The Sun's role for decadal climate predictability

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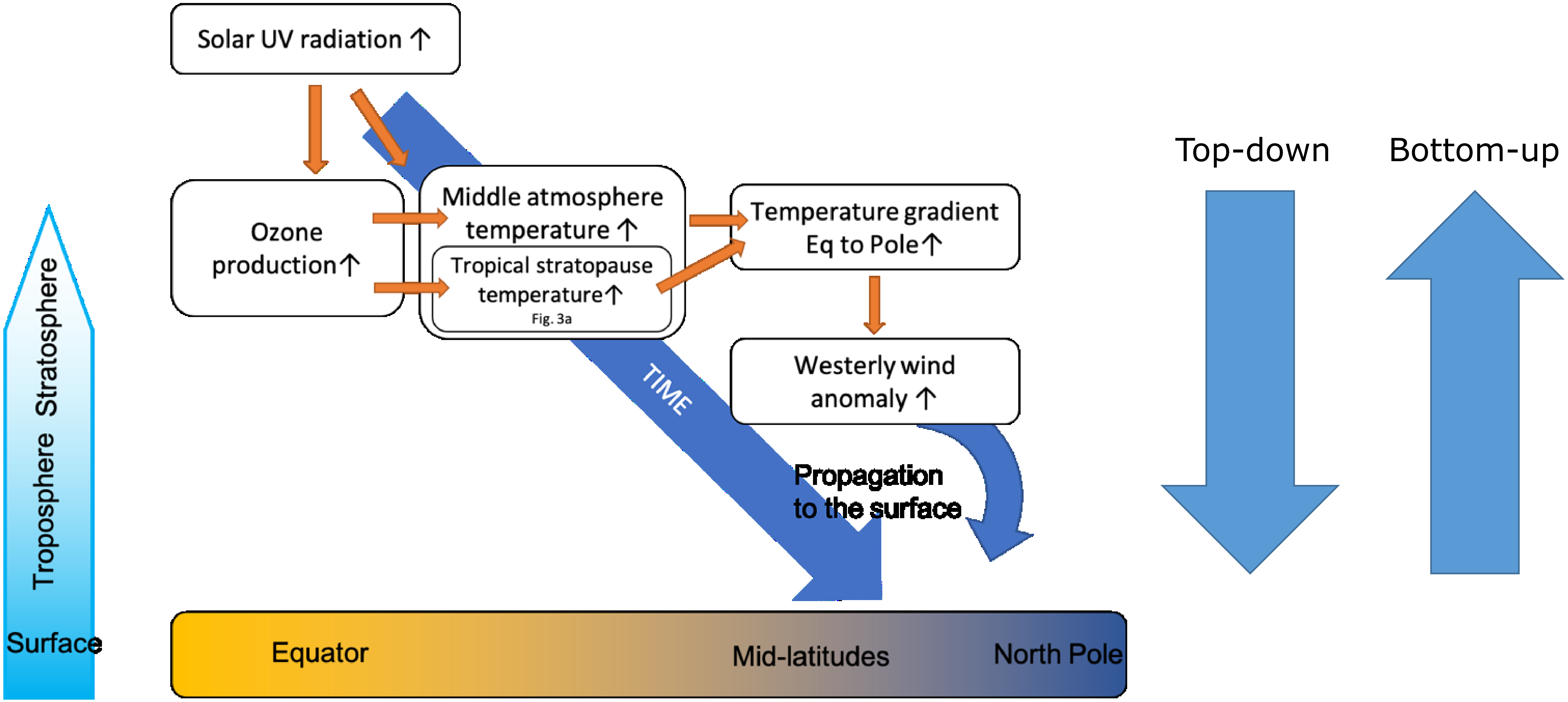
Outline

1. the solar surface signal
2. the concepts of decadal predictions
3. the Sun’s role for decadal climate predictability

… on a decadal time scale = 11-year solar cycle
… in the North Atlantic

Solar signal's path to surface



The solar surface signal

Some literature:

North Atlantic Oscillation / top-down mechanism
Gray et al. 2016, doi 10.1002/qj.2782
Ma et al. 2018, doi 10.1088/1748-9326/aa9e94
Kuroda et al. 2021, doi 10.1029/2021JD035519

Pacific / bottom-up mechanism
Meehl et al. 2009, doi 10.1126/science.1172872
Misios et al. 2019, doi 10.1073/pnas.1815060116

Outline

1. the solar surface signal
2. **the concepts of decadal predictions**
3. the Sun's role for decadal climate predictability

Decadal climate predictions

- Evolution of the climate system: externally forced + internally generated
- “historical” simulations with ESMs include effect of increase in greenhouse gases etc. (external)
- Idea: Internal variability on longer time scales (multi-annual and above) could be predicted
- → Decadal predictions want to exploit skill from externally forced AND internally generated components
- External component: reaction of the system, extracted by **averaging ensemble** simulations
- Internal component by **initialization** close to observed state

DMI

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The Sun's role in decadal climate predictability in the North Atlantic

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Abstract. Despite several studies on decadal-scale solar influence on climate, a systematic analysis of the Sun's contribution to decadal surface climate predictability is still missing. Here, we disentangle the solar-cycle-induced climate response from internal variability and from other external forcings such as greenhouse gases. We

Experimental design

- Variations in radiation are small
- Observations are limited
- Solar cycle is variable

→ we need a lot of data to disentangle
1) internal variability
2) signal caused by external forcing
3) signal caused by solar cycle

