Signal, Noise and Predictability in North Atlantic Regime Systems

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** Funded by a Thomas Phillips and Jocelyn Keene JRF*

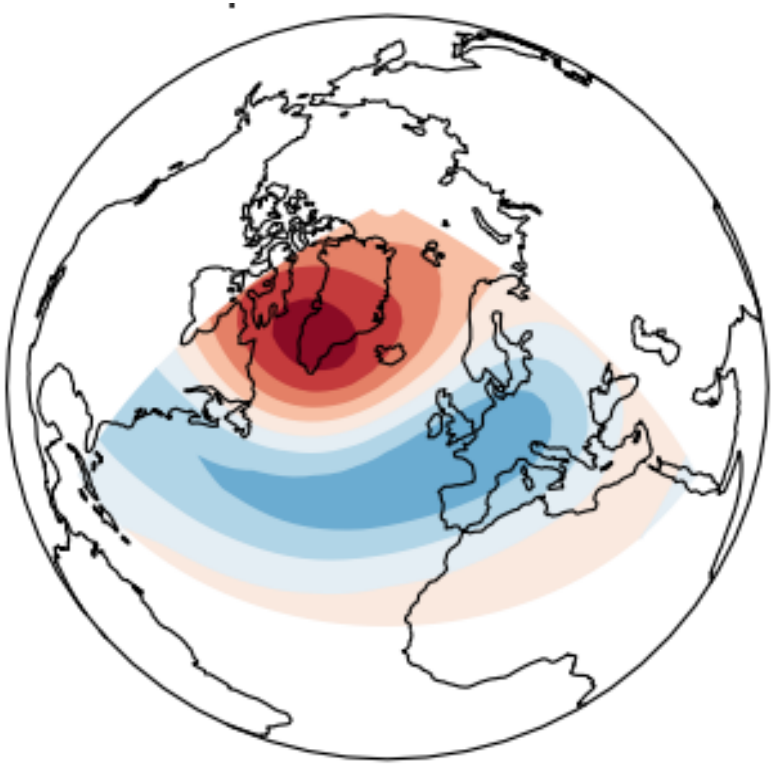
General Note

The work presented is focused on NAO/North Atlantic predictability.

But the framework can be applied to any region influenced by existence of weather regimes, including e.g. the North Pacific.

1. Motivation

Winter NAO ≈ European/Eastern-US winter weather

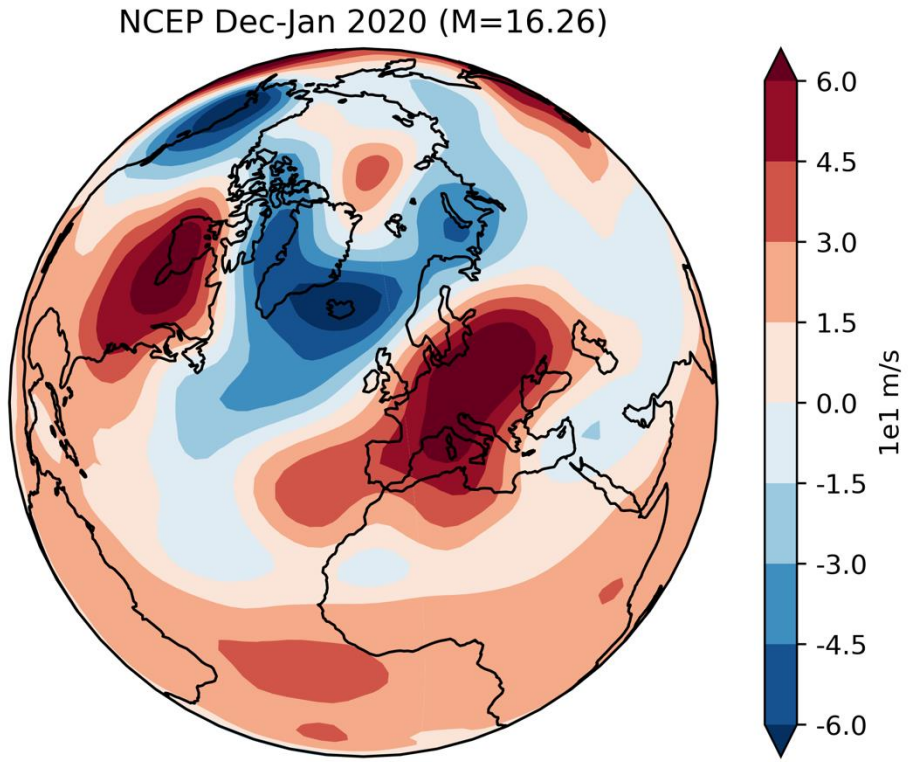


NAO = North Atlantic Oscillation

1. Motivation

Recent example: winter 2020

Z500



Strong positive NAO!

Z500 = Geopotential at 500 hPa

1. Motivation

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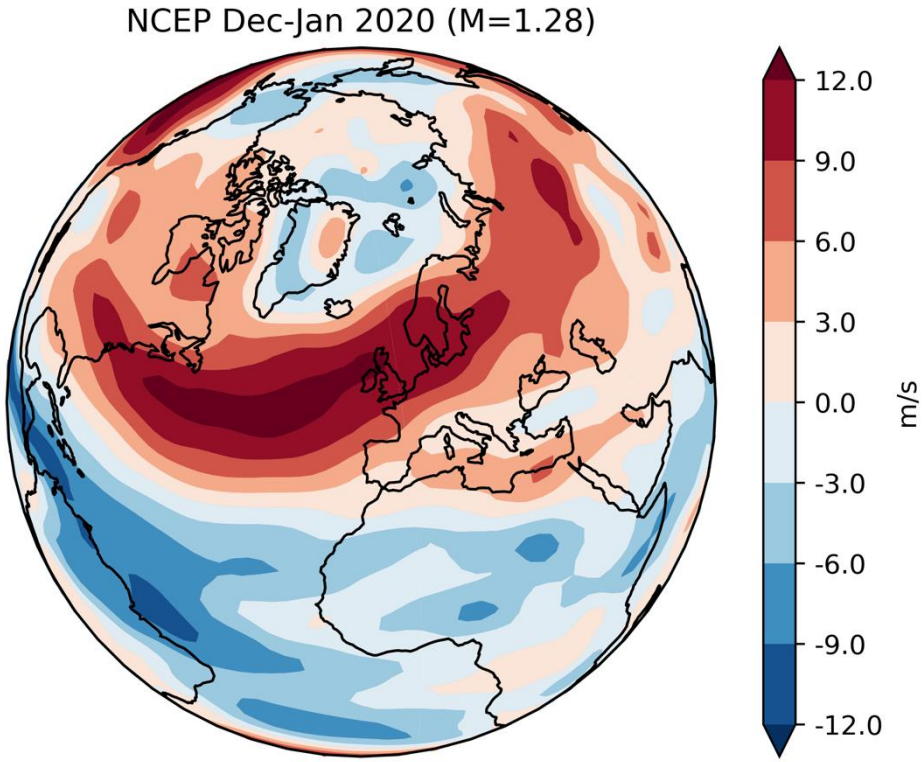
View from the jetstream

