Met Office

# Missing eddy feedback may explain weak signal to noise ratios in climate predictions

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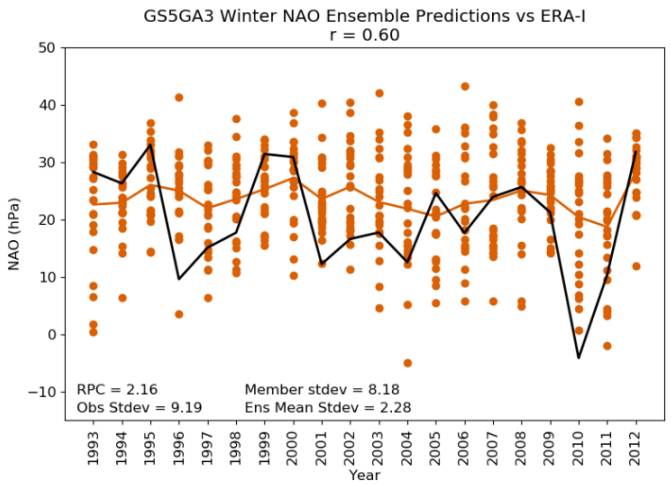
# Signal-to-noise error



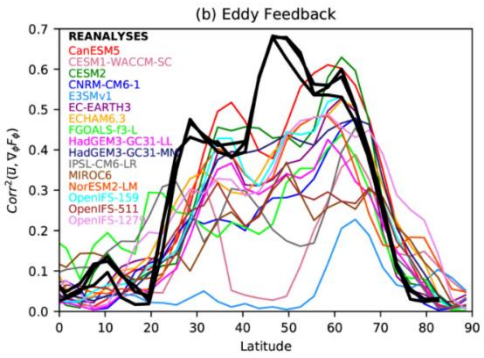

**SIGNAL-TO-NOISE**

RPC = Skill of model in predicting observations / Skill in predicting ensemble members

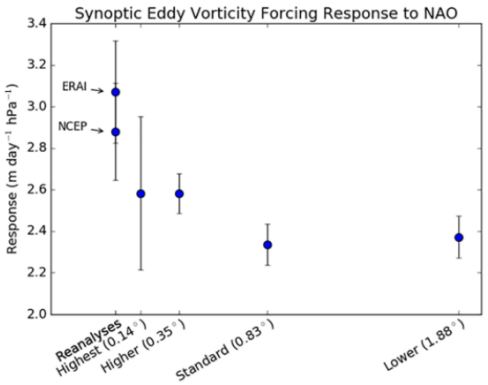
RPC > 1 → model is underconfident

Predictable signals around 10 times too small in decadal forecasts → require 100 times more ensemble members to detect signal

# Signal-to-noise and eddy feedback




*Smith et al., 2022*




*Scaife et al., 2019*

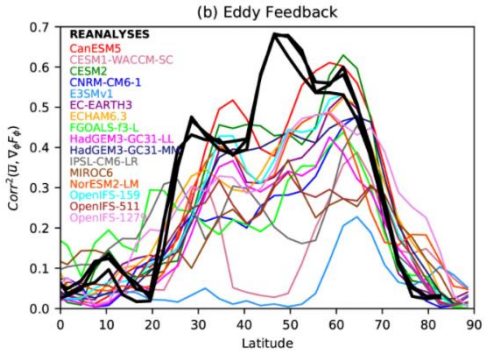
## EDDY FEEDBACK

Eddy feedback is the process whereby interaction with small scale transient eddies amplifies large scale quasi-stationary climate anomalies in the mid latitudes.

One hypothesis for signal-to-noise paradox is eddy feedback deficiency in climate models

Require very high spatial resolution to fully resolve eddy feedback – this won't be realised in climate predictions/projections for a long time

