Variations in the radiation exposure within the Columbus module of the ISS measured during the DOSIS and DOSIS 3D experiments

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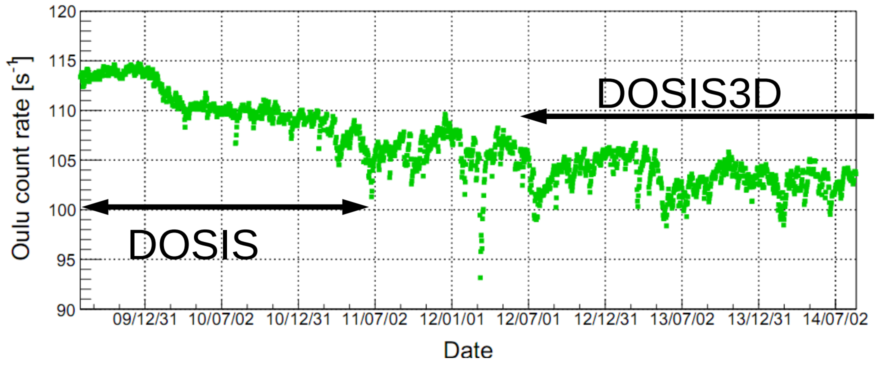
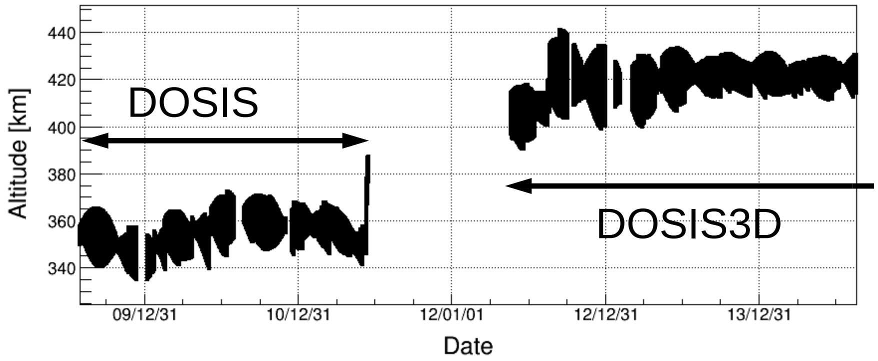
DLR

Motivation

- DOSIS: July 2009 – June 2011
- DOSIS3D: May 2012 – today (continued)



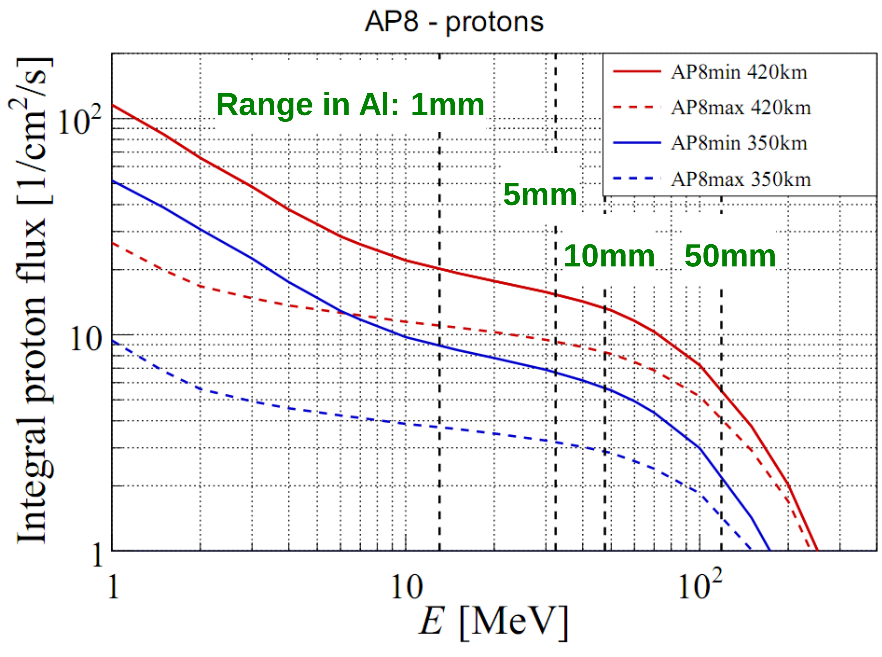
- Increased solar activity:
  - GCR ↓
  - SAA ↓

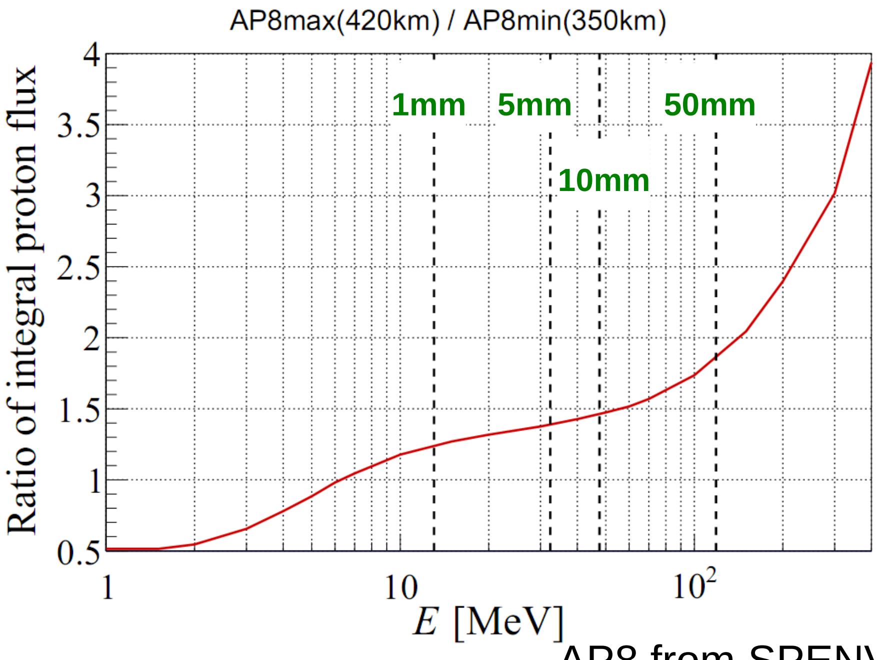


- Increased altitude, 350 km to 420 km:
  - GCR →
  - SAA ↑↑

AP8 prediction for trapped protons ISS orbit average

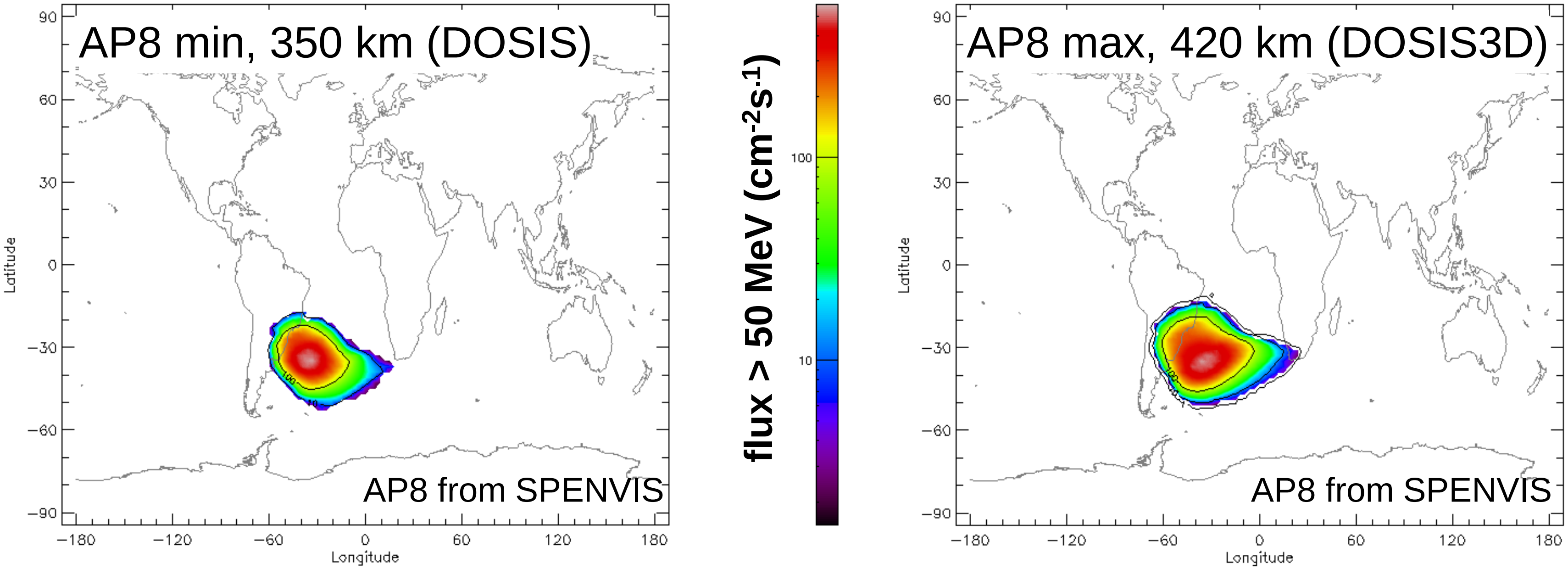
- Increase with altitude
- Decrease with solar activity
  → From DOSIS to DOSIS3D: Increase predicted





