SMHI / Rossby Centre

# Decadal Climate Prediction at SMHI

Torben Koenigk, Mihaela Caian, Klaus Wyser

**Potential Predictability in EC-Earth**

**The Decadal Prediction System**

**Results from decadal hindcast prediction**

**Results from real-time prediction**

# Processes with potential for predictability

ENSO: seasonal time-scales

Land-surface processes: soil moisture, vegetation

Persistence: e.g. SST, ice, snow anomalies affect the atmosphere aloft. Via teleconnection processes remote regions could be affected.

Advection of SST and ice anomalies: seasonal to interannual time-scales

Decadal processes: e.g in the Arctic; variation of sea ice parameters on decadal time-scale, cyclonic and anticyclonic circulations regimes, AO/NAO, PDO

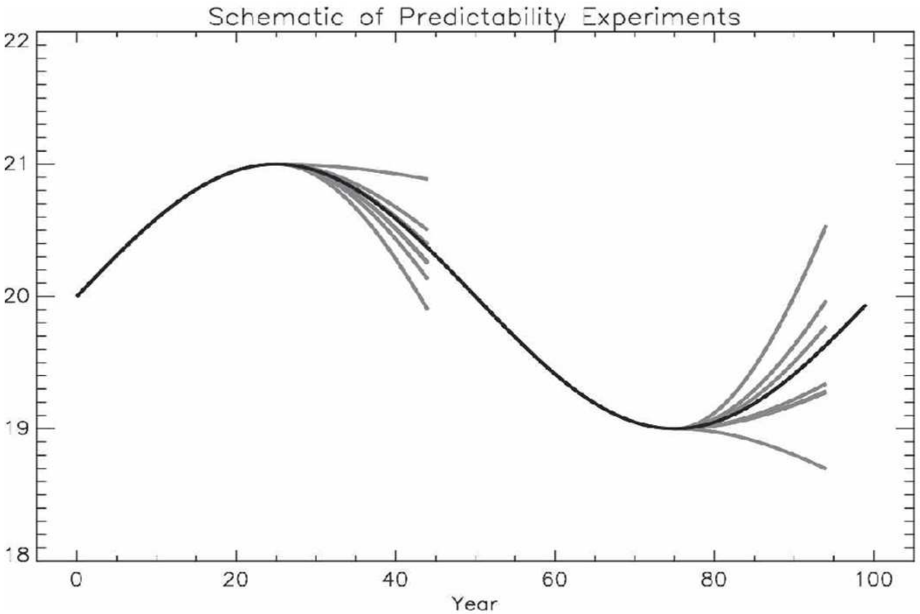
Multi-decadal variations in the ocean: MOC, heat transports

(Solar cycle)

(Trends)

# Potential Predictability: the upper limit of predictability

**Are real world predictions meaningful?**
**Can predictions be further improved?**




**How?**

Try to predict the model ”reality”:

Perform ensemble simulations from different conditions of the models ctrl-run.

Members use the same initial conditions except for a small perturbation (unrealistic small).

**Under the assumption that the model realistically simulates real climate, the model potential predictability provides the limit of real world predictability.**

**But:**
Potential predictability depends on the model.
→ The upper limit of real world predictability might be higher (or lower).

# Prognostic Potential Predictability

## Model

**EC-Earth:** V2.1
IFS (cycle 31r1): T159/L62
NEMO2.0/ LIM2: ORCA1/L42

## Ctrl-run

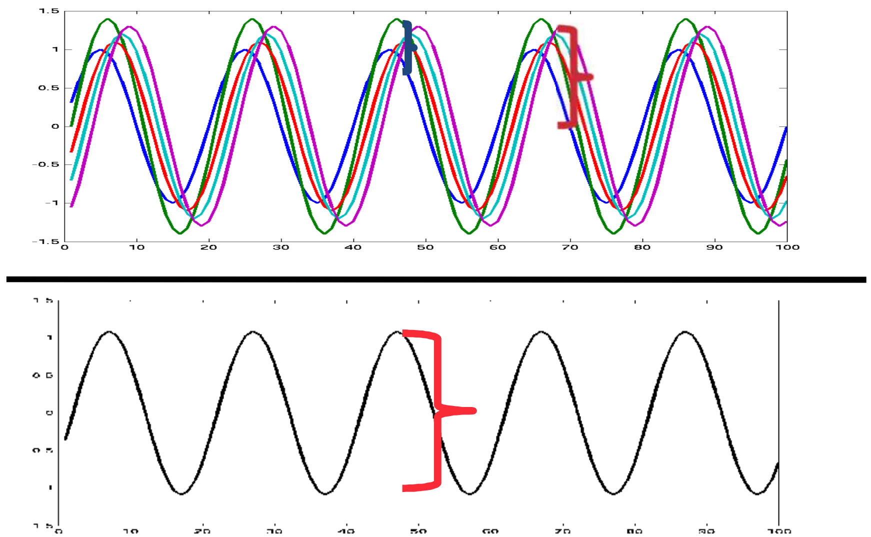
400-year simulations with present-day conditions

## Ensemble experiments

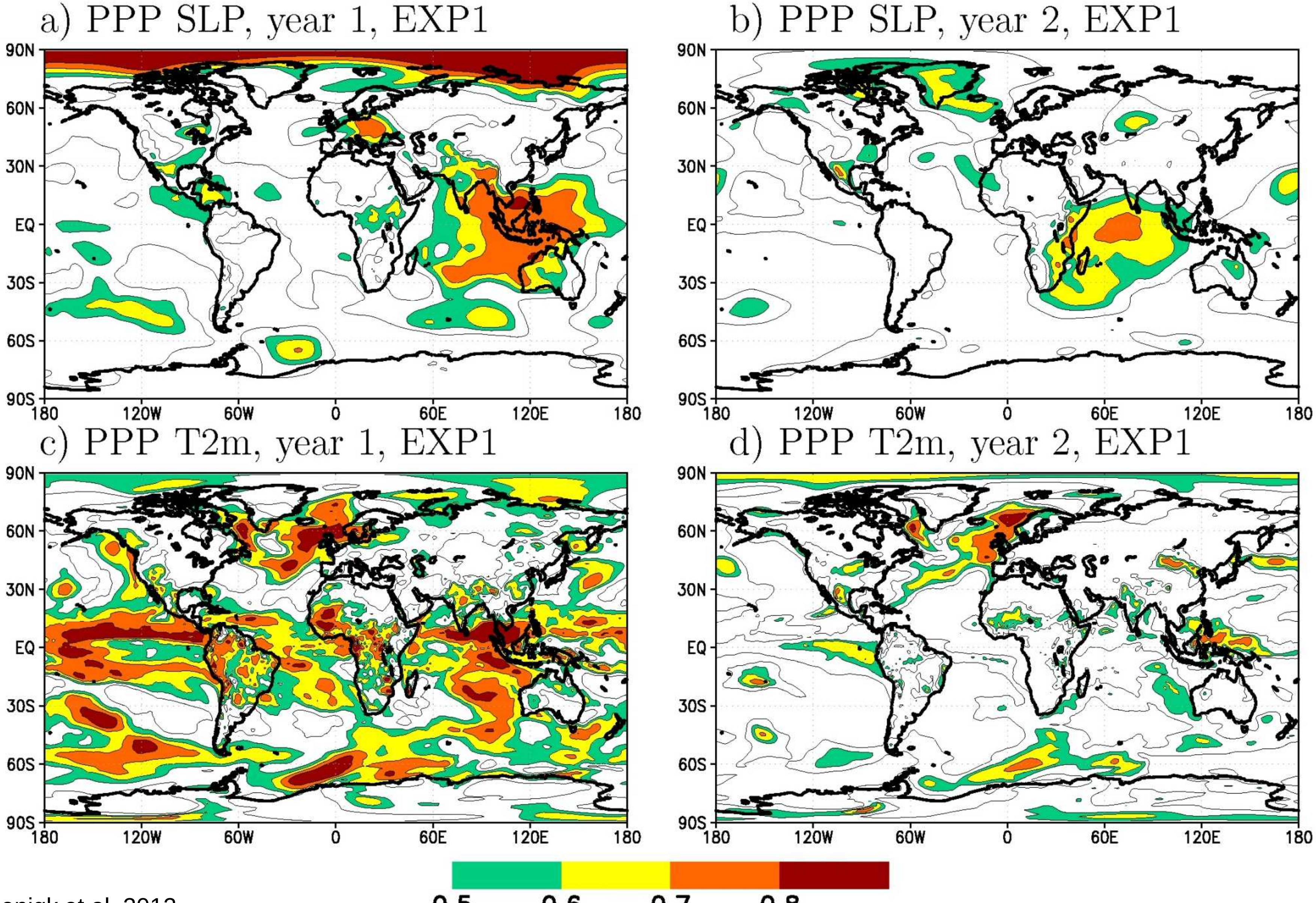
9 ensembles with 6 members each.

$$PPP(t) = 1 - \frac{Var_{ens}(t)}{Var_{ctrl}}$$

PPP→1: perfect predictability
(Variance among members small compared variance in ctrl-run)
PPP→0: no predictability
(Variance among members of same size than variance in ctrl-run)

