

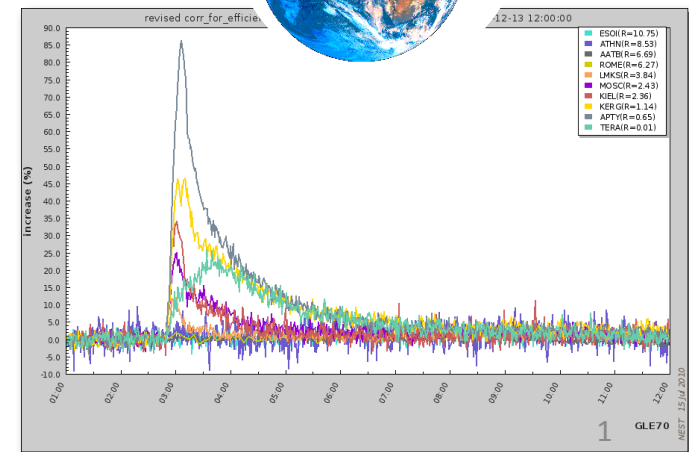
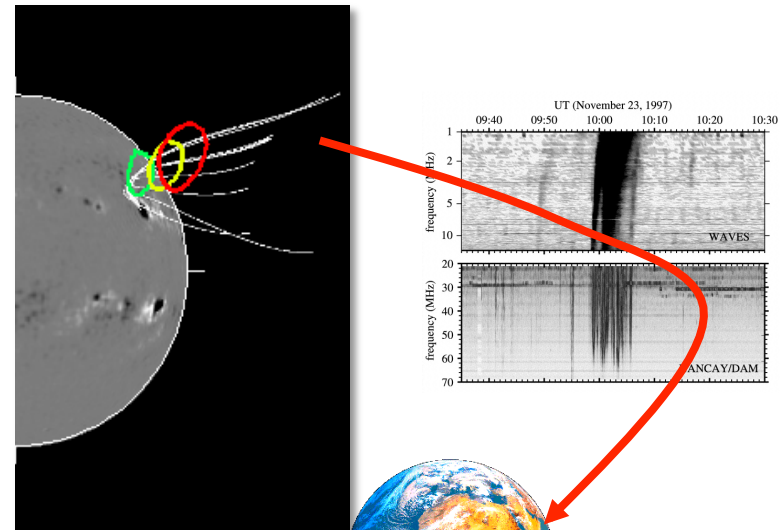
# Radio Monitoring of the Sun (Nançay) and cosmic rays (CERCLE)

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# Solar radio observations and cosmic ray monitoring

## Outline

- 2 observing services at Paris Observatory:
  - Solar-dedicated instruments of the Nançay astronomy station (Radioheliograph, ORFEES spectrograph)
  - Nançay decametric spectrograph (Jupiter, Sun)
  - Cosmic ray monitoring using ground-based detectors (neutron monitors)
- Observations for research and space weather applications

