

Solar Particle Events and the Influence on Aircrew Doses

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EURADOS Annual Meeting AM2009

Workshop „Cosmic Radiation and Aircrew Exposure“

Braunschweig, 30 January 2009

Selection of recent papers on the topic:

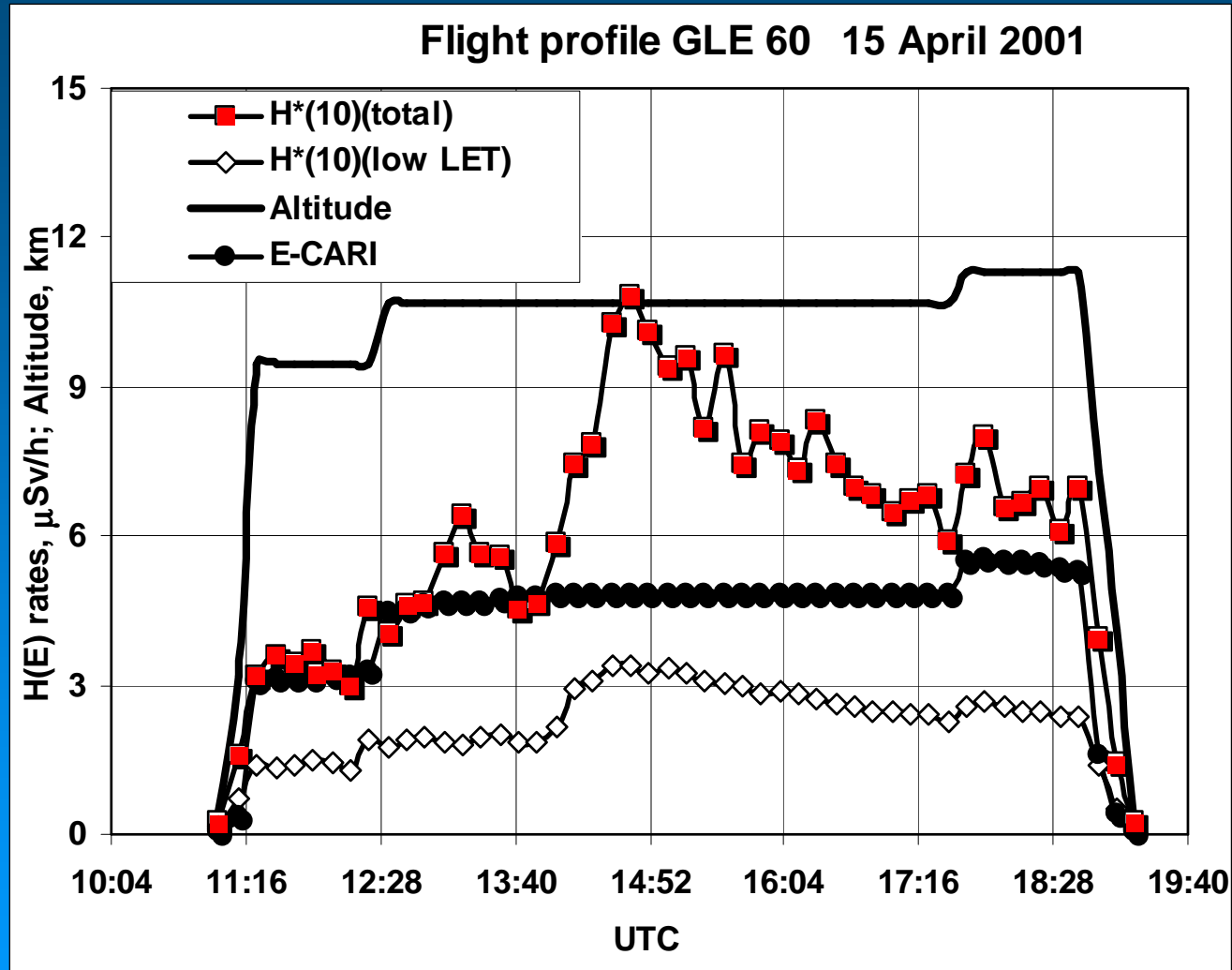
Beck, P., et al. (CONRAD, WP6, Subgroup-B()), *Validation of modelling the radiation exposure due to solar particle events at aircraft altitudes*, Radiation Protection Dosimetry (2008), Vol. 131, No. 1, pp. 51–58 doi:10.1093/rpd/ncn238

Bütikofer, R., et al., *Effective radiation dose for selected intercontinental flights during the GLEs on 20 January 2005 and 13 December 2006*, Proc. 21st European Cosmic Ray Symposium, Košice, Slovakia, 2008

Iles, R. H. A., et al., *The Effect of Solar Particle Events at Aircraft Altitudes*, Proc. Space Weather Workshop, 2001, 17-19 December 2001, ESTEC, Noordwijk, The Netherlands, 2001

Neal, J. S., and L. W. Townsend, *Multiple Solar Particle Event Dose Time Profile Predictions using Bayesian Inference*, Radiation Protection Dosimetry (2005), Vol. 116, No. 1–4, pp. 38–42 doi:10.1093/rpd/nci093

The Phenomenon



LIULIN measurements of GLE 60 during a flight from Prague to New York. The calculation using the code CARI-6 does not include the radiation exposure of the GLE (adapted from Spurny and Dachev, Radiat. Prot. Dosim. **95**, 273–275, 2001).

The Origin

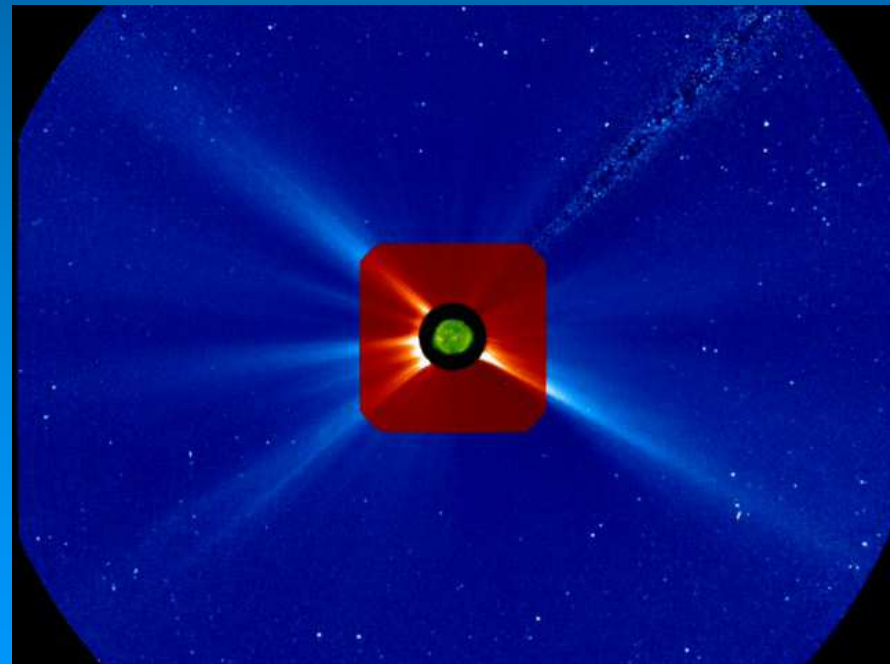
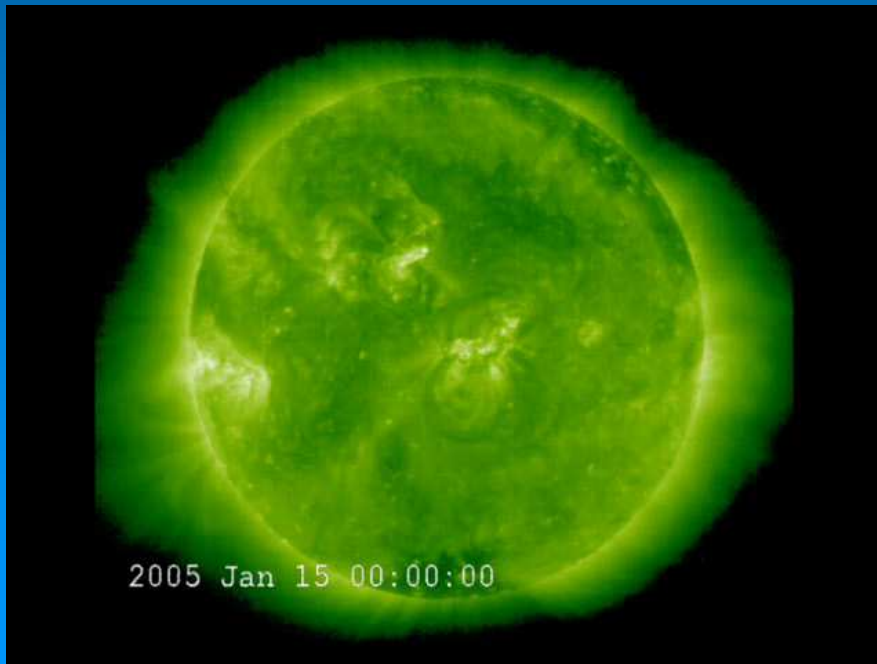
EIT

