The Impact of the Halloween Storms on Radiation Exposure in Aviation: 10 Years After

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DLR

Outline

- Introduction
- Case Study (GLE 65, 29 October 2003)
- Lessons Learnt
- Summary

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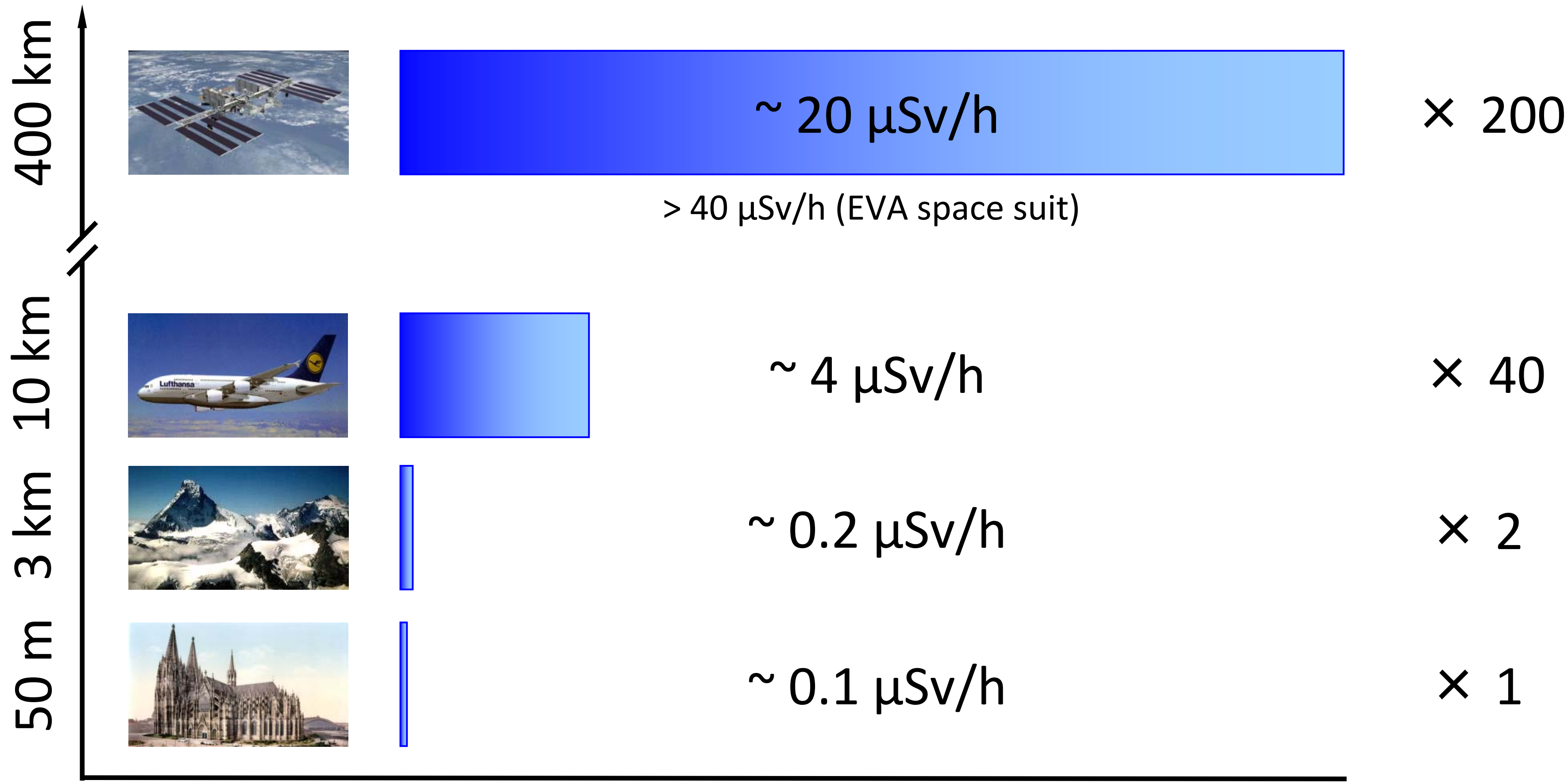
Space Weather Impacts on Aviation

- Ionospheric effects (communications, navigation)
- Ionising Radiation (biological effects, avionics)
- Ground infrastructure (power supply, airports, ATM, etc.)

Comparison of Radiation Exposure



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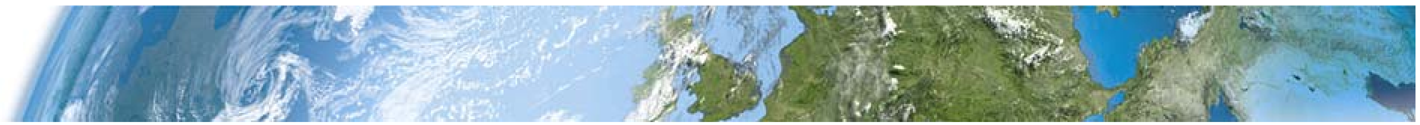
Background Information: Radiation Protection in Aviation

