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The decadal climate prediction skill with focus on the North Atlantic region

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ARCPATH

BLUE ACTION

EUCP European Climate Prediction system

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Motivation

- Climate predictions on decadal time scale involve an accurate description of the initial state of the climate system while accounting for response to the changes in external forcing. The decadal predictability is influenced by the mutual interaction of the internal excited, and external forced modes of variability.
- The North Atlantic region is one of the most challenging regions for long term predictions, as a wide range of local and remote modes of variability interplay in the region. Yet it is a key region impacting the climate and society substantially.
- This study attempts to assess the skill of decadal predictions in a number of ensembles of initialized decadal prediction experiments using earth system models that are available in the recent years.

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Models, experiments and methods

Model	# Dec. Pred. members	# Historical (+SSP2-4.5) members	Comments/prediction period
CESM LENS	40	42	CESM large ensembles project, post-cmip5, 1970-2017
CanCM4	10	10	CMIP5, 1970-2005
GFDL-CM2p 1	10	10	CMIP5, 1970-2005
HadCM3	10	10	CMIP5, 1970-2005
EC-Earth3	10 (15)	10 (15)	EC-Earth3, Decadal Prediction System with **anomaly initialization**; CMIP6, 1979-2017

- Models are initialized every year (Nov. 1), and have an ensemble of at least 10 members for both the decadal predictions and the historical (+SSP2-4.5/RCP4.5) experiments
- 10-year Initialized predictions (lead-time 1-10 years). A lead–time 1 year means predicting the average over the year beginning the following January
- Observations: NCEP or NOAA 20th Century Reanalysis for near surface temperature for TAS, and ECMWF ORAS5 ocean reanalysis for SSTs
- No detrending. Compare historical experiments and predictions to isolate influence of initialization (using the same number of ensemble members)
- Statistical significance by Month-Carlo methods

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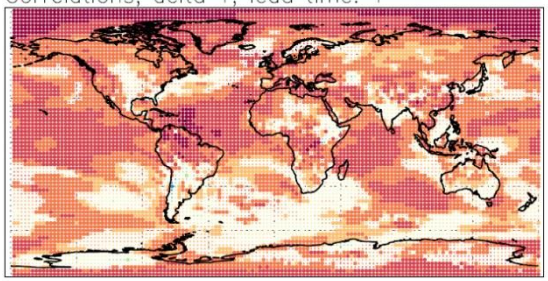
Skill gained from initialization

