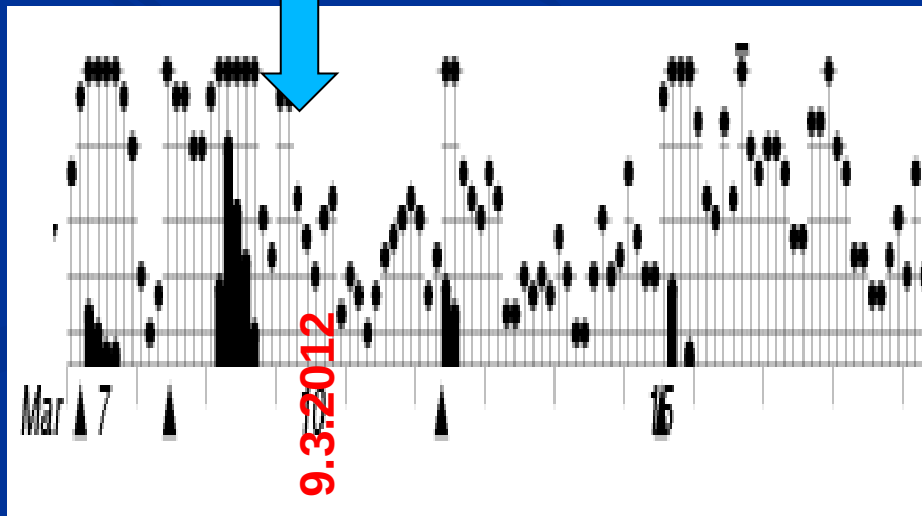
March 2012 CMEs …





… impacts on Magnetosphere

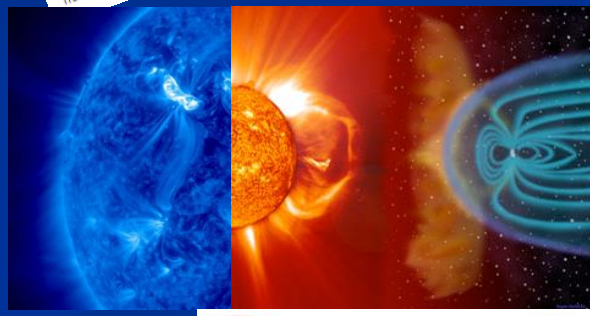




OUTLINE - MARCH 2012 SPACE AND ATMOSPHERIC EVENTS

1. **INTRODUCTION:** THE PROBLEM

2. **MAJOR SOLAR-GEOMAGNETIC SUPERTORM**
- THE SOLAR PARTICLE EVENT
- MAGNETOSPHERIC INJECTION EVENTS
- IONOSPHERIC ENERGETIC ELECTRON
- PRECIPTATION.



3. **EXTREME METEOROLOGICAL EVENTS:**
- EAST USA / KANADA HEAT WAVE
- GREECE / EUROPE /AUSTRALIA / WINDS / RAINFALLS,
- GLOBAL LOW / MIDDLE ATMOSPHERIC PICTURE

4. **CORRELATION OF SPACE – METEOROLOGICAL EVENTS**

5. **DISCUSSSION & CONCLUSIONS**

The **influence of space weather to the Earth's climate**

has been a controversial scientific issue for a long time.

Statistical results suggest that

there is **a long time scale correlation**,

but no **short time scale** correlations

have been confirmed so far.

March 2012 extreme events

have been well known both

in space and atmospheric communities

as well as in the public,

(in particular, **from the historic heat wave in North America**).

A few reports at scientific & social sites

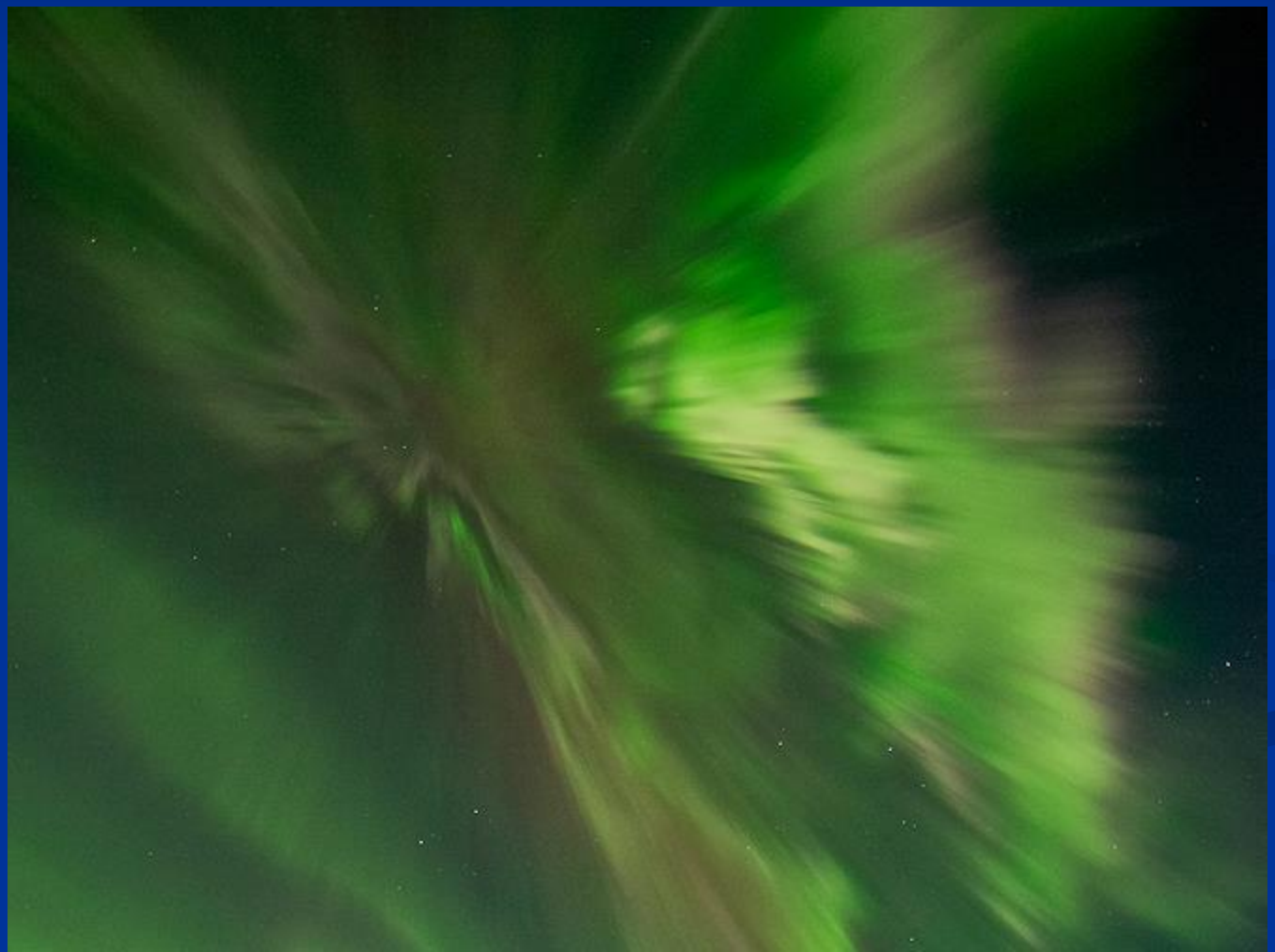
In the following few slides

An aurora on March 8, 2012

shimmering over snow-covered mountains in Faskrudsfjordur, Iceland. (*Image courtesy of Jónína Óskarsdóttir)*

NASA news

http://www.nasa.gov/mission_pages/sunearth/news/News030712-X5-4.html



…the meteorological events were found

not consistent with “atmospheric models”…

but the “atmospheric models” used have not

still included space weather extreme

phenomena

A. Papaioannou et al.: SEPServer STEREO SEP catalogues

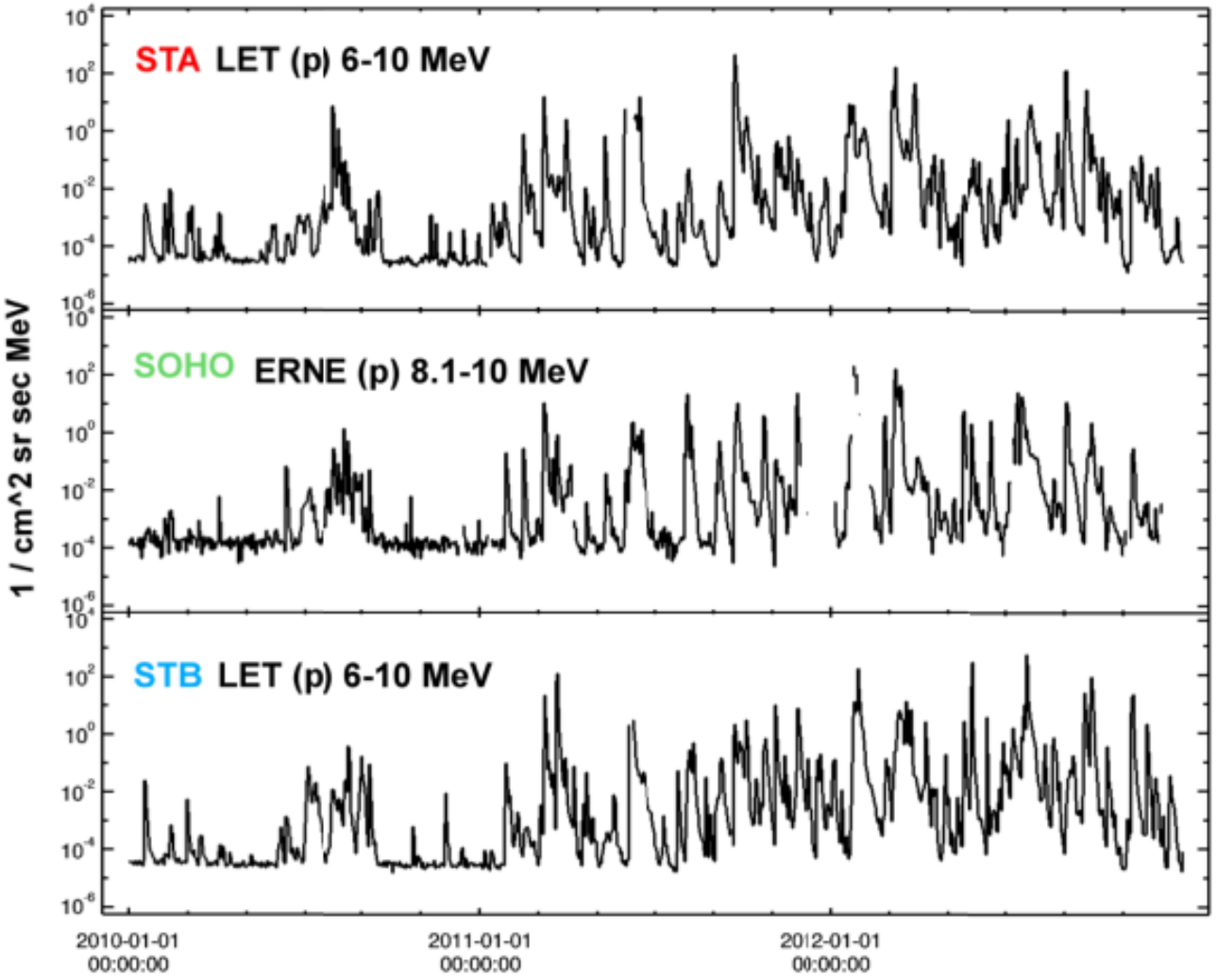


Fig. 9. Averaged proton intensities at STA (*top panel*), SOHO (*middle panel*), and STB (*bottom panel*) as a fu
See text for details.

