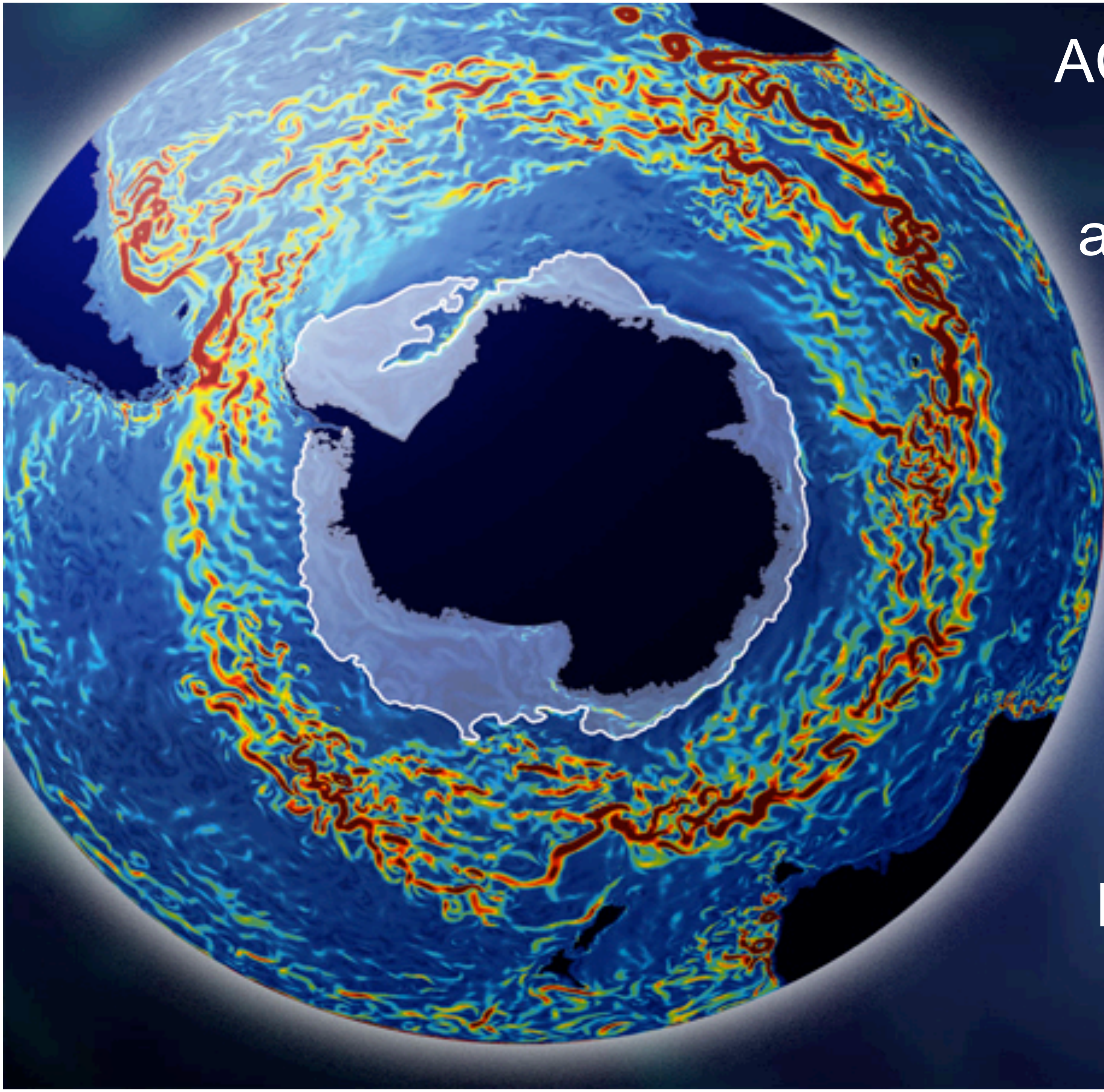


ACC transport sensitivity to air-sea fluxes

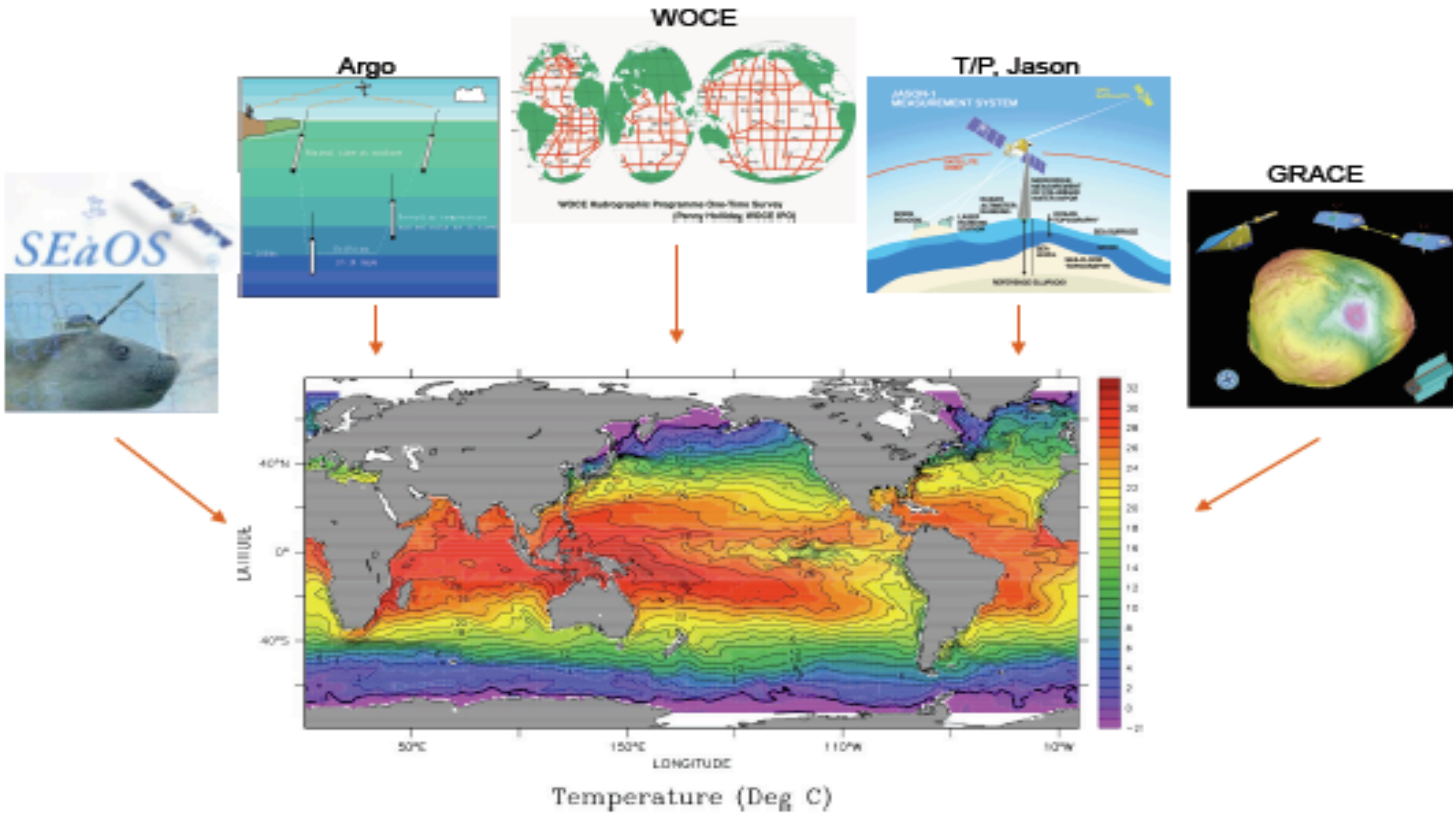
Matt Mazloff
SIO-UCSD

Southern Ocean State estimate (SOSE):
Adjoint, (4d-var) method optimization

non-sequential – no nudging

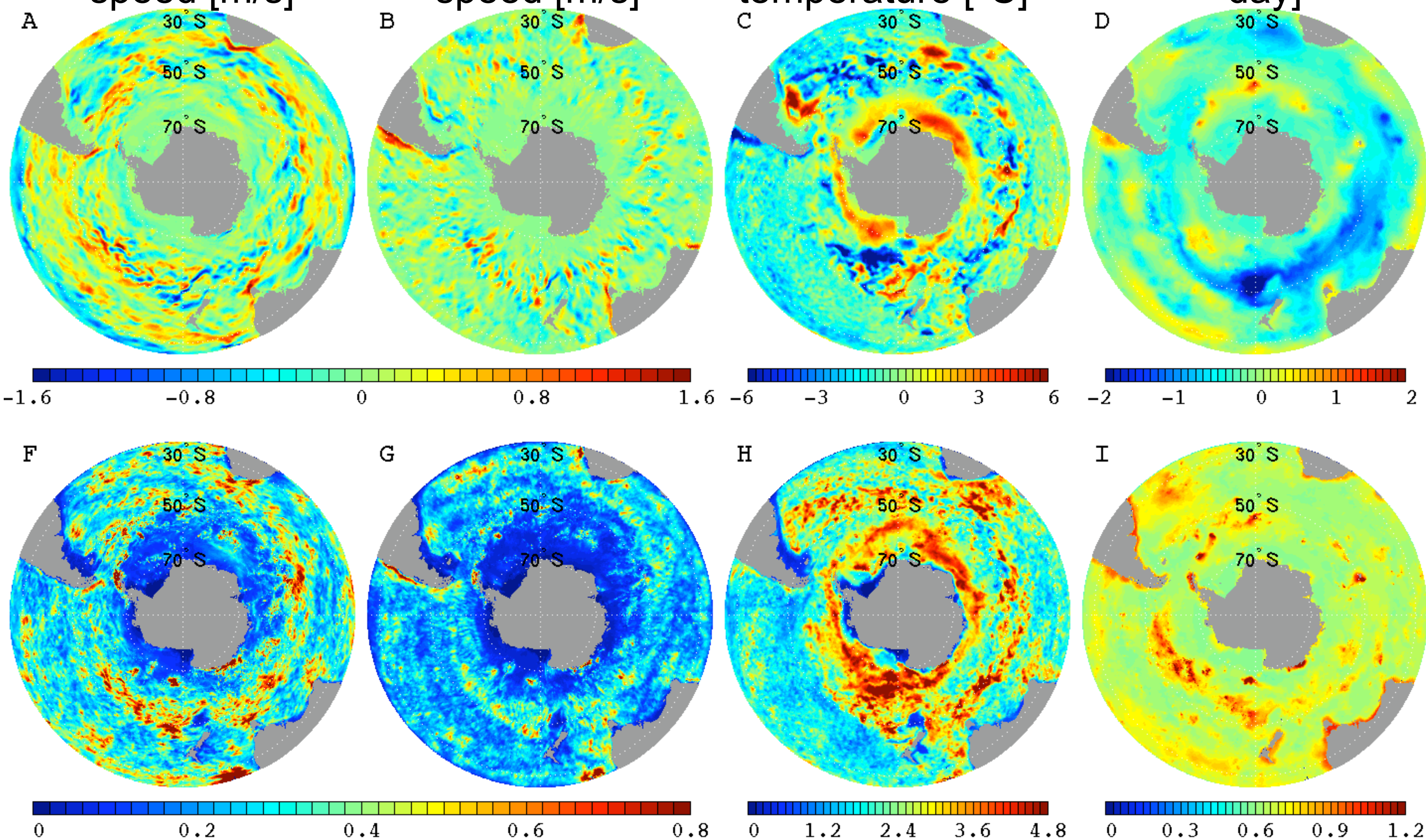
$$J = (\text{obs} - \text{model})^2 \sigma^{-2}$$

