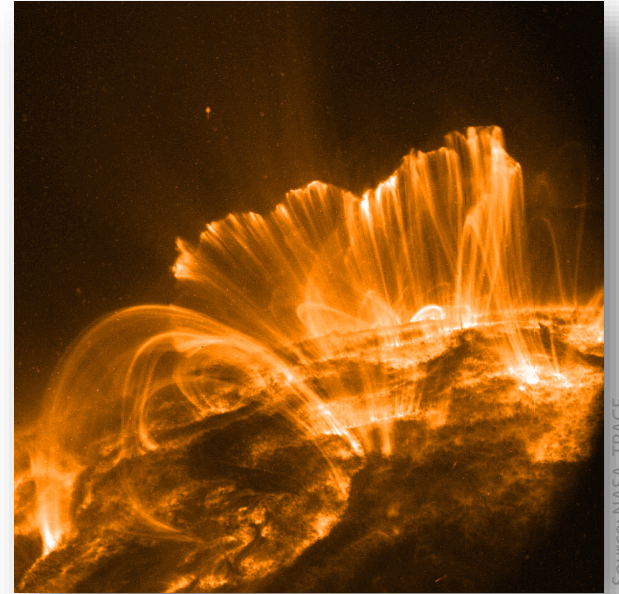

Comparison of calculated radiation exposure for selected flight routes and events

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Content

- Introduction
- Calculation codes/models
- Selected flights
- Data obtained
- Comparison



Source: NASA, TRACE

Comparison of calculated radiation exposure

- Nine codes/models, results anonymized
- Three selected flights
(transatlantic, polar route, southern hemisphere)
- Galactic Cosmic Radiation
- Solar Cosmic Radiation (Ground Level Enhancements)
- Operational quantity ambient dose equivalent $H^*(10)$
- Radiation protection quantity effective dose E (ICRP-60)
- Route doses and dose rates

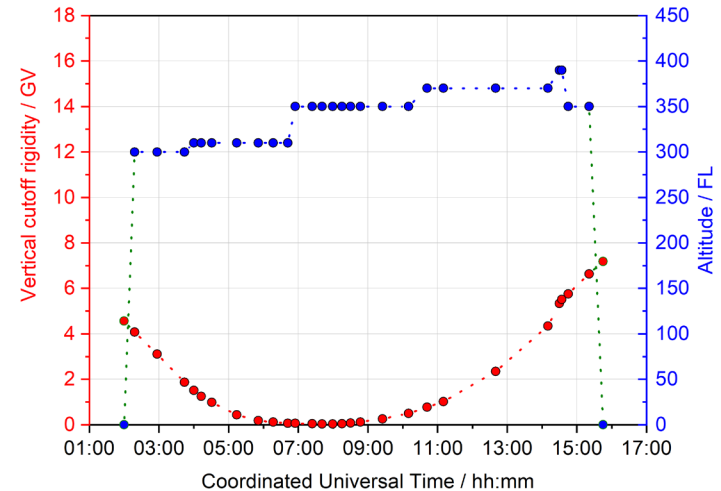
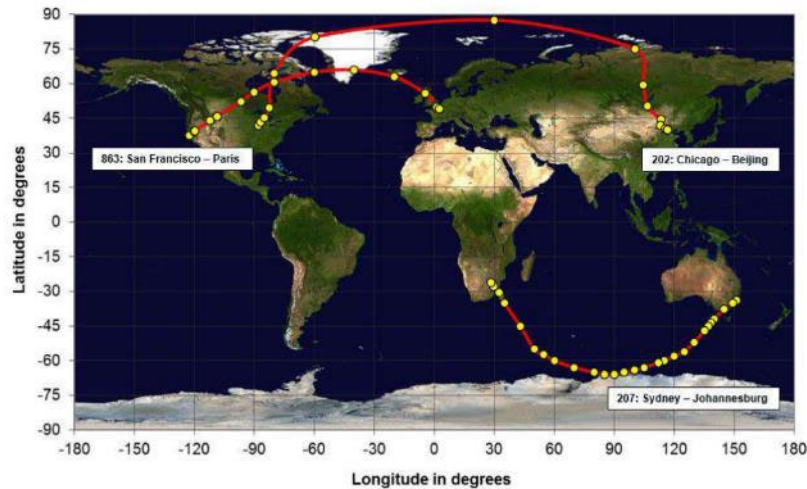
Nine codes /models participated during the comparison

