THE RELATIONSHIP BETWEEN 13-YEAR LATITUDE SURVEY DATA (NUNTIYAKUL ET AL. 2014) VS. MAWSON NEUTRON MONITOR DATA

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OUTLINE

- Introduction
  - Cosmic rays
  - Solar modulation
  - Cosmic ray spectra
  - Crossover Problem
- Observation
  - Latitude survey
  - McMurdo station
  - Mawson station
- Data reduction
- Result and disscusion

WHAT ARE COSMIC RAYS ?

- High Energy particles or γ-rays from space
- sources of cosmic rays :
  - from solar winds, solar storms → solar energetic particles
  - from supernova explosions inside the Galaxy → galactic cosmic rays
  - from gamma-ray bursts (GRBs), AGN outside the Galaxy → extra galactic cosmic rays

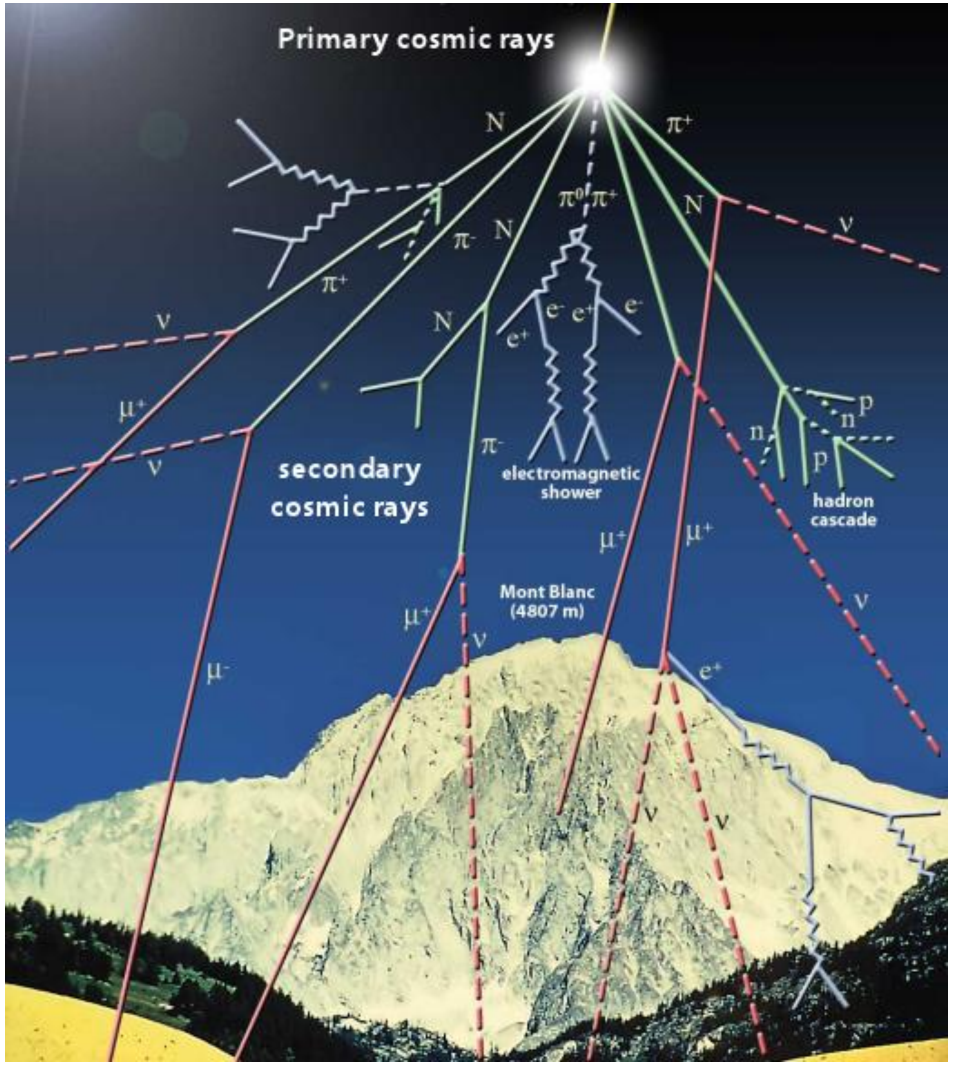
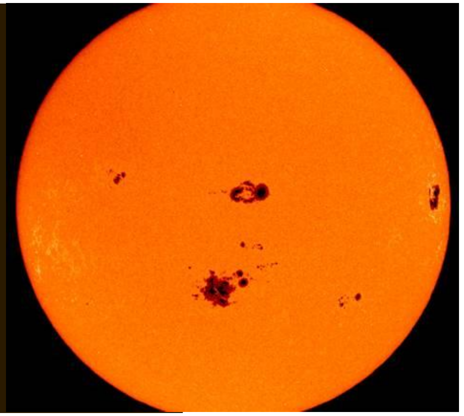


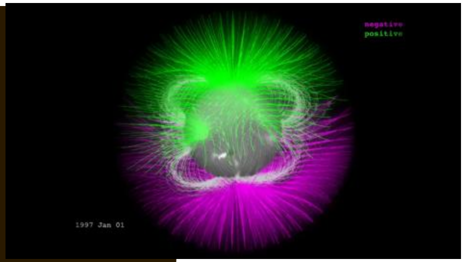
Fig 1. Schematic diagram of a cosmic ray air shower. (Credit: CERN)

