

SPACE WEATHER INTRODUCTORY COURSE



Collaboration of



Solar-Terrestrial Centre of Excellence



Koninklijke luchtmacht

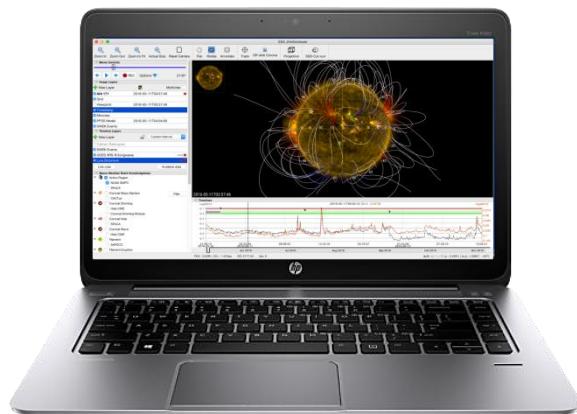
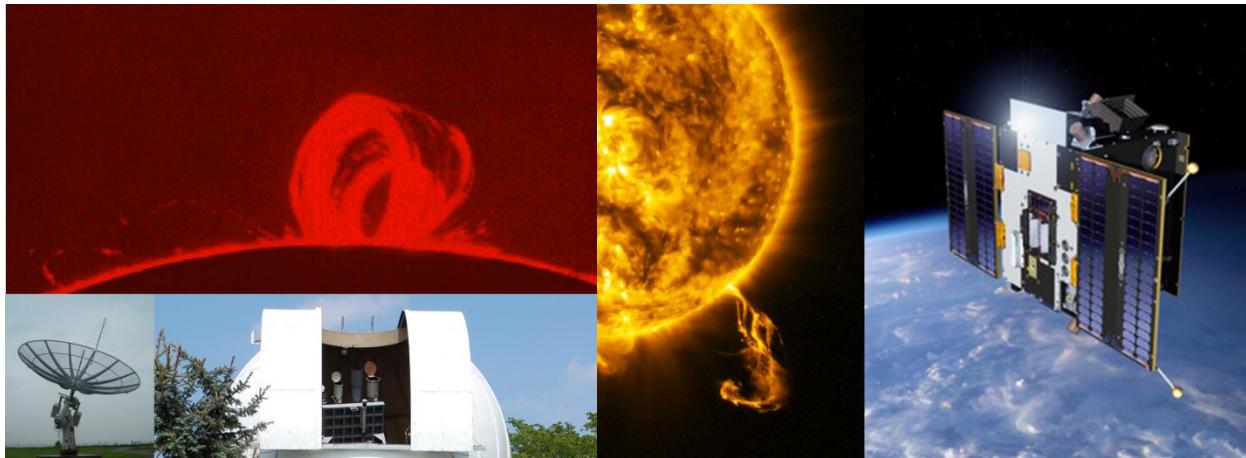


Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

SPACE WEATHER INTRODUCTORY COURSE



- Introduction
- Sensors
- The eruptive Sun
- Magnetosphere
- Ionosphere
- Space weather effects
- SIDC/RWC & exercises



