HelmholtzZentrum münchen
German Research Center for Environmental Health

Application of ALARA to Cosmic Ray Exposures

14th European ALARA Network Workshop
ALARA in Existing Exposure Situations

September 4th, 2012

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German Research Center for Environmental Health

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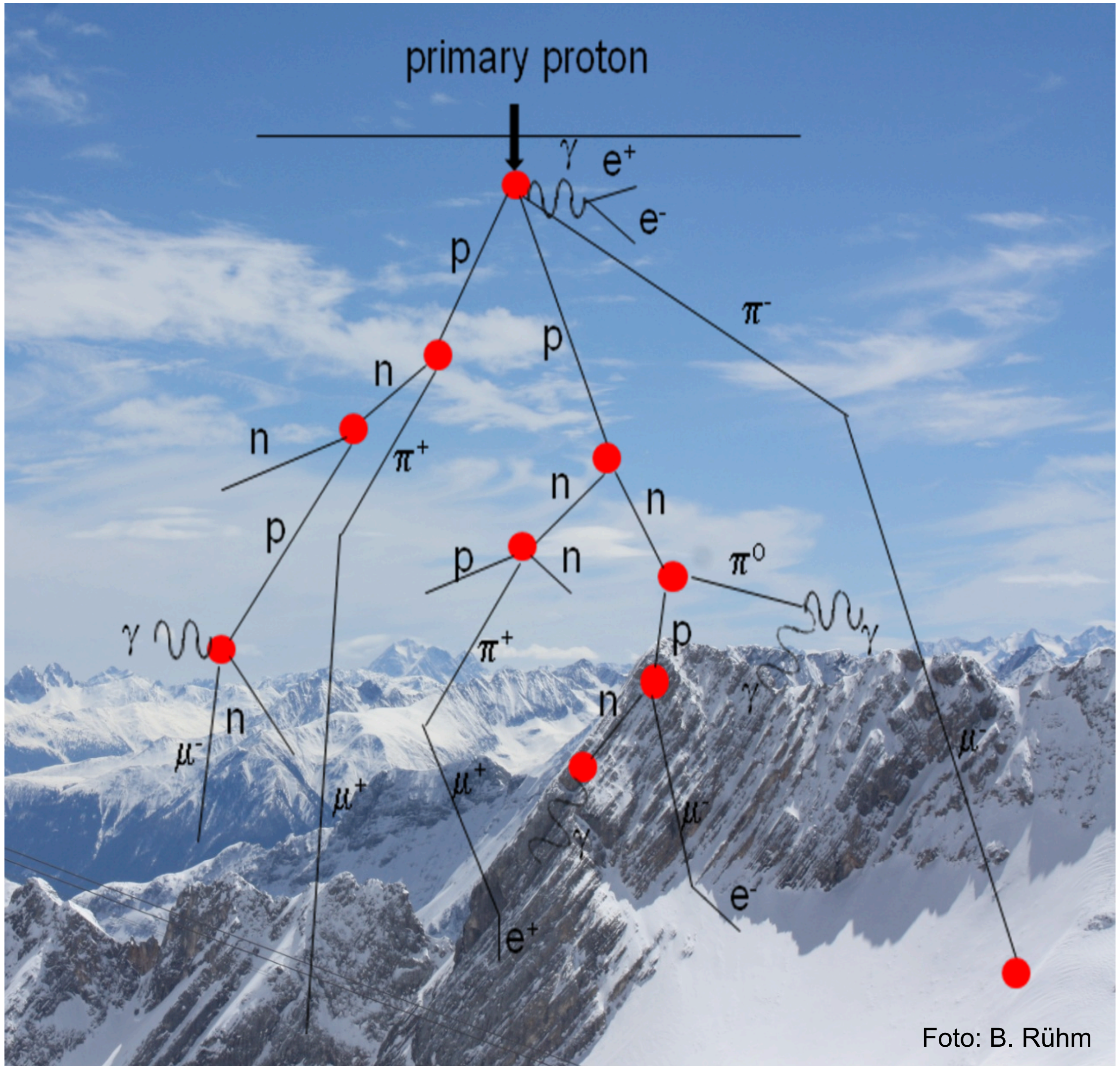