# Eddy feedback parameter




*Smith et al., 2022*

Want to test that eddy deficiency and signal-to-noise error are linked

Define parameter for eddy feedback: $Corr^2(divF_y, u)$, 25N-72N, DJF

Compute eddy feedback parameter and signal-to-noise metrics for several seasonal forecast systems

$$RPC = \frac{r_{mo}}{r_{mm}}$$

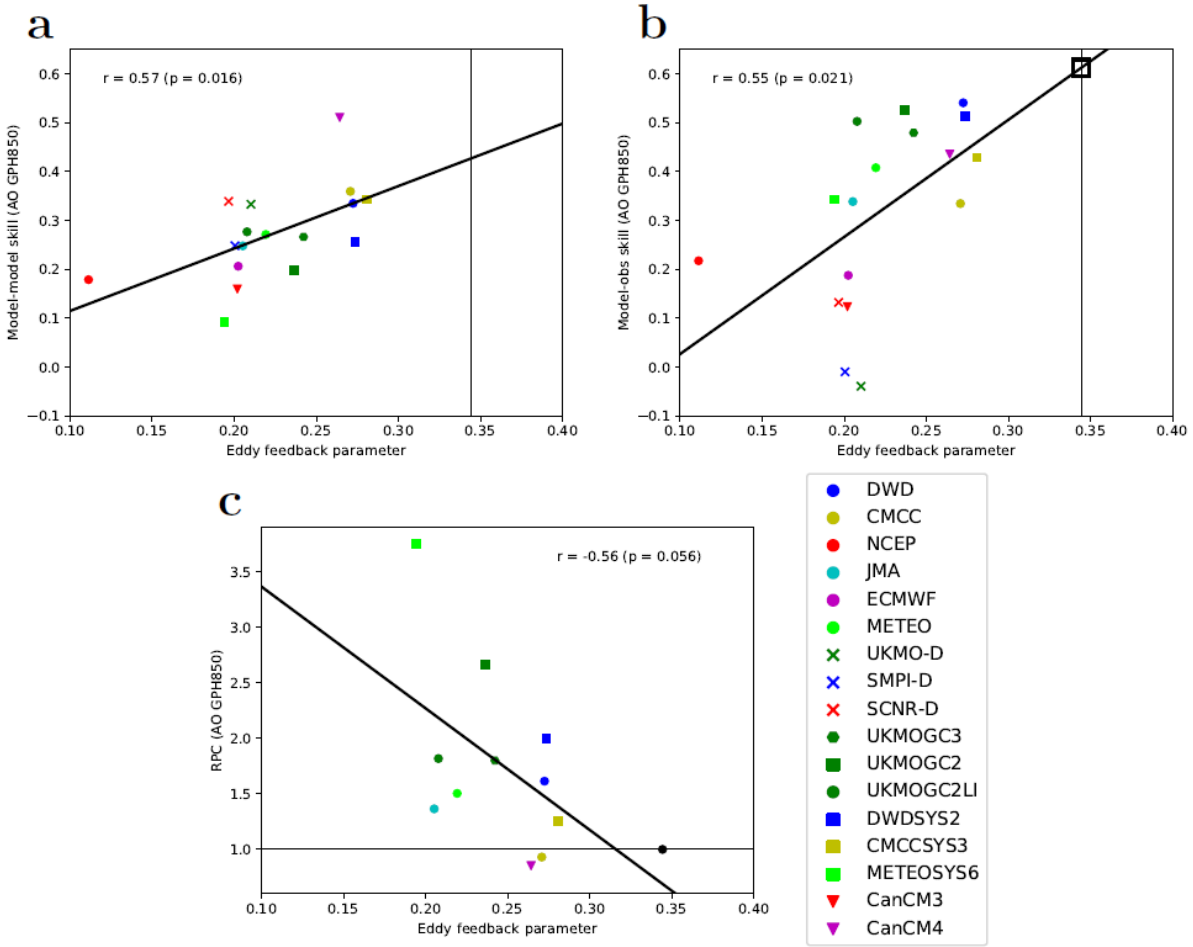
| Forecast system | Number of ensemble members | |
|---|---|---|
| DWD | 30 | C3S |
| CMCC | 40 | C3S |
| NCEP | 24 | C3S |
| JMA | 10 | C3S |
| ECMWF | 25 | C3S |
| METEO | 25 | C3S |
| UKMO-D | 9 | DEMETER |
| SMPI-D | 9 | DEMETER |
| SCNR-D | 9 | DEMETER |
| UKMOGC3 | 28 | C3S |
| UKMOGC2 | 56 | C3S |
| UKMOGC2LI | 56 | C3S |
| DWDSYS2 | 30 | C3S |
| CMCCSYS3 | 40 | C3S |
| METEOSYS6 | 25 | C3S |
| CanCM3 | 10 | NMME |
| CanCM4 | 10 | NMME |

# Skill/RPC vs eddy feedback

Significant positive correlation of eddy feedback and model skill → increased eddy feedback consistent with increased AO forecast skill