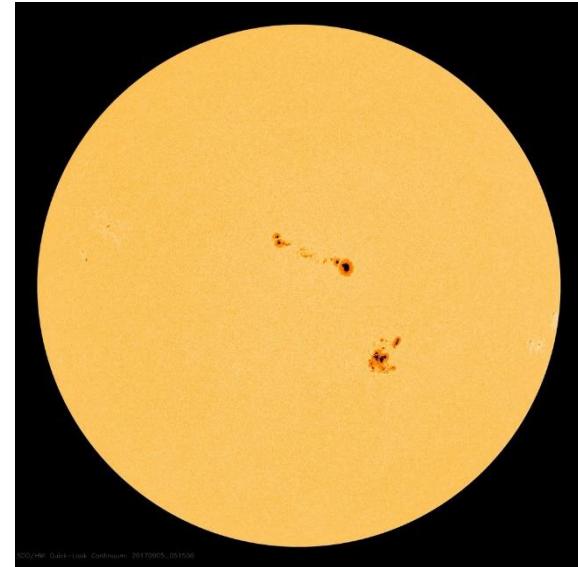
Sensors

Jan Janssens, Dr Christophe Marqué

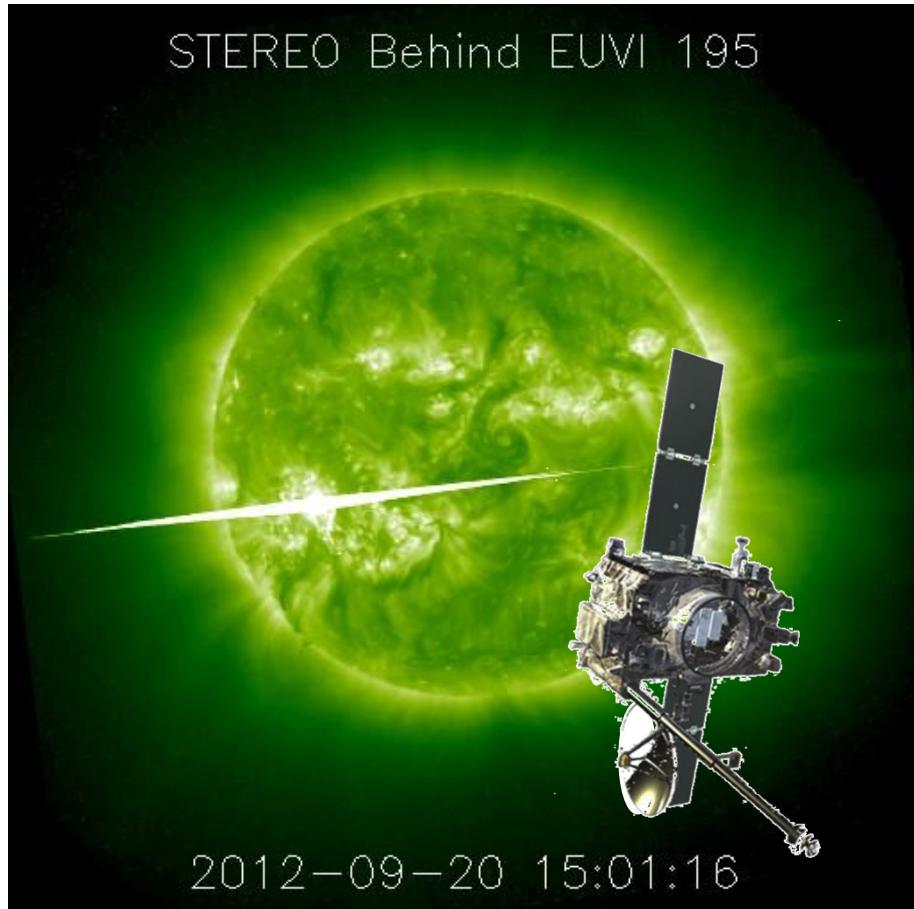


Sensors 1/3

- **Groundbased sensors**
 - Visible light
 - Radio domain
 - Human
 - Magnetosphere-Ionosphere
 - Geomagnetism
 - Neutron monitors
 - Dourbes



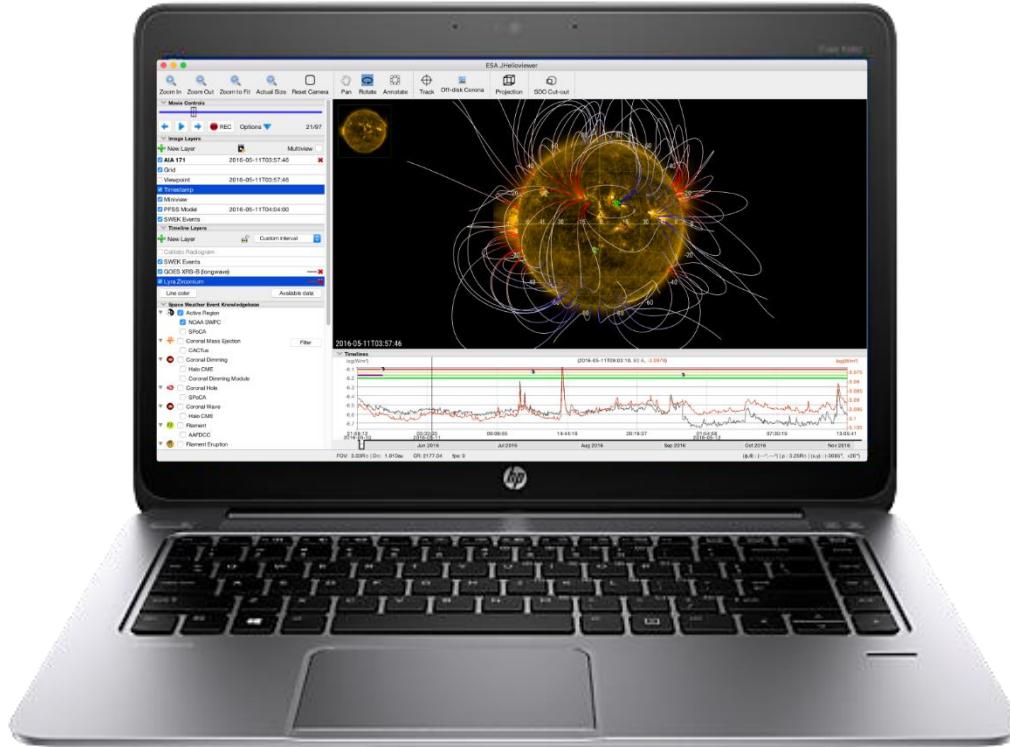
Sensors 2/3



- **Spacebased sensors**
 - GOES
 - SDO
 - PROBA2
 - SOHO
 - ACE
 - DSCOVR
 - STEREO

