Observations and Calculations of SPE

Presenter: Clive Dyer, QinetiQ

Team: Peter Truscott, Fan Lei, Alex Hands,

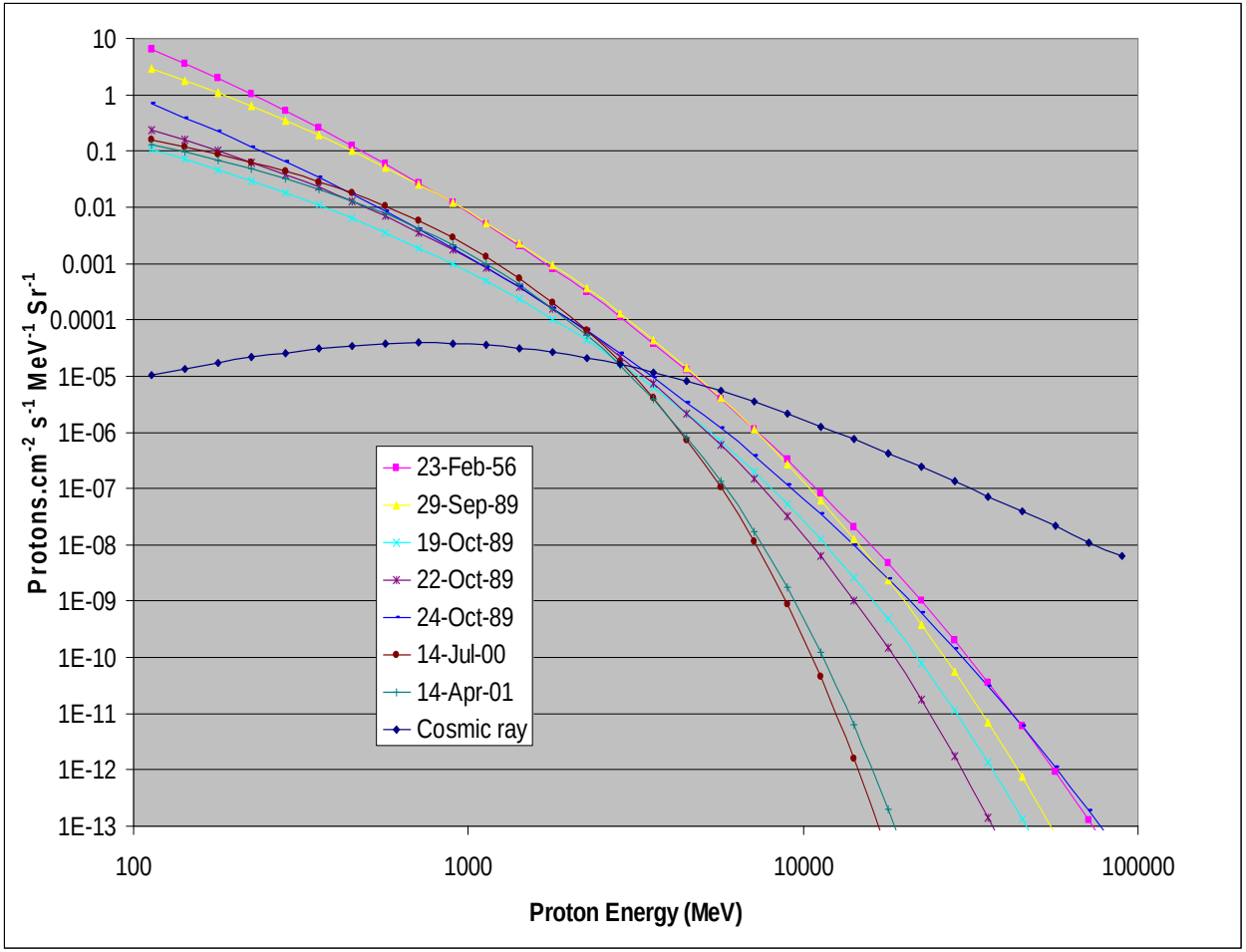
Occasion: EURADOS Workshop on “Cosmic Radiation and Aircrew Exposure”

30/01/2009

Estimation of Solar Particle Events Using QARM

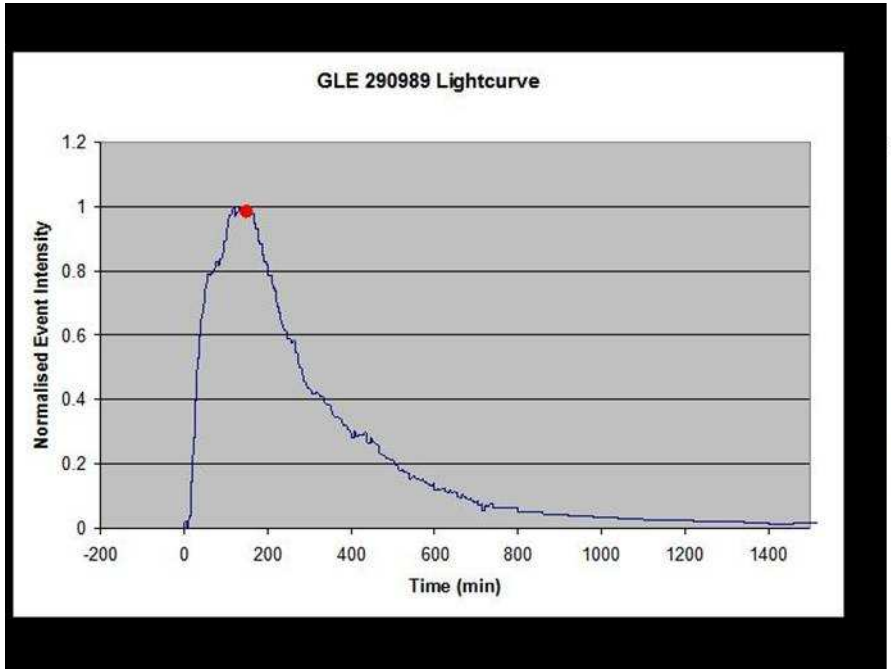
- QARM model includes 7 solar particle events.
- Spectra are derived from ground level neutron monitors at various cut-off rigidities plus low energy point from GOES.
- 4 of these have been validated against CREAM data from Concorde during Sept-Oct 1989.
- Event of 15 April 2001 validated against Spurny-Dachev data for Prague to New York
  - Additional data from FRA to DFW being examined.
- Model is then used to explore environments for various routes, geomagnetic conditions and relative timings of events and flights.

