FUTURE MODES

Atlantic meridional overturning circulation and the prediction of North Atlantic sea surface temperature

Klöwer et. al

WHAT IS THE KIEL CLIMATE MODEL AND CANONICAL CORRELATION ANALYSIS?

- KCM
  - Forcing methodology
  - Low resolution
  - No flux correction
  - Forced with constant level of [GHG] (348ppm at this time)
  - Good model for internal variability and realistic depictions of ENSO and SST variability in North Atlantic and Pacific
- Canonical Correlation Analysis (CCA)
  - "A way of measuring the linear relationship between two multidimensional variables."
  - Similar to EOF
  - Works on cross-correlation matrix

WHAT ARE SOME UNCERTAINTIES PRESENTED?

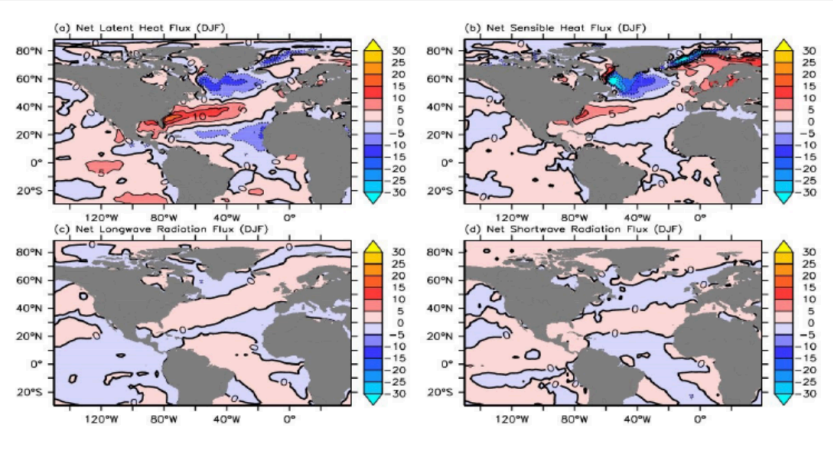
- Only have measurements to estimate AMOC strength since 2004
- Models have large biases
- Drift in North Atlantic SST/Large SST biases in North Atlantic

- Relatively low resolution (almost 4x4 degree grids)
- Only accounts for heat flux driving AMOC

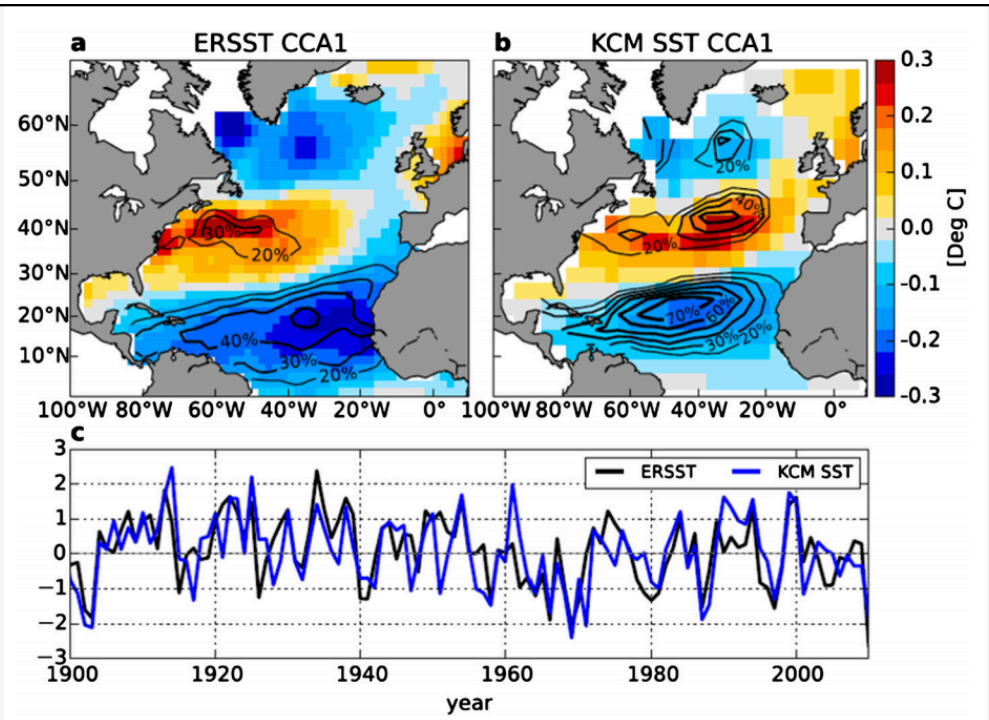
- Model does not capture SST variability not driven by NAO-related heat flux or AMOC.
- Model does not account for AMOC-related SST signal not described by CCA21
- When linear trend is added back, effects of external forcing may not be represented

