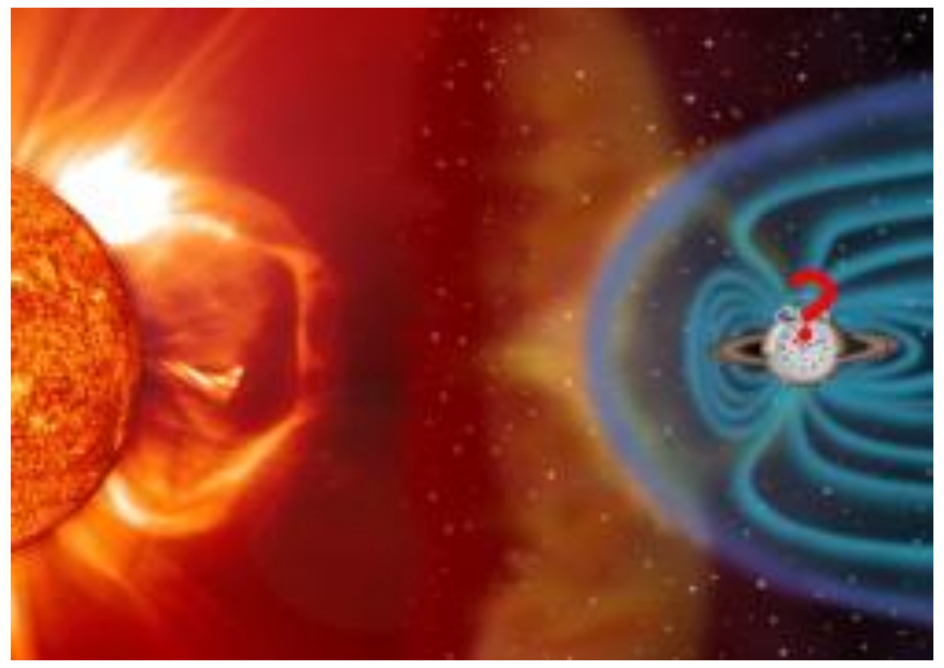
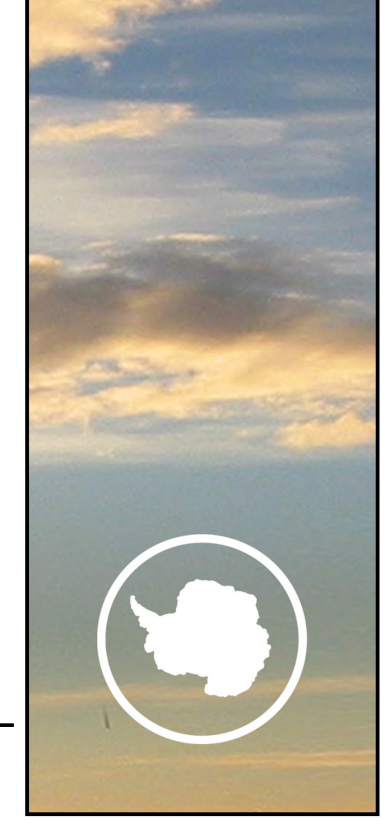


Non-linear and Non-stationary Influences of Geomagnetic Activity on the Winter North Atlantic Oscillation