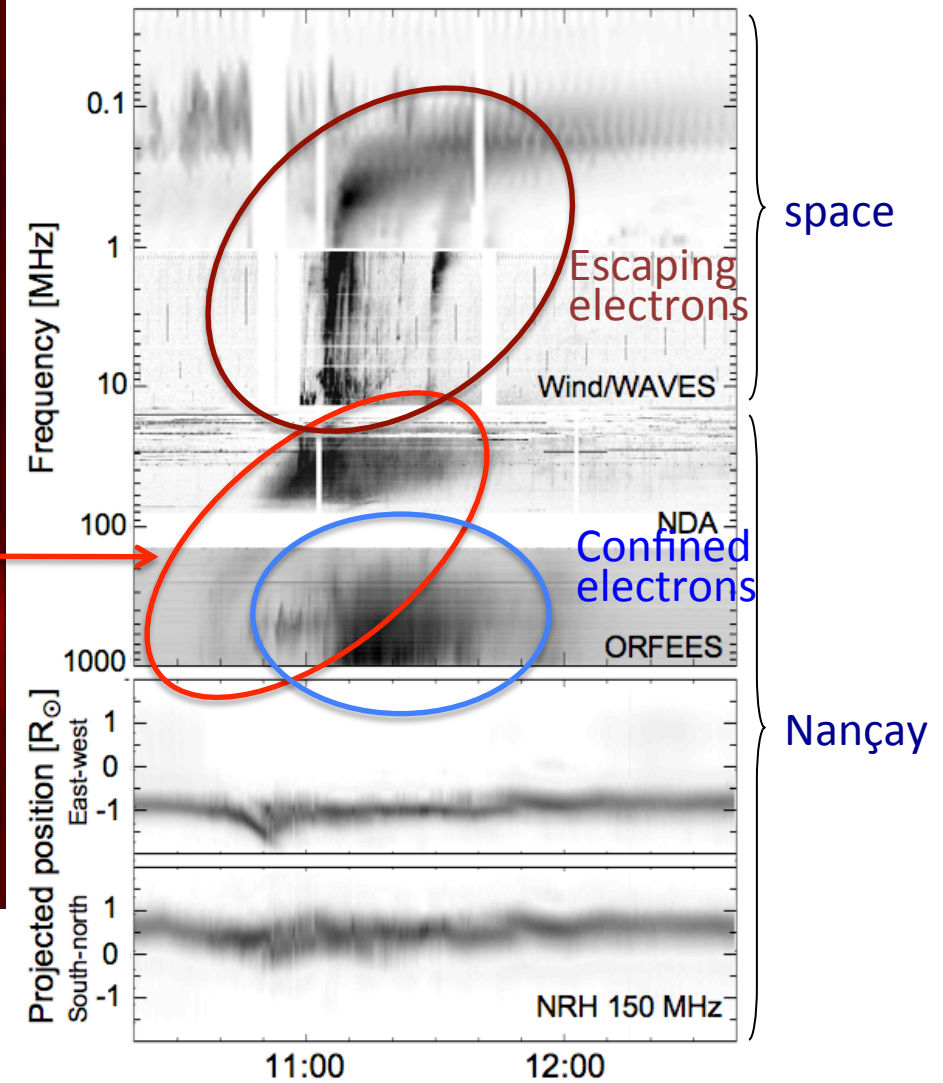
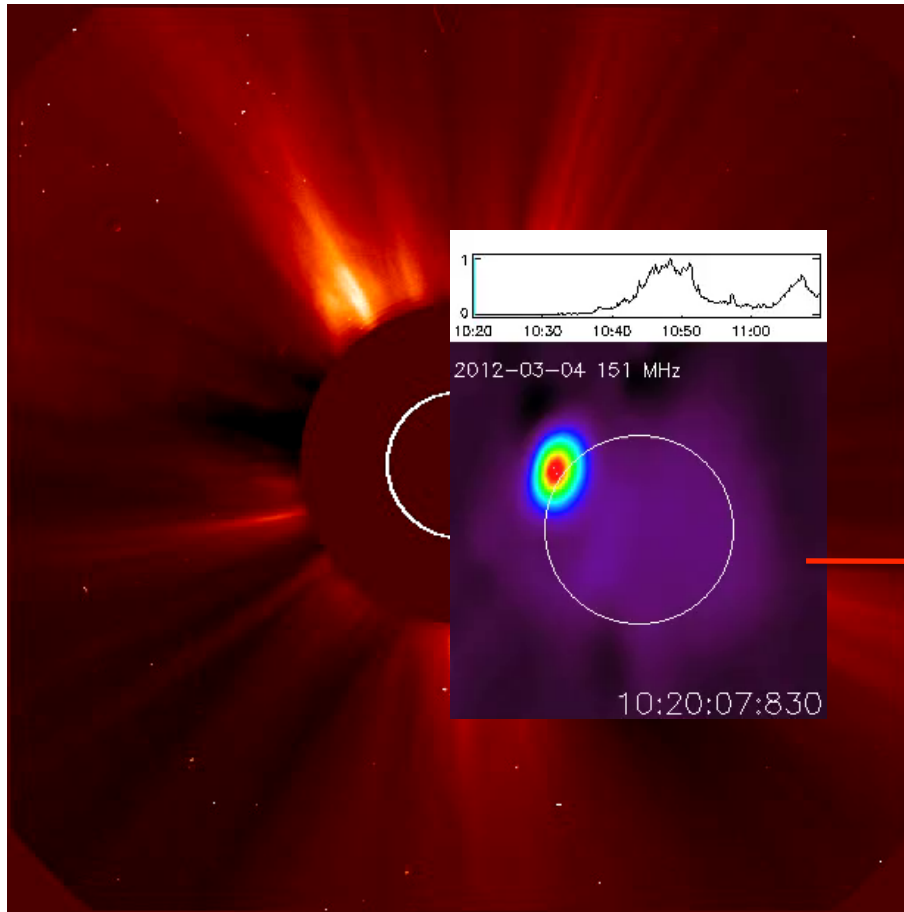
# Solar radio observations at Nançay Observatory

## Spectrography & imaging at dm-m radio waves



- Continuous monitoring, ~8:30-15:30 UT, 1 GHz – 10 MHz (ionosphere permitting)
- A unique combination of complementary instruments
  - **Radioheliograph (NRH)**; imaging up to 10 frequencies, 150-450 MHz),
  - **Spectrography low/middle corona** (<0.5 solar radii; 1 GHz – 130 MHz; **ORFEES**, since 2012)
  - **Spectrography high corona** (10-80 MHz; **Decametre Array NDA**)

# NRH, NDA, ORFEES, Wind/WAVES Eruptive activity



- Solar radio emission related with a CME
- Electron (particle) acceleration in the corona
- Electron (particle) escape to IP space