TAS correlations between ensemble mean and OBS: CESM LENS

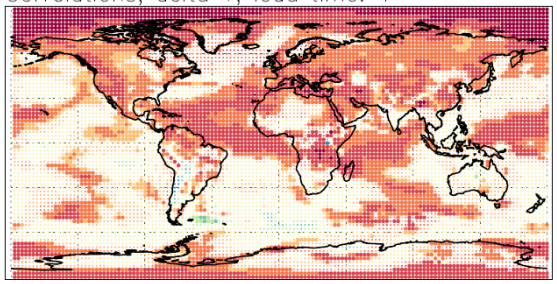
Forecast Lead time 1 year

Correlations, delta 1, lead time: 1



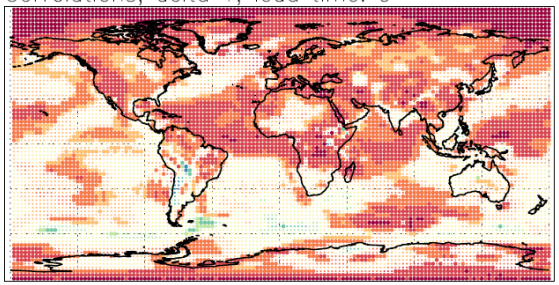
Forecast Lead time 4 years

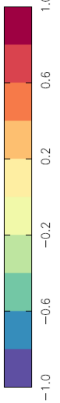
Correlations, delta 1, lead time: 4



Forecast Lead time 9 years

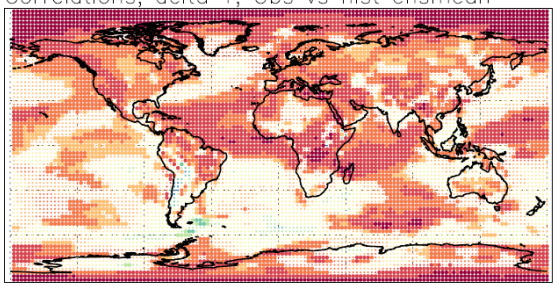
Correlations, delta 1, lead time: 9





Historical+SSP2

Correlations, delta 1, Obs vs hist ensmean



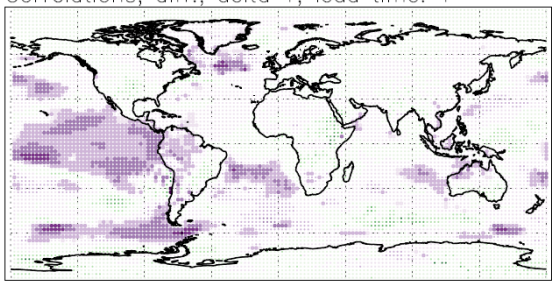
- Strong correlations for lead-time 1 year
- Good skills remain in many regions for longer lead-time due to the forced variability
- For long lead-time only little improvement by initializations except for the North Atlantic sub-polar gyre regions

(large dots indicate where are significant to the 95% level)