SOLAR MODULATION



Credit: NASA

Credit: NASA/GSFC/PFSS



http://neutronm.bartol.udel.edu/modplot.html

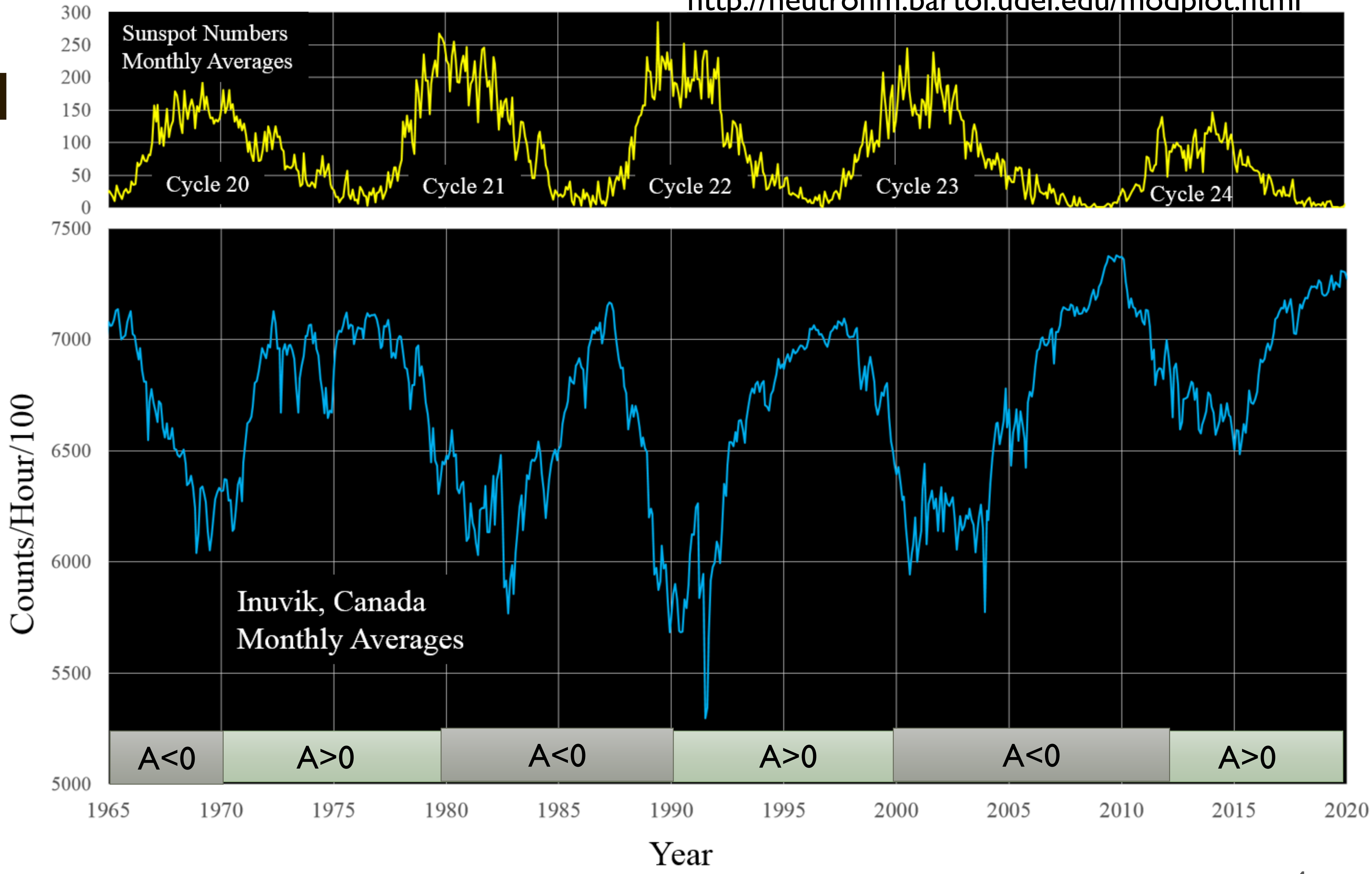


Fig 3. Solar modulation

COSMIC RAY SPECTRA

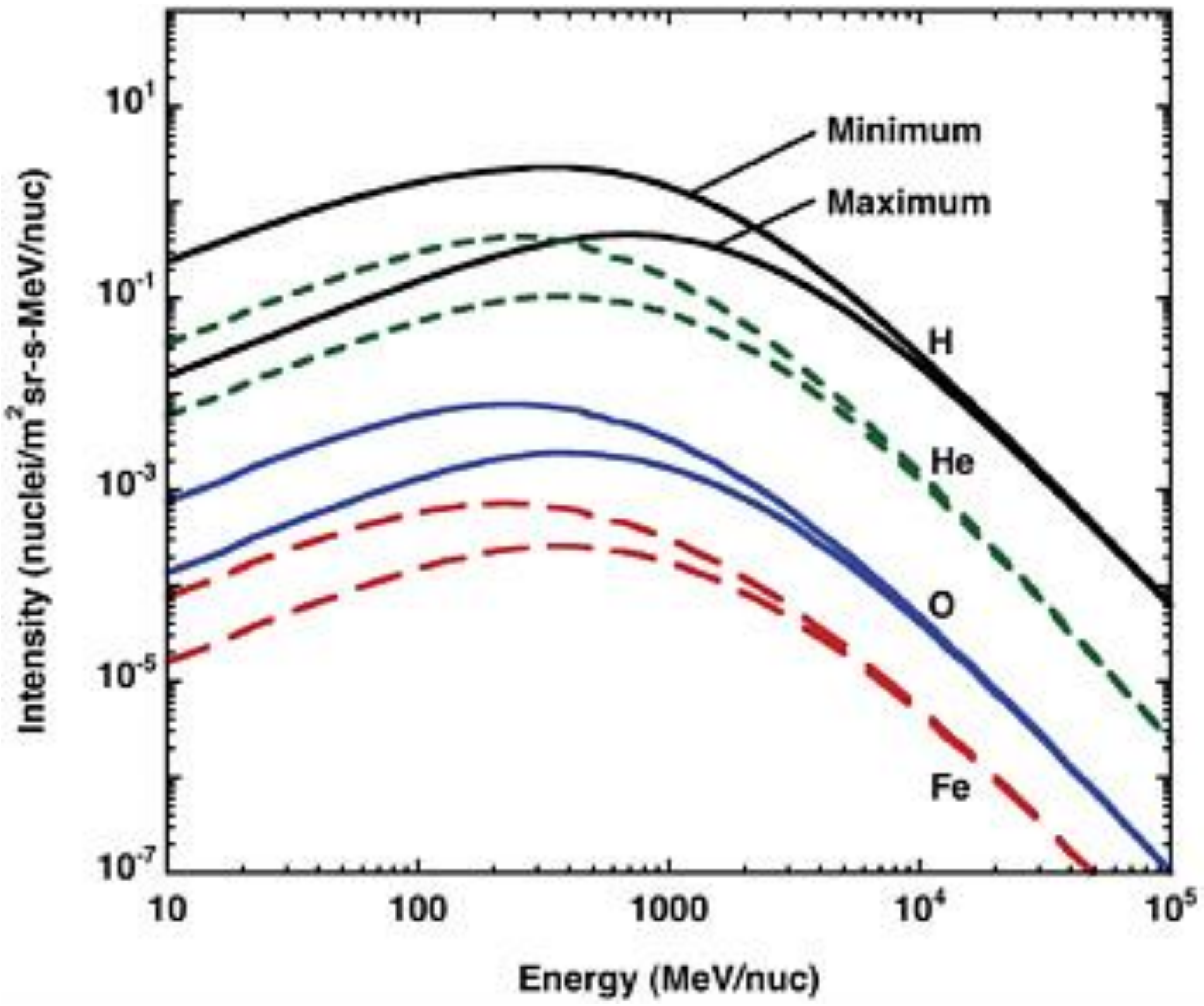


Fig 4. cosmic ray spectra of ion during solar minimum and solar maximum conditions. (Courtesy of R.A. Mewaldt, California Institute of Technology)

CROSSOVER

(Moraal et al.,1989)

(Nuntiyakul et al., 2014)

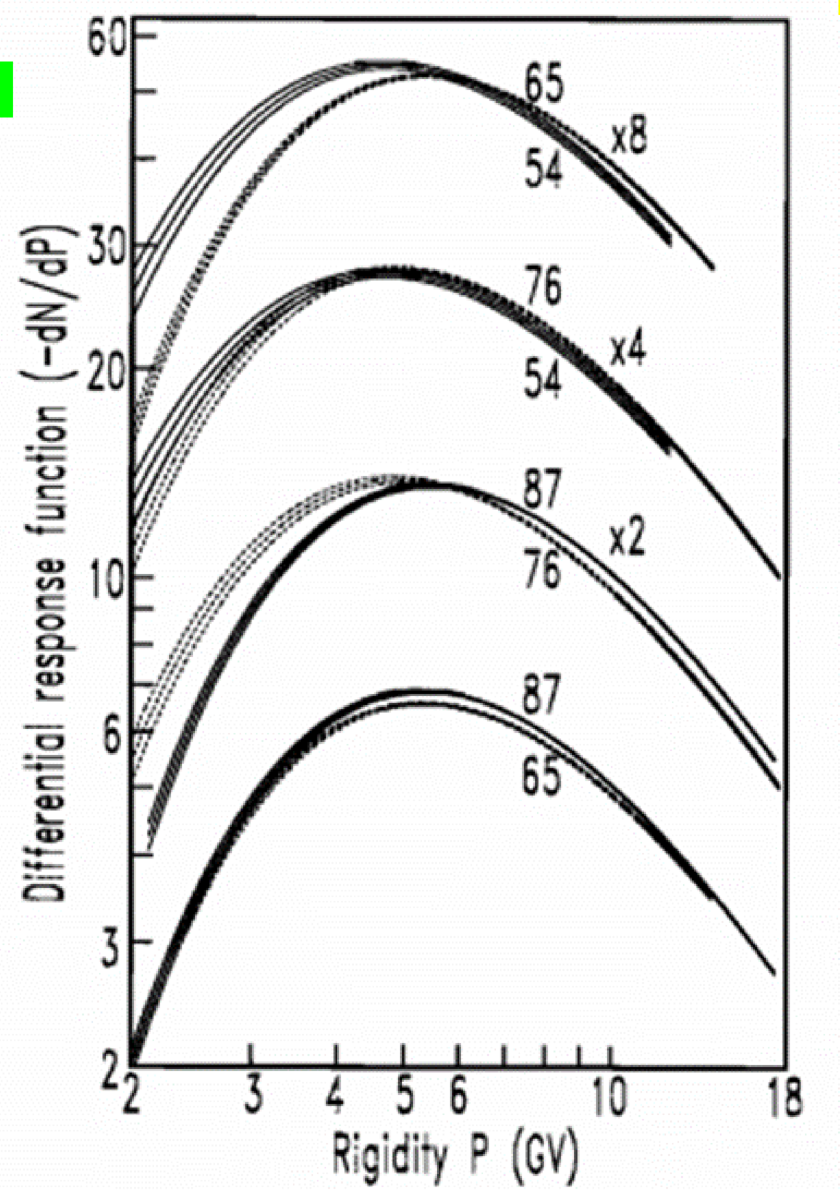


Fig 6. Differential response functions (Moraal et al.,1989)

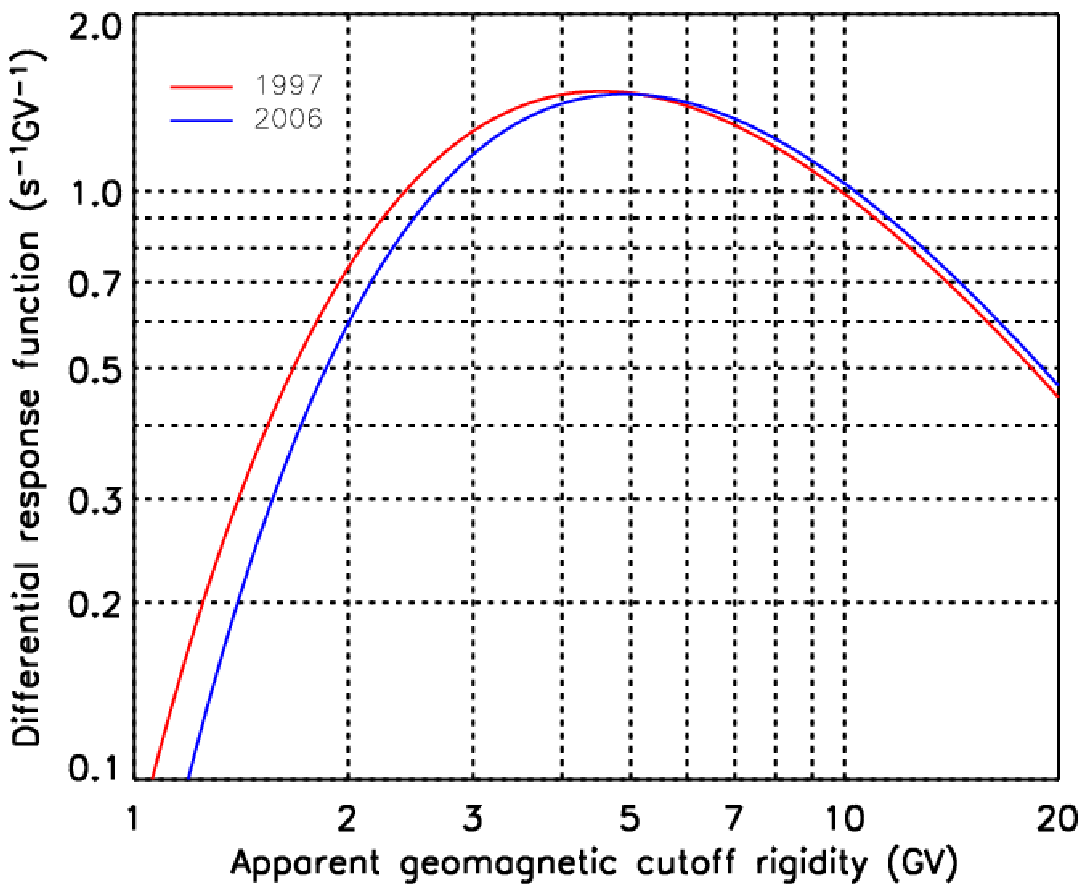
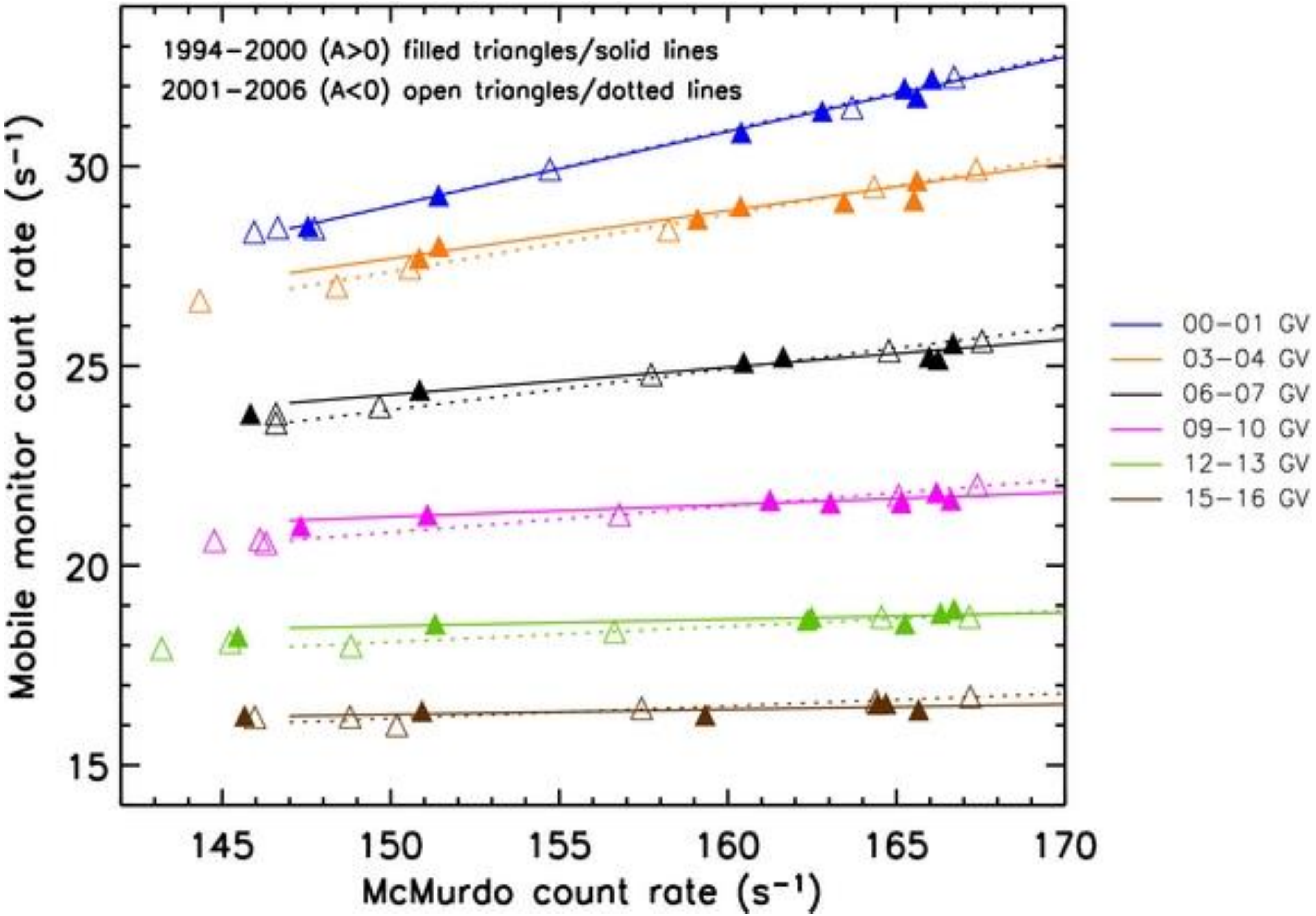