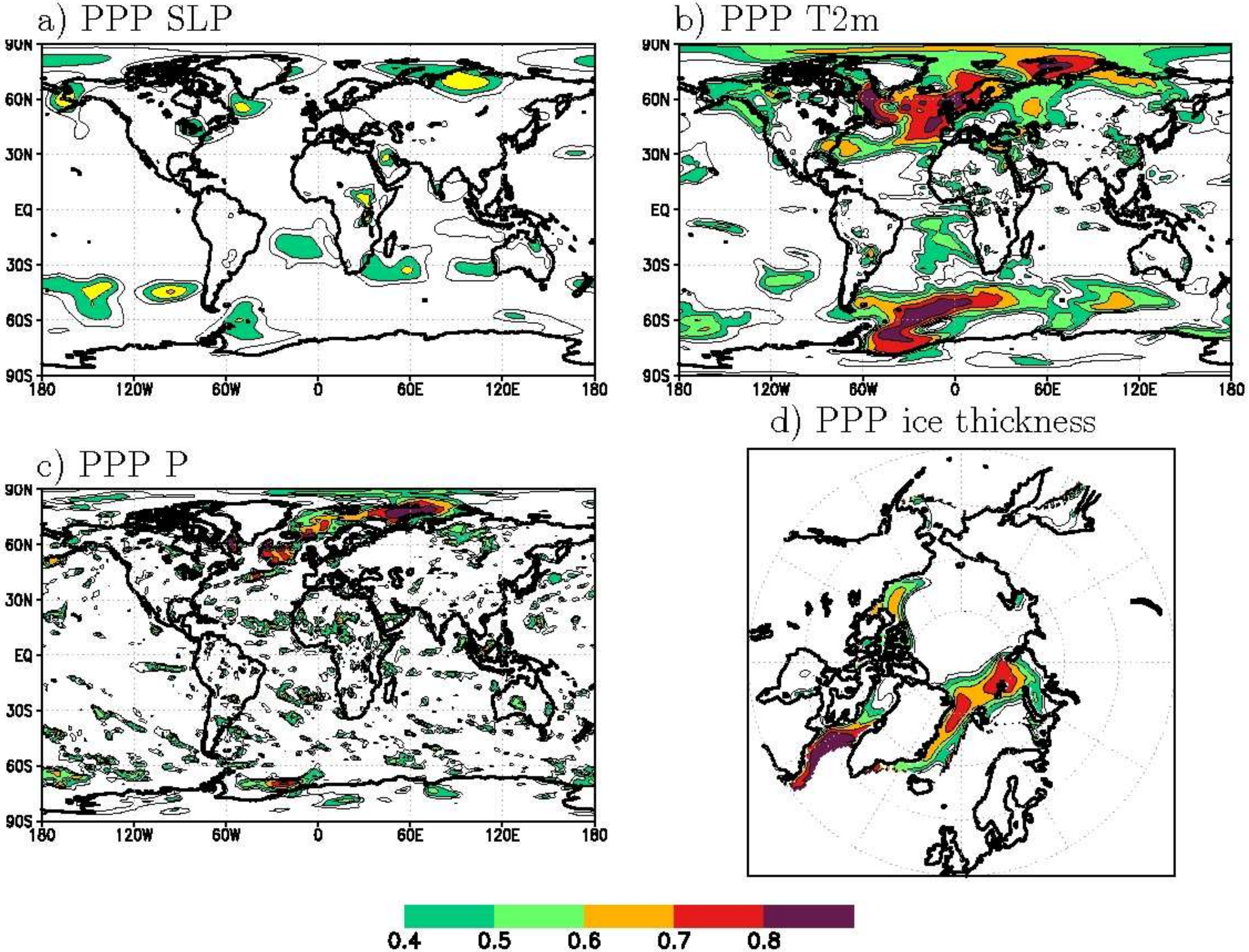


# Interannual potential predictability




Koenigk et al. 2012

# Decadal Potential Predictabilty

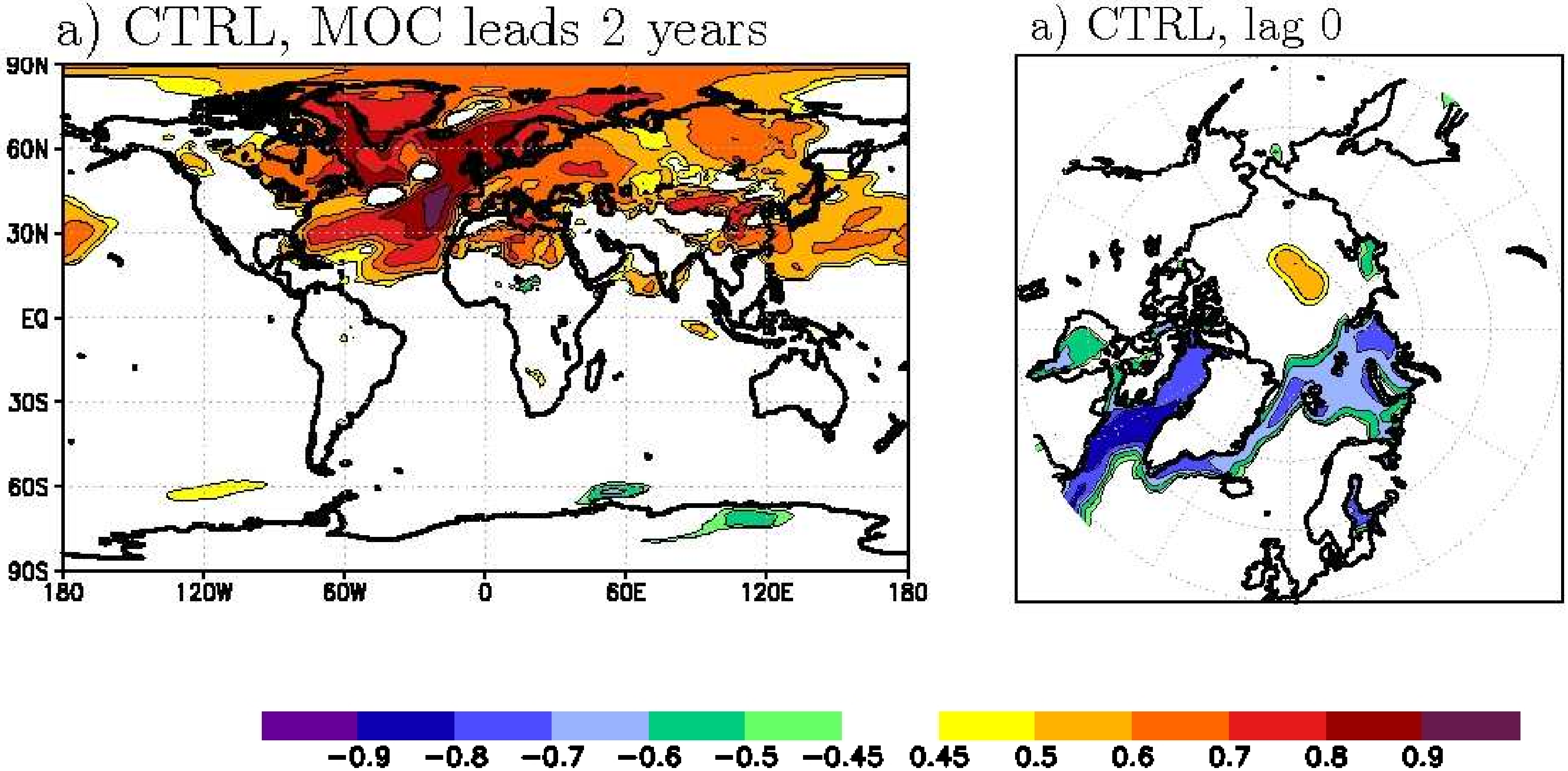



averaged over year 1-10

# Decadal correlation MOC – T2m, sea ice

SMHI

T2m    ice thickness



# Decadal real-world predictions

SMHI

**Model: EC-Earth**

EC-EARTH v2.3 (CMIP5-version)

(ongoing predictions with EC-Earth3 in EU-project SPECS)

**Method:** Anomaly initialization for ocean and ice

**Initial conditions:**

**Ocean:** Nemovar-S4 initial day anomaly to Nemovar-S4 1960-2005 climatology, added to EC-Earth climatology, for: u,v,t,s, 1960-2005

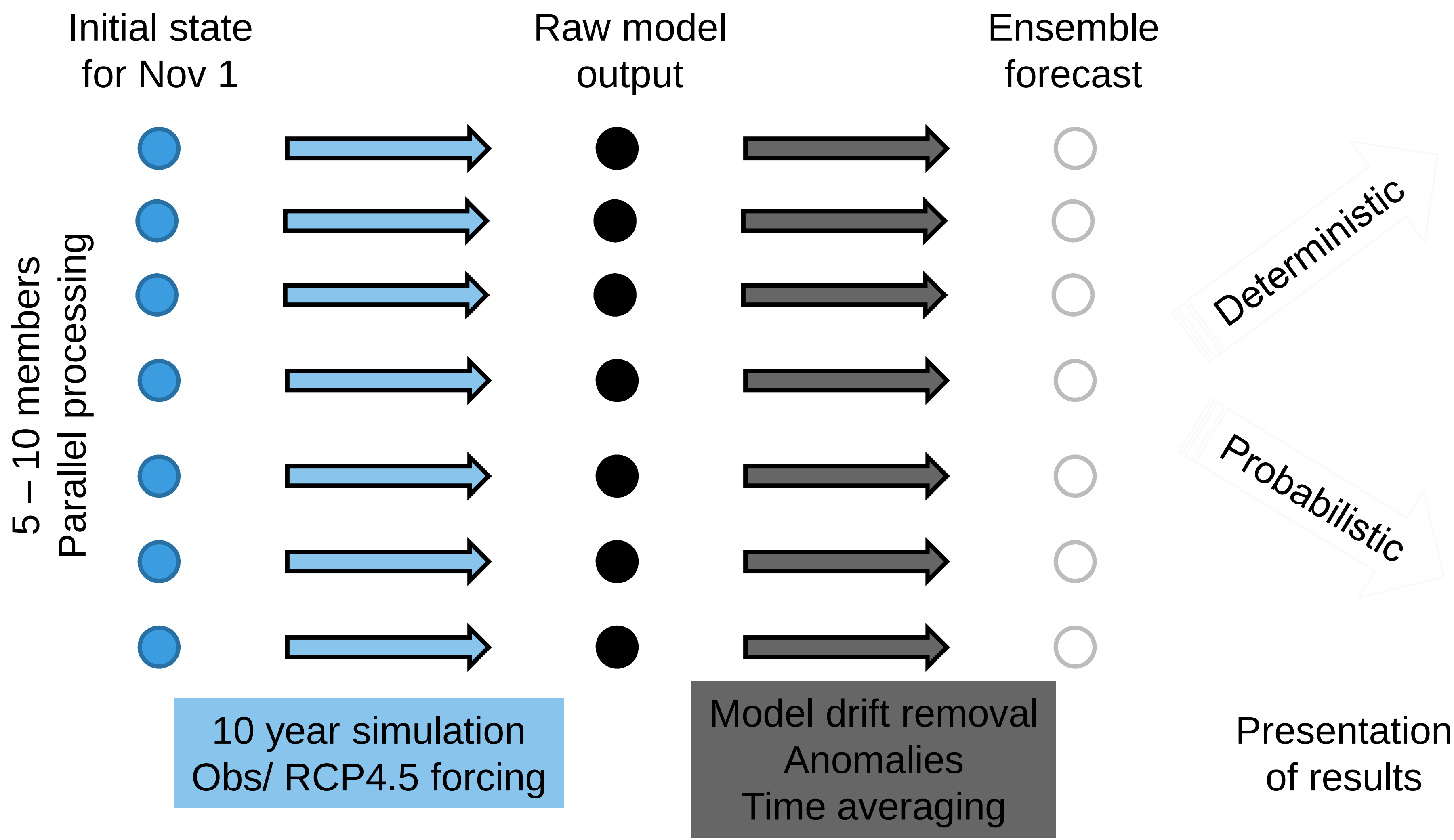
**Ice:** Forced ocean/ice run (NEMO/LIM2) day anomaly to its 1960-2005 climatology, added to EC-Earth climatology for: Ice thickness, ice concentration, temperature, velocity, snow

