

# Uncertainty in 21<sup>st</sup> Century Projections of the Atlantic Meridional Overturning Circulation



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## 1 Atlantic Meridional Overturning

The Atlantic Meridional Overturning Circulation (AMOC; Ganachaud and Wunsch 2003, Skrokosz et al. 2012) transports a large amount of heat towards the high latitudes of the North Atlantic and warms large parts of the northern hemisphere. For the 21<sup>st</sup> century, a weakening of the AMOC is expected due to surface freshening in the subpolar North Atlantic (Thorpe et al. 2001). Models agree on the weakening but not on its amplitude: the spread between the models is large compared to the mean weakening-signal (Schmittner et al. 2005, Weaver et al. 2012).

Based on two large model ensembles we quantify the major sources of uncertainty found in the AMOC projections.

## 2 Quantifying uncertainty

### Model projections:

We analyze models from the Coupled Model Intercomparison Project Phase 3 (CMIP3) and Phase 5 (CMIP5). The 21<sup>st</sup> century scenarios used here are SRES B1, A1B, and A2 for CMIP3; and RCP4.5 and RCP8.5 for CMIP5.

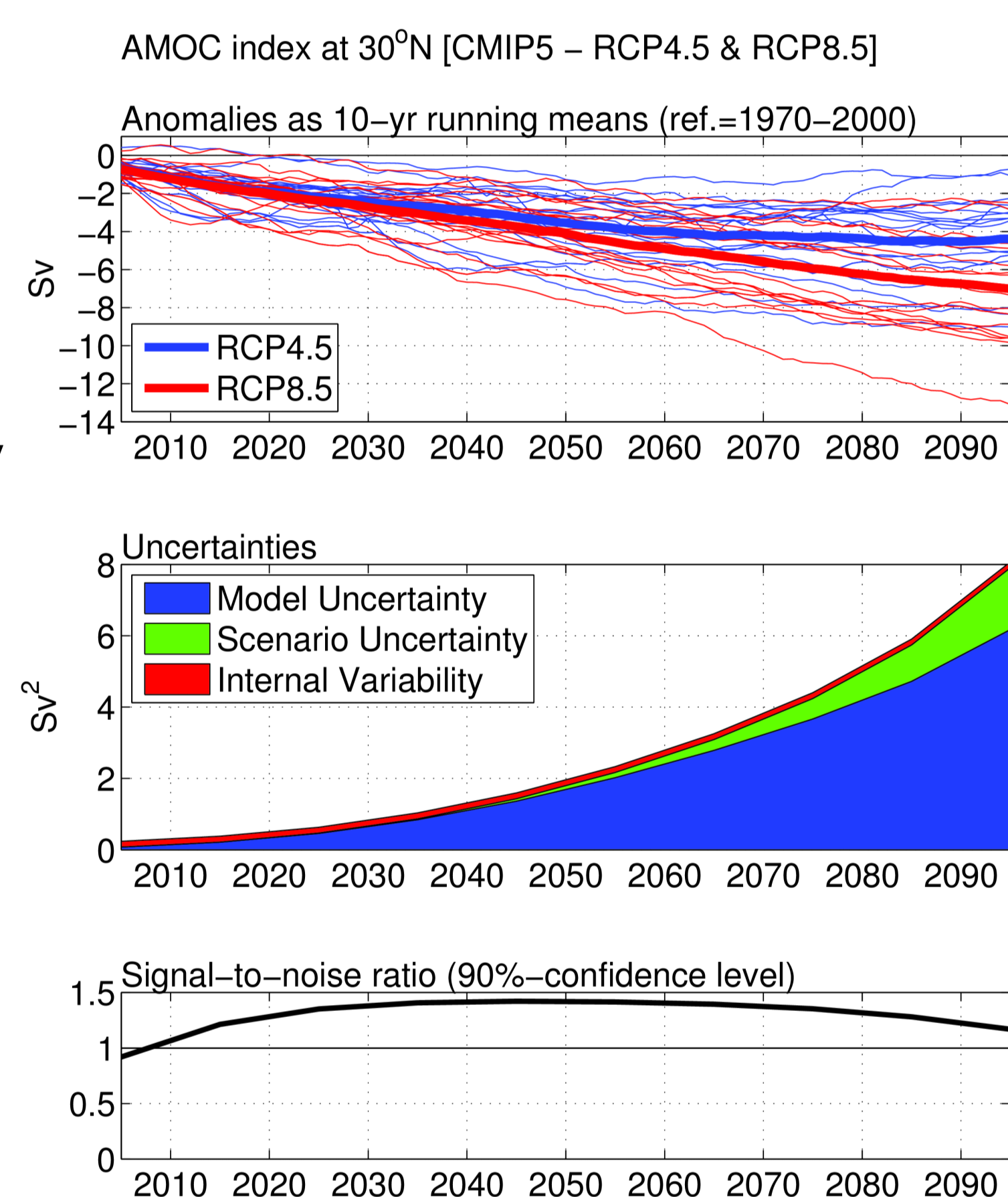
### Statistical method:

We distinguish three sources of uncertainty: internal variability, scenario uncertainty, and model uncertainty. The quantification is based on the method by Hawkins and Sutton (2009). As a reference period we use the years 1970-2000.

