Global skill of SST initialised hindcasts 10 years ago and today

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GEOMAR
Short hindcast period and external forcing hinder the assessment of decadal predictability

Keenlyside and Ba (2010)
Short hindcast period and external forcing hinder the assessment of decadal predictability

Keenlyside and Ba (2010)
Two approaches to SST initialised hindcasts

1. Nudged ECHAM5/MPIOM coupled model SST to observations (Keenlyside et al. 2005, 2008)

2. NorCPM – assimilate SST using EnKF into NorESM (Counillon et al. 2014, submitted)

Comparisons

• Seasonal hindcasts
• Decadal hindcasts

Other challenges

• Model systematic error in AMOC (Reintges et al. 2016)
2008: SST nudging strategy

- Model: ECHAM5/MPIOM Climate model (IPCC AR4 version)
- Initial conditions: Coupled model SST anomalies restored to observations
- Boundary conditions: 20th century/A1B radiative forcing

Nudging constant varies with latitude

Keenlyside et al. (2005,2008)
# Seasonal hindcasts: 1980-1999

<table>
<thead>
<tr>
<th>ECHAM5/MPIOM</th>
<th>NorCPM</th>
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<tbody>
<tr>
<td>Atmos. res.</td>
<td>T63 (~1.8°), 31 levels</td>
</tr>
<tr>
<td>Ocean res.</td>
<td>1.5° ave., z-coord., 40 lev.</td>
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<tr>
<td>DA</td>
<td>Nudging</td>
</tr>
<tr>
<td>SST</td>
<td>Full (NCEP)</td>
</tr>
<tr>
<td>Start</td>
<td>May 1st</td>
</tr>
<tr>
<td>Ensemble size</td>
<td>9</td>
</tr>
</tbody>
</table>
Skill in forecasting ENSO (Niño3.4 SST)

Anomaly initialised NorCPM
No obvious forecast drift

Full field init. ECHAM5/MPIOM
Large SST drift

Which has greater forecast skill?
Skill in forecasting ENSO (Niño3.4 SST)

**SST climatology**

- OBS
- NORESM-ANA
- MPI2
- NorESM-PRED

**Anomaly Correlation**

- ECHAM5/MIPOM
- NorCPM
Skill in forecasting September SST anomalies

ECHAM5/MPIOM (Lead month 7)

NorCPM (Lead month 8)

Anomaly correlation

Steffi Gleixner
Decadal hindcasts

<table>
<thead>
<tr>
<th></th>
<th>ECHAM5/MPIOM</th>
<th>NorCPM</th>
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<tbody>
<tr>
<td>Atmos. res.</td>
<td>T63 (~1.8º), 31 levels</td>
<td>1.9ºx2.5º, 26 levels</td>
</tr>
<tr>
<td>Ocean res.</td>
<td>1.5º ave., z-coord., 40 lev.</td>
<td>1º ave, Isopycnal, 53 lev.</td>
</tr>
<tr>
<td>DA</td>
<td>Nudging</td>
<td>EnKF (30 member)</td>
</tr>
<tr>
<td>SST</td>
<td>Anomaly (NCEP)</td>
<td>Anomaly (HadISST2)</td>
</tr>
<tr>
<td>Period</td>
<td>1955-2005</td>
<td>1952-2010</td>
</tr>
<tr>
<td># start dates</td>
<td>11, once every 5 years</td>
<td>30, once every 2 years</td>
</tr>
<tr>
<td>Ensemble size</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Forcing</td>
<td>Historical/A1B no volcanoes repeat solar cycle</td>
<td>Historical/RCP8.5</td>
</tr>
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</table>
Summary in 2008

• Decadal prediction skill achieved for the North Atlantic Sector & Tropical Pacific, above that expected from radiative forcing

• Internal decadal variability may offset expected warming over the next decade, regionally and globally

• Caveat - model suffers from significant biases, but nevertheless results are promising
Correlation skill for SST for 1-10 year mean

ECHAM5/MPIOM - Initialised
9 hindcasts, 1955-2005

NorCPM - Initialised
27 hindcasts, 1952-2014

Radiative forcing only, 3 member
Radiative forcing only, 30 member

Ingo Bethke
NorCPM: SST averaged over North Atlantic (40-60N)

SST [40N–60N, 80W–20E] (°C)

Lead (yr)

Correlation

Ingo Bethke
NorCPM: Subpolar gyre index

SPG sea level anomaly (m)

Correlation

Lead (yr)

Ingo Bethke
AMOC in the two initialisation approaches agree

ECHAM5/MPIOM, SST anomaly nudging: AMOC at 30N

NorCPM, SST anomaly EnKF: AMOC at 45N & 26N

Francois Counillon
AMOC hindcasts

NorCPM, SST anomaly EnKF: AMOC at 24N

AMOC strength at 24°N (Sv)
Model error dominates uncertainty AMOC response to external forcing

Approach following Hawkins and Sutton 2008

Future changes in AMOC 30N – CMIP5

Although geostrophic transport dominates the time-mean AMOC, both geostrophic and Ekman transports are important in explaining the AMOC variability. We derived the Ekman contribution to the AMOC model uncertainty at 30°N from the wind stress curl field (Visbeck et al. 2003).

The Ekman component of model uncertainty is shown together with the remaining model uncertainty and the other two uncertainty sources in Fig. 3. The Ekman contribution (yellow) is rather small and becomes comparable to the AMOC uncertainty due to the internal variability by the...
Future changes in AMOC 30N – CMIP5

(d) AMOC 30N [RCP4.5 & RCP8.5] 10-yr Running Mean

(f) AMOC 30N and 48N [RCP4.5 & RCP8.5] Signal-to-Noise Ratio
Future changes in AMOC 30N – CMIP5

- Model uncertainty dominates upper ocean density anomalies north of 40N in the Atlantic
- This is linked to salinity and surface freshwater budget uncertainties in high-latitudes
Future changes in North Atlantic SPG strength – CMIP3

(a) SPG [RCP4.5 & RCP8.5] 10-yr Running Mean

(b) SPG [RCP4.5 & RCP8.5] Uncertainties

Model Uncertainty
Scenario Uncertainty
Internal Variability

Sv
Sv^2
Future changes in North Atlantic SPG strength – CMIP3

(a) SPG [RCP4.5 & RCP8.5] 10-yr Running Mean

(c) SPG [RCP4.5 & RCP8.5] Signal-to-Noise Ratio
Future changes in North Atlantic SPG strength – CMIP3

(a) SPG [RCP4.5 & RCP8.5] 10-yr Running Mean

- Model uncertainty appears related to density anomalies over bathymetry (J-bar term)
Summary of skill of the two SST initialisation

1. Seasonal and decadal prediction skill of the two approaches (nudging and EnKF) appear similar.

2. Initialisation enhances prediction skill in the subpolar North Atlantic, but in NorCPM external forcing gives more skill.

3. Initialisation may provide some skill in ECHAM5/MPIOM in the tropical Pacific.

4. Model errors dominate uncertainty in externally forced changes in AMOC and SPG strength.

Thank you for your attention.