Regime-dependent predictability and forecast error spectra of initialized forecasts

Subseasonal predictability: A phase-space perspective

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Judith Berner

National Center for Atmospheric Research

Acknowledgements

- Thanks to Laura Ferranti, Susanna Corti, Yaga Richter, Hannah Christensen

Regimes in climate

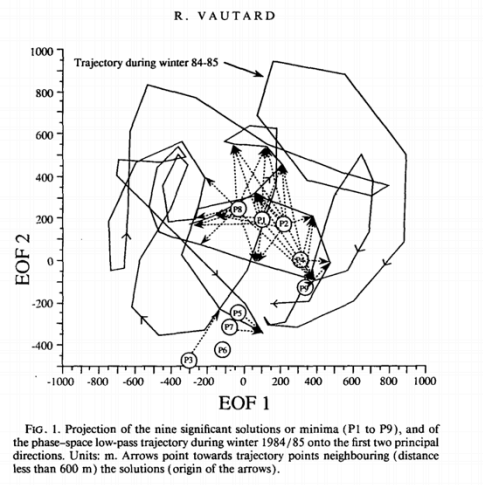
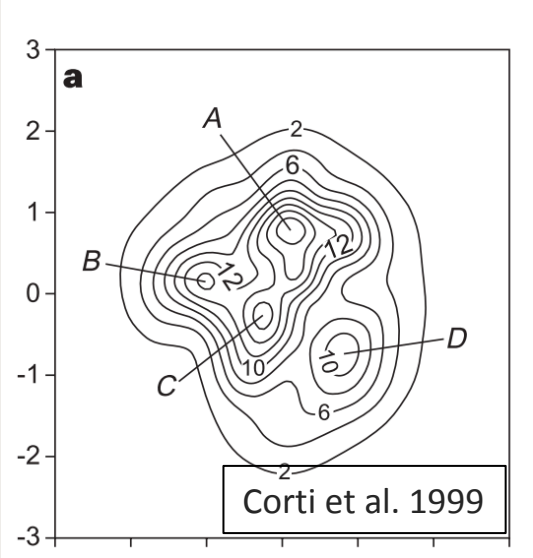


FIG. 1. Projection of the nine significant solutions or minima (P1 to P9), and of the phase-space low-pass trajectory during winter 1984/85 onto the first two principal directions. Units: m. Arrows point towards trajectory points neighbouring (distance less than 600 m) the solutions (origin of the arrows).

Vautard 1990



Corti et al. 1999

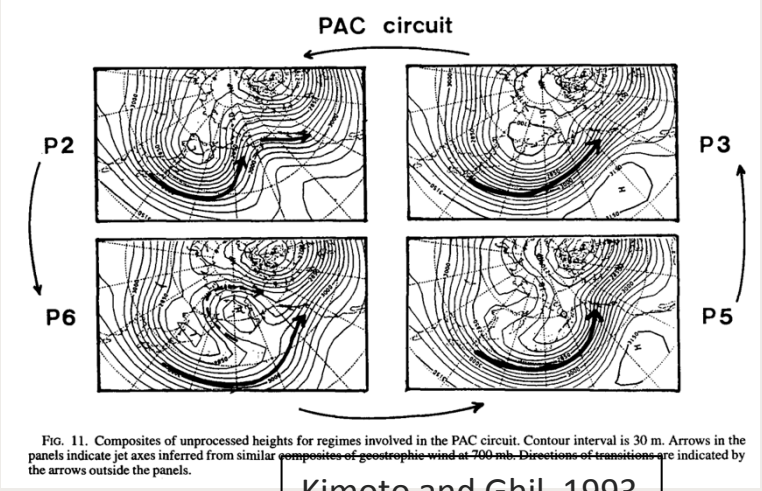
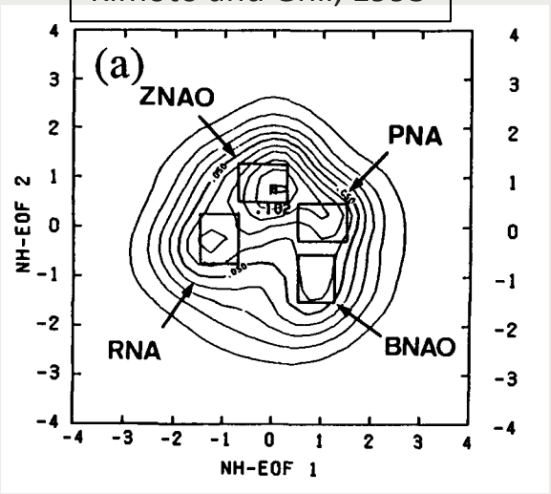


FIG. 11. Composites of unprocessed heights for regimes involved in the PAC circuit. Contour interval is 30 m. Arrows in the panels indicate jet axes inferred from similar composites of geostrophic wind at 700 mb. Directions of transitions are indicated by the arrows outside the panels.

Kimoto and Ghil, 1993



- E.g. Vautard 1990, Kimoto and Ghil, 1993; Corti et al. 1999
- Identification of regimes and preferred transitions
- Climate statistic perspective, often expressed as transition matrix

Flow-Dependent Verification of the ECMWF Ensemble over the Euro-Atlantic Sector

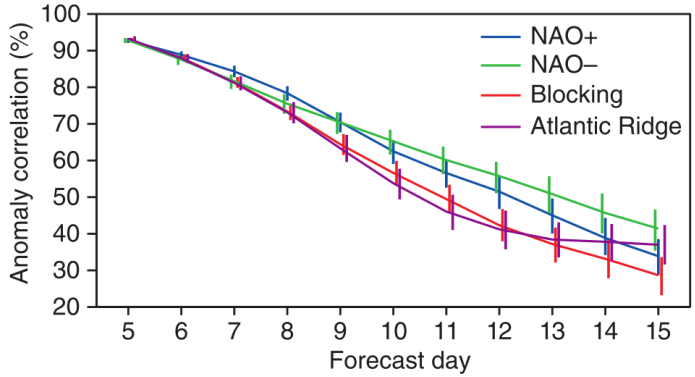


Figure 3. Anomaly correlation of the ensemble means over Europe (12.5°W–42.5°E, 35.0°N–75.0°N) for the four forecast categories as a function of forecast range. Red refers the BL regime, blue to the NAO+, green to the NAO− and violet to the AR regime. The bars, based on 1000 subsamples generated with the bootstrap method, indicate the 95% confidence intervals.

Ferranti et al.2015

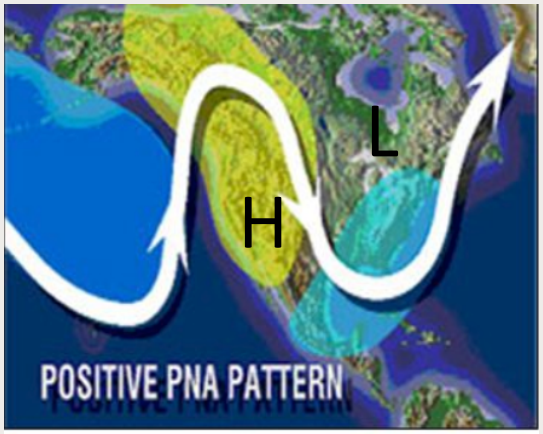
- Extended predictability of states that project at initial time on NAO-
- Initialized forecasts

Experiment Setup

- Potential predictability in daily output of CESM1.1 (Large ensemble)
- 400 years
- Not initialized!
- Perfect Model Scenario
- Project onto EOF phase space

- Z500 anomalies
- Extended Winter Oct-Mar
- NAO region 20:80°N, 90°W:40°E
- PNA region 20:85°N, 120°E:120°W

