Testing the robustness of observed AMOC fingerprints in a perfect model framework

Rhea Alexander-Turner, Pablo Ortega and Jon Robson NCAS-Climate, Department of Meteorology, University of Reading, UK

DYNAMOC

University of Reading

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

MOTIVATION

The Atlantic Meridional Overturning Circulation (AMOC) plays a key role in the climate of the North Atlantic, and is related to important climate impacts (or fingerprints; *Zhang 2008*). These AMOC fingerprints could be useful to estimate the AMOC's variability back in time, or to predict its impacts in the future. For example, direct measurements from the RAPID array (*Smeed et al 2014*) suggest that the AMOC can drive sea surface temperature (SST) changes several months ahead (Fig 1; *Duchez et al., 2016)*, an encouraging result for seasonal predictability. However, with only 12 years of continuous observations, the validity of this result over longer time periods is uncertain.

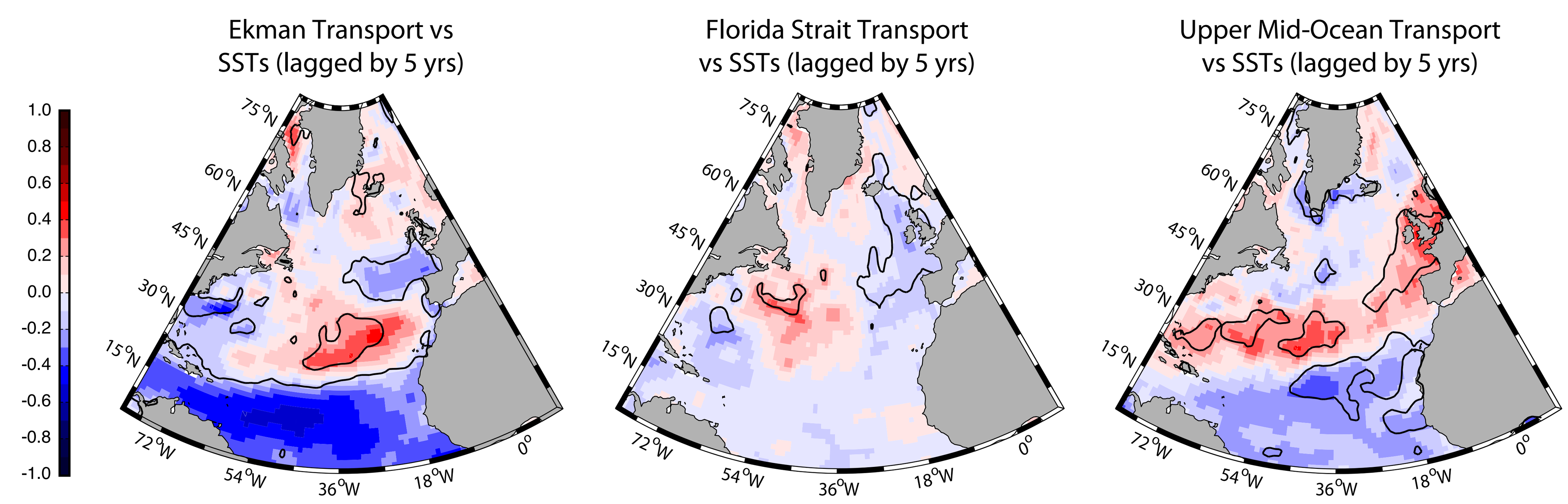

Fig. 1: Lagged correlations between North Atlantic SSTs and AMOC components measured by RAPID at 26°N: the Ekman (left), Florida Strait (middle) and Upper Mid-Ocean (right) transports. All data is detrended, deseasonalised and smoothed with a 2-month running mean. Black contours show 95% significance levels according to a Monte Carlo test. Figure from *Duchez et al (2016)*.