Fig 5. Differential response functions for two survey years, near solar minimum, of opposite polarity and similar modulation level. A crossover is apparent at 4.9 GV. (Nuntiyakul et al., 2014)

CROSSOVER

Fig 6.

Alternative presentation of the averaged data using selected rigidity bins and superimposing the data for different solar magnetic polarities. A filled triangle is used to indicate positive (A > 0) solar magnetic polarity with solid lines showing the linear fits. Open triangles indicate data for negative (A < 0) solar magnetic polarity while the dotted lines are linear fits to these data. There are clear differences in cosmic ray modulation before and after the solar magnetic polarity reversal. (Nuntiyakul et al., 2014)



LATITUDE SURVEY

Fig 8. 3NM64 installed inside the container for latitude survey (Nuntiyakul et al., 2014)

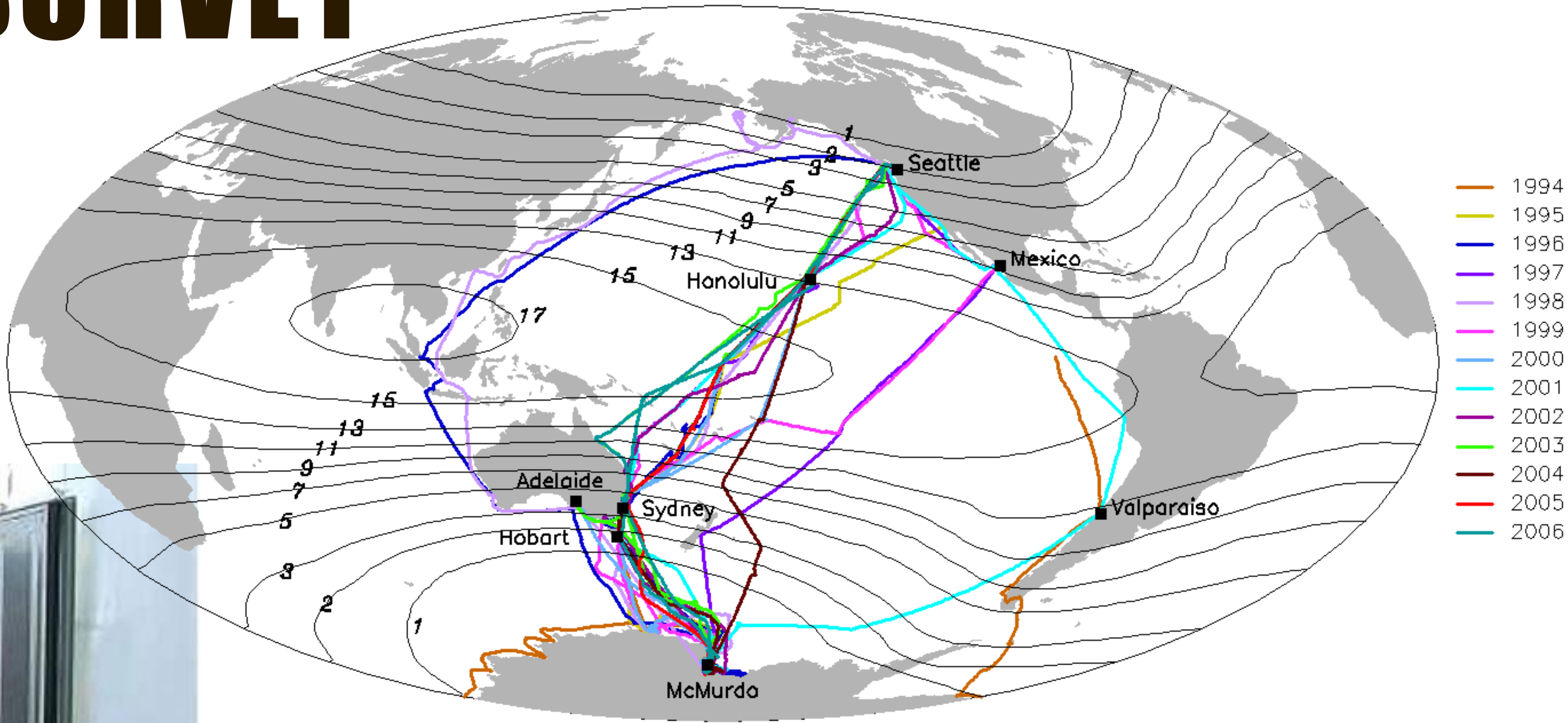
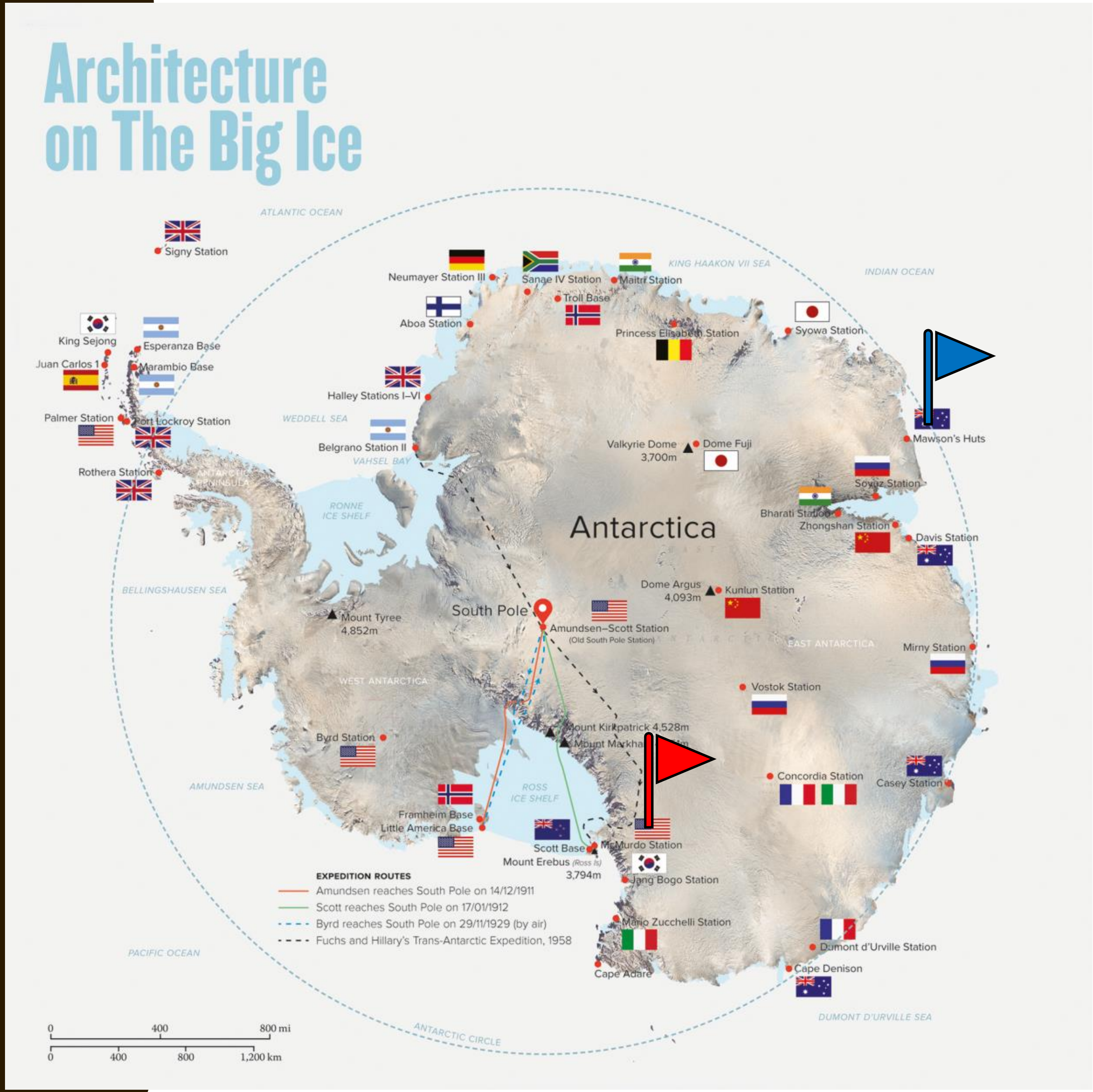


Fig 7 . The track of the ship-borne neutron monitor latitude surveys for 1994-2007, superimposed on contours of the vertical cutoff rigidity. (Nuntiyakul et al., 2014)