Pacific North American Pattern

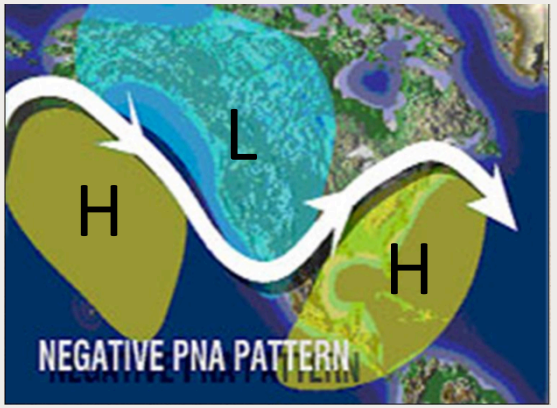


PNA+

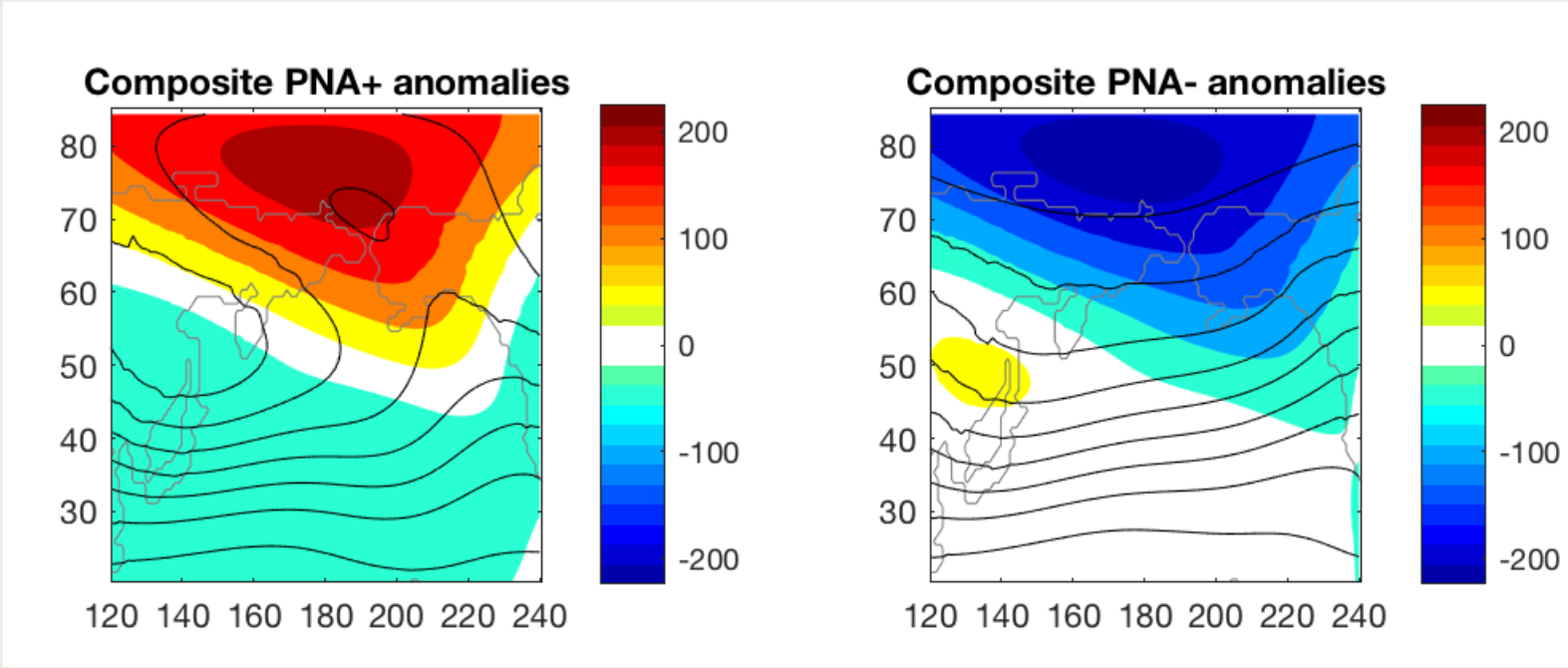
- Ridge over Western North America and trough over Easters North America
- Warm and dry in the west
- Cold and wet in the South East

PNA-

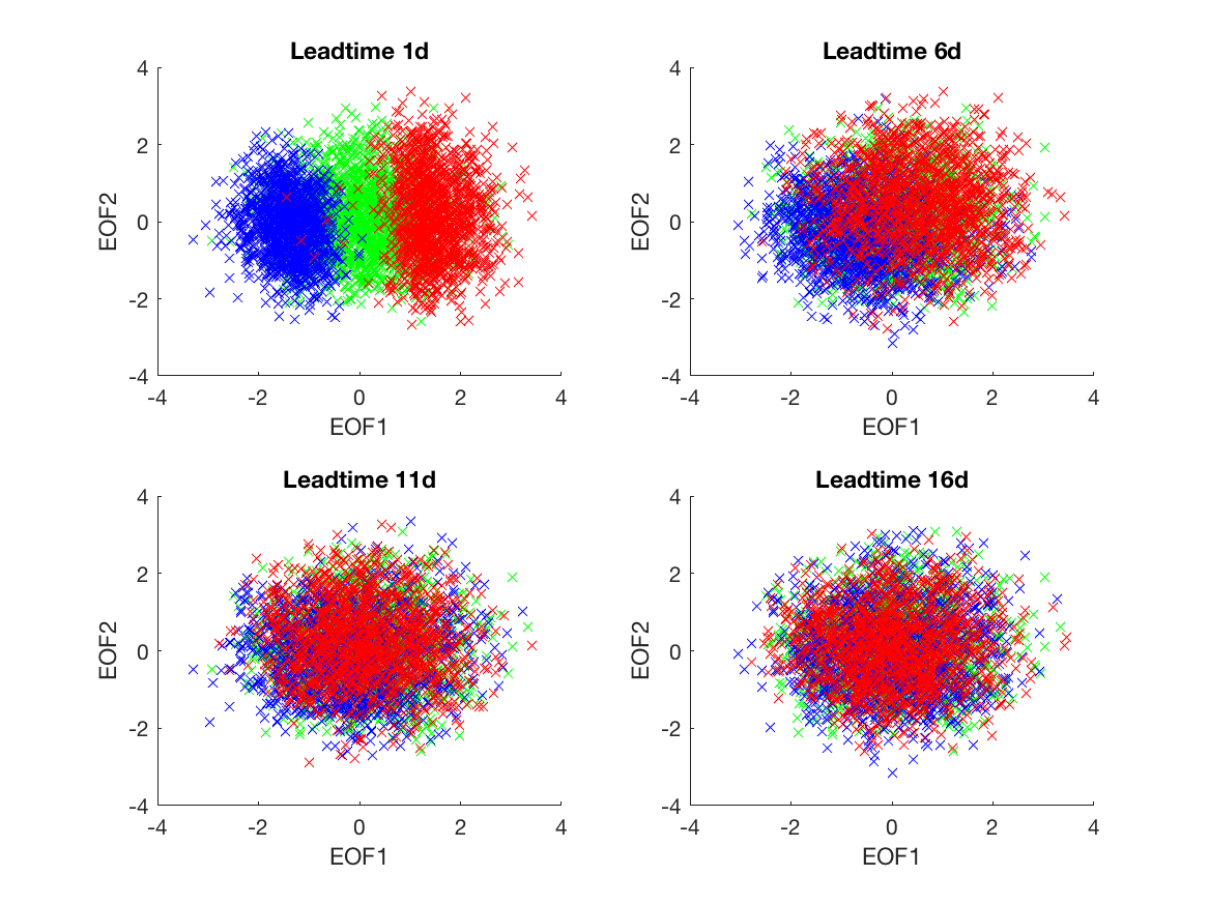
- Ridge over Western North America and trough over Eastern North America
- Cold and moist in the west
- Warm and dry in the South East



Composites

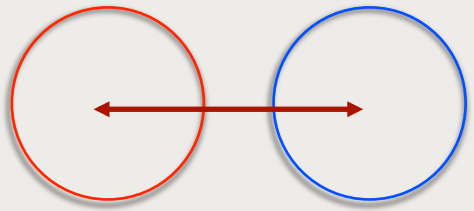

Composite PNA+ anomalies
80
70
60
50
40
30
120 140 160 180 200 220 240
200
100
0
-100
-200
Composite PNA- anomalies
80
70
60
50
40
30
120 140 160 180 200 220 240
200
100
0
-100
-200