Code / Model	SCR Input data	SCR Dose Assessment Approach	GCR Input Data	GCR Dose Assessment Approach	Reference
AVIDOS 2.0 / SOLARDOS	- neutron monitor data - primary time dependent SCR characteristics (isotropic spectrum)	GEANT4 (PLANETOCOSMICS), ICRP60 / 103 (ICRP, 1991; ICRP, 2007)	(Gaisser, 2001) (Beck, 2007)	FLUKA,GEANT4 (PLANETOCOSMICS), ICRP60 / 103 (ICRP, 1991; ICRP, 2007)	(Beck, 2007) (Latocha, 2009) (Latocha, 2016)
EPCARD.Net 5.4.3 / GEANT4-GLE Module	- primary time dependent SCR characteristics (isotropic spectrum) - neutron monitor database (NMDB)	GEANT4 (HMGU-Application), ICRP60	(Badhwar, 1996) (Burger, 2000)	FLUKA, GEANT4 (HMGU-Application), ICRP60	(Roesler, 2002), (Mares, 2009), (Pioch, 2012) www.helmholtz-muenchen.de/epcardnet
FDOScalc 2.0	Not applied	semi-empirical	n.a.	semi-empirical	(Schrewe, 2000) (Wissmann, 2006) (Wissmann, 2010)
JISCARD EX WASAVIS	n.a.	Determination of SEP flux Air-shower simulation by PHITS ICRP60 / 103	(Nymmik, 1992)	PHITS-based analytical code PARMA ICRP60 / 103	(Yasuda, 2011) (Sato, 2008; 2014) (Kataoka, 2014)
PANDOCA	- neutron monitor data - primary, time dependent SCR characteristics (anisotropic spectrum) - satellite data	GEANT4 (PLANETOCOSMICS), ICRP60	(Matthiä, 2013)	GEANT4 (PLANETOCOSMICS), ICRP60	(Matthiä, 2009) (Matthiä, 2009a) (Matthiä, 2014)
PCAIRE	not applied	semi-empirical	n.a.	n.a.	(Lewis, 2001) (Lewis, 2002) (Lewis, 2004) (Takada, 2007)
BERN GLE Model	- neutron monitor data - primary time dependent SCR characteristics (anisotropic spectrum)	GEANT4 (PLANETOCOSMICS), ICRP60	(Gleeson, 1968a) (Garcia, 1975) (Caballero, 2004) Helicentric potential from https://www.faa.gov/data_research/research/med_humanfac/aeromedical/media/MV-DATES.zip	GEANT4 (PLANETOCOSMICS), ICRP60	(Desorgher, 2005) (Desorgher 2006)
QARM 1.0	n.a.	n.a.	(Badhwar, 2001)	n.a.	(Lei, 2004) (Lei, 2006) (Dyer, 2007) (mcnpx.lanl.gov)
SIEVERT PN 1.0, SIGLE	- neutron monitor data - primary, time dependent SCR characteristics (including North/South anisotropy)	semi-empirical, ICRP60	(Badhwar, 2001)	EPCARD.NET 5.4.3, ICRP60	(Lantos, 2003a) (Lantos, 2003b) (Lantos, 2004) (Lantos, 2006) (sievvert-system.org) (Bottollier-Depois, 2007)

Selected flight routes for the comparison

Three Selected flights

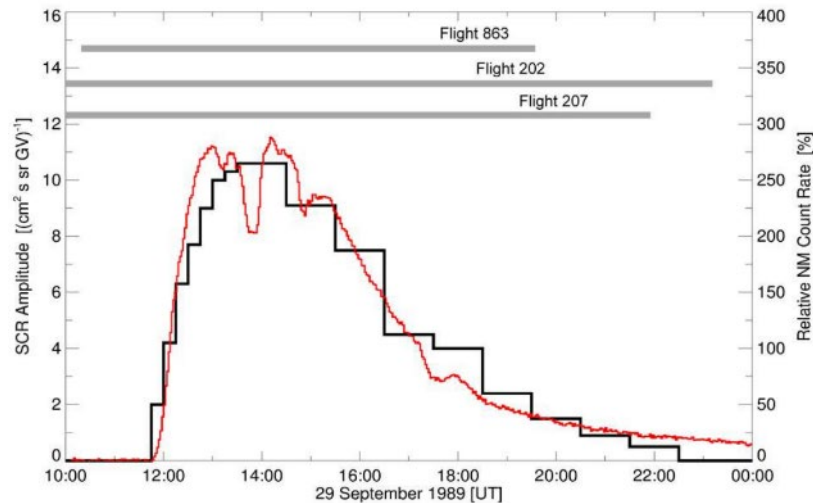
Example Flight Profile **207**
Sydney – Johannesburg



Selected flight times for GLE42 and GLE69

GLE42

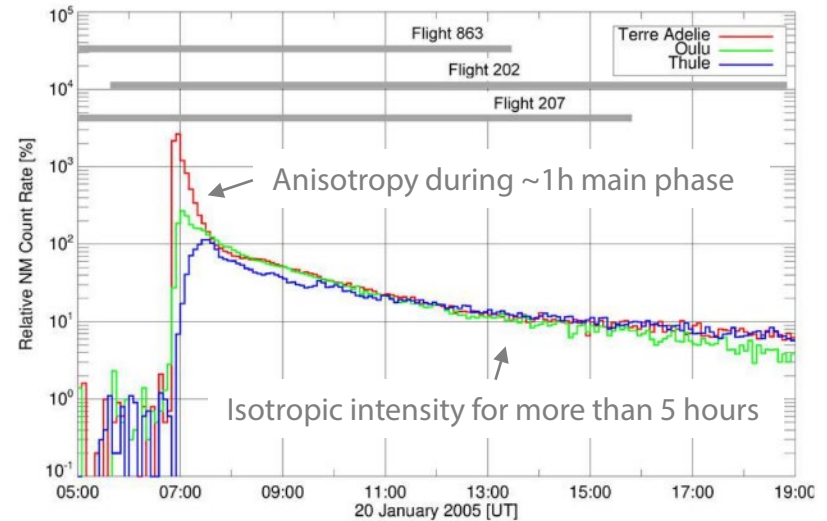
Sept. 29, 1989



Relative counting rates of the NM station McMurdo

GLE69

Jan. 20, 2005

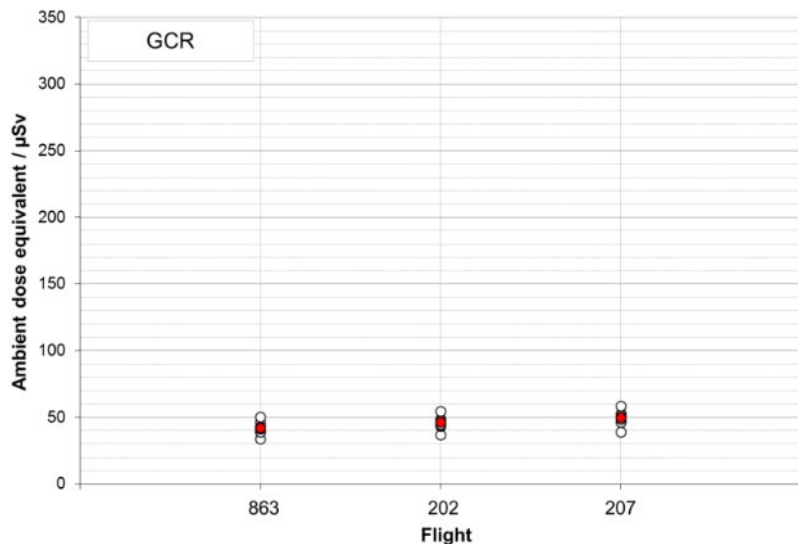


Relative counting rates of the NM stations Terre Adelle, Oulu, Thule

Comparison of calculated radiation exposure

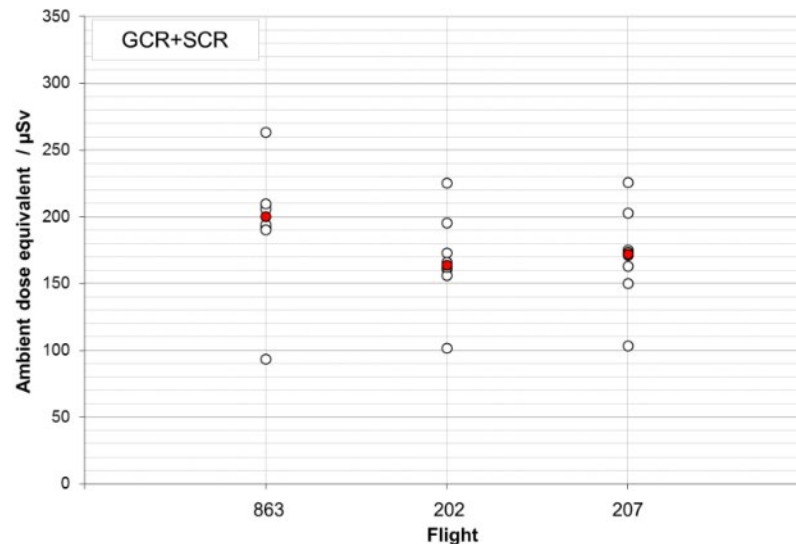
GCR in $H^*(10)$

Sept. 29, 1989



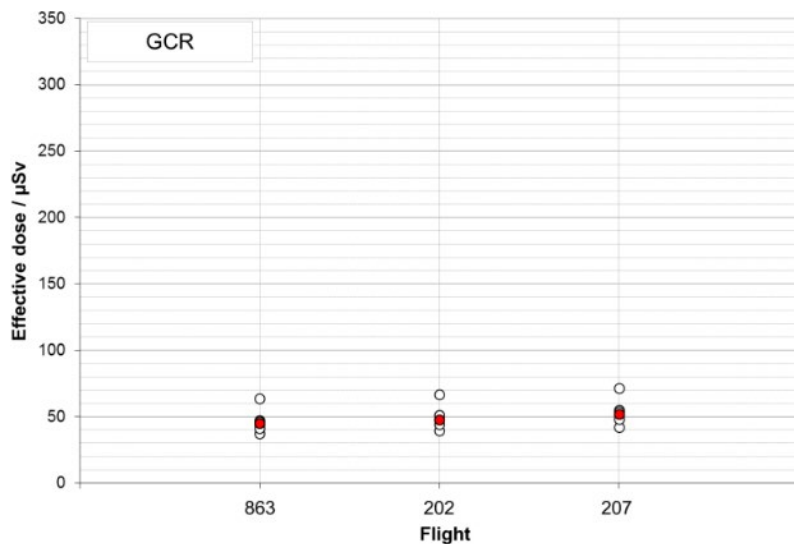
GCR + $\text{SCR}_{\text{GLE42}}$ in $H^*(10)$

Sept. 29, 1989

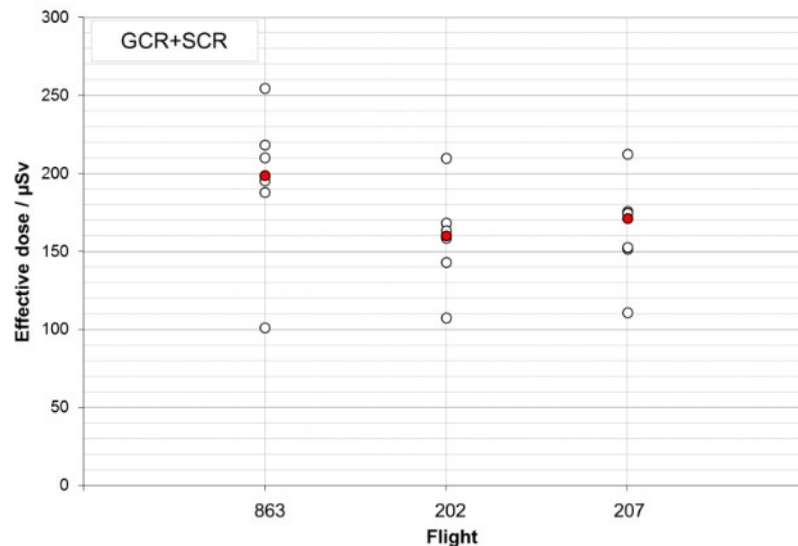


Comparison of calculated radiation exposure

GCR in E
Sept. 29, 1989



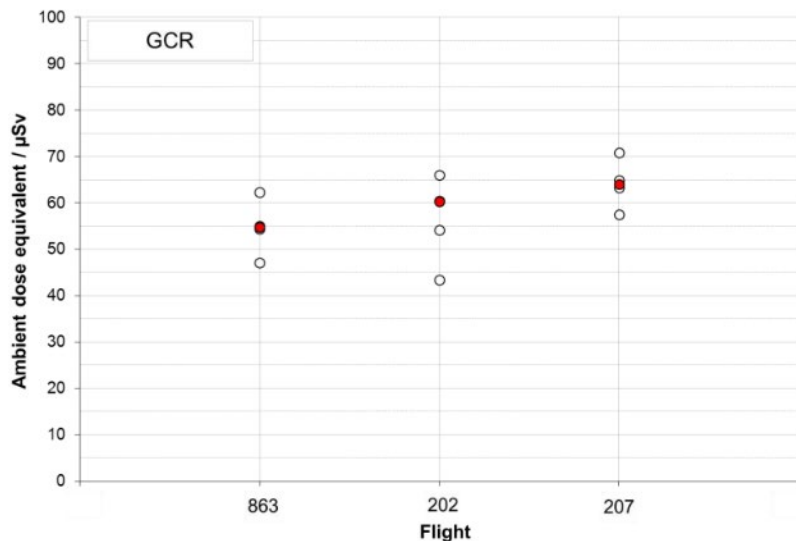
GCR + $\text{SCR}_{\text{GLE42}}$ in E
Sept. 29, 1989



Comparison of calculated radiation exposure

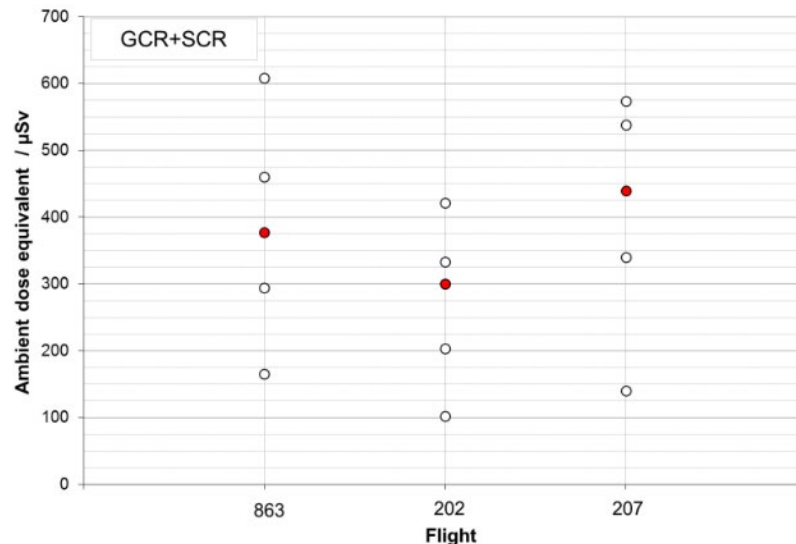
GCR in $H^*(10)$

Jan. 20, 2005



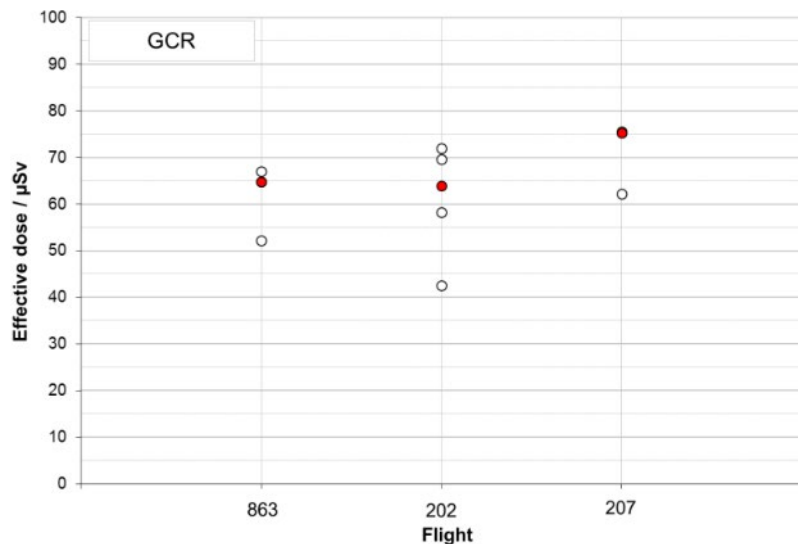
GCR + $\text{SCR}_{\text{GLE69}}$ in $H^*(10)$

Jan. 20, 2005

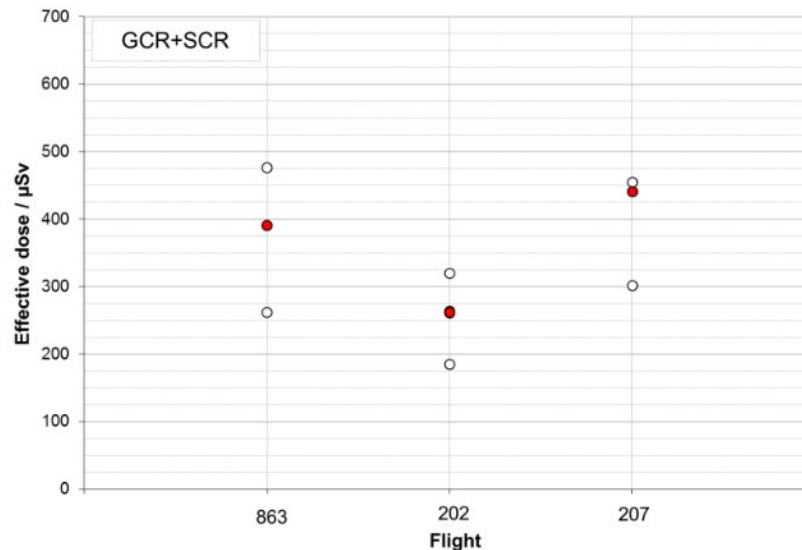


Comparison of calculated radiation exposure

GCR in E
Jan. 20, 2005

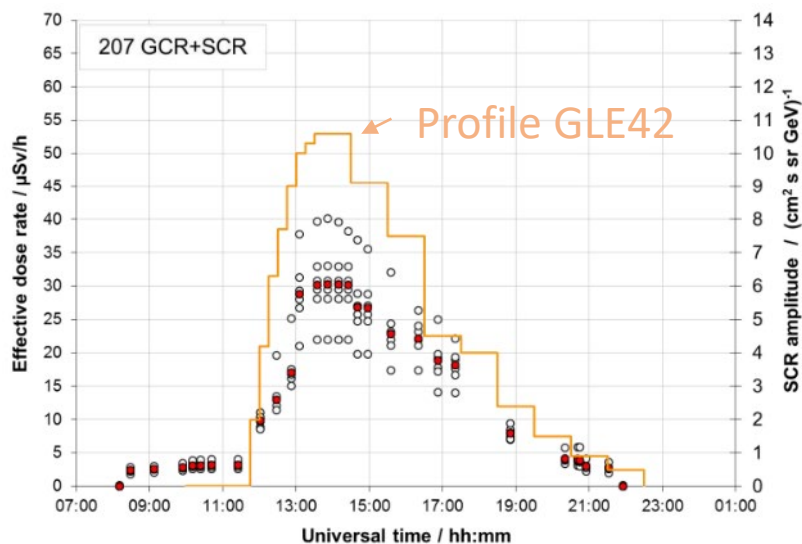


GCR + $\text{SCR}_{\text{GLE69}}$ in E
Jan. 20, 2005

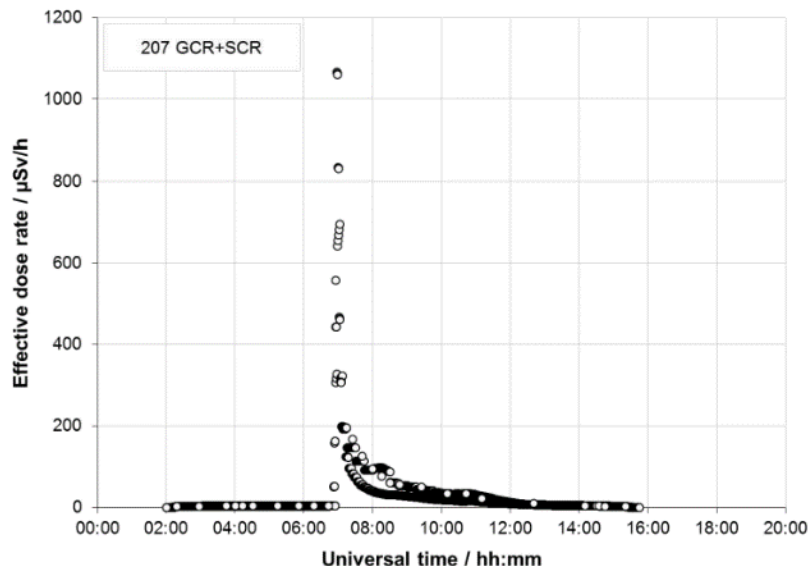


Comparison of calculated radiation exposure

GCR + $\text{SCR}_{\text{GLE42}}$ in E
Sept. 29, 1989, flight 207

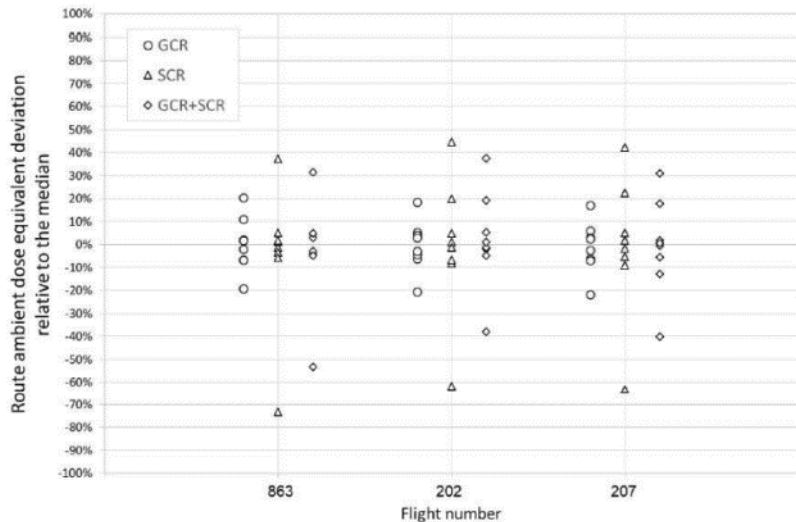


GCR + $\text{SCR}_{\text{GLE69}}$ in E
Jan. 20, 2005, flight 207

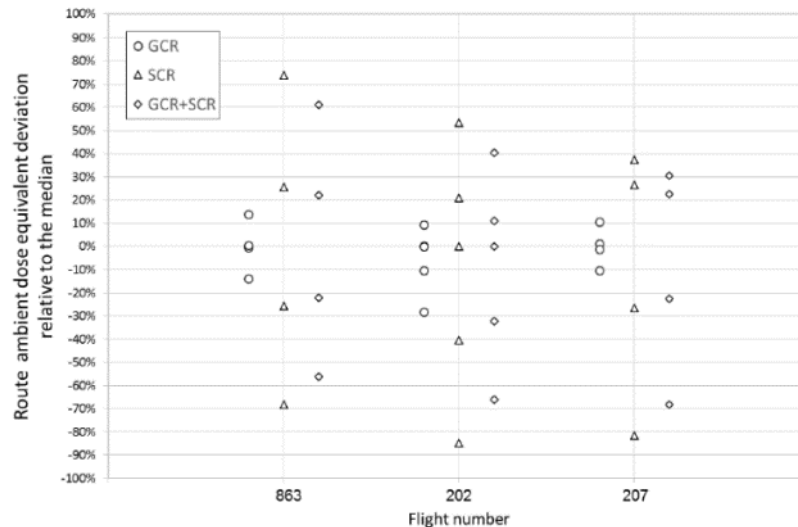


Relative deviation $H^*(10)$ from the respective median in %

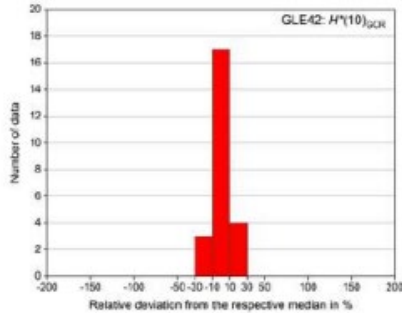
GLE42
Sept. 29, 1989



GLE69
Jan. 20, 2005

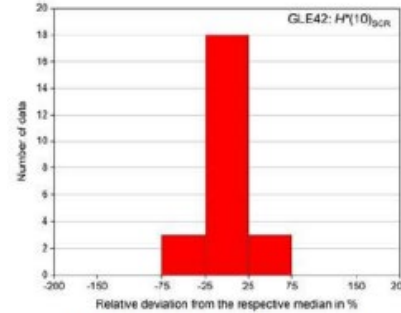


Relative deviation $H^*(10)$ from the respective median in %



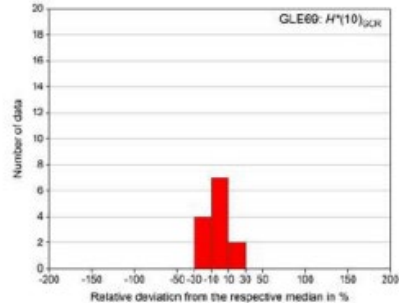
GCR_{GLE42}: 11%

GLE42: GCR, $H^*(10)$, 11% (1σ)



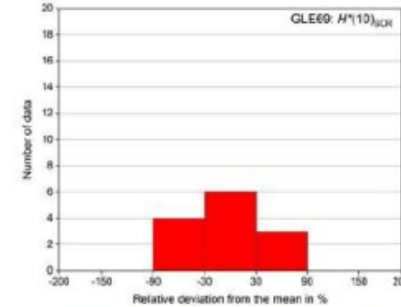
SCR_{GLE42}: 29%

GLE42: SCR, $H^*(10)$, 29% (1σ)



GCR_{GLE69}: 11%

GLE69: GCR, $H^*(10)$, 11% (1σ)



SCR_{GLE69}: 50%

GLE69: SCR, $H^*(10)$, 50% (1σ)