Correlation difference with/without initializations

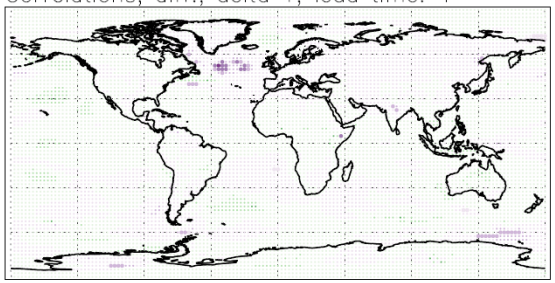
Fcst.-Hist. Lead time 1 year

Correlations, diff., delta 1, lead time: 1



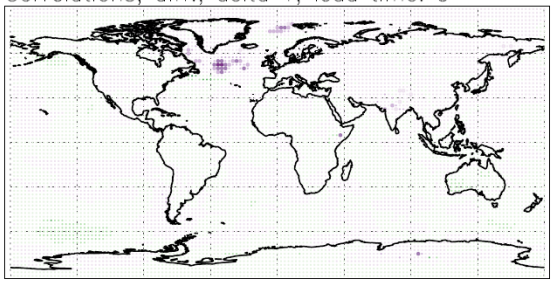
Fcst.-Hist. Lead time 4 years

Correlations, diff., delta 1, lead time: 4



Fcst.-Hist. Lead time 9 years

Correlations, diff., delta 1, lead time: 9



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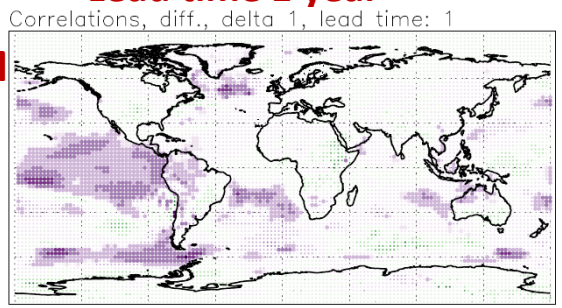
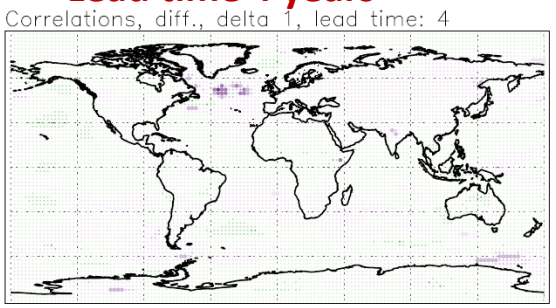
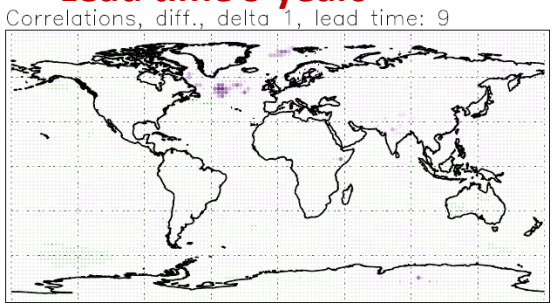
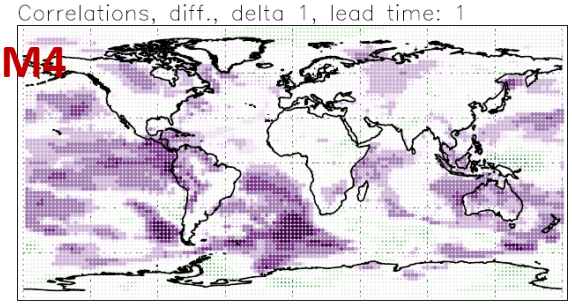
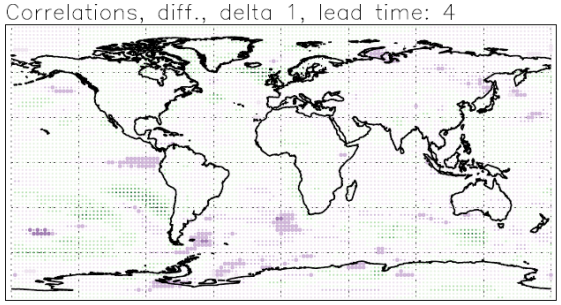
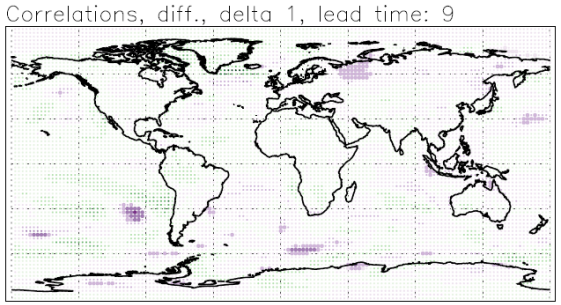
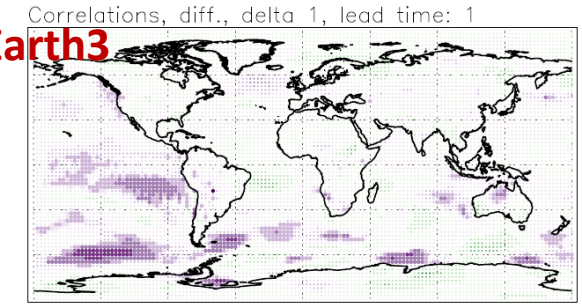
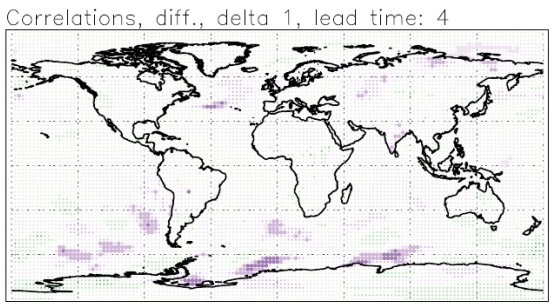
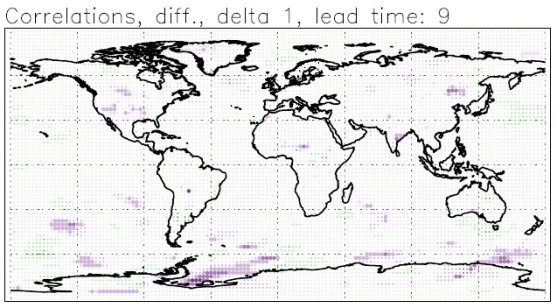
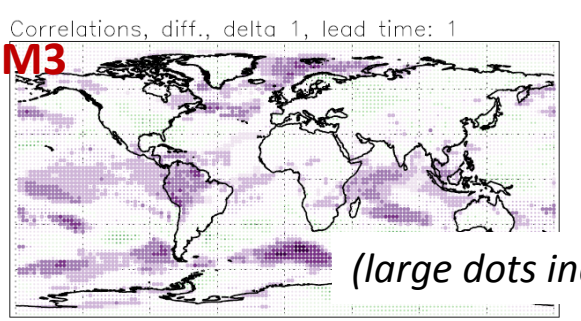
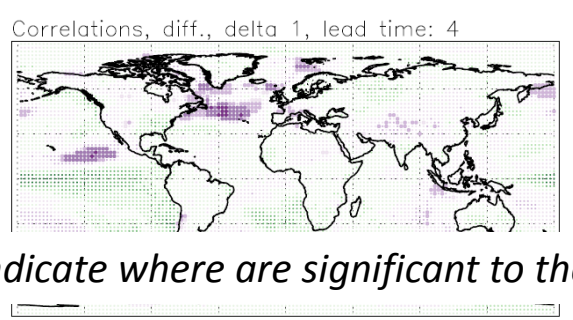
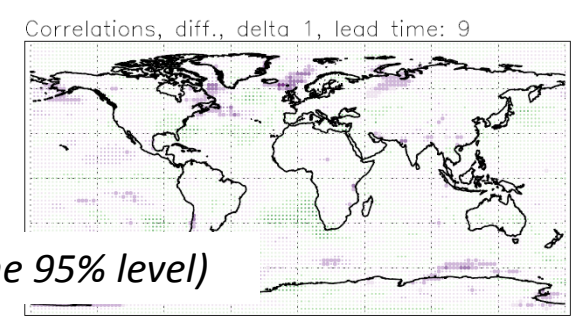
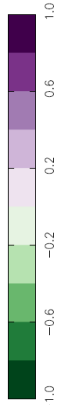
Comparing models