U850



Atmosphere getting stuck in a particular circulation regime for a long time

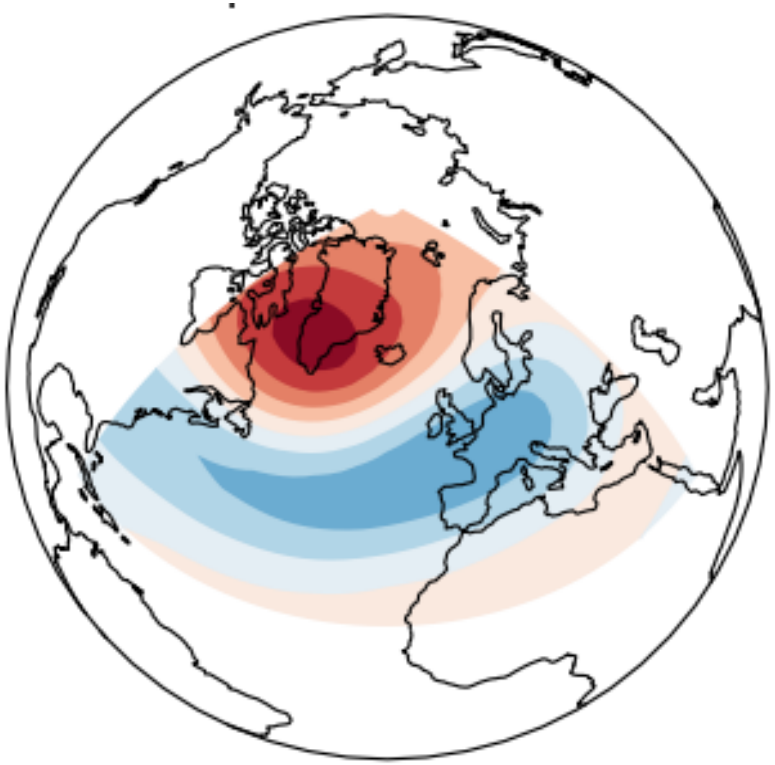
Extreme weather + predictable signals

U850 = Zonal winds at 850hPa

1. Motivation

Problem: `**Signal-to-noise paradox**'

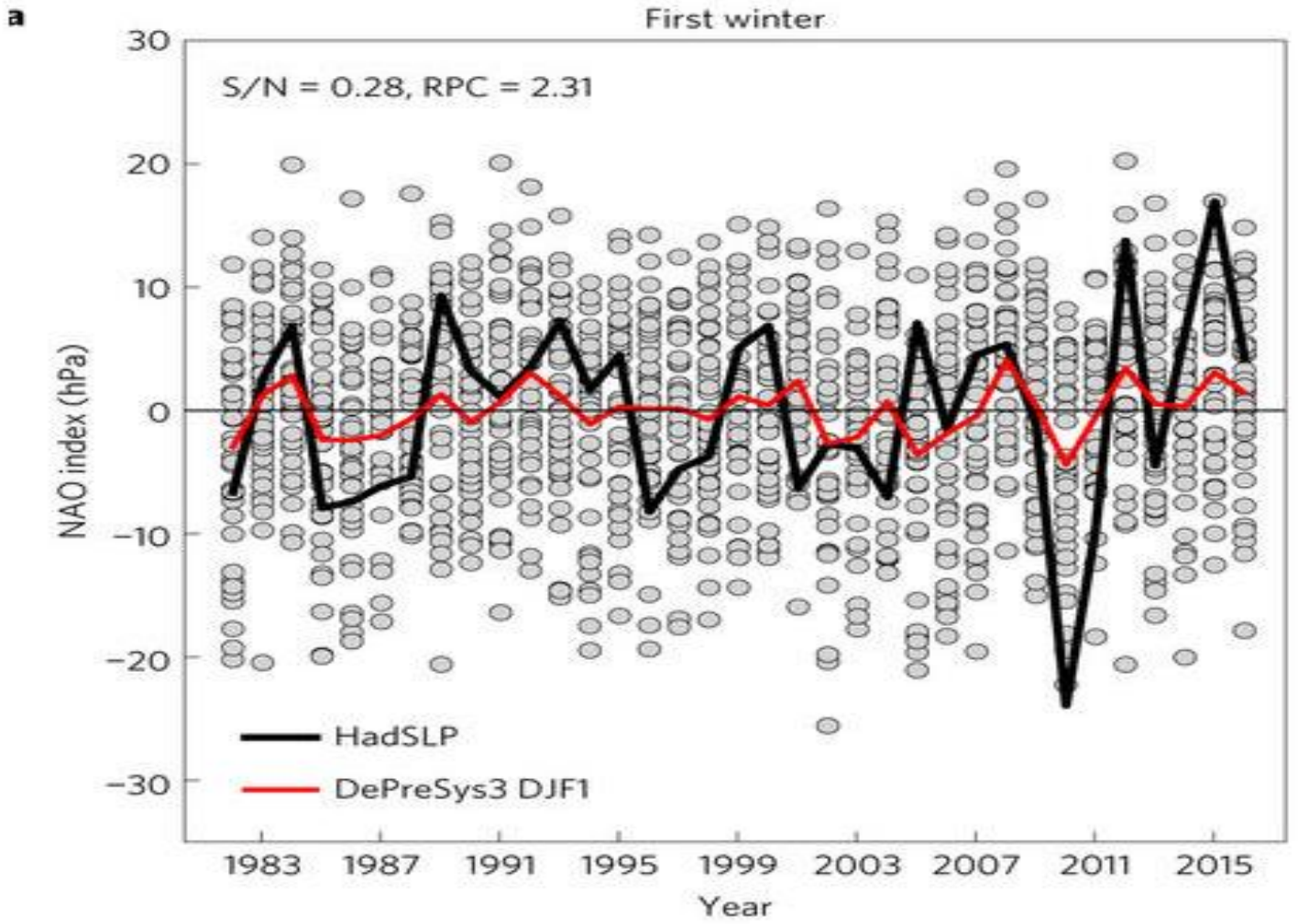
A robust feature across all skillful models and across all timescales.



Scaife et al. (2014)
Eade et al. (2014)
Dunstone et al. (2016),
Siegert et al. (2016)
Scaife and Smith (2018)
Baker et al. (2018),
Strommen and Palmer (2019)

1. Motivation

- **Dunstone et al (2016): UK Met Office predicting the NAO**



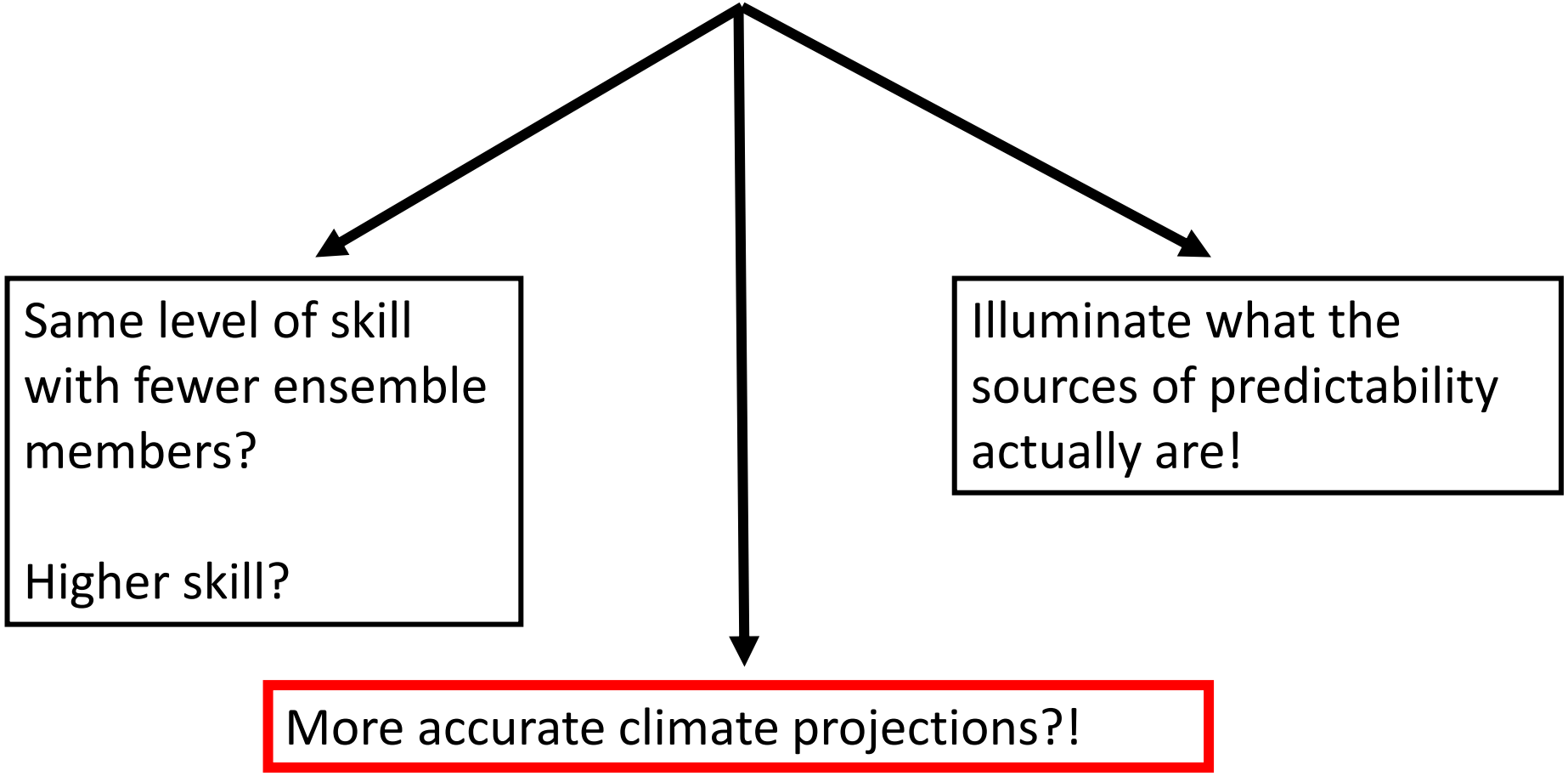
Very low signal-to-noise ratio!

