Cooling or Warming Atmosphere due to Slowing down of the Atlantic Meridional Overturning circulation (AMOC) ?

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Abstract

The IPCC predicted that it is “very likely” that the AMOC would experience a slowing during the 21st century. Most global climate models predict that Europe should cool in response to such an AMOC reduction. And yet, recent nonlinear analytical calculations (Sandal and Nof, 2008, JPO) as well as physical principles, suggest that local regions should exhibit warming, not cooling. The idea behind the warming is that, since the water heat capacity is much larger than that of the air, and, since the air-sea heat flux is proportional to the temperature difference between the warmer ocean and the cooler atmosphere, the heat flux can only significantly reduce when the atmosphere warms and the ocean (slightly) cools.

Background

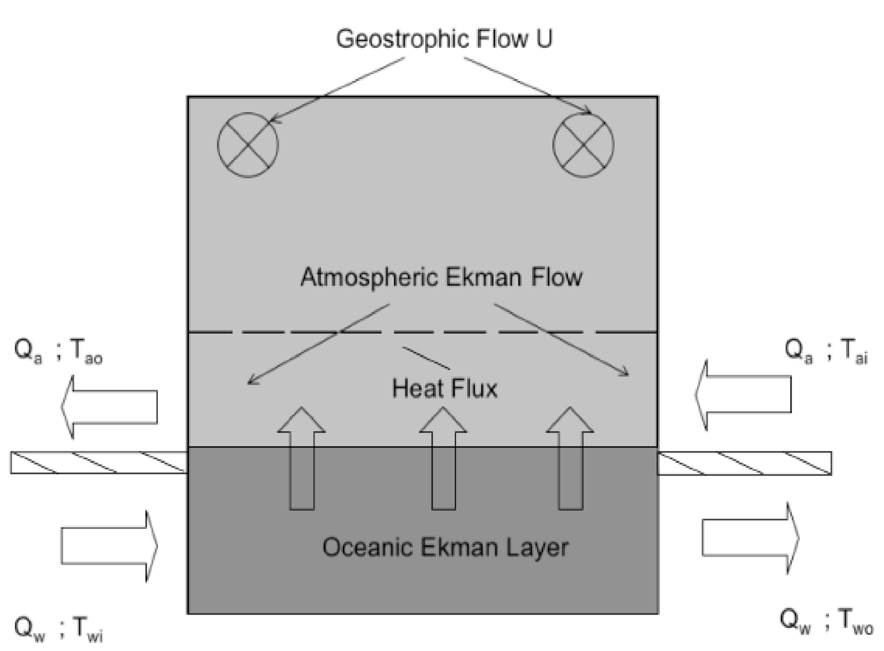
Numerical models (e.g. Stouffer et al 2006) based on hosing experiments suggest that a reduction in AMOC transport results in a reduced heat flux to the atmosphere. Therefore, less heat is transferred to the atmosphere which means that the atmosphere cools and there is less warming.

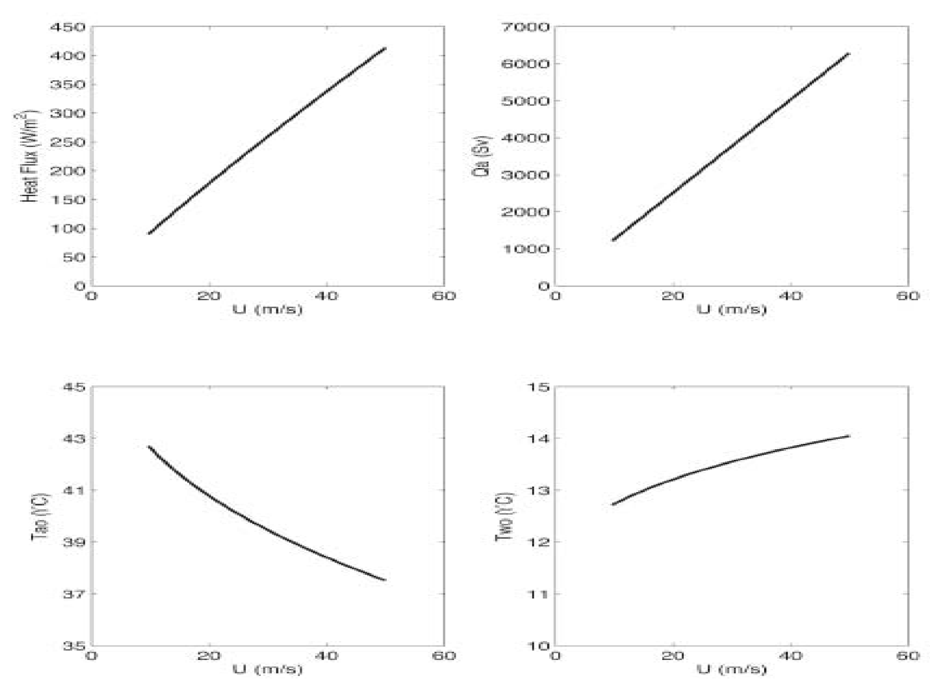
However, preliminary results show that there will be “local” warming.

A One Dimensional Jet model (Nof et al. GAFD 2009, *submitted*)

Heat exchange between the ocean and the atmosphere can be explained through an ultra simple one dimensional model. An atmospheric jet with a geostophric speed U and width L forces an atmosphere and ocean Ekman layers, whose mass transports are equal and opposite to each other and to the heat exchange. There is *no convection* in this model and it shows that upon decreasing U, both the mass transports and the heat flux reduce but the exiting atmospheric temperature increases.