Significant negative correlation of eddy feedback and RPC → increased eddy feedback consistent with reduced signal-to-noise error

Regression line crosses RPC = 1 close to observed value of eddy feedback



# ENSO teleconnection

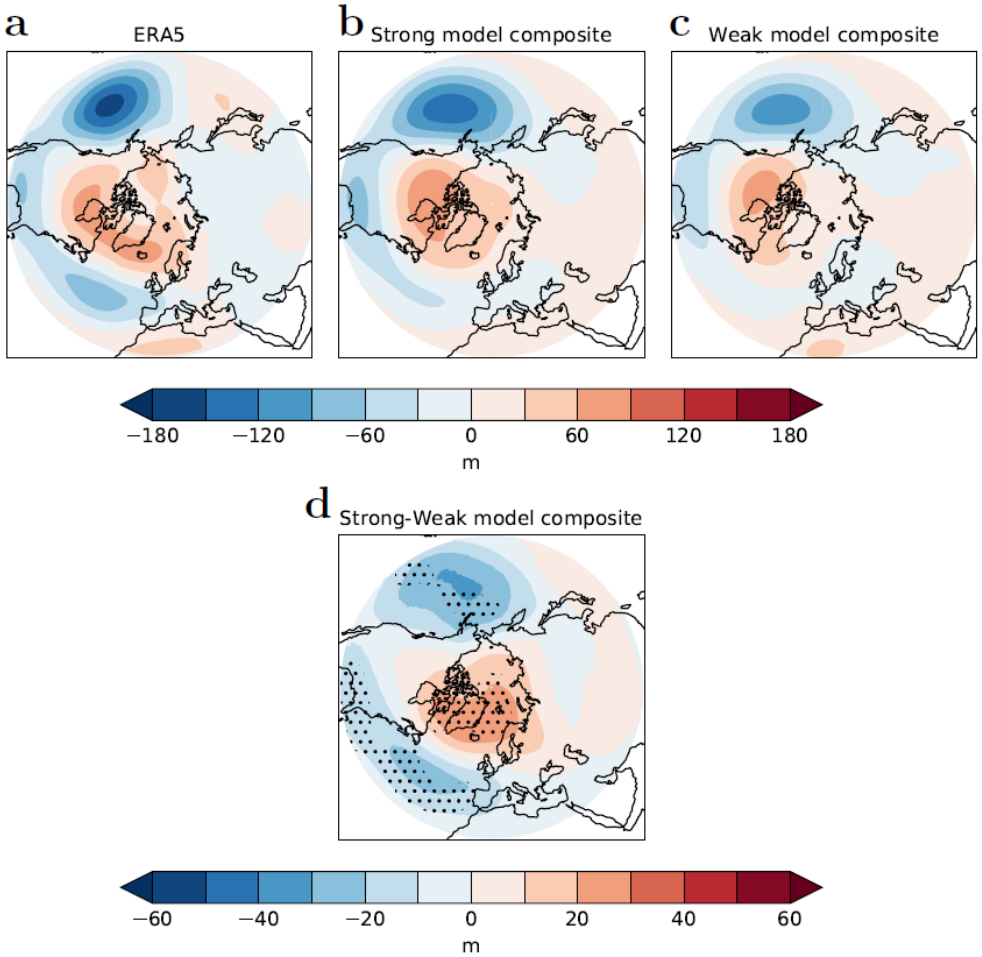
ENSO teleconnection to AO
(via stratosphere)

Assess using anomalies of geopotential height (500hPa) [El Nino – La Nina]

Teleconnection strength is deficient in all models but stronger in models with more accurate eddy feedback

Difference between strong/weak eddy feedback model response looks like observed response

Increased eddy feedback → stronger teleconnection in models → stronger simulated predictable signals