- Characterization of radiation field by dose quantities (D, E, H*(10), dD/dt, dE/dt, dH*(10)/dt, etc.)
- Radiation field in dependence on GCR and solar cycle is well understood
- Radiation protection and dose limits regulated by EU law
- Dose quantities can be assessed by measurement or calculation
- Several models for additional SWx contributions (GLEs)



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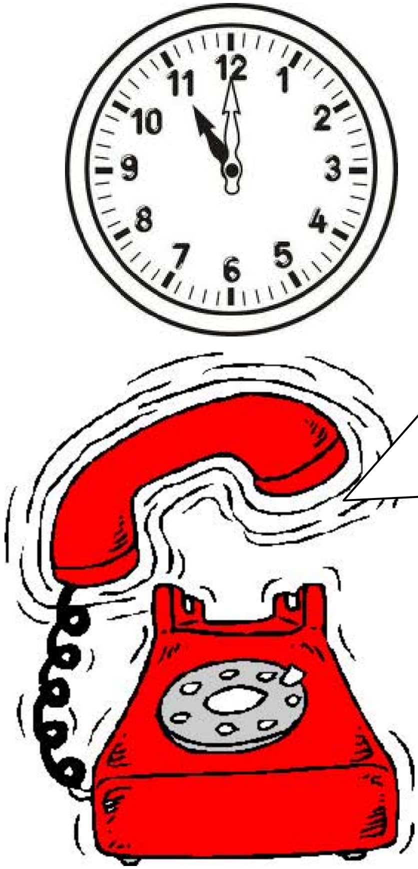
Background: October 2003

TV reported on SPEs and gave rise to public awareness all over the world.

Due to the public pressure some airlines even operated their flights at lower altitudes between 29. and 31. October.

GLE 65: 28./29. October 2003



Some airlines just started flying at lower altitudes !

What are we supposed to do ?

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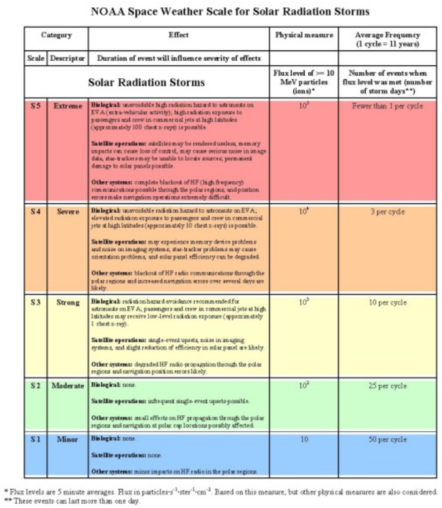
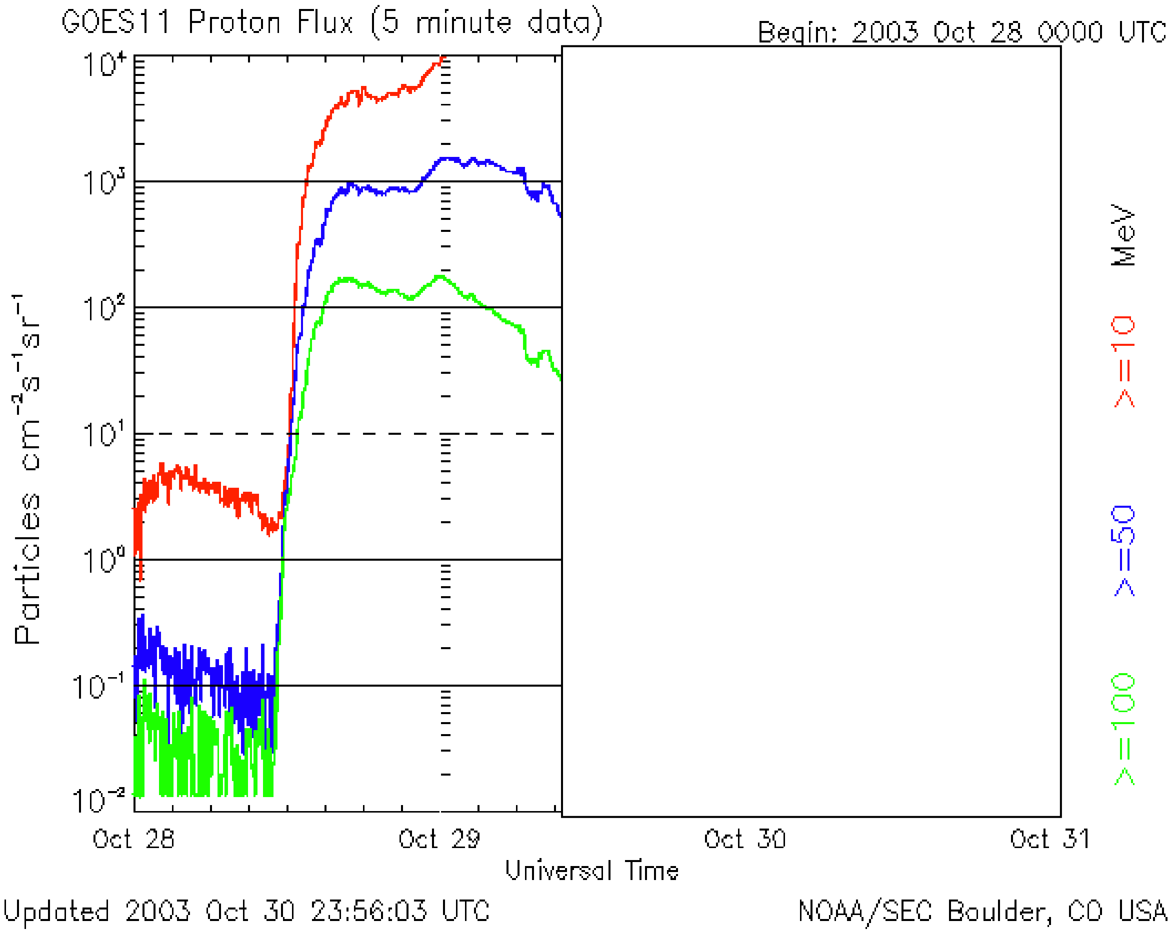
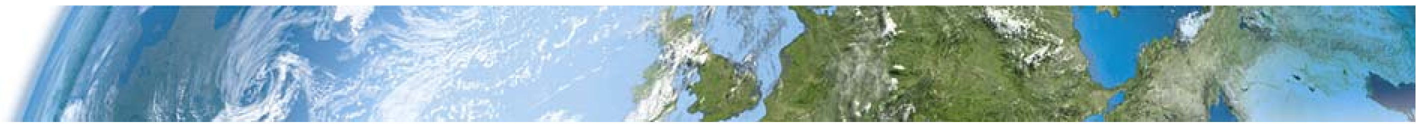