Solar Flare / Coronal Mass Ejection CME

Example: 20 January 2005

**SOHO Extreme Ultraviolet
Imaging Telescope**

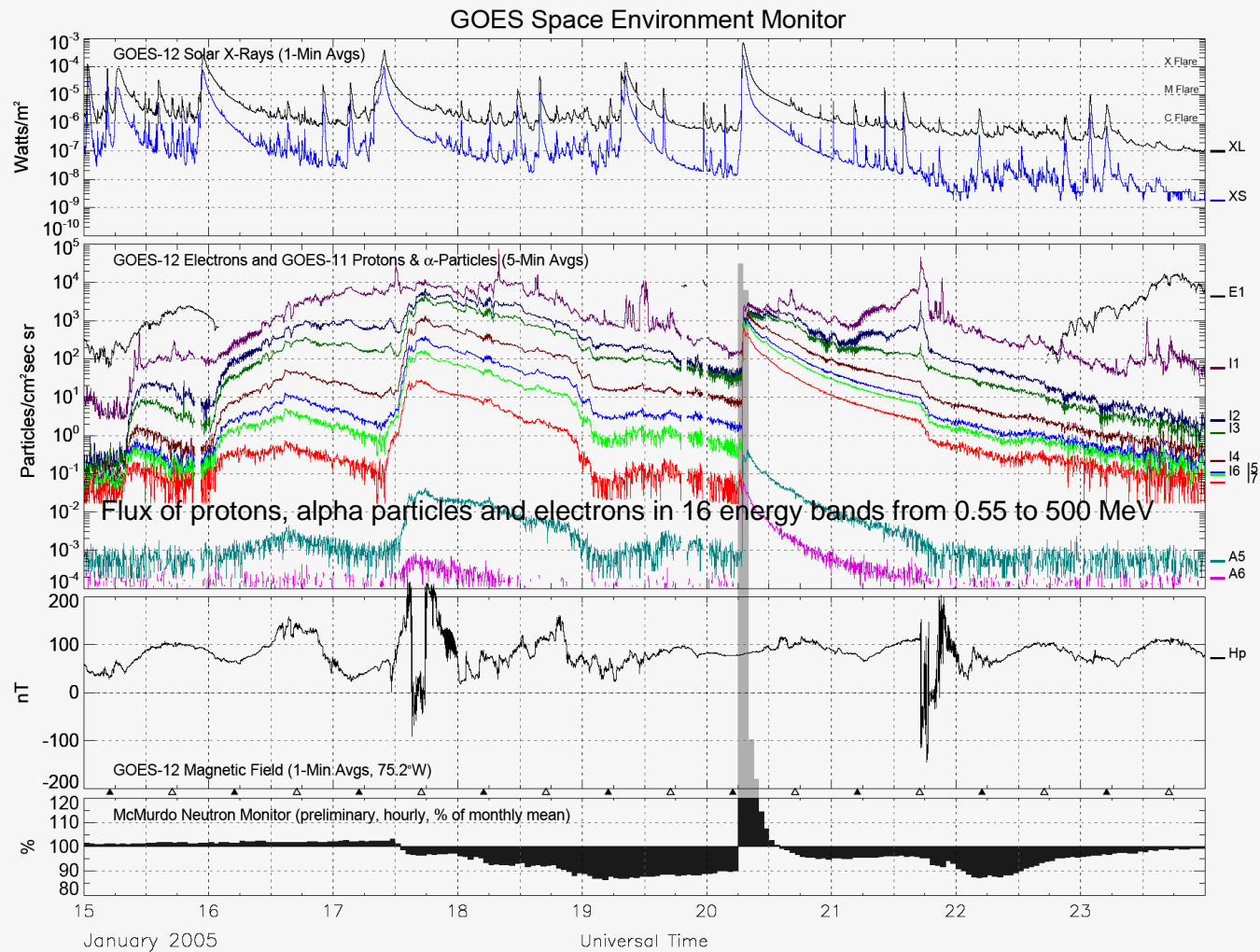
SOHO LASCO Coronagraph



NASA/Goddard Space Flight Center, Scientific Visualization Studio

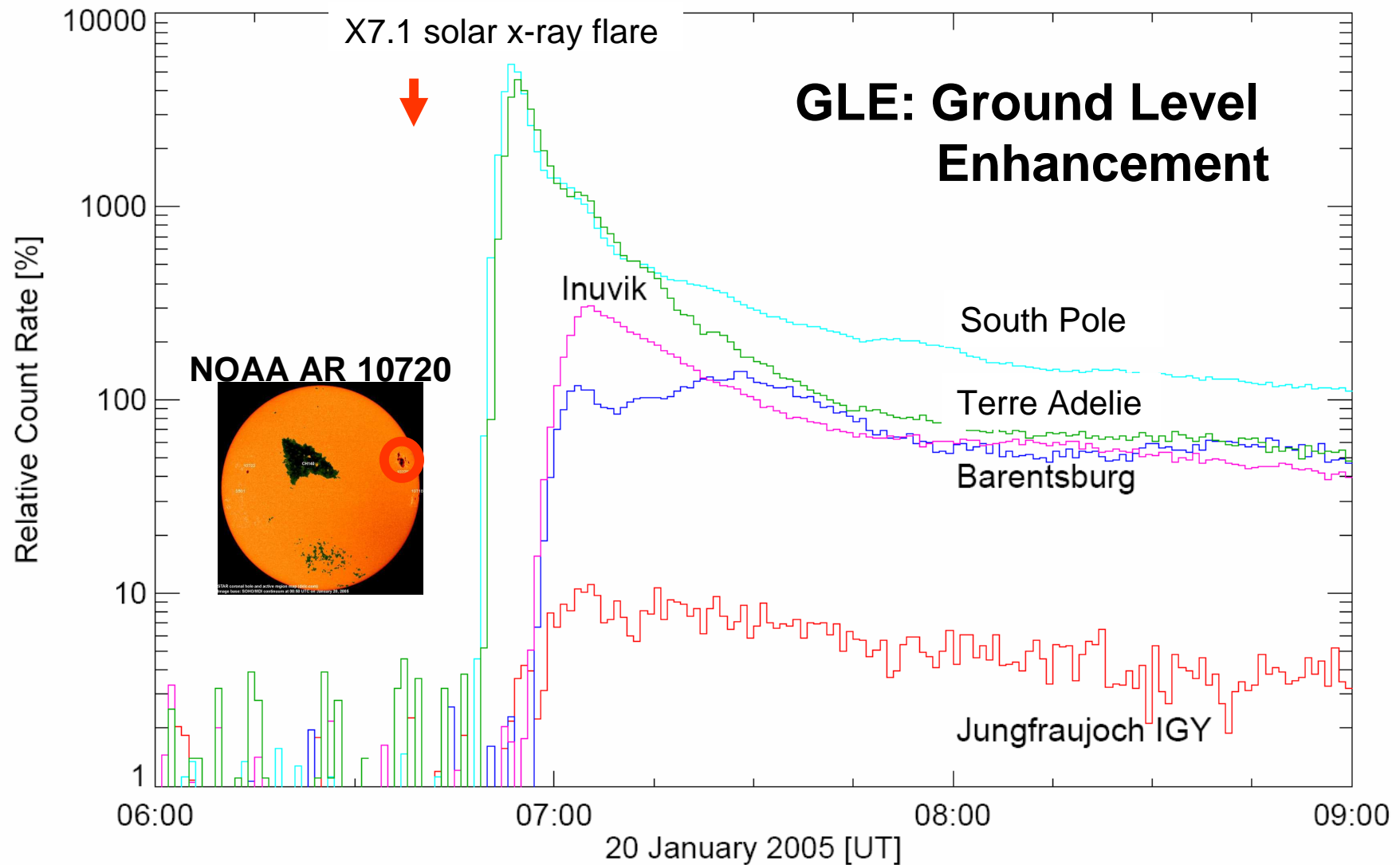
The Manifestation

Example: 20 January 2005



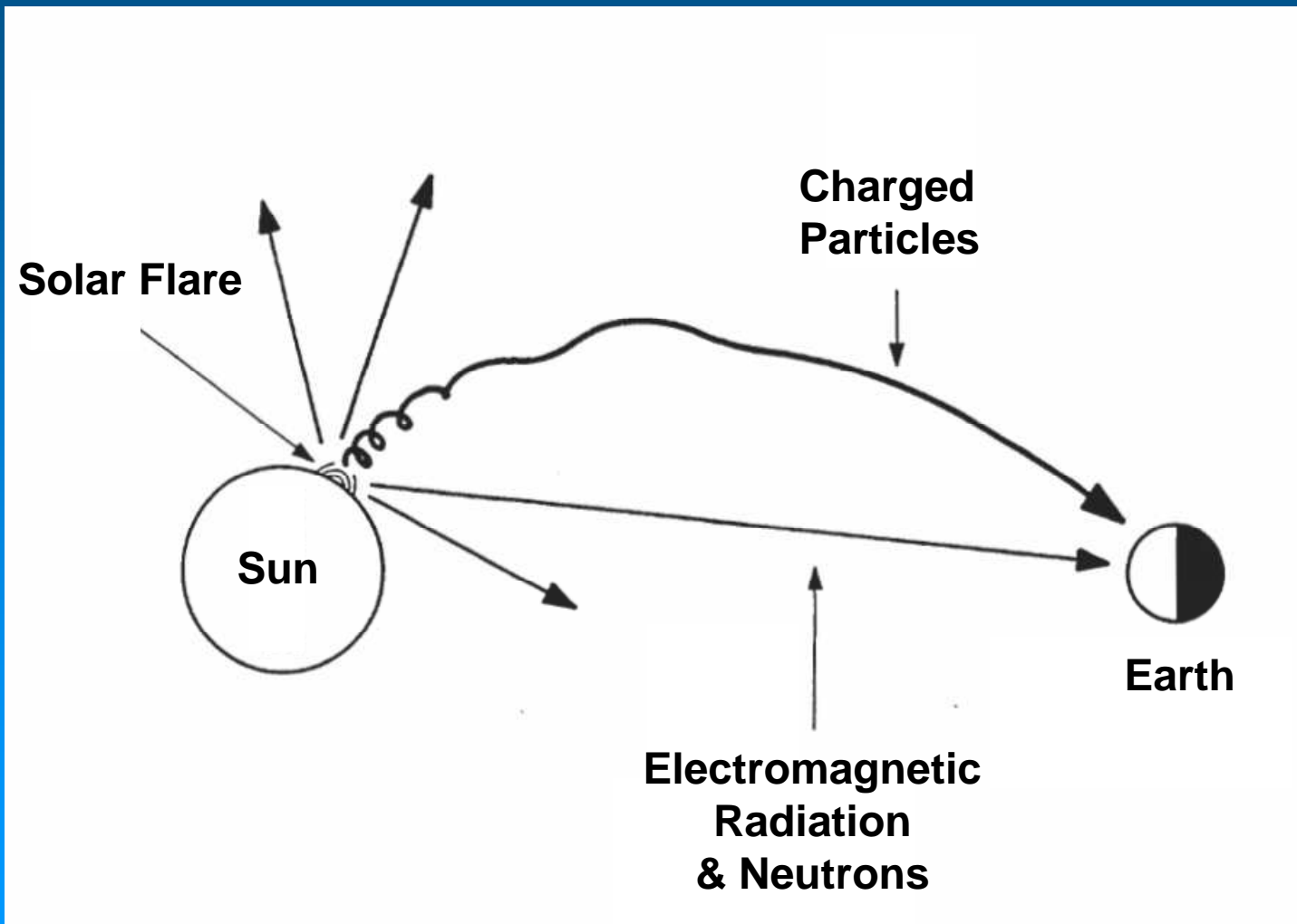
Neutron Monitor Observations

Example: 20 January 2005