## 3 The dominating uncertainty in AMOC projections: Model spread

**Model uncertainty** is the dominating source of uncertainty in AMOC projections. Internal variability is important only during the first few decades and scenario uncertainty only during the last few decades.

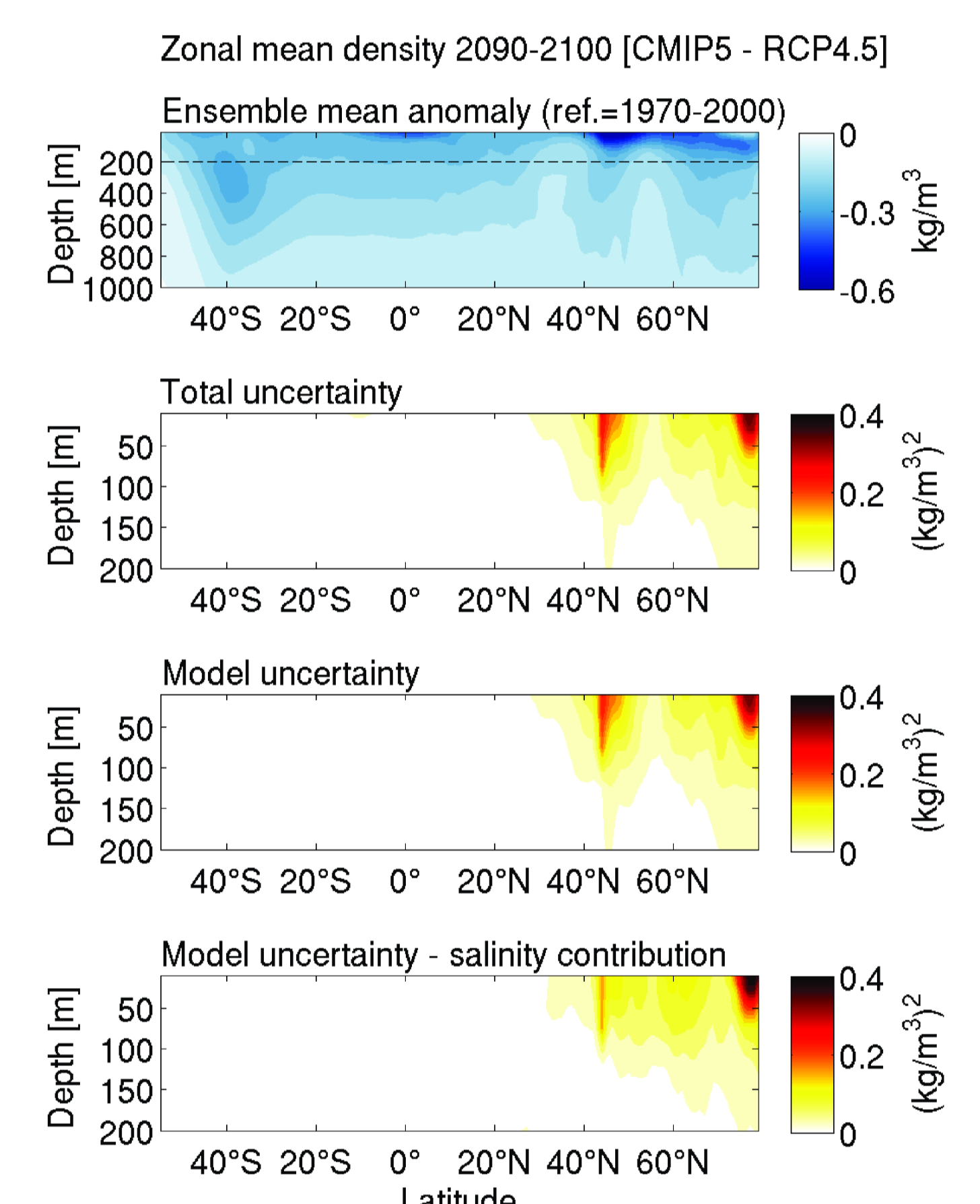
From the year 2010 the signal-to-noise ratio (90%-confidence) exceeds unity. This means that the AMOC's ensemble-mean decadal change is larger than the uncertainty. The signal is therefore detectable.



