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RESEARCH ARTICLE

Interrelationship between the North Atlantic Oscillation and Solar cycle

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Abstract

Understanding the influence of solar variability on the Earth's climate requires knowledge of solar variability, solar interactions, and the mechanisms explain the response of the Earth's climate system.

The NAO (North Atlantic oscillation) is one of the most dominant modes of global climate variability. Like El Niño, La Niña, and the Southern Oscillation, it is considered as free internal oscillation of the climate system not subjected to external forcing. It is shown, to be linked to energetic solar eruptions. Surprisingly, it turns out that features of solar activity have been related to El Niño and La Niña, also have an significant impact on the NAO. The climate of the Atlantic sector exhibits considerable variability on a wide range of time scales. A substantial portion is associated with the North Atlantic Oscillation (NAO), a hemispheric meridional oscillation as atmospheric mass with centers of action near Iceland and over the subtropical Atlantic. NAO- has a related impacts on winter climate extend from Florida to Greenland and from northwestern Africa over Europe far into northern Asian region.

In the present work solar cycle 22 was implemented via sun spots number and area and there interrelationship with NAO index and discussed their dependency which consequently that could be used to predict the behavior of NAO index in the next solar cycle as an indicator to climatic variability.

INTRODUCTION

One of the most prominent teleconnection patterns in all seasons is the North Atlantic Oscillation (NAO) (Barnston and Livezey 1987). The NOA combines parts of the East-Atlantic and West Atlantic patterns originally identified by Wallace and Gutzler (1981) for the winter season. The NAO consists of a north-south dipole of anomalies, with one center located over Greenland and the other center of opposite sign spanning the central latitudes of the North Atlantic between 35N and 40N. The positive phase of the NAO reflects below-normal heights and pressure across the high latitudes of the North Atlantic and above-normal heights and pressure over the central North Atlantic, the eastern United States and western Europe. The negative phase reflects an opposite pattern of height and pressure anomalies over these regions. Both phases of the NAO are associated with basin-wide changes in the intensity and location of the North Atlantic jet stream and storm track, and in large-scale modulations of the normal patterns of zonal and meridional heat and moisture transport (Hurrell 1995), which in turn results in changes in temperature and precipitation patterns often extending from eastern North America to western and central Europe (Walker and Bliss 1932, van Loon and Rogers 1978, Rogers and van Loon 1979).

Strong positive phases of the NAO tend to be associated with above-averagel temperatures in the eastern United States and across northern Europe and below-average temperatures in Greenland and oftentimes across southern Europe and the Middle East. They are also associated with above-average precipitation over northern Europe and Scandinavia in winter, and below-average precipitation over southern and central Europe. Opposite patterns of temperature and precipitation anomalies are typically observed during strong negative phases of the NAO. During particularly prolonged periods dominated by one particular phase of the NAO, anomalous height and temperature patterns are also often seen extending well into central Russia and north-central Siberia.

The NAO exhibits considerable interseasonal and interannual variability, and prolonged periods (several months) of both positive and negative phases of the pattern are common. The wintertime NAO also exhibits significant multi-decadal variability (Hurrell 1995, and Bell and Chelliah 2006). For example, the negative phase of the NAO dominated the circulation from the mid-1950 through the 1978/79 winter. During this approximately 24-year interval, there were four prominent periods of at least three years each in which the negative phase was dominant and the positive phase was notably absent. In fact, during the entire period the positive phase was observed in the seasonal mean only three times, and it never appeared in two consecutive years.

The solar cycle 22 lasted 9.7 years, beginning in September 1986 and ending in May 1996. The maximum smoothed sunspot number (monthly number of sunspots averaged over a twelve-month period) observed during the solar cycle was 158.5 (July 1989), and the minimum was 8. The maximum is identical with that of solar cycle 3, making it the equal third highest peak on record. There were a total of 309 days with no sunspots during this cycle.

The odd numbered cycles tend to be more intense than their preceding even numbered cycles, and the general trend of cycle amplitudes was increasing up to cycle 23. For this reason, many researchers thought that cycle 23 might have exceeded cycle 22, the third largest in recorded history, which peaked in 1989, and could, have been larger than cycle 19, which was the largest in recorded history and which peaked in 1957-8; however, cycle 23 was not a record setter. Cycles 22 and 23 together created our previous 22-year Hale Cycle. This is shown in figure 1.