Evolution of states in EOF state space



Skill from Mean

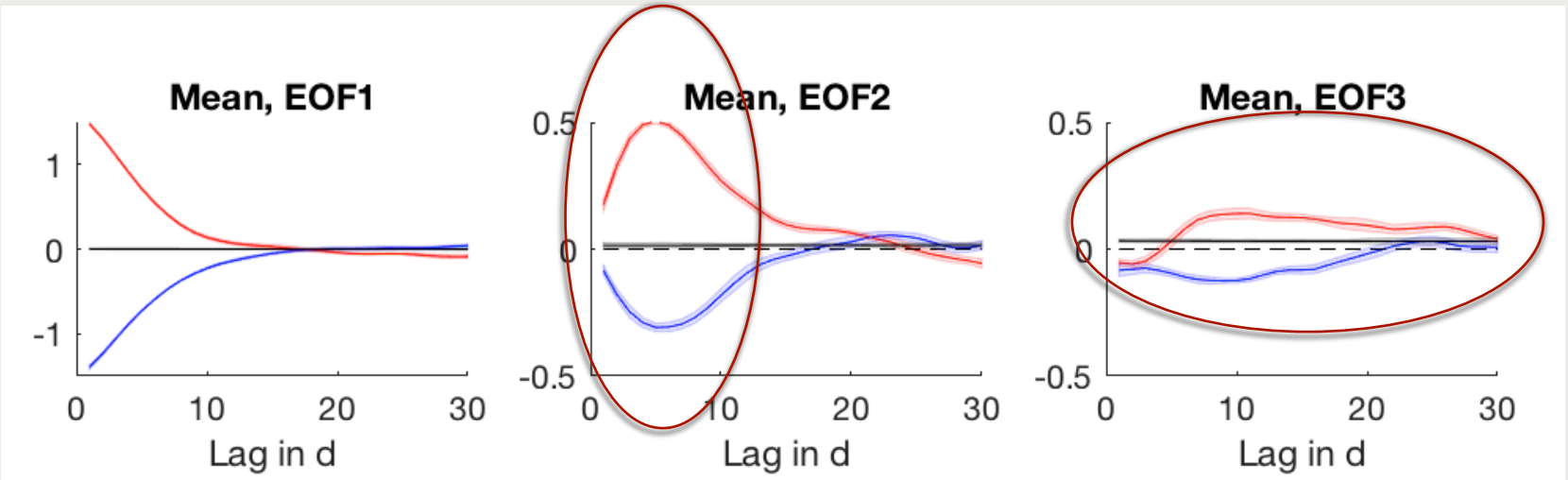
Forecast
Distribution p



Climatological
distribution q

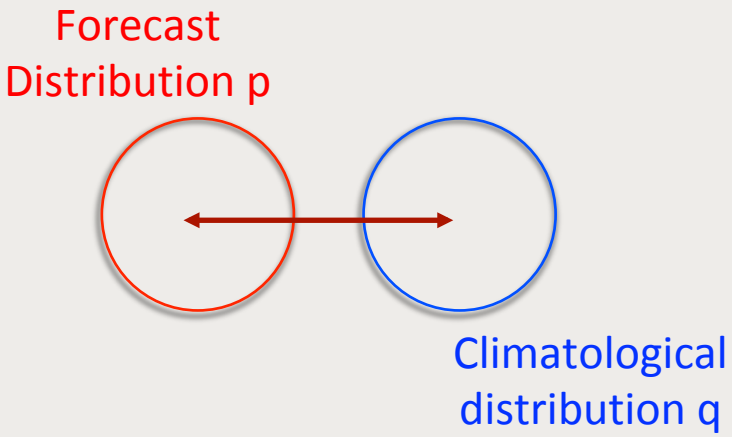
Predictive skill comes from the difference of the ensemble mean forecast to the climatological mean

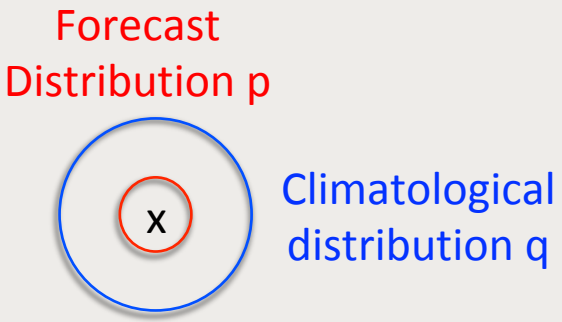
Evolution of cluster means



- Potential predictability from mean of EOF1 out to 15 days
- Potential predictability from mean of EOF3 out to 30 days
- Preferred regime transitions lead to deviations from climatology (e.g. with max at day 7 in EOF2)

Skill from spread

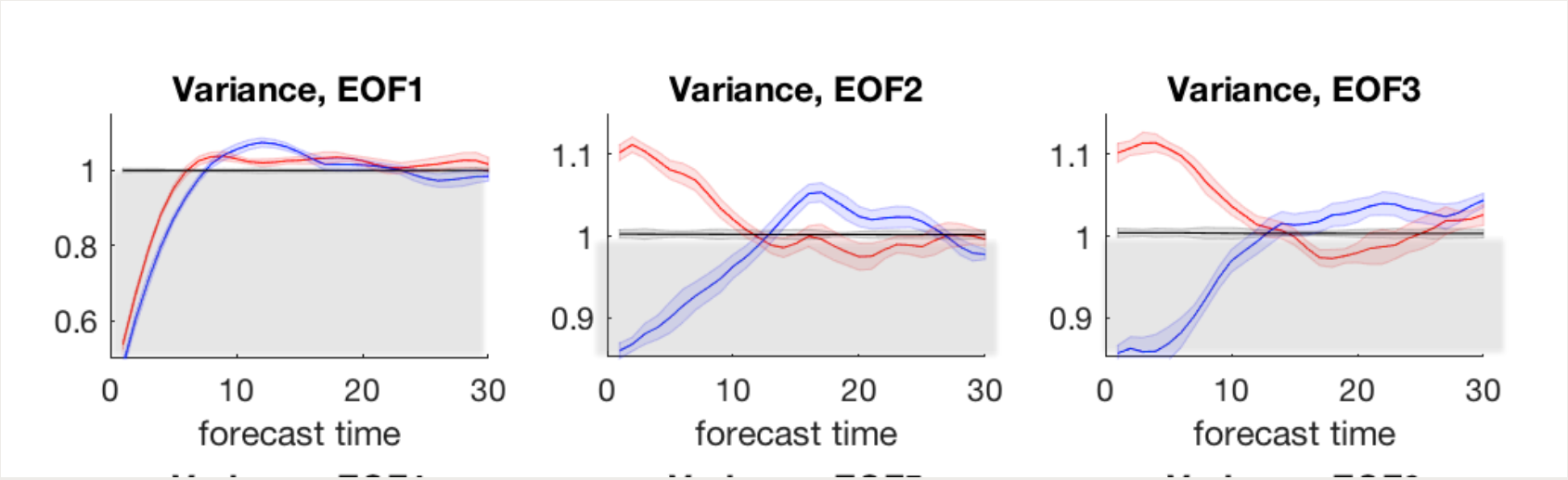




Predictive skill comes from the difference of the ensemble mean forecast to the climatological mean

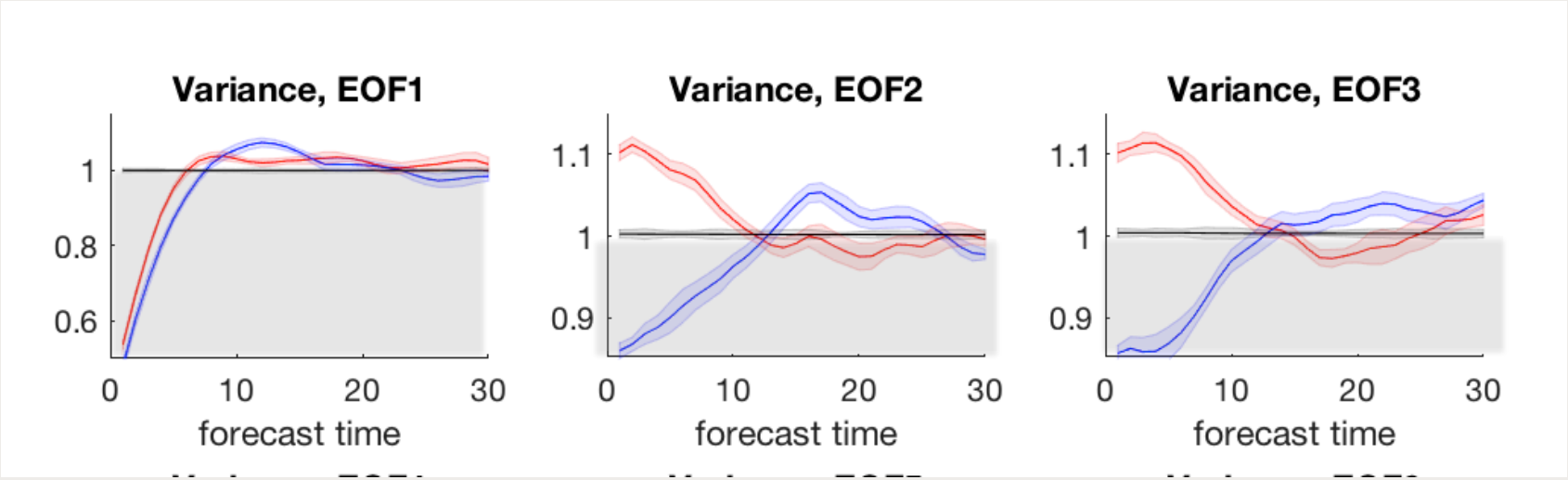
Predictive skill comes from difference of the forecast variance with the climatological variance

