NH winter forecast skill of AO and NAO indices: results and sampling issues

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Reusing material from earlier talks given together with

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Outline

- Intro: ECMWF System 4
- Predicting NH winter circulation modes
- Challenges of sampling
- Discussion

System 4 configuration

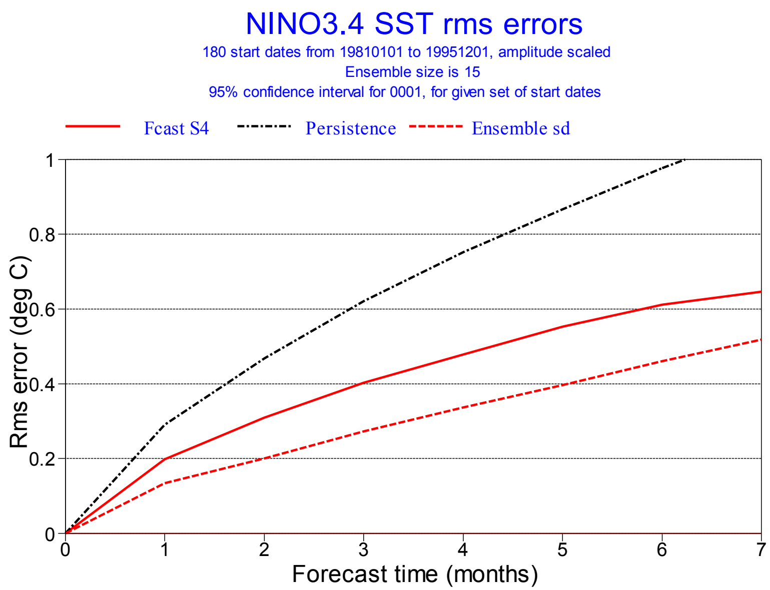
- IFS: T_L255L91 Cy36r4

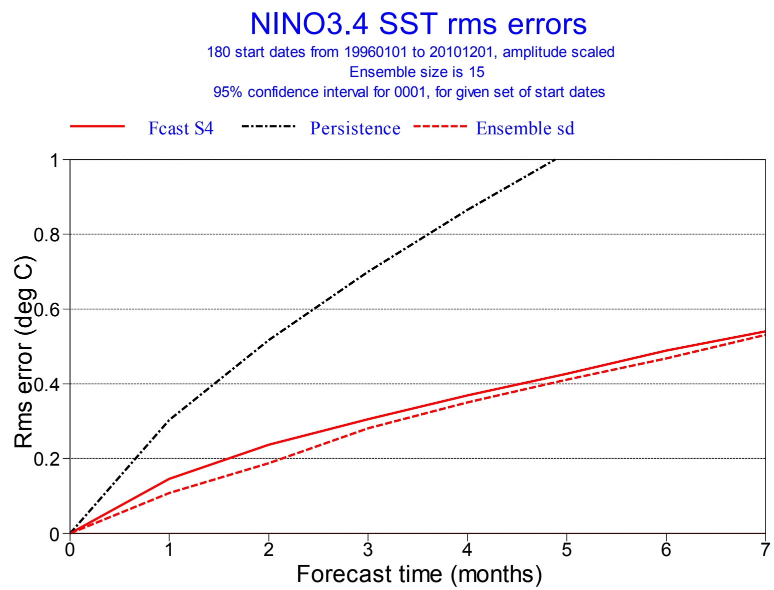
- Real time forecasts:
  - 51 member ensemble forecast to 7 months
  - SST and atmos. perturbations added to each member

- Back integrations from 1981-2010 (30 years)
  - 15 member ensemble every month
  - 15 members extended to 13 months once per quarter

