On the **lagged** solar/NAO signal: forced response or internal variability?

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Gray et al., 2010
The solar-NAO signal: observations

NAO like signal approx. 3-4 years after solar MAX

Gray et al 2013

Gray et al 2016
The solar-NAO signal: climate models (1)

NAO signal at ~ Lag 0 yr
The lagged solar-NAO signal: climate models (2)

• NAO signal at ~ lag 4 yr → Bottom-up (ocean feedback)

Scaife et al., 2013 GRL

Andrews et al., 2015 ERL
The lagged solar-NAO signal: climate models (3)

- NAO signal at ~ lag 1-2 yr

→ synchronization of decadal mode due to top-down (i.e. from the stratosphere) *145-year long simulation*

Thieblemont et al., 2015 NatComm
Objectives

• Revisit the solar/NAO relationship in multiple re-analysis products of SLP (if any, identify robust lag!)

• Examine (long) coupled model experiments with interactive ozone chemistry and realistic forcing, to assess the contribution of solar vs natural variability in driving NAO variations on decadal time-scales
SLP regression against Sunspot number in four reanalysis of 20th century
The lagged solar-NAO signal: is it robust in reanalysis data?

Chiodo et al., in prep.
Correlation arising due to stronger solar foring...?
Can we reproduce this signal in models?

- 2 runs using CESM-WACCM4 (Marsh et al., 2013), constant (2000) BCs, coupled ocean, interactive ozone chemistry ... and 500 yr long

WACCM_SOL vs WACCM_NOSOL
Solar signal in 500-yr simulation

WACCM_SOL

K / Wm-2 (annual mean)

a) 1 K warming at stratopause
b) No response in the troposphere...
Is the model’s response to solar cycle realistic...?

Excellent agreement between WACCM_SOL and SSU data, suggesting that heating is correct... so solar forcing and response are realistic.

Direct comparison with SSU satellite data (1979-2014) – Seidel et al., 2016
Solar signal in SLP
(100 year windows) lag 2 year regression

2 out of 5 windows yield NAO-like signal (300-400; 400-500)
Why is the “signal” non-stationary?

How random is this apparent solar-NAO signal?

Do “mocking” exercise...

• Perform the same lag regression, in runs without a solar cycle (i.e., using a “fake” solar index...)

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TSI-SLP regressions (with a +2 years lag) → 100-year windows with best OBS “match”
What are the odds of finding OBS signal just by chance...?

SLP (+) signals in subtropical Atlantic resembling the OBS are **not at all uncommon** in the integrations, even in those **without a solar cycle**
How can we get a “solar signal” when there is no solar forcing...?

Solar-SLP regressions (lag 2) on a sinusoidal index with $T \sim 11$ yr

The NAO-like pattern seems due to **unforced decadal variability**
Is there intrinsic decadal NAO variability, “mapping” onto indices with decadal oscillations (TSI/UV?)

30-50 yr: AMO...?

15-20 yr mode with spectral power leaking onto 10 yr

3-8 yr : ENSO...?
Variability in 1000-year piCONTROL

LENS-CAM5

NAO-like pattern arises from unforced decadal variations in SLP (even on 100-year time-scales!)
Is the lag of the correlation t-dependent?

1) Dipole of correlations (-/+), consistent with lag solar/NAO hypothesis

2) Significant negative correlation near lag 0

3) Significant positive correlations at negative lags
Key points (1)

• “NAO-like” solar signal arises 2 years after peaks of solar irradiance. We confirm earlier findings, and show that is robust in all re-analysis datasets.

• A lagged NAO signal can be reproduced in some centennial windows of a long WACCM4 run (signal is there, even though it’s sporadic...)

Chiodo et al., in prep.
Key points (2)

- A similar lagged NAO signal can also be reproduced in single centennial-long windows in simulations without a solar cycle.

- This behavior seems linked to decadal variability, which may (or may not) come into phase with the 11-year solar cycle.

- This suggests that null-hypothesis (i.e., internal variability in the NAO) cannot be rejected.

Chiodo et al., in prep.
Key points (3)

- Care is needed when interpreting lagged solar/NAO signals, in observations and centennial long model simulations (large NAO variability even on centennial t-scales, see Deser et al., 2016)

- Should we look at other regions for more robust and hence more predictable solar signals (e.g. North Pacific, or ENSO [Meehl 2009])?

Chiodo et al., in prep.