solve for IC and atm. state



Time-mean (upper plots) differences from the NCEP/NCAR atmospheric state and their standard deviations (lower plots)

zonal wind speed [m/s] | meridional wind speed [m/s] | Atmospheric temperature [^oC] | Precipitation [mm/day]



Atmospheric flux constraints (fields and uncertainty estimates) are vital to ocean state estimation

Where these constraints may be most useful?

Where do air-sea fluxes most influence the ocean state?

MODEL SENSITIVITY CALCULATIONS IN FORWARD & REVERSE

▶ Finite difference approach:

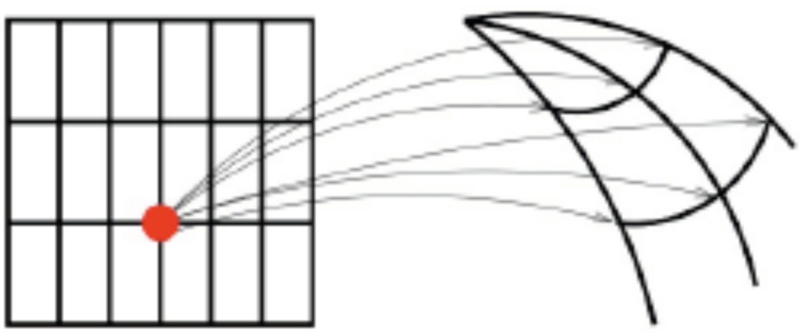
- Take a "guessed" anomaly (SST) and determine its impact on model output (MOC)
- Perturb each input element (SST(i, j)) to determine its impact on output (MOC).

▶ Reverse/adjoint approach:

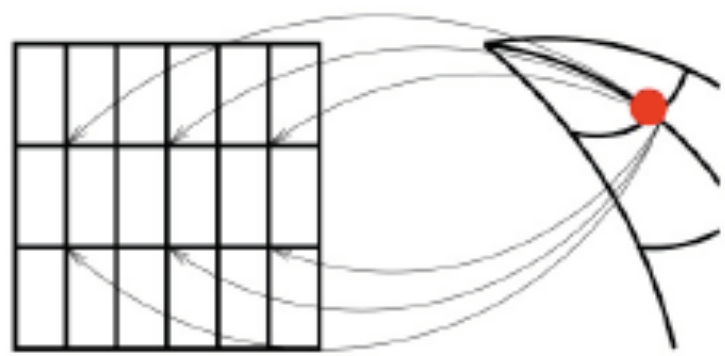
- Calculates "full" sensitivity fi eld $\frac{\partial \, \mathrm{MOC}}{\partial \, \mathrm{SST}(x,y,t)}$
- Approach:

  Let $\mathcal{J} = \mathrm{MOC}$, $\vec{u} = \mathrm{SST(i,j)}$

  $$\longrightarrow \boxed{\vec{\nabla}_u \mathcal{J}(\vec{u})} = \frac{\partial \, \mathrm{MOC}}{\partial \, \mathrm{SST}(x,y,t)}$$



