Assimilation of PAGES2k temperature reconstructions with a GCM

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Content

Assimilation of PAGES2k temperature reconstruction using GCM ensemble member selection. Lessons learned on

- information propagation on decadal timescales (online vs offline DA)

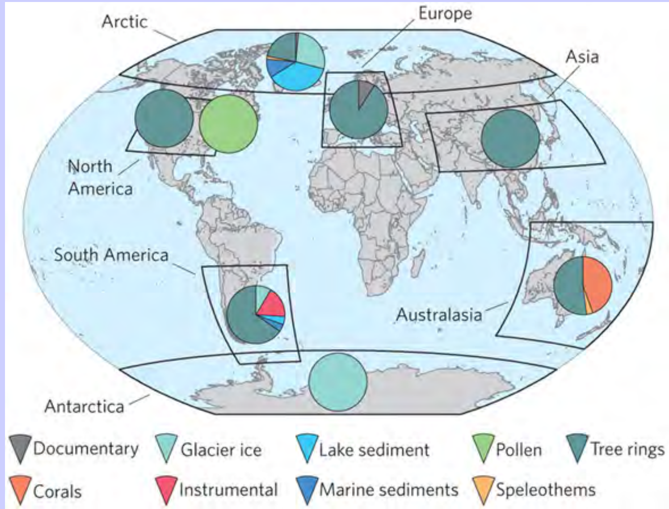
- information propagation to sub-continental spatial scales

Note: this is a pragmatic setup that

- avoids the need for forward modelling/PSM

- uses regional inversions based on expert knowledge, in which hopefully some of the proxy noise is averaged out

Data assimilation with ECHAM6/MPI-OM



Model: ECHAM6/MPI-OM (T31L31, MPI-ESM-CR))

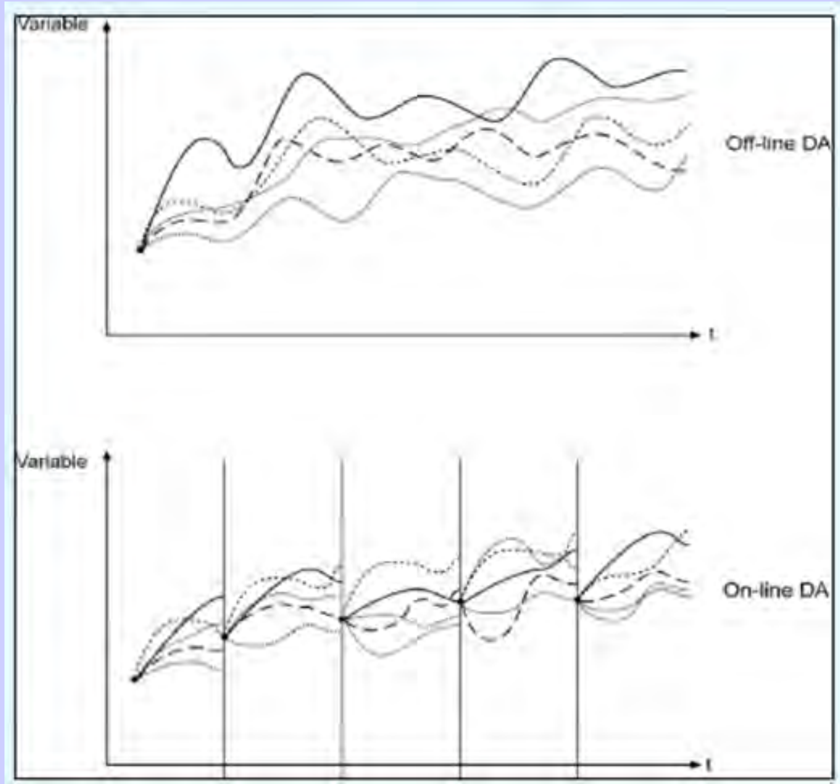
Data: PAGES2k NH continental reconstructions
(Arctic: annual; Europa, Asia: summer;
North America: decadal mean of annual)

Method:

- **ensemble member selection, on-line and transient off-line**

- **cost function evaluated for decadal means**

$$CF(t) = \sqrt{\sum_{i=1}^{k} \left(T^i_{mod}(t) - T^i_{prx}(t)\right)^2}$$



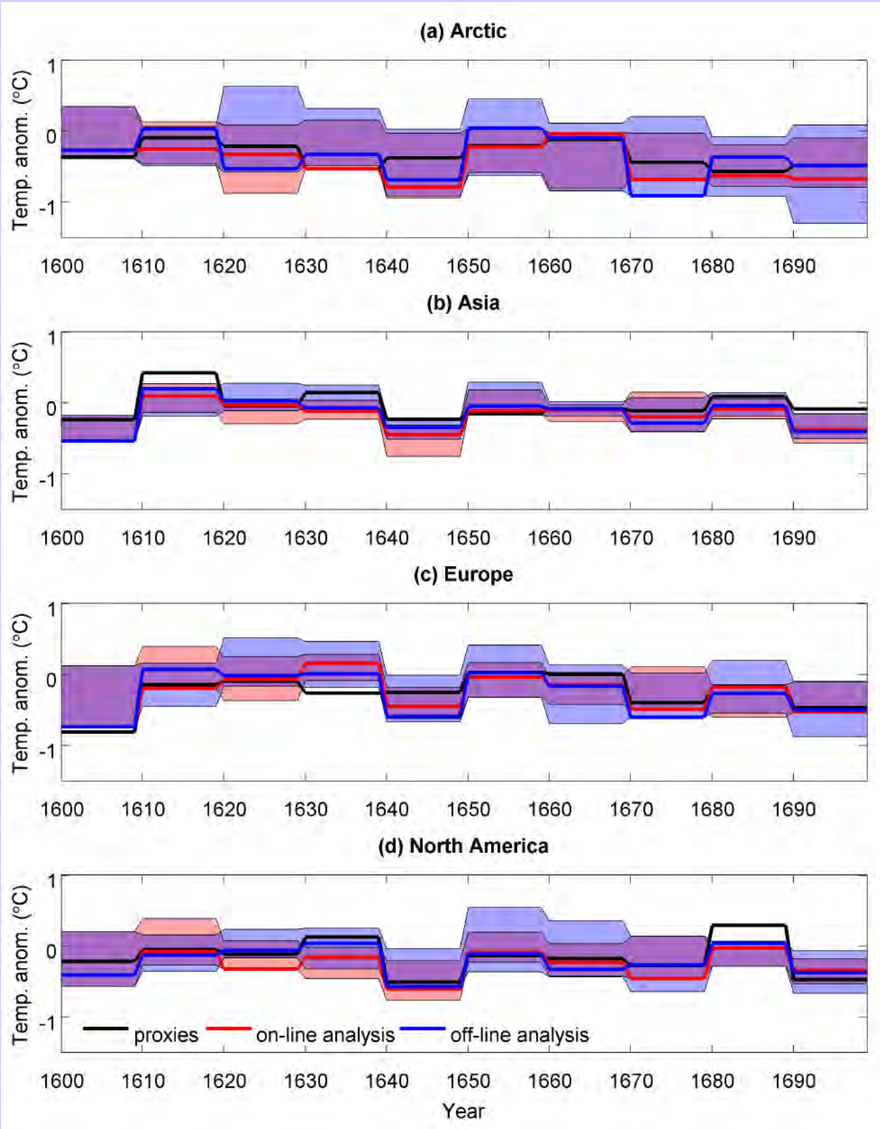
Experiments:

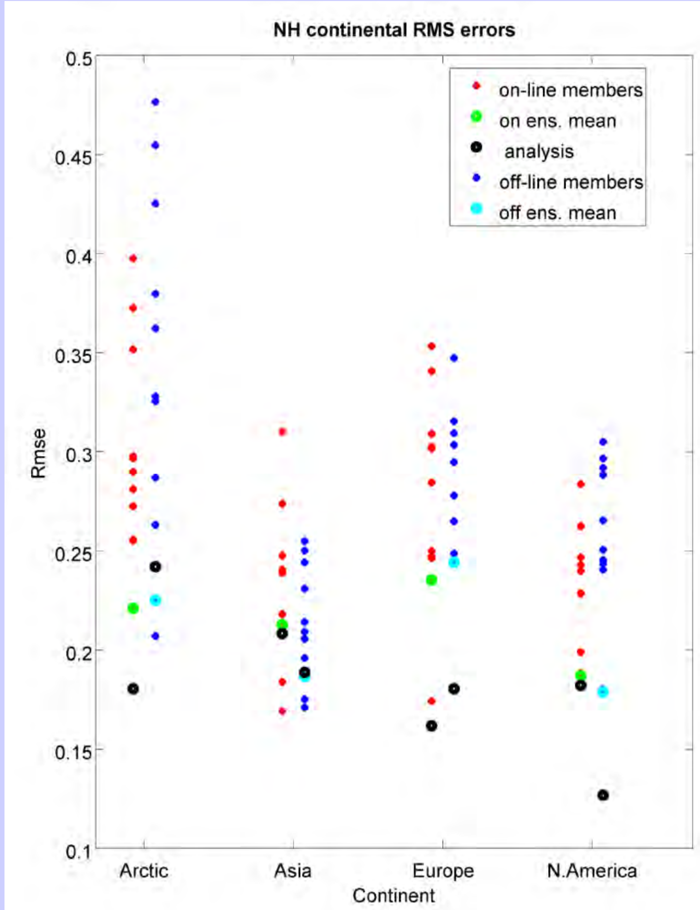
- **1600 - 1700 AD (10 ensemble members)**

- **1750 - 1950 AD (20 ensemble members)**

(Matsikaris, Widmann and Jungclaus, Climate of the Past, 2015, 2016; Clim Dyn. 2016)

Online vs offline ensemble member selection with ECHAM6/MPI-OM





similar skill of on-line and off-line DA

similar or better than ensemble means

no useful information propagation (IP) on decadal timescales; potential reasons:

- **there is no IP in the model (and reality)**
- **there is IP, but it is wrong**
- **initial conditions are wrong, ocean state is not confined**

(Matsikaris, Widmann and Jungclaus, Climate of the Past, 2015)

