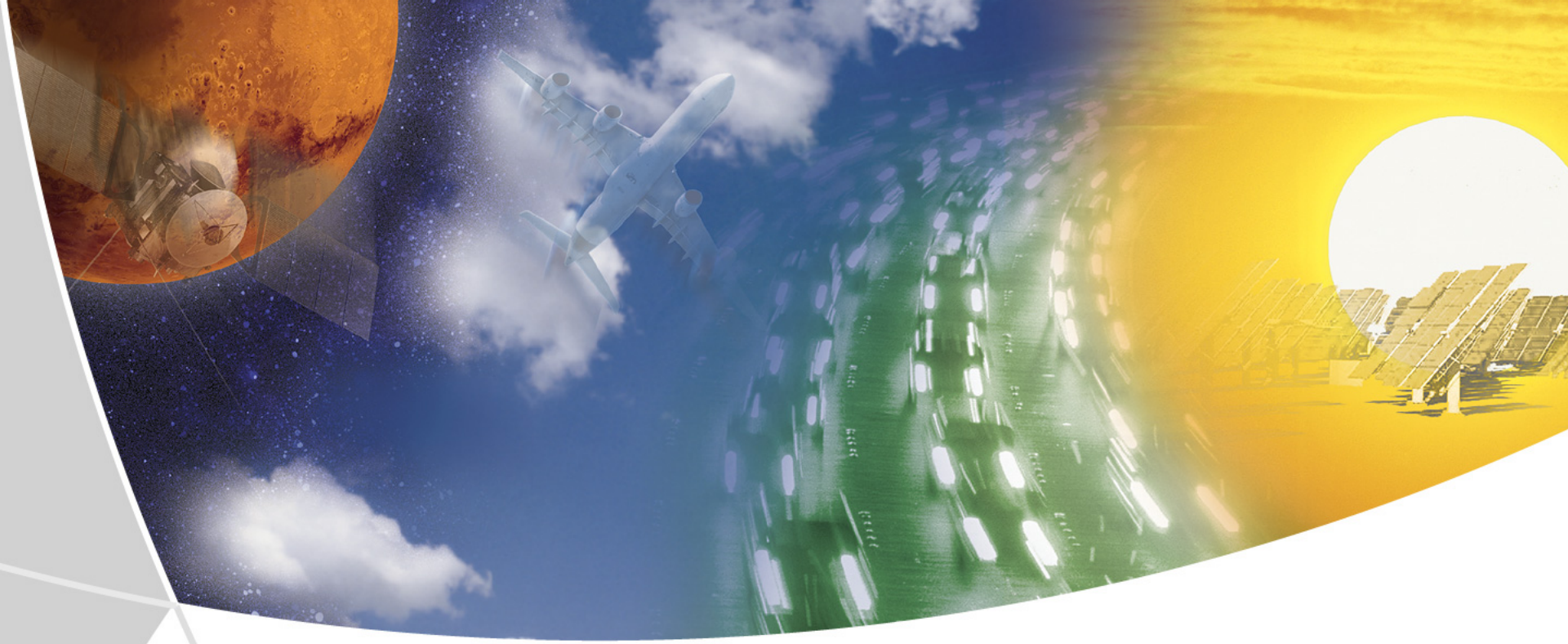

Radiation Protection in Aviation
The Importance of Space Weather

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Introductory Remark

Radiation can be dangerous.

So can ignorance.

Outline

- Introduction
- Galactic Cosmic Radiation
- Solar Particle Events (SPE, “Solar Flares“)
- Summary

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Introduction

- In the EU aircrew members are legally treated as radiation workers if they are exposed to at least 1 mSv/year.
- Background radiation exposure in the US is about 3 mSv/year on average.
- The annual occupational radiation exposure of aircrew is about 1 - 7 mSv due to galactic cosmic rays.
- Dose rates depend on altitude, geomagnetic latitude and solar cycle.
- Media coverage and reports on solar radiation storms (SPEs) have aroused an increased awareness among aircrew and passengers.

