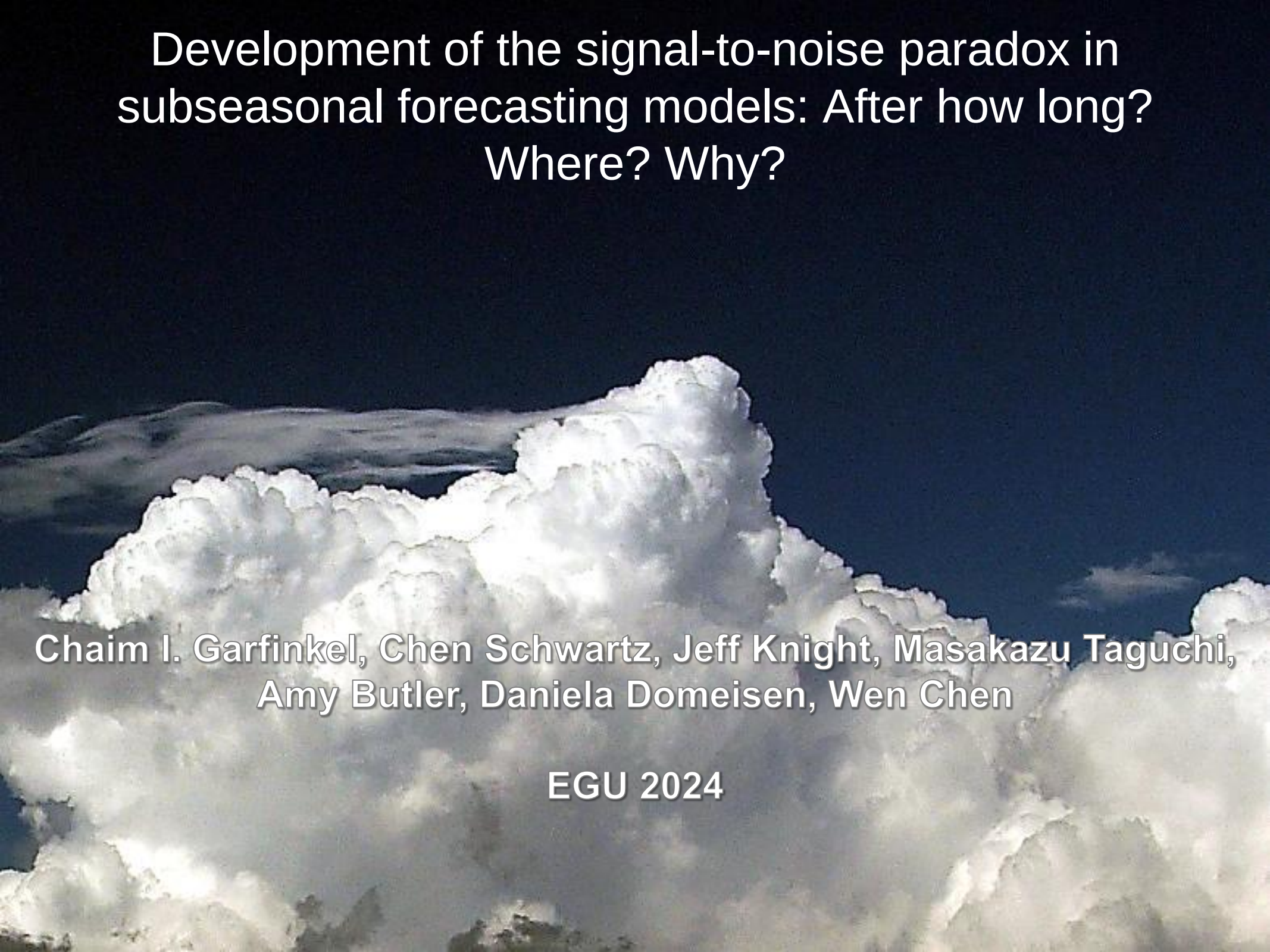
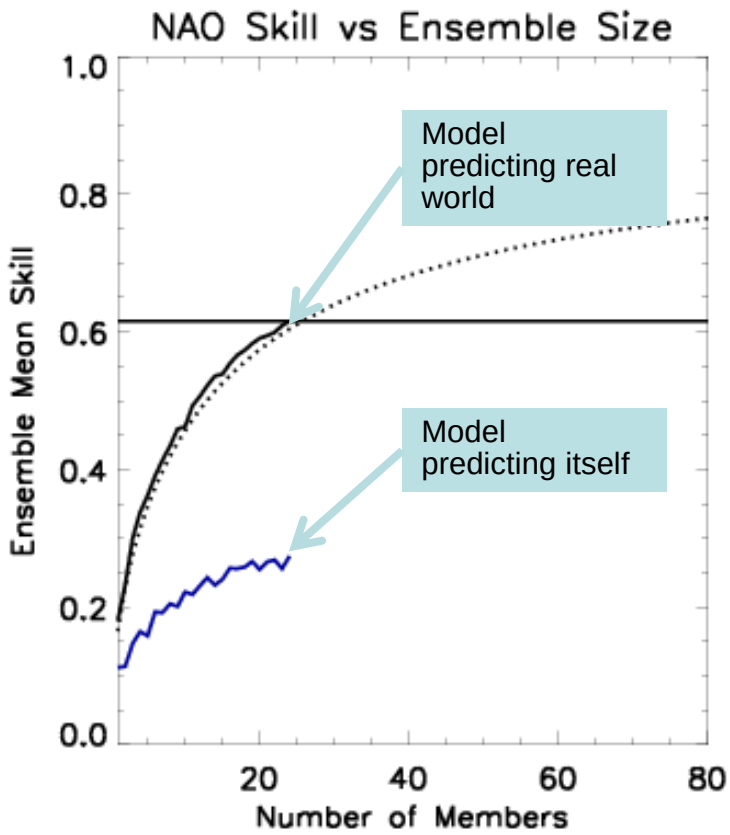
Development of the signal-to-noise paradox in subseasonal forecasting models: After how long? Where? Why?



Chaim I. Garfinkel, Chen Schwartz, Jeff Knight, Masakazu Taguchi, Amy Butler, Daniela Domeisen, Wen Chen

EGU 2024

Signal to Noise paradox



Paradox: models predict the real world better than themselves despite perfectly representing themselves

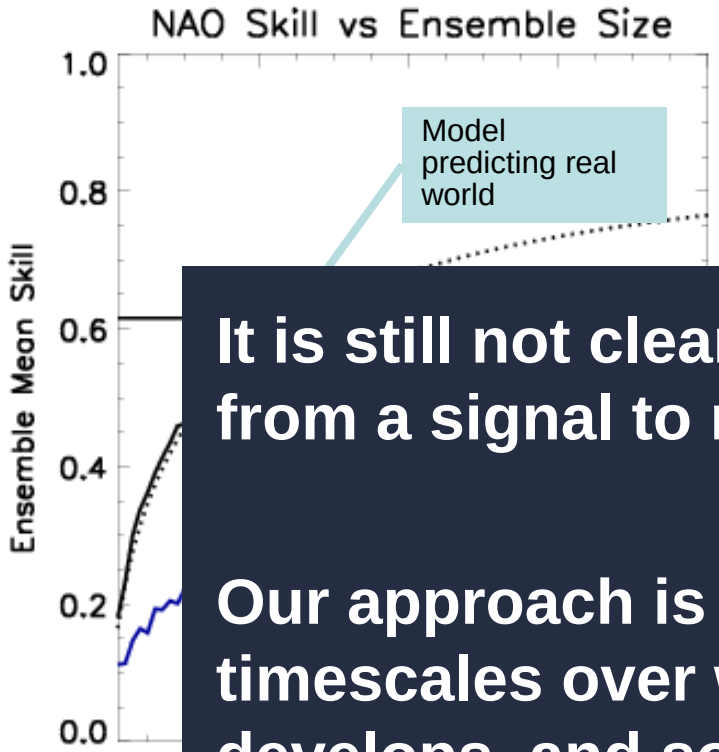
Members NOT alternate realisations of obs

Need a very large ensemble to extract the predictable signal

Models should not be taken at face value

Eade et al 2014, Scaife et al 2014, Dunstone et al 2016, 2018, Siegert et al 2016, Baker et al 2018, Scaife and Smith 2018

Signal to Noise paradox



Paradox: models predict the real world better than themselves despite perfectly representing themselves

sations of obs

to extract the al

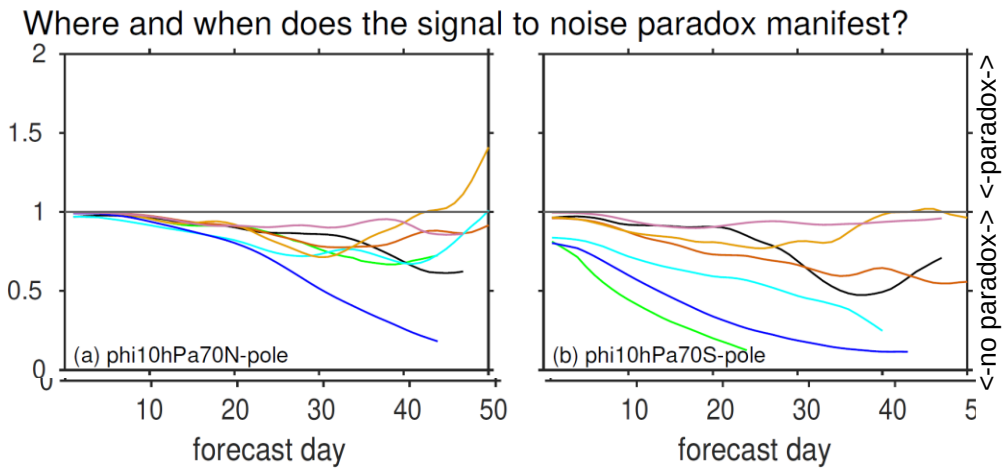
at face value

It is still not clear why models suffer from a signal to noise paradox.