HOW RELIABLE CAN THE CONCLUSIONS OF THIS PAPER BE GIVEN THESE?

- Meh?



- Figure 1S: Spatial maps of regression coefficients of (a) net latent heat flux (b) net sensible heat flux (c) net longwave flux and (d) net shortwave radiative flux onto NAO index during boreal winter (December-February, DJF). Units are W/ m2 .



WHAT IS THIS FIGURE SHOWING? WHICH SEEMS TO BE MORE SIGNIFICANT?

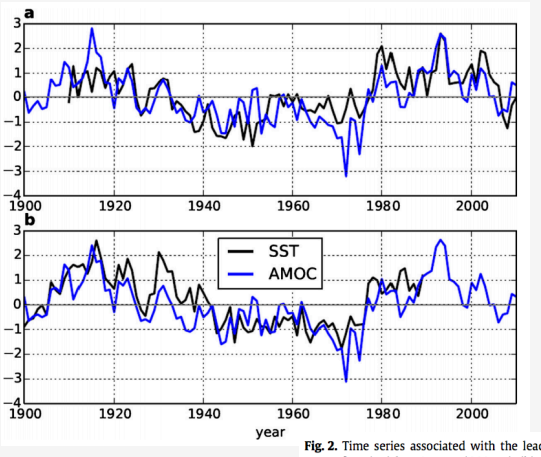


Fig. 2. Time series associated with the leading CCA modes. (a) The time series obtained from the CCA when the observed North Atlantic SSTs lead the AMOC (overturning streamfunction) by 10 years (CCA_{-10}). (b) The time series obtained from the CCA when the AMOC leads the observed North Atlantic SSTs by 21 years (CCA_{21}). The time has been adjusted in both panels to account for the time lag. The CCAs were performed on annual means and the data were linearly de-trended prior to the analysis. The time series are dimensionless.

- Both show strong multi-decadal signatures
- Perhaps a bit better matched at CCA21 than CCA10
- Overall very much the same

WHAT'S WITH THE OPPOSITE SIGNS IN FIGURE 3A AND 3B? WHAT ARE THEY SHOWING?

