Multi Wavelength Studies of the Solar Atmosphere: Celebrating the Career of Costas Alissandrakis

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Determination of the Kanzelhöhe sunspot group positions: manual versus automatic method

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AIMS

- Analysis of high-precision positions and rotational velocities of sunspot groups for the time period 1874 – 1976:
  - dependence of the differential rotation of sunspots on:

    - the phase of the cycle (Balthasar and Wöhl, 1980, A&A, 92, 111)

    - time (Brajša et al. 2006, Solar Phys., 237, 365)
  - relationship between the solar rotation and activity (Brajša et al. 2007, Astron. Nachr. 328, 1013.)

Main aim: to extend analysis 1977 – present

(using *Kanzelhöhe Observatory for Solar and Environmental Research* sunspot drawings and white light images – **KSOsd and KSOwli)**

- temporal variations on KSOsd analysed only for the period 1947-1981 (Lustig, 1983, A&A ,125, 355)

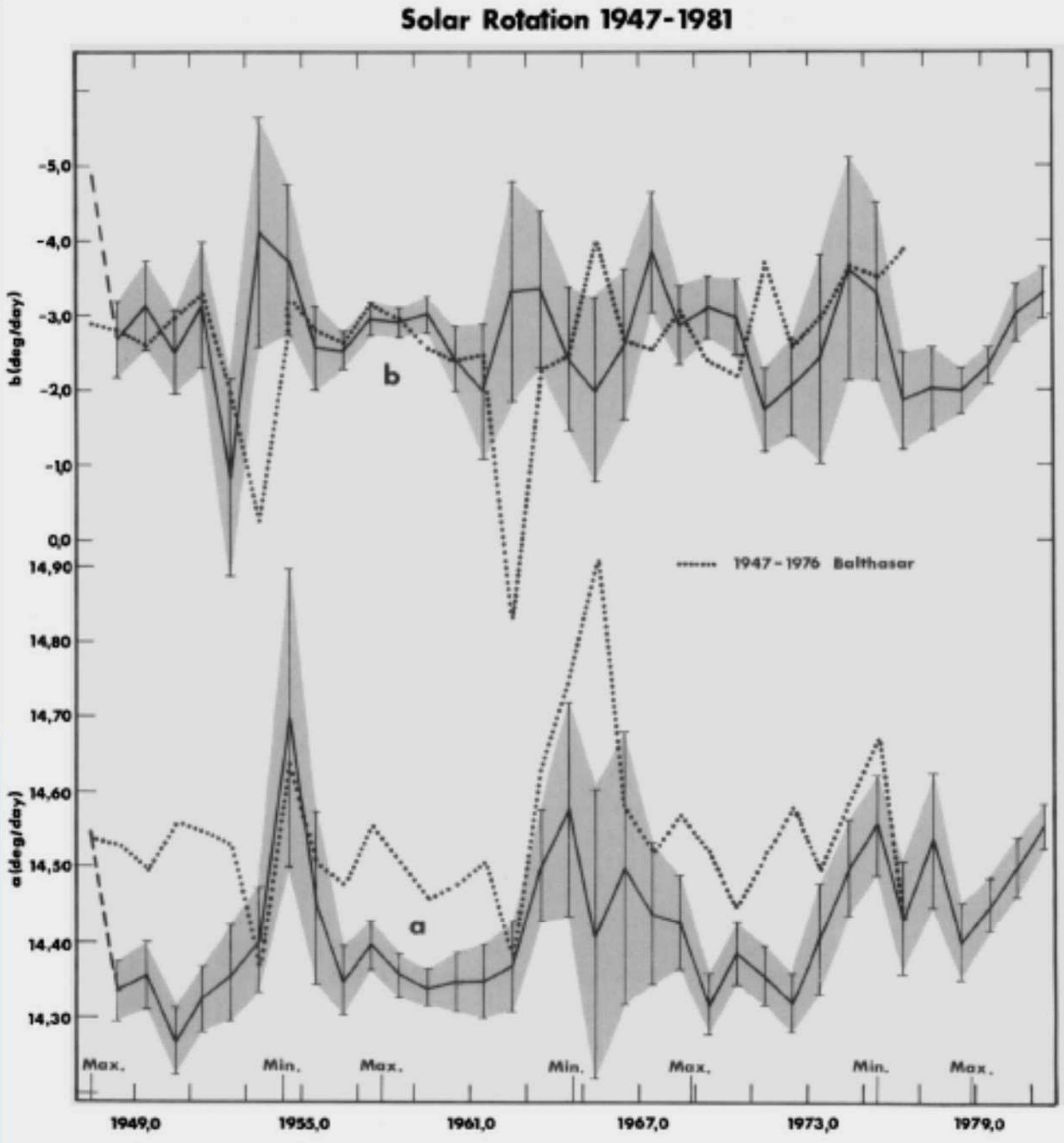


Fig. 1. Sideral rotation from 1947–1981. Annual mean values of the coefficients *a* and *b*. The results of Balthasar are given for comparison by the dotted line

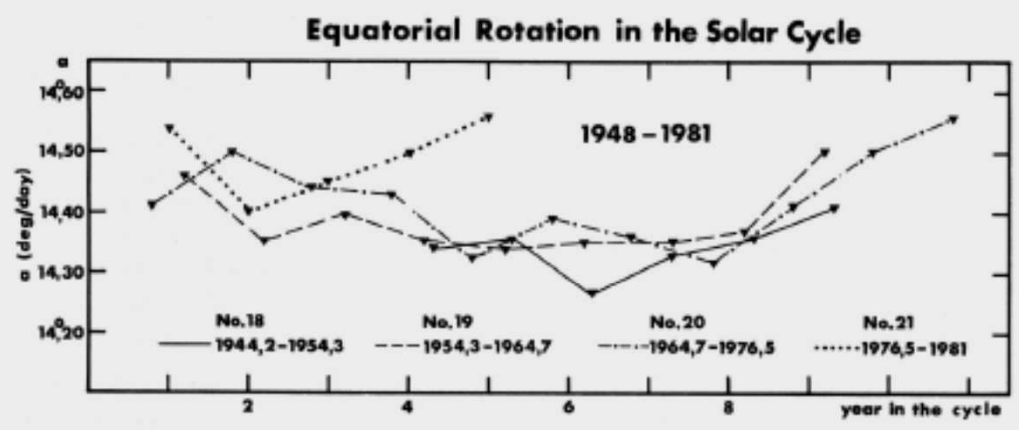


Fig. 2. Sideral equatorial rotation in the solar cycle No. 18–21 (1947–1981)

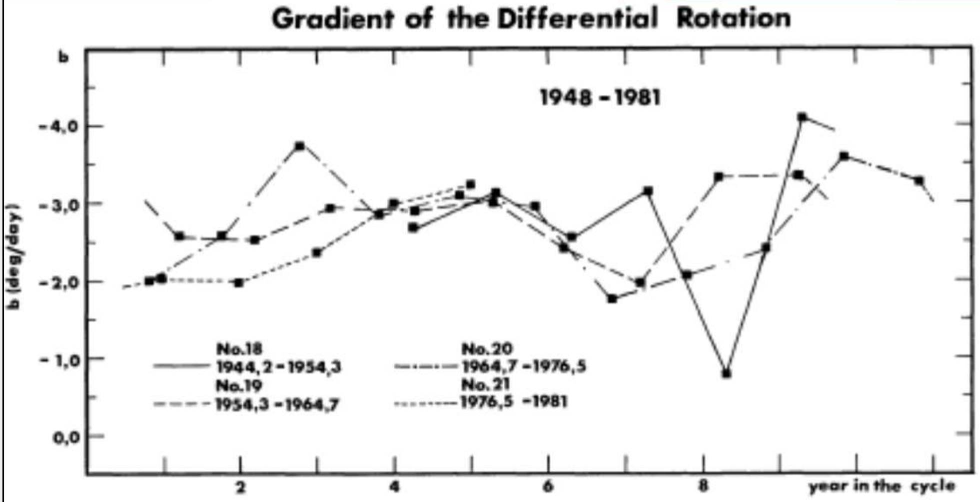


Fig. 3. Gradient of the differential rotation in the cycle No. 18–21

➢ Lustig, 1983, A&A ,125, 355

AIMS

The main idea:

- provide a continuation of the investigations done in Lustig (1983)
- analyze the relationship between the solar rotation and activity

Determination of the heliographic positions:

- solar cycles nos. 20 – 24 were processed (51 year period, 1964 – 2015)
- for the first time, solar cycle no. 21 is examined completely (previously, it was just partially processed), as well as solar cycles nos. 22-24
- solar cycle no. 20 represents the overlapping part (our work and Lustig, 1983)

METHODS

two procedures for determination of the heliographic positions of sunspot groups

MANUAL (INTERACTIVE) METHOD
(1964 – 2010)

KSOsd

special software *Sungrabber*

AUTOMATIC METHOD
(2010-2015)

KSOwli

the algorithm for automatic recognition of the sunspot groups

MANUAL vs. AUTOMATIC

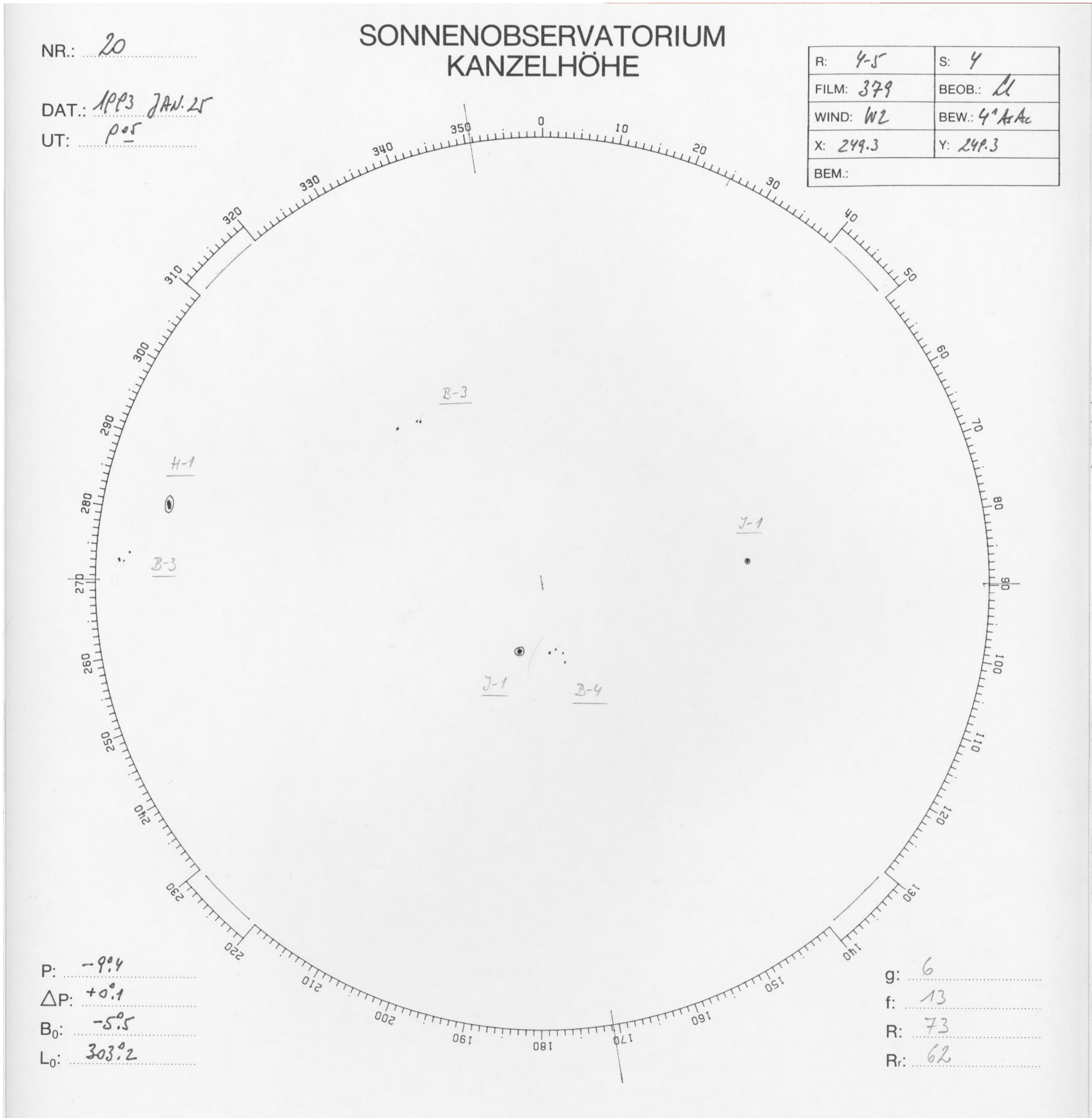
2014

2014 – max of the cycle no. 24

MANUAL METHOD (1964 – 2010)

- processing of the KSOsd

- a special software for the determination of tracer’s positions in full disk solar images – ***Sungrabber**** (Hržina et al., CEAB, 2007, 31, 273).