**Atmosphere**: ERA analysis

**Perturbations:** different members of NEMOVAR; time-lag

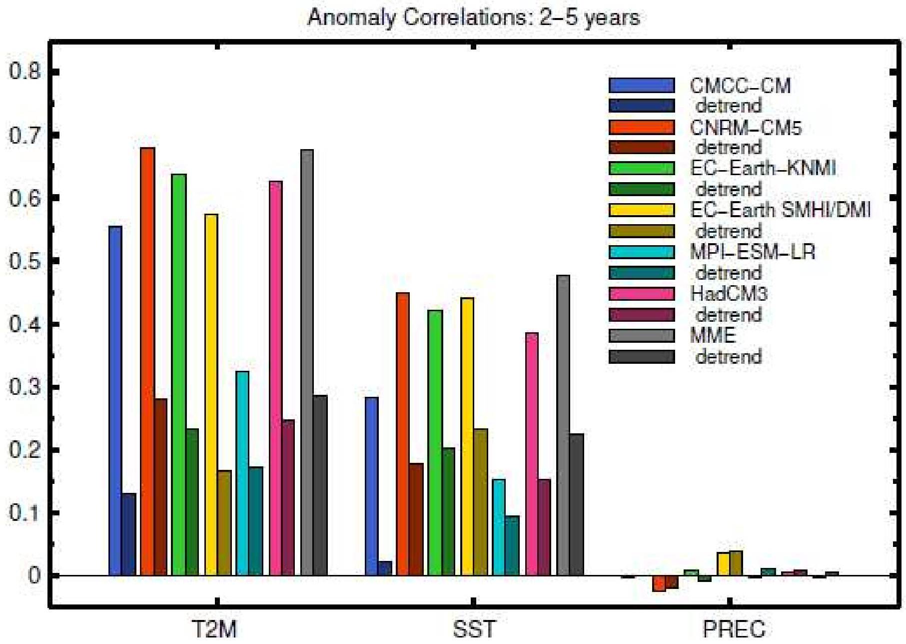
**Start dates:** 1 Nov, every year, 1960-2005

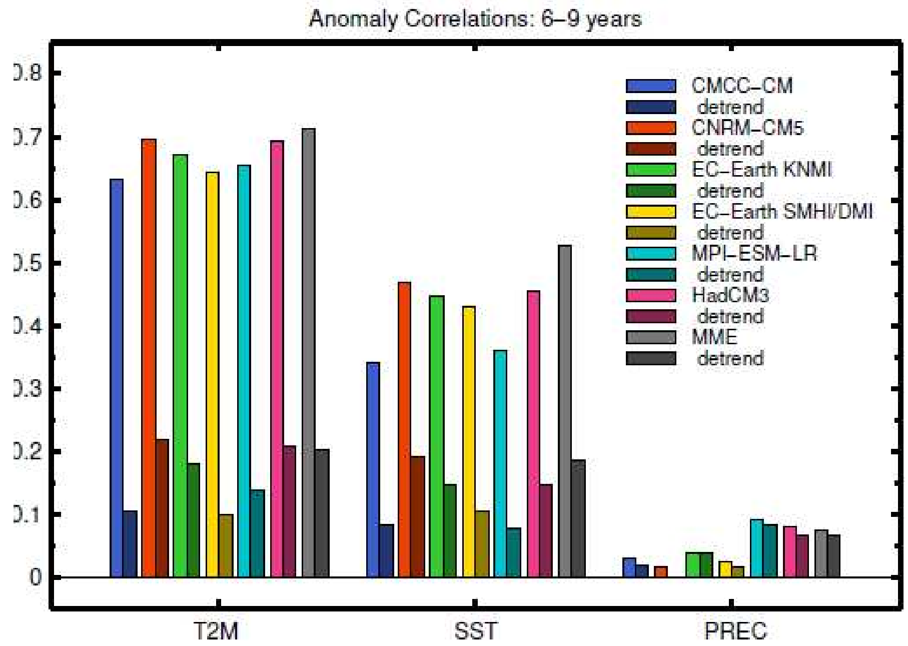
# Hindcast and real-time decadal forecast