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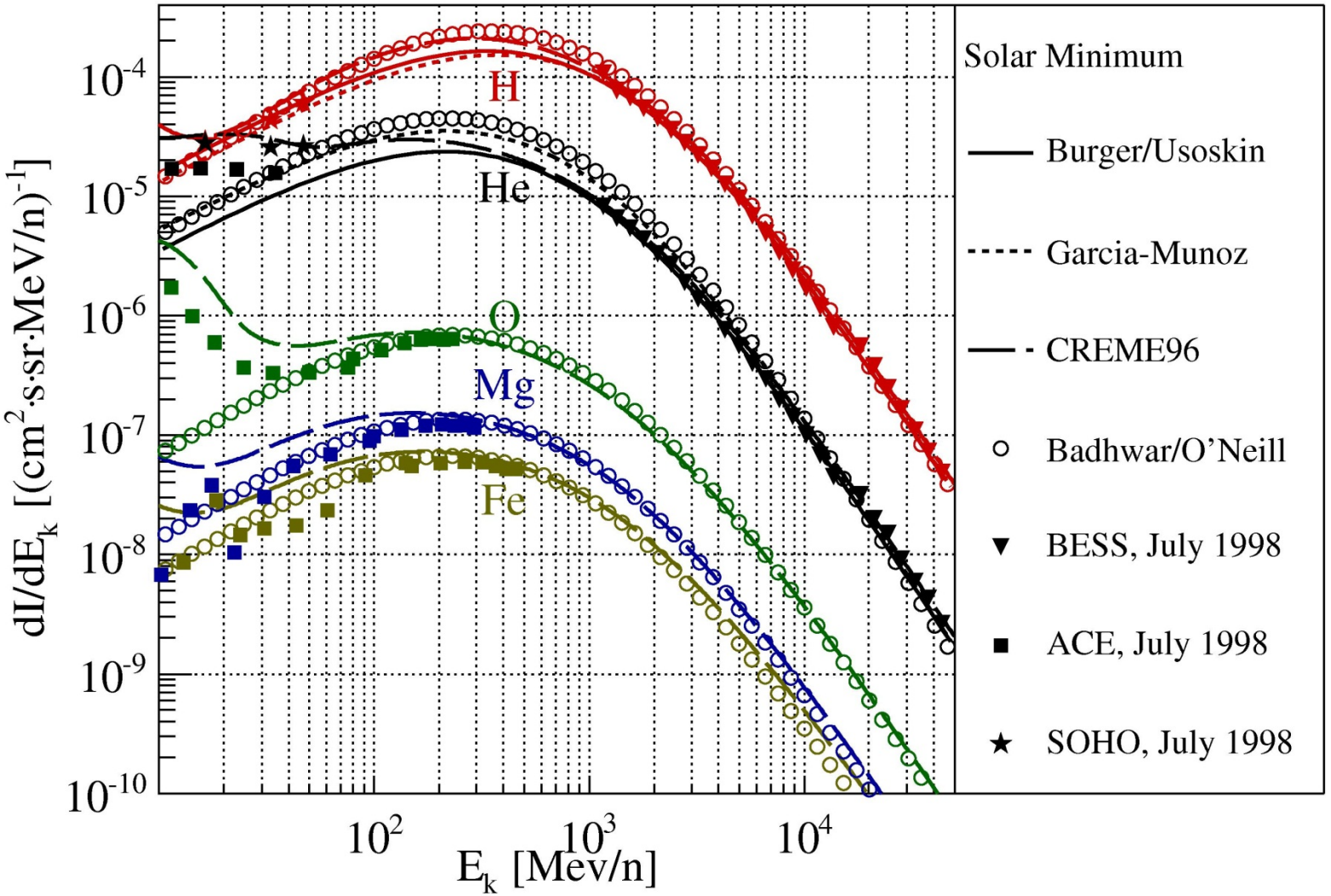