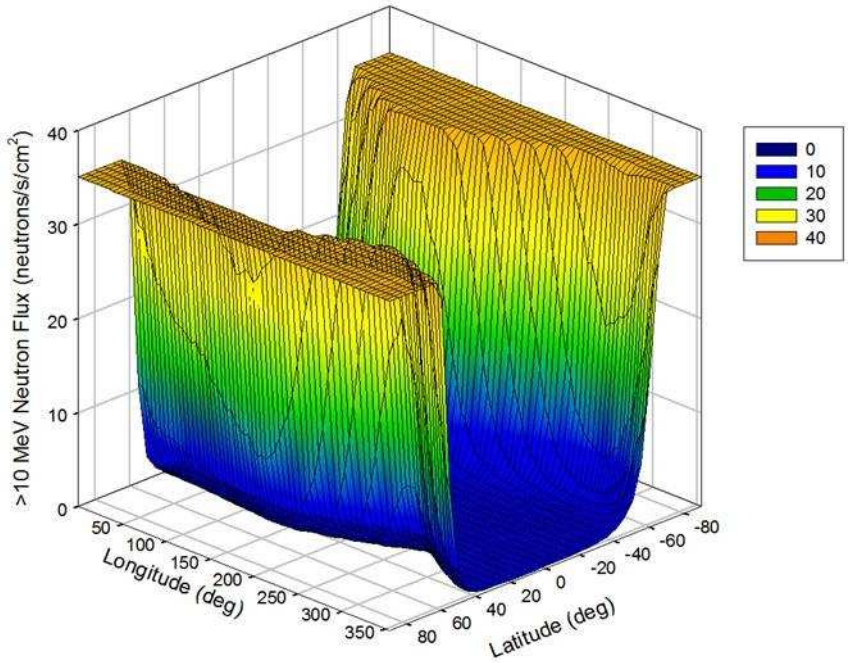
Solar Particle Event Spectra for Major Ground Level Events (GLE)



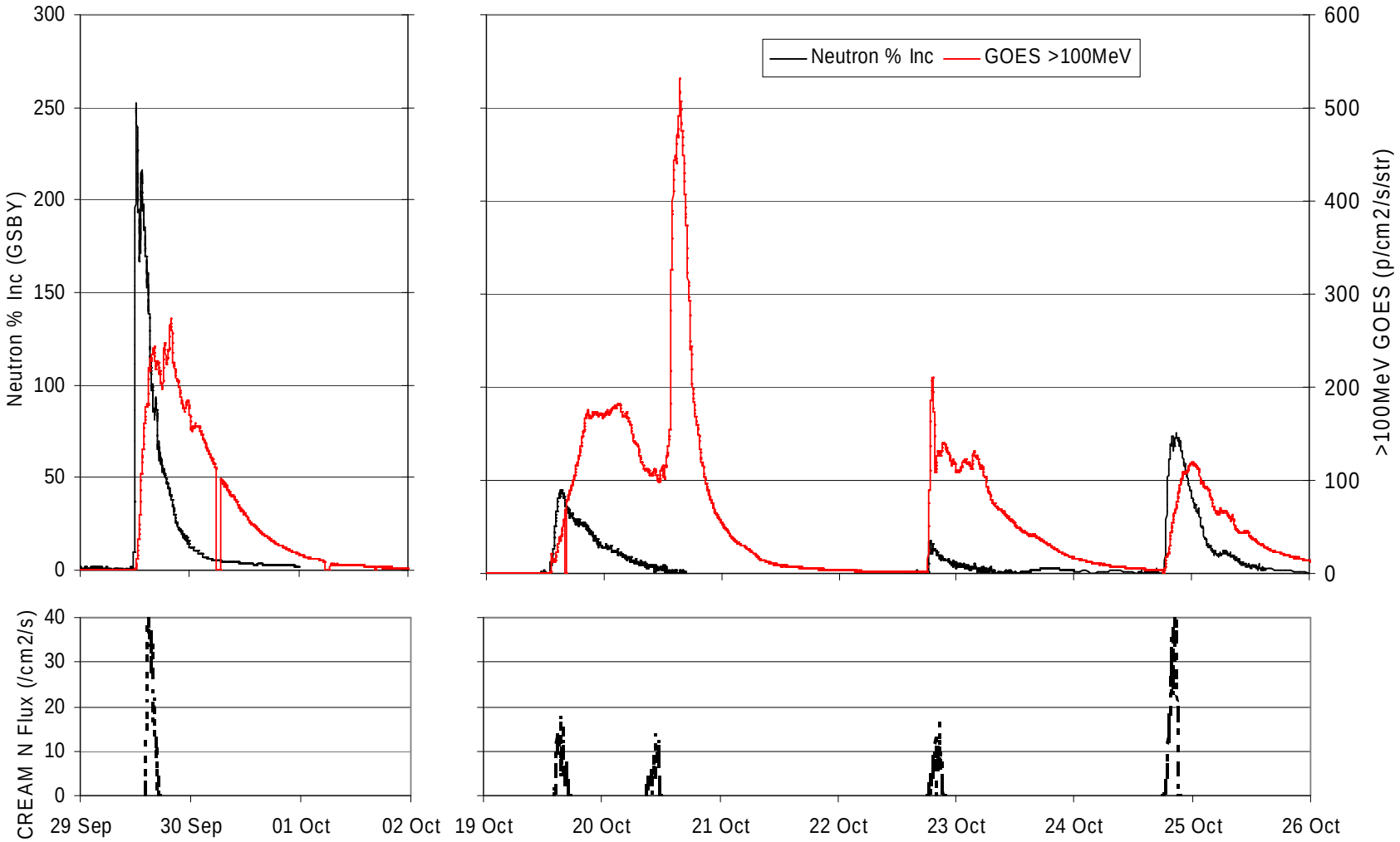
- Derived from neutron monitor (NM) and GOES data
- Correspond to the peak spectrum (worst case)
- Event profile according to NM data

The solar particle event of 29/09/1989.
Calculated Neutron Flux at 12 km altitude at event maximum