Data assimilation for palaeoclimate with ECHAM6/MPI-OM

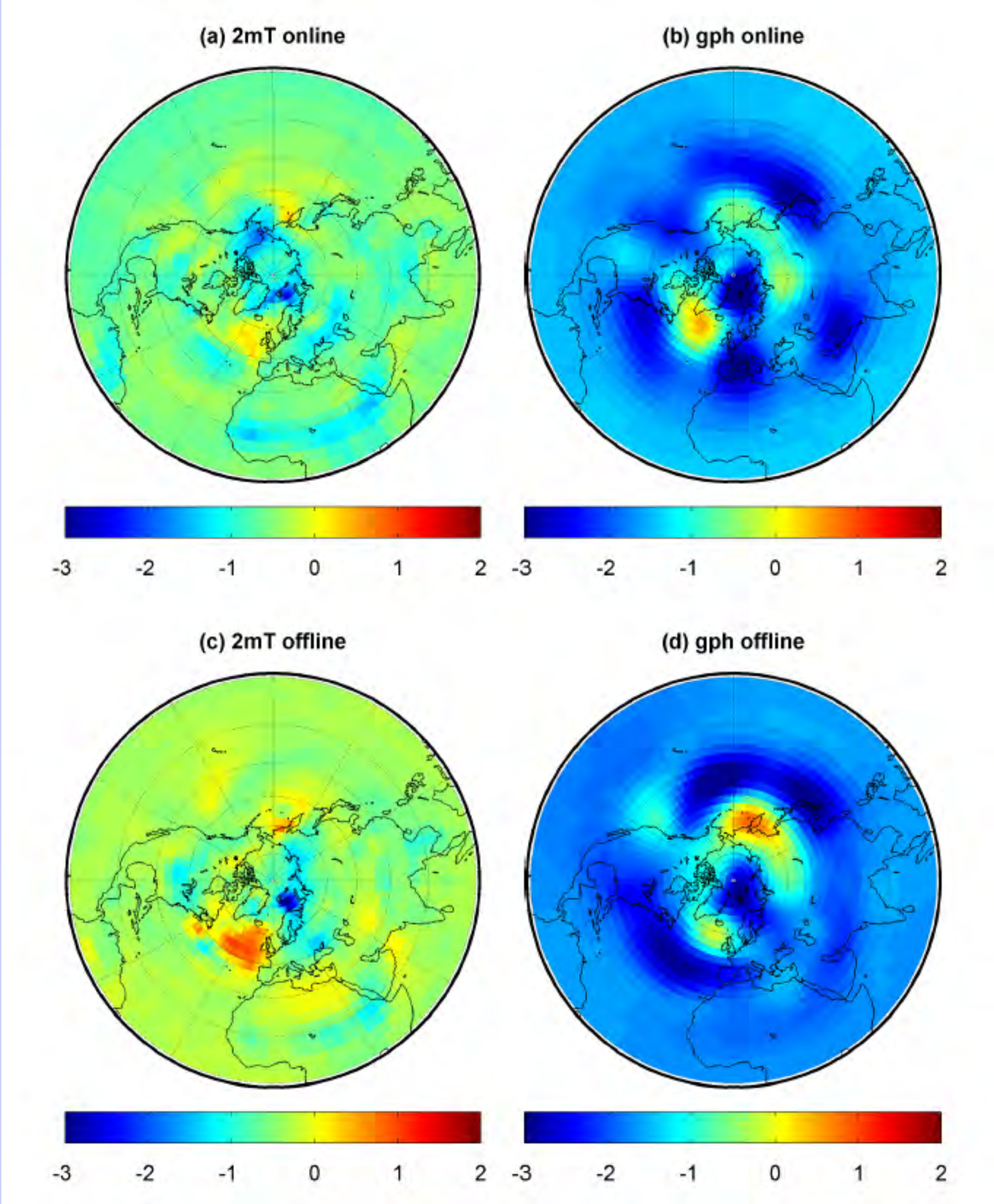
1640 – 1649 AD
2m temperature and 500 hPa gph anomalies wrt 1961-1990 AD

Assimilation of PAGES 2k continental temperature anomalies

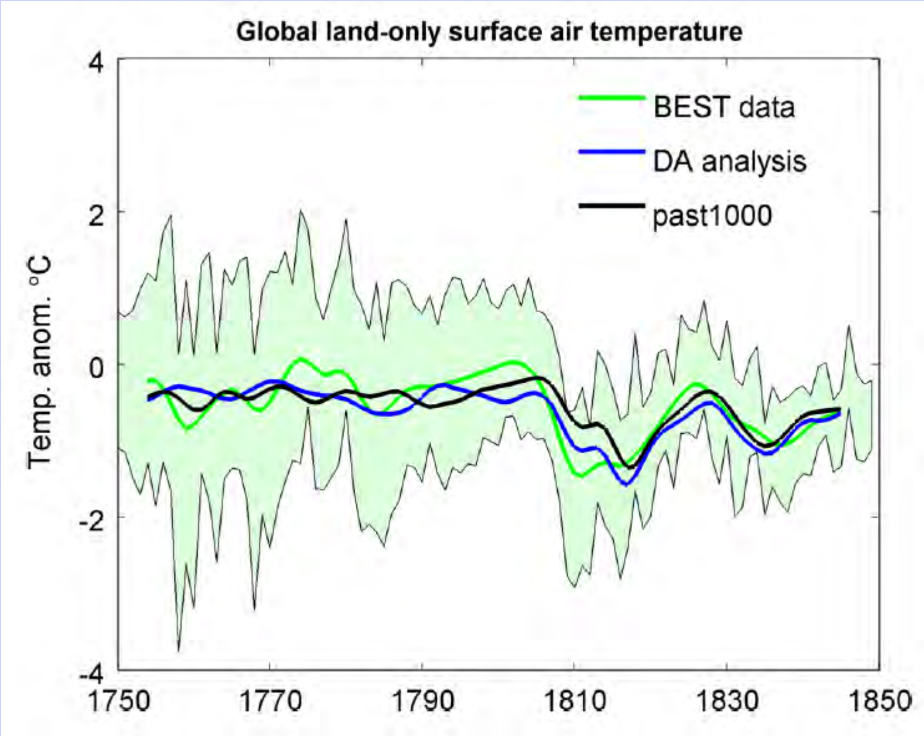
Empirical reconstruction for NAO index (Luterbacher): - 0.28