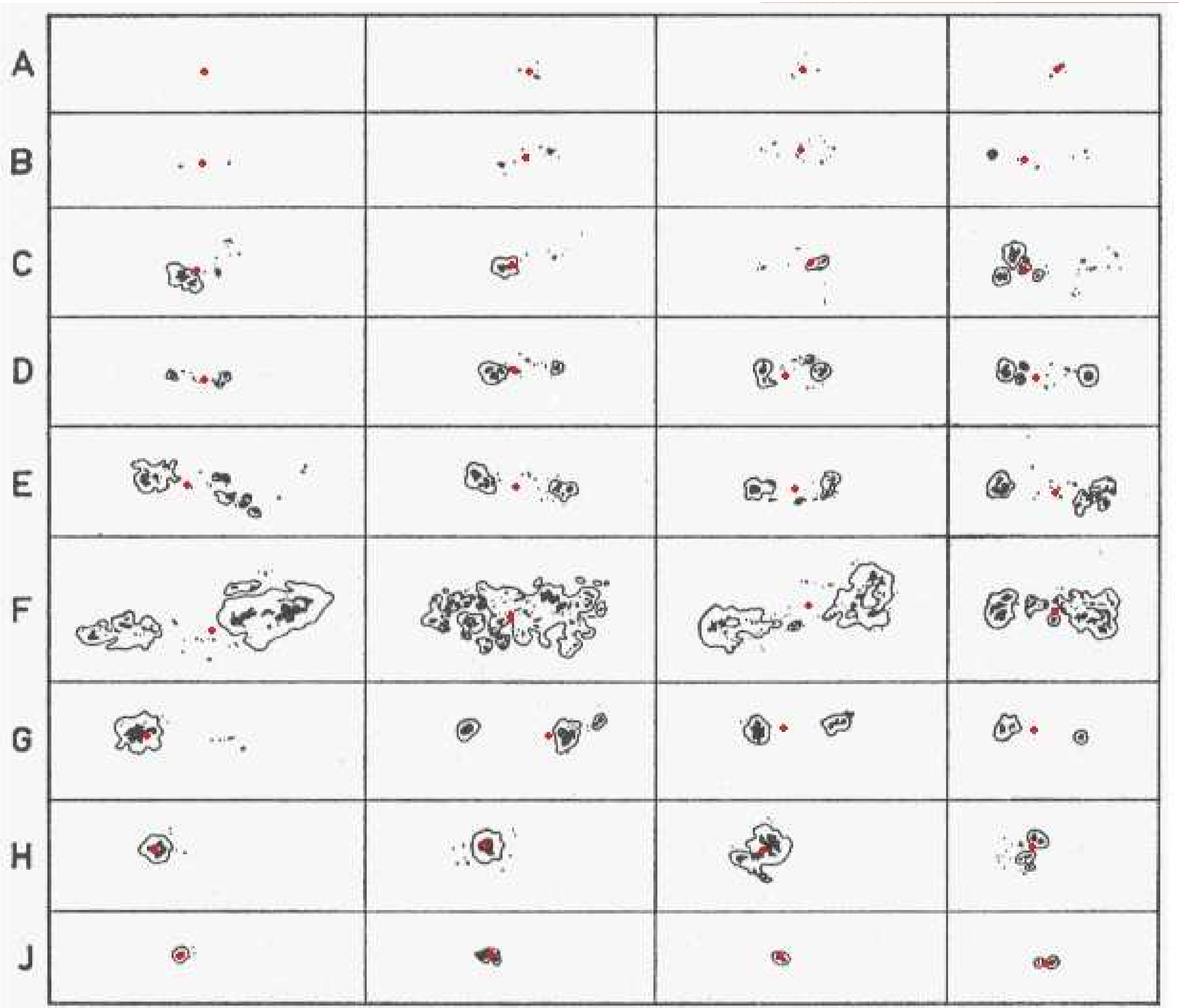


Kanzelhöhe drawing (25th Jan. 1993)

* www.zvjezdarnica.hr/sungrabber

MANUAL METHOD (1964 – 2010)

- interactive, visual estimation of the area weighted positions of sunspot groups were applied

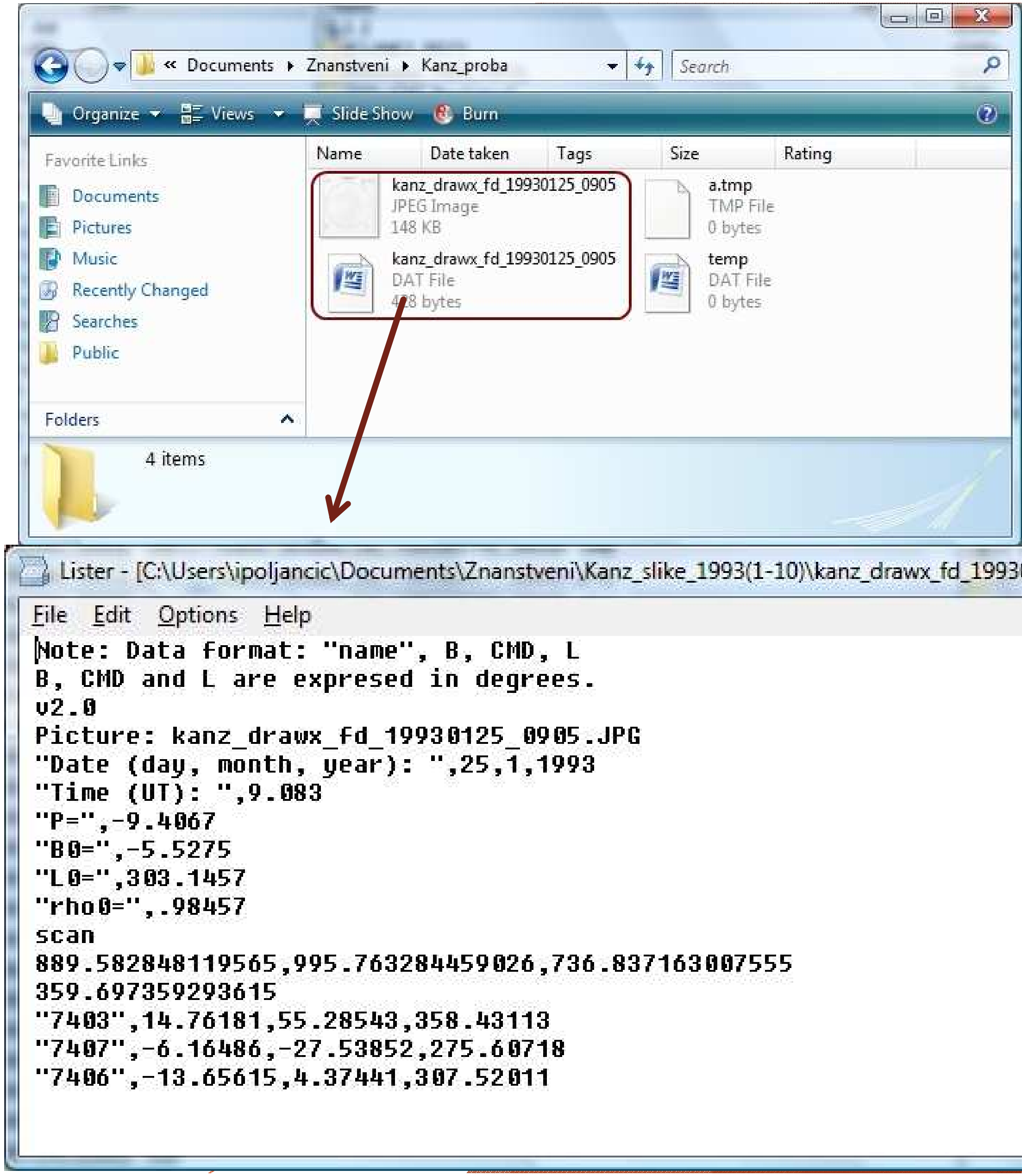


MANUAL METHOD (1964 – 2010)

- interactive, visual estimation of the area weighted position of sunspot groups by the observer

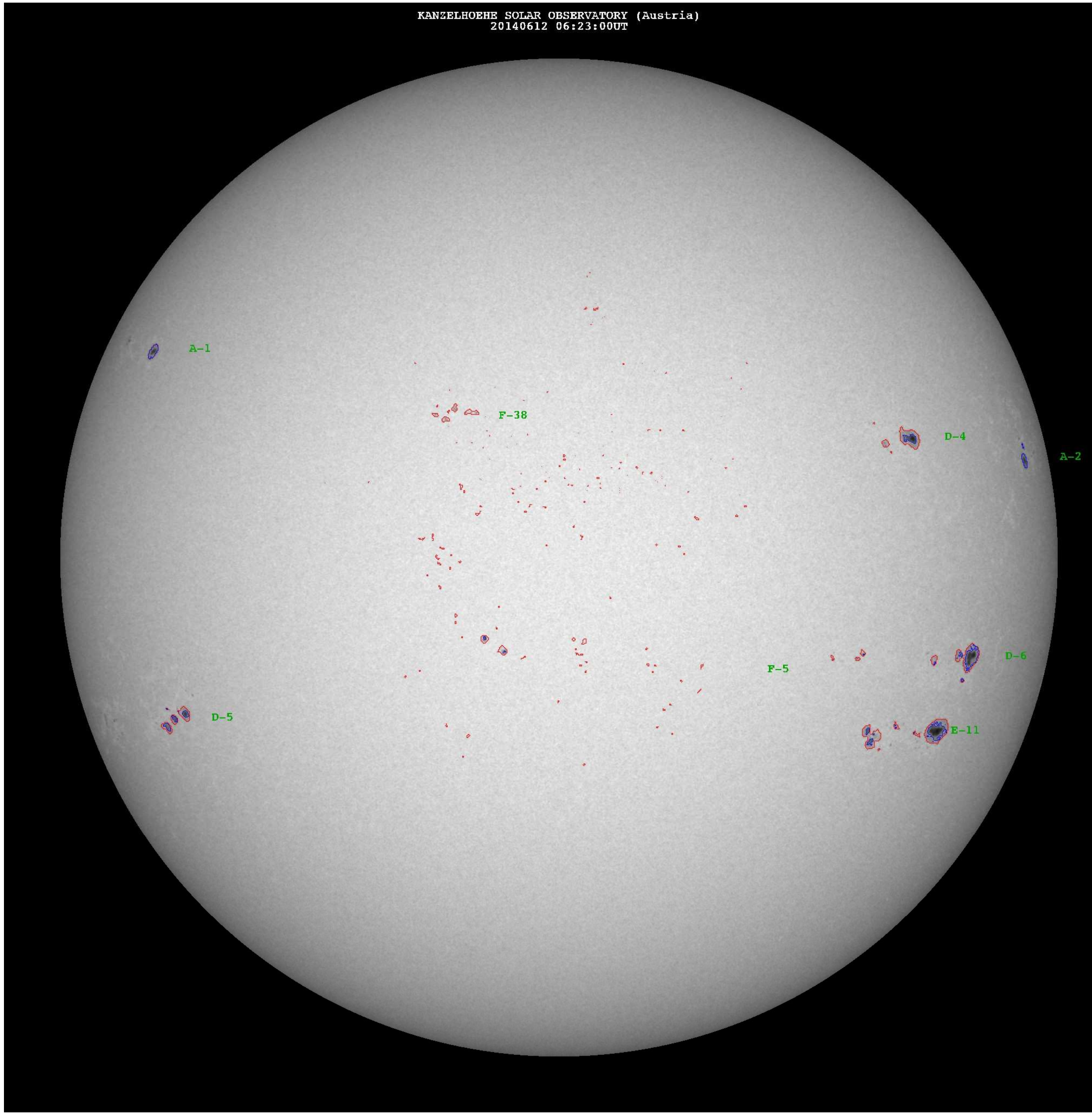
- the differences between Sungrabber coordinate determinations of the two observers are negligible - approximately 0.1 deg, always less then 0.2 deg (Poljančić et al., 2010, Sun and Geosphere, 5(2), 52)