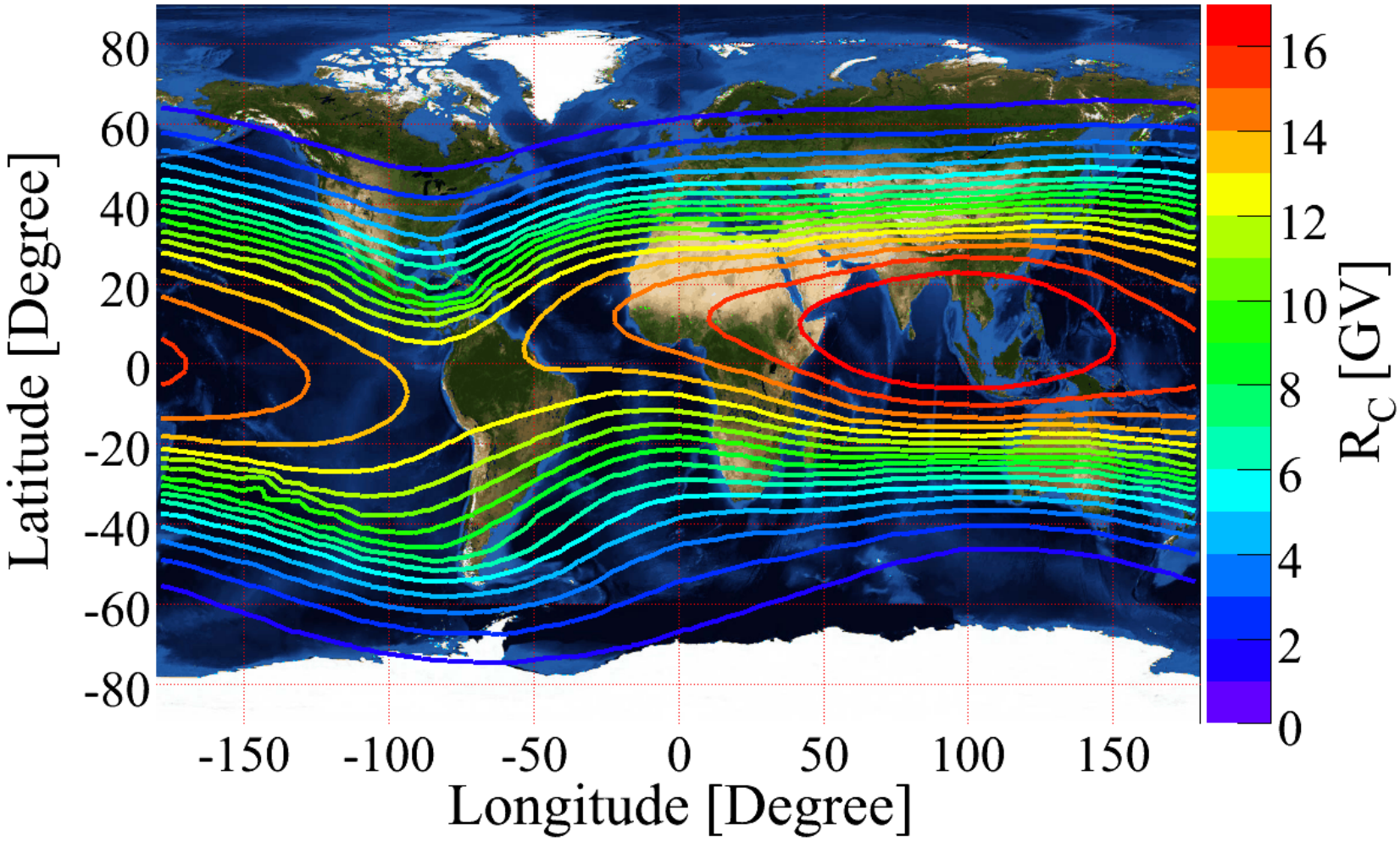
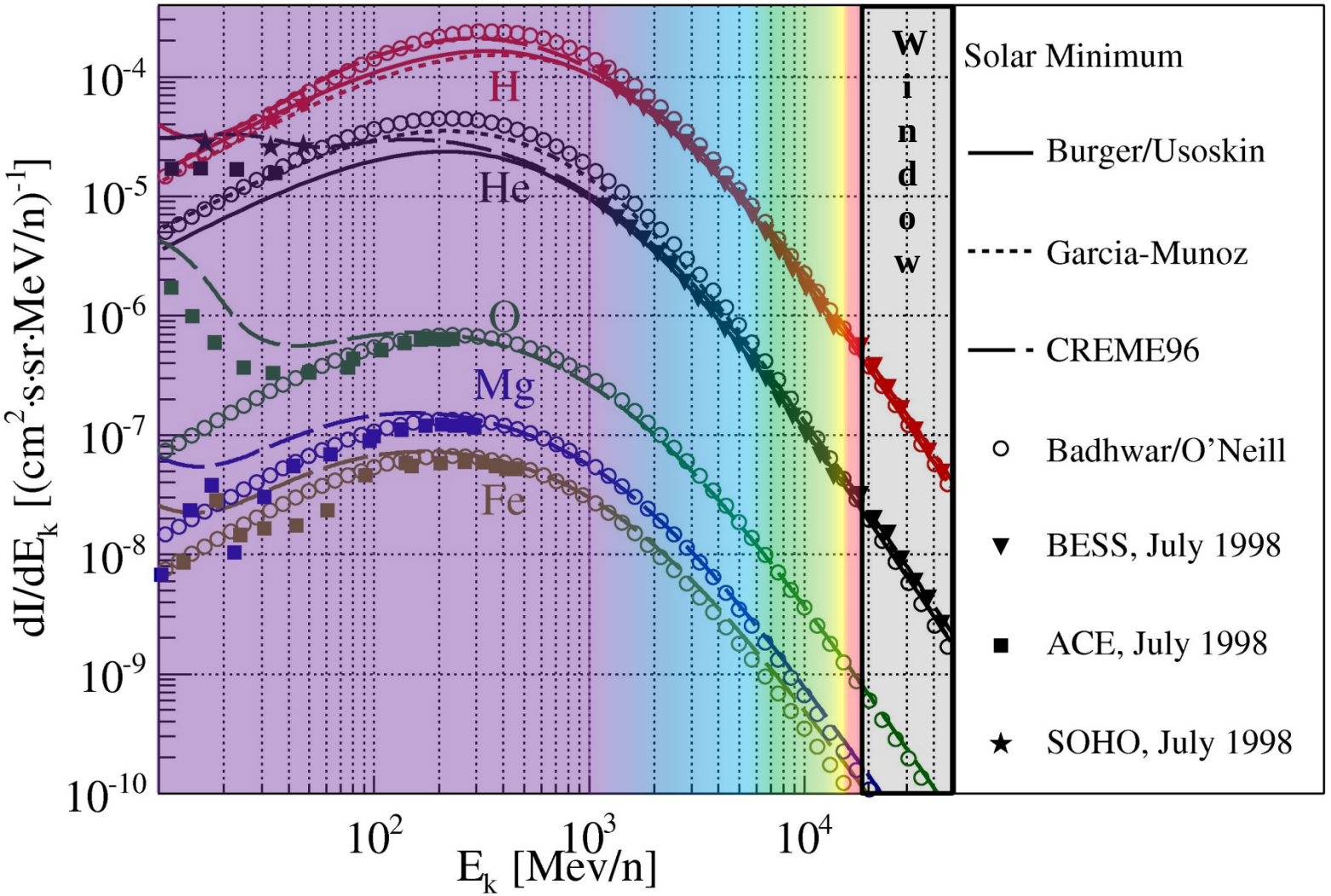
Introduction: GCR at 1 AU



