Impact of Large-Scale Tropical Precipitation Anomalies on the Overturning and Interior Watermass Structure of a Coupled Climate Model

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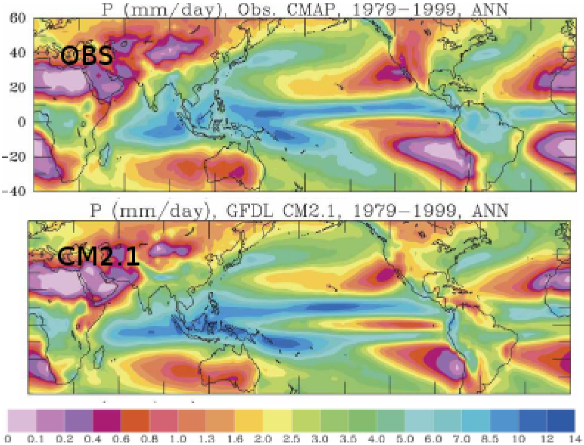
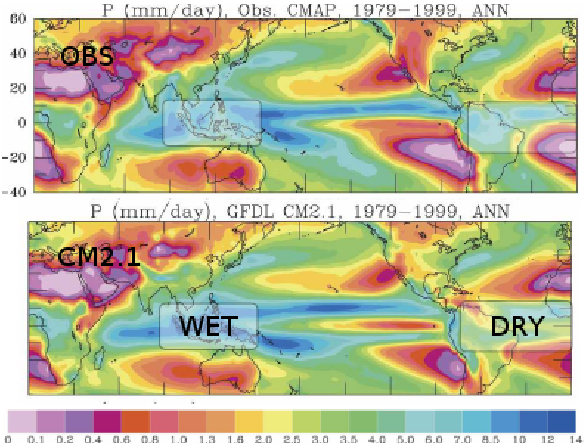
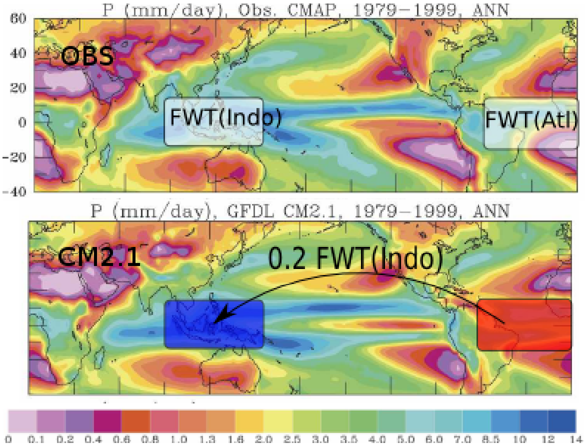
from Dai (2006)



Annual precipitation ($mm\,day^{-1}$) from observations (top) and CM2.1 (bottom) 1979-1999.



CM2.1 (and CM2G) has too much precip over Indonesia and too little over the Amazon basin and the Tropical Atlantic.



Biased Freshwater Flux estimate $FWT^{*}_{Indonesia} \approx 1.2\, FWT_{Indonesia}$ (0.2Sv) displaced from the tropical Atlantic.

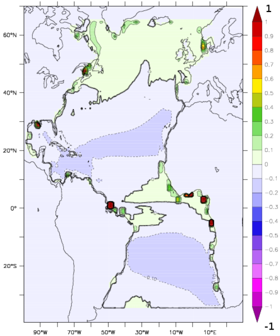
Surface buoyancy ($-\rho\, g$) flux ($kg\, m^{-1}\, s^{-3}$) due to heating and freshwater ,

$$\begin{aligned} F_b &= g\,(\alpha c_p^{-1} Q + \beta S(0) F_w) \\ Q &= Q_{sw} + Q_{lw} + Q_{evap} + Q_{sensible} \\ F_w &= Precip - Evap + Runoff + Calving \end{aligned} \tag{1}$$

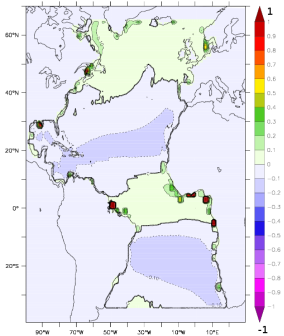
Estimated freshwater flux bias,

$$\begin{aligned} FWT^*_{Indonesia} &= \int_{Indonesia} F^*_w dx\, dy = 1.2\, FWT_{Indonesia} \\ FWT^*_{TrAtl} &= FWT_{TrAtl} - 0.2\, FWT_{Indonesia} \end{aligned} \tag{2}$$

