National Oceanography Centre

Ocean Heat Transport's Response to Future Climate Projections

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CMIP5/CMIP6 Data

A reference period (2070-2099) of rcp.26/ssp126 and rcp8.5/ssp585 future climate projections are compared to a reference period (1970-1999) of the historical simulation.

CMIP5 (16 historical, rcp2.6 and rcp8.5):

bcc-csm1-1, bcc-csm1-1-m, BNU-ESM, CanESM2, CCSM4, CESM1-CAM5, CNRM-CM5, GFDL-ESM2G, GFDL-ESM2M, GISS-E2-R, IPSL-CM5A-LR, IPSL-CM5A-MR, MPI-ESM-LR, MPI-ESM-MR, NorESM1-M, NorESM1-ME

CMIP6 (12 historical, ssp126 and ssp585):

ACCESS-CM2, ACCESS-ESM1-5, BCC-CSM2-MR, CAMS-CSM1-0, CESM2-WACCM, CNRM-CM6-1, CNRM-ESM2-1, FGOALS-f3-L, HadGEM3-GC31-LL, IPSL-CM6A-LR, MPI-ESM1-2-LR, UKESM1-0-LL

Ocean Heat Transport Computation

Total Heat Transport

$$H(y,t) = \rho_o c_p \int_{-h}^{0} \int_{x_W}^{x_E} v^* T \, dx dz$$

Overturning Heat Transport

$$H_{ov}(y,t) = \rho_o c_p \int_{-h}^{0} \int_{x_W}^{x_E} \langle v^* \rangle \langle T \rangle \, dx dz$$

Azonal (a.k.a. Gyre) Heat Transport

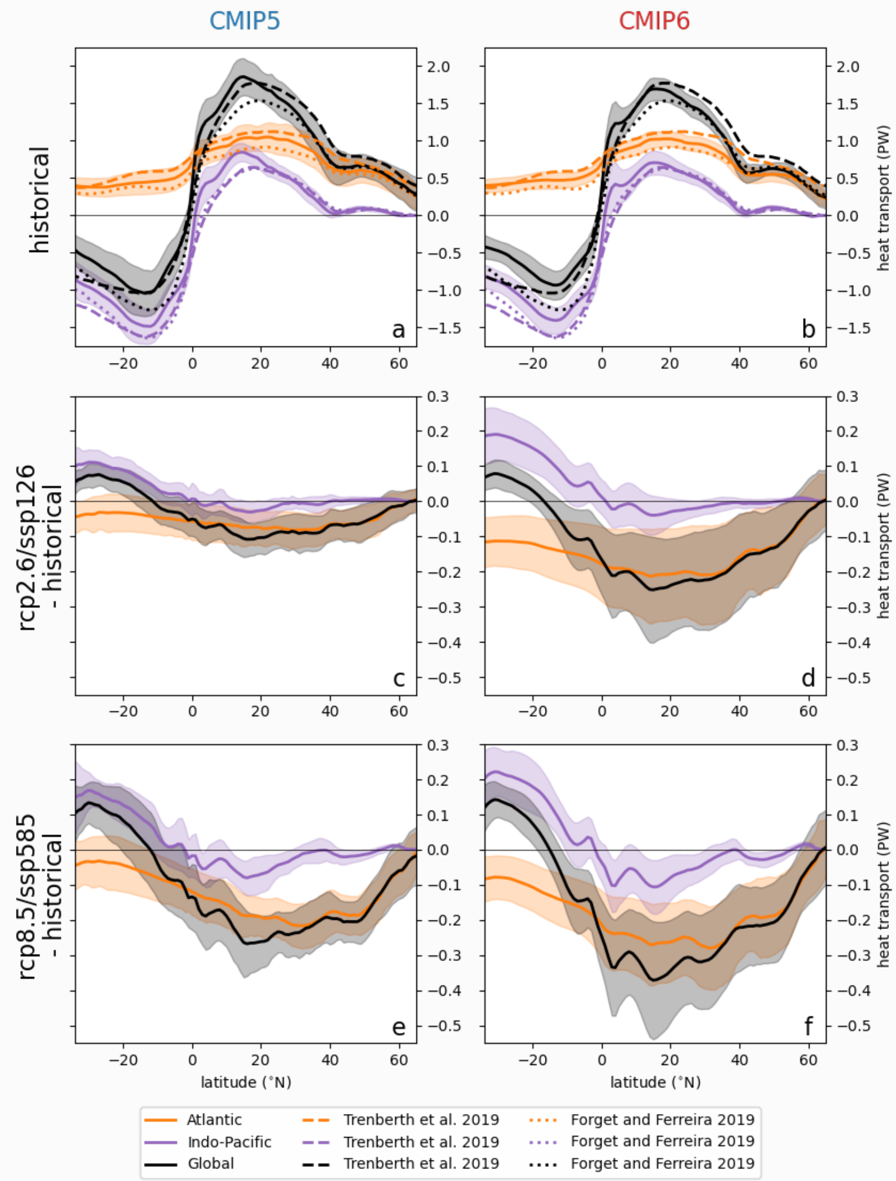
$$H_{az}(y,t) = \rho_o c_p \int_{-h}^{0} \int_{x_W}^{x_E} v^{*\prime} T' \, dx dz$$