Our approach is to analyze the timescales over which the paradox develops, and so hope to provide some insight into its possible causes.

Eade et al 2014, Scaife et al 2014, Dunstone et al 2016, 2018, Siegert et al 2016, Baker et al 2018, Scaife and Smith 2018

Where is the signal-to-noise paradox present on subseasonal timescales?



$$\mathrm{RPC}^2 = r_{mo}^2 / r_{mm}^2$$

r_{mo}: correlation of ensemble mean with obs

r_{mm}: correlation of ensemble mean with randomly chosen member left out

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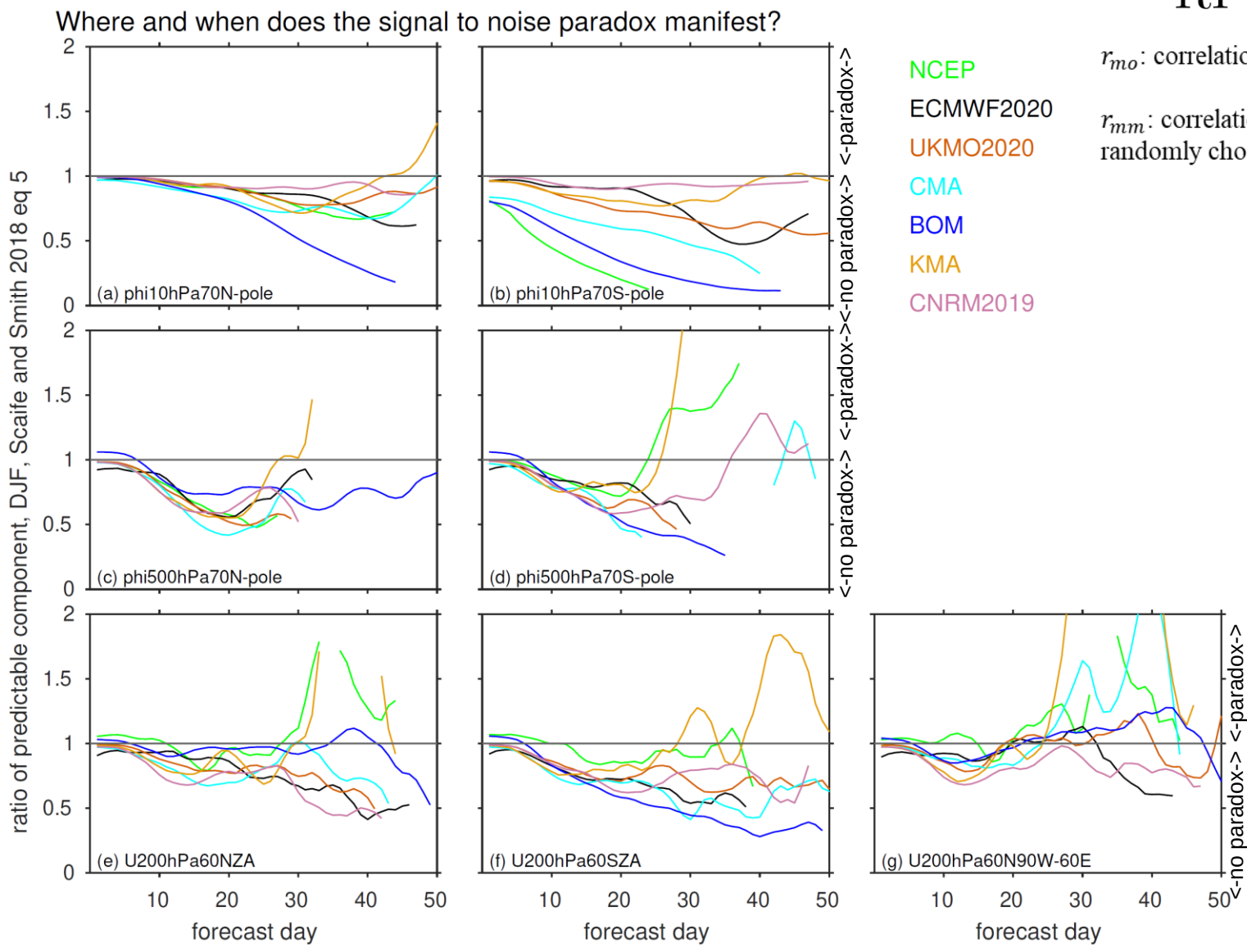

NCEP
ECMWF2020
UKMO2020
CMA
BOM
KMA
CNRM2019

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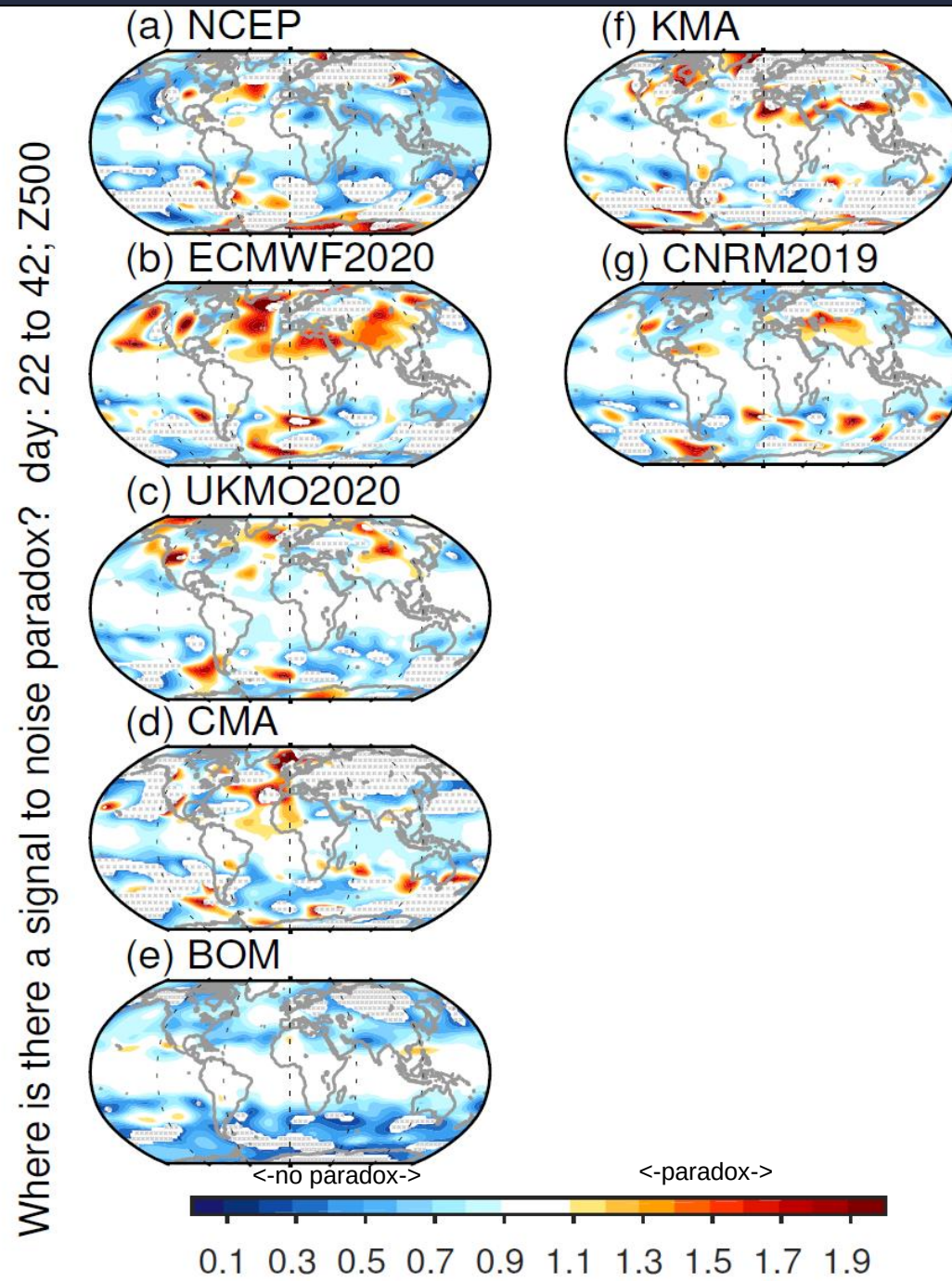