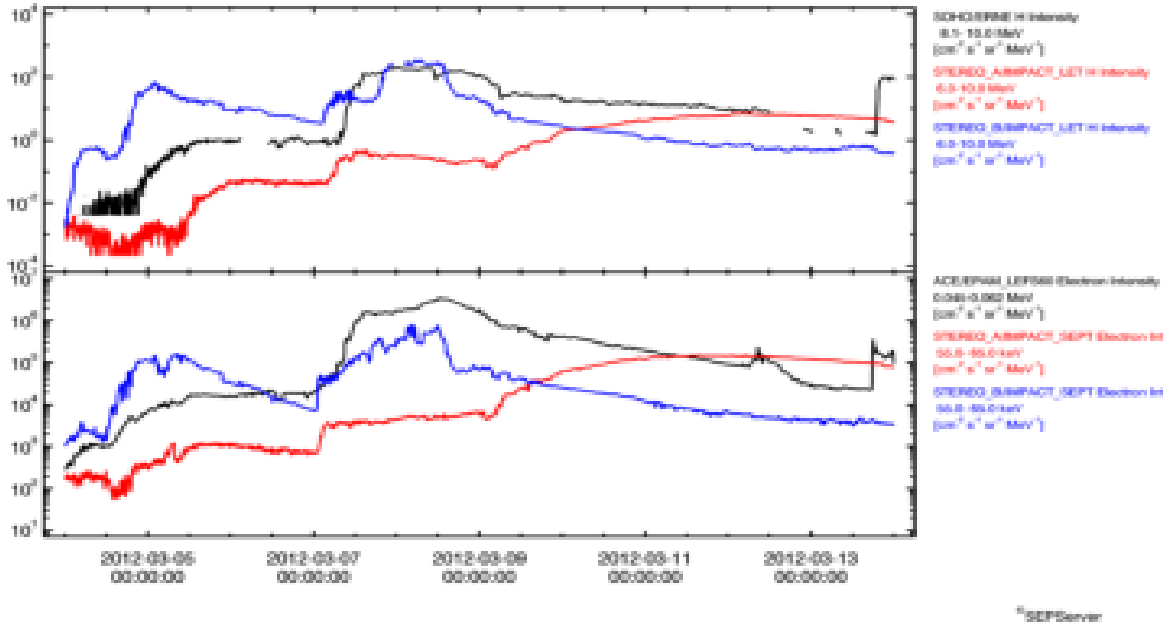


Fig. 10. The series of multispacecraft SEP events of 2012 March 04–14. *Top panel* illustrates protons from STA/LET, SOHO/ERNE, and STB/LET whereas the *bottom panel* refers to electron recordings from STA/SEPT, ACE/EPAM, and STB/SEPT. See text for details. This figure was created at SEPServer `http://server.sepserver.eu`.

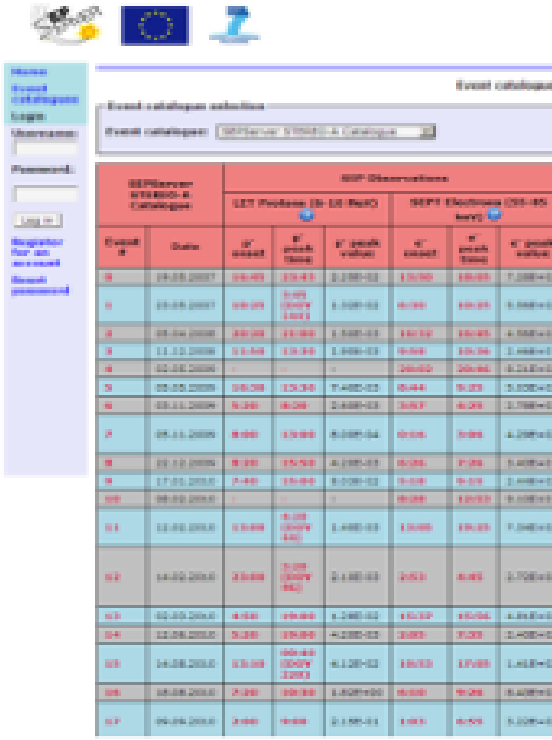


Fig. 11. A snapshot of the actual STEREO catalogues.

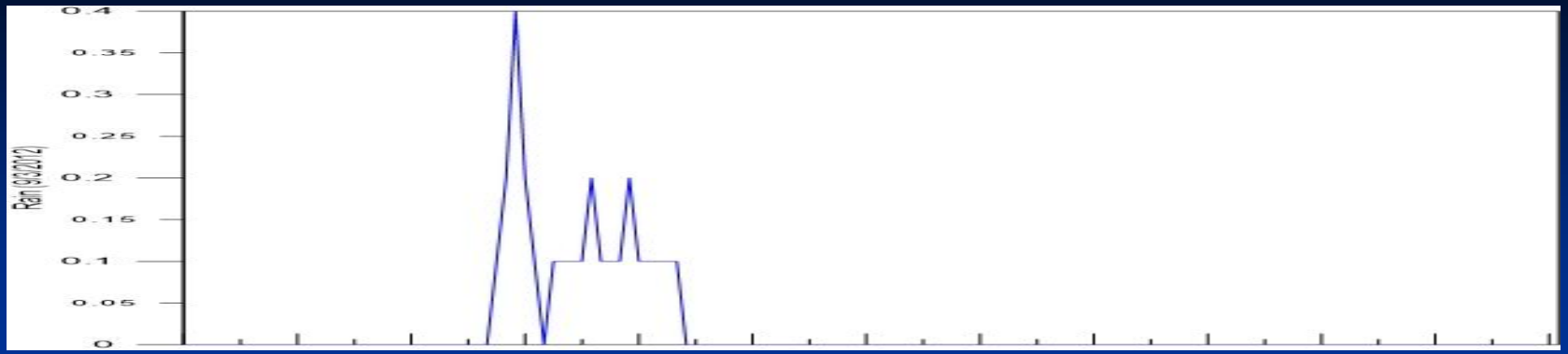
associations to the relevant solar phenomena from Bucík et al. (2009); Lario et al. (2013) and Dresing et al. (2013). All of this information is summarized in Table 5.

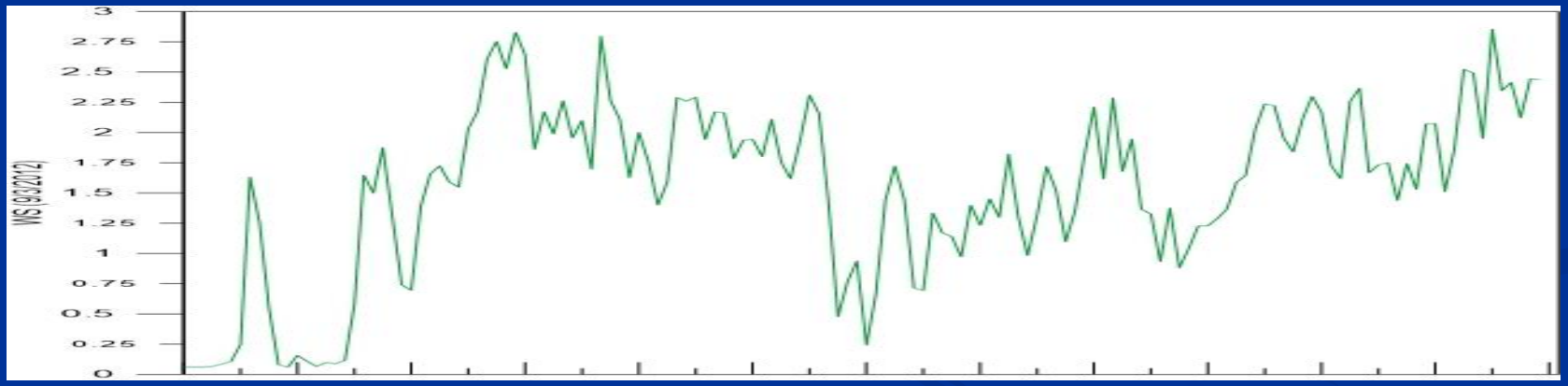
5. Summary of results

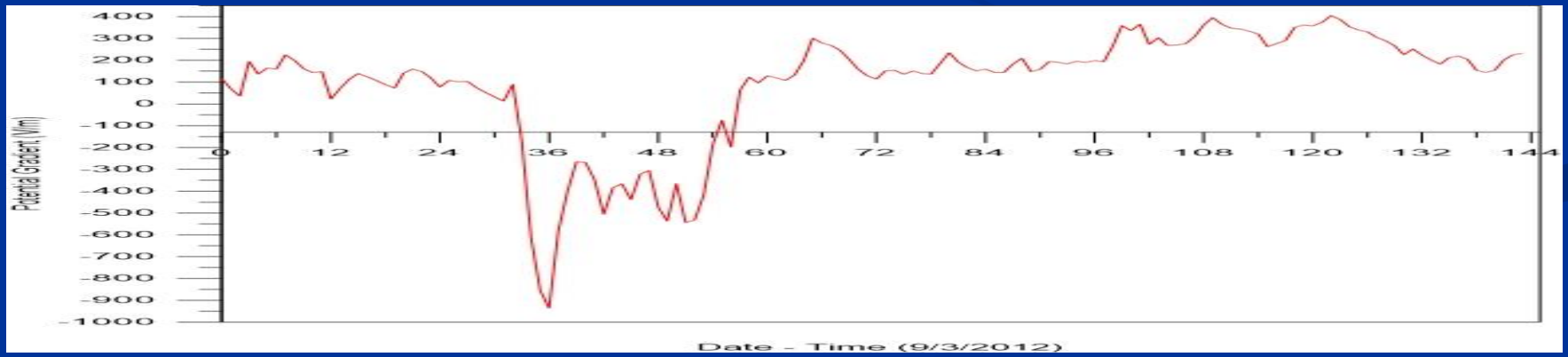
Using the methodology that has been furnished in Sect. 3.1, we have identified a total of 130 SEP events for STA (see Table 1)

and 108 SEP events for STB (see
the number of events per year f
2012 when the solar cycle 24 see

In Table 1 we present the S
at STA. Column 1 gives the n
first one starting at 0, Cols. 2, a
of the SEP event at LET 6–10
the peak value of the SEP even


Rain (9/3/2012)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0


WS (9/3/2012)
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0


Potential Gradient (V/m)
400
300
200
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
0
12
24
36
48
60
72
84
96
108
120
132
144
Date - Time (9/3/2012)

A correlation between Space and Meteorological events

has **not** been checked...

