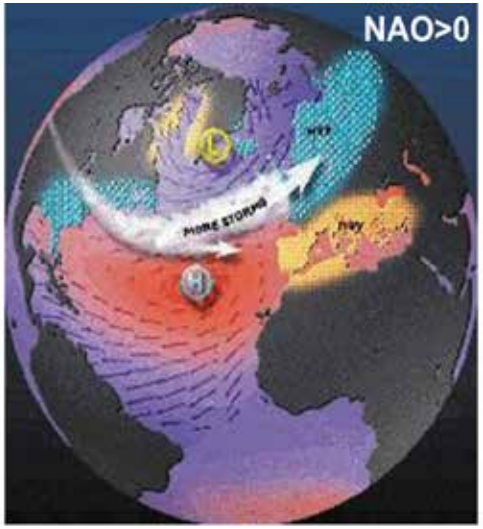
On the **lagged** solar/NAO signal: forced response or internal variability?

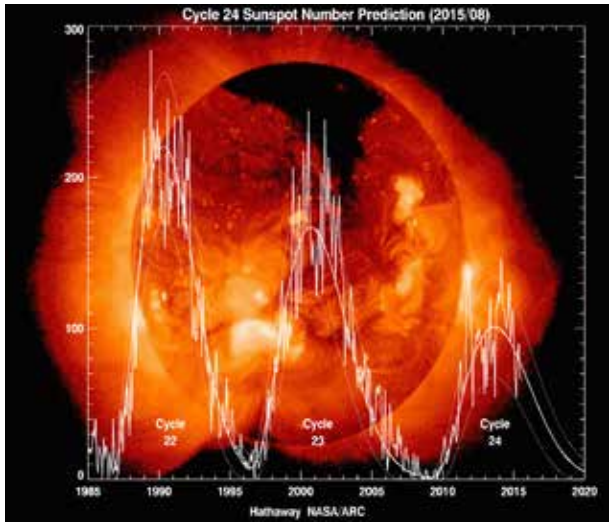
G. Chiodo (1), J. Oehrlein (1), L.M. Polvani (1)
J. Fyfe (2) and A.K. Smith(3)



1: Columbia University
New York (NY), USA

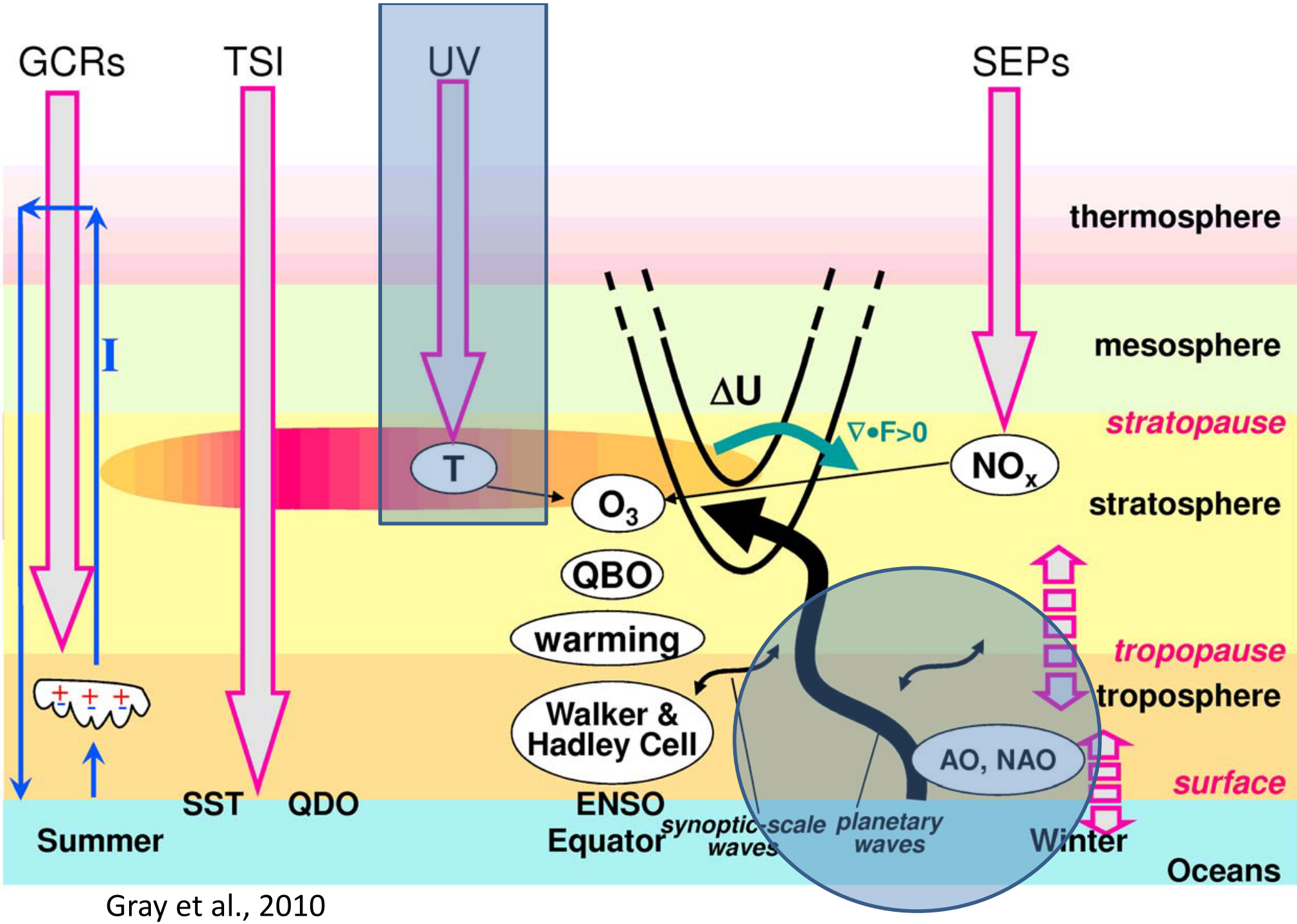
2: Environment and Climate Change, Victoria, Canada

3: NCAR, Boulder (CO), USA



COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

WACCM

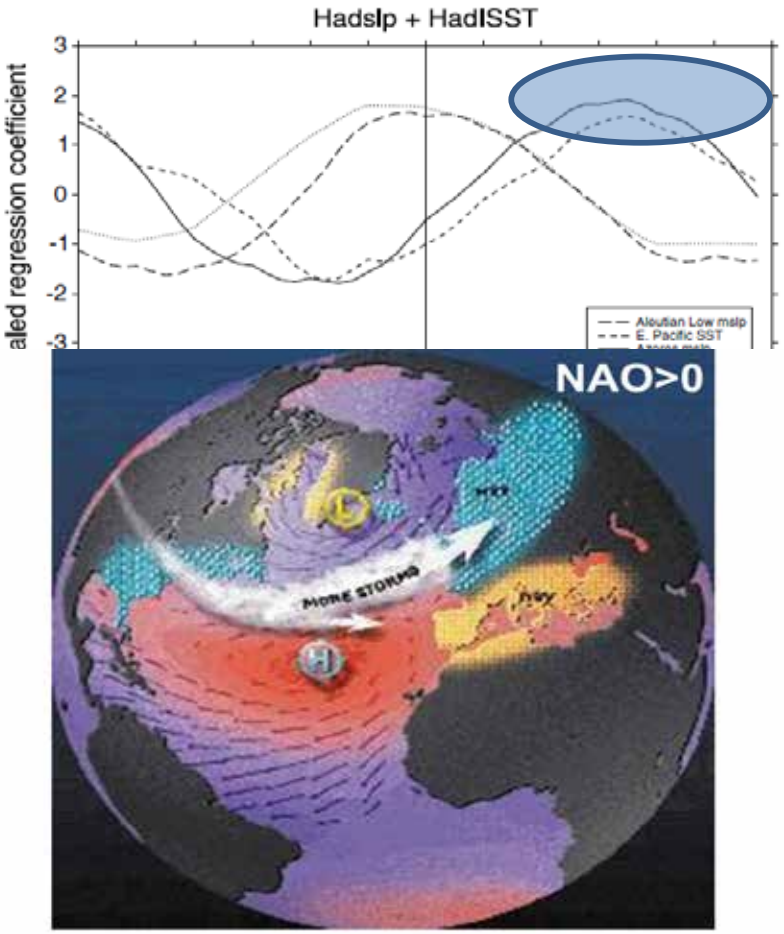


Gray et al., 2010

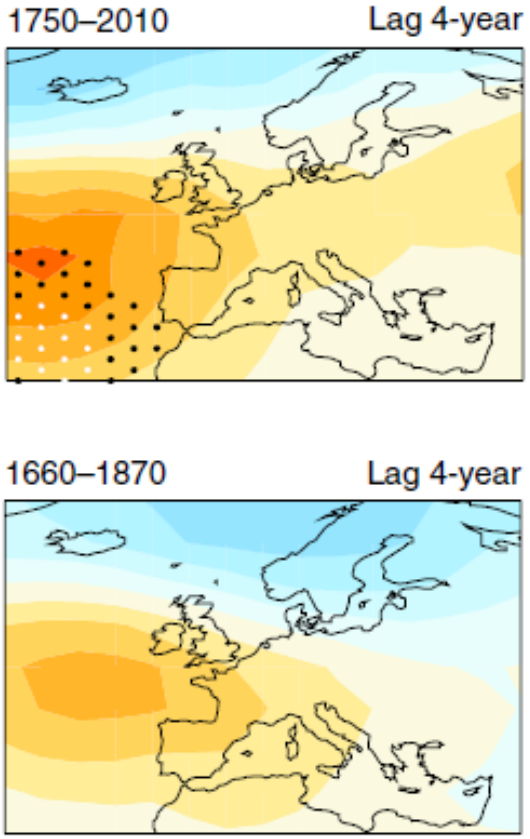
The solar-NAO signal: observations

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

Gray et al 2013



Gray et al 2016



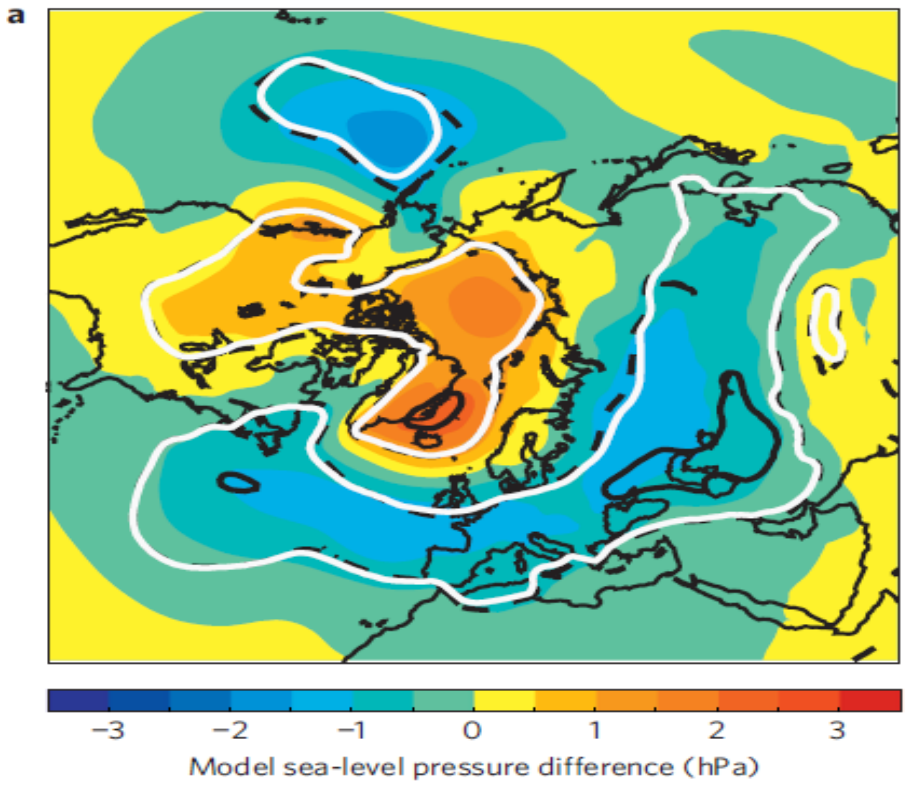
The solar-NAO signal: climate models (1)

nature geoscience
LETTERS
PUBLISHED ONLINE: 9 OCTOBER 2011 | DOI: 10.1038/NGEO1282

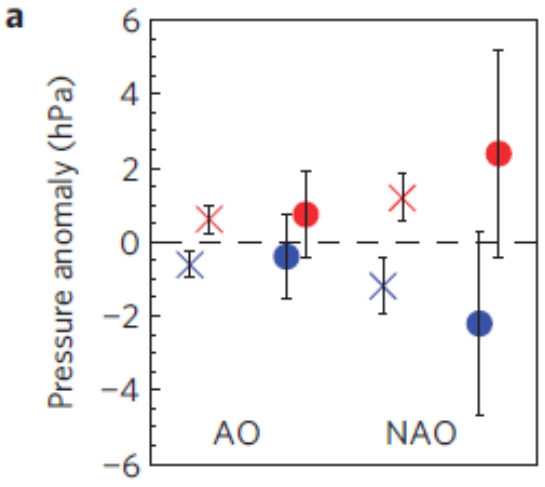
Solar forcing of winter climate variability in the Northern Hemisphere

Sarah Ineson[1]*, Adam A. Scaife[1], Jeff R. Knight[1], James C. Manners[1], Nick J. Dunstone[1], Lesley J. Gray[2] and Joanna D. Haigh[3]

NAO signal at ~ **Lag 0 yr**



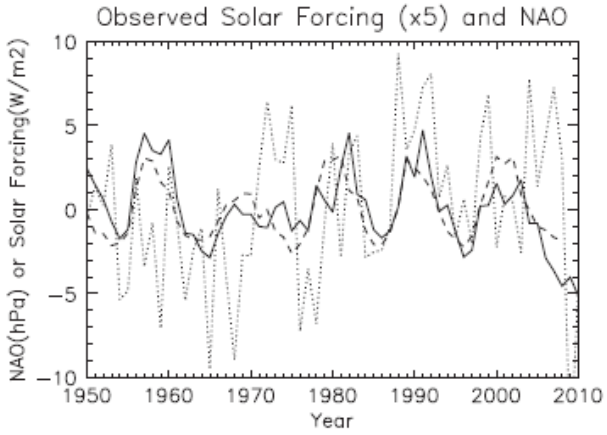
at

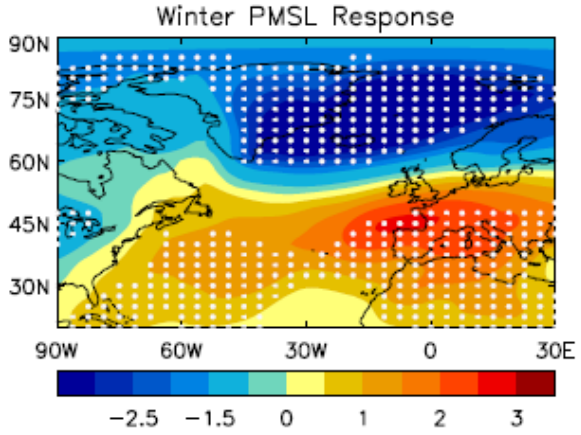


The **lagged** solar-NAO signal: climate models (2)

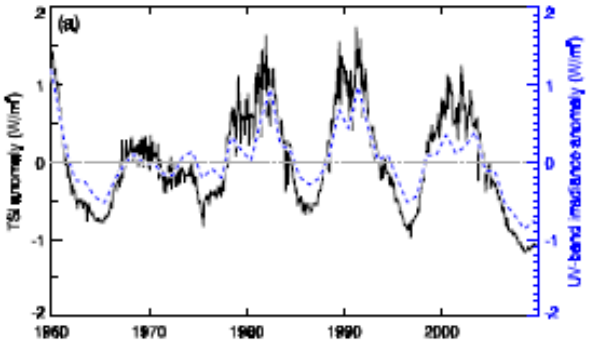
- NAO signal at ~ **lag 4 yr** → Bottom-up (ocean feedback)

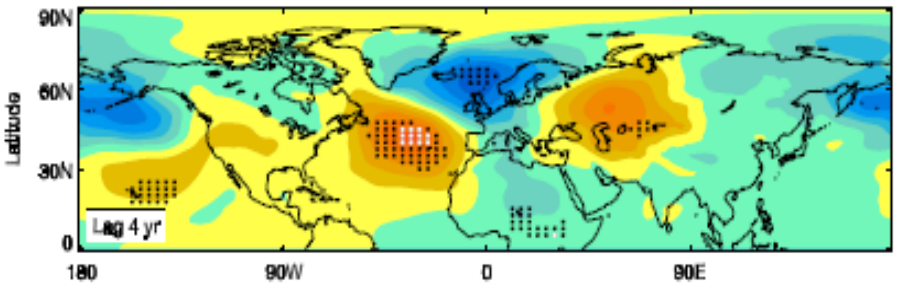
Scaife et al., 2013 GRL





Andrews et al., 2015 ERL

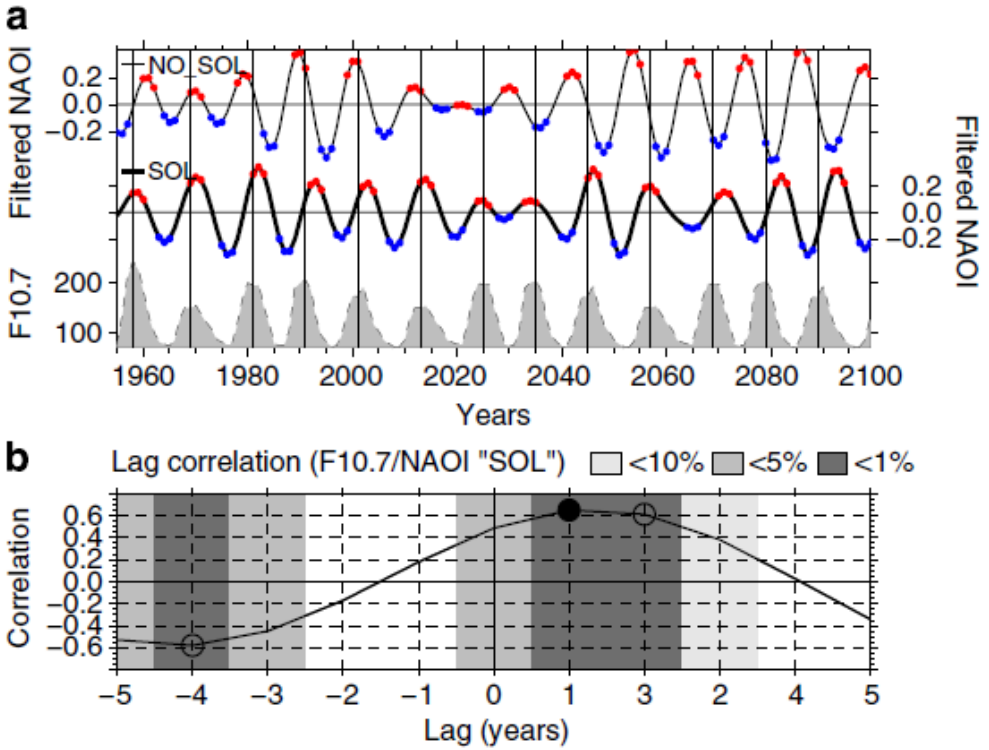


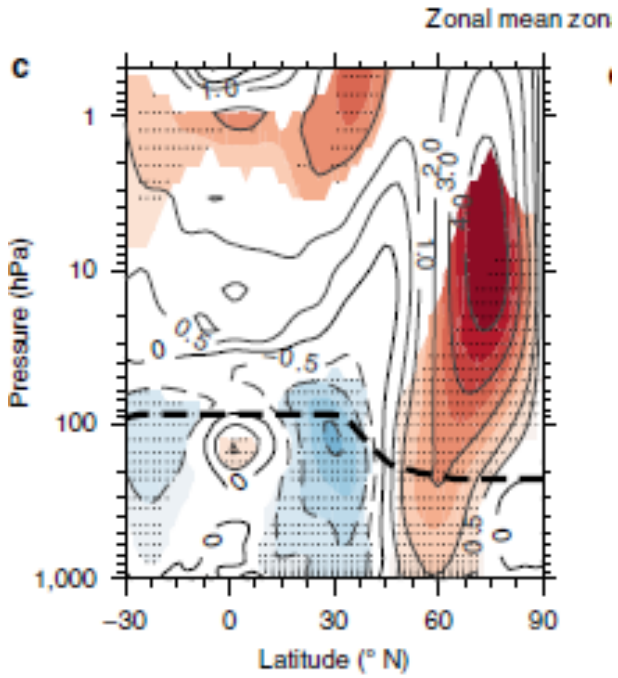


The lagged solar-NAO signal: climate models (3)

- NAO signal at ~ **lag 1-2 yr**

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





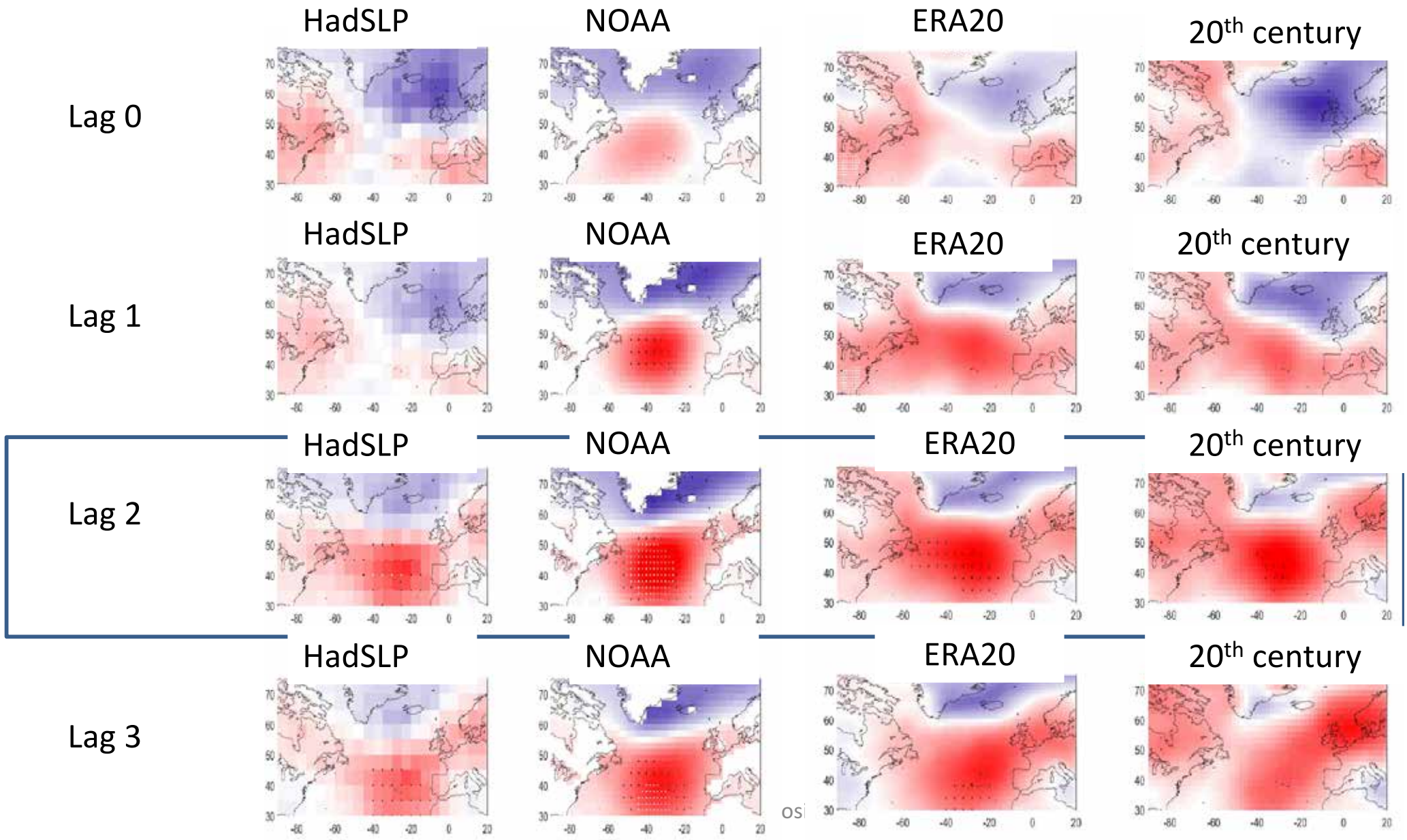
Thieblemont et al., 2015 NatComm

Objectives

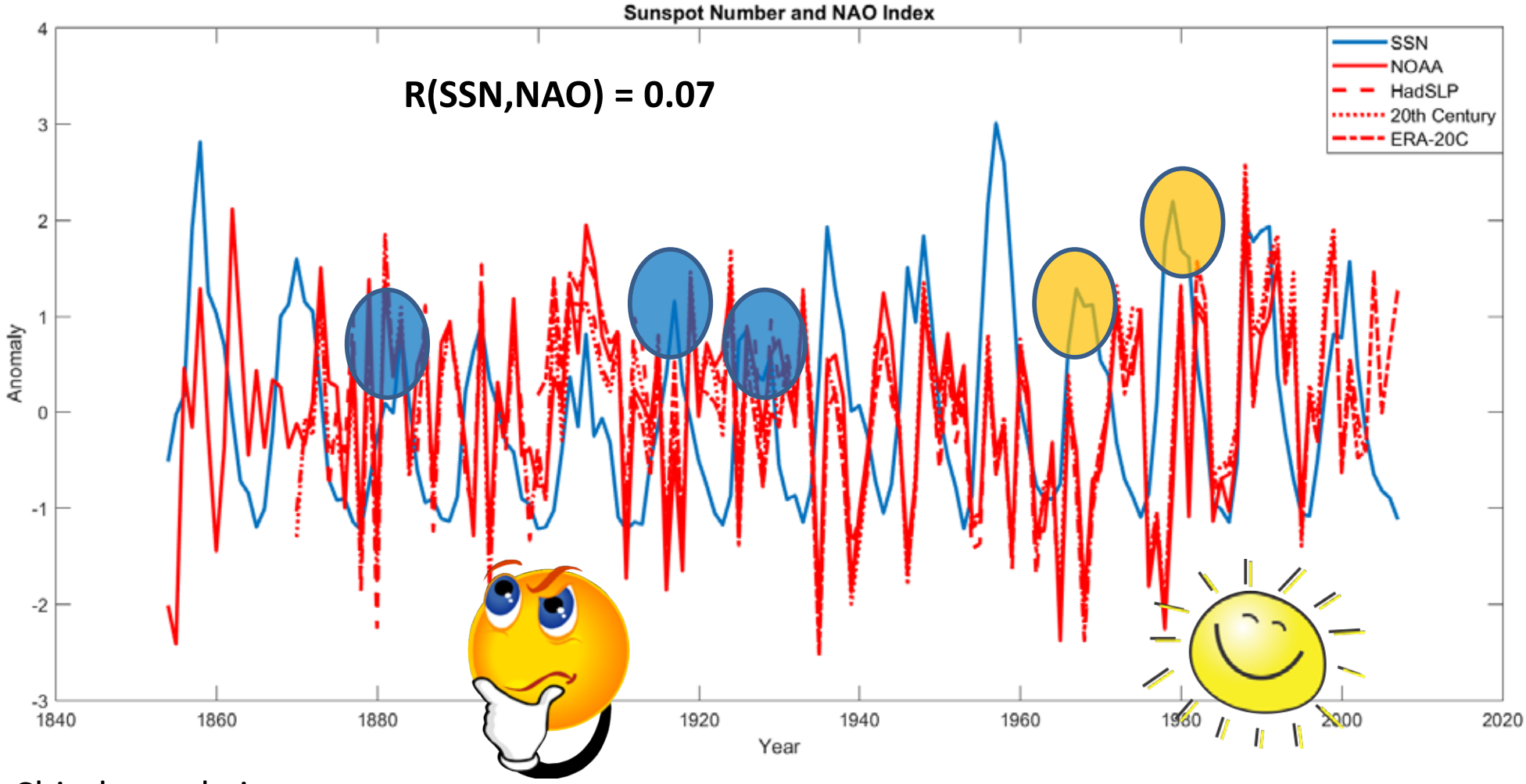
- Revisit the solar/NAO relationship in **multiple** re-analysis products of SLP (if any, identify **robust** lag!)

- 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 agains Sunspot number in four reanalysis of 20th century

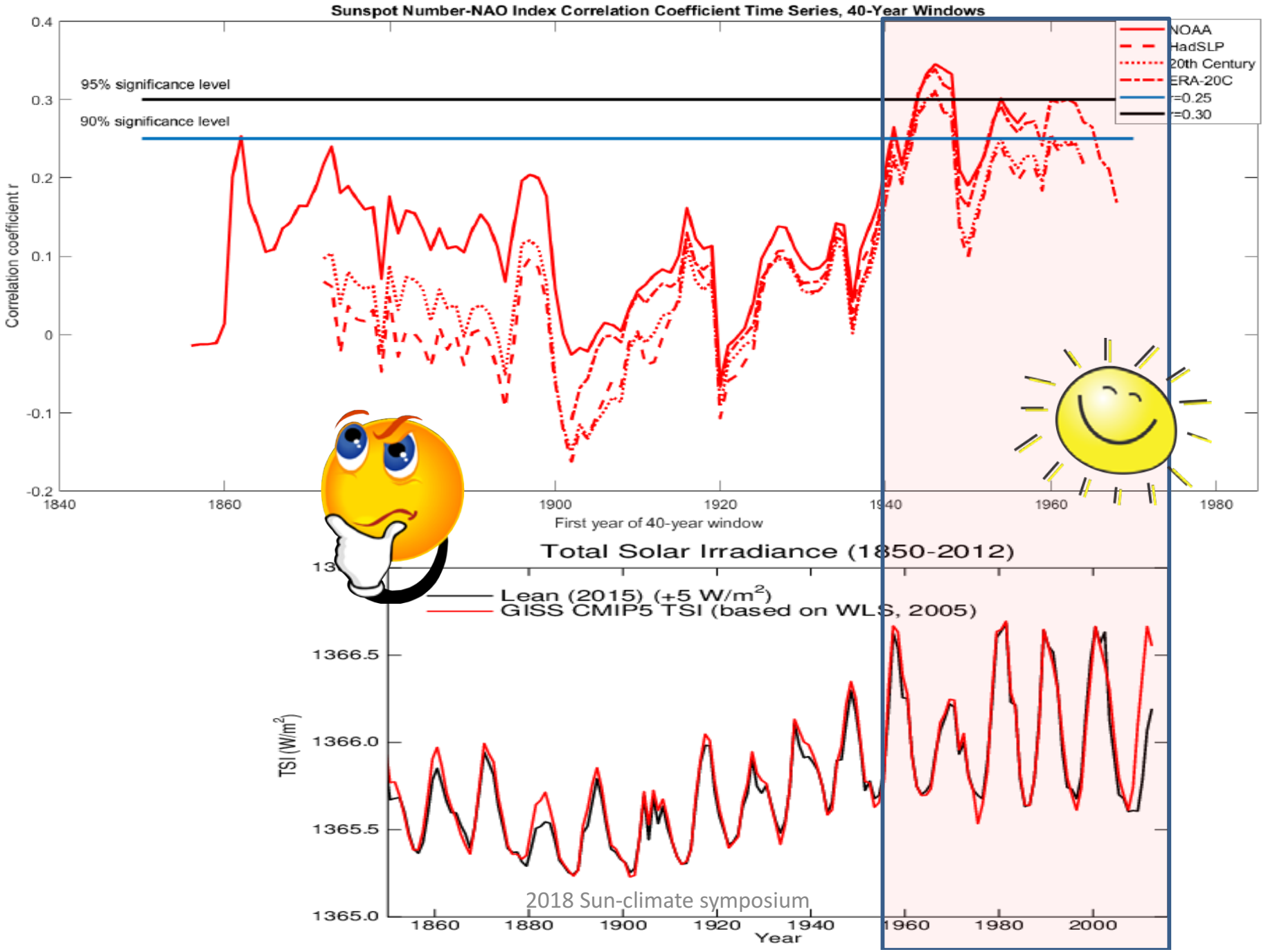


The lagged solar-NAO signal: is it robust in reanalysis data?



Chiodo et al., in prep.

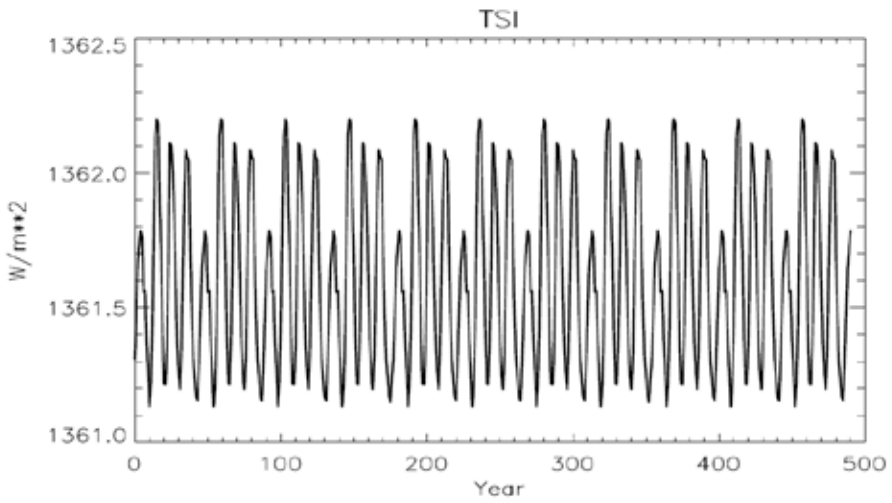
Correlation arising due to stronger solar foring…?

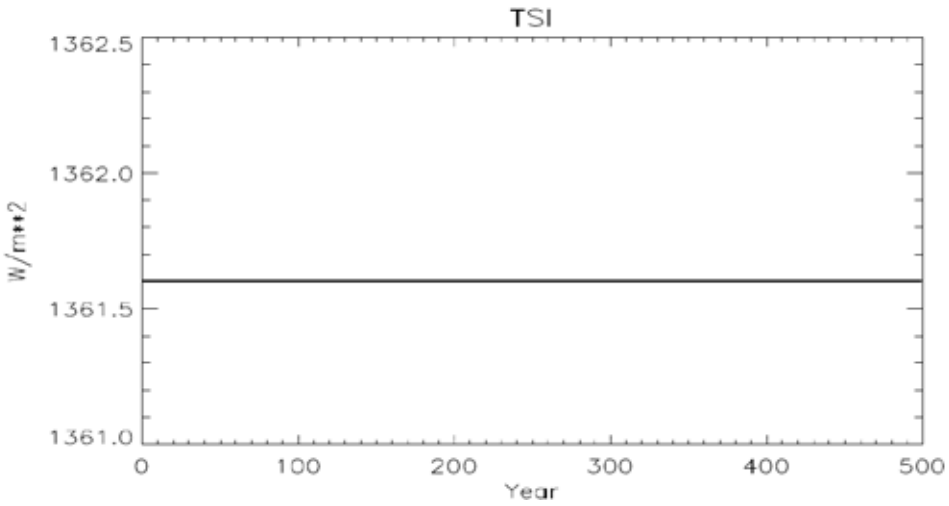


Can we reproduce this signal in models?

- 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

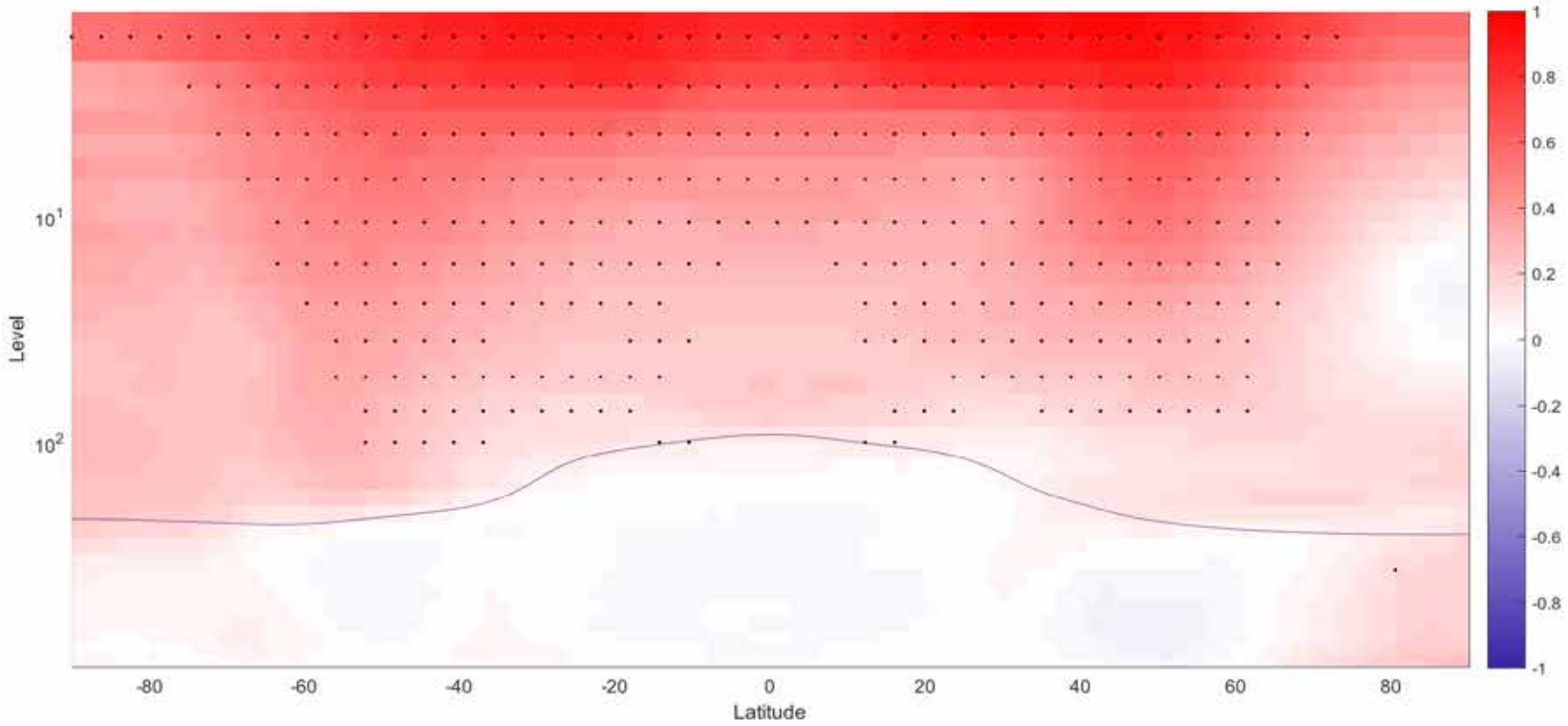




Solar signal in 500-yr simulation

WACCM_SOL

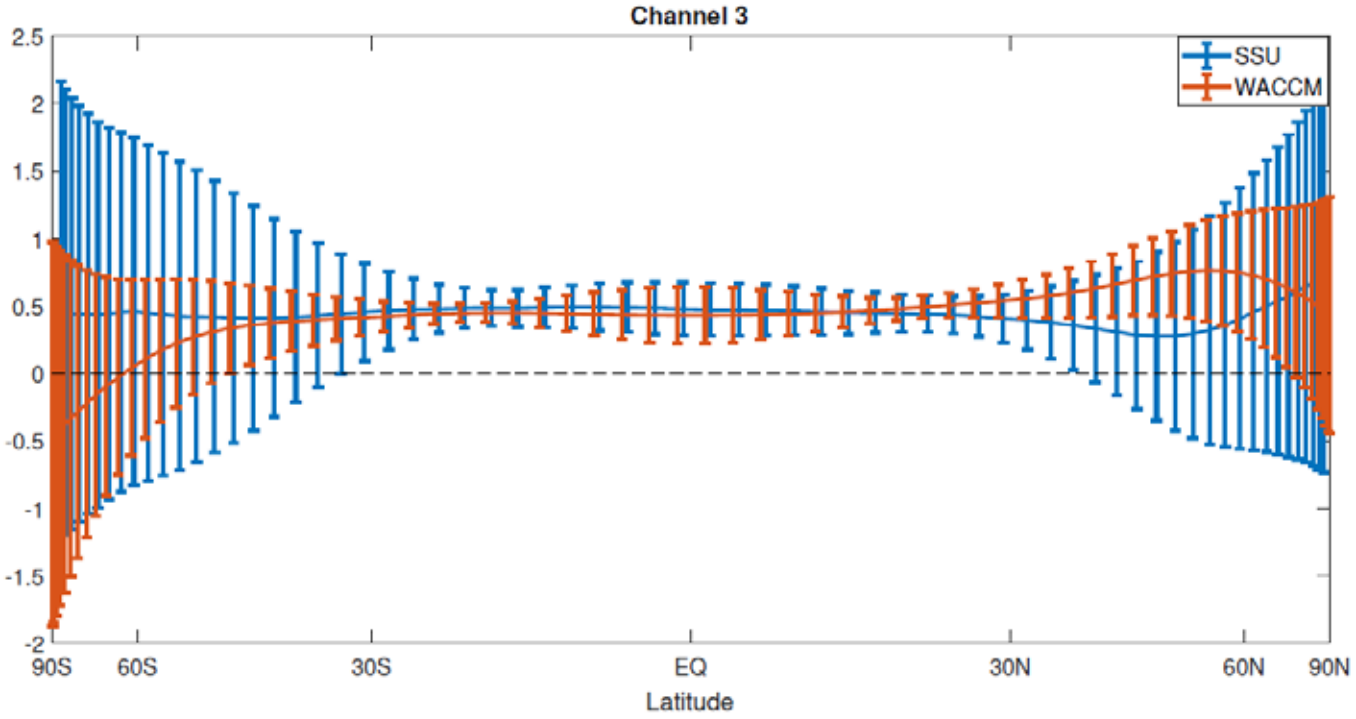
K / Wm-2 (annual mean)

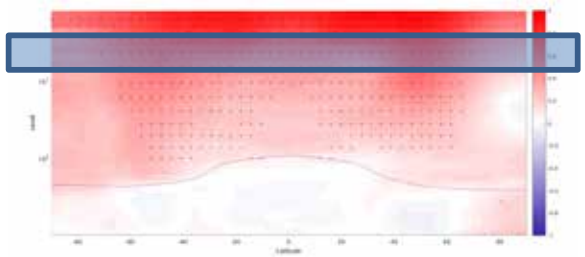


a) 1 K warming at stratopause

b) No response in the troposphere…

Is the model's response to solar cycle realistic…?

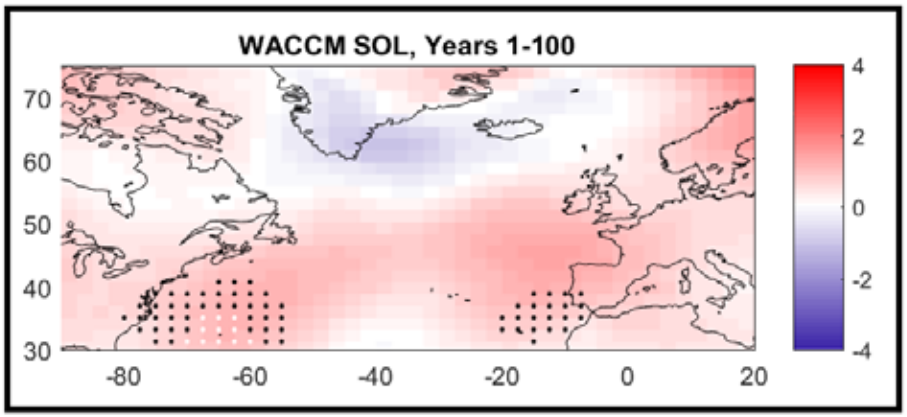


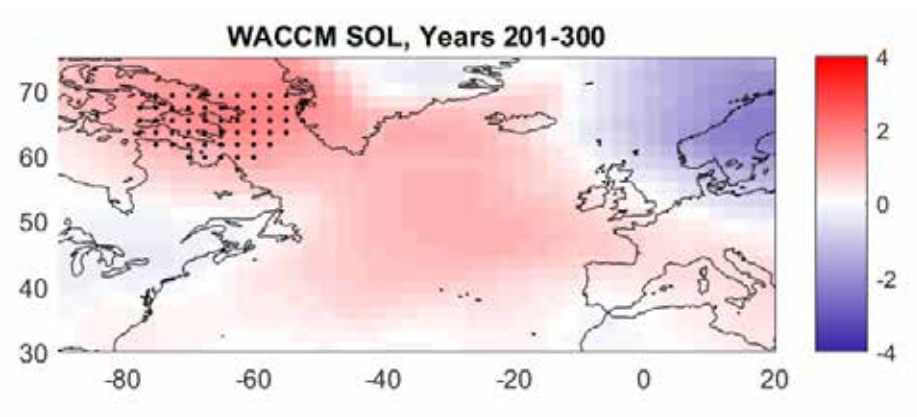


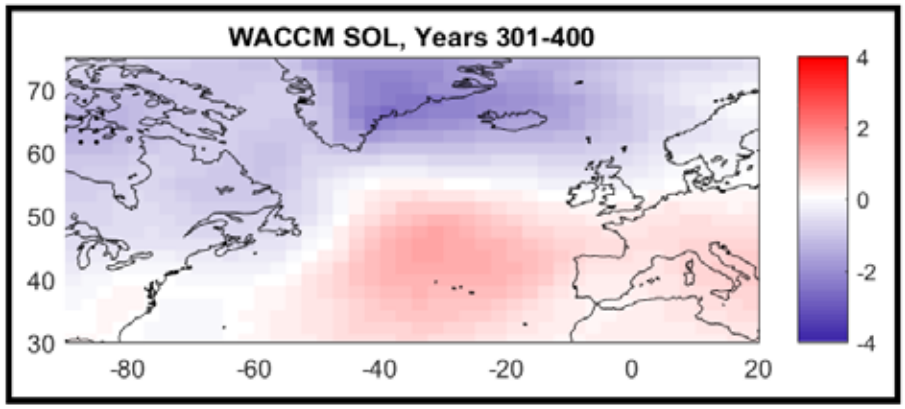
Direct comparison with SSU satellite data (1979-2014) – Seidel et al., 2016

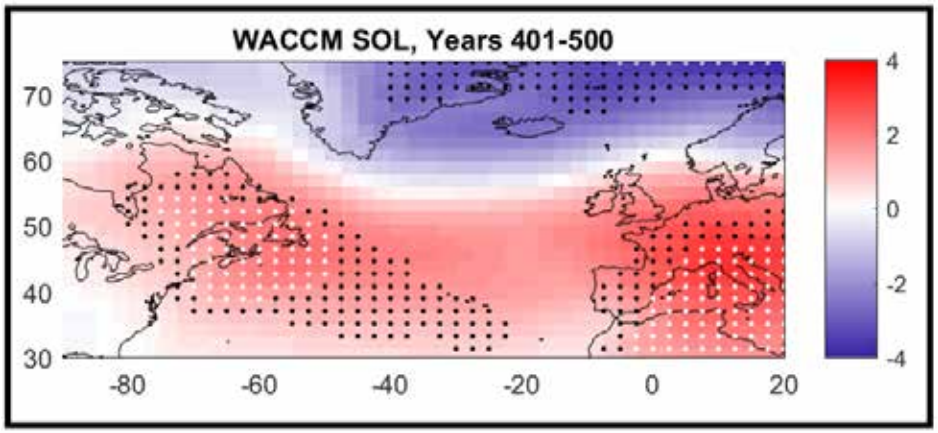
Excellent agreement between WACCM_SOL and SSU data, suggesting that heating is correct… so solar **forcing** and **response** are **realistic**

Solar signal in SLP
(100 year windows) lag 2 year regression









2 out of 5 windows yield NAO-like signal (300-400; 400-500)

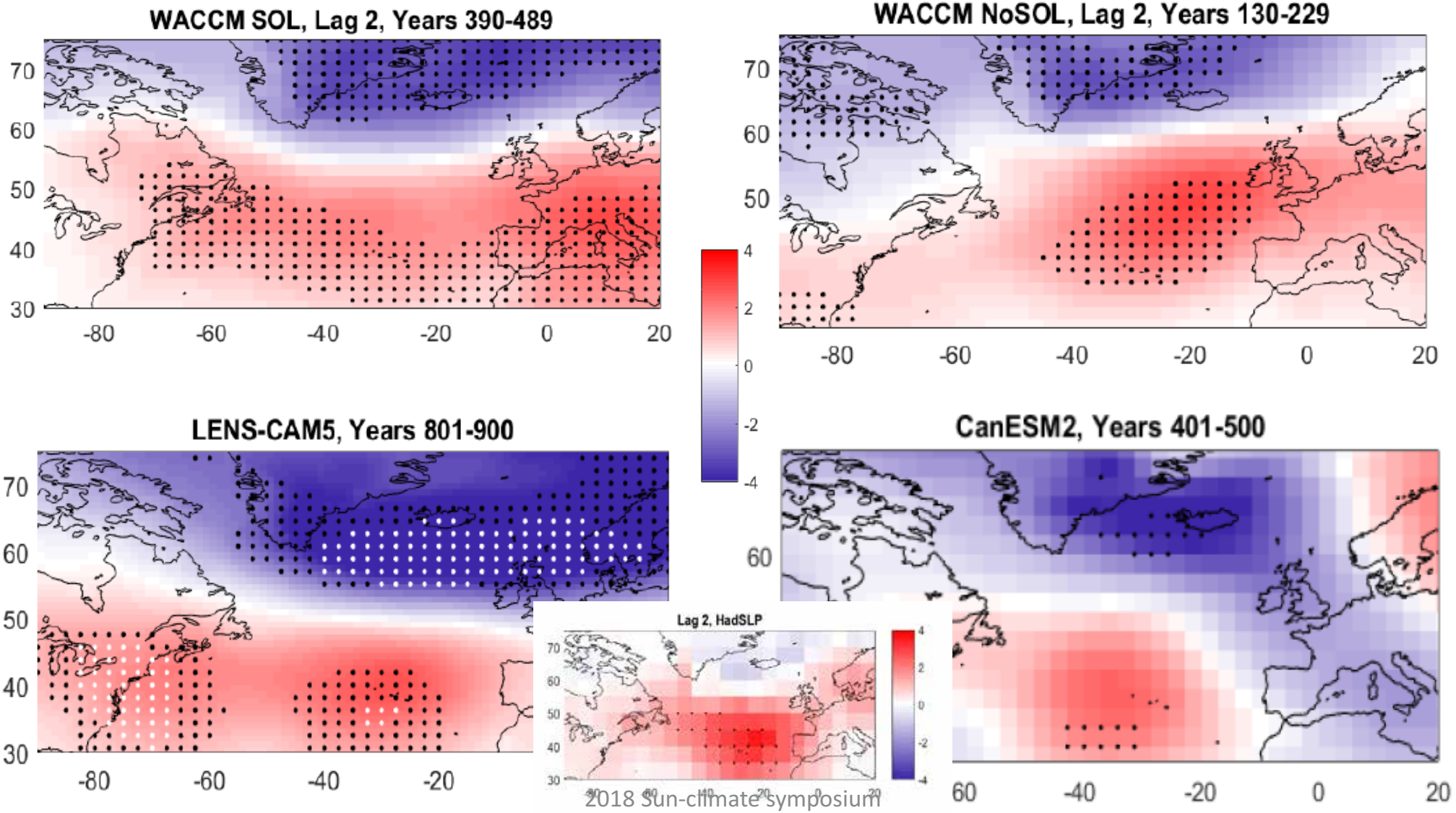
Why is the “signal” non-stationary?

How random is this apparent solar-NAO signal?

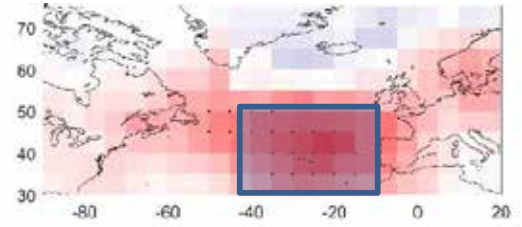
Do “mocking” exercise…

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

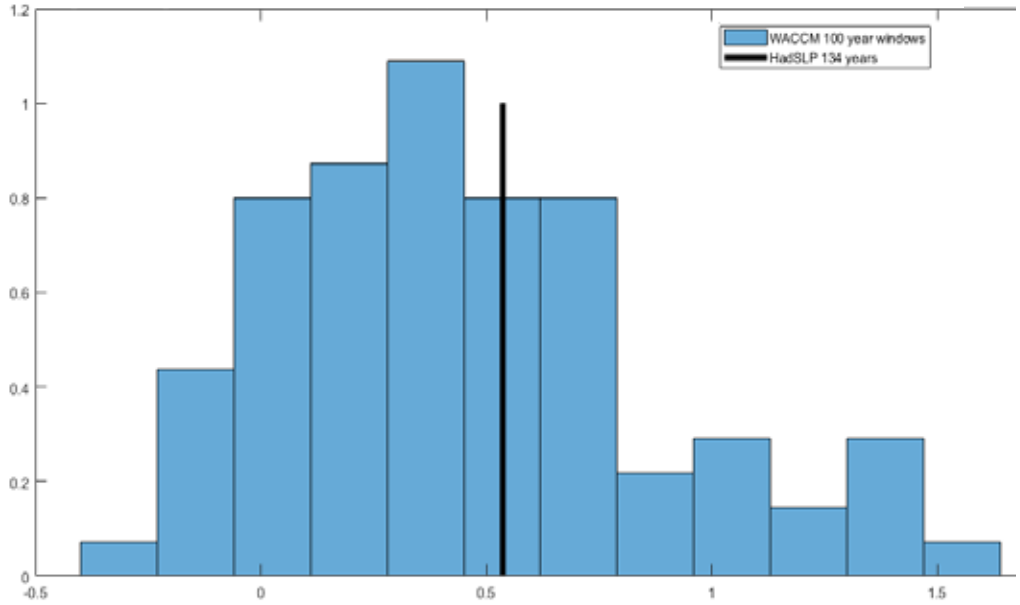
TSI-SLP regressions (with a +2 years lag)
→ 100-year windows with best OBS “match”)



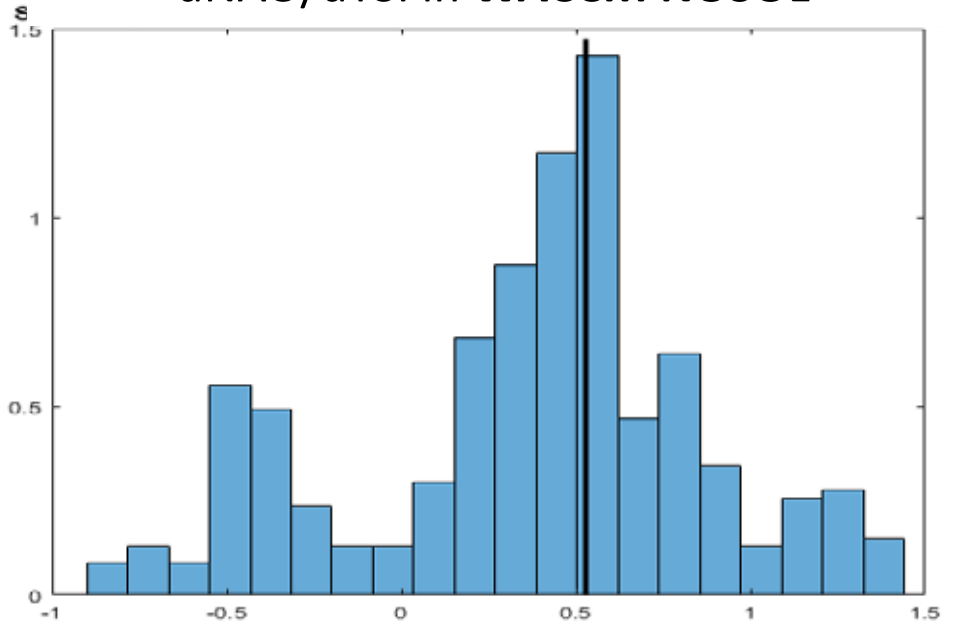
What are the odds of finding OBS signal just by chance…?



dNAO/dTSI in **WACCM SOL**



dNAO/dTSI in **WACCM NOSOL**

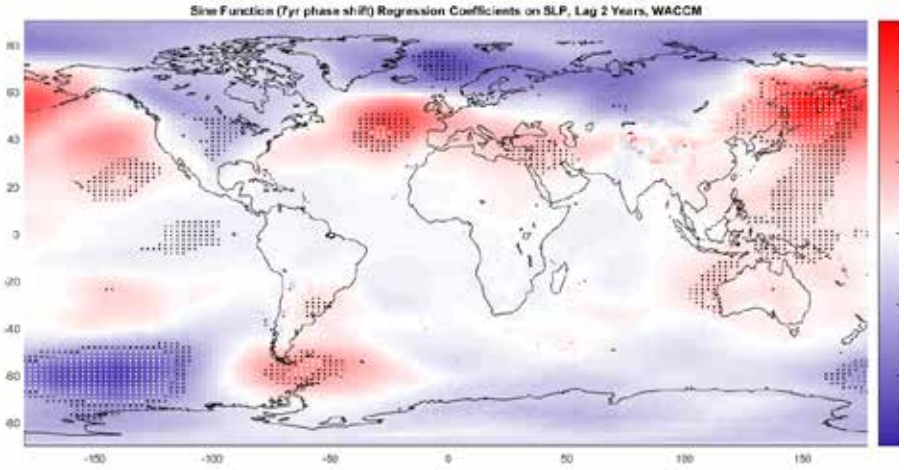


SLP (+) signals in subtropical Atlantic resembling the OBS are **not at all uncommon** in the integrations, even in those **without a solar cycle**

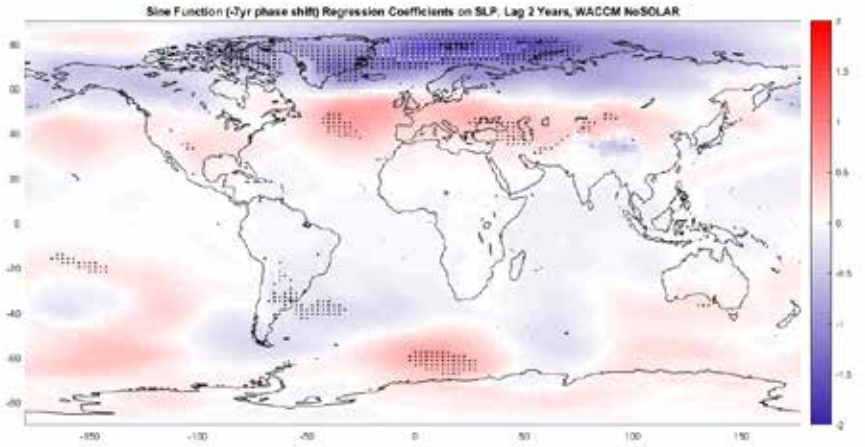
How can we get a “solar signal” when there is no solar forcing…?

Solar-SLP regressions (lag 2) on a **sinusoidal index** with T~11 yr

SOL

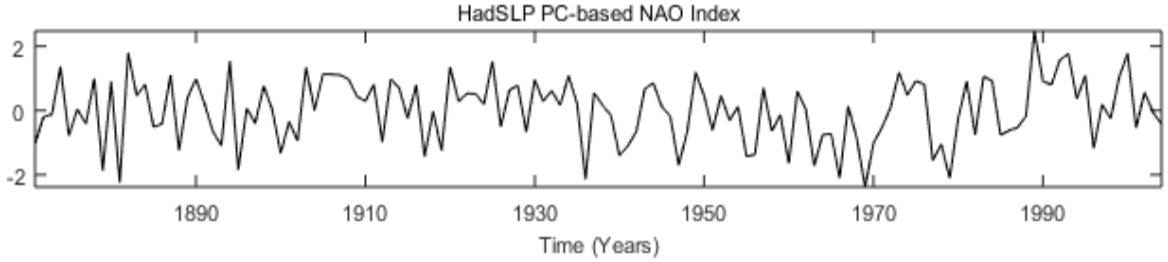


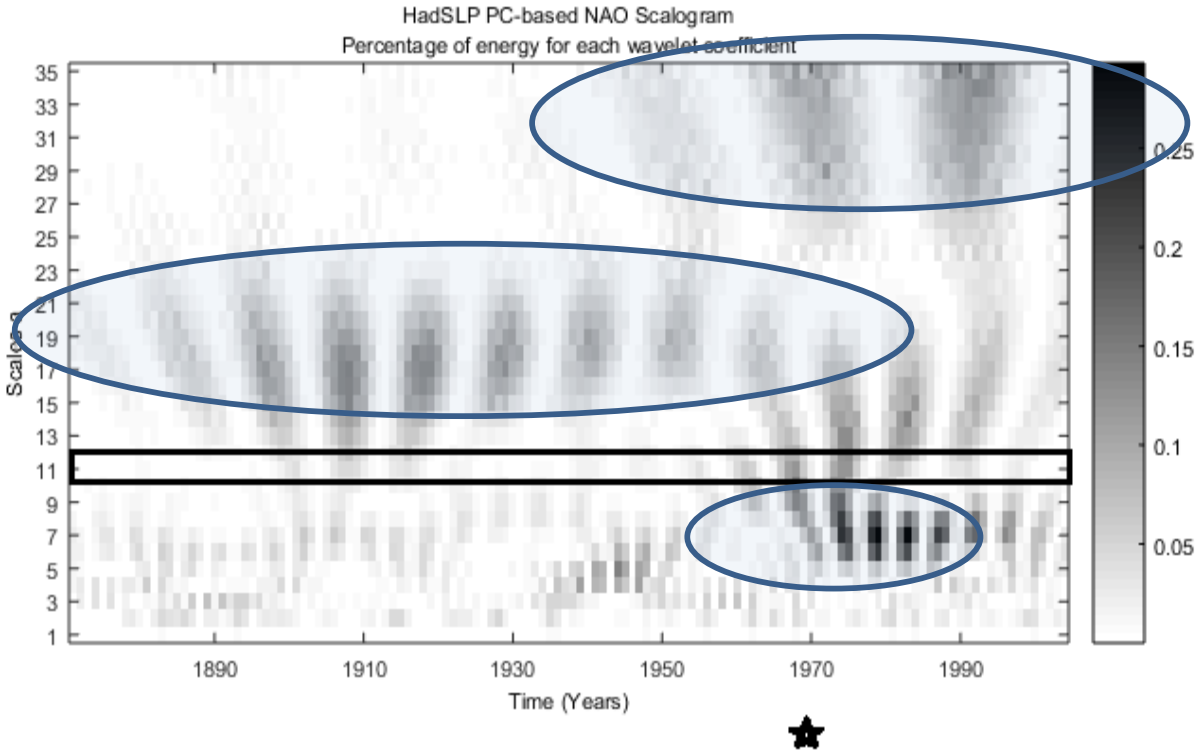
NOSOL



The NAO-like pattern seems due to **unforced decadal variability**

Is there intrinsic decadal NAO variability, “mapping” onto indices with decadal oscillations (TSI/UV?)



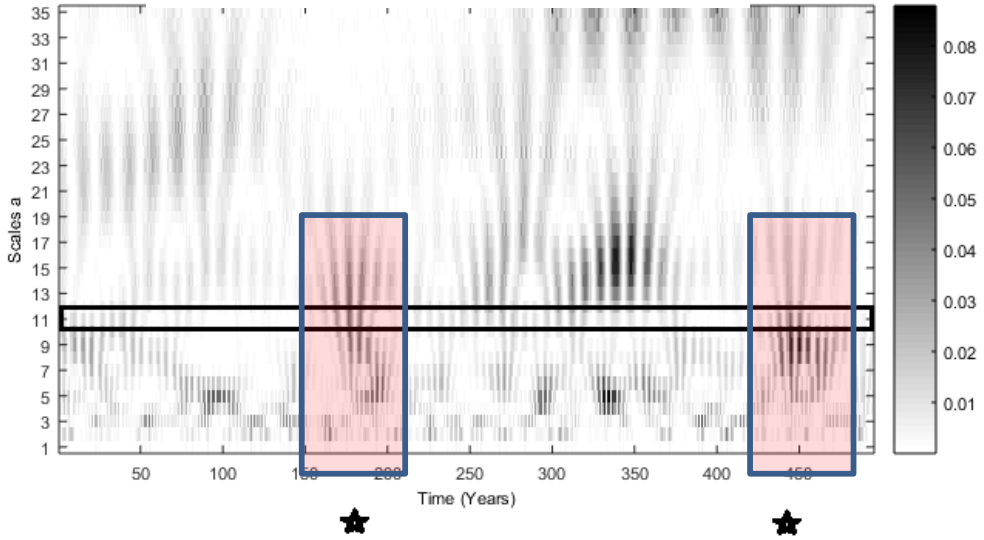


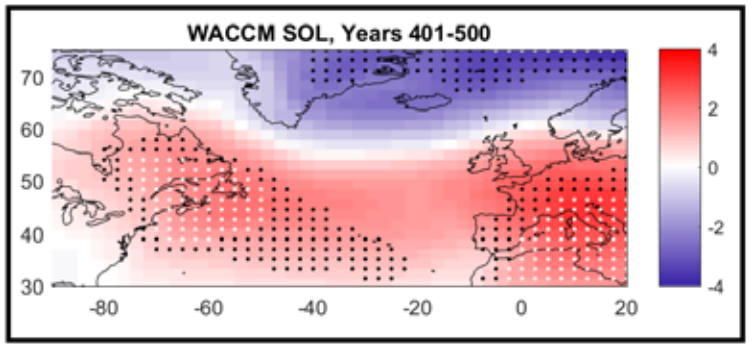
30-50 yr: AMO…?

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

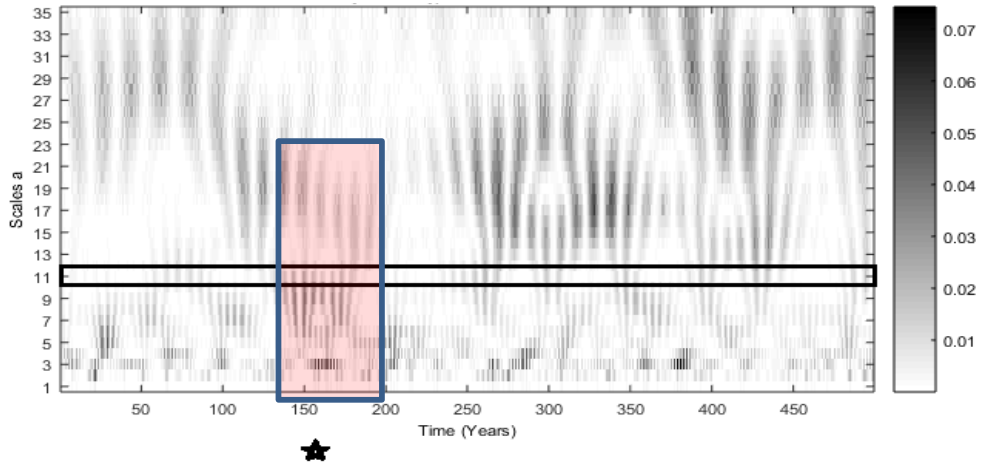
3-8 yr : ENSO…?

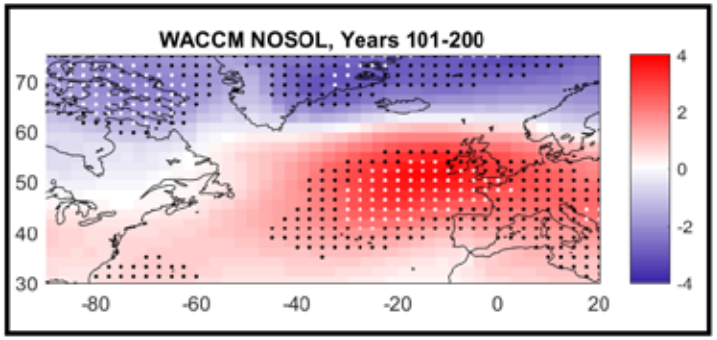
WACCM_SOL





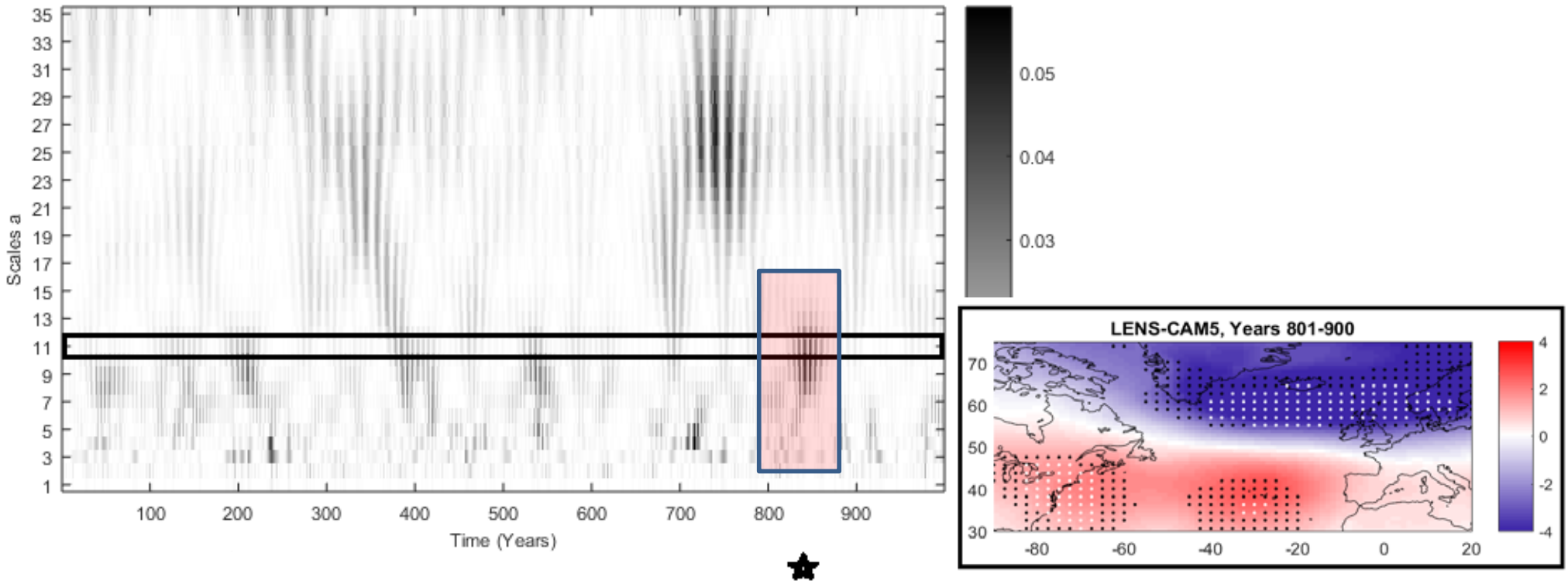
WACCM_NOSOL





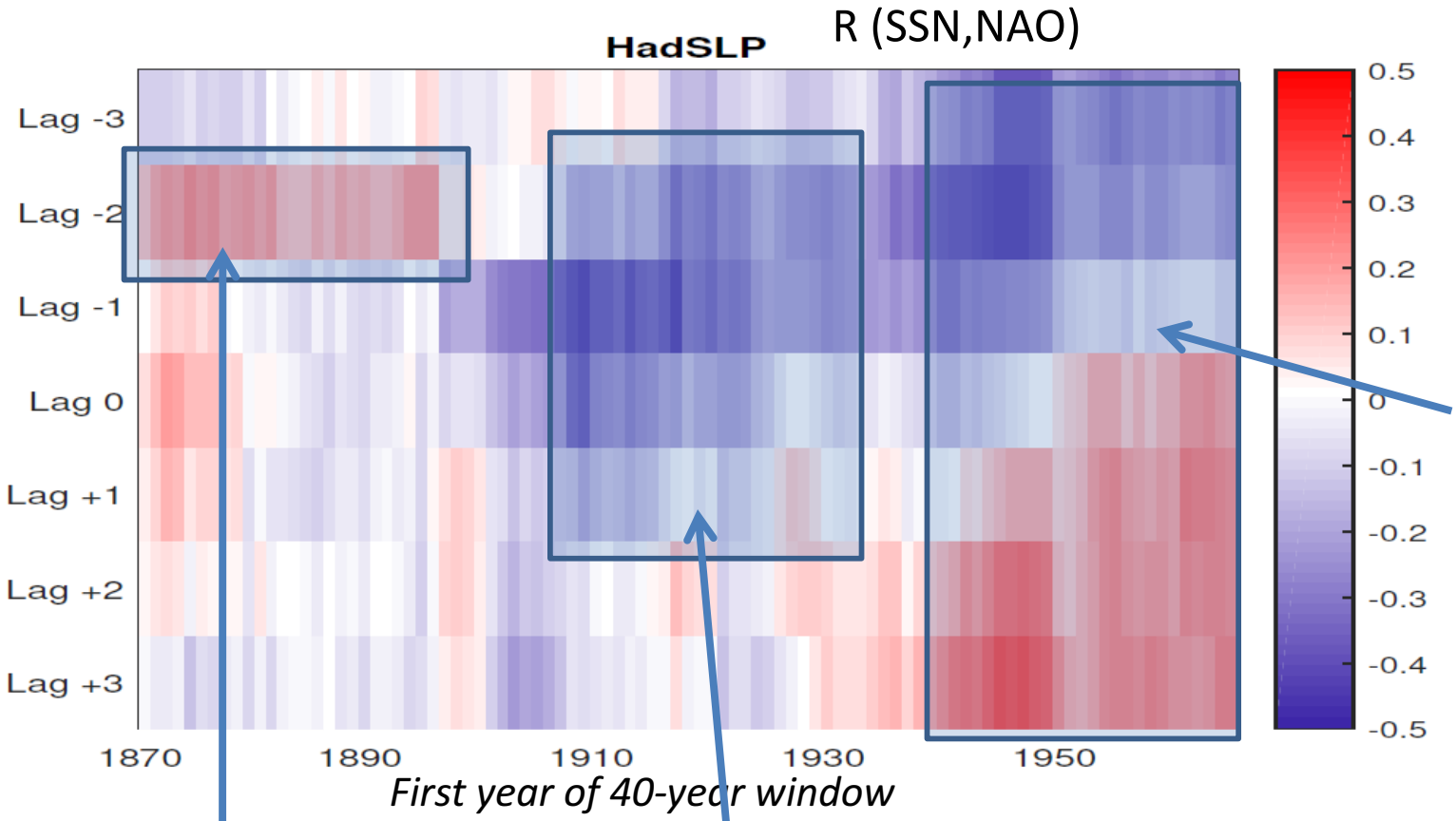
Variability in 1000-year piCONTROL

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.