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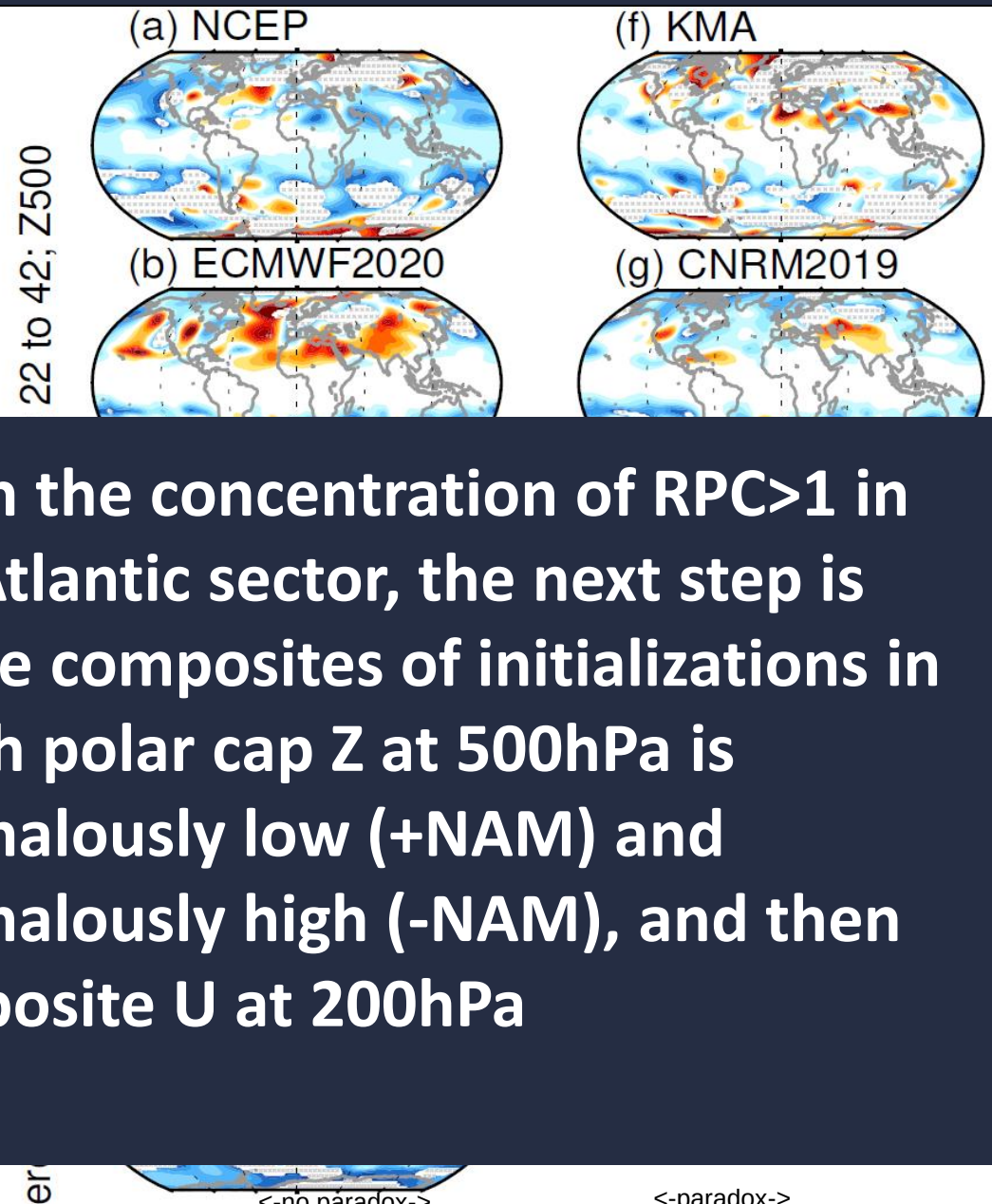

Given the concentration of RPC>1 in the Atlantic sector, the next step is create composites of initializations in which polar cap Z at 500hPa is anomalously low (+NAM) and anomalously high (-NAM), and then composite U at 200hPa

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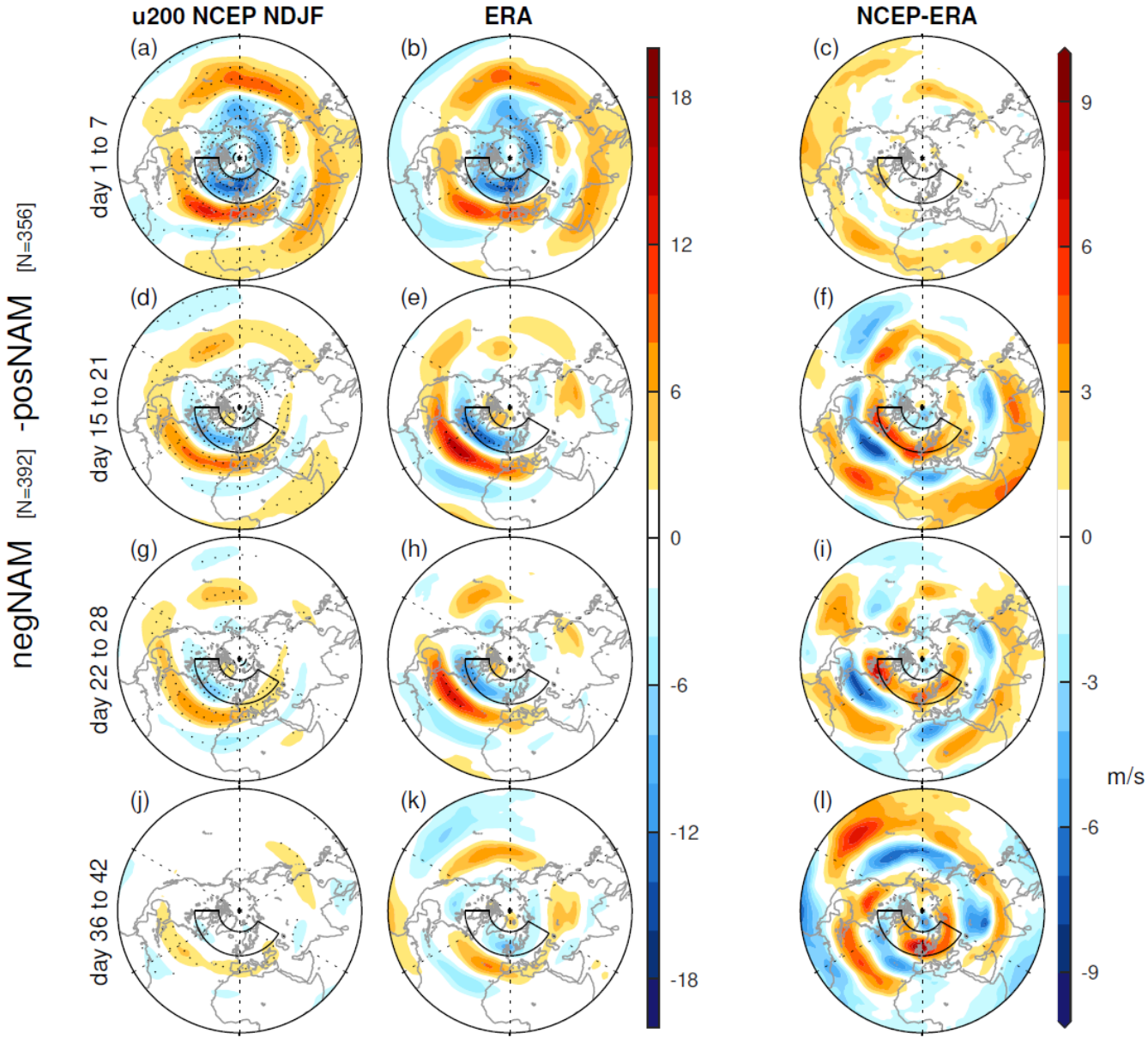
Overly weak NAM persistence



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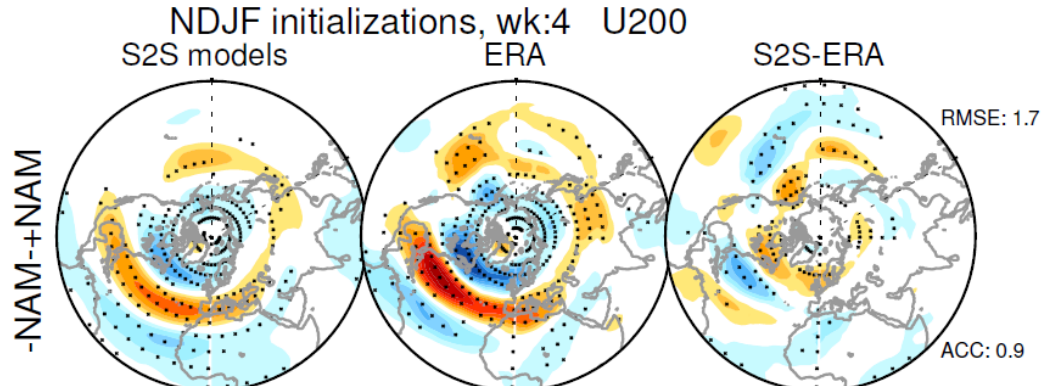