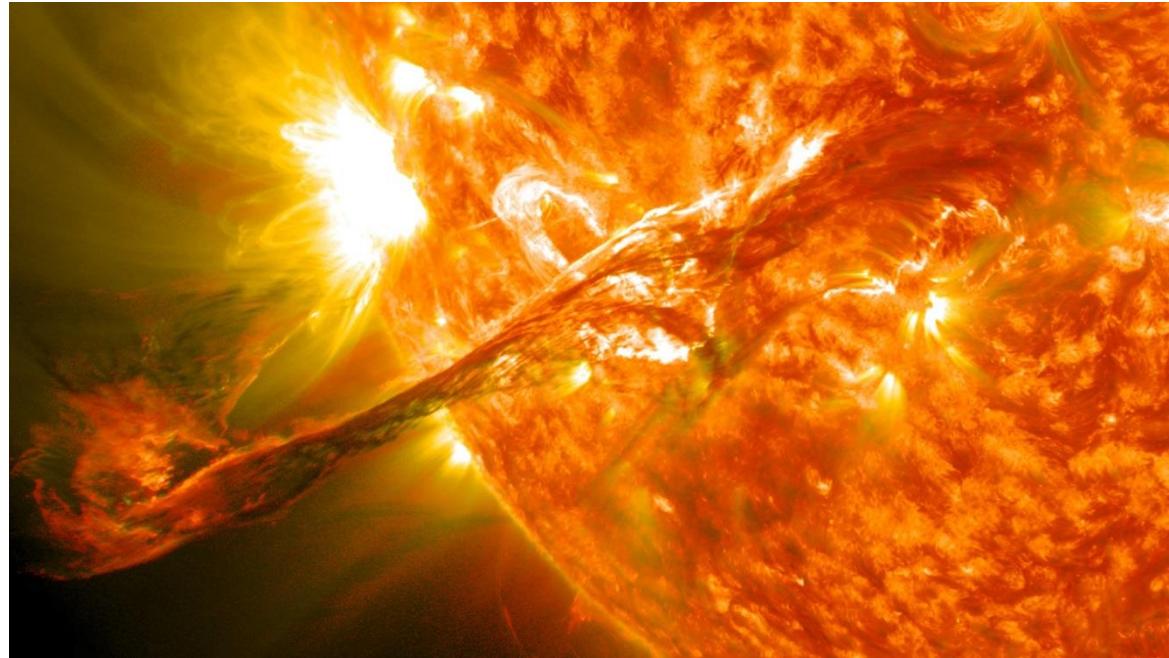


Sensors 3/3



- Tools
- Overviews



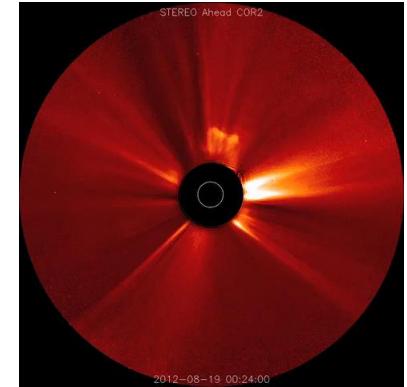
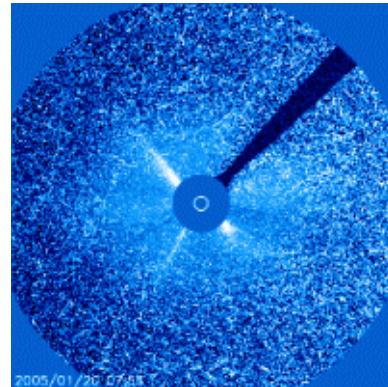
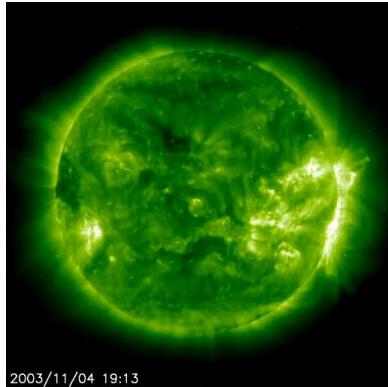
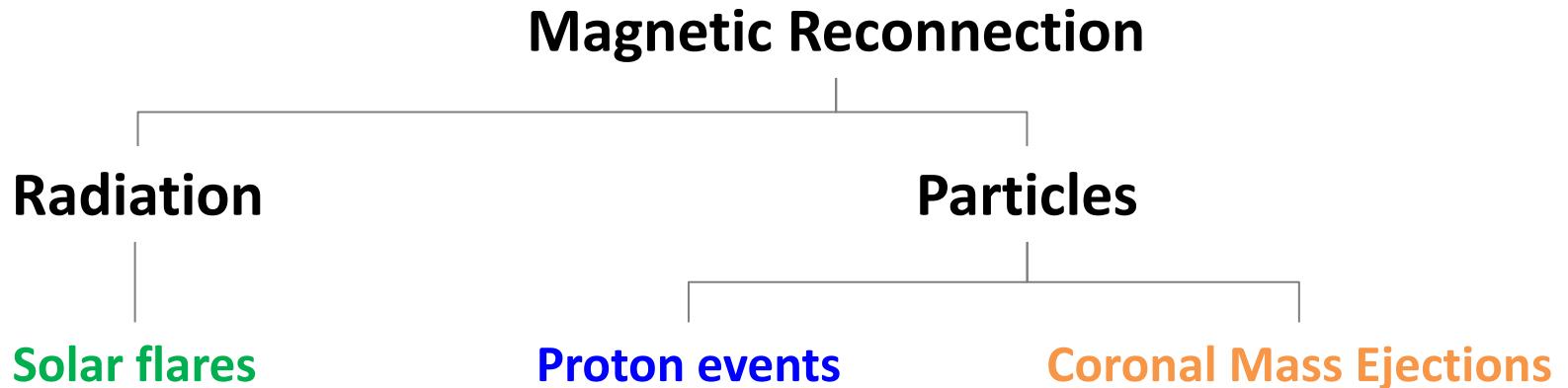