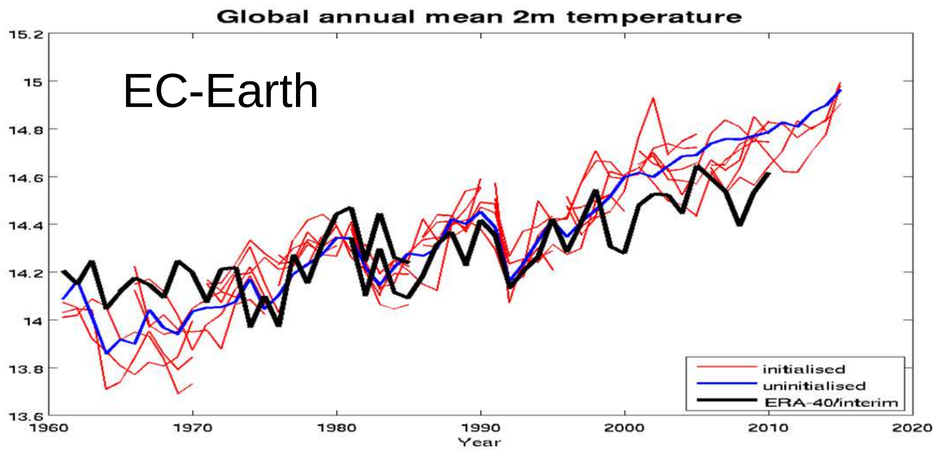


# How good are decadal forecasts?

Evaluate hindcasts (COMBINE project, CMIP5 simulations)
Global mean values

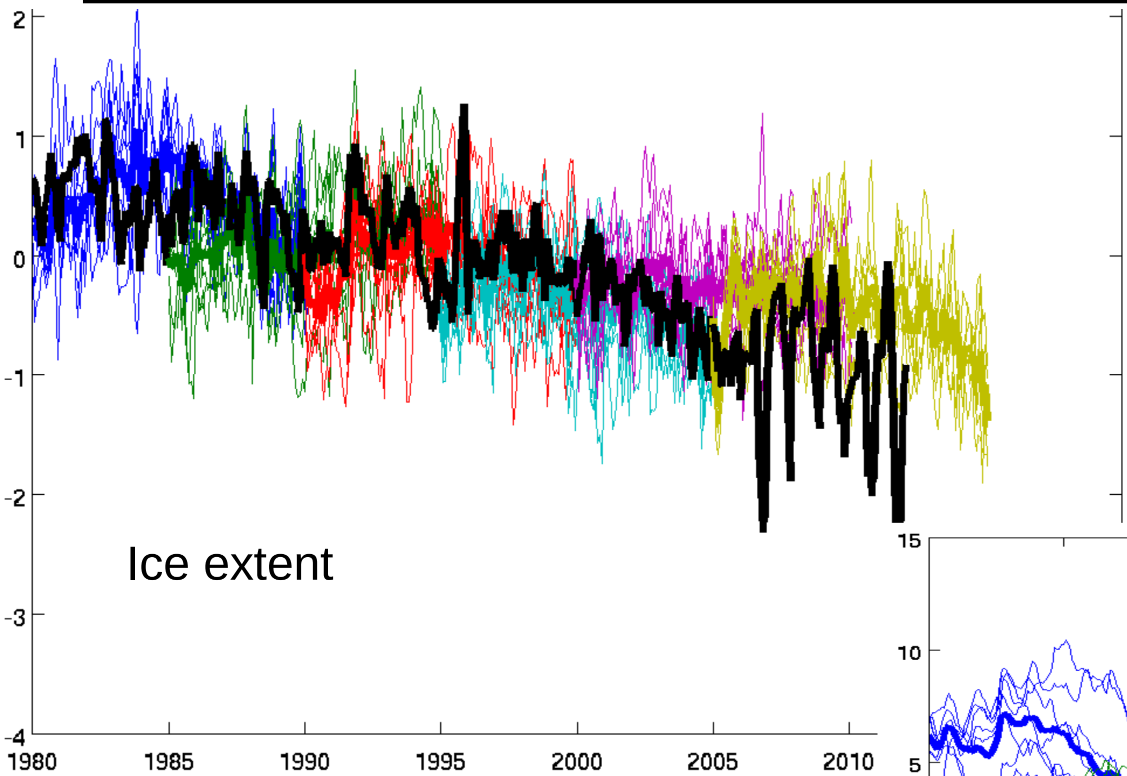


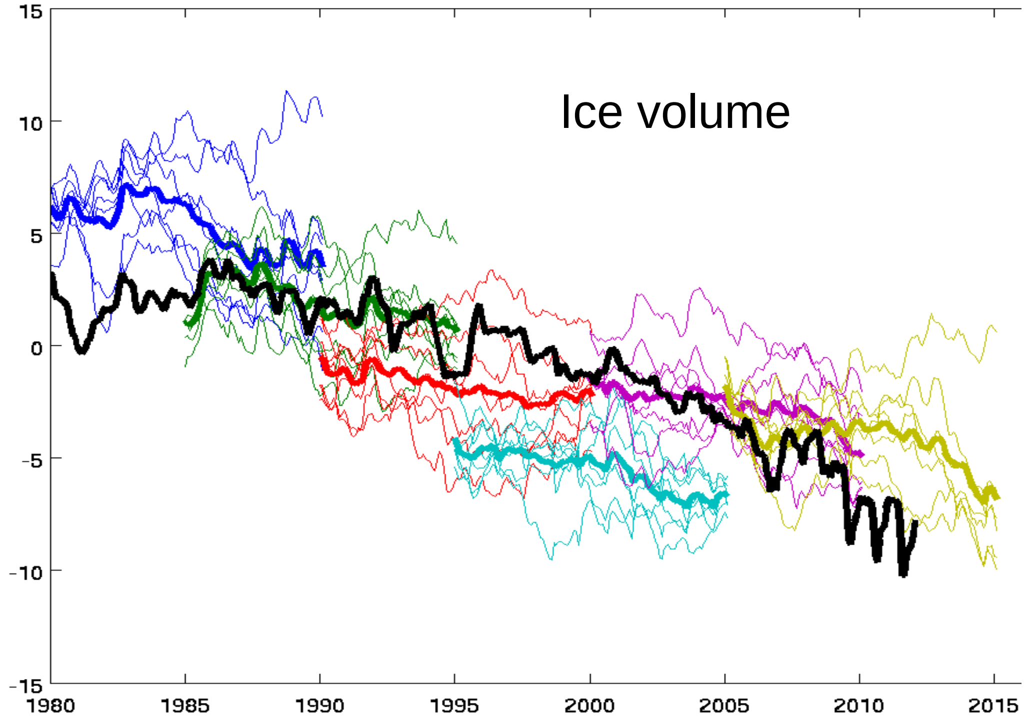



# EC-Earth: Ice predictions

SMHI




Anomalies relative to observed mean annual cycle of 1980-2009




Only 5 startdates are shown
7 ensemble members (coloured, thin)
Ensemble mean (coloured, thick)
Observed (black, thick)

