Assessing the impact of random corrections of the atmospheric component in seasonal predictions with CNRM-CM

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Why introduce perturbations in ARPEGE-Climate ?

- Account for model inadequacies
- "Perturbation/correction" approach
- Ensemble generation for seasonal forecasts

Purpose of the study

- Atmospheric nudging as a means of estimating the long-term tendency errors of the model
- Investigate the impact of randomly correcting these errors on seasonal forecast quality

Presentation outline

1. The "stochastic dynamics" technique in ARPEGE-Climate
2. Impact on seasonal re-forecasts with CNRM-CM : global assessment
3. Focus on impacts on Northern Hemisphere mid-latitudes

General philosophy

Atmospheric model error reduction

- Approach based on atmospheric nudging studied in European project POTENTIALS
- Nudging of prognostic variables (Jeuken et al., 1996) as a means of estimating atmospheric model initial tendency errors
- In-run correction of mean errors estimated by nudging can improve model mean state (Guldberg et al., 2005)
- No clear impact on seasonal prediction scores

Nudging

$$\frac{\partial X}{\partial t}(t) = \mathbf{M}(X(t), t) + \frac{X^{\text{ref}}(t) - X(t)}{\tau}$$

General idea for the method designed at CNRM : use this approach to estimate model corrections and draw perturbations of the atmospheric model prognostic variables from within this correction population.

References : Batté L. and Déqué M. 2012 (Geophys. Res. Lett.) and 2016 (Geosc. Mod. Dev.)

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Implementation in CNRM-CM

Estimation of the perturbation population

- Nudged coupled seasonal re-forecast run : NDJF 1979/80–2012/13
- **Weak nudging** ($\tau = 1$ month) of temperature, vorticity and specific humidity in the atmosphere towards ERA-Interim
- Tapering in the upper and lower levels of the atmosphere
- $\delta X(t) = \frac{X^{\text{ref}}(t) - X(t)}{\tau}$ stored each day

Nudging

$$\frac{\partial X}{\partial t}(t) = \mathbf{M}(X(t), t) + \frac{X^{\text{ref}}(t) - X(t)}{\tau}$$

In-run perturbations

- Use $\delta\tilde{X}$, correction term from another year, as a perturbation for time t in seasonal re-forecast for year y
- Different sets of corrections are drawn for each ensemble member
- Corrections are simultaneous for the three fields, drawn from other years of the re-forecast period, within the same calendar month

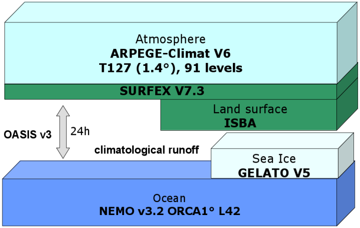
Perturbations

$$\frac{\partial X}{\partial t}(t) = \mathbf{M}(X(t), t) + \delta\tilde{X}(t)$$

Coupled seasonal re-forecasts with CNRM-CM

Boreal winter (NDJF) ensembles

- REF : reference coupled model experiment without perturbations
- "Stochastic dynamics" experiments :
  - SMM : random monthly mean corrections of ARPEGE tendency errors applied to each member
  - S5D : random sequences of five consecutive days of error corrections applied to each member
- 30-member ensembles ; NDJF 1979/80–2012/13 re-forecast period (34 years)



(Voldoire et al. 2013)

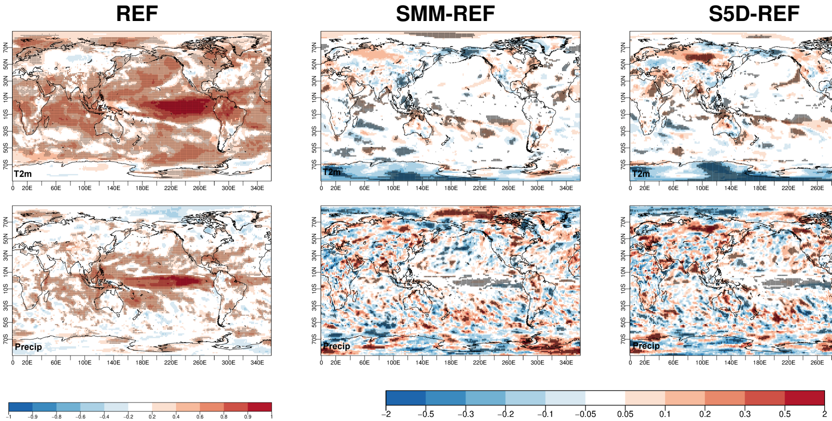
Initialization

- Atmosphere : ERA-Interim (Dee et al., 2011)
- Ocean : NEMOVAR reanalysis

Evaluation

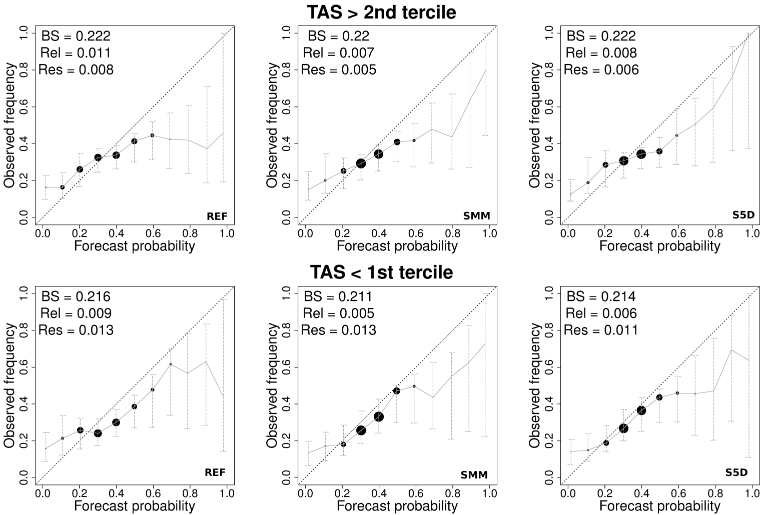
- ERA-Interim as reference
- CRU for surface temperature over land
- Deterministic and probabilistic forecast quality