↓

Need large ensemble to get reliable predictability (>100 members??)

1. Motivation

Understanding the nature of the `signal-to-noise paradox'

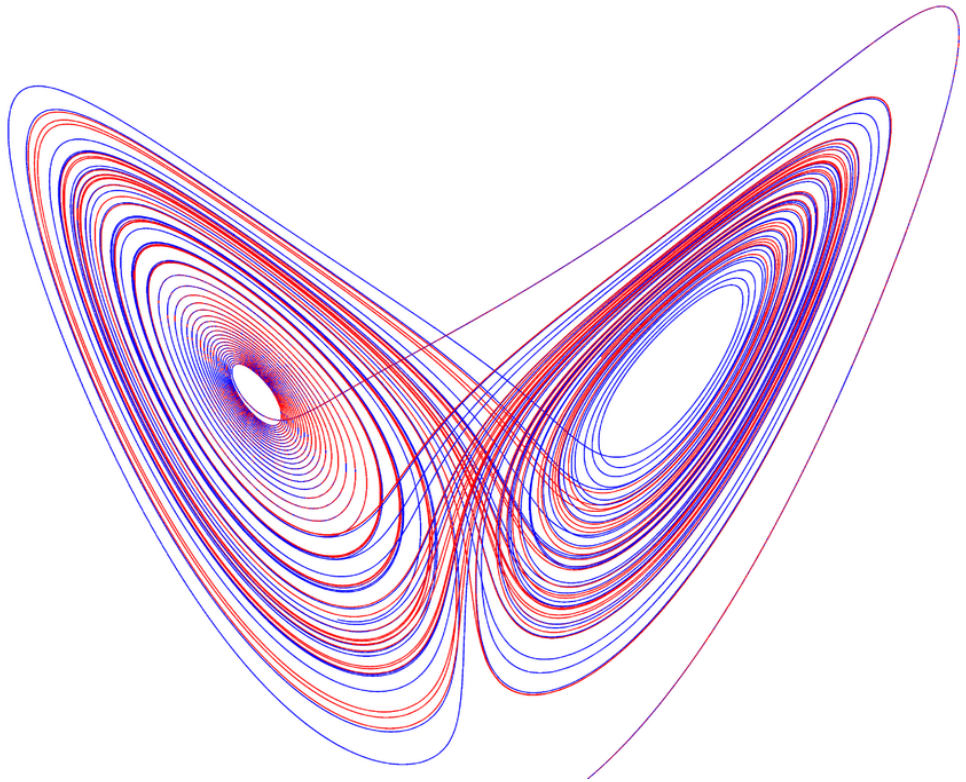


Athanasiadis et al. (2020) and Smith et al. (2020)

1. Motivation

- Many studies suggest the North Atlantic circulation is influenced by existence of weather regimes

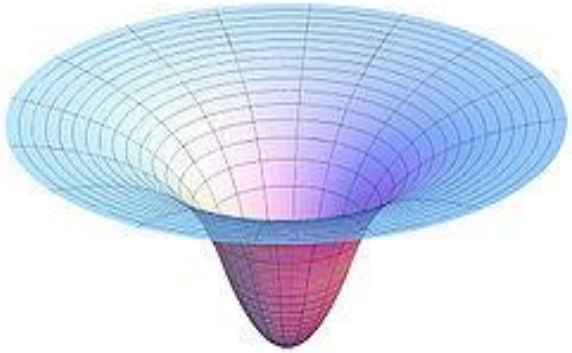
→ is this having an effect on predictability?



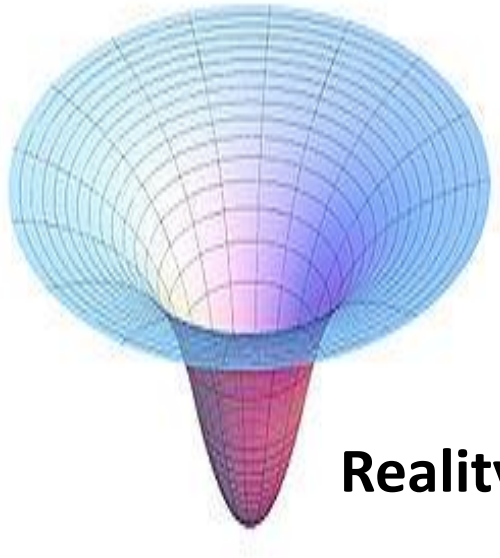
2. Regime Dynamics

- **Strommen and Palmer (2019):** *if* NAO skill is driven by regime dynamics, and models struggle with regime persistence, *then* you get signal-to-noise paradox!

→ **maybe the problem is bad regime structure in models**
(*a known problem in most models*)