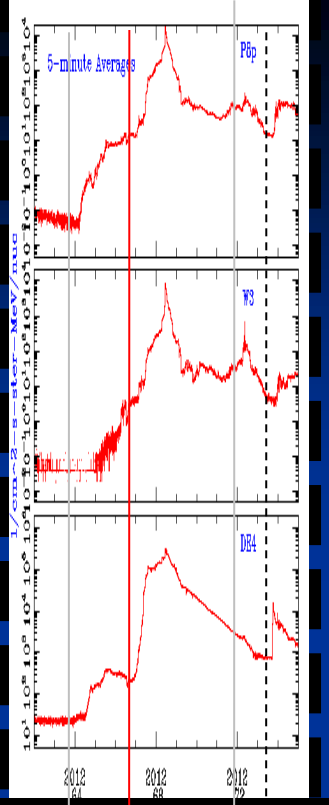
…the meteorological events were found

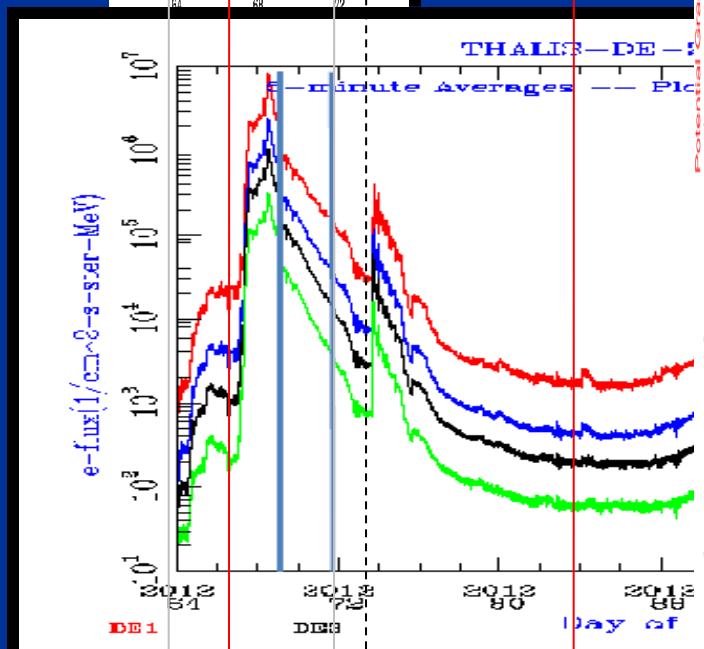
not consistent with atmospheric models…

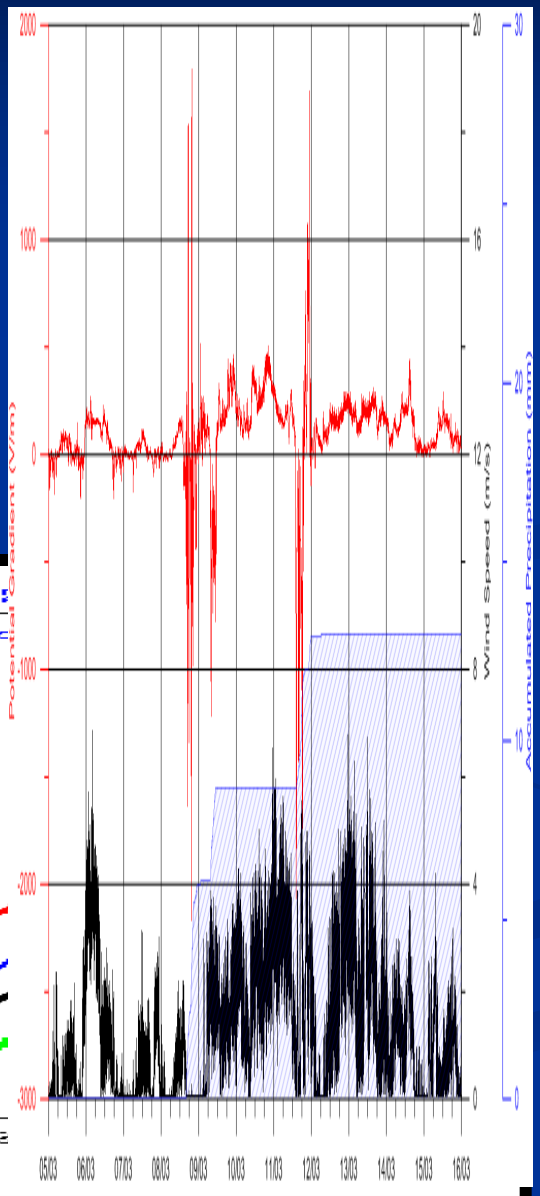
Correlation between Extreme Space and Atmospheric variations

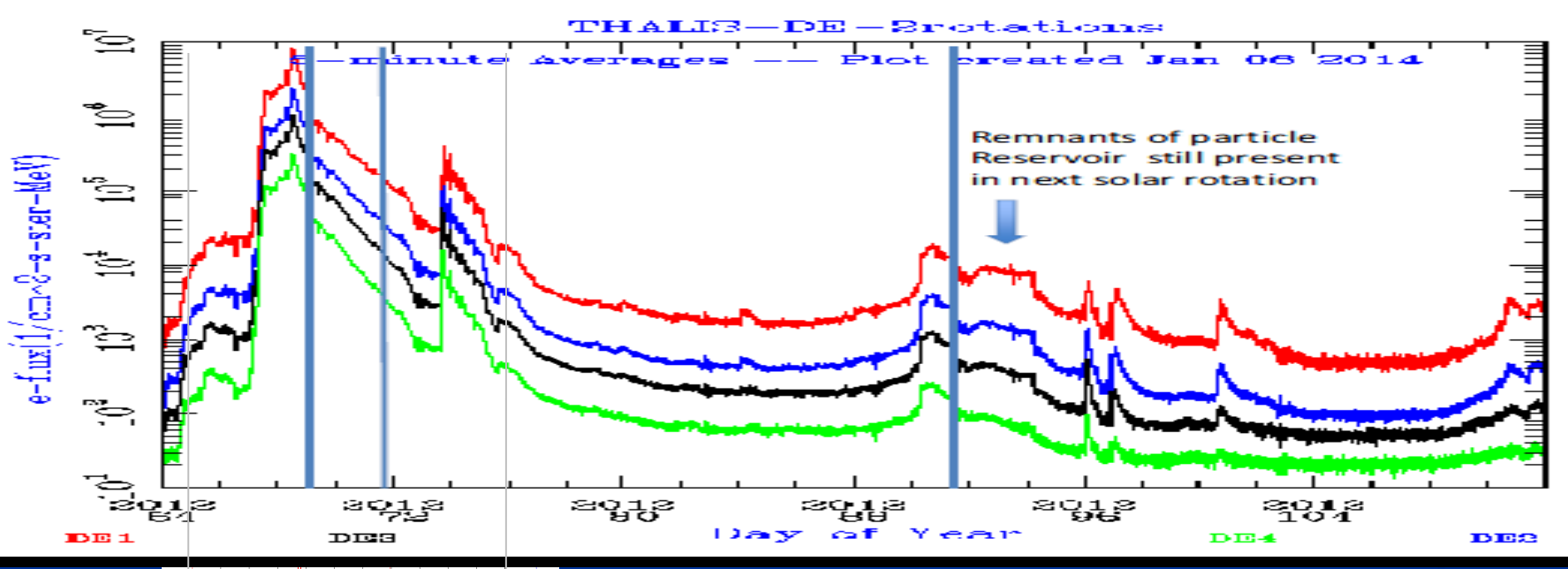
March 2012 superstorm

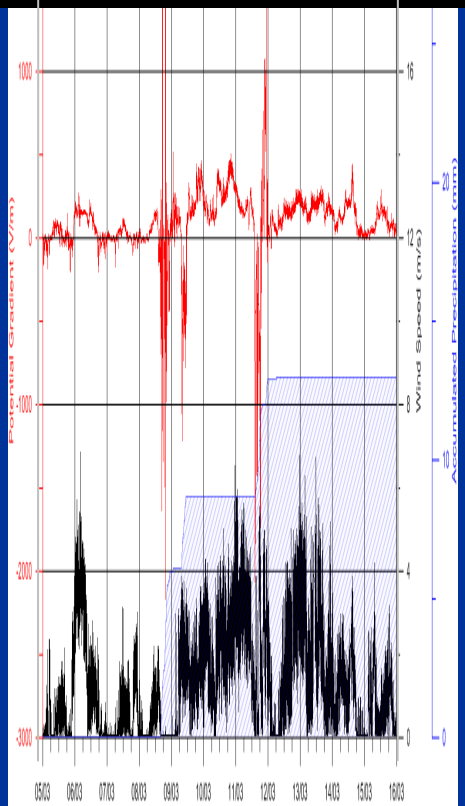
2. MAJOR SOLAR-GEOMAGNETIC SUPERTORM


5-minute Averages
P6p
W3
D24
1/cm^2-s-ster-MeV/nuc
2012 64
2012 68
2012 72


THALIS—DE—5
5-minute Averages —— Plo
e-flux(1/cm^2-s-ster-MeV)
DE1
DE3
Day of


Potential Gradient (V/m)
Wind Speed (m/s)
Accumulated Precipitation (mm)
05Q3
06Q3
07Q3
08Q3
09Q3
10Q3
11Q3
12Q3
13Q3
14Q3
15Q3
16Q3


THALES—DE—Protations
5—minute Averages —— Plot created Jan 06 2014
Remnants of particle
Reservoir still present
in next solar rotation
Day of Year
DE1
DE3
DE4
DE5


Potential Gradient (V/m)
Wind speed (m/s)
Accumulated Precipitation (mm)

Correlation between Extreme Space and Atmospheric variations

March 2012 superstorm

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NASA Measures Impact of Huge Solar Flare on Earth's Atmosphere 03.23.12

A key NASA instrument that can directly measure the impact of solar events on the Earth's upper atmosphere has weighed in on the huge flare that impacted Earth last week.

The flare was considered one of the largest solar events in years. Although its impact on the power grid and communications was minimal due to the angle it hit Earth,

its direct interaction with the upper atmosphere was measured by NASA's SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) instrument orbiting on the TIMED (Thermosphere, Ionosphere, Mesosphere,