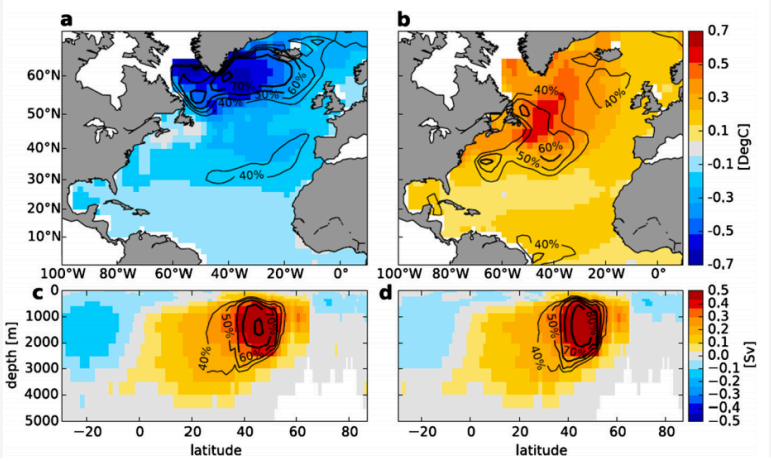
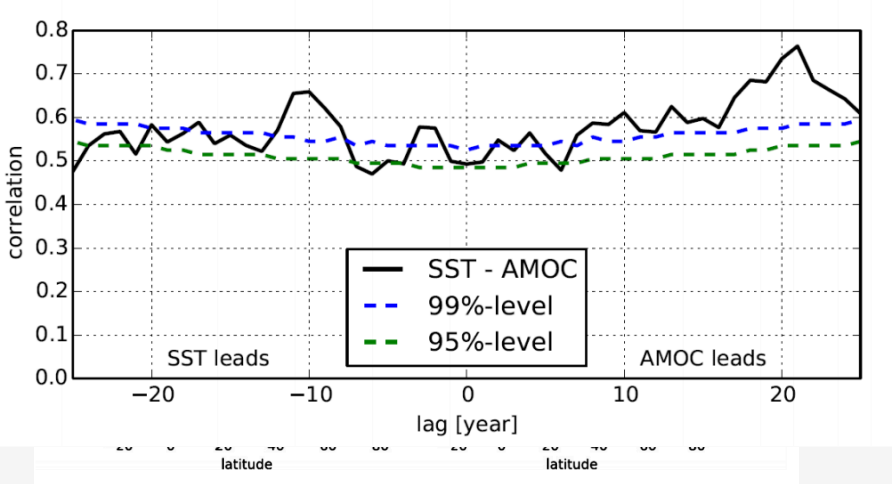


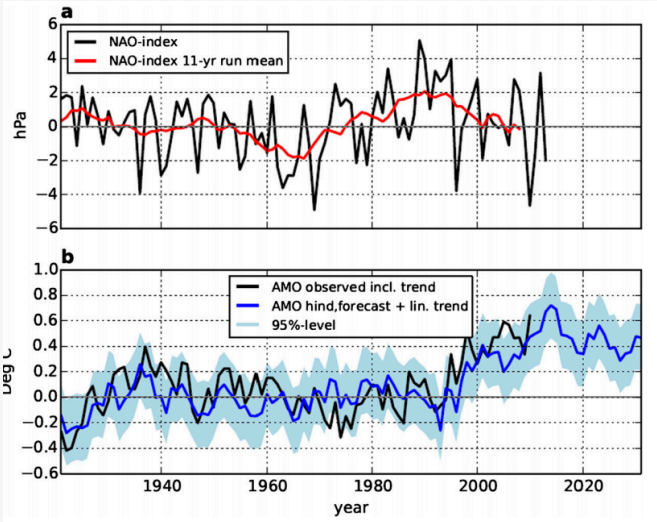
Fig. 3. (a, c) Anomalous North Atlantic SST (°C) and overturning streamfunction (Sv), when the observed North Atlantic SSTs lead the AMOC by 10 years (CCA_{-10}). (b, d) Anomalous North Atlantic SST (°C) and overturning streamfunction (Sv), when the AMOC leads the observed North Atlantic SSTs by 21 years (CCA_{21}). The locally explained variances are shown by contours and are statistically significant at the 95% level where they exceed 40%. To assess the statistical significance the number of effective degrees of freedom was used, which accounts for the autocorrelation in the time series. The strong negative SST anomaly in the subpolar North Atlantic in (a) is highly significant with explained variances up to 80%. In (b) the explained variances are particularly high along the path of the North Atlantic Current and in the Caribbean, with values of 50% and even above in selected regions. The overturning anomalies in panels (c) and (d) exhibit the highest explained variances (w.r.t. to annual means) in the midlatitudes and subtropics down to about 3000 m.