NOAA Space Weather Scale for Solar Radiation Storms

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Solar Radiation Storms			Flux level of >= 10 MeV particles (ions)*	Number of events when flux level was met (number of storm days**)
S 5	Extreme	**Biological:** unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); high radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 100 chest x-rays) is possible. **Satellite operations:** satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. **Other systems:** complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	**Biological:** unavoidable radiation hazard to astronauts on EVA; elevated radiation exposure to passengers and crew in commercial jets at high latitudes (approximately 10 chest x-rays) is possible. **Satellite operations:** may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. **Other systems:** blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	**Biological:** radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in commercial jets at high latitudes may receive low-level radiation exposure (approximately 1 chest x-ray). **Satellite operations:** single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. **Other systems:** degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	**Biological:** none. **Satellite operations:** infrequent single-event upsets possible. **Other systems:** small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S 1	Minor	**Biological:** none. **Satellite operations:** none. **Other systems:** minor impacts on HF radio in the polar regions.	10	50 per cycle

* Flux levels are 5 minute averages. Flux in particles·s^{-1}·$ster^{-1}$·cm^{-2}. Based on this measure, but other physical measures are also considered.
** These events can last more than one day.





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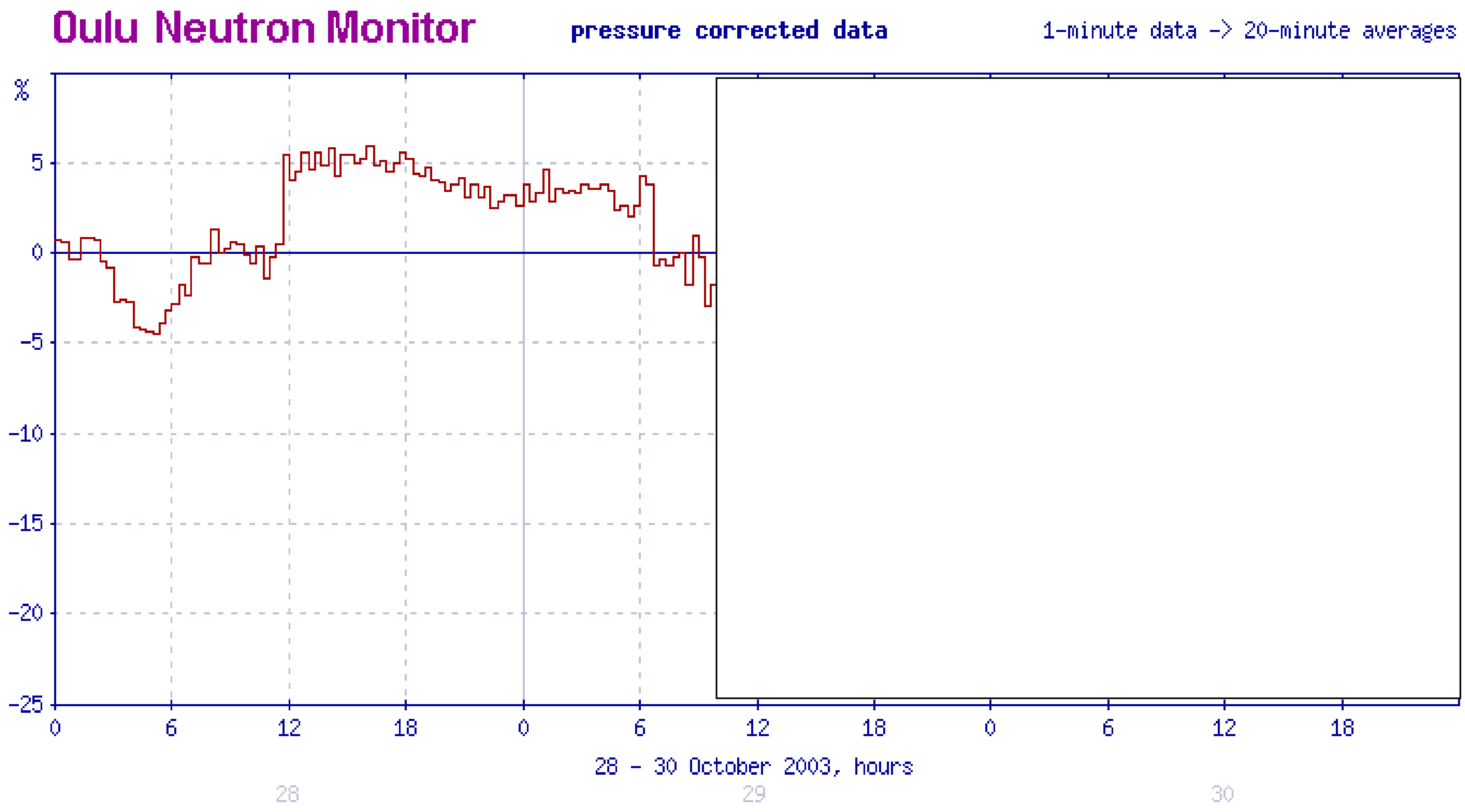

