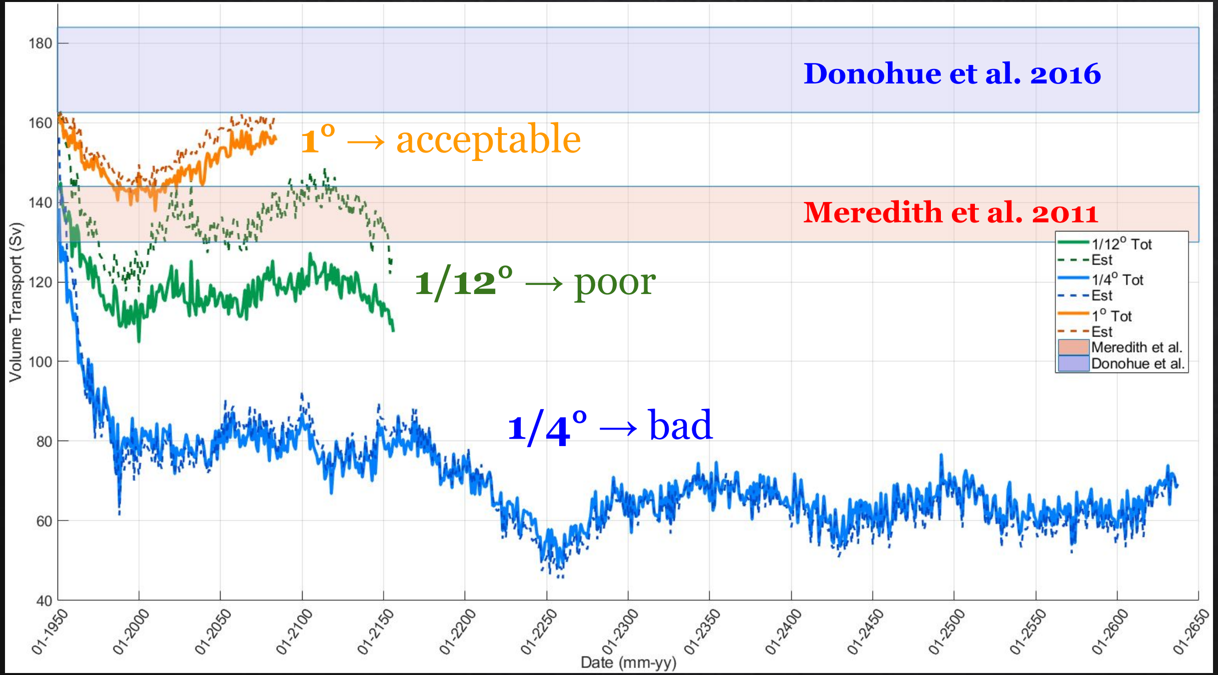
Antarctic Circumpolar Current Biases in a hierarchy of HadGEM3-GC3.1 Models

Keywords: ACC, Volume Transport, Decomposition

Volume Transport: Section 66.5°W



- ➔ Strong resolution dependence of the ACC in UK-CMIP6 model (NEMO).
- ➔ ACC through the Drake Passage weakens significantly in 1/4° and 1/12° resolution models.
- ➔ Decompose ACC transport using:
  - ◆ North/South boundary densities.
  - ◆ Bottom velocities, Wind stress.

$$Q_{Est} = Q_N + Q_S + Q_{Beta} + Q_{Ek} + Q_{bot}$$

- ➔ Higher resolution models suggest an initial localised return flow along Antarctic coast, indicated by:
  - ◆ Slumping of isopycnals near southern boundary.
- ➔ Strengthening of the Weddell gyre.

