South Asian Monsoon Response to Weakening of Atlantic Meridional Overturning Circulation in a Warming Climate

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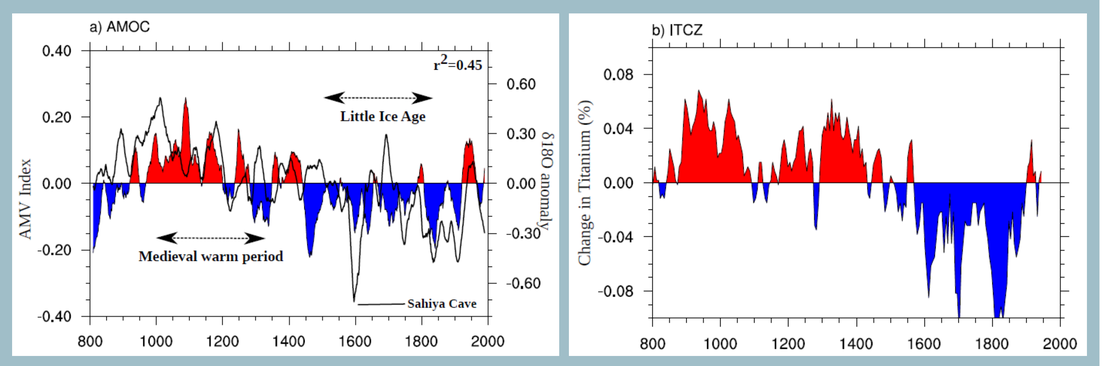
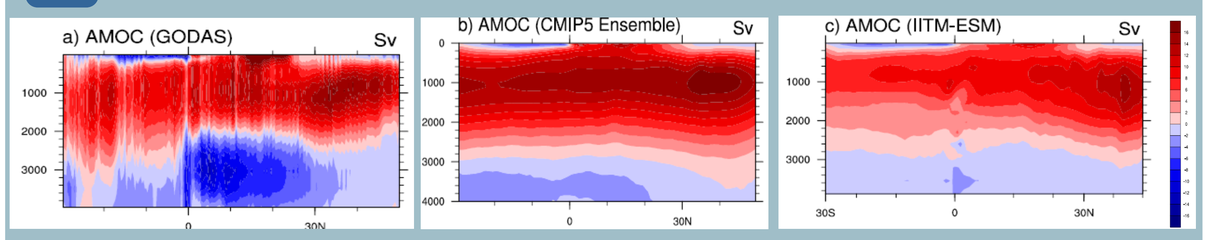
Abstract

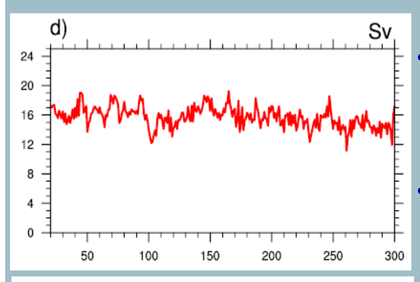
- Observational records and climate model projections reveal a considerable decline in the Atlantic Meridional Overturning Circulation (AMOC). Changes in the AMOC can have a significant impact on the global climate. Sustained warming due to increased greenhouse gas emissions is projected to weaken the AMOC, which in turn can lead to changes in the location of Inter-tropical Convergence Zone (ITCZ), oceanic and atmospheric large-scale circulation, tropical precipitation and regional monsoons.
- Using proxy records, observations and CMIP6 simulations of IITM Earth System Model (IITM-ESM), we investigate the changes in the AMOC and associated changes in the large-scale circulation and precipitation patterns over the South Asian monsoon region. Transient CO2 simulation and additional model sensitivity experiments with realistic surface heat and freshwater perturbation anomalies under the experimental protocol of Flux Anomaly Forcing Model Intercomparison Project (FAFMIP) performed with IITM-ESM reveal a decline in the strength of AMOC.
- The weakening of AMOC is associated with enhanced heat and freshwater forcing in the North Atlantic resulting in the reduction of northward oceanic heat transport and an enhanced northward atmospheric heat transport. Changes in AMOC lead to weakening of large-scale north-south temperature gradient and regional land-sea thermal gradient, which in turn weaken the regional Hadley circulation and, monsoon circulation over the South Asian region.
- Both the FAFMIP and transient CO_2 experiments reveal consistent results of weakening South Asian Monsoon circulation with a decline of AMOC, while precipitation exhibits contrasting responses as precipitation changes are dominated by the thermodynamic response. The suite of observational and numerical analysis provides a mechanistic hypothesis for the weakening of South Asian monsoon circulation concomitant with a weakening of AMOC in a warming climate.