Drivers of space weather – The eruptive Sun

Jan Janssens

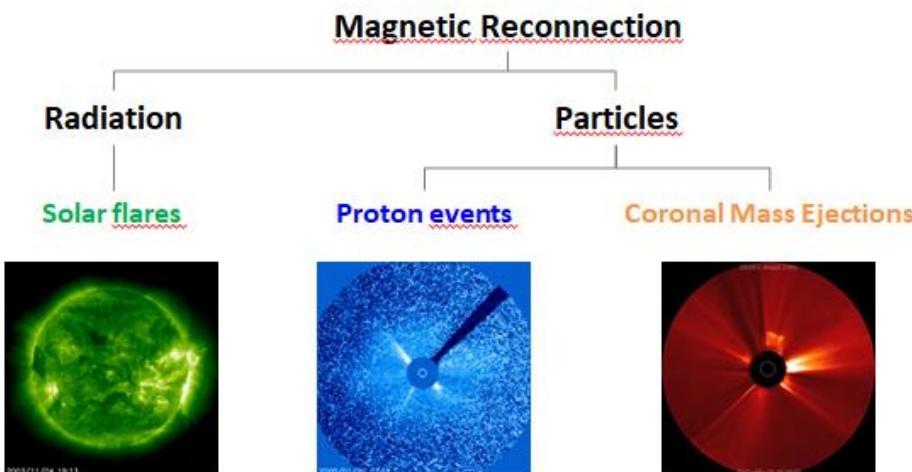


The eruptive Sun 1/3



The eruptive Sun 2/3

- Solar Eruptions



- Solar flares**

- Standard model
 - Outlook & Features
- Classification
 - H α , x-ray, NOAA scale (R)
- Different types
 - Spotless flares, WLF,...
- Radio bursts
- Flare predictions
 - McIntosh, Hale, filaments



The eruptive Sun 3/3

- **Proton events**
 - ≥ 10 MeV proton flux ≥ 10 pfu
 - Classification
 - Impulsive vs. Gradual
 - SEP vs. ESP
 - NOAA Scale (S)
 - Forecasting
 - Strong flare
 - Wide and fast CME
 - Western solar hemisphere
- **Coronal Mass Ejection**
 - Morphology
 - Classification & Terminology
 - SCORE (speed), width/shape,...
 - Stealth, Cannibalism, FTE, Deflection
 - True vs. Plane-of-the-Sky speed
 - Bz
 - ICME





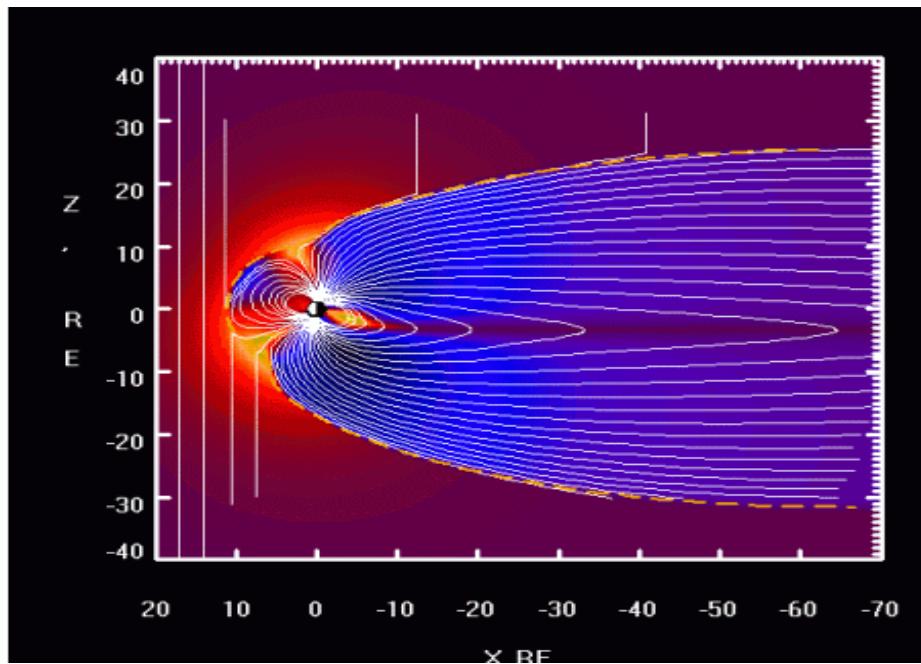
The Magnetosphere

Jan Janssens, Dr Johan De Keyser (BISA)