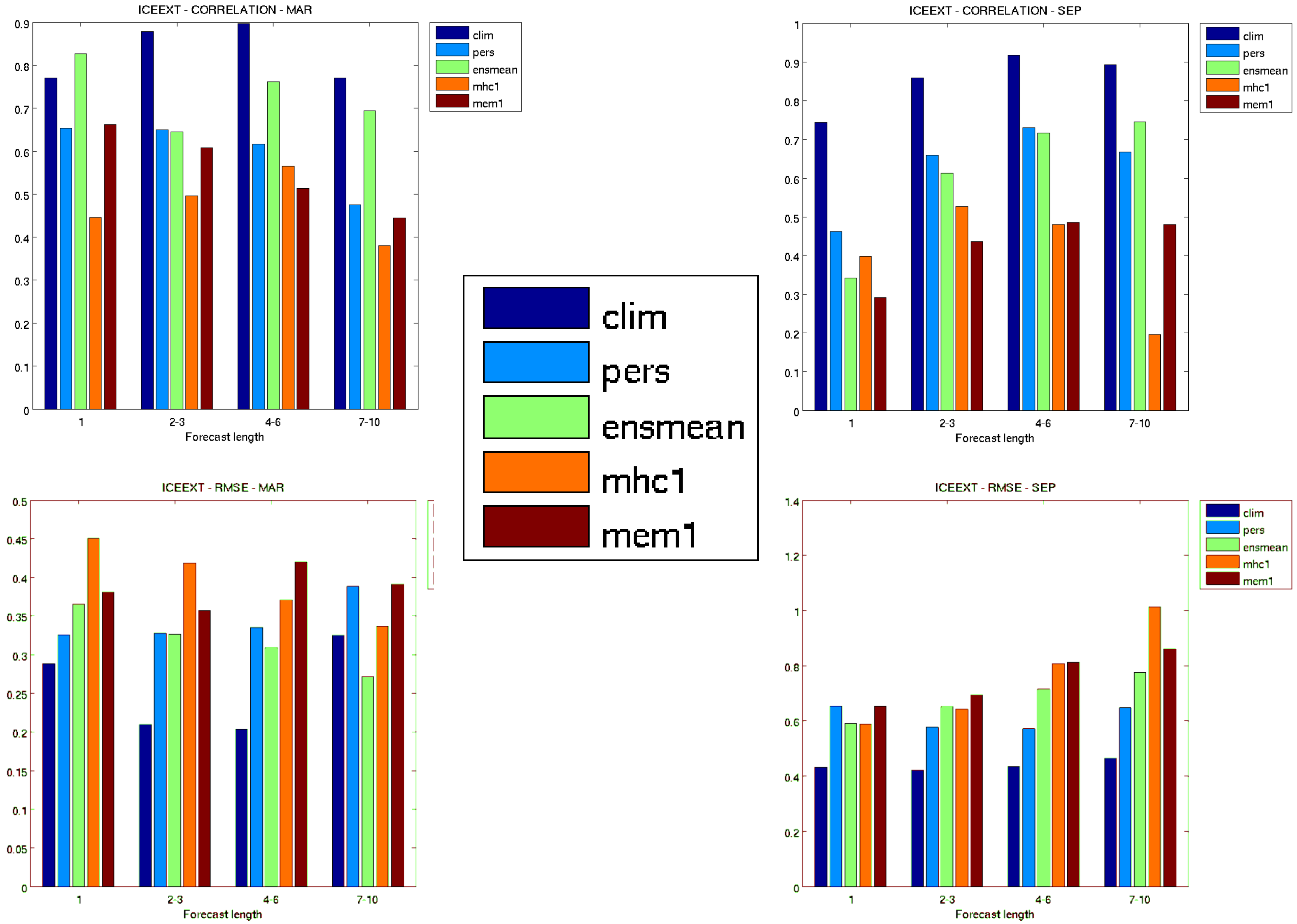
# EC-Earth

SMHI

March

## Sea-ice extent

September



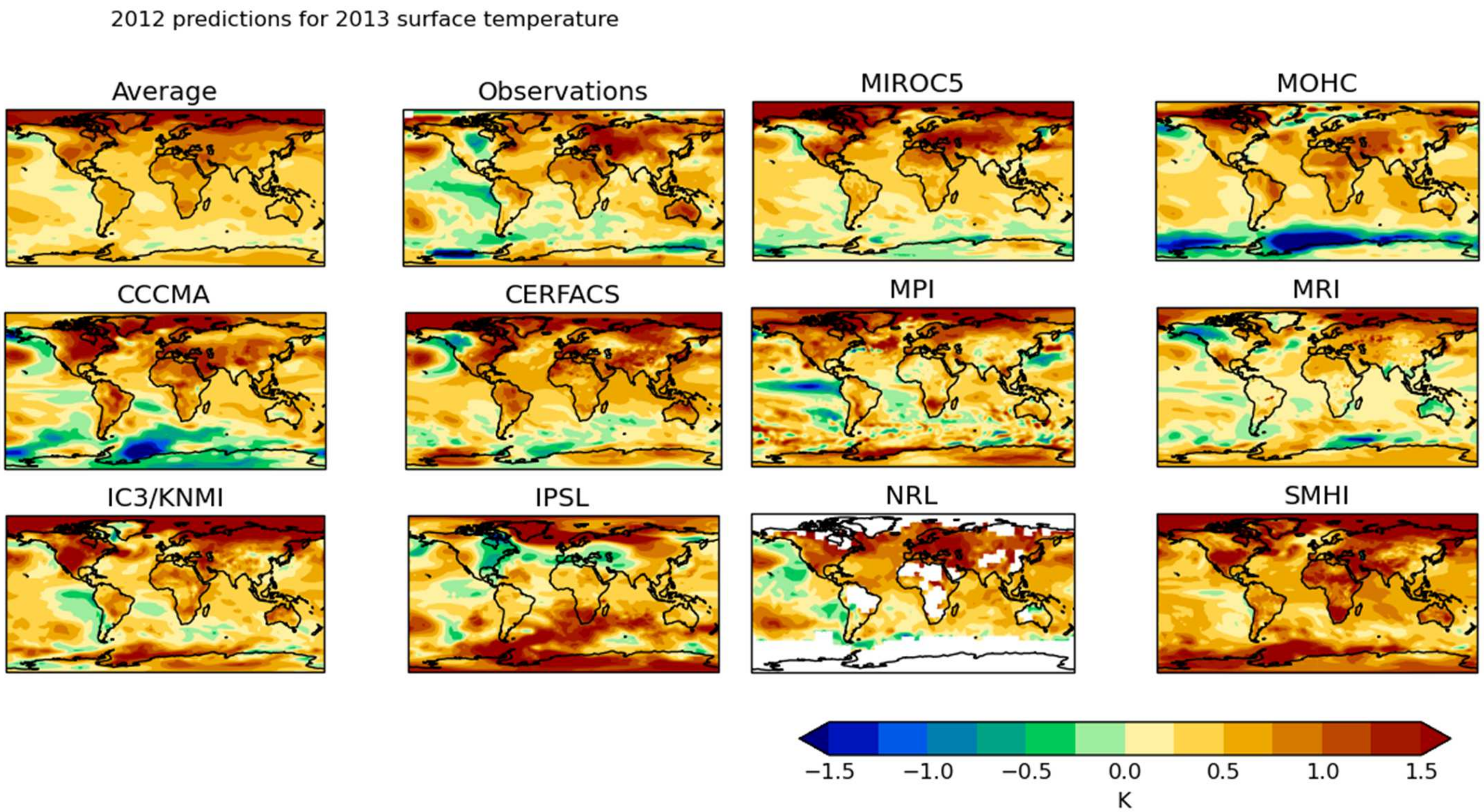

Correlation

RMSE

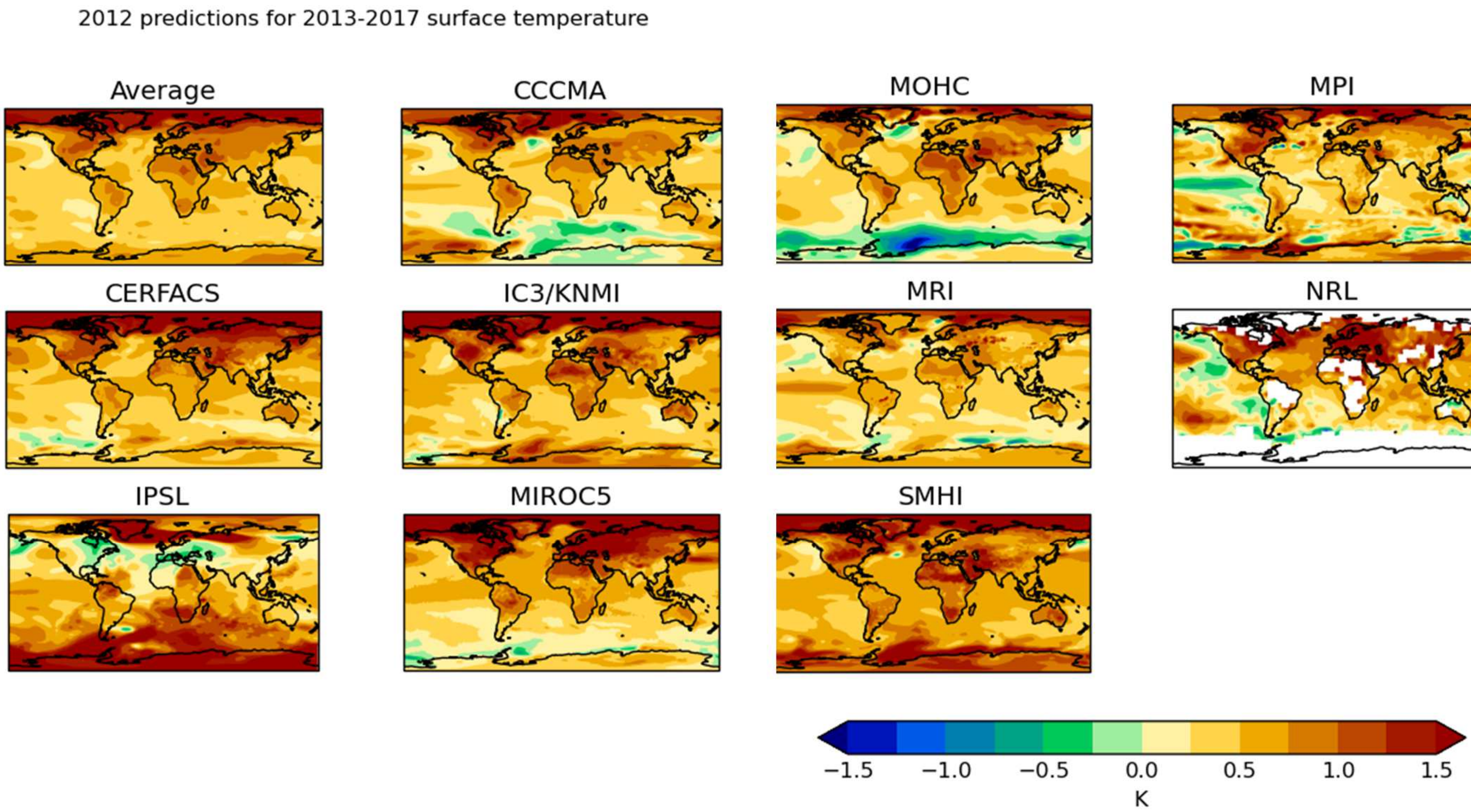
# Real-time predictions

SMHI is contributing to multi-model decadal prediction initiative:

http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel



# Real-time predictions: T, year 1-5




http://www.metoffice.gov.uk/research/climate/seasonal-to-decadal/long-range/decadal-multimodel

# Current issues on decadal prediction

**a) Lack of observations,**

-especially in the ocean, are limiting forecast verification as well as development
and testing of initialization and prediction systems.
It is crucial to maintain and enhance the existing observing systems.

**b) Initialization, process understanding and new sources of predictability**

- processes not yet initialized: sea-ice (thickness), frozen soil, ocean below sea-ice, snow cover, soil moisture, stratospheric process, land surface and vegetation;
- Improved initialization, consistent, starting in right phase, correcting for position, variance mismatch
- skill may depend on initial state (e.g. AMOC+ more predictable state)
- predictability under climate change

**c) Ensembles**

- large number of ensemble members needed
- Realistic initial perturbations

# Current issues on decadal prediction

**d) Reducing model uncertainty:**
Systematic errors in models affect predictions. Need to identify, understand and reduce these errors.
Higher resolution is needed and parameterizations and coupling of additional climate subsystems should be improved.

