Multidecadal MOC Variability

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Take home message: Internal multidecadal MOC variability matters even on a global scale
Outline

1. General remarks
2. Dynamical considerations
3. Internal vs. external variability
4. Predictability and prediction
1. General remarks

Strong multidecadal variability is observed in the global mean SAT
Uncertainties in global change projections

Hawkins and Sutton 2009
Societal relevance of multidecadal variability

Is the cause of the multidecadal variability external or internal?

Latif et al. 2009
Zonal mean temperatures during the 20th century
SST in the North Atlantic may record MOC changes

Hurrell et al., BAMS, 2009

Does the multidecadal variability originate in the Atlantic/Arctic?
2. Dynamical considerations
The North Atlantic Oscillation
The NAO spectrum is almost white, so that a simple stochastic scenario may apply.

associated SAT anomalies
Most evidence points towards the “ocean-only” oscillator.
The Atlantic SST dipole, an index of relative MOC variations

The variability in the dipole index will be used in the following as surrogate of MOC variability
Ocean-atmosphere interactions

Latif et al. 2006
3. Internal vs. external variability

Northern Hemisphere SAT anomaly rel. to 1951-1980

annual means

- annual means
- linear trend
- 21-year running mean

Semenov et al. 2009
The IPCC models reproduce the warming in the global mean. This does not leave much room for internal variability.
AMO impact, SAT 1978-2007?

The last decades may contain a strong contribution from internal variability

Semenov et al. 2009
Diagnostic approach to separate external and internal climate signals during the 20\textsuperscript{th} century

\[ T(x,y,t) = \alpha \cdot \psi(x,y) \cdot F(t) + R(x,y,t) \]

\[ F(t) = \log[\text{CO}_2(t-11\text{yr})/\text{CO}_2(0)] \]

\[ \psi(x,y) = 1\text{st EOF of multi-model ensemble mean 20\textsuperscript{th} century SAT} \]

\[ R(x,y,t) = \text{Residual internal variability} \]

\[ T(x,y,t) = \alpha \cdot \psi(x,y) \cdot F(t) + R(x,y,t) \]

\[ \psi(x,y) = 1^{\text{st}} \text{eof of multi-model mean} \]

20\text{th} \text{century temperature (87\%)}

\[ F(t) = \log[\text{CO}_2(t-11\text{yr})/\text{CO}_2(0)] \]
Proof of concept in the model world

Approach works fine in the model world
Observed global SAT and fitted external component

- Observed global SAT
- Fit to ensemble mean of 20C runs
- Sampling uncertainty + internal variability
- Fit to observations
The most recent period

Implication: Climate sensitivity is too high
The internal variability during the most recent decades

The last decades contain indeed a strong contribution from internal (MOC) variability
The leading mode from the annual residuals $R(x,y,t)$ is ENSO

$$T(x,y,t) = \alpha \cdot \psi(x,y) \cdot F(t) + R(x,y,t)$$
Indices of internal variability (PDO, AMO) from R(x,y,t)

The analysis recovers the decadal variations in the PDO and the AMO.
4. Predictability and prediction

Shifts in PDFs of European SAT from decade to decade in response to THC changes (Pohlmann et al. 2004)
Predictability

Potential (diagnostic) predictability of SAT

Classical (prognostic) predictability

Boer 2004

Latif et al. 2006b
Interannual vs. decadal potential predictability

interannual (1-5 years)

decadal (10-100 years)

Obtained from the Kiel Climate Model (KCM)

Latif et al. 2009
Prediction of global SAT for the next decade

Hurrell et al., BAMS, 2009
Prediction of global SAT and MOC

(A) Global average surface temperature

BAMS 2009

(B) Atlantic SST dipole index

Hurrell et al., BAMS, 2009
Conclusions

• There is strong evidence that the multidecadal SAT variability in the Atlantic (and globally) is driven (at least partly) by variations in the MOC

• A stochastic scenario is most plausible, in which the ocean is driven by the low-frequency portion of the atmospheric variability (NAO)

• However, the atmospheric response to SST anomalies is still not understood and the role of coupled feedbacks is unclear

• MOC variability appears to be predictable about a decade ahead

• The most recent decades contain a strong contribution from the AMO (MOC) even on a global scale. This raises questions about the average climate sensitivity of the IPCC models