3. EXTREME METEOROLOGICAL EVENTS

Correlation between Extreme Space and Atmospheric variations

March 2012 superstorm

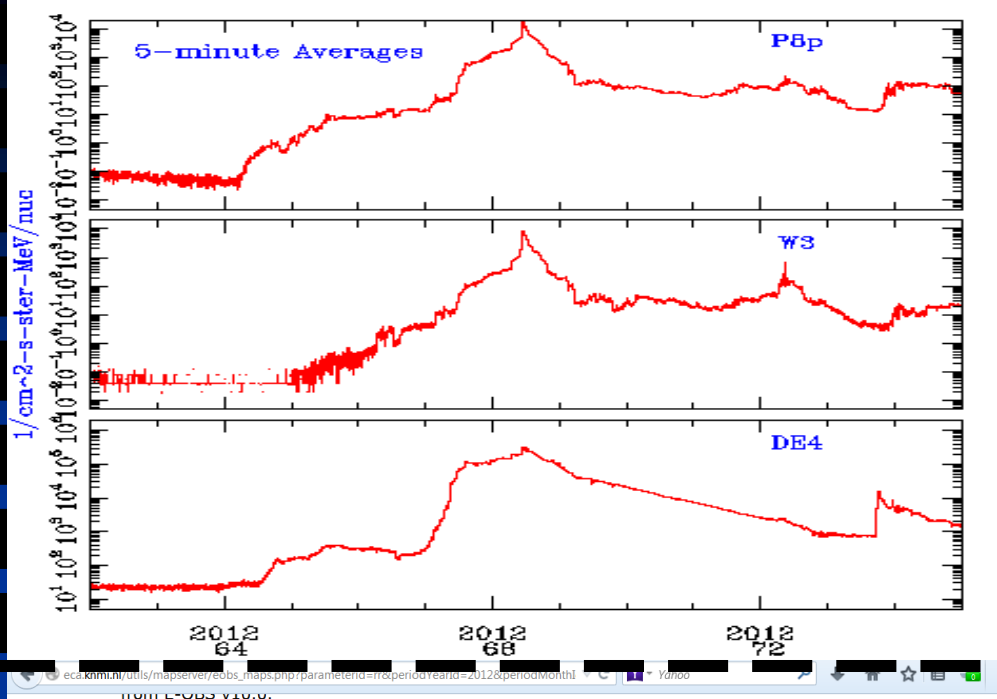
Greece extreme effects

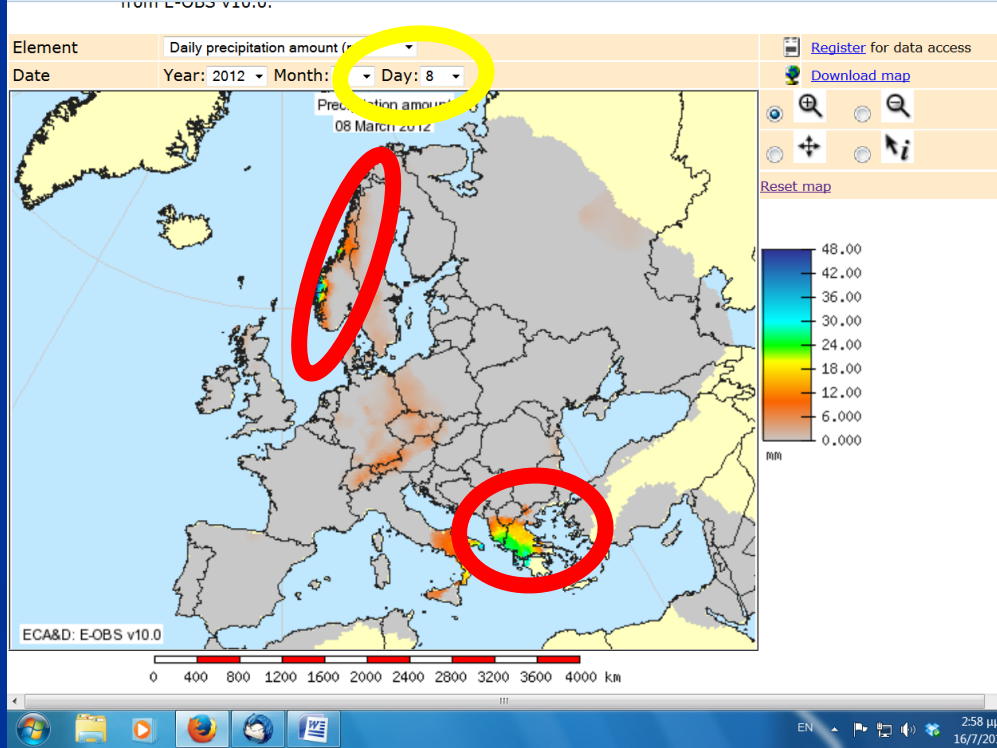
“8. 3. 2012 (day 68): The leading edge of the March 6 coronal mass ejection (CME), reached NASA's Advanced Composition Explorer (ACE) satellite at 5:42 AM EST”.

(**NASA News /** http://www.nasa.gov/mission_pages/sunearth/news/News030712-X5-4.html)

followed by rainfalls in Greece!

(and north Europe)

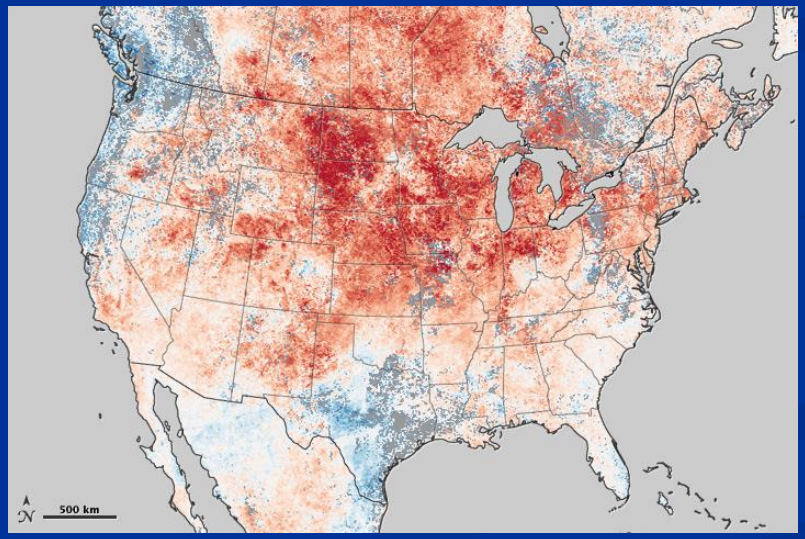




Correlation between Extreme Space and Atmospheric variations

March 2012 superstorm

USA-Canada March 2012 extreme effects

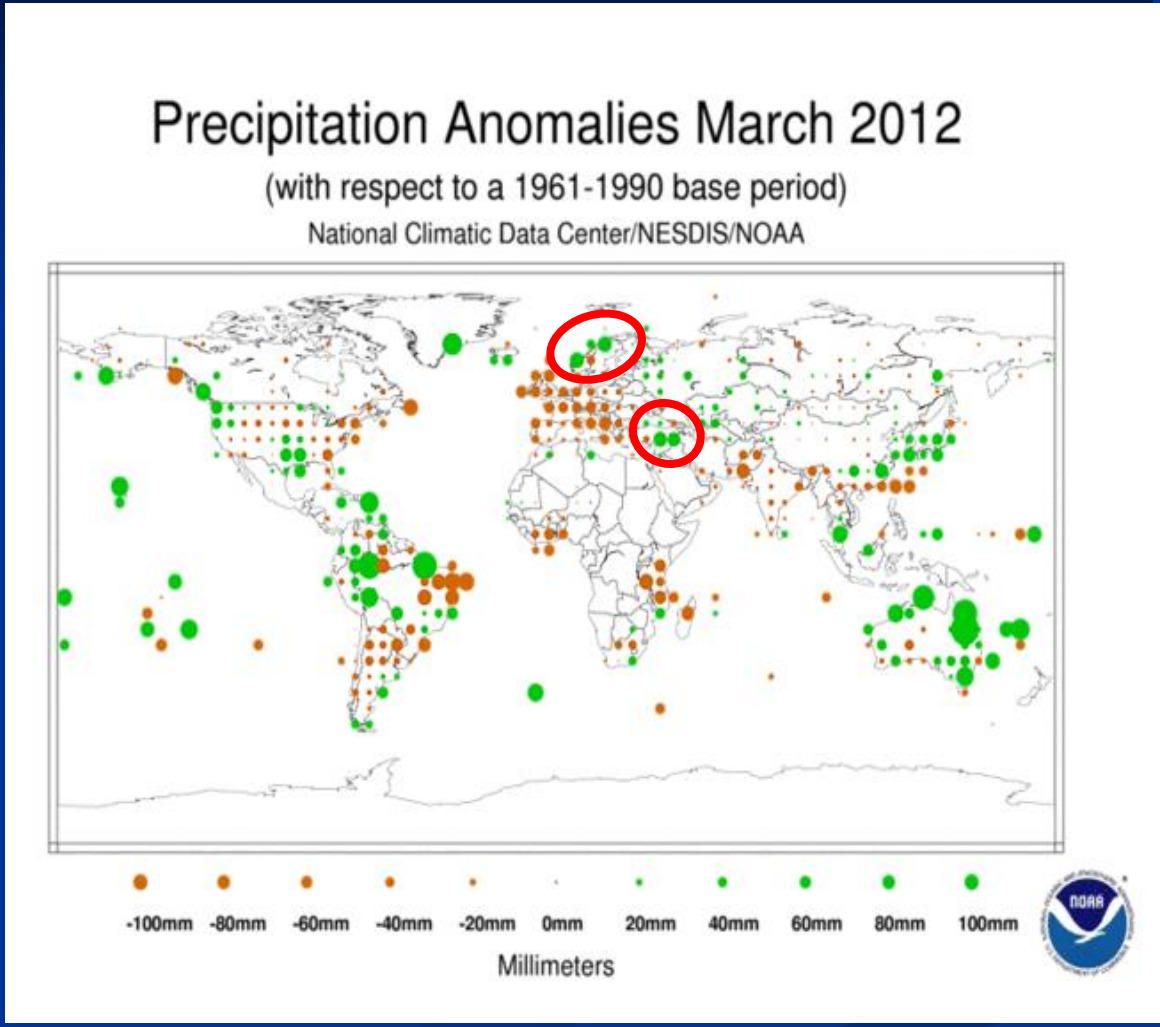


Correlation between Extreme Space and Atmospheric variations

March 2012 superstorm

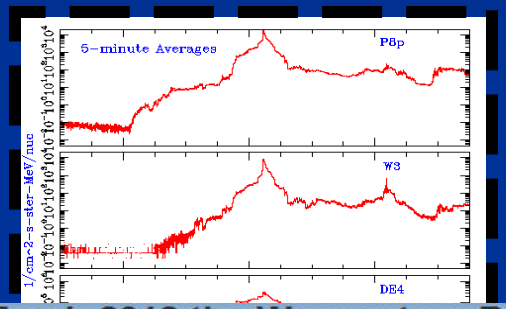
Global metheorological variations

March 2012 Global Precipitation Anomalies…



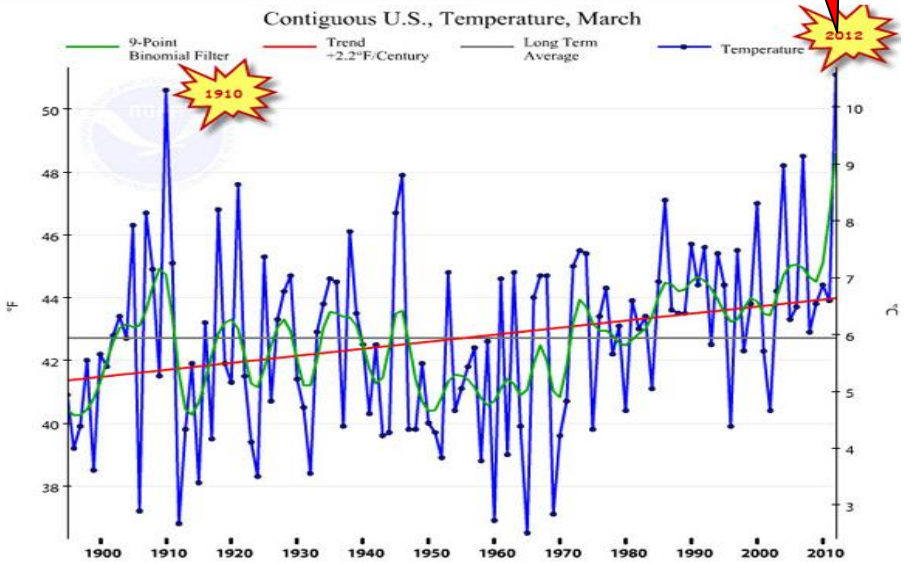
…increased precipitation in South East & North West Europe

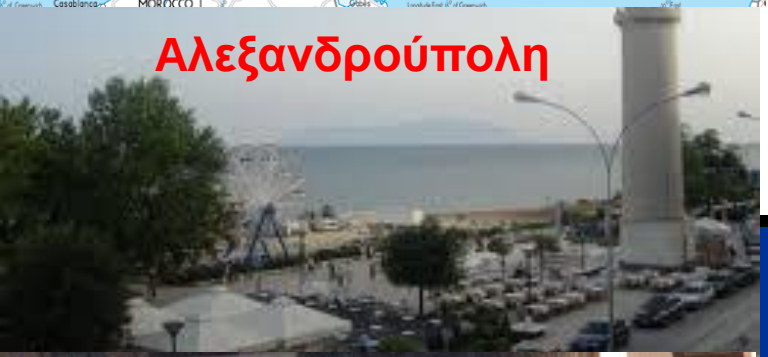
Particle precipitation (ACE, NOAA)… is related with NO and CO2 peaks, and temperature extreme values (in USA)