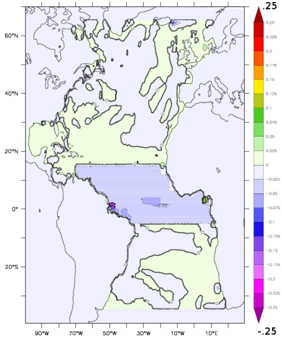
CM2G* biased



CM2G^{adj} adjusted

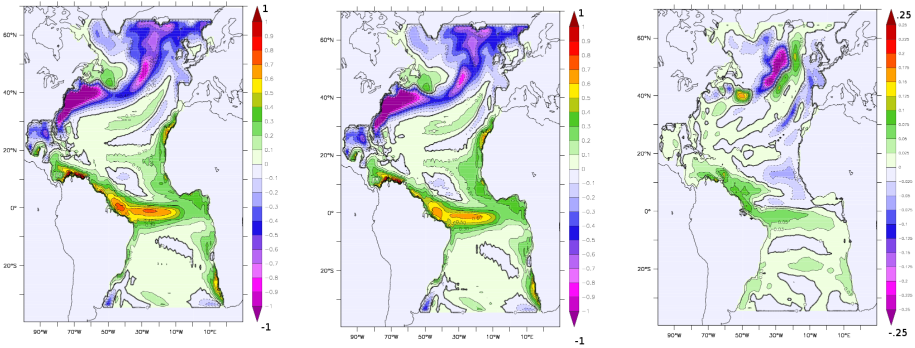


$CM2G^* - CM2G^{adj}$

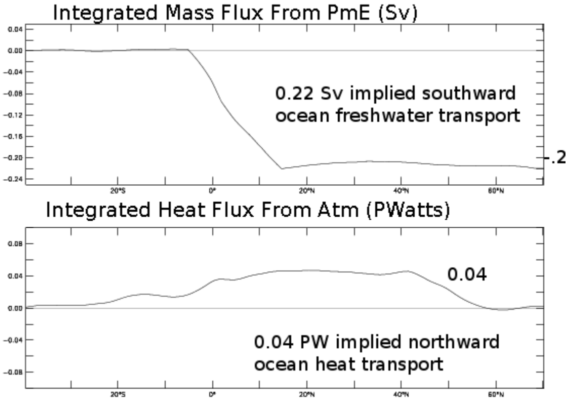


Atlantic haline buoyancy forcing ($10^{-4} kg\, m - 1 s^{-3}$) in $CM2G^*$ (yr1-100) (left), adjusted (middle), biased-adjusted (right).

CM2G* biased | CM2G^{adj} adjusted | $CM2G^* - CM2G^{adj}$



Atlantic thermal buoyancy forcing ($10^{-4} kg\, m-1 s^{-3}$) in $CM2G^*$ (yr1-100) (left), adjusted (middle), biased-adjusted (right).



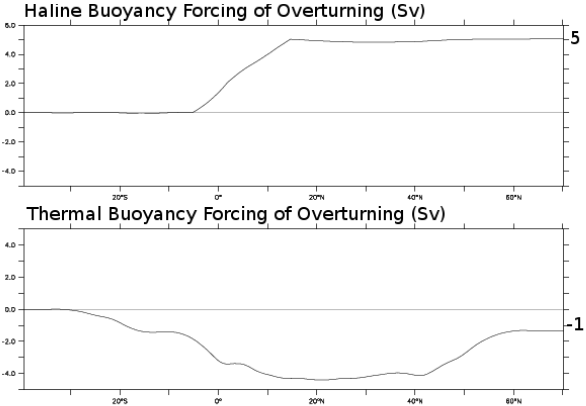
Implied ocean northward freshwater transport (biased - adjusted) in units of Sv (top). Implied ocean heat transport in units of PWatts (bottom). Model years 1-100.

Simple scaling argument for AMOC,

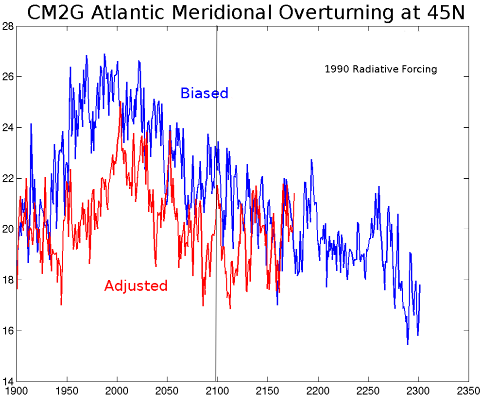
$$-\Delta\Psi\left(B_{in}-B_{out}\right)=\int_{Atl}\Delta F_b(x,y)dxdy, \tag{3}$$

where, $\Delta\Psi$ and ΔF_b are change in strength of the AMOC and buoyancy forcing respectively. B_{in} and B_{out} are the buoyancy of the surface and deep branch:

$$\begin{aligned} B_{in}-B_{out} &= -g\left(\rho_{in}-\rho_{out}\right) \\ &\approx 10 kg\, m^{-2}\, s^{-2} \end{aligned}$$