- three observers



AUTOMATIC METHOD (2010-2015)

- processing of the KSOwli
- the algorithm for automatic recognition of the sunspot groups – (Watson et al., 2009, SoPh, 260, 5)
- morphological image processing – an erosion following a dilation
- successive erosion and dilation are used for the elimination of small objects (marking, calculating the area)



AUTOMATIC METHOD (2010-2015)

- we used **raw fits images** and corresponding **dat files** acessible via the Kanzelhoehe ftp
- for a single day, we used just **one fits** file which produced dat file with the highest memory
- **fits header** - P and Bo
- the corresponding **dat file** - solar radii and X and Y pixel coordinates
- center based on center of gravity
- calculations from Meuss (Astronomical algorithms)

* 20140612_0623_prez.dat

```
20140612_0623
Size (Pixel): 2048, 2048
Center (Pixel): 1024.18, 1024.51
Radius (Pixel): 922.778
Number of Umbrae:            192
 Umbra Penumbra Position   CenterX  CenterY  UArea  PArea  Region
    4       21    S 21/W 53   1704      694      9   1471   12085
    7       21    S 20/W 56   1735      699      2   1471   12085
   12       21    S 19/W 55   1737      716      1   1471       0
    8       26    S 20/W 50   1679      700      6     79   12085
    9       27    S 19/E 57    301      711    119    271   12087
   10       34    S 19/W 46   1645      710      8     89   12085
   15       41    S 18/E 53    322      739      4    395   12087
   16       47    S 17/E 56    300      745      6     13   12087
   19       92    S 12/W 50   1717      828     16    169   12080
   20       95    S 11/W 34   1530      836      1     45   12088
   21       96    S 11/W 37   1574      838      1     57   12088
   29      297    N 11/W 72   1883     1203    189    189   12079
   32      310    N 14/W 47   1672     1243    286   1009   12082
   30      312    N 13/W 72   1880     1230     21     21   12079
   31      314    N 13/W 42   1627     1230      1    153   12082
   33      352    N 25/E 64    275     1404    309    331   12090
  362      362    S 24/W 03   1070      642     13     13       0
 ...

Region  Type   Length  UArea   PArea    Np   cx   cy  cenx  ceny
     0  F-120  101.26   1341    1853     4 1011 1012  -0.7  -0.1
12079    A-2    2.24    210       0     0 1882 1205  71.1  11.2
12080    D-6    8.06    803    1535     5 1781  837  56.6 -11.0
12082    D-4    6.40    305       0     2 1669 1242  45.7  14.0
12085   E-11   14.32    933    2544    10 1694  700  51.4 -19.3
12087    D-5    4.47    336     858     5  316  724 -54.0 -18.0
12088    F-5   22.36     52     185     3 1342  813  20.1 -11.7
12089   F-38   27.29    626       0     0  859 1281 -10.4  16.2
12090    A-1    0.10    309       0     0  275 1404 -64.0  24.0
```

METHODS

- Identification of sunspot groups:
  - Greenwich Photoheliographic Results, GPR
  - Debrecen Photoheliographic Data, DPD

- Rotation velocities were calculated by:

a) **daily-shift method (DS)**, i.e., from the daily differences of the Central Meridian Distance (CMD) and the elapsed time

$$\omega_{syn} = \frac{\Delta CMD}{\Delta t} \quad \text{(Eq. 1)}$$

b) **<u>robust</u> linear least-square fit (LSQ)** from the function $CMD(t)$ for each tracer