Correlation difference between with/without initialization

	Lead time 1 year	Lead time 4 years	Lead time 9 years
CESM LENS			
CanCM4			
EC-Earth3			
HadCM3			

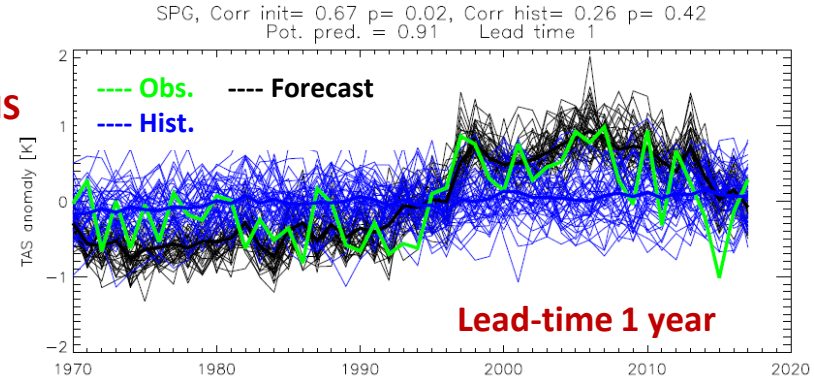


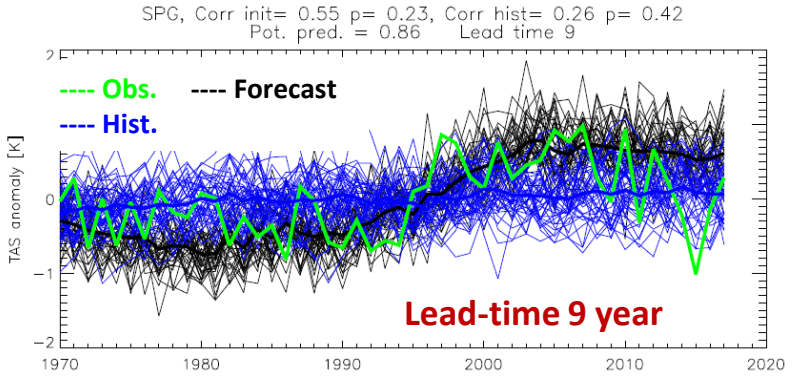
(large dots indicate where are significant to the 95% level)

A closer look at the subpolar gyre region

TAS in the North Atlantic Subpolar gyre region (40–15°W, 50–60°N)