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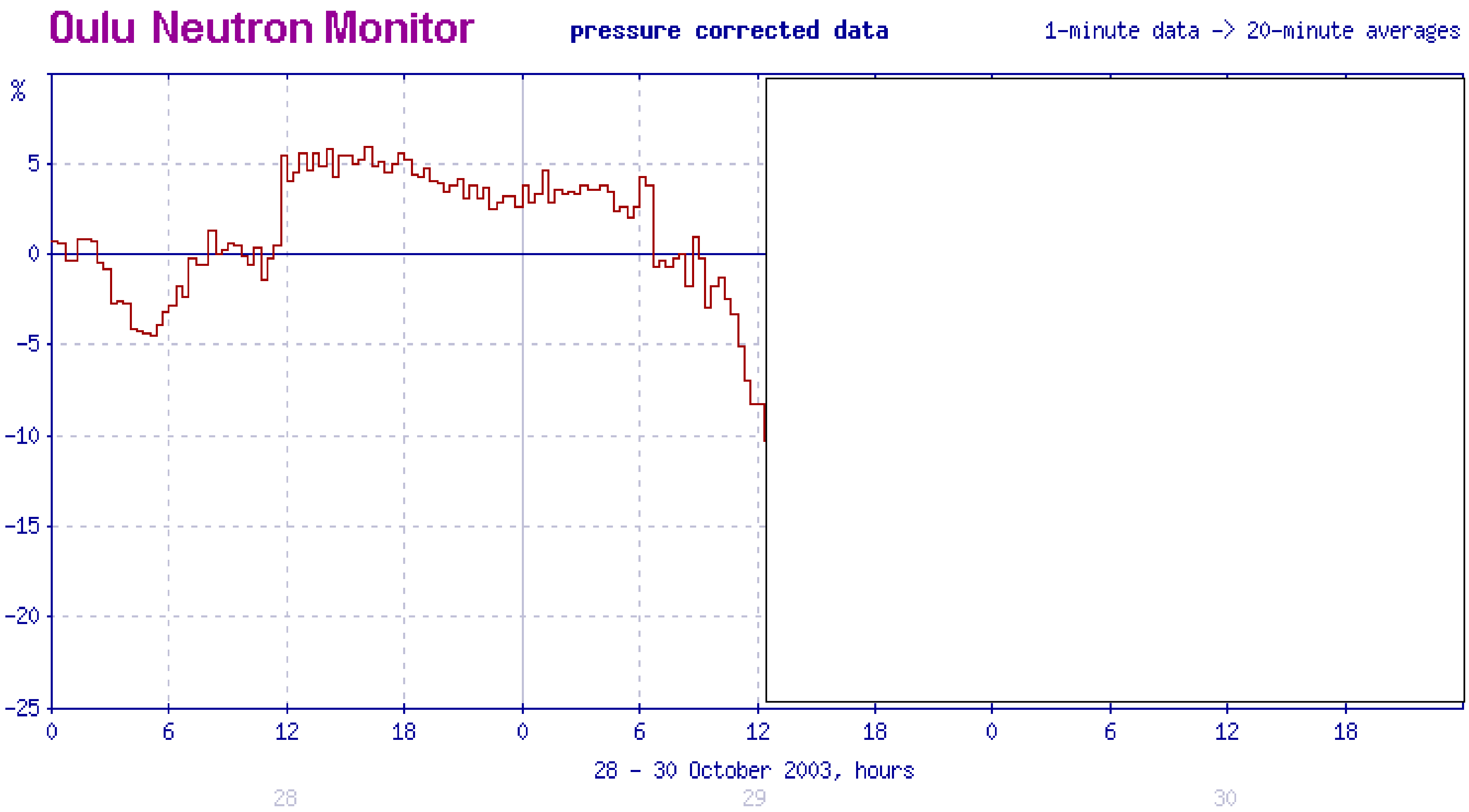