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Antarctic Circumpolar Current Biases in a hierarchy of HadGEM3-GC3.1 Models

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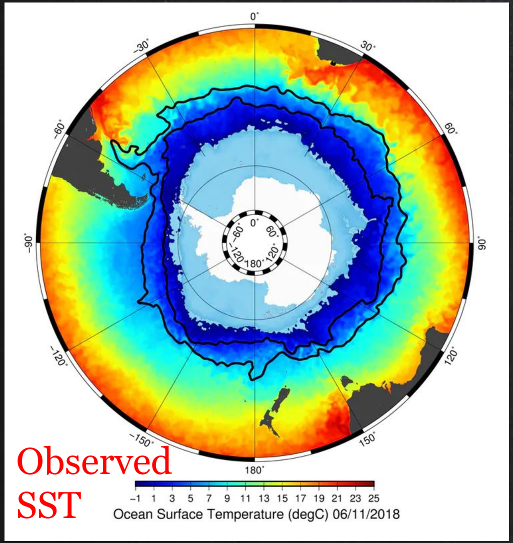
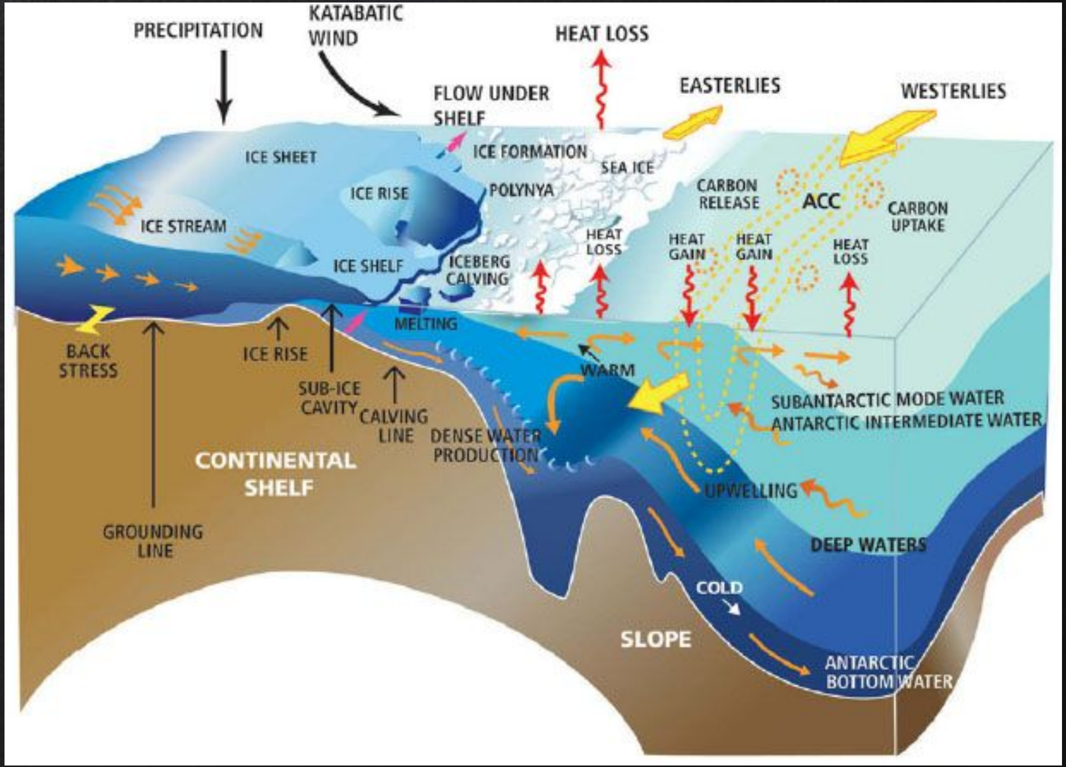
The Antarctic Circumpolar Current (ACC)

Helen E. Phillips : https://theconversation.com/explainer-how-the-antarctic-circumpolar-current-helps-keep-antarctica-frozen-106164