Global assessment of impact on re-forecast skill



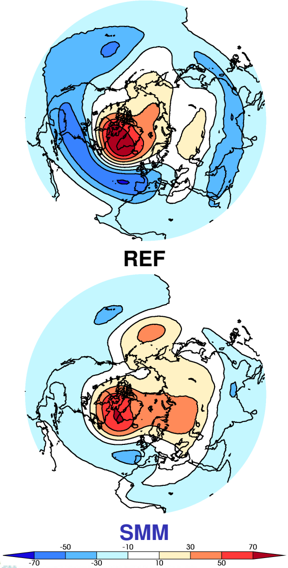
Left column : correlation of DJF near-surface temperature REF re-forecasts with ERA-Interim (top) and total precipitation with GPCP v2.2 (bottom). Center and right : difference in correlation coefficient for these variables in SMM and S5D, respectively, w.r.t. REF.

Probabilistic skill assessment

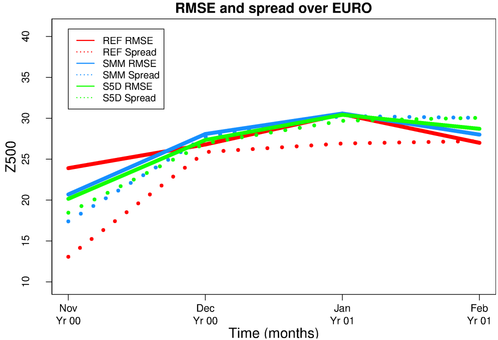


Reliability diagrams and Brier Score decomposition for near-surface temperature REF, SMM and S5D re-forecasts over Europe (with respect to CRU TS3 data, Harris et al. 2014).

DJF Z500 seasonal re-forecast



Mean bias for DJF Z500 DJF w.r.t ERA-Interim (m)

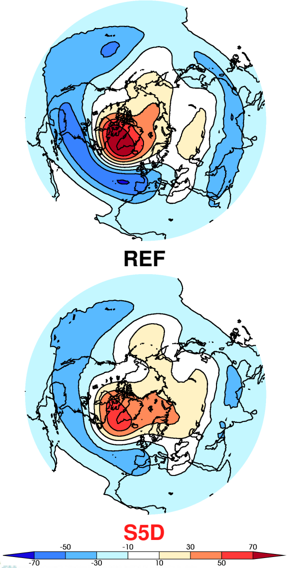


Evolution with forecast time of ensemble spread and RMSE for Z500 over Europe (12.5W-42.5E, 35N-75N)

Impact on bias and spread-skill ratio

- Z500 bias in CNRM-CM seasonal re-forecast very similar to the NAO pattern
- SD perturbations reduce the bias and improve the model spread-skill ratio

DJF Z500 seasonal re-forecast



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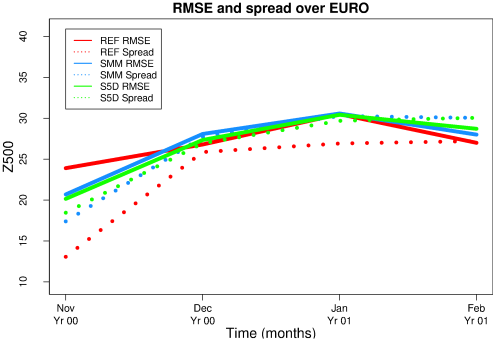

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North Atlantic weather regimes and NAO index

Weather regime statistics and NAO skill

	NAO+		Blocking		NAO-		Atl. Ridge		NAO index
Run	*Freq.*	*Length*	*Freq.*	*Length*	*Freq.*	*Length*	*Freq.*	*Length*	*r*
ERA-I	32.1%	9.48	24.4%	7.14	18.8%	9.27	16.6%	5.85	-
REF	26.5%	8.28	23.4%	6.56	24.0%	8.90	16.8%	6.41	0.41
SMM	28.0%	8.36	23.8%	6.78	21.8%	9.35	17.1%	6.38	0.38
S5D	28.0%	8.35	23.8%	6.97	21.9%	9.16	17.1%	6.38	0.54

- Perturbations generally improve weather regime frequency when compared to ERA-Interim statistics
- They also improve the regime residency w.r.t. REF even when it is too short
- Very little difference is found between both methods
- NAO skill is best with S5D

Conclusions

An original method for in-run model error correction

- Atmospheric nudging is used in a preliminary run to estimate model errors
- These estimates are then randomly substracted from the model during seasonal forecast runs

Impact on boreal winter seasonal re-forecast quality

- Very little systematic impact on overall re-forecast skill
- Improvements in model systematic error and spread-skill ratio for Z500
- Some improvement in weather regime representation and NAO skill

Limitations and future work

- How τ- and frequency-dependent are results ? (ongoing work)
- Limited impact on ensemble spread : combination with SPPT-like methods

Thank you for your attention !

Batté, L. and Déqué, M. (2016) : Randomly correcting model errors in the ARPEGE-Climate v6.1 component of CNRM-CM : applications for seasonal forecasts, *Geosci. Model Dev.* 9 : 2055-2016, DOI : 10.5194/gmd-9-2055-2016