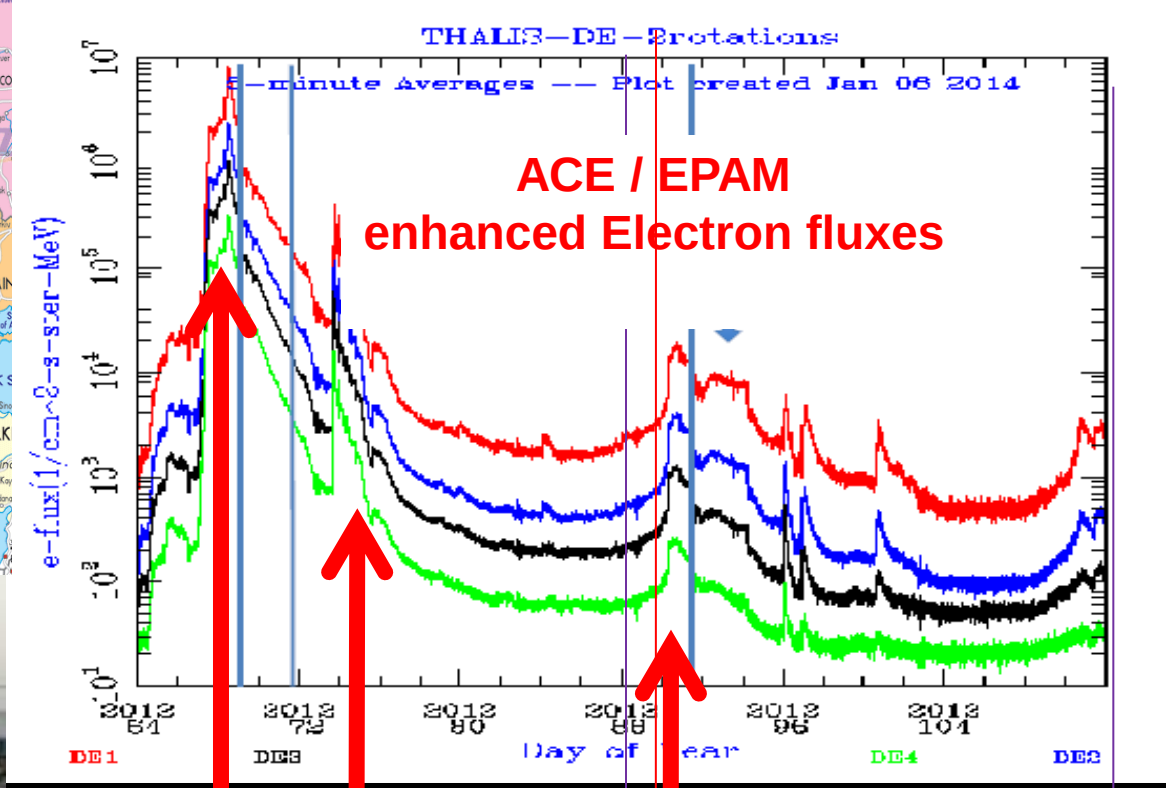


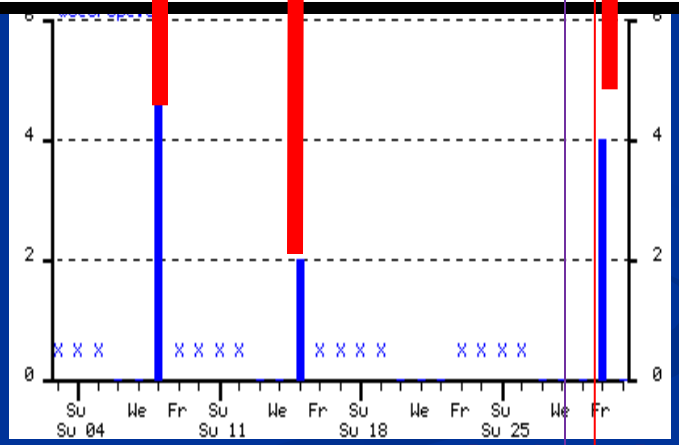
NOAA: March 2012 the Warmest on Record

by Chris Dolce, weather.com Meteorologist



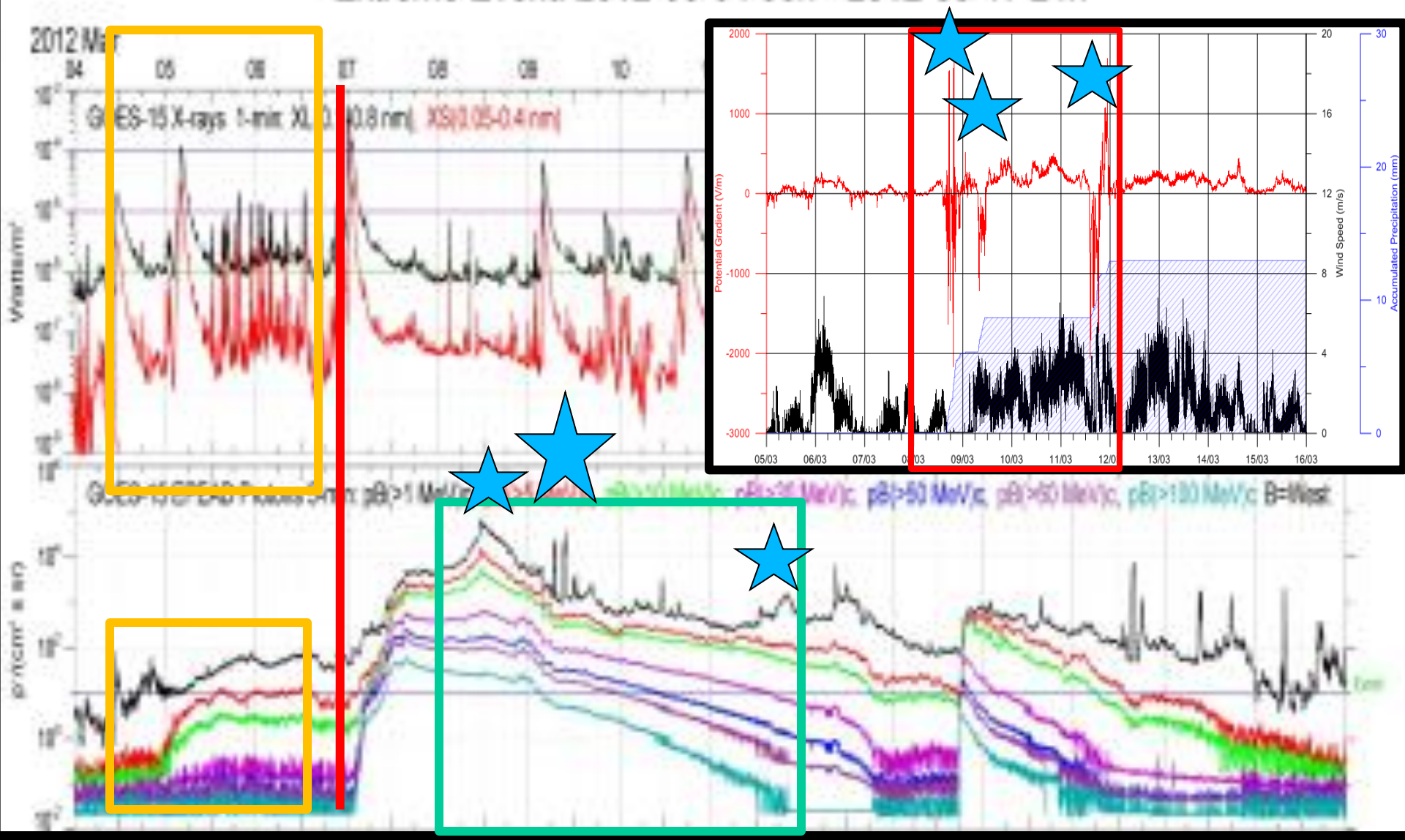






Rainfall in Alexandroupoli / North Greece on days of SEP

Extreme Event: 2012-03-04 00h - 2012-03-17 24h

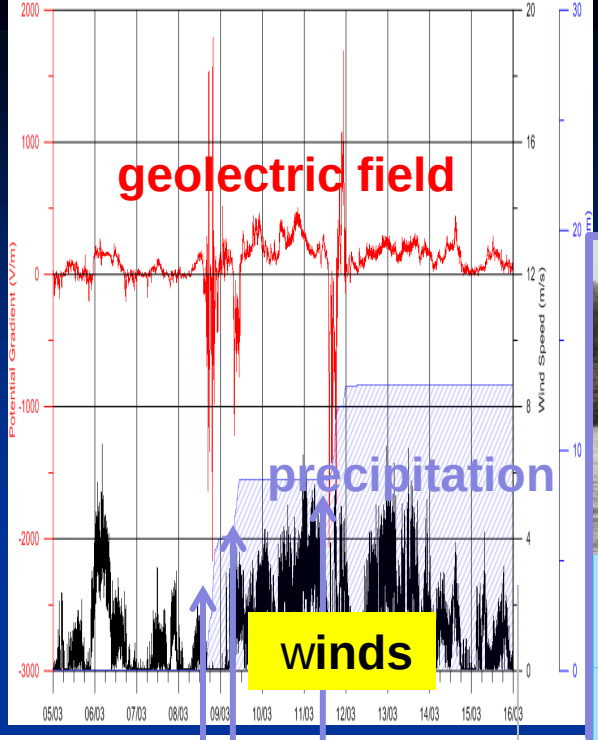


Rainfalls, intense (>1500 V/m) fluctuating geolectric field, and winds in South East Europe (Xanthi, Greece)

were observed **almost simultaneously** with

geomagnetic storms (Dst) and electron precipitation (not shown here)

on days 8-11 11.3.2012

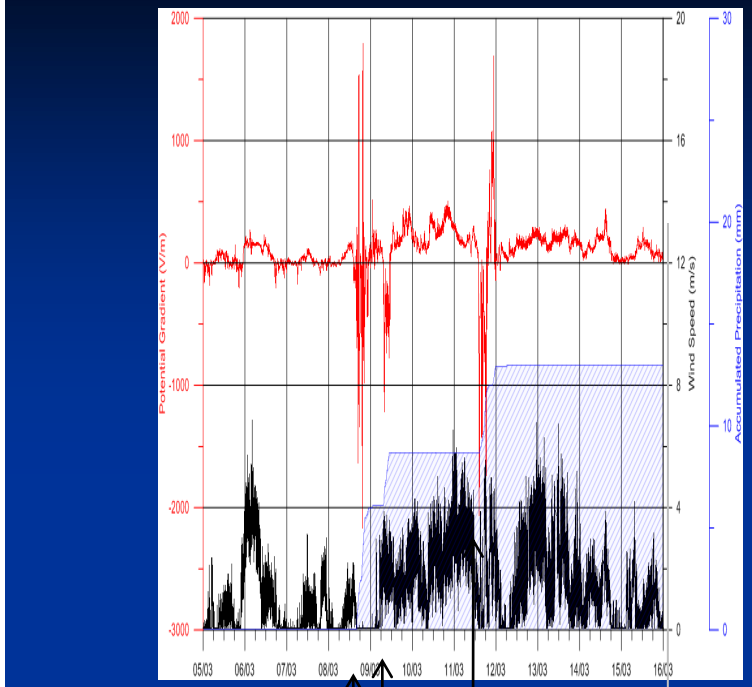


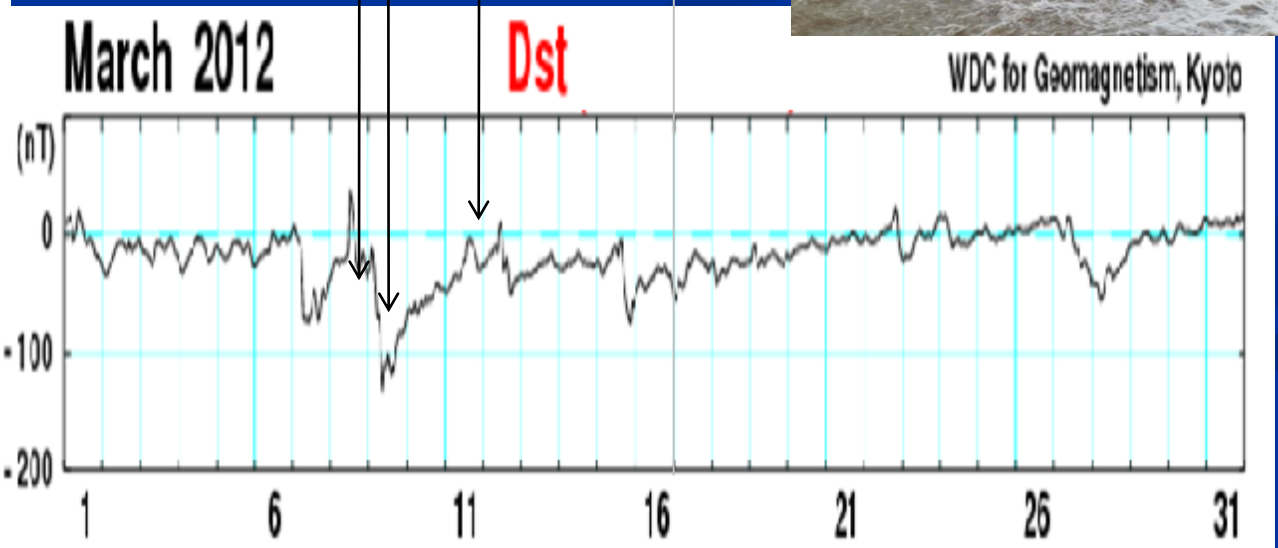
strong winds, rainfalls and intense (>1500 V/m) fluctuating geolectric fields in South East Europe (Greece) were observed

