



Impact of internal oceanic variability on simulated oxygen distributions and associated mechanisms.

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The influence of interannual variability of physical forcing on the mean ocean oxygen state is tested in two model simulations using the PISCES ocean biogeochemical model. PISCES is forced by a monthly output from (1) 500 years of interannually varying physical fields (IAV), and (2) 500 years of the constant climatology calculated from the IAV physical fields (CLIM). Unexpectedly, while the 500 years mean of the physical fields is identical, we find that the 500 years mean biogeochemical fields of the two experiments differ. These differences must originate from non-linearities in either physical or biogeochemical processes. On a global annual average, both experiments slightly overestimate oxygen concentrations in the upper ocean and underestimate observed oxygen concentrations in the deep ocean. In some oceanic regions, the inclusion of interannual variability in the forcing considerably improves the representation of the temporal mean oxygen concentration. This is especially found in the eastern equatorial Pacific (EEP), which harbors one of the largest oxygen minimum zones (OMZ) of the ocean. The better (lower) EEP oxygen concentrations in IAV may be explained by larger differences in the subduction regions of the Southern Ocean, the main oxygen source ventilating the EEP. Here in the IAV experiment oxygen concentrations are considerably lower in almost the entire water column, except for the very surface layer, so that less oxygen is entering the ocean. We find that in IAV the surface ocean is more stratified with regard to biogeochemical variables (e.g. oxygen, nutrients, ideal age). Especially an increase in the ideal age of water masses in the subsurface Southern Ocean, accompanied by stronger oxygen depletion, strongly points towards a higher sensitivity of ocean mixing to phases of stronger stratification (compared to climatological mean conditions) and a weaker influence of anomalously strong (deep) mixing, which would tend to reduce vertical gradients. Additional sensitivity experiments, systematically isolating the impact of interannual variability on either ocean physics or biogeochemistry, indeed reveal that the non-linear physical processes (mixing) play a dominant role in driving this difference between the two runs, whereas biogeochemical processes (e.g. oxygen solubility, temperature dependent remineralization) play a minor role. Overall our experiments suggest that the common strategy to spin-up biogeochemical models with a constant climatological forcing has some caveats as the internal variability of the circulation fields may result in a different oxygen mean state. This may lead to the erroneous interpretation of interannually forced (e.g. transient) model experiments that are started from a biogeochemical spin-up forced by a constant climatology. Furthermore, a change in the mean biogeochemical state of the ocean is not necessarily associated with a change in the mean climate, but could also be driven by changed climate variability.