Cosmic Radiation

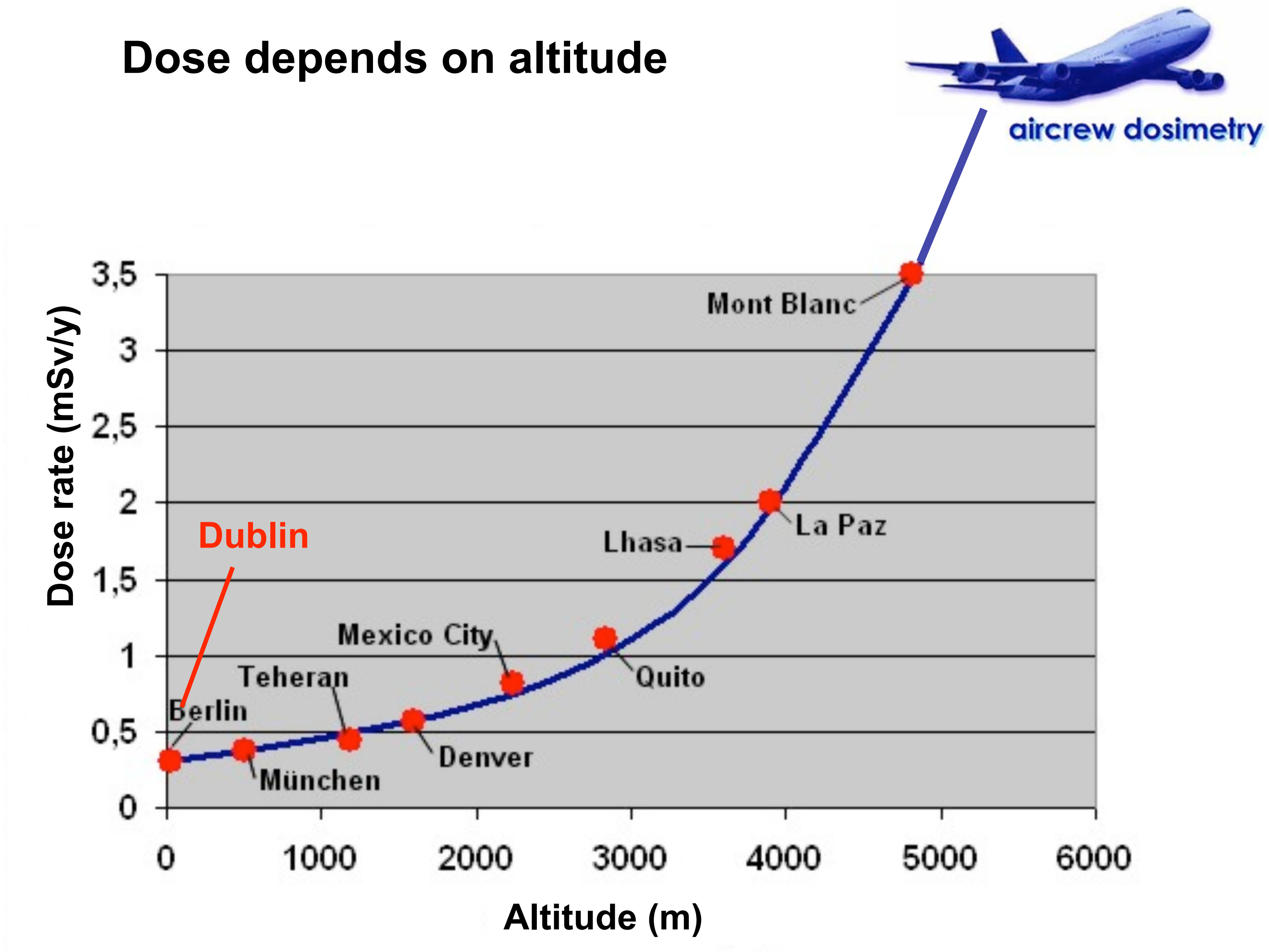
Primary cosmic radiation:
galactic and solar component
mainly p (85%), Helium nuclei (12%)

Interaction with atmosphere
(N, O, Ar)
>> **secondary cosmic radiation**:
(p, n, π^+, π^-, π^0, μ^+, μ^-, e^-, γ, …)