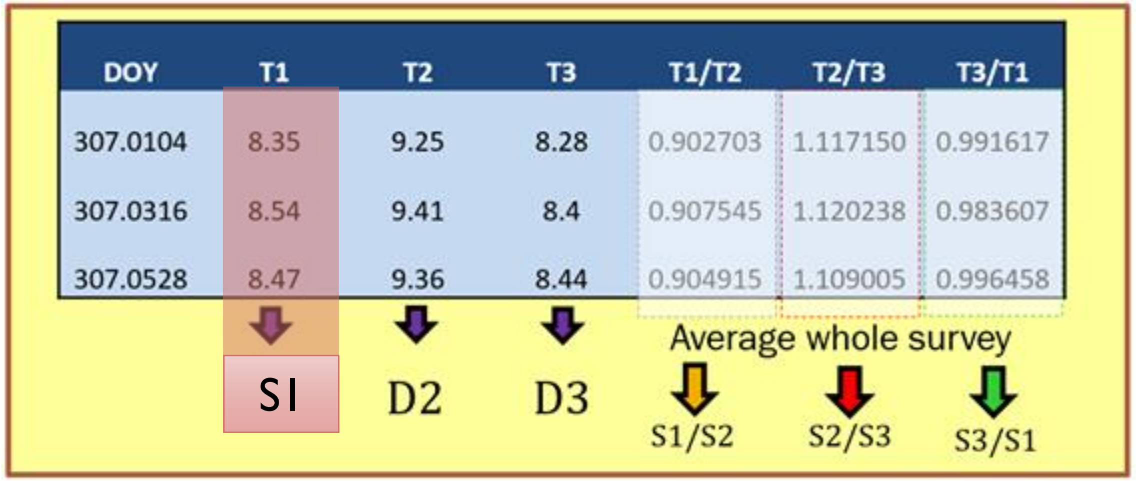
Mawson Station

- Detector Type : Feb 1986 - Oct 2002 - 6NM64
  Oct 2002 - 18NM64.
- Latitude : 67.60S
- Longitude : 62.88E
- Altitude : 0 m
- Rigidity (1965) : 0.22 GV

McMurdo Station

- Detector Type: 18-tube NM64
- Latitude: 77.9S
- Longitude: 166.6E
- Altitude: 48 m
- Rigidity : 0.01 GV

DATA REDUCTION



DOY	T1	T2	T3	T1/T2	T2/T3	T3/T1
307.0104	8.35	9.25	8.28	0.902703	1.117150	0.991617
307.0316	8.54	9.41	8.4	0.907545	1.120238	0.983607
307.0528	8.47	9.36	8.44	0.904915	1.109005	0.996458

1 : Tube ratio cleaning

- If one tube was removed

  -> tube 1, corrected count = $\left(\frac{s_1+s_2+s_3}{s_2+s_3}\right)(D_2 + D_3)$

- If two tubes were removed

  -> remaining actual count rate x average ratio of whole survey

  -> Only Tube 1 remaining, corrected count Tube 2 = $\left(\frac{D_1}{s_1/s_2}\right)$

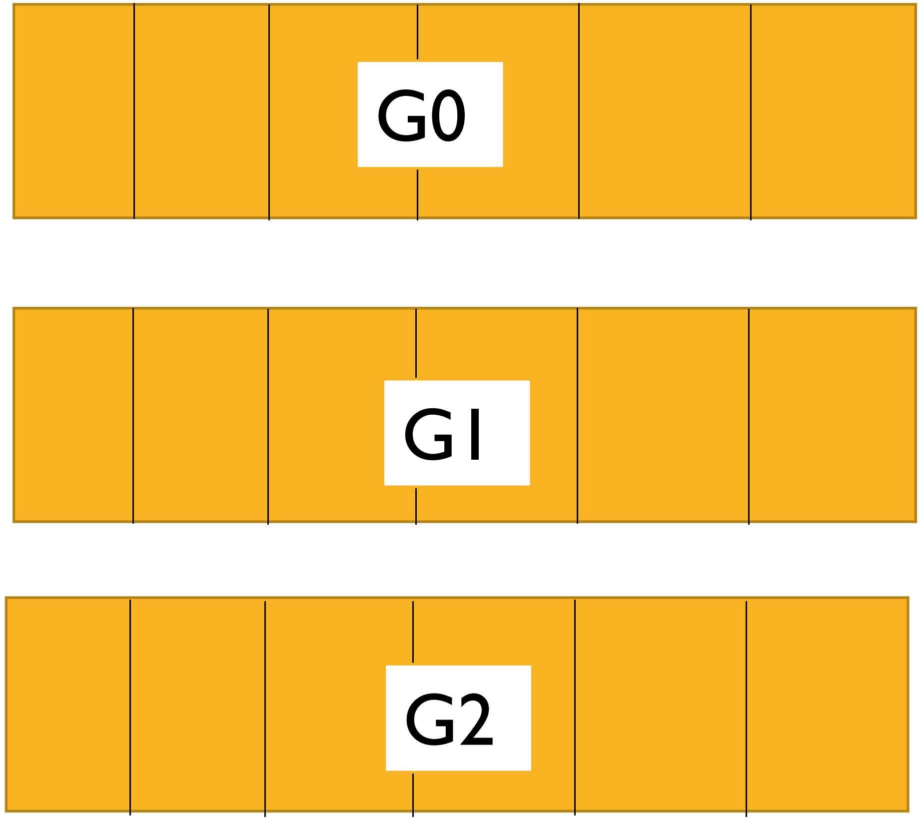
  , corrected count Tube 3 = $\left(\frac{D_1}{s_1/s_3}\right)$

- If three tubes were removed -> DATA GAP

Applied for Mobile NM And Mawson NM data since Oct 2002 to Dec 2002

NM DATA OUTPUT FROM MAWSON

- Provide hourly count rate data
- Change from 6NM64 to 18NM64 from 2002 day 290



II : Pressure correction

Barometric pressure was corrected using Equation as follow;

Pressure coefficient [% per mmHg]

$$\beta = 1.006 - 0.0153 P_c$$

Apparent cutoff rigidity [GV]

Pressure [mmHg]

Count rate corrected for tube and pressure

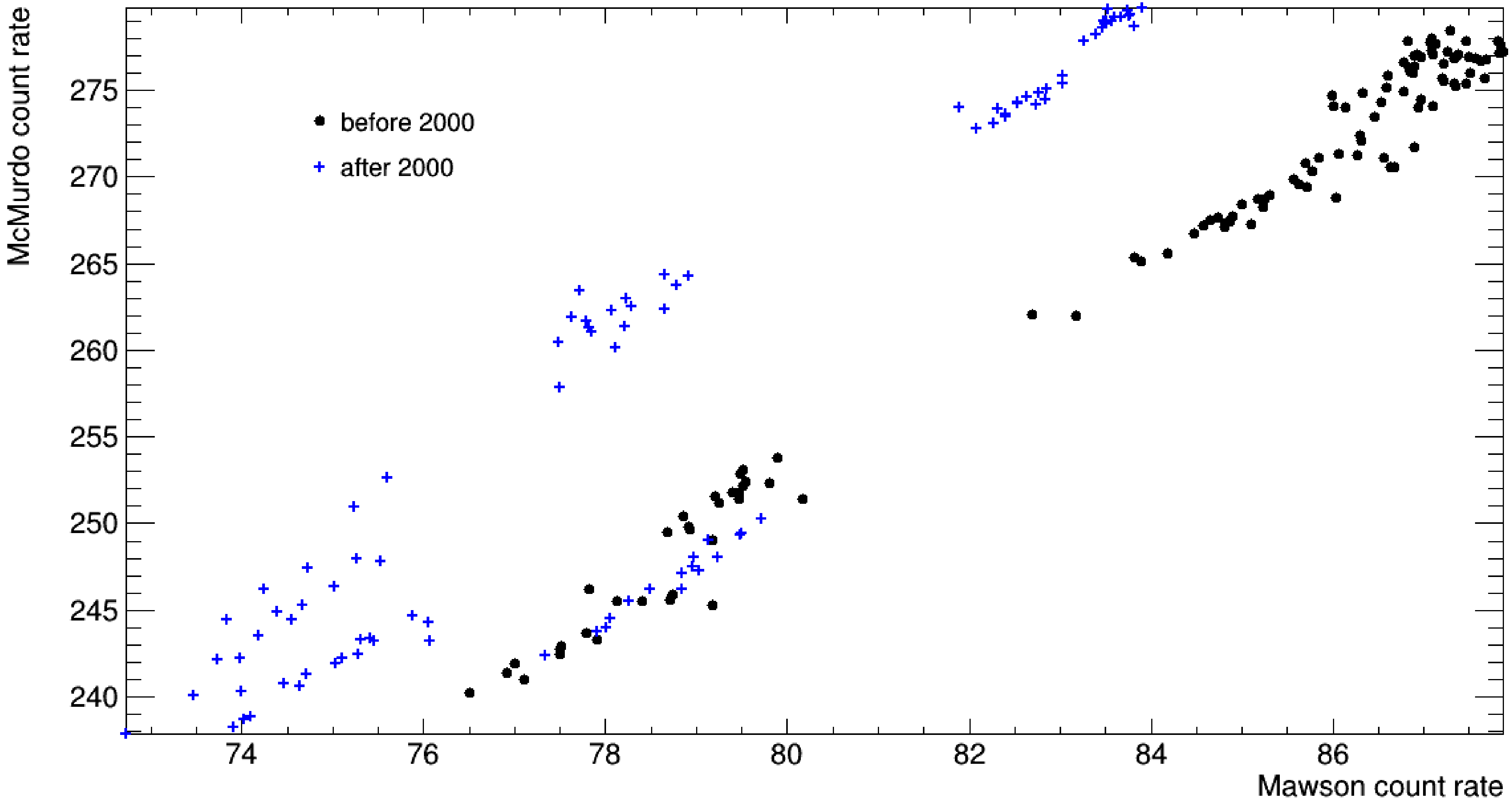
$$C_{TP} = C_T e^{\beta (P - P_{ref})}$$

Standard atmospheric pressure [mmHg] (760 mmHg for McMurdo and Mobile survey)