Models

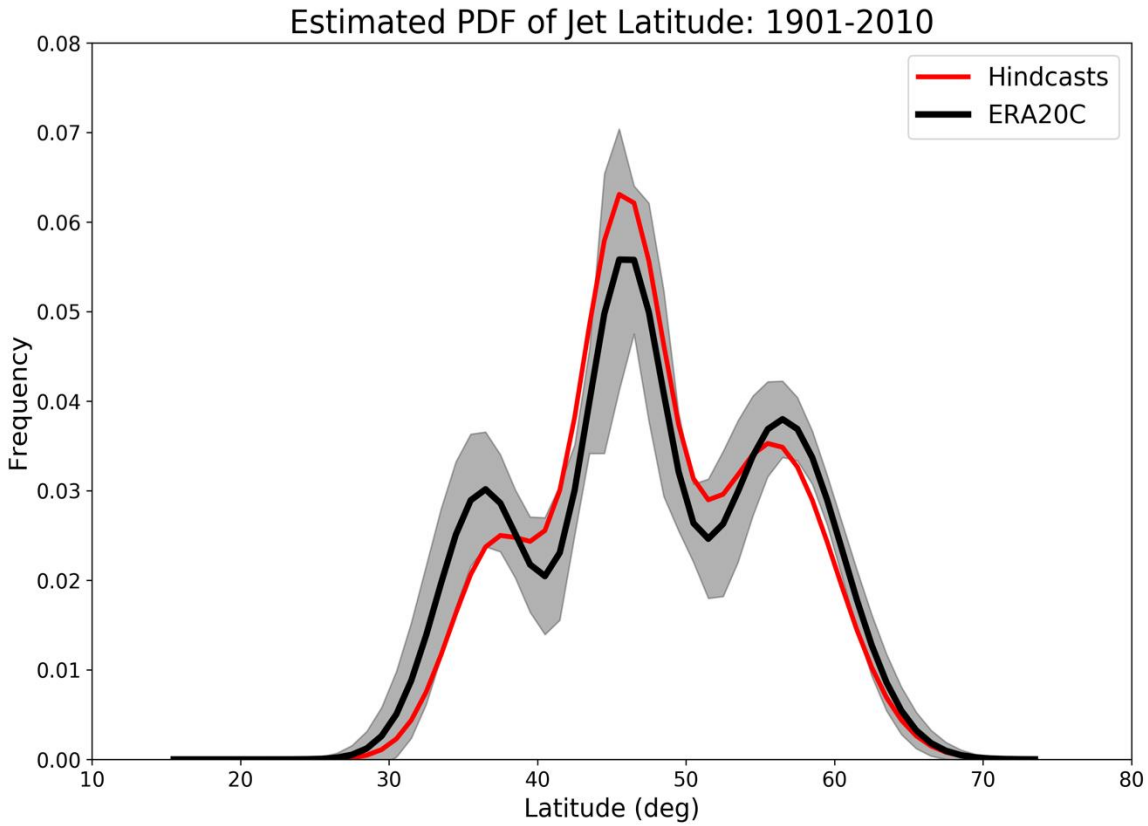


Reality

2. Regime Dynamics

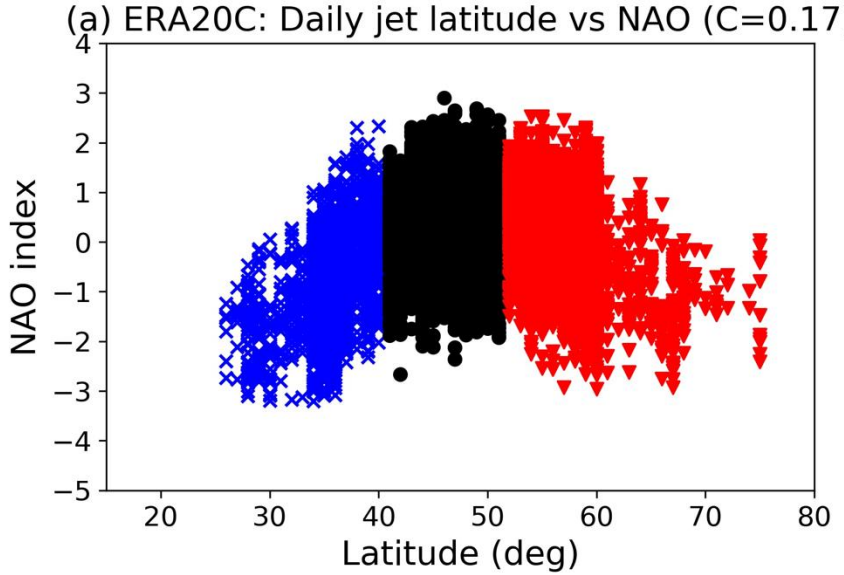
- **Strommen (2020):** Remove the conditional! NAO signal/noise in the ECMWF model (IFS) *can* be explained by regime dynamics

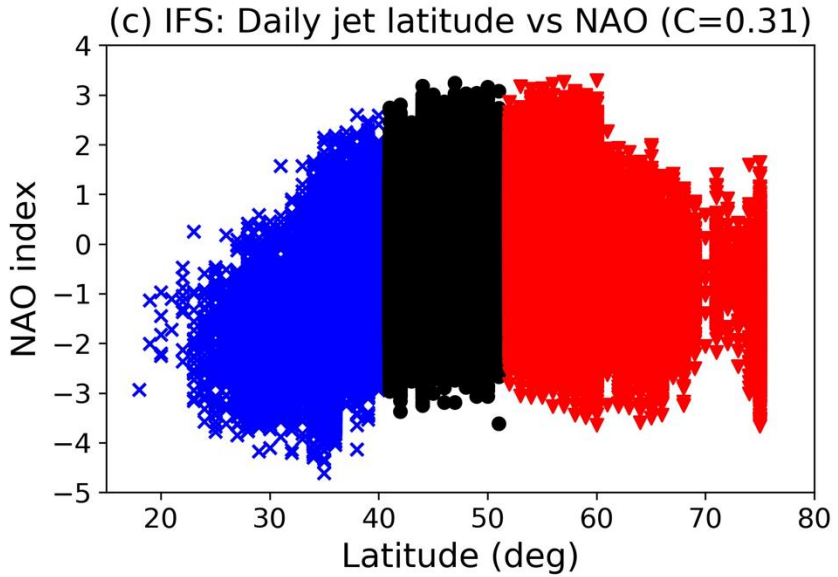