Main Goal: To test the stability and robustness of AMOC fingerprints for lead-times of several months ahead

Indeed, these fingerprints might be sensitive to the period considered

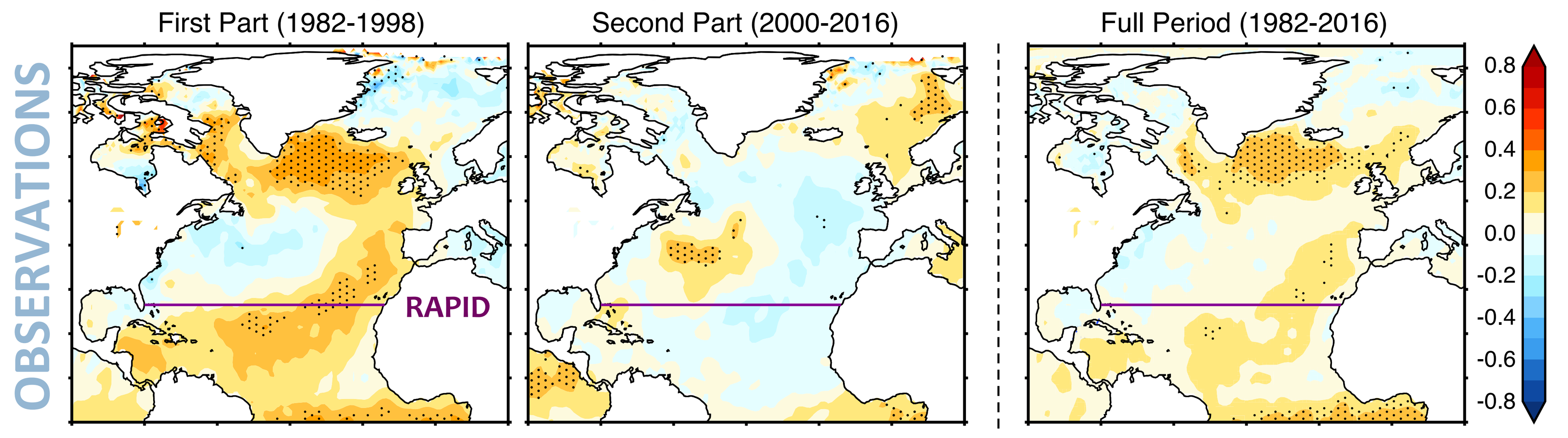

Fig. 2: Observed correlations between the Florida Strait transport (FST) at 26°N and the SST fields lagged by 5 months, in the periods: 1982-1998, 2000-2016 and 1982-2016. All data was processed as in Fig. 1.

The FST, for which longer observations exist, has different SST fingerprints depending on the period used. This might hold for the other components

We will now use a 120-yr long preindustrial control simulation with HadGEM3-GC2 (GC2) as a "perfect model" framework