Count rate corrected for tube

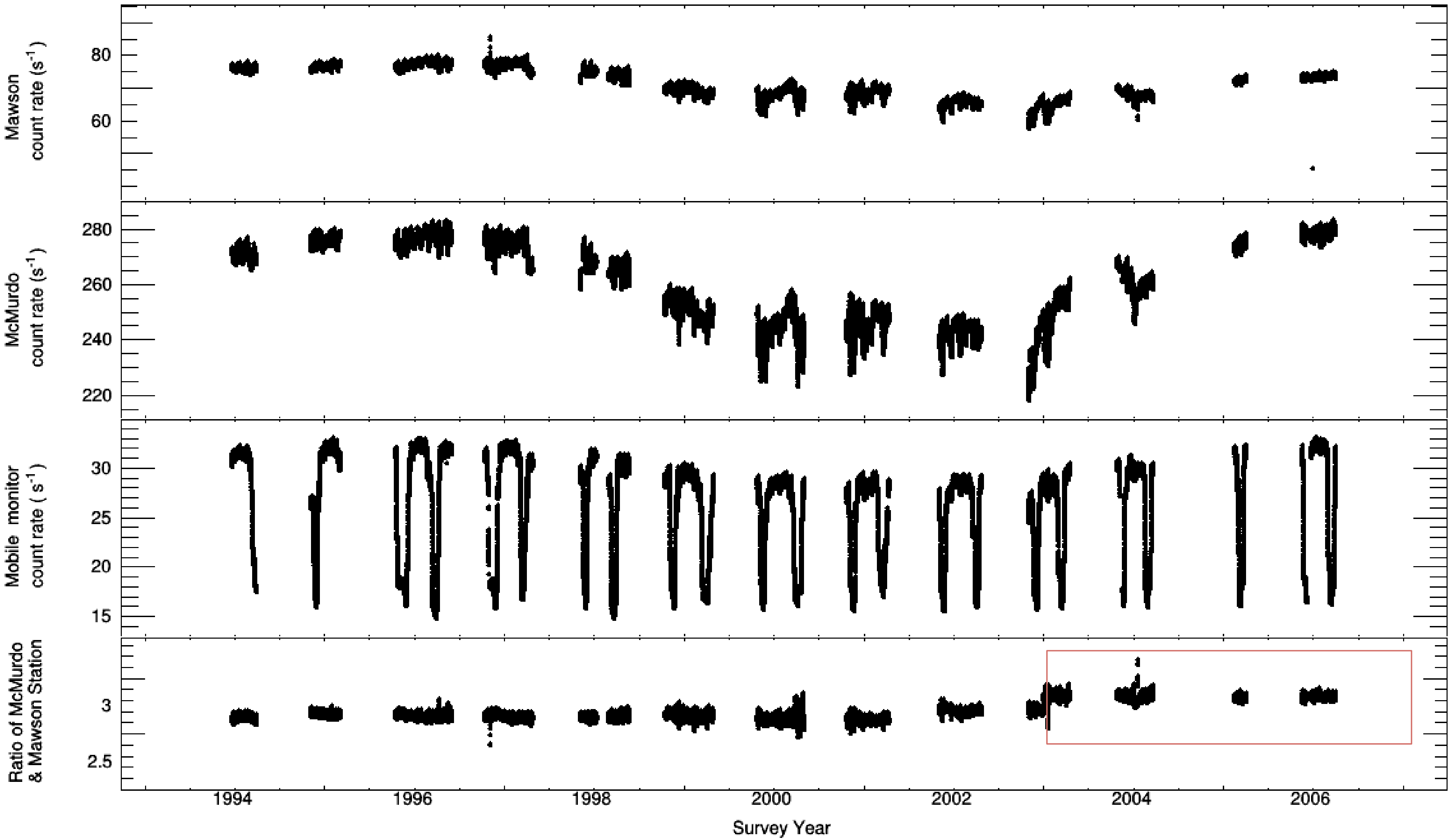
Mawson station
Standard atmospheric pressure: 990.0 mb
Barometric coefficient (2004): -0.708%/mb
* 1 mbar = 0.750062 mmHg

Applied for All data set



The relationship between McMurdo and Mawson NM pressure corrected count rate

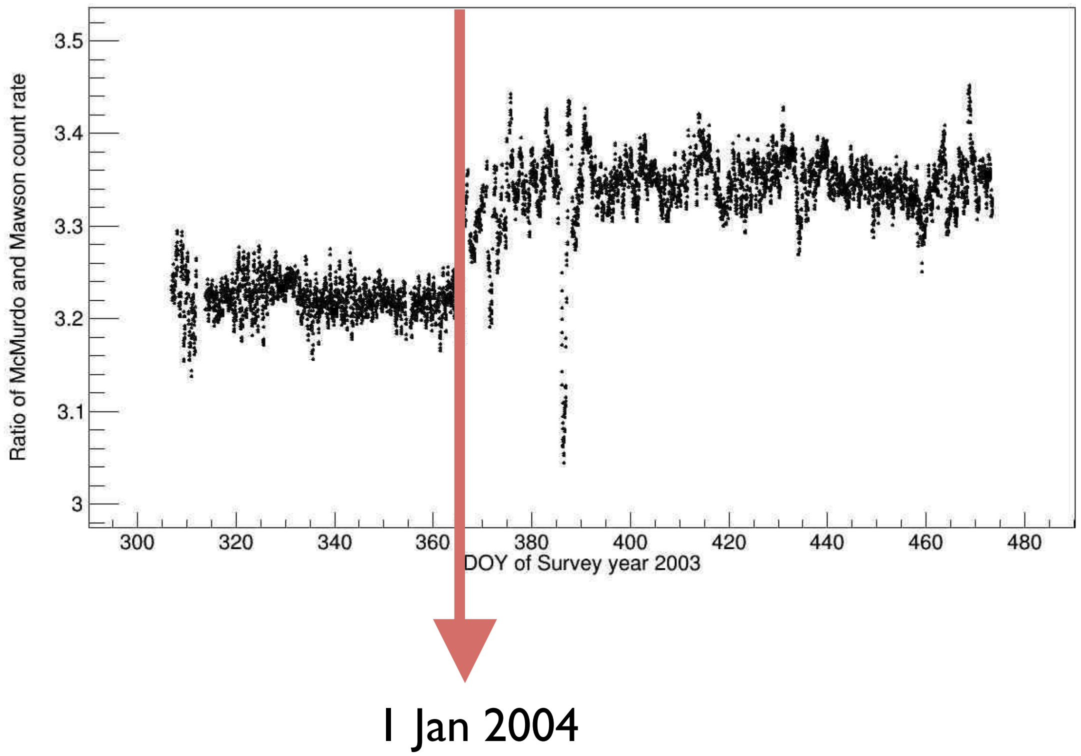
Before ratio corrected

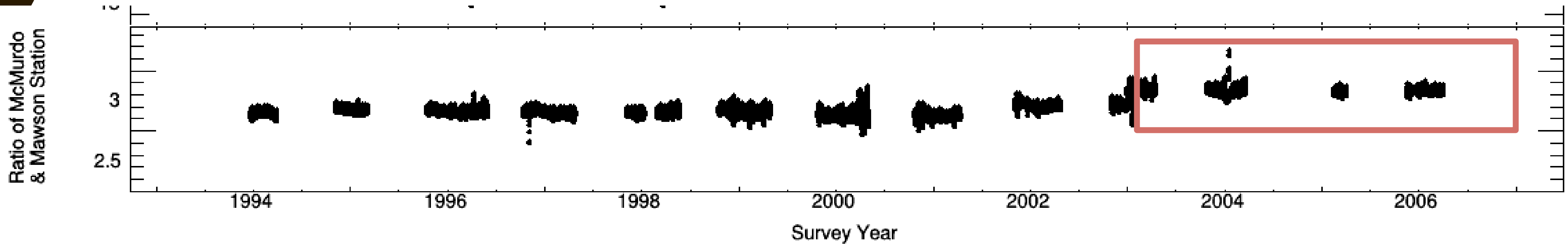


III : Ratio corrected

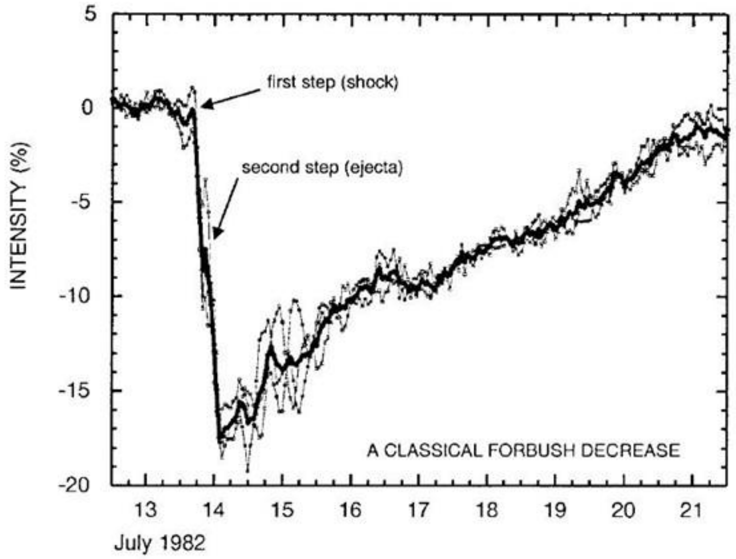
- **Renormalize factor**

Year	Factor
1994 - 2003	1
2004 - 2007	1.0533





V - I : Forbush decreases removing



- The criterion for rejection was a maximum percentage decrease (%D) > 10 in the McMurdo neutron monitor, which occurred three times during our mobile monitor surveys.

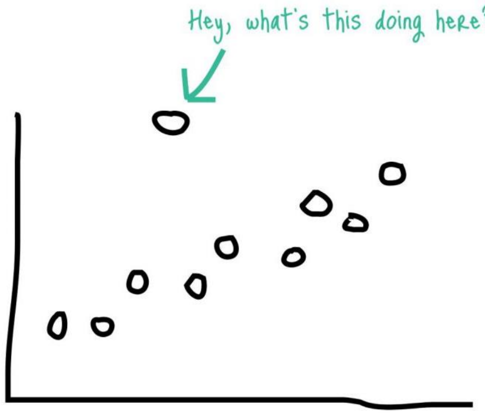
- The intervals that were excluded from our analysis due to the three FDs were:

1) from 2004 November 7 to 2004 November 18 (%D = 11.6),
2) from 2004 January 17 to 2004 January 26 (%D = 14.3),
3) from 2006 December 6 to 2006 December 25 (%D = 10.8).