Proxy data evidence

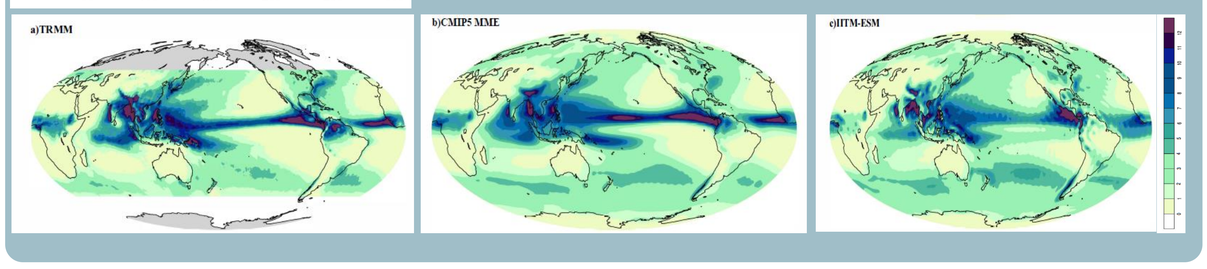
Association between AMOC and South Asian monsoon







- **300 year Preindustrial-control simulation from IITM-ESM shows a realistic representation of Atlantic meridional overturning circulation (AMOC), one of the dominant climate drivers.**
- **Global and South Asian summer monsoon are also well simulated**



FAFMIP; FAF-HEAT and FAF-FRESH

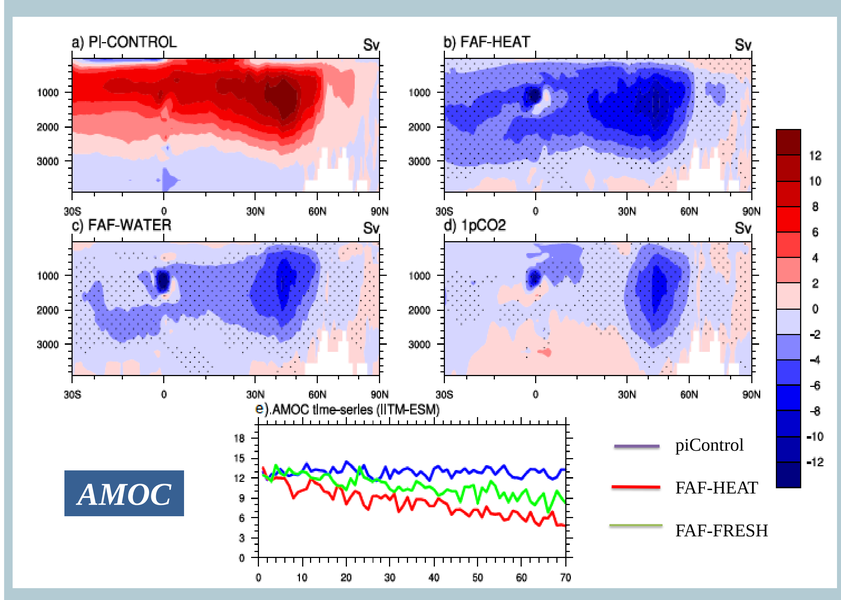
•Net Surface heat flux (W/m^2) anomaly used as forcing

•Net Precipitation – evaporation ($kg/m^2.s^{-1}$) anomaly used as forcing

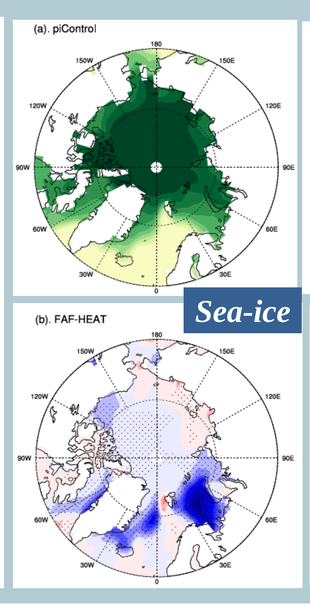
- Partitioning of the temperature change between effects of local addition of heat and changing heat transports using 3dimensional ocean tracers; Added heat (T_A)and Redistributed heat (T_R)
- T_R is a passive tracer (it doesn't affect density)
- We initialize T_R to potential temp (theta) at the start of the experiment.
- T_R gets transported similar to theta; except it doesn't feel the perturbation (F)
- SST is computed from T_R and therefore not directly affected by F.
- T_A is the added heat tracer which can only feel the perturbation.
- T_R deviates from the potential temperature as the time progresses; and perturbation is felt directly by T_A