Evolution of cluster variance



- Potential predictability from variance of EOF1 out to 6 days for PNA+ (8 for PNA-);
- Potential predictability from variance of EOF2/EOF3 out to 12 days for PNA-
- Preferred regime transitions lead to decrease in variance of EOF2/EOF3 for the first few days

Evolution of cluster variance



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=> Relative entropy

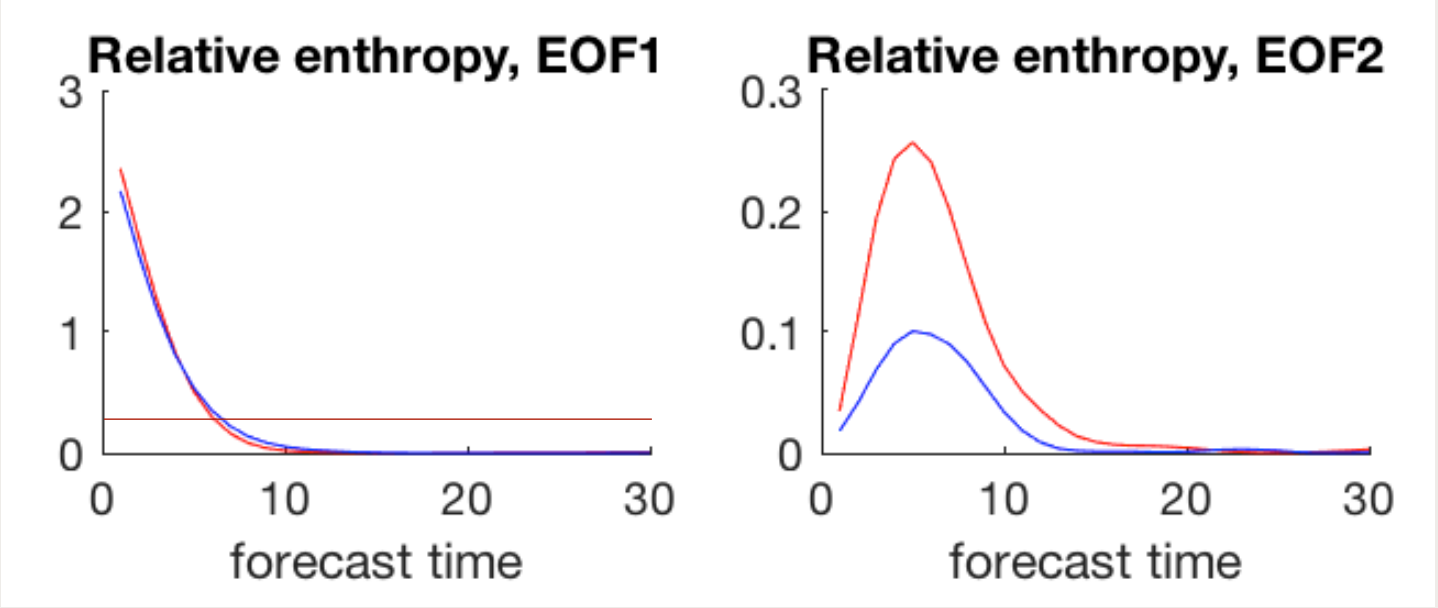
Relative entropy R (Kullback Leibler distance)

$$R = \sum_i p_i \ln\left(\frac{p_i}{q_i}\right),$$

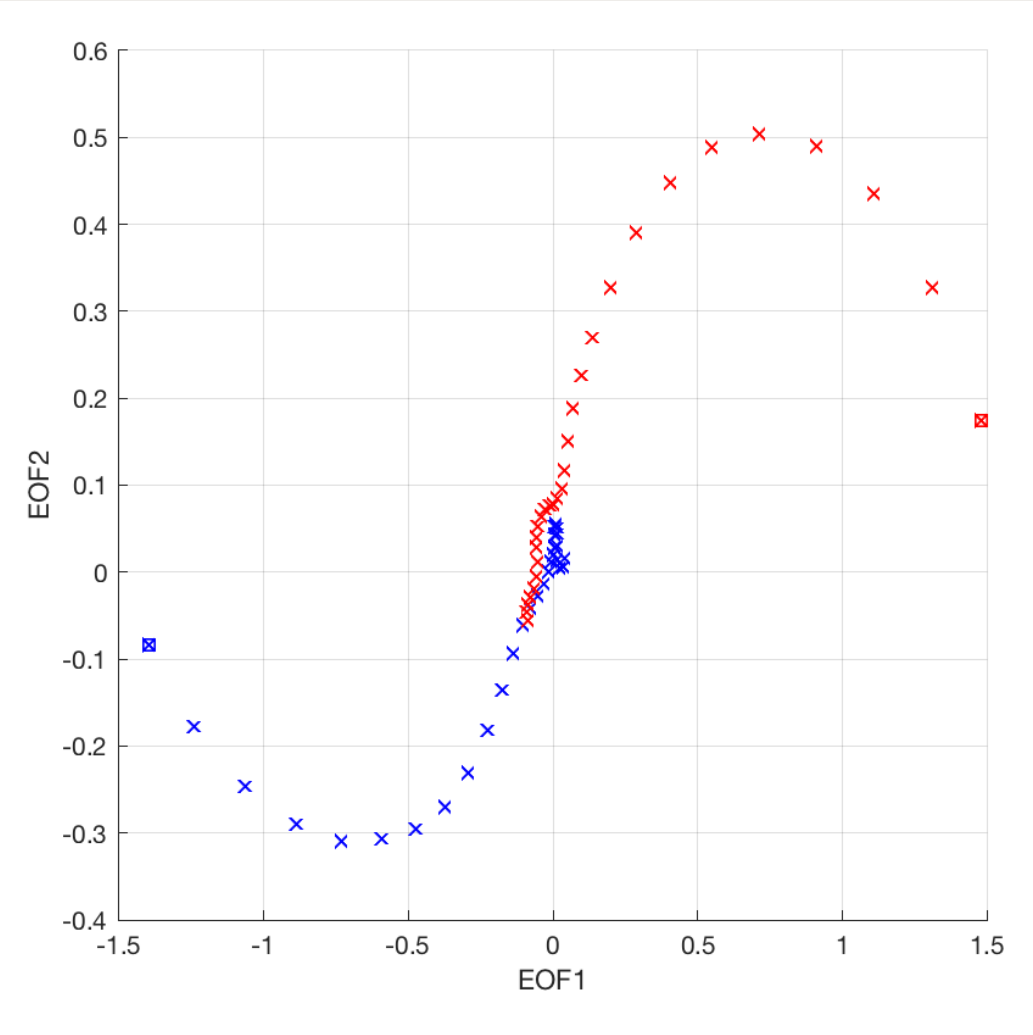
- Climatological distribution q, Forecast distribution p
- As for long lead times approaches R->0
- E.g. Kleeman 2002

$$R = \frac{1}{2}\left[\ln\left(\frac{\sigma_q^2}{\sigma_p^2}\right) + \frac{\sigma_p^2}{\sigma_q^2} + \frac{(\mu^p)^2}{\sigma_q^2} - 1\right],$$