AP8 from SPENVIS

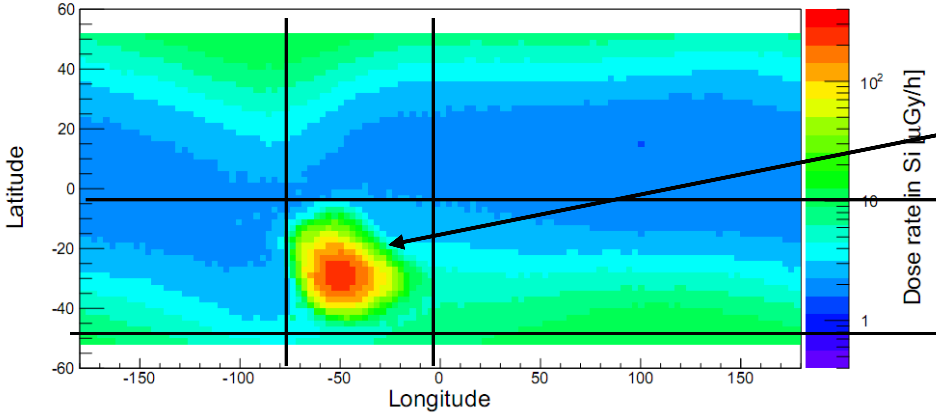
AP8 prediction for trapped protons, *E* > 50 MeV



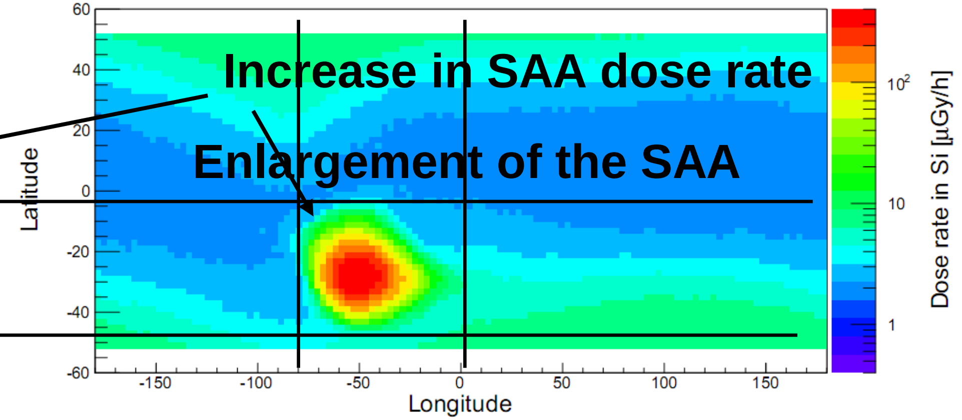
Dose rates in Si, DOSIS and DOSIS3D (DOSTEL2)

Acknowledgement: NASA, R. GAZA for SAA position data

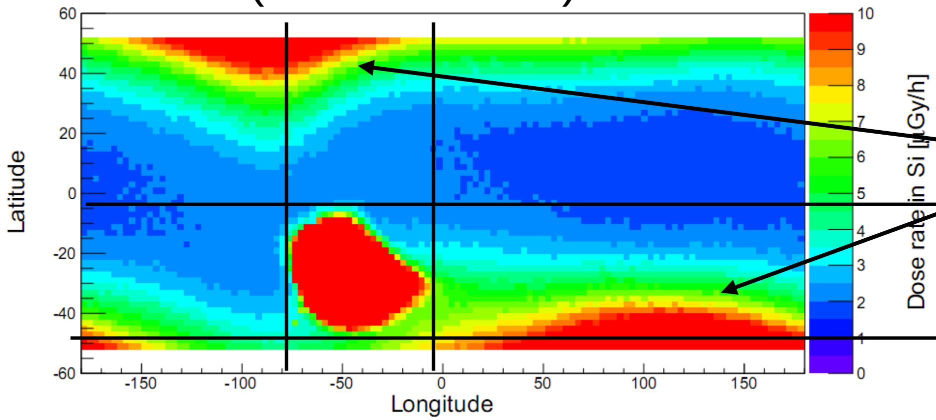
DOSIS



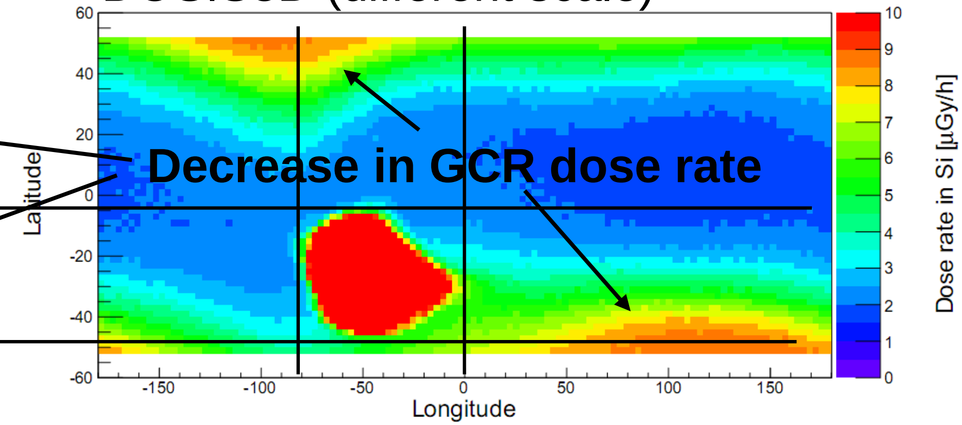
DOSIS3D



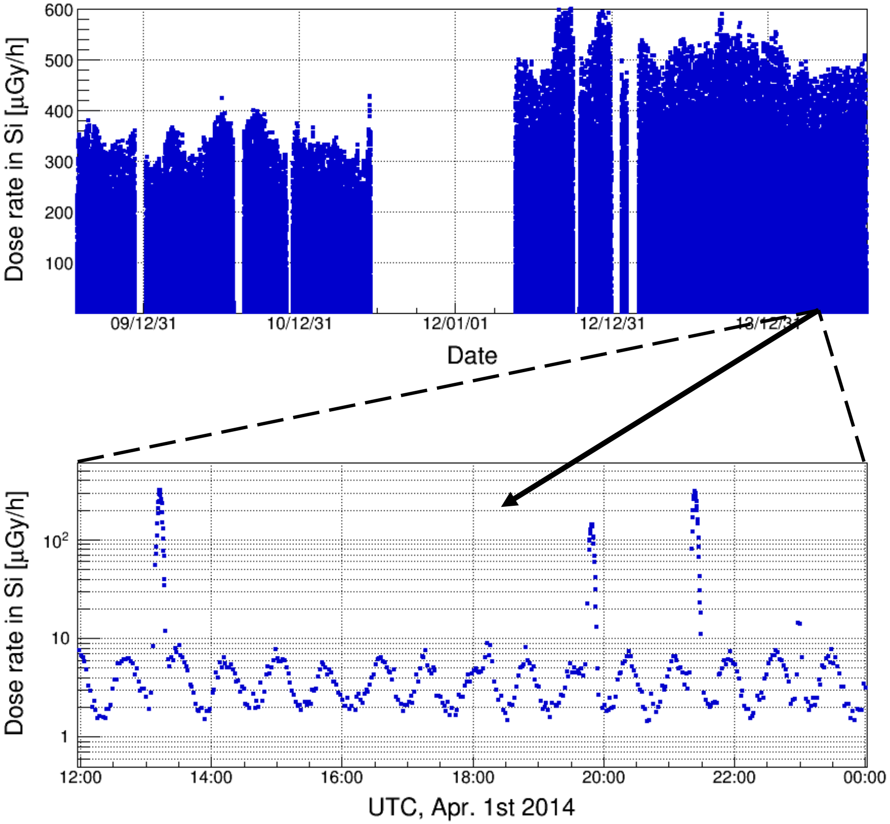
DOSIS (different scale)