Impact of ***one input*** on ***all outputs***

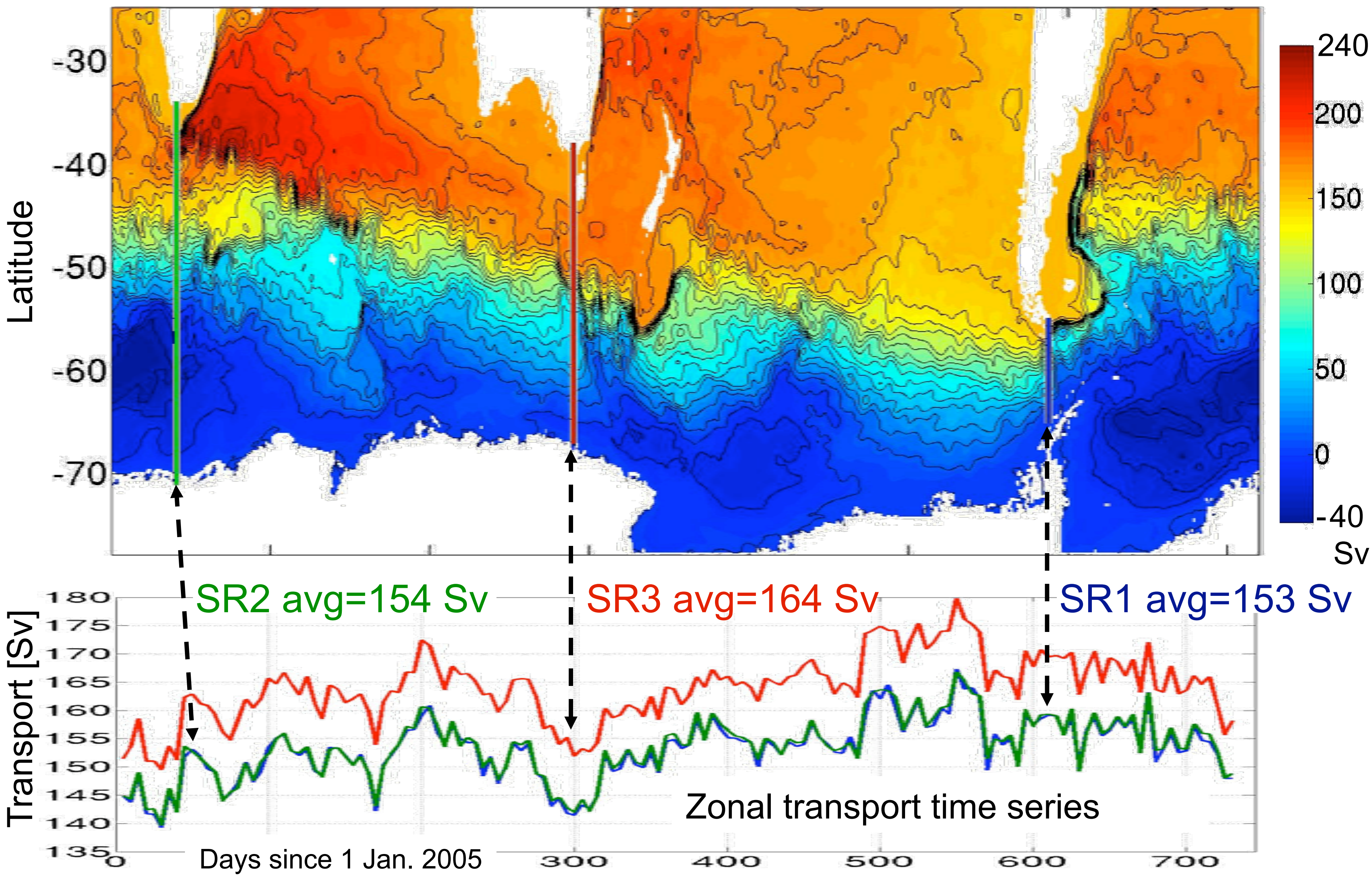


Sensitivity of ***one output*** to ***all inputs***

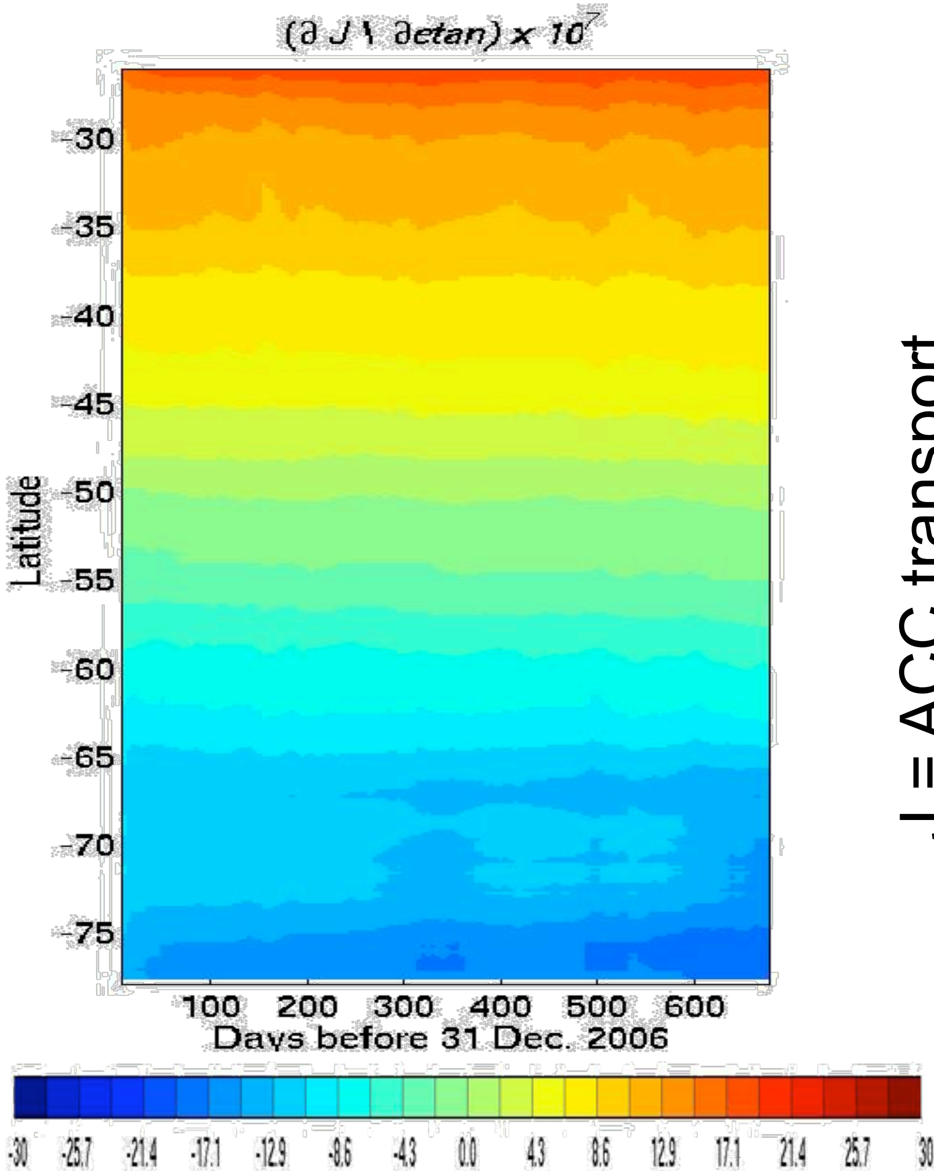
Slide courtesy P. Heimbach (MIT)

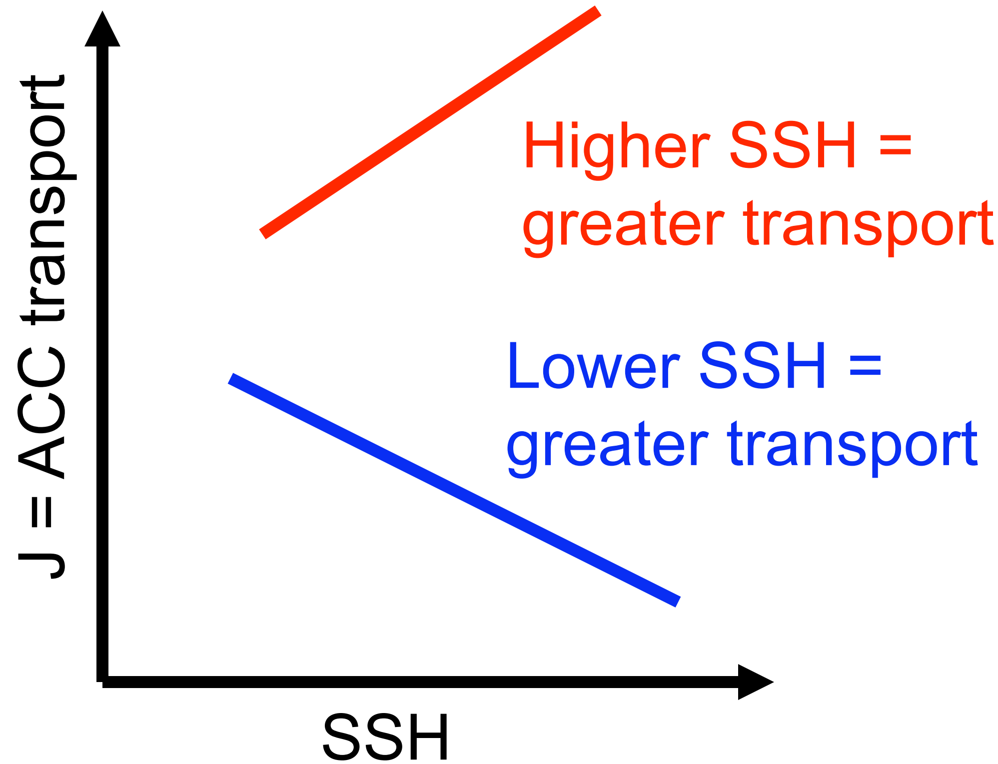
ACC transport

Vertically integrated transport streamfunction [Sv]



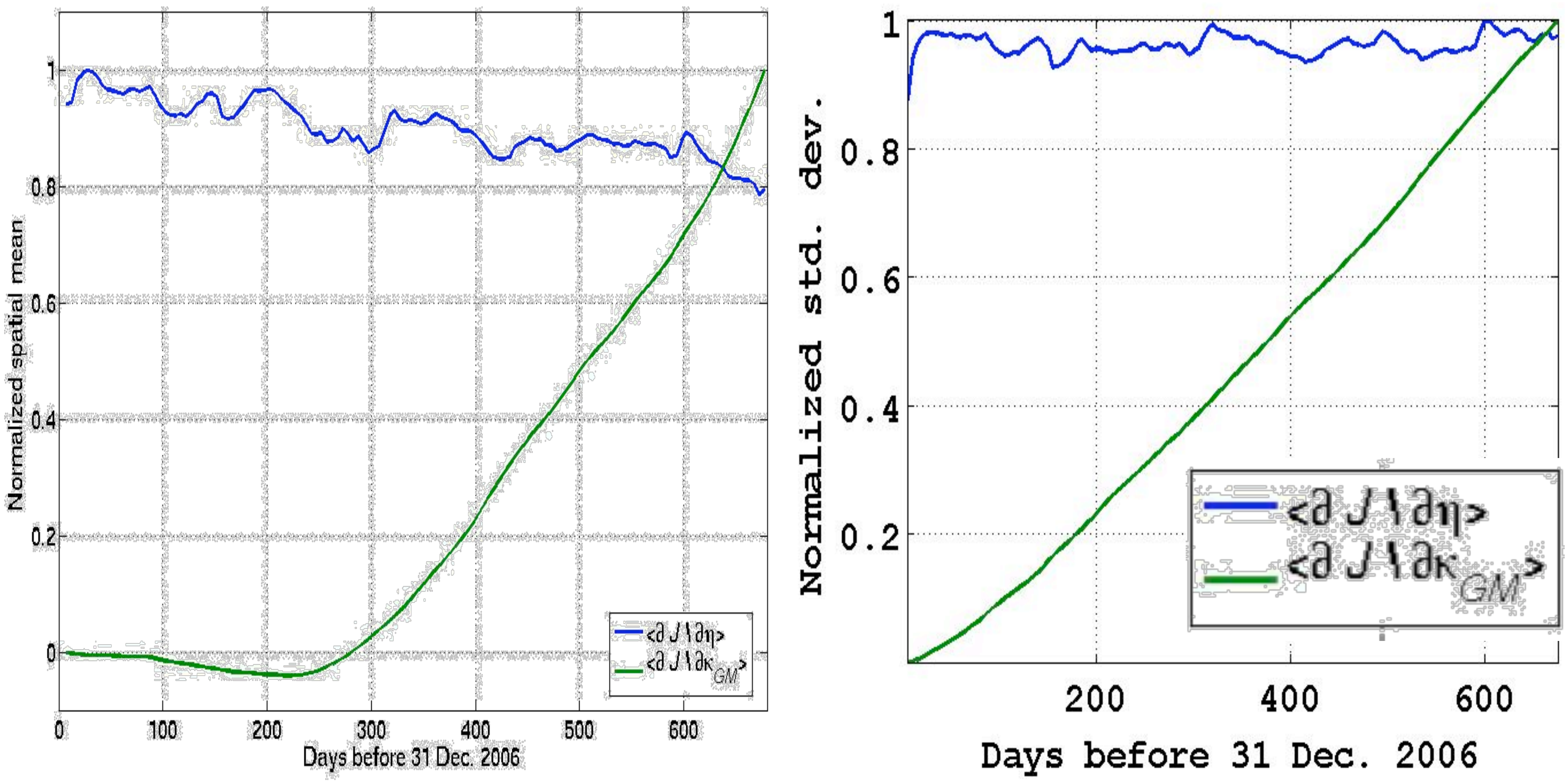
ACC transport sensitivity with respect to average sea surface height (*∂J/ ∂ssh*) [Sv•m^{-1}]