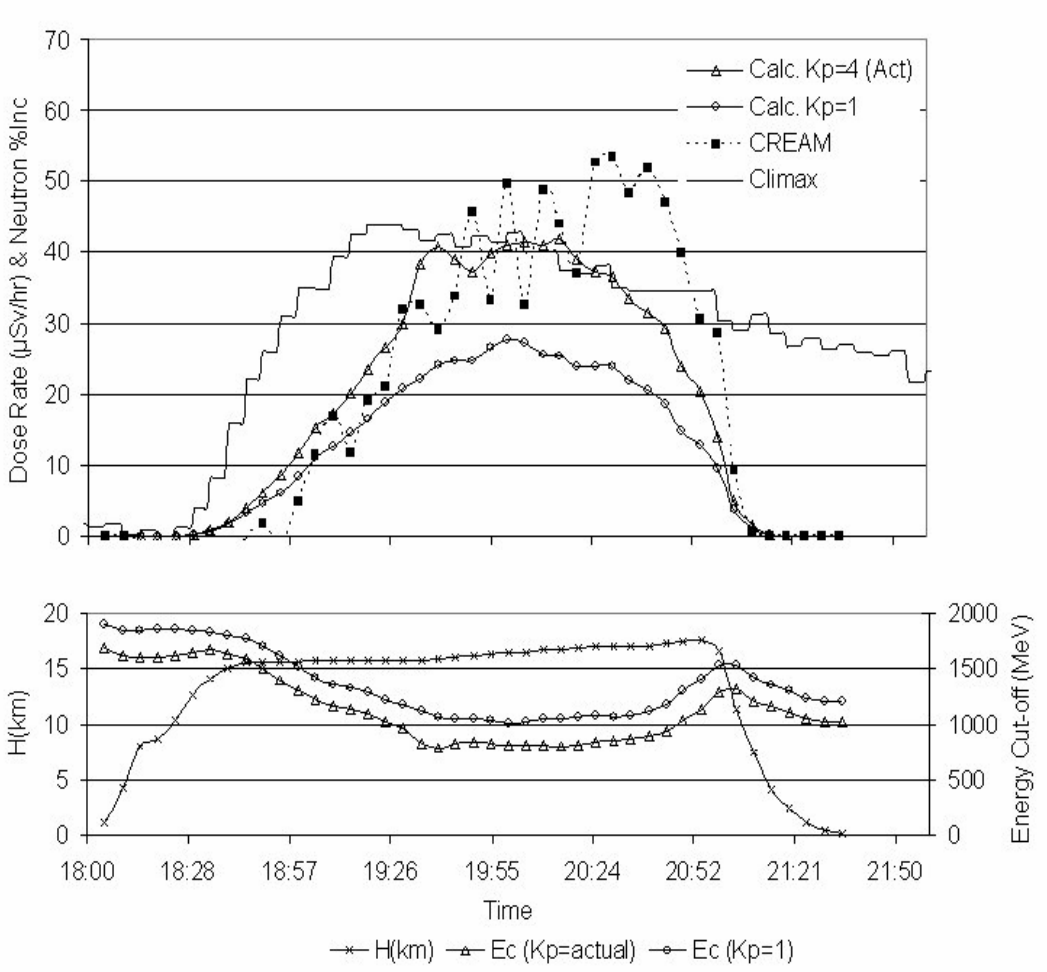




Neutron increases from CREAM on Concorde cf GOES protons and ground level neutron monitor at Goose Bay



The importance of Kp index

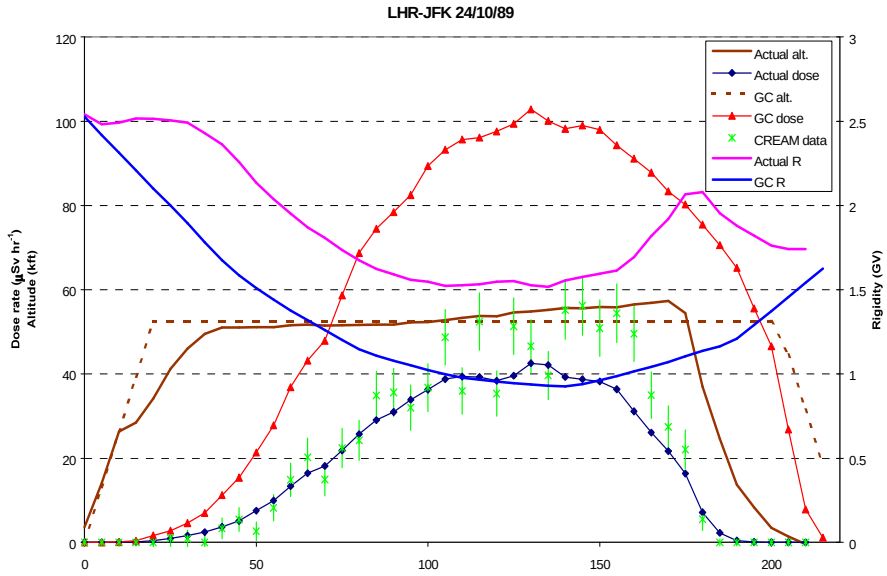


CREAM data taken on Concorde during the 24 Oct 1989 event

The geomagnetic conditions were disturbed with Kp =4 leading to factor 1.5 increase in dose rate.

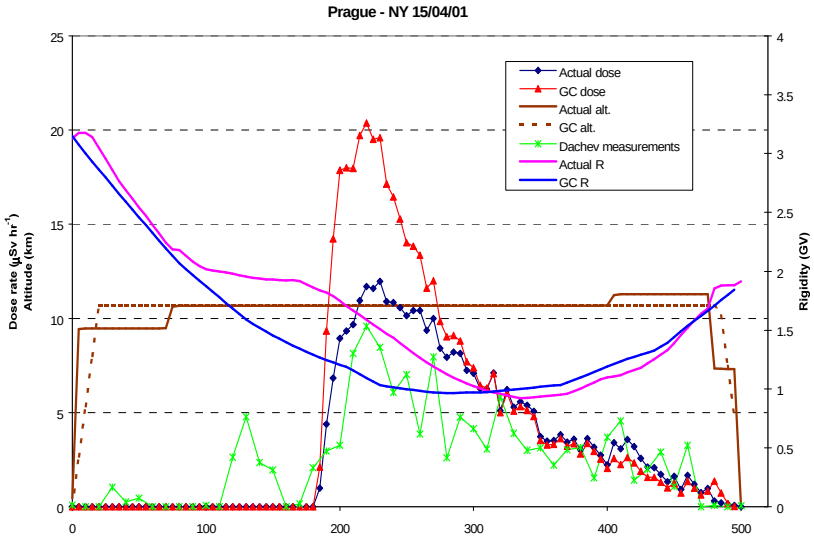
Influence of Actual Route cf Great Circle

LHR-JFK 24 October 1989



Concorde route during event of 24 October 1989 (Kp = 4).
Data from CREAM.
Peak dose rate on great circle route would have been factor 2.5 higher cf actual route.