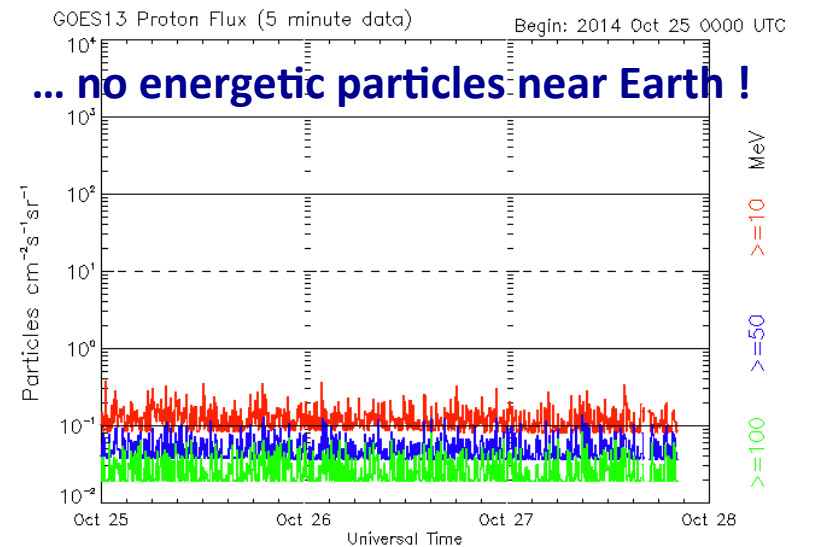
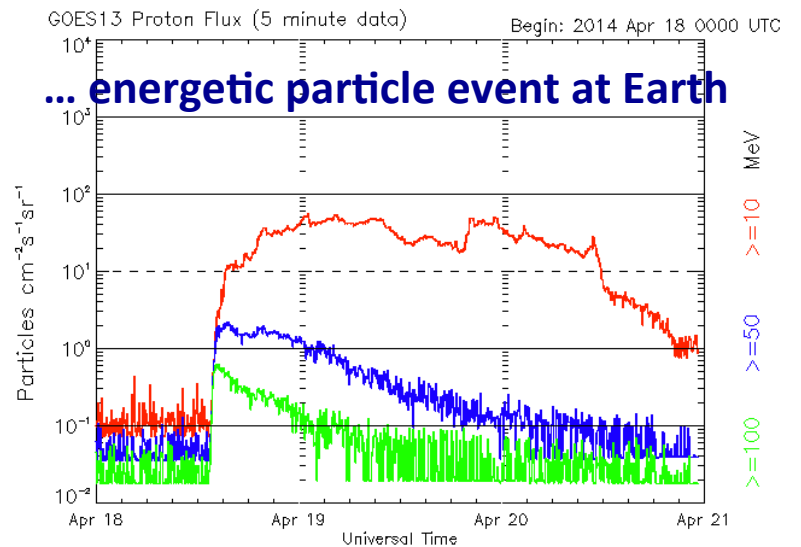
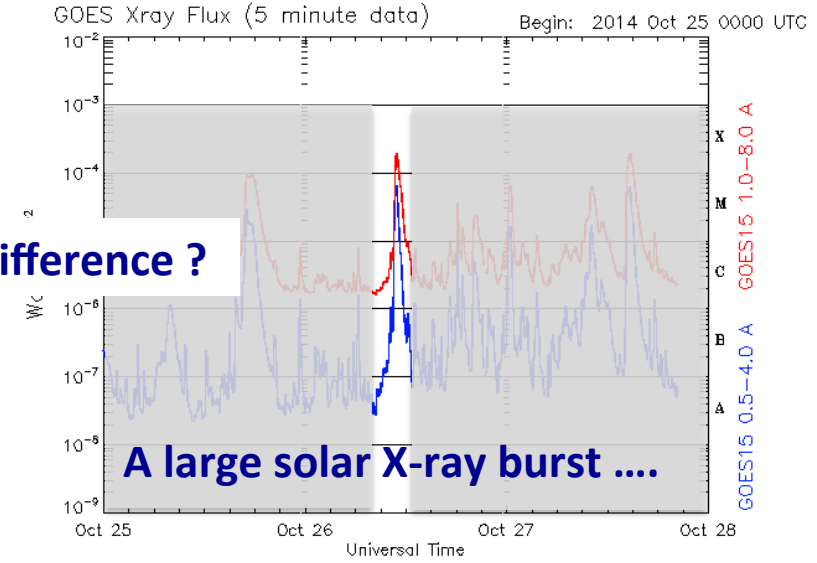
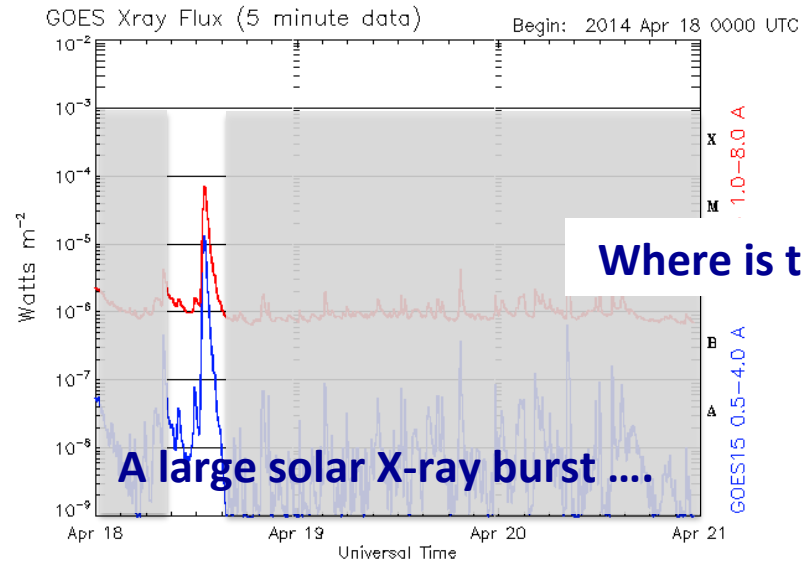
2012 March 04