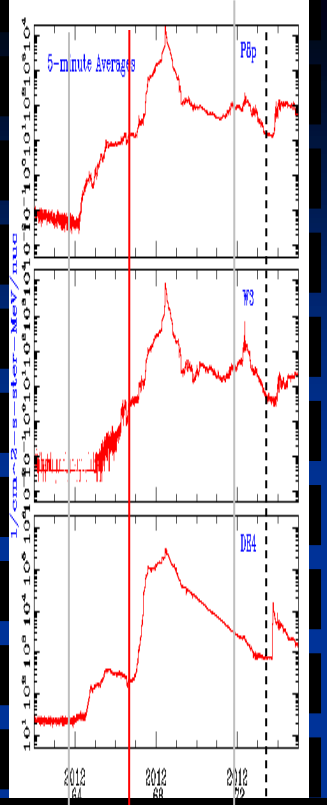
almost simultaneously

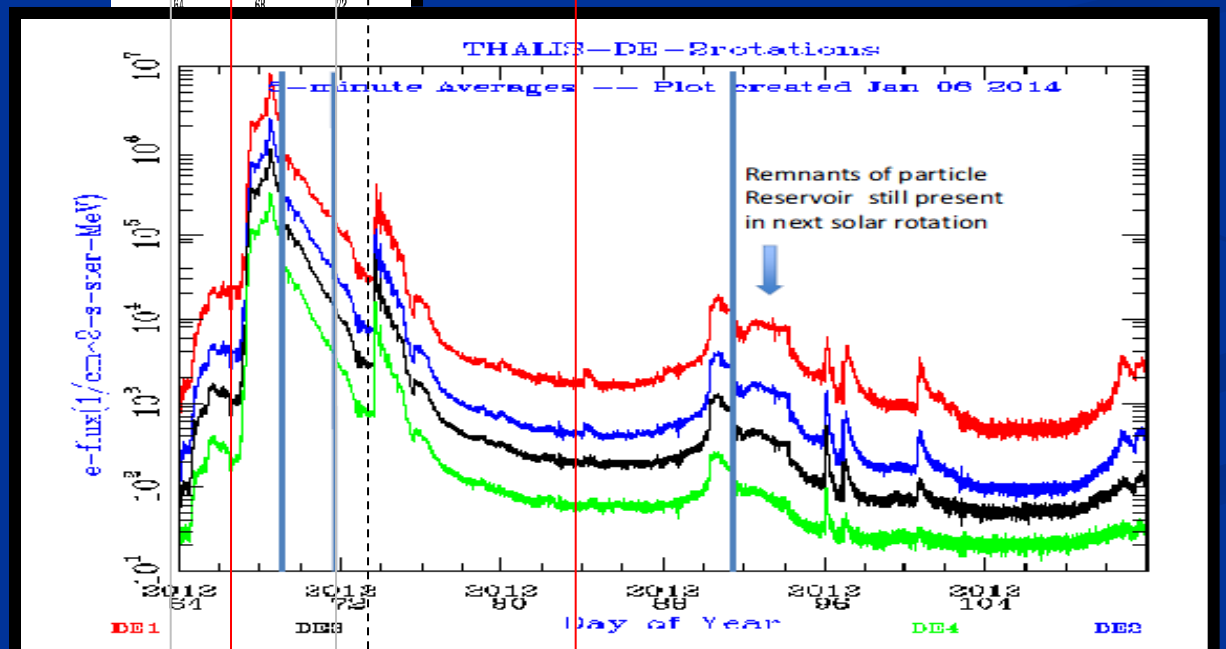
with geomagnetic storms **(Dst)** on days 8, 9 and 11.3.2012