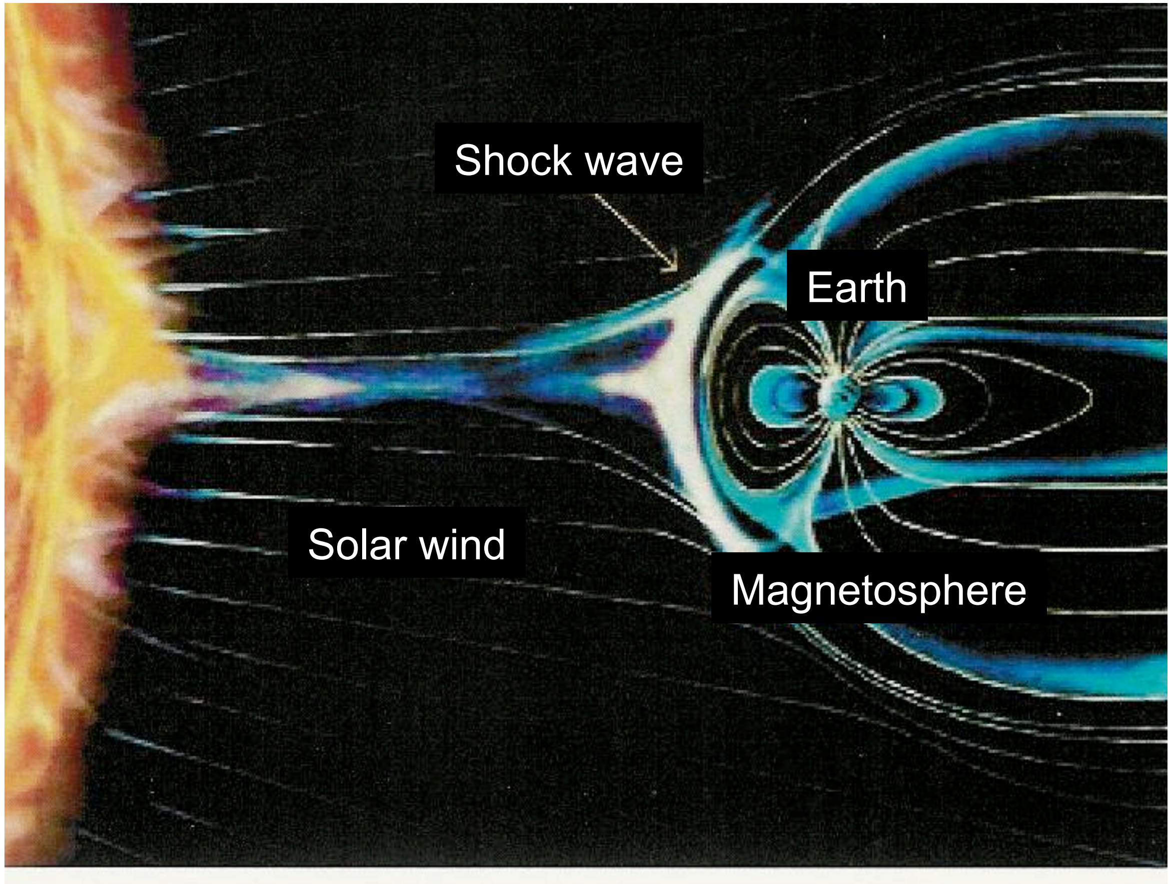
- Electrons/photons
- Hadrons
- Muons

Exposure with ionising radiation
- at ground level
- during flights

Dose depends on altitude



Dose depends on geomagnetic field

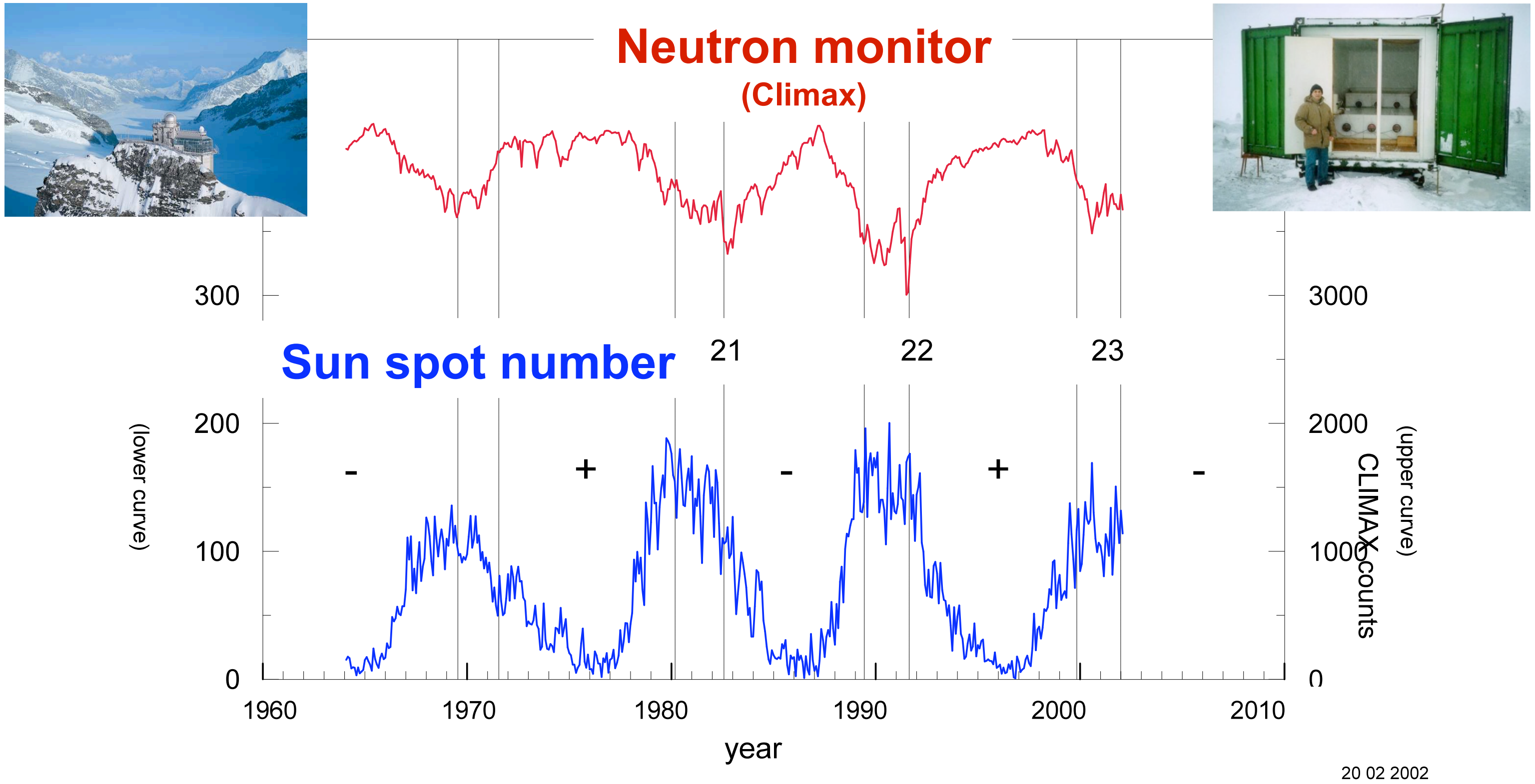


(Source: MPI für Sonnensytemforschung)

Dose depends on solar activity / solar magnetic field

Jungfraujoch

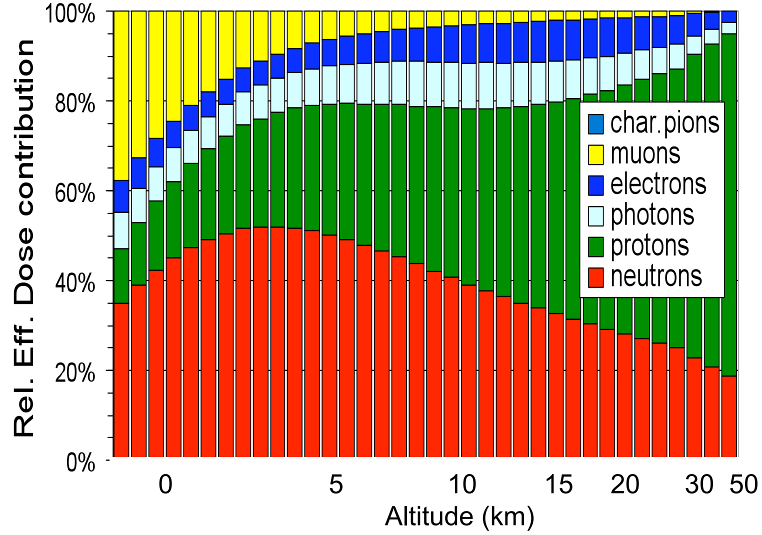
Barentsburg



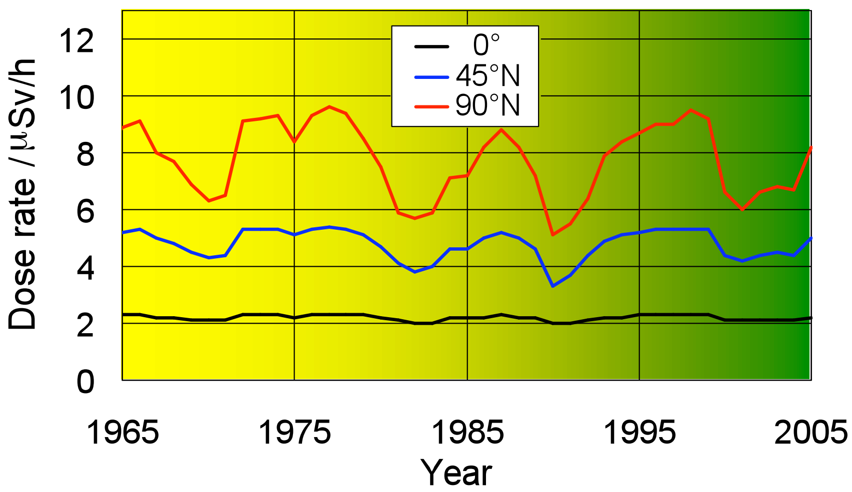
- Sun activity high > Dose rate low
- Sun activity low > Dose rate high