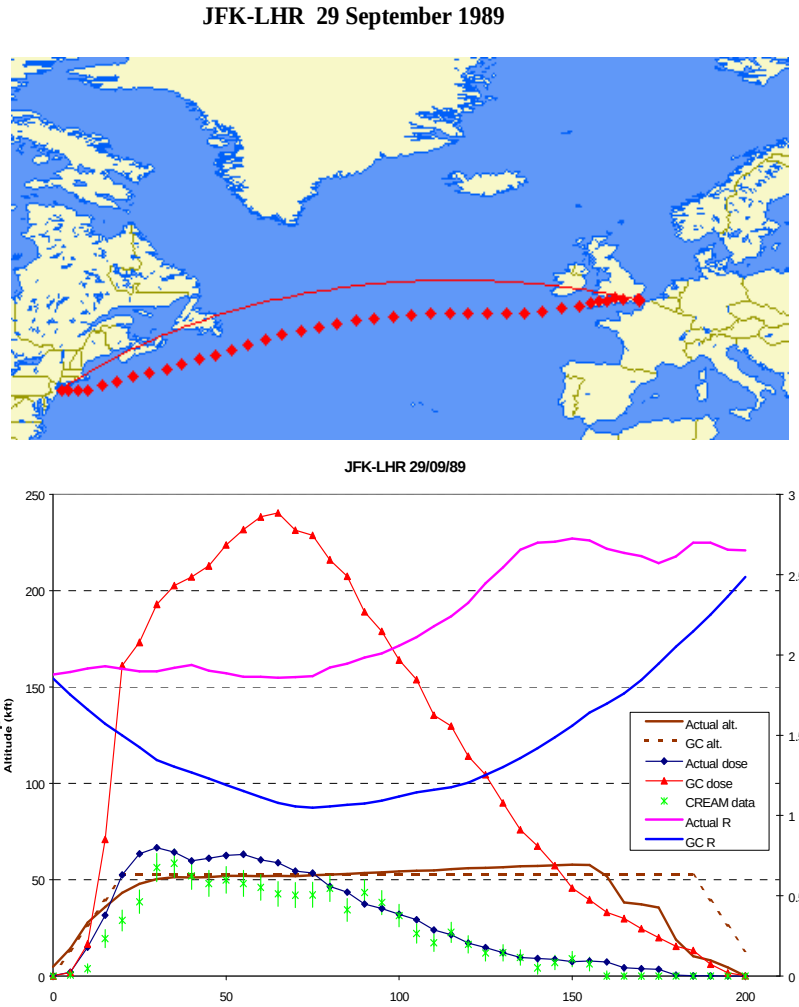
GLE60 (Kp =3) : PRG-JFK
Great Circle vs. Actual Flight path



Data from Spurny & Dachev

QARM gives reasonable agreement and shows that a small deviation from great circle gave factor 2 reduction in peak dose rate.

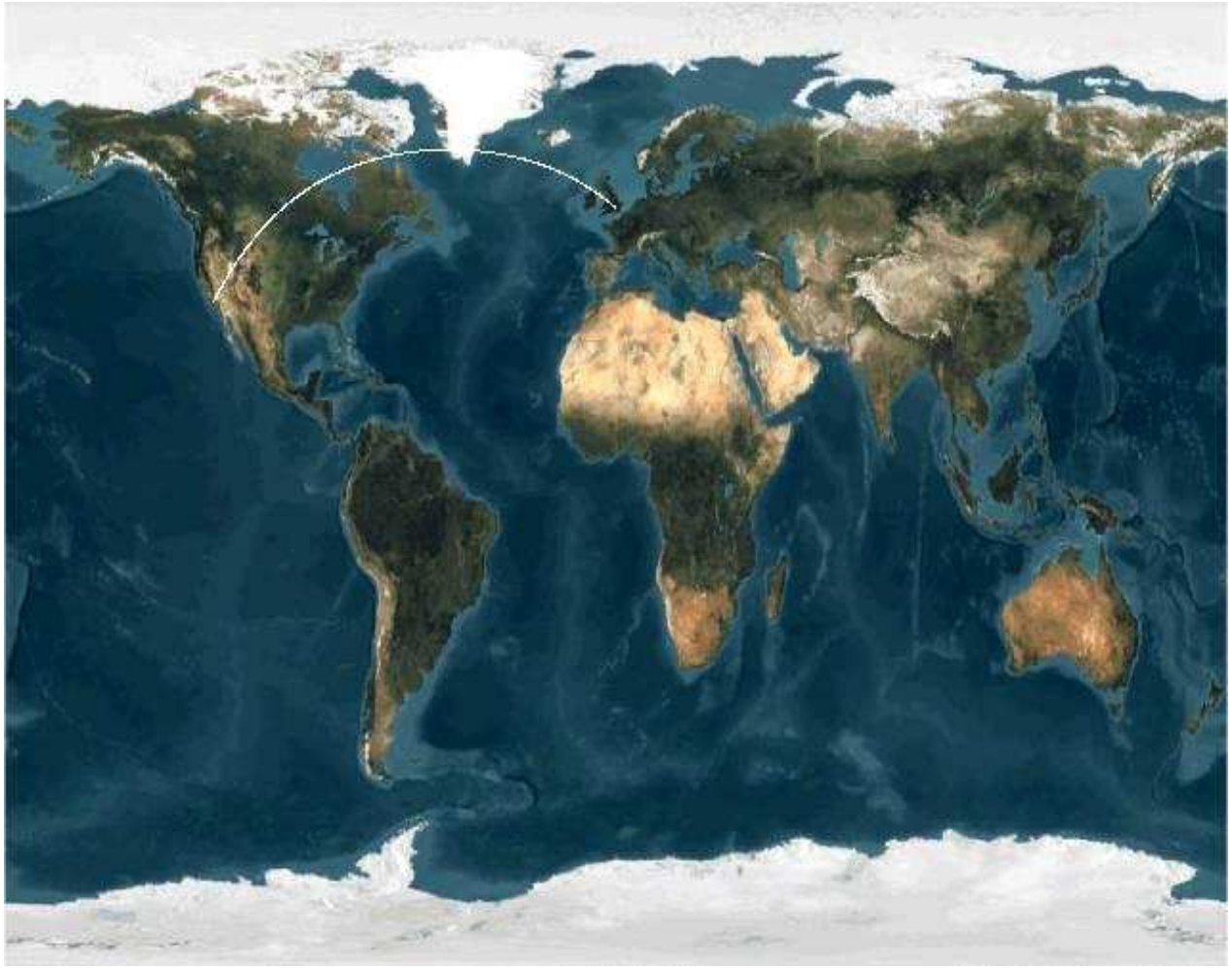
GLE42 (Kp =2): JKF-LHR
Great Circle vs. Actual Flight path