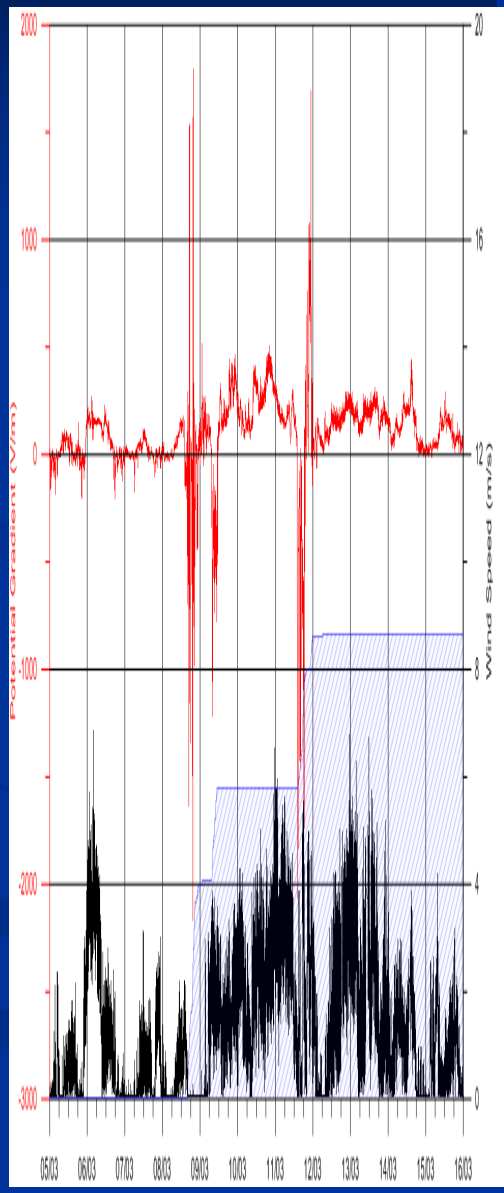
Ξάνθη

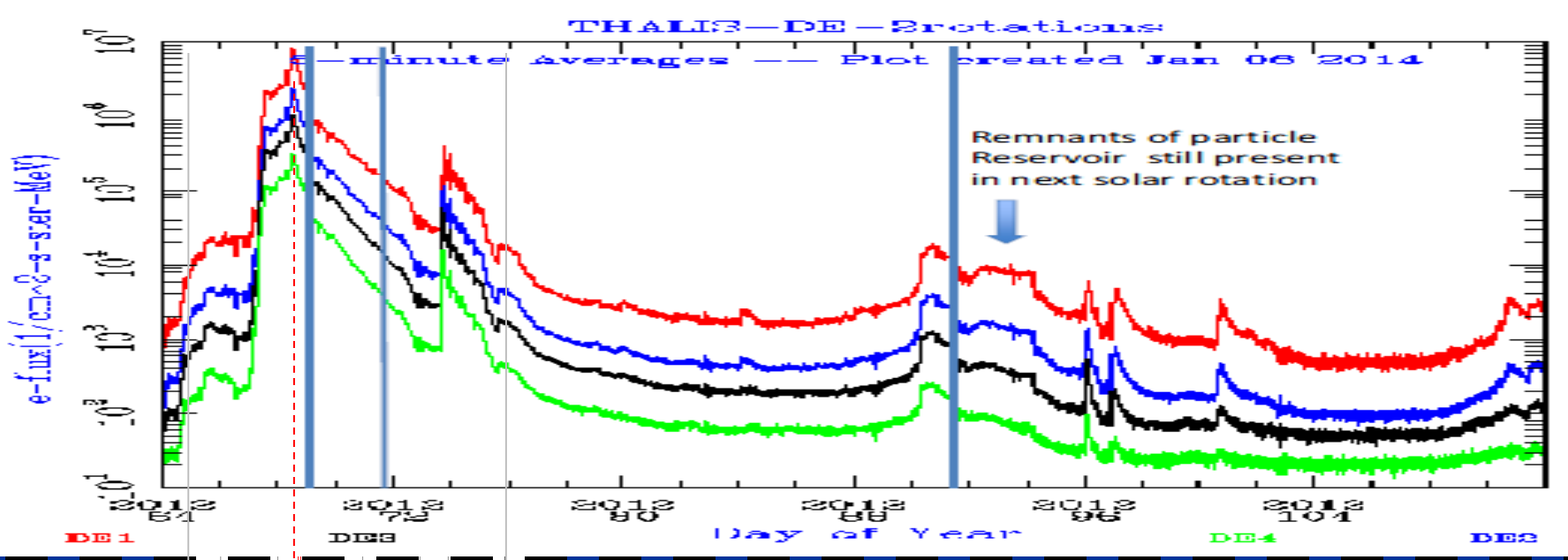


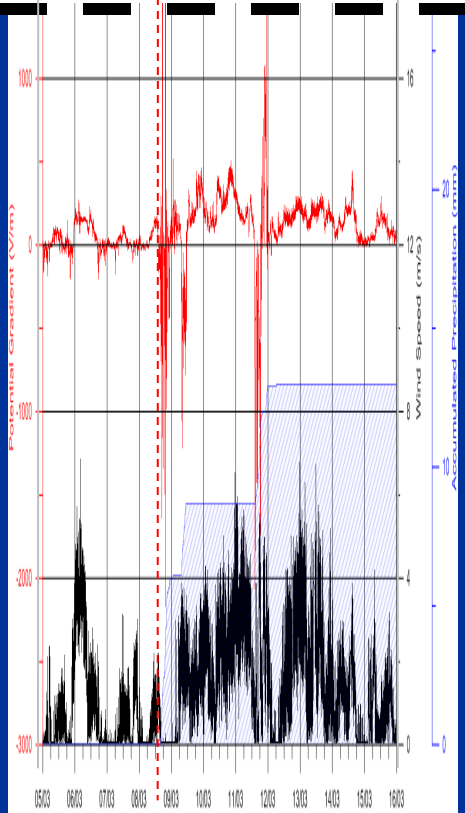


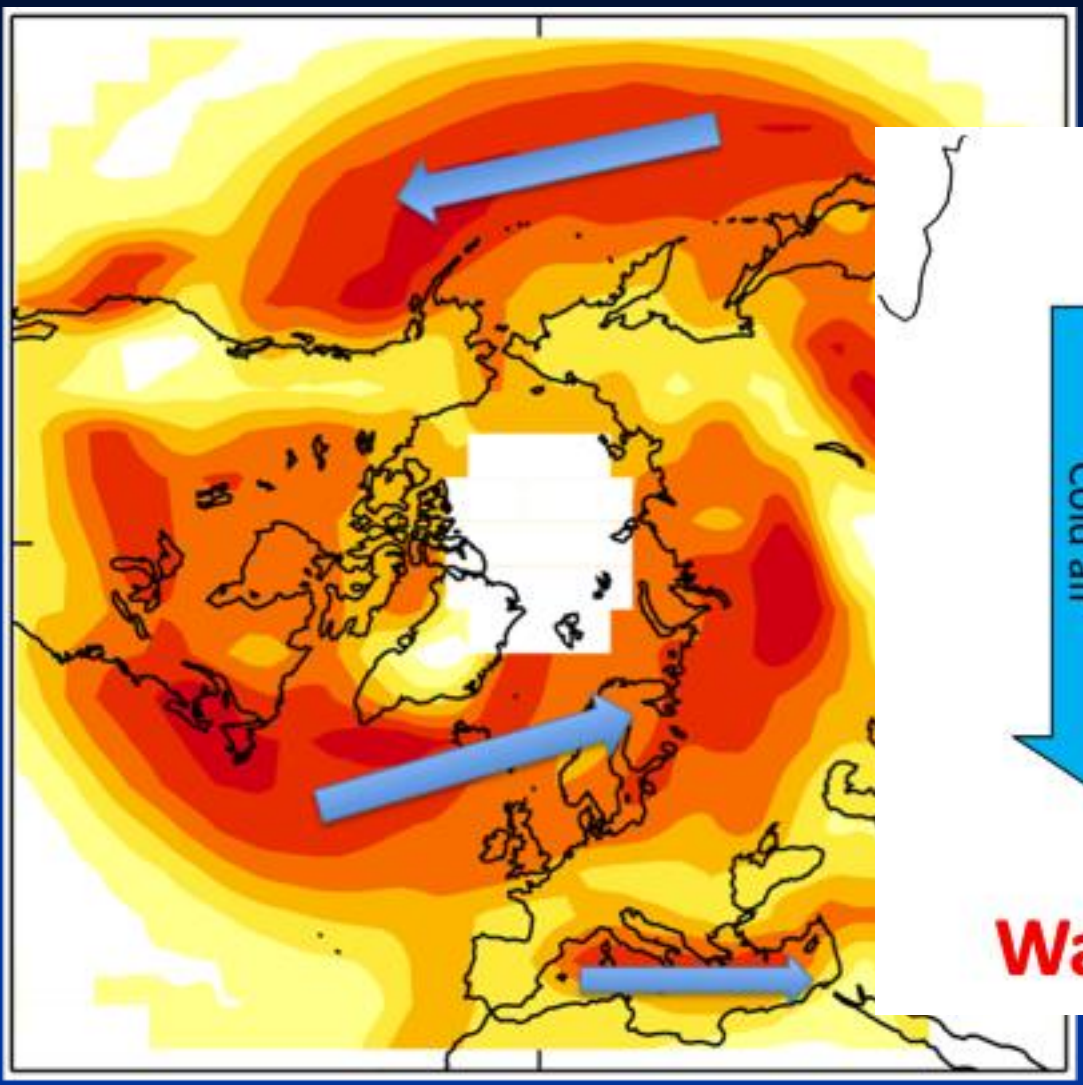

5-minute Averages
P6p
W3
D24
1/cm^2-s-ster-MeV/nuc
2012 64
2012 68
2012 72

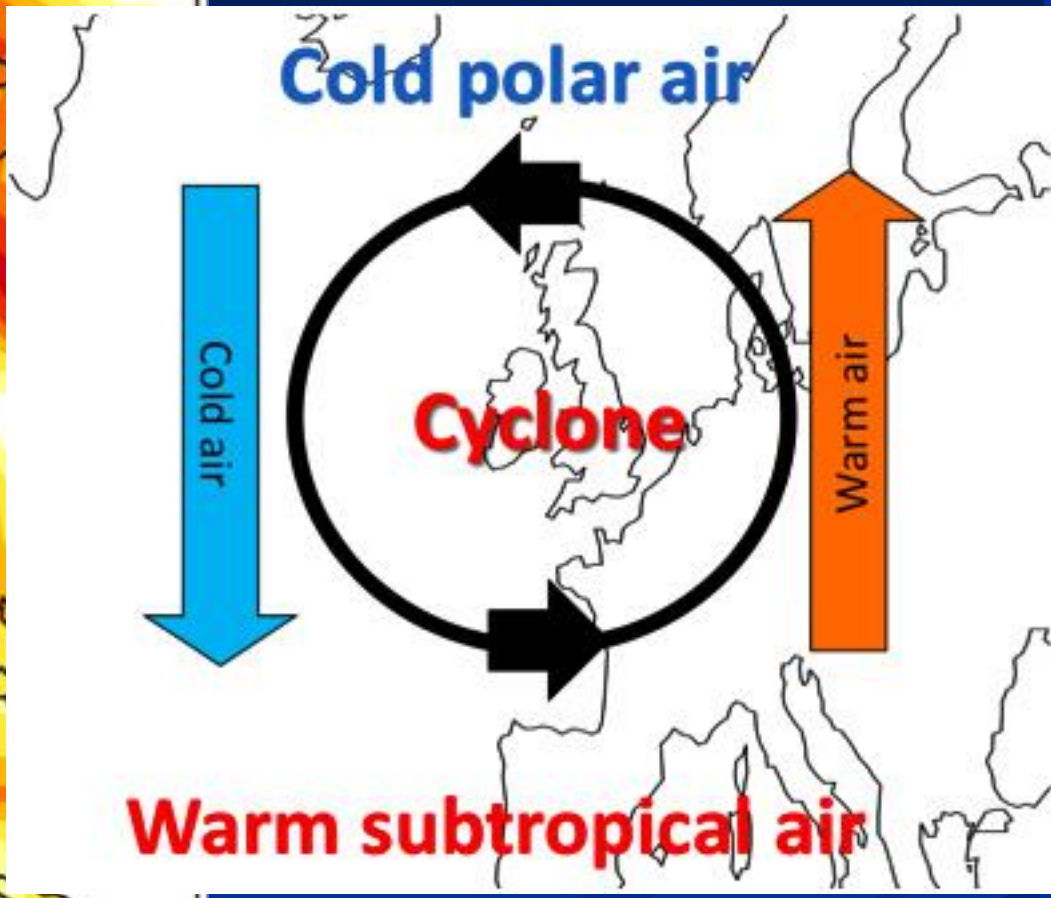

THALES—DE—2rotations
5—minute Averages —— Plot created Jan 06 2014
Remnants of particle
Reservoir still present
in next solar rotation
e-flux(1/cm^2-s-ster-MeV)
Day of Year
2012 64
2012 72
2012 80
2012 88
2012 96
2012 104
DE1
DE3
DE4
DE2

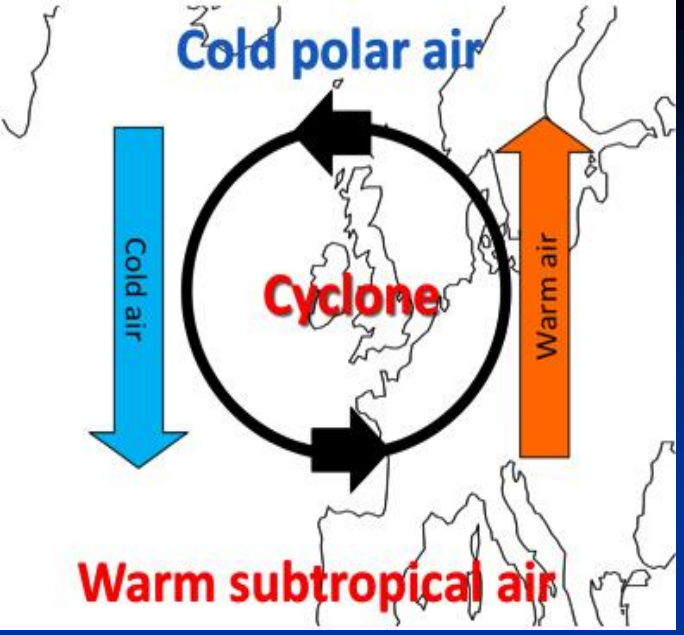

Potential Gradient (V/m)
Wind Speed (m/s)
2000
1000
0
-1000
-2000
-3000
20
16
12
8
4
0
0503
0603
0703
0803
0903
1003
1103
1203
1303
1403
1503
1603


THALES—DE—Protations
5—minute Averages —— Plot created Jan 06 2014
Remnants of particle
Reservoir still present
in next solar rotation
e-flux(1/cm^2-s-sr-MeV)
Day of Year
DE1
DE3
DE4
DE5


Potential Gradient (V/m)
Wind speed (m/s)
Accumulated Precipitation (mm)




Cold polar air
Cold air
Cyclone
Warm air
Warm subtropical air



Circulation around a storm in the Northern Hemisphere: warm air is moved polewards and upwards ahead of the storm while cold air sinks as it moves equatorwards behind the storm.

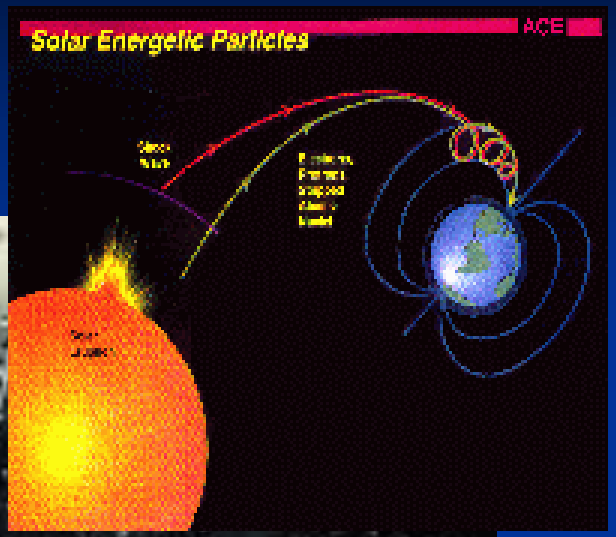
Either way, the warmer air moves upwards, cooling as it does so. As the rising air cools, the water vapour it contains begins to condense into small liquid water droplets. To the onlooker on the ground, large groups of these droplets appear as clouds, the familiar harbingers of rain.

Small droplets, however, do not necessarily cause rain. While the droplets remain small the maximum speed at which they fall through the air is low.

The rain comes when the droplets begin to grow larger - whether by colliding and coalescing with each other or simply by gradual growth from further condensation. Larger droplets are able to reach greater fall-speeds and they are then able to leave the cloud and drop to the ground.

Correlation between Extreme Space and Atmospheric variations

March 2012 superstorm



5. Discussion & Conclusions

“Recently…energetic particle forcing…., in the form of **electron and proton precipitation into the atmosphere**, has sparked interest due to it’s potential influence on stratospheric circulation . …**energetic particle forcing driving dynamical changes in the atmosphere** that are as intense as those arising from the known solar irradi**ance** variations”.

Seppala and Clilverd (2014)

A series of various Space and atmospheric data reveal

a short time (days / minutes)

correlation between space and meteorological

events during the March 2012 superstorm

(in particular between 8-13.3.2012),

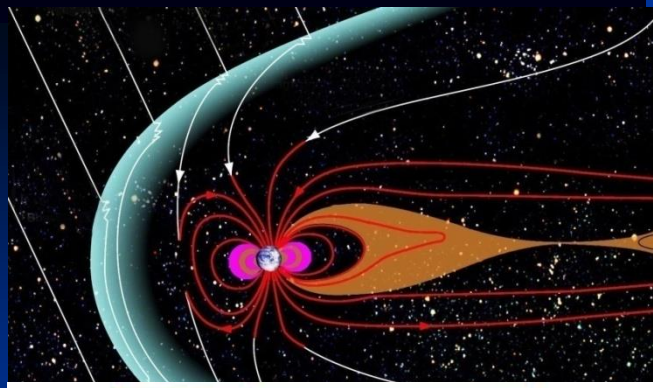
in Greece, north America and all over the globe.