Calculations with EPCARD

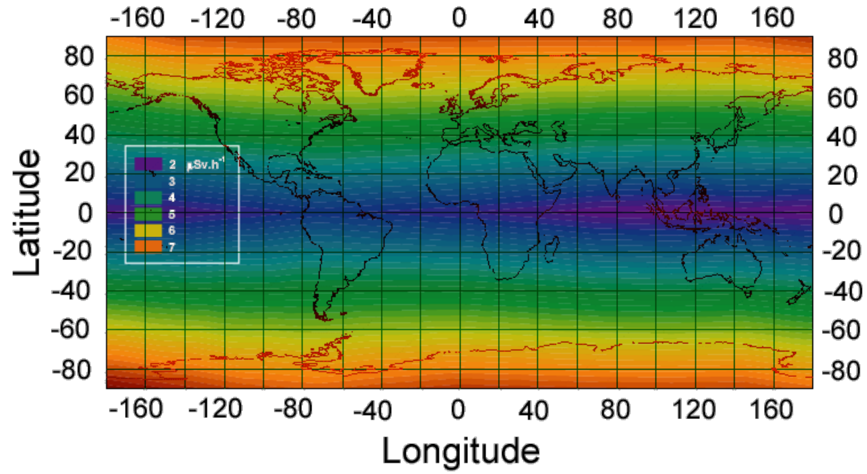
Altitude (near equator, solar minimum)



Solar cycle (11,3 km altitude)



Geomagnetic coordinates
(11,3 km altitude, April 2005)



>> rule of thumb:
5 μSv / hr in 10 km

ICRP 103 - Three types of exposure situations

- **Planned exposure situations:**
  - planned introduction and operation of radiation sources
- **Emergency exposure situations:**
  - unexpected situation e.g. during operation of a planned situation
  - malicious event such as e.g. nuclear accident
  - require urgent attention
- **Existing exposure situations:**
  - already exist when a decision on control has to be taken, e.g.
    - exposure to radon in houses,
    - exposure to naturally occuring radioactive material (NORM),
    - exposure from past events and accidents
    - **air crew exposure to cosmic radiation**

Exclusion and exemption

"Exposures that are not amenable to control are those for which control is obviously impractical, such as exposure to cosmic rays at ground level." (ICRP 103, §53)

Exposures in aviation and in space

"In Publication 60, the Commission recommended that exposures to cosmic radiation be part of occupational exposure in the operation of commercial jet aircraft and space flight."

"At that time, the Commission had already noted that the only practical regulatory measures were controlling individual exposure through the **control of flying time and route selection**. The Commission maintains this view."

(ICRP 103, §189)

Exposure of pregnant / breast-feeding workers

"However, if a female worker has declared (i.e., notified her employer) that she is pregnant, additional controls have to be considered to protect the embryo/fetus."

"The working conditions of a pregnant worker, after declaration of pregnancy, should be such as to ensure that the additional dose to the embryo/fetus would not exceed about 1 mSv during the remainder of the pregnancy."

(ICRP 103, §186)

Occupational exposure of pilots and cabin crew in Germany

(Source: BfS report of dose registry, 2005) > G. Frasch

EU-Directive 96/29 EURATOM:

Protection against significantly increased exposure by *natural* radiation

In Germany following StrlSchV 2001:

Air crew members must be monitored if

a) They are employed by an airline

b) Expected annual effective dose > 1 mSv

>> Airlines must quantify doses since August 2003

Category	Individuals	Dose records
Commercial aviation	29.078	297.398
Non-commercial aviation	133	1.262
German airforce, NATO	993	6.561
total	**30.204**	**305.221**

About 70% by HMGU-code **EPCARD**

EPCARD

aircrew dosimetry

European **P**rogram Package for the **C**alculation of **A**viation **R**oute **D**oses

Lufthansa · Lufthansa CityLine · Condor · LTU · Lufthansa Cargo (The business to business class.) · DaimlerChrysler Aviation · Germania · Condor

www.helmholtz-muenchen.de/epcard/

Annual effective dose, Germany, 2005 (BfS report, G. Frasch et al.)

Occupation	**monitored** individuals	annual dose	collective dose
4. NPPs (maintenance)	9,073	1,0 mSv	9,4 Person-Sv
3. Radiography	2,030	1,1 mSv	2,1 Person-Sv
2. NPPs (cleaning)	756	1,4 mSv	1.1 Person-Sv
1. Air crew	**31,227**	**2,0 mSv**	**62,2 Person-Sv**

For comparison in medicine: 240,000 / 0,07 mSv / 16,4 Person-Sv

Air crew is important both in terms of mean annual effective dose and collective dose

Europe, 2009: EAN-Report

Country	Number of exposed individuals	Mean annual effective dose (mSv)	Maxiumum annual effective dose (mSv)
Belgium	2,912	**1.27**	4.77
Czech Republic	2,158	**1.09**	3.85
Denmark	3,824	**1.8**	6.0
France	19,830	**2.2**	5.5
Germany	36,596	**2.3**	7.0
Ireland	9,726 (> 1 mSv)	**-**	-
Lithuania	213	**-**	-
Slovenia	322	**1.16**	1.74
Sweden	1,431 (> 1 mSv)	**2.55**	5.43
UK	about 40,000	**about 2**	-

In terms of radiation protection, air crew is a specific cohort!

Dose distribution

- usually, most of monitored workers show zero dose
- very rarely, they may get more than 10 mSv (e.g., accidents)

- monitored air crew has at least 1 mSv/year by definition
- almost impossible to get more than 10 mSv (Solar Particle Events - SPEs??)

