Moist isentropic overturning circulation responses in PAMIP experiments

Alexandre Audette, Paul Kushner, Robert Fajber, Yannick Peings, Gudrun Magnusdottir

PAMIP workshop - 25 June 2019
**Meridional heat transport**

\[ \iint v \frac{dp}{g} \, dx \]

in a warming atmosphere

---

**Global warming**

- Global increase of SSTs
- Increase of the amount of moisture in the atmosphere (following Clausius-Clapeyron).
- Increase of the zonal mean MSE
- More warm air advected towards the poles.

---

**Polar amplification**

- Diminution of the EQ-POLE MSE gradient.
- Less baroclinicity, weakening of the eddies at high latitudes.
- Eddies are strongly linked to the MSE gradient
- Less warm air advected by the eddies.

(Caballero and Langen, 2005; Wu and Pauluis, 2013)
Meridional heat transport

\[ \int \! \int v \frac{dp}{g} \, dx \]

in a warming atmosphere

Global warming

- Global increase of SSTs
- Increase of the amount of moisture in the atmosphere (following Clausius-Clapeyron).
- Increase of the zonal mean MSE
- More warm air advected towards the poles.

Polar amplification

- Diminution of the EQ-POLE MSE gradient.
- Less baroclinicity, weakening of the eddies at high latitudes.
- Eddies are strongly linked to the MSE gradient
- Less warm air advected by the eddies.

Can the PAMIP experiments isolate these effects?

( Caballero and Langen, 2005; Wu and Pauluis, 2013)
<table>
<thead>
<tr>
<th>Experiment #</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>CTL</td>
<td>PdSST and PdSIC - WACCM</td>
</tr>
<tr>
<td>1.4</td>
<td>SST</td>
<td>FutSST and PdSIC - WACCM</td>
</tr>
<tr>
<td>1.6</td>
<td>SIC</td>
<td>PdSST and FutArcSIC - WACCM</td>
</tr>
</tbody>
</table>
Opposing effects of SST increase and sea ice loss

\[ \bar{X} : \text{Zonal mean} \]
\[ X' : \text{Deviation} \]
Northward MSE transport
Northward MSE transport
Overturning circulation on different vertical coordinates

- Circulation on pressure levels doesn’t take into account the mass transport due to eddies and doesn’t take into account the effect of moisture.
Overturning circulation on different vertical coordinates

• Circulation on pressure levels doesn’t take into account the mass transport due to eddies and doesn’t take into account the effect of moisture.

• Changing vertical coordinate:
  • **DSE** doesn’t include the effect of condensation, **MSE** does.
Effect of SST increase and sea ice loss on the moist isentropic circulation
The Statistical Transformed Eulerian Mean (STEM) and possible linearizations

- Statistical approximation of the isentropic mass transport.

\[ \psi = \psi(\bar{v}, \overline{MSE}, \overline{v'MSE'}, \overline{MSE'^2}) \]

- We can separate the contributions of the input variables through the following linearization. (Wu & Pauluis, 2013)

\[ \delta \psi = \delta_{\bar{v}} \psi + \delta_{MSE} \psi + \delta_{v'MSE'} \psi + \delta_{MSE'^2} \psi + \delta_{NL} \psi \]
The Statistical Transformed Eulerian Mean (STEM) and possible linearizations

• Statistical approximation of the isentropic mass transport.

\[ \psi = \psi(\overline{v}, \overline{MSE}, \overline{v'MSE'}, \overline{MSE'^2}) \]

• We can separate the contributions of the input variables through the following linearization. (Wu & Pauluis, 2013)

\[ \delta \psi = \delta_{\overline{v}} \psi + \delta_{\overline{MSE}} \psi + \delta_{\overline{v'MSE'}} \psi + \delta_{\overline{MSE'^2}} \psi + \delta_{NL} \psi \]
Effect of $\Delta MSE$ 

Effect of $\nu'MSE'$

Response to SST perturbation

($\Delta MSE\psi > 0$)

Response to SIC perturbation

($\Delta MSE\psi > 0$)

($\nu'MSE'\psi > 0$)

($\nu'MSE'\psi < 0$)
## Summary

<table>
<thead>
<tr>
<th>Process</th>
<th>Circulation response dominated by</th>
<th>Result</th>
<th>Local strength of perturbation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea ice loss</td>
<td>$v'MSE'$ (&lt;0)</td>
<td>Slow down of the circulation. Less MSE transport in and out of the Arctic.</td>
<td>11%</td>
</tr>
<tr>
<td>SST increase</td>
<td>$\overline{MSE}$ (&gt;0)</td>
<td>Air is transported in and out of the Arctic on higher MSE levels.</td>
<td>30%</td>
</tr>
</tbody>
</table>
References


Effect of SST increase and sea ice loss on the moist isentropic circulation (Scaled by $\cos \phi$)
Effect of $\delta_{\text{MSE}}$  
$(\delta_{\text{MSE}} \psi > 0)$

Effect of $\delta'_{\text{MSE}}$  
$(\delta'_{\text{MSE}} \psi > 0)$

(Scaled by $\cos \phi$)

Response to SST perturbation

Response to SIC perturbation

$(\delta_{\text{MSE}} \psi > 0)$

$(\delta_{\text{MSE}} \psi < 0)$