GC2 represents the annual cycle of the AMOC at 26°N fairly well

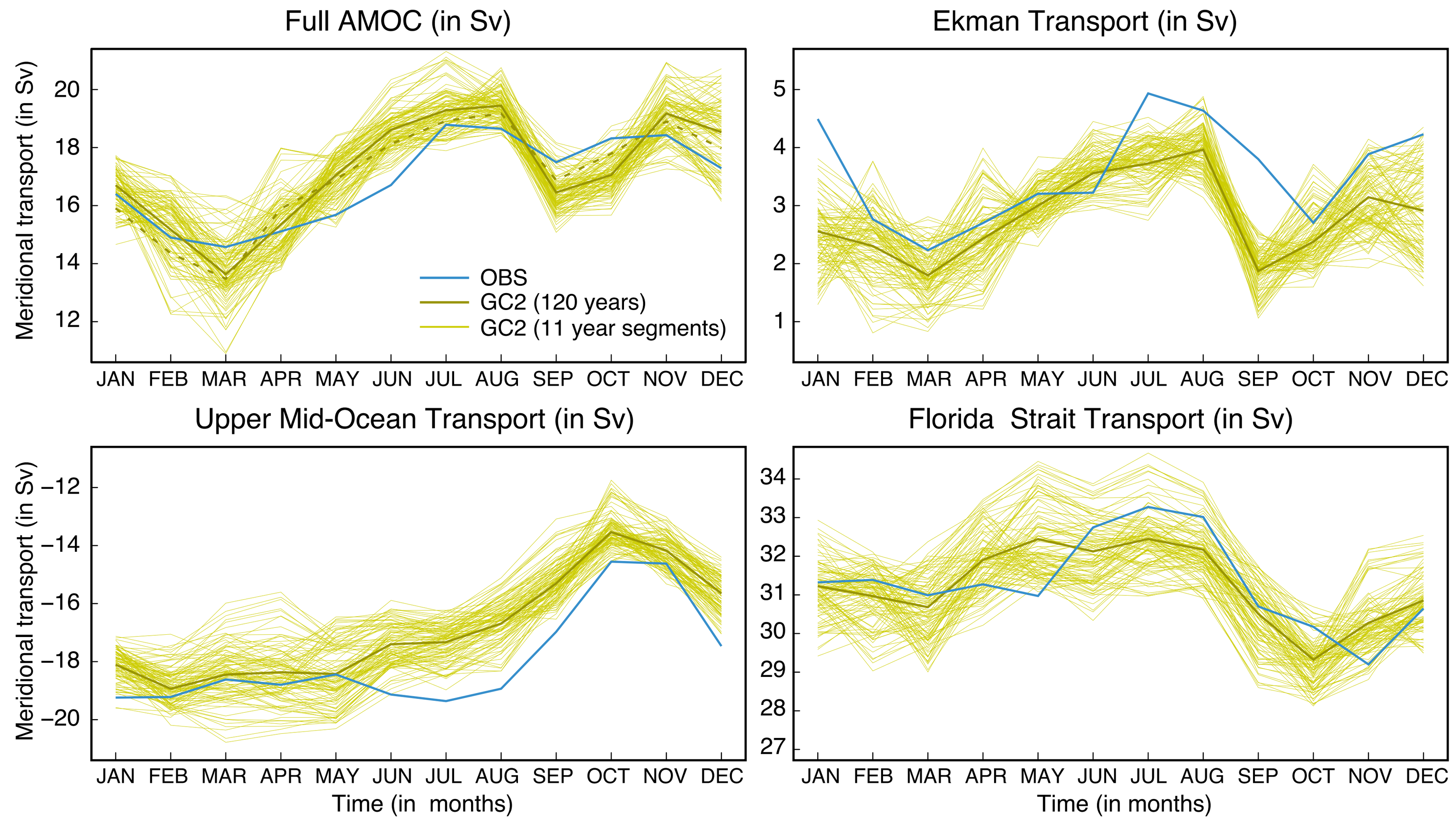

Fig. 3: Annual cycle of the different AMOC components for the 11 years of RAPID observations (blue), the 120 years of GC2 data (thick yellow), and all possible 11 year segments in GC2 (thin yellow lines).

But, how robust are the 11-yr AMOC fingerprints within the model?