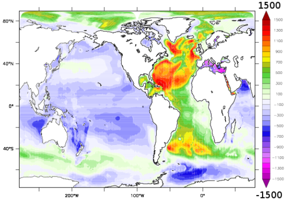
Haline (top) and Thermal (bottom) forced $\Delta\Psi$ (Sv). Assuming no change in storage. Net change $\approx 4Sv$. Model years 1-100.



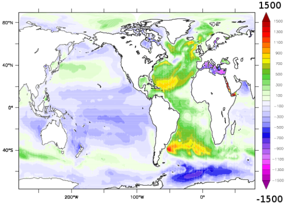
Eulerian overturning streamfunction max at 45N stronger by $\approx$ 2.5 Sv over the first two centuries in CM2G*. The buoyancy estimate is $\approx$ 4 Sv.

- The response of CM2G to a 0.2 Sv change in the tropical inter-basin atmospheric freshwater transport yields $\approx$ 2.5 Sv change in the strength of AMOC.
- Partial compensation of haline-driven overturning change by thermal feedbacks.
- The change in the overturning circulation brings with it a change in the basin thermohaline structure.
- Column integrated bias in CM2G is dominated by a warm/salty North Atlantic. We attribute this to atmospheric moisture transport bias.

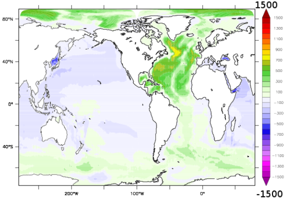
CM2G* biased SALT



CM2G^{adj} adjusted SALT

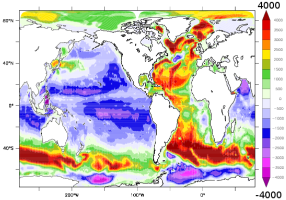


$CM2G^* - CM2G^{adj}$ SALT

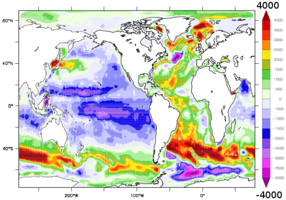


Column integrated salinity bias (*psu m*,), years 300-399.

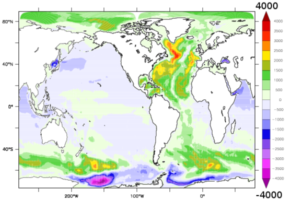
CM2G* biased TEMP



CM2G^{adj} adjusted TEMP

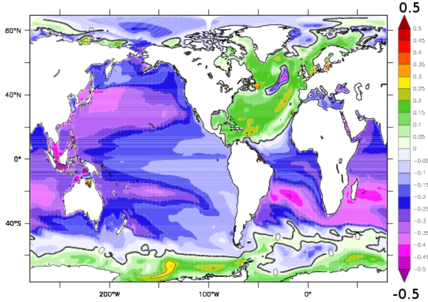


$CM2G^* - CM2G^{adj}$ TEMP

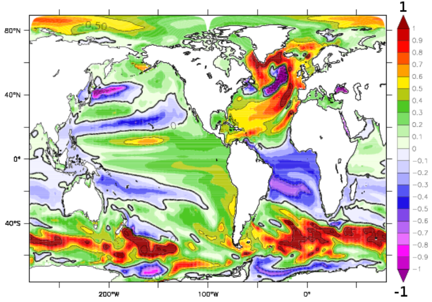


Column integrated temperature bias (^{o} $C\,m$), years 300-399.

CM2G* - CM2G^{adj} 0-500 SALT (psu)

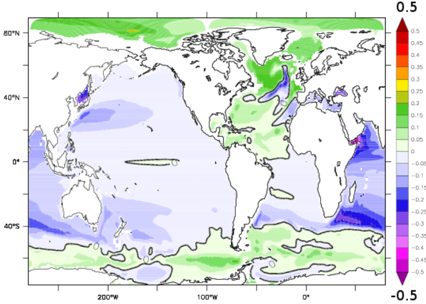


CM2G* - CM2G^{adj} 0-500 TEMP (degC)

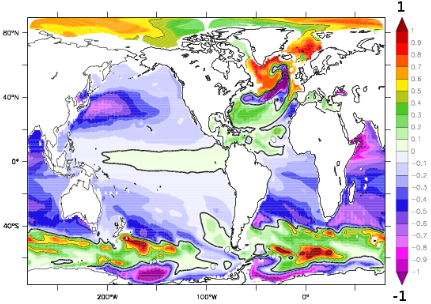


0 – 500m sensitivity years 300-399.