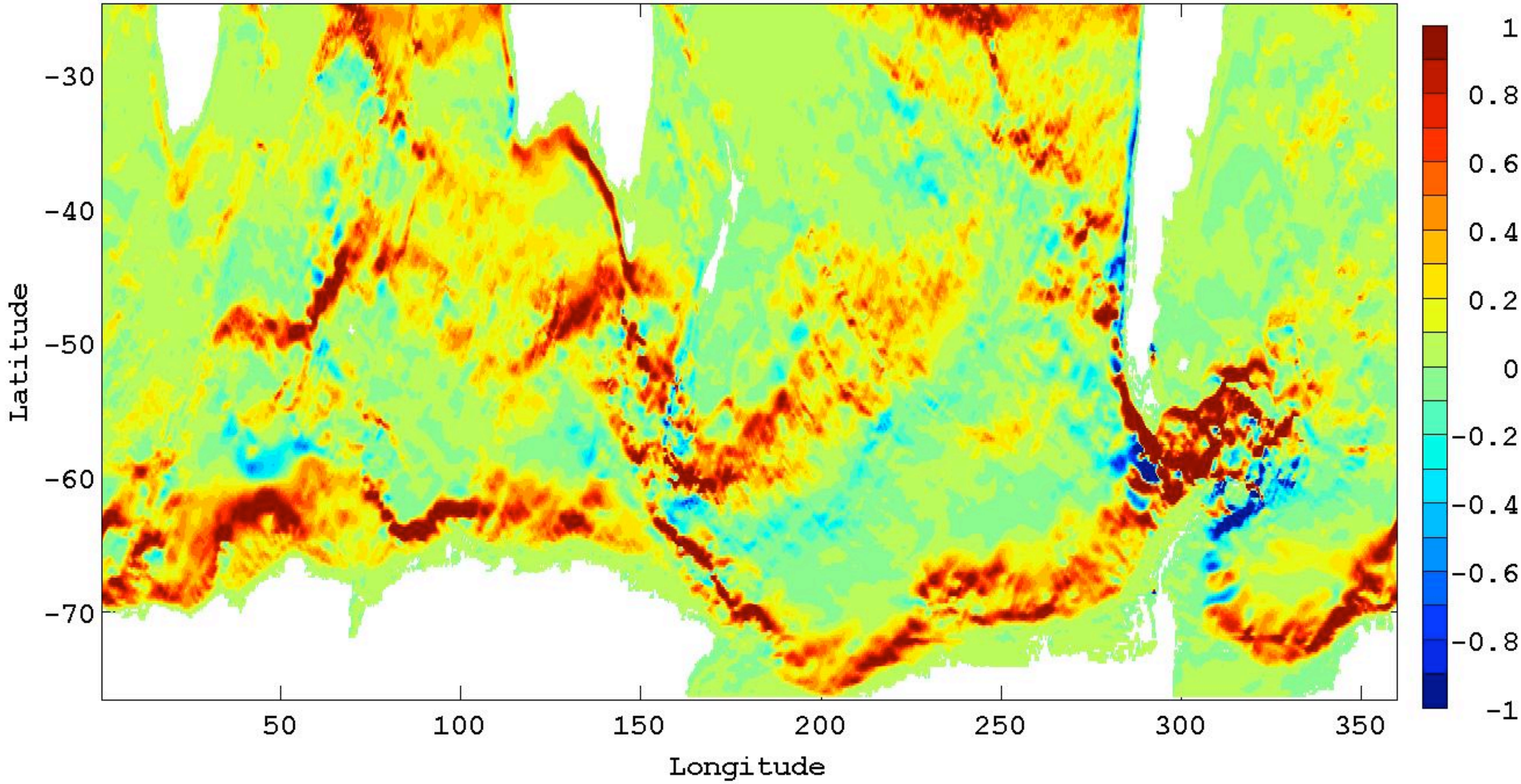


Baroclinic vs. barotropic sensitivities

Normalized spatial mean (left) and std. dev. (right) of ACC transport sensitivity to sea surface height and GM coefficient



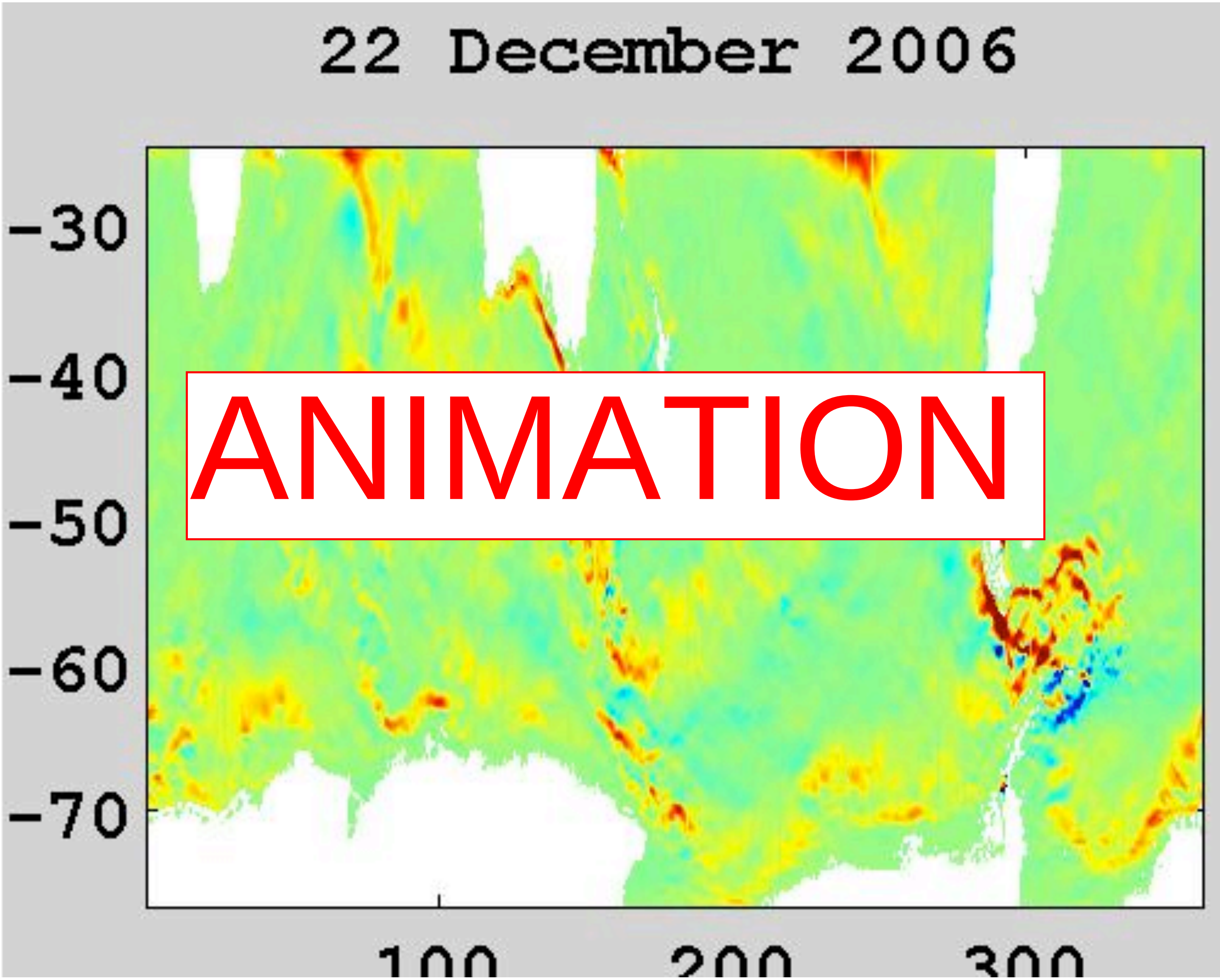
ACC transport sensitivity with respect to zonal velocity



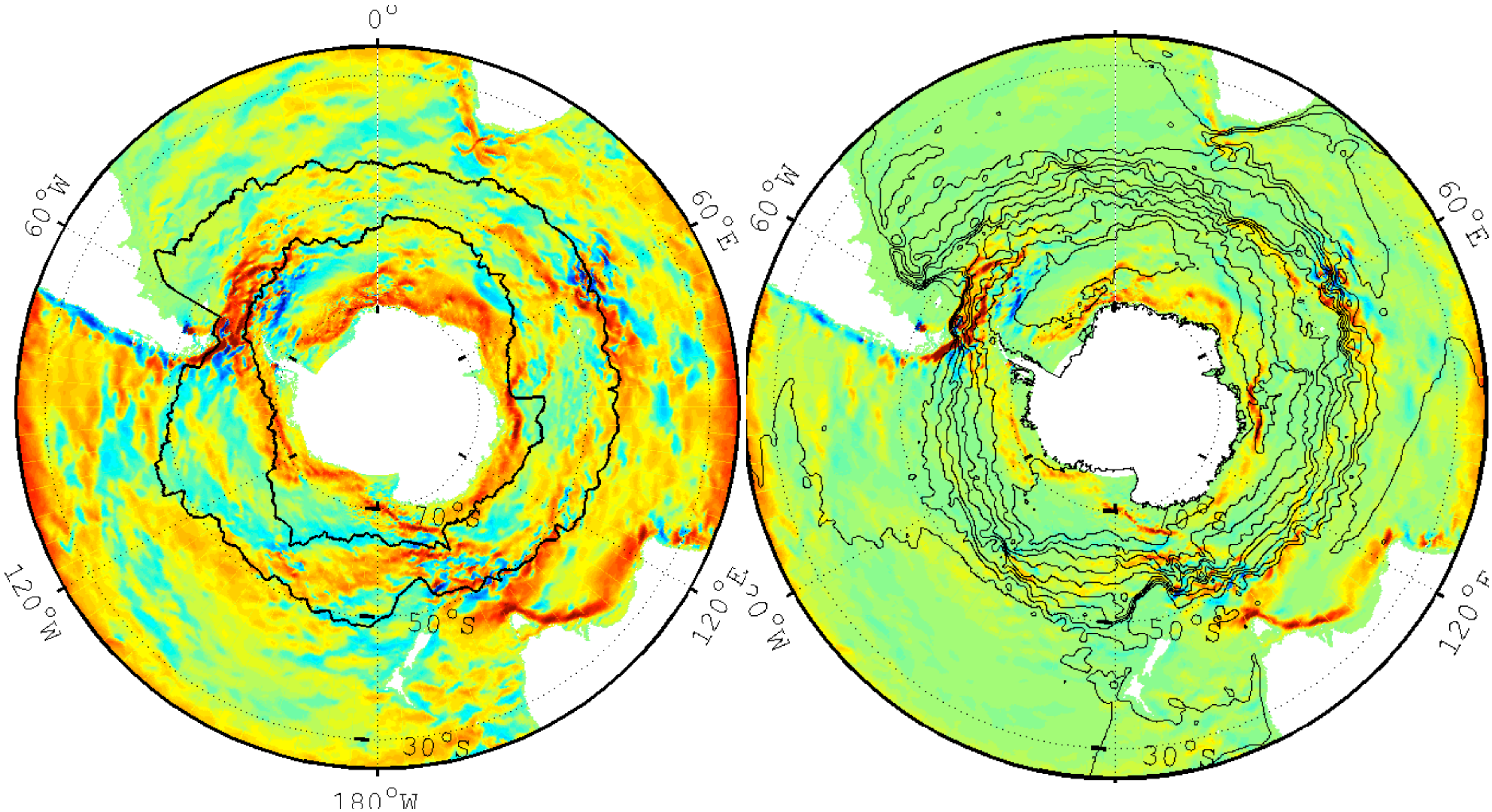
Positive sensitivity means eastward ***u*** = greater transport