- NAO vs. AMO
  - Annular vs. multi/decadal
- Overturning the same either way

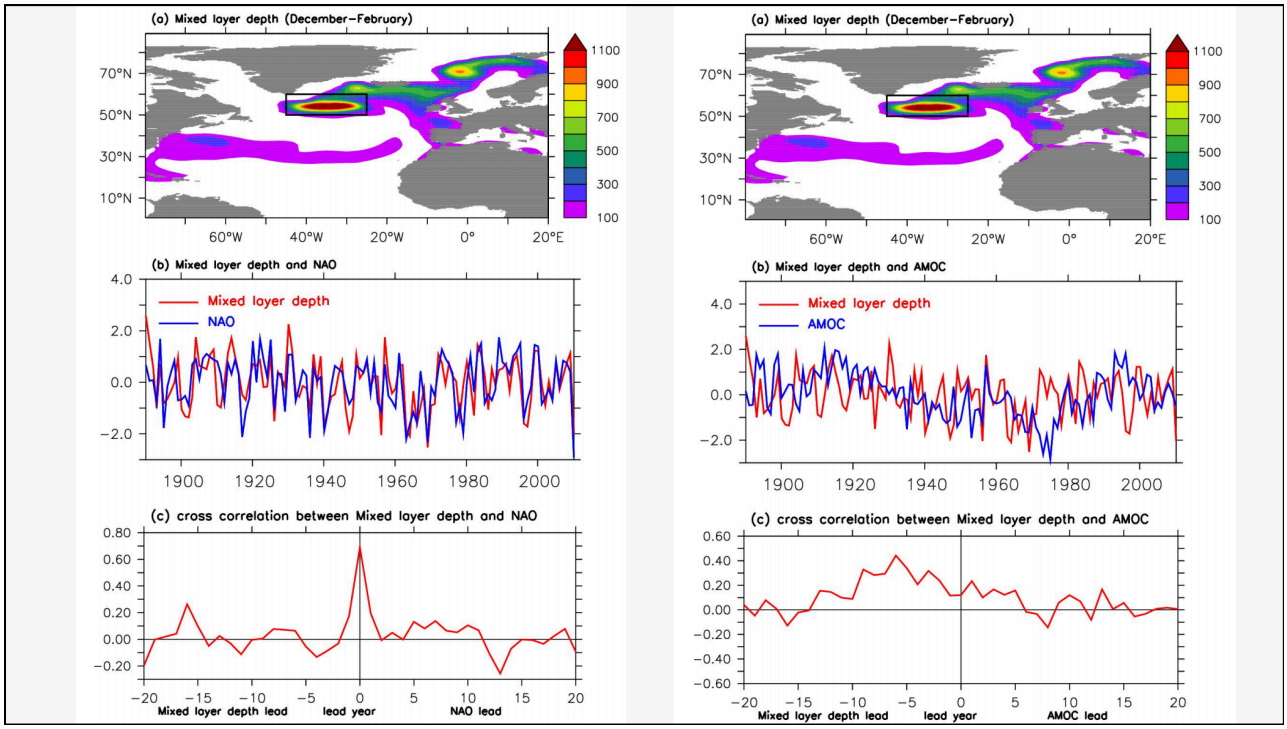
WHY WOULD THE 21 YEAR LAG BE A BETTER PREDICTOR THAN THE 10 YEAR LAG?



USING AMOC AS A PREDICTOR



- What is 4a showing us?
  - AMO is decreasing, possibly due to decreasing NAO
- What does that mean for 4b?



TAKE HOME POINTS, ARE WE CONVINCED?

- AMOC is a good predictor of SSTs in the past and might be good for the future
  - Strong memory in response to Heat Flux Forcing
- The Cold Bias
  - Overestimation of SST forecast potential
- Lots of aspects of AMOC that are ignored for the sake of the model
  - How realistic especially considering the impact of aerosols?
- AMOC could be the link between NAO and North Atlantic SST
- "It is largely unknown how this [relationship between AMOC and atmospheric forcing] will affect the decadal forecast skill."

THE ROLE OF ATLANTIC MULTI-DECADAL OSCILLATION IN THE GLOBAL MEAN TEMPERATURE VARIABILITY

Chylek et al. 2016

GOAL:

- Examine the relative contribution of AMO in the global mean temperature variability in both the past (1900-2015) and the future (2015-2100)

INTRODUCTION

- Earth has experienced a considerable warming during the past century.
- The division between natural and anthropogenic components remains unclear.

EXPLANATORY VARIABLES USED IN RECENT STUDIES

- Natural radiative forcing: top of the atmosphere solar variability (SOL), Volcanic aerosols (VOLC)
- Anthropogenic radiative forcing: anthropogenic well mixed greenhouse gases (GHG) and aerosols (AER)
- Oceanic influence: ENSO index (ENSO)

Quesiton: GHGA is the combined radiative forcing of GHG and tropospheric aerosols. Why did the paper pick GHGA as a variable and not use GHG and aerosols as two separate variables in the regression analysis?

Table 2 Linear regression models considered

n	Set of explanatory variables	% Variance
1	GHGA, SOL, VOLC, (ENSO)	93.68
2	GHGA, SOL, (VOLC), (ENSO), AMO, (PDO)	95.68
3	GHGA, SOL, (VOLC), AMO, (PDO)	95.66
4	GHGA, SOL, AMO, (PDO)	95.60
5	GHGA, SOL, AMO	95.51

Question: Why is including AMO as one of the explanatory variables in the regression analysis a reasonable choice?

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Question: Why is including AMO as one of the explanatory variables in the regression analysis a reasonable choice?

1. The residual of the first model listed on the table was found to be correlated with the AMO .
2. Tree rings and ice core data proves that AMO existed for thousands of years before the beginning of the anthropogenic influences.

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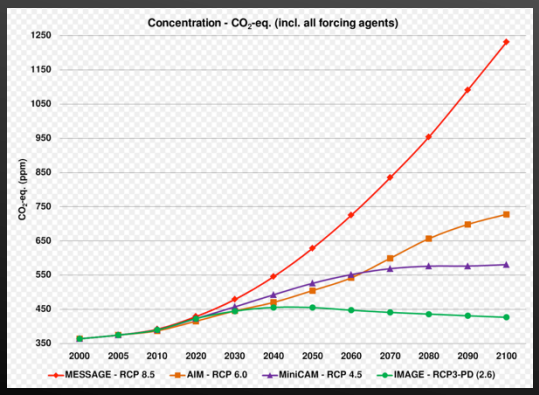
Why did the paper use RCP 4.5 for their analysis but not the others?



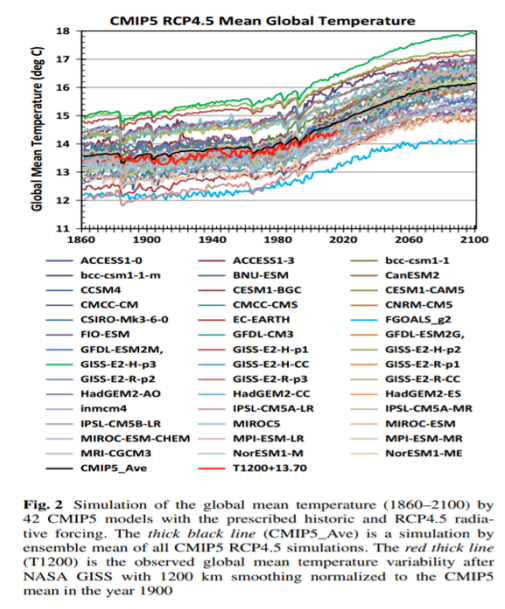
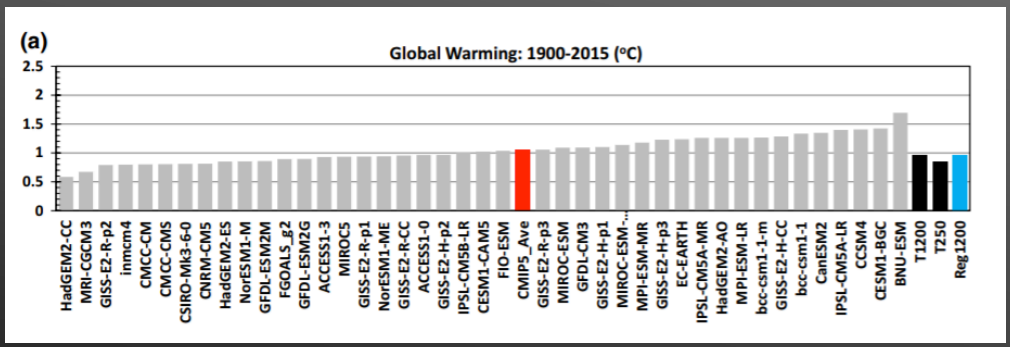


Fig. 2 Simulation of the global mean temperature (1860–2100) by 42 CMIP5 models with the prescribed historic and RCP4.5 radiative forcing. The *thick black line* (CMIP5_Ave) is a simulation by ensemble mean of all CMIP5 RCP4.5 simulations. The *red thick line* (T1200) is the observed global mean temperature variability after NASA GISS with 1200 km smoothing normalized to the CMIP5 mean in the year 1900

Temperature increase between the years 1900 and 2015 varies between 0.58 °C and 1.70 °C
Mean increase: **1.05 °C**

Observed global warming between the years 1900 and 2015 was **0.95 °C**

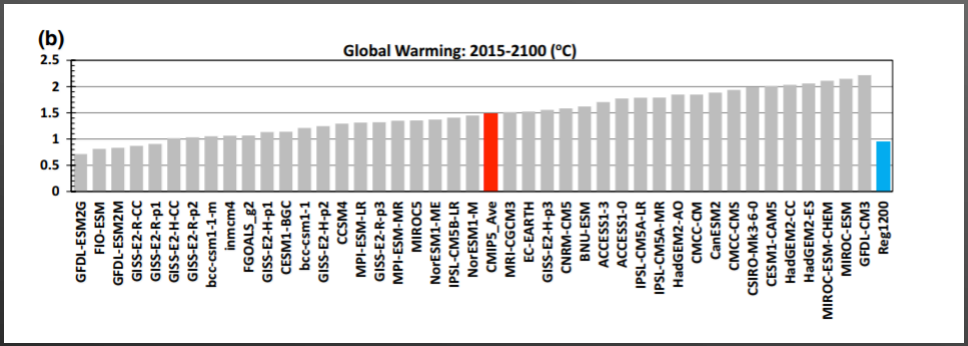


Regression: 0.96 °C
Observation: 0.95 °C
Mean cmip5: 1.05 °C

What are the assumptions that the paper makes in order to project the future temperature trend using the regression model?

What are the assumptions that the paper makes in order to project the future temperature trend using the regression model?

1. A cyclic behavior that repeats the twentieth century AMO cycle.
2. The solar variability is assumed to repeat its past behavior
3. RCP 4.5



Regression model projects another 0.95 °C warming before the end of 21st century

"9 CMIP5 models that simulate both the historic global mean temperature increase (1900–2015) and the models' projected 2015–2100 warming within ±0.25 °C of that obtained by a regression model"

Table 3 The AMO and the GHGA contributions to the global warming within the past (1975–2005) and the expected future AMO cycle for the AMO_K index after Kaplan et al. (1998), AMO_TS index according to Trenberth and Shea (2006), AMO_O after van Oldenborgh et al. (2009), and AMO_P after Parker et al. (2007)

	1975–2005	1975–2005	Twenty-first century	
	AMO (°C)	GHGA (°C)	AMO (°C)	GHGA (°C)
AMO_K	0.20	0.49	0.20	0.21
AMO_TS	0.13	0.54	0.13	0.25
AMO_O	0.13	0.58	0.13	0.25
AMO_P	0.17	0.51	0.17	0.24

The fraction of warming attributed to the AMO will more than double in the twenty-first century due to levelling off of the anthropogenic GHGA radiative forcing under the RCP4.5 scenario (see also Fig. 5)