Makes use of the trimodal jet latitude regimes



(*Woollings et al. 2010*)

2. Regime Dynamics





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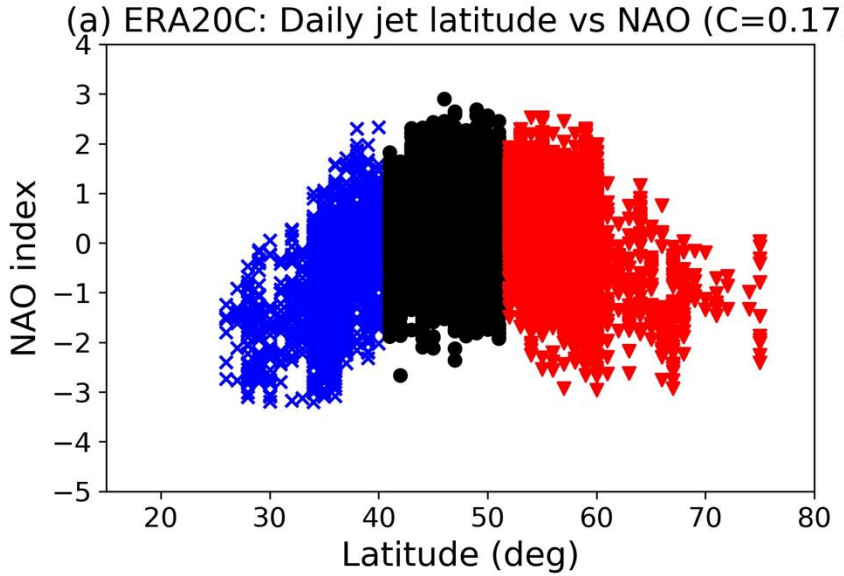
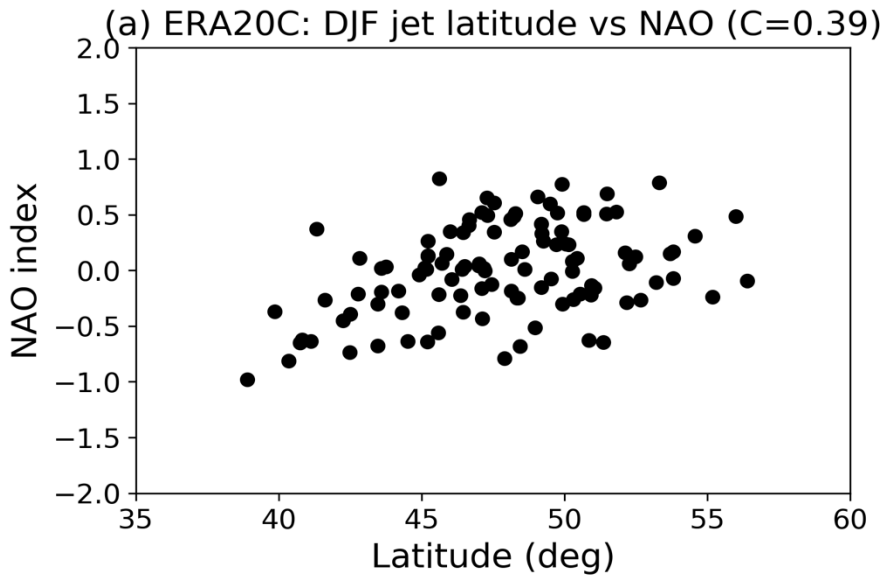
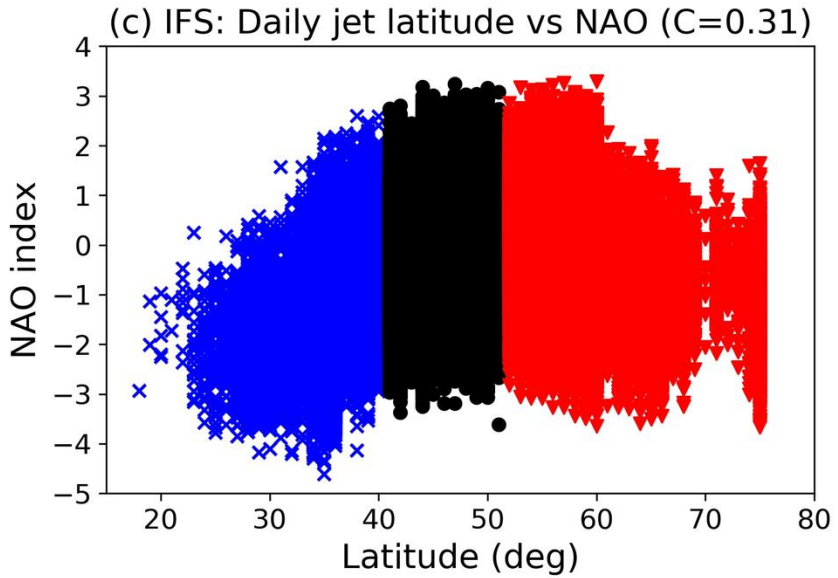
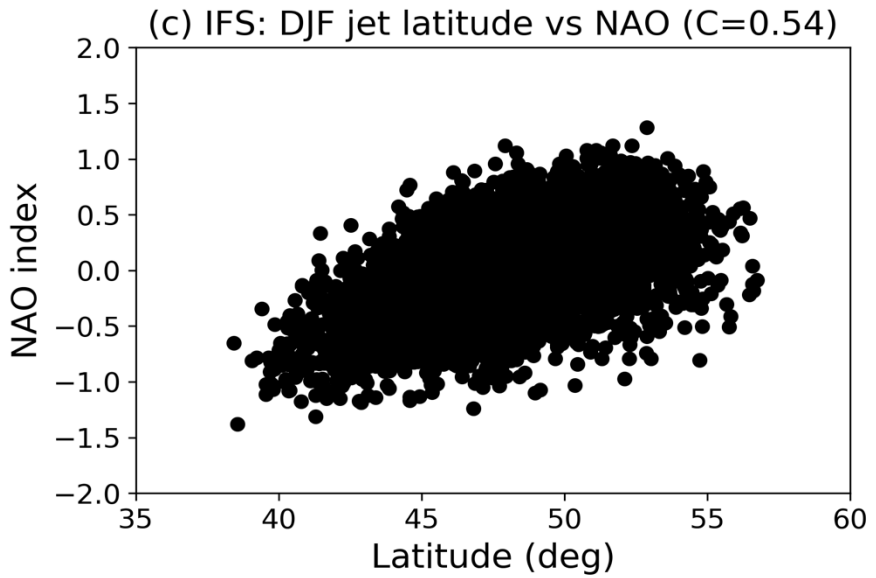