Negative sensitivity means westward *u* = greater transport

Sensitivity to zonal momentum flux [Sv m^2 N^{-1}]x10^{-8}



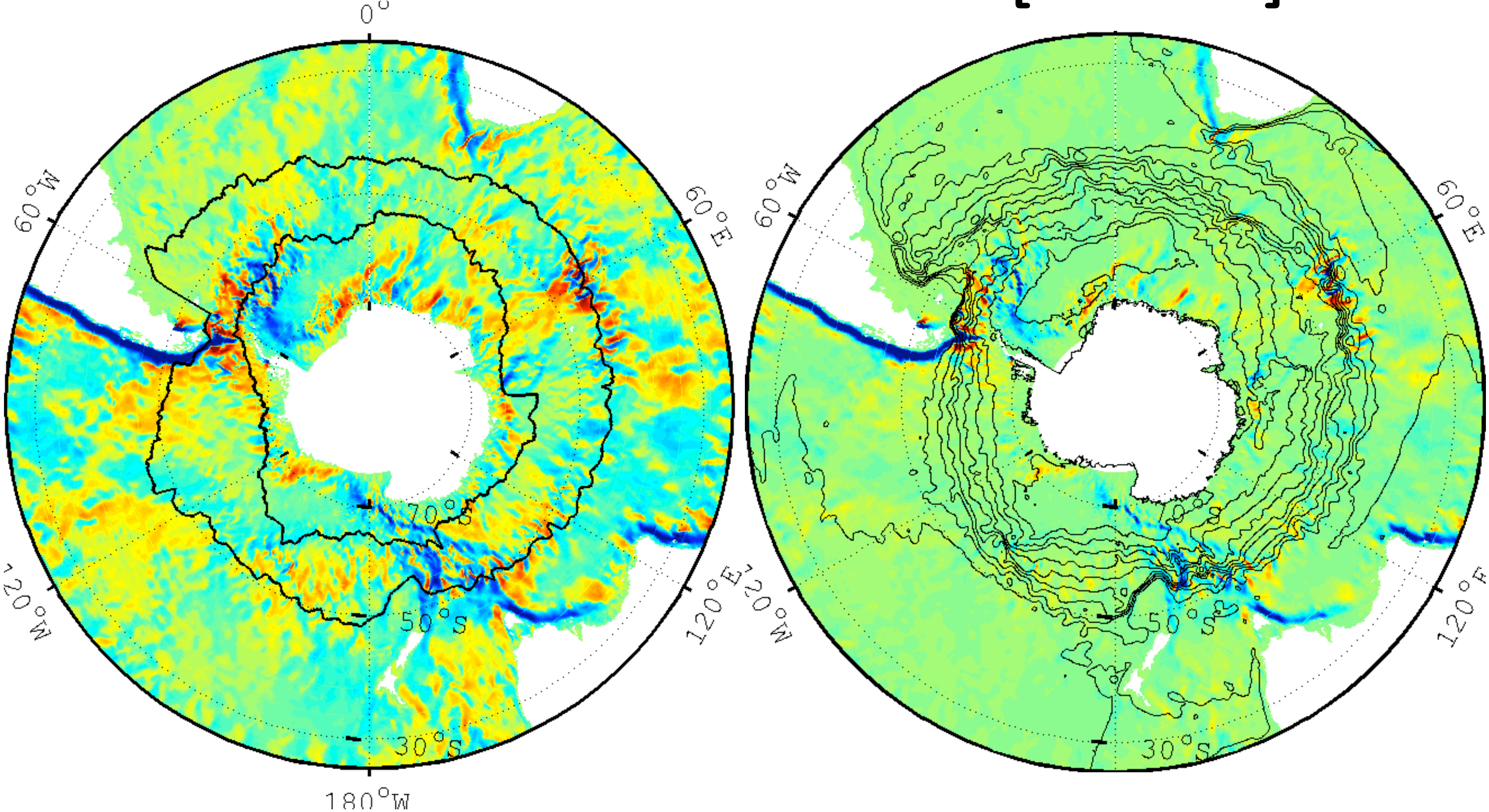
Sensitivity of 2006 mean DP transport to 1 Jan. 2006 air-sea zonal momentum flux [Sv m^2 N^{-1}]



Positive sensitivity means eastward ***u*** = greater transport

Negative sensitivity means westward *u* = greater transport

Sensitivity of 2006 mean DP transport to 1 Jan. 2006 air-sea meridional momentum flux [Sv m^2 N^{-1}]

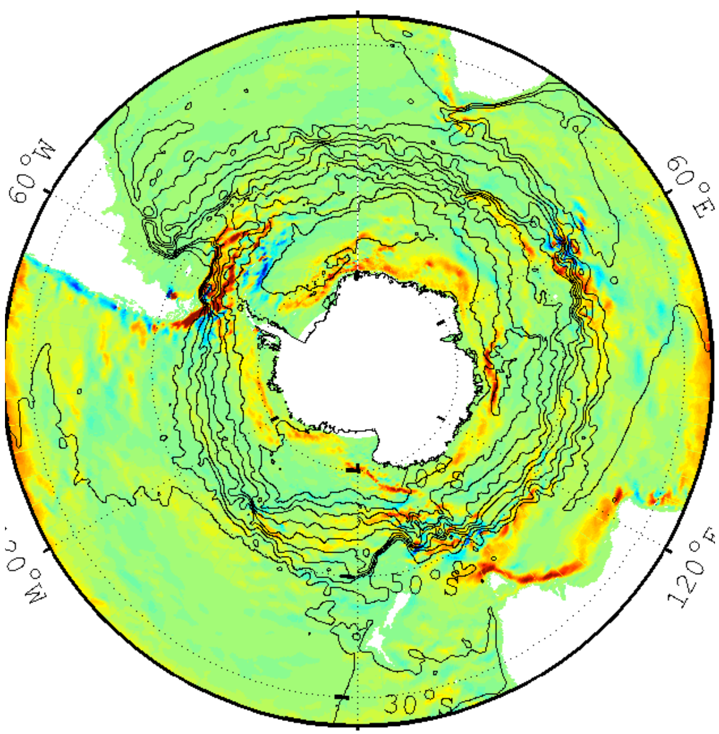


Positive sensitivity means equaterward ***v*** = greater transport

Negative sensitivity means poleward *v* = greater transport

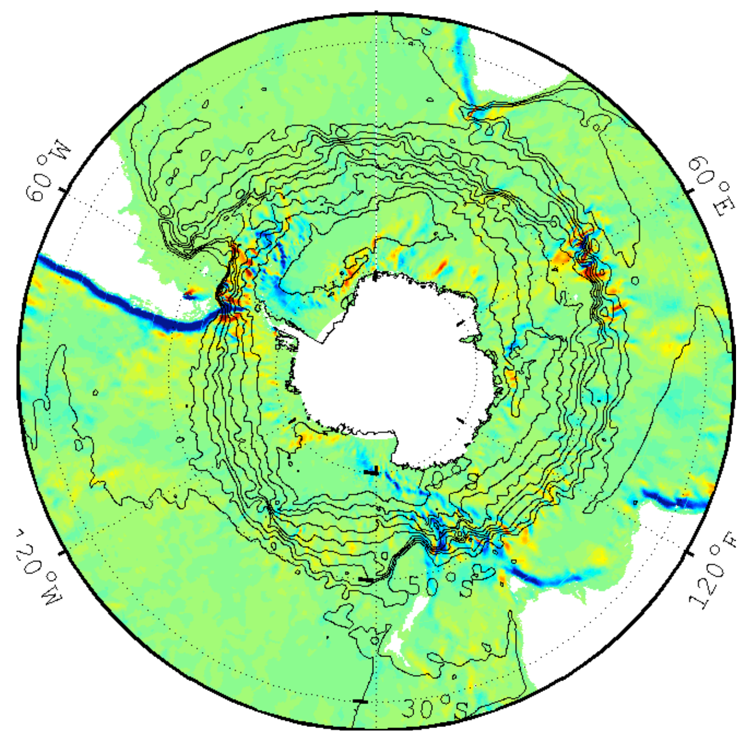
Summary of sensitivity to momentum flux

- Small scale local sensitivities with a complicated structure
- Relatively constant in time (short time-scale reaction)
- Regions of greatest influence are around complex topography and eastern boundaries