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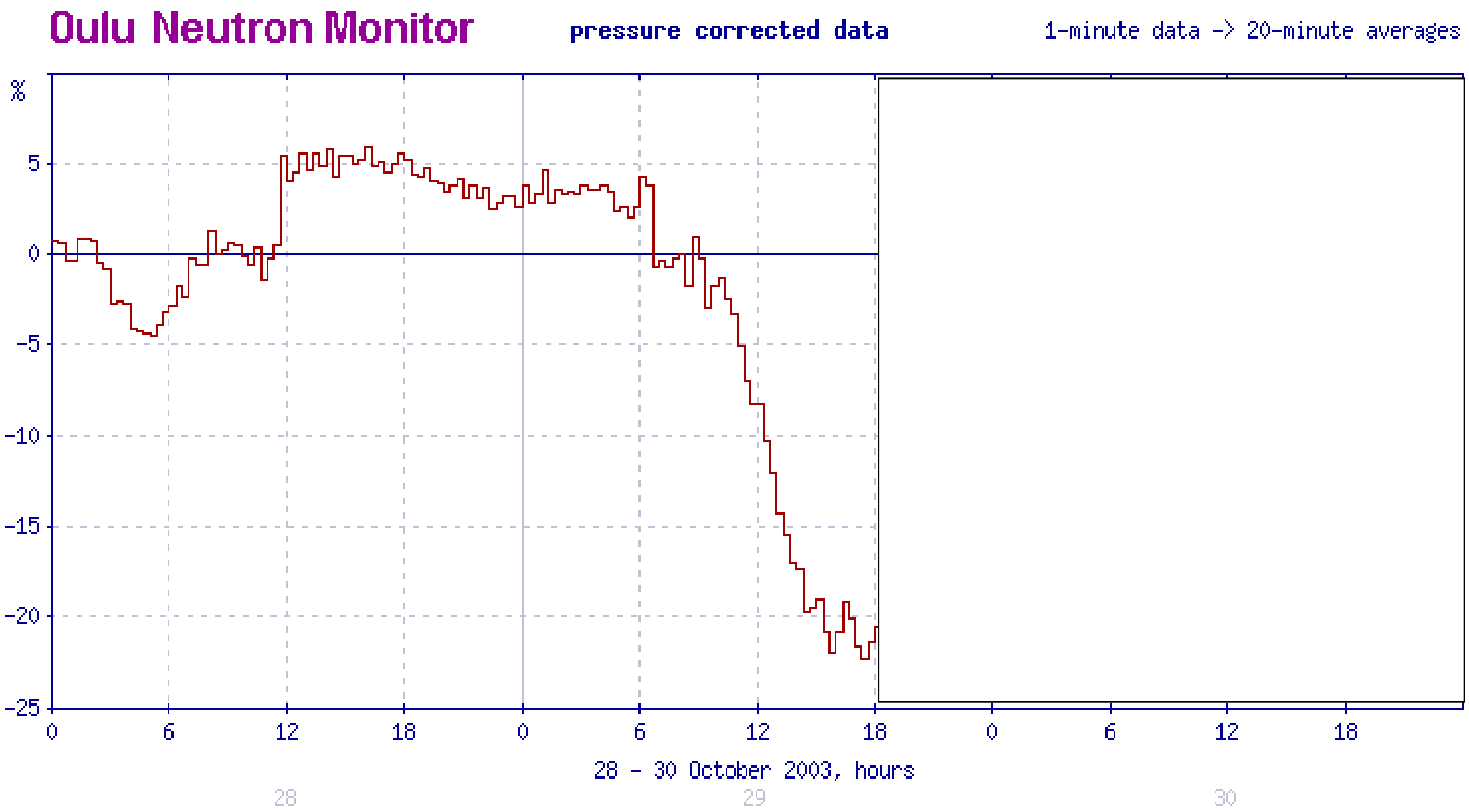