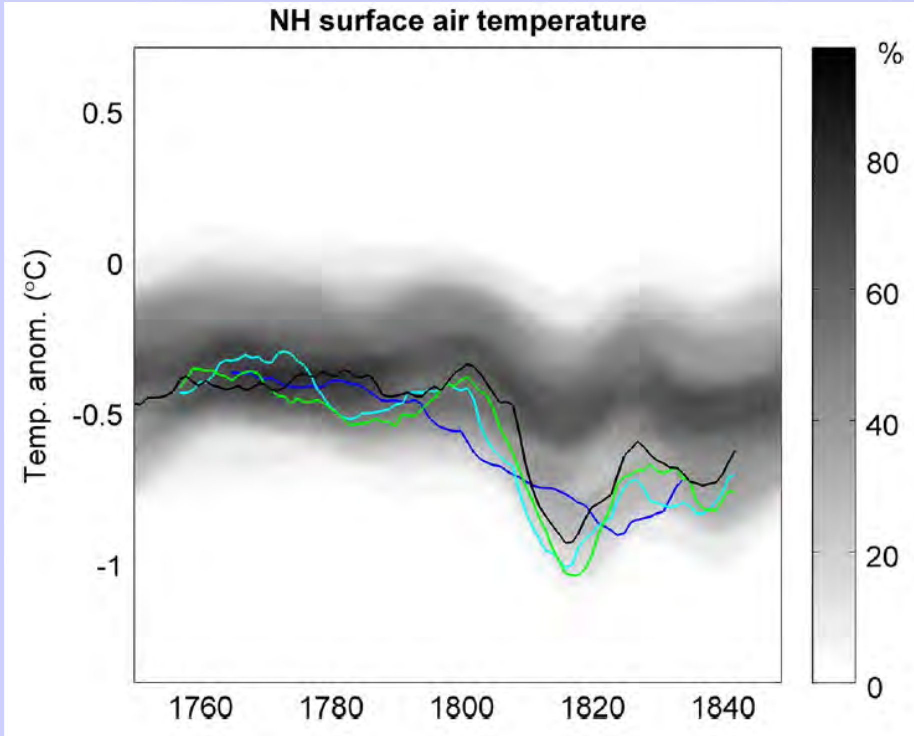
‚Suggests' skill in constraining large-scale circulation

(Matsikaris, Widmann and Jungclaus, Climate of the Past, 2015)



Global and northern hemispheric temperatures 1750 - 1850 in DA with ECHAM6/MPI-OM





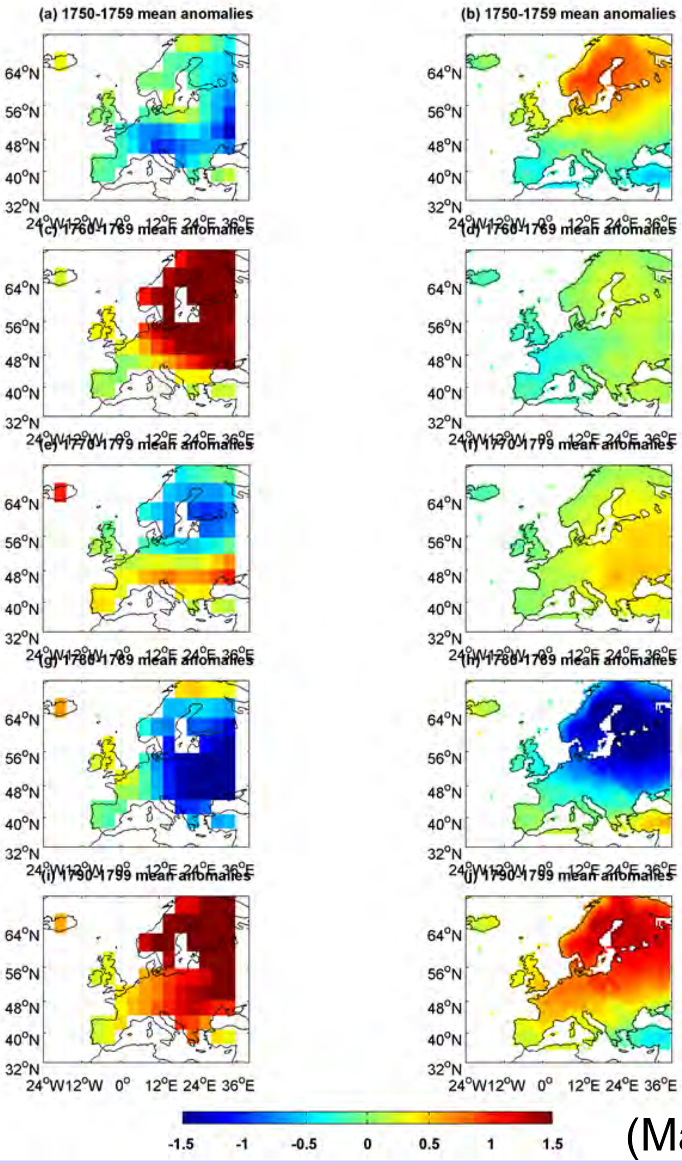
Standard forced and DA simulation are similar, forced variability dominates

Consistent with reconstructions

(Matsikaris, Widmann and Jungclaus, Climate Dynamics, 2016)