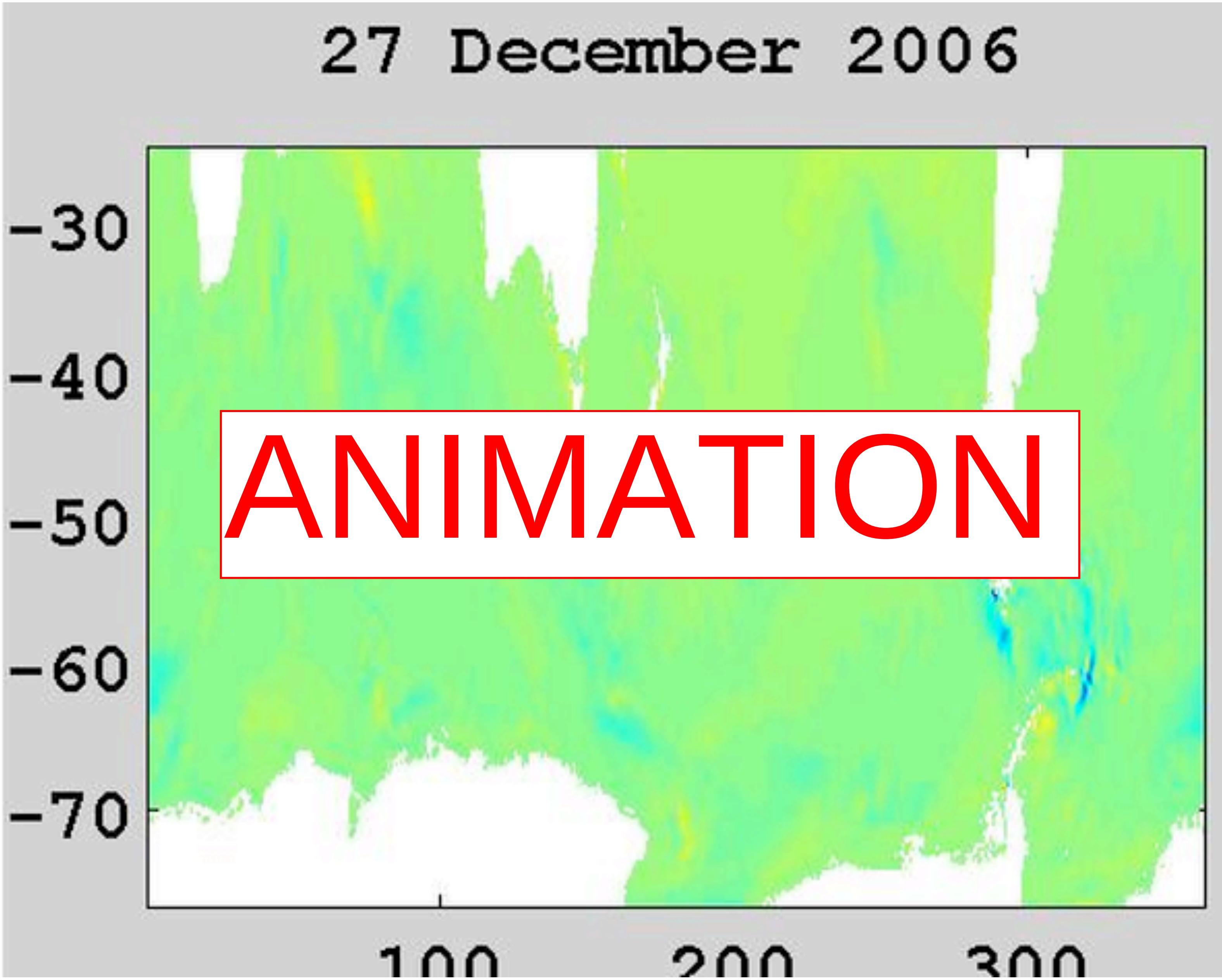


<=Ustress

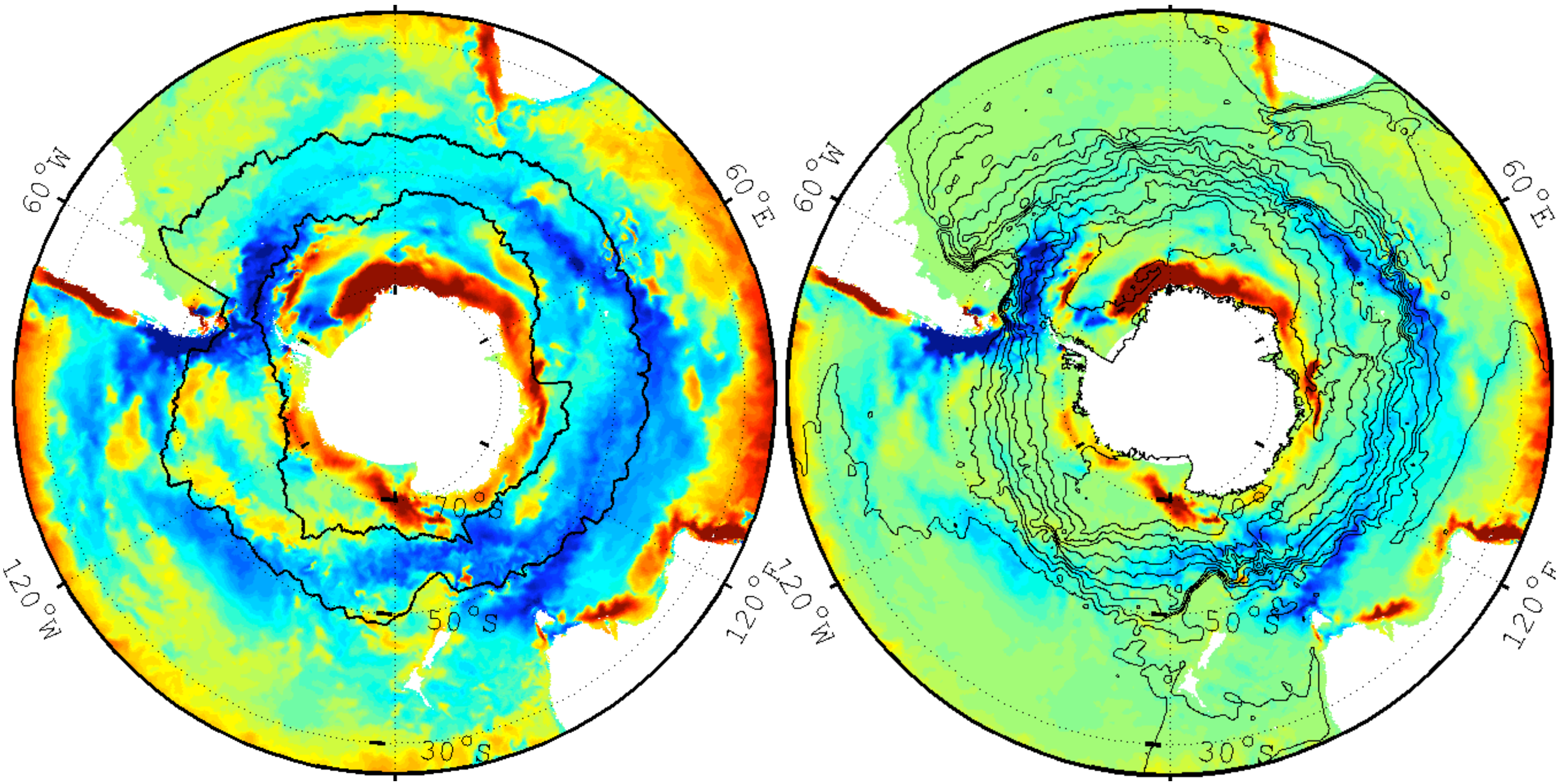
Vstress=>



Sensitivity to air-sea heat flux [Sv m^2 W^{-1}]



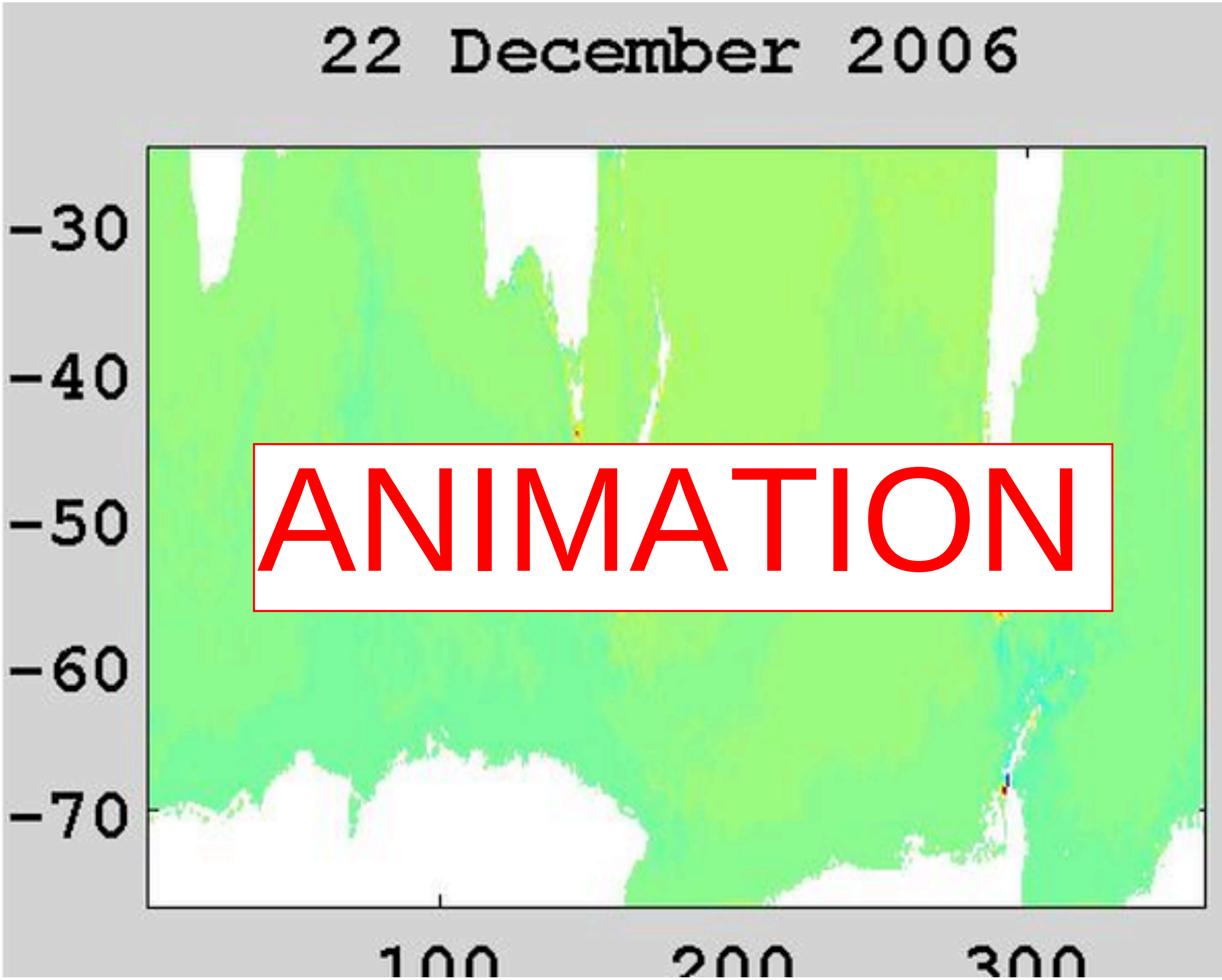
Sensitivity of 2006 mean DP transport to 1 Jan. 2006 air-sea heat flux [Sv m^2 W^{-1}]