# Radio astronomy and space weather

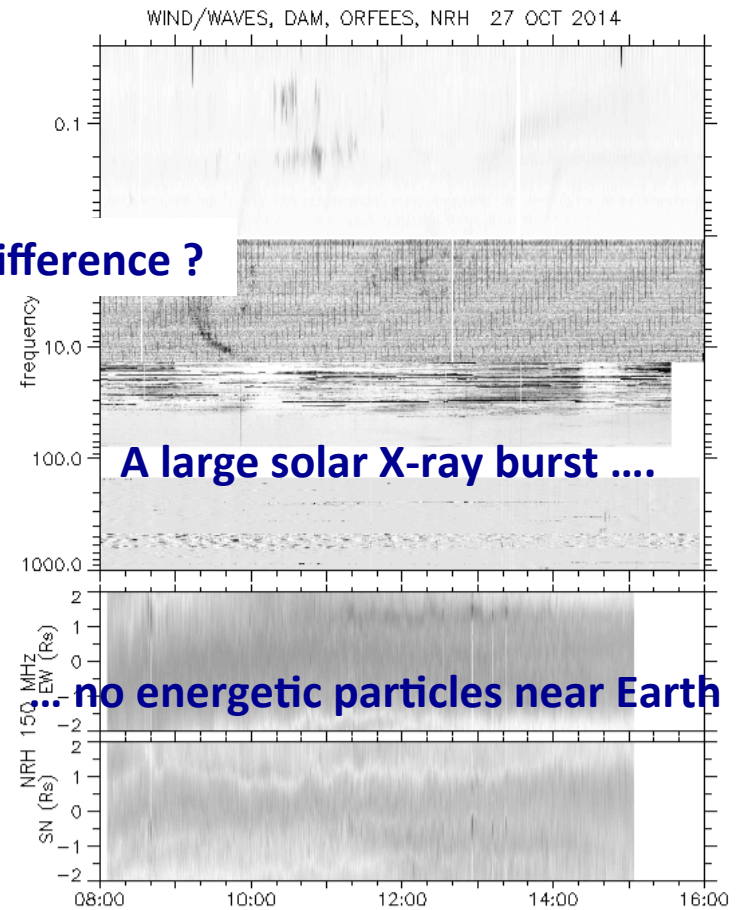
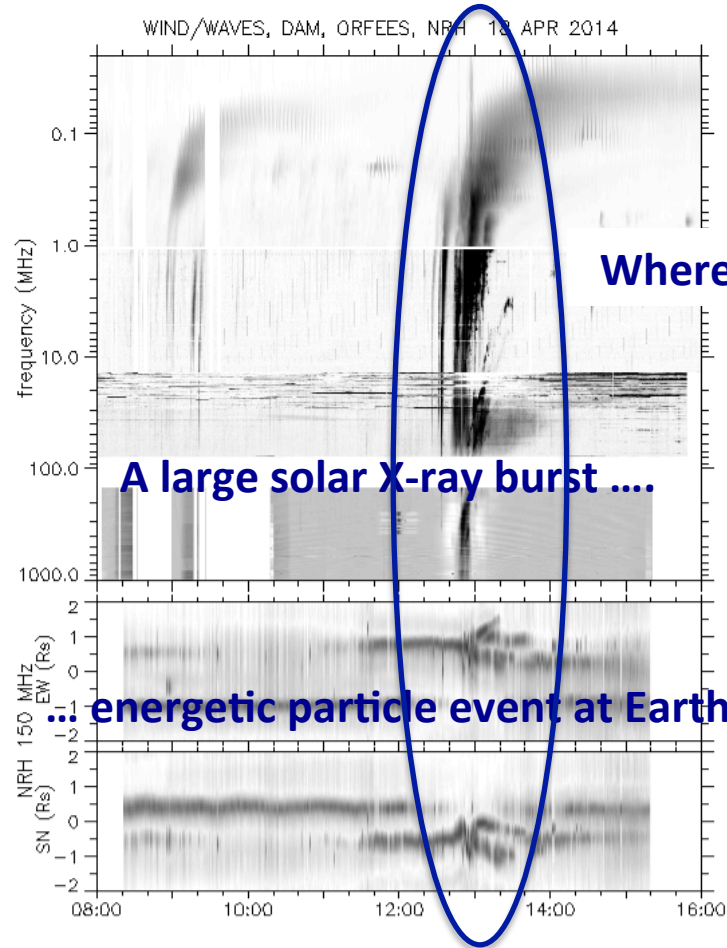
## Solar energetic particles

