Phase coherence between solar/geomagnetic activity and climate variability from stratosphere to troposphere and North Atlantic Oscillation

Milan Paluš[1] and Dagmar Novotná[2]

[1]Institute of Computer Science, [2]Institute of Atmospheric Physics, AS CR, Prague, Czech Republic

Abstract

- Beginning from 1950's, Paluš and Novotná (J. Atmos.Sol.-Terr. Phys. 71, 923–930, 2009) observed statistically significant phase coherence among oscillatory modes with the period of approximately 7–8 years detected in monthly time series of sunspot numbers, geomagnetic activity aa index, NAO index and near-surface air temperature from several mid-latitude European stations.
- Using again the oscillatory modes with the period 7–8 years, here we study longitudinal, latitudinal and altitudinal patterns of phase coherence between solar/geomagnetic activity and NCEP/NCAR and ERA40 monthly mean air temperature.
- Applying the conditional phase coherence, we identify the role of the North Atlantic Oscillation (NAO) in transfer of solar/geomagnetic influence from the stratosphere to the troposphere.

Northern Hemisphere patterns of phase coherence

- Paluš and Novotná (Nonlin. Processes Geophys., 18, 251-260, 2011) studied Northern Hemisphere patterns of phase coherence between solar/geomagnetic activity and NCEP/NCAR and ERA40 near-surface air temperature in period 7-8 years oscillatory modes.
- Both the reanalysis datasets provide consistent patterns of areas with marked phase coupling between solar/geomagnetic activity and climate variability observed in continuous monthly data, independent of the season, however, confined to the temporal scale related to the oscillatory periods about 7-8 years.

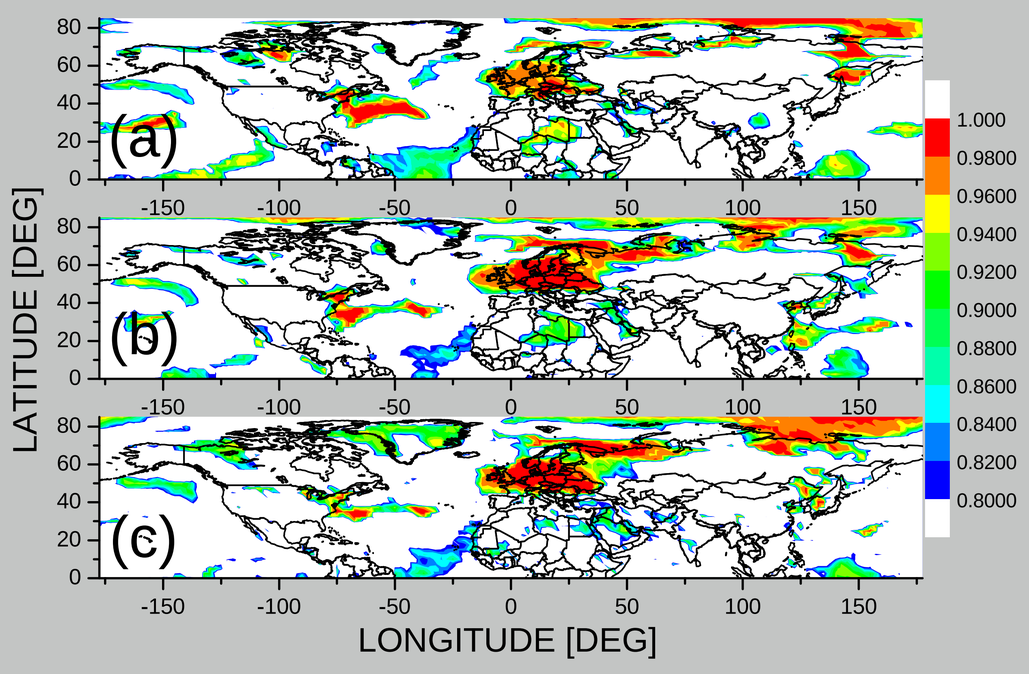


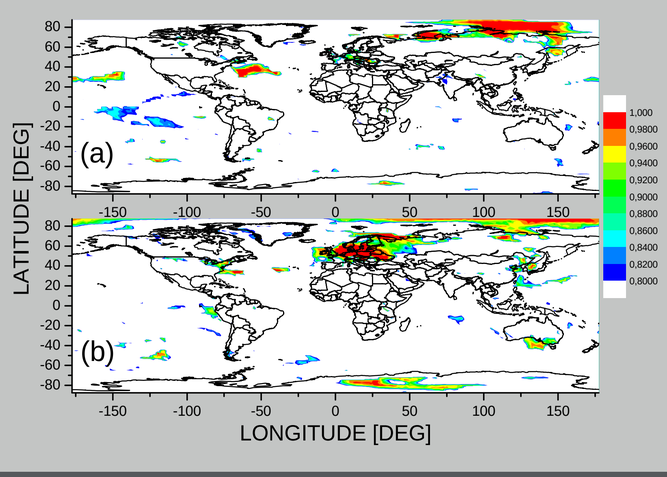
Fig. 1. Significance for phase coherence between (a) NCEP/NCAR surface air temperature (SAT) and geomagnetic aa-index; (b) NCEP/NCAR SAT and NAO index; (c) ERA40 SAT and NAO index; for the oscillatory modes with the period 7–8 years.

All figures show surrogate data (null hypothesis of independence) percentile crossed by the actual coherence values. I.e., for values larger than 0.96 (orange) the coherence is significant on $p < 0.04$, for values larger than 0.98 (red) the coherence is significant on $p < 0.02$.

Note that areas of phase coherence of SAT with the aa-index are confined within the areas of phase coherence between SAT and NAO.

Conditional phase coherence: surface

Fig. 2. Significance for the conditional phase coherence: (a) coherence between SAT and aa-index conditioned on NAO; (b) coherence between SAT and NAO conditioned on aa-index; for the oscillatory modes with the period 7–8 years.



Conditional phase coherence: stratosphere

Fig. 3. Significance for (a) coherence between isobaric level 30 hPa air temperature and aa-index; (b) conditional coherence between 30 hPa air temperature and aa-index conditioned on NAO index; for the oscillatory modes with the period 7–8 years.

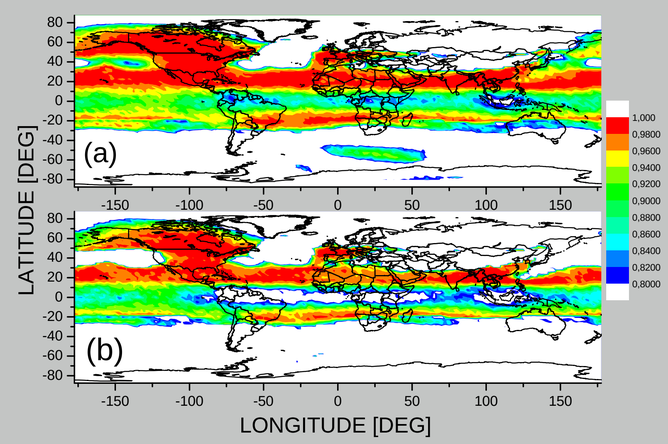
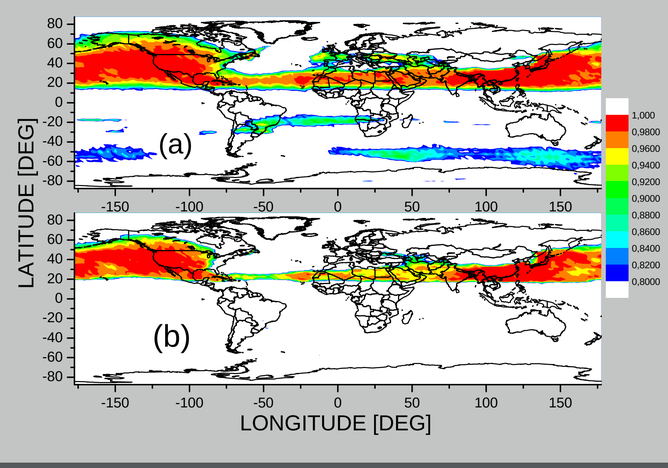


Fig. 4. Significance for (a) coherence between isobaric level 30 hPa air temperature and NAO index; (b) conditional coherence between 30 hPa air temperature and NAO index conditioned on aa-index; for the oscillatory modes with the period 7–8 years.



Conditional phase coherence: from stratosphere to troposphere

Fig. 5. Significance for coherence between (a) temperature and aa-index; (b) temperature and aa-index conditioned on NAO index; (c) temperature and NAO index; (b) temperature and NAO index conditioned on aa-index; for the oscillatory modes with the period 7–8 years, for the latitude 52.5°N.

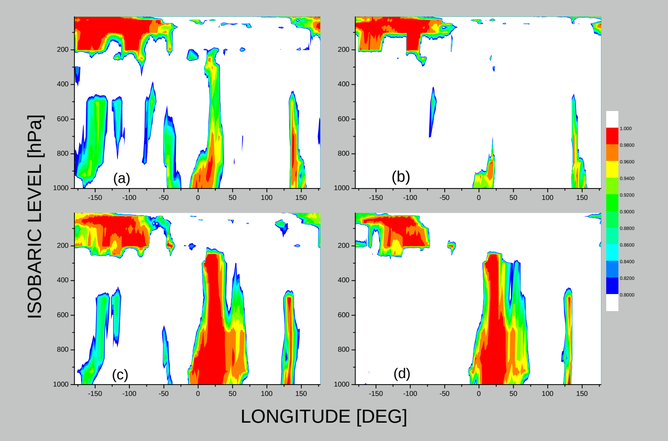
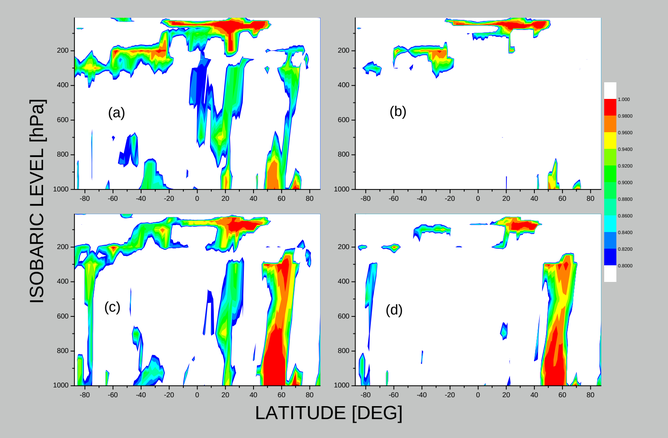


Fig. 6. Significance for coherence between (a) temperature and aa-index; (b) temperature and aa-index conditioned on NAO index; (c) temperature and NAO index; (b) temperature and NAO index conditioned on aa-index; for the oscillatory modes with the period 7–8 years, for the longitude 7.5°E.



Conclusion

- Statistical evidence for coupling between solar/geomagnetic activity and climate variability has been obtained from continuous monthly data, independent of the season, QBO phase, however, confined to the temporal scale related to oscillatory periods about 7–8 years.
- The response to solar/geomagnetic activity is not homogenously distributed over the atmosphere, but it shows latitudinal, longitudinal and altitudinal dependence.
- In the surface air temperature, as well as in the troposphere, the areas of significant coupling with geomagnetic/solar activity are confined within the areas of coupling with the NAO.
- The conditional phase coherence reveals the NAO as the variable mediating the coupling between surface/tropospheric temperature and geomagnetic activity.
- In the stratosphere the coupling temperature–geomagnetic aa-index is not affected by the NAO index.
- This analysis suggests that the NAO plays an important role in transfer of solar/geomagnetic influence from the stratosphere to the troposphere.

- **Supported by Czech Science Foundation project No. P103/11/J068.**