Analytical solution for the One Dimensional Jet Problem





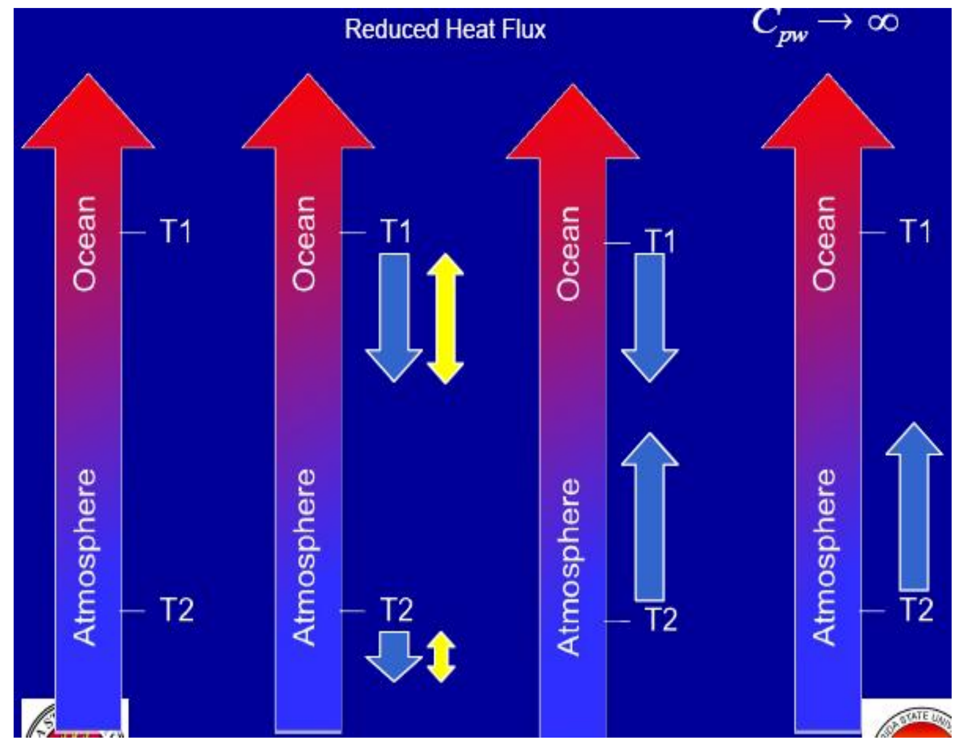
The plots on the right show that upon decreasing U, both the mass transports and the heat fux reduce but the exiting atmospheric temperature increases.

Key Points

Latent and sensible heat fluxes are proportional to the temperature difference $(T_W - T_A)$

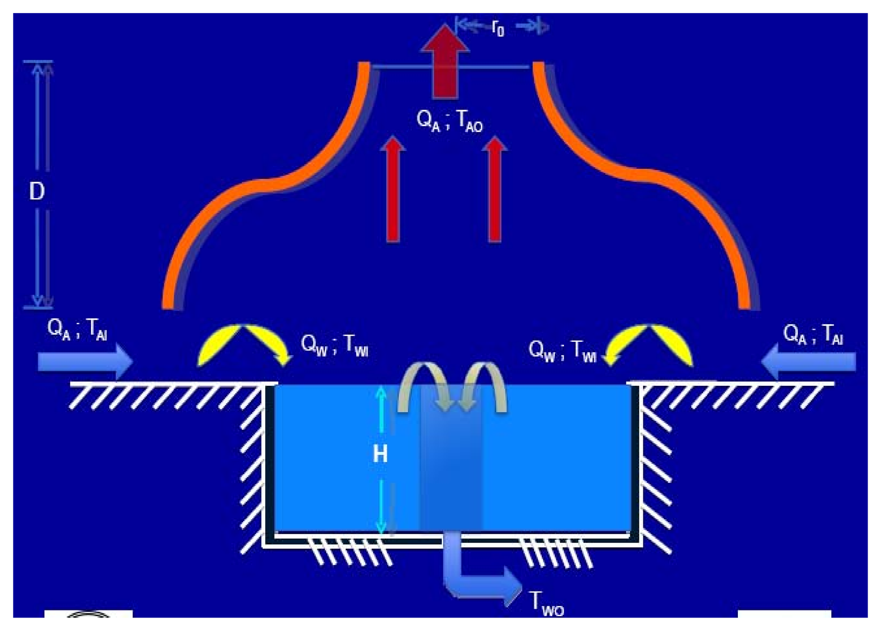
Heat Capacity of water is four times the heat capacity of air.

Only way to significantly decrease the heat flux is to warm the air.



Current work: The Conceptual Hot Spring Model

Heat exchange between the ocean and the atmosphere can also be explained by *including convection.* We use a conceptual hot spring model to show that when the transport of water decreases, the heat flux to the atmosphere decreases, the atmosphere warms not cools.



High temperature water is responsible for heating the air closer to the hot spring and hence generating convection in the atmosphere

Warm water loses its heat to the atmosphere.

Summary

- Lowering transport results in smaller amount of air participating in convection and hence reducing the heat flux.
- A reduced heat flux from the ocean to the atmosphere causes the ocean to cool and the atmosphere to *warm, not cool.*

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References

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Sandal, C. and D. Nof, 2008: A new analytical model for Heinrich events and climate instability.*J. Phys. Oceanogr.,* 38, 451-466.