DOSIS3D (different scale)

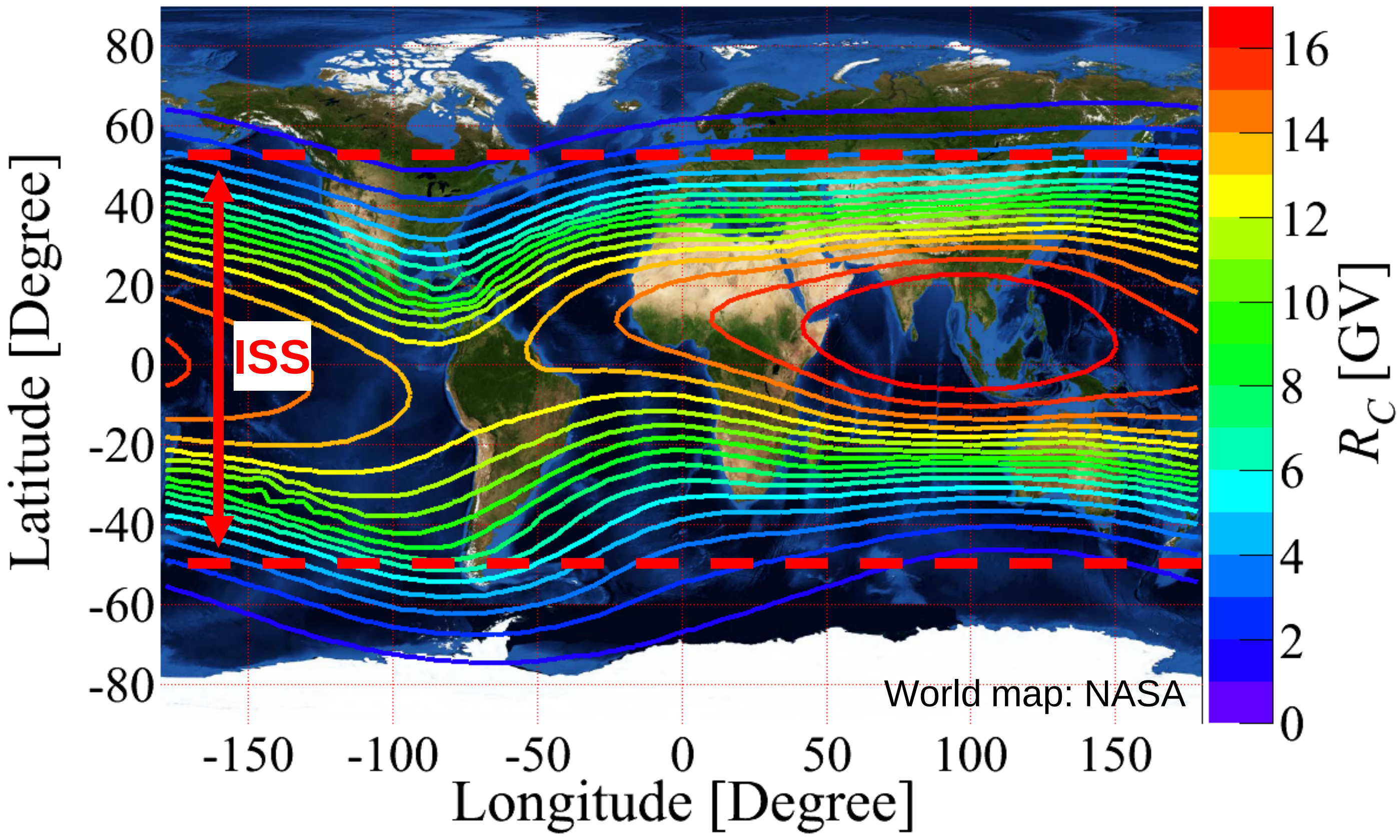


DOSIS and DOSIS3D (DOSTEL2)
Temporal variation of dose rates

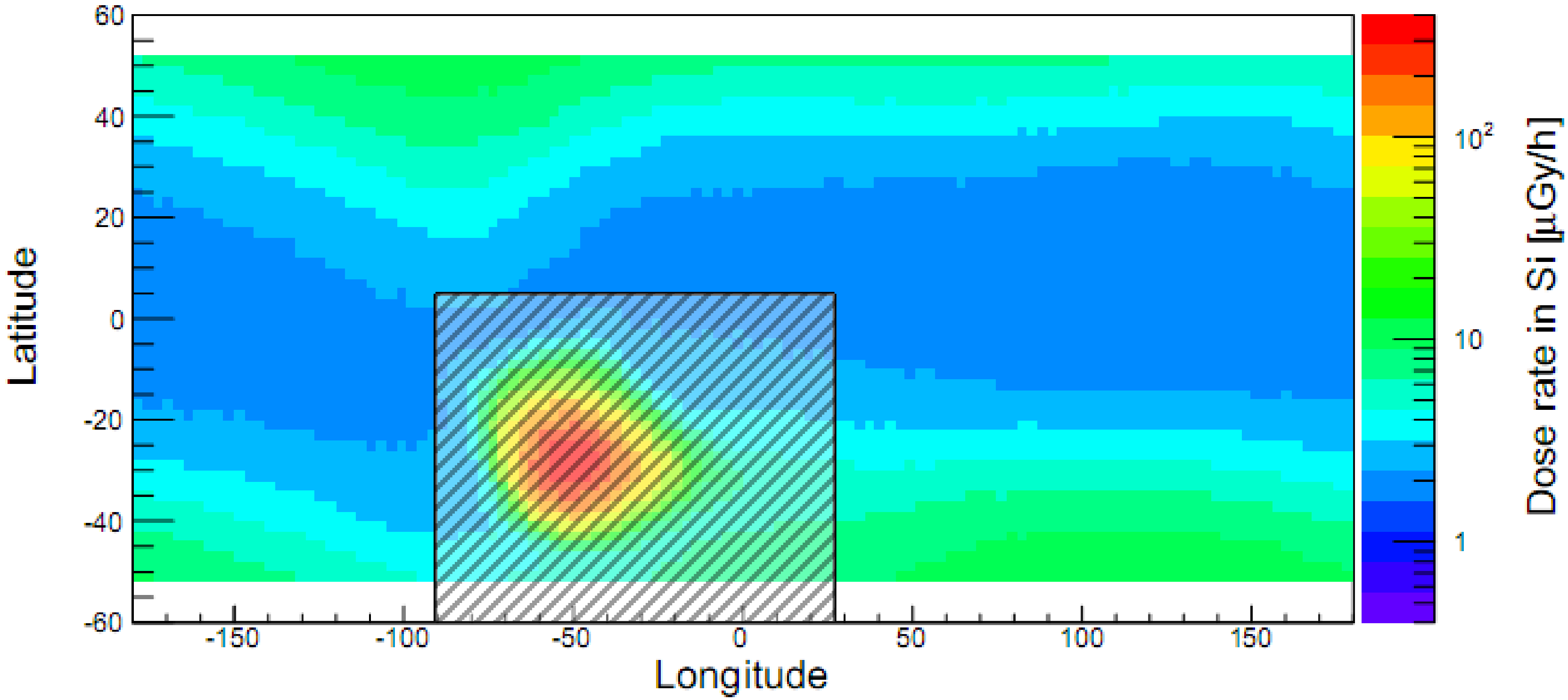


- Separate SAA and GCR:
  - Select GCR by geographical criterion
  - Group GCR dose rates in classes of cut-off rigidity R_C
  - Select from all dose rates:
    GCR ≤ mean dose rate + 3σ
    SAA > mean dose rate + 3σ

