The Bjerknes Feedback in the Tropical Atlantic

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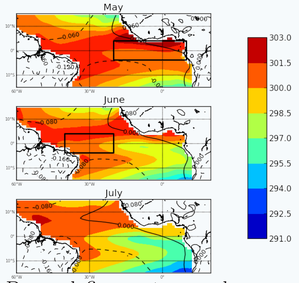
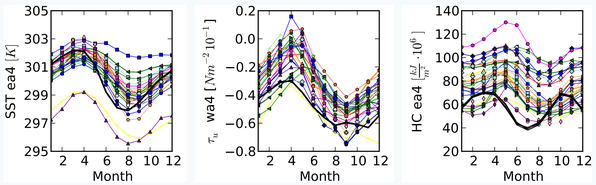
The annual cycle

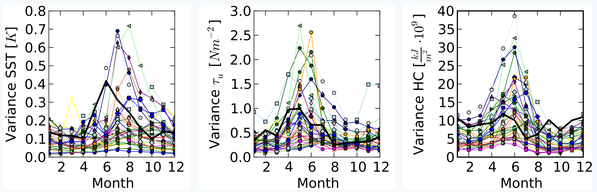
The Bjerknes feedback is closely connected to the annual cycle, the strongest mode of variability in the tropical Atlantic.
Hence, it is important for the models to reproduce the annual cycle. Selected CMIP5 model performance is shown below.



Boxes define eastern and western indices, EA4 and WA4.



Annual cycles of SST (EA4), τ_u (WA4), and HC (EA4).



Annual cycles of variance of SST, τ_u, and HC.

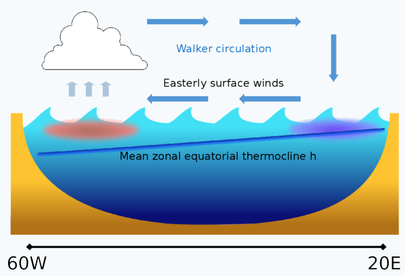
Amost all GCM's fail to reproduce the annual cycle. Both amplitude and timing of the key variables SST, τ_u and HC display large errors. Their inter-annual variances are also incorrect.

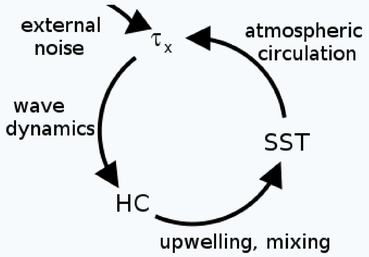
References

ORAS4 ocean reanalysis:
M. A. Balmaseda, K. Morgensen, A. T. Weaver *Q.J.R.Meteorol.Soc. 139* (2013)
ERAInterim atmosphere reanalysis:
D. Dee, S. Uppala et al, *Q.J.R.Meteorol.Soc. 137* (2011)
Model output:
K. Taylor, R. Stouffer, G. Meehl, *Am.Meteorol.Soc. 93* (2012)

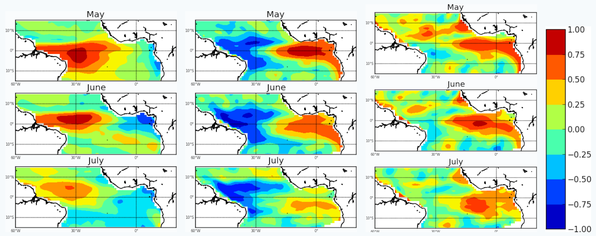
What is the Bjerknes feedback?

- Air-sea interaction in the tropics
- SST'$_{east}$ $\rightarrow$ τ_u'$_{west}$
- τ_u'$_{west}$ $\rightarrow$ HC'$_{east}$
- HC'$_{east}$ $\rightarrow$ SST'$_{east}$



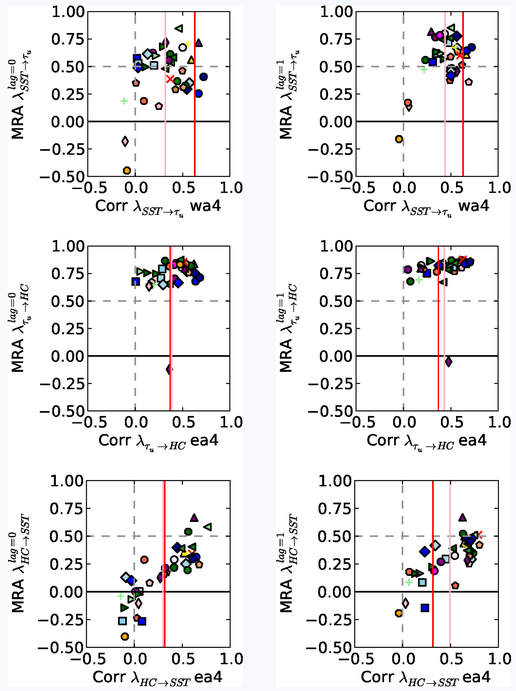


Can we find the Bjerknes feedback in models and reanalysis?



Reanalysis shows significant correlation (when absolute value exceeds 0.35) with distinct patterns between the three variable pairs:
SST $\rightarrow$ τ_u, τ_u $\rightarrow$ HC, and HC $\rightarrow$ SST.
The patterns obtained from the models differ from those to different extents.

The MRA on the y-axis of the plots on the right shows the agreement between model and reanalysis pattern obtained from correlating the variable pairs. On the x-axis the correlation strength between variable a and variable b is shown (averaged over the region of interest, WA4/EA4). The red line shows the reanalysis correlation strength, the pink line the model ensemble average. A model resembling renalysis would be situated on the red line on the intercept with 1 on the y-axis.



SST$\rightarrow$ τ_u roughly located in the upper right without models lagging reanalysis. Improved when correcting for the wrong annual cycle.

While correlation differs, patterns of τ_u $\rightarrow$ HC simulated by GCM's are very similar to renalysis pattern.

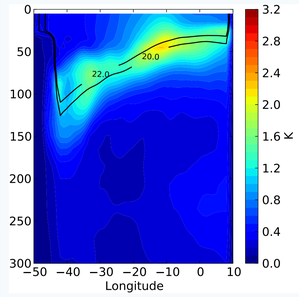
With or without lag, model-reanalysis agreement stays low for HC$\rightarrow$SST.

Abbreviations

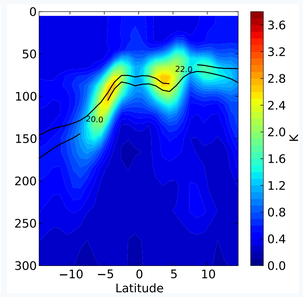
HC: heat content
τ_u: zonal wind stress
MRA: model-reanalysis agreement

Subsurface problems

Comparing subsurface structure of temperature variances gives an explanation for the spatial misrepresentation of HC $\rightarrow$ SST.



Equatorial cross section.



30 ^{o}W cross section.

None of the GCM's can reproduce either profile of the cross sections.

Conclusions

⇒ **GCM's simulate $SST \rightarrow \tau_u$ and $\tau_u \rightarrow HC$ reasonably well**

⇒ **Especially when correcting for errors in seasonality**

⇒ **$HC \rightarrow SST$ "weak link"**

⇒ **Incorrectly modeled subsurface structures**

Subsurface structure errors can be due to problems in ocean modelling as well as atmospheric modelling.

Next steps

- Can wind (stress) correction improve the simulation of the Bjerknes Feedback?
- Design experiments driven by reanalysis wind stress
- Analyze subsurface structure and variability performance in tropical Atlantic