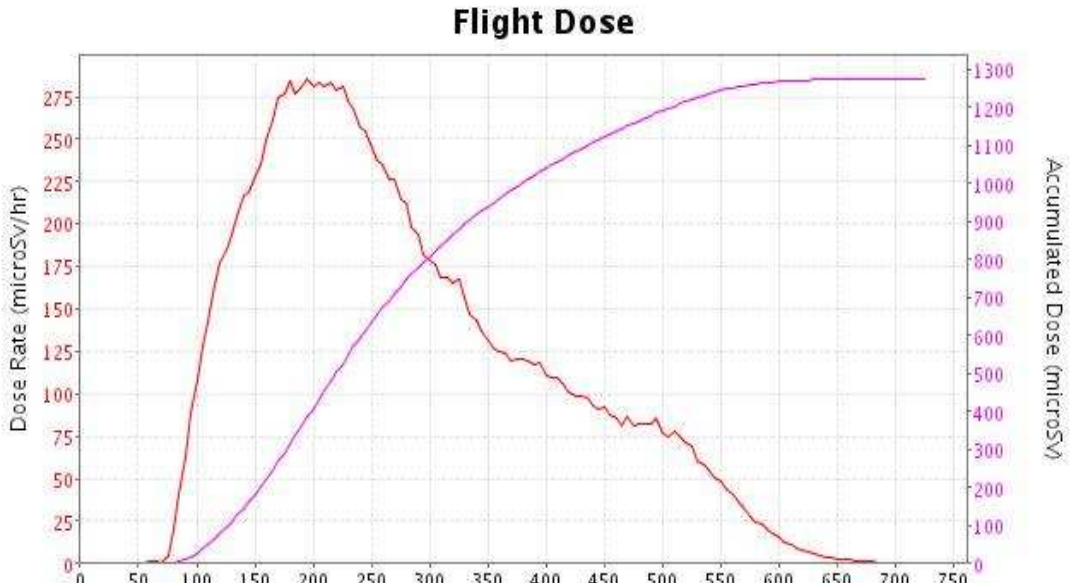


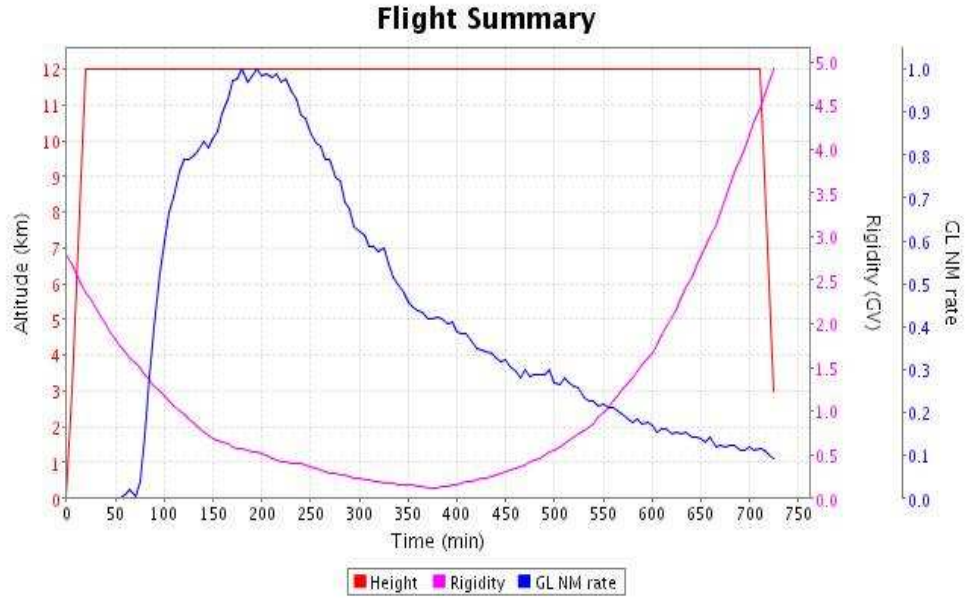
Concorde route during event of 29 September 1989 (Kp = 2). Data from CREAM.

Peak dose rate on great circle route would have been factor 5 higher cf actual route.