- Assuming 1D Gaussians

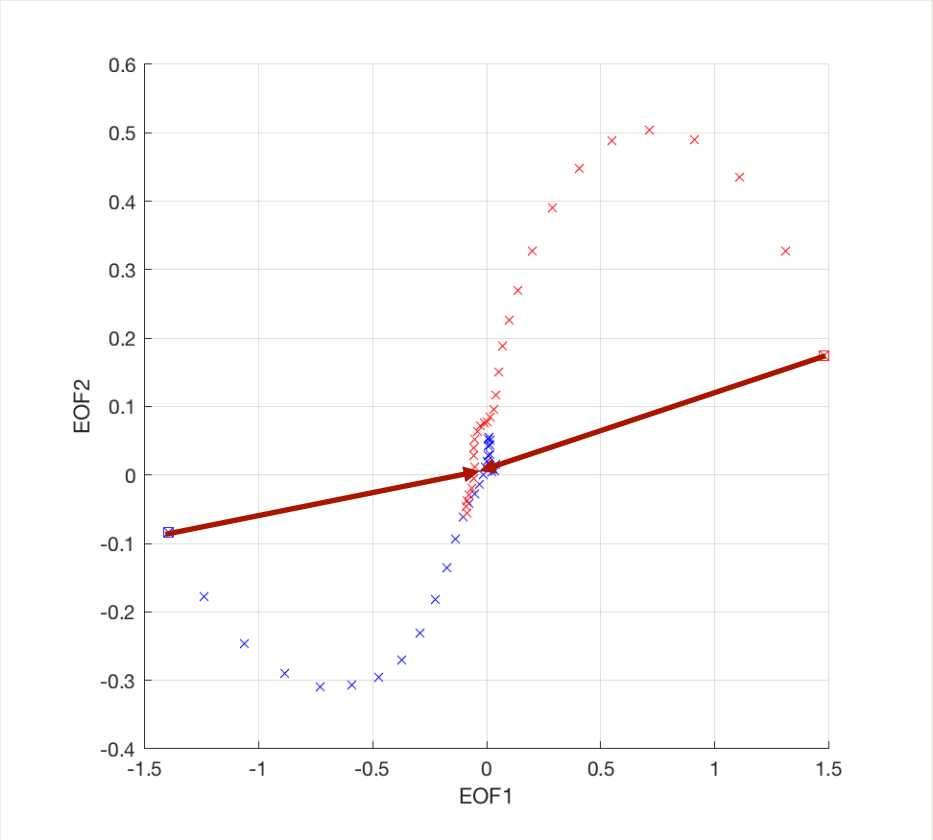


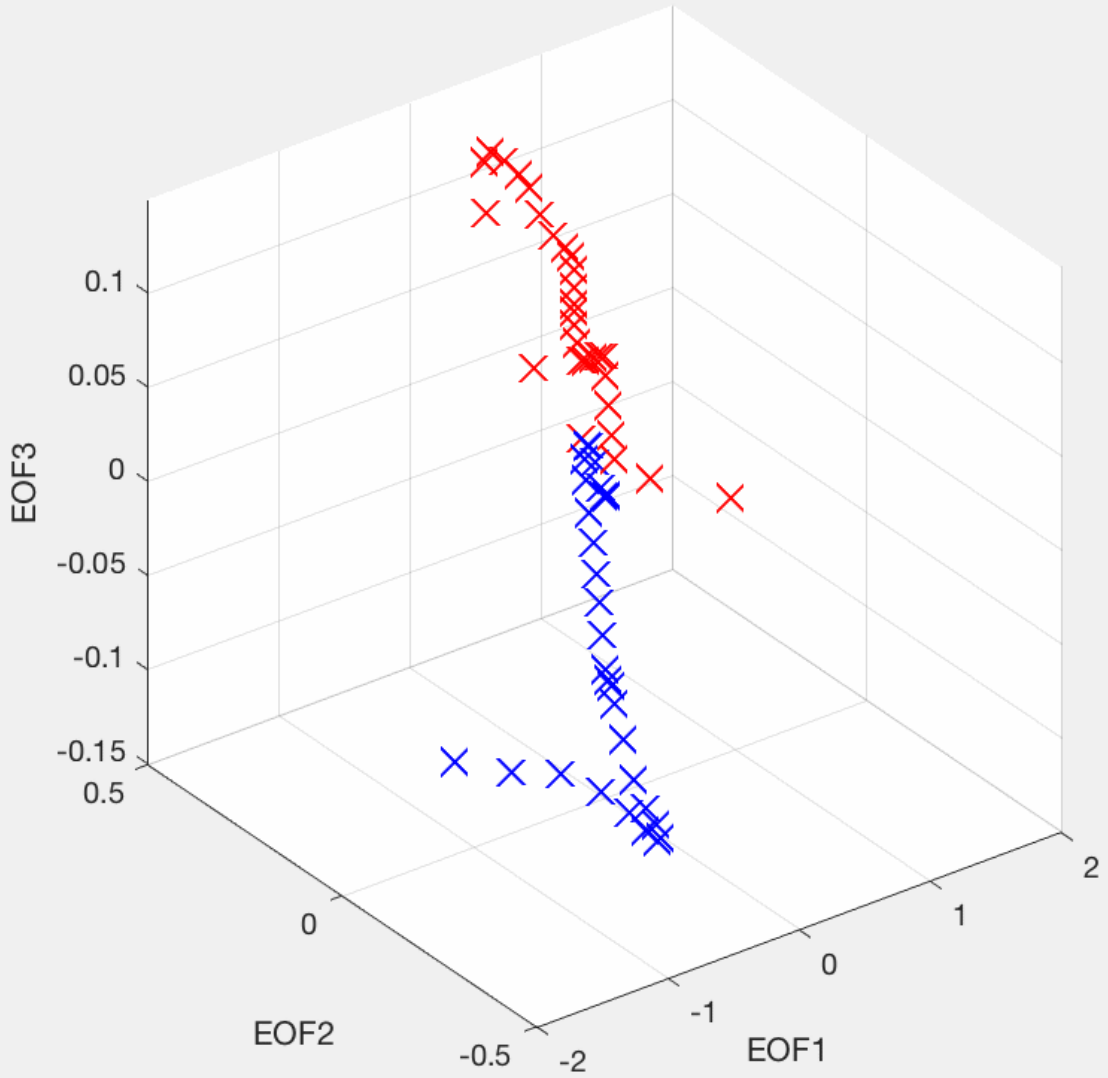
Evolution of cluster mean

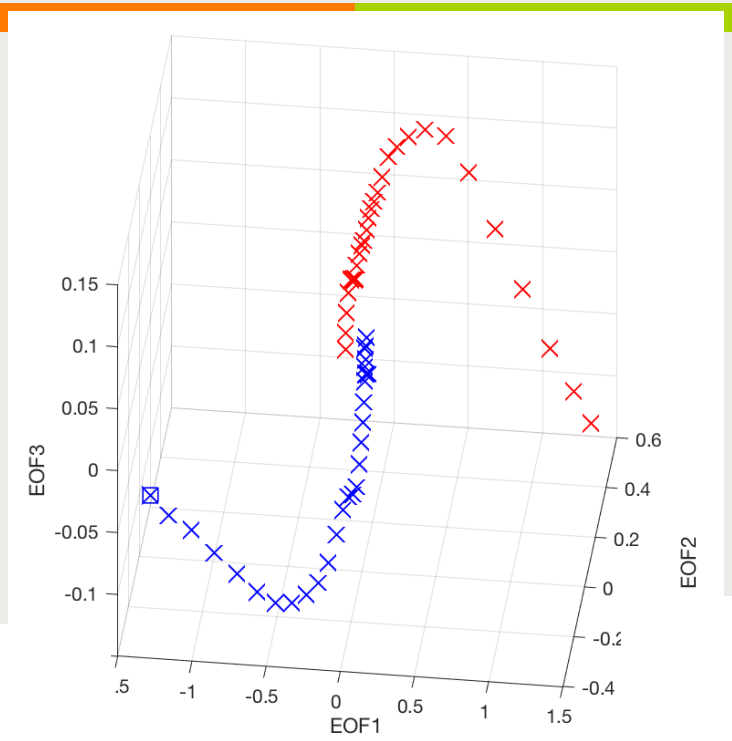


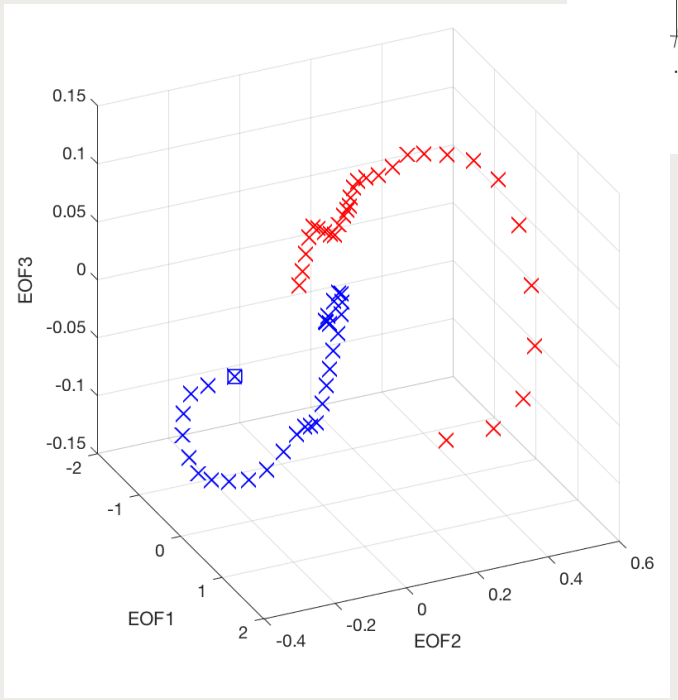
Evolution of cluster variance

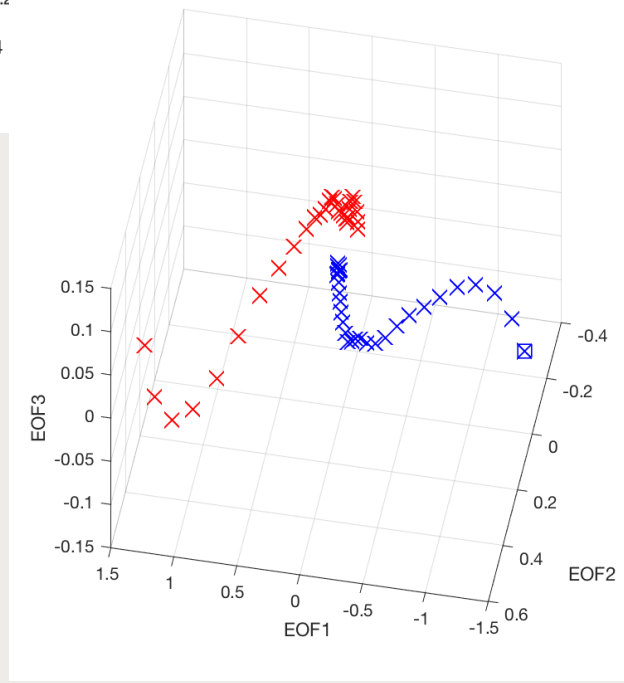
Persistence




EOF3
0.1
0.05
0
-0.05
-0.1
-0.15
0.5
0
-0.5
EOF2
-2
-1
0
1
2
EOF1


EOF3
0.15
0.1
0.05
0