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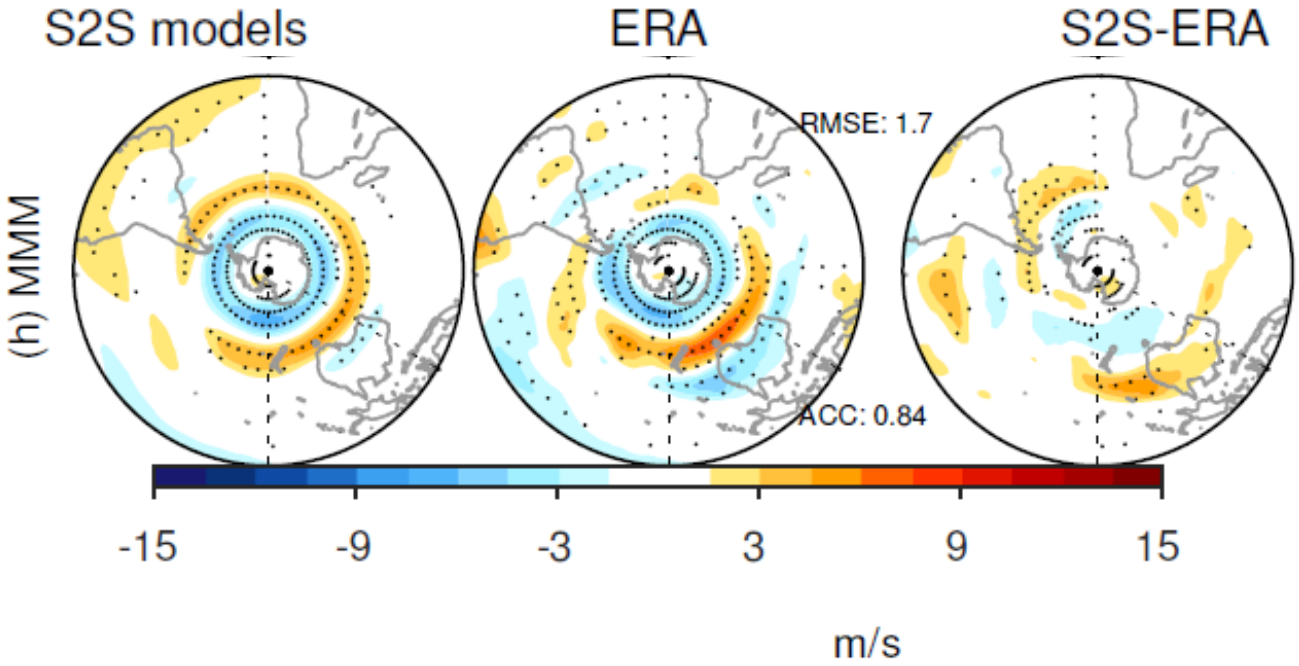
The SAM is too persistent, if anything

-SAM minus +SAM ND initializations; U200 in week 4



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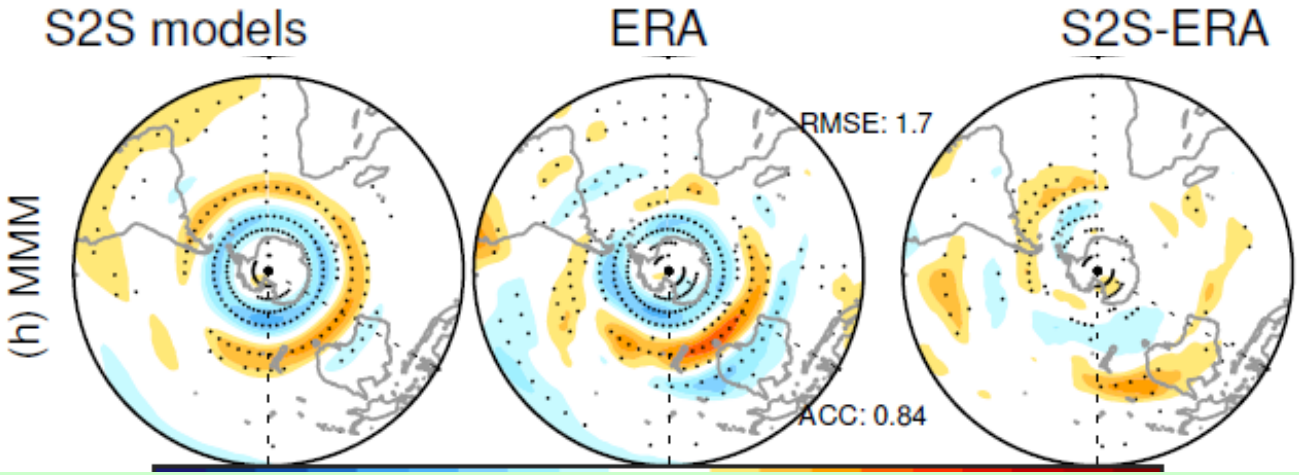

Is the problem the stratosphere?

Is the problem synoptic eddy feedback?

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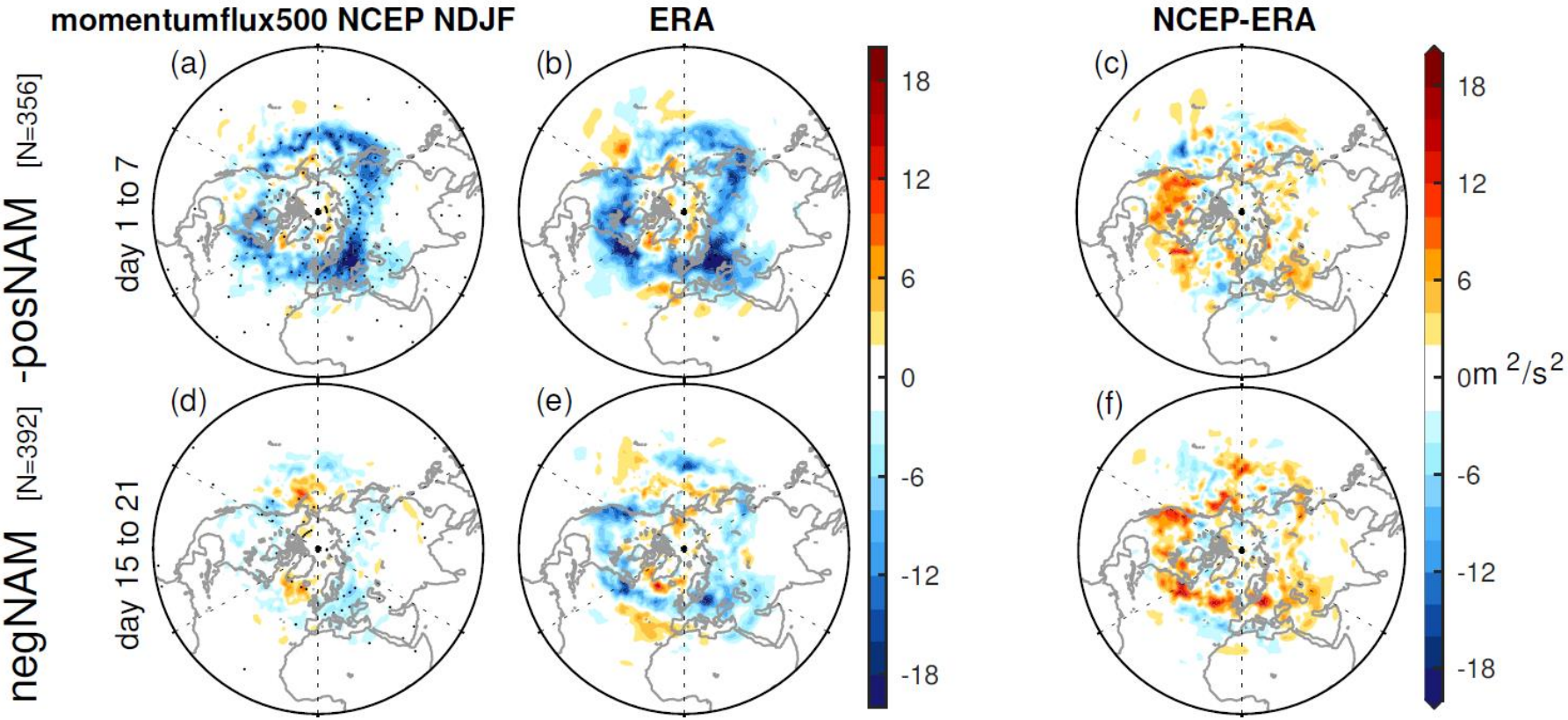
Eddy feedback too weak (transient eddy u'v')