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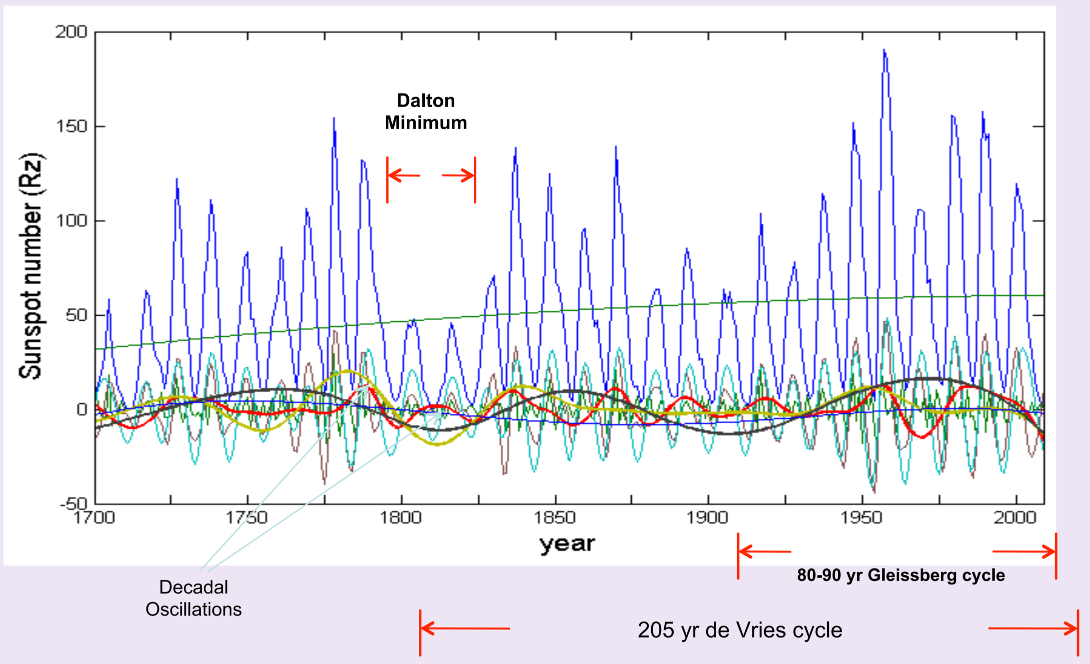
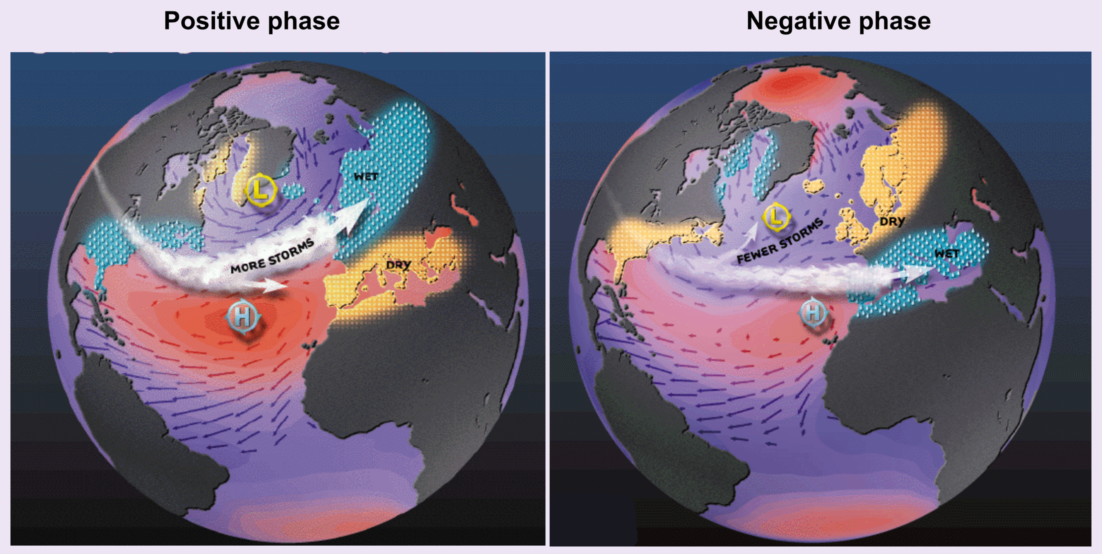
ABSTRACT: The relationship between the geomagnetic aa index and the winter North Atlantic Oscillation (NAO) has previously been found to be non-stationary, being weakly negative during the early 20th century and significantly positive since the1970s. The study reported here applies a statistical method called the Generalised Additive Modelling (GAM) technique to elucidate the underlying physical reasons. We find that the relationship between *aa* index and the NAO during Northern Hemispheric winter is generally non-linear and can be described by a concave shape with a negative relation for small to medium *aa* and a positive relation for medium to large *aa*. The non-stationary character of the *aa*-NAO relationship may be ascribed to two factors. Firstly, it is modulated by the multi-decadal variation of solar activity. This solar modulation is indicated by significant change points of the trends of solar indices around the beginning of solar cycle 14, 20 and 22 (*i.e.* ~1902/1903, ~1962/1963, and ~1995/1996). Coherent changes of the trend in the winter time NAO followed a few years later. Secondly, the *aa*-NAO relationship is dominated by the *aa* data from the declining phase of even-numbered solar cycles, implying that the 27-day recurrent solar wind streams may be responsible for the observed *aa*-NAO relationship. It is possible that an increase of long-duration recurrent solar wind streams from high latitude coronal holes during solar cycles 20 and 22 may partially account for the significant positive *aa*-NAO relationship during the last 30 years of the 20th century.