Cut-off rigidity (R_C) map

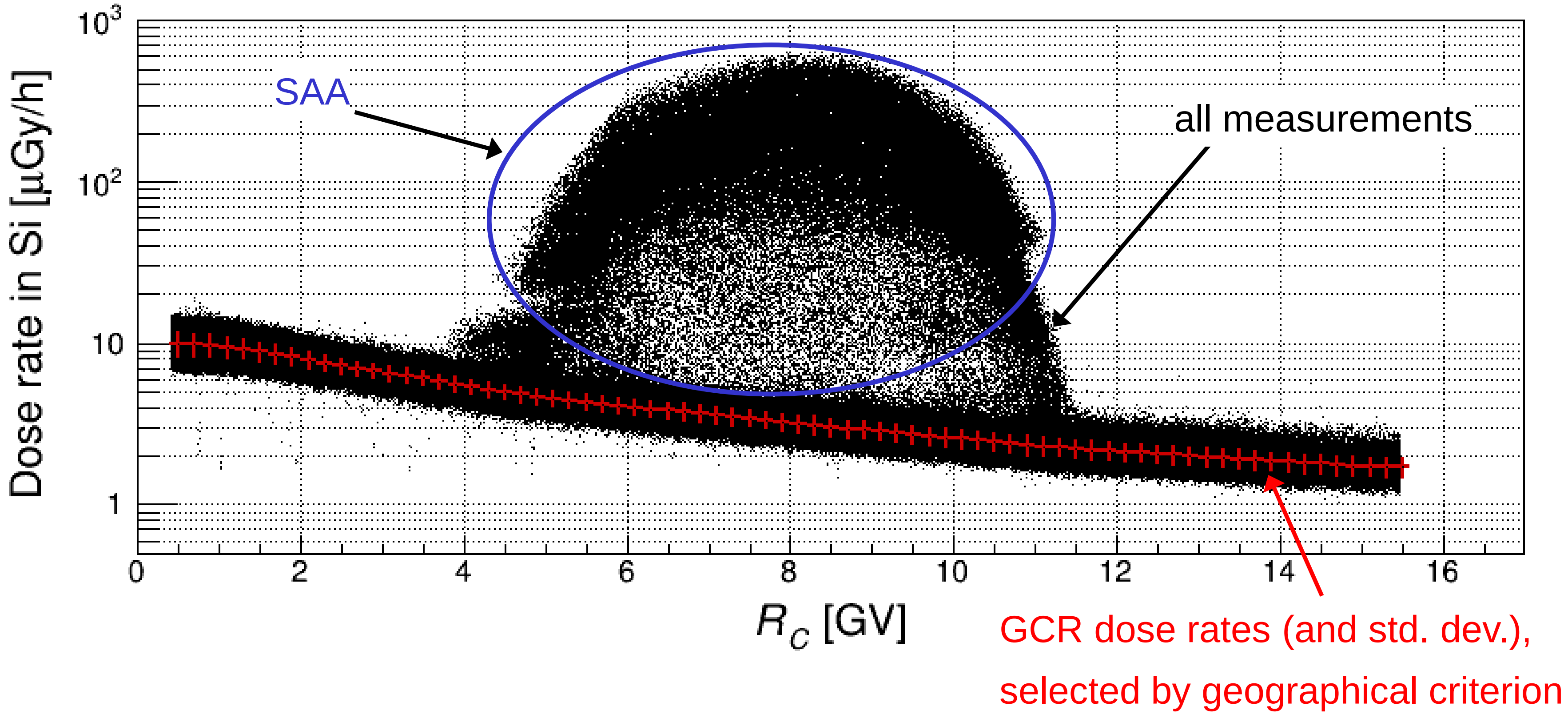


Dose rates from DOSIS/DOSIS3D (DOSTEL2)



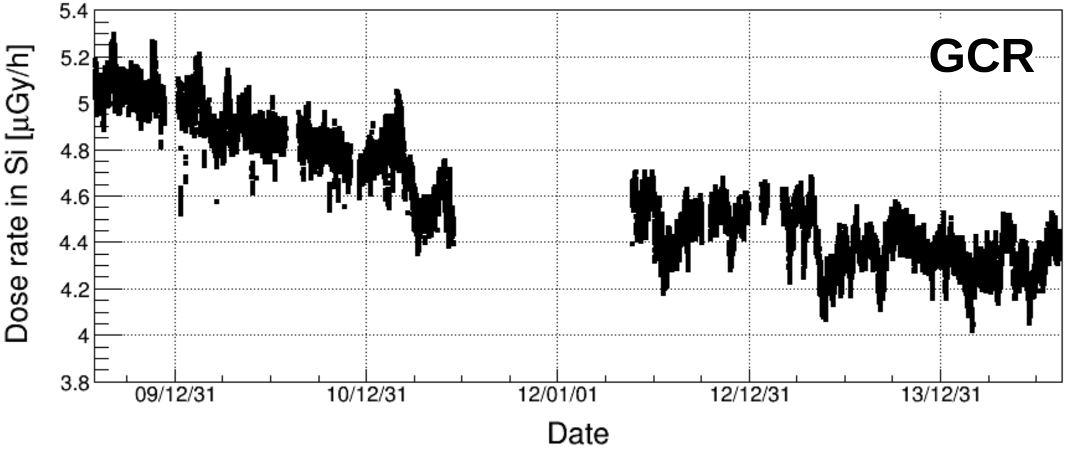
- Selection critierion: latitude > 10° or longitude > 25 ° or longitude<-90 °
- Fill dose rate vs cut off rigidity histogram

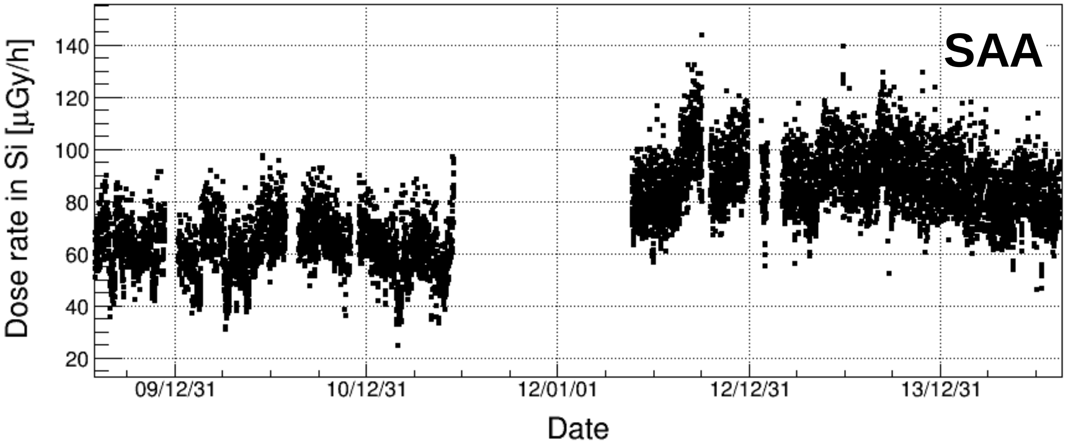
Dose rate versus cut-off rigidity R_C



- 3σ criterion: all measurements, where the dose rate is larger than the mean + 3σ are taken to be within the SAA

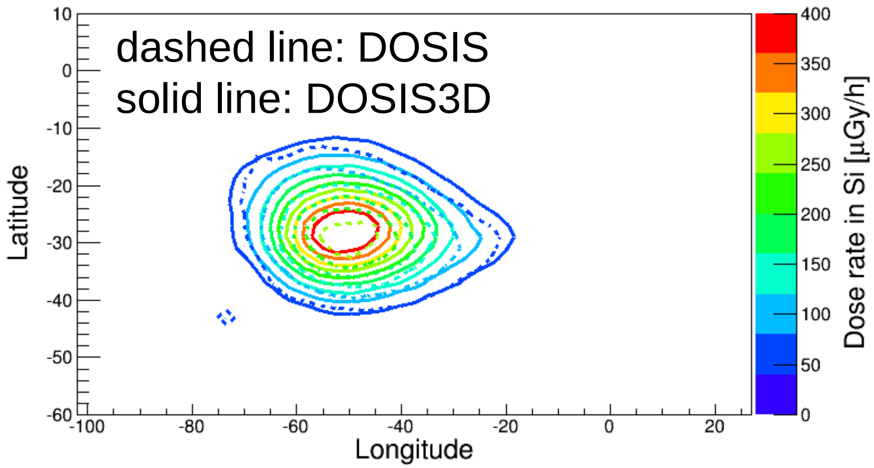
Separated dose rates GCR and in the SAA DOSIS/DOSIS3D, DOSTEL2