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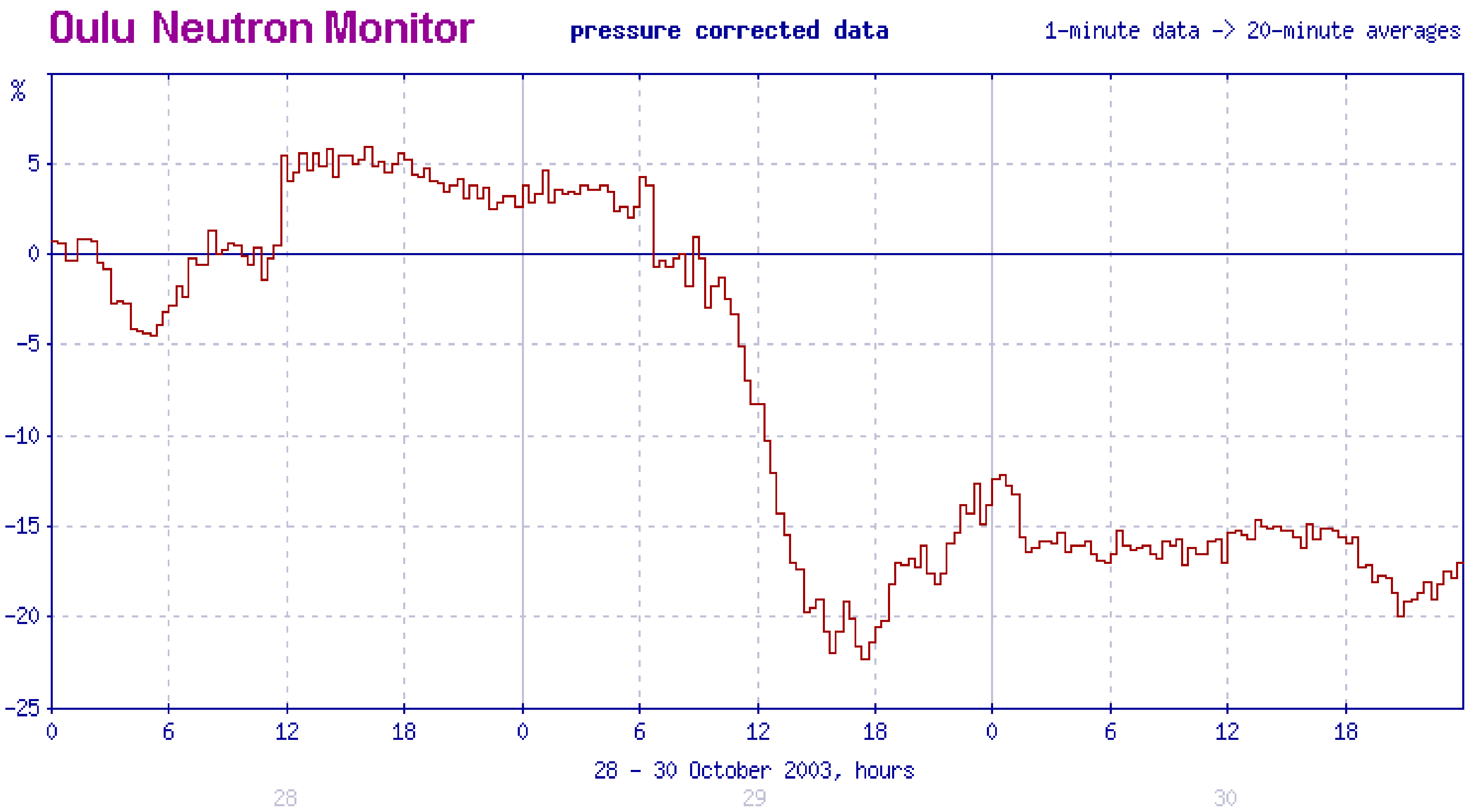