<http://www.solarmonitor.org>



# Radio astronomy and space weather

## Solar energetic particles



<http://radio-monitoring.obspm.fr/>

- Radio emission at dm-m-wavelengths as an indicator (i) of a CME, (ii) that energetic particles escape from the Sun and may reach the Earth

# Solar radio observations at Nançay Observatory

## Data distribution

- BASS2000 (<http://bass2000.obspm.fr/>); Solar synoptic data (France, Coimbra, Brussels)

Event #	Date	SEP Observations					Solar observations		Comments	
		SOHO/ERNE	SOHO/EPHIN e <sup>+</sup>	ACE/EPAM (0.18-0.31 MeV)	e <sup>-</sup> onset	e <sup>-</sup> PAD	start time	end time		
0	24.09.1997	3:59	1.50E-03	3:12	3:14	3:43	irregular	0:00	3:59	
1	07.10.1997	14:43	8.00E-04	13:15	13:23	13:45	moderate	12:00	15:00	
2	04.11.1997	6:41	1.50E-01	6:16	6:16	6:19	beam	4:50	7:59	

- SEPServer: Particle and EM data for SEP events ([server.sepsserver.eu](http://server.sepsserver.eu))

- Radio-dedicated database, in relation with STEREO/SECCHI (<http://secchirh.obspm.fr/>):

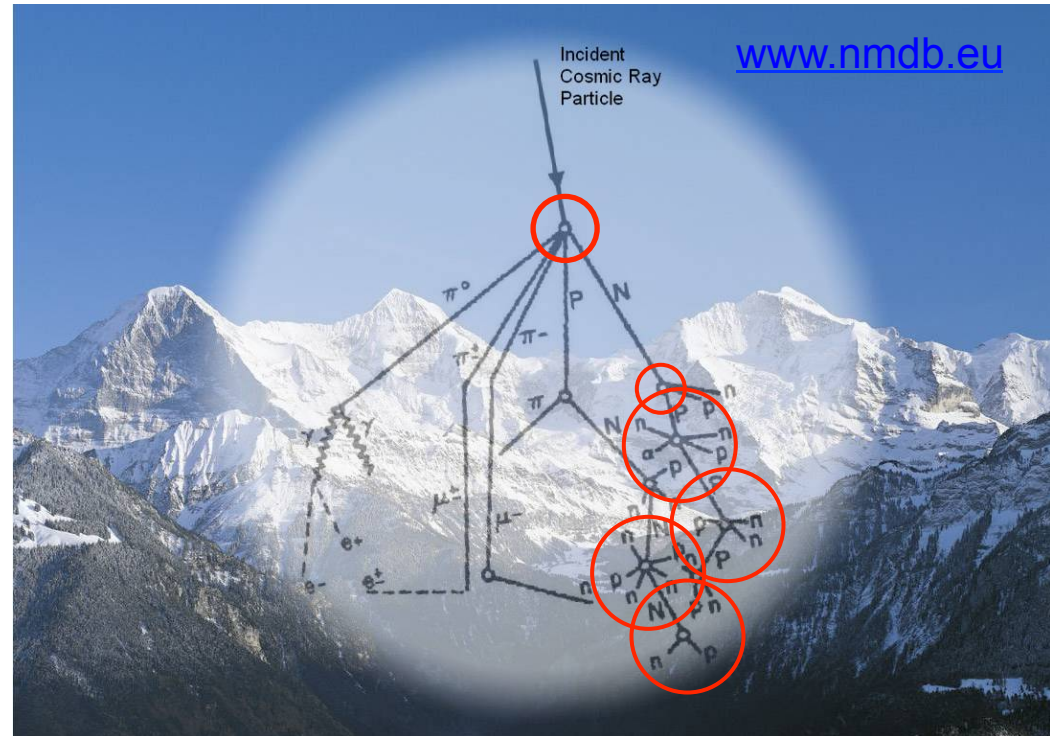
- Spectrographic data Nançay, ARTEMIS (Greece), Humain, Wind/WAVES, STEREO/WAVES)
- NRH overview movies

- Common data base NRH, ORFEES, NDA under construction in Nançay
- Specific real-time products: FEDOME (French Air Force)

# Cosmic rays at Earth

## Atmospheric cascade

- Impact of a HE particle on the Earth's atmosphere (O, N) :
- Successive expulsions of nucleons (protons, neutrons)
- Cascade to ground if  $E(\text{primary}) > 450 \text{ MeV}$