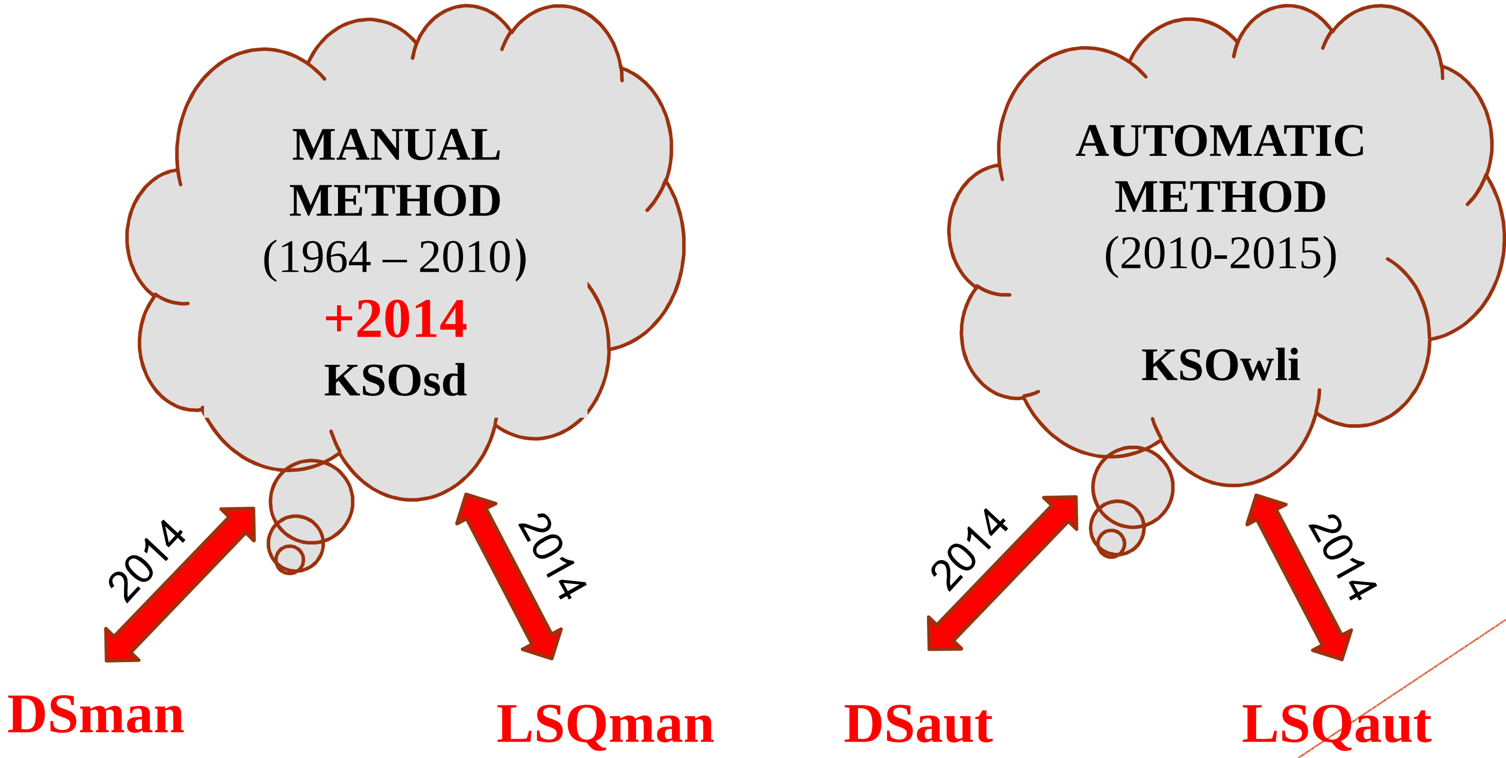
RESULTS

- the solar differential rotation $\omega(b) = A + B \sin^2 b$ (Eq. 2)

- **Filters:**
  - ± 58° in CMD (in order to avoid solar limb effects)
  - 8 – 19 deg/day in sidereal rotation velocity (to eliminate any gross errors resulting from misindentification of sunspot groups)
  - in both methods (DS, LSQ) - assigning the velocity to the latitude and time of the first position measurement (Olemskoy&Kitchatinov, 2005, 31, 706)
  - robust linear least square fit (cases with only two dots excluded)

RESULTS

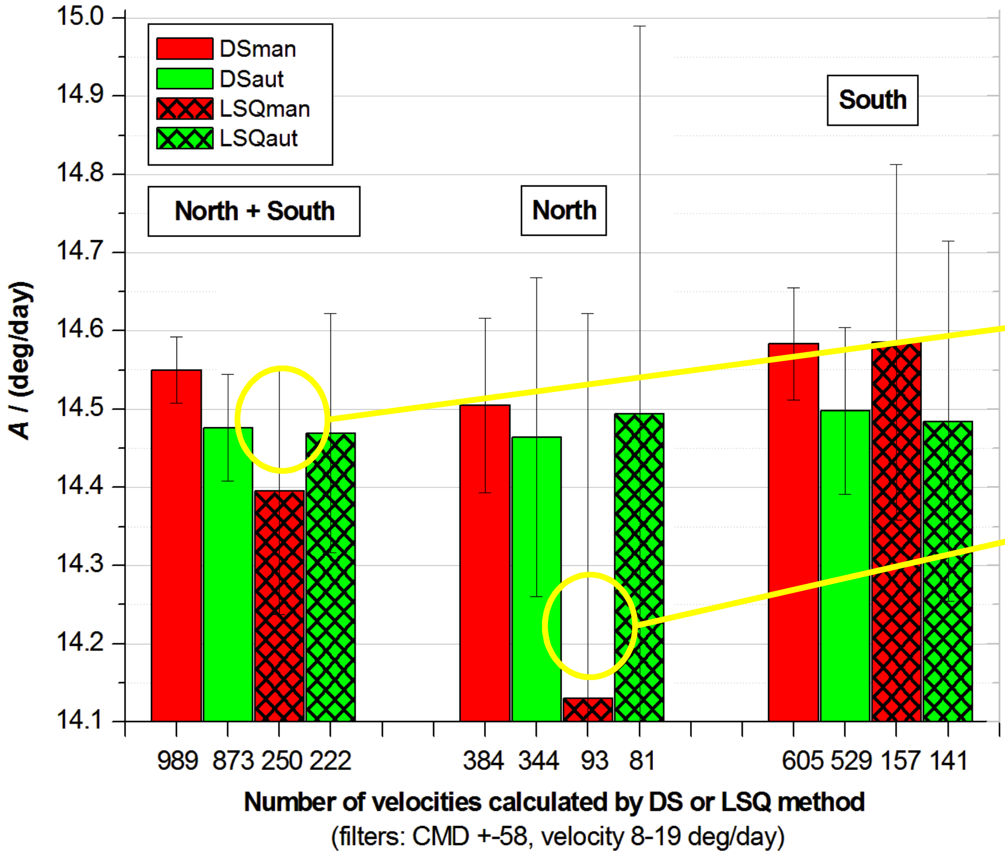
- two methods for the heliographic positions determination have been used (1964 – 2015)
- in order to be able to discuss them simultaneously – automatic vs. manual comparison („calibration”)



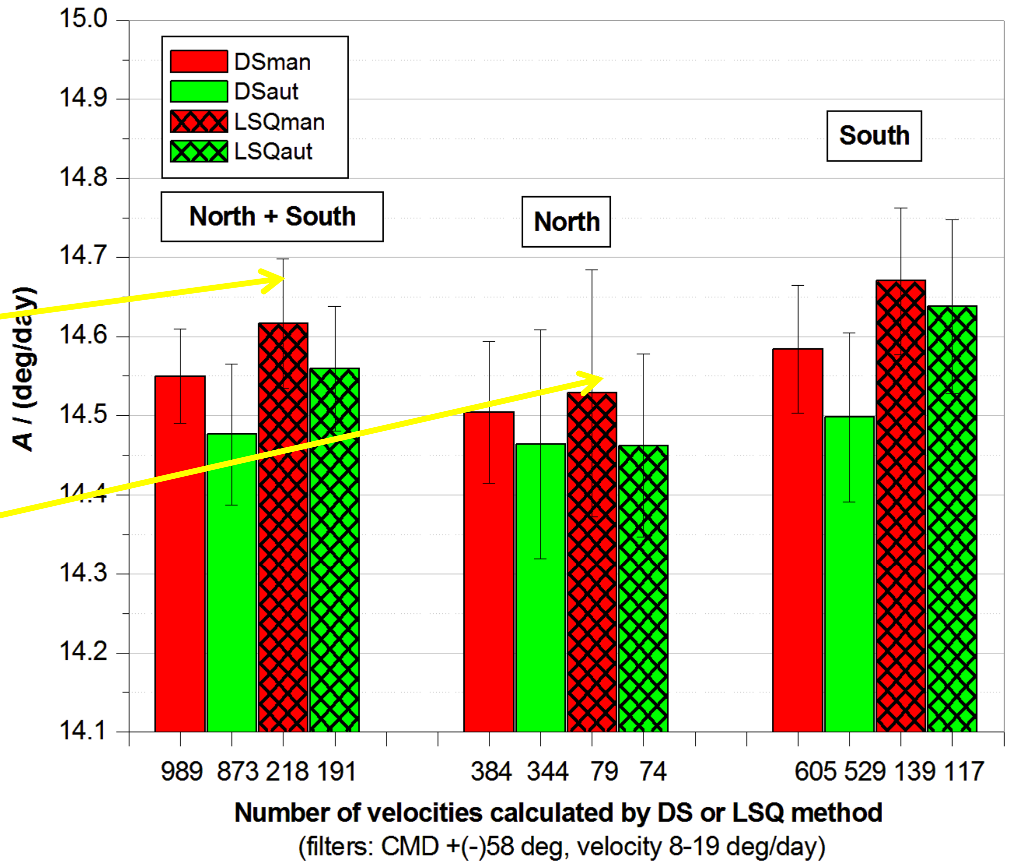
RESULTS for 2014
(differential rotation coefficient *A*)

LSQ fit - DS method more precise than LSQ method
- LSQman North – obvious errors in identification of sunspot groups etc.