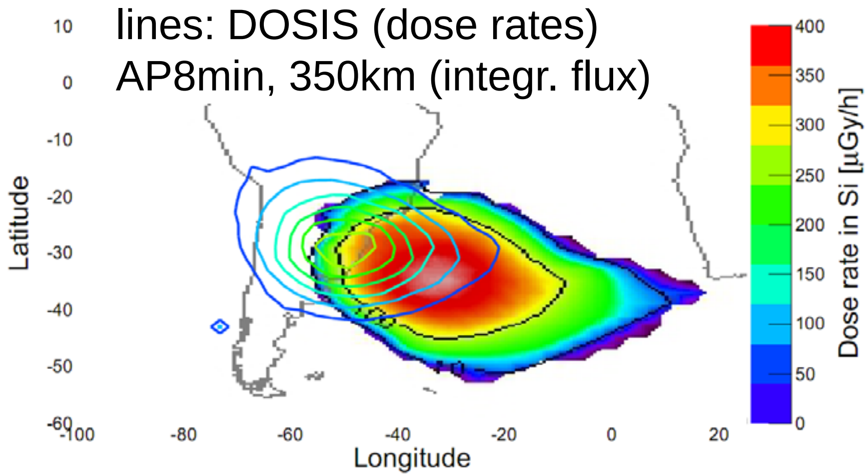


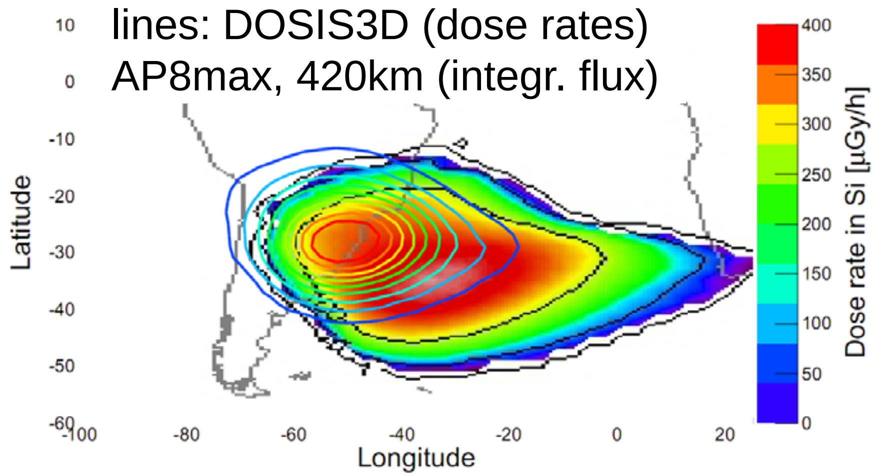
- Moving average over 16 orbits (≈1day)
- GCR: decrease of about 10-15%
- SAA: increase of about 50%

SAA boundaries, DOSIS and DOSIS3D (DOSTEL2)

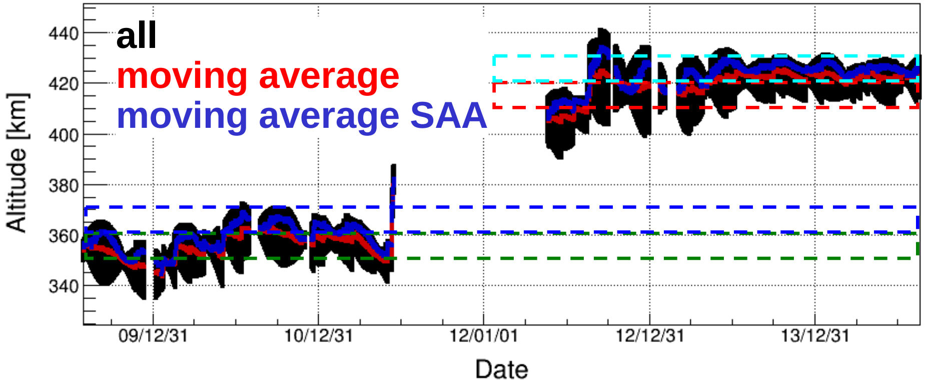


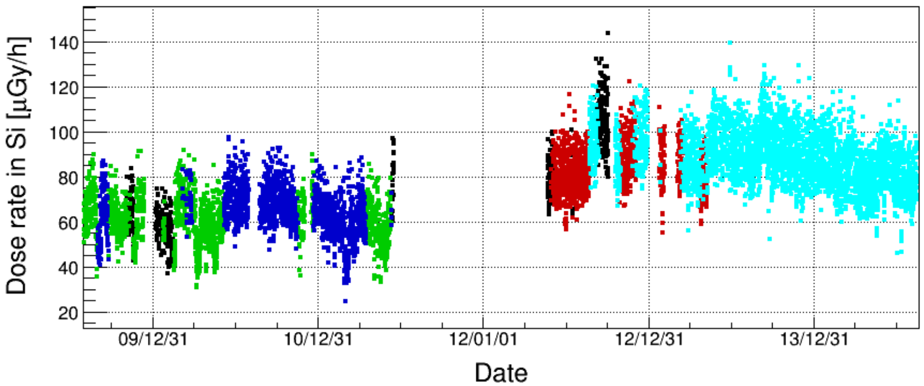
- Enlargement of the SAA
- Increased peak dose rates for DOSIS3D against DOSIS
- „Displacement“ of SAA compared to AP8





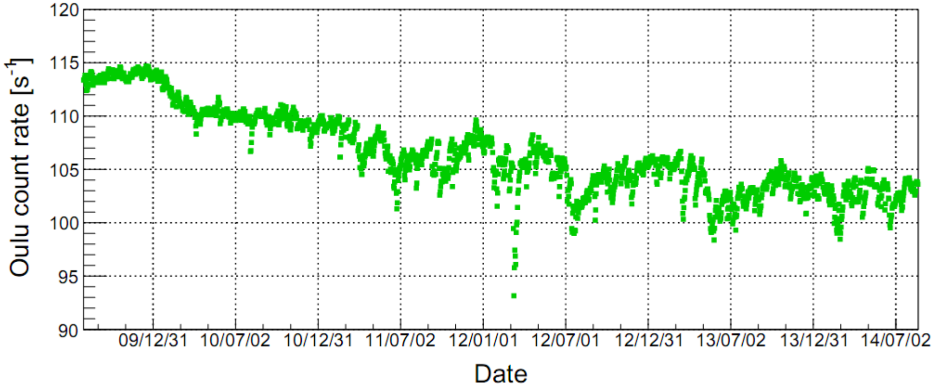
Analysis of SAA dose rates

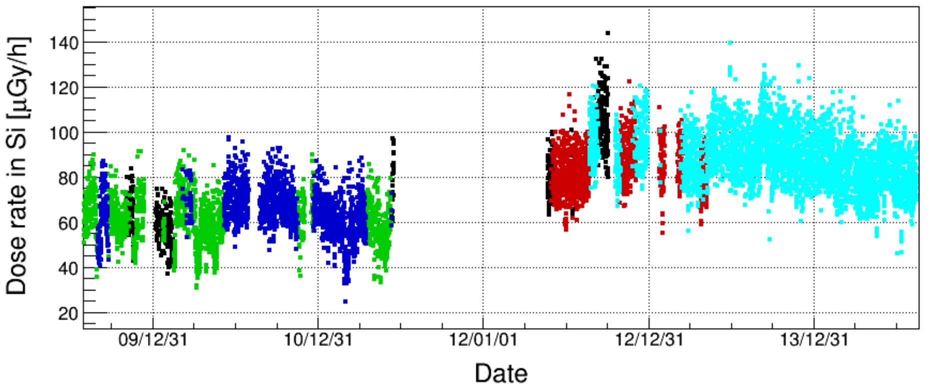




- SAA dose rate strongly altitude dendent
- Solar cycle dependency?
- Average altitude
- Seperation for altitudes:
    - 350 km – 360 km
    - 360 km – 370 km
    - 410 km – 420 km
    - 420 km – 430 km