The data presented here and data analysis to be presented in the near future suggest that a combination of two physical processes may be responsible for the most striking atmospheric extreme events of March 2012:

(1) Energetic Particle precipitation during storms forcing a positive North Atlantic Oscillation (NOA) effect, for instance between 6-13.3.2012

(2) a direct influence of Energetic Particle precipitation on the middle latitude atmosphere, as in the case of days 8-11.3.2012

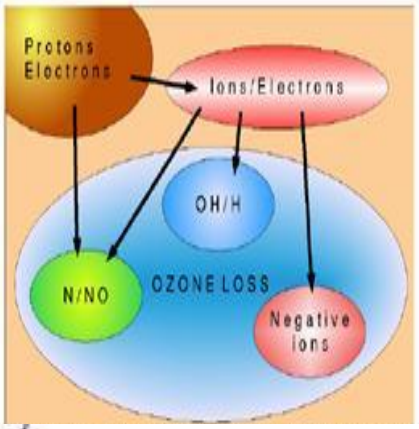
1st mechanism



>geomagnetic activity INCREASEs

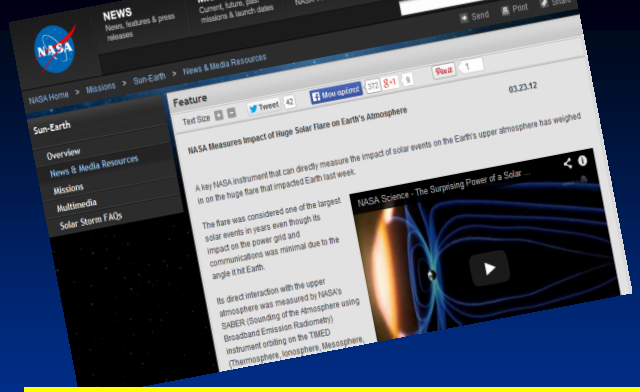
>energetic electron precipitation INCREASES

>NOx production INCREASES

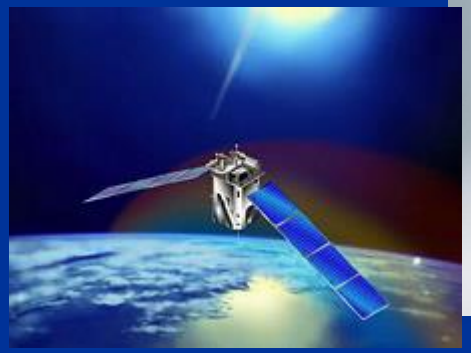


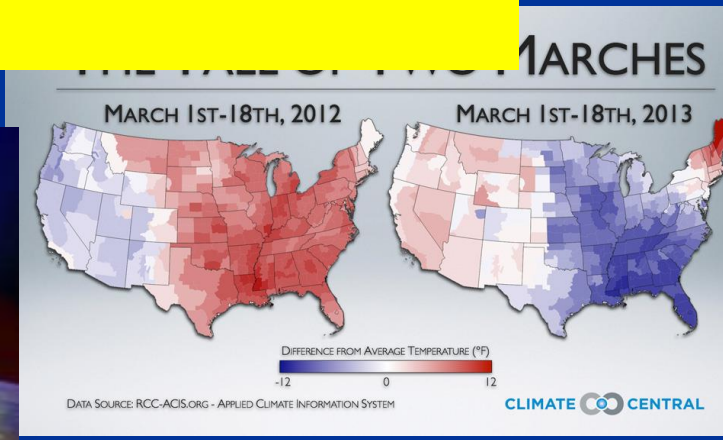
> The NOx production leads to ozone depletion in the stratosphere

which causes changes in the radiative budget and the mean meridional circulation. In the presence of sunlight ozone absorbs solar shortwave radiation resulting in heating of the atmosphere.



Space weather a good tool to understand unexplained so far extreme meteorological phenomena



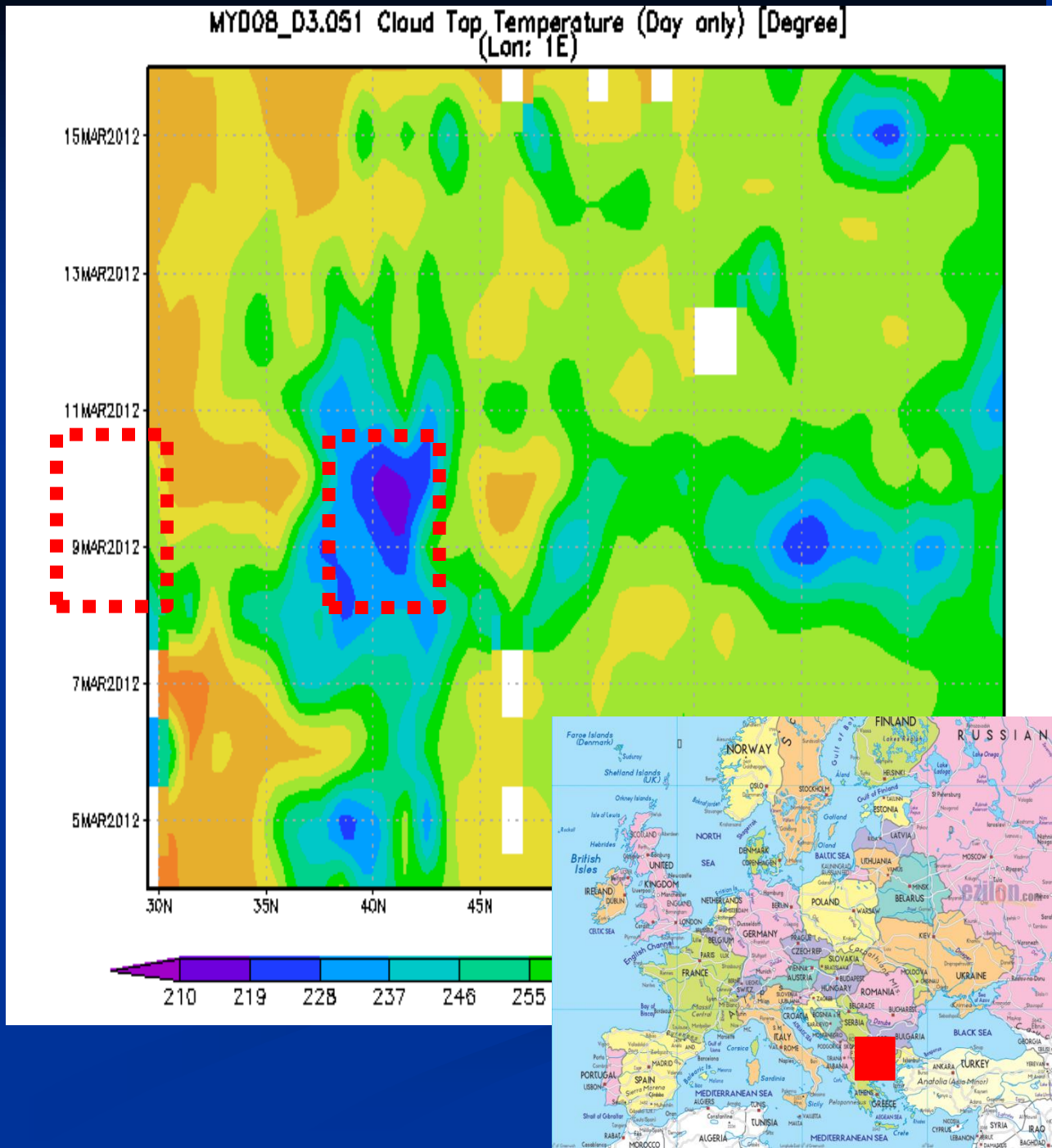


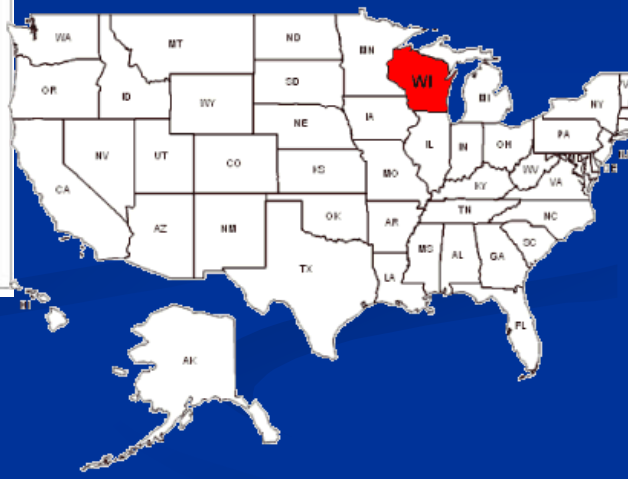

ΞΑΝΘΗ
XANTHI


DEMOKRITOS

MODIS
30-70 deg. latitudes
at Greek longitudes

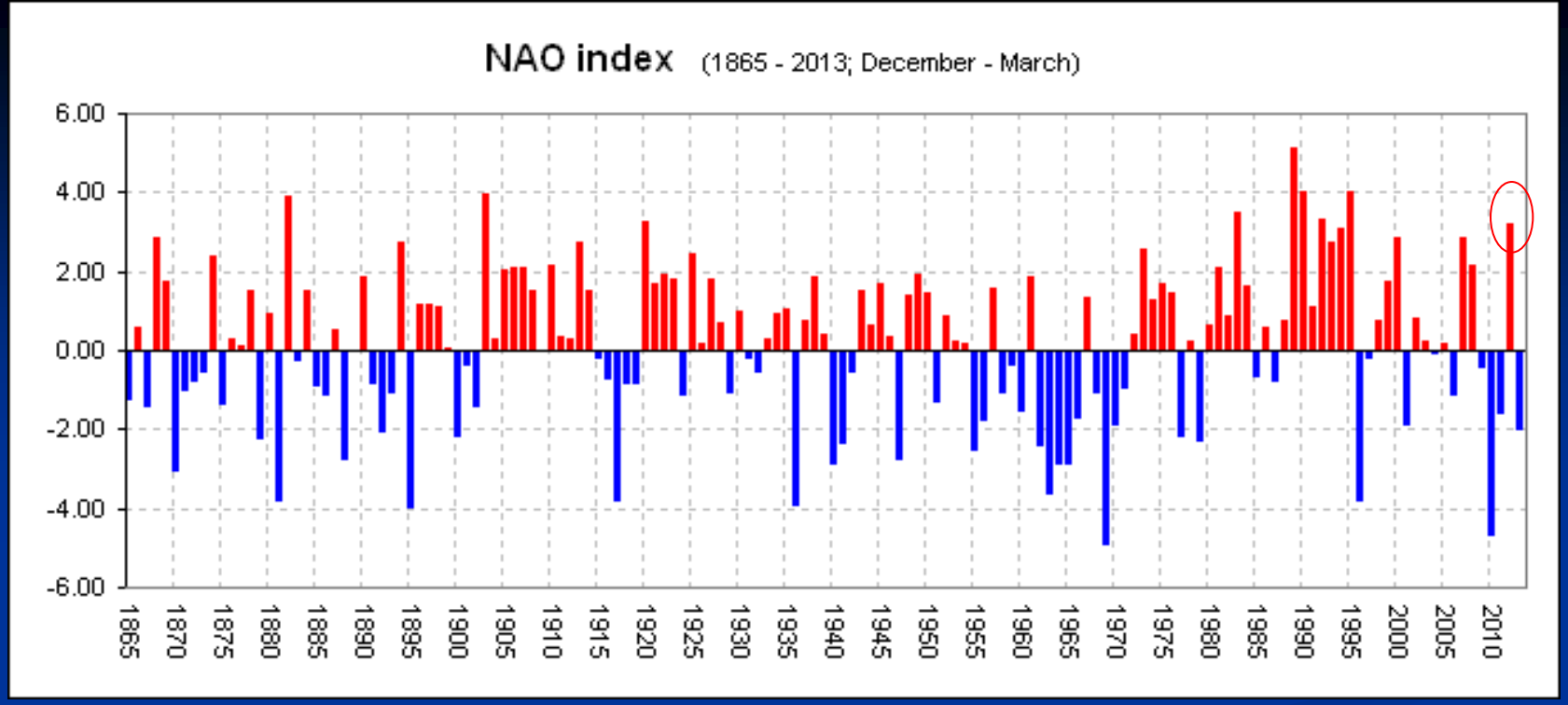
8-11.3.2012: Lowest Cloud Top Temperatures





Correlation between

geomagnetic index Dst – Temperature



Positive NOA index

on March 2012

was related with

westward cloud motion

in two directions

(north – south East Europe