-0.05
-0.1
.5
-1
-0.5
0
0.5
1
1.5
EOF1
0.6
0.4
0.2
0
-0.4
EOF2


EOF3
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-2
-1
0
1
2
EOF1
-0.4
-0.2
0
0.2
0.4
0.6
EOF2


EOF3
0.15
0.1
0.05
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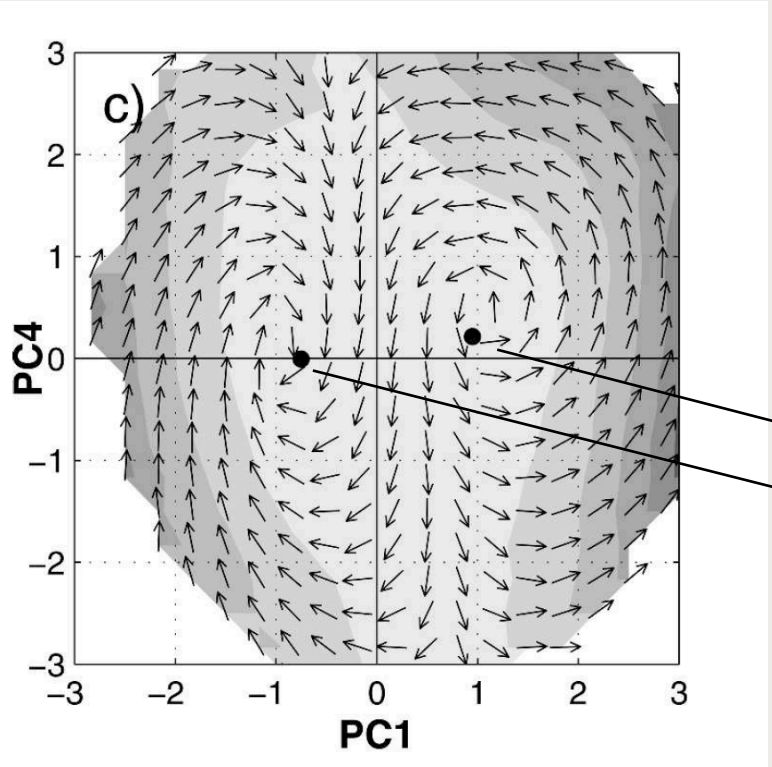
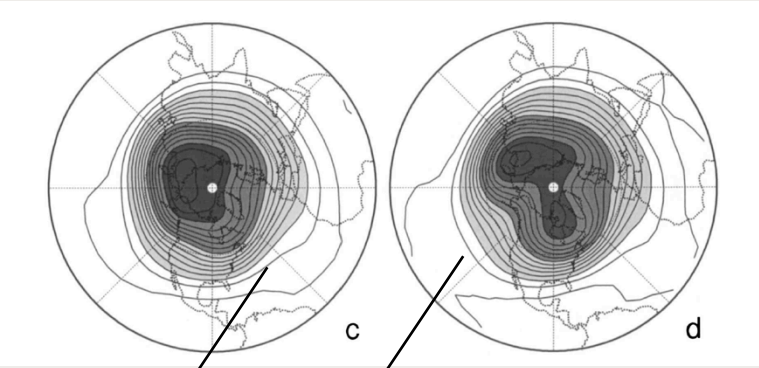
-0.05
-0.1
-0.15
1.5
1
0.5
0
-0.5
-1
-1.5
EOF1
-0.4
-0.2
0
0.2
0.4
0.6
EOF2