  - 51 members for Feb/May/Aug/Nov starts

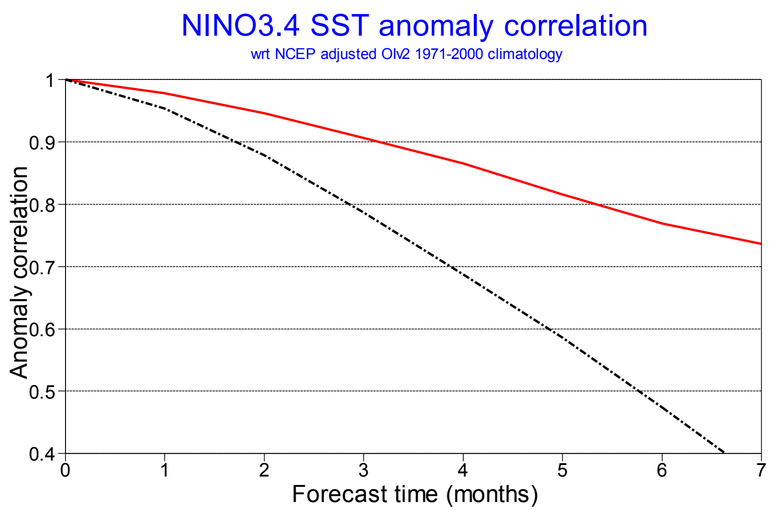
ENSO forecasts are good .....

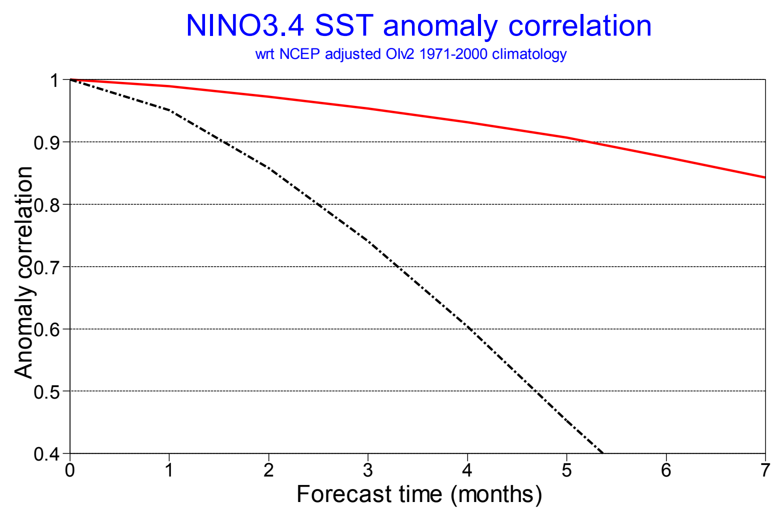




1981-1995

1996-2010

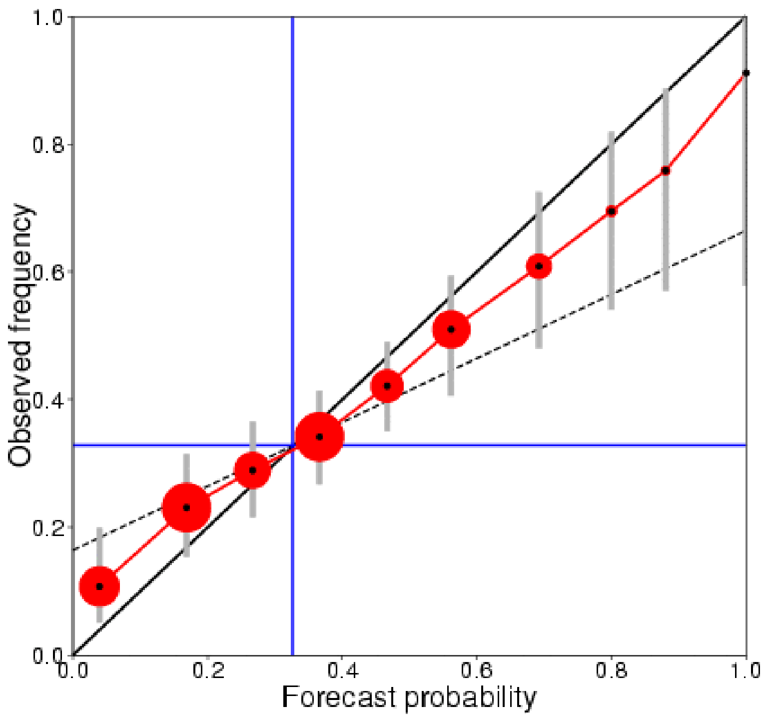




So are probabilistic scores ....