Sex distribution

- almost no female pilots
- but about 80% females among cabin crew

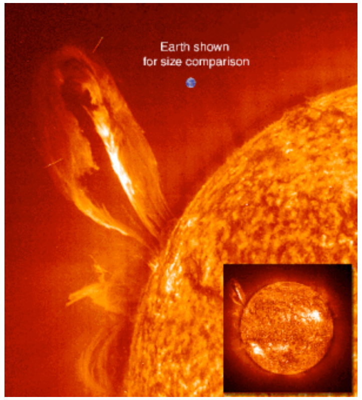
See talk by G. Frasch tomorrow

Age distribution

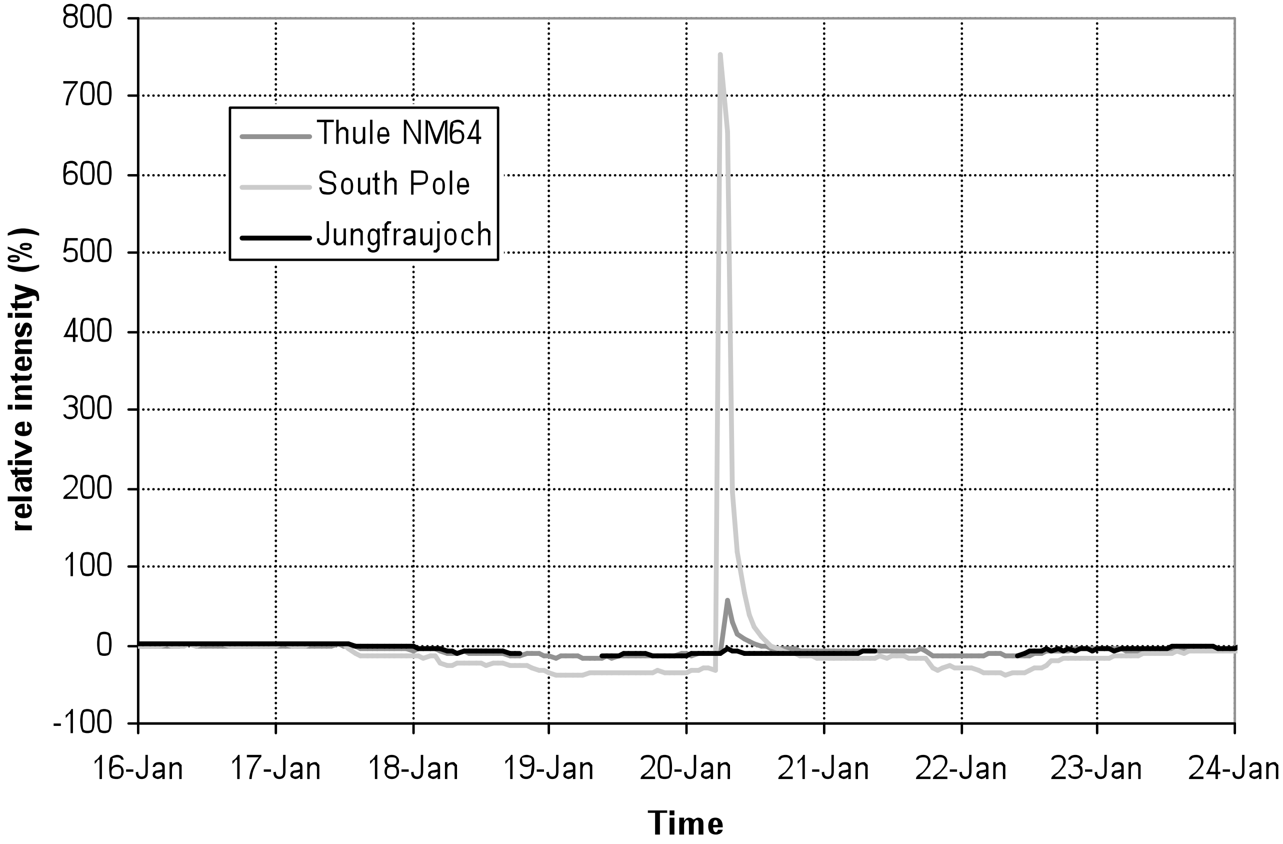
- many young women before pregnancy
- some older women who fly again after having gotten children

- those who are young wish to fly long, and thus get larger doses
- while those who are older wish to fly shorter (family!) and thus get lower doses

Solar Flares > Ground Level Enhancements (GLEs)