LHR to LAX Great Circle Route

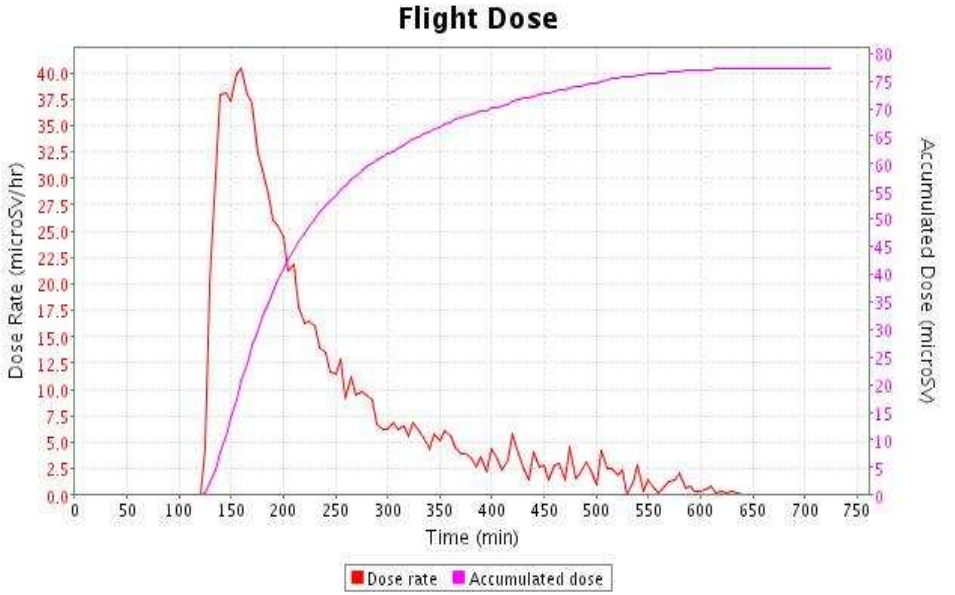


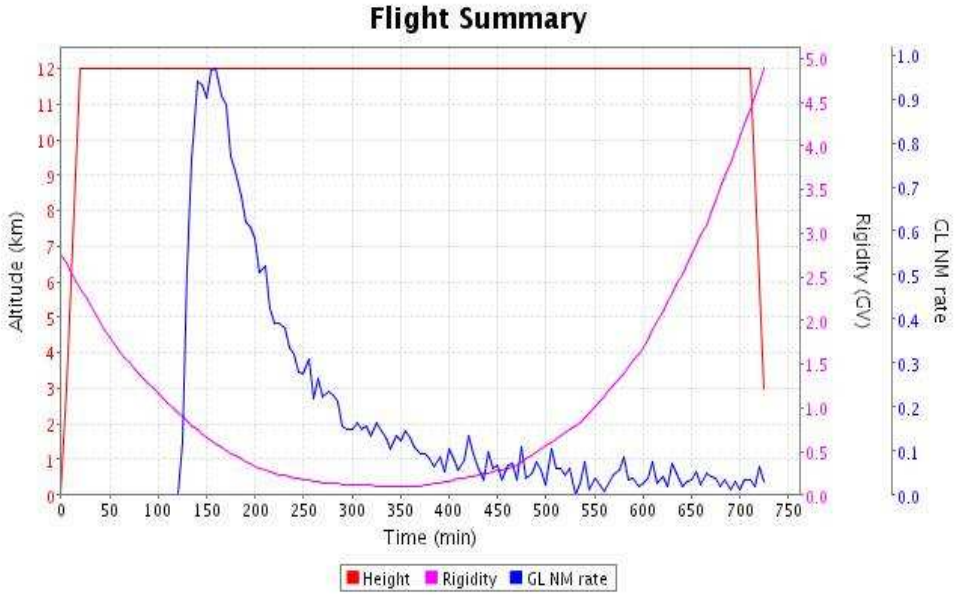




Influence of
Solar Particle Event
of 29 Sept 1989
on LHR-LAX
Flight; Kp=0

Worst case event start
is 1 hour after take-off





Influence of
Solar Particle Event
of 15 April 2001
on LHR-LAX
Flight; Kp=0

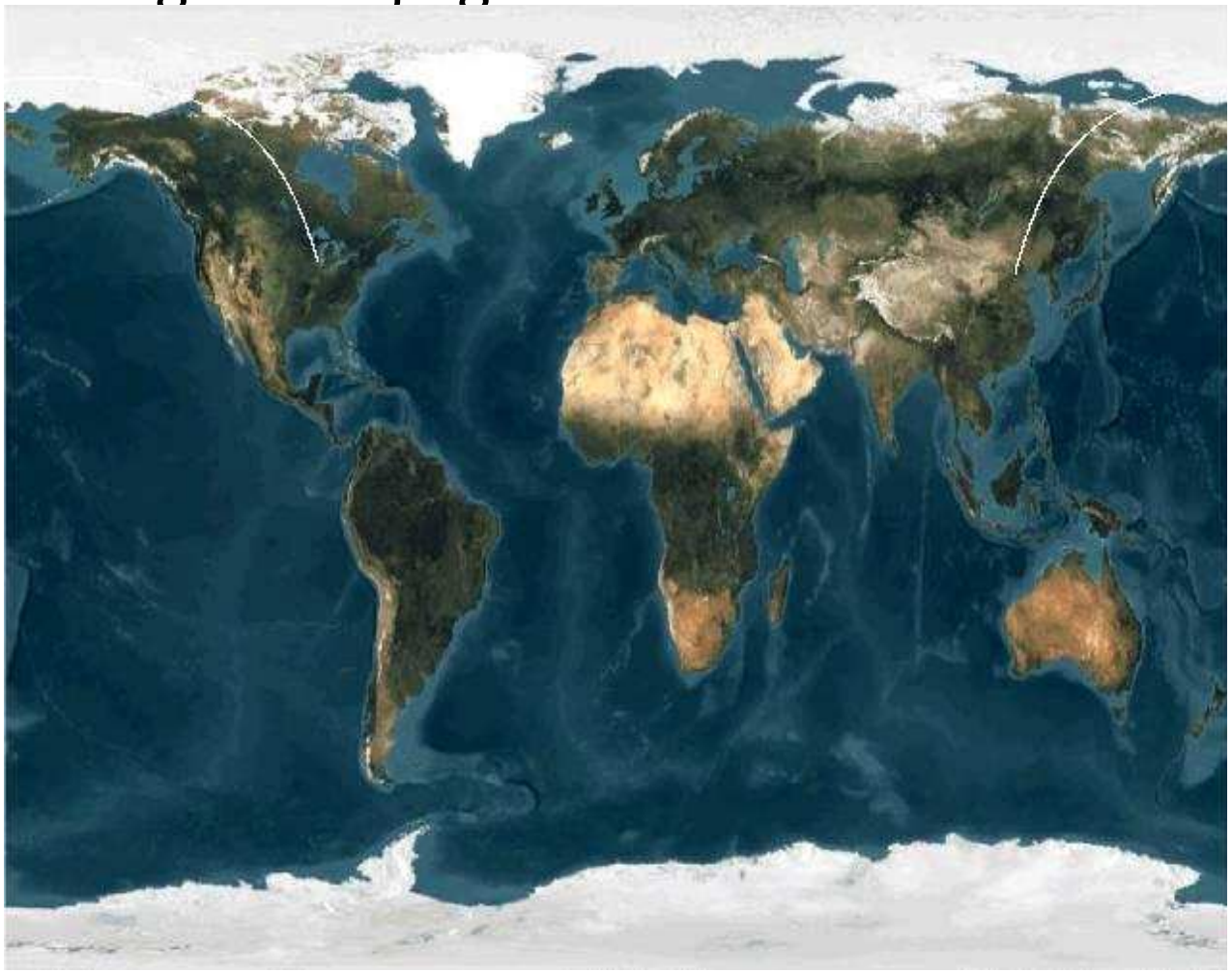
Worst case event start
is 2 hours after take-off.