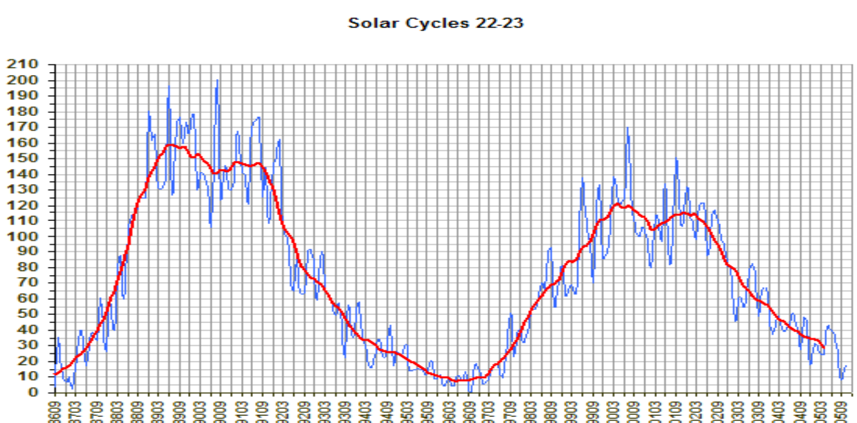

Fig. 1: solar cycle 22 and 23 (Jan Alvestad / Data from sunspot index Data center in Brussels)

Possible relation between solar activity and the Earth's

Climate has received considerable attention during the last 200 years. Periods with many sunspots and faculae correspond with periods with higher irradiance in the visual spectrum and even stronger response in the ultraviolet, which acts on the ozone level. It is also proposed that galactic cosmic rays can act as cloud condensation nuclei, which may link variations in the cloud coverage to solar activity, since more cosmic rays penetrate the Earth's magnetic field when the solar activity is low. A review of possible connections between the Sun and the Earth's climate is given by Gray and et al. (2010). Based on strong correlation between the production rate of the cosmogenic nucleids ^{14}C and ^{10}Be and proxies for sea ice drift, Bond et al. (2001) concluded that extremely weak perturbations in the Sun's energy output on decadal to millennial timescales generate a strong climate response in the North Atlantic deep water (NADW). This affects the global thermohaline circulation and the global climate. The possible sun–ocean–climate connection may be detectable in temperature series from the North Atlantic region. Since the ocean with its large heat capacity can store and transport huge amounts of heat, a time lag between solar activity and air temperature increase is expected.

At its simplest, the relationship between the solar magnetic field strength and the Earth’s climate is this: lower magnetic field strength means few sunspots, fewer sunspots means less solar wind, less solar wind means more galactic cosmic rays, more galactic cosmic rays means more low level cloud formation, more low level clouds means more sunlight reflected back into space, which in turn means less heating of the Earth’s surface and atmosphere (figure.2). Climate is not a random walk. If we can find a solar physicist to give us a prediction of solar activity, we can use that to make a prediction of climate. That prediction will be good for perhaps twenty-five years out.

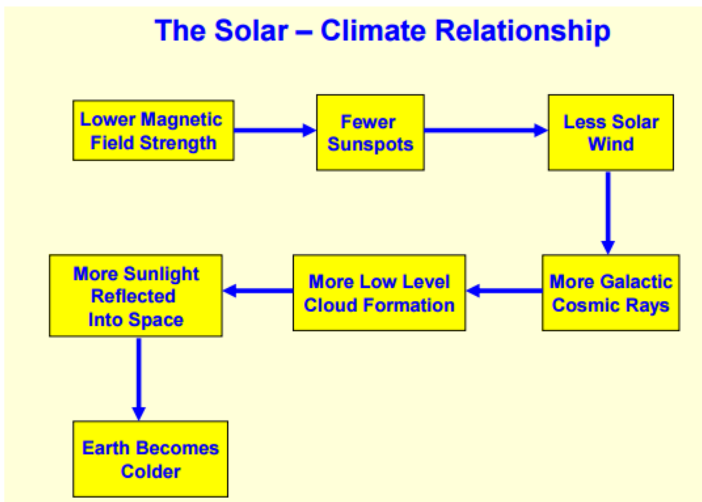

Fig.2: The Solar-Climate Relationship

Investigation of the relation between solar cycle and the NAO index

3.1 Data source:

Solar cycle 22 data is Data obtained from: (http://solarscience.msfc.nasa.gov/SunspotCycle.shtml)
NAO Data for same period of cycles22 obtained from:
(http://www.cpc.ncep.noaa.gov/data/teledoc/telecontents.shtml)

3.2 Statistics

After statistics has been done on data we got (Table 1) that shows the frequency distribution of NAO index verses the number of spots of Solar Cycle 22 and was classified as number of spots appearing per day. It also shows that NAO indices are normally distributed (fig.3) for each category of sun spot number appearing per day. We can see the peak of distribution lies between the values of -1 and 1.This normal distribution is applied for all days no matter how many spots appeared per day

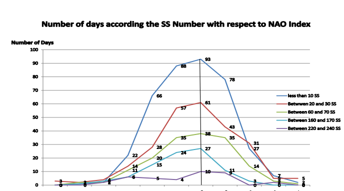

Fig. 3: Normal distribution of NAO index with respect to SS number per day.