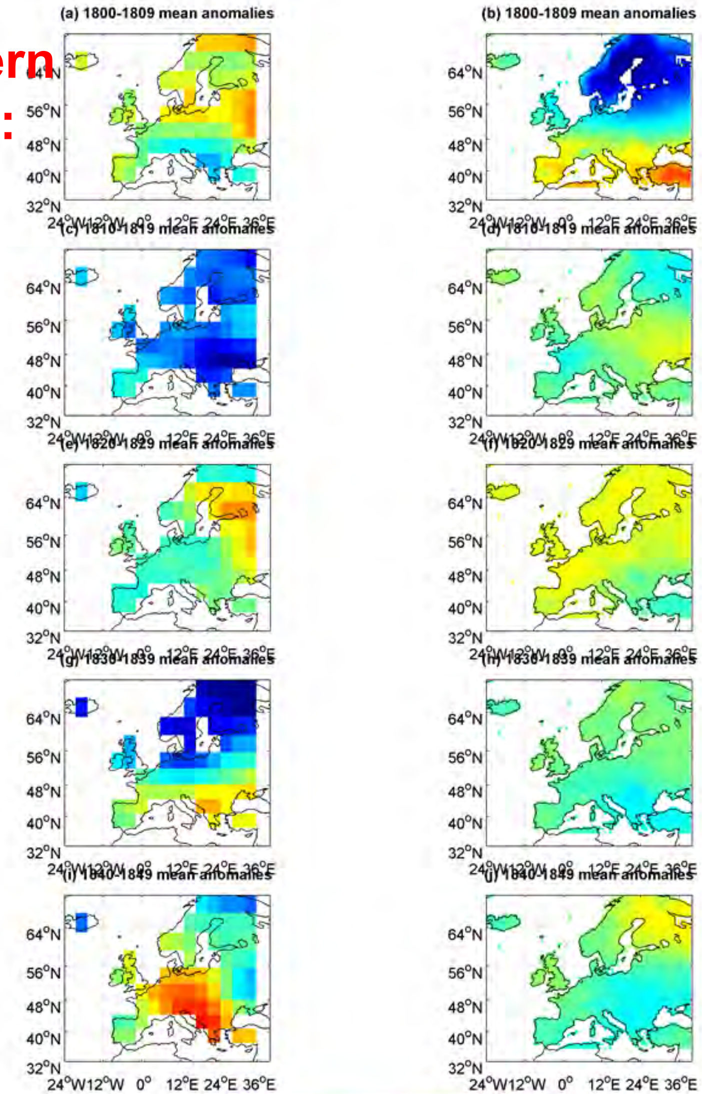
Decadal mean winter temperatures 1750 - 1850 simulated (DA) and empirical reconstruction (Luterbacher)