**e) Output analysis**
- appropriate bias correction and decadal metrics

**f) Societal usefulness**s of decadal climate predictions should be assessed.

# Real-time predictions: T, year 6-10

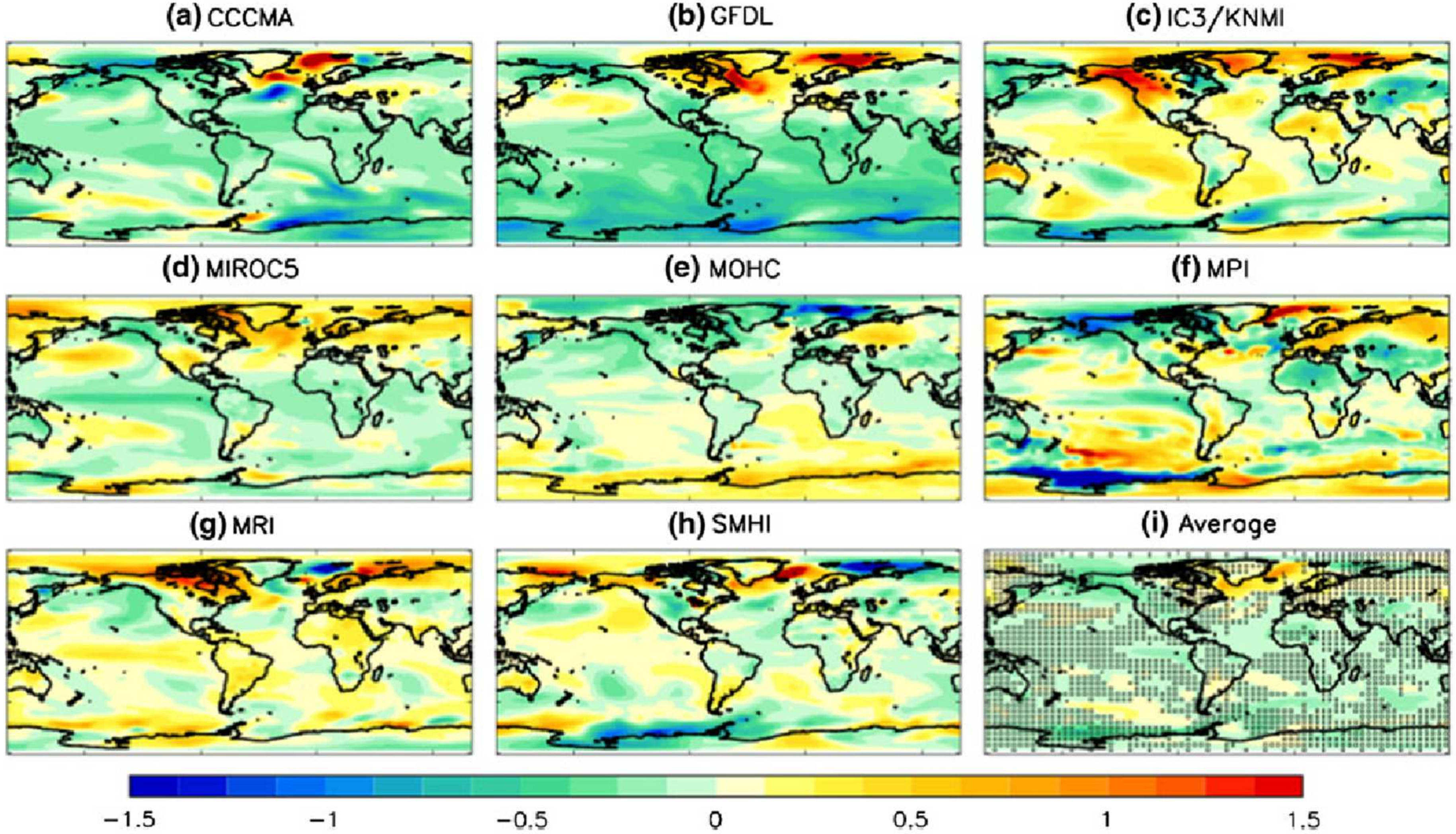



**Fig. 7** Impact of initialization (as Fig. 6) on forecasts of the period 2016–2020

Smith et al. 2013, Figure 7

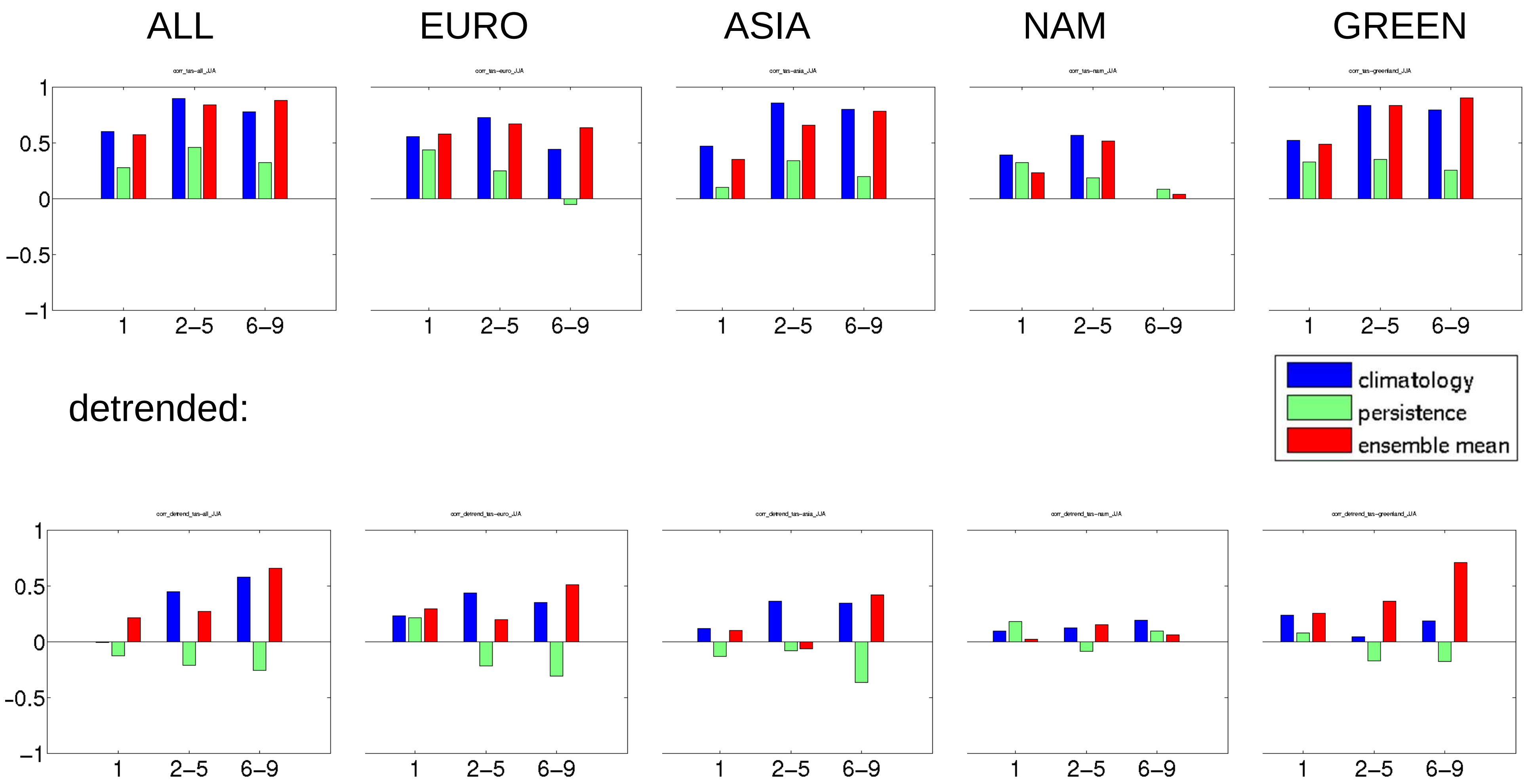
# PPP for regional means, T2m, y1-10 and variances in CTRL-runs

SMHI

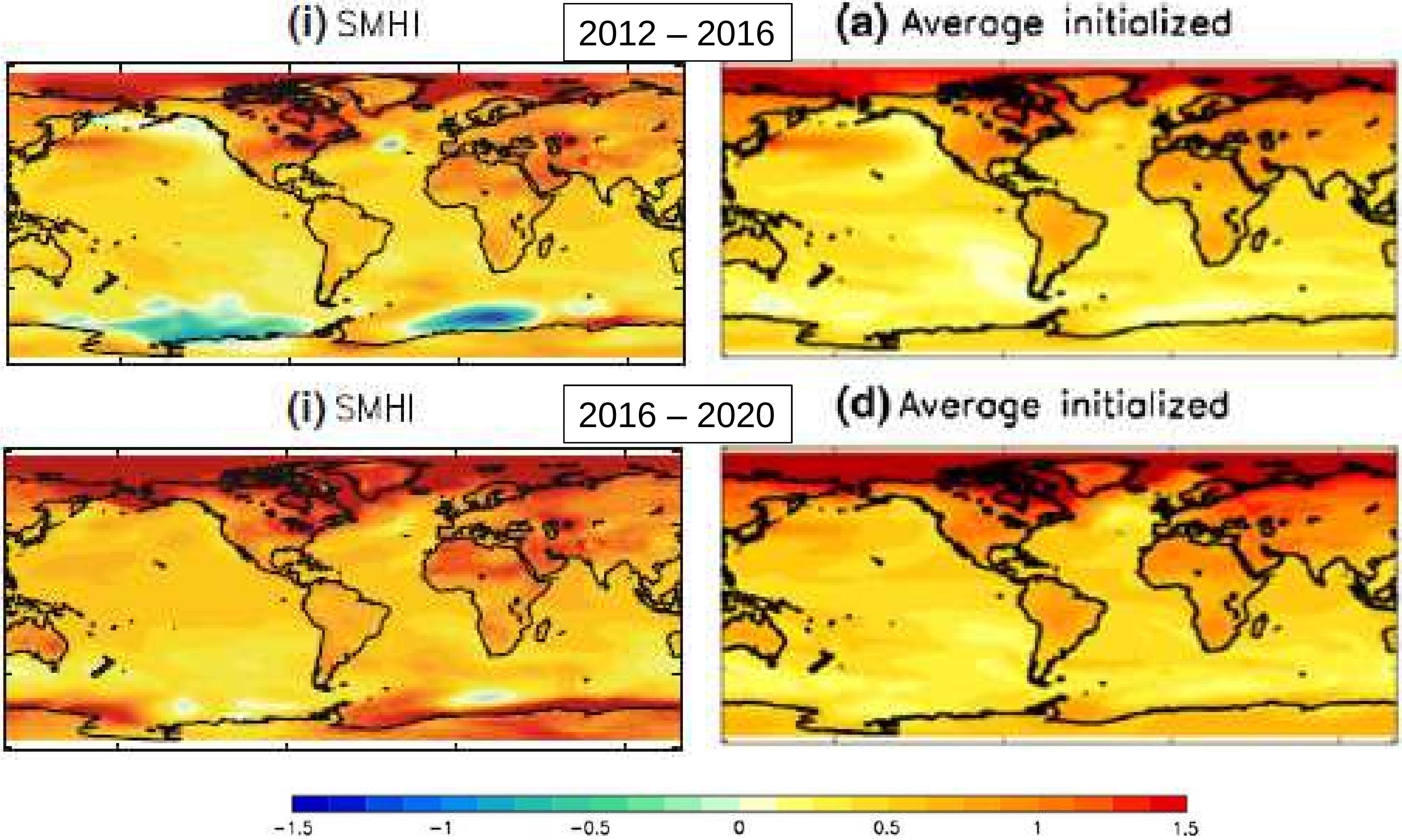
| Region | PPP CTRL/ Var Ctrl-v2.1 | PPP ALB /Var Alb |
|---|---|---|
| North Atlantic (10-60W,30-60N) | **0.85** / 0.057 | **0.83 /** 0.037 |
| Europe (0-60E,30-60N) | **0.72** / 0.041 | **0.78 /** 0.037 |
| Africa (10W-40E, -30S–30N) | **0.57** / 0.004 | 0.26 / 0.005 |
| S. Asia (60-130E, 10-40N) | **0.71** / 0.005 | 0.42 / 0.004 |
| N Asia (60-150E, 40-70N) | 0.39 / 0.062 | **0.58 /** 0.055 |
| N America (70-150W, 30-70N) | 0.42 / 0.015 | 0.45 / 0.009 |
| S America (40-80W, 50S-10N) | 0.11 / 0.003 | -0.13 / 0.002 |
| Australia (110-155E, 40S-10S) | 0.27 / 0.009 | 0.03 / 0.005 |
| Antarctic (0-360E, 90S-70S) | 0.35 / 0.039 | 0.16 / 0.025 |
| Arctic (0-360E, 70-90N) | **0.77** / 0.264 | **0.76 /** 0.189 |
| Labrador Sea (48-65W,45-65N) | **0.87** / 0.369 | **0.79 /** 0.161 |
| global | **0.85** / 0.004 | **0.67 /** 0.004 |

**PPP increases if we average T2m over larger regions but decadal variance is small except for high northern latitudes.**

# Anomaly correlation Temperature JJA



SMHI



(i) SMHI
2012 – 2016
(a) Average initialized
(i) SMHI
2016 – 2020
(d) Average initialized
−1.5
−1
−0.5
0
0.5
1
1.5

# Adding value to decadal predictions

Climate services

Downscaling

Targeted predictions for end users

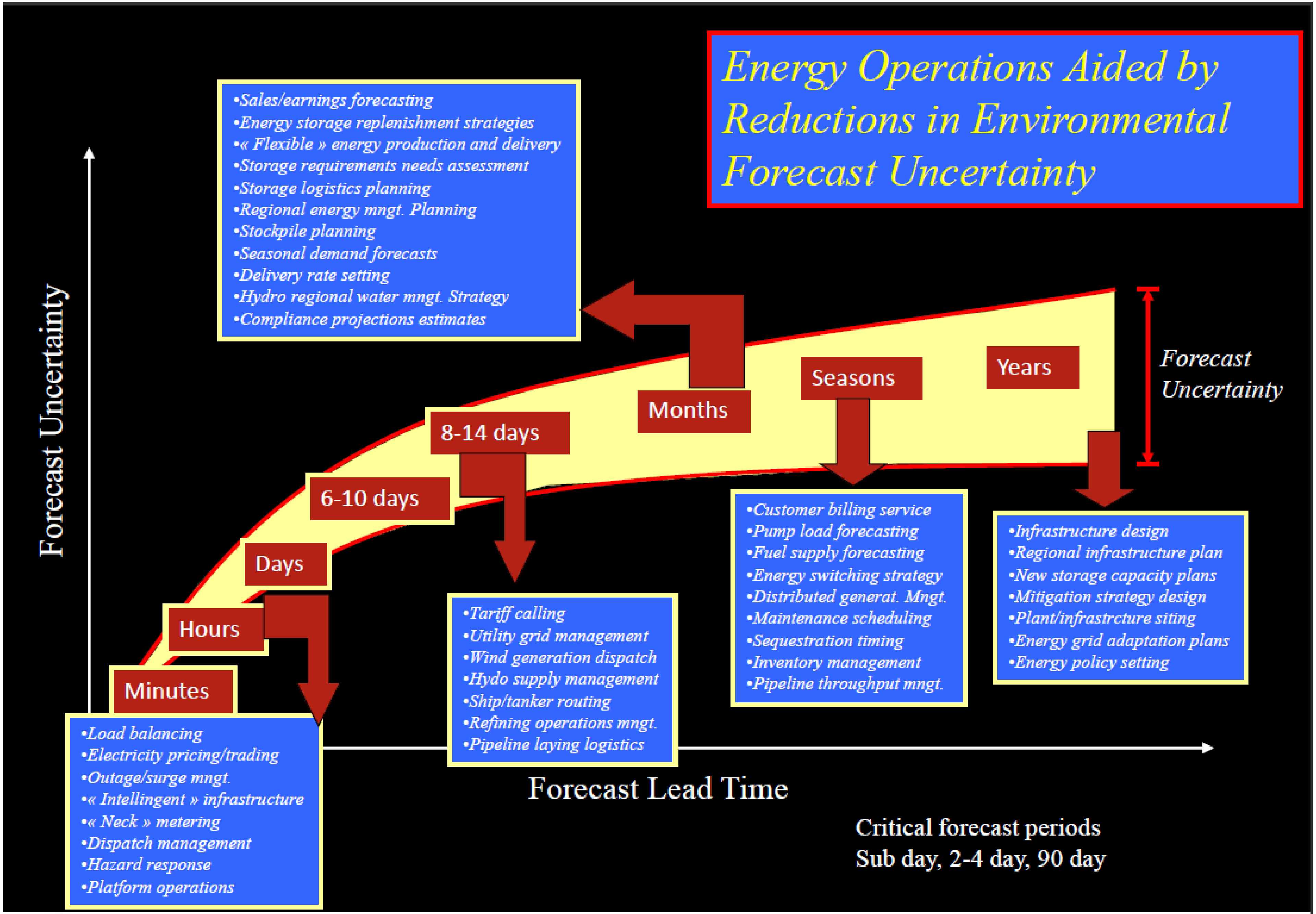
**Who wants decadal predictions?**
**What do they want?**
**What can we provide?**