Motivation: Decadal & centennial-scale variation of the Sun and its possible effect on climate change



North Atlantic Oscillation (NAO)



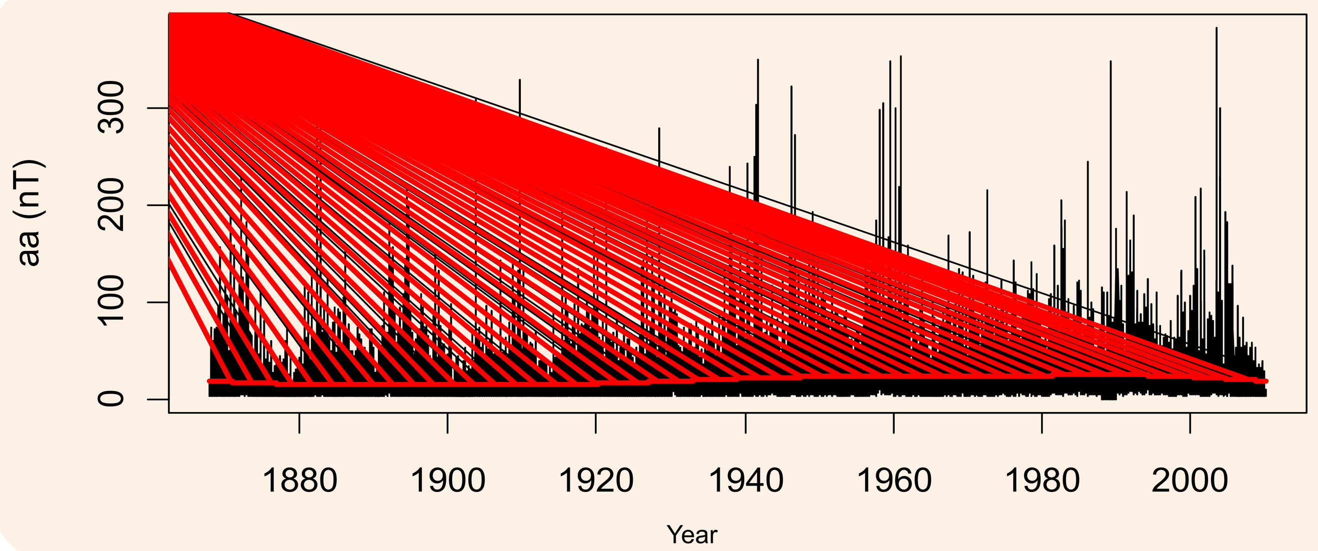
Source: http://www.ldeo.columbia.edu/res/pi/NAO/

The NAO, a dominant mode of broad-scale climate variability in the Northern Hemisphere, is most active during winter months. It is critical to understand the mechanisms that control and affect the NAO and its temporal evolution as it is associated with large variations in weather and climate over much of the globe on interannual and longer time scales.

Positive NAO phase: strengthened westerly winds over the North Atlantic Ocean. Stronger westerlies bring more warm moist air to the European continent and gives rise to milder maritime winters.

Negative NAO phase: corresponds to colder than normal European winters.