The Magnetosphere

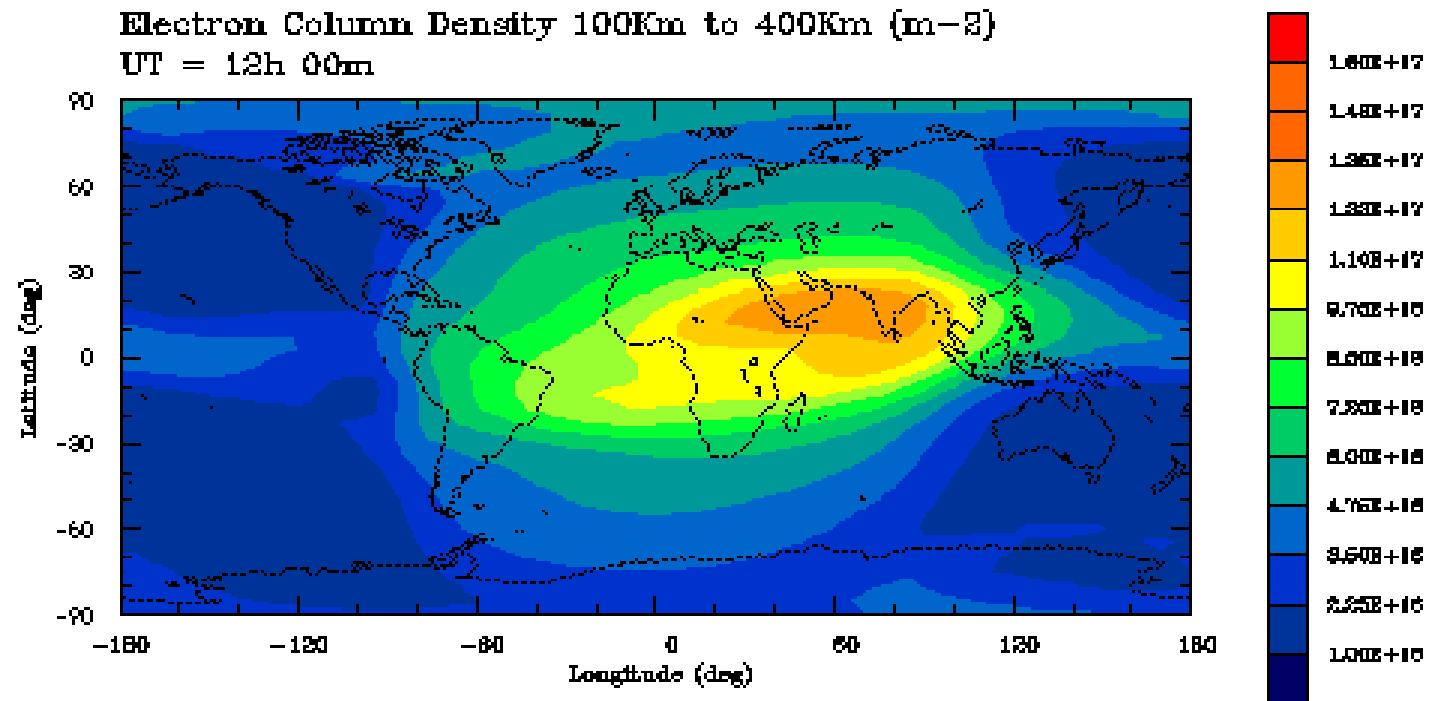
- The geomagnetic field
- Main features
- Geomagnetic (sub)storms
- Measuring magnetic fields
 - Geomagnetic indices
 - Networks
- Miscellaneous



Ionospheric Storm UT = 12h 00m

Electron Column Density 100Km to 400Km (m^{-2})