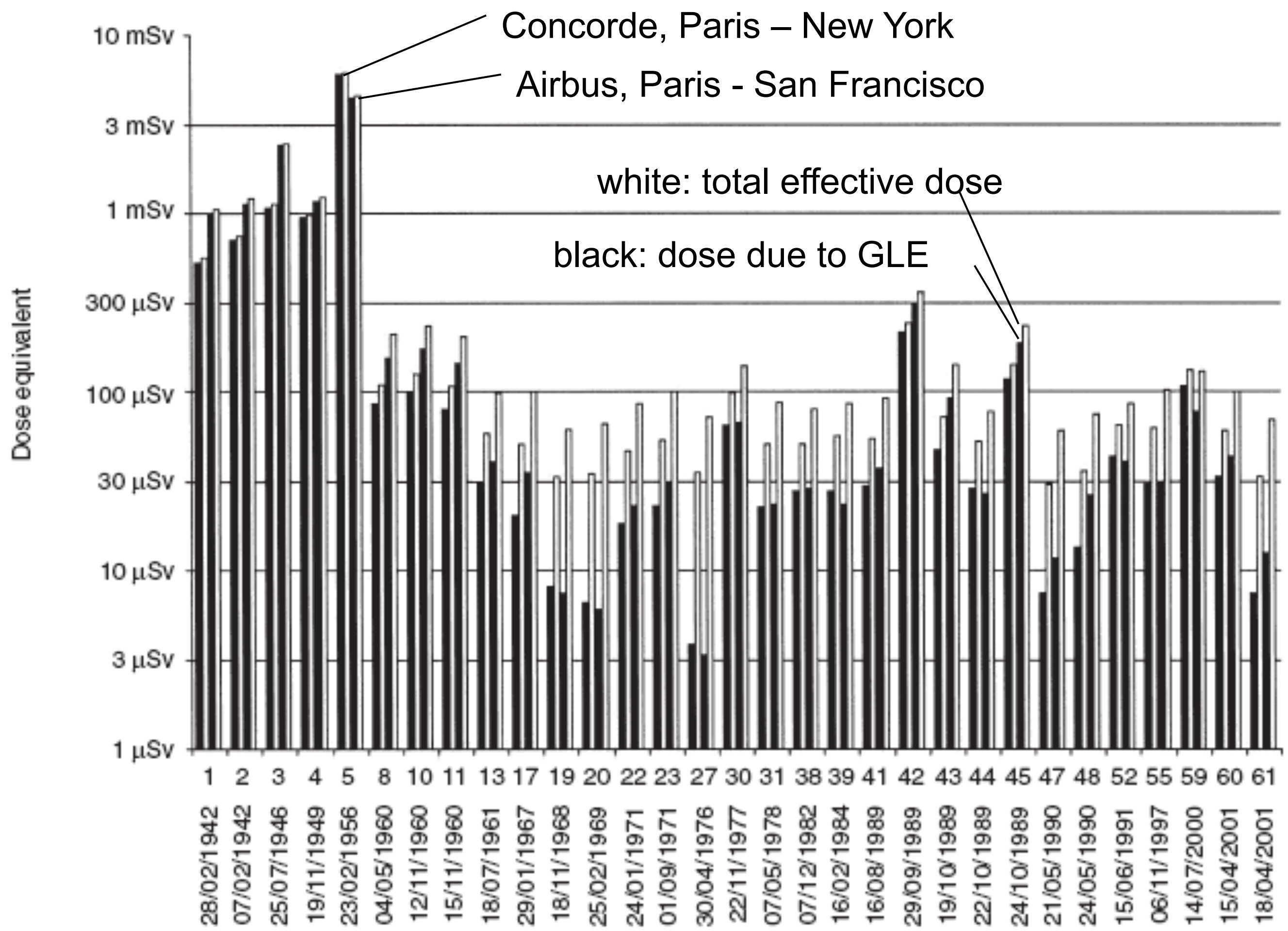
Example: GLE 69 on 20 January 2005



Neutron monitor close to South Pole:

Increase of relative hourly count rate compared to normal by a factor of 8

Doses during certain flights – rough estimates



(from Lantos and Fuller, 2003)

- About 50 GLEs in about 50 years
- **Single flight might lead to doses > 1 mSv!**
- Largest GLE ever recorded: Carrington event 1859
- Route doses > 10 mSv
  C. Pioch, priv. comm.
  ????

The Principle of Optimisation of Protection

The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be **kept as low as reasonably achievable, taking into account economic and societal factors**.

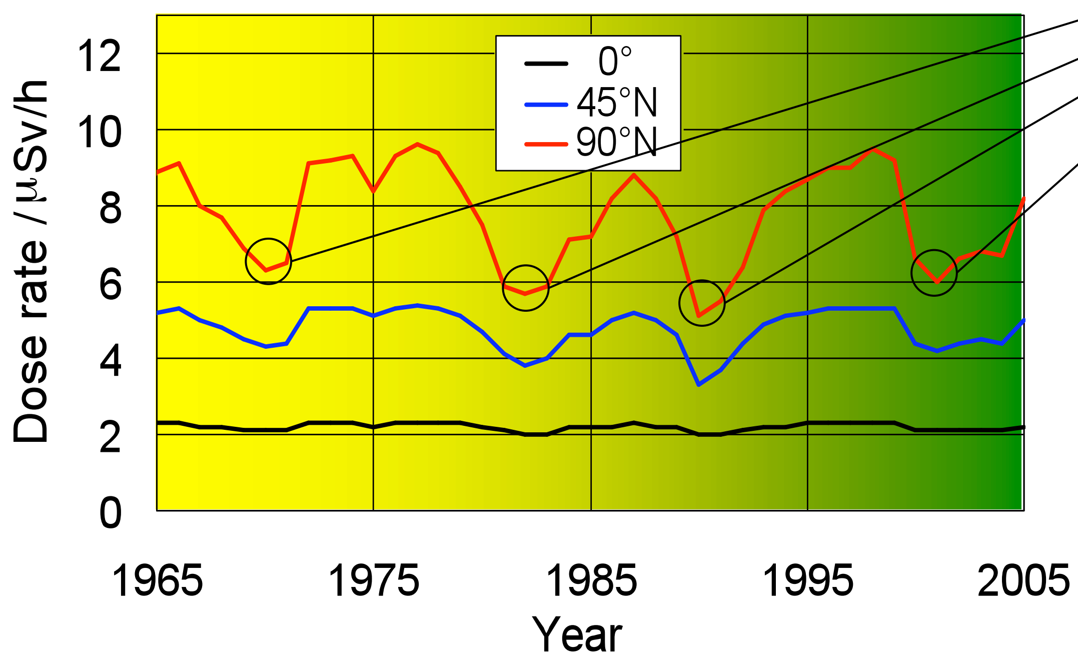
ALARA (ICRP 103, §203)

The 4 A's in German Radiation Protection

- **A**bstand (distance)
- **A**ktivität (source activity)
- **A**bschirmung (shielding)
- **A**ufenthaltsdauer (duration of exposure)