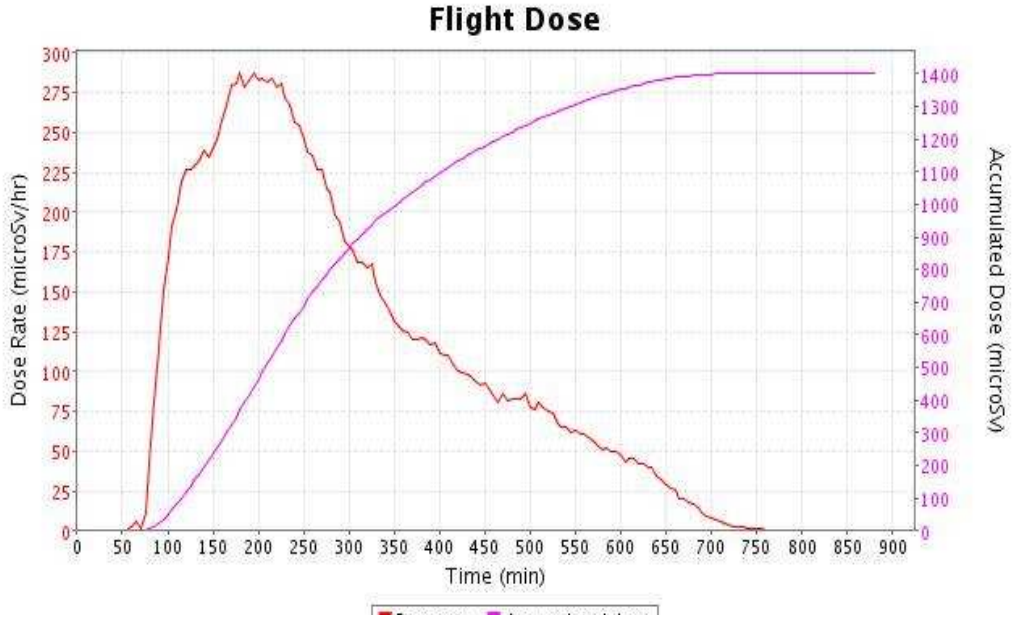
Solar Particle Event Doses for LHR-LAX at 12 km Estimated Using QARM

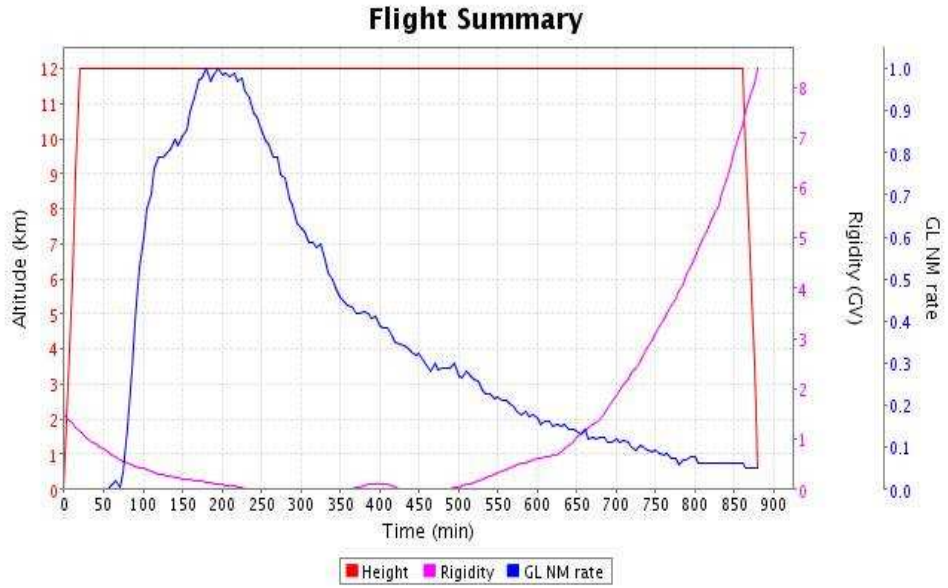
Event	23 Feb 1956	29 Sept 1989	19 Oct 1989	22 Oct 1989	24 Oct 1989	14 July 2000	15 April 2001
W/C Event Start (hrs)	3	1	0	1	1	2	2
Peak Dose Rate (mSv/hr)	1.82	0.29	0.022	0.039	0.049	0.013	0.041
Route Dose (mSv)	2.27	1.28	0.12	0.15	0.25	0.031	0.078

Note: Additional to GCR Route Dose of 0.05-0.06 mSv
Geomagnetic Conditions Quiet.
W/C increase for Sept 89 gives 1.33 mSv for Kp=6
Event start measured wrt take-off.