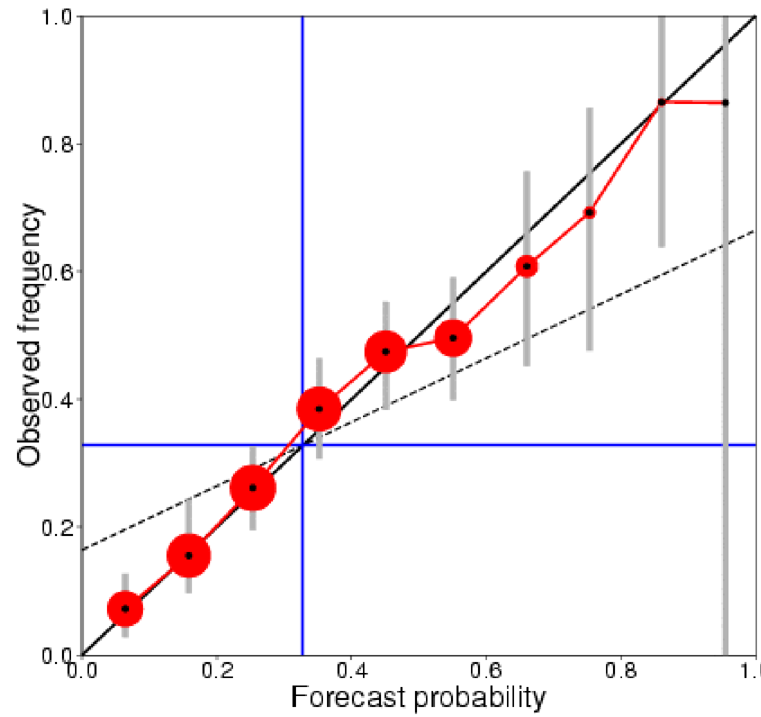
15 members

JJA Europe T2m>upper tercile
Re-forecasts from 1 May, 1981-2010
Reliability score: 0.987
ROC skill score: 0.38



51 members

JJA Europe T2m>upper tercile
Re-forecasts from 1 May, 1981-2010
Reliability score: 0.996
ROC skill score: 0.43