Where: $v^* = v - \dfrac{\int_{-h}^{0} \int_{x_W}^{x_E} v \, dx dz}{\int_{-h}^{0} \int_{x_W}^{x_E} dx dz}$ $\quad \langle \cdot \rangle = \dfrac{\int_{x_W}^{x_E} \cdot \, dx}{\int_{x_W}^{x_E} dx}$ $\quad \cdot' = \cdot - \langle \cdot \rangle$

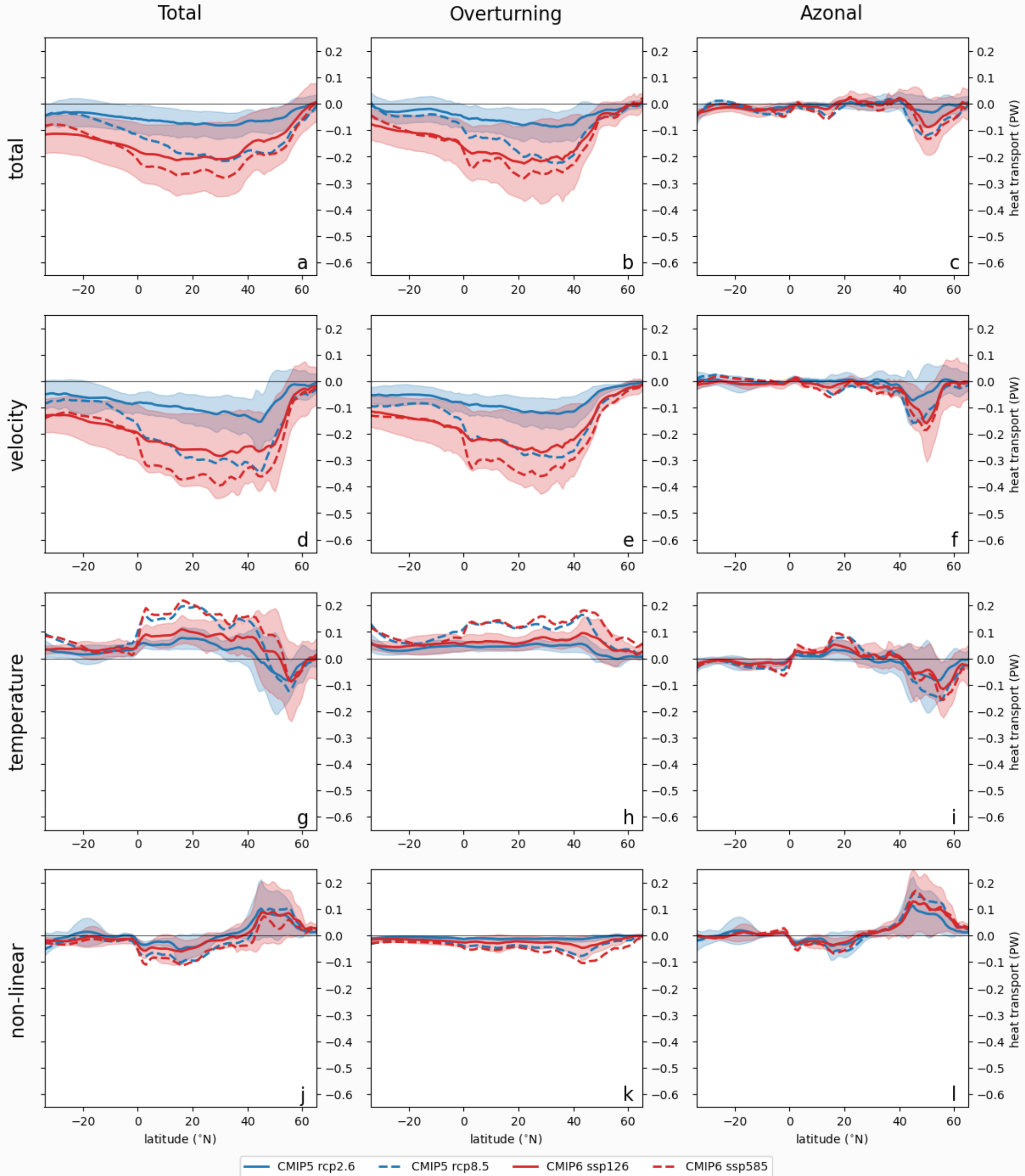
Temperature driven changes: v held constant using 1970-1999 seasonal cycle
Velocity driven changes: T held constant using 1970-1999 seasonal cycle
Non-linear changes = OHT – Temperature Driven Changes – Velocity Driven Changes