Nonlinear phase-space dynamics

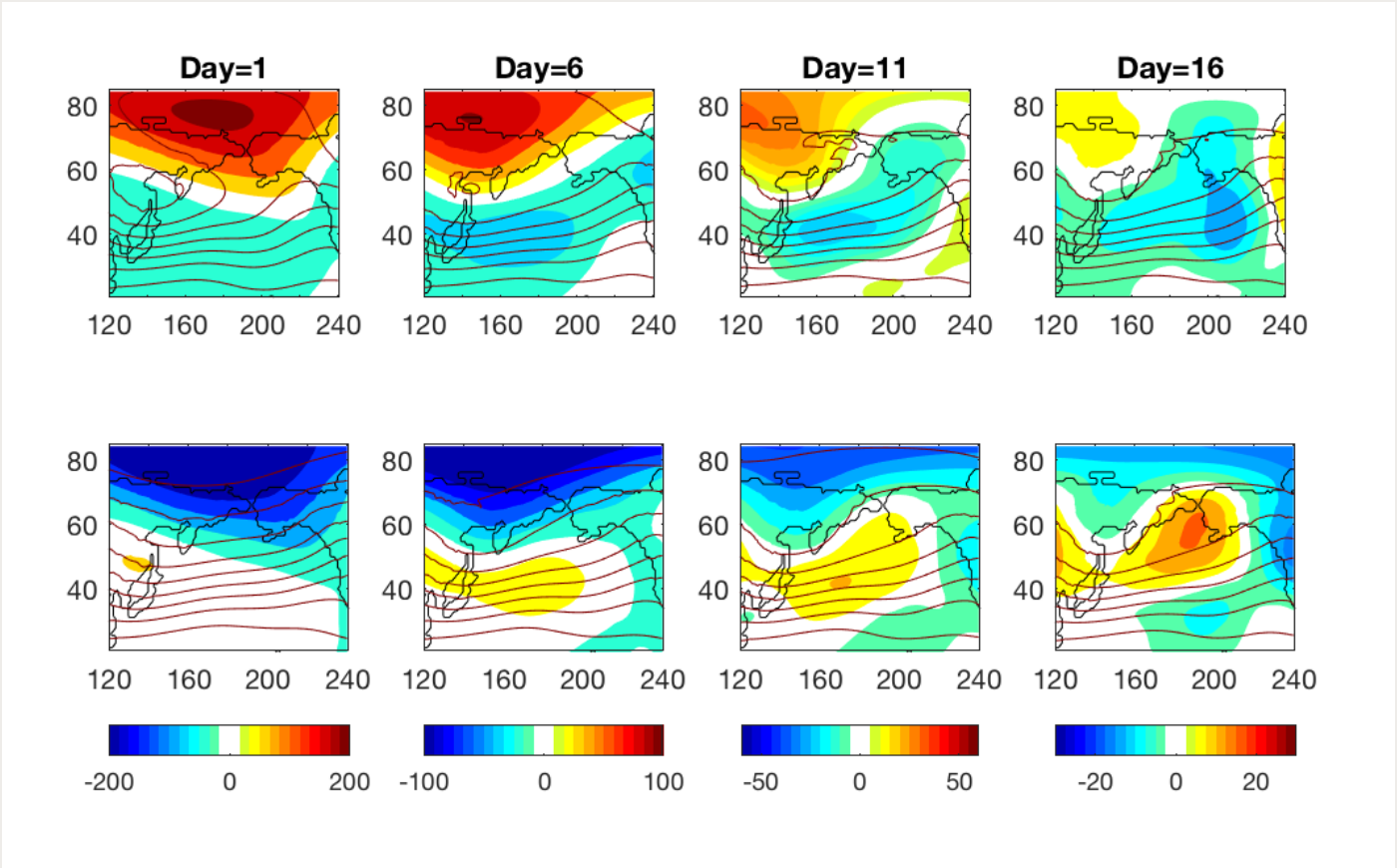




Zonal and block regimes

Branstator and Berner, 2007

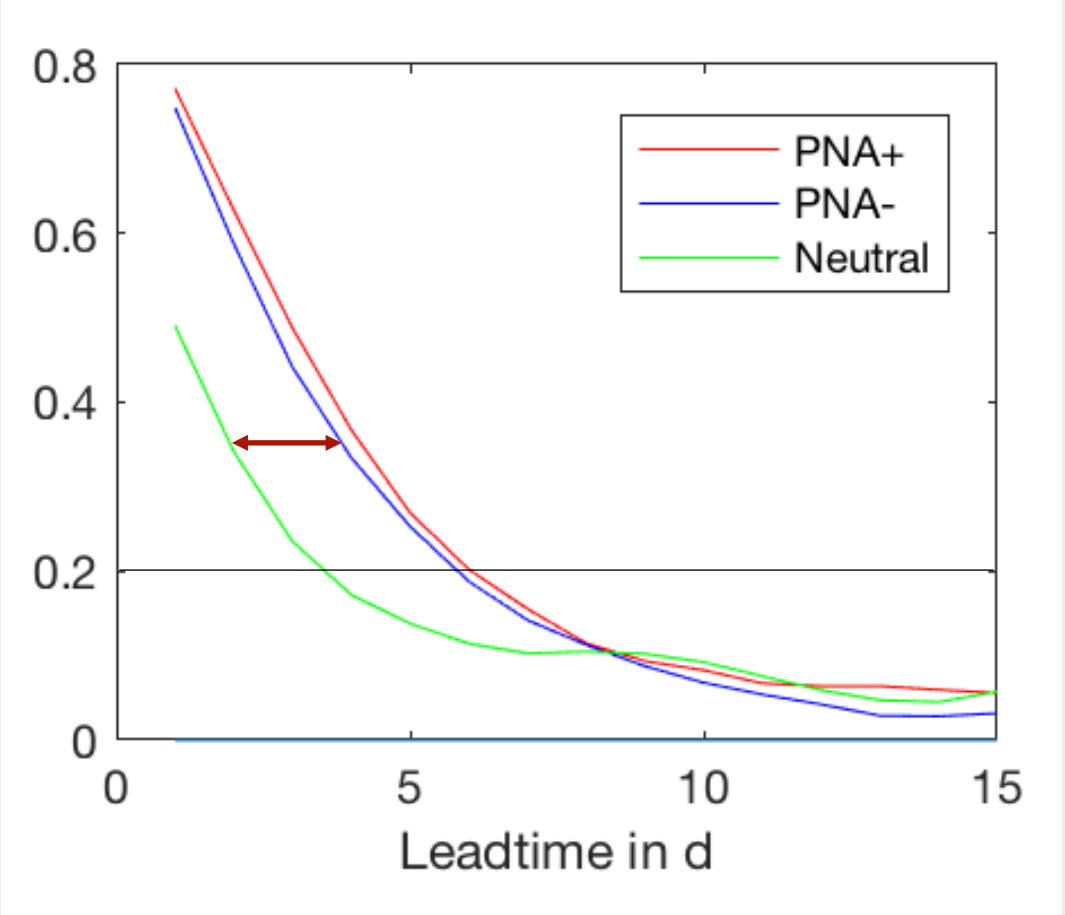
Evolution of cluster means



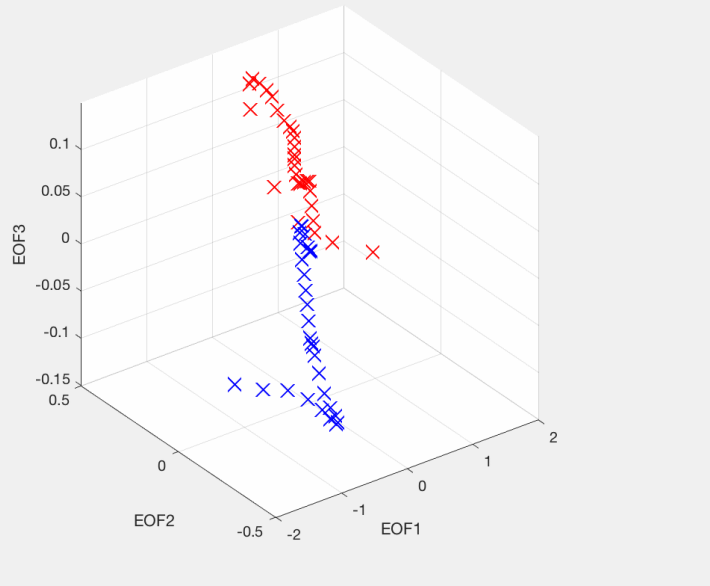
Anomaly correlation in perfect model scenario

$$ACC = \frac{\sum_{i=1}^{n}(v_i - \bar{v})(o_i - \bar{o})}{\sqrt{\sum_{i=1}^{n}(v_i - \bar{v})^2 \sum_{i=1}^{n}(o_i - \bar{o})^2}}$$

- ACC= Correlations between forecast and verifying observations
- Here: analogues (excluding >+/-2d from initialization) are used as verifying observations
- Conservative estimate



Conclusions



- Extended potential predictability for states initialized in +/- phases of NAO and PNA by 2-3 days
- Preferred regimes transitions in daily data
  - Not just statistical concept, but reflected as skill of initialized forecasts
  - More than persistence!!

Future work

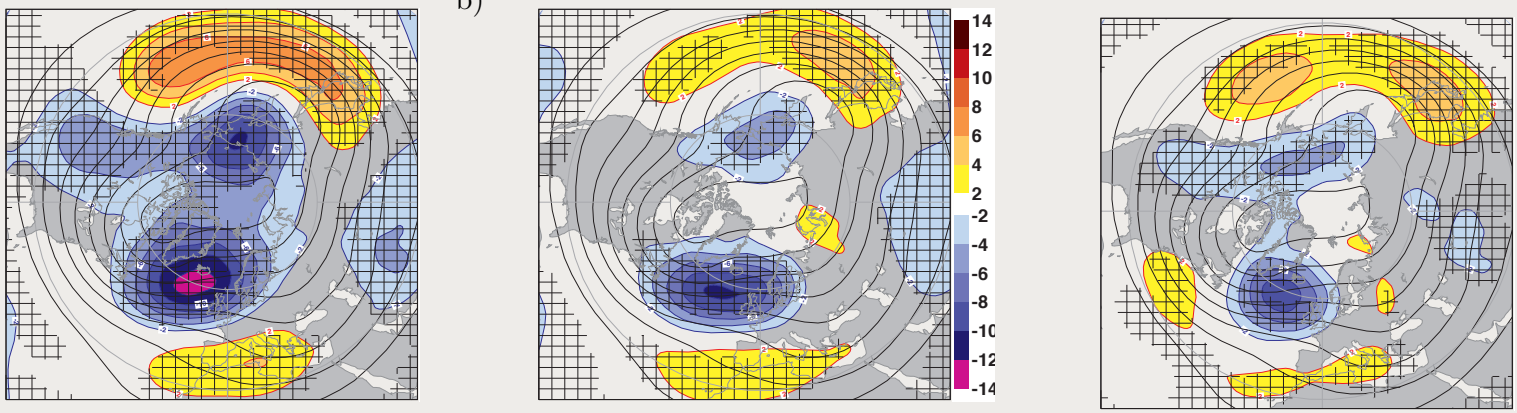
- Better phase space (optimal persistence pattern?)
- Sensitivity to resolution
- Stochastic parameterization
- Other teleconnections, e.g. El Nino, MJO