Simulated **Luterbacher**



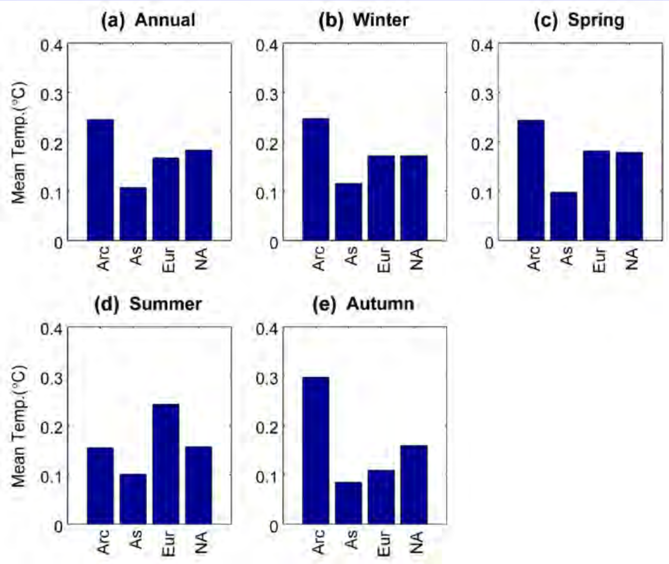
mean pattern correlation: - 0.03

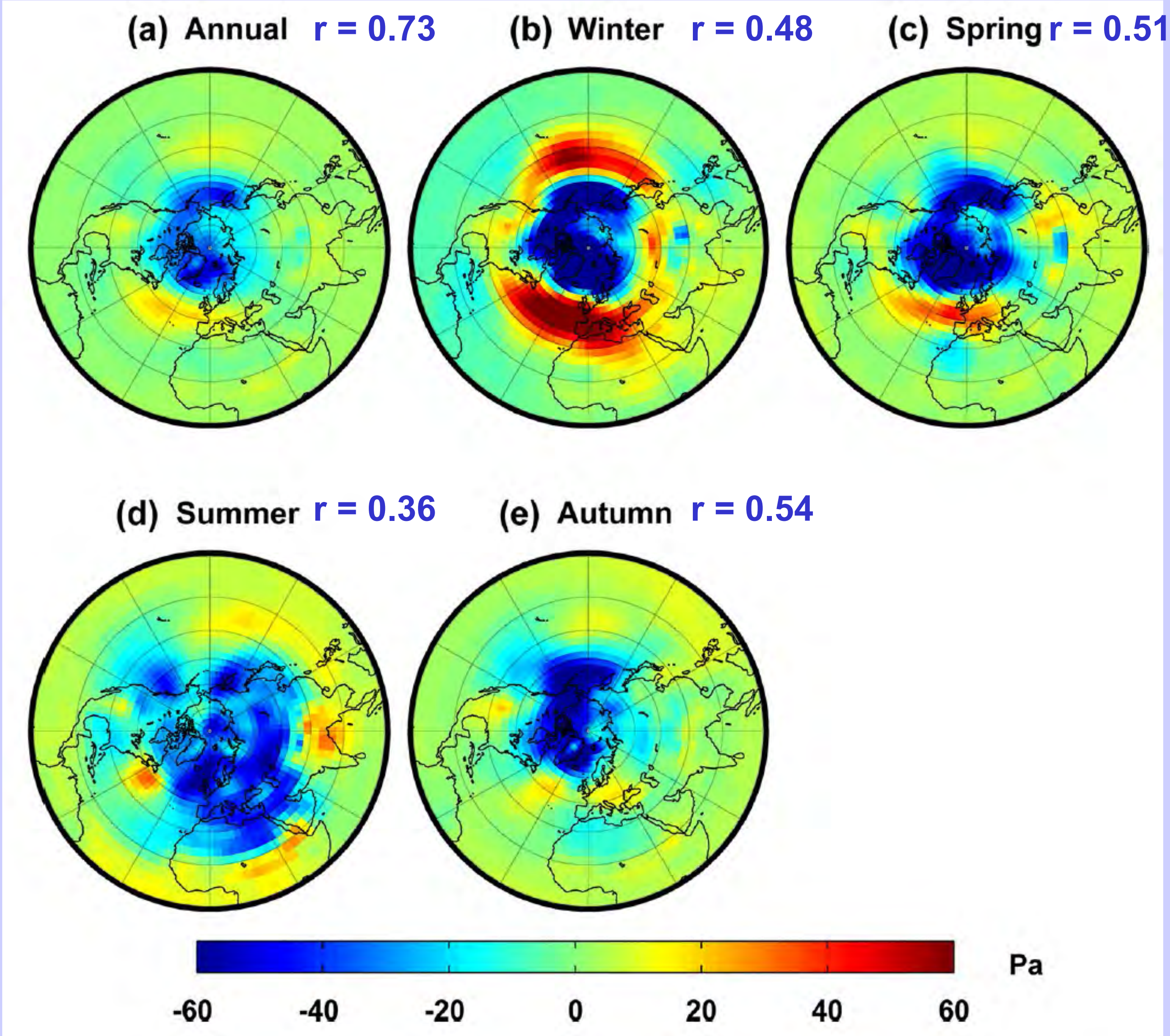
Simulated **Luterbacher**



(Matsikaris et al., Clim Dyn. 2016)

Coupling (MCA) between temperature for NH PAGES2k regions/seasons and SLP in 1000 year GCM control run





Temp: Same sign in
all continents

SLP: NAM structure for
annual, winter, spring

Links are reproduced with DA for annual, winter and spring (r = 0.81, 0.82, 0.82), but not for summer and autumn (0.17, -0.01)

(Matsikaris, Widmann and Jungclaus, Climate Dynamics, 2016)

EOF 1 of NH SLP in ECHAM6/MPI-OM 1000 year control run

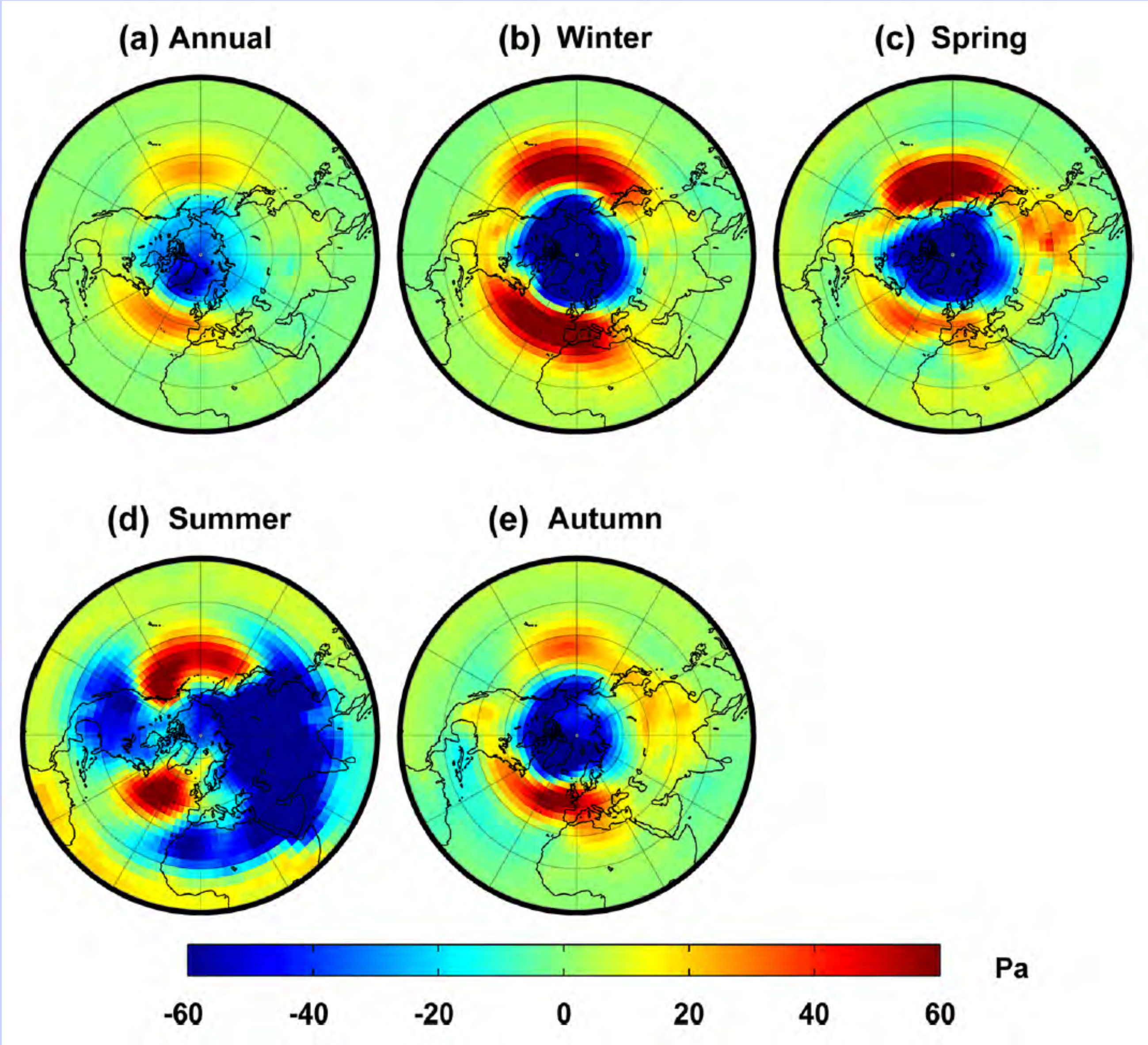
similar to NAM for annual and all seasons but summer