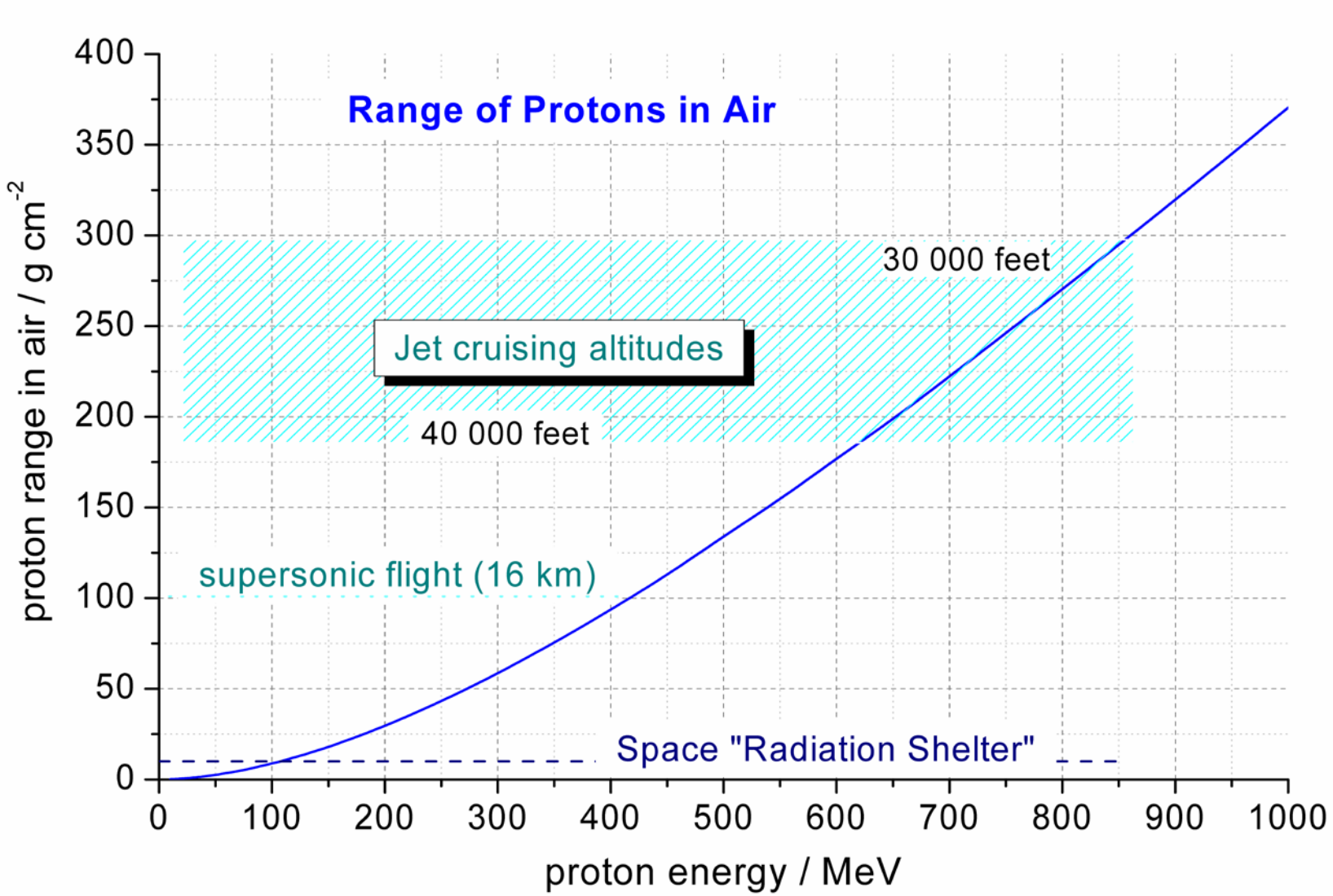
Geomagnetic Shielding



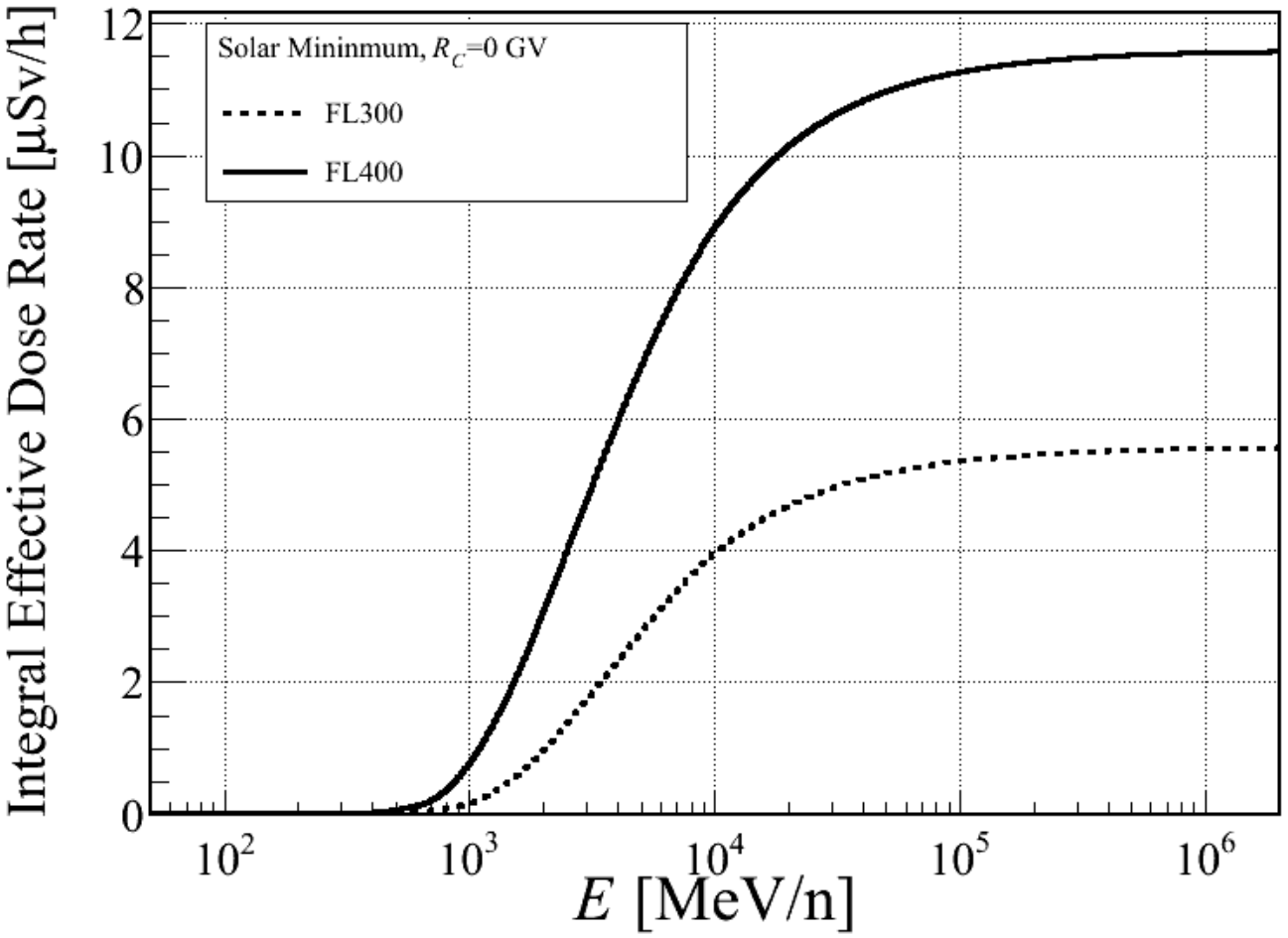
Geomagnetic Shielding



Atmospheric Shielding: Range of Protons in the Atmosphere

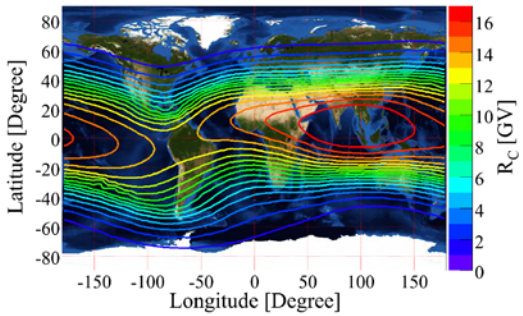