- Detection: neutron monitors

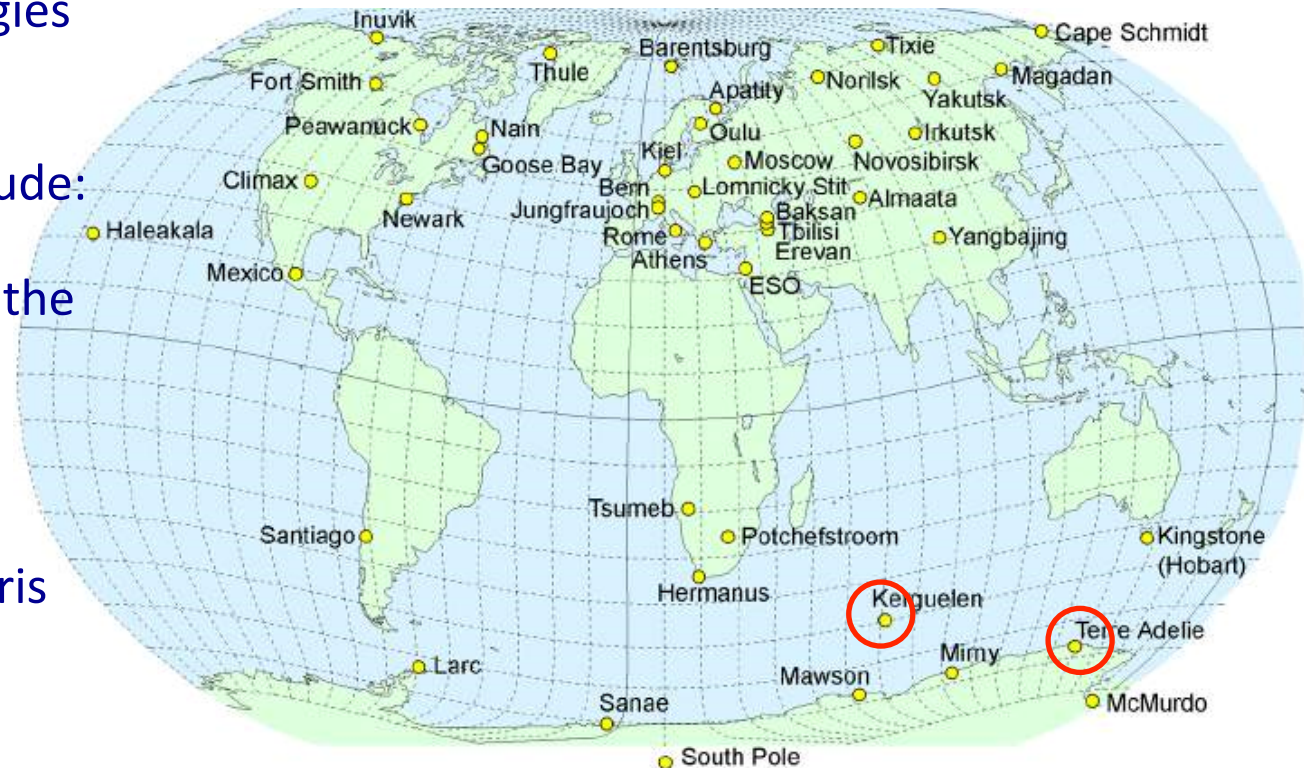




# Cosmic rays at Earth

## The worldwide network of neutron monitors

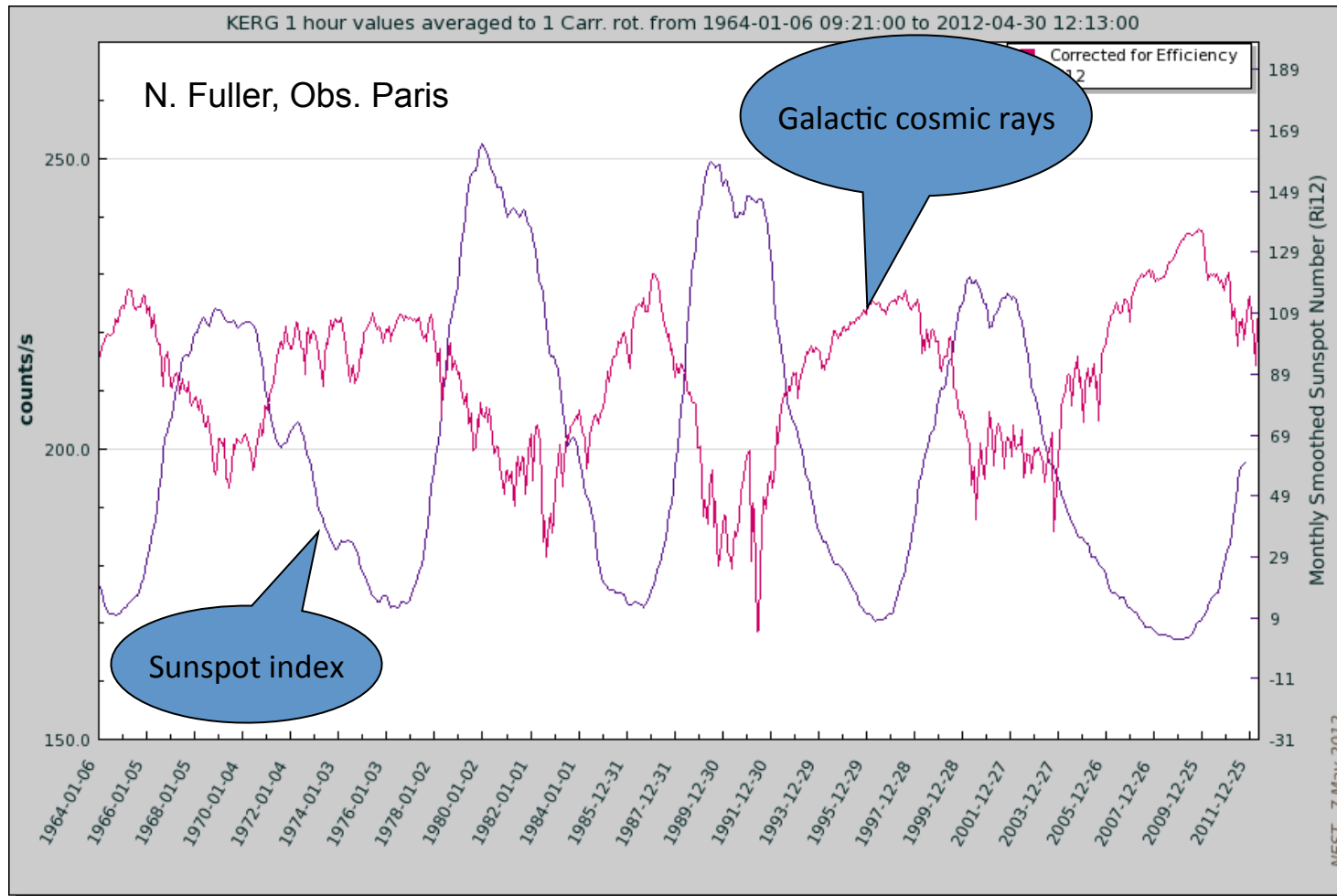
- Distribution in geomagnetic latitude: different cutoff energies => energy spectrum
- Distribution in longitude: different arrival directions outside of the magnetosphere => angular distribution