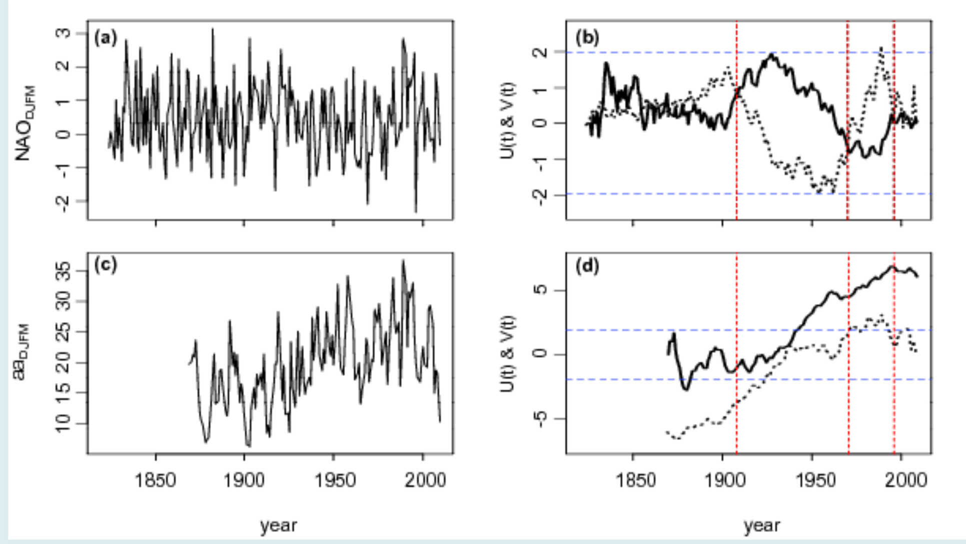
Geomagnetic *aa* index



The level of magnetic disturbance from year to year increased substantially from a low around 1900 to a high around 2003, then decreased since then

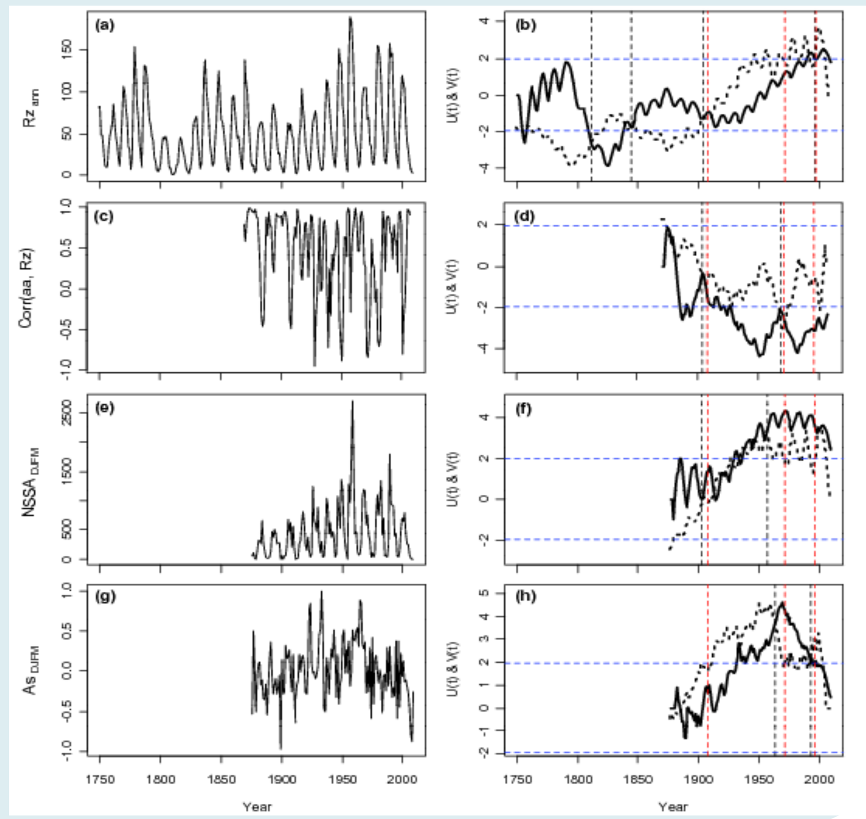
Low Frequency effect: based on sequential Mann-Kendall test

- There was no significant change in NAO trend before 1907/1908. From 1908, NAO started to decrease until 1970/1971 and then increase until 1995/1996.
- No significant change of trend in aa can be detected by SMK test. Over the extended period of 1869-2009, the long-term trend of the NAO is not statistically related to that of geomagnetic activity.

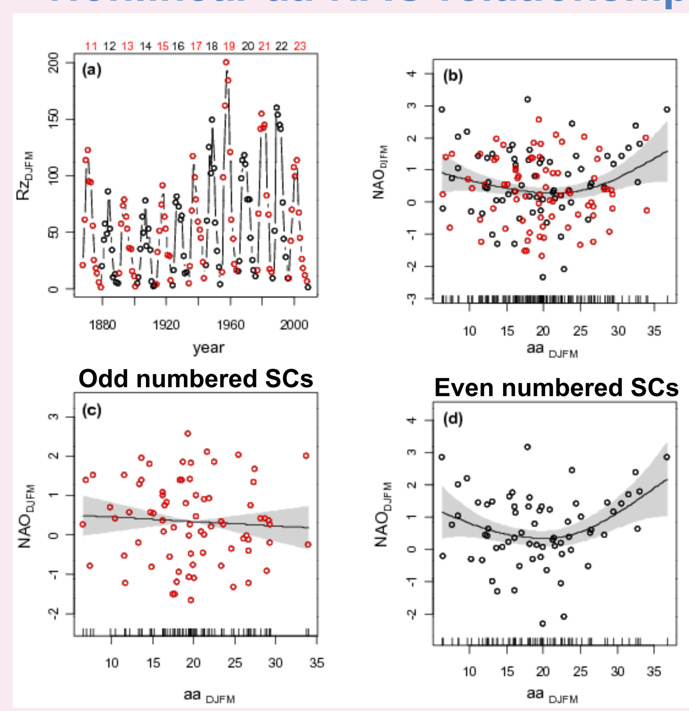


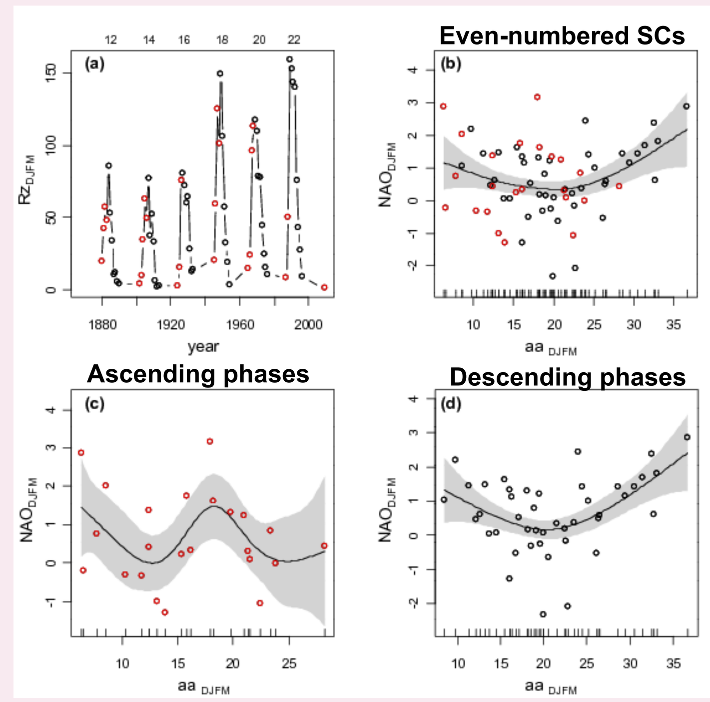
Finding 1: changes of solar activity at a multi-decadal scale might have an effect on the change of the winter NAO trend

- Change points of the trend in Rz occur just before those in the NAO while the SMK test found no long-term connection between aa and the NAO
- significant change points of the trend in corr(aa, Rz) are also found around 1903 and 1968;
- 1902 and 1957 are detected as significant change points of the trend of DJFM mean sunspot area in the Sun's North Hemisphere;
- 1963 and 1993 are found as significant change points of the trend of north-south asymmetry of sunspot number As.



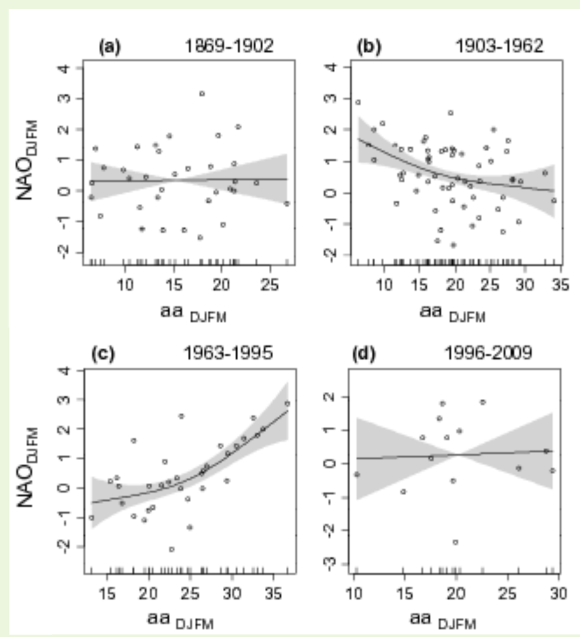
Nonlinear aa-NAO relationship: Based on Generalized Additive Model

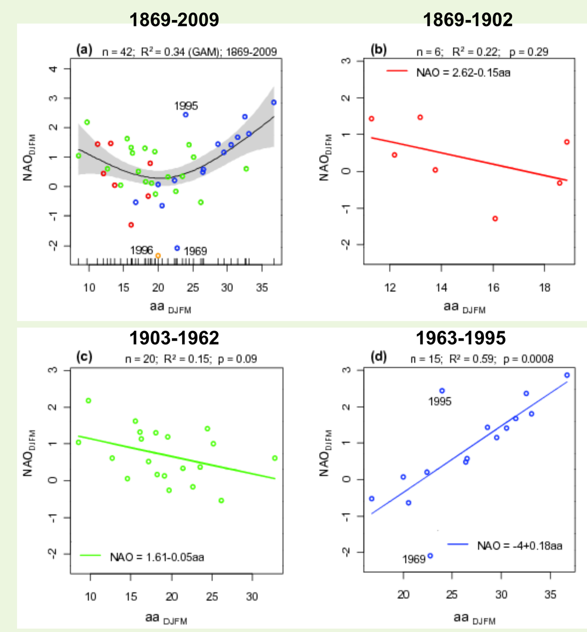




Finding 2: A non-linear aa-NAO relationship that is dominated by the declining phase of even-numbered Solar Cycles (SCs) suggesting that high speed recurrent solar wind streams may be the cause of the aa-NAO relationship.

Non-stationary behavior of the aa-NAO relationship:





Finding 3: the non-stationary behavior of the *aa*-NAO relationship may be due to a threshold response of the winter NAO to geomagnetic forcing.

Conclusion

- The *aa*-winter-NAO relationship is non-linear and non-stationary
- It is modulated by the multi-decadal variation of solar activity
- The 27-day recurrent solar wind streams may be responsible for the observed aa-NAO relationship.
- An increase of long-duration recurrent solar wind streams from high latitude coronal holes during solar cycles 20 and 22 may partially account for the significant positive *aa*-NAO relationship

Reference: Li, Y., H. Lu, M. J. Jarvisb, M. A. Clilverd and B. Bates, 2011: Non-linear and Non-stationary Influences of Geomagnetic Activity on the Winter North Atlantic Oscillation. *J. Geophys. Res.*, doi:10.1029/2011JD015822.