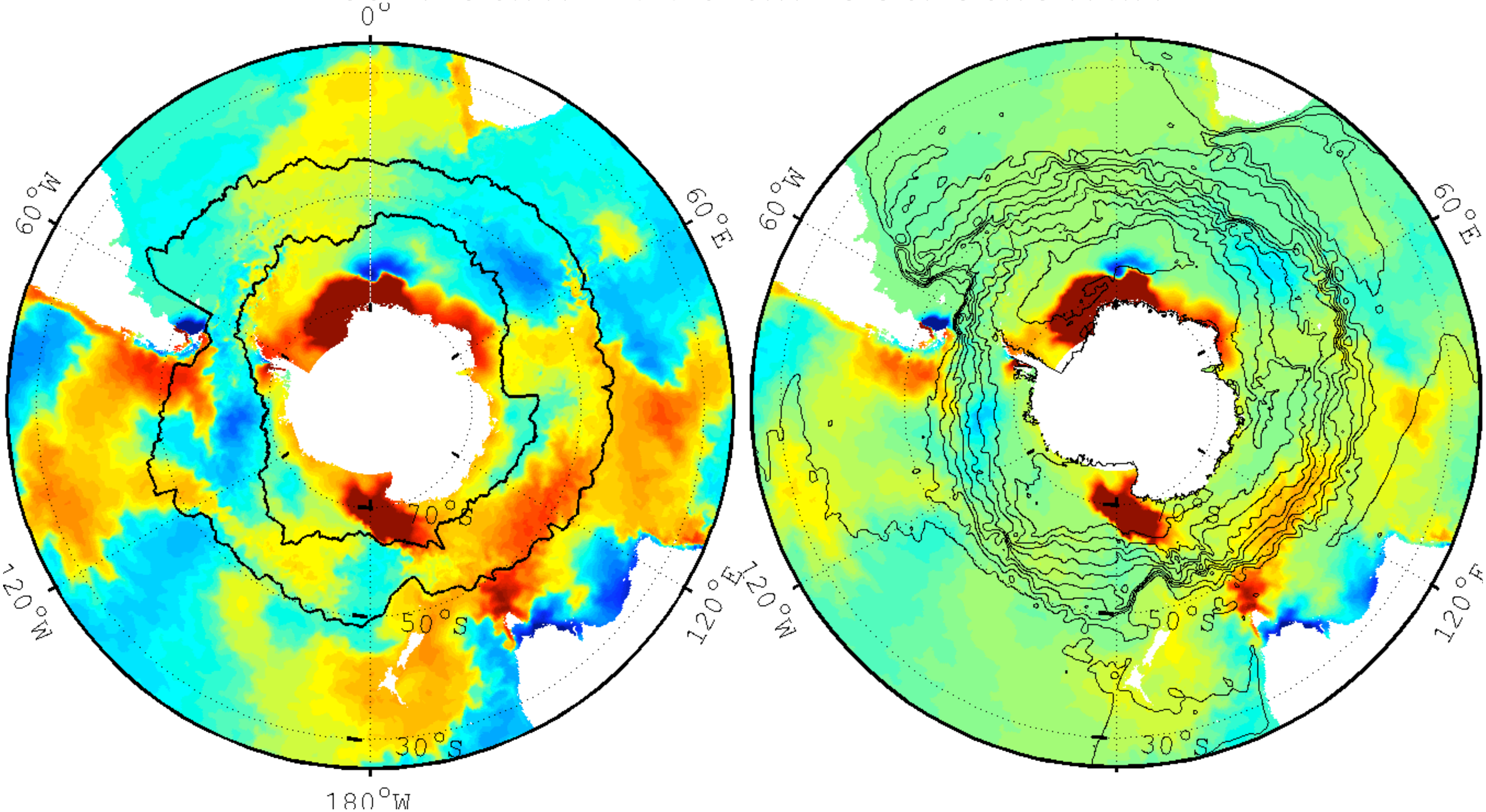
Pos. means cooling the ocean (heat flux > 0) = greater transport

Neg. means warming the ocean (heat flux < 0) = greater transport

Sensitivity to air-sea salt flux [Sv s m^2 g^{-1}]



Sensitivity of 2006 mean DP transport to 1 Jan. 2006 air-sea salt flux

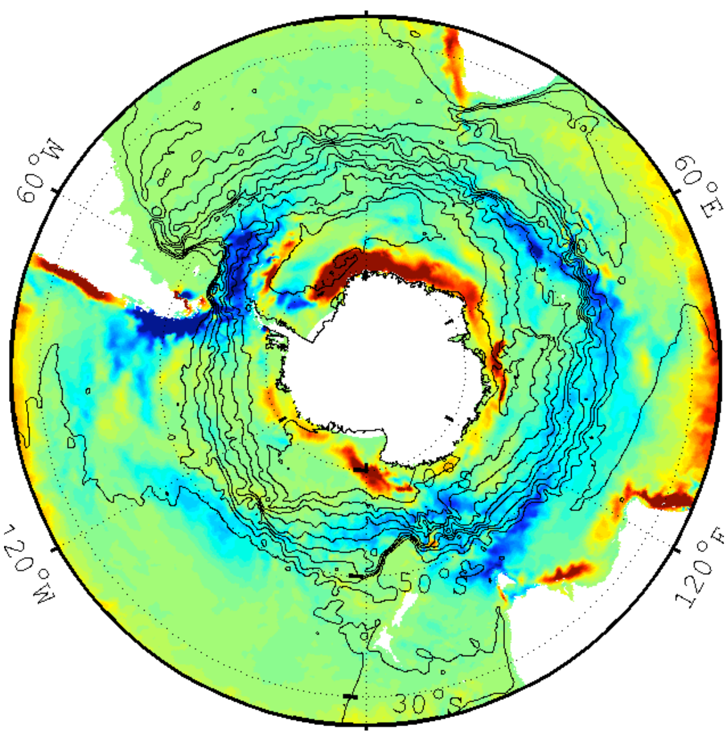


Pos. means salinifying the ocean (EmP > 0) = greater transport

Neg. means freshening the ocean (EmP < 0) = greater transport

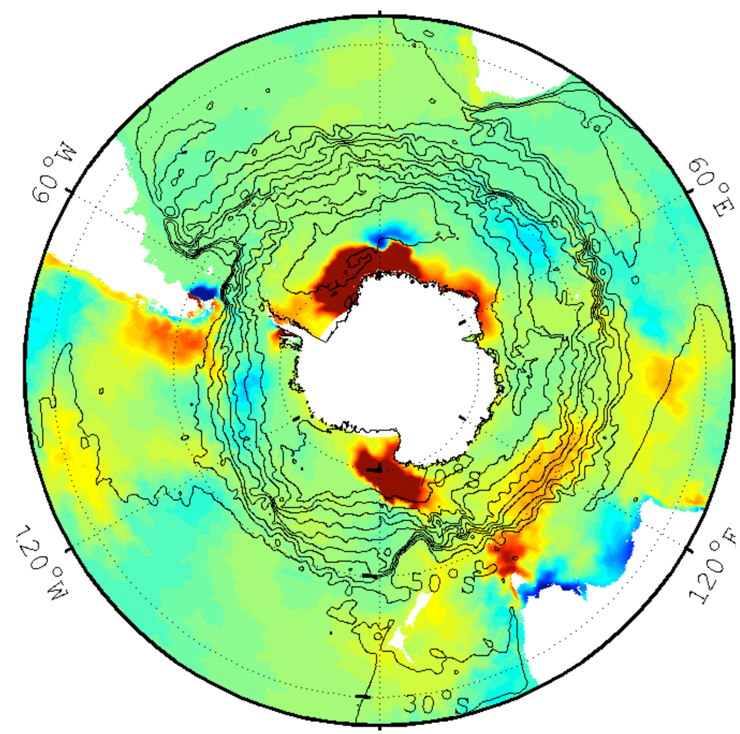
Summary of sensitivity to buoyancy flux

- A strong seasonal cycle, peaking in August (Austral winter)
- Large scale with an up-stream signature.
- Enhanced in the southeastern subtropical gyres, in the eastern boundary regions, in the polar gyres, and regions of complex topography