- France: 2 stations
  - Kerguelen Island
  - Terre Adélie
- Data: [www.nmdb.eu](http://www.nmdb.eu)





# Cosmic rays at Earth

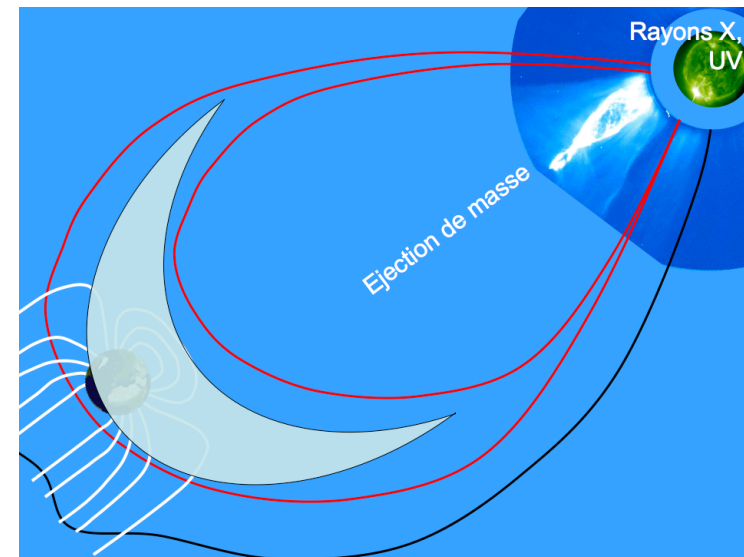
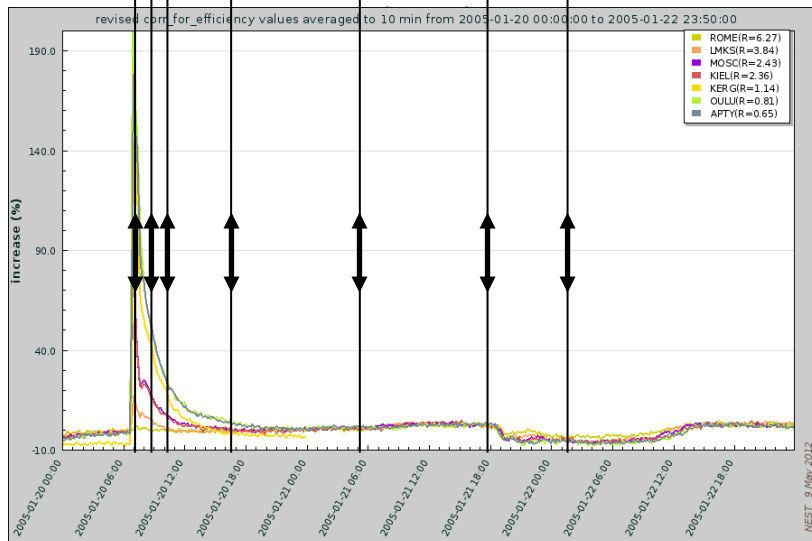
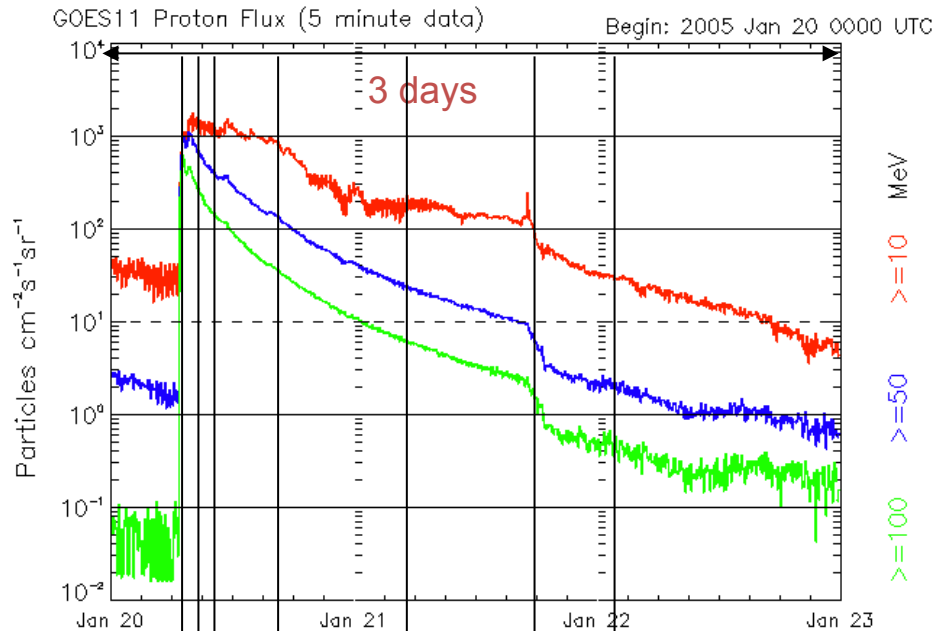
## Modulation by the heliospheric magnetic field