Climate indices

Forecast quality assessment

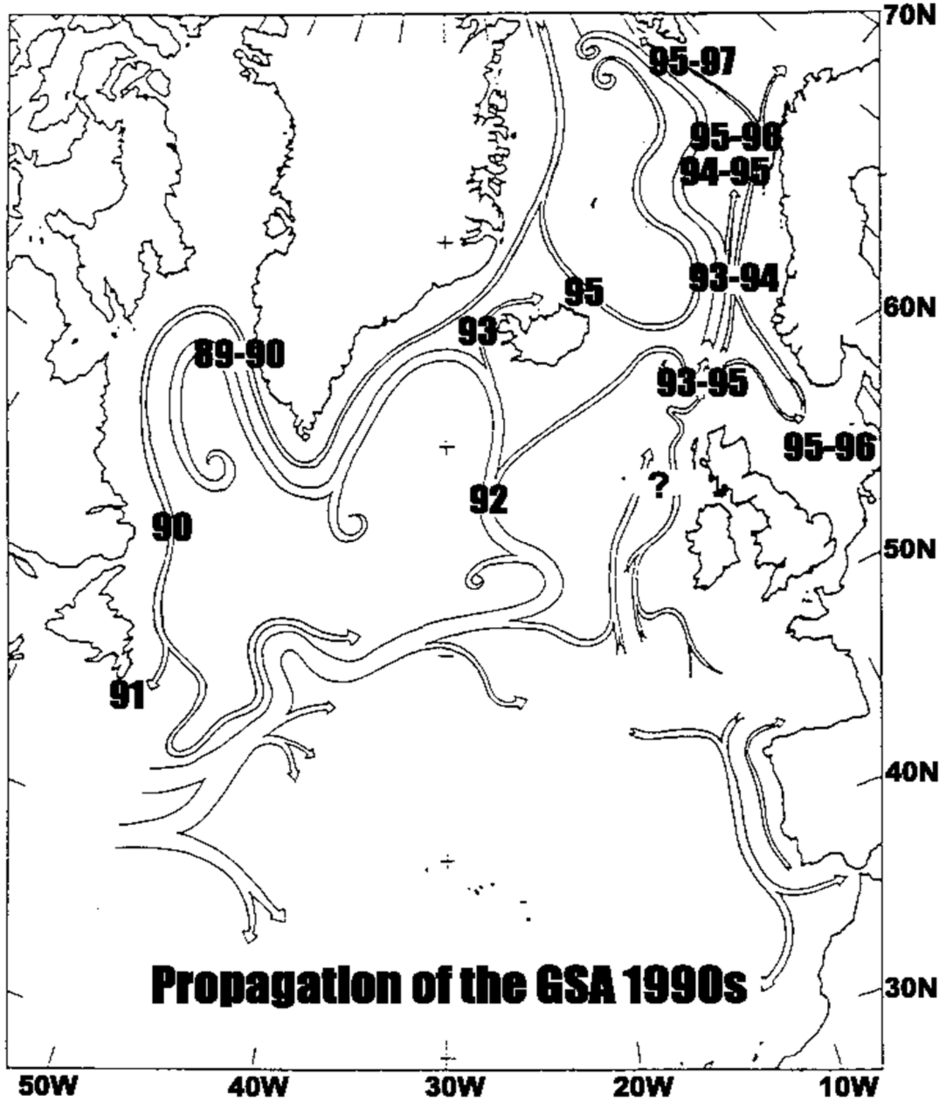
Bias correction for impact modeling

# Energy Operations Aided by Reductions in Environmental Forecast Uncertainty



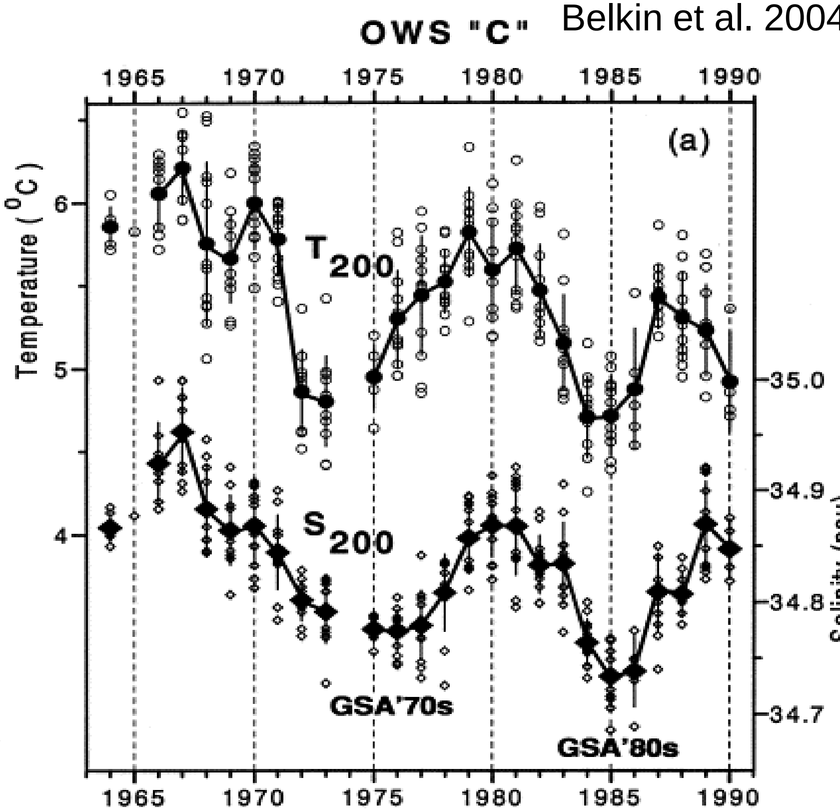

*From GEOSS 10-Year Implementation Plan Reference Document*
*Courtesy of M.G. Altalo, Science Applications International Corp.*