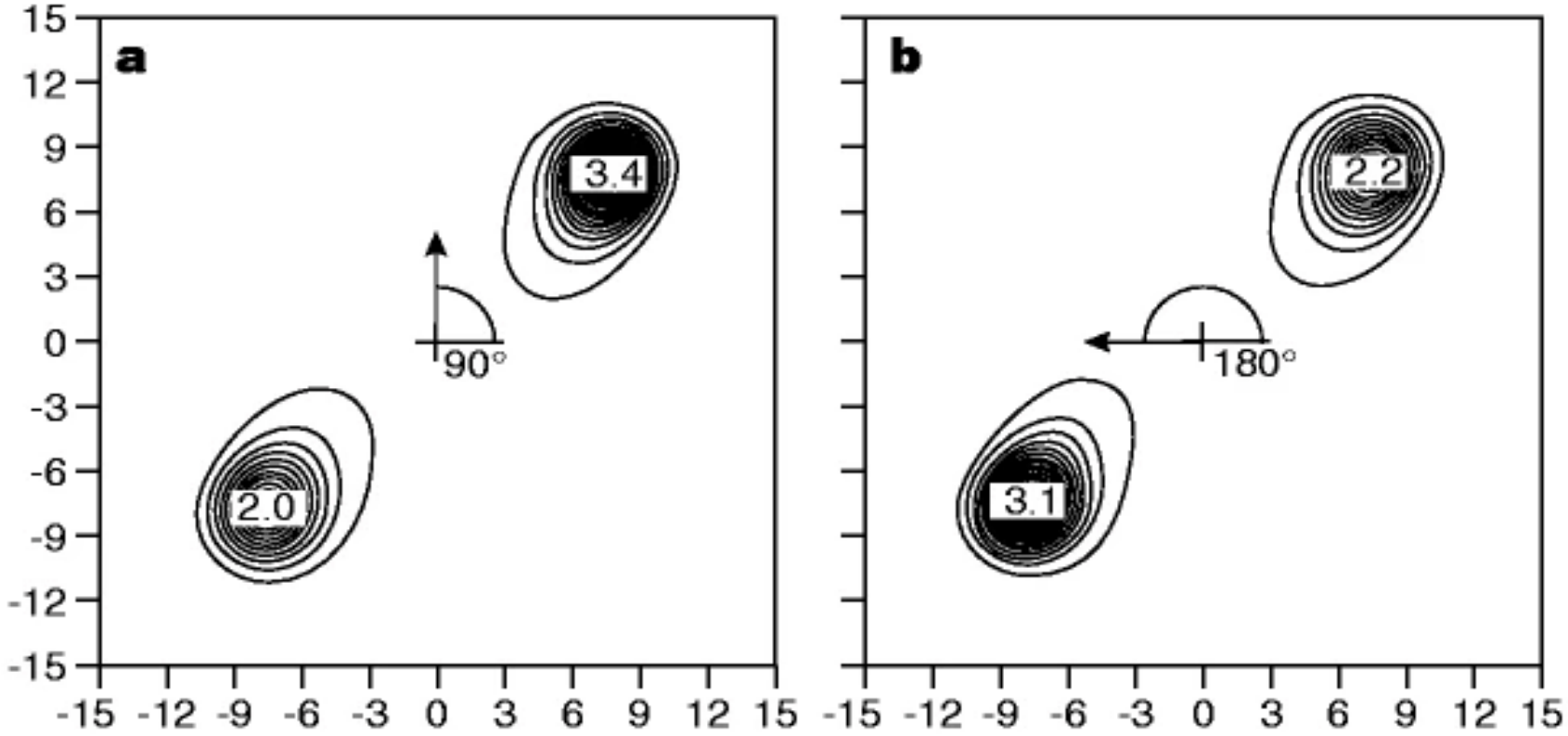


Monthly/seasonal means smooths away important structure

2. Regime Dynamics

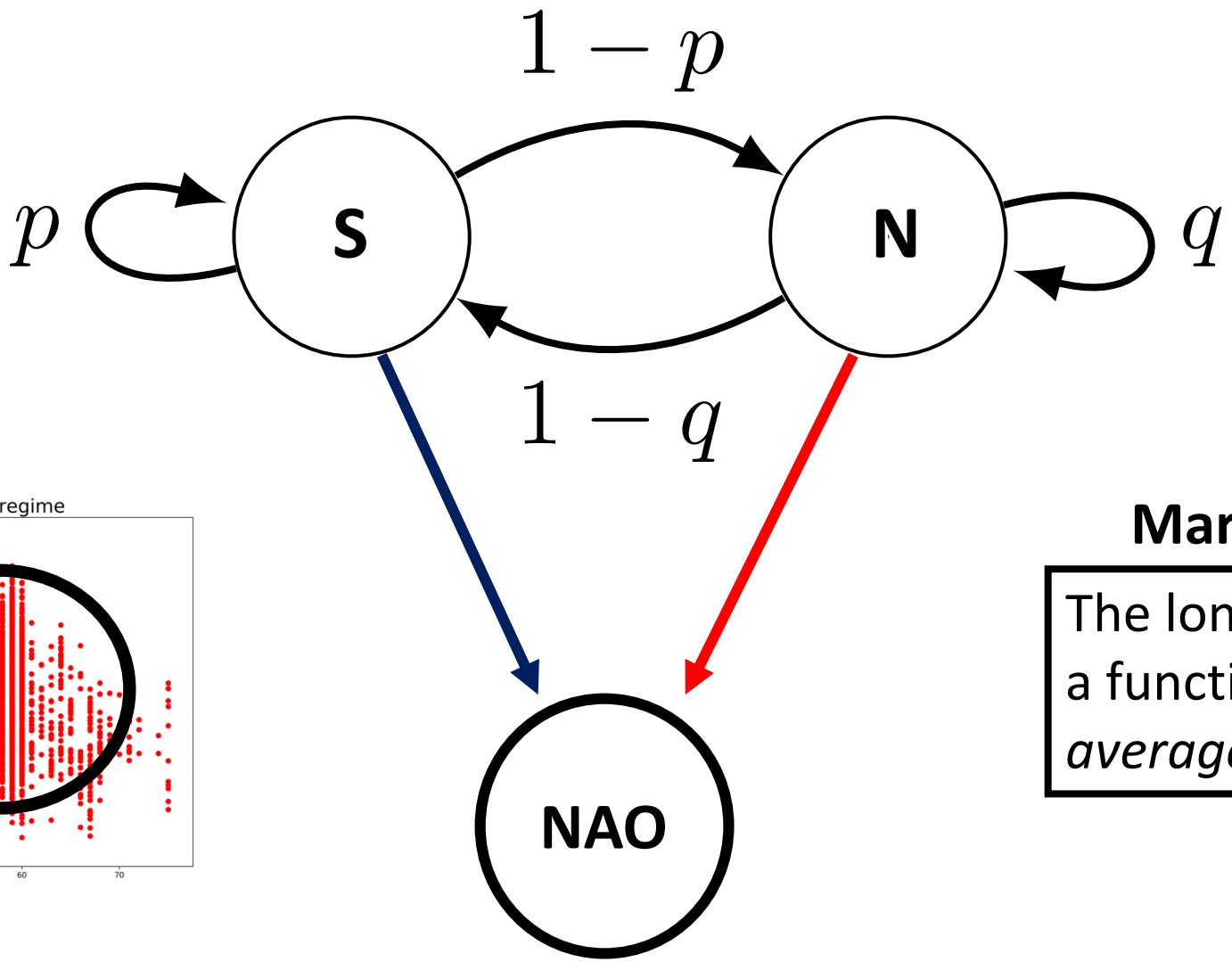
- Lorenz 63 system shows the way

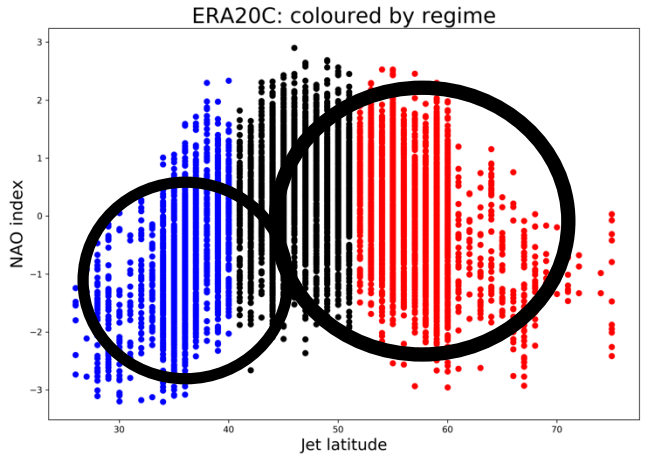
Forcings don't change the regimes, they change relative frequencies



Corti, Molteni and Palmer (1999)