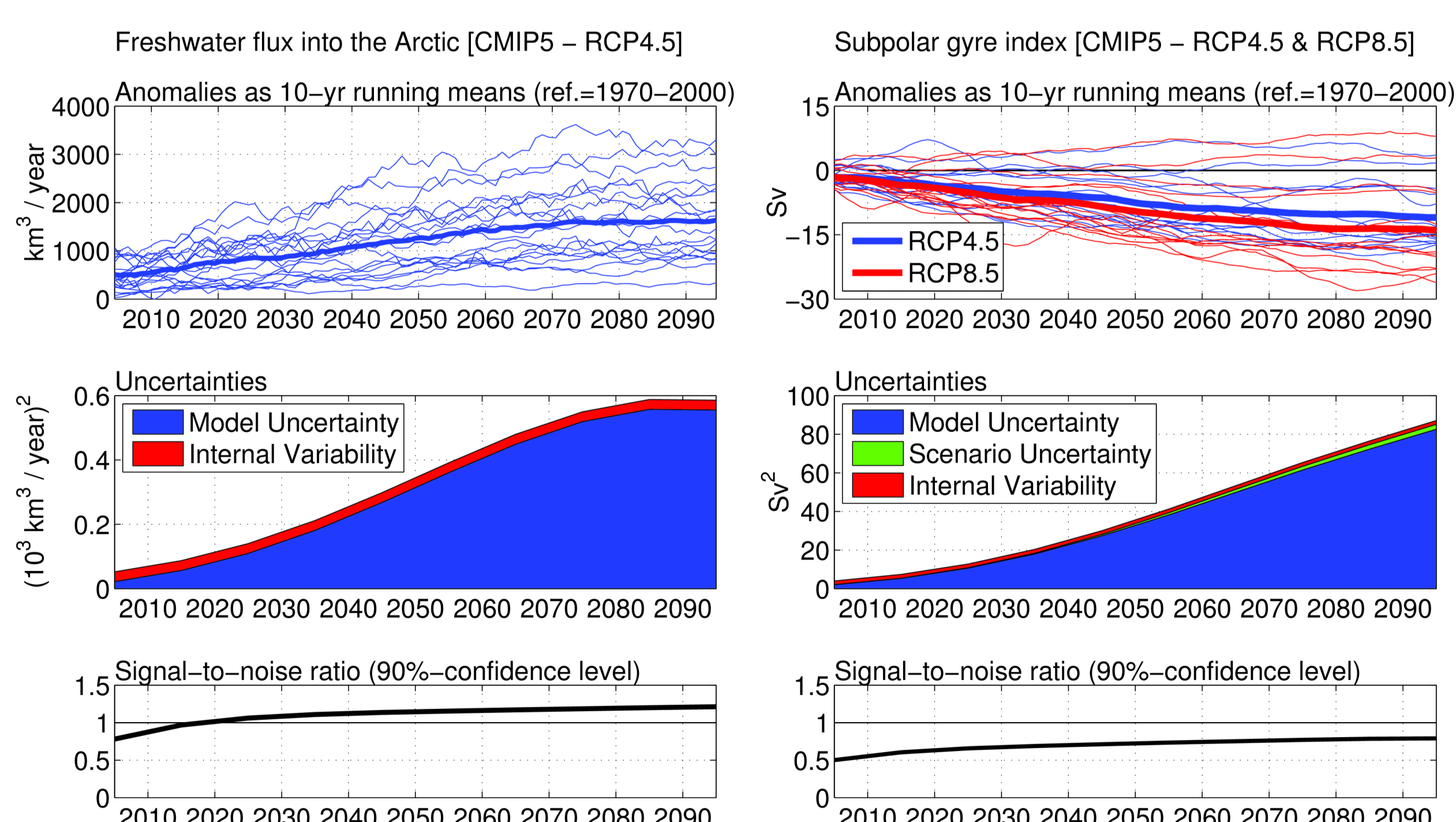
## 4 The source of model uncertainty: Salinity projections

What is the source of such high model uncertainty found in the AMOC projection? The AMOC is density- and wind-driven. We find that wind-driven processes are negligible and **salinity** is the major source for AMOC model uncertainty.

Salinity and consequently density projections are highly uncertain, especially in the surface layers of the high latitudes in the North Atlantic, where the sinking regions of the AMOC are located.



## 5 Uncertain freshwater fluxes and gyre circulation



Salinity changes in the subpolar North Atlantic are driven by freshwater flux at the ocean surface and by horizontal advection, e.g. within the subpolar gyre. Both variables are subject to large model uncertainty.

## 6 Conclusions

All analyzed models project a weakening AMOC for the 21<sup>st</sup> century. Still, the strength of this signal is uncertain.

### Uncertainties in the AMOC projection:

- The major source for uncertainty is the large spread between the models. Model uncertainty dominates over uncertainty arising from the choice of the emission scenario and over internal variability.
- Large model uncertainty in the North Atlantic is also present in the high latitude freshwater flux and in the subpolar gyre. This affects the salinity and consequently the density in the surface layers. The deep-convection sites are affected which finally impacts the AMOC.

### CMIP3 vs. CMIP5

The major findings from the CMIP5 ensemble are confirmed also by the CMIP3 models. Some improvement from CMIP3 to CMIP5 is reflected in the larger signal-to-noise ratio of AMOC and of the high latitude freshwater flux.

Reintges, A., T. Martin, M. Latif, N.S. Keenlyside (2016): Uncertainty in twenty-first century projections of the Atlantic Meridional Overturning Circulation in CMIP3 and CMIP5 models; *Climate Dynamics*

### References

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