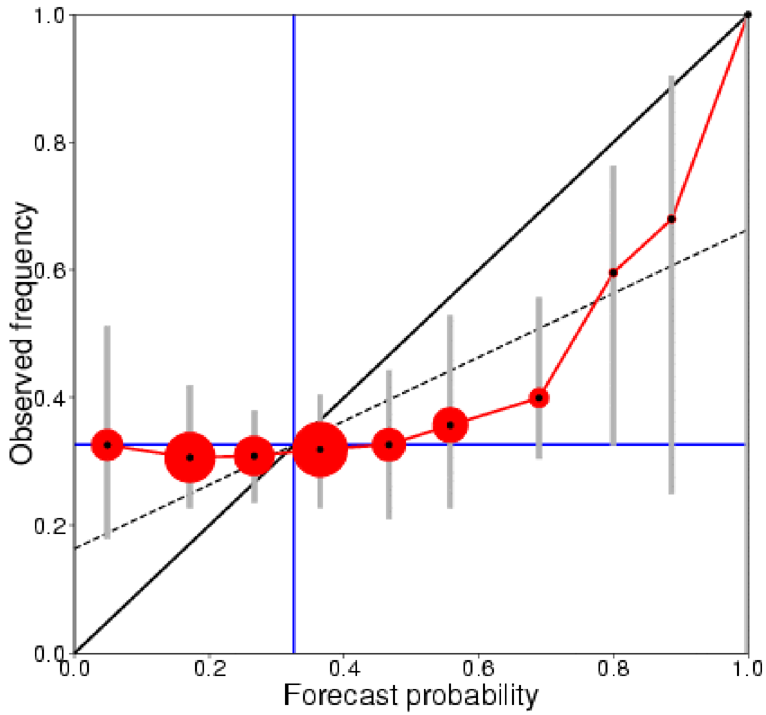


(Figures from Susanna Corti)

Ensemble size important for low-signal areas

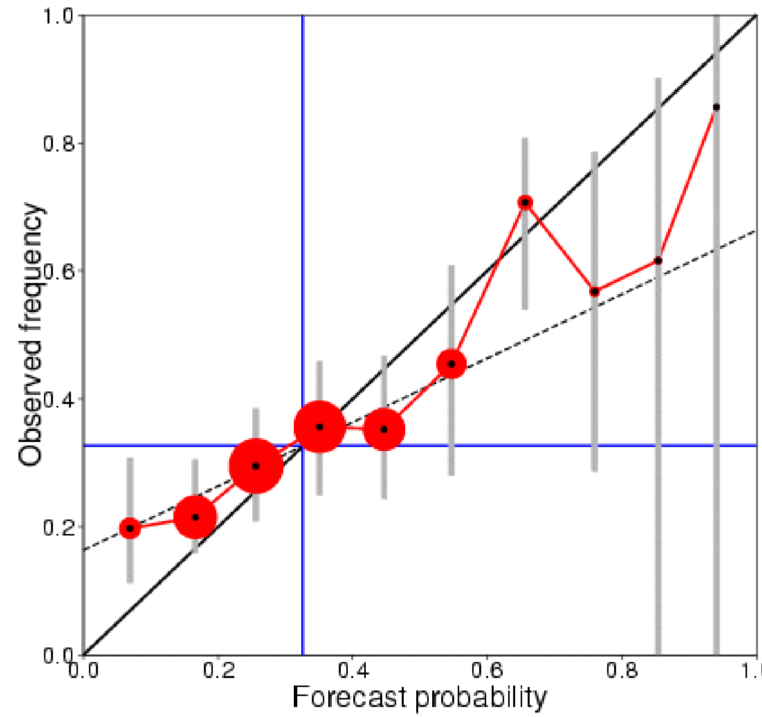
15 members

DJF Europe T2m>upper tercile
Re-forecasts from 1 Nov, 1981-2010
Reliability score: 0.902
ROC skill score: 0.06



51 members

DJF Europe T2m>upper tercile
Re-forecasts from 1 Nov, 1981-2010
Reliability score: 0.981
ROC skill score: 0.22



(Figures from Susanna Corti)