Source activity – Anticorrelation with Sun Activity

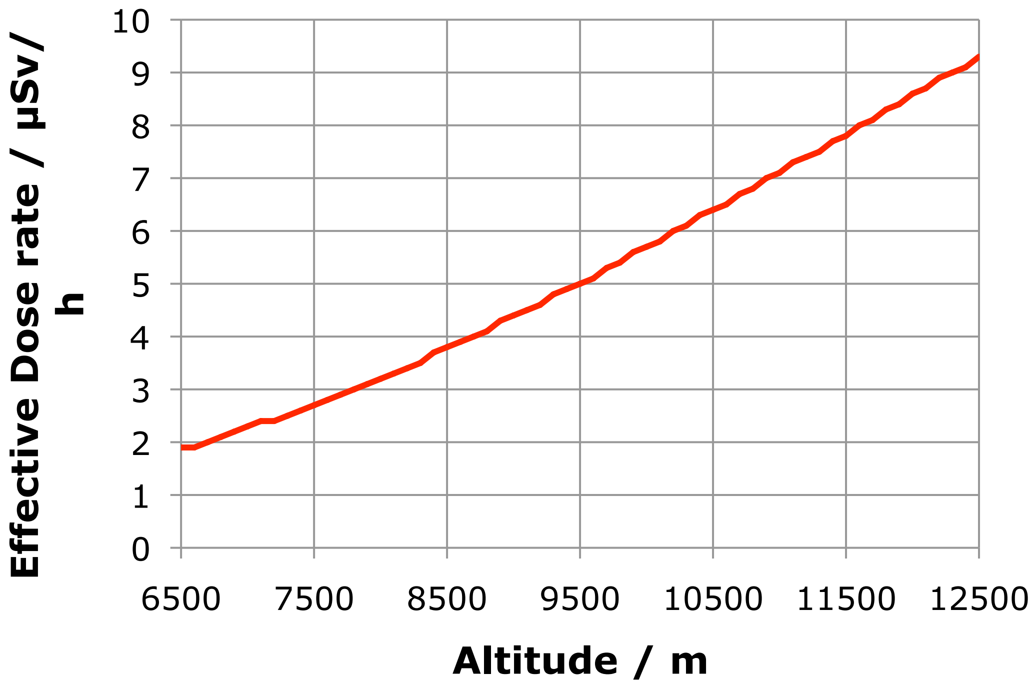
Solar cycle (11,3 km altitude)



- Should one allow flying only during periods with high solar activity?
- One may save about 30% of the dose!
- Would this be reasonable in terms of economic and societal factors??

Shielding by Atmosphere – Flight Altitude

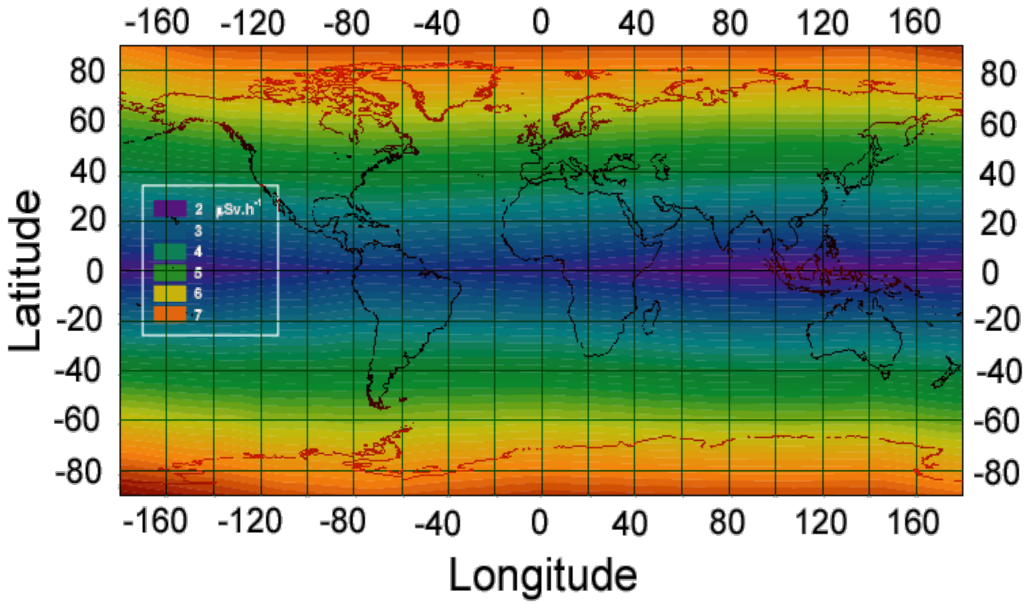
- Dose rate above Dublin
- On September 1st, 2012
- Calculated with EPCARD on website



- Dose rate decreases with decreasing flight altitude
- One may save about 50% of dose (11.7 km compared to 8.7 km)!
- Recommend to limit flight altitude?
- Would probably reduce collective dose
- Costs would increase due to increased fuel consumption
- Risks for accidents increase the lower one flies
- Would this be „reasonable“ in terms of economic and societal factors?
- Option for SPE?

Shielding by Geomagnetic field

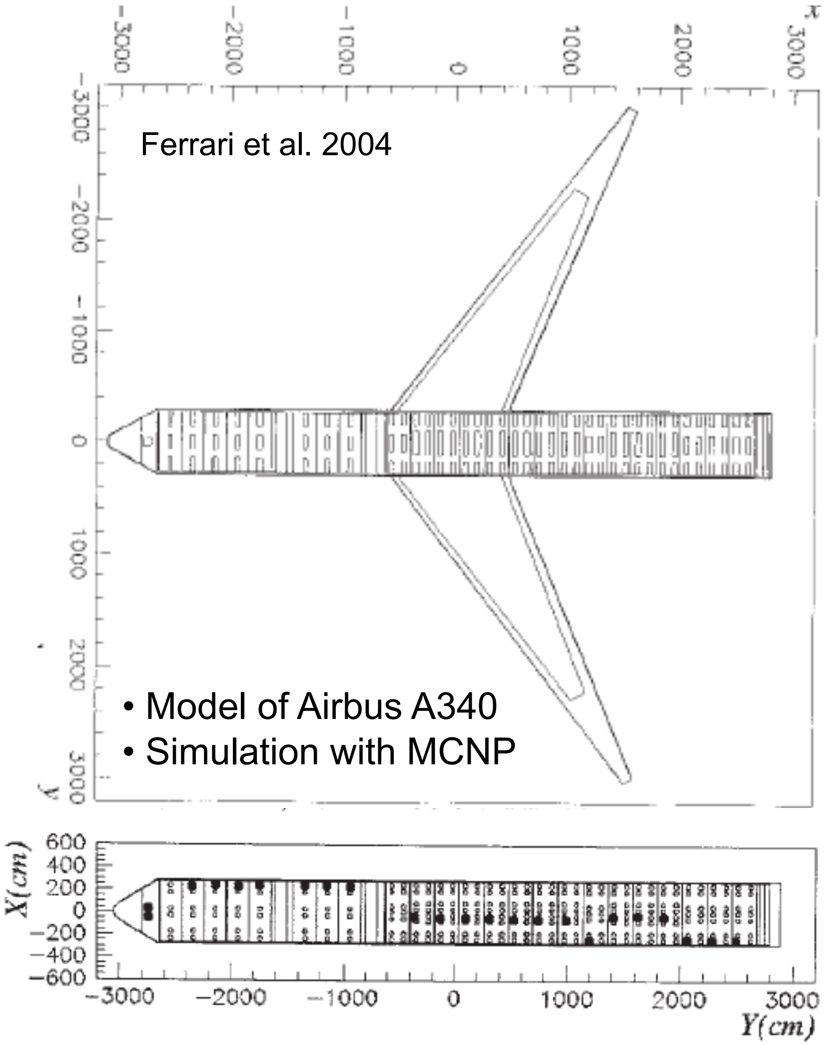
Geomagnetic coordinates
(11,3 km altitude, April 2005)



