Solar differential rotation analysis from Kanzelhöhe sunspot drawings

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Kanzelhöhe Observatory is the only observatory in Austria for solar and environmental research being part of the Institute of Physics at the Karl-Franzens University of Graz (online service began in February 2000, the complete archives of sunspot drawings since 1947 were digitized).

AIMS. Within the project intended to investigate the behavior of the solar differential rotation during several cycles we plan to process sunspot drawings from *Sonnenobservatorium Kanzelhöhe* for solar cycles nos. 20 - 24. As part of this analysis, we present here the results for the solar cycles no. 20 and no. 22.

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)
- dependence of solar rotation on 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 and to compare various data sets

METHODS. The positions of sunspot groups were determined using a special software for determination of tracer's positions in full disk solar images – ***Sungrabber**** (Hržina et al., CEAB, 2007, 31, 273).

Identification of sunspot groups:
Cycle 20 (Greenwich Photoheliographic Results, GPR)
Cycle 22 (Debrecen Photoheliographic Data, DPD)

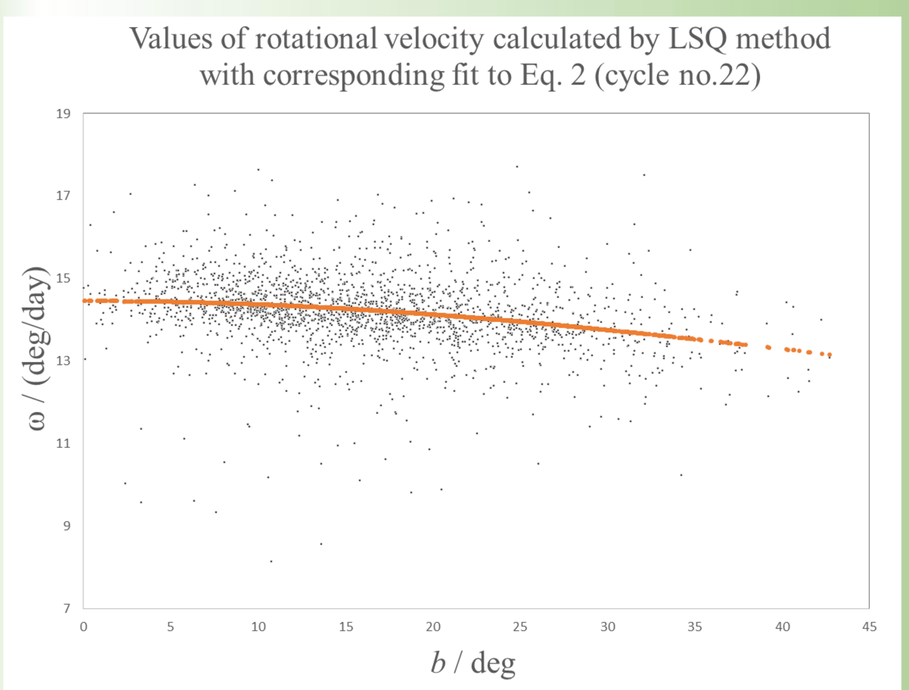
Cycle	Method	Number of velocities calculated
20	DS	5399
20	LSQ	1619
22	DS	8346
22	LSQ	2097

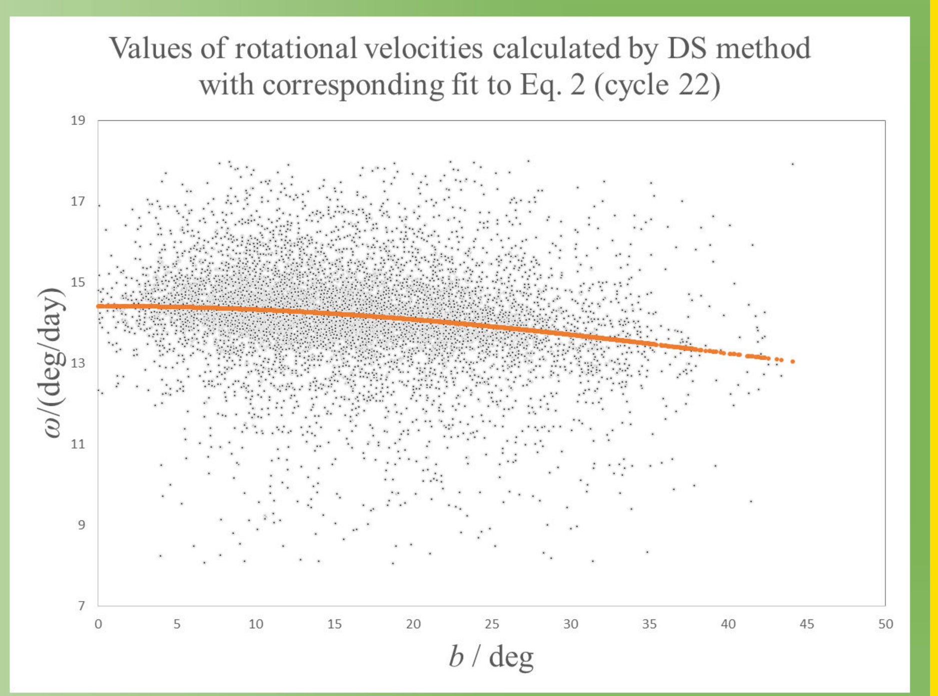
Rotation velocities were calculated by:
a) **daily-shift method (DS)**, i.e., from the daily differences of the Central Meridian Distance (CMD) and the elapsed time