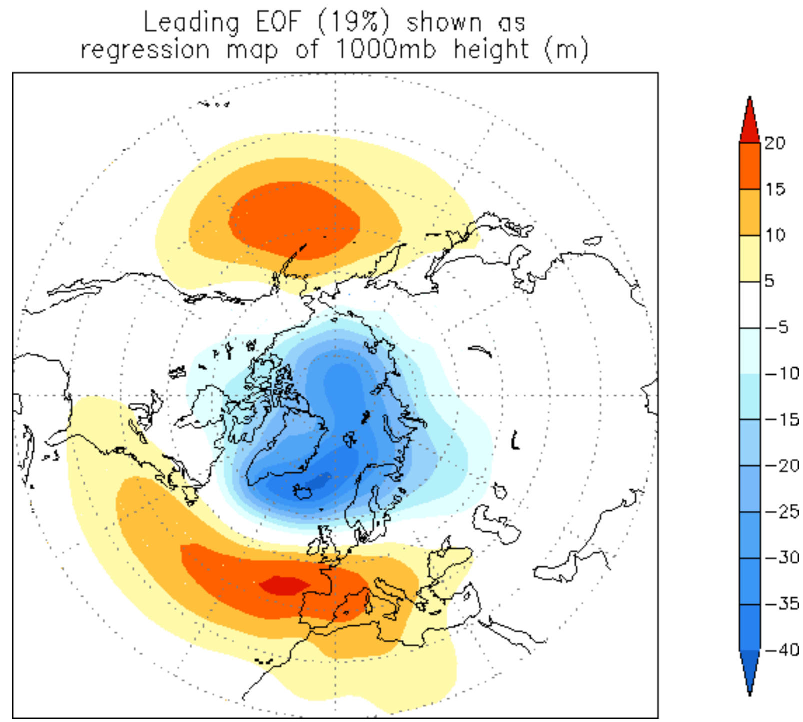
Arctic Oscillation

Calculated as first EOF of monthly mean MSLP anomalies, poleward of 20N.

Use same method as CPC, but using ERA interim analysis, 1981-2010.

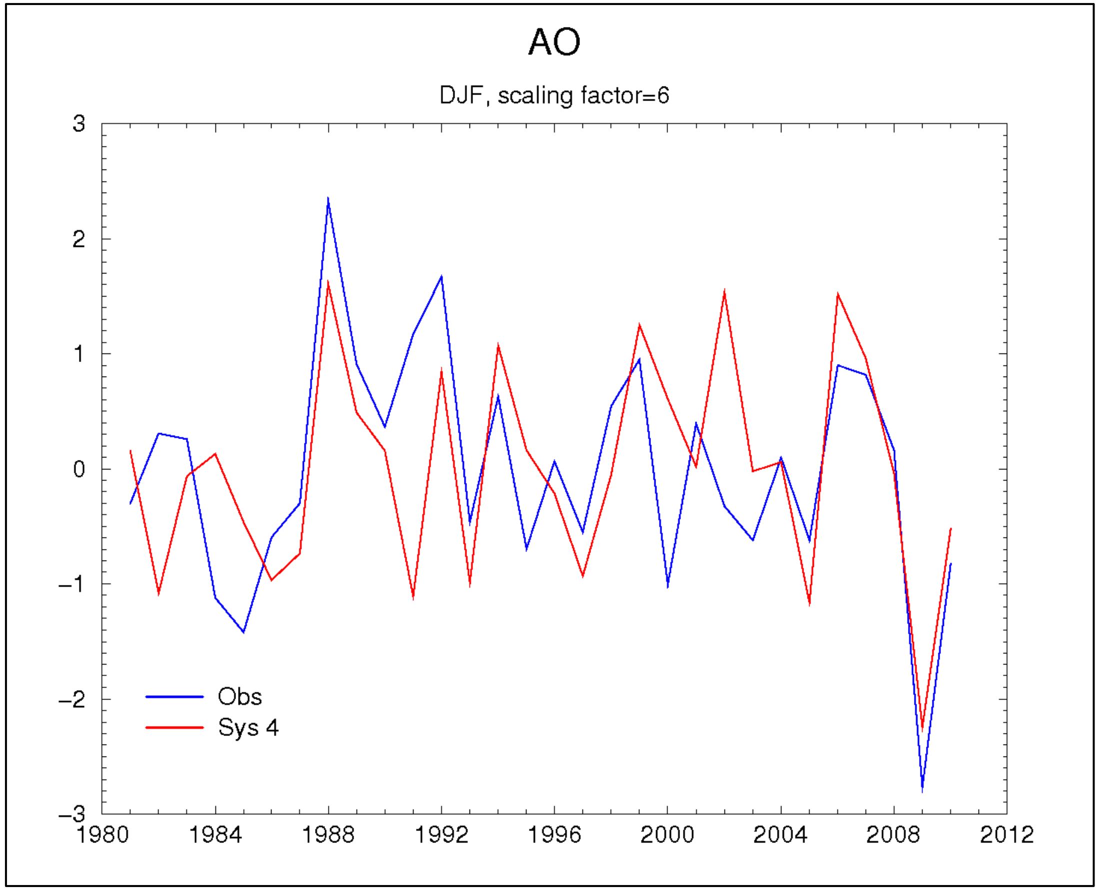
Model and analysis time-series both obtained by projection onto ***observed*** EOF.