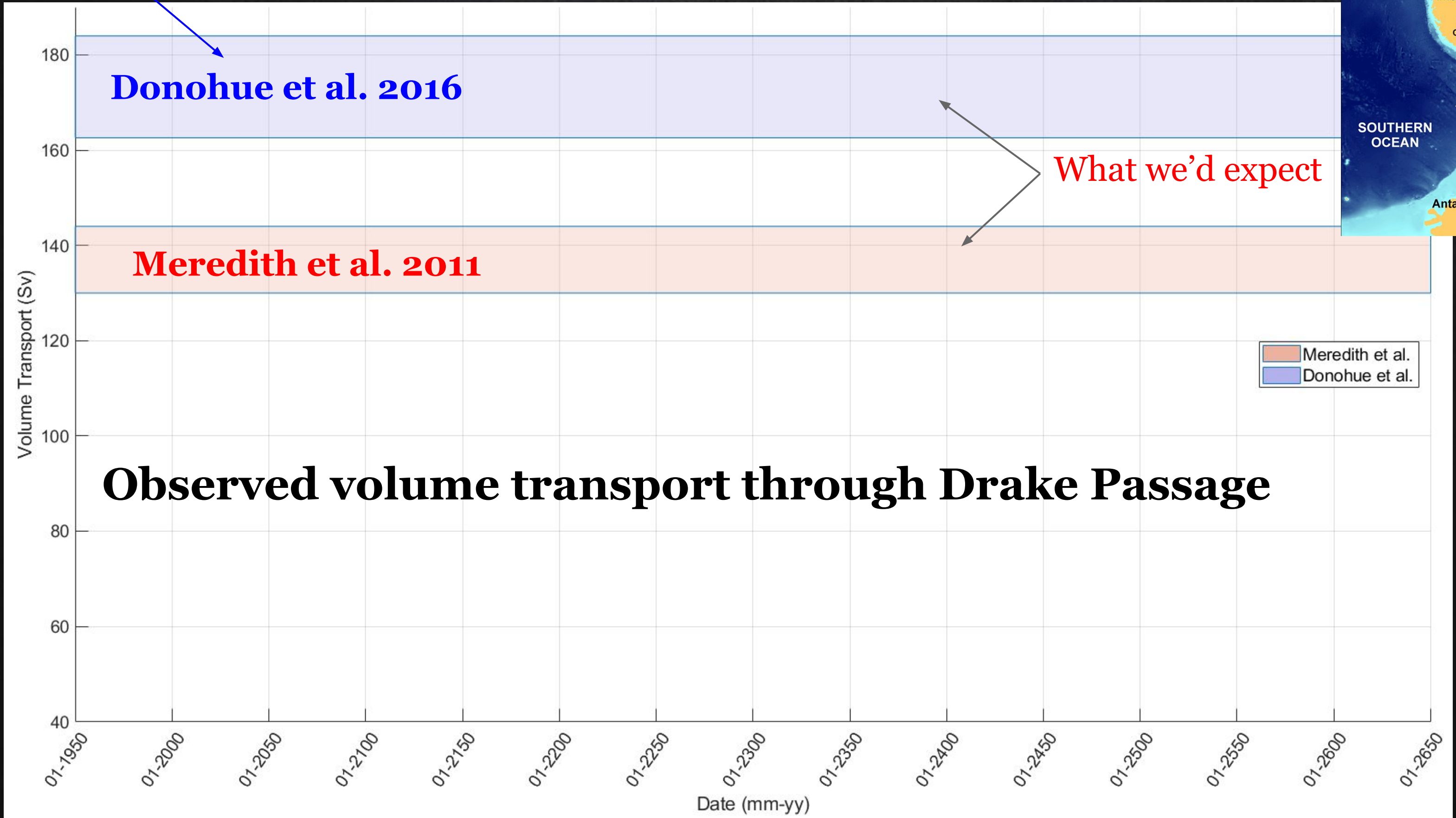
- ➔ Unique bathymetry, lack of zonal boundary
- ➔ Strong westerly winds
- ➔ Eqtr → Pole temperature gradient
- ➔ Tilts N → S isopycnals upwards
- ➔ Eastward flowing circumpolar current
- ➔ Transports heat, carbon, nutrients to the major ocean basins



Future Science Opportunities in Antarctica and the Southern Ocean (2011)

Motivation

Includes depth-dependent flow estimate



https://www.iastoppers.com/18th-january-2018-current-affairs-analysis-iastoppers/drake-passage-map-ias/