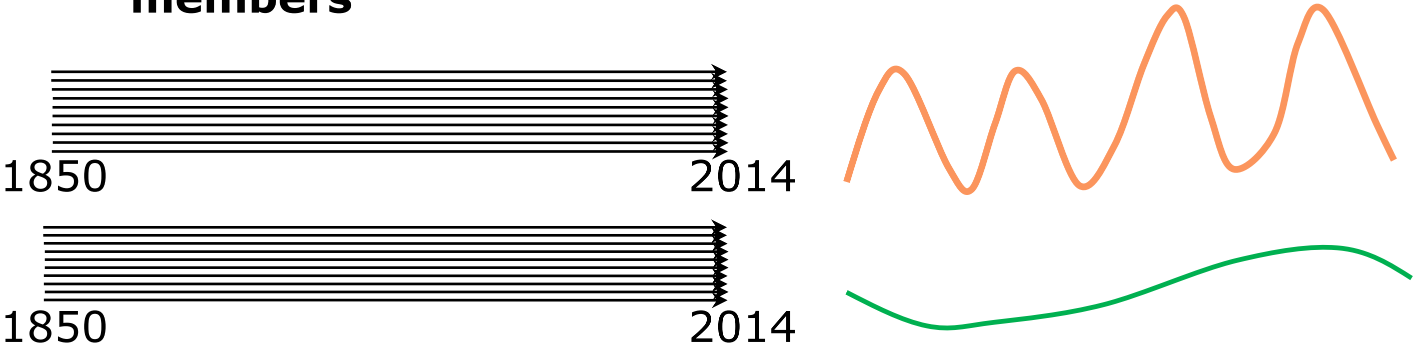
CESM-WACCM (1.0.6) Experiments

10 ensemble members

Solar forcing

1. Solar-Full

2. Solar-Low-frequency



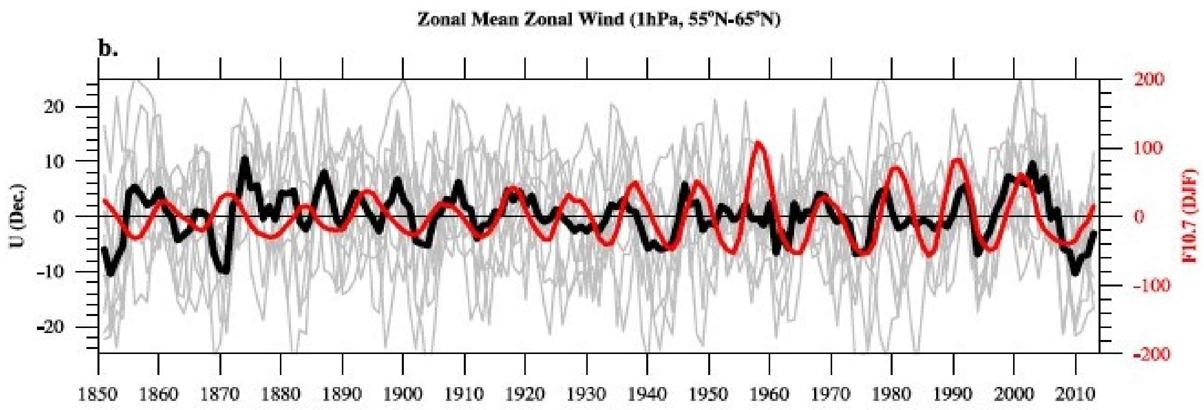
Isolation of the solar signal

External forcing signal: Ensemble mean LOWFREQ

Ext. forcing signal incl. solar signal: Ensemble mean FULL

Ens.mean Solar-Full Ens.mean Solar-Low-freq. Solar 11-Year

Internal var.:
Individual members FULL
minus ensemble mean FULL



Potential predictability variance fraction

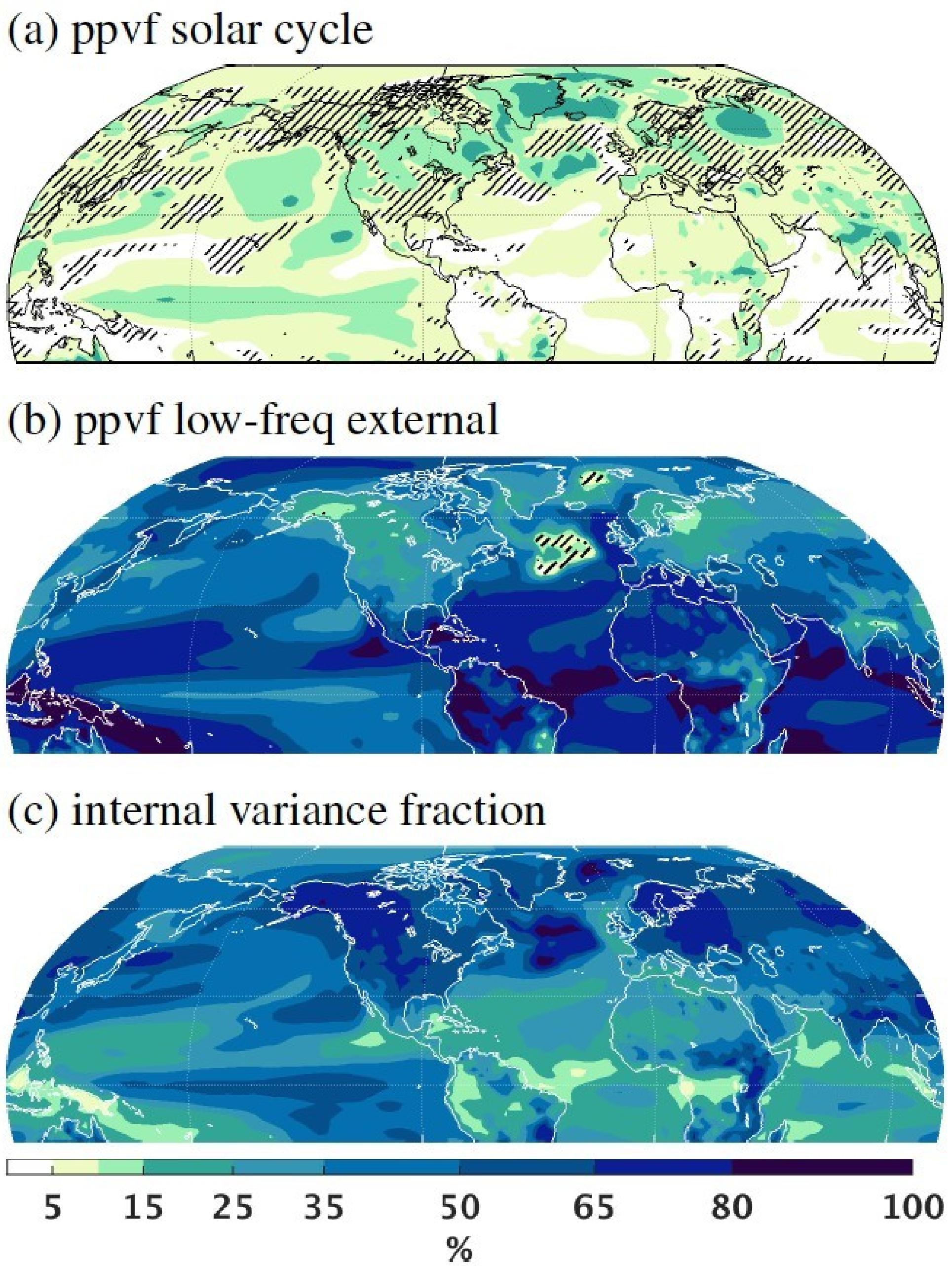
of surface temperature

PPVF (Boer 2004) to quantify the fraction of decadal variability

(a) forced by the 11-year solar cycle
(b) forced by all other external forcings
(c) due to internal variability

Steps:

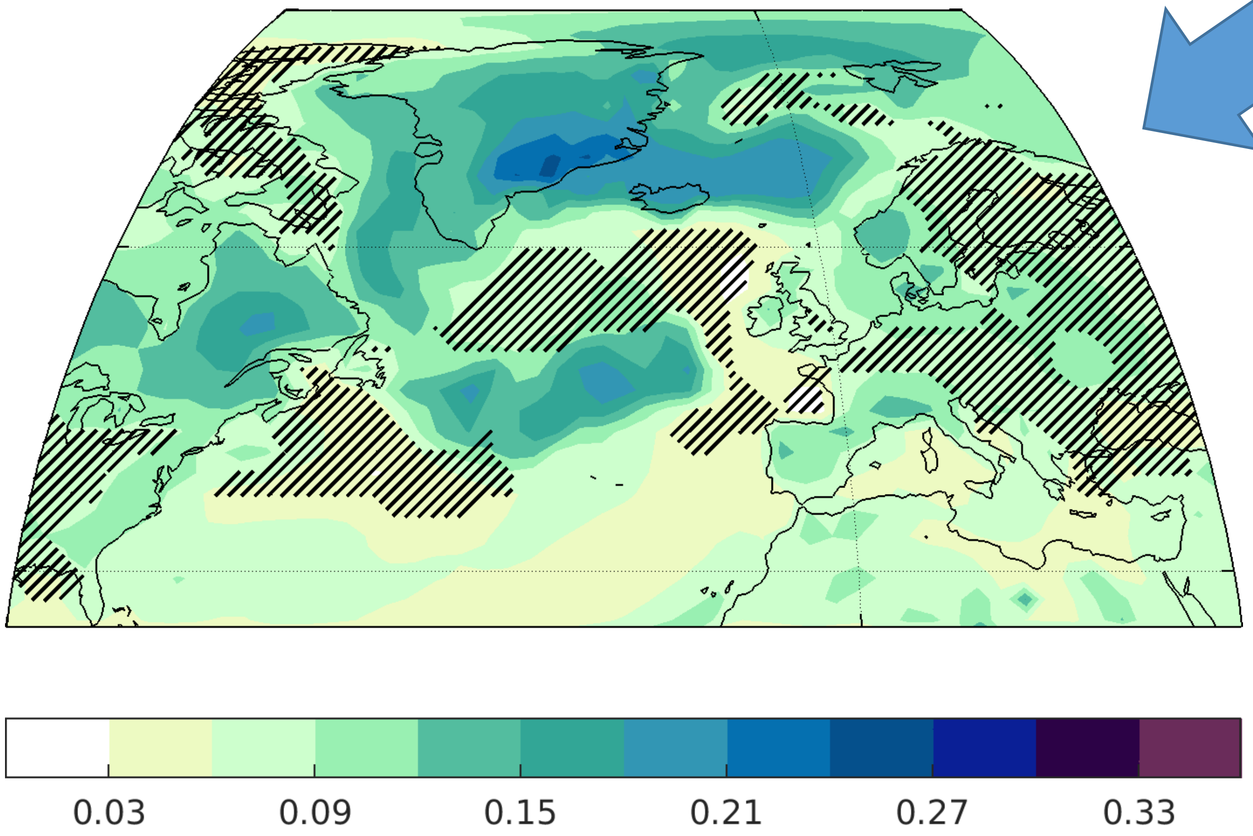
1) 8-year running mean
2) disentangle components
3) calculate variance
4) divide by total variance

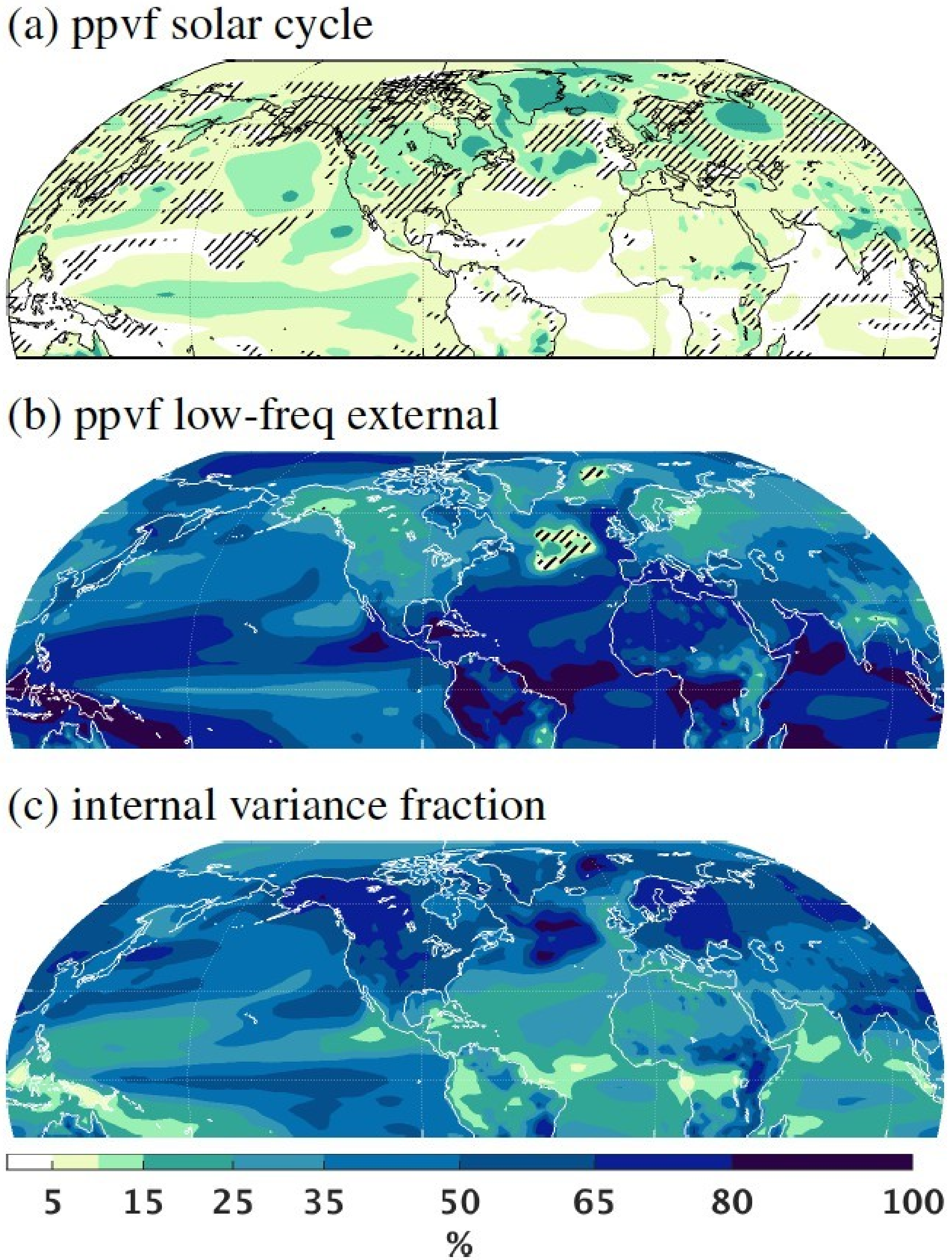


Statistically insignificant regions ($p>0.05$) are hatched.

Potential predictability variance fraction

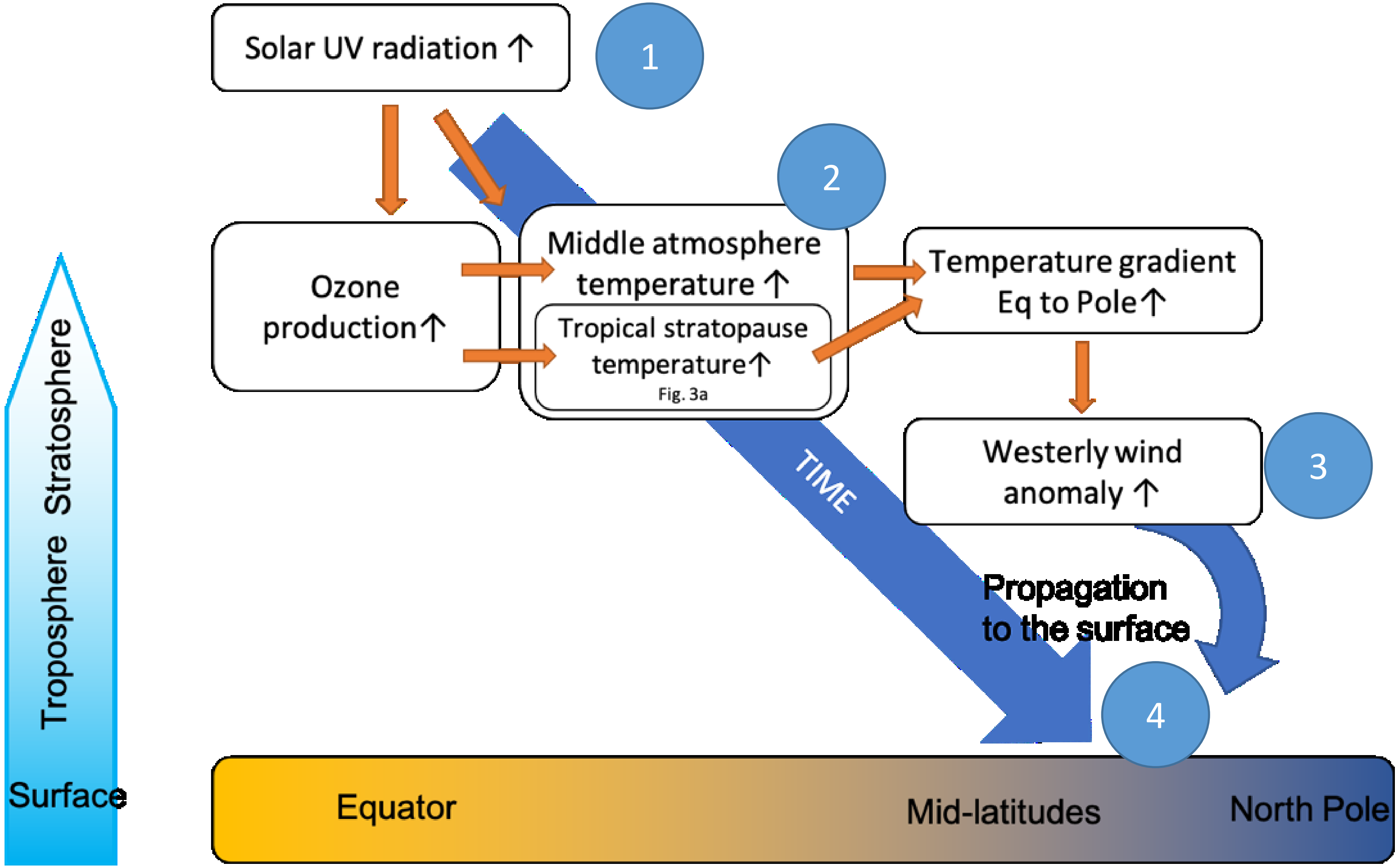
of surface temperature





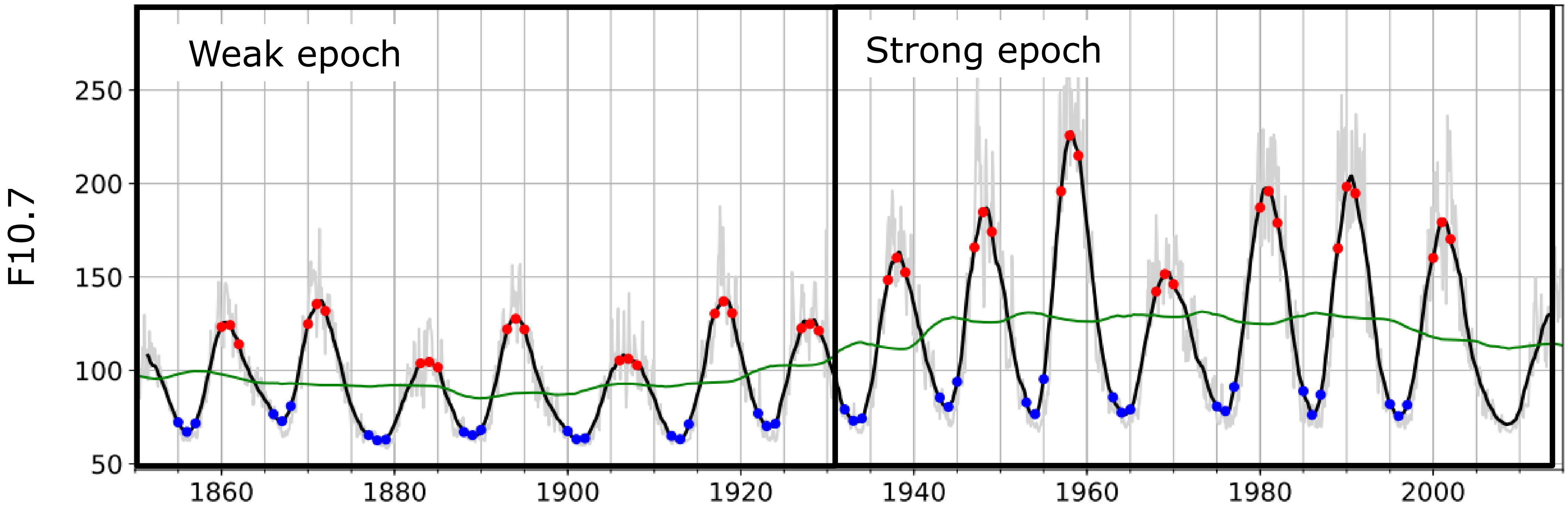
Statistically insignificant regions (p>0.05) are hatched.

Solar signal's path to surface



Solar variability

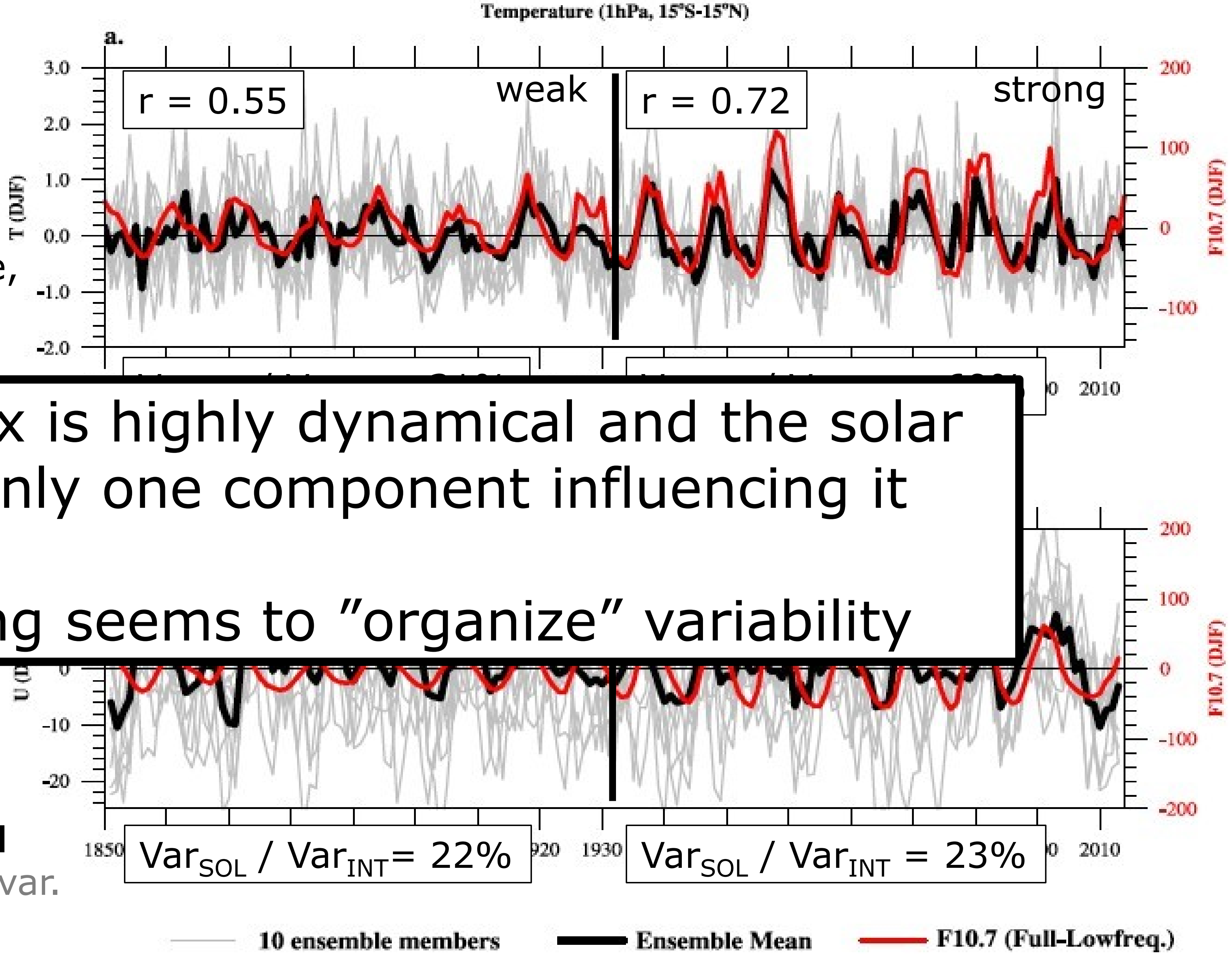
1



-- 3 year running mean

2

Tropical stratopause temperature, winter season (DJF)



- Polar vortex is highly dynamical and the solar forcing is only one component influencing it
- Solar forcing seems to ”organize” variability

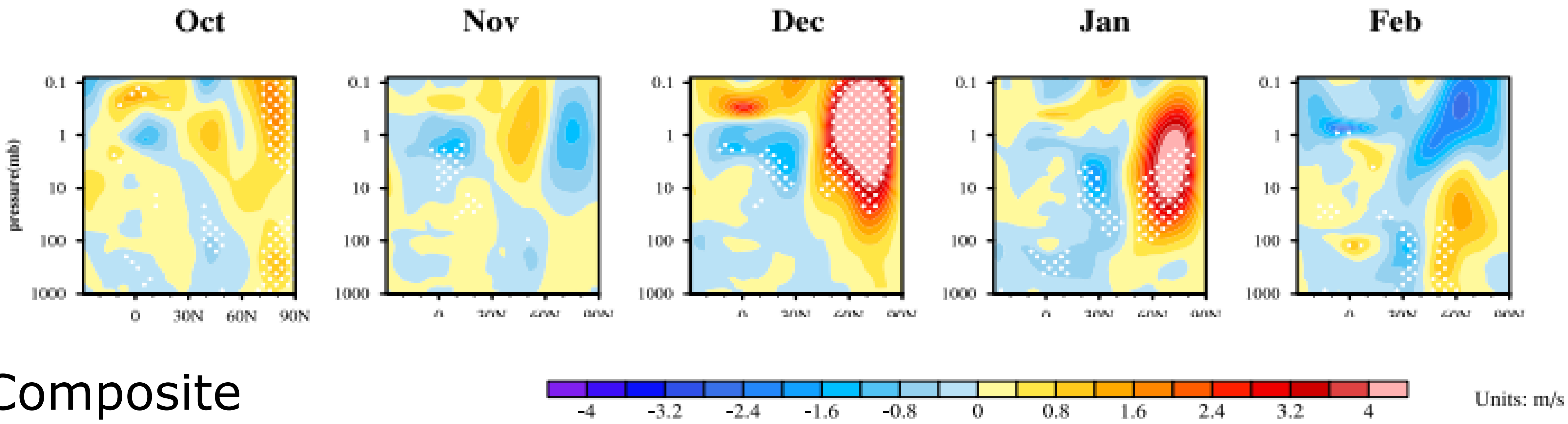
Zonal mea
December,
a 3-year running mean

LOWFREQ subtracted →

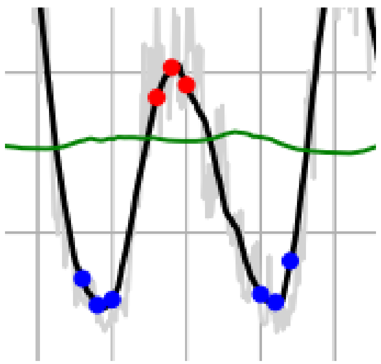
Ens.mean – 11-yr solar signal

Members – solar signal plus int. var.

Propagation of zonal mean zonal wind



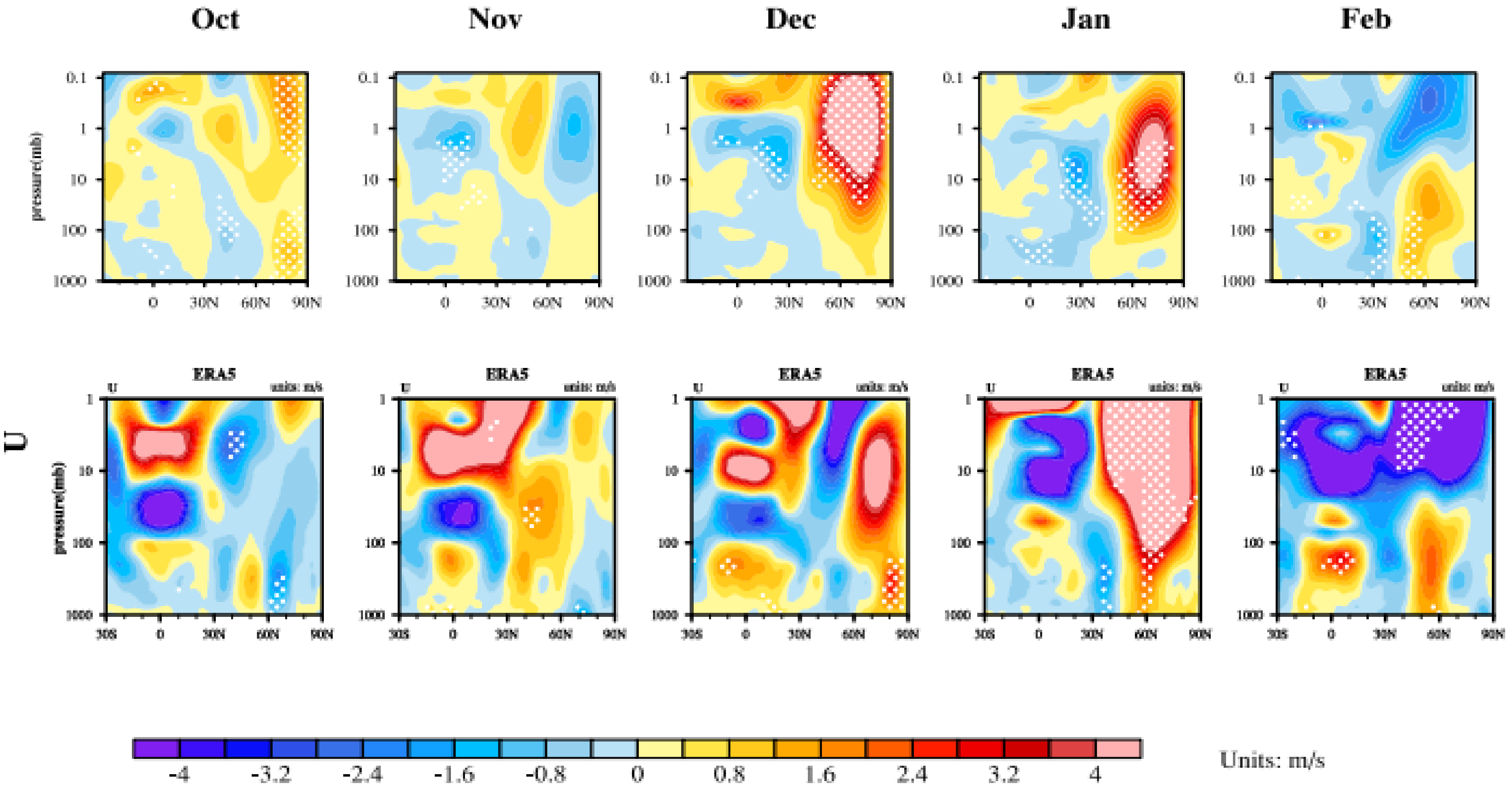
Composite differences between solar max. and min., strong epoch, 3 years around, lag 0



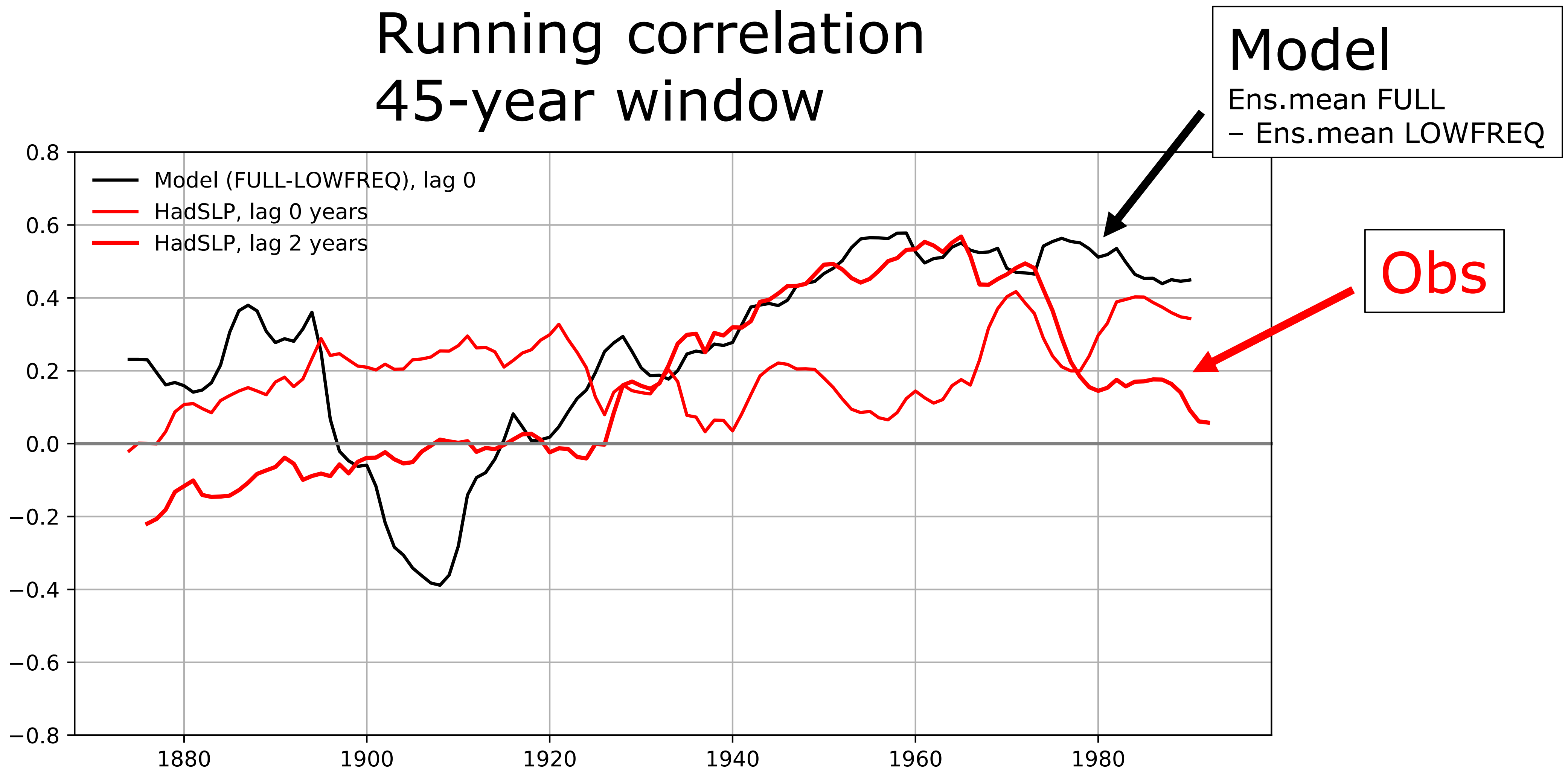
Propagation of zonal mean zonal wind

Strong epoch
(1932 - 2004)

ERA5
Oct - Feb
(1979 - 2015)



Solar signal in NAO



Gain in skill

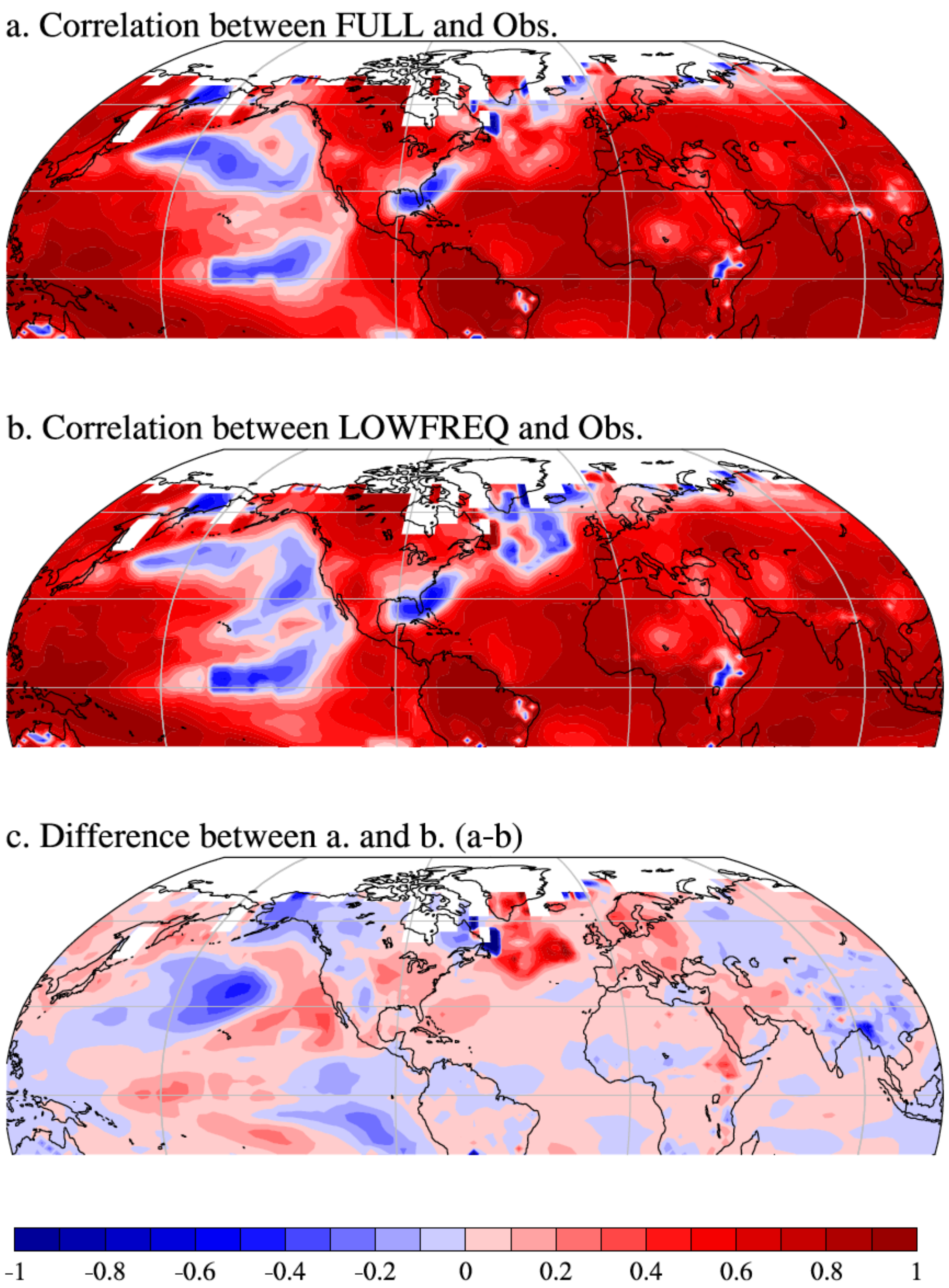
Correlation coefficients of DJF averaged surface air temperatures, 8-year running mean, between

a) observations and FULL ens.mean

b) observations and LOWFREQ ens.mean.

c) Correlation differences between a. and b.

During the strong epoch.



Summary

1) solar surface signal is small, but non-negligible
2) only found when solar cycle amplitude is large enough
3) only in Feb in our model (careful with DJF means)
4) solar cycle “organizes” internal variability
5) adding the solar cycle increases skill in the North Atl. region
6) *potentially useful for decadal predictions!*

Thank you for your attention!