Solar Cosmic Rays

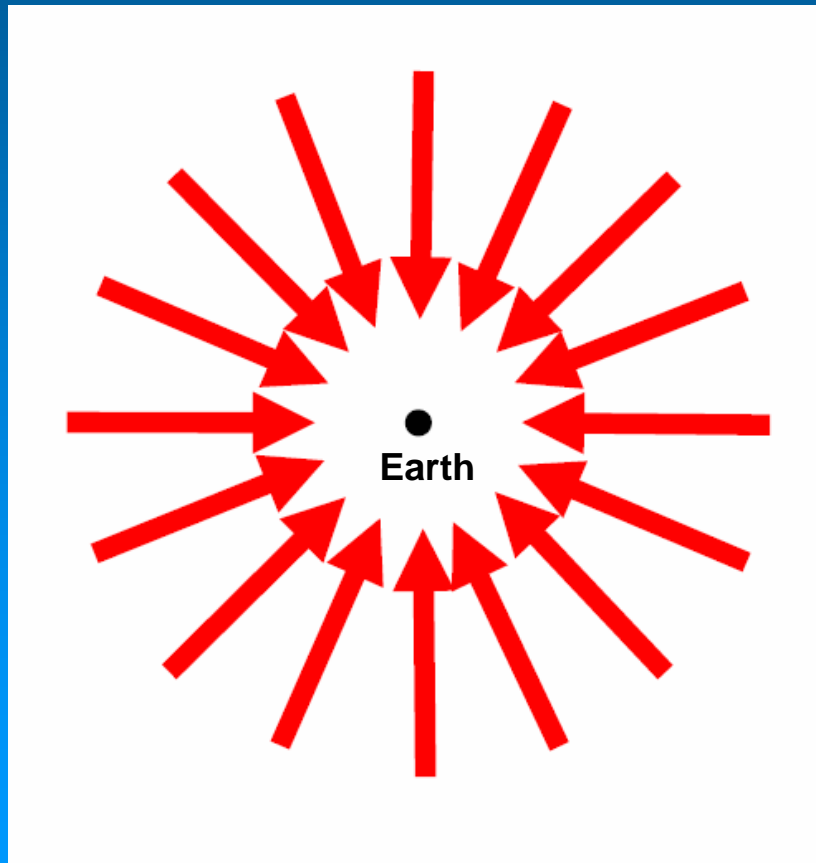
their path from the Sun to the Earth



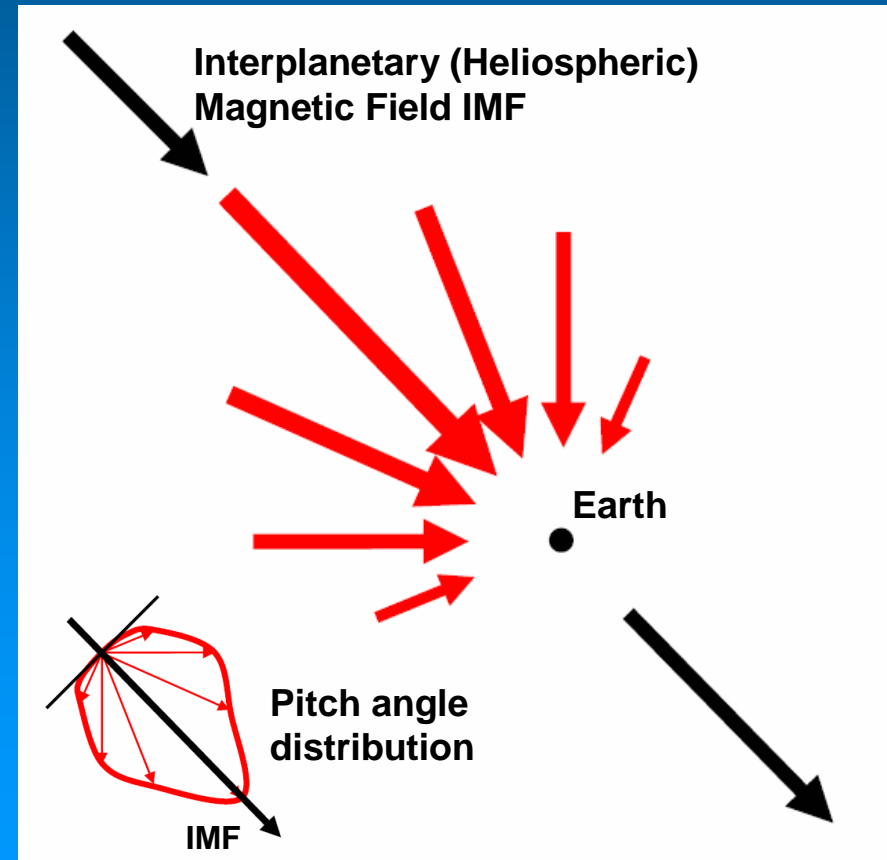
SCR Anisotropy

Example: 20 January 2005

GCR



SCR

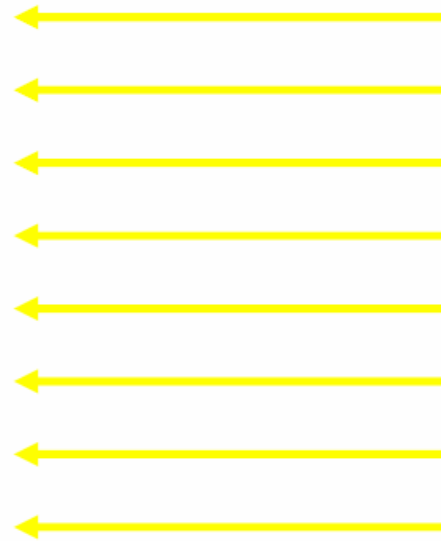
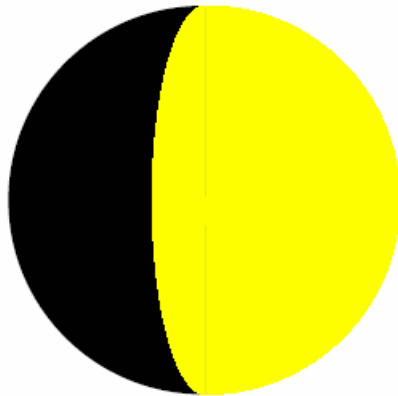


Solar Cosmic Ray Access to Earth

Electromagnetic Radiation

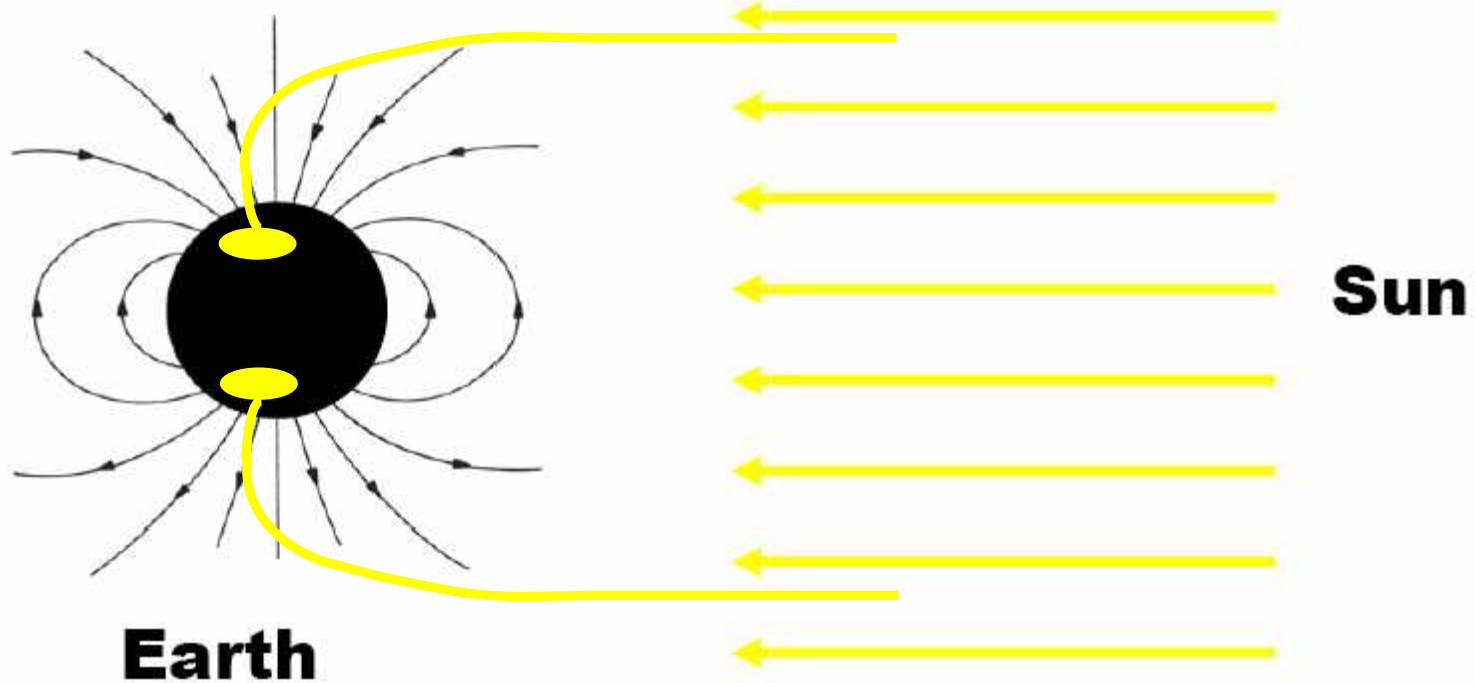
(visible light, radio waves, X- & γ -rays)