3. The Markov Model



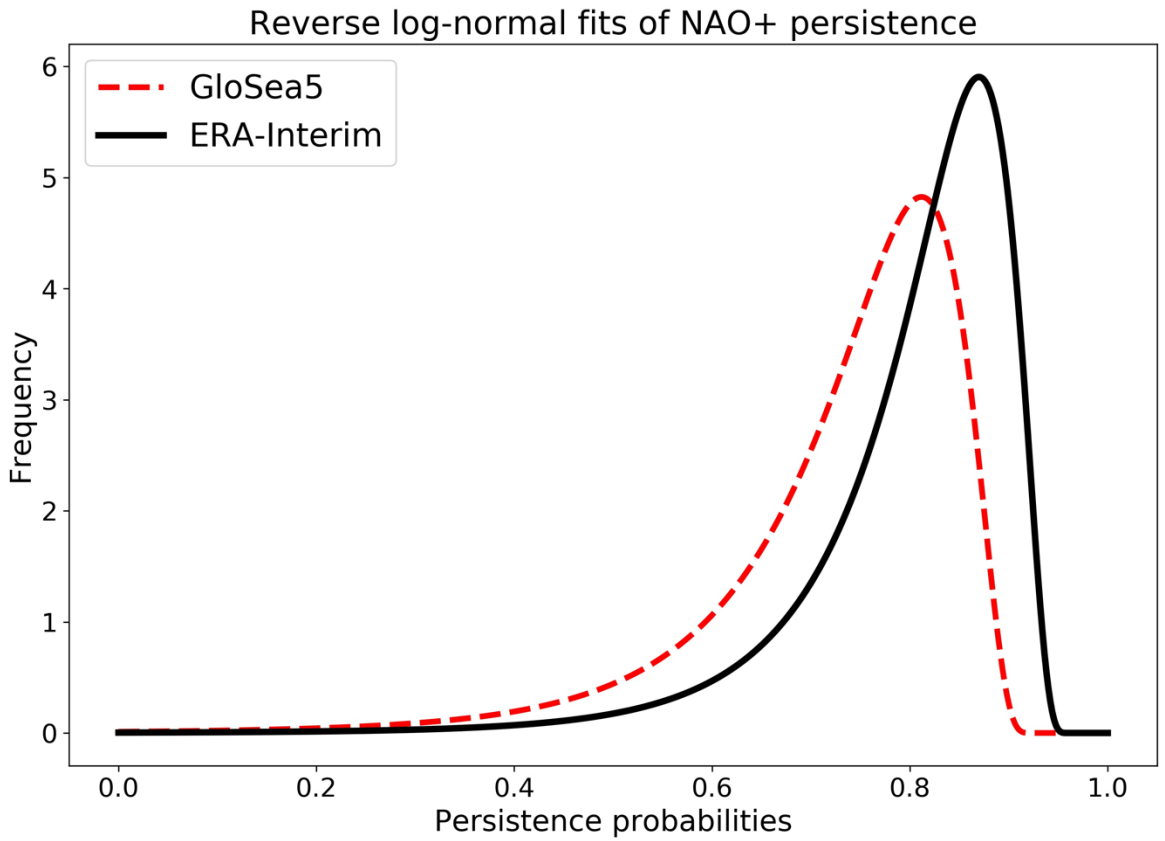


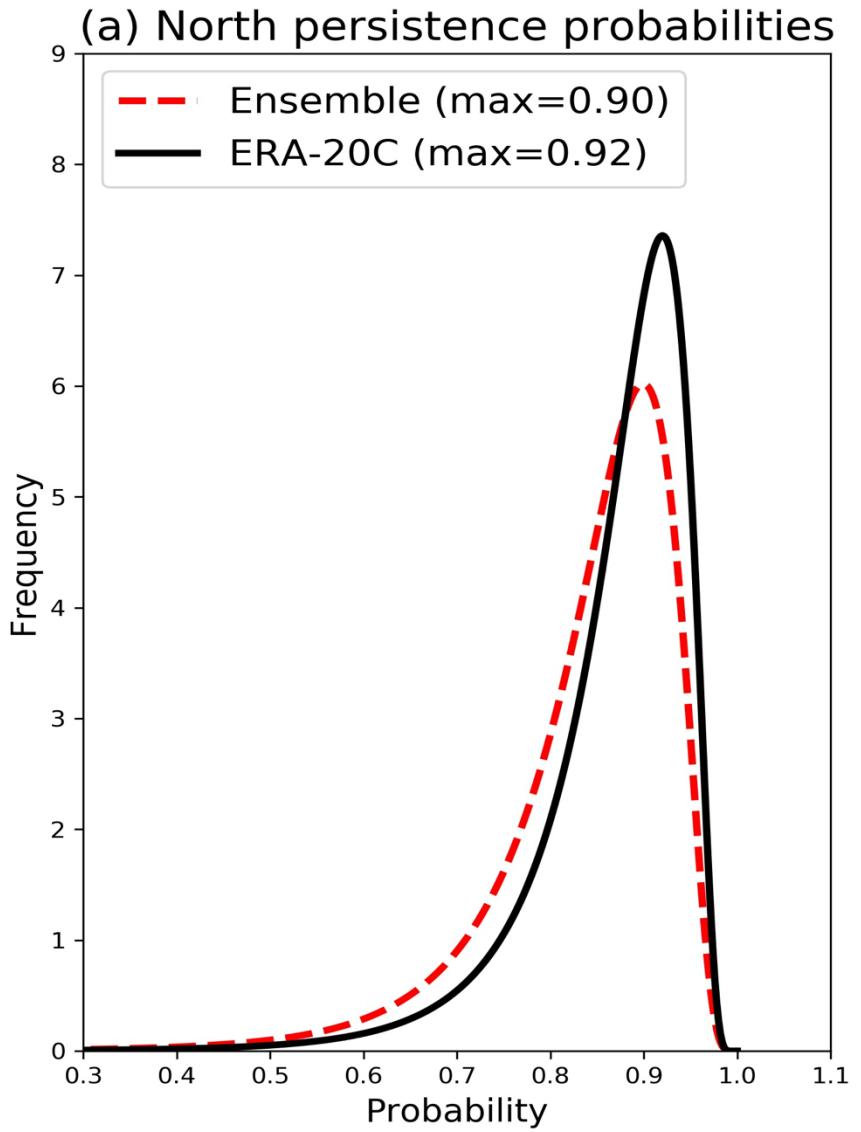
Markov chain maths

The long-term mean NAO is a function of **p, q** and the *average* blue/red arrow

3. The Markov Model

Forecast Models often have too little persistence





3. The Markov Model

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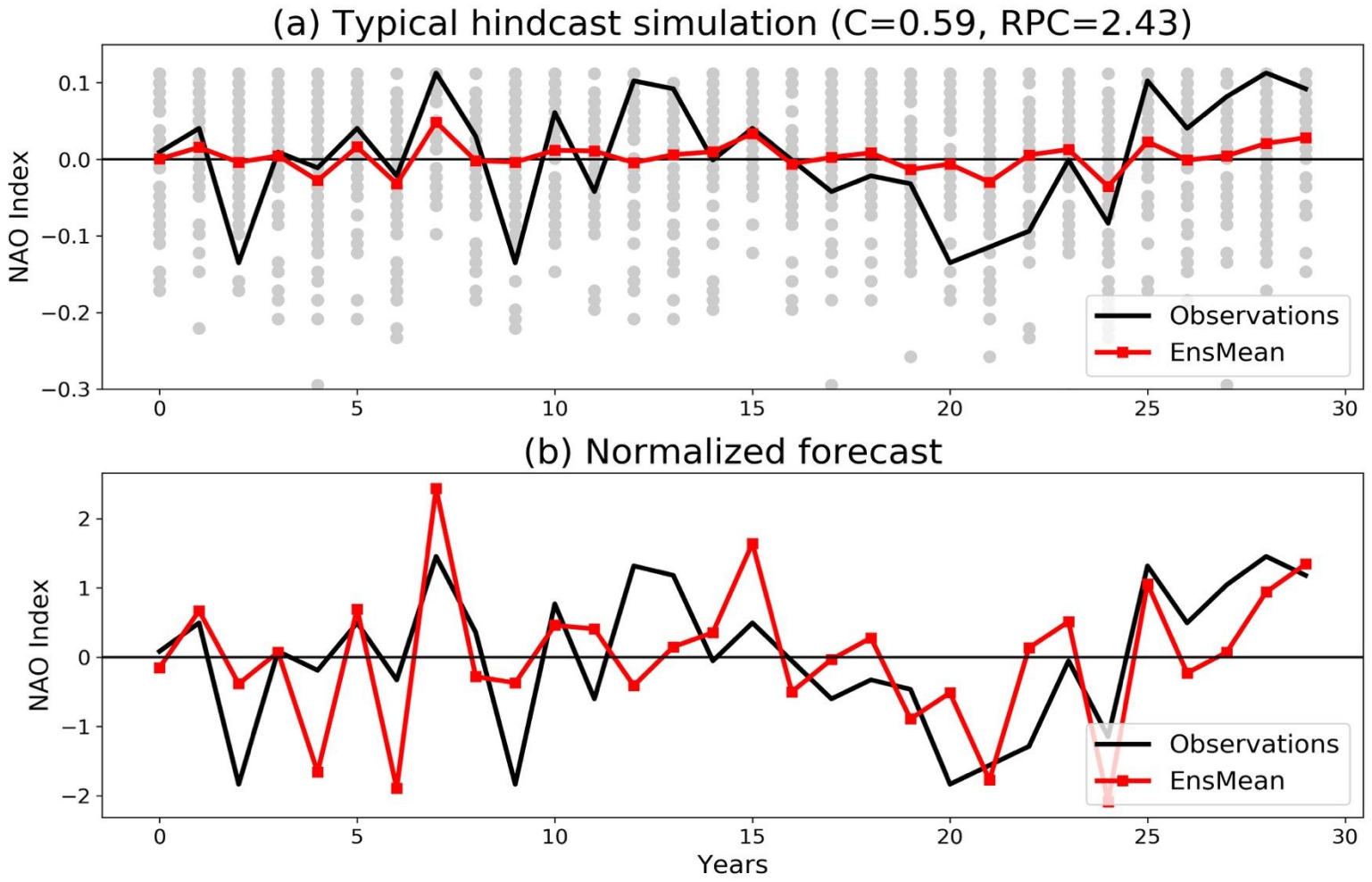
With this framework one can completely reproduce the IFS NAO skill and signal/noise ratios, including the `paradox'.