UT = 12h 00m



A. Burns, T. Killeen and W. Wang

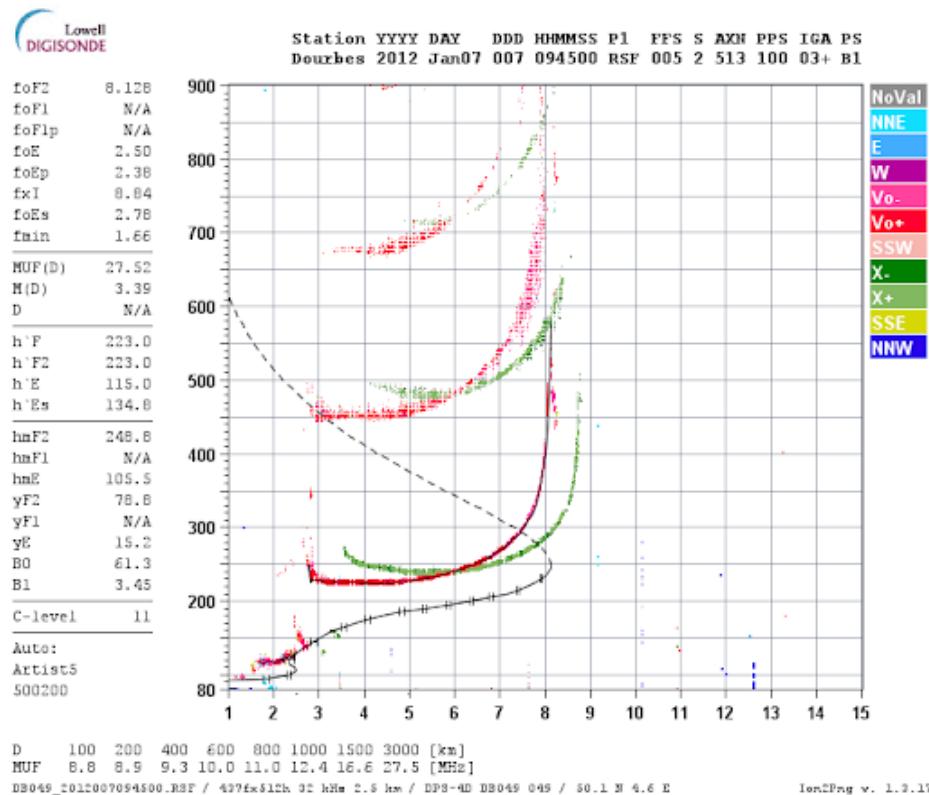
The Ionosphere

Jan Janssens, Dr Nicolas Bergeot, Dr Jean-Marie Chevalier



The ionosphere

- Introduction
- Units and Terminology
 - TEC, foF2, Ionogram, MUF,...
- Main features
 - Coupling magnetosphere
 - EIA, EPB, TID
 - Ionospheric scintillation
- Ionospheric variability
- GNSS
 - What & How
 - Error sources
 - Error remedies
- ROB/RMI GNSS products



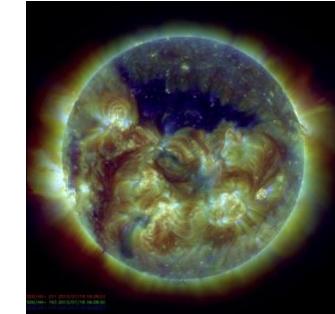
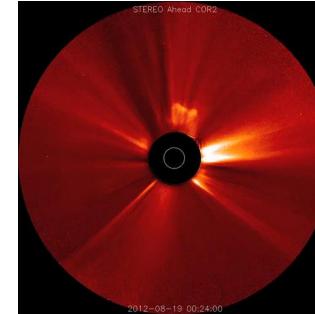
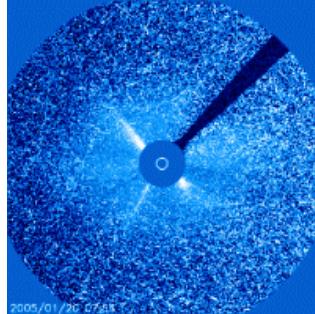
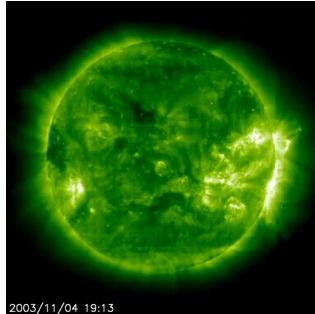
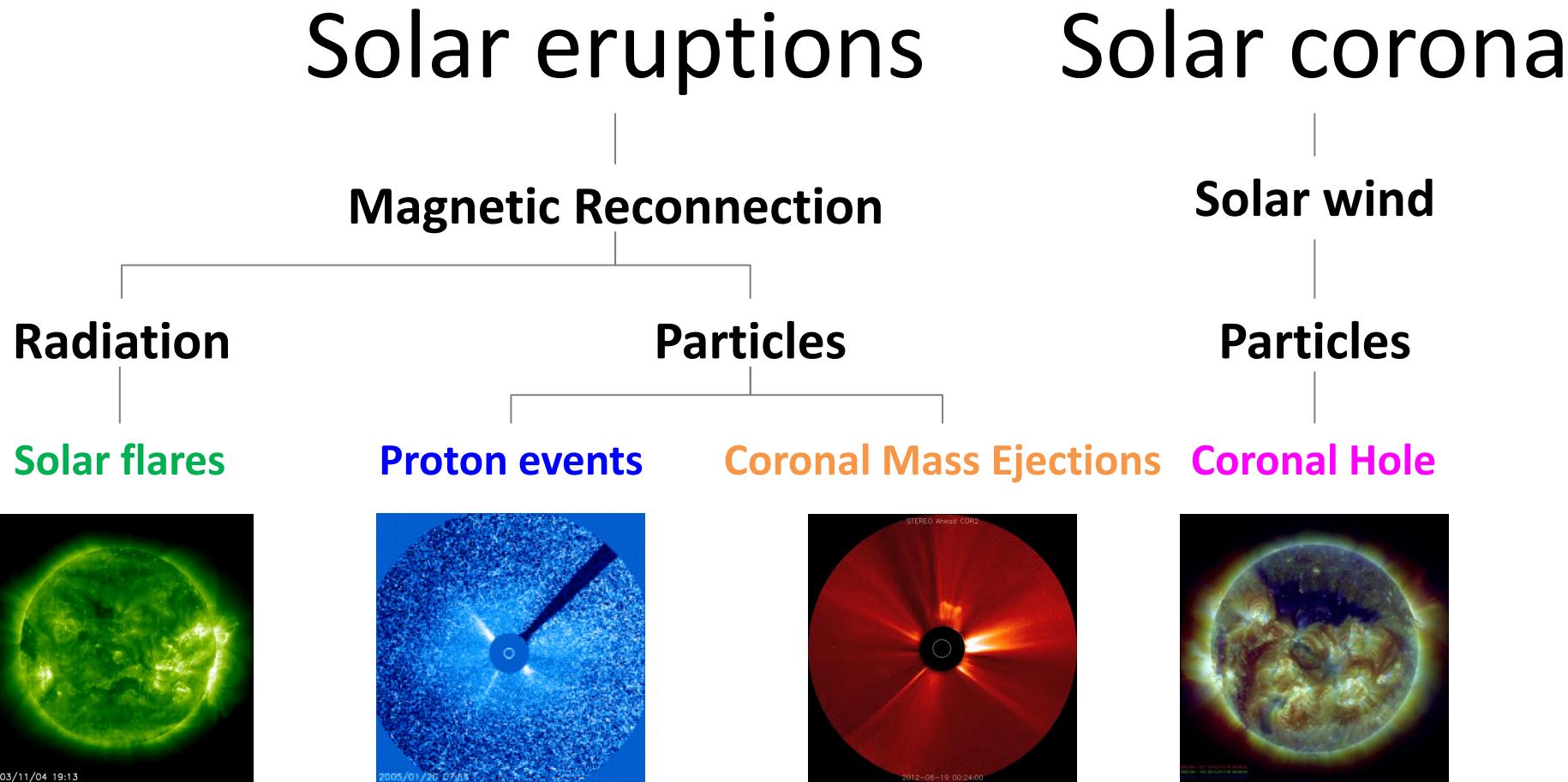