CESM LENS

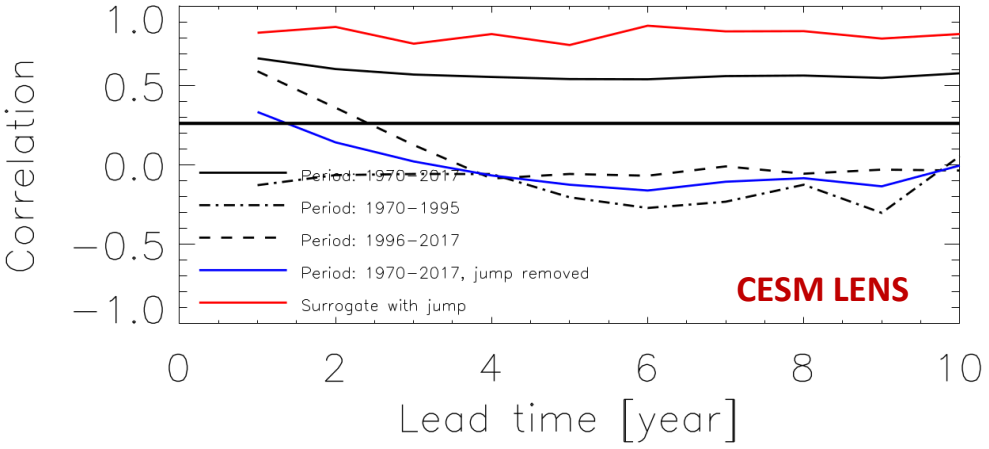




Deconstructing the skill in the Subpolar gyre region

- Large skill for all lead-times (right figure, full black curve) when the full period 1970-2017 is considered. Thick black straight line is the historical experiment
- Weak or no skill for the periods before and after 1996 (dashed black curves)
- Removing the jump in 1996 from observations results in weak skill for lead-times longer than 1 year (blue curve).
- Keeping only the jump in 1996 in the observations gives large skill for all lead-times (red curve).

Correlation between ensemble mean and observations for TAS subpolar gyre region



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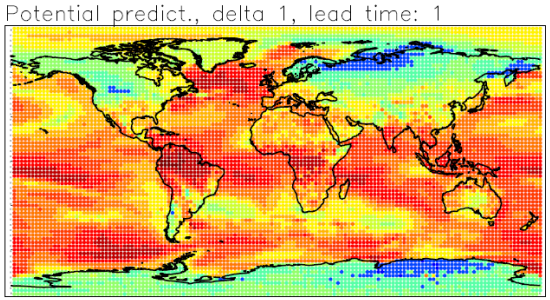
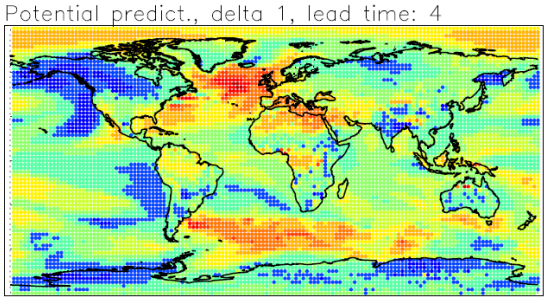
Potential predictability

CESM LENS

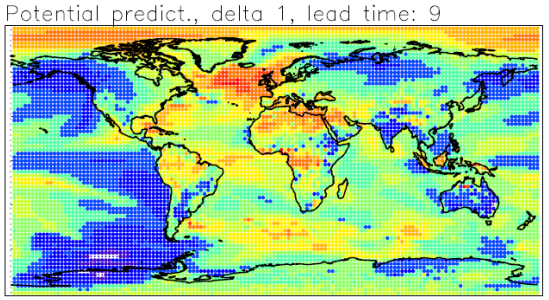
Forecast Lead time 1 year



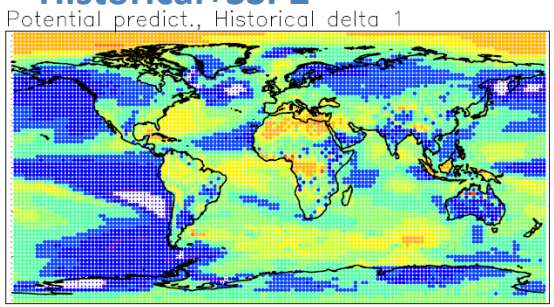
Forecast Lead time 4 years

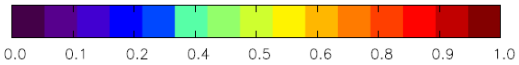


Forecast Lead time 9 years



Historical+SSP2





- Potential predictability measures the ensemble mean spread relative to the total spread of the ensemble members
- The North Atlantic subpolar gyre region sticks out with large potential predictability in the initialized experiments even for long lead time in comparison with the uninitialized experiments

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Summary

- Models agree that for lead-times between 4 and 10 years little effect of initialization is found except in the NA sub-polar gyre region. This (well-known) result is found across all the models and is robust to temporal and spatial smoothing.
- This skill in the North Atlantic subpolar gyre region seems to a large degree to be related to the shift towards warmer temperatures around 1996. Weak or no skill is found when only the sub-periods before and after 1996 are considered.
- The potential predictability confirms the difference between the historical and the initialized experiments in the North Atlantic subpolar gyre region.

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