66.5°W

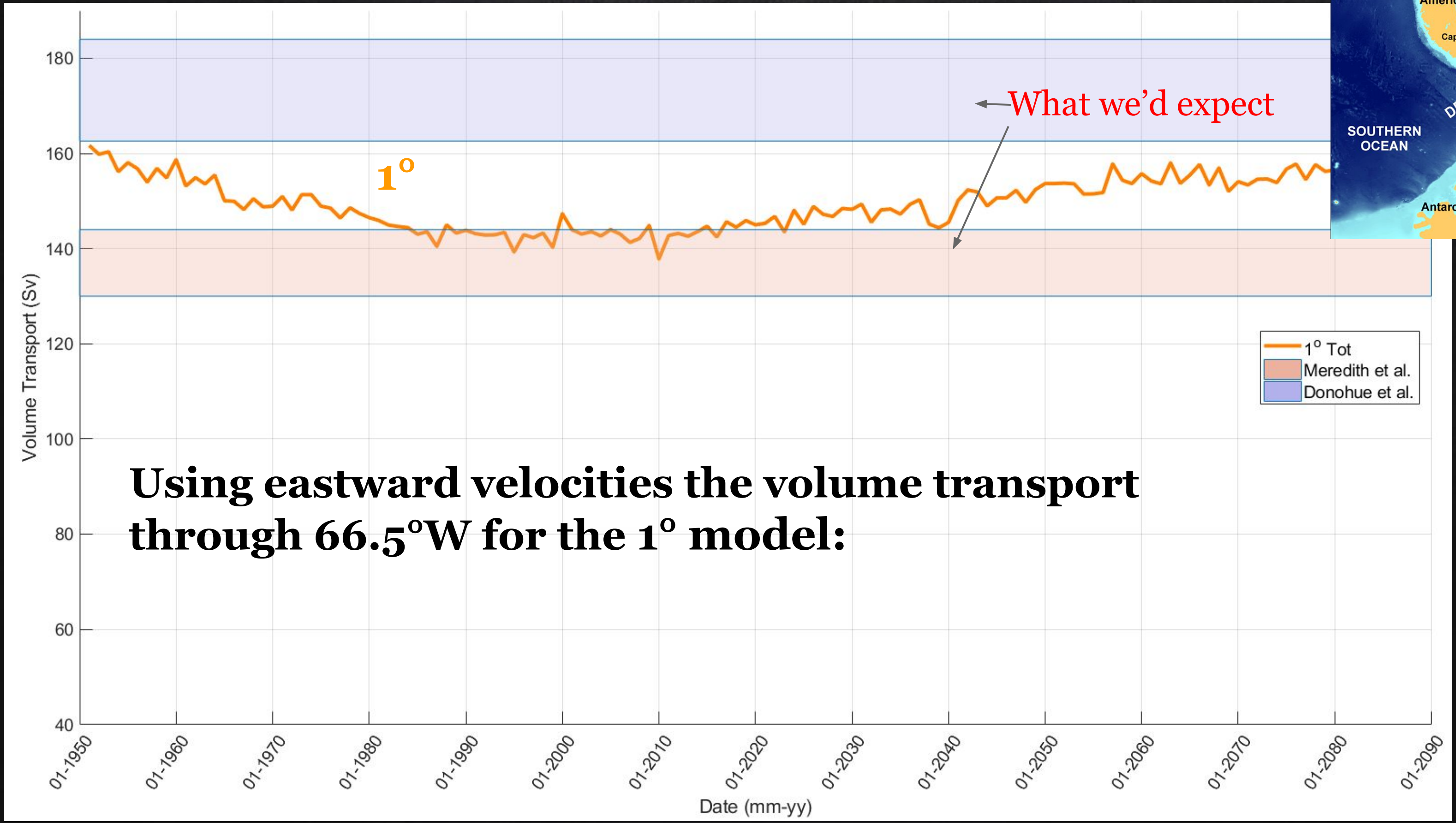
Model:

Prototype HadGEM3-GC3.1

N216 Atmosphere

Annual-means

Motivation



Using eastward velocities the volume transport through 66.5°W for the 1° model:

