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Air-sea interaction constrains on effective and transient climate sensitivity

Jacek Piskozub
Institute of Oceanology PAS, Physical Oceanography, Sopot, Poland (piskozub@iopan.gda.pl)

The reason the Earth has a radiative imbalance in the warming world is its heat capacity, due mostly to the existence of oceans. The air-sea heat flux into the ocean comprises over 90% of the imbalance, making (paradoxically) the oceans the best place to measure the difference between downwelling shortwave and upwelling longwave top-of-the-atmosphere radiative fluxes. This difference will be present until the oceans adjust to the radiative forcing which takes centuries. In a world of ever increasing radiative forcing this creates the difference between observed ("effective") and equilibrium temperature (and hence between effective and equilibrium climate sensitivity).

The way oceanographers calculate heat fluxes across the air-sea interface is by "bulk formulas" assuming it being proportional to the difference of temperature between surface air and water layers. I used the same approach to the difference of temperature anomalies between the Earth surface and bulk ocean, the latter being the effect of cumulative air-sea heat flux. The approach builds in the concept of "ocean heat uptake efficiency" but makes it explicitly dependent on past heat uptake by the ocean. This is tantamount to assuming that mixing in the ocean will not change which as a first approximation is supported by reconstruction of overturning volumes in past climates (even if some decrease in mixing is expected in future due to increased stratification). This simple assumption allows calculating the ratios of transient and equilibrium climate sensitivities as well as effective sensitivity values for different scenarios of radiative forcing changes, without using circulation models. The results showing the effective sensitivity values as a function of lime are approximate due to the simple assumption but may be used to constrain the transient sensitivity from above (meaning a constrain of equilibrium/transient sensitivity ratio from below) basing on ocean mixing not expected to increase in a warming world.