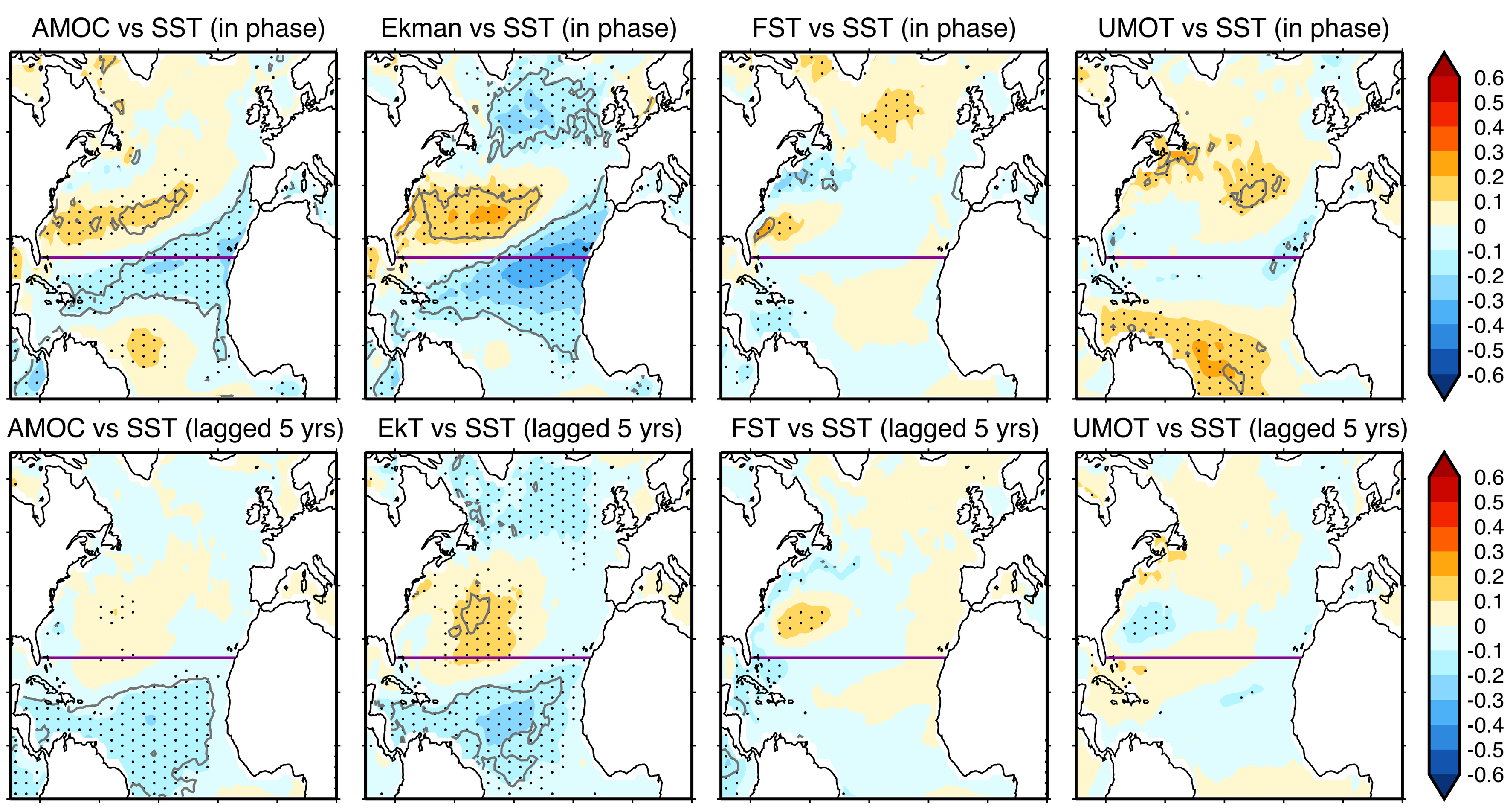

Fig. 4: Correlations between the AMOC components and the in-phase (top) and 5-month lagged (bottom) SST fields using the 120-yrs of GC2 data. Stippling highlights correlation values that are significant at the 95% confidence level. Grey contour lines enclose regions where the sign of the correlation is consistent in more than 90% of the 11-year segments in GC2.

Only the Ekman transport (EkT) shows consistent fingerprints in the full 120-year period and across the 11-year segments, in particular at lag 0

How consistent are model fingerprints with those from observations?

How many years are necessary to constrain the long-term model fingerprints robustly?