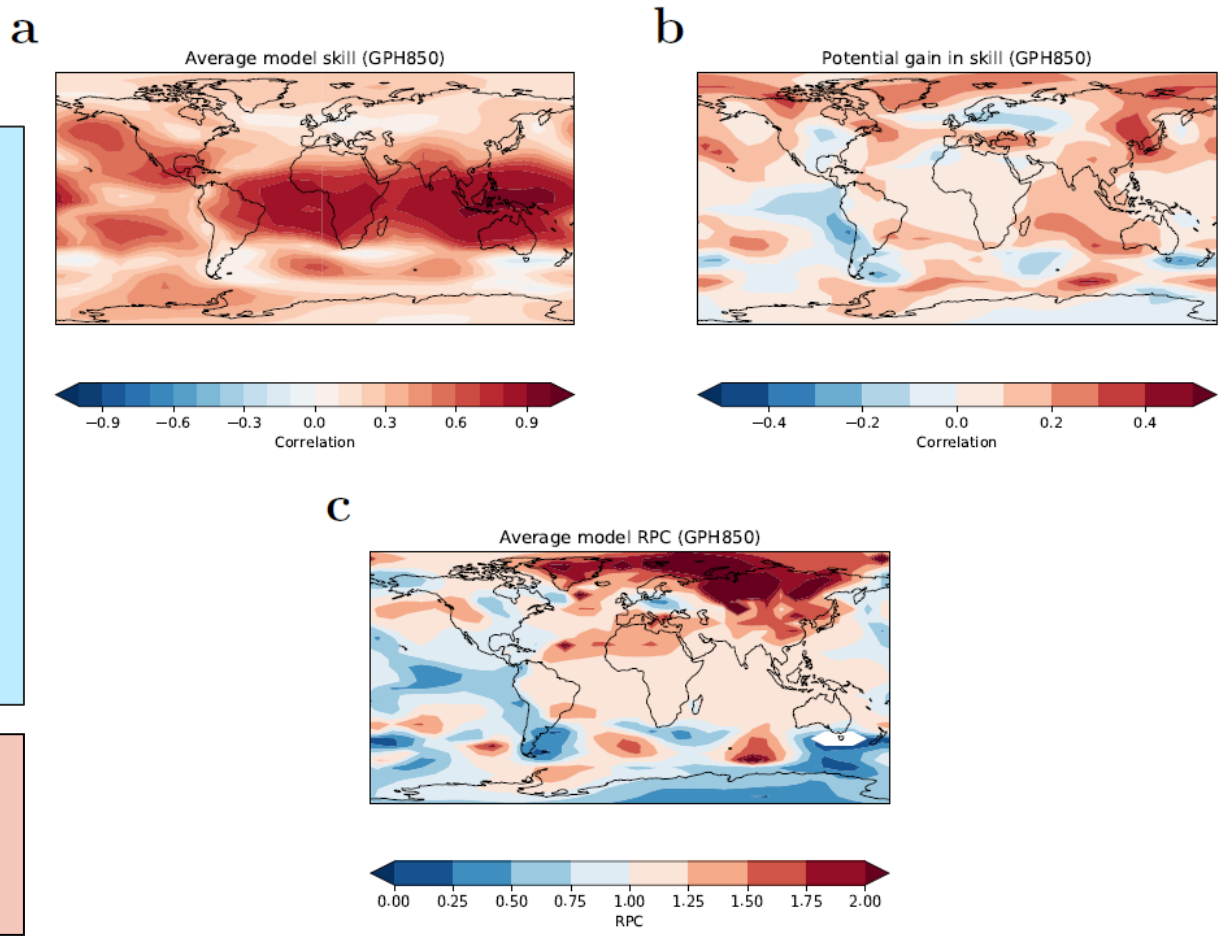
# Regional skill

*Define average skill and potential skill → potential gain in skill*

Potential gain in skill from removing eddy feedback deficiency is comparable to current model skill in extratropics (i.e. skill could be doubled)

Regions with greatest potential gain in skill correspond to regions with worst signal-to-noise error

Improved eddy feedback in seasonal forecast systems *could* reduce their signal-to-noise error and improve their skill



# Summary

Increased eddy feedback

- is strongly linked with a reduced signal-to-noise error (RPC ≈ 1 if the eddy feedback in forecast systems is equal to that in the reanalysis)
- is strongly linked with increased model-model and model-observed skill.

Skill could roughly double in many extratropical regions (including NAO) if eddy feedback were of a realistic magnitude

The regions where there is potentially the greatest skill to be gained by improved eddy feedback correspond closely to those regions where the signal-to-noise error is largest

*Motivates an increased effort to both understand the physical mechanisms underlying eddy feedback and to conceive how to implement imposed eddy feedback or a parameterisation of missing eddy feedback in forecast systems.*

Hardiman, Steven C., et al. (2022), Missing eddy feedback may explain weak signal-to-noise ratios in climate predictions, npj Clim. Atmos. Sci., 5, 57, doi: https://doi.org/10.1038/s41612-022-00280-4