Polar Great Circle Route
Chicago to Beijing

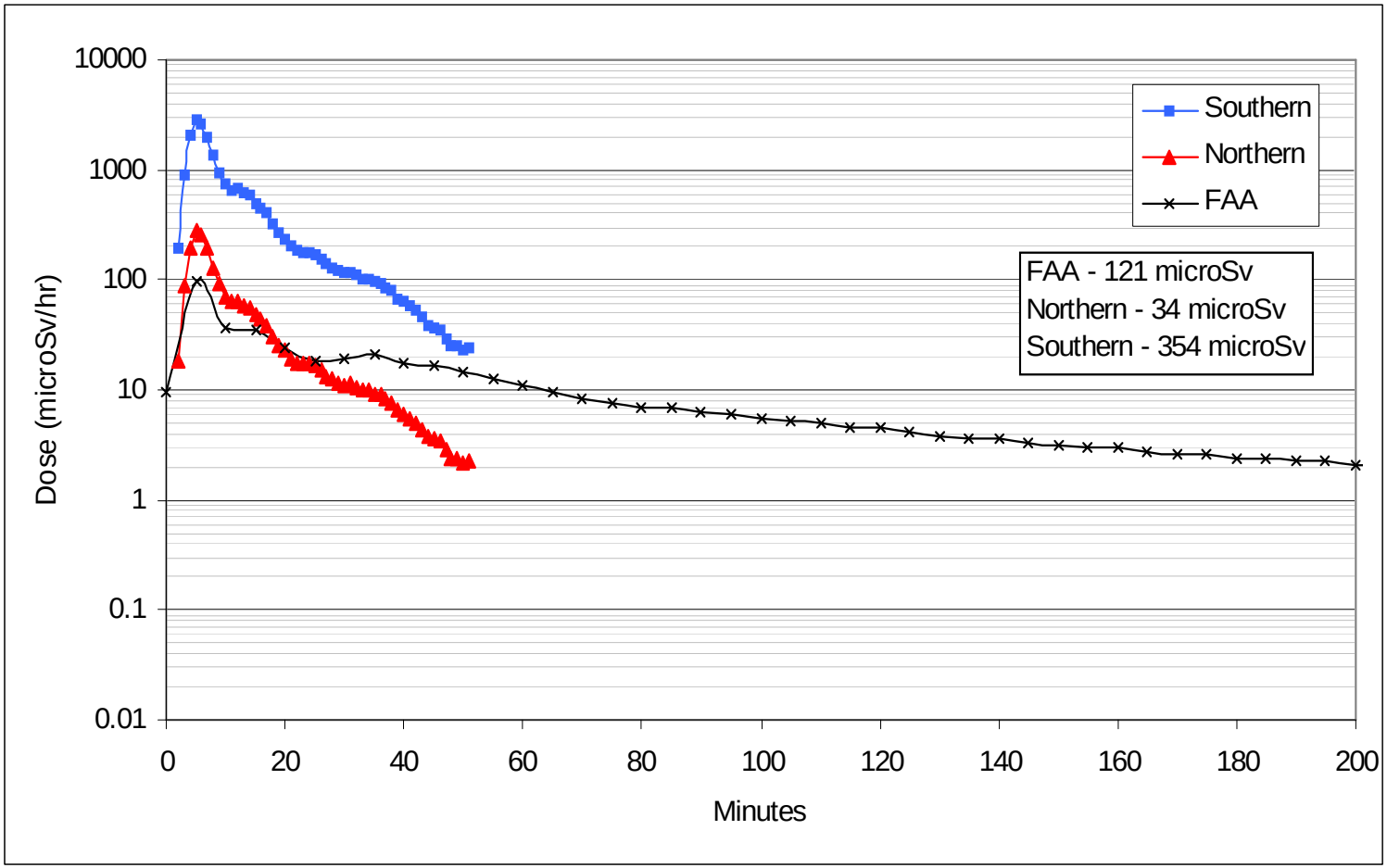




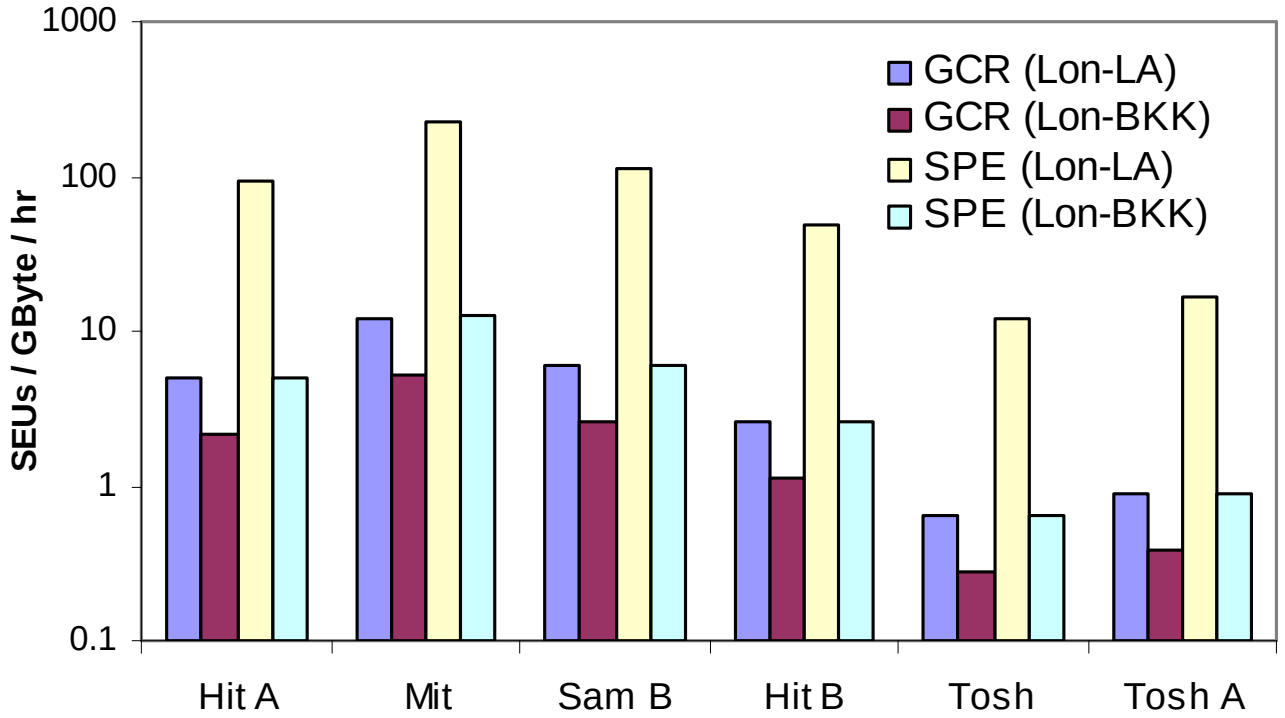


Influence of solar particle event of 29 Sept 1989 on Chicago to Beijing Flight.
Accumulated dose is 1.4 mSv

Calculated dose rates for SPE of 20 Jan 2005 for high latitude routes at 39000 ft



Upset rates in SRAMs for flights to 12 km for GCR solar min and SPE of 29 Sept 1989.



Summary

- QARM is an engineering model of atmospheric radiation environment and allows for time variations in GCRs, SPEs and geomagnetic cut-off.
- It has been widely validated and can be applied to radiation effects/protection applications in microelectronics and personnel.
- Validations of SPE calculations for 5 events have been made against flight observations.
- Energetic solar particle event that are seen as GLEs can significantly enhance the radiation field in the atmosphere **leading to route doses that can exceed 1 mSv together with high SEE rates.**
- Accurate assessment of the enhanced radiation to a flight requires good knowledge of
  - The event proton spectrum and its time variation
  - The exact geomagnetic conditions
  - Detailed flight path (great circle approximations inadequate)
- **Sensitivity to flight path implies possibility of radiation reduction.**
- QARM is available online: qarm.space.qinetiq.com
- Solar particle events are far from isotropic
  - **Neutron Monitors provide crucial data**
  - **Accurate dose can be obtained only from real-time onboard monitors**
- **Need to deploy onboard monitors widely for next solar maximum.**

RayHound Compact Aircraft Radiation Monitor

Screen display for peak of 29 Sept 89 SPE at 12 km & high lat; e.g. LHR-LAX, SYD-JNB MDW-PEK

260x107x57 mm
1.16 kg

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