Correlation of our observed time-series with CPC is 0.996.



EOF (from CPC)

AO re-forecast skill



Correlation (30y) =0.608

26 years (no volcanoes)
Correlation = 0.73

Surprising because model AO is very noisy ….

Statistical analysis

```
Unbiased variance estimates: Obs/Tot/Int/Ext:      1.0000      0.8390      0.8316      0.0074

Model/obs stddev ratio:   0.9159
Model/obs stddev ratio interval:       0.693   1.129
Bootstrap over nens, pval for ratio=1:  0.7960

==========================================
SNR actual                        :   0.0941
SNR jackknife over nens           :   0.0202  0.1029  0.1857
==========================================

==========================================
ACC actual                        :   0.6085
ACC basic bootstrap over nens     :   0.5568  0.7121  0.8144
ACC basic bootstrap over nyears:      0.2052  0.6069  0.8326
==========================================

ACP from internal sampling: -0.2947  0.0583  0.4010
Mean ACC for nens-1:   0.6049
p val of measured acc if model perfect:    0.9996
```

← model variability consistent with obs

← 95% interval due to ensemble size

← bigger uncertainty range here

← only a 0.0004 chance we could get this correlation

- **Model skill for these years is relatively high**
- **Model predictability limit must be wrong (because we exceed it so much)**

ECMWF

Other teleconnection patterns

	ACC	S/N	ACP	P-val
PNA (EOF)	0.696	0.64	0.54	0.065
NAO (EOF)	0.465	0.13	0.10	0.017

PNA has high skill and high predictability
NAO has moderate skill, and low predictability

NAO skill is, like AO, higher than expected

Does resolution help?