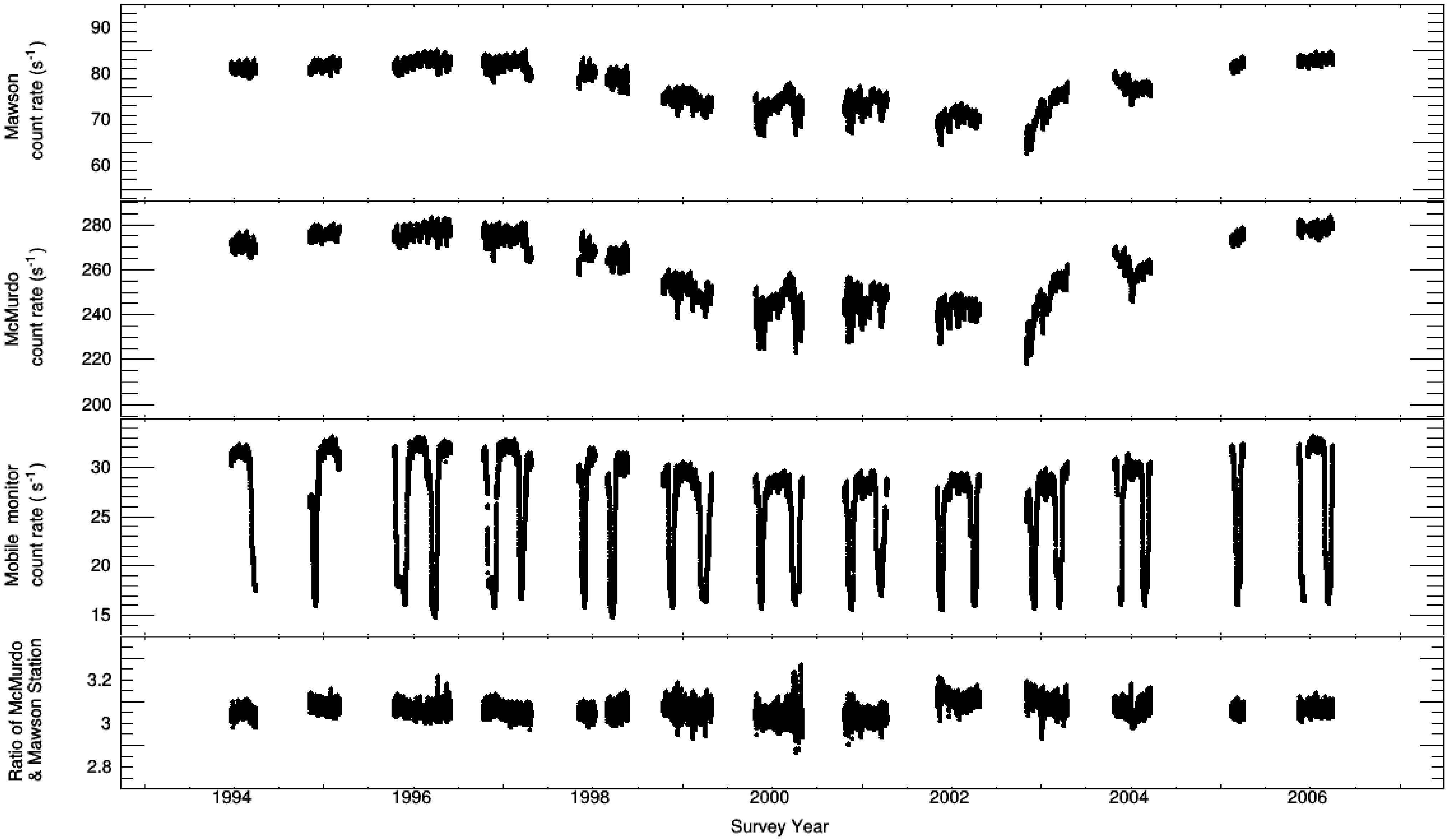
Applied for All data set

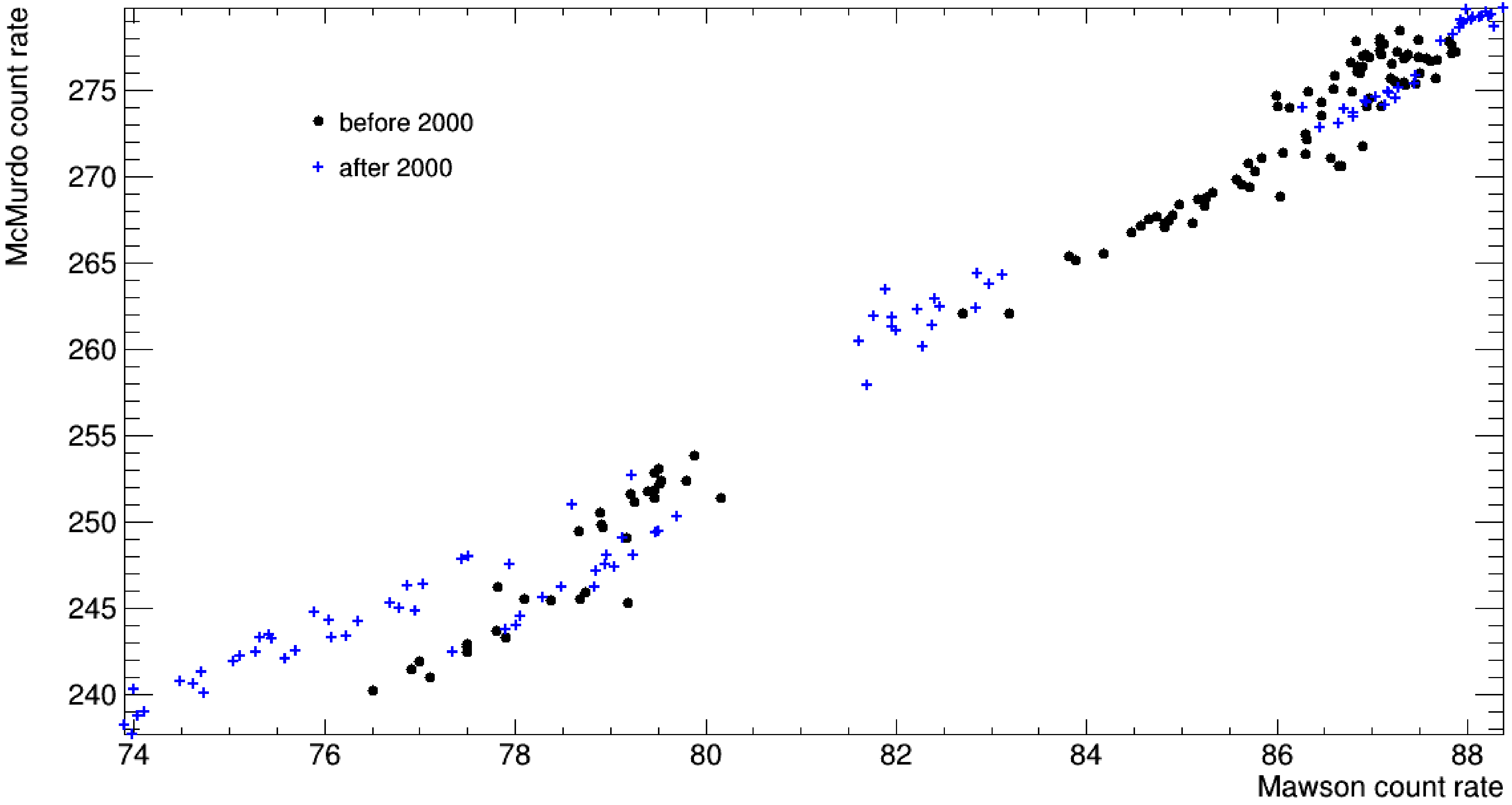
V - II :Electronic setup removing

- Outliner data points were removed

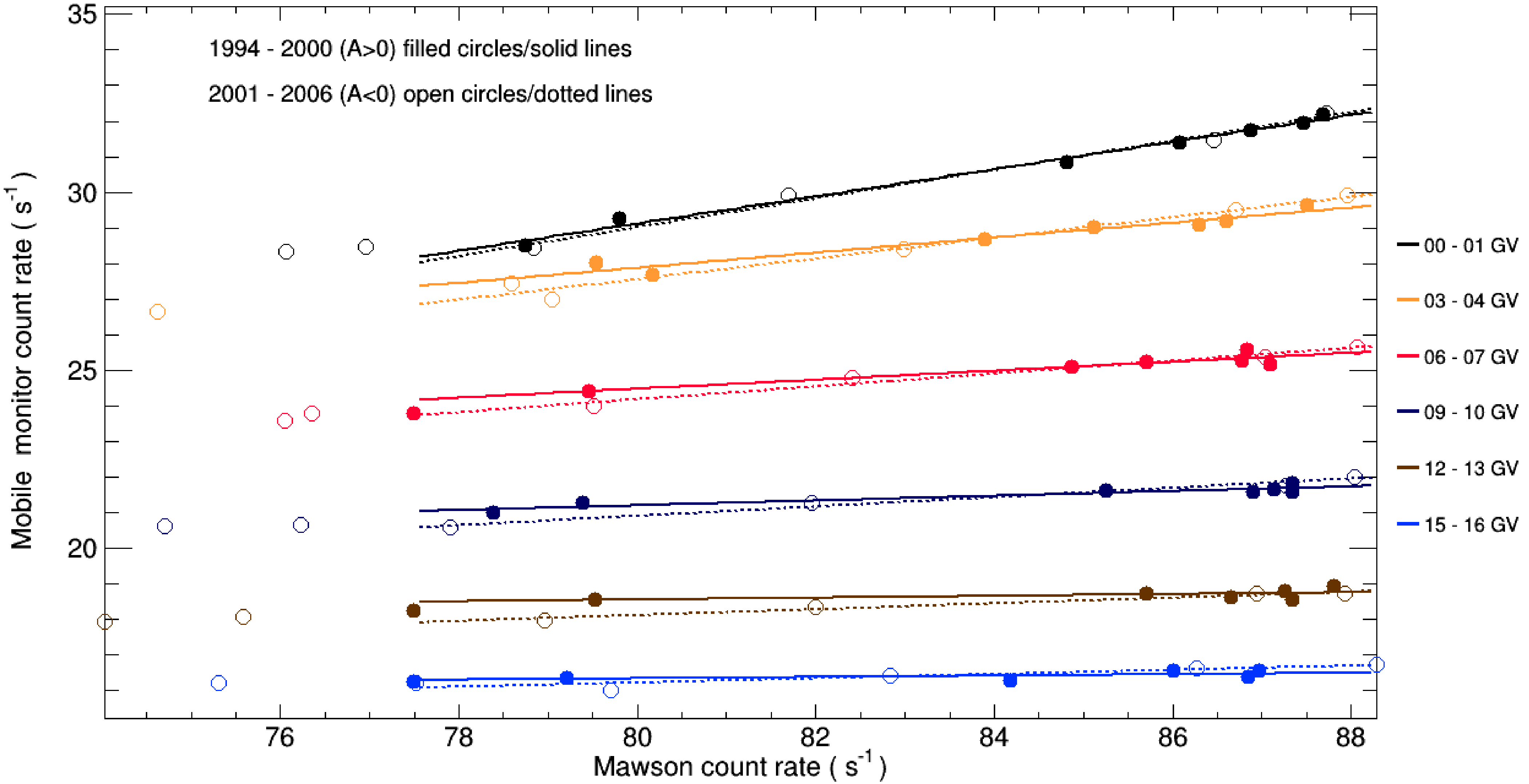


After applied ratio corrected, removed FD and outlier





The relationship between McMurdo and Mawson NM pressure and ratio corrected count rate



The relationship between Mobile monitor and Mawson count rate in 1994 – 2006 survey year

WHAT'S NEXT

Analysis Survey year 2018 – 2020 using Mobile monitor data from ChangVan Project

Combine with 13 Survey year data

Result????