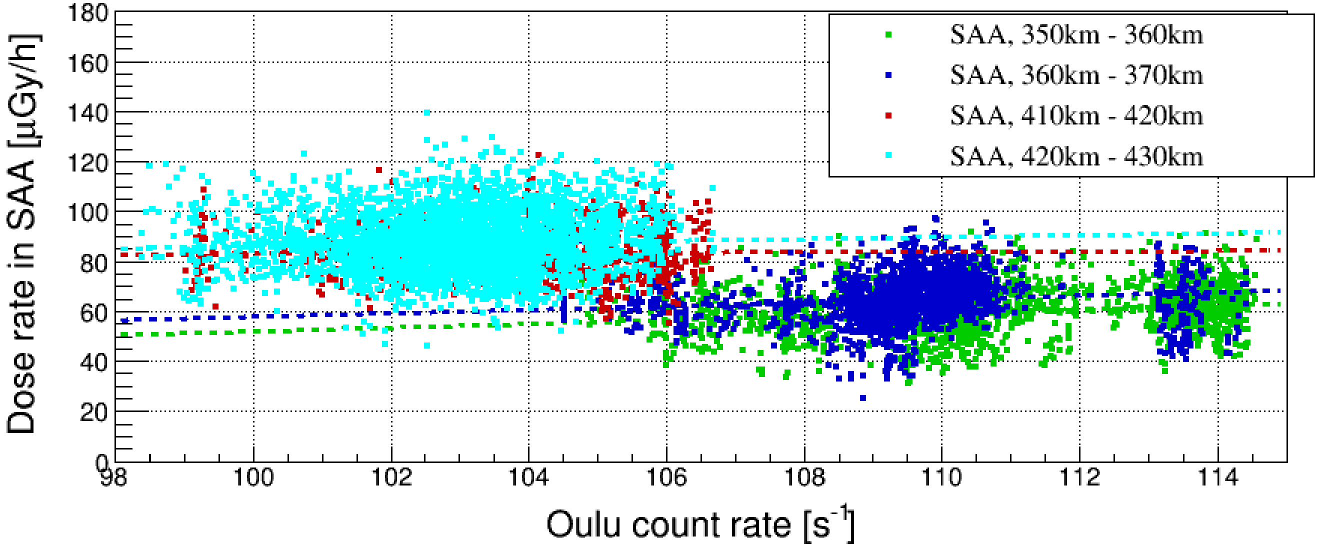
Analysis of SAA dose rates





- SAA dose rate strongly altitude dendent
- Solar cycle dependency?
- Average altitude
- Seperation for altitudes:
  - 350 km – 360 km
  - 360 km – 370 km
  - 410 km – 420 km
  - 420 km – 430 km
- Relate SAA dose rate to NM count rate in each altitude interval

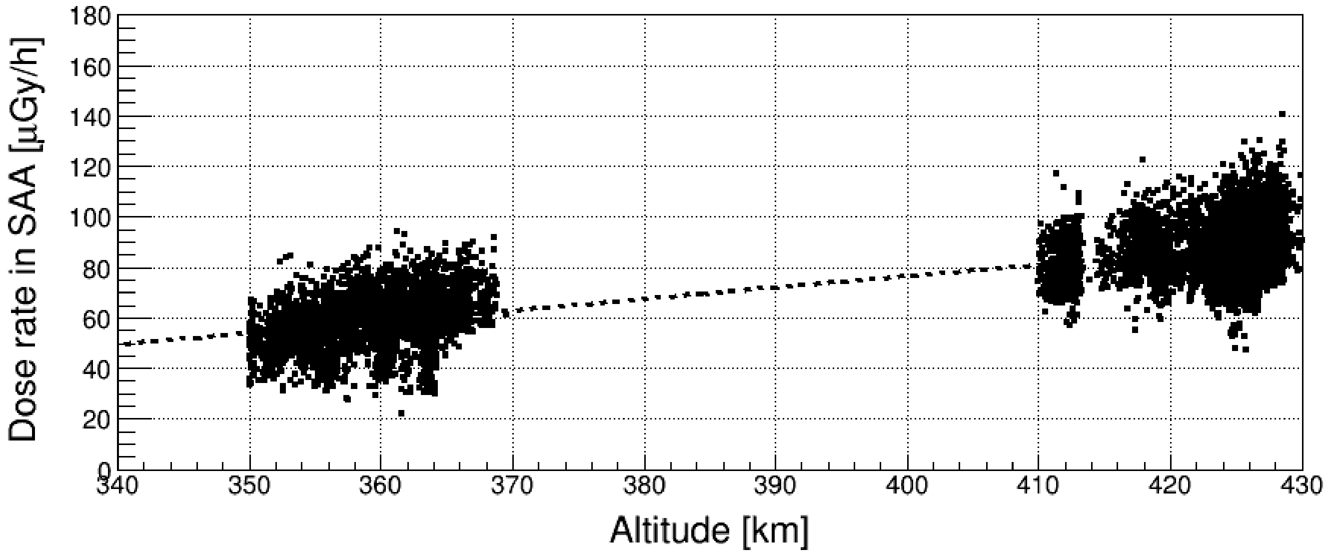
Solar cycle dependence of SAA dose rates



- Dose rate vs Oulu NM count rate (1/s):
  350km - 360km: ***d* = (0.73*count rate - 20.5) µGy/h**
  360km - 370km: ***d* = (0.74*count rate - 16.4) µGy/h**
  410km - 420km: ***d* = (0.10*count rate + 73.9) µGy/h**
  420km - 430km: ***d* = (0.39*count rate + 46.8) µGy/h**

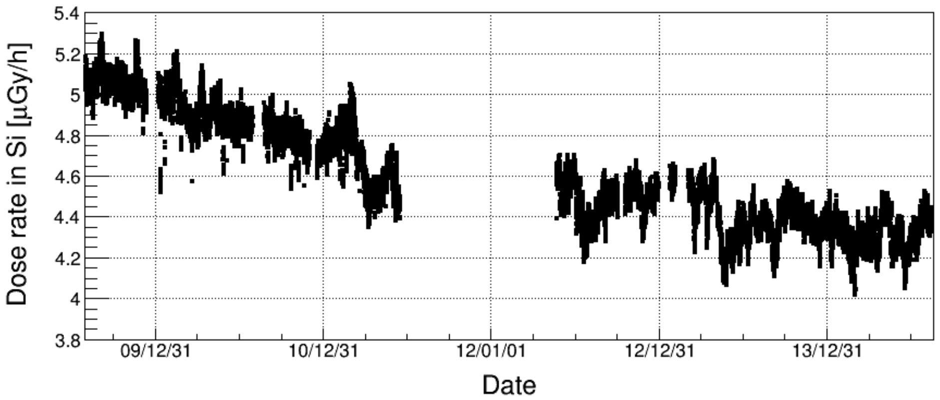
- Normalize to 105 counts/s using linear relationships: altitude dependence