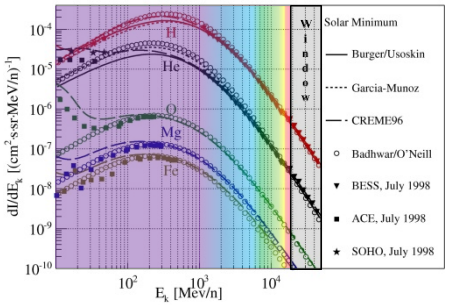
Atmospheric Shielding: Simulation with PANDOCA

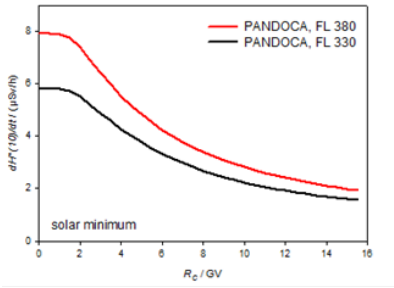


Radiation Field at Aviation Altitudes

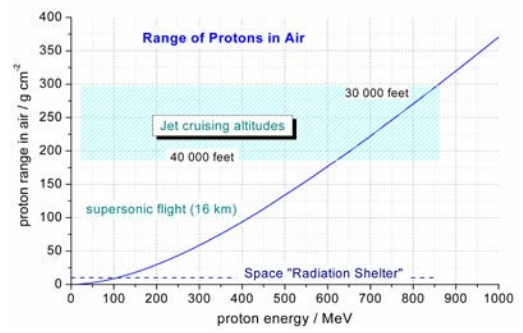
Geomagnetic shielding:

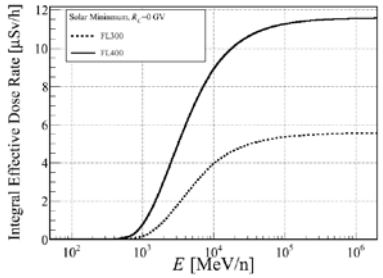


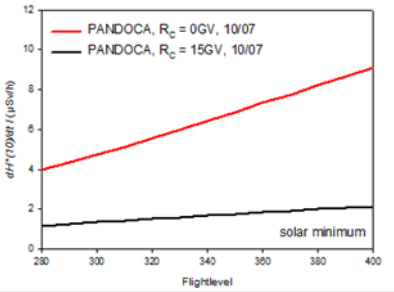




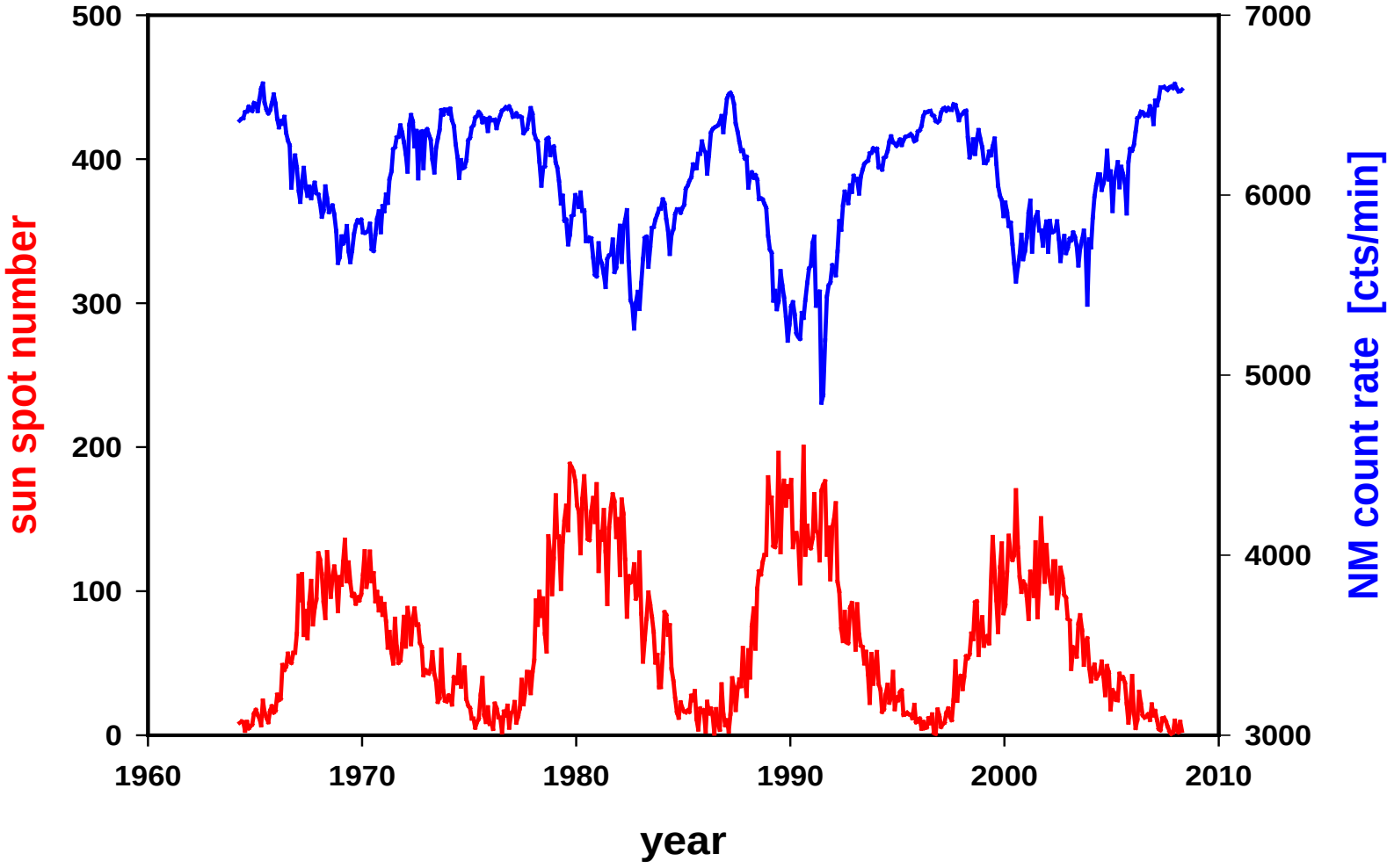
Atmospheric shielding:



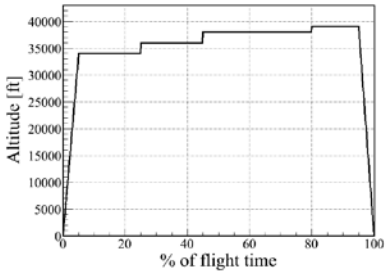




Space Weather: Temporal Variation

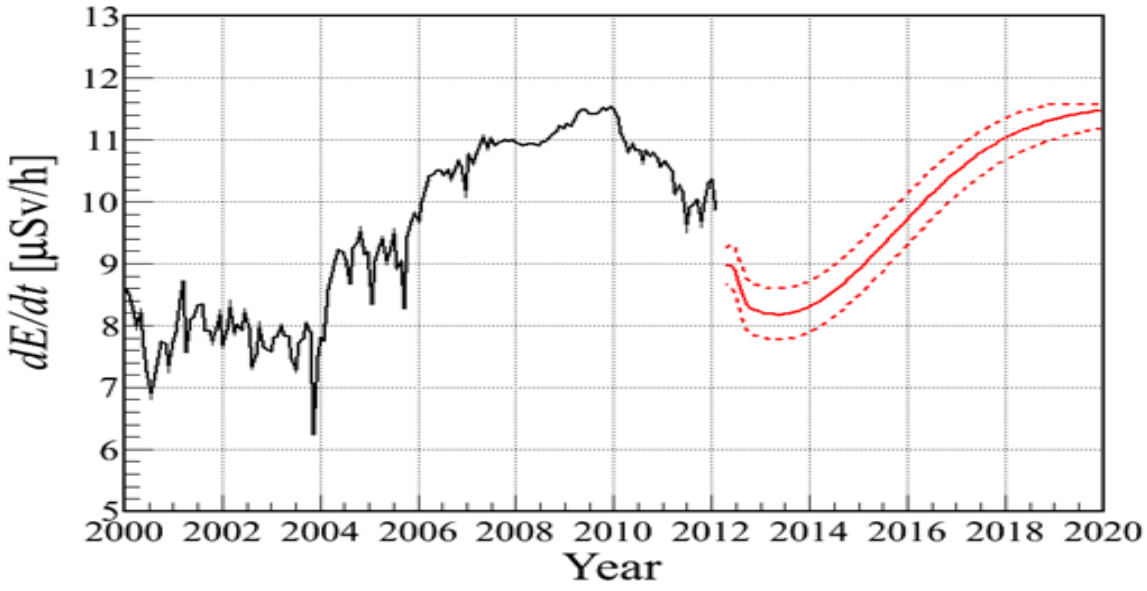


Examples – Variation within the Solar Cycle (calculated with PANDOCA)



	Minimum (12/2009) Effective dose / µSv	Maximum (01/2002) Effective dose / µSv	Variation
FRA-JFK	65	45	31%
FRA-DEN	84	56	33%
FRA-LAX	95	64	33%

Dose rate at
FL400, R_c = 0 GV:



Forecast based on:
http://www.swpc.noaa.gov/ftpdir/weekly/Predict.txt

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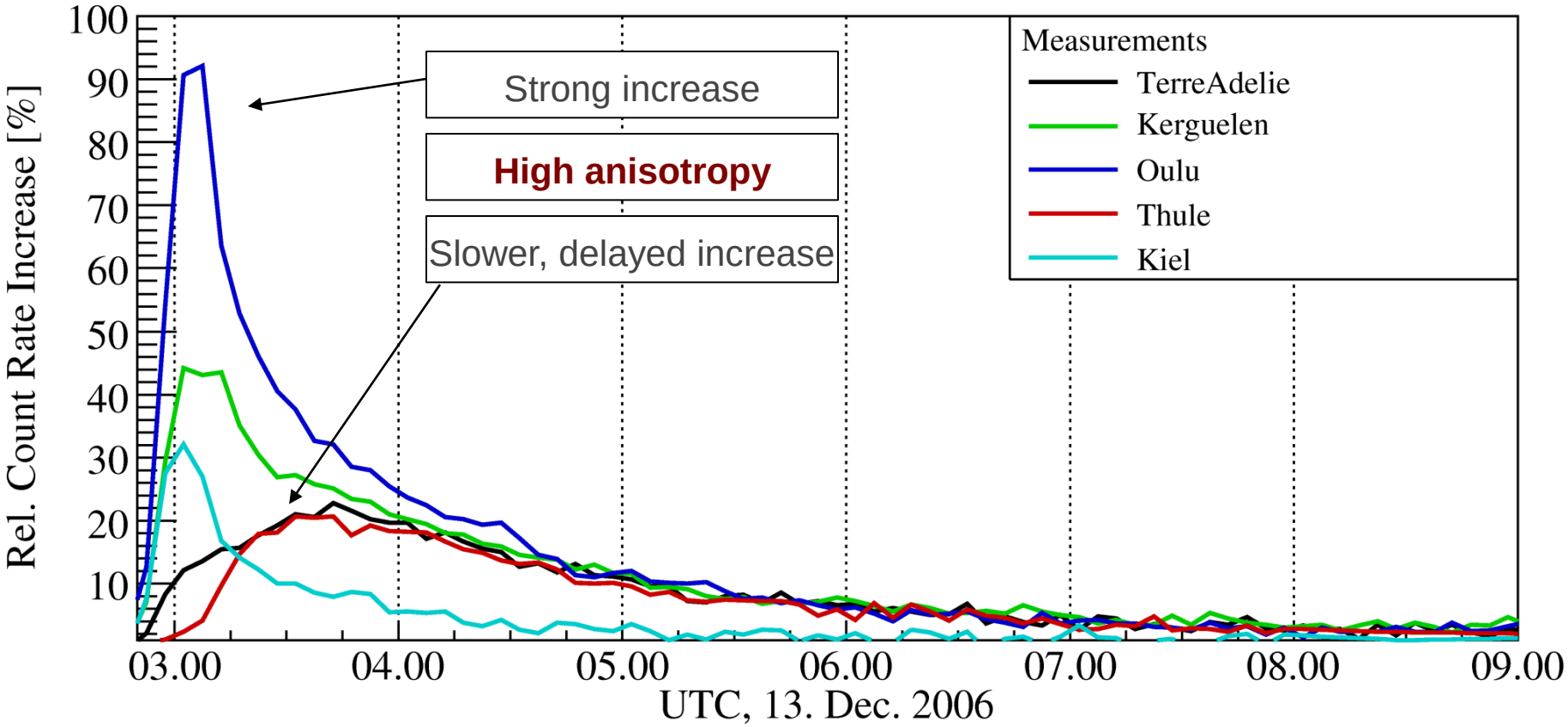
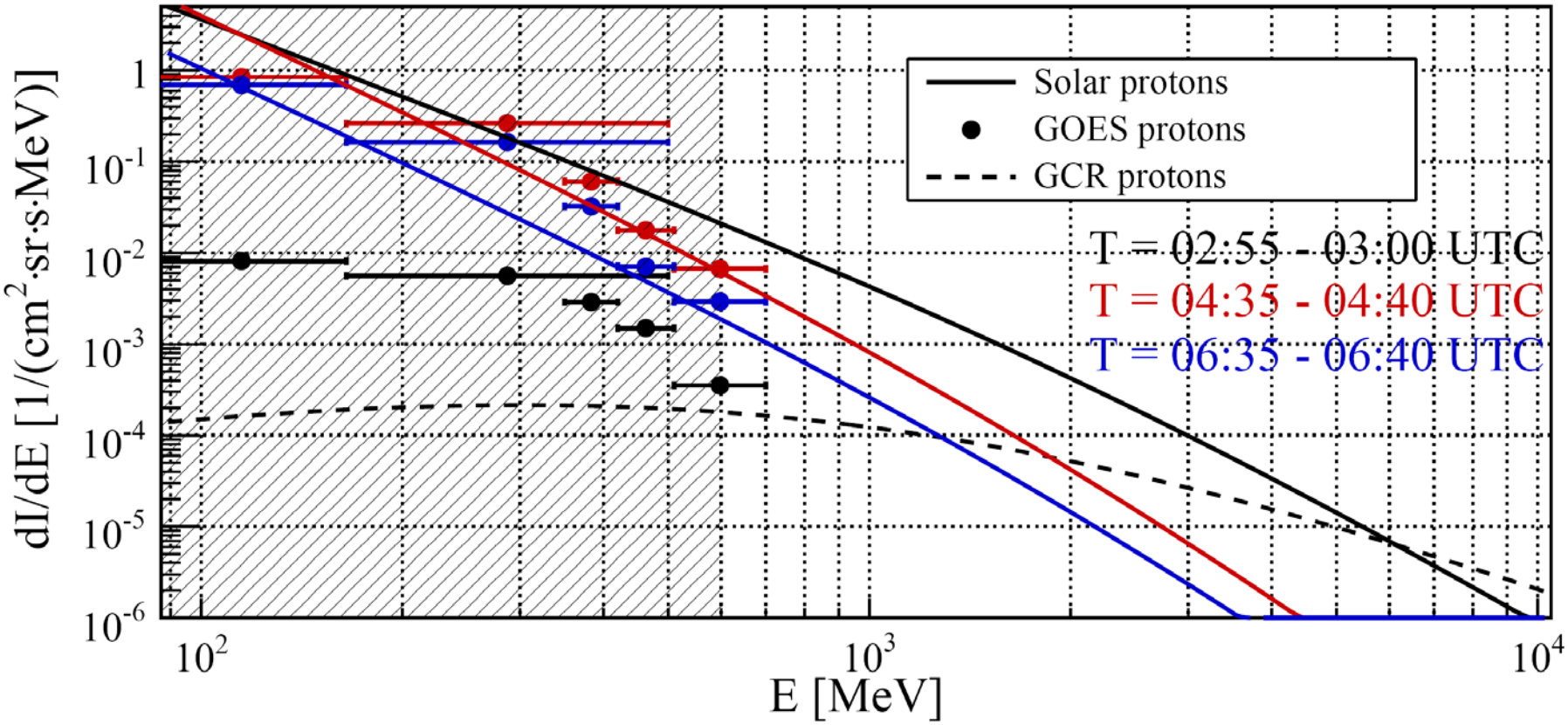
GLE 70: Neutron Monitor Count Rate Increases



GLE70: Primary Proton Spectra



- Softening of the spectrum
- Decrease in intensity

Results – Analysis of GLEs

	Date	Spectral index	Effective Dose increase (Flights on the northern hemisphere)
GLE42	Sept. 29th, 1989	3.5-6	Up to 600%
GLE60	April 15th, 2001	3.5-6	Up to 130%
GLE69 (1)	Jan. 20th, 2005	5.5-7	Up to 130%
GLE70 (2)	Dec. 13th, 2006	4.5-6	Up to 30%

(1) *Matthiä et al., 2009, J. Geophys. Res., 114*

(2) *Matthiä et al., 2009, Radiat. Prot. Dosimetry, 136*

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Summary

- The reduction of the dose rates due to the galactic cosmic radiation from solar minimum to solar maximum is up to 40% (FL400, R_c = 0 GV).
- Additional dose contributions from SPEs are possible.
- The effect of an SPEs on the dose rates at aviation altitudes does not only depend on the particle flux but also on the energy spectrum of the impinging particles due to geomagnetic and atmospheric shielding.
- Reduction of dose rates due to the shielding of GCRs is possible as well.
- A modified scale for the warning against increased exposure to radiation at aviation altitudes based on spectral information might be considered.

Questions, etc.

Paracelsus (1538):

"Dosis sola facit venenum"

(The dose alone makes the poison)