Solar Neutrons

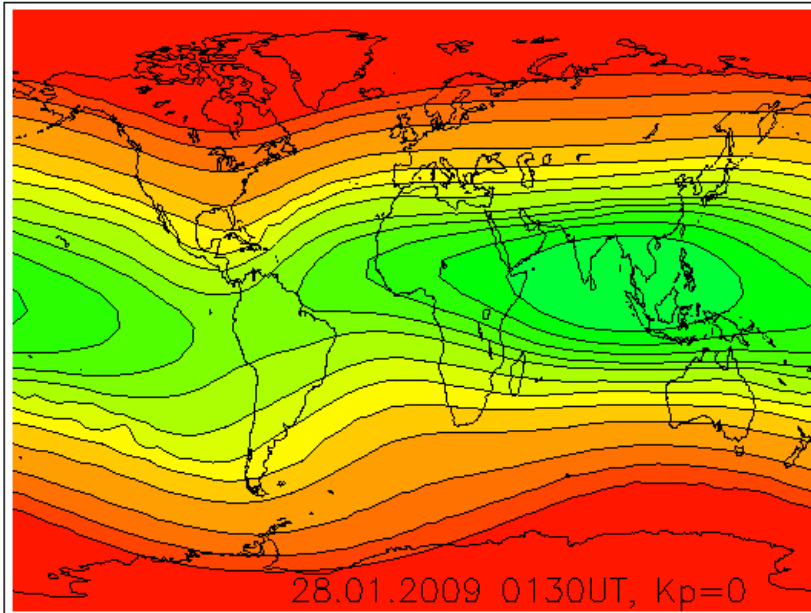


Solar Cosmic Ray Access to Earth

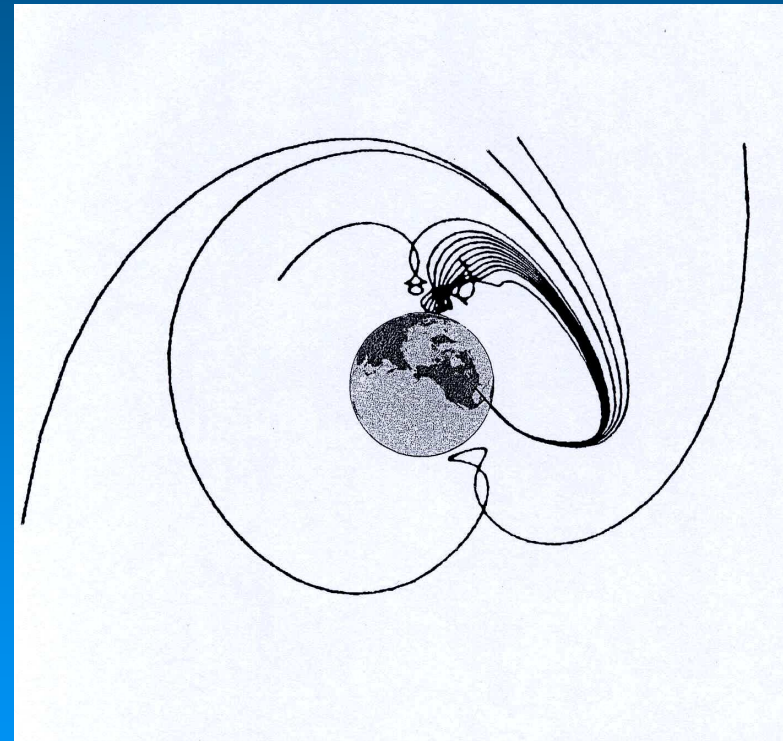
Solar Protons



Geomagnetic Effects: Cutoff Rigidities & Asymptotic Directions



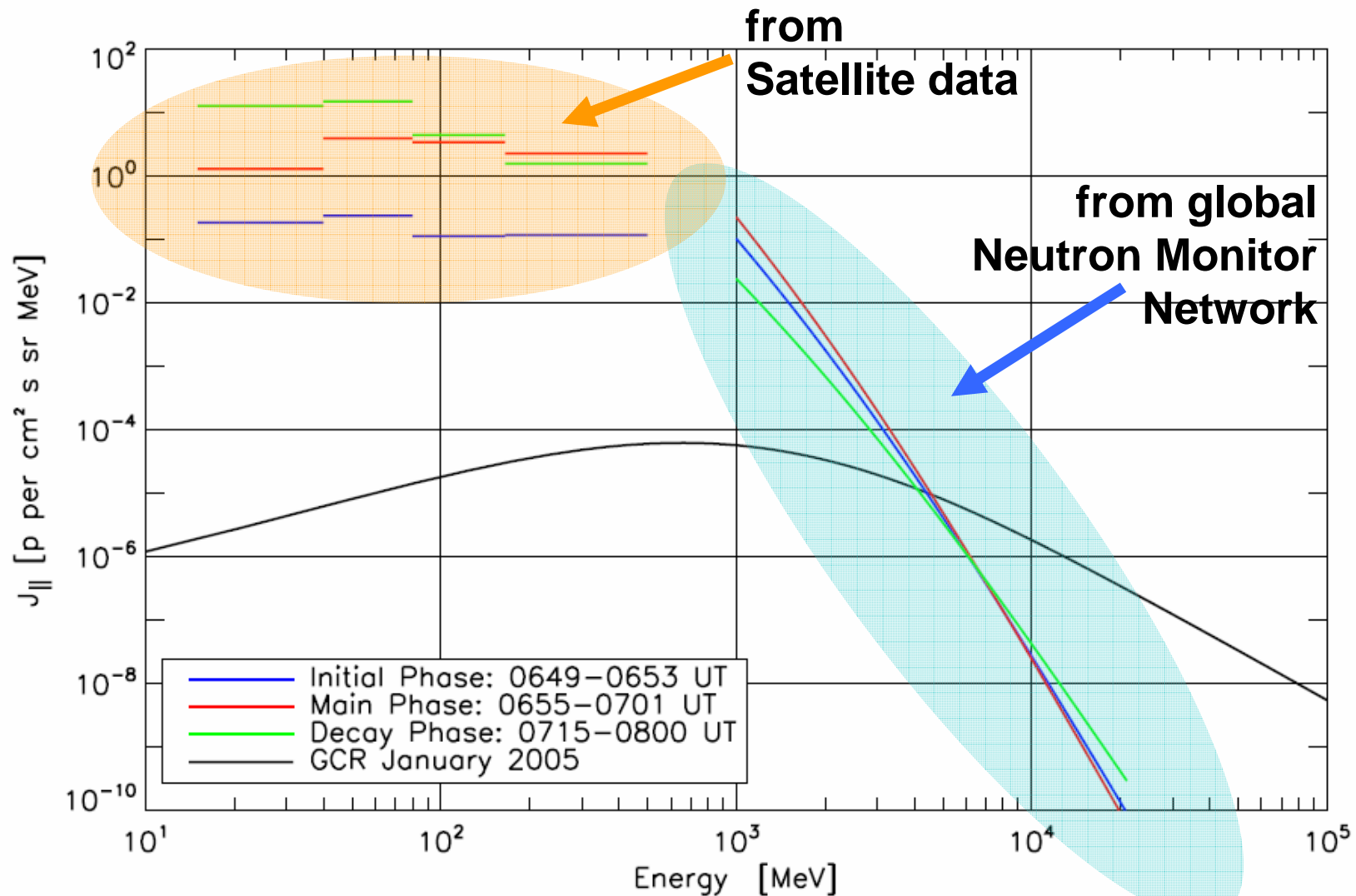
Cutoff Energy / Cutoff Rigidity
in near-real time
<http://cosray.unibe.ch/>



Cosmic Ray Trajectories
see e.g. Smart et al., *Space Sci. Rev.* 93, 305-333, 2000

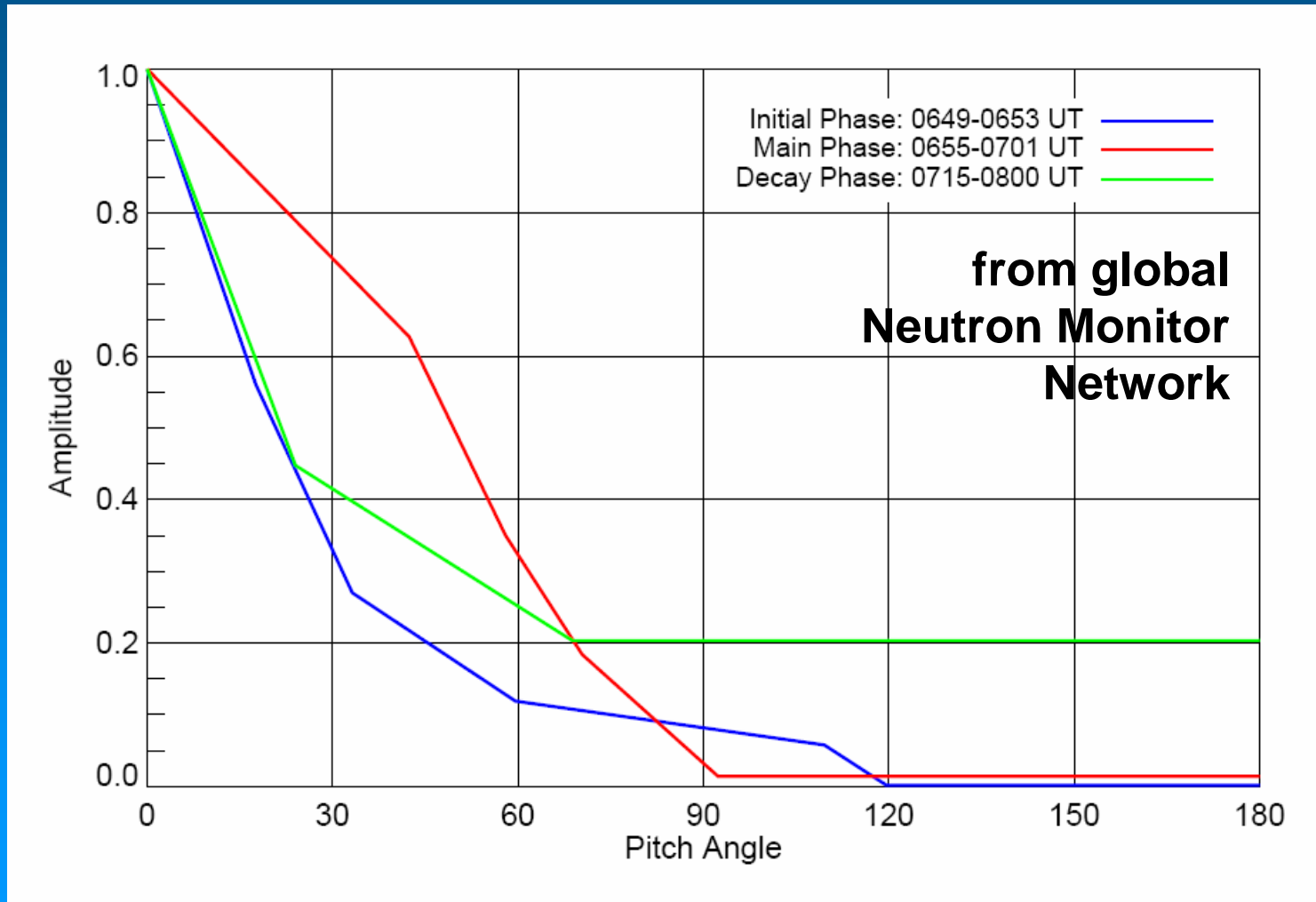
SCR Spectrum

Example: 20 January 2005



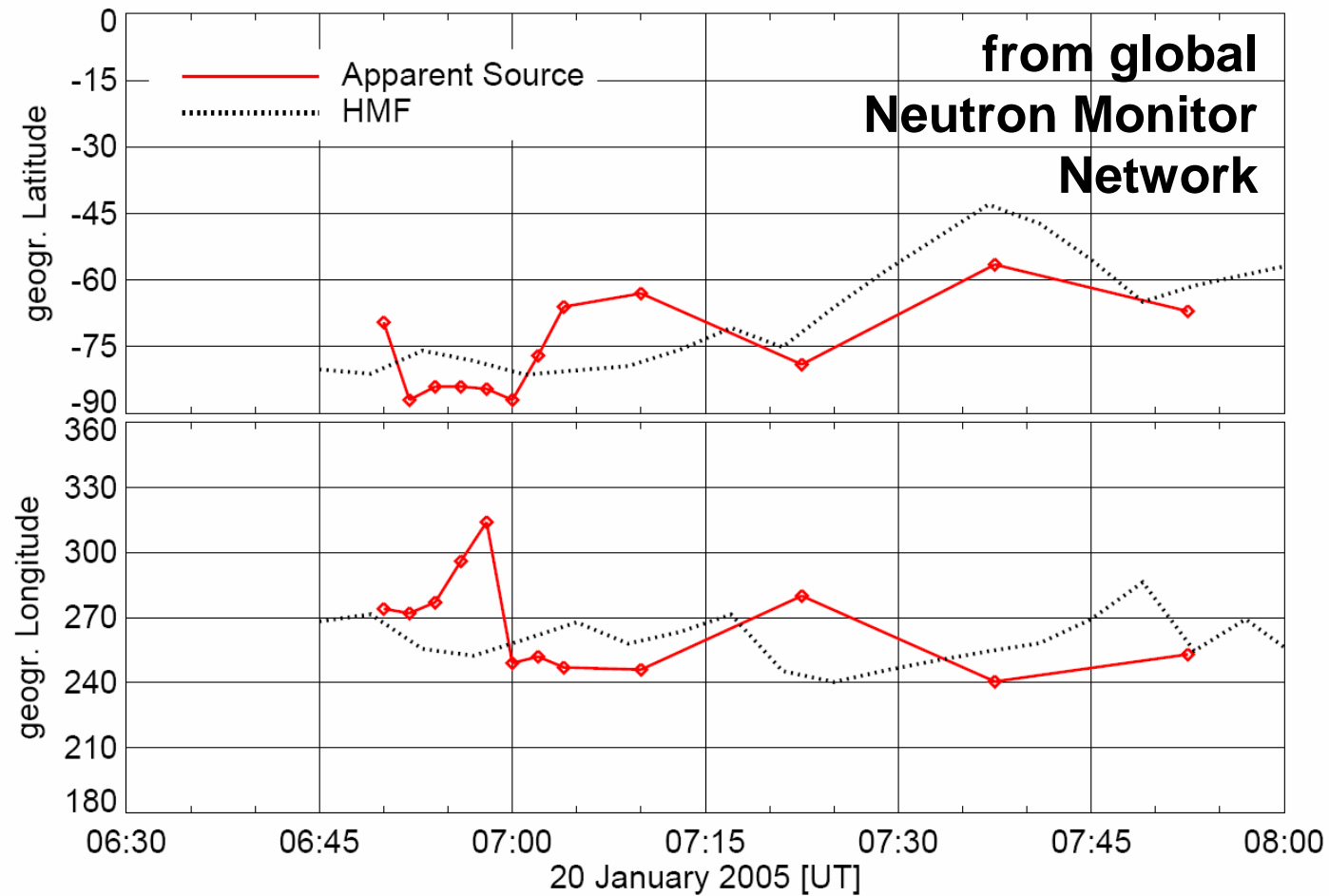
SCR Pitch Angle Distribution

Example: 20 January 2005

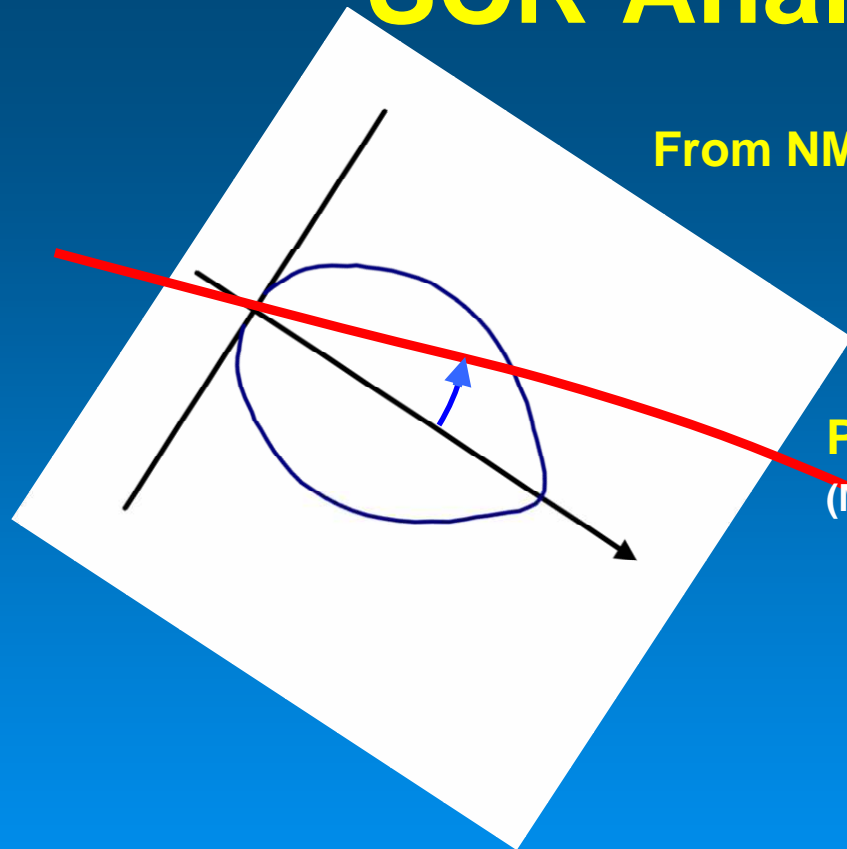


SCR Apparent Source Position

Example: 20 January 2005



SCR Analysis Method



From NM Data:

- outside of the Magnetosphere
- Apparent Source Direction
- Pitch Angle Distribution
- Rigidity Spectrum

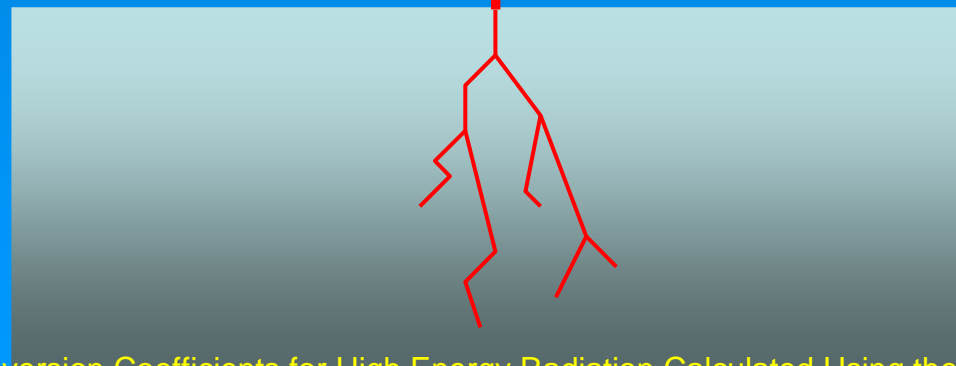
PLANETOCOSMICS: - Asymptotic Directions
(MAGNETOCOSMICS) - Cutoff Rigidities

Spectrum at the top of the Atmosphere for specified arrival directions

PLANETOCOSMICS:
- Cascade in the Atmosphere
- Secondary Spectra

Secondary Spectra → Dosage

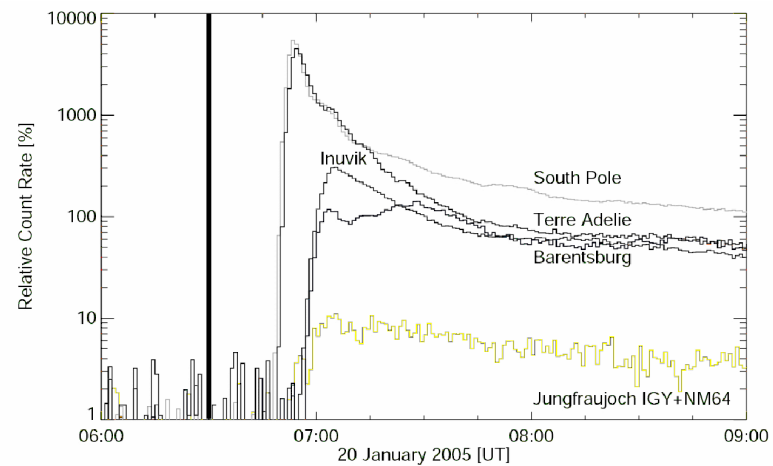
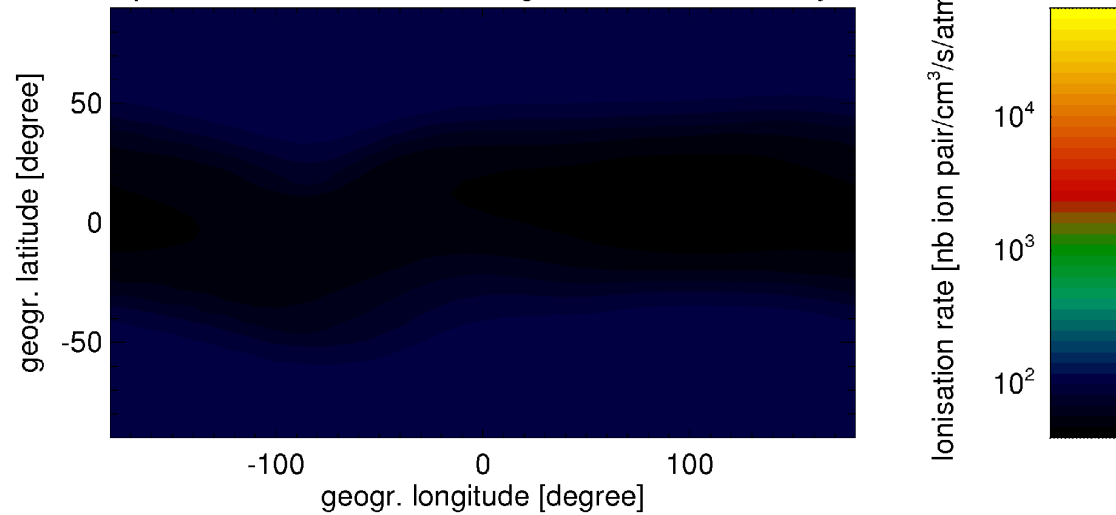
Pelliccioni et al., Overview of Fluence to Effective Dose and Fluence to Ambient Dose Conversion Coefficients for High Energy Radiation Calculated Using the FLUKA Code, Radiation Protection Dosimetry 2000;88:4:279-297



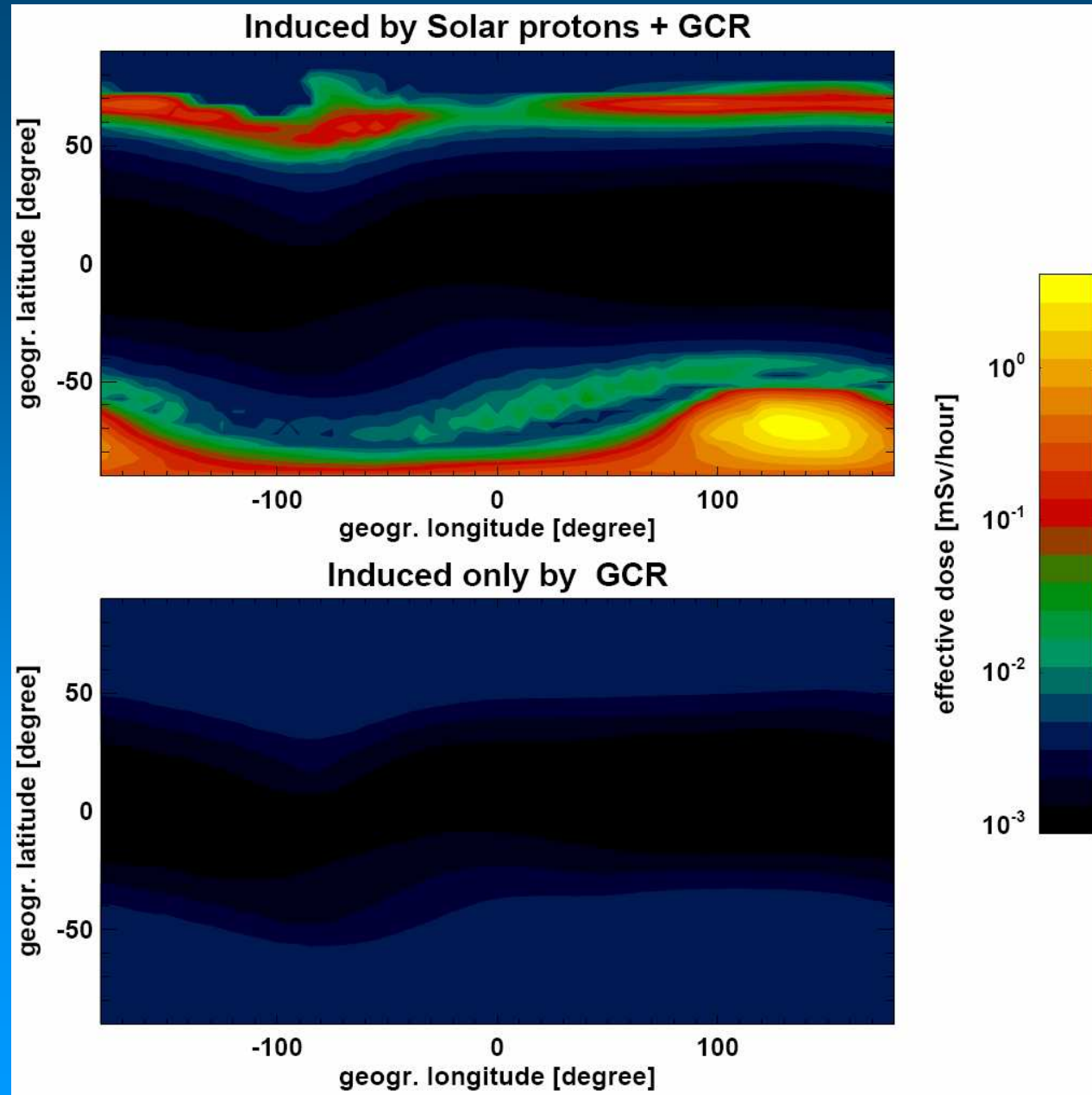
The 20 January 2005 GLE

Ionisation at 250 g cm⁻²

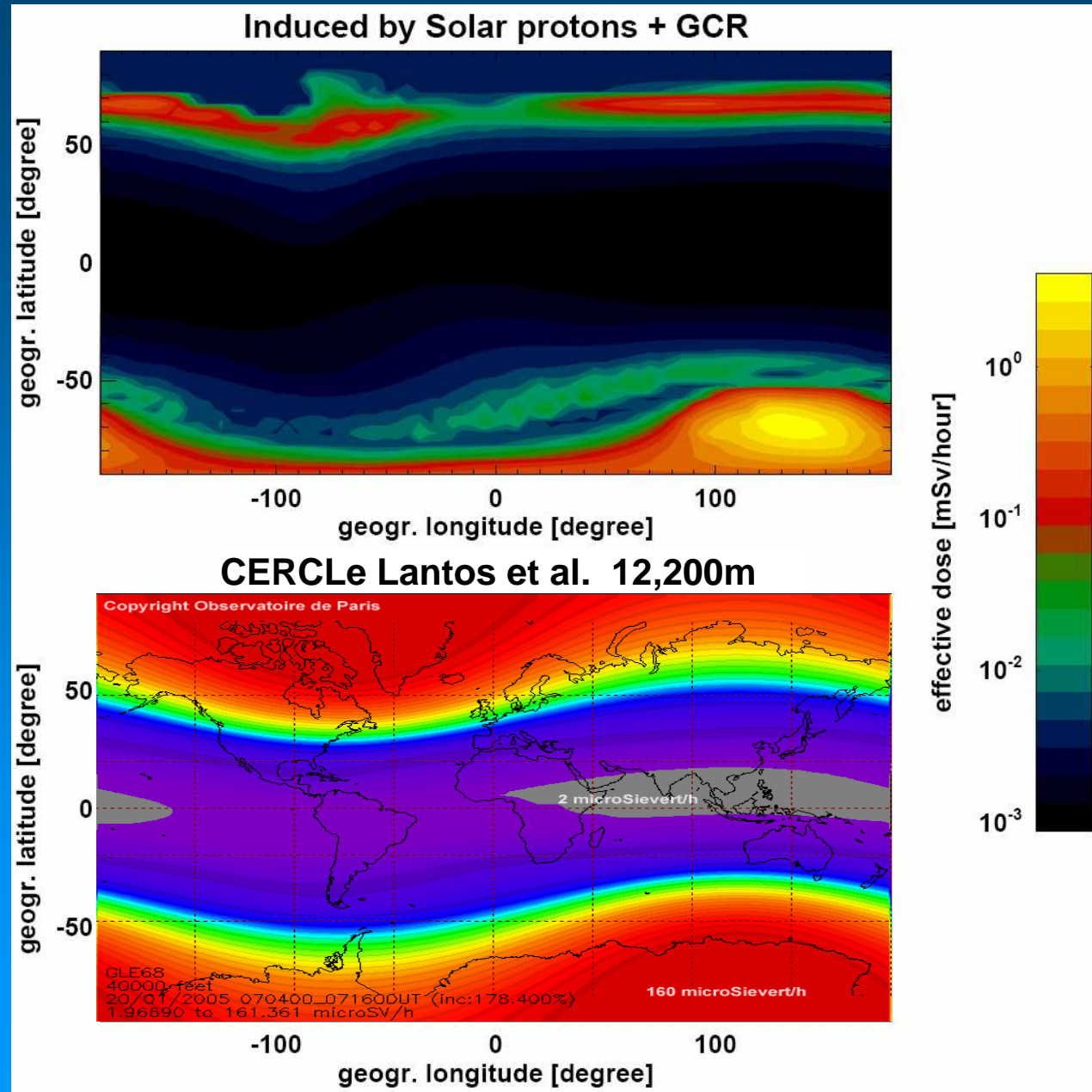
Atmospheric ionisation at 250 g/cm², 20th January 2005