THANK YOU

REFERENCES

Nuntiyakul, W., Evenson, P., Ruffolo, D., Sáiz, A., Bieber, J. W., Clem, J., … Humble, J. E. (2014). LATITUDE SURVEY INVESTIGATION OF GALACTIC COSMIC RAY SOLAR MODULATION DURING 1994-2007. *The Astrophysical Journal*, *795*(1), 11. https://doi.org/10.1088/0004-637x/795/1/11

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CUTOFF-RIGIDITY

- $R_c = [M \cos \lambda^4]/\{r^2 \,[\,1 + (1 - \sin \epsilon \sin \xi \cos \lambda^3\,)^{1/2}]^2\}$

Where

- R_c is the geomagnetic cutoff rigidity (in MV)
- λ is the latitude
- M is the magnitude of the dipole moment (in G cm^3)
- r is the distance from the dipole center in centimeters(in cm)

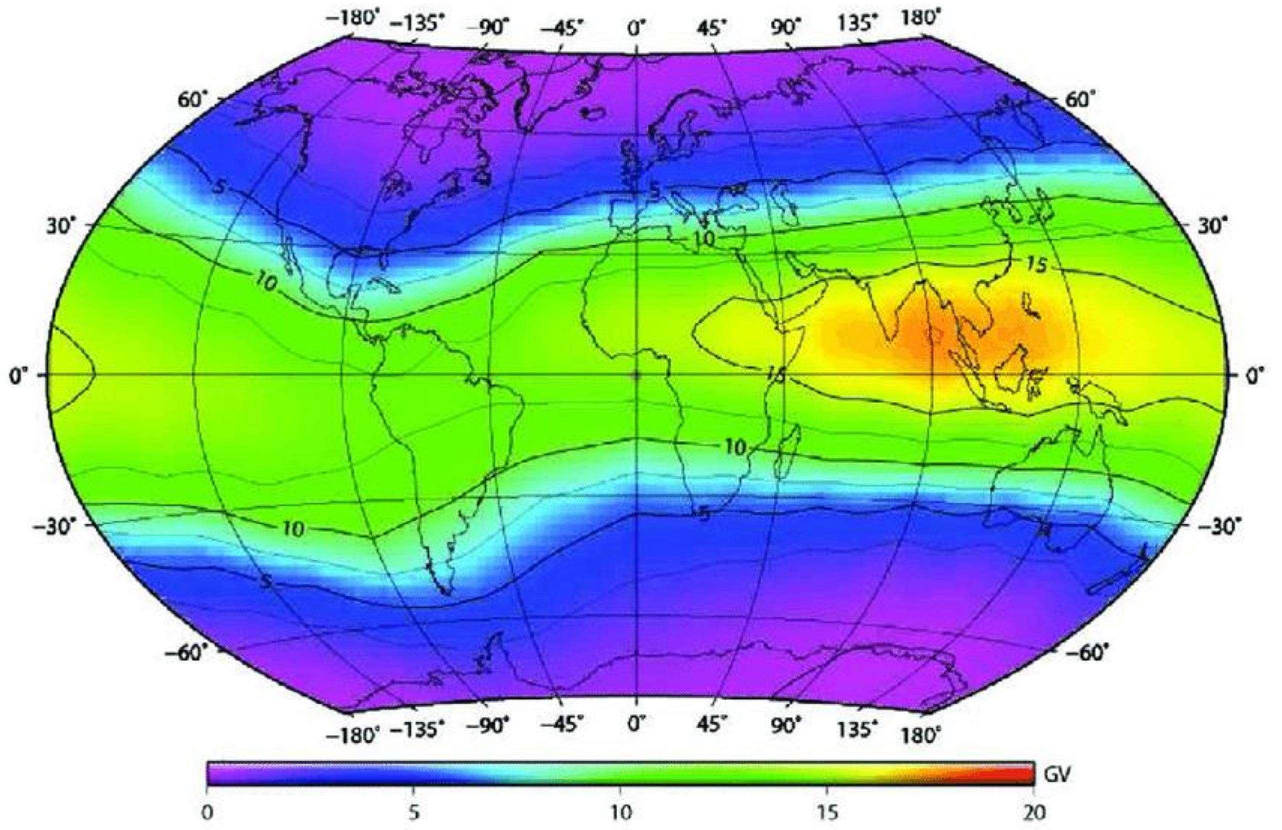


Fig 11. The effective vertical geomagnetic cutoff-rigidity (Nevalainen, Usoskin & Mishev, 2013)

DIFFERENTIAL RESPOND FUNCTION

$$N(P_c) = N_0\left(1 - e^{-\alpha P_c^{-\kappa}}\right),$$

$$N(P_c) = \int_{P_c}^{\infty} DRF(P)dP,$$

$$DRF(P) = N_0 \alpha P^{-\kappa-1} \kappa e^{-\alpha P^{-\kappa}}.$$

$$DRF(P) = -\left[\frac{dN}{dP_c}\right]_p = \sum G(P)M(P,t)Y(P,h)$$

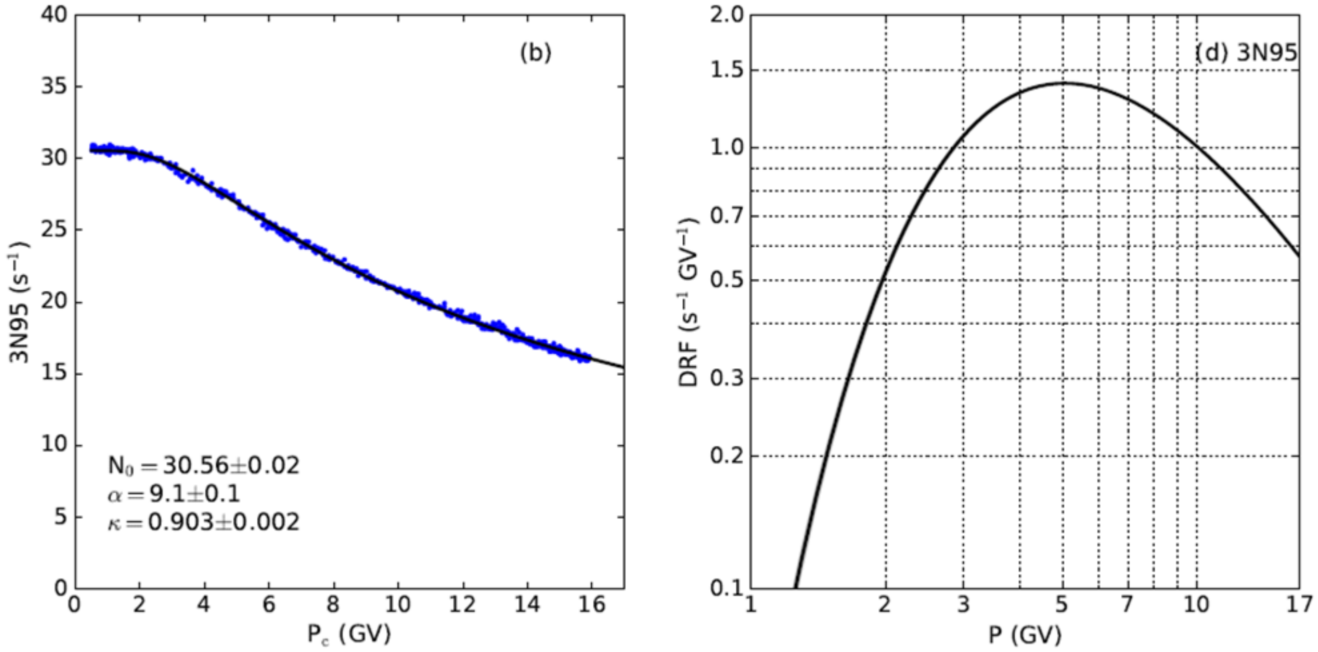
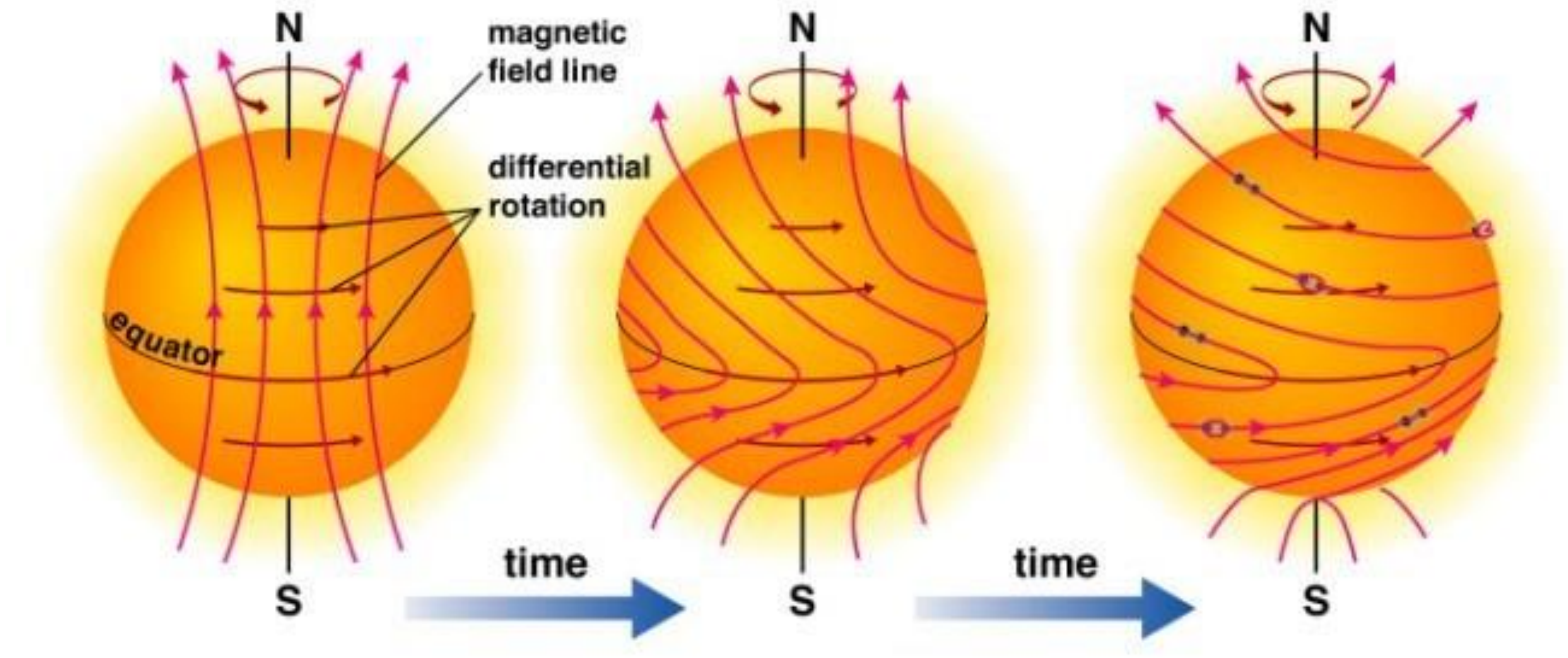
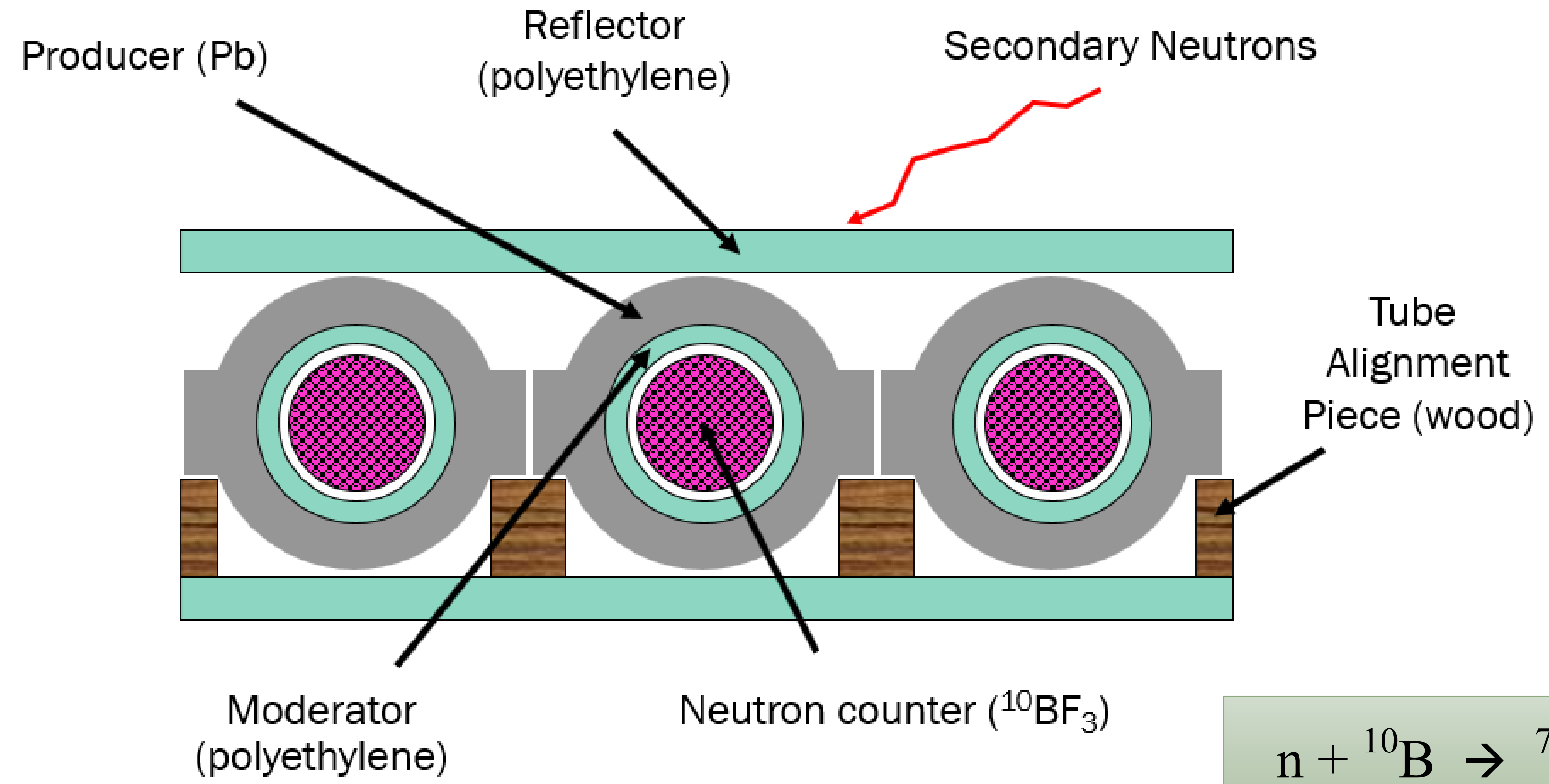