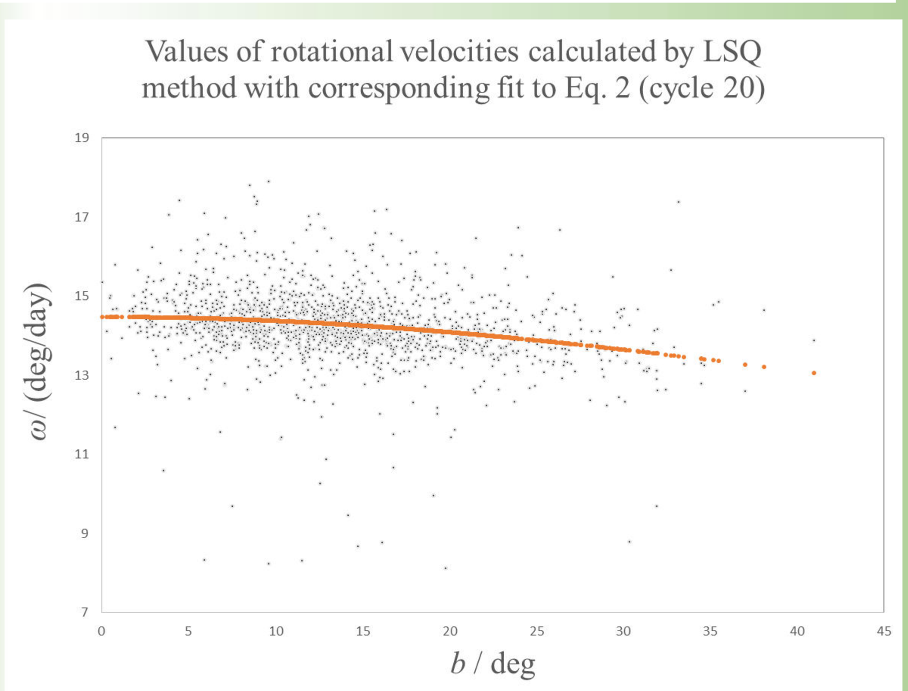
$$\omega_{syn} = \frac{\Delta CMD}{\Delta t} \qquad \text{(Eq. 1)}$$