land – sea contrast in summer

similar to MCA patterns for annual, winter, and spring

DA reproduces the link when the MCA pattern is similar to EOF 1

Even then there is still substantial unexplained variability in SLP TEC and in local temperature (given correct SLP TEC)

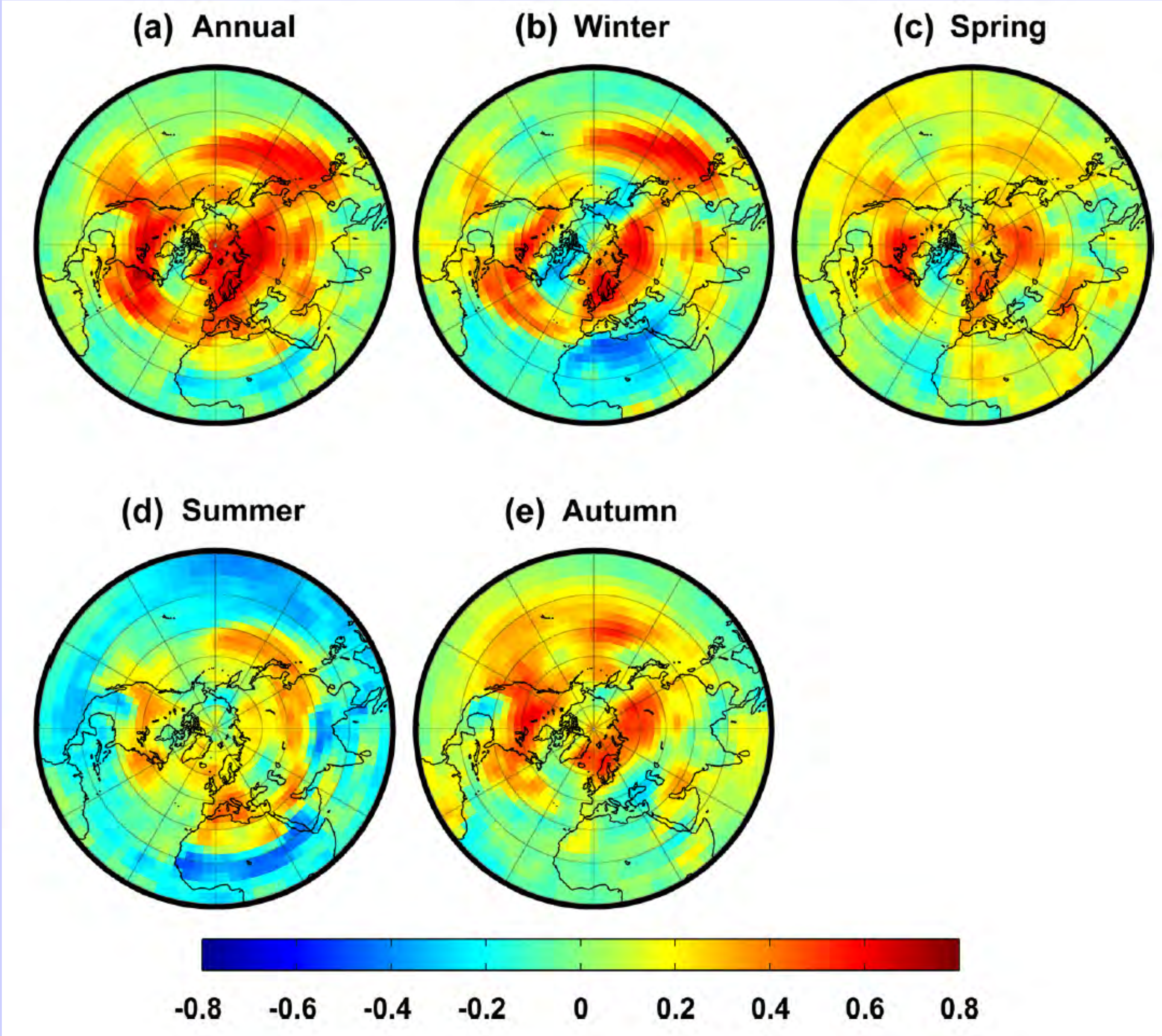


(Matsikaris, Widmann and Jungclaus, Climate Dynamcs, 2016)

