CIRCULATION CHANGES IN THE WINTER LOWER ATMOSPHERE AND LONG-LASTING SOLAR/GEOMAGNETIC ACTIVITY

Josef Bochníček[1], Hana Davídkovová[1,2], Pavel Hejda[1] and Radan Huth[2,3]

[1]Institute of Geophysics, Academy of Sciences of the Czech Republic

[2]Faculty of Science, Charles University

[3]Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic

Prague, Czech Republic

INTRODUCTION

- The relationship between solar activity, or parameters closely related to solar activity, and winter lower atmosphere data, changes very strongly in time. That is the reason, why the relationship was often questioned (Pittock, 1983).

Li et al. (JGR 2011)

- The analysis of time dependence of the relationship (geomagnetic activity x NAO). This relationship has nonstationary character – modulation by the multidecadal variation of solar activity.

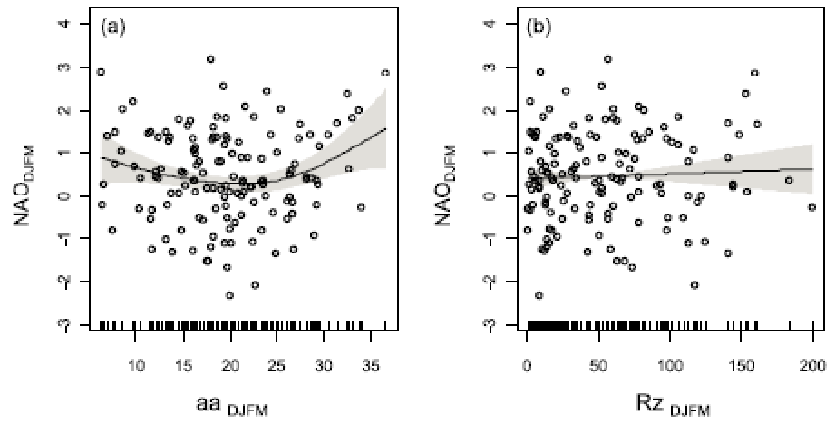


Figure 1. (a) Scatterplot of the December-March mean NAO_{DJFM} against the December-March mean geomagnetic *aa* index aa_{DJFM} from the period of 1869–2009. (b) Scatterplot of NAO_{DJFM} against the December-March mean sunspot number Rz_{DJFM} from the period of 1825–2009. The black lines denote the GAM fitting while the shaded region shows the 95% confidence interval for GAM model. When the output of the GAM is linear, only the linear model and its 95% confidence interval are shown. The small vertical bars inside of the *x* axis represent the corresponding values of Rz_{DJFM} and aa_{DJFM} for all the samples.

Li et al. (JGR, 2011)

INTRODUCTION

- Significant change points of the **trend of solar indices** around the years ~1902/1903, ~1962/1963, and ~1995/1996.
- Coherent changes of the trend in winter NAO – a few years later.

Li et al. (JGR, 2011)

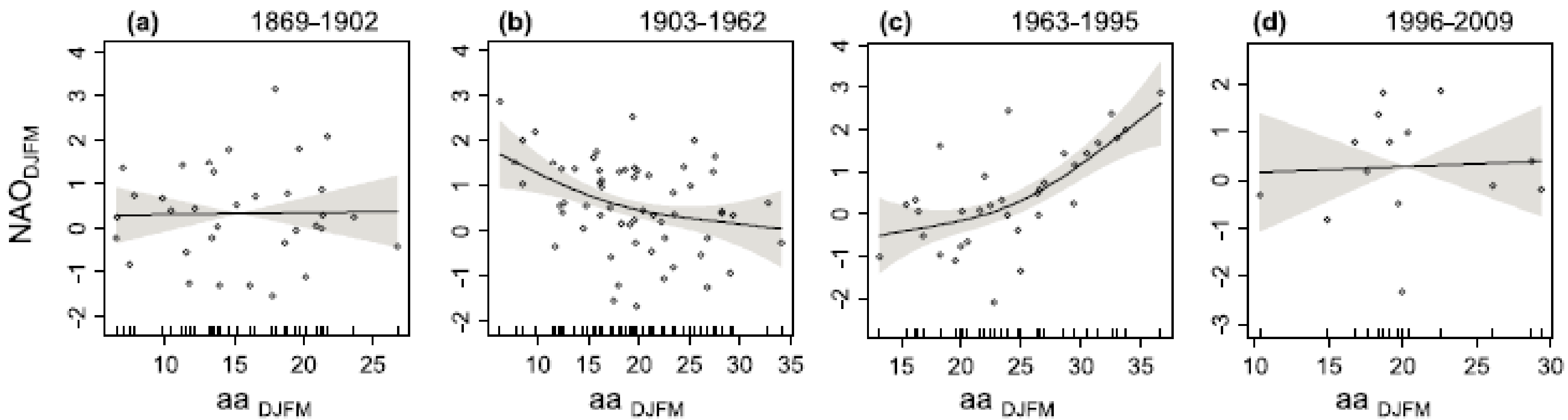


Figure 4. Same as Figure 1a but for the subperiods of (a) 1869–1902, (b) 1903–1962, (c) 1963–1995, and (d) 1996–2009. See Table 2 for detailed statistical estimates.

- Multidecadal modulation of the relationship between winter geomagnetic activity and the NAO by solar activity signifies that **the Sun is more likely to affect lower atmosphere by multiple mean** and **the effects of solar and geomagnetic activity take place with different timescales.**

AIM OF THE STUDY

- to compare the effects of solar and geomagnetic activity on the distribution of geopotential height (GPH) anomalies in the winter period (December-March) of years 1950-2002

DATA AND PROCESSING

- The distribution of **GPH anomalies** in lower atmosphere is described by 60-day anomalies from their long-term (1950-2002) daily average at 20 hPa/850 hPa.
- The **60-day mean values** of solar/geomagnetic activity and GPH anomalies were calculated in five-day step over whole winter period.
- The GPH data were obtained from NCEP/NCAR reanalysis data, Boulder, USA.
- The values of sunspot number R and geomagnetic Kp index were adopted from NOAA Geophysical Data Center, Boulder, USA.

DATA AND PROCESSING

- In view of papers describing the change in the lower atmosphere data around the year 1970 (Thompson et al., 2000, 2010; Thejll et al., 2003; Li et al., 2011), the analyzed interval 1950-2002 was divided into two parts: **1950-1969 and 1970-2002**.

- The analysis was carried out using **composite maps** representing distribution of 60-day GPH anomalies in the time of high solar activity ($R \geq 100$), as well as high geomagnetic activity ($\Sigma Kp \geq 20$).

- Each studied 60-day interval contained all cases which are characterized by an average 60-day value of index $R \geq 100$, and the daily sum of geomagnetic index $\Sigma Kp \geq 20$.

- The relevance of GPH anomalies was estimated using the Monte Carlo nonparametric test (Lu et al., 2007). The results of test show on highlight regions which should be paid more attention.

RESULTS

1. **Time interval 1950 - 1969**

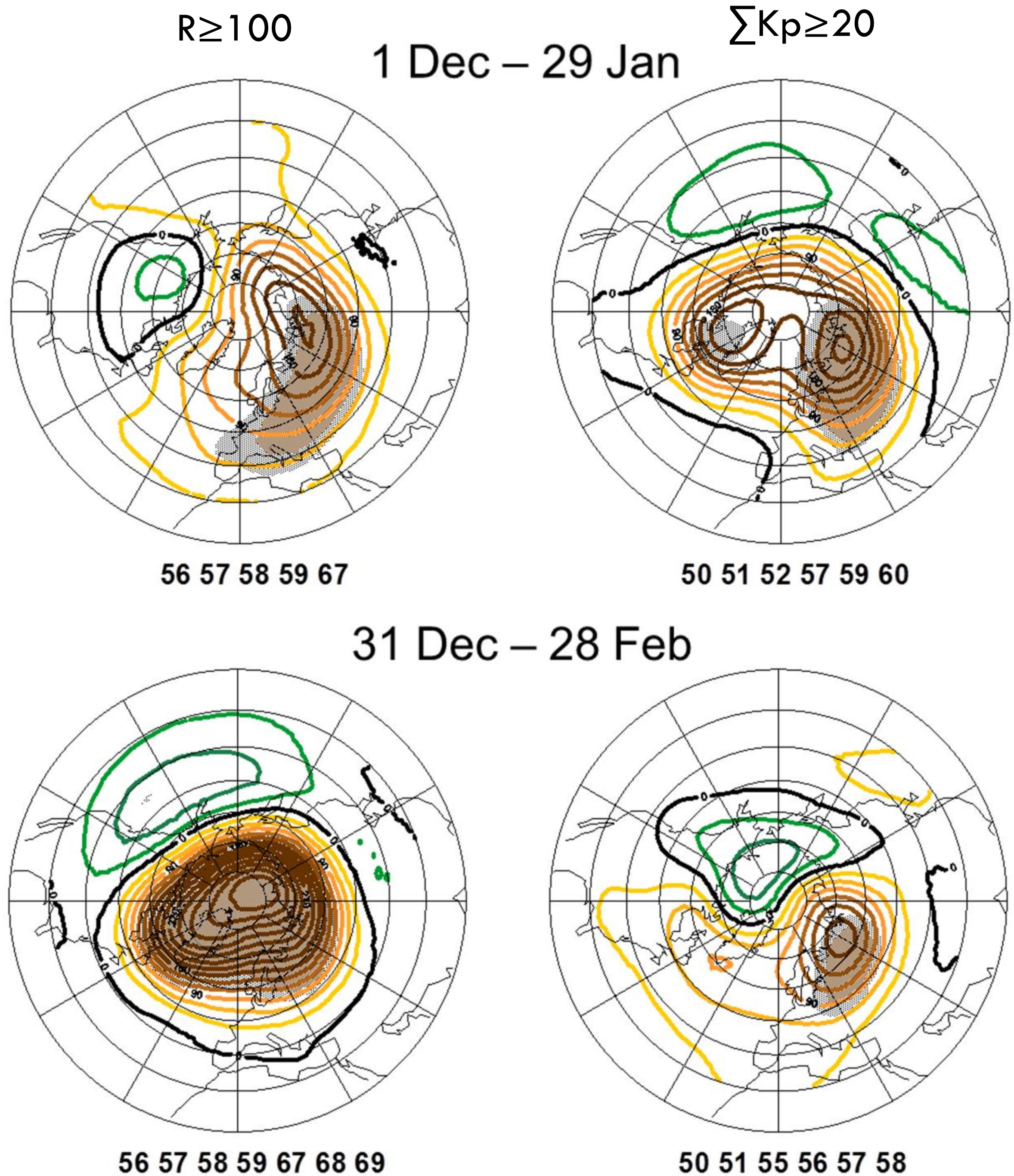
$R \geq 100$; $\Sigma Kp \geq 20$

- stratosphere (20 hPa)
- lower troposphere (850 hPa)

1950 - 1969

STRATOSPHERE (20 hPa)

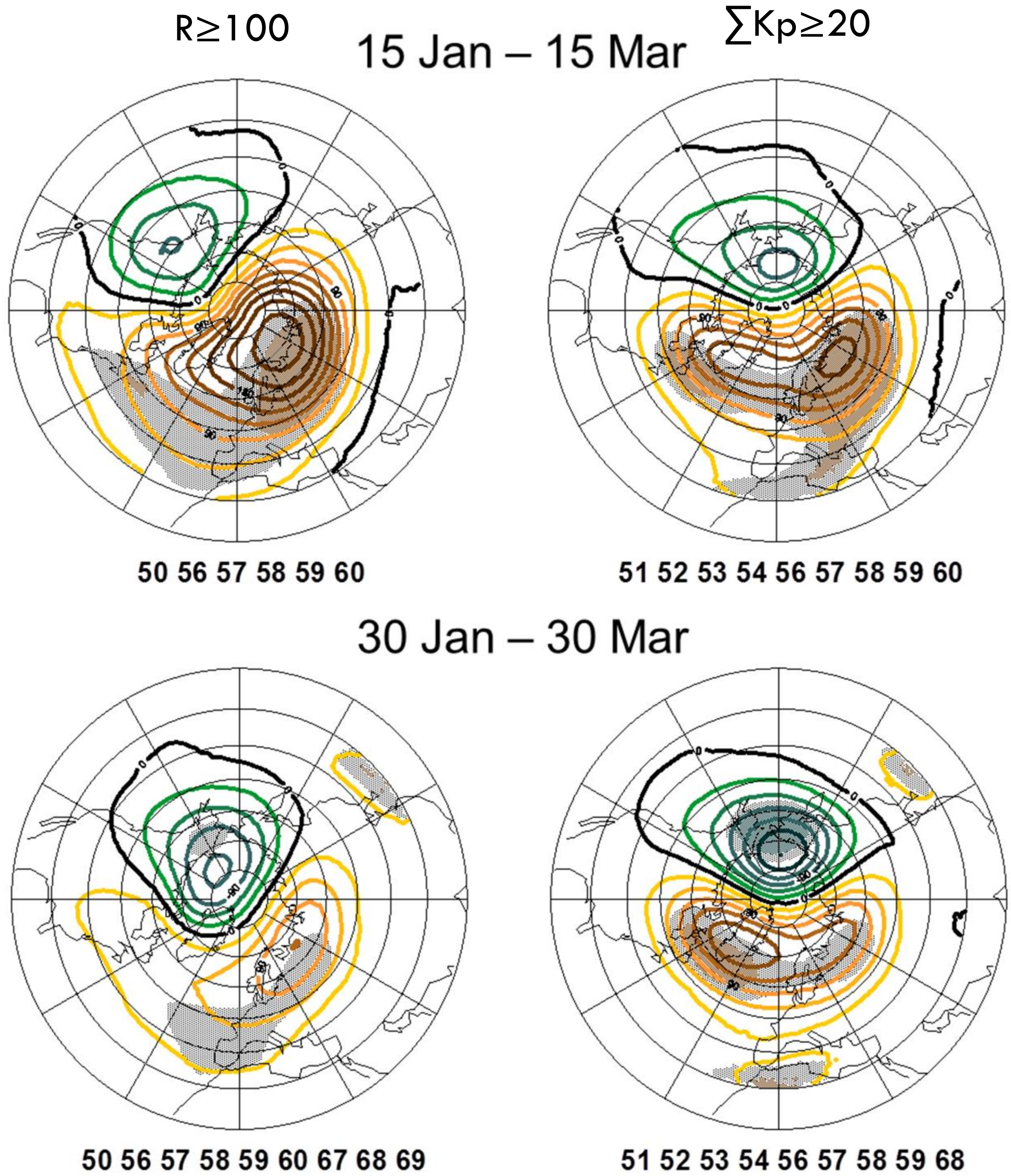
- **high solar as well as high geomagnetic activity was associated with the occurrence of significant pozitive anomaly in the polar region**



1950 - 1969

STRATOSPHERE (20 hPa)

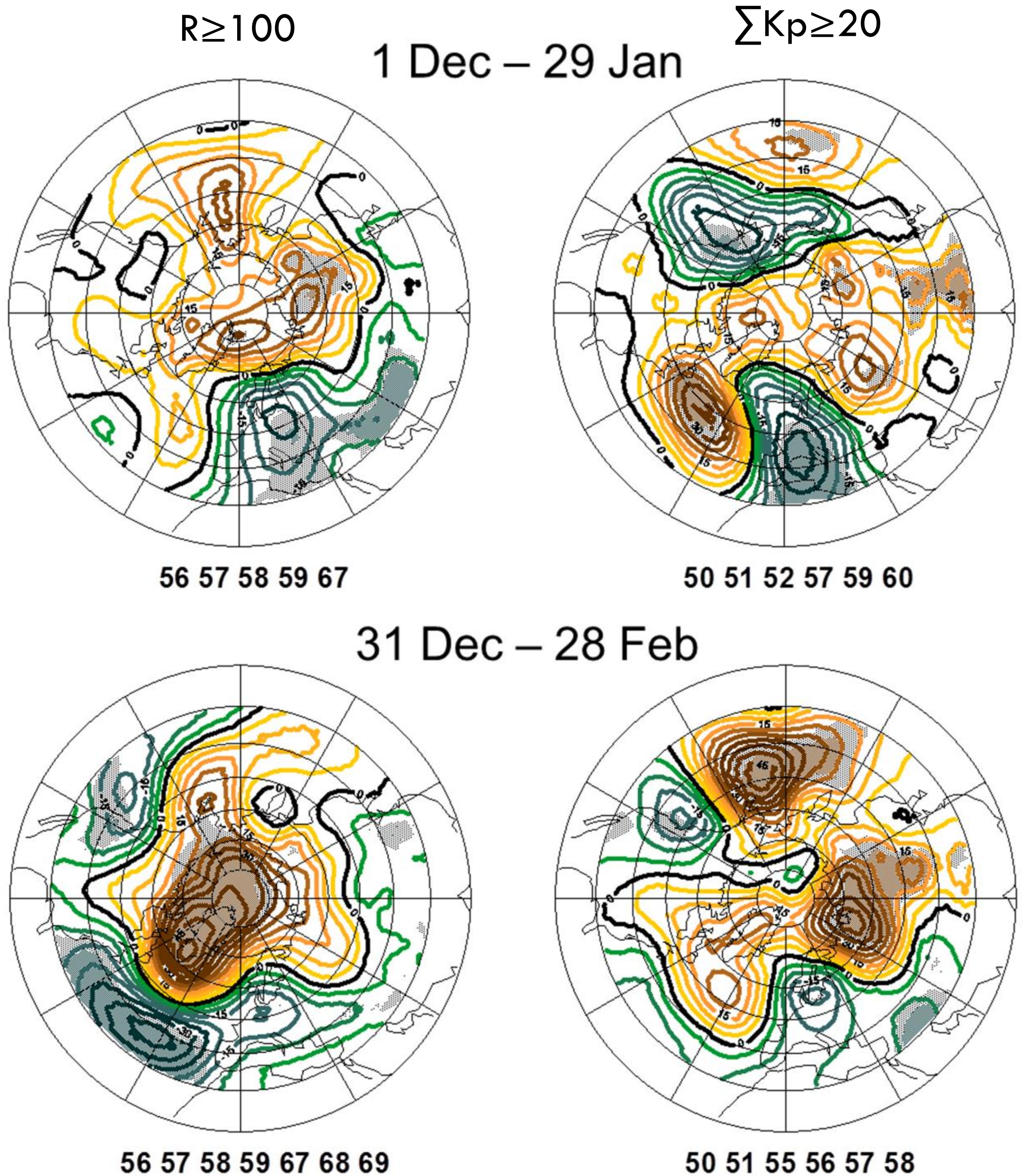
- **high solar as well as high geomagnetic activity was associated with the occurrence of significant pozitive anomaly in the polar region**



1950 - 1969

TROPOSPHERE (850 hPa)

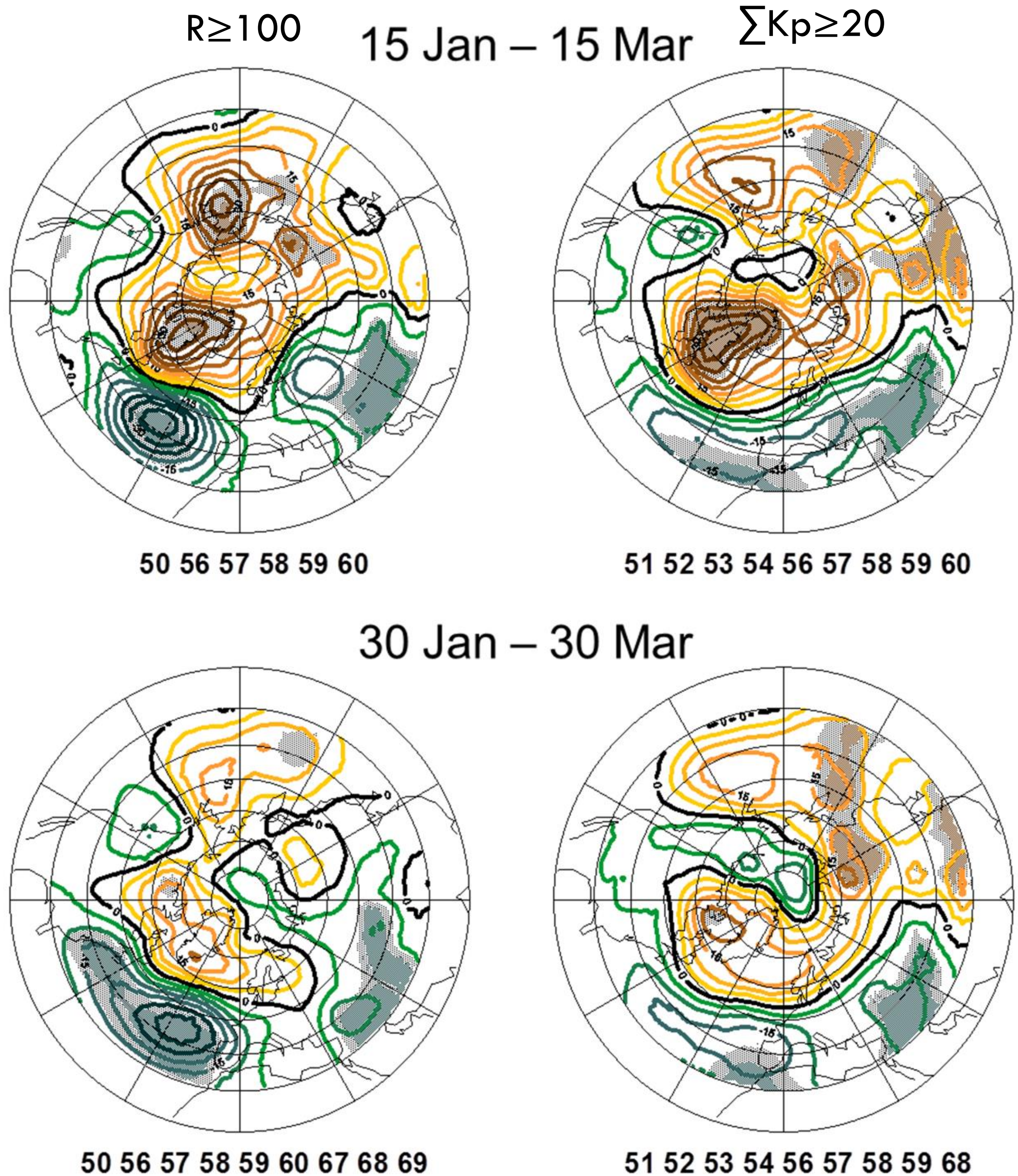
- **pronounced GPH anomalies are detected only during the second half of the winter period. The distribution of GPH anomalies on the maps compiled with regard to solar activity was similar to the distribution on the maps compiled with regard to geomagnetic activity**



1950 - 1969

TROPOSPHERE (850 hPa)

- **pronounced GPH anomalies are detected only during the second half of the winter period. The distribution of GPH anomalies on the maps compiled with regard to solar activity was similar to the distribution on the maps compiled with regard to geomagnetic activity**



RESULTS

2. Time interval 1970 - 2002

R≥100; ΣKp<20 R<100; ΣKp≥20 R≥100; ΣKp≥20

- stratosphere (20 hPa)
- lower troposphere (850 hPa)

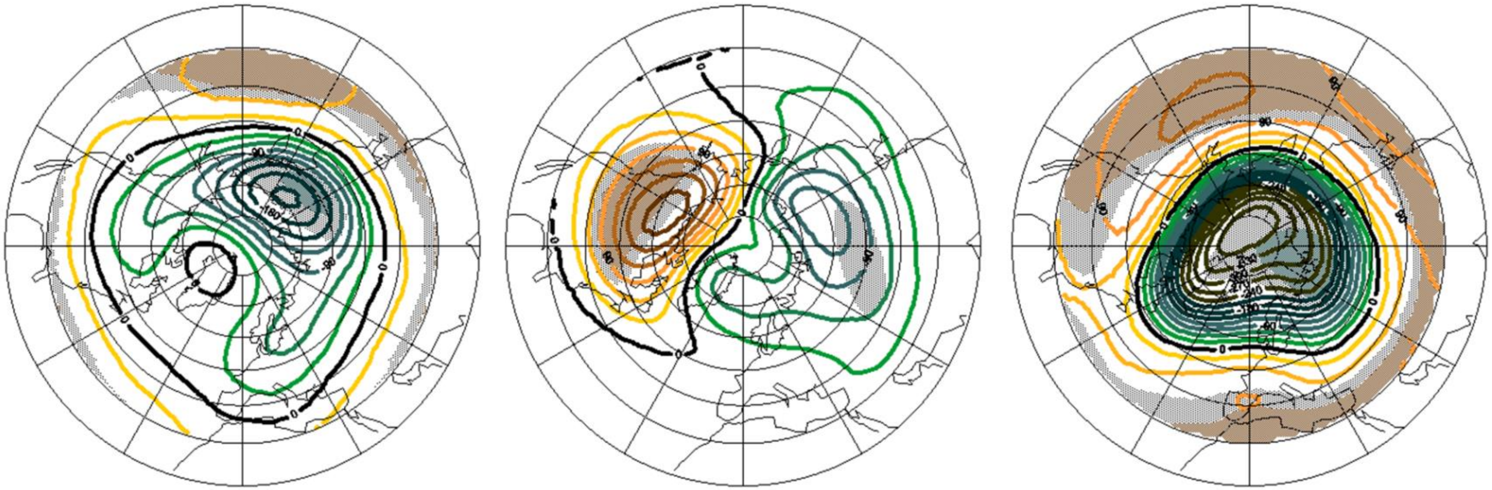
✓ 60-day intervals with high solar activity (R≥100), as well as 60-day intervals with high geomagnetic activity (ΣKp≥20), occur in the interval 1970-2002 frequently enough to be able to select a sufficient number of situations with (R≥100; ΣKp<20), (R<100; ΣKp≥20) and (R≥100; ΣKp≥20) from these 60-day intervals.

STRATOSPHERE
(20 hPa)

1970 - 2002

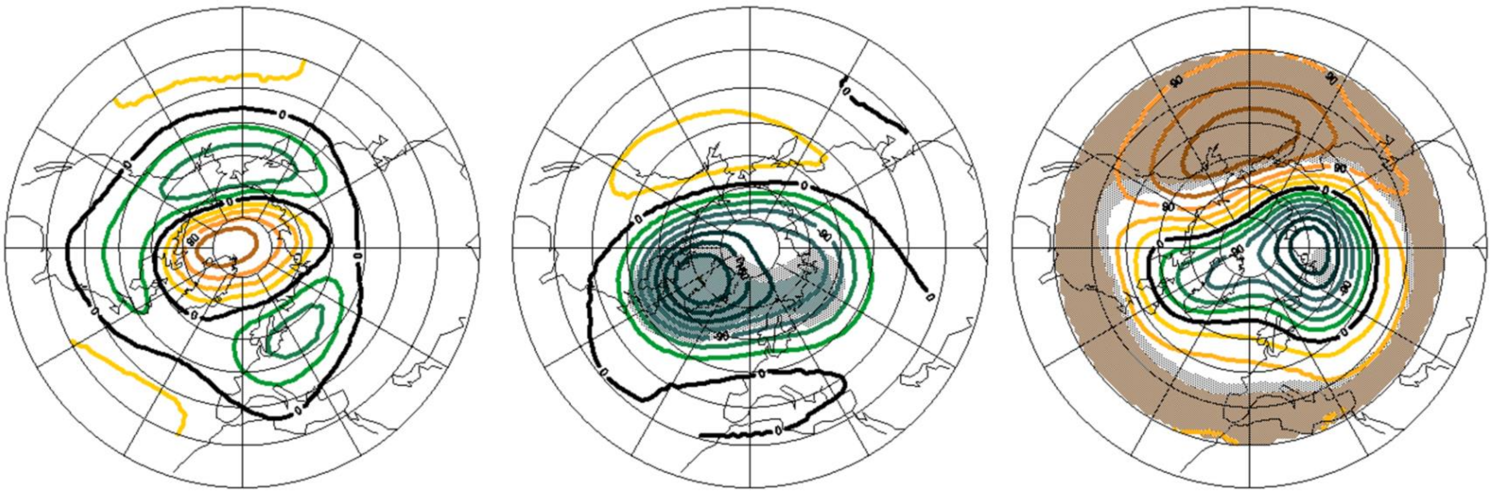
R≥100; ∑Kp<20 | R<100; ∑Kp≥20 | R≥100; ∑Kp≥20

1 Dec – 29 Jan



78 79 80 81 90 01 | 74 82 84 92 93 | 88 89 91

31 Dec – 28 Feb

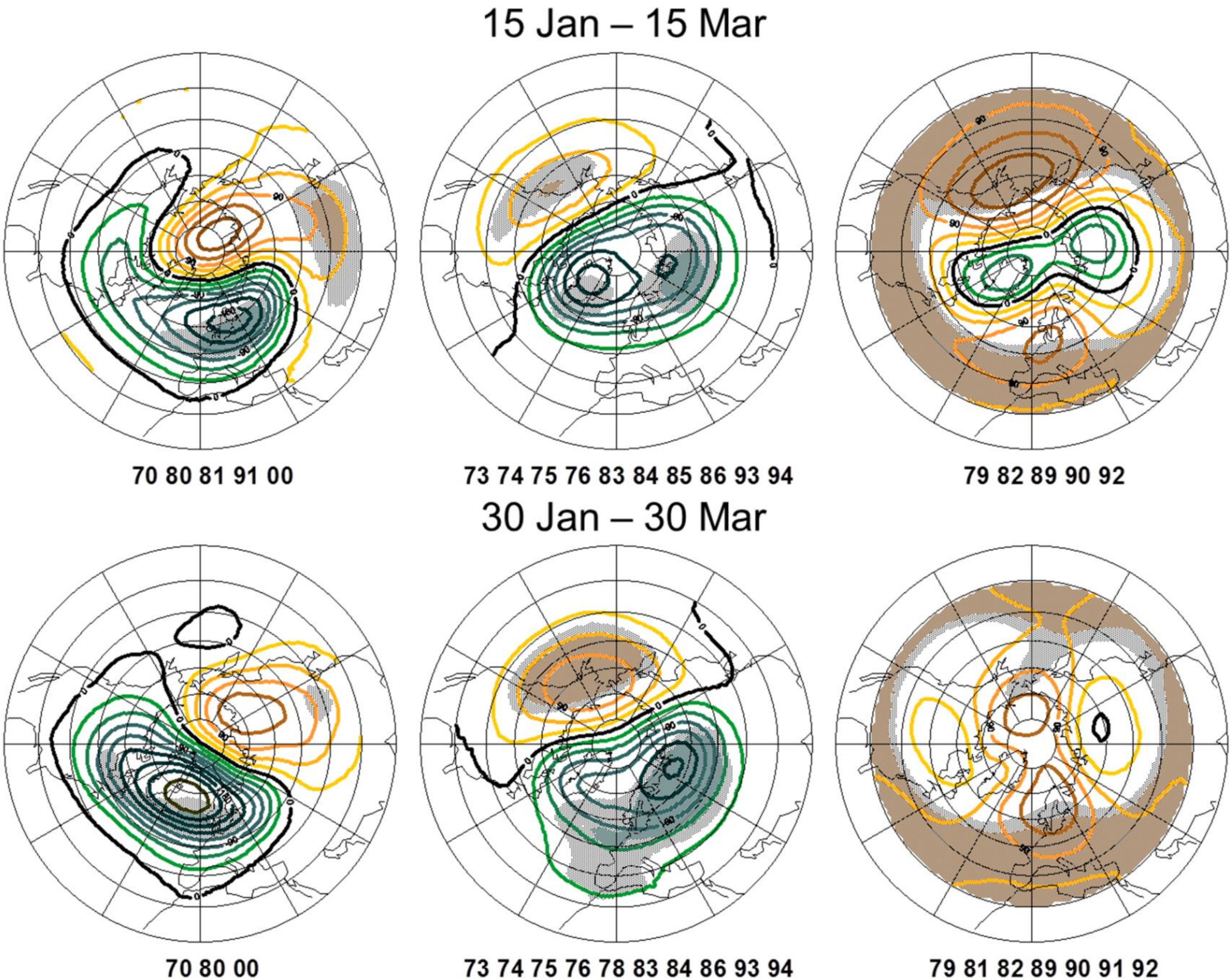


79 80 90 01 | 72 73 74 75 82 83 84 85 92 93 99 02 | 78 81 88 89 91

STRATOSPHERE
(20 hPa)

1970 - 2002

R≥100; ∑Kp<20 | R<100; ∑Kp≥20 | R≥100; ∑Kp≥20



1970 – 2002, Stratosphere (20 hPa)

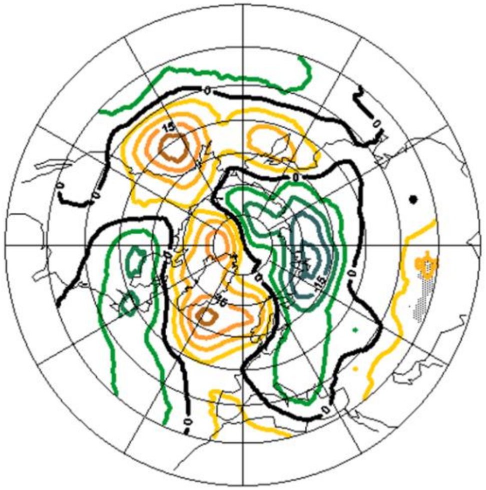
- Pozitive GPH anomalies at lower and middle latitudes – **high solar activity attenuates the Brewer-Dobson (DB) circulation**.
  - Weaker BD circulation means **weaker upwelling in the equatorial lower stratosphere**.
    - Pozitive ozone anomalies, pozitive temperature anomalies are reflected in pozitive GPH anomalies.

TROPOSPHERE
(850 hPa)

1970 - 2002

R≥100; ∑Kp<20 | R<100; ∑Kp≥20 | R≥100; ∑Kp≥20

1 Dec – 29 Jan



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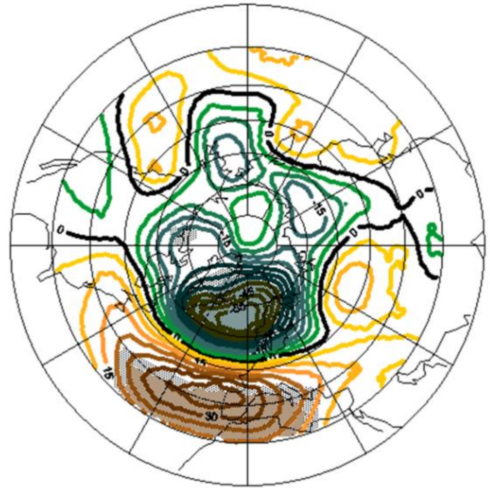

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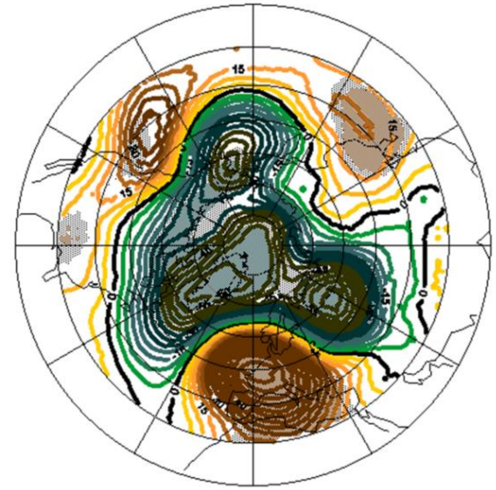

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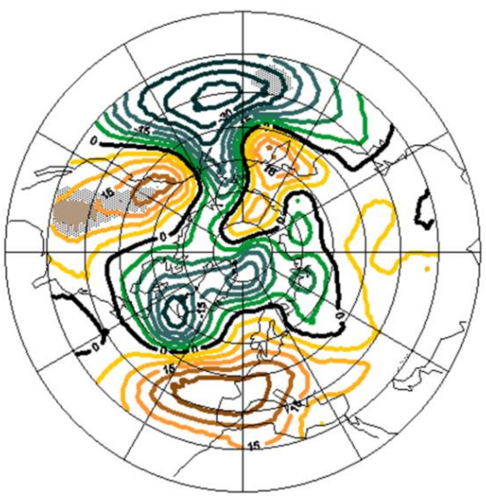
31 Dec – 28 Feb



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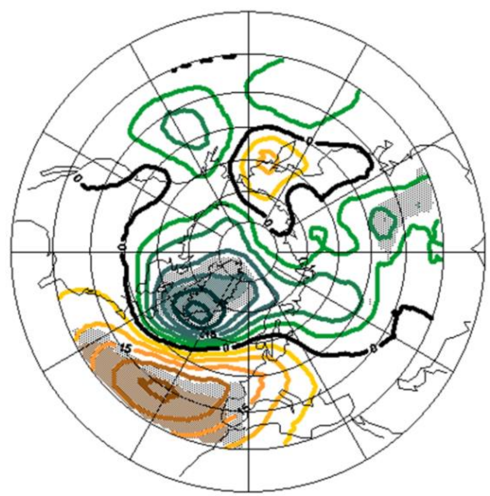

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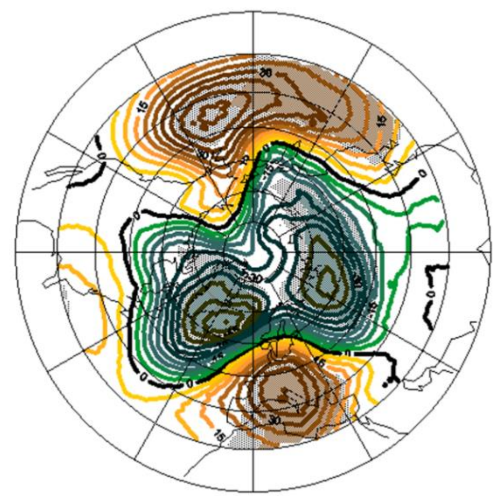

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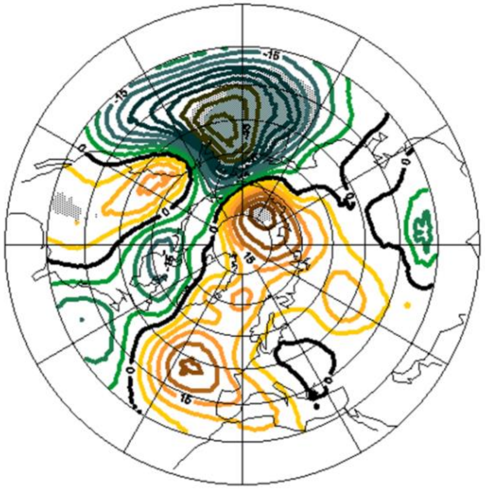
TROPOSPHERE
(850 hPa)

1970 - 2002

$R \geq 100$; $\sum Kp < 20$ | $R < 100$; $\sum Kp \geq 20$ | $R \geq 100$; $\sum Kp \geq 20$

15 Jan – 15 Mar



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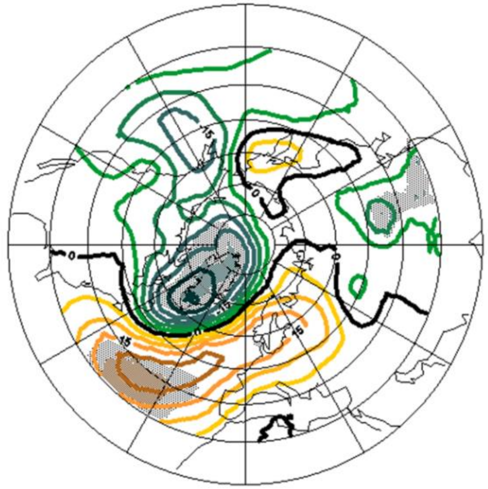

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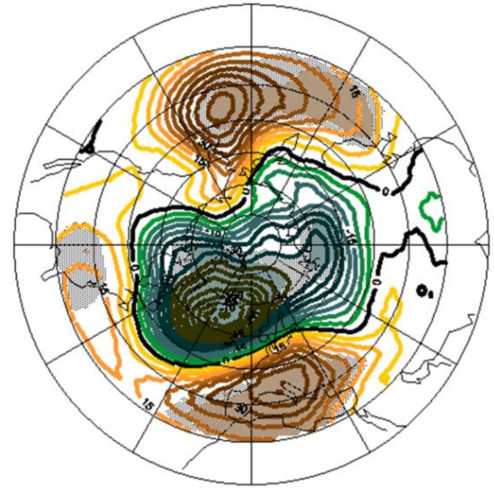
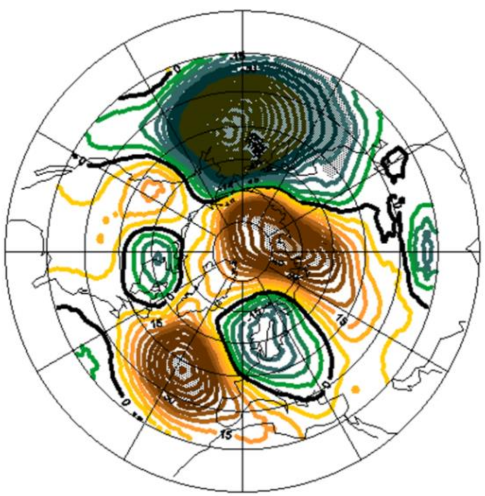


79 82 89 90 92

30 Jan – 30 Mar



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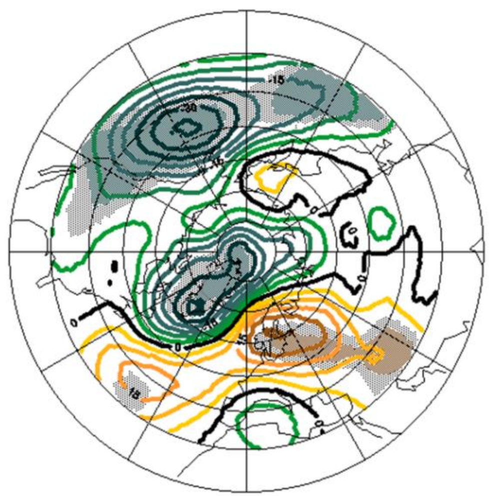

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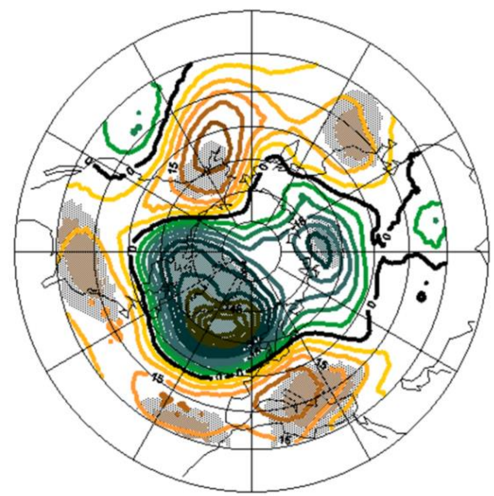

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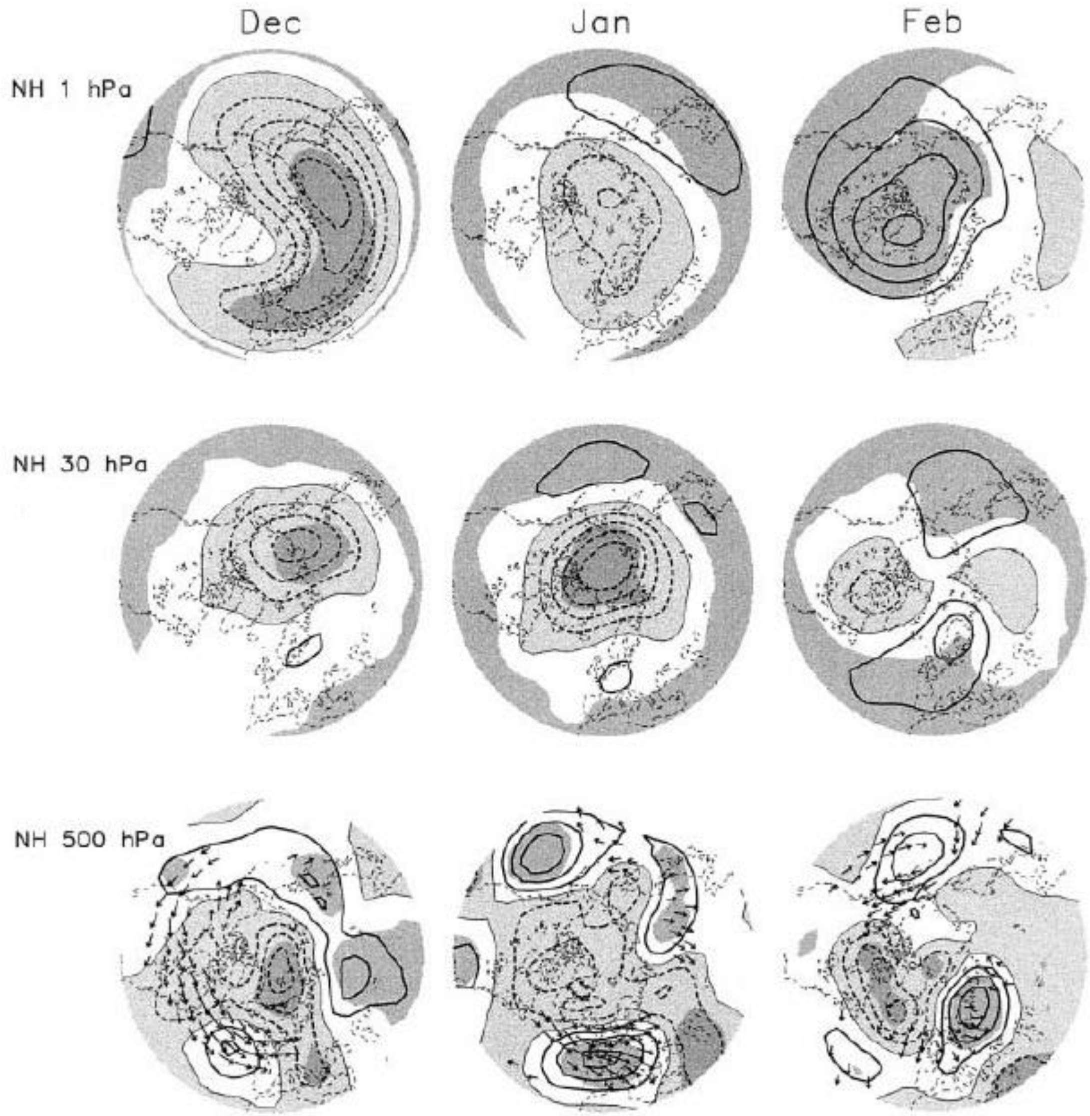


Fig. 7. Time evolution of the geopotential height differences between solar maximum and minimum from December to February in the Northern Hemisphere winter. Levels of 1 hPa, 30 hPa, and 500 hPa are shown at upper, middle, and lower panels, respectively. Contour intervals for 1-hPa, 30-hPa, and 500-hPa levels are 200 m, 100 m, and 30 m, respectively, and contours of negative value are shown by dashed line. Light shading indicates negative areas, and thick shading indicates areas where absolute values of Student's-t are larger than 1.5. Arrows at 500-hPa levels show the difference of the horizontal component of wave activity flux by Plumb (1985).

Kuroda and Kodera (J. Met. Soc. Jap., 2002)

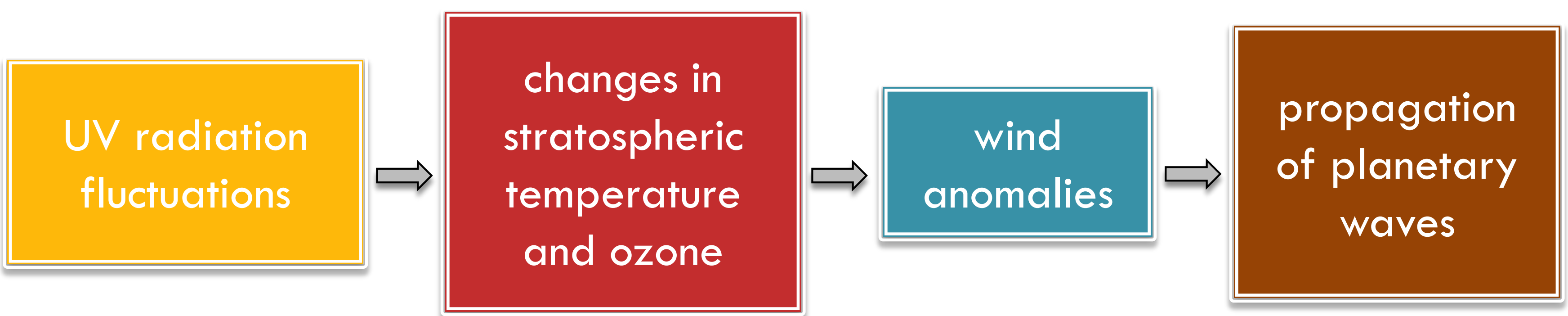
Interval of years 1979-1999

MECHANISMS: Solar activity

- The UV radiation fluctuations can induce significant **changes in stratospheric temperature and ozone**.

  - Variations in both ozone and temperature in the stratosphere could induce **wind anomalies** and therefore influence the **propagation of planetary waves** in the winter hemisphere.

(Balachandran and Rind, 1995; Balachandran et al., 1999; Haigh, 1996, 2003; Gray et al., 2010; Marchand et al., 2012)



MECHANISMS: Geomagnetic activity

- The solar wind modulates the current flow in the global electric circuit, evidently causing changes in the temperature and wind dynamics in the troposphere.

  (Lundstedt, 1984; Tinsley, 2000)

- The solar-wind generated disturbance in the ionosphere propagates downward through the atmosphere.

  (Boberg and Lundstedt, 2002 in accord with Richmond and Thayer, 2000)

- The solar wind induced geomagnetic activity may perturb atmospheric circulation dynamically through a change in planetary wave reflection conditions.

  (Arnold and Robinson, 2001)

- Energetic particle precipitations (EPP) associated with geomagnetic activity affect processes in the lower atmosphere.

  (Lu et al., 2007, 2008; Seppälä et al., 2009)

CONCLUSIONS

1950-1969

Stratosphere (R≥100; ΣKp≥20)

- significant **pozitive GPH anomalies** in the polar region

Troposphere (R≥100; ΣKp≥20)

- **pronounced GPH anomalies** in the second half of the winter period
- distribution of GPH anomalies **resembled the negative phase of the NAO**

CONCLUSIONS

1970-2002, Stratosphere

$R \geq 100$; $\Sigma Kp < 20$

- **negative GPH anomalies** in the polar region at the beginning and end of the winter period

$R < 100$; $\Sigma Kp \geq 20$

- **negative GPH anomalies** in the polar region in the course of the whole winter period

$R \geq 100$; $\Sigma Kp \geq 20$

- **pronounced negative GPH anomalies** in the polar region, with the exception of the end of the winter period

CONCLUSIONS

1970-2002, Troposphere

$R \geq 100$; $\Sigma Kp < 20$

- **negative GPH anomalies** over the Pacific in the second half of the winter period

$R < 100$; $\Sigma Kp \geq 20$

- the distribution of **GPH anomalies resembled the pozitive phase of the NAO**

$R \geq 100$; $\Sigma Kp \geq 20$

- **pronounced GPH anomalies**, the distribution of which **resembled the pozitive phase of the NAO** and the see-saw pattern between the Mediterranean and the Russian regions

CONCLUSIONS

- The composite maps, constructed from the sets ($R \geq 100$; $\Sigma Kp < 20$), ($R < 100$; $\Sigma Kp \geq 20$) and ($R \geq 100$; $\Sigma Kp \geq 20$) indicate that, in 1970-2002, ***changes occurred in the distribution of the anomalous GPH values over the Atlantic and Eurasia, mainly in connection with the change of geomagnetic and not solar activity.***

- A close relationship between solar activity and the changes of atmospheric fields in the lower troposphere can be explained by ***temporal concurrence of high values of solar and geomagnetic activity.***

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Thank you for your attention!

Circulation changes in the winter lower atmosphere and long-lasting solar/geomagnetic activity

J. Bochníček[1], H. Davídkovová[1,2], P. Hejda[1], and R. Huth[2,3]

[1]Institute of Geophysics, Academy of Sciences of the Czech Republic, Boční II/1401, 141 31 Prague, Czech Republic
[2]Faculty of Science, Charles University, Albertov 6, 128 43 Prague, Czech Republic
[3]Institute of Atmospheric Physics, Academy of Sciences of the Czech Republic, Boční II/1401, 141 31 Prague, Czech Republic

Correspondence to: J. Bochníček (jboch@ig.cas.cz)

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Abstract. The paper describes the association between high long-lasting solar/geomagnetic activity and geopotential height (GPH) changes in the winter lower atmosphere, based on their development in the Northern Hemisphere in the winter periods (December–March) of 1950–1969 and 1970–2002. Solar/geomagnetic activity is characterised by the 60-day mean of the sunspot number R/by the 60-day mean of the daily sum of the Kp index. The GPH distributions in the lower atmosphere are described by 60-day anomalies from their long-term daily average at 20 hPa/850 hPa. The data

The distribution of GPH anomalies in the lower troposphere was substantially affected by situations in which, together with high solar activity, also high geomagnetic activity occurred.

Keywords. Magnetospheric physics (General or miscellaneous) – Meteorology and atmospheric dynamics (General circulation) – Solar physics, astrophysics, and astronomy (General or miscellaneous)