Changes in OHT

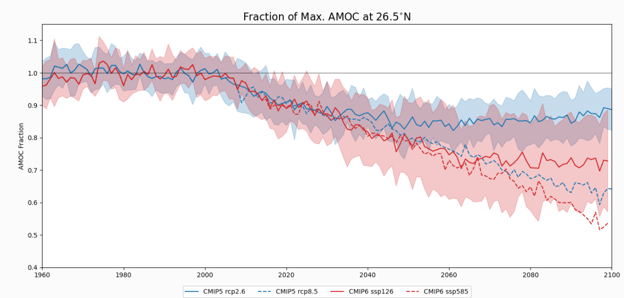
- Little difference between CMIP5 and CMIP6 historical mean Ocean Heat Transport (OHT)
- In the Atlantic the northward OHT is reduced throughout the entire basin
- In the Indo-Pacific mainly the poleward OHT is reduced in the southern hemisphere
- The response of the OHT in CMIP6 relative to CMIP5 is much larger and most notable for the weaker rcp2.6/ssp126



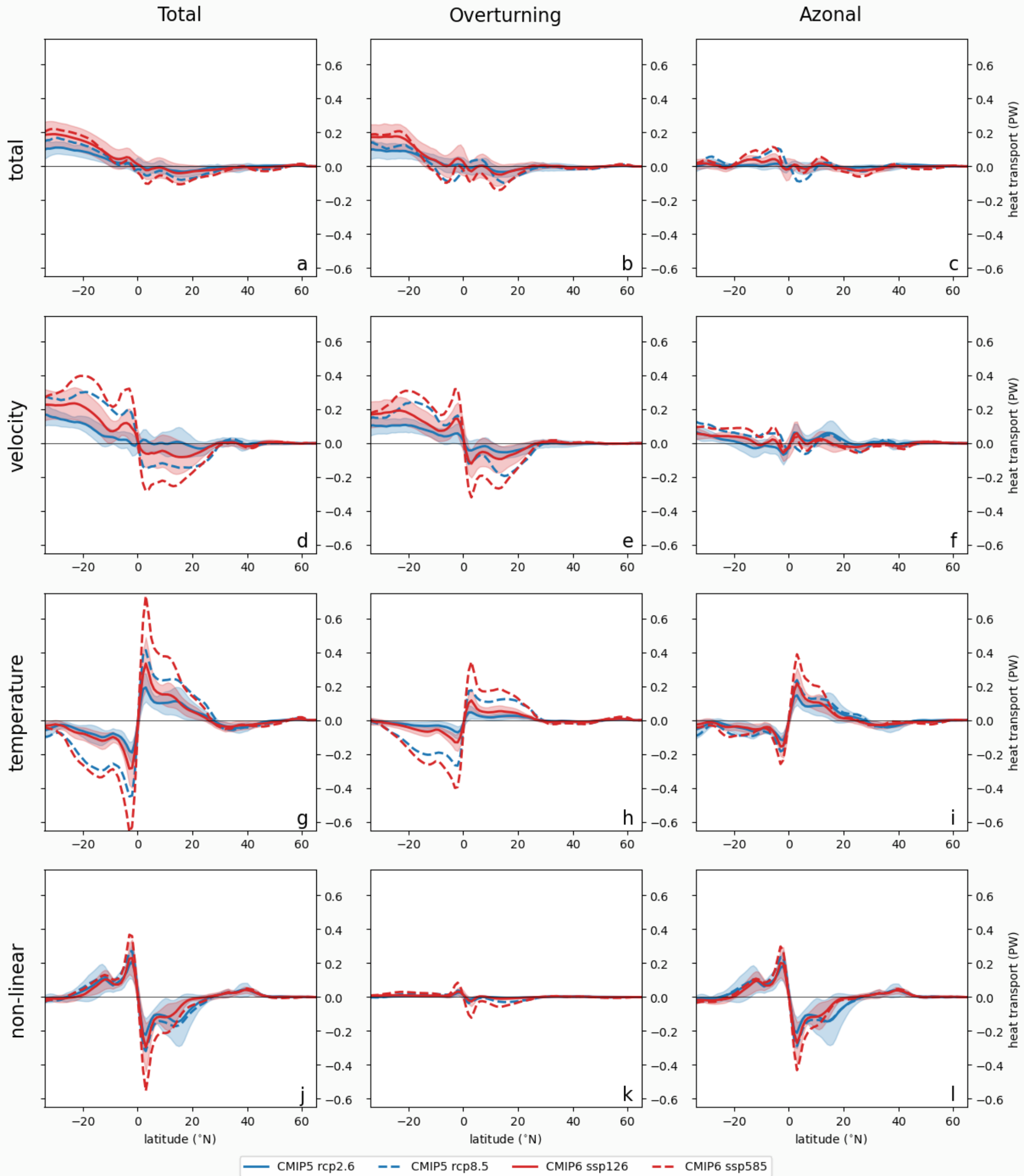
Atlantic OHT Decomposition



- Changes in Atlantic OHT in response to rcp2.6/ssp126 (solid lines) and rcp8.5/ssp585 (dashed lines) future scenarios for CMIP5 and CMIP6 with respect to historical. Shading is +/- 1 standard deviation of model distribution for rcp2.6/ssp126
- The columns are the total, overturning and azonal components of the Atlantic OHT, going left to right. The rows show the full OHT, velocity driven, temperature driven and non-linear changes in OHT when moving top to bottom. This means the top left is the non-decomposed OHT (panel a) .
- In the Atlantic the northward OHT is reduced throughout the entire basin mainly through the velocity driven overturning component (panel e), while the zonal mean temperature damp the velocity driven response (panel h). Differences between CMIP5/CMIP6 and the scenarios can be attributed to the differences in the AMOC (see below, AMOC strength relative to 1970-1999 mean).
- The azonal OHT changes mainly take place in the Subpolar Gyre (panel c), with the temperature and velocity driven changes being damped by the non-linear changes.



Indo-Pacific OHT Decomposition



- Changes in Indo-Pacific OHT in response to rcp2.6/ssp126 (solid lines) and rcp8.5/ssp585 (dashed lines) future scenarios for CMIP5 and CMIP6 with respect to historical. Shading is +/- 1 standard deviation of model distribution for rcp2.6/ssp126
- The columns are the total, overturning and azonal components of the Indo-Pacific OHT, going left to right. The rows show the full OHT, velocity driven, temperature driven and non-linear changes in OHT when moving top to bottom. This means the top left is the non-decomposed OHT (panel a) .
- Similar to the Atlantic, in the Indo-Pacific the majority of OHT changes come from the overturning component in the southern hemisphere (panel b). However, unlike the Atlantic the temperature driven changes (panel h) counter act the majority of the velocity driven changes (panel e) with just a bit of velocity driven change in the southern hemisphere remaining.
- The Indo-Pacific has very little to almost no azonal changes in the OHT (panel c). Unlike the Atlantic the velocity changes have very little impact (panel f) while the temperature driven azonal changes (panel i) are mostly counteracted by the non-linear changes (panel l).

Conclusions

- The response of the OHT to future climate projections at most latitudes is a reduction in poleward heat transport globally
- Throughout the Atlantic basin the changes in the OHT is a reduction in northward heat transport with the velocity driven overturning component contributing the majority of the change in OHT. This change in OHT is associated with the projected AMOC decline.
- In the Indo-Pacific the interaction between the different components of the OHT result in a reduction in the OHT in the southward heat transport in the southern hemisphere from the remaining velocity driven overturning component.
- As expected the changes in OHT are larger in rcp8.5/ssp585 relative to rcp2.6/ssp126. However, the changes in OHT are larger in CMIP6 relative to CMIP5, which is most notable in the weaker future projection scenario, rcp2.6/ssp126.

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BLUE ACTION

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