Mean systematic error of 500 hPa geopotential height fields in ECMWF IFS

LOWRES

HIGHRES

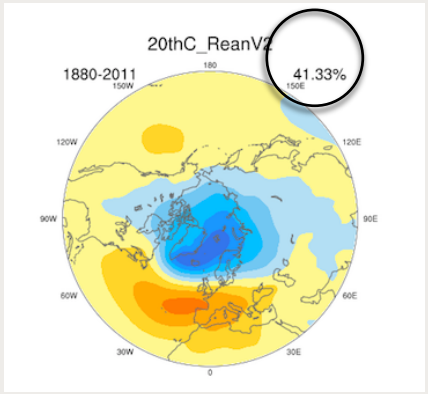
SKEBS

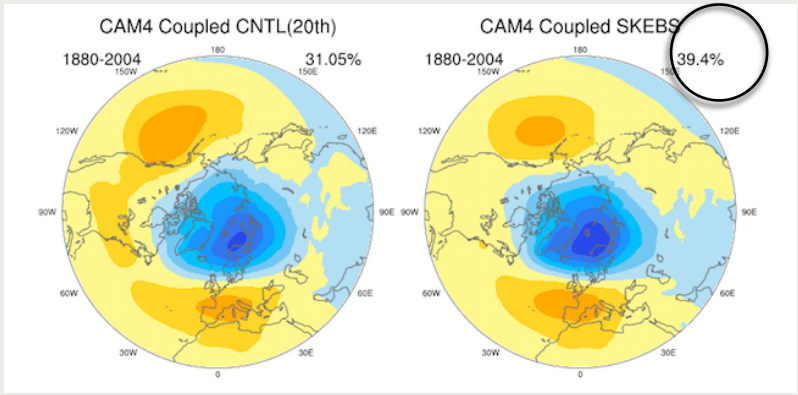


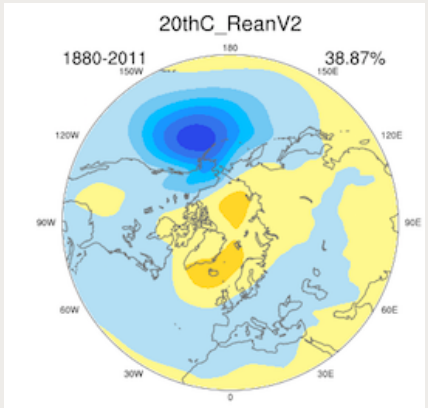
- Reduction of z500 bias in all simulations with model-refinement

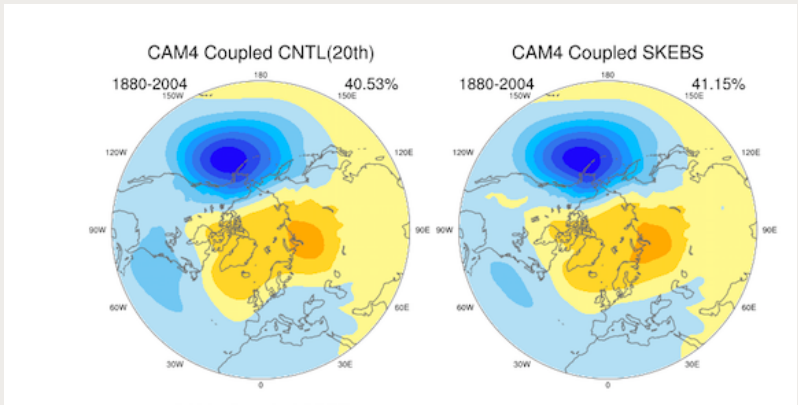
Berner et al., 2012

NAO and PNA in CESM

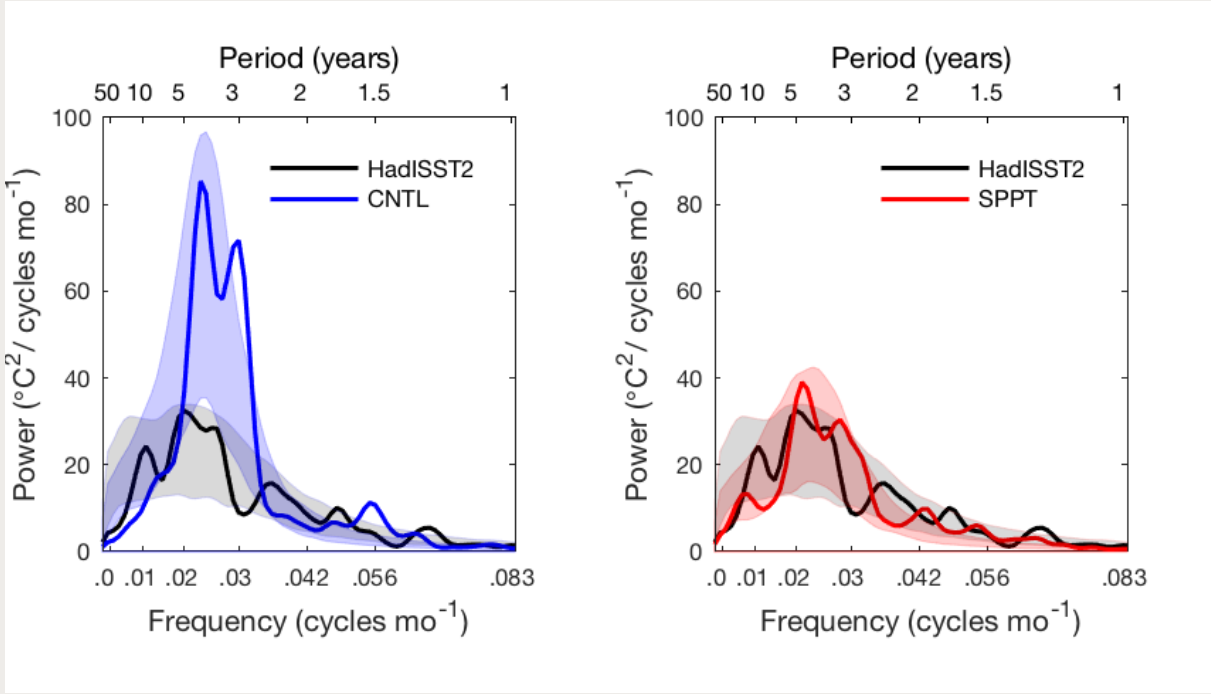






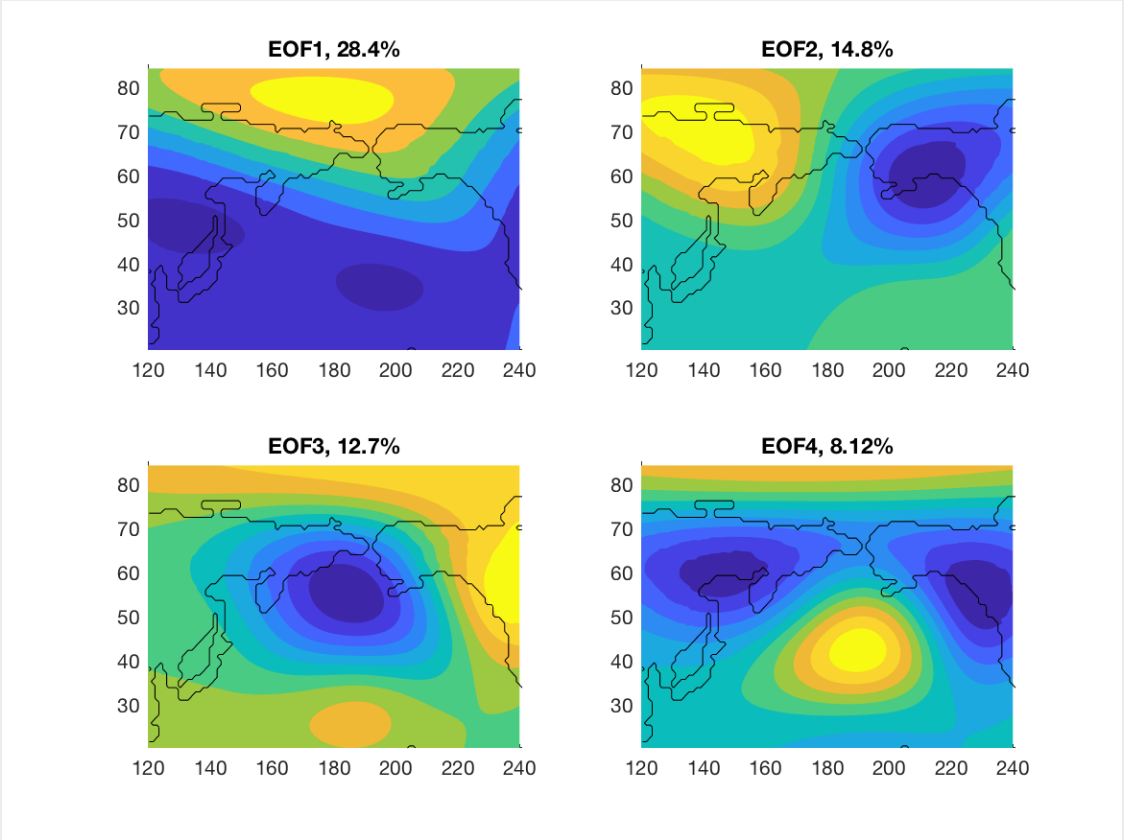


Berner, Sardeshmukh, Christensen, "On the dynamical mechnisms governing ENSO Irregularity" Thursday P-C3-02



Berner et al., *J. Clim.* 2018

EOFs


EOF1, 28.4%
EOF2, 14.8%
EOF3, 12.7%
EOF4, 8.12%
80
70
60
50
40
30
120
140
160
180
200
220
240