LSQ fit:

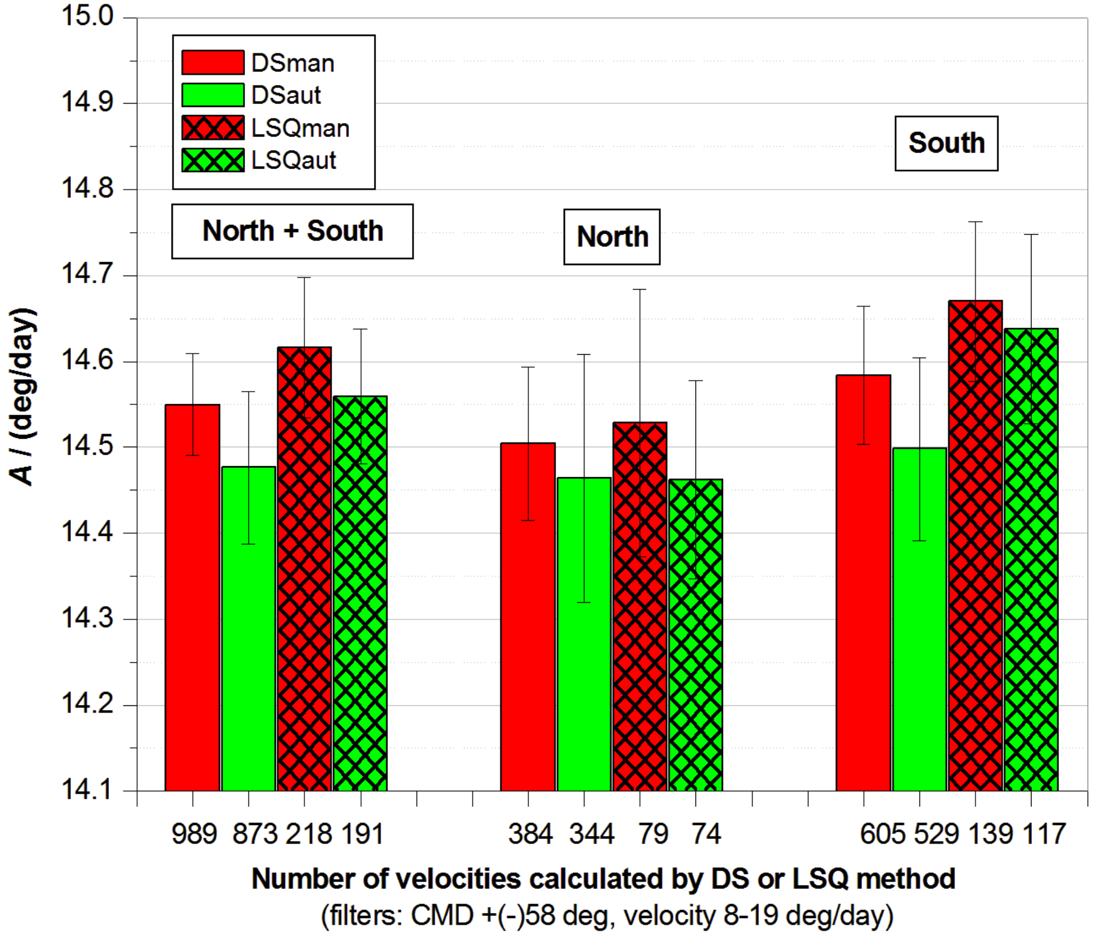


Robust LSQ fit:



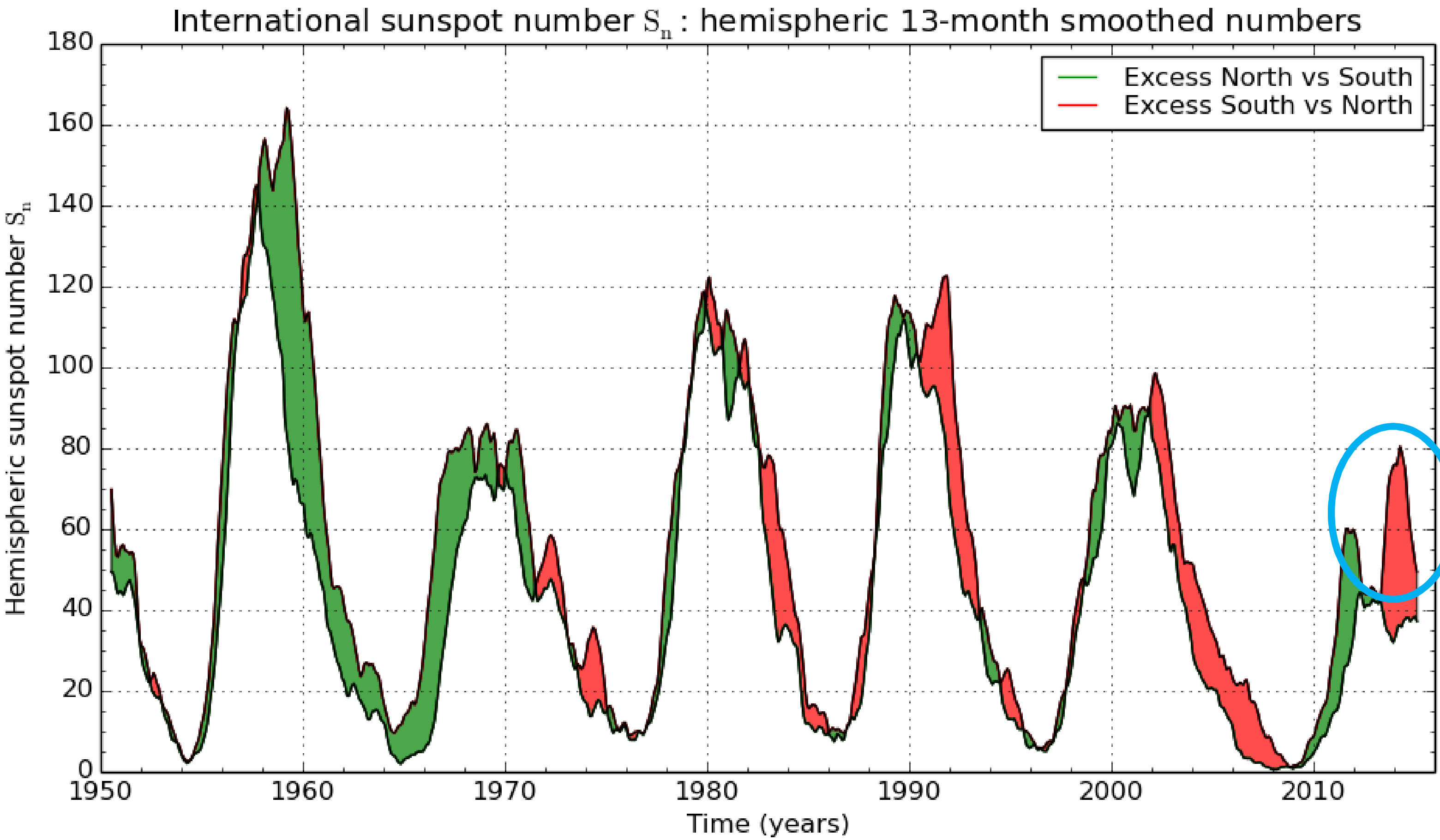
RESULTS for 2014
(differential rotation coefficient *A*)

- robust LSQ fit – DS and LSQ precisions equalized (error bars)
- for all cases lower velocity values for North
- all measurements (N+S, N, S) are within the **1 common sigma** – it is possible to use the methods simultaneously



The North and South components of the monthly smoothed sunspot number (SILSO)

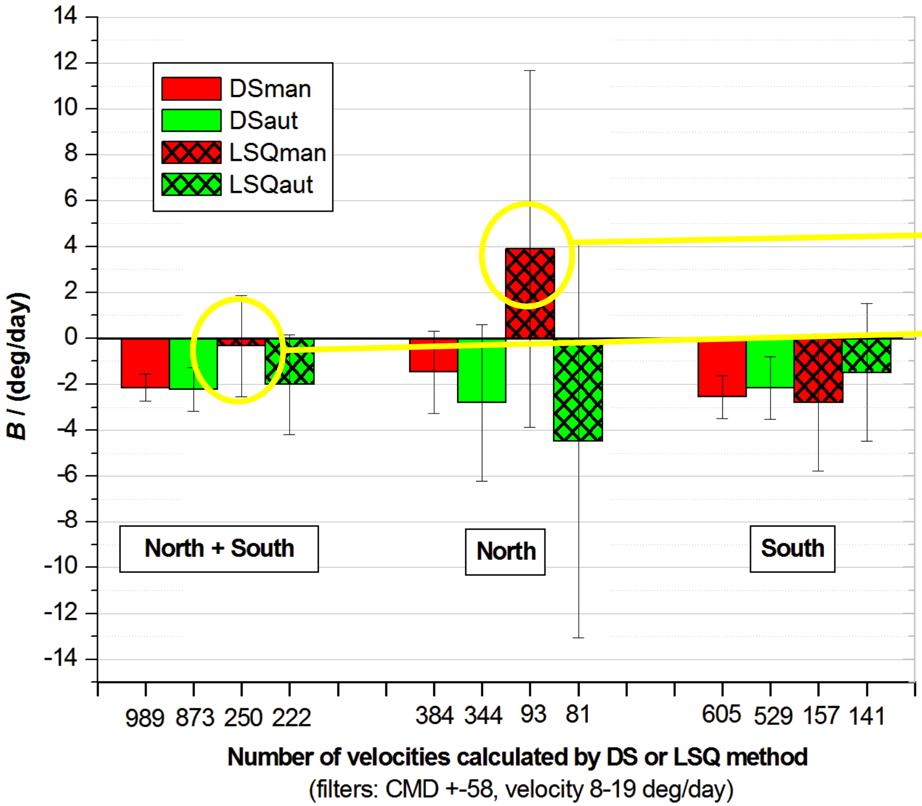
- Green – North number higher than the South number
- Red – South number higher than the North number
- explains the difference between the number of calculated velocities for North and South



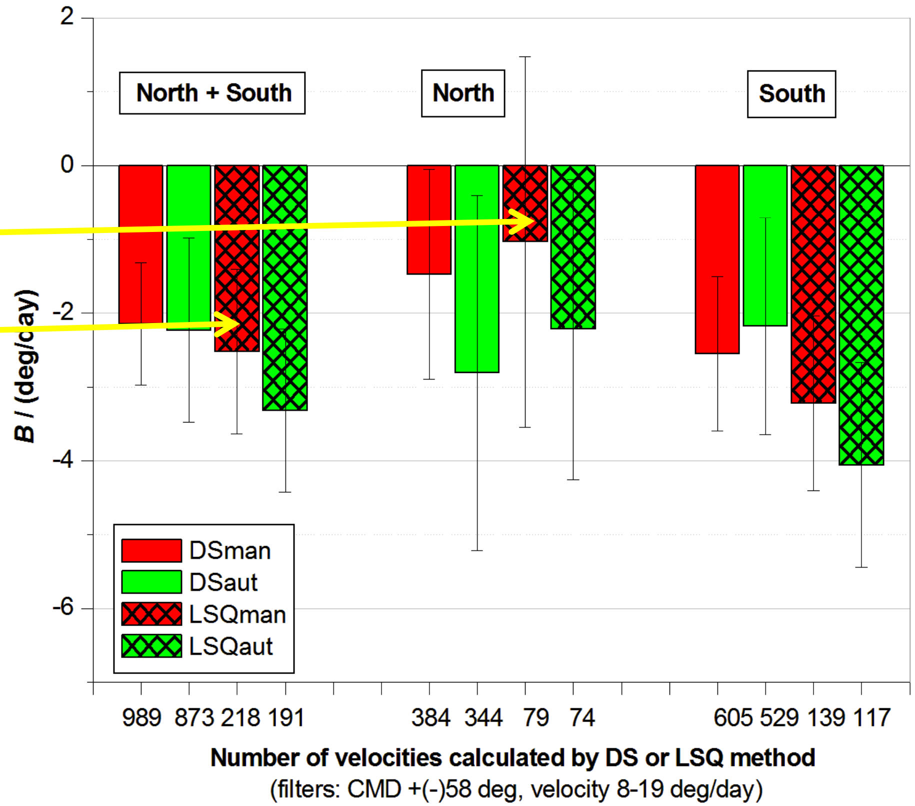
SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2015 September 1

RESULTS for 2014
(differential rotation coefficient *B*)

