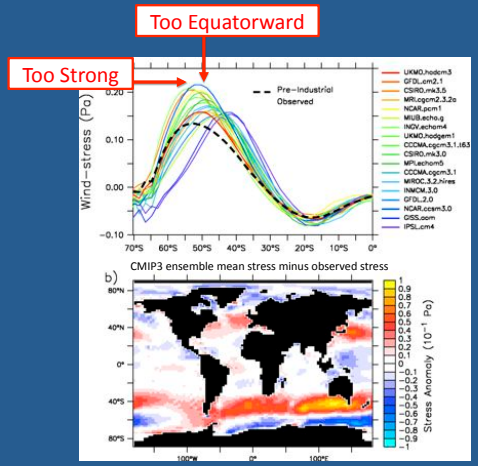
Ocean Carbon Uptake Influenced by Model Wind Bias

Neil C. Swart[1] and John C. Fyfe[2]

[1]School of Earth and Ocean Sciences, University of Victoria, Victoria, BC, Canada (ncswart@uvic.ca).
[2]Canadian Centre for Climate Modelling and Analysis, Victoria, BC, Canada.

UVic Climate Modelling Group

1. Pre-Industrial Wind-Stress Bias



The CMIP3 models pre-industrial Southern Hemisphere winds shown here are systematically equatorward displaced and strong biased relative to an observed pre-industrial wind-stress derived from four reanalysis products including the NOAA-CIRES 20th century reanalysis[1]. The available CMIP5 models show a similar bias.

2. Question:

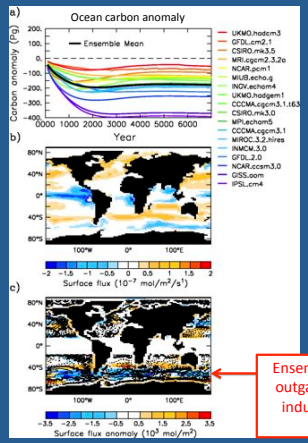
Is ocean carbon uptake in coupled carbon-climate models influenced by model pre-industrial wind-stress bias?

3. Experimental Design

The UVic ESCM[2] is forced with the pre-industrial wind-stress from 18 CMIP3 models and compared with a control run using observed winds.

Using a single intermediate complexity model forced with the CMIP3 winds eliminates the influence of inter-model differences (e.g. ocean mixing) and isolates the effect of wind-biases on ocean carbon.

4. Reduced Equilibrium Carbon Storage

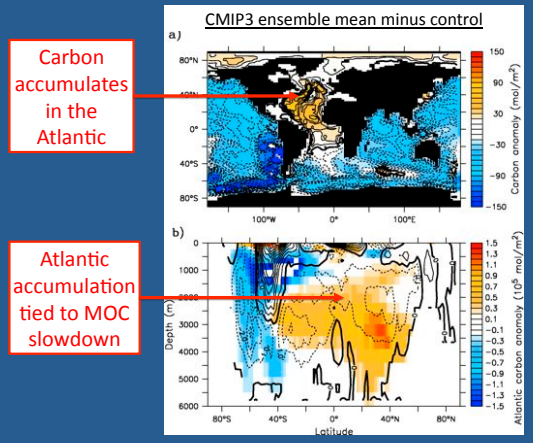


(a) Wind-stress biases reduce equilibrium carbon storage relative to the control.

(c) For the CMIP3 ensemble mean, positive Ekman pumping anomalies (contours) in the Southern Ocean lead to anomalous outgassing (shading). Fields time-integrated from year 0 –2000. Maps show CMIP3 ensemble mean minus control.

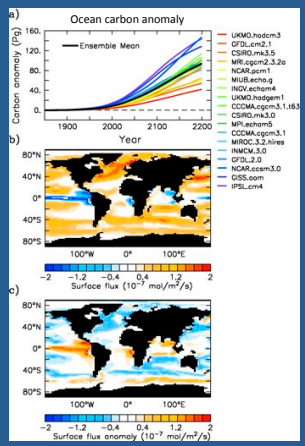
Ensemble mean anomalous outgassing driven by wind-induced Ekman pumping anomalies.

5. Changed Ocean Carbon Distribution



(a) Wind-biases cause carbon accumulation in the Atlantic, with reduced carbon storage in the Pacific for the CMIP3 ensemble mean relative to the control.
(b) The Atlantic accumulation is associated with a slowdown of the MOC. The MOC slowdown occurs because the CMIP3 equatorward biased winds reduce the Indo-Atlantic salt flux (Agulhas leakage). See the paper for a model-by-model breakdown.

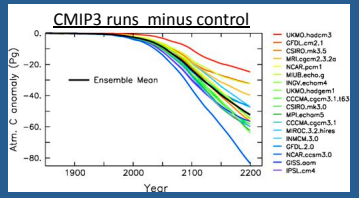
6. Excessive Transient Carbon Uptake



(a) CMIP3 runs overestimate ocean carbon uptake relative to the control under emissions that are historical (1850 -2000), then SRES A2 (2000 – 2100), and constant thereafter.
(c) Increased uptake is due to anomalously low equatorial outgassing. This is caused by low deep-water carbon concentrations established in pre-industrial equilibria (4). Maps show CMIP3 ensemble mean minus control.

7. Reduced Atmospheric CO_2

•Atmospheric CO_2 concentrations in the 21st century are lower in the CMIP3 runs than in the control. This results from the excessive ocean carbon uptake in (6).



8. Conclusions and Implications

•CMIP3 pre-industrial wind-stress biases lead to:

1. Reduced equilibrium ocean carbon storage.
2. Redistribution of carbon in the ocean.
3. Excess ocean carbon uptake during climate-change experiments.
4. An under-estimate of 21st century atmospheric CO_2, and thus an altered carbon-climate response.

•The available CMIP5 models show similar wind-biases too, which will likely lead to the carbon cycle errors we describe, relative to simulations with unbiased winds.

9. References

[1]Compo, G.P. et al., The Twentieth Century Reanalysis Project, Q. J. Roy. Meteor. Soc., 654, 1-28 (2011).
[2]Weaver, A.J et al., The UVic Earth System Climate Model: Model Description, Climatology, and Applications to Past, Present and Future Climates, Atmos. Ocean, 29, 1-68 (2001).

For details see: Swart, N.C. and J.C. Fyfe, Ocean carbon uptake and storage influenced by wind bias in global climate models, *Nature Climate Change*, (in press).