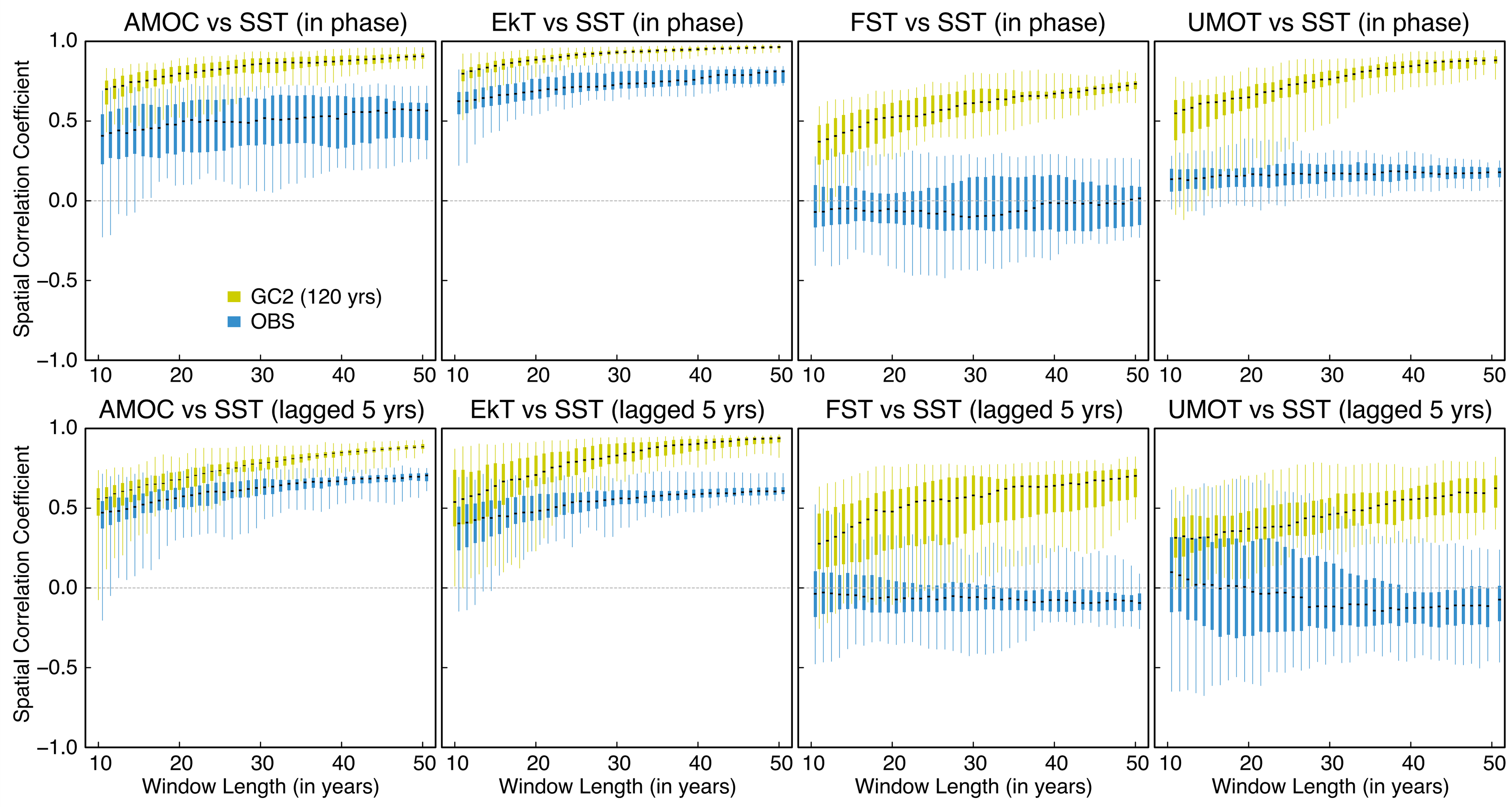

Fig. 5: Box-and-whisker plot of the spatial correlation maps between the AMOC components and the SST fields in the observations (blue) and the full GC2 run (yellow) and an ensemble of equivalent correlation maps obtained using segments of different length in GC2.

Overall, both the FST and upper mid ocean transport (UMOT) need sampling windows **> 30 yrs** to capture the long-term model fingerprints consistently

Both variables show some agreement with observations, but only for short sampling windows (**< 20 yrs**), and especially for the lagged SST fingerprints

Are the 11-year observed SST fingerprints represented in the model?

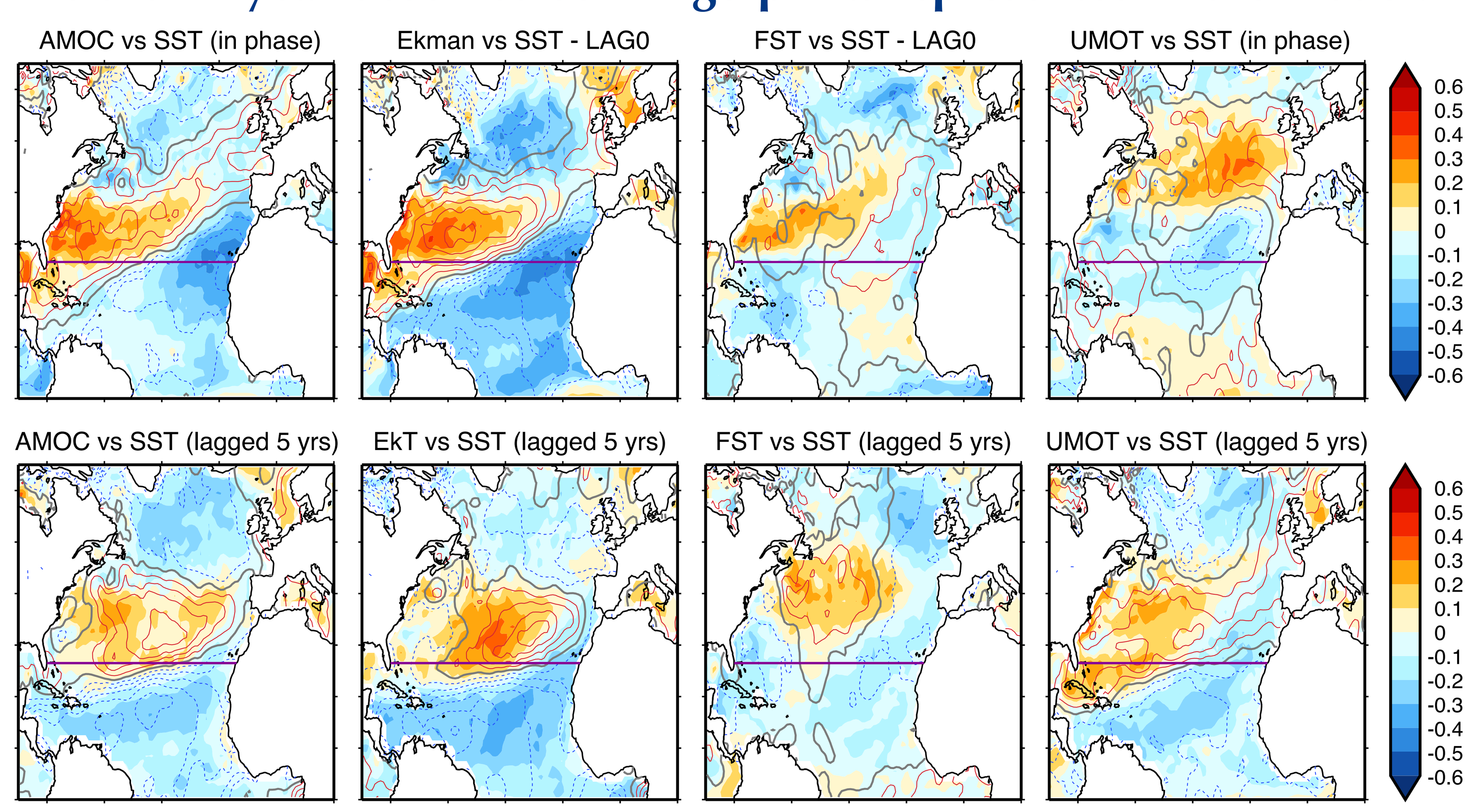

Fig. 6: Correlations between the AMOC components and the in-phase (top) and 5-month lagged (bottom) SST fields in GC2 (shaded) and the observations (contours). For GC2, these correlations represent the mean correlation pattern for the five 11-year segments with the largest spatial correlation coefficients in Fig 5.

At lag 0 only the simulated EkT fingerprints (and partly the UMOT) show spatial similarities with the observed correlation patterns (in contours)

An overall agreement is seen for the lagged SST fingerprints, which suggests that the model is capable of simulating the observed correlations. This supports the use of the model to test the robustness of SST fingerprints through time

WRAP-UP MESSAGES

- GC2 reproduces reasonably well the lagged SST fingerprints in observations
- Simulated fingerprints for UMOT & FST are sensitive to the chosen window
- At least 2 more decades of RAPID observations are necessary to determine their potential for seasonal prediction of SST changes in the North Atlantic

REFERENCES

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