LSQ fit



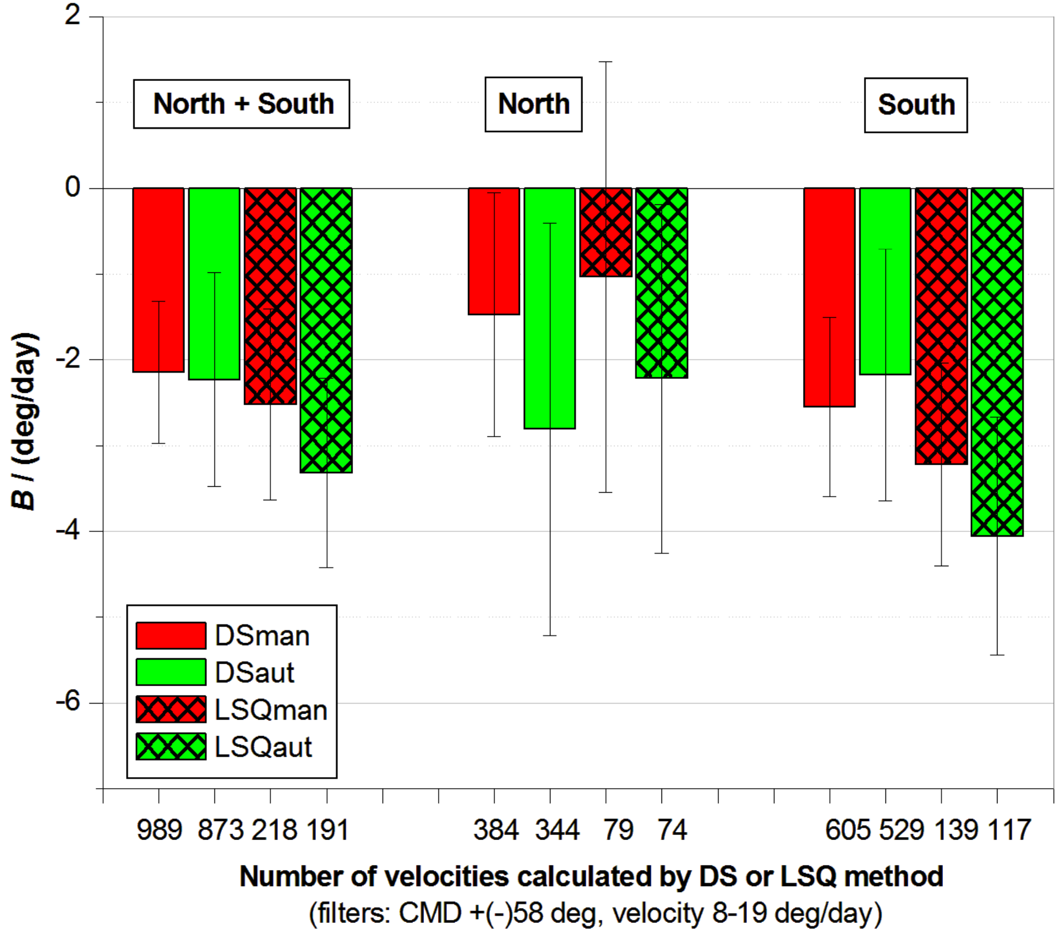
Robust LSQ fit

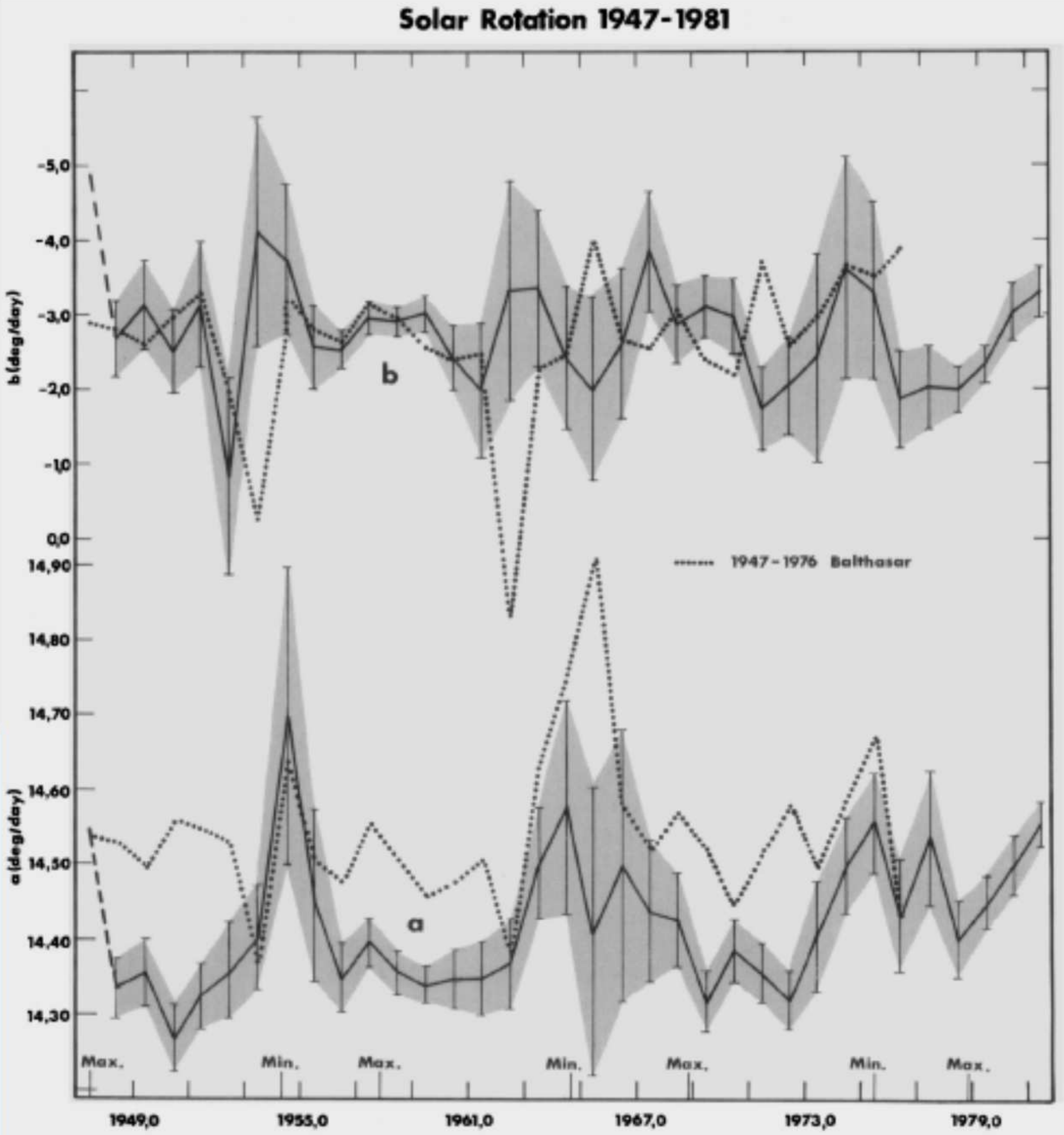


RESULTS for 2014
(differential rotation coefficient *B*)

The same conclusions as for coefficient *A*:

- robust LSQ fit – DS and LSQ precisions equalized (error bars)
- for all cases lower absolute *B* values for North (except for DSaut)
- all measurements (N+S, N, S) are within the **1 common sigma** – it is possible to use the two methods simultaneously





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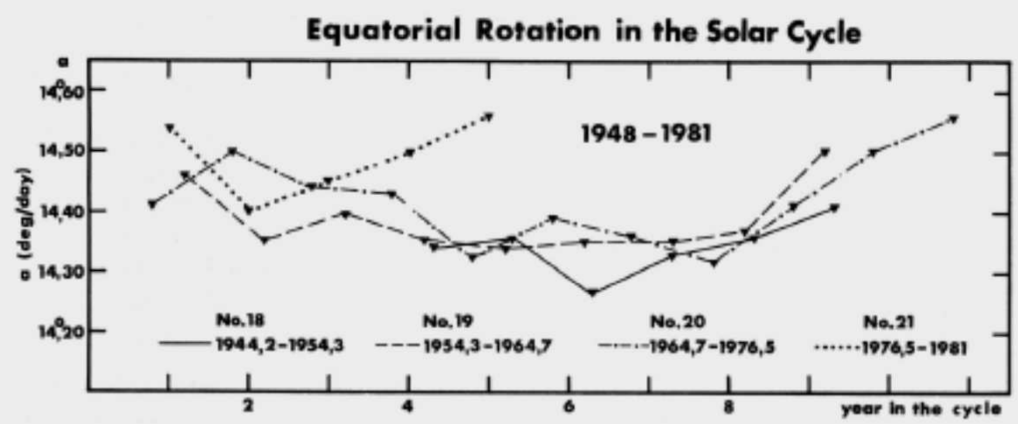

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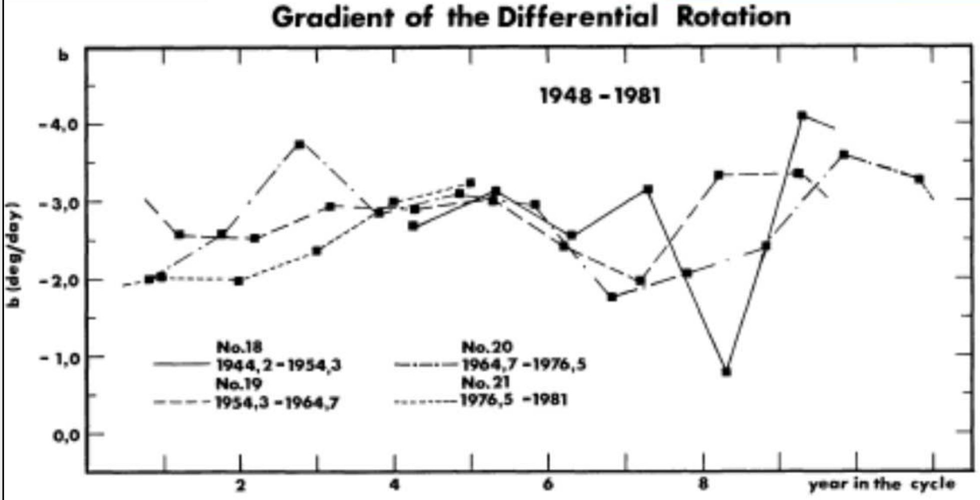

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Thank you!

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