CM2G* - CM2G^{adj} 500-1000 SALT (psu)

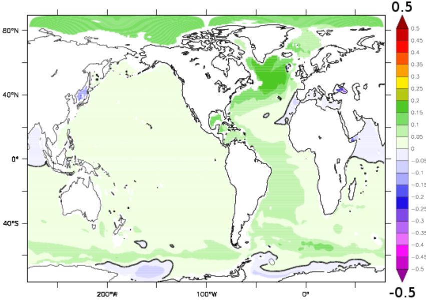


CM2G* - CM2G^{adj} 500-1000 TEMP (degC)

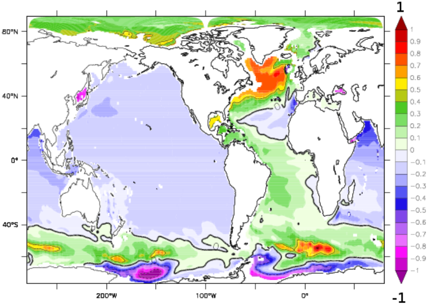


500 – 1000m sensitivity years 300-399.

CM2G* - CM2G^{adj} 1000-2000
SALT (psu)

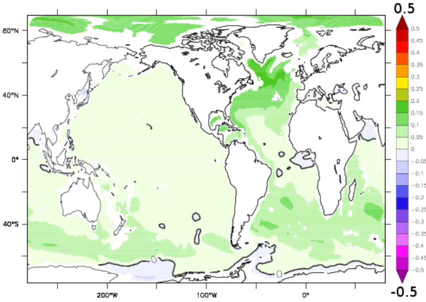


CM2G* - CM2G^{adj} 1000-2000
TEMP (degC)

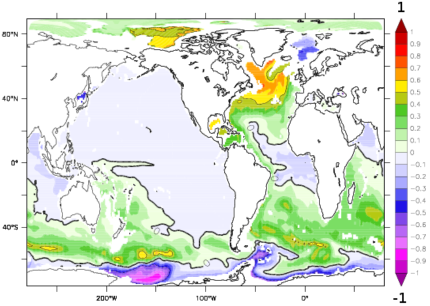


1000 – 2000m sensitivity years 300-399.

CM2G* - CM2G^{adj} 2000-3000
SALT (psu)

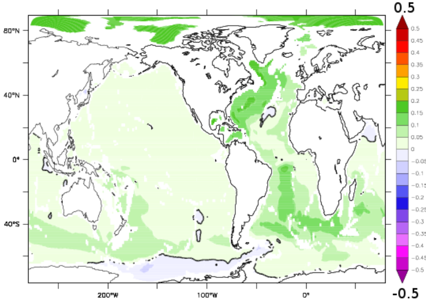


CM2G* - CM2G^{adj} 2000-3000
TEMP (degC)

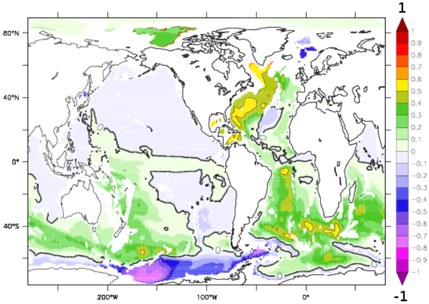


2000 – 3000m sensitivity years 300-399.

CM2G* - CM2G^{adj} 3000-3500
SALT (psu)



CM2G* - CM2G^{adj} 3000-3500
TEMP (degC)



3000 – 3500m sensitivity years 300-399.

- CM2 Walker Cell bias: Excessive atmospheric moisture transport to Indonesia from Amazon.
- Results in stronger AMOC ($\approx$ 2.5 Sv per 0.2 Sv change in atmospheric FWT).
- AMOC sensitivity is consistent with change in haline buoyancy forcing with partial compensation from thermal forcing.
- AMOC-induced change in vertical watermass structure.
- CM2G North Atlantic temperature (warm) and salinity (salty) bias is attributed to Walker Cell bias.
- There are long time scale adjustments involving transport from the North Atlantic to the Southern Ocean as well as shallow circulation adjustments in all basins.
- We emphasize the importance of an accurate tropical hydrological cycle in coupled models to the ability to simulate and predict the overturning circulation and ocean watermass properties.