Space weather effects

Jan Janssens



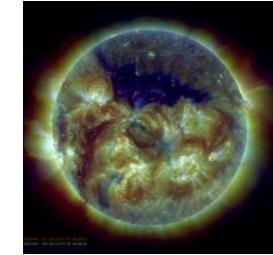
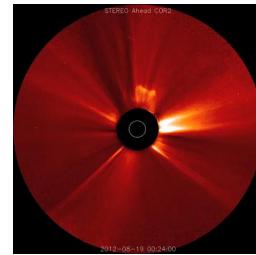
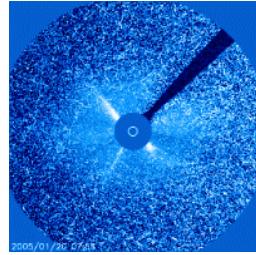
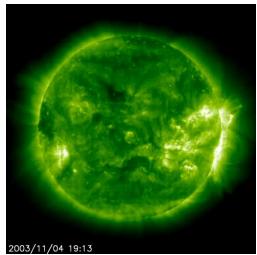
Drivers of disturbed space weather



Disturbed Space weather

Causes

Solar flares Proton events Coronal Mass Ejections Coronal Holes



	Solar flares	Proton events	Coronal Mass Ejections	Coronal Holes
Arrival	Immediately	15 min to a few hours	20 to 72+ hours	2 to 4 days
NOAA scales	R1 (minor) => R5 (extreme)	S1 (minor) => S5 (extreme)		G1 (minor) => G5 (extreme)
Parameter	M1 => \geq X20	Pfu ($>10\text{MeV}$): 10 => 10^5		Kp = 5 => Kp = 9
Duration	Minutes to hours	Hours to days		Days
Protection	Earth's atmosphere	Earth's magnetic field		Earth's magnetic field

Effects

Radio communications	Satellites	Satellites
Radar interference	Astronauts & Airplanes	Aurora
	Communication/Navigation	Communication/Navigation
	Ozone	Electrical Currents (GIC)

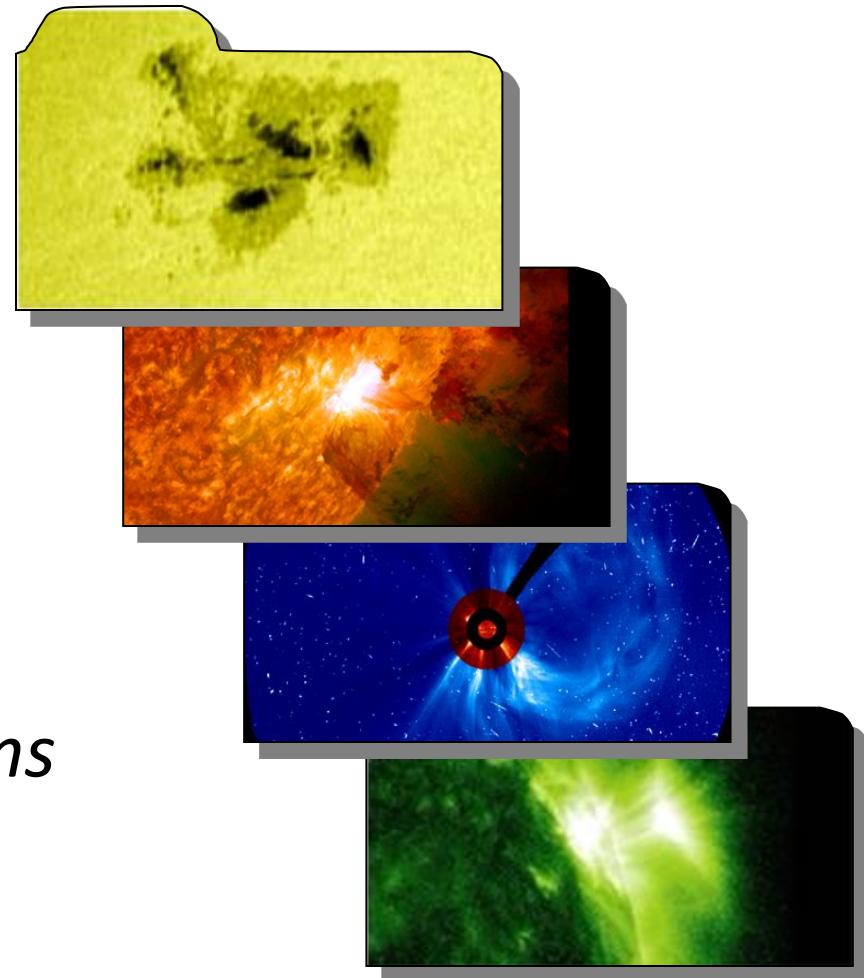
Space Weather effects (SWx effects)