Dosage
at
 300 g cm^{-2}
(~10,000m)



Dosage
at
 300 g cm^{-2}
(~10,000m)

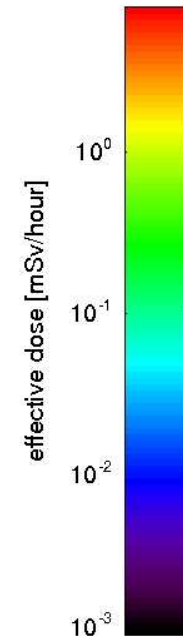
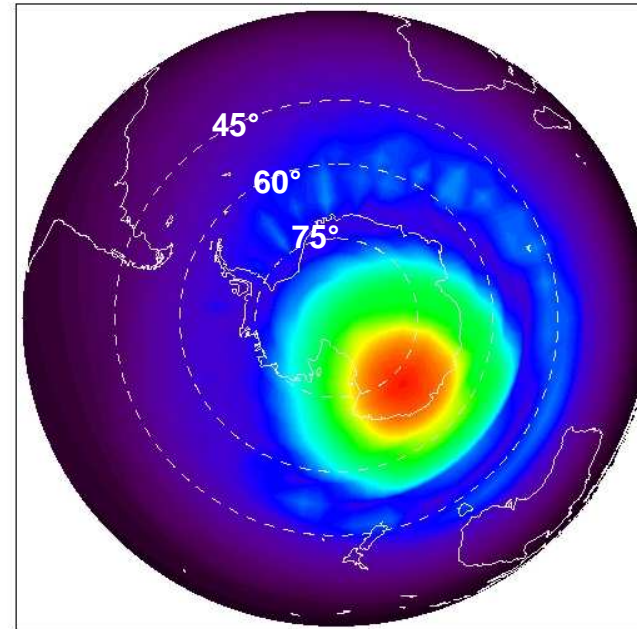
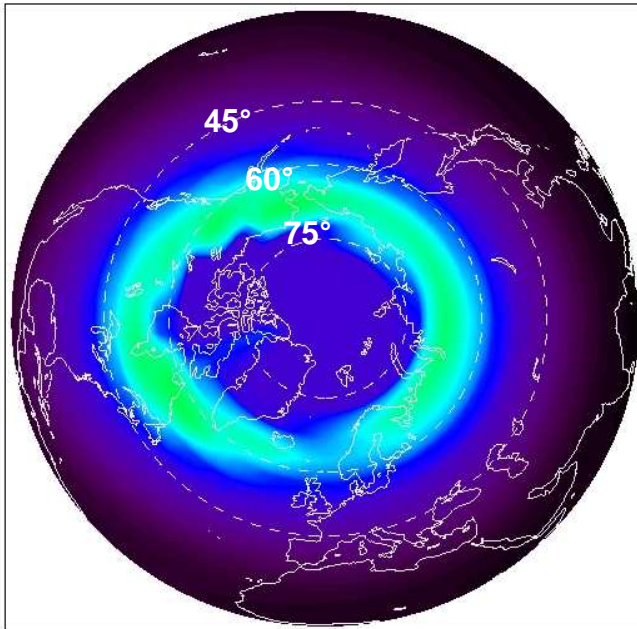
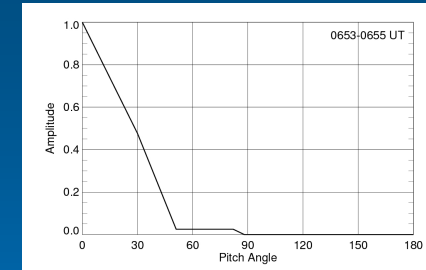


The 20 January 2005 GLE

Maximum Phase Real
Apparent Source 84.5°S, 264°E / Anisotropy

North

South

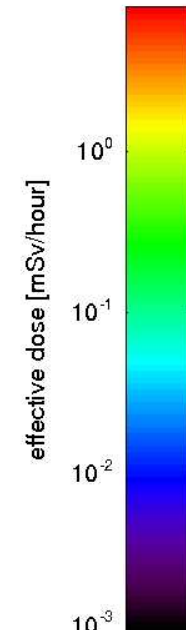
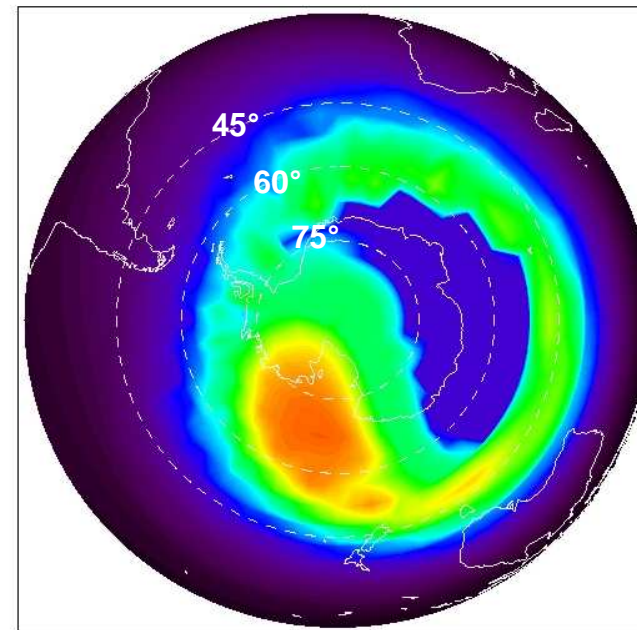
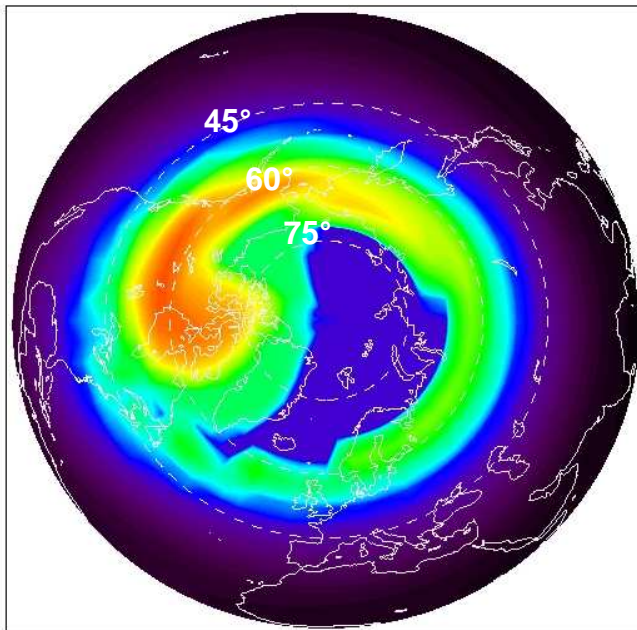
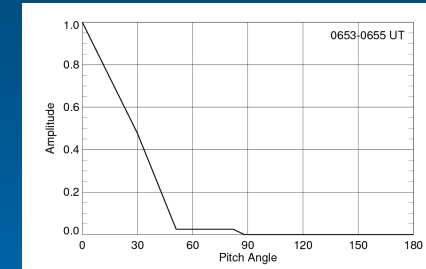


The 20 January 2005 GLE

Maximum Phase Simulation
Apparent Source 0°S, 264°E / Anisotropy

North

South

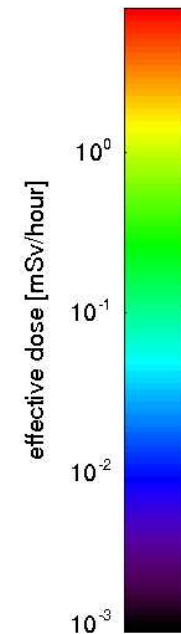
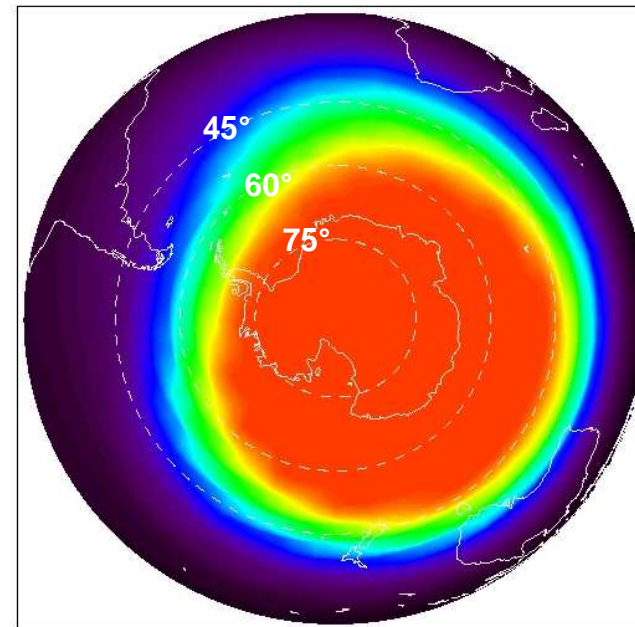
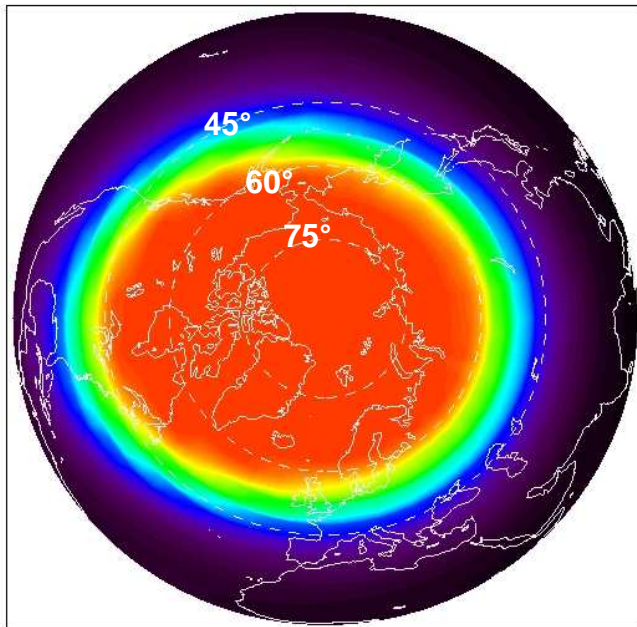