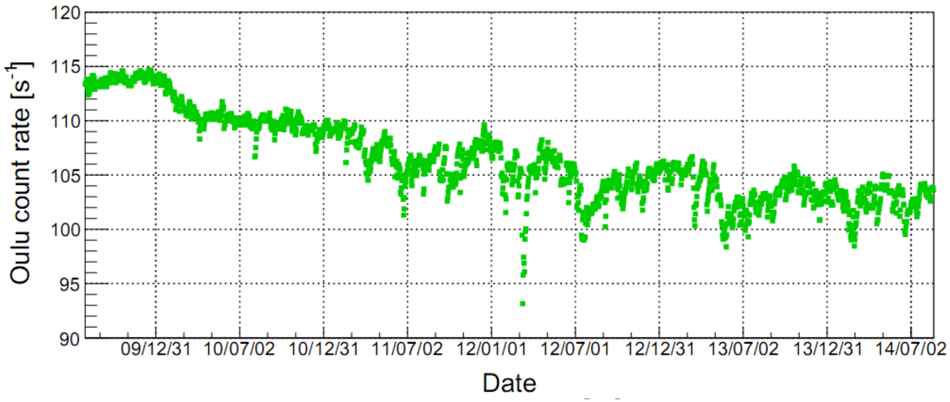
Altitude dependence of SAA dose rate



SAA dose rate vs altitude: ***d*** **= (0.45*altitude/km - 103.8) µGy/h**

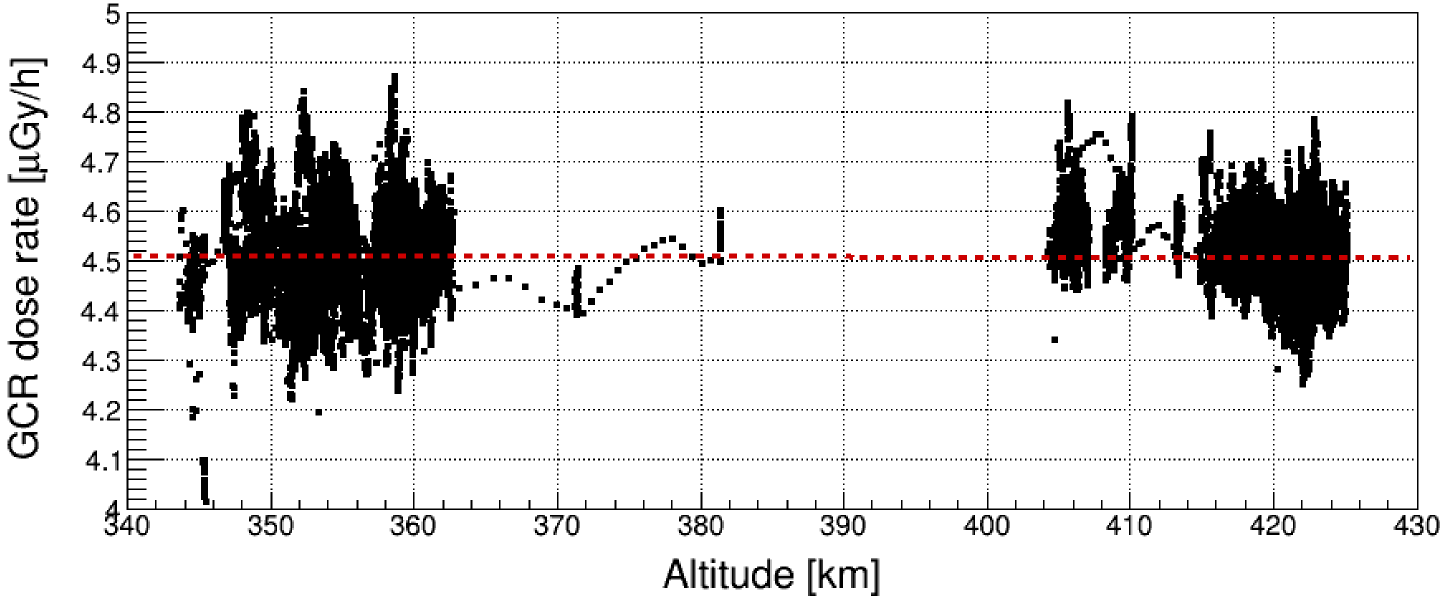
Analysis of GCR dose rates





- Obvious solar cycle dependency
- Dose rates vs. Oulu count rates:
  ***d* = (0.063*count rate - 2.15) µGy/h**
- Normalize to 105 counts/s: altitude dependence

Altitude dependence of GCR dose rate



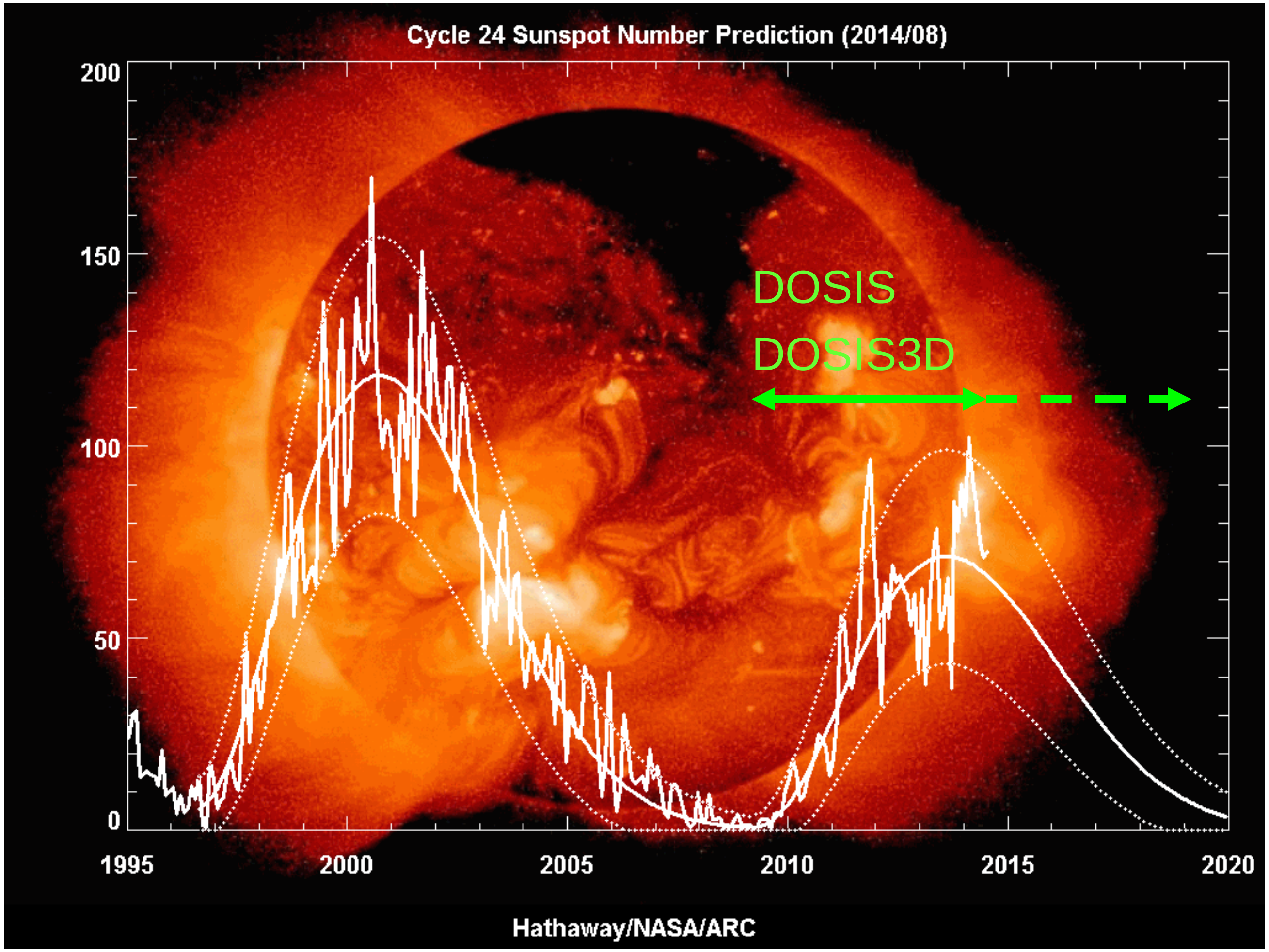
GCR dose rate vs altitude: ***d* = (-5.2*10^{-5}*altitude/km + 4.53) µGy/h**