- Modulation due to the cyclic variation of the heliospheric magnetic field

# Cosmic rays at Earth

## Solar energetic particle events and CMEs



- Scenario from Sun to Earth:
  - Flare, particle acceleration
  - CME, particle acceleration
  - ICME, particle acceleration
  - ICME at Earth, particle acceleration and screening of galactic cosmic rays (Forbush decrease)

# Cosmic rays at Earth

## Radiation dose monitoring: civil aircraft

- Legal obligation to monitor radiation doses
- At aircraft altitudes: cosmic rays
  - continuous contribution from galactic cosmic rays (modulated by solar activity)
  - sporadic addition of solar energetic particles
- France: IRSN + Paris Obs. + IPEV
  - ground-based measurements of cosmic rays
  - neutron monitors at Kerguelen Islands (Indian Ocean) and Terre Adélie (Antarctica)

The screenshot shows the SIEVERT PN website. At the top left is the IRSN logo (Institut de Radioprotection et de Sécurité Nucléaire). The main navigation bar includes 'Home', 'Cosmic radiation', and 'Calculate the dose received'. The content area is divided into three columns: a central article titled 'SIEVERTPN' with a world map showing radiation dose distribution, a 'FREQUENTLY ASKED QUESTIONS' section with three questions and answers, and a 'LINKS AND USEFUL INFO' section with a video player. The footer contains logos for IRSN, dgac, IPEV, and Helmholtz Zentrum München, along with a 'Professionals access' button and a footer menu with 'Legal information', 'Glossary', 'Sitemap', and 'Contact'.

The screenshot shows the 'Calculate the dose received' form. It is divided into two main sections: 'DEPARTURE' and 'ARRIVAL'. The 'DEPARTURE' section has a dropdown for 'Country' set to 'SOUTH AFRICAN REP', a dropdown for 'City' set to 'JOHANNESBURG', a text input for 'Date (local)' set to '21/01/2005', and a time input for 'Time (local)' set to '00:00'. The 'ARRIVAL' section has a dropdown for 'Country' set to 'NEW ZEALAND', a dropdown for 'City' set to 'AUCKLAND', a text input for 'Date (local)' set to '21/01/2005', and a time input for 'Time (local)' set to '23:00'. At the bottom, there is a dropdown for 'Type of aircraft' set to 'Subsonique'. The form is titled 'Calculate the dose received' at the top.

[www.sievert-system.org](http://www.sievert-system.org)

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- Observations for research and space weather applications:
  - Solar corona and eruptive activity
  - High-energy particles from the Sun and the Galaxy
  - Space weather services for civil aviation and the French Air Force