The 20 January 2005 GLE

Maximum Phase Simulation
Isotropic Event

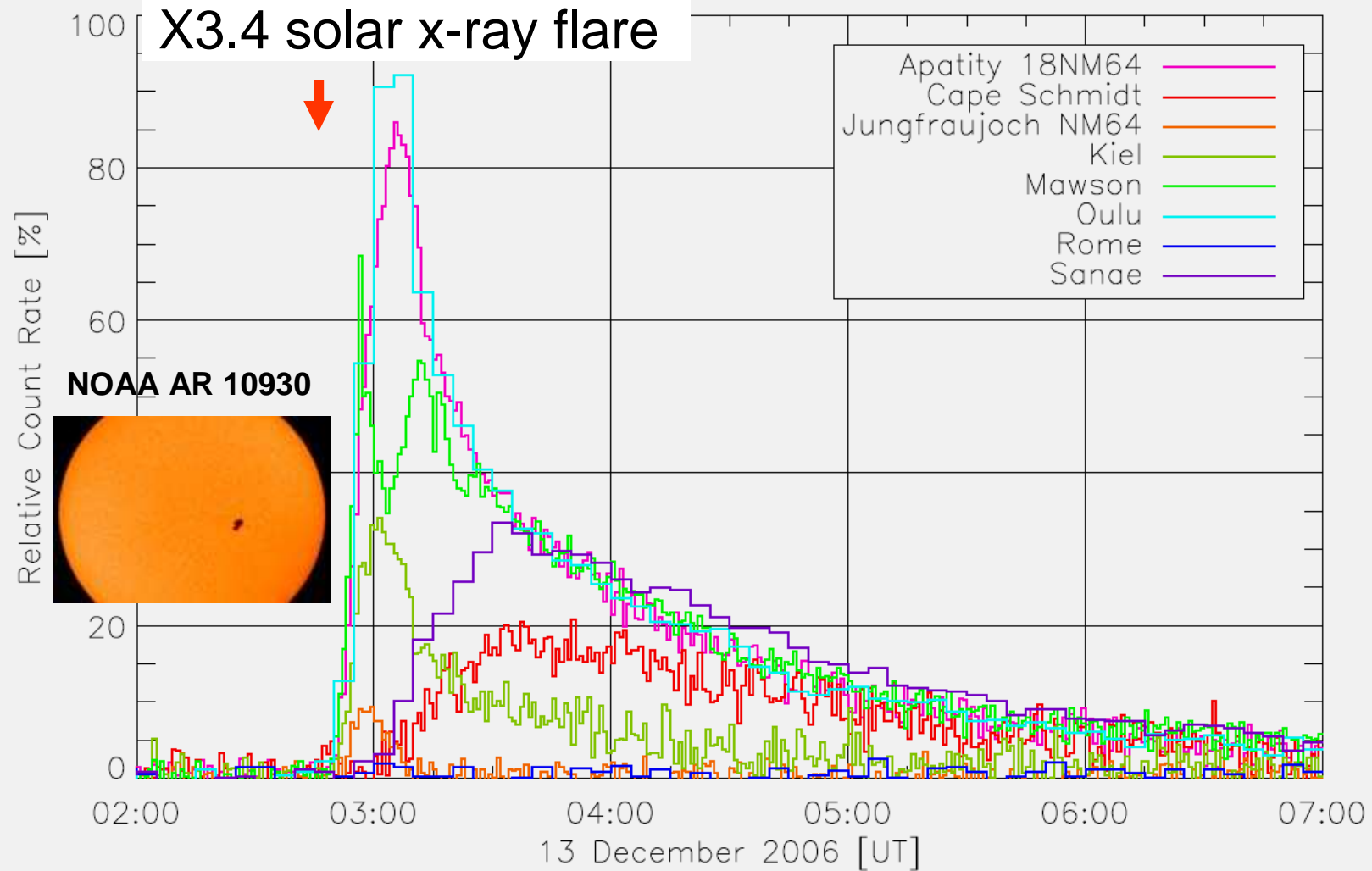
North

South



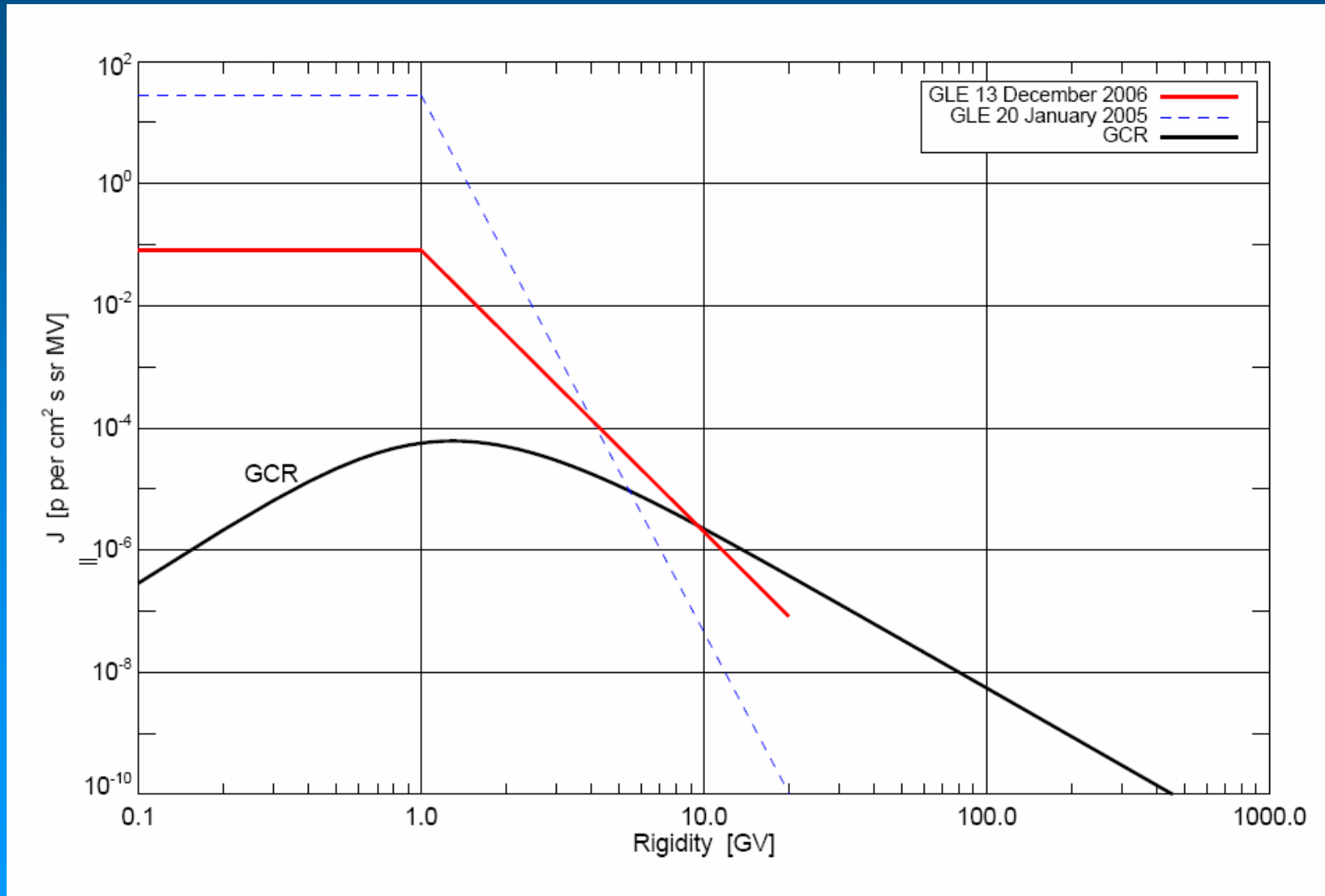
The 13 December 2006 GLE

Neutron Monitor Observations



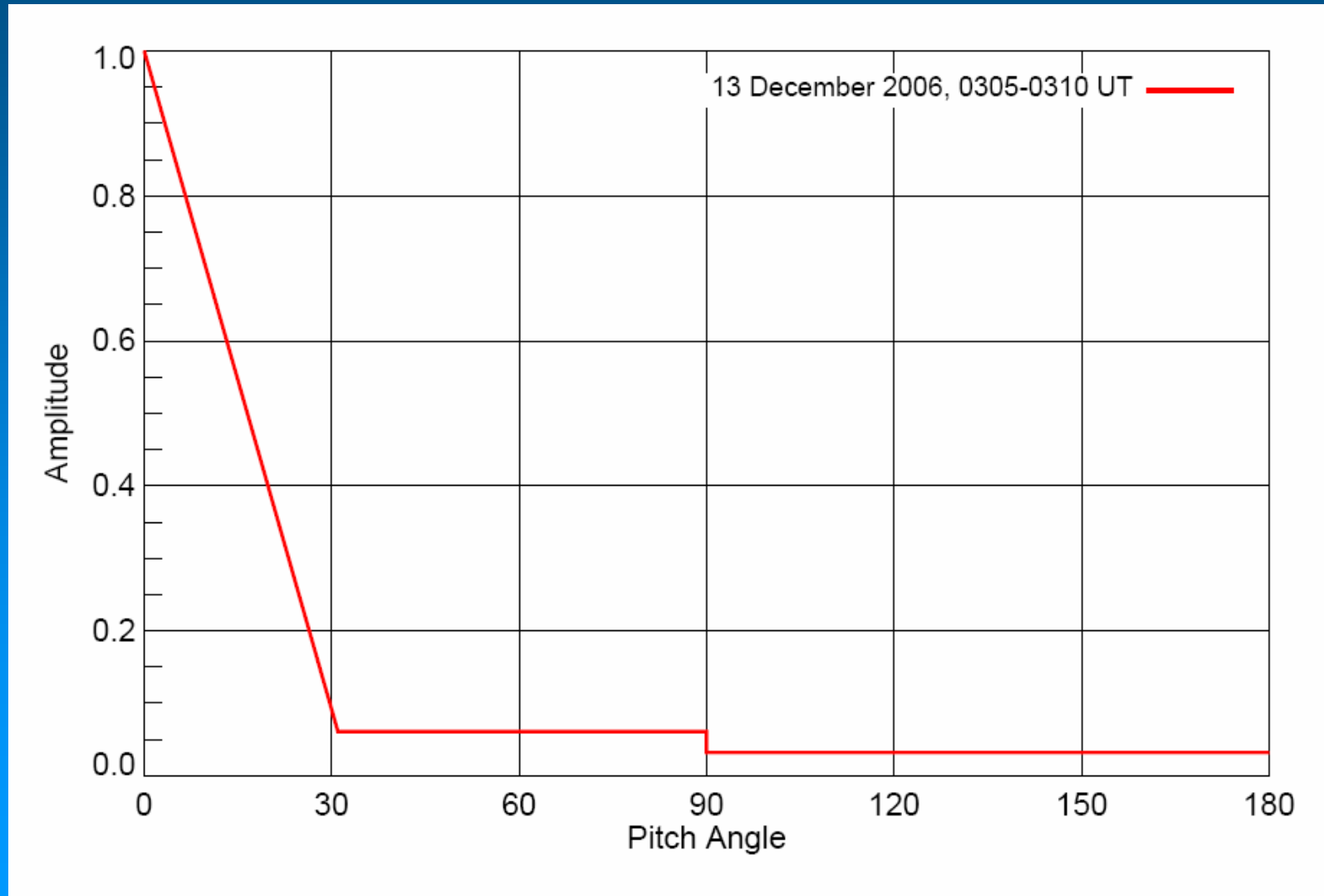
Spectrum

Maximum Phase

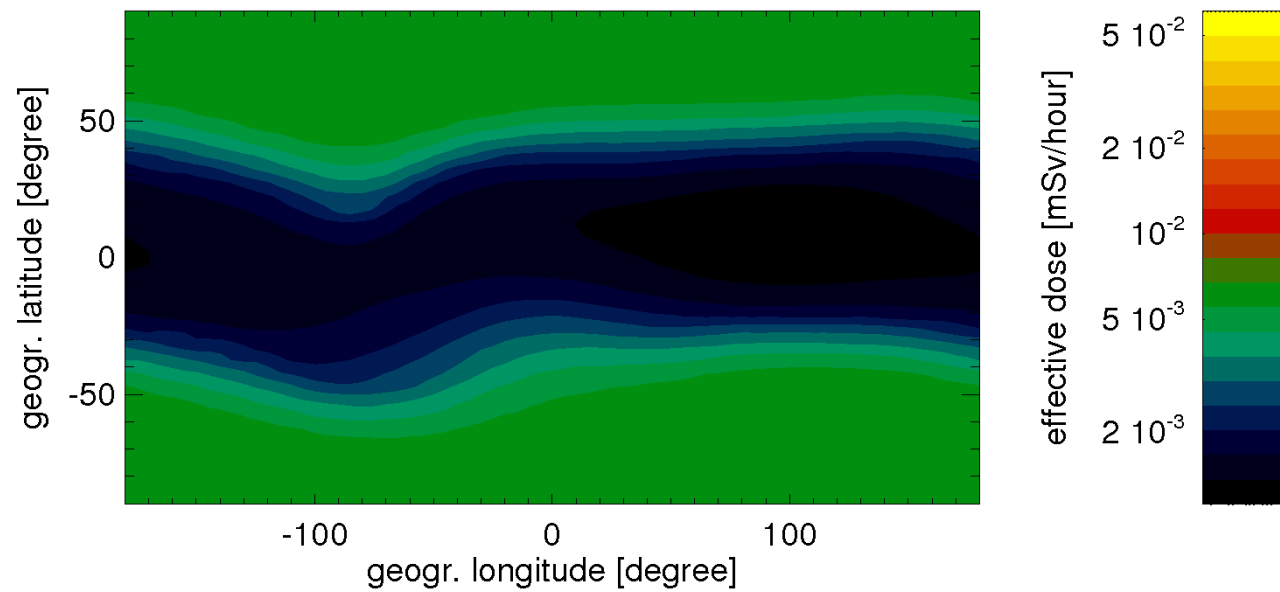
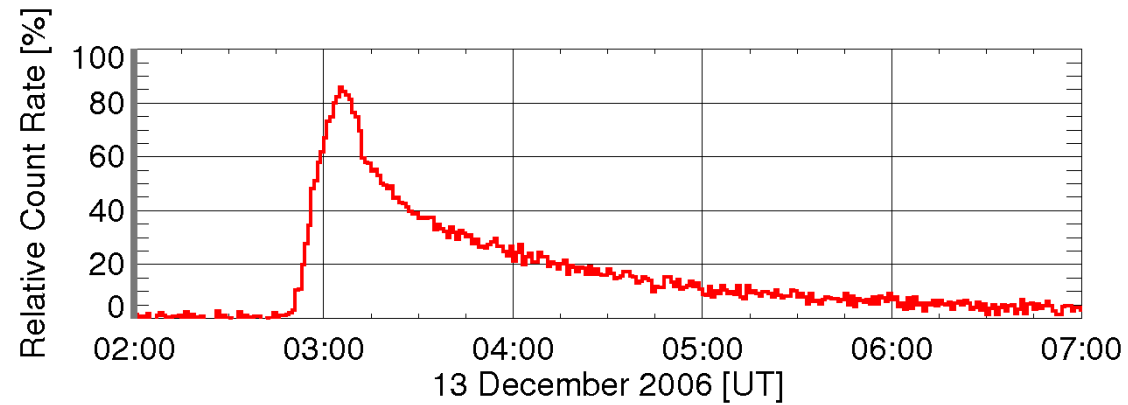


Pitch Angle Distribution

Maximum Phase



Aircrew Doses



Comparison

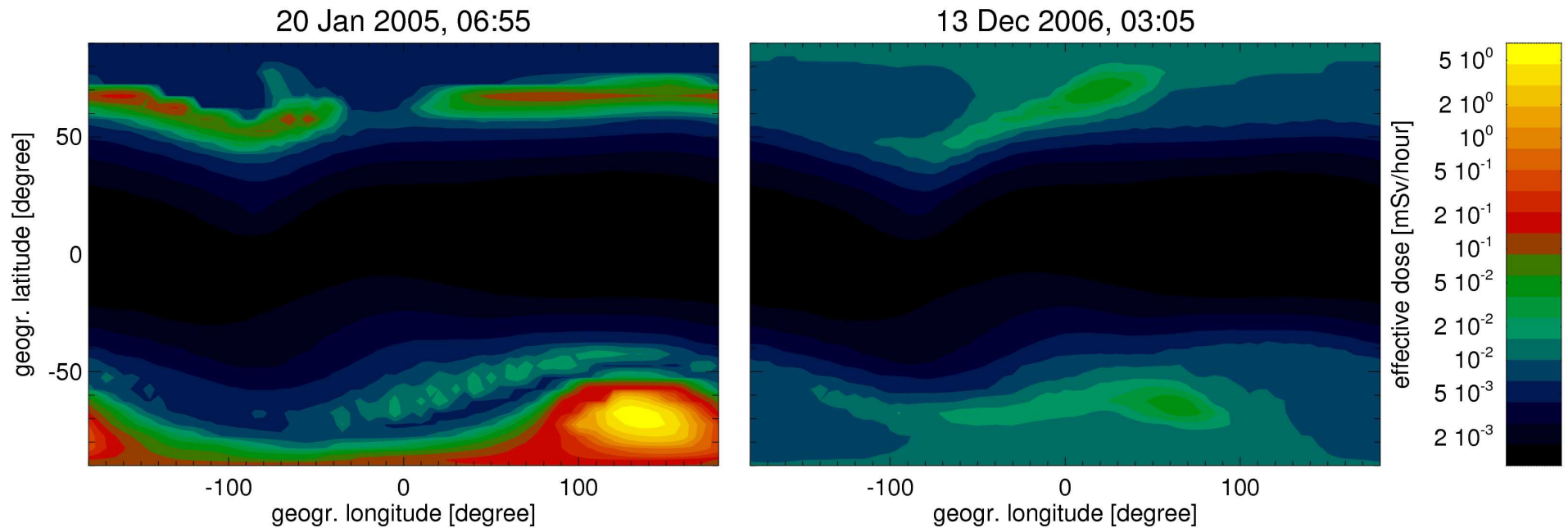
20 January 2005

13 December 2006

Effective Dose at Aircraft Altitude

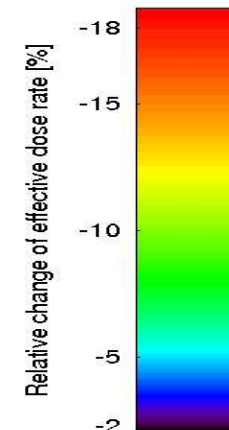
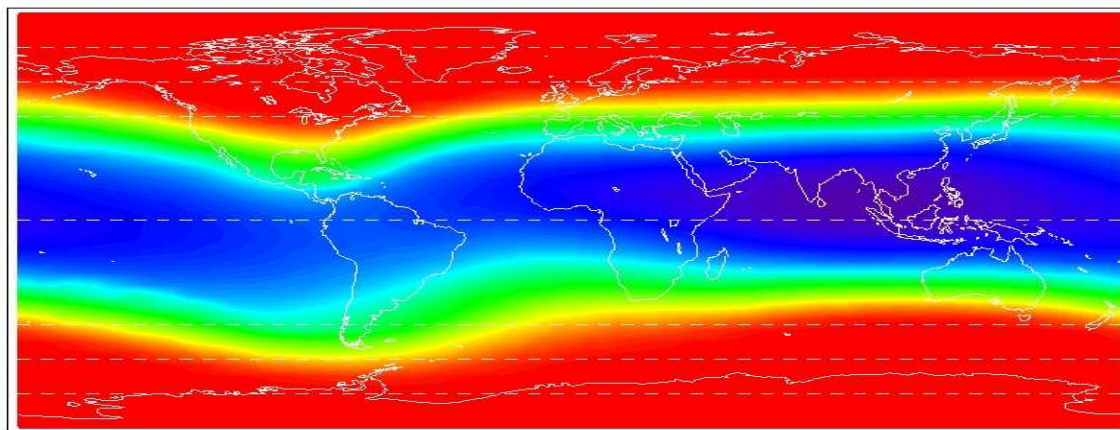
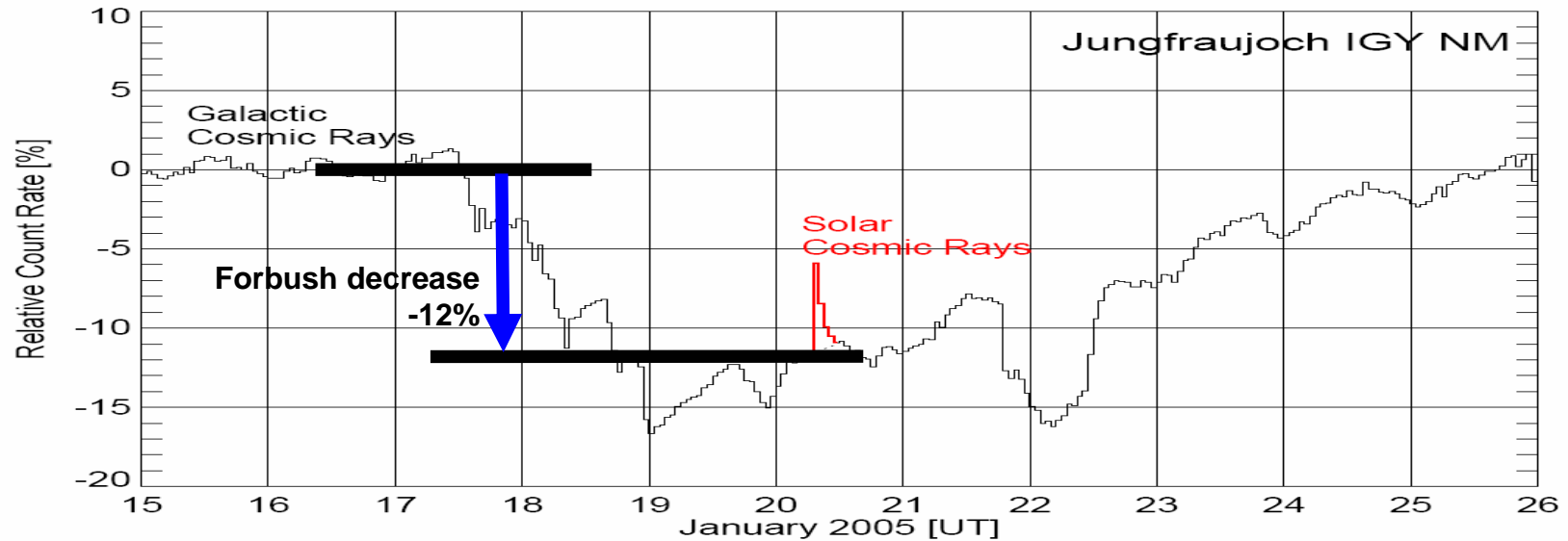
20 January 2005 / 13 December 2006

Comparison at Event Maximum



**Solar Cosmic Ray Events
(GLEs)
often occur during
Forbush decreases
and
geomagnetically perturbed
time periods**

The 20 January 2005 GLE



Summary, Conclusions, and Outlook

- Energetic solar particle events are rare, unpredictable, and of short duration
- A realistic evaluation of aircrew doses due to SCR is by far more complex than the evaluation of GCR doses
- Anisotropy effects are important
- Crucial role of neutron monitors
- Aircrew doses at high latitudes ($> 45^\circ$) can increase by orders of magnitude
- Today: time consuming post event analysis
- Future: near real-time evaluation
 - FP-7 project NMDB (Neutron Monitor Data Base)