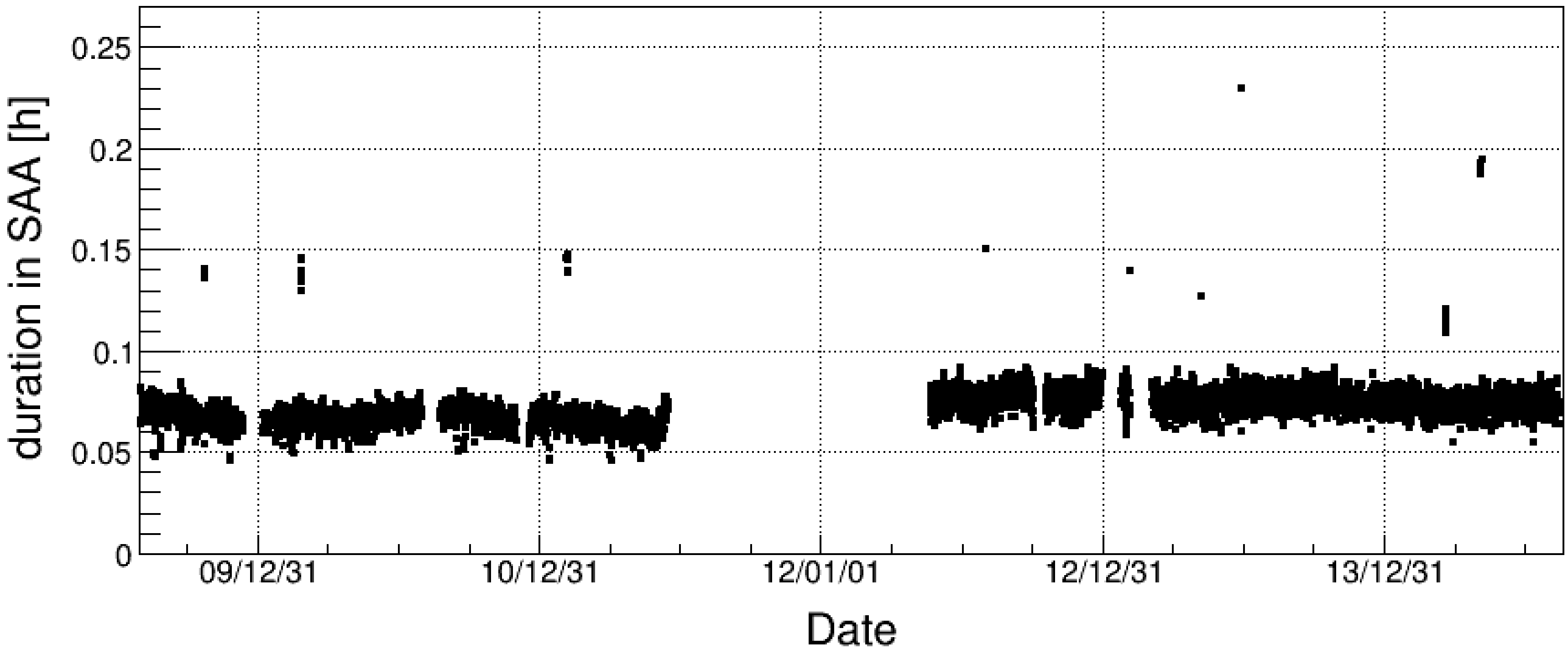
Summary

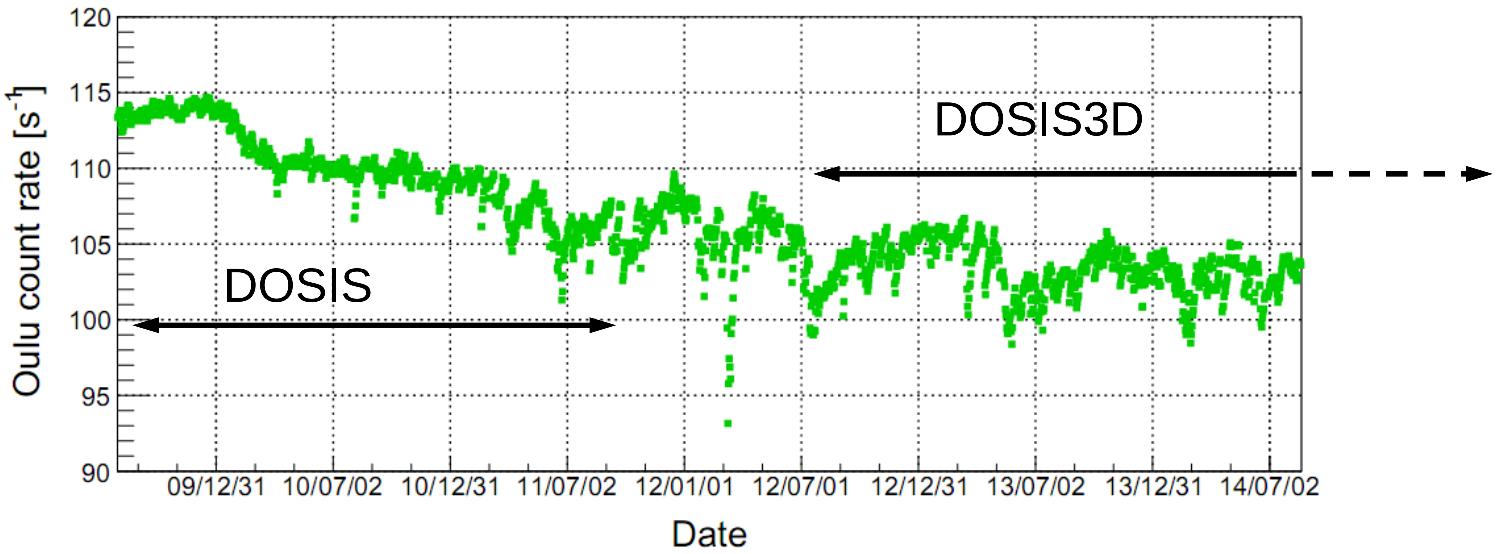
- DOSIS/DOSIS3D data covers
  - solar minimum to (weak) solar maximum
  - 350 km to 430 km altitude

- Although two separate sets in altitude and solar modulation, we can determine dose rates for
  - SAA / GCR
  - Altitude dependence:
    - Increase of SAA dose rates with altitude
    - Constant GCR dose rates
  - Solar cycle dependence
    - Decrease of both GCR and SAA dose rates for increasing solar activity

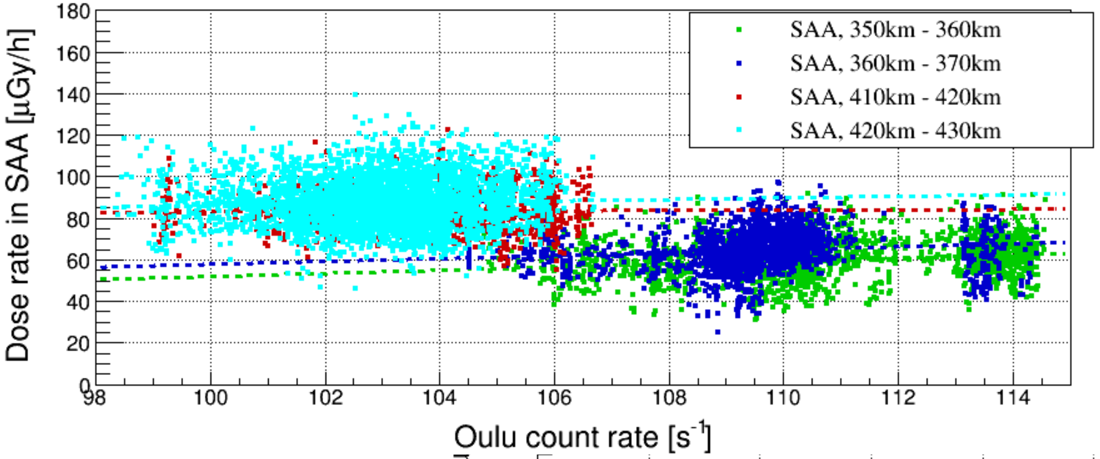
Outlook

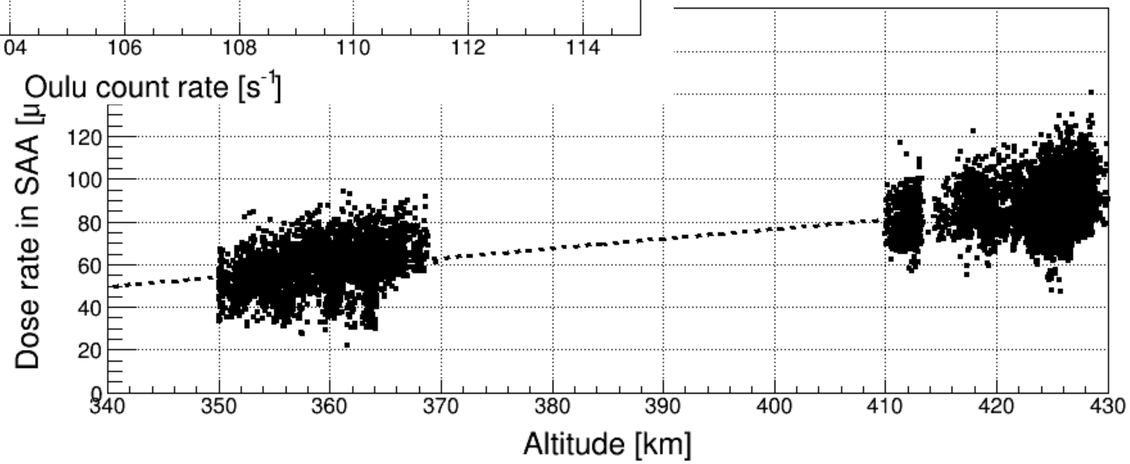

Cycle 24 Sunspot Number Prediction (2014/08)
200
150
100
50
0
1995
2000
2005
2010
2015
2020
DOSIS
DOSIS3D
Hathaway/NASA/ARC


duration in SAA [h]
0.25
0.2
0.15
0.1
0.05
0
09/12/31
10/12/31
12/01/01
12/12/31
13/12/31
Date



Oulu count rate [s^{-1}]
120
115
110
105
100
95
90
DOSIS3D
DOSIS
09/12/31
10/07/02
10/12/31
11/07/02
12/01/01
12/07/01
12/12/31
13/07/02
13/12/31
14/07/02
Date





- SAADoseRateVsOulu for 350km - 360km: 0.726879*x + -20.5215
- SAADoseRateVsOulu for 360km - 370km: 0.739017*x + -16.4283
- SAADoseRateVsOulu for 410km - 420km: 0.0995159*x + 72.984
- SAADoseRateVsOulu for 420km - 430km: 0.391782*x + 46.7922

- SAADoseRateVsAltitude for 350km - 430km: 0.451042*x + -103.845