Number of days distributed according the SS Number with respect to NAO Index intervals

NAO Index / SS Number	< -2.5	-2.5--2	-2--1.5	-1.5--1	-1--0.5	-0.5-0	0-0.5	0.5-1	1-1.5	1.5-2	>= 2	Total Days per " SS Number " interval
0-9	0	1	2	22	66	88	93	78	27	7	2	386
10-19	1	2	8	29	70	77	98	76	39	7	2	409
20-29	3	2	4	14	28	57	61	43	31	5	5	253
30-39	0	1	11	17	21	39	59	40	26	13	1	228
40-49	2	2	5	18	30	38	58	33	19	3	1	209
50-59	2	2	6	14	22	37	38	27	23	7	1	179
60-69	0	2	2	11	20	35	38	35	14	3	1	161
70-79	0	1	3	6	18	35	28	39	17	6	0	153
80-89	0	1	3	7	29	32	46	22	12	0	0	152
90-99	0	0	0	14	29	27	32	34	15	1	0	152
100-109	1	1	3	12	21	26	34	29	13	4	2	146
110-119	0	1	2	15	25	30	34	33	13	5	0	158
120-129	0	4	2	9	24	22	34	33	14	4	0	146
130-139	0	2	2	6	17	33	26	24	8	6	1	125
140-149	0	1	3	19	16	30	34	14	5	2	1	125
150-159	0	0	2	13	18	26	20	10	8	0	0	97
160-169	0	1	3	6	15	24	27	11	3	0	0	90
170-179	0	0	6	7	15	19	26	11	3	0	0	87
180-189	0	0	0	8	11	19	13	13	2	3	0	69
190-199	0	0	3	9	10	13	11	3	3	6	0	58
200-209	0	0	1	5	9	14	14	4	3	1	0	51
210-219	0	0	1	5	11	9	11	6	1	1	0	45
220 -239	0	0	2	6	5	4	10	9	0	2	0	38
240 - 269	0	0	0	1	4	6	7	5	3	2	0	28
>= 270	0	0	0	0	0	2	7	0	2	5	0	16
Total Days per "NAO Index" interval	9	24	74	273	534	742	859	632	304	93	17	3561
												Grand Total

Table 1: Sunspot Number distributed with respect to NAO index

3.2.1 Statistical analysis by chi square method:

The Test used to determine the association between two variables. The procedure of the test includes following steps:

- Calculate the chi-squared test statistic, (χ^2), which resembles a normalized sum of squared deviations.
- Determine the degrees of freedom, **df**, of that statistic, which is essentially the number of frequencies reduced by the number of parameters of the fitted distribution.
- Compare to the critical value from the chi-squared
- Distribution with **df** degrees of freedom, which in many cases gives a good approximation of the distribution of (χ^2).

Tchouproff Contingency Coefficient:

$$\rho_\tau = \sqrt{\frac{\chi^2}{n\sqrt{df}}}$$

The chi-square distribution returns a probability for the computed chi-square and the degree of freedom. A probability of zero shows a complete dependency between two categorical variables and a probability of one means that two categorical variables are completely independent.

(ρ_τ) measures the amount of dependency between two categorical variables.

$$\rho_\tau = \sqrt{\frac{152.114}{4262 * \sqrt{36}}} = 0.077$$

Thus, there is a very high dependence between **SS Number** and NAO Index.

$$\chi^2 = 152.114$$
$$df = (7-1) * (7-1) = 36$$

$$\rho_\tau = \sqrt{\frac{5.85}{140 * \sqrt{12}}} = 0.109$$

Thus, there is a very high dependence between **SS Area** and NAO Index

$\chi^2 = 5.85$ $df = (7-1) * (3-1) = 12$

3.2.2 Correlation relation

The correlation relation shows an inverse weak relation, between sunspot numbers, sunspot area and NAO index for solar cycle 22 (Table 2).

Sunspot Number

Monthly

	SS number	*NAO index*
SS number	1	
NAO index	-0.141	1

Yearly

	SS number	*NAO index*
SS number	1	
NAO index	-0.306	1

Sunspot Area

Monthly

	SS area	*NAO index*
SS number	1	
NAO index	-0.130	1

Yearly

	SS area	*NAO index*
SS number	1	
NAO index	-0.299	1

Table 2: Yearly correlation of ss. number and NAO

Conclusions:

In this paper we studied the influence of solar variability on the Earth's climate .by introducing solar variability, solar interactions, and the mechanisms determining the response of the Earth's climate system. Solar cycle 22 was implemented via sun spots number, area and there interrelationship with NAO index and discussing their dependency. A normal distribution of NAO index was found for daily distribution of sunspot number no matter how many spots were found in that day. The peak of the previously mentioned normal distribution lies between -1, 1 values of NAO indices. A very high dependence was found between sunspots number and NAO Index when a Chi square test applied. Also a very high dependence was found between sunspots area and NAO Index when a Chi square test applied. Correlation of yearly sunspot number and NAO indicates an inverse medium linear relationship that indicates change in solar cycle has an influence on climate change which is represented by the NAO index.

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