Fig 12 Dorman function fits to neutron monitor data (b) and show the resulting differential response functions (DRFs) (d) (Nuntiyakul et al., 2018)

WHAT CAUSES THE SUN'S MAGNETIC FIELD FLIP?



STANDARD NEUTRON MONITOR (NM64)



$$n + {}^{10}B \rightarrow {}^{7}Li + \alpha$$

Fig 2. Standard neutron monitor (3NM64)

(Adapted from NM Bootcamp 2020 slide, Nuntiyakul)

NM64 RESPOND ENERGY

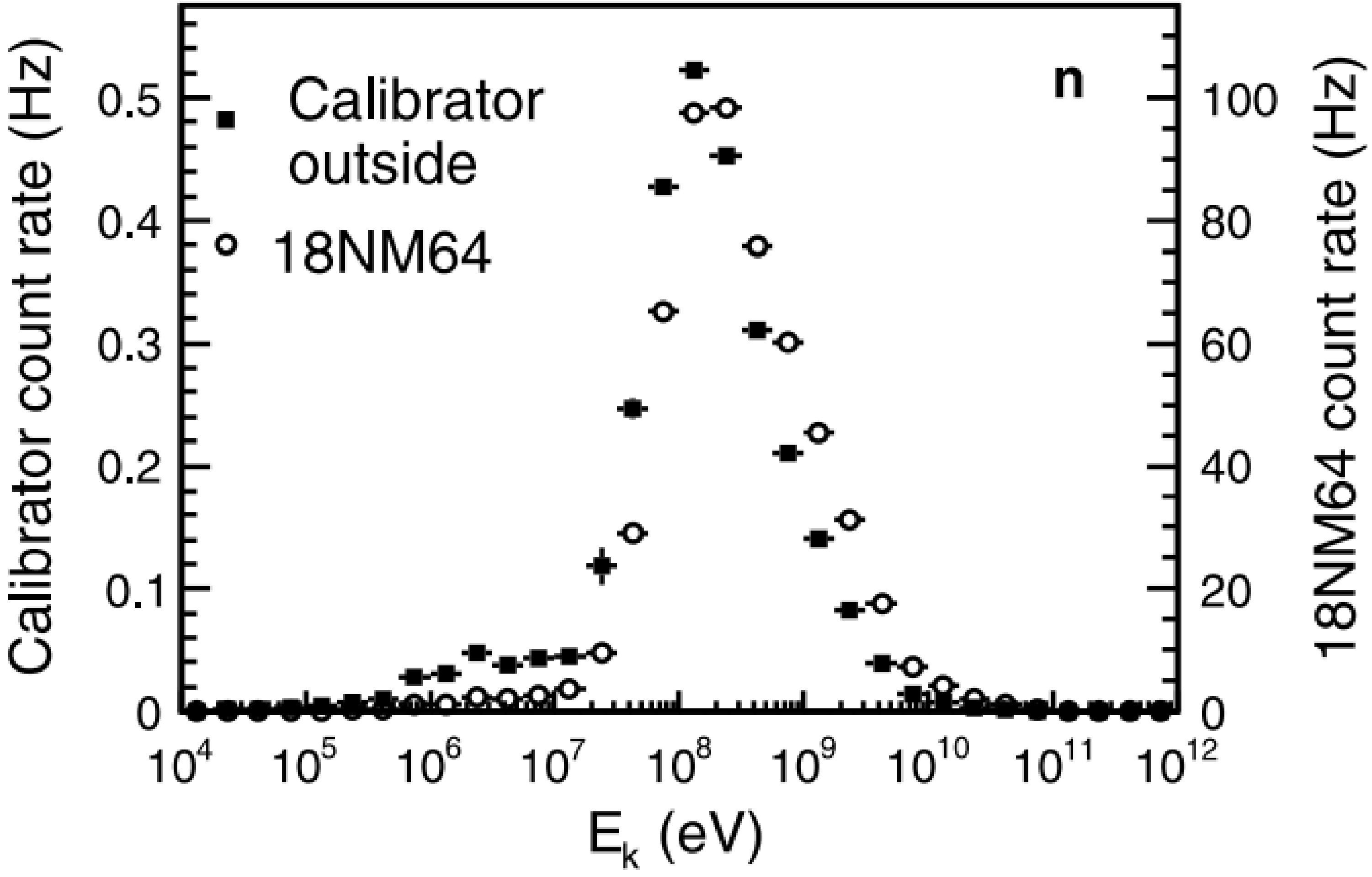


Fig 13
Simulated neutron monitor count rates produced by various types of atmospheric secondary cosmic rays arriving to ground level (Aiemsa-ad et al.. 2015)

GEOMAGNETIC CUTOFF RIGIDITY

➢ Rigidity is defined as momentum per unit charge

$$P = Br = pc/q$$

magnetic field, momentum, rigidity, gyroradius, charge

➢ The magnetic field of the Earth excludes particle below a well-defined rigidity at any given location known as cutoff rigidity

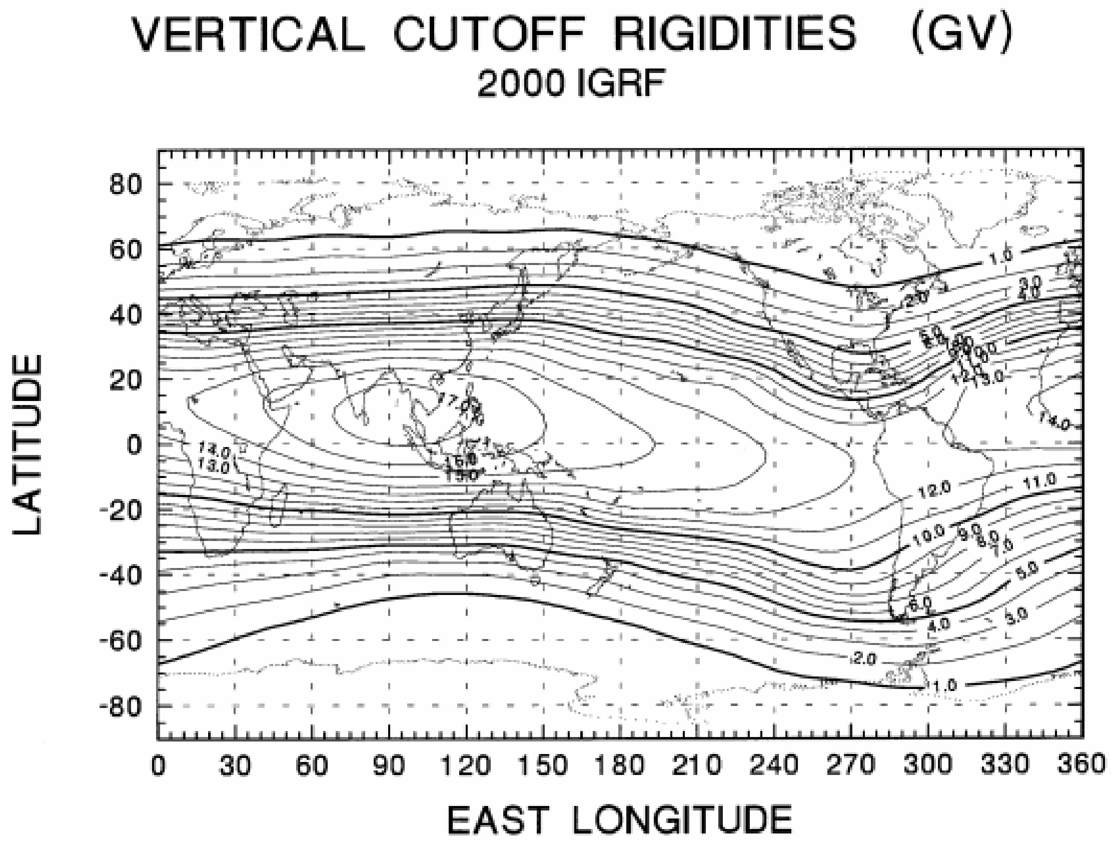


Fig 7. Rigidity contours for vertical geomagnetic cutoff rigidities for epoch 2000. (Smart & Shea, 2006)

Vertical cutoff rigidity
→ the minimum rigidity for a vertical incident particle

Apparent cutoff rigidity
→ an estimate rigidity for each possible direction of incident particle

III : Solar modulation correction

Nuntiyakul et al., 2014