4. Discussion

1. The importance of local processes: eddy forcing

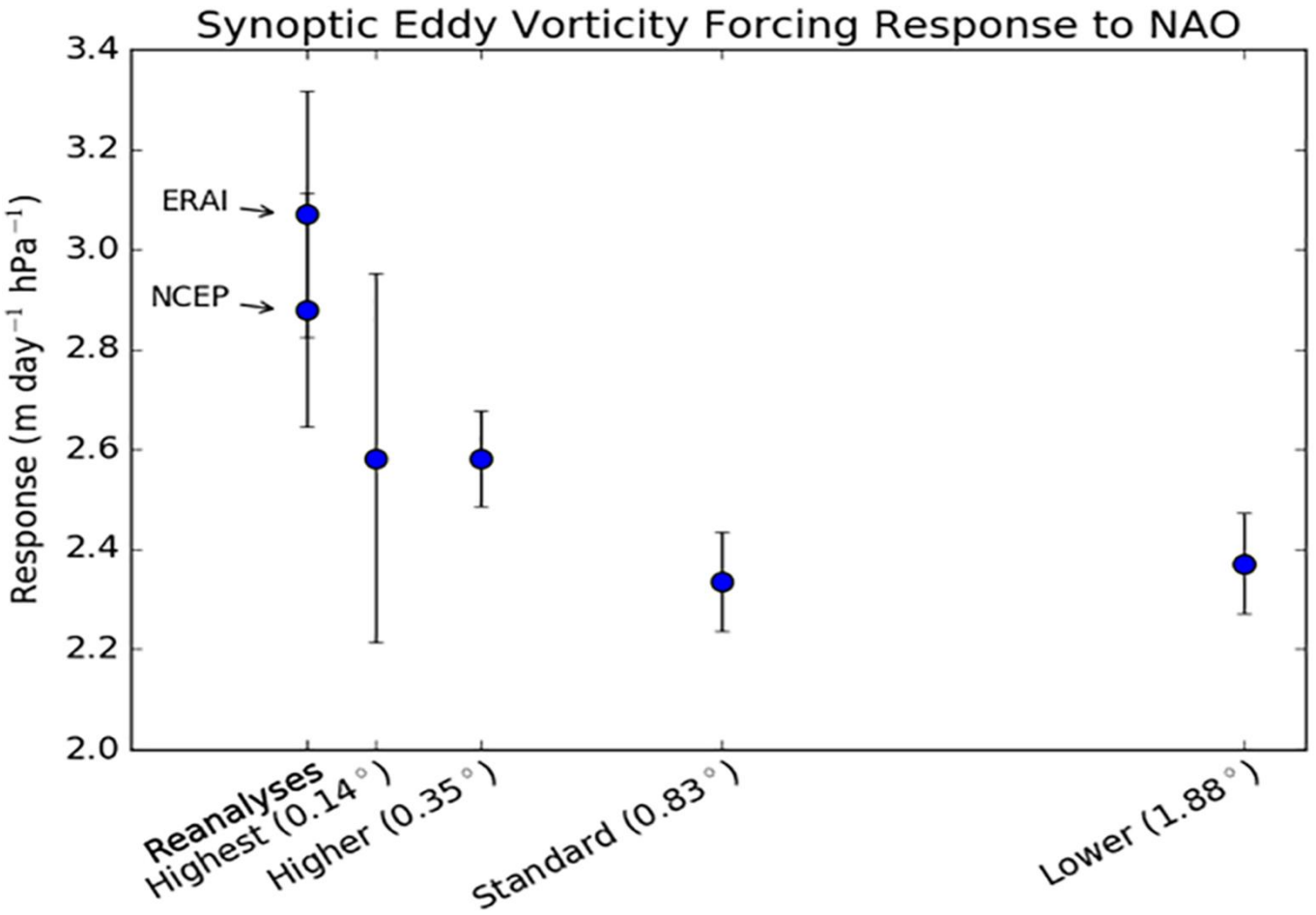
- Extensive literature on role of eddies forcing/feedbacks on maintaining circulation anomalies

  Hoskins et al. (1983), Shutts (1983), Robinson (1996), Lorenz and Hartmann (2001, 2003), Barnes and Hartmann (2010), Zurita-Gotor et al. (2014), etc. etc. etc.

- Involves interaction across scales → difficult at lower resolutions!

4. Discussion

1. The importance of local processes: <u>eddy forcing</u>



Step change in eddy forcing at ~15km horizontal resolution?

→ the need for high-res!

Taken from Scaife et al., *"Does increased atmospheric resolution improve seasonal climate predictions?", 2019.*

4. Discussion

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Routes to Ultra-High-Res Models

1. **Fugaku** Supercomputer at 16 bit ≈ Exascale.

   (and nothing is lost from running at low precision)

2. **Destination Earth**: EU Project to support ‘Green New Deal’

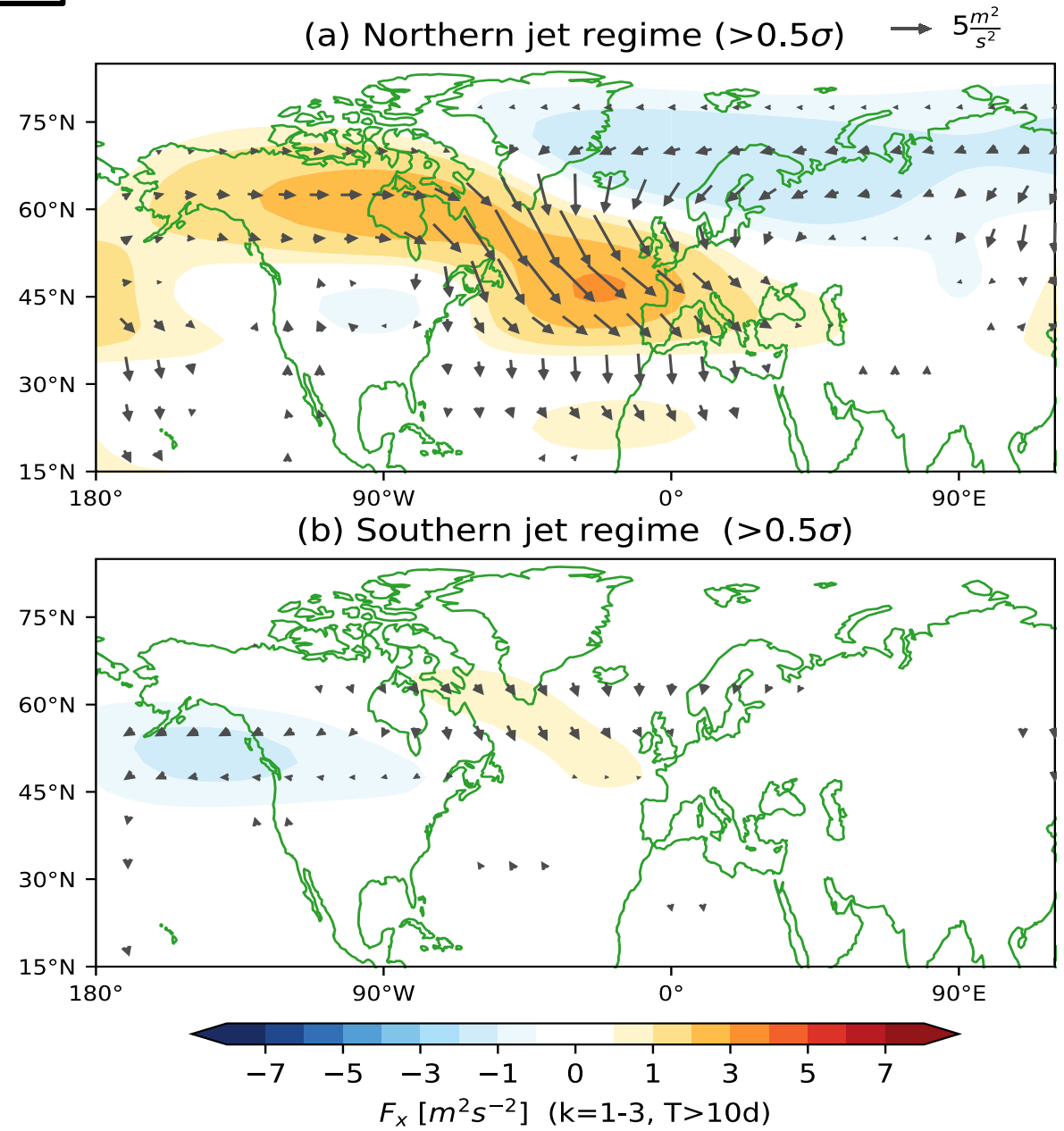
4. Discussion

2. Resolving the `tug of war'

$$NAO = A\pi_{North} + B\pi_{South}$$

Each regime makes its own contribution to the total.
External forcing may project onto *specific* regimes.

ERAInterim



Asymmetry in forcing from tropical quasi-stationary waves?

Work in progress with Bernat Jimenez-Esteve

(ETH Zurich)

5. Conclusions

- Regime dynamics can capture non-linear behaviour and shed light on predictability with a simple Markov model.
- The ECMWF model skill at predicting the winter NAO can be attributed entirely to its skill at capturing jet regime dynamics.
- The role of model persistence in driving `signal-to-noise paradox'.
- Better eddy forcing (and hence persistence) might require a leap to exascale computers and ultra high-res models. Possibly beneficial impact of stochastic physics?