# Great Salinity Anomalies

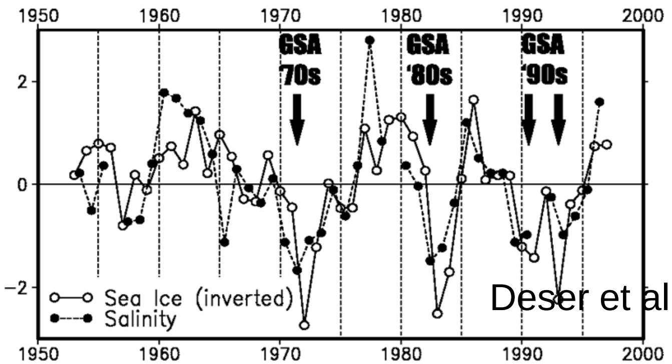



Belkin et al. 2004

Belkin et al. 2004



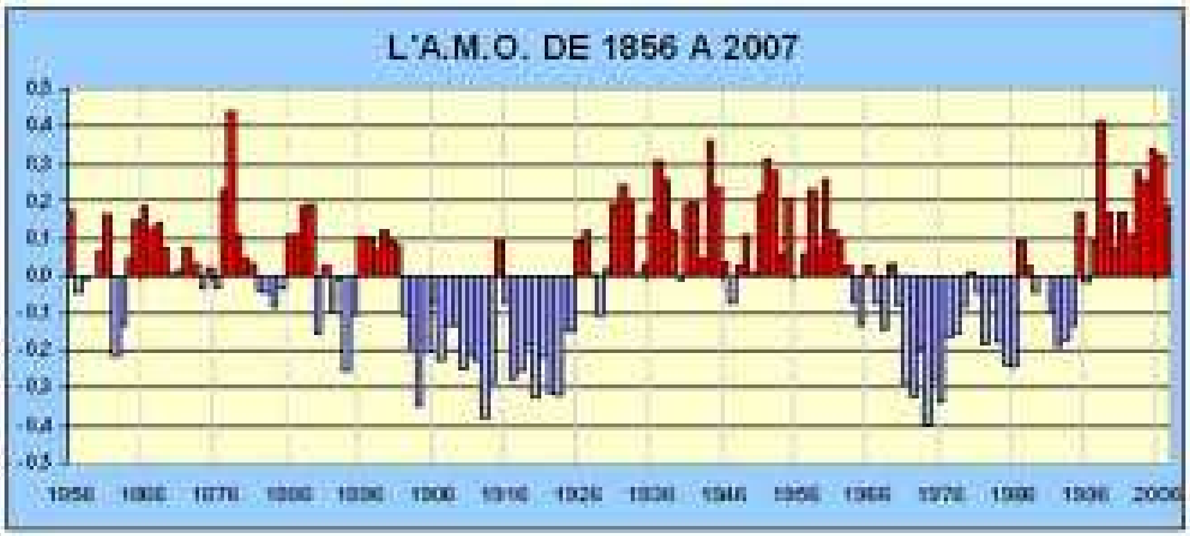

**Salinity and temperature as observed by OWS BRAVO in the Labrador Sea**



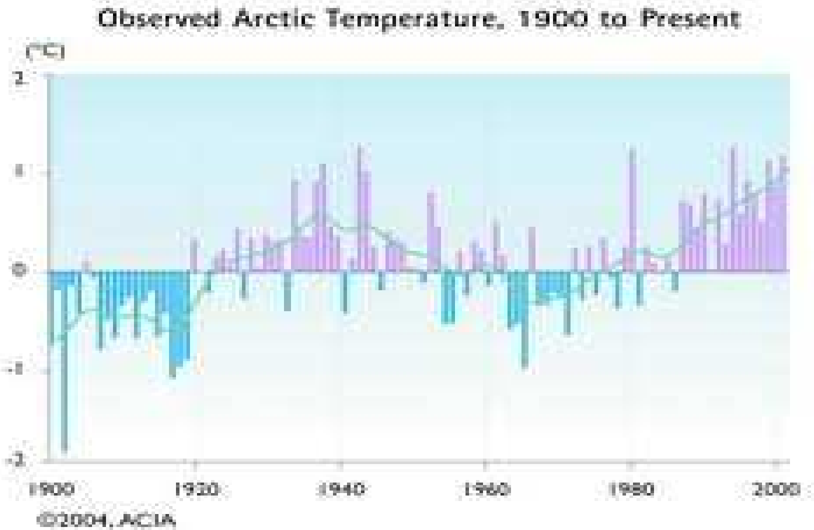

Deser et al. 2002

**Winter sea ice index and 100m April-July salinity in Davis Strait**

# Multi-decadal SST-variations




AMO-index

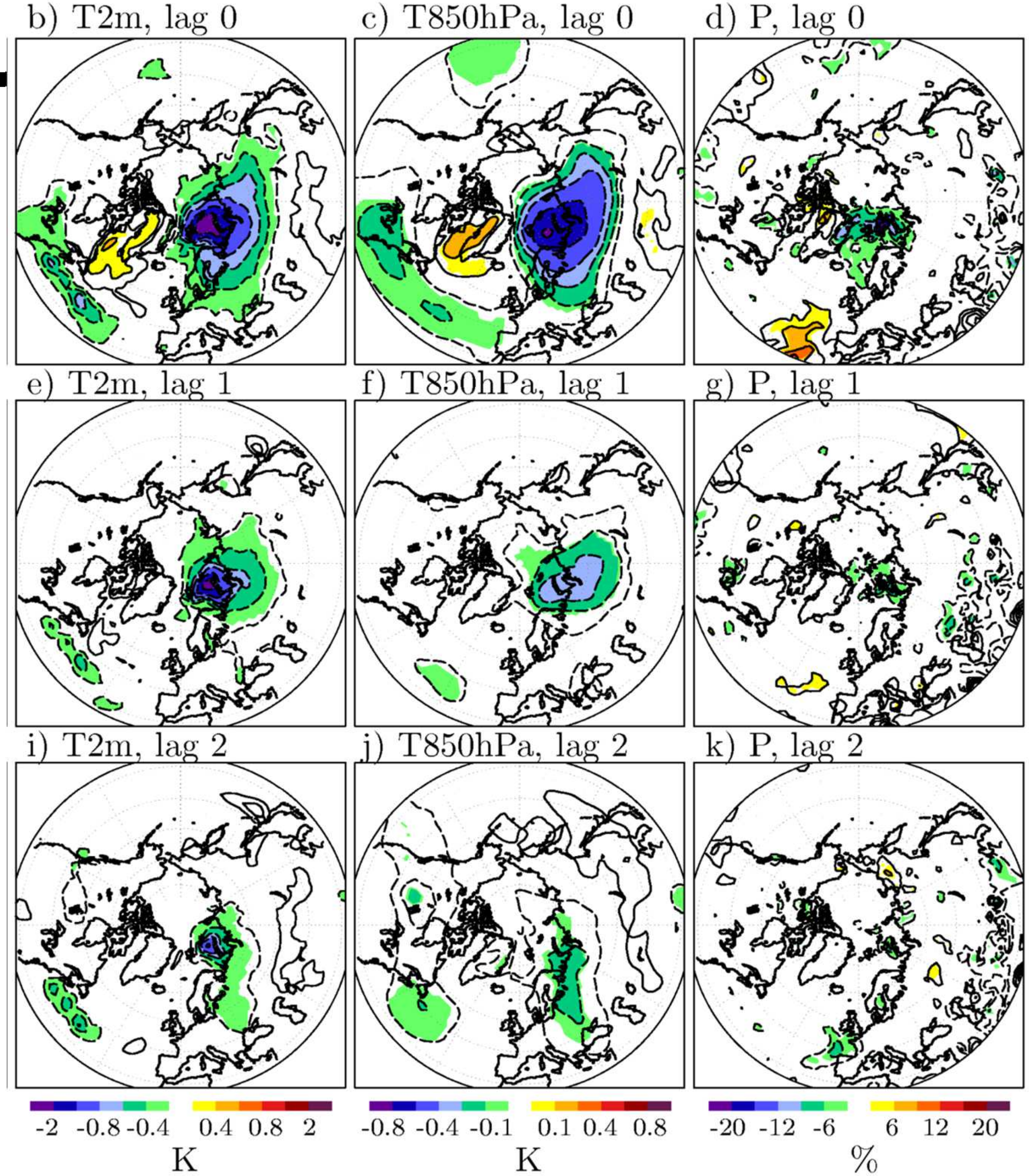



Arctic
2m -temperature

# Sea ice anomalies in the Barents Sea

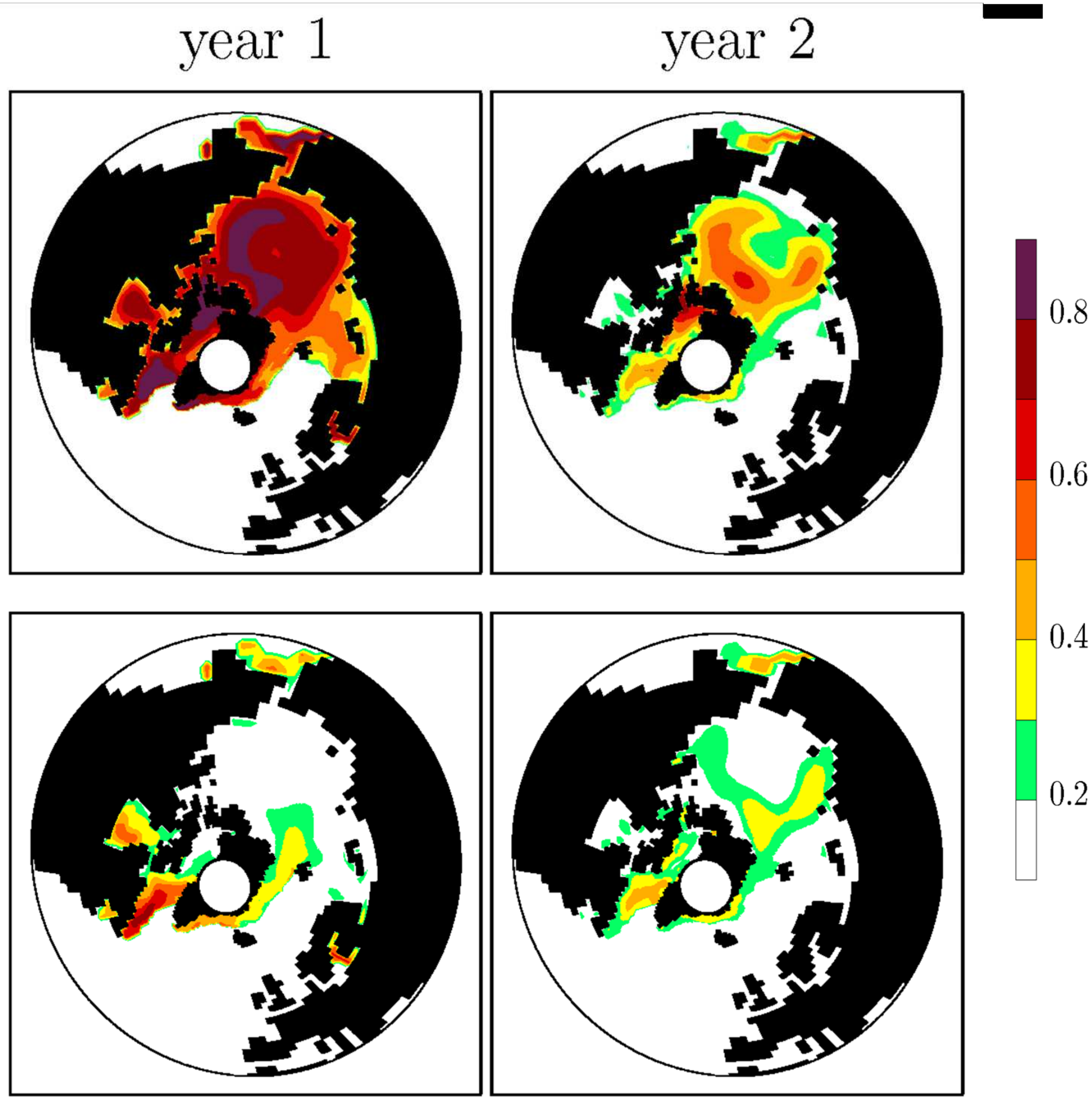
**Composite analysis:**
**500-year pre-industrial ctrl with ECHAM5/ MPI-OM**

**Annual mean response 2m air temperature, 850 hPa temperature and precipitation at lag 0, 1, 2 after high Barents Sea ice volume. Significant regions are coloured.**




Koenigk et al. 2009

# Potential predictability: sea ice thickness




Top: Predictability of annual mean sea ice thickness in the first two years after initialization in January.

Bottom: Gain of predictability.

Koenigk et al. 2009