Correlations SLP TEC1 with local temperatures in ECHAM6/MPI-OM 1000 year control simulation

Correlations in Europe are typically between 0 and 0.6

Large fraction of local temperature variability not explained by leading coupled circulation pattern

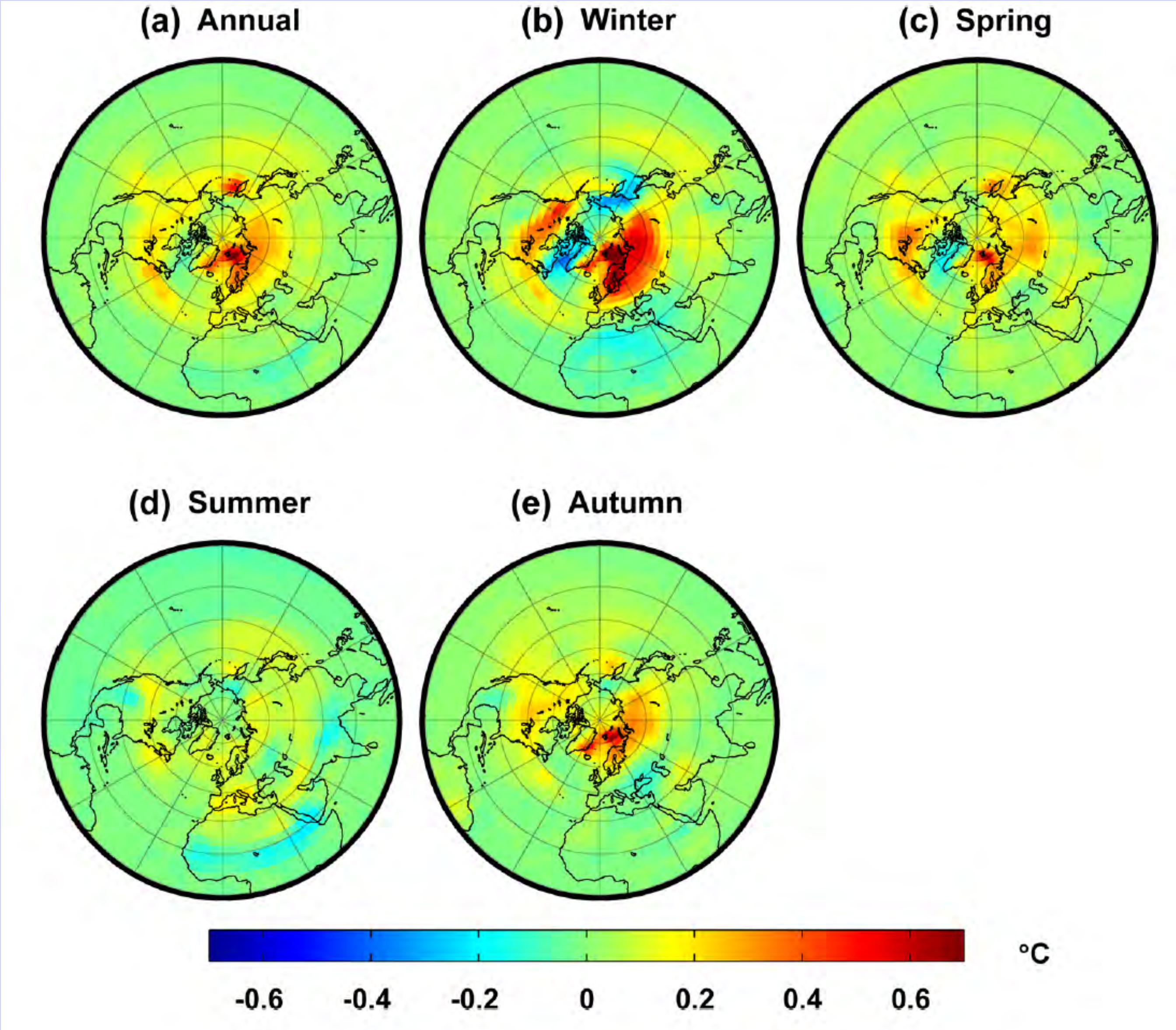


(Matsikaris, Widmann and Jungclaus, Climate Dynamics, 2016)

Regression coefficients local temperatures against SLP TEC1 in ECHAM6/MPI-OM 1000 year control simulation

Not uniform within PAGES2k regions

Better estimates for the SLP MCA patterns (e.g. annular modes) could be explained by using more regional temperatures.



(Matsikaris, Widmann and Jungclaus, Climate Dynamics, 2016)

Comments and questions on spatial and temporal scales

- State estimation and process undertanding require constraining leading circulation patterns.

- Assimilation on continental-scales is too coarse, but local scale might be too fine (errors and dimensionality of state space).

  Optimal scale is not known and may depend on variable and DA method. Avoiding upscaling based on teleconnection might be a good idea, but regional averages can be expected to be OK.

  Optimal locations are not straightforward, as we want to constrain more than one circulation mode. Yet some general guidance based on understanding of main features of atmospheric circulation might be possible.

- Spatial variability in hydrological variables is higher than for temperature. Model biases may be more problematic.

- Which temporal resolution should be used for DA?