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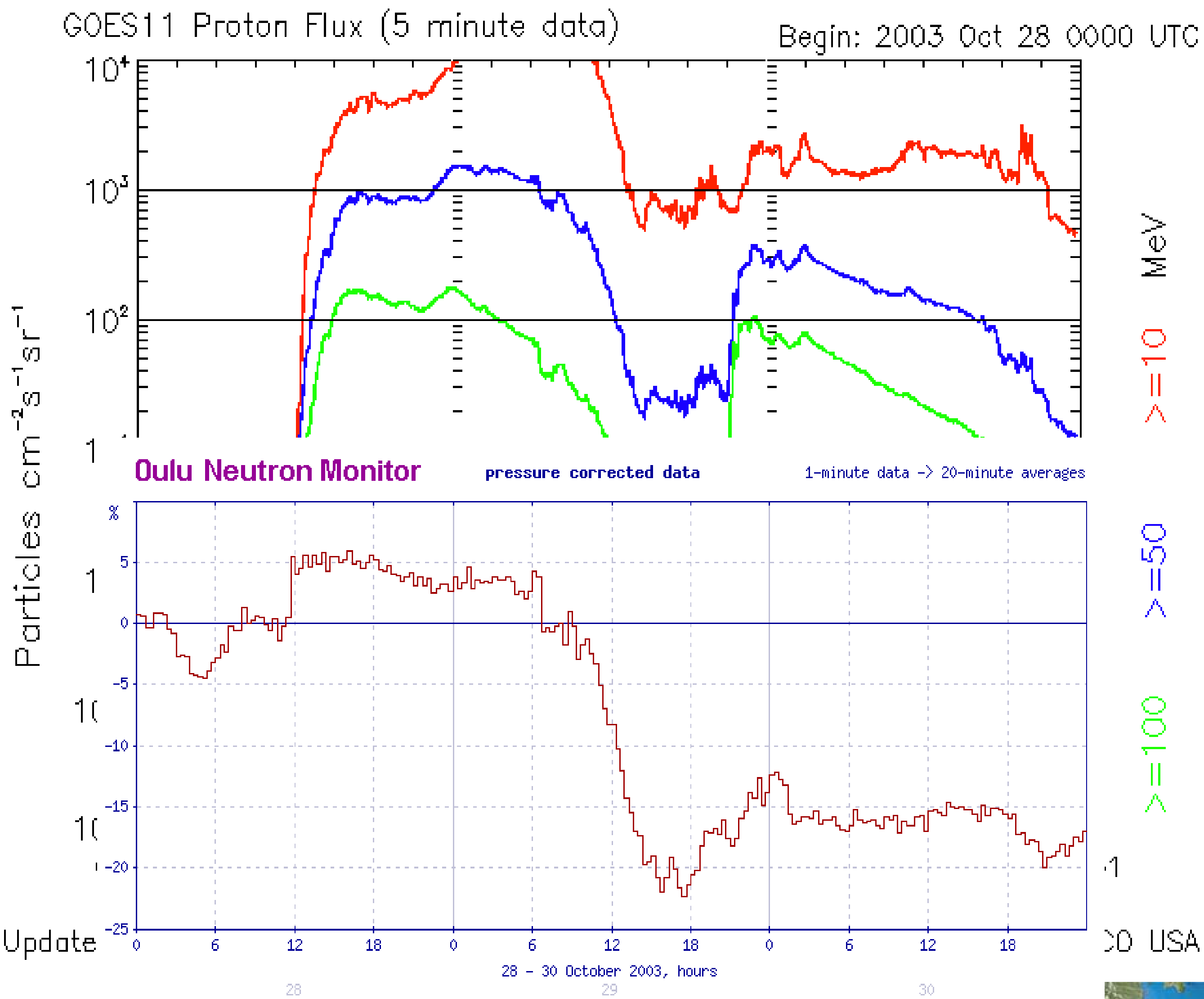
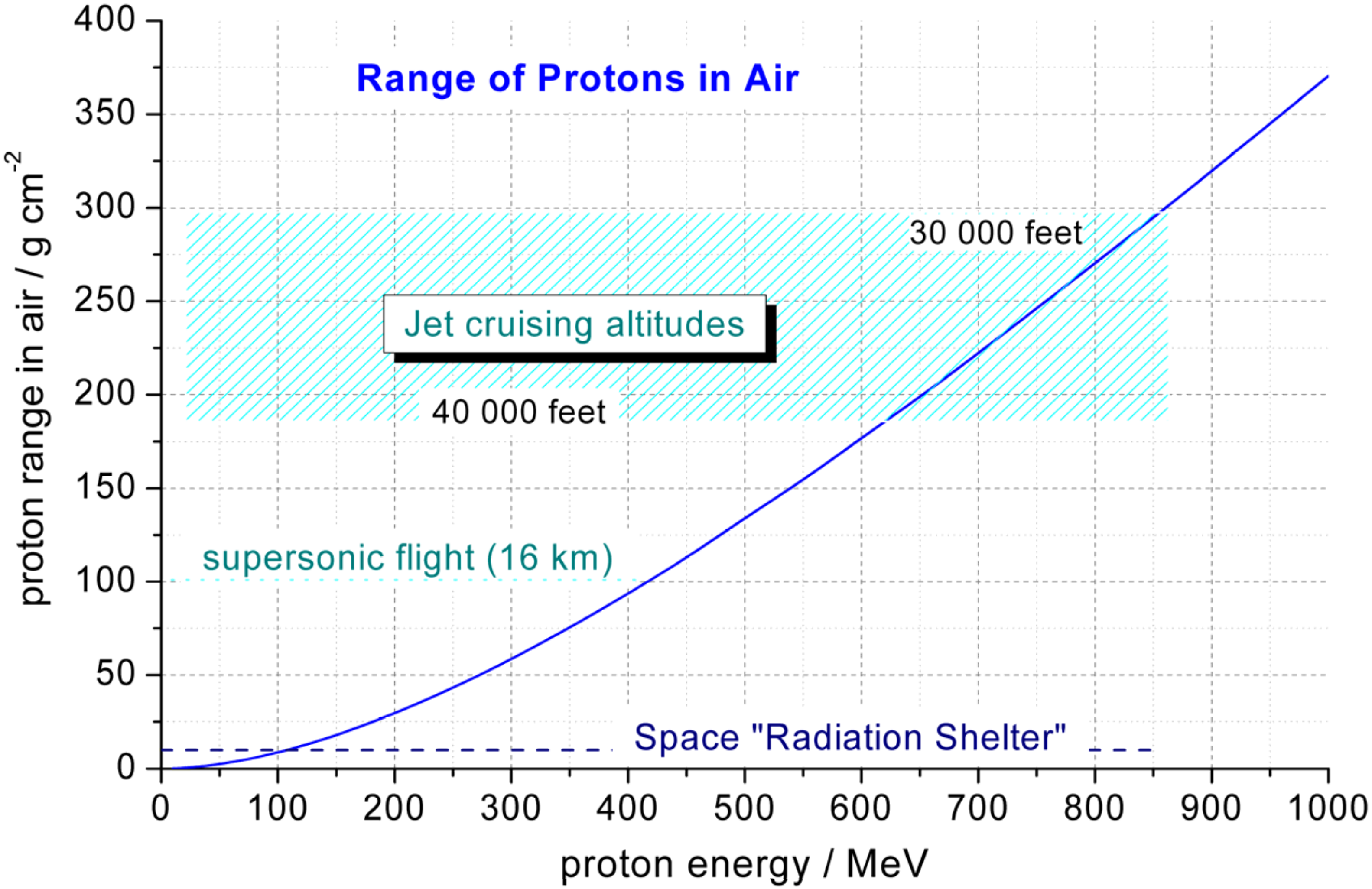
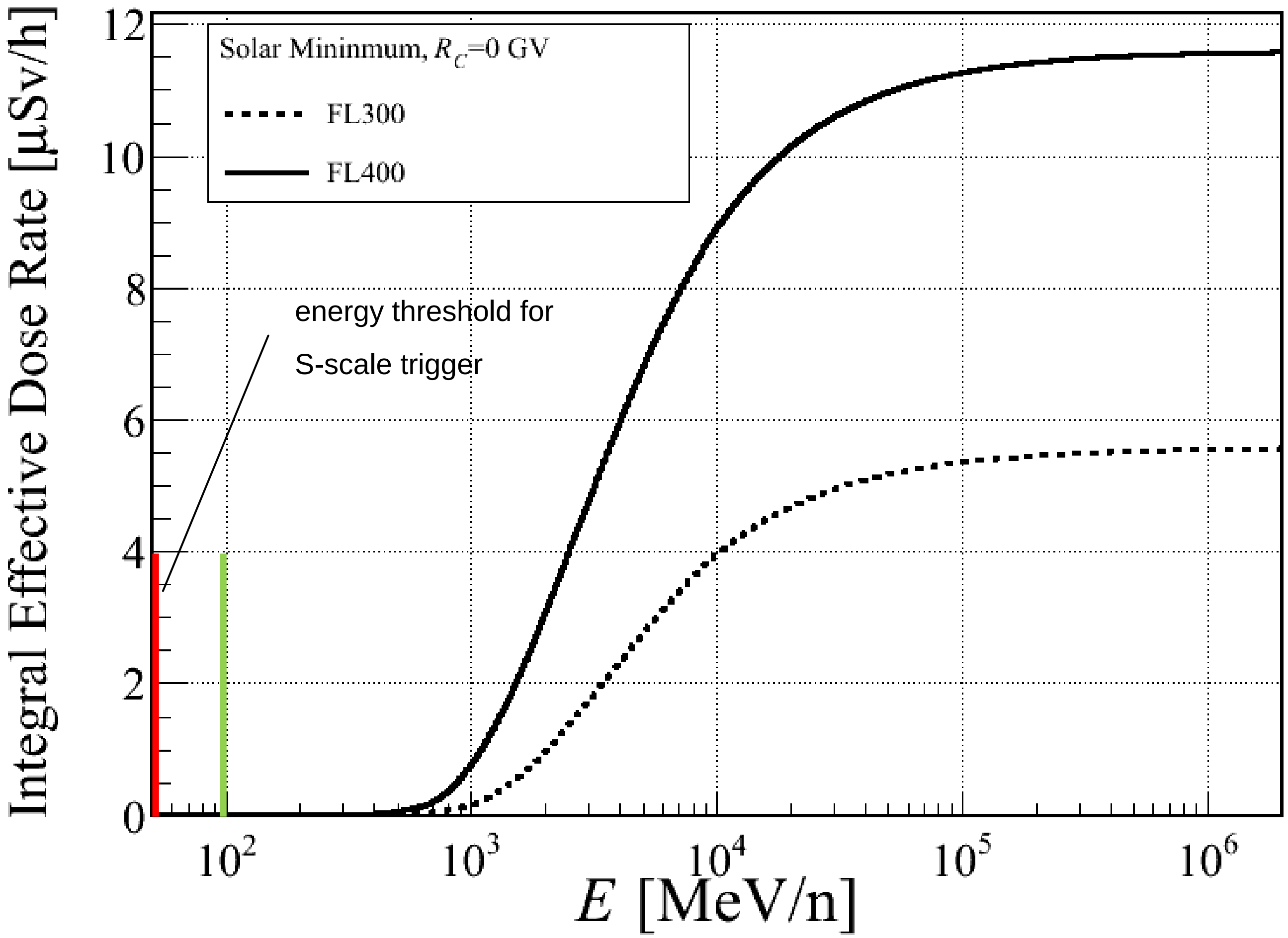


Atmospheric Shielding: Range of Protons in the Atmosphere



What energy is relevant (Simulation with PANDOCA)?



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Lessons learnt

- Significant increase in dose rates -> strong GLE (not GLE 65)
- Operational satellite data -> different scenario (lower energy)
- Particle spectra during the Halloween storms were soft (!)
- Nowcast models for dose rates have been developed (not op.)
- Incomplete information + public pressure = inappropriate reaction

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- SPEs with a significant high energy component are still **<u>unpredictable</u> !!!**

- Solar Particle Events can cause temporary increases in radiation exposure at aviation altitudes as a function of the corresponding energy spectrum.

- Warnings should be based on dose rates instead of particle flux (need for internationally accepted trigger threshold(s), e.g. dose rate < 0.2 mSv/h, flight dose < 0.5 mSv, etc.).

- Nowcast models for dose rates at aviation altitudes have been developed and have to be made operational (ground monitors, IT-infrastructure, action plan, etc.).

- International coordination in case of a significant Solar Particle Event (SPE) is highly recommended (dose assessment, communication, etc.).

Questions, etc.

Paracelsus (1538):

“Dosis sola facit venenum“

(The dose alone makes the poison)