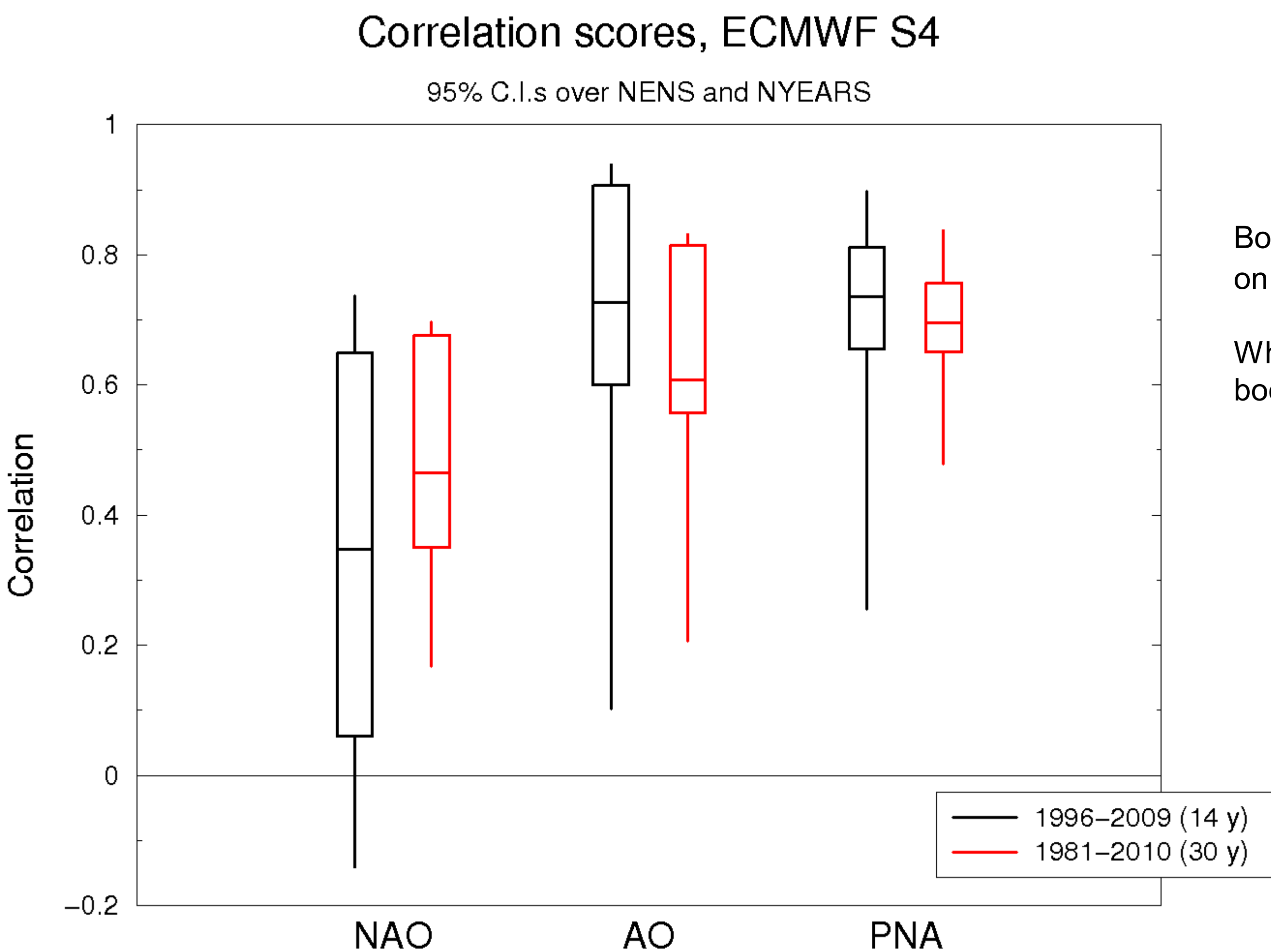
Project Minerva has run the ECMWF coupled model at different atmospheric resolutions. We have 30 years of winter forecasts, with 51 member ensembles:

	T319		T639	
	ACC	**S/N**	**ACC**	**S/N**
PNA (EOF)	0.68	0.69	0.69	0.73
NAO (EOF)	0.36	0.17	0.63	0.18

S/N does not seem to be affected by resolution.

NAO structure and skill is significantly (at 5% level) improved by higher atmosphere resolution.

Challenge: sampling errors are large!

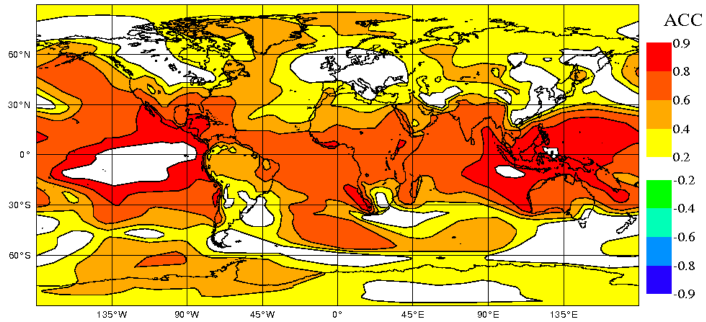


Box = 95% interval, bootstrapping on ensemble size

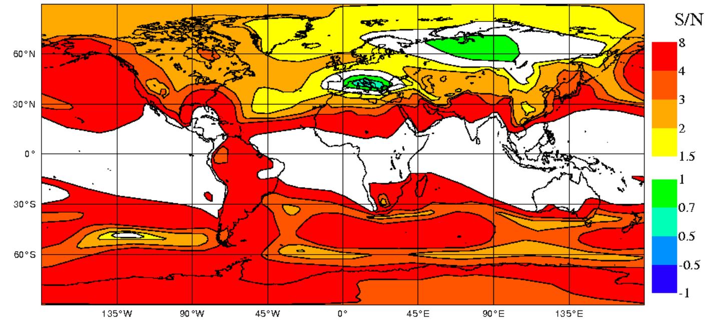
Whiskers = 95% interval, bootstrapping on years included