- Dose rate depends on geomagnetic latitude
- Should one recommend to reduce number of polar flights?
- Costs would increase due to longer flight distances
- Doses may increase due to longer flight times
- Should one recommend to limit number of polar flights for air crew with higher doses?

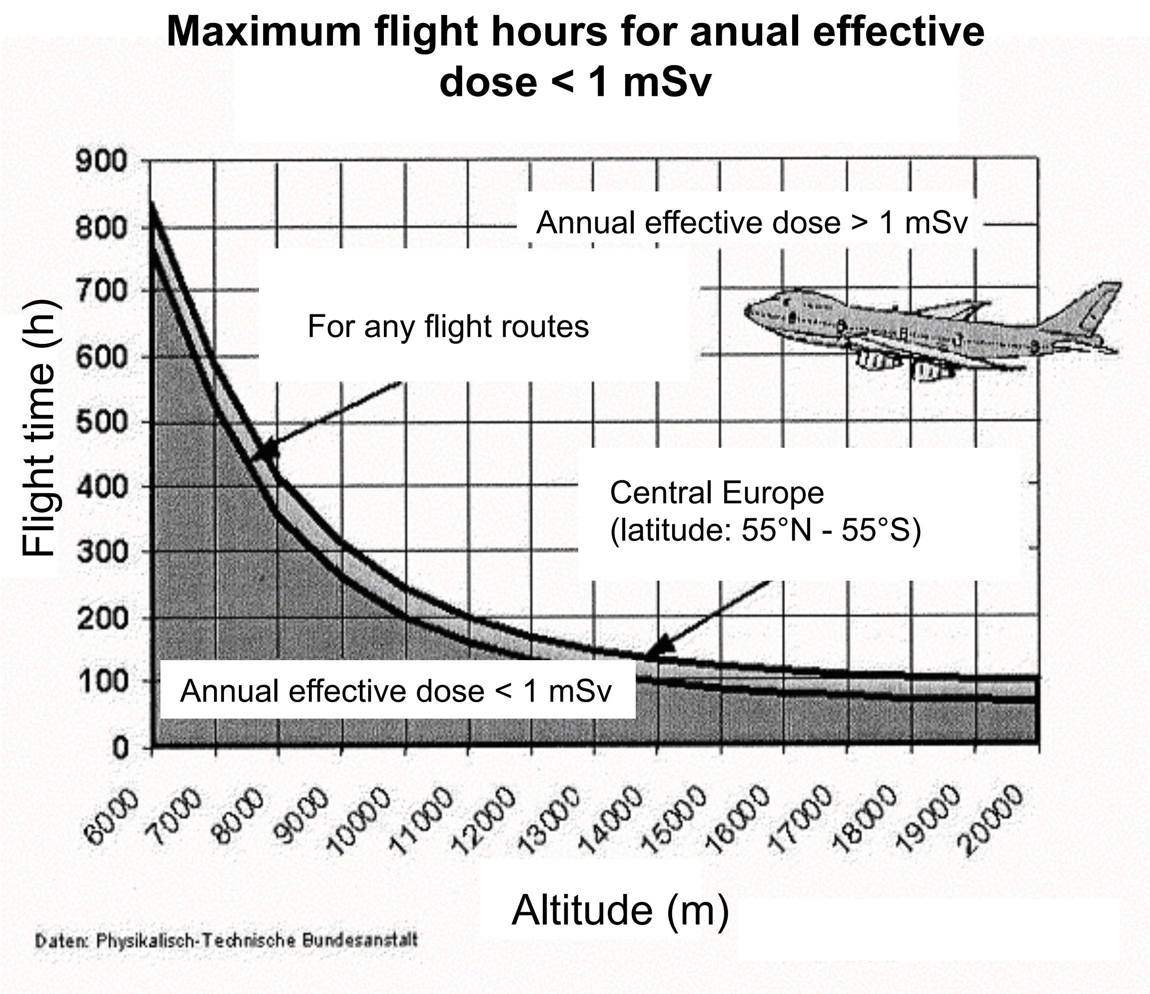
- Would this be reasonable in terms of economic and societal factors?

Shielding by Aircraft



- Effective dose in cockpit about 10% less than that free in air
- Effective dose for passengers up to 27% less than free in air
- Depends on seat position, level of fuel, geomagnetic shielding; number of passengers
- Should one allow air crew to serve specific seats only?
- Should one increase shielding due to structure material of an air craft?
- Costs would probably dramatically increase
- Would this be reasonable in terms of economic and societal factors?

Duration of Exposure – Flight time



- Dose depends on flight time
- Usually 900 block hours allowed
- Assume mean 5 µSv/h
- Corresponds to 4.5 mSv annual effective dose
- One may suggest to share the dose between individual crew members
- Reduction of block hours increases costs (more staff needed), but would probably not reduce collective dose

Summary

- Air crew important both in terms of mean annual effective dose and collective dose
- Mean annual effective doses to air crew: up to 2.5 mSv
- Individual annual effective Doses to air crew: up to 7 mSv
- Quite a number of parameters influence exposure (time, altitude, shielding, …)
- Difficult to find reasonable (in terms economic and societal factors) recommendations
- For those with high doses: perhaps avoid polar routes, reduce flight times
- For women at young ages (being at higher risk than older women): keep exposure as low as reasonably achievable
- For women: declare pregnancy asap
- Warnings for GLEs: still to be developed (if at all possible)
- Note: With ICRP 103, effective doses decrease by about 30% (radiation weighting factors)

Thank You!