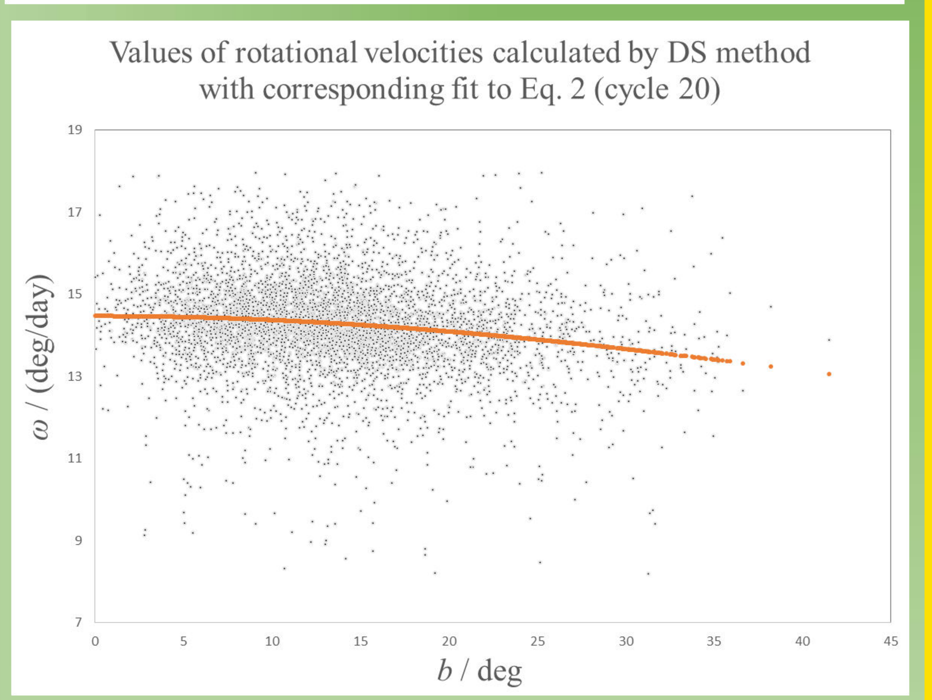
b) **linear least-square fit (LSQ)** from the function *CMD*(*t*) for each tracer.

RESULTS. The solar differential rotation $\omega(B) = A + B\sin^2 b$ (Eq. 2) is determined for solar cycles no. 20 and no. 22 treating the northern and southern hemispheres together ($|b|$is used).







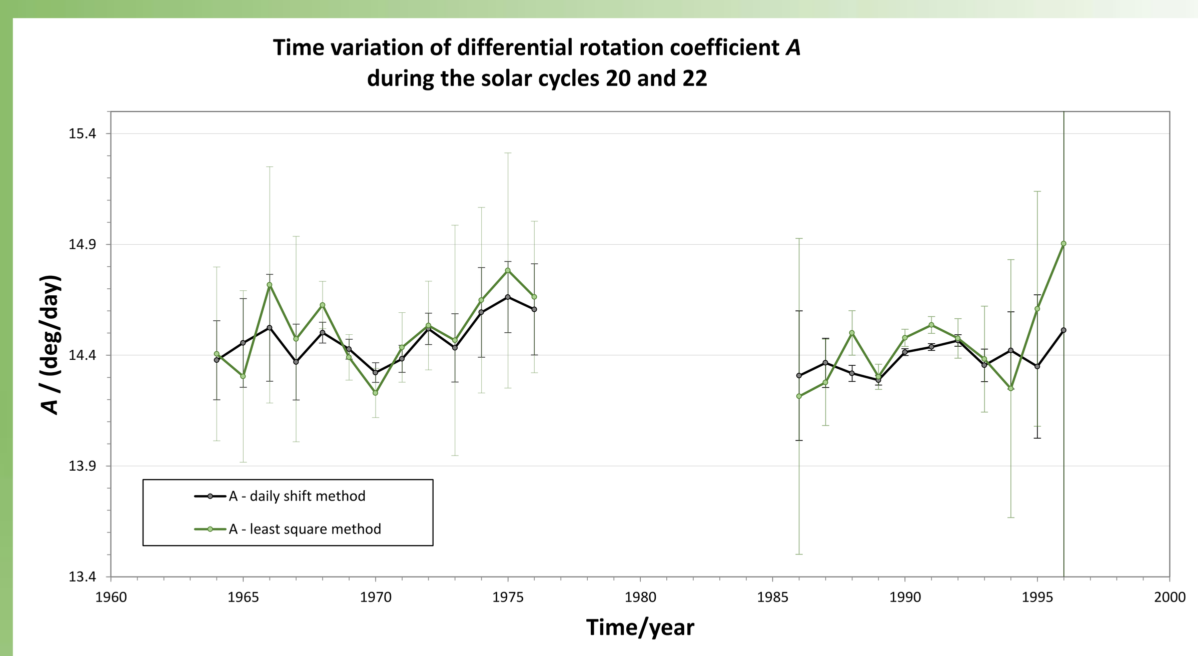


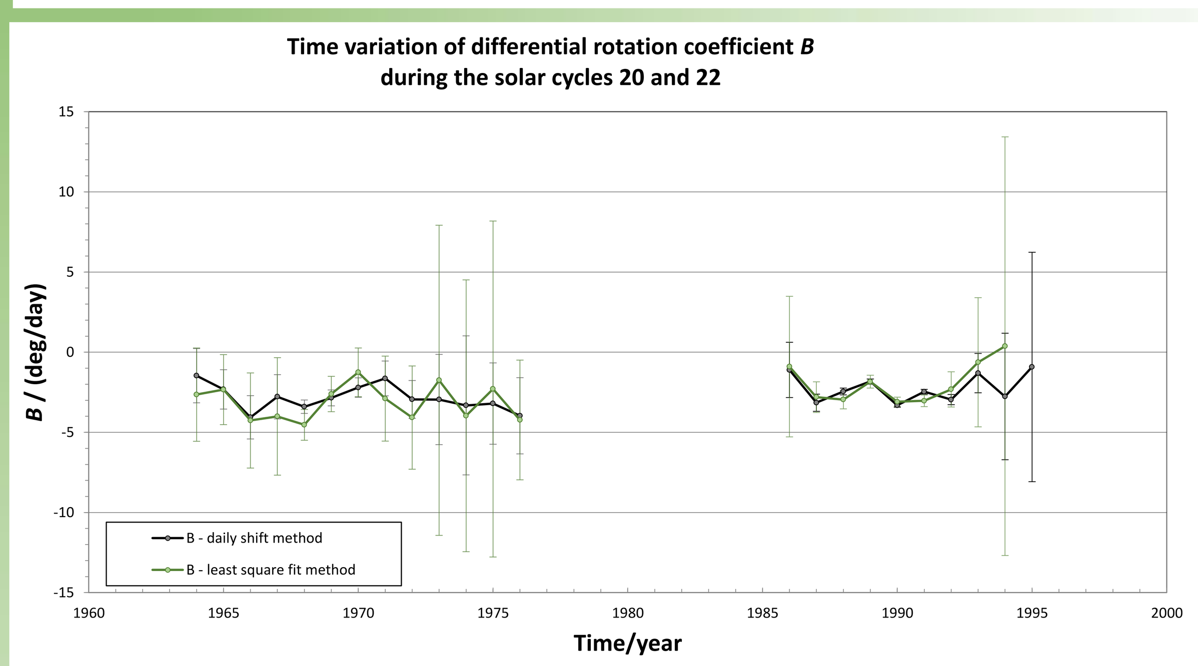
Filters:

- ± 58° in CMD (in order to avoid solar limb effects)
- 8 – 18 deg/day in sidereal rotation velocity (to eliminate any gross errors resulting from misindentification of sunspot groups)
- in daily – shift method - assigning the velocity to the latitude and time of the first measurement of position (Olemskoy&Kitchatinov, 2005, 31, 706)

RESULTS. Differential rotation laws:

Cycle 20 (LSQ): $\omega(B) = (14.474 \pm 0.033) + (-3.301 \pm 0.361)\sin^2 b$
Cycle 20 (DS): $\omega(B) = (14.468 \pm 0.023) + (-3.215 \pm 0.262)\sin^2 b$
Cycle 22 (LSQ): $\omega(B) = (14.459 \pm 0.028) + (-2.818 \pm 0.229)\sin^2 b$
Cycle 22 (DS): $\omega(B) = (14.413 \pm 0.021) + (-2.829 \pm 0.167)\sin^2 b$





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CONCLUSIONS.

The rotation parameter *A* obtained with the DS method has a lower value than the same parameter obtained with the LSQ method. Our results for both solar cycles are in a qualitative agreement with earlier investigations.

Our results indicate slightly higher values of rotation parameter *A* toward the end of the cycles (activity minimum), although the errors show that these changes are not significant. Rotation parameter *B* toward the end of cycle 20 shows lower values. This can indicate anticorrelation of *A* and *B* (Balthasar & Wöhl, A&A, 1980, 92,111).

Authors	Cycle 20 $A \pm \sigma_A$ $B \pm \sigma_B$	Cycle 22 $A \pm \sigma_A$ $B \pm \sigma_B$
Balthasar, Vásquez and Wöhl, 1986 (A&A, 155, 87)	14.53 ± 0.02 -2.73 ± 0 17	-
Pulkkinen and Tuominen, 1998 (A&A, 332, 748)	14.52 ± 0.01 -2.59 ± 0.14	14.44 ± 0.02 -2.29 ± 0.15
Khutsishvili, Gigolashvili and Kvernadze, 2001 (Solar Phys., 206, 219)	14.75 ± 0.12 -2.47 ± 1.25	-

* www.zvjezdarnica.hr/sungrabber