Understanding the role of ocean feedback in a Fully coupled ocean-atmosphere interaction

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Introduction

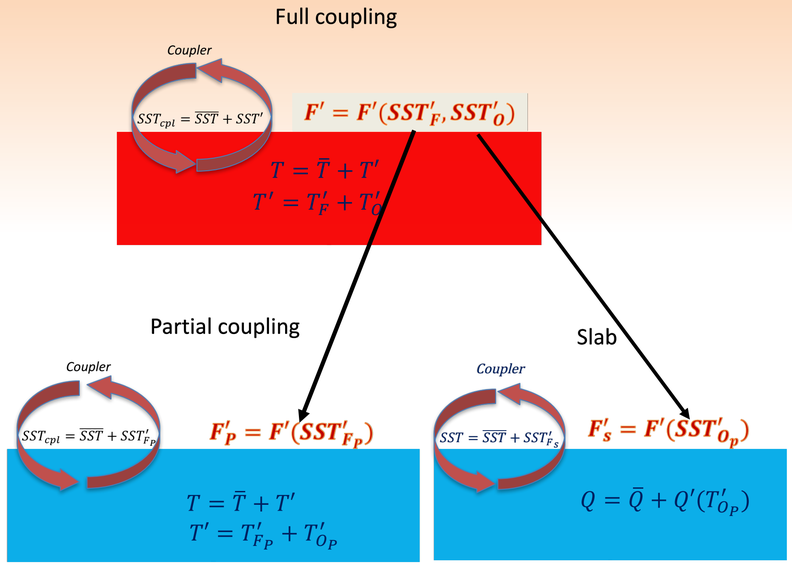
CO_2 increase forces SST anomalies both directly through radiative effect and indirectly through ocean circulation change. Ocean circulation change can feedback to surface interactions to modify climate sensitivity by changing the spatial pattern of ocean heat uptake (OHU). To date the exact role of ocean circulation change is yet to be separated from the fully coupled response to CO_2 forcing. We use a new experimental design, implemented in the CESM system to isolate this ocean dynamical feedback and its effects on SST and OHU.

Method

- Ocean temperature anomaly is decomposed using passive tracers, into components due to surface heat flux and ocean circulation anomalies respectively, both in fully coupled and partially coupled simulations
- Partial coupling is achieved by removing the ocean-circulation-change-induced SST anomaly in the bulk formula for surface heat flux
- A slab model simulation is performed with a Q-flux anomaly forcing, diagnosed from the mixed layer heat content anomaly component, due to the ocean circulation change from the partially coupled simulation

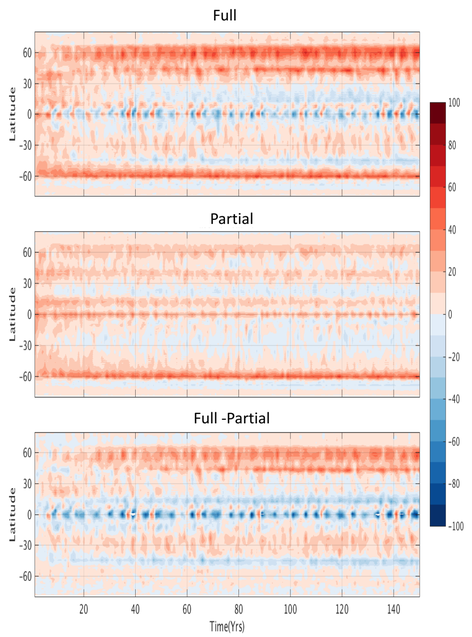
Experiments

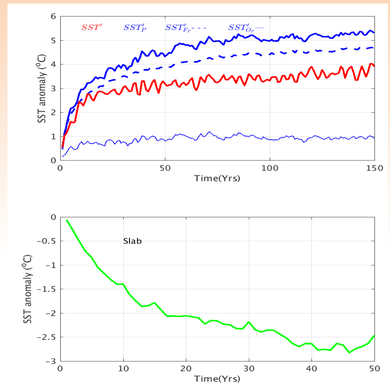
Name	Run (Yrs)	Description
Full	150	Fully coupled 4xCO_2 abrupt experiment (*Full SST response coupled to the atmosphere*)
Partial	150	Partially coupled 4xCO_2 abrupt increase experiment (*Decomposed ocean heat conv. SST anomaly response is removed from coupling*)
Slab	50	Slab OHU ocean experiment (*Q-flux anomaly derived from ocean heat conv. temperature anomaly component*)



Heat uptake Pattern

- Passive OHU pattern (Partial) evolves quickly (within the first 20-yrs)
- Active OHU pattern due to ocean dynamical feedback (Full –Partial) evolves more slowly (within first 70-yrs.)
- Passive and active OHU response has both low and high latitude patterns.
- Passive OHU causes the Southern high latitude uptake.
- Active OHU causes large Northern high latitude and negative tropical uptake





Global average SST

- The change of ocean circulation change by itself, acts to warm the net global SST in the partially coupled simulation (i.e. SST'_{O_P}).
- With feedback from the atmosphere (in the fully coupled ($SST' - SST'_P$) and slab runs), it acts to cool SST

Climate sensitivity

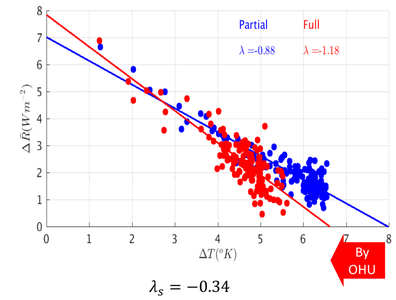
$$R(t) = F(t) - \lambda \Delta T(t)$$

- The total climate feedback parameter (CFP) can be decomposed into passive and active ocean components i.e.

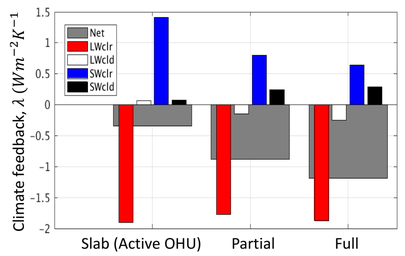
$$\lambda_f \simeq \lambda_p + \lambda_s$$

(f=full; p=partial; s=slab)

- The active OHU reduces climate sensitivity by increasing CFP from λ_p to λ_f
- Efficacy of active OHU > 1 i.e ($\varepsilon = \frac{\lambda_{co2}}{\lambda_s} = \frac{-0.75}{-0.34} = 2.2$; λ_{co2} is from 4xco2 increase slab run with climatological Q-flux (not shown))
- Efficacy of active OHU attributed to the larger SW clr feedback



$\lambda_s = -0.34$



Conclusions

- Partial coupling experiment succeeds in separating the OHU pattern forced directly by CO_2 increase from that induced by ocean circulation change.
- OHU pattern caused by ocean circulation change is characterized both positive N.H. high latitude uptake and negative uptake in the tropics.
- This ocean dynamical change induced OHU has an efficacy of 2.2, thanks to the enhanced positive clear sky SW feedback.