NH winter forecasts

MSLP Anom. correlation fuhg(101)-ERA-Int 1981-2010DJF
Global z-mean acc: 0.575 NH:0.339 TR:0.729 SH:0.381

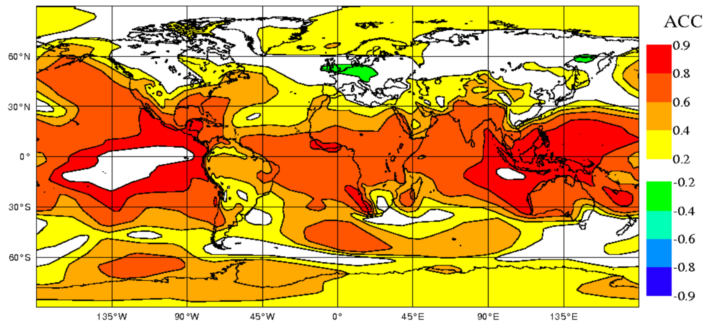


MSLP Ens. mean S/N ratio fuhg(101)-ERA-Int 1981-2010DJF
Global rms: 8.92 NH:3.16 TR:11.8 SH:4.67

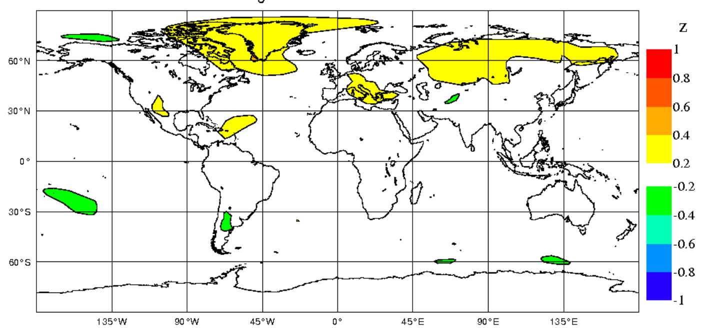


Even with 101 members, ensemble mean signal not always well defined

MSLP Anom. correlation fulf(101)-ERA-Int 1981-2010DJF
Global z-mean acc: 0.563 NH:0.279 TR:0.72 SH:0.413



Fisher z transform diff fuhg(101)-fulf(101) 1981-2010DJF
sigma: 0.272 mean: 0.0175



Conclusions

- **S4 has substantial skill in predicting AO phase over a 30 year period**
  - How typical this is of expected future performance is unknown
  - Amplitude of model signal is too weak
  - Models are noisy
- **Scores are unstable**
  - Sensitive to choice of years, especially for shorter periods
  - Relative skill of AO and NAO indices can vary between model versions
- **Higher resolution (to T639)**
  - **DOES** help NAO in particular (quite big improvement)
  - Does **NOT** help S/N ratios
  - … according to a single experiment

Conclusions - Sampling

- **Sampling over NYEARS**
  - Is an obvious problem for systems without high S/N ratios
  - Skill estimates need as many years as possible, but there are limits
  - We need to understand sources of skill to know how far back we can go (to 1979? to 1960? Even earlier??)

- **Ensemble size is often too small**
  - Given how noisy our models are, we should probably be doing our experiments with ensembles O(100) to get clean results

- **Costs**
  - So all we need are very high resolution models, large ensembles, lots of start dates … and lots of different experiments to improve our models.