- *Introduction*
- *SWx effects from*
 - *Solar flares*
 - *Proton events*
 - *ICMEs*
 - *Coronal holes*
- ***Historical solar storms***
- ***SC24 solar storms***



Space Weather effects (SWx effects)

- *Introduction*
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- *Historical solar storms*
- ***SC24 solar storms***





Space Weather into practice – SIDC/RWC & URSlgram

Jan Janssens



SIDC/RWC & URSlgram

- SIDC/RWC
- URSlgram
 - Overview features
- SWx alerts
- Exercises

:Issued: 2014 Apr 17 1325 UTC
:Product: documentation at <http://www.sidc.be/products/tot>
#-----#
DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
#-----#
SIDC URSlGRAM 40417
SIDC SOLAR BULLETIN 17 Apr 2014, 1304UT

SIDC FORECAST (valid from 1230UT, 17 Apr 2014 until 19 Apr 2014)
SOLAR FLARES : Active (M-class flares expected, probability >=50%)
GEOMAGNETISM : Quiet (A<20 and K<4)
SOLAR PROTONS : Quiet

PREDICTIONS FOR 17 Apr 2014 10CM FLUX: 180 / AP: 013
PREDICTIONS FOR 18 Apr 2014 10CM FLUX: 184 / AP: 007
PREDICTIONS FOR 19 Apr 2014 10CM FLUX: 188 / AP: 005

COMMENT: Eleven sunspot groups were reported by NOAA today. NOAA ARs 2035,2036, and 2037 (Catania numbers 24, 25, and 26 respectively) maintain the beta-gamma configuration of the photospheric magnetic field. The strongest flare of the past 24 hours was the M1.0 flare peaking at 19:59 UT yesterday in the NOAA AR 2035 (Catania number 24). The flare was associated with an EIT wave and a weak coronal dimming, but the associated CME was narrow and is not expected to arrive at the Earth.

We expect further flaring activity on the 3-level, especially in the NOAA ARs 2035 and 2037 (Catania numbers 24 and 26 respectively) as well as in the NOAA AR 2042 (no Catania number yet) that yesterday appeared from behind the east solar limb, with a good chance for an M-class event.

Since yesterday evening the Earth is situated inside a solar wind structure with an elevated interplanetary magnetic field magnitude (occasionally up to 10 nT). It may be a weak ICME or the compression region on the flank of an ICME that missed the Earth. The solar origin of this structure is not clear. The north-south magnetic field component Bz was not strong, so no significant geomagnetic disturbance resulted (K index stayed below 4). Currently the solar wind speed is around 380 km/s and the IMF magnitude is around 8 nT.

We expect quiet to unsettled (K index up to 3) geomagnetic conditions, with active geomagnetic conditions (K = 4) possible, but unlikely.

TODAY'S ESTIMATED ISN : 145, BASED ON 17 STATIONS.
99999

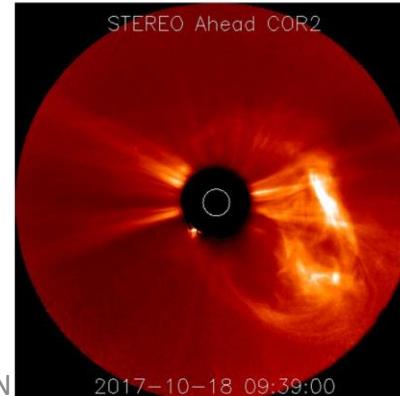
SOLAR INDICES FOR 16 Apr 2014
WOLF NUMBER CATANIA :///
10CM SOLAR FLUX : 184
AK CHAMONIX LA FORET : 012
AK WINGST : 004
ESTIMATED AP : 004
ESTIMATED ISN : 139, BASED ON 29 STATIONS.

NOTICEABLE EVENTS SUMMARY
DAY BEGIN MAX END LOC XRAY OP 10CM Catania/NOAA RADIO_BURST_TYPES
16 1954 1959 2004 S14E09 M1.0 IN 24/2035 II/2
END



10.7cm Radio flux

Exercise: CME classification



- This is a STEREO-A coronagraphic image from a CME on 18 October 2017 at 09:39UT, which had a true speed of about 1080 km/s.

- How would you label this CME?
 - Symmetric - full halo
 - Asymmetric - partial halo
- Where would you rank this CME on the SCORE scale?
 - S – C – O – R – E
- Would you expect this CME to be an FTE?
 - Yes / No



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