Garfinkel

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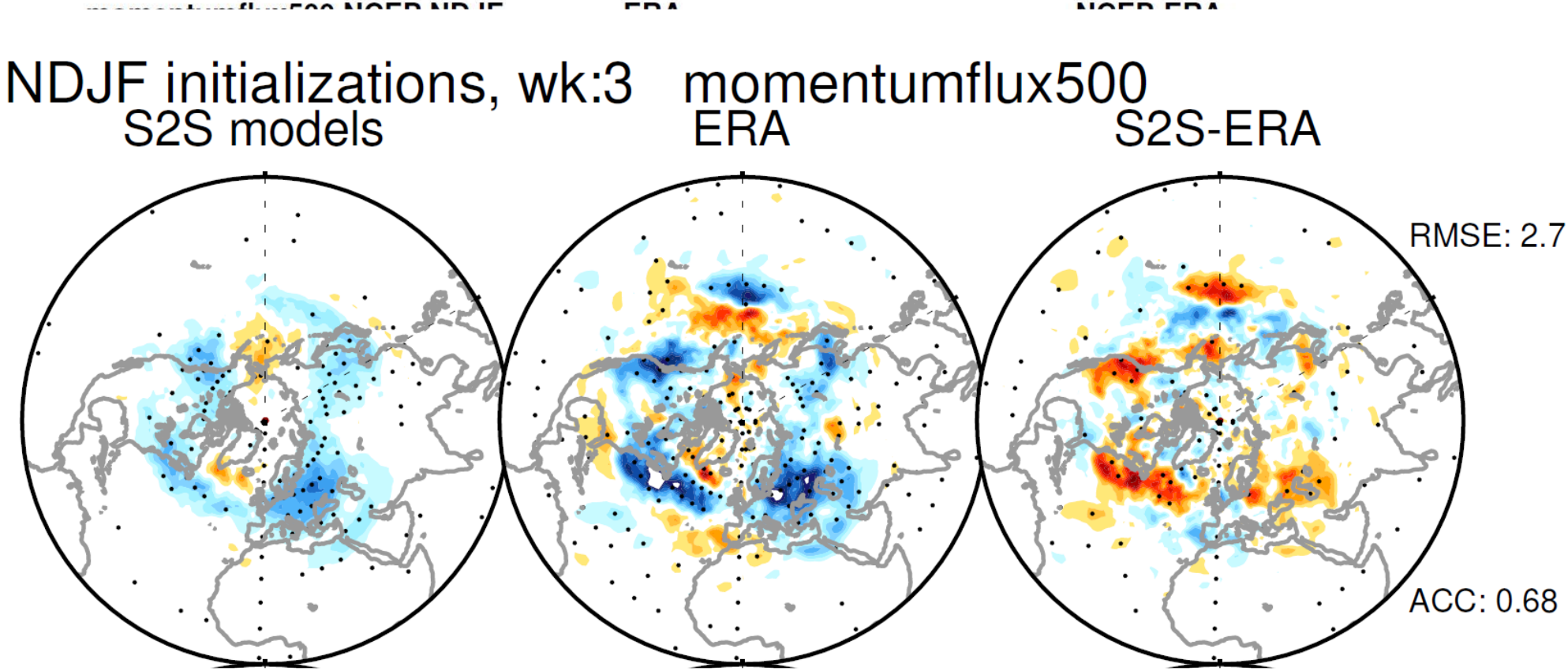
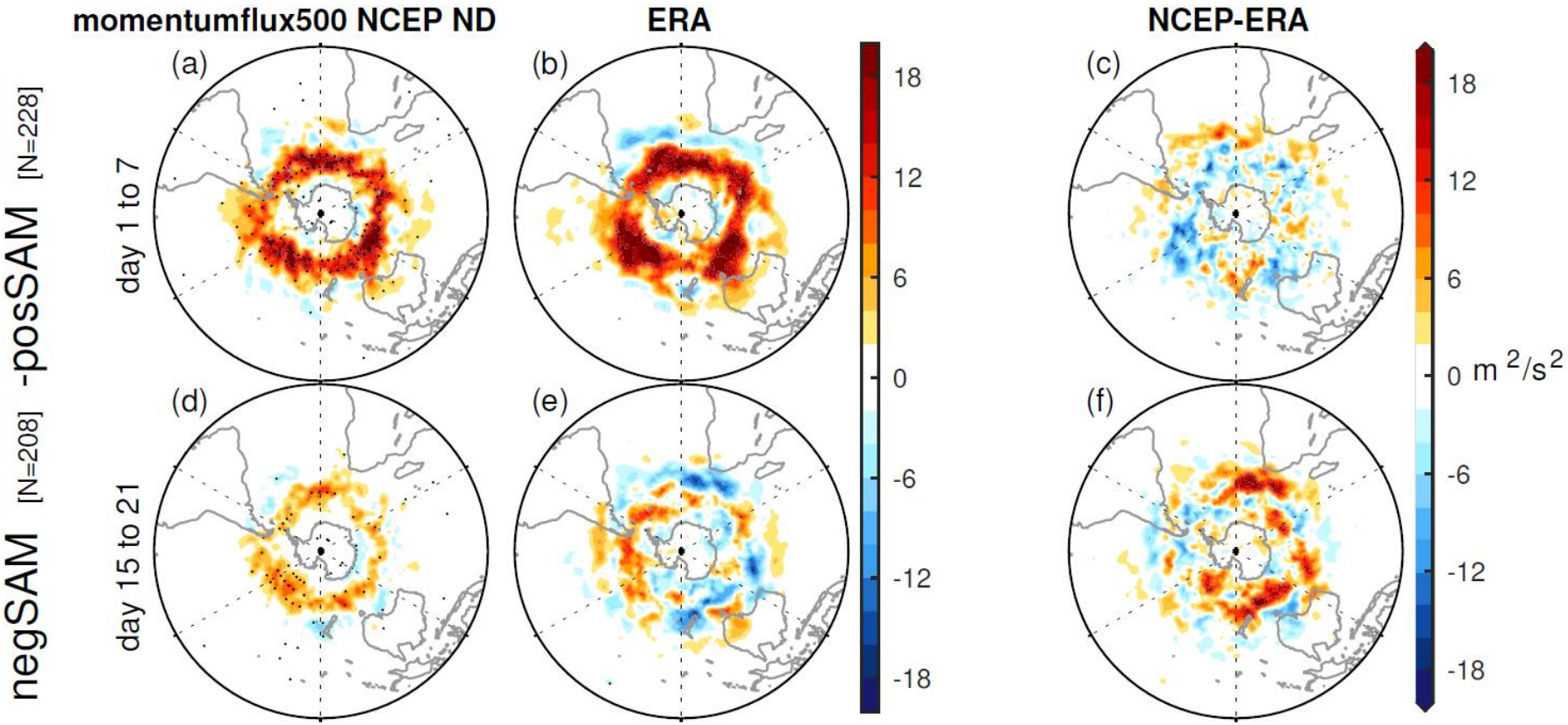


Garfinkel

In SH, eddy feedback too strong if anything



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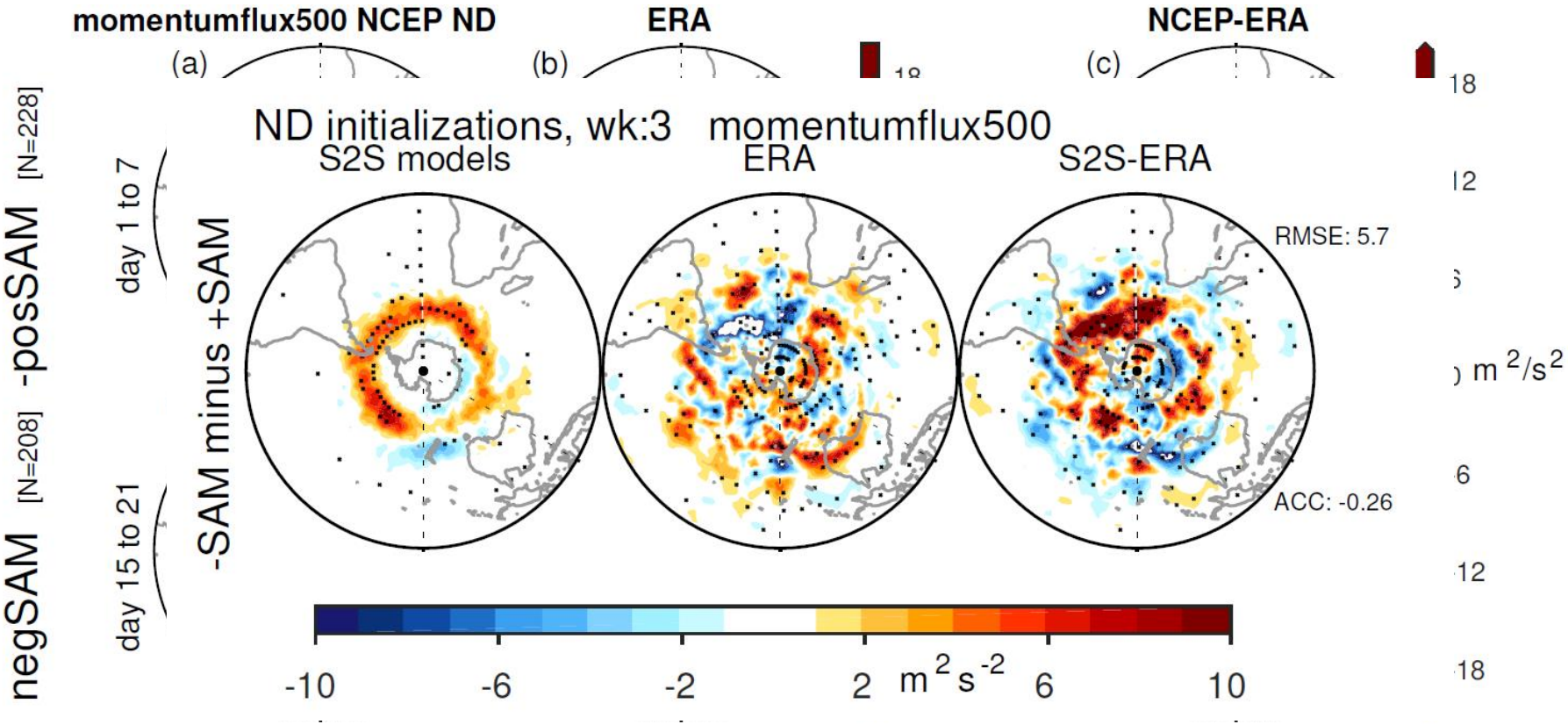