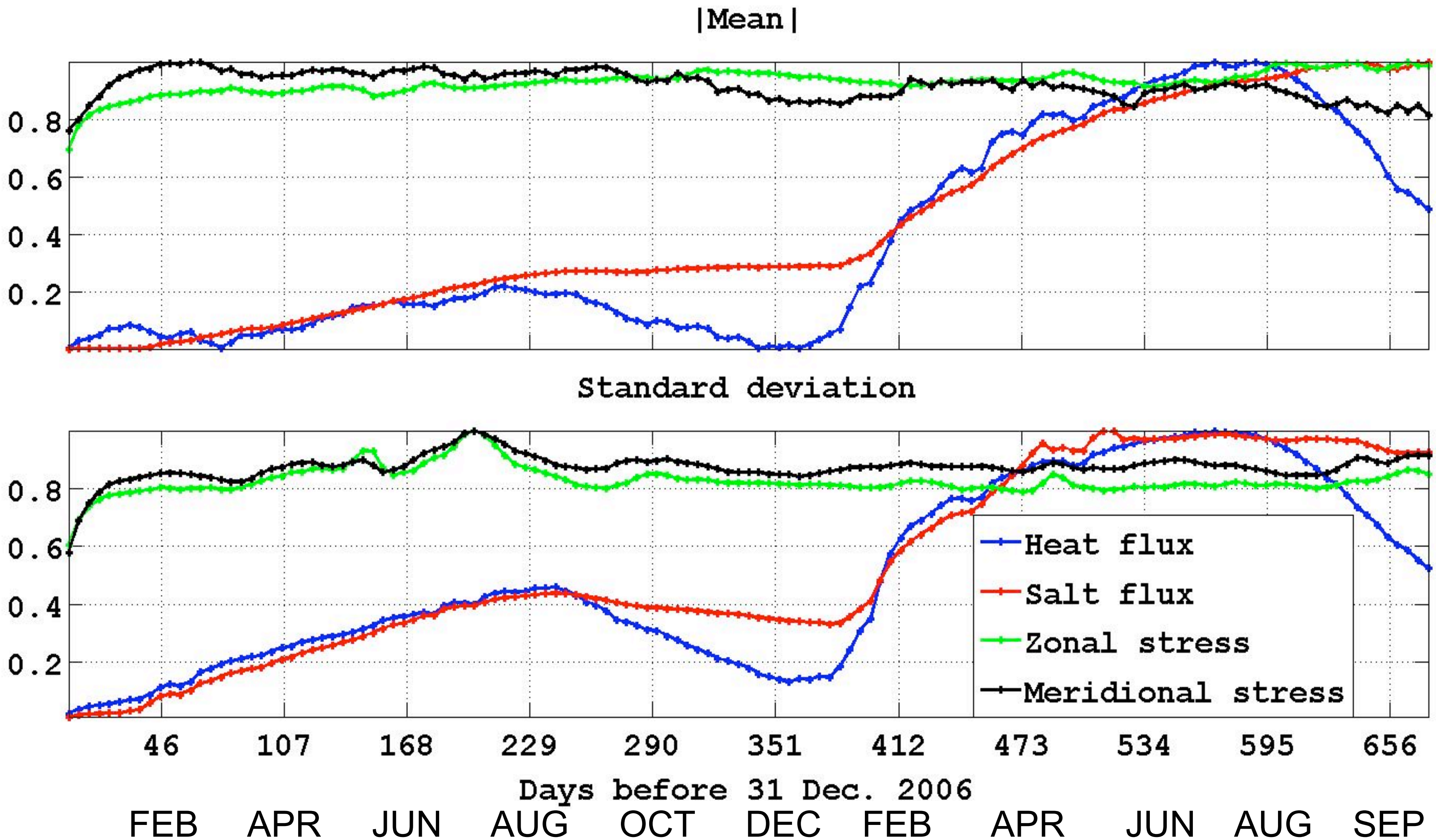


<= Hflux

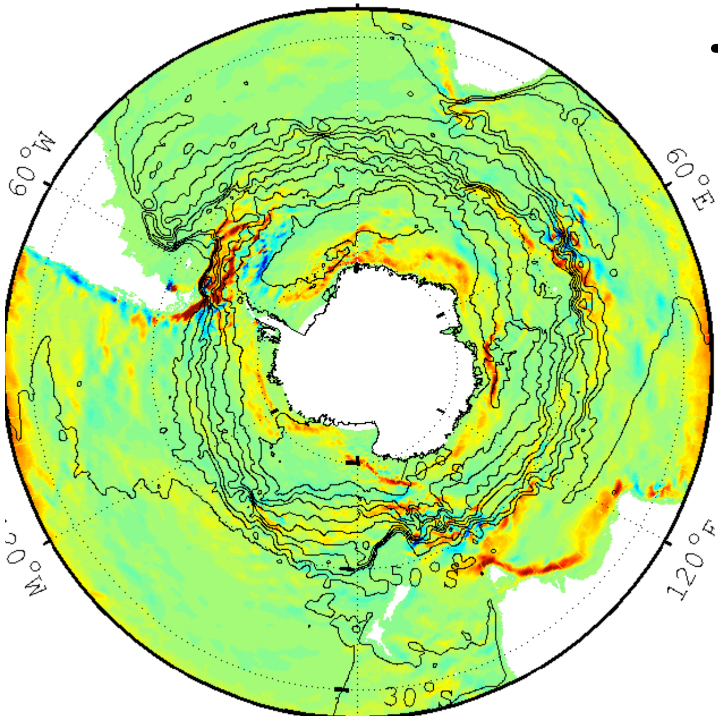
Sflux =>



Temporal dependence of ACC transport sensitivity to surface fluxes. Spatial std. dev. & mean

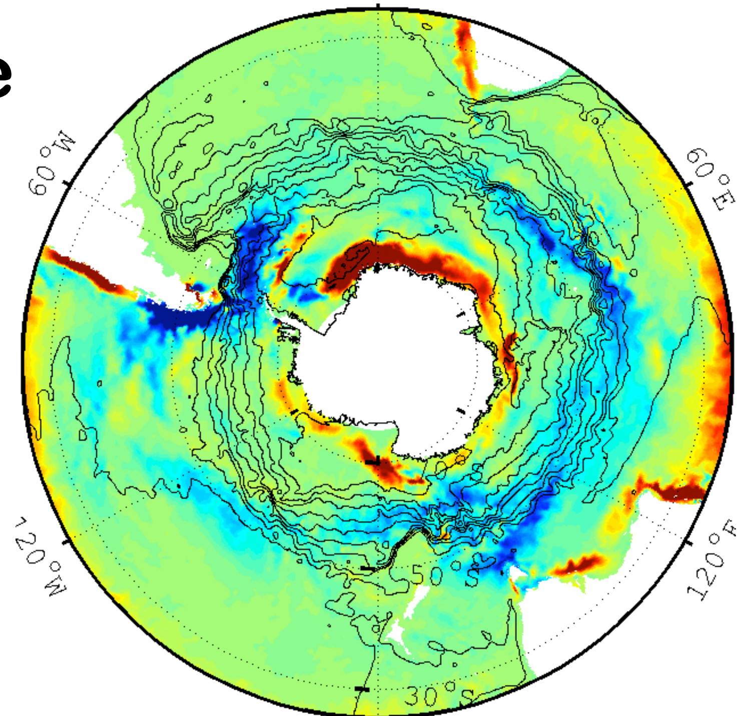


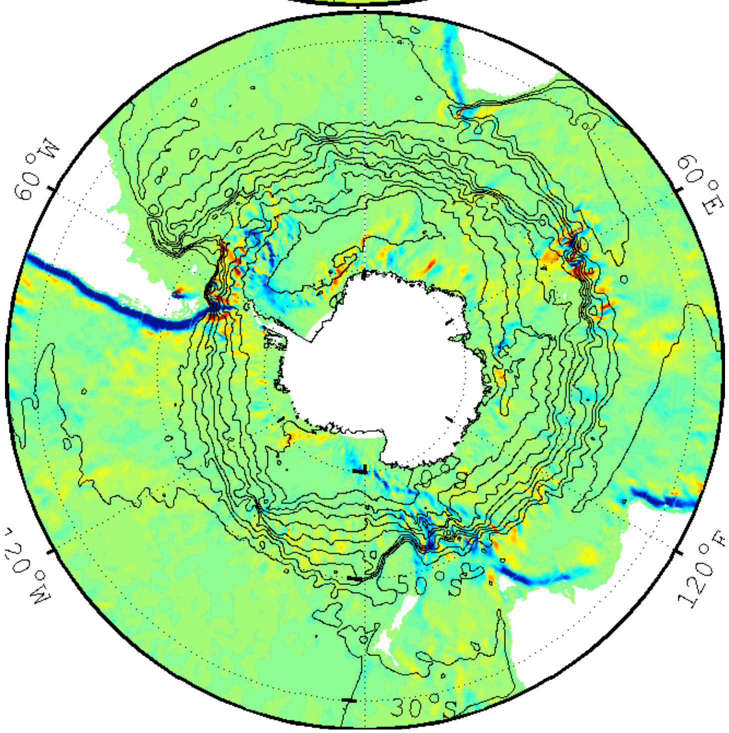
Time average



<=Ustress

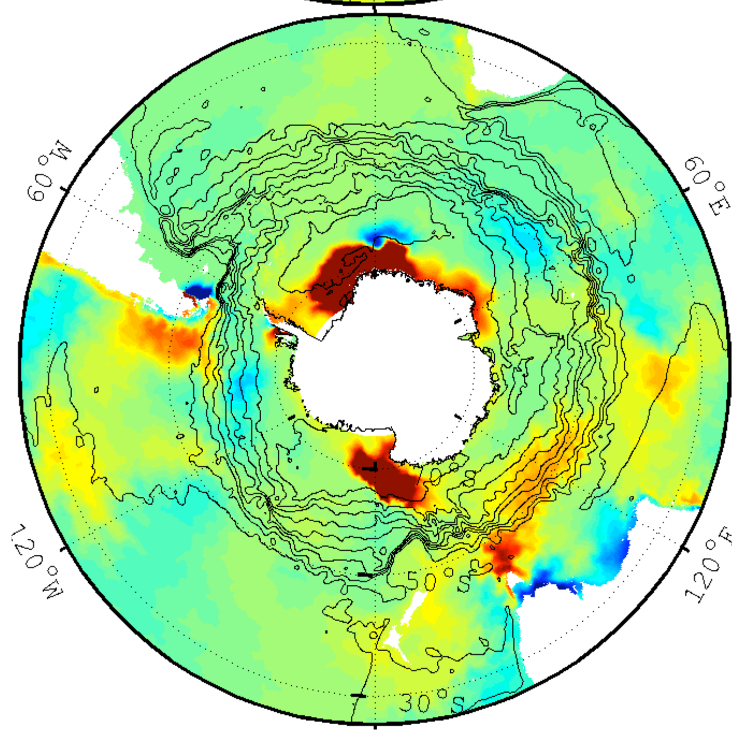
Hflux =>





<=Vstress

Sflux =>



Summary

- The adjoint model highlights locations where the ocean is especially responsive to the atmospheric state
- The sensitivity of Drake Passage transport is not straightforward to understand… (future work)
- Buoyancy flux sensitivities
  - have a strong seasonal cycle, peaking in August (Austral winter)
  - are larger scale with an up-stream signature.
  - are enhanced in the southeastern subtropical gyres, the eastern boundary regions, the polar gyres, and regions of complex topographically (e.g. the Campbell Plateau, the Drake Passage, and the Kerguelen Plateau)
- Momentum flux sensitivities
  - are relatively constant in time
  - are small scale and enhanced in the eastern boundary regions, in regions of complex topographically, and around Antarctica