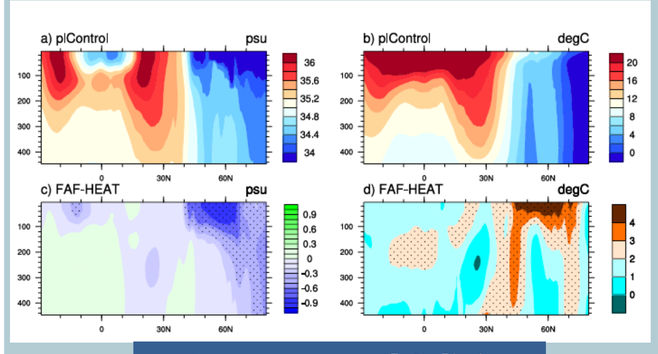
$$\frac{\partial \theta_p}{\partial t} = \frac{\partial T_R}{\partial t} + \frac{\partial T_A}{\partial t}$$

Response of AMOC to FAFMIP and 1pctCO2

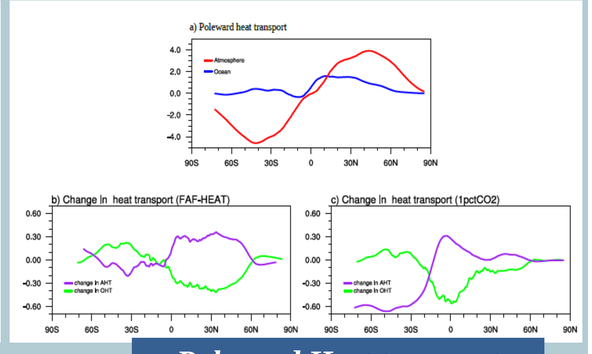


AMOC





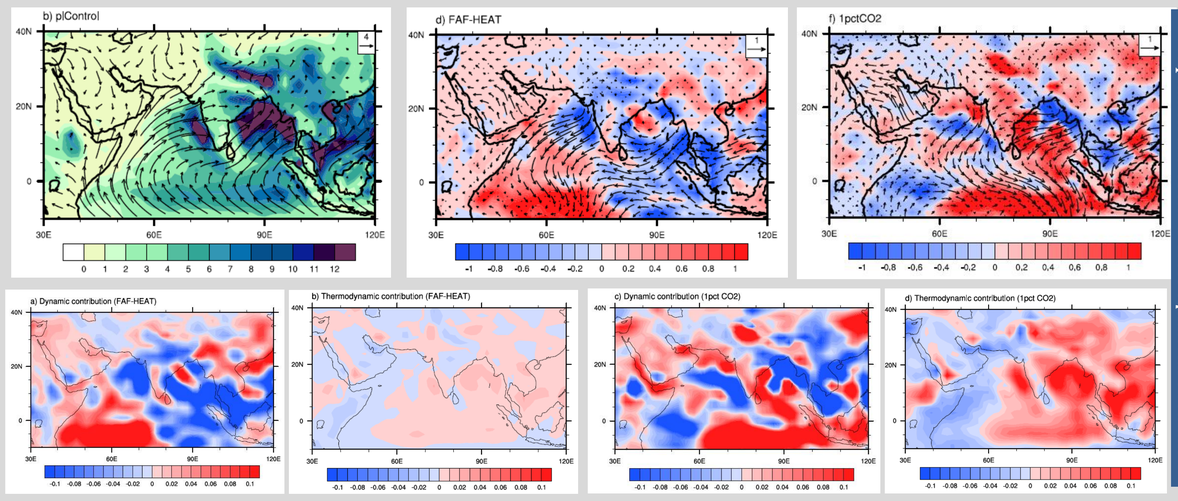
Temperature and Salinity



Poleward Heat transport

South Asian monsoon response to weakening of AMOC

- It is interesting to note that there is a considerable decline in the Atlantic OHT in FAF-HEAT associated with a weakening of AMOC .
- The reduction of OHT is associated with a cooling in the Northern hemisphere (NH) and warming in the Southern hemisphere. In FAF-HEAT, we observe a north-south temperature gradient with cooling in the northern hemisphere and warming in the southern hemisphere.
- This inter-hemispheric SST difference in-turn leads to a southward shift of the ITCZ, as ITCZ is located in the warmer.



Water vapor budget

Highlights

- We distinguish the process of AMOC weakening quantitatively by imposing surface heat fluxes (FAF-HEAT) and fresh water fluxes (FAF-WATER) individually. We find an enhanced weakening of AMOC in FAF-HEAT rather than FAF-WATER experiment indicating the importance of the heat flux on AMOC weakening
- The second novel aspect of our study is with a suite of experiments we demonstrate that the South Asian monsoon circulation weakens in response to weakening AMOC, while precipitation changes are dominated by thermodynamic response.

References

Sandeep et al., (2020) South Asian Monsoon Response to Weakening of Atlantic Meridional Overturning Circulation in a Warming Climate (Accepted)

Swapna et al., (2018). Long-Term Climate Simulations Using the IITM Earth System Model (IITM-ESMv2) with Focus on the South Asian Monsoon. doi: https://doi.org/10.1029/2017MS001262