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Conclusions

S2S models develop RPC much greater than 1 by week 4

Paradox is particularly pronounced in the North Atlantic sector

The causes of this can be diagnosed by contrasting initializations during +NAM with initializations during -NAM

The NAM signal decays too quickly in all models, with the bias more pronounced for +NAM

Possible causes include the stratospheric signal decaying too quickly as well as overly weak NH eddy feedback (and these two causes may be linked)

In contrast, the stratospheric signal in the SH persists realistically, and SH eddy feedback is too strong. This is consistent with a weaker signal to noise paradox in the SH.

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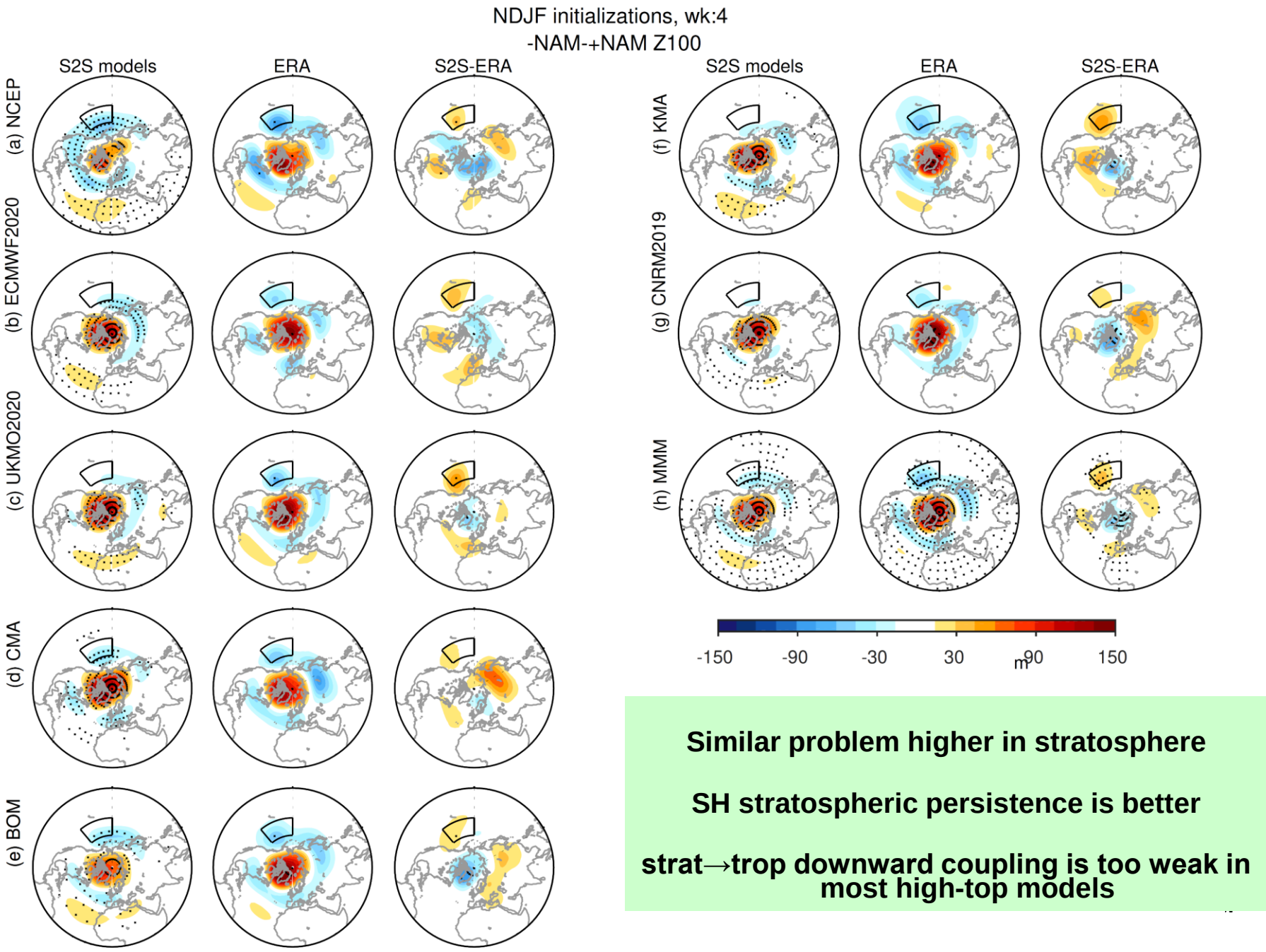
The stratospheric signal decays too quickly

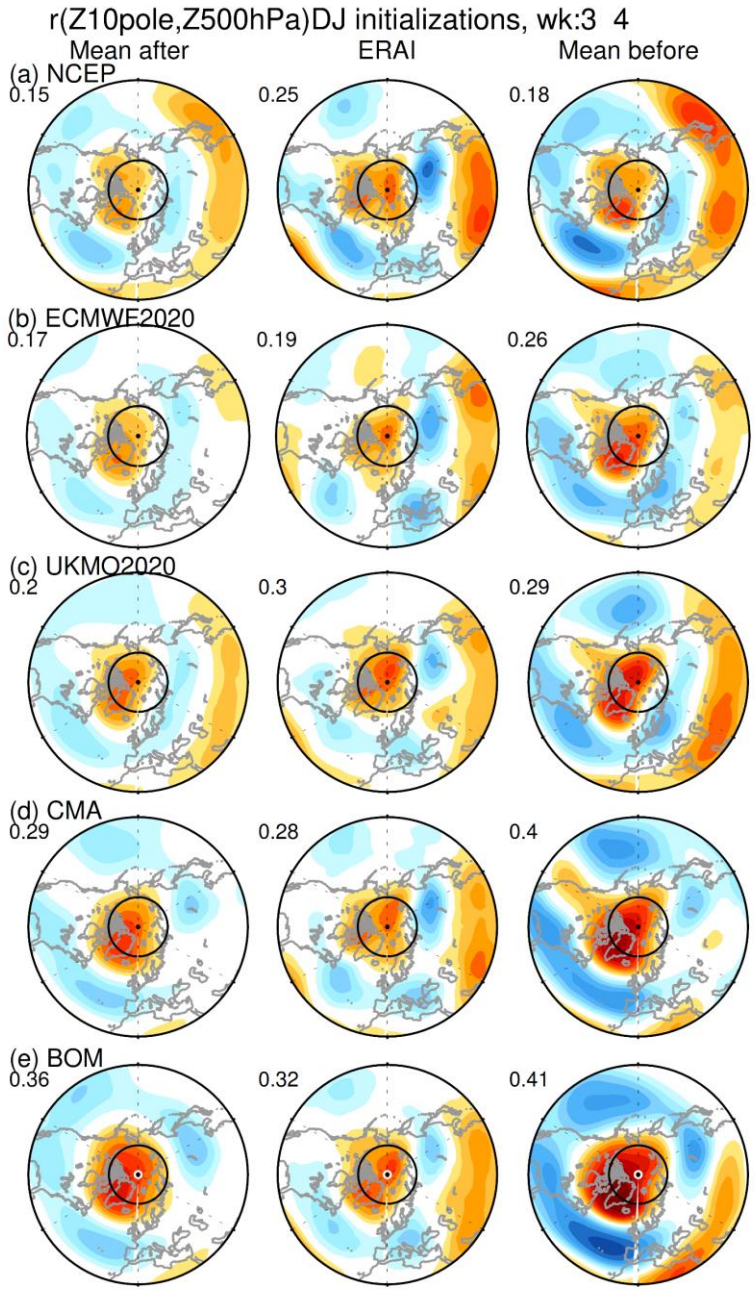


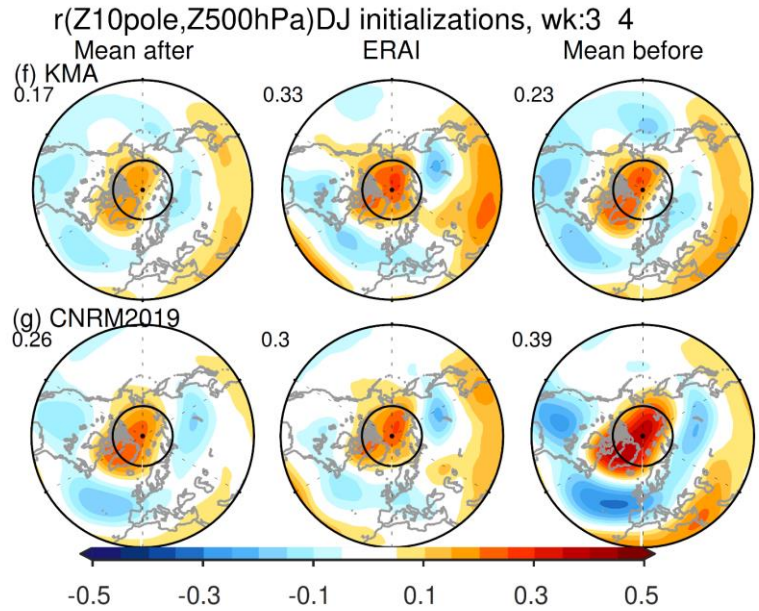
Similar problem higher in stratosphere

SH stratospheric persistence is better

strat→trop downward coupling is too weak in most high-top models

Biases in downward coupling





Similar problem higher in stratosphere

SH stratospheric persistence is better, however downward coupling is too weak

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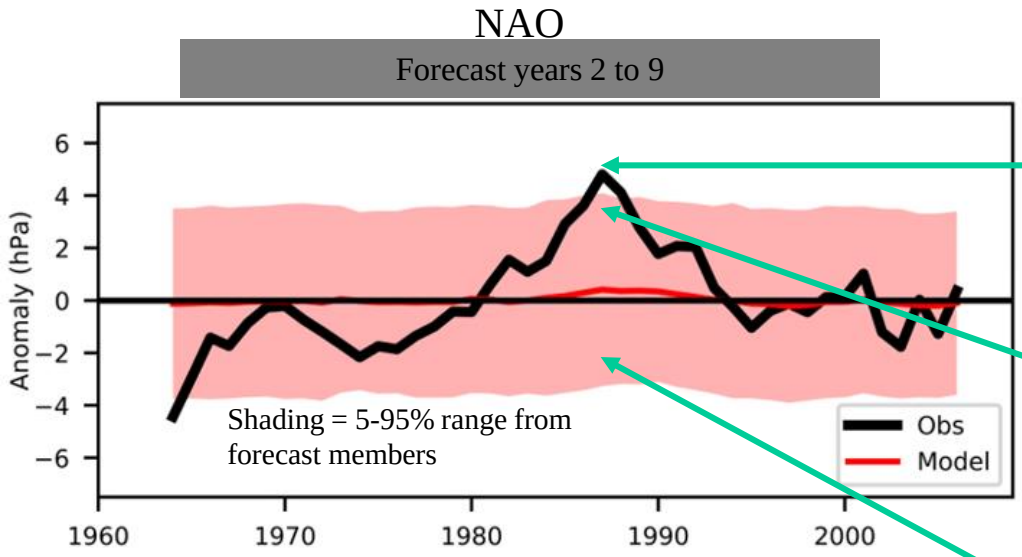
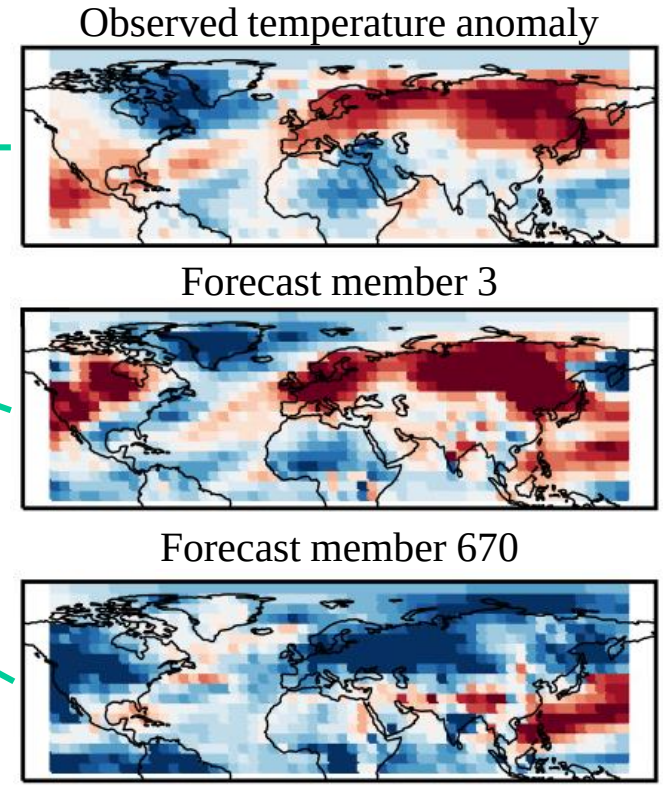
Irreducible internal variability?





CMIP5 + CMIP6 decadal predictions

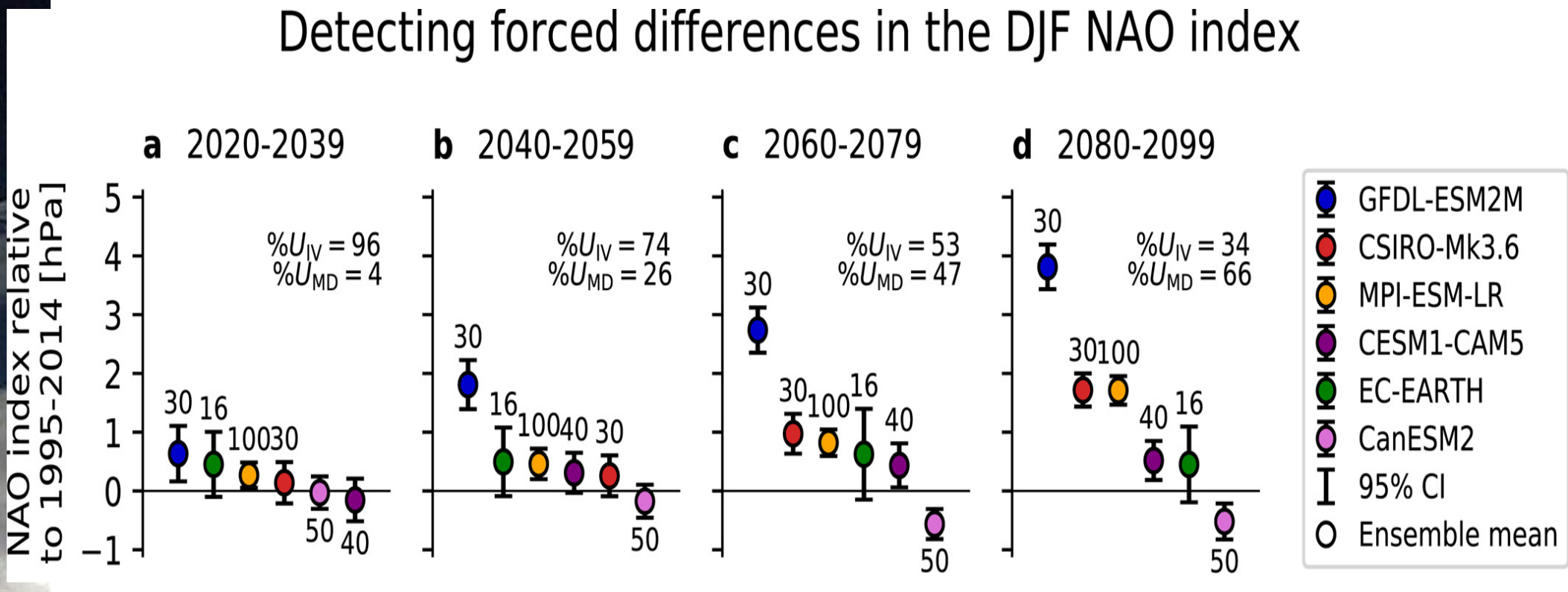
Almost no signal in ensemble mean (red curve)

Irreducible internal variability if models taken at face value

BUT this can be tested…

Smith et al 2020

Uncertainty in dynamical response to climate change



McKenna and Maycock 2021, GRL

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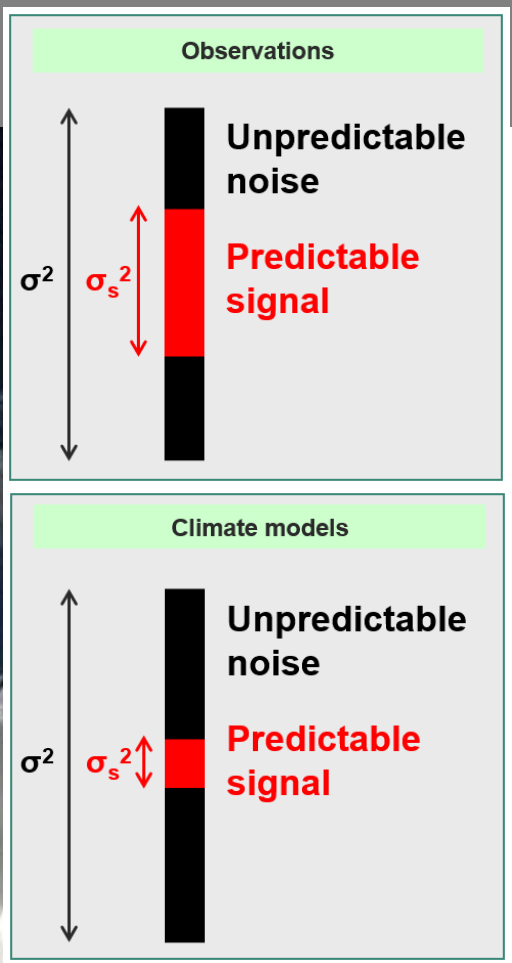
Ratio of predictable components



Observations: Predictable Component PC >= r (anomaly correlation)

Models: PC = $\frac{\sigma_{ensemble\ mean}}{\sigma_{ensemble\ members}}$

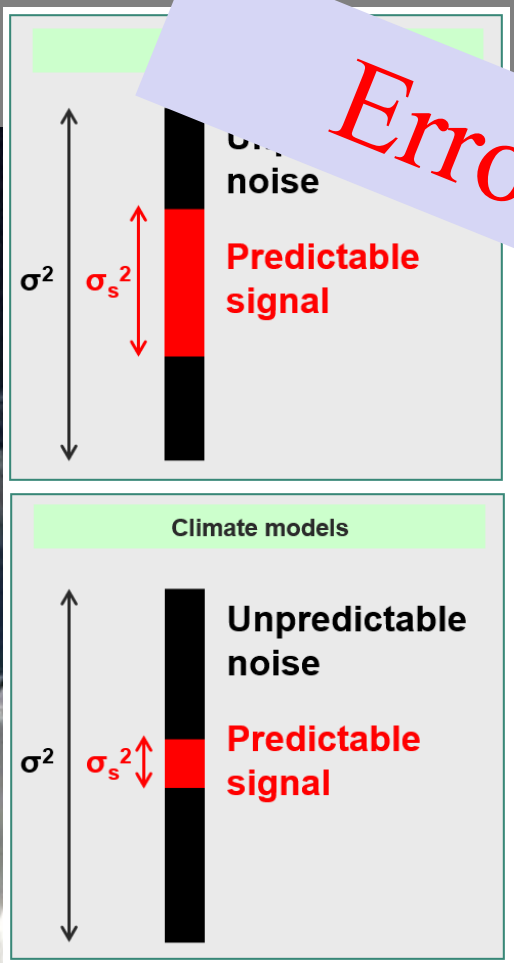
Ratio of predictable components (RPC) >= $\frac{r}{\sigma_{ensemble\ mean}/\sigma_{ensemble\ members}}$

RPC should be one

RPC > 1 shows the signal to noise error

Eade et al 2014, Scaife and Smith 2018

Ratio of predictable components



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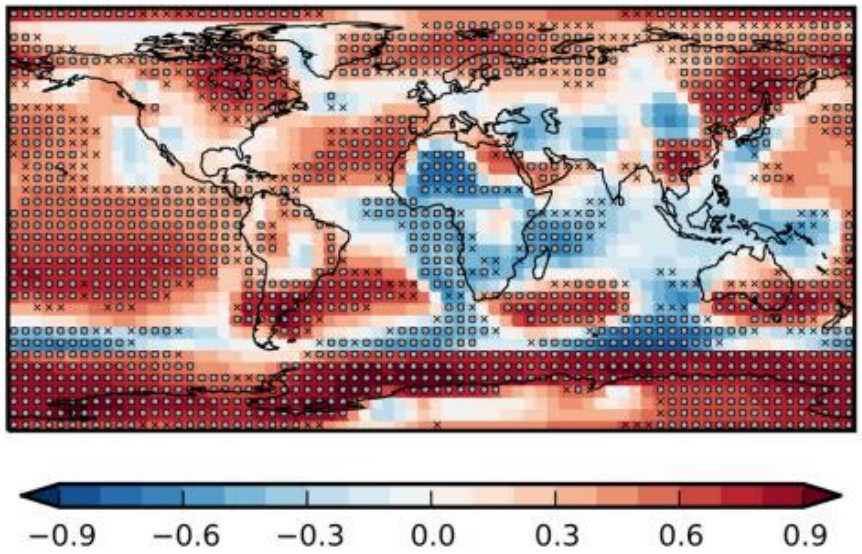
Error not seen in total variability

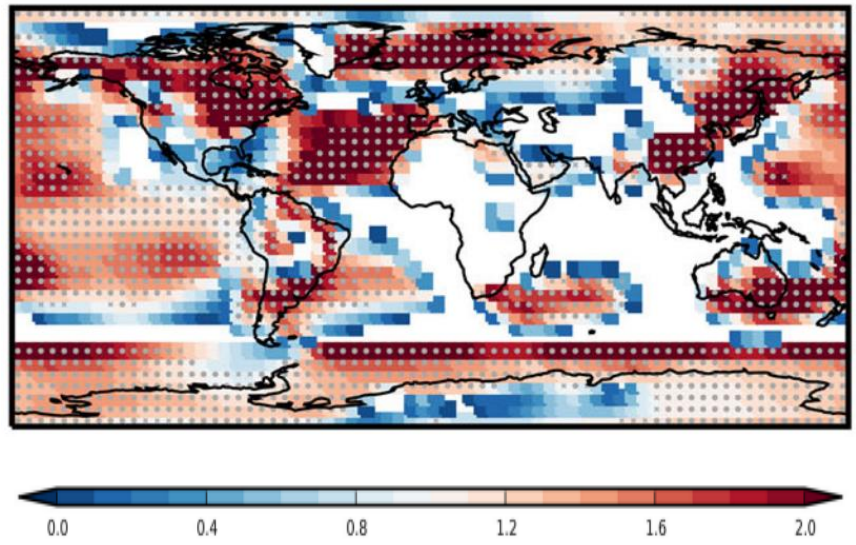
Eade et al 2014, Scaife and Smith 2018

A key issue

MSLP skill (years 2-9)



Error in magnitude of signal (RPC)

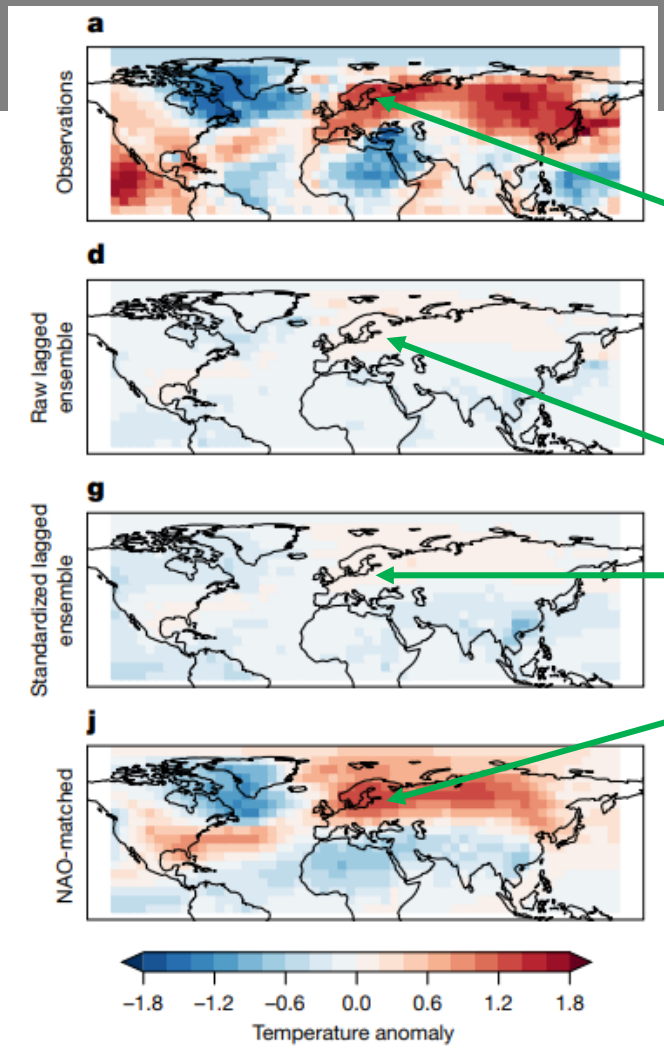


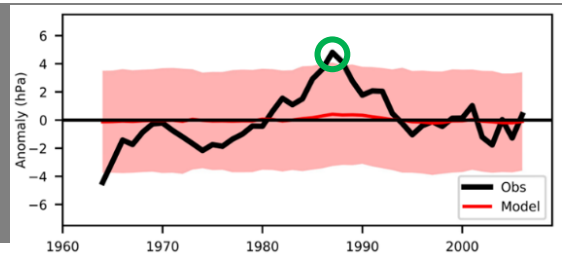
Wherever there is skill the modelled signals are too small!

Smith et al 2019, 2020

Scaife et al, ASL, 2016

NAO impacts not captured





$T = T_{DYN} + T_{THERMO} + \varepsilon$

Real world: $T_{DYN} >> T_{THERMO}$

Ensemble mean: $T_{DYN} << T_{THERMO}$ because NAO signal too small

Scaling retains the incorrect ratio T_{DYN}/T_{THERMO}

Can be overcome by selecting ensemble members with correct magnitude of NAO

Standard D&A approach will not work

Need to look at models in new ways

Smith et al 2020, 2022