



IASON FREE*

Concepts and Comparisons to In-Flight Measurements

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***Flight Route Effective Dose Estimation**



Introduction

Business Unit IASON-FREE

Professional Aircrew Dose Assessment Center

- since 2004 certified flight-code IASON FREE 1.3.0
- since 2007 certified aircrew dose assessment service
- 2009 accreditation for computational aircrew dosimetry with our flight-code
- acts as laboratory according EN ISO/IEC 17025 (has to prove conformity as well as competence on a regular basis against „official“ and external experts)



Overview

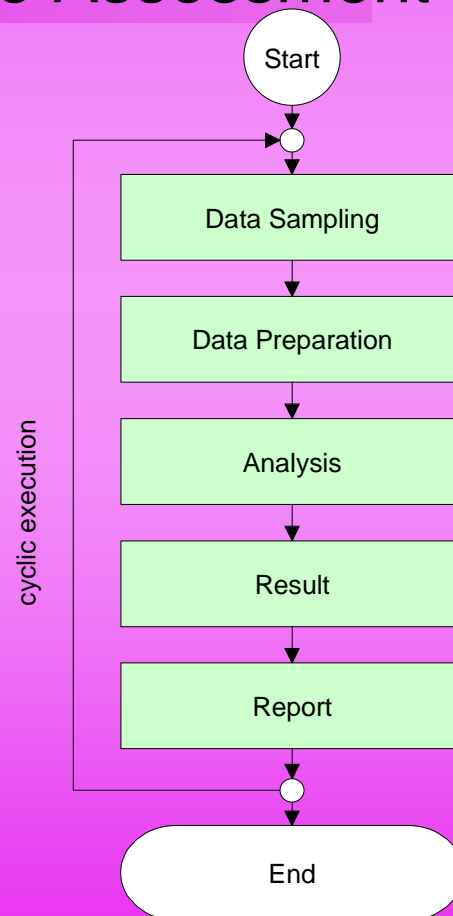
General Remarks

IASON-FREE

- Concepts
- Comparisons to In-Flight Measurements
 - quiet conditions
 - transient effects (SPE, FD)

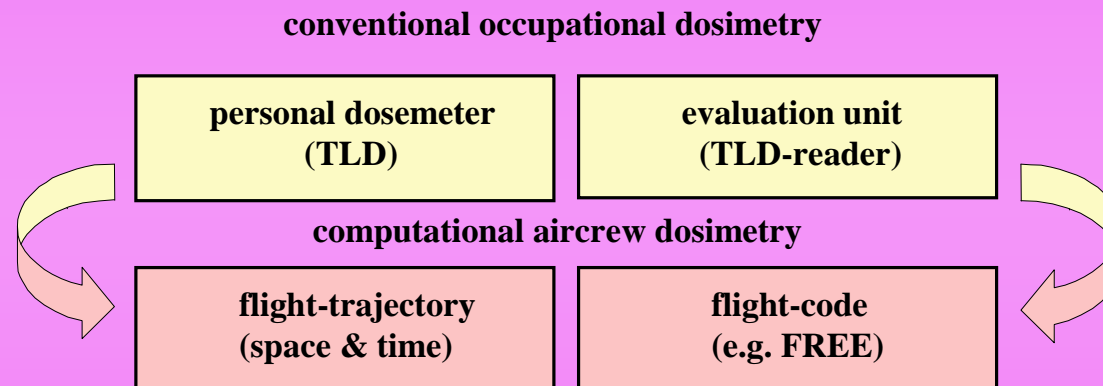
General Remarks

The Aircrew Dose Assessment Process



General Remarks

The Aircrew Dose Assessment Process



Good precise results are only possible, if :

- the flight-trajectory is provided in sufficient detail
- if the flight-code is sensitive to all possible effects



IASON-FREE Concepts

IASON –FREE 1.3.0

includes GCR part as well as transient effects (SPE, FD)

Relies completely on Base Codes of O'Brien

- Plotinus (GCR+FD)
- Solar Suite
 - > FOA (GLEs)
- Deterministic, first principle „physics“ codes
- Are analytical solutions to the Boltzmann equation which govern the process
- do not depend on any in-flight-measurements



Concepts

FREE-GCR-Part

Intention to mirror/clone the the base code completely
-> no introduction of a „flight-code“ effect

Because of many internal details:

-> no usage of data reduction techniques

-> but solve the problem with a Brute Force Attack

Triangulation

(Space/Modulation Parameter)

Precalculation, Interpolation

(Multivariate B-Spline Methods)



Concepts GCR-Part

Altitude Triangulation (dominant parameter):

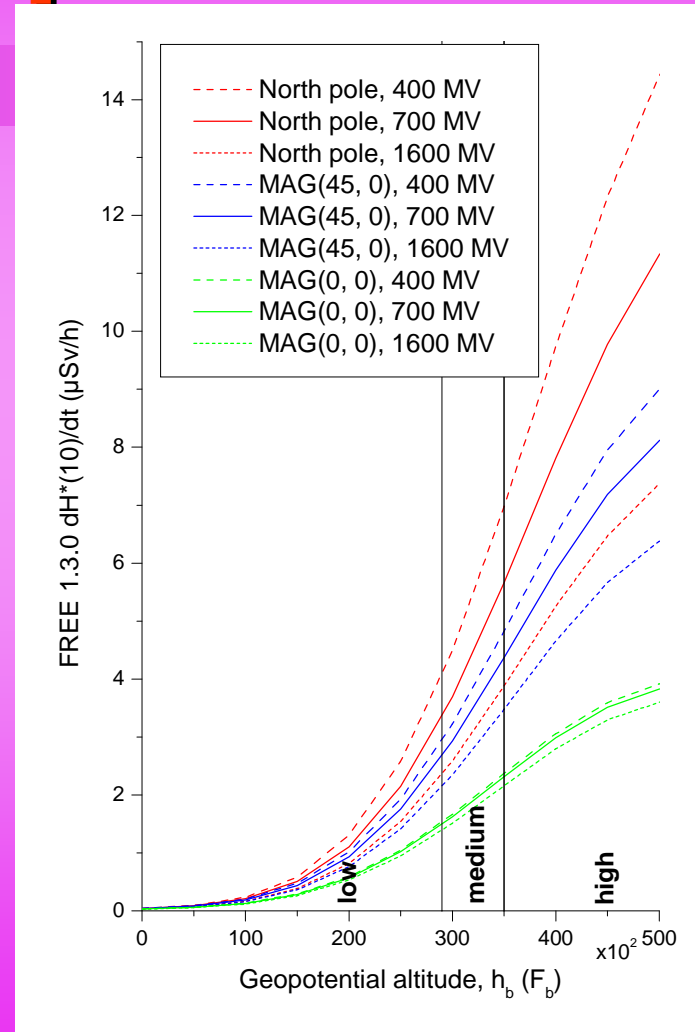
0-80 000 feet, calculated all usual flightlevels exactly,

Other range:

equally spaced in atmospheric depth (81 pts)

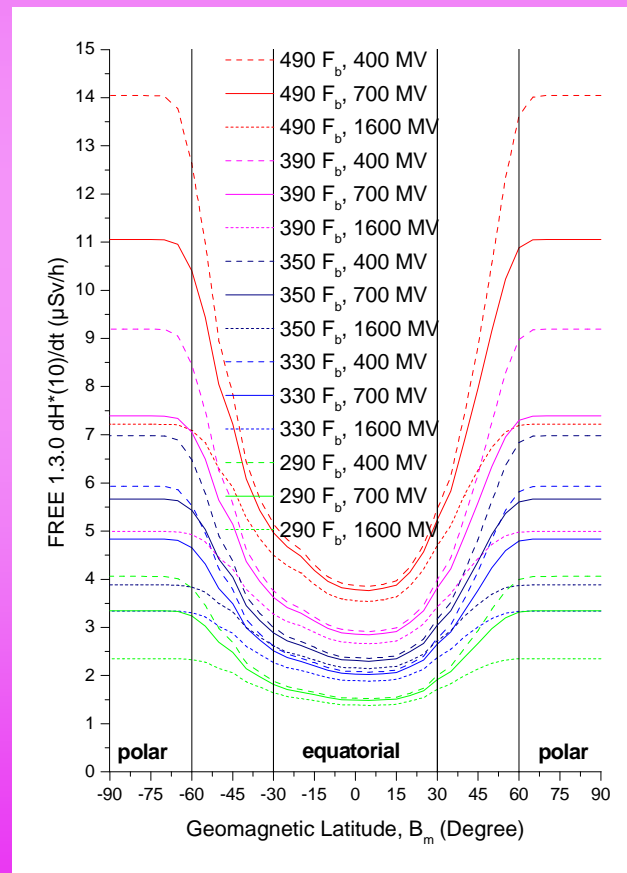
- No averaged particle fluence-to-dose conversion coefficients !

Concepts GCR-Part



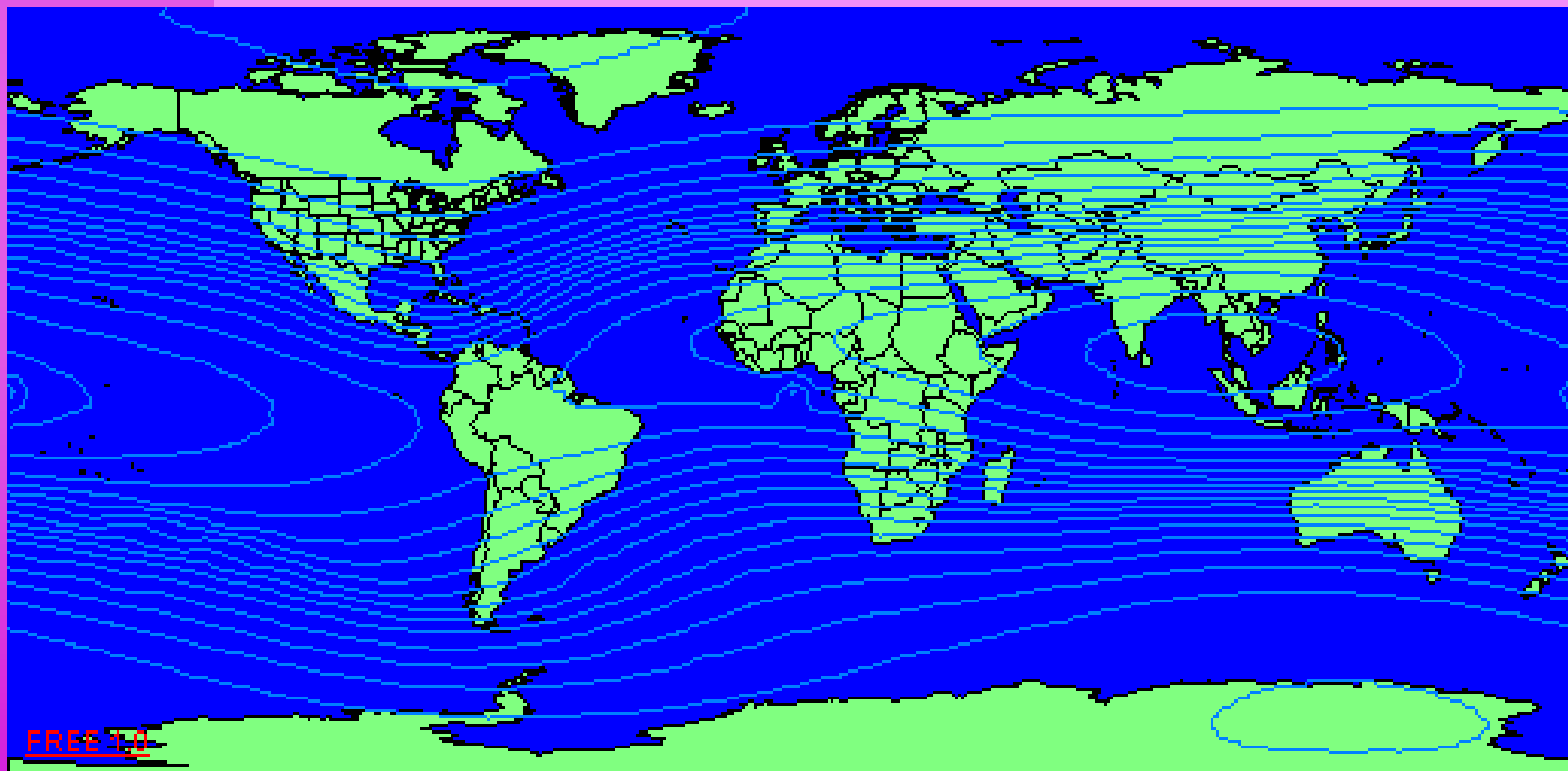
Concepts GCR-Part

Geomagnetic Triangulation



Concepts GCR-Part

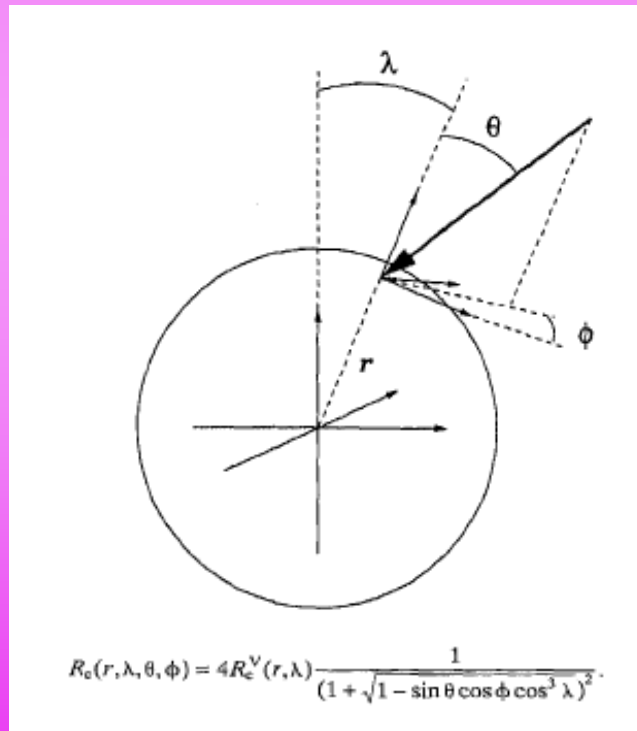
Geomagnetic Triangulation
„Yield Approximation“



Concepts GCR-Part

Geomagnetic Triangulation:

Geomagnetic shielding depends on incident particle direction:



Heinrich, Spill 1979

JGR 84,A8,4401-4404

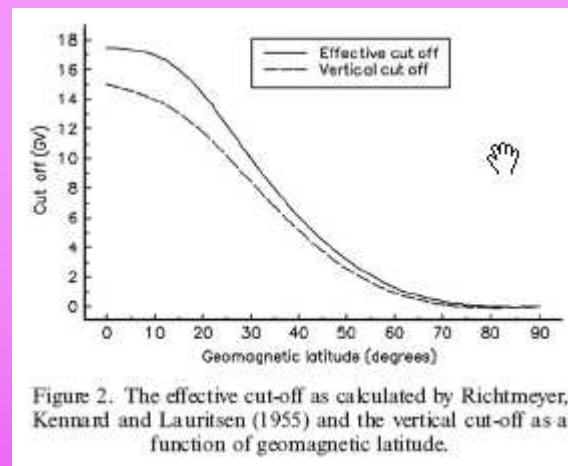
= f(position)

= f(longitude, latitude)

Concepts GCR-Part

Geomagnetic Triangulation:

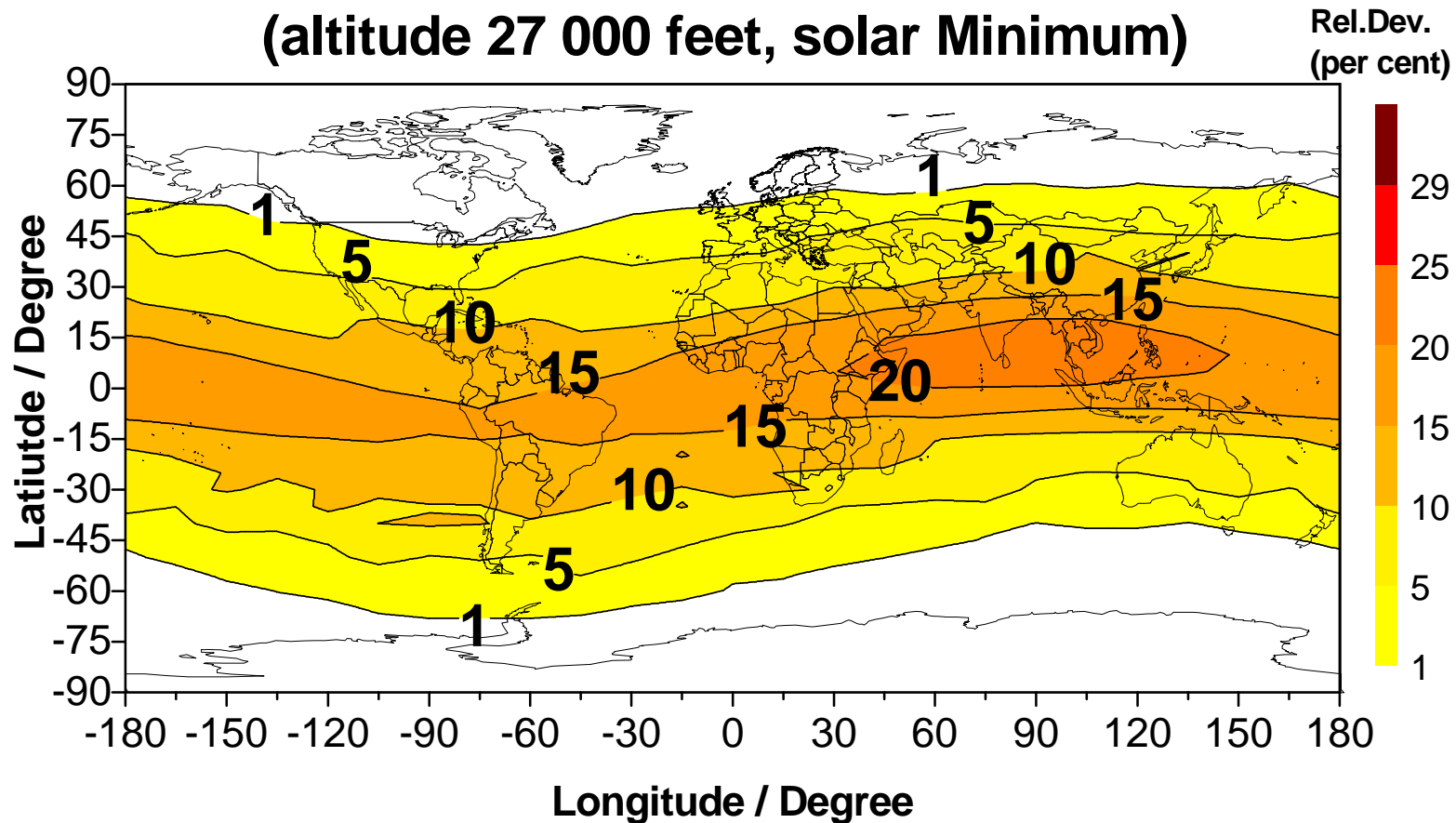
Yield approximation leads to an overestimation of doses except on the poles



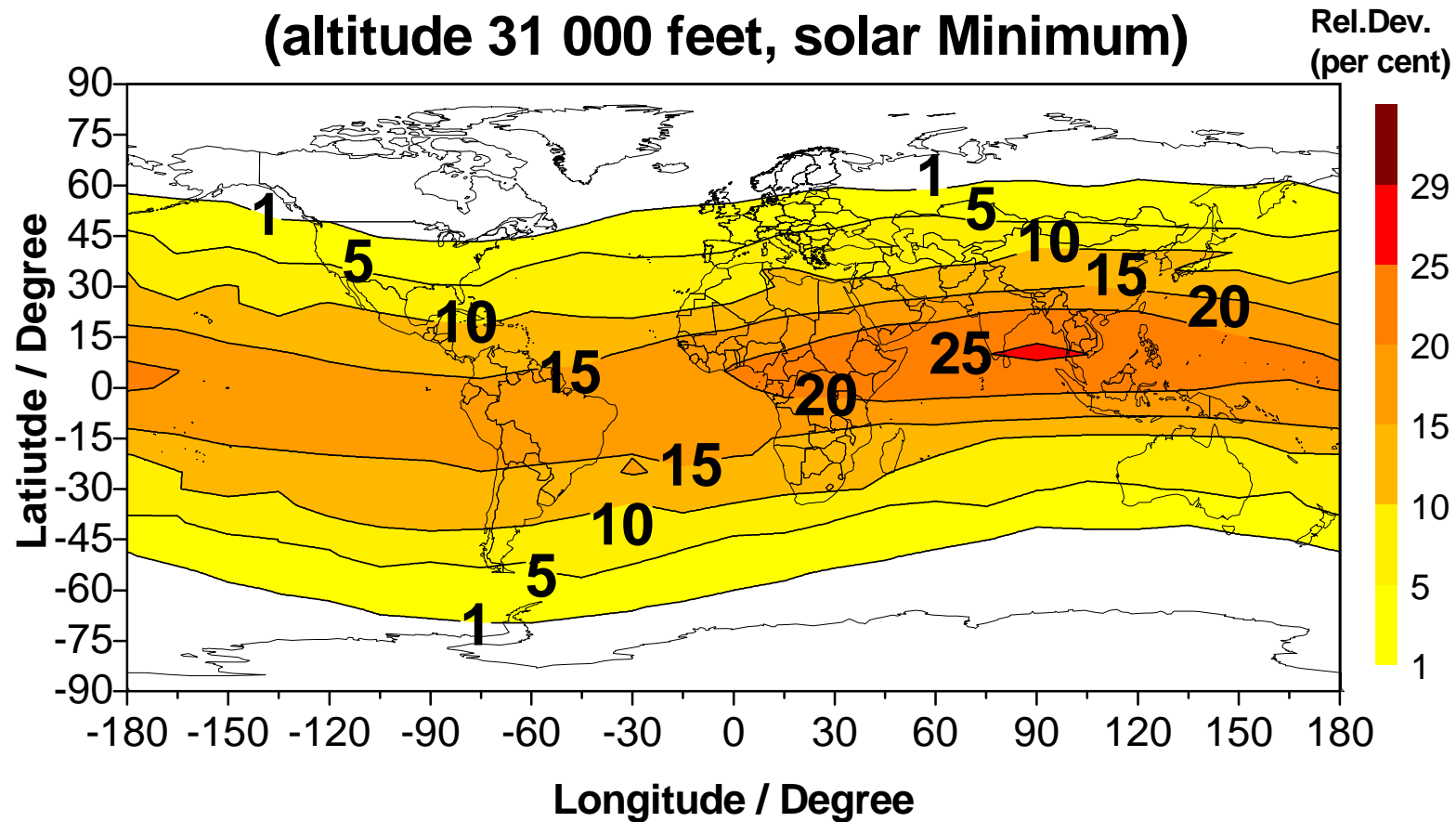
O'Brien, RPD (2008) Vol. 128, No.3, pp.259-260

O'Brien et.al. Proceedings AOGS 2008, Busan

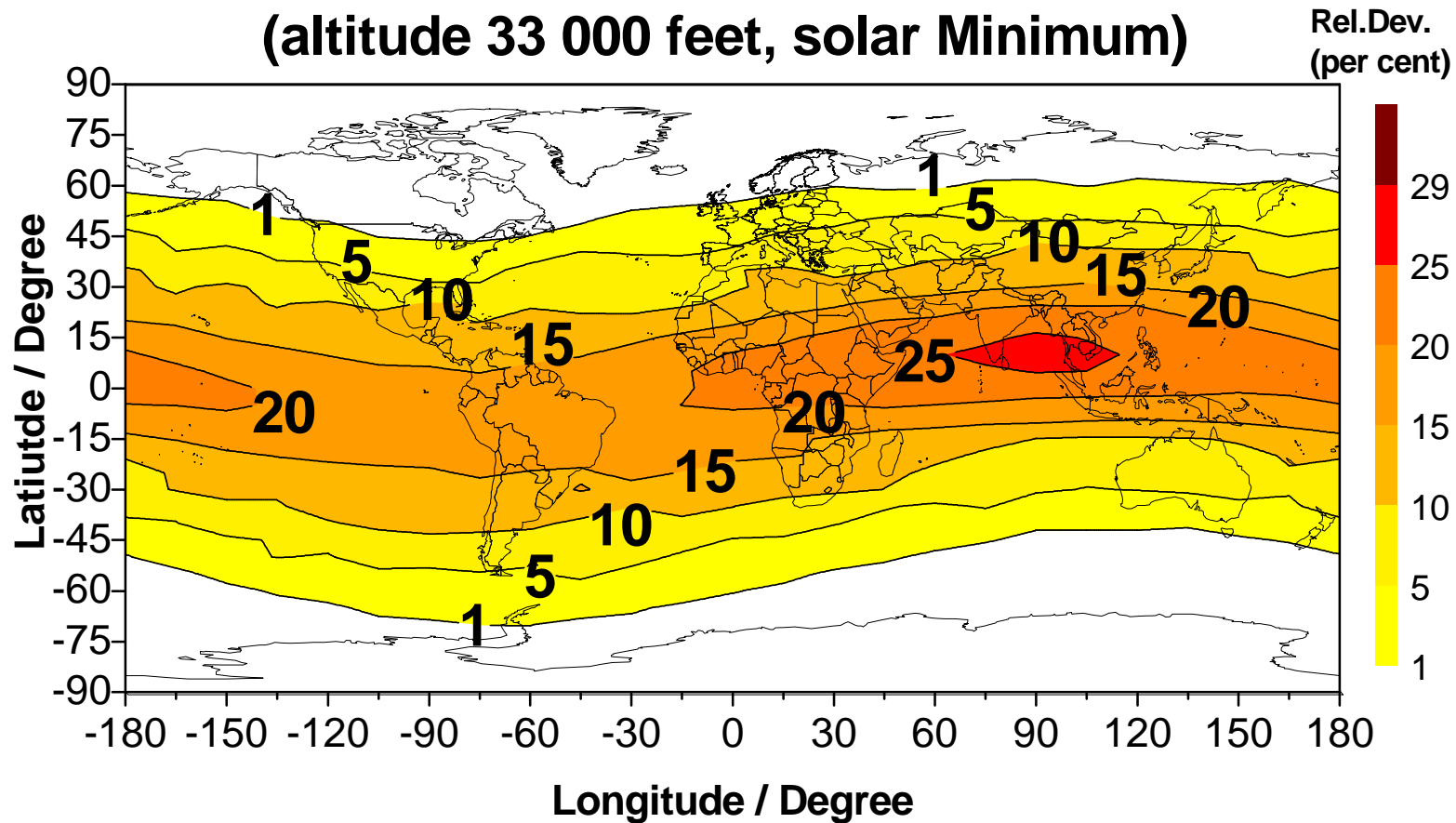
World map overestimation of effective dose using vertical cutoff alone (altitude 27 000 feet, solar Minimum)



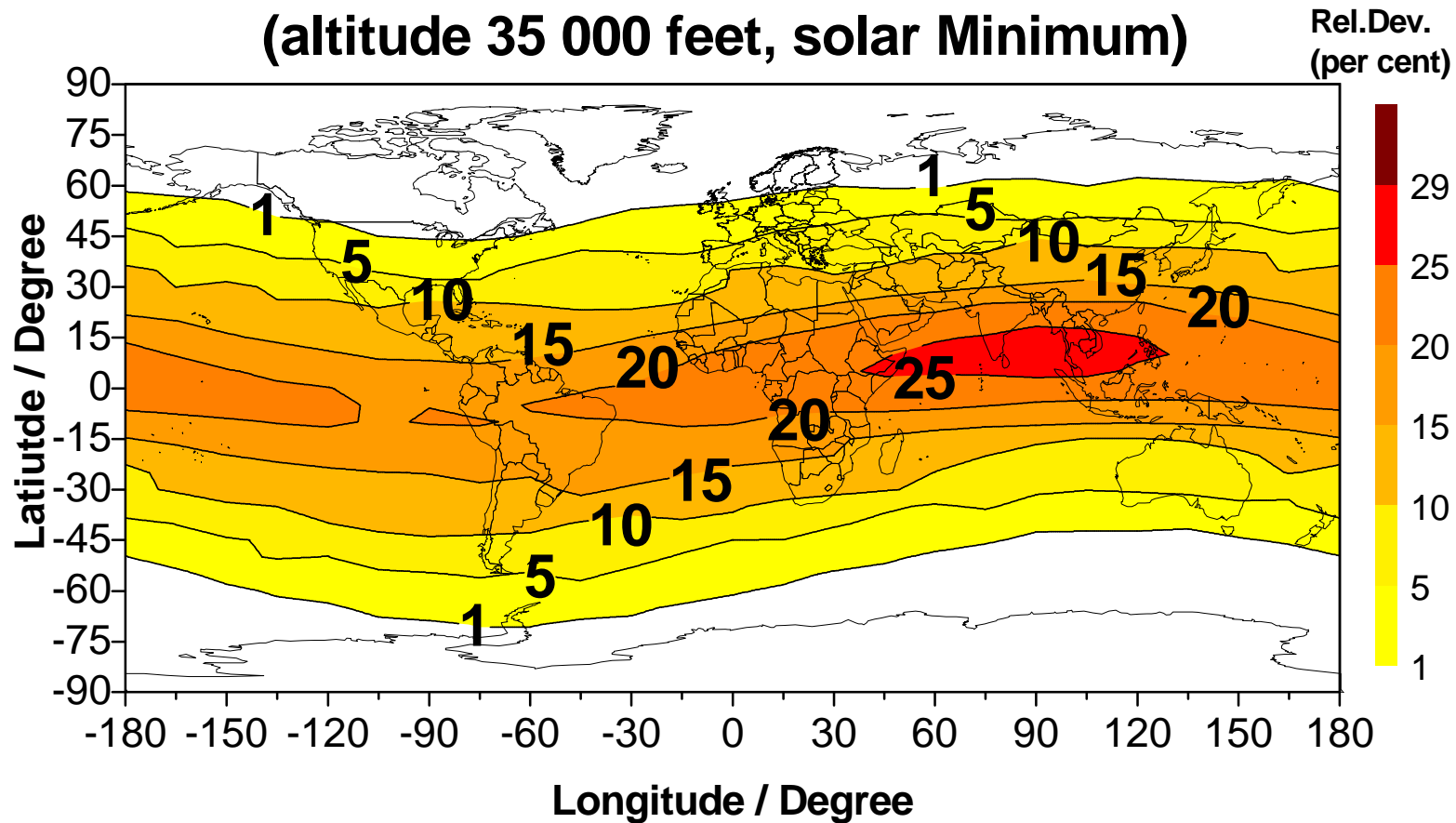
World map overestimation of effective dose using vertical cutoff alone (altitude 31 000 feet, solar Minimum)



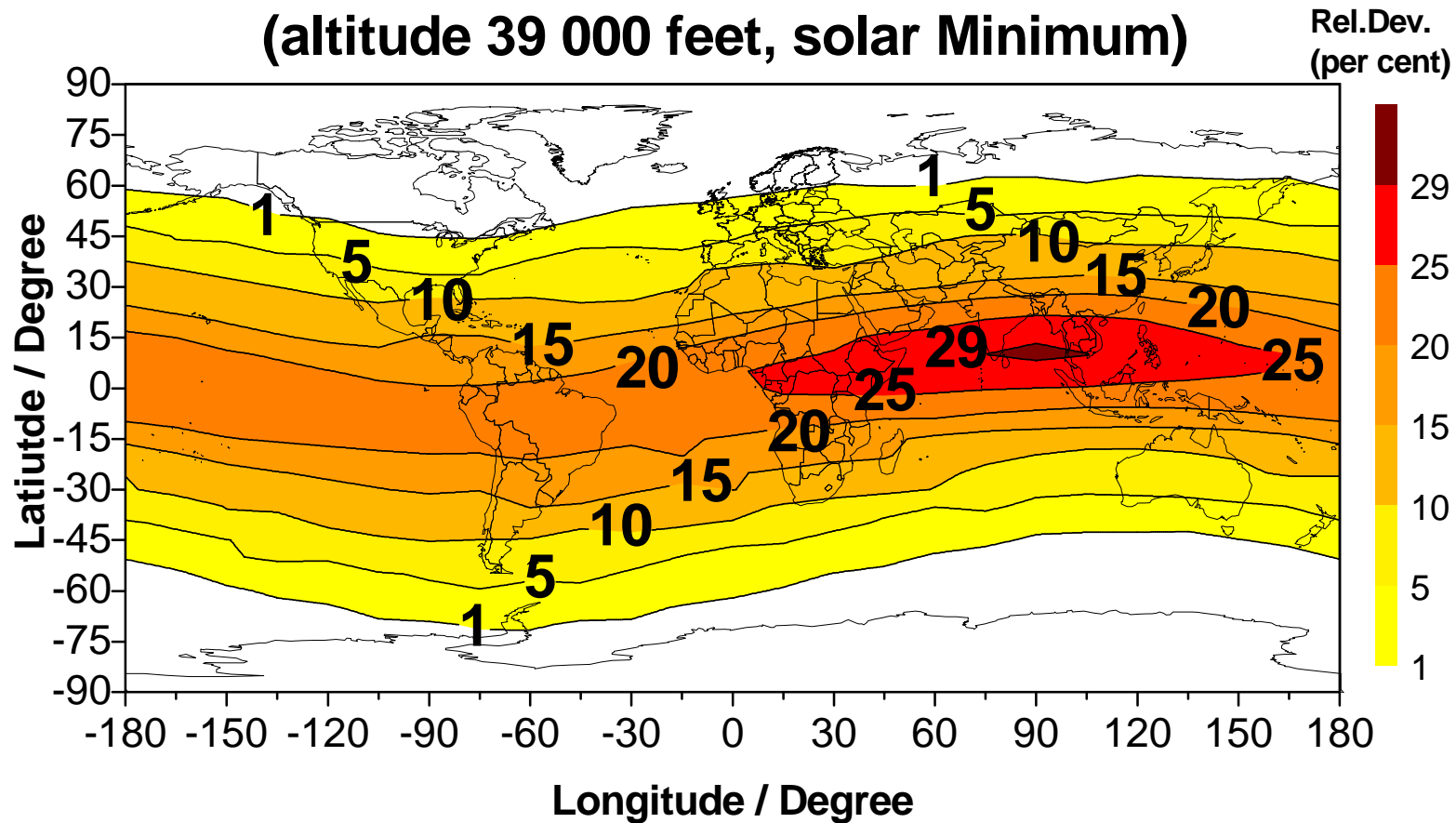
World map overestimation of effective dose using vertical cutoff alone (altitude 33 000 feet, solar Minimum)



World map overestimation of effective dose using vertical cutoff alone (altitude 35 000 feet, solar Minimum)



World map overestimation of effective dose using vertical cutoff alone (altitude 39 000 feet, solar Minimum)





Concepts GCR-Part

Geomagnetic Triangulation:

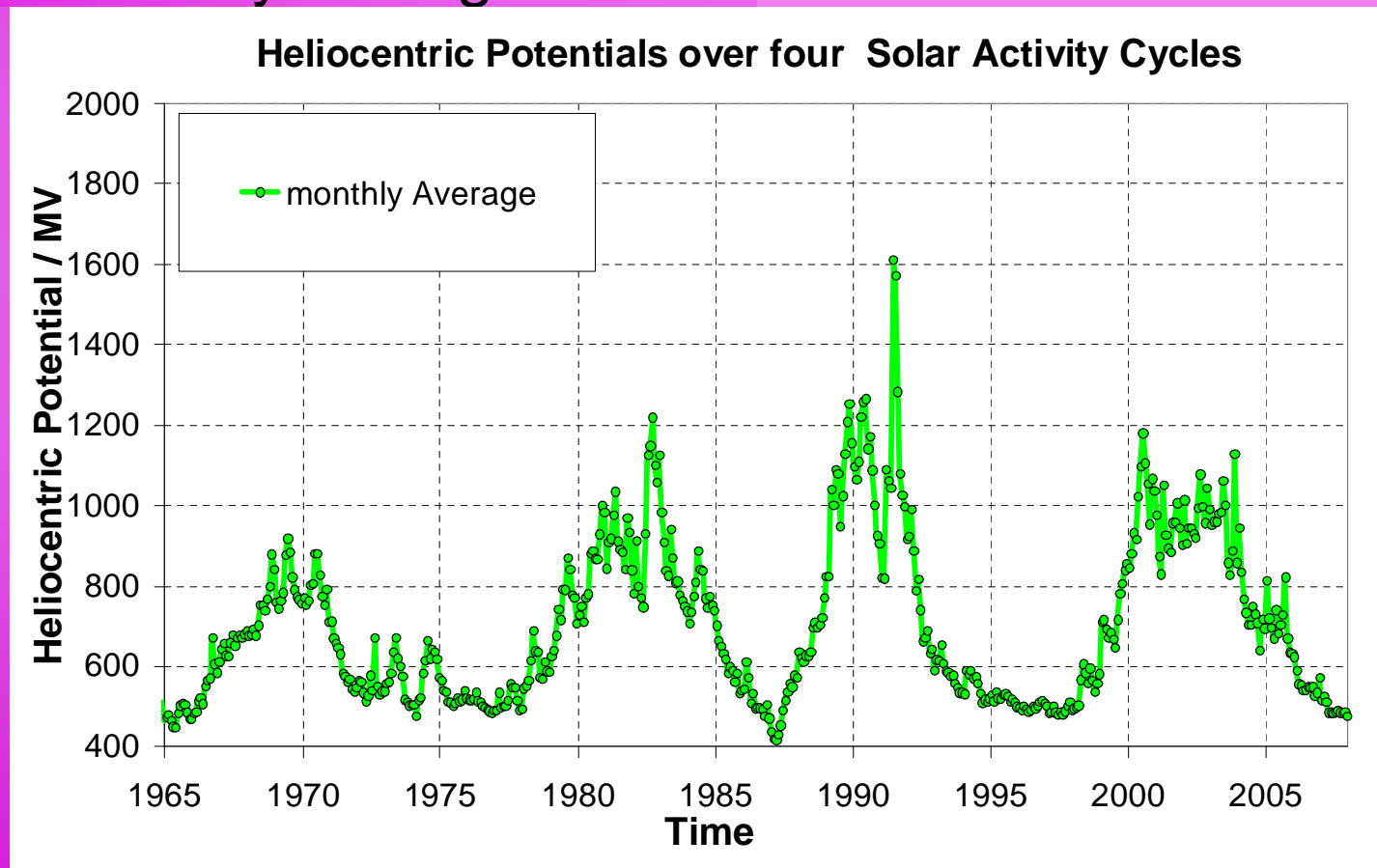
-> Word Grids in Latitude (mesh 3x closer) and
Longitude

(925 Pts. / grid)

-> one spatial world grid in location and altitude:
74925 Pts.

Concepts GCR-Part

Solar Activity Triangulation:





Concepts GCR-Part

Solar Activity Triangulation:

As the cycles are not uniform (sinusoidal model is only an approximation, long term effects)

Considered Values from 0 – 3000 MV (extrapolation possibility) so that we are not restricted from the possible range.

18 Points, Mesh is closer at low potentials (Solar Minimum)

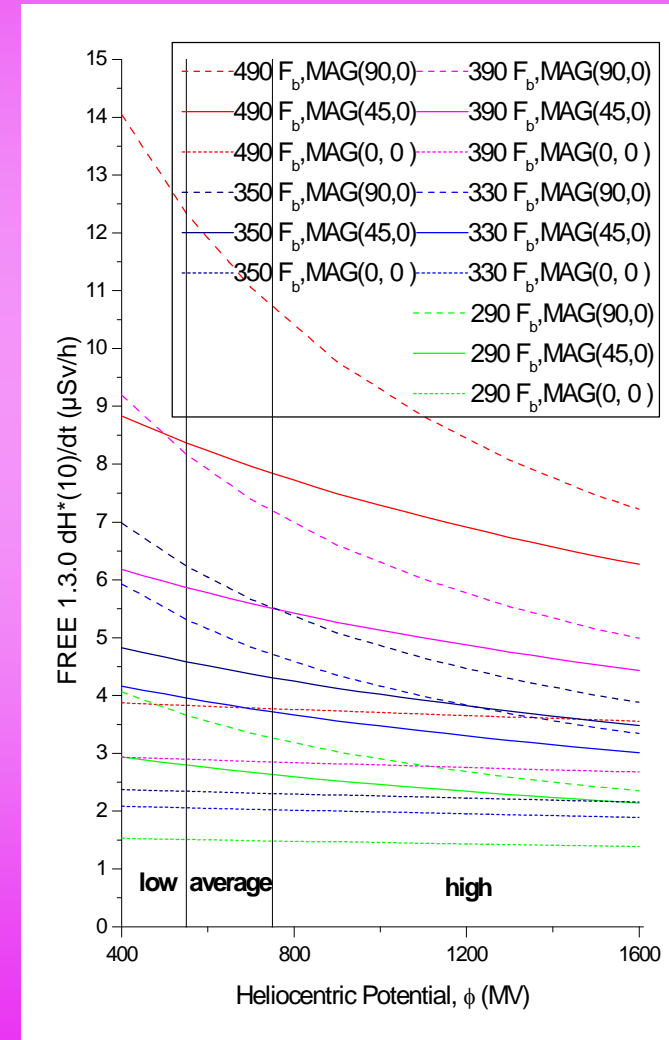
Extended to very high Potentials (FD)

Linear Inter- /Extrapolation within Mesh and outside range ->Total Points 1 348 650

Concepts GCR-Part

Solar Activity Triangulation:

Potentials anticorrelate
with dose
Latitude effect
of solar modulation
Strong concave at higher
Latitudes and altitudes
(linear interpolation
problematic)





Concepts transient Effects

„Treatment of Forbush Decreases“

Heliocentric potential model widely used to treat
Solar modulation

Has been shown to be valid in the inner atmosphere
($r < 20$ AU) under undisturbed conditions
(Caballero-Lopez, Moorall, JGR 109, 2004)

Kieran O'Brien

Cosmic-ray propagation through the disturbed
heliosphere

Acta Astronautica, Volume 60, Issues 4-7, February-
April 2007, Pages 541-546



Concepts transient Effects

„Treatment of Forbush Decreases“

The stationary, source free, one dimensional solution to The cosmic ray transport equation was solved with Runge-Kutta methods. These calculations have been applied to the treatment of FDs. FDs calculated with this method produce spectra that are in good agreement with the potential as determined from NM data.

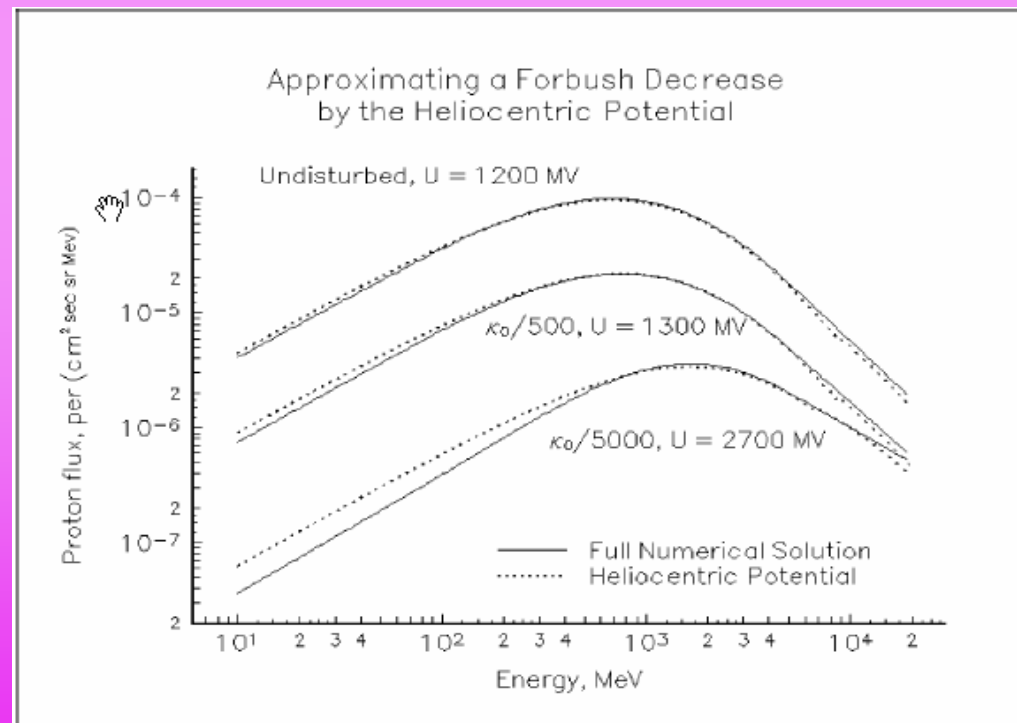
-> Heliocentric potential is a good approximation at the earth orbit to the full numerical solution even under extrem cases.

Concepts transient Effects

„Treatment of Forbush Decreases“

Usage of hourly Heliocentric Potentials

Database since November 1964





Concepts transient Effects

„Treatment GLEs – FOA Method“

$$\begin{aligned}\dot{E}_{\text{SPE-FOA}}(\text{RelInc}_{\text{NM}_{\text{Ref}}}, R_C, h) &= C_1 \times C_2 \times \text{RelInc}_{\text{NM}_{\text{Ref}}} \\ C_2 &= C_2(\text{RelInc}_{\text{NM}_{\text{Ref}}}, R_C, h)\end{aligned}$$

$$C_2(\text{RelInc}_{\text{NM}_{\text{Ref}}}, R_C, h) = \frac{\dot{E}_{\text{SPE-Adjoint}}(\text{Date-Time}, R_C, h)}{\text{RelInc}_{\text{NM}_{\text{Ref}}}(\text{Date-Time})}$$

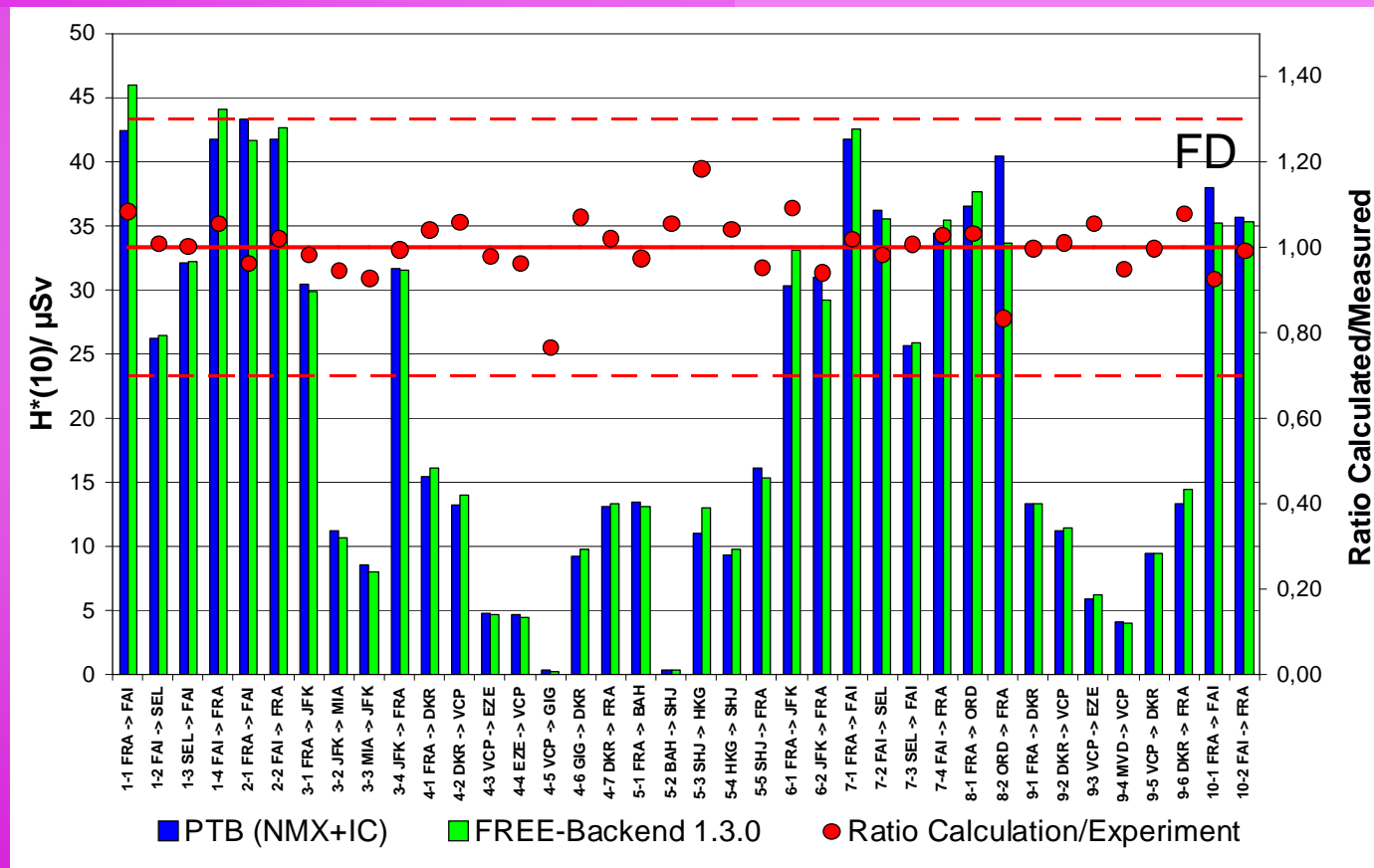


Comparisons to In-Flight Measurements

- quiet conditions**
- transient effects**

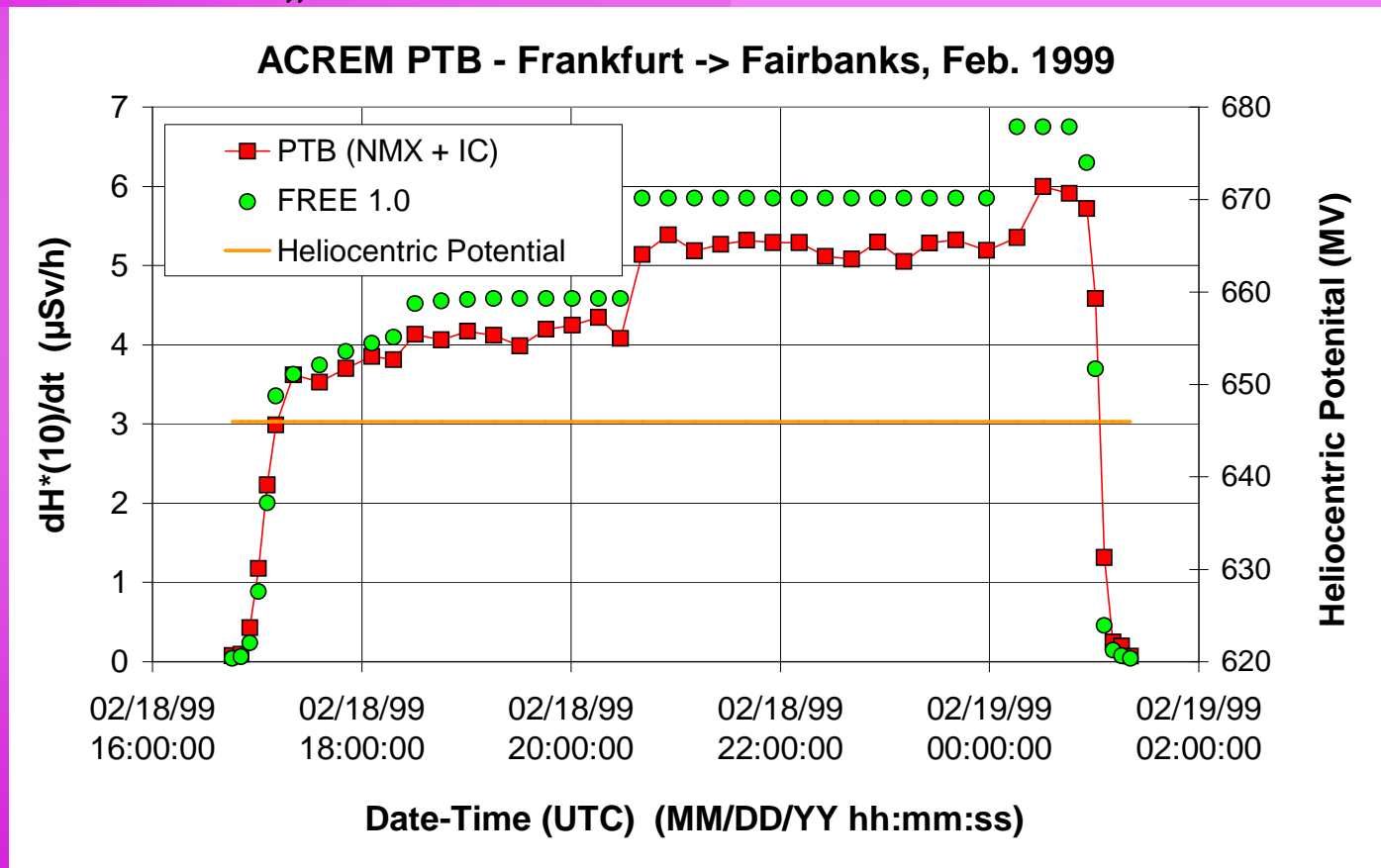
Comparisons

ACREM PTB



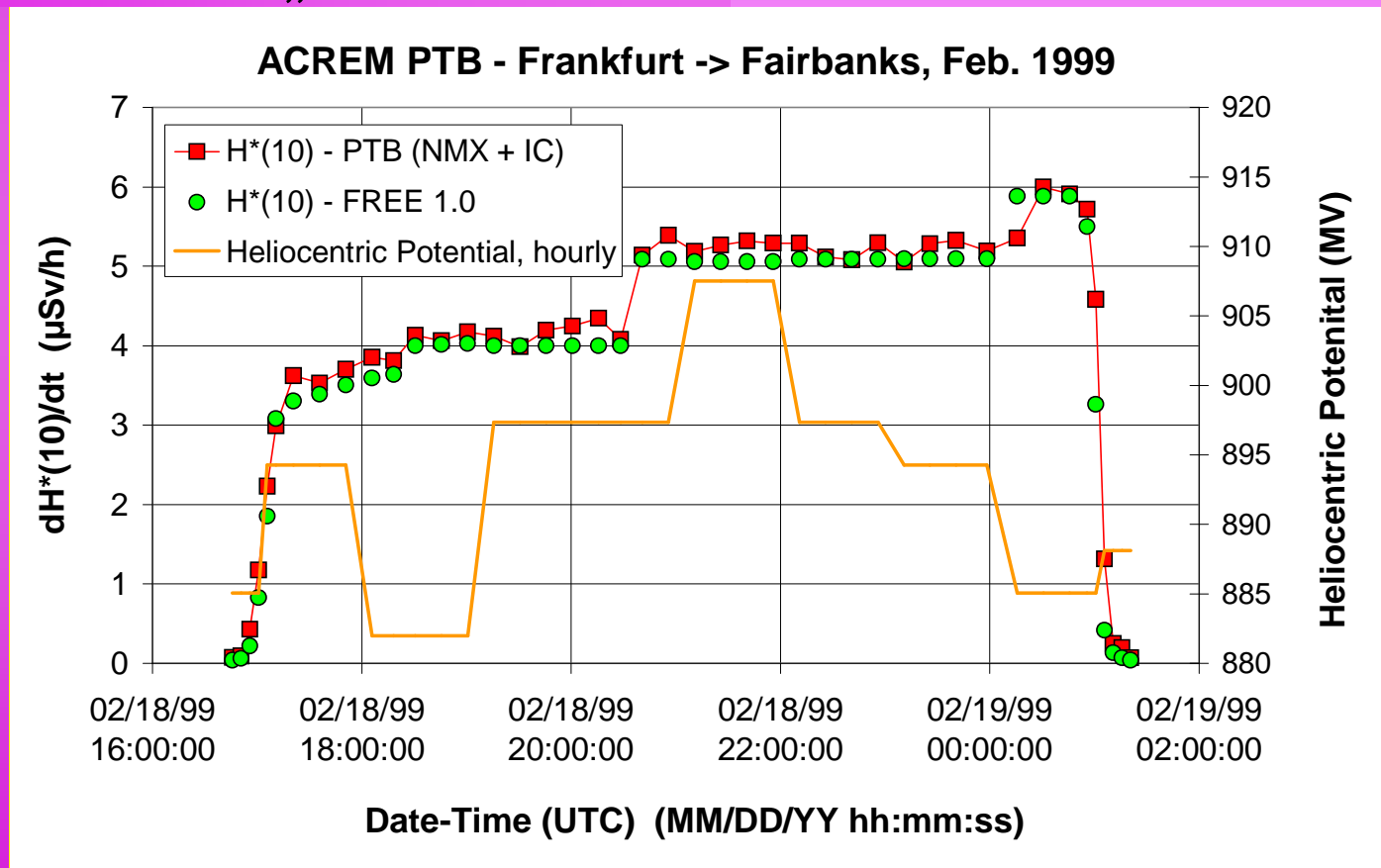
Comparisons

ACREM PTB „FD“



Comparisons

ACREM PTB „FD“





Comparisons

Comparisons with experimental results of many groups within the framework of EURADOS WG5 published in Radiation Protection 140

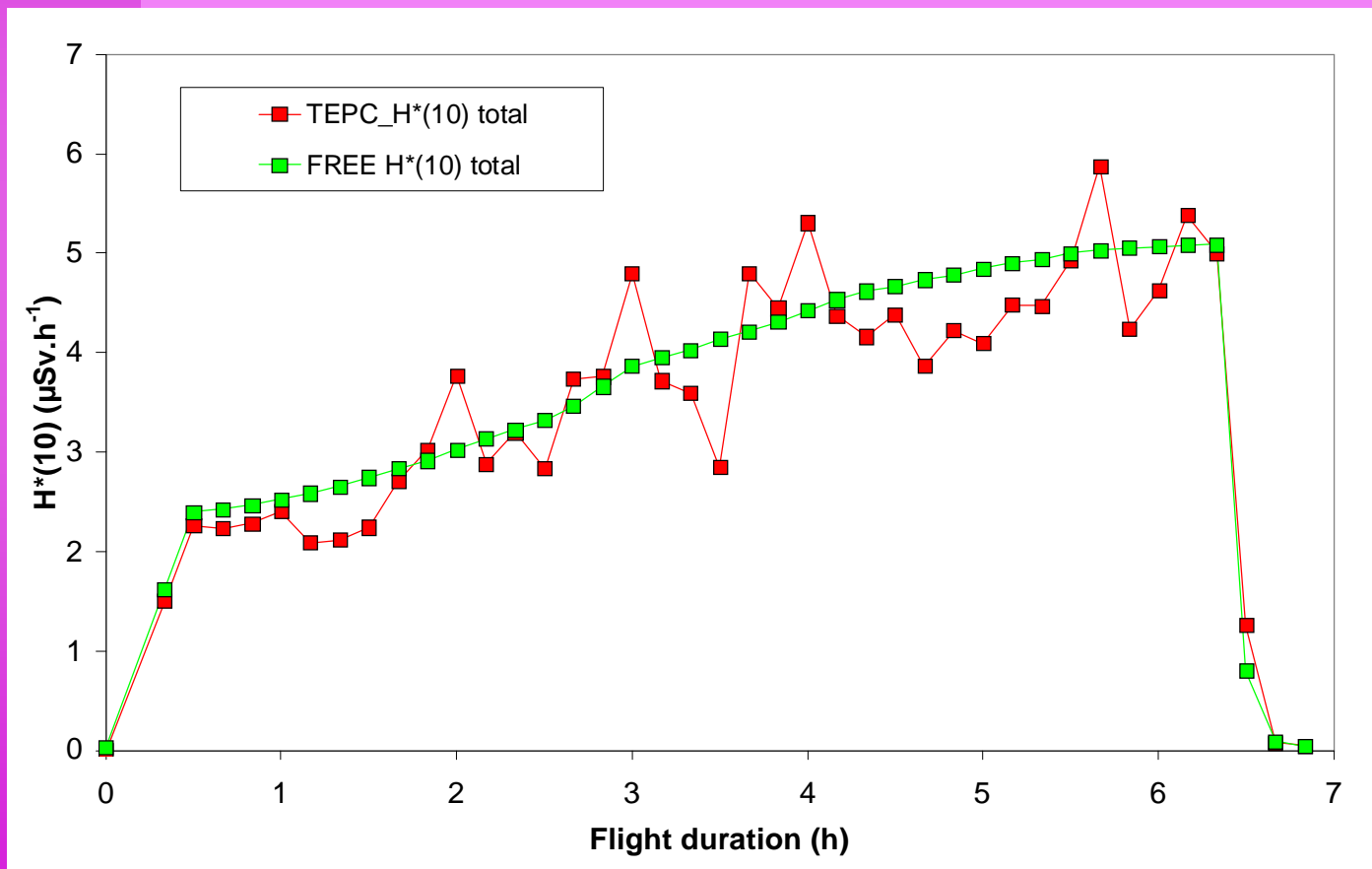
We will participate other comparisons and programmes
Request for comparisons are always welcome !

New Comparisons



IRSN Tokyo->Fairbanks (4.April 2002)

	TEPC	FREE	Rel.Dev. FREE	FREE/TEPC
H*(10)	21,91	22,80	4,03	1,04



New Comparisons



CAATER Campaign (5./6. May 2003)

Measurements over Aalborg (N57E8) and

Rome(N42E12) at constant flight conditions

	Flightnumber	FREE H10 tot	Experiment ro	FREE Rel.Dev
Position		μSv	μSv	%
N57E8FL400	1	14.05	14.13	-0.54
N57E8FL320	2	7.52	7.38	1.95
N42E12FL400	3	9.51	9.32	2.03
N42E12FL320	4	5.55	5.27	5.25

Position	dH10 tot/dt	FREE	Avg Experime	FREE Rel.Dev	Avg TEPC	FREE Rel.Dev
N57E8FL400	1	6.48	6.52	-0.54	6.54	-0.85
N57E8FL320	2	3.76	3.69	1.95	3.62	3.92
N42E12FL400	3	4.39	4.30	2.03	4.12	6.49
N42E12FL320	4	2.66	2.53	5.25	2.36	12.83



New Comparisons transient/short term Effects

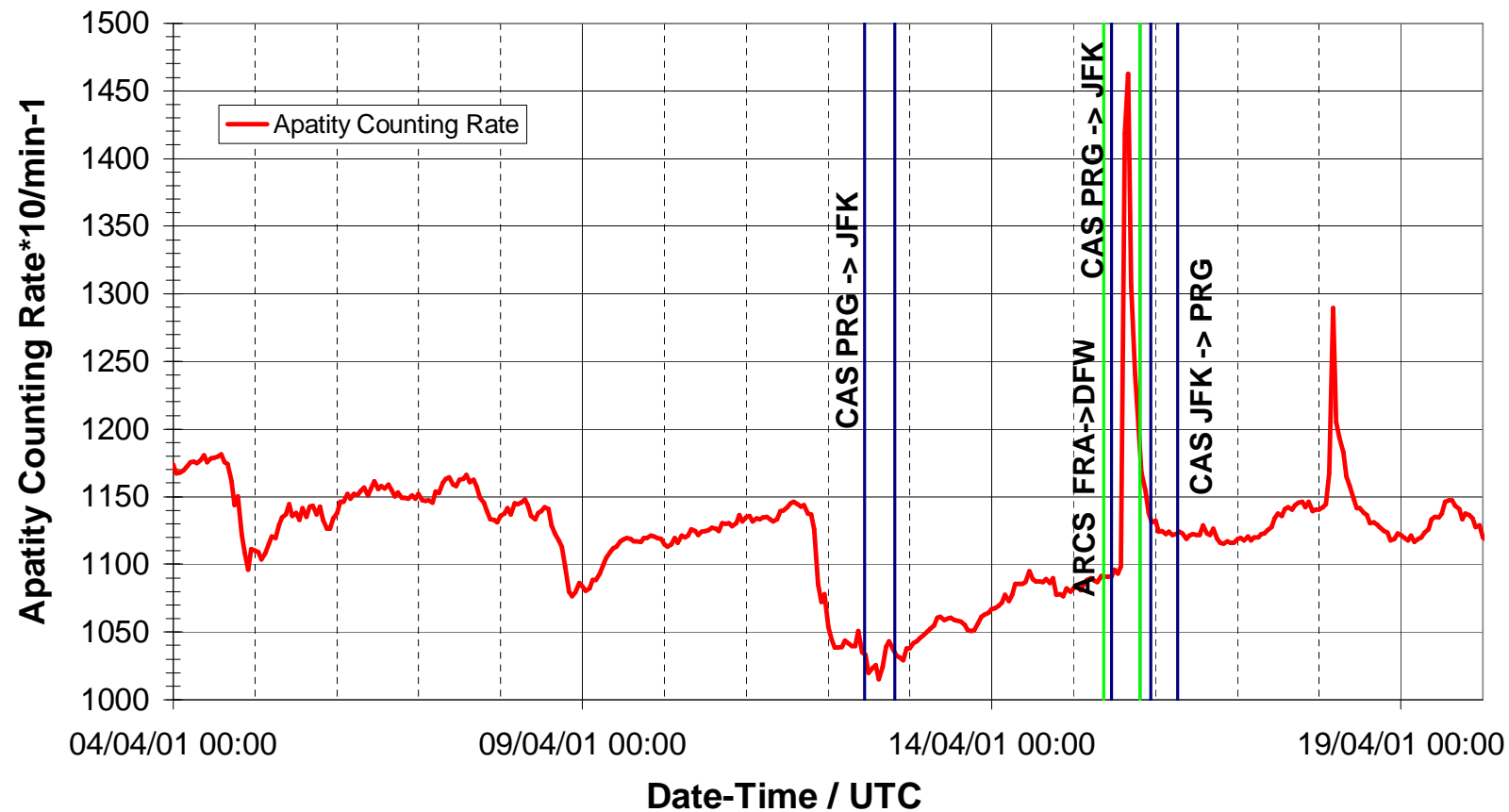
Presentations of comparisons with in-flight measurements during two months with very disturbed conditions, that are very well documented by measurements of different groups.

April 2001

Oktober 2003

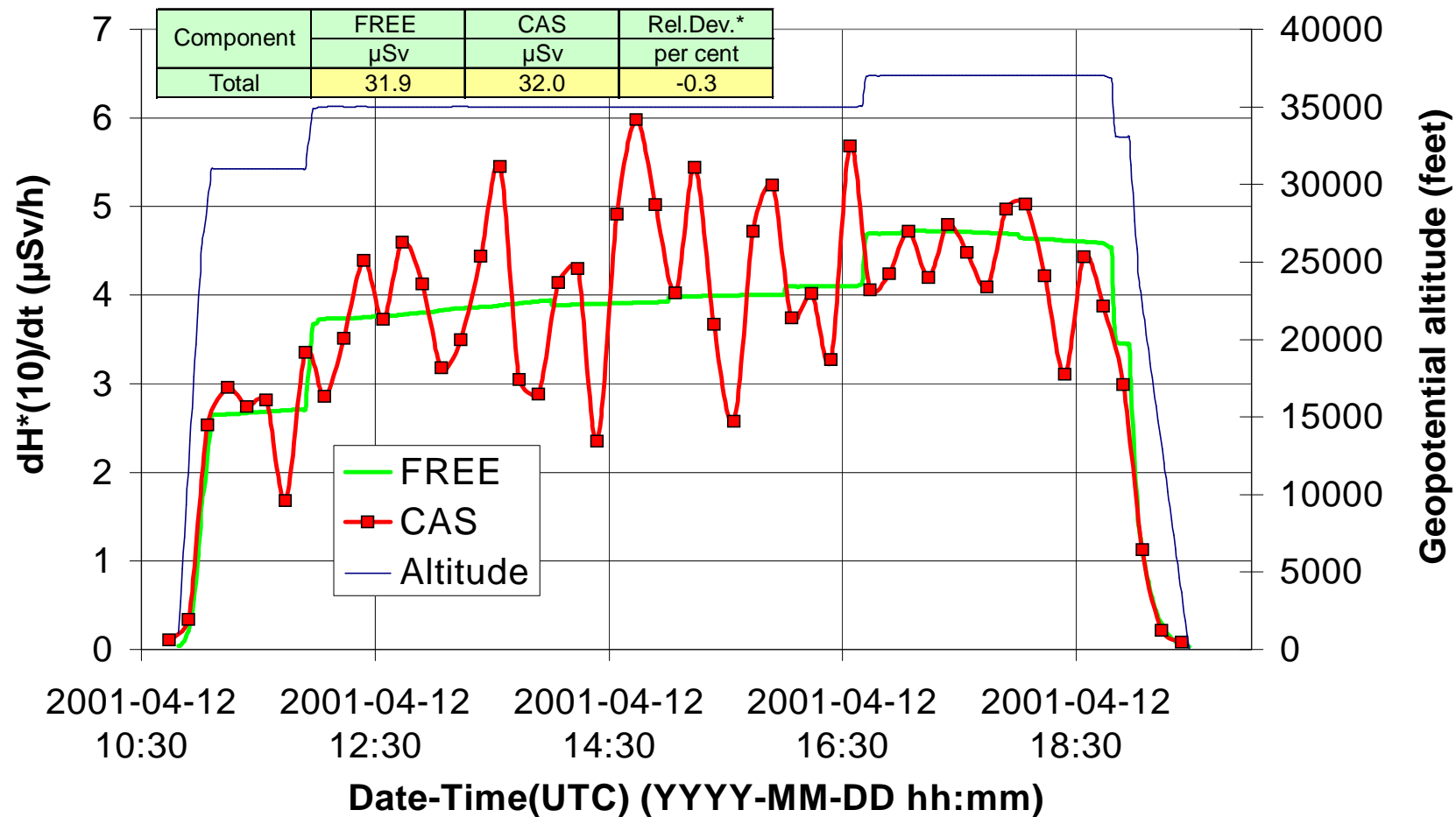
transient/short term Effects

Transient Effects during April 2001



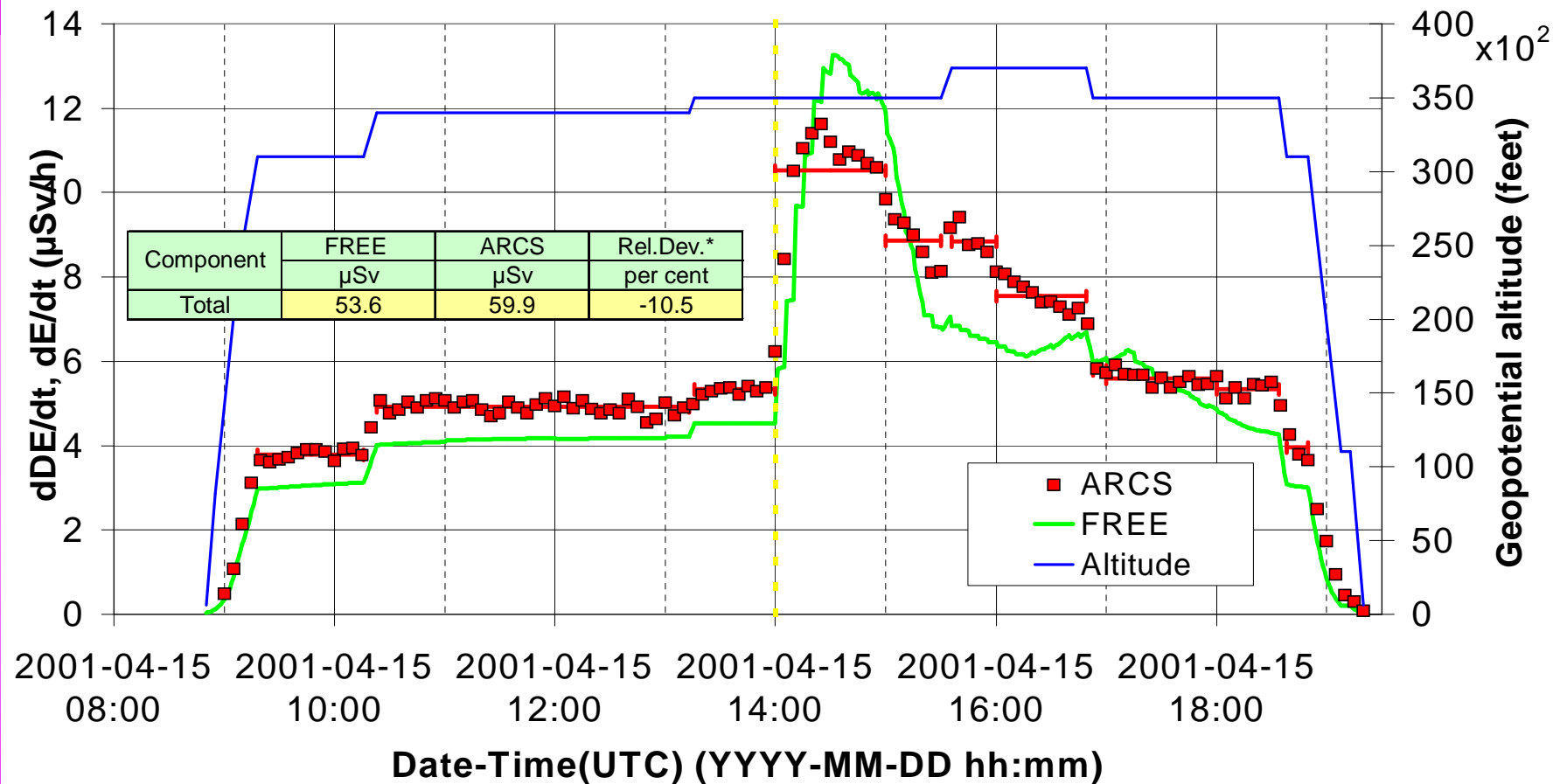
transient/short term Effects

FD 12.04.2001 Comparisons CAS, PRG->JFK



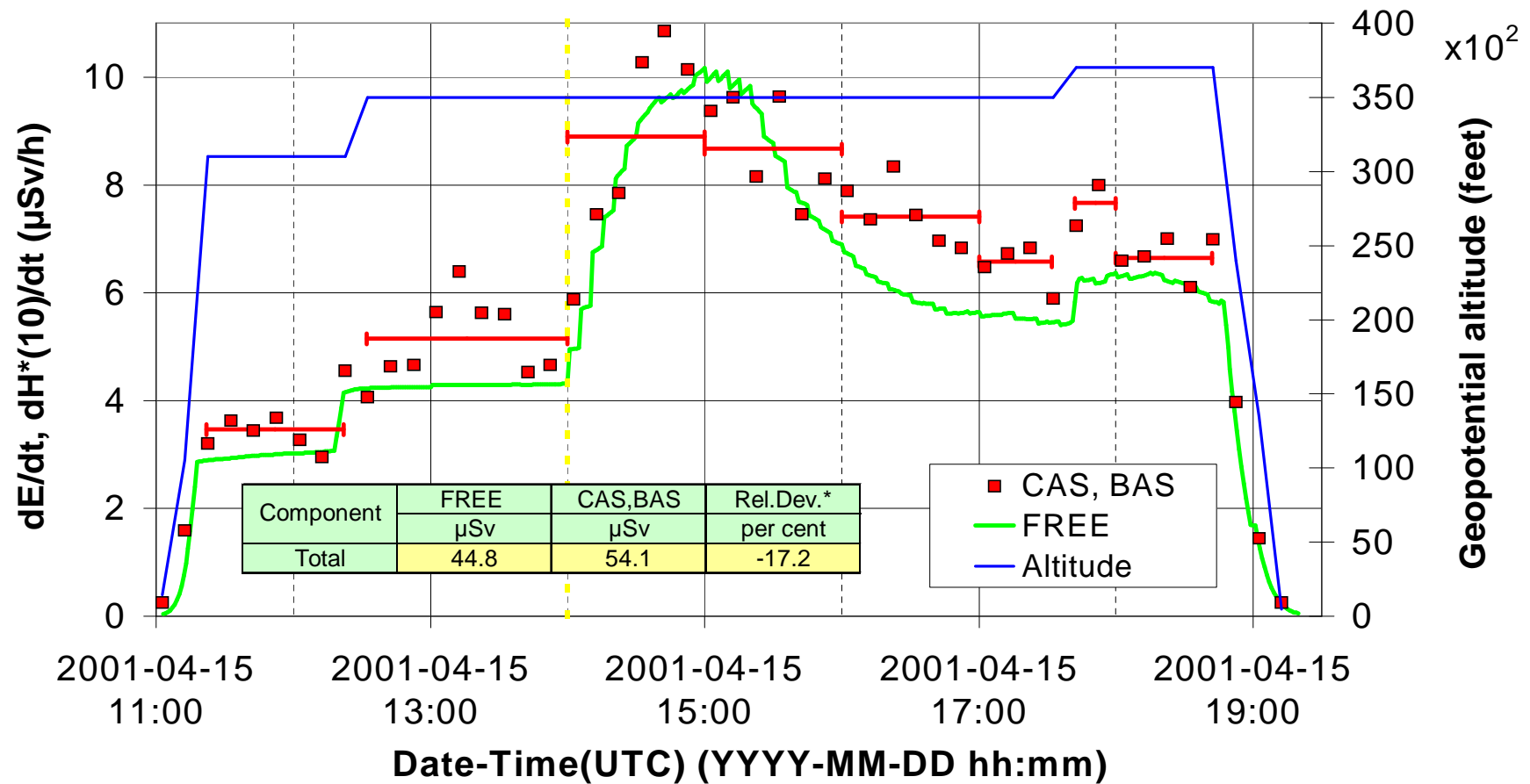
transient/short term Effects

GLE 60 Comparisons FRA-DFW



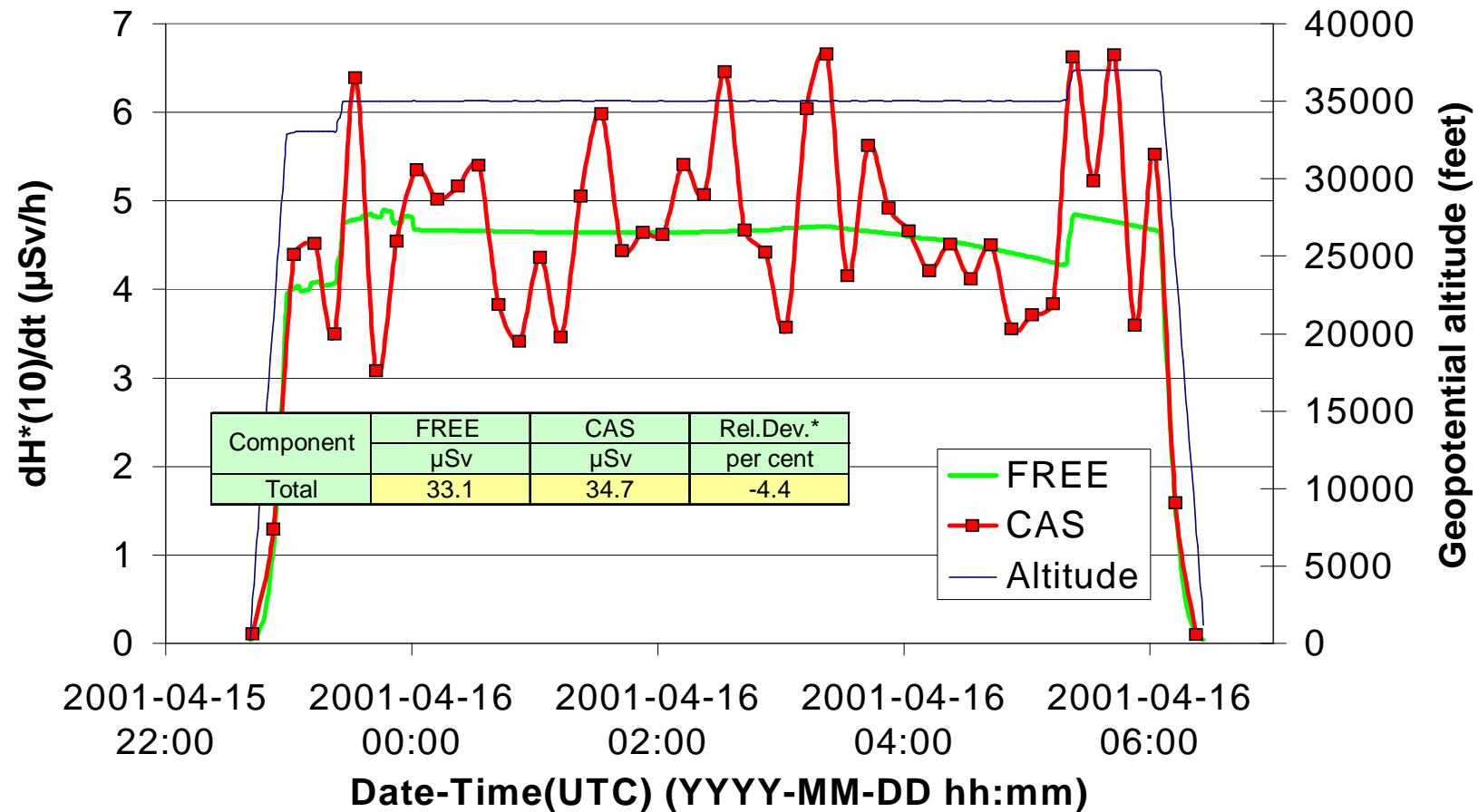
transient/short term Effects

GLE 60 Comparisons CAS, PRG->JFK



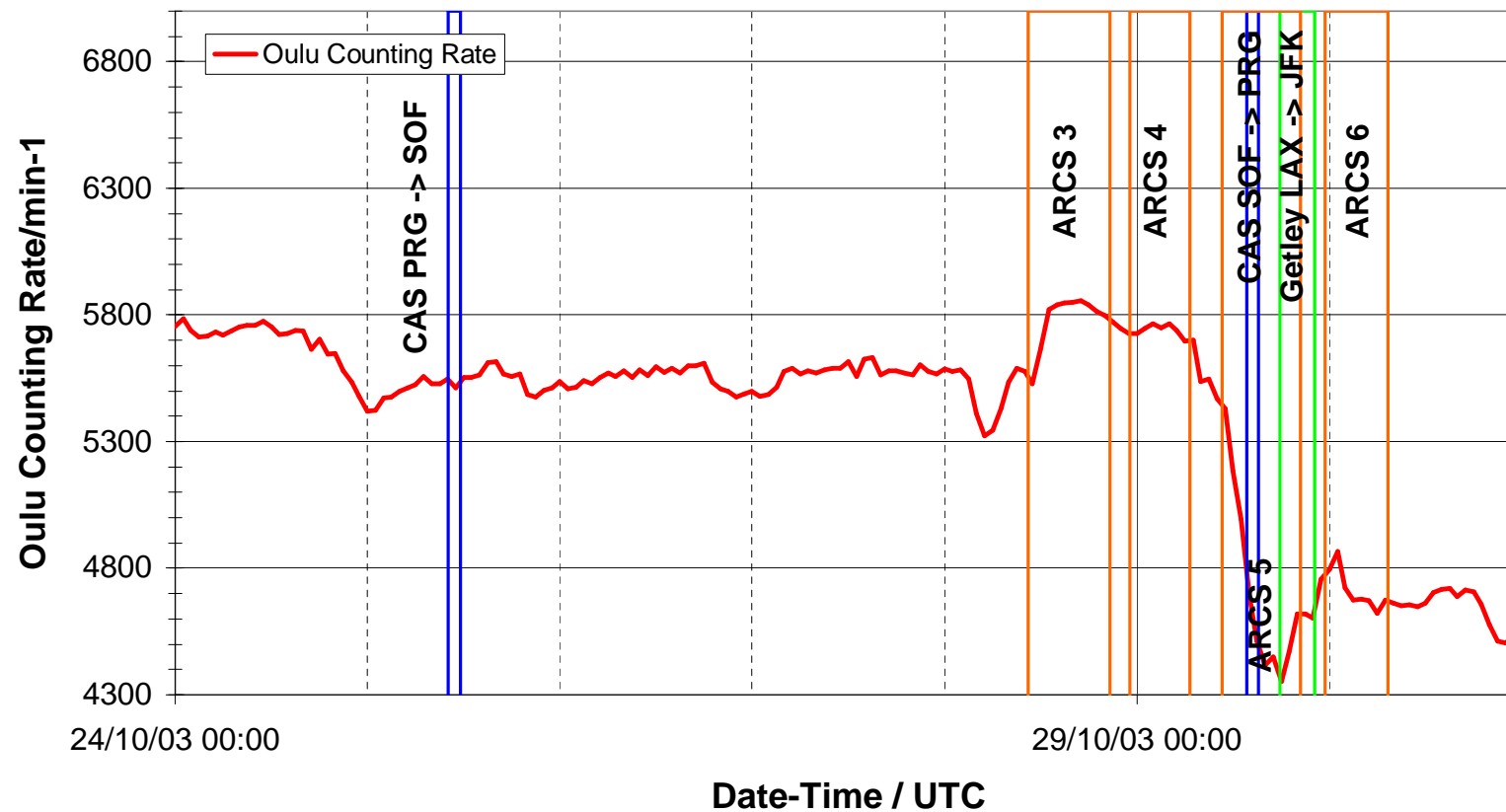
transient/short term Effects

Comparisons CAS, JFK->PRG shortly after GLE 60



transient/short term Effects

Transient Effects during October 2003





transient/short term Effects

Flight	transient Effect	Start	End	FREE H*(10)	Exp. H*(10)	Rel.Dev. FREE
CAS, PRG->SOF		25/10/2003 10:04	25/10/2003 11:34	4.27	4.78	-10.63
ARCS 3, Munich-Chicago	GLE 65	28/10/2003 10:30	28/10/2003 20:50	61.87	46.36	33.45
ARCS 4, Chicago->Munich	GLE 65	28/10/2003 23:15	29/10/2003 08:00	33.59	32.76	2.54
ARCS 5, Munich-Chicago	DFB	29/10/2003 10:30	29/10/2003 20:30	26.67	23.35	14.26
CAS, SOF -> PRG	DFB	29/10/2003 13:41	29/10/2003 15:10	3.27	3.30	-0.77
Getley, LAX -> JFK	DFB+GLE66	29/10/2003 17:50	29/10/2003 22:12	13.85	12.00	15.41
ARCS 6, Chicago-Munich	DFB+GLE66	29/10/2003 17:50	30/10/2003 08:00	24.89	23.40	6.39

Such highly disturbed months are big challenges for all flight-code developers.

IASON-FREE is already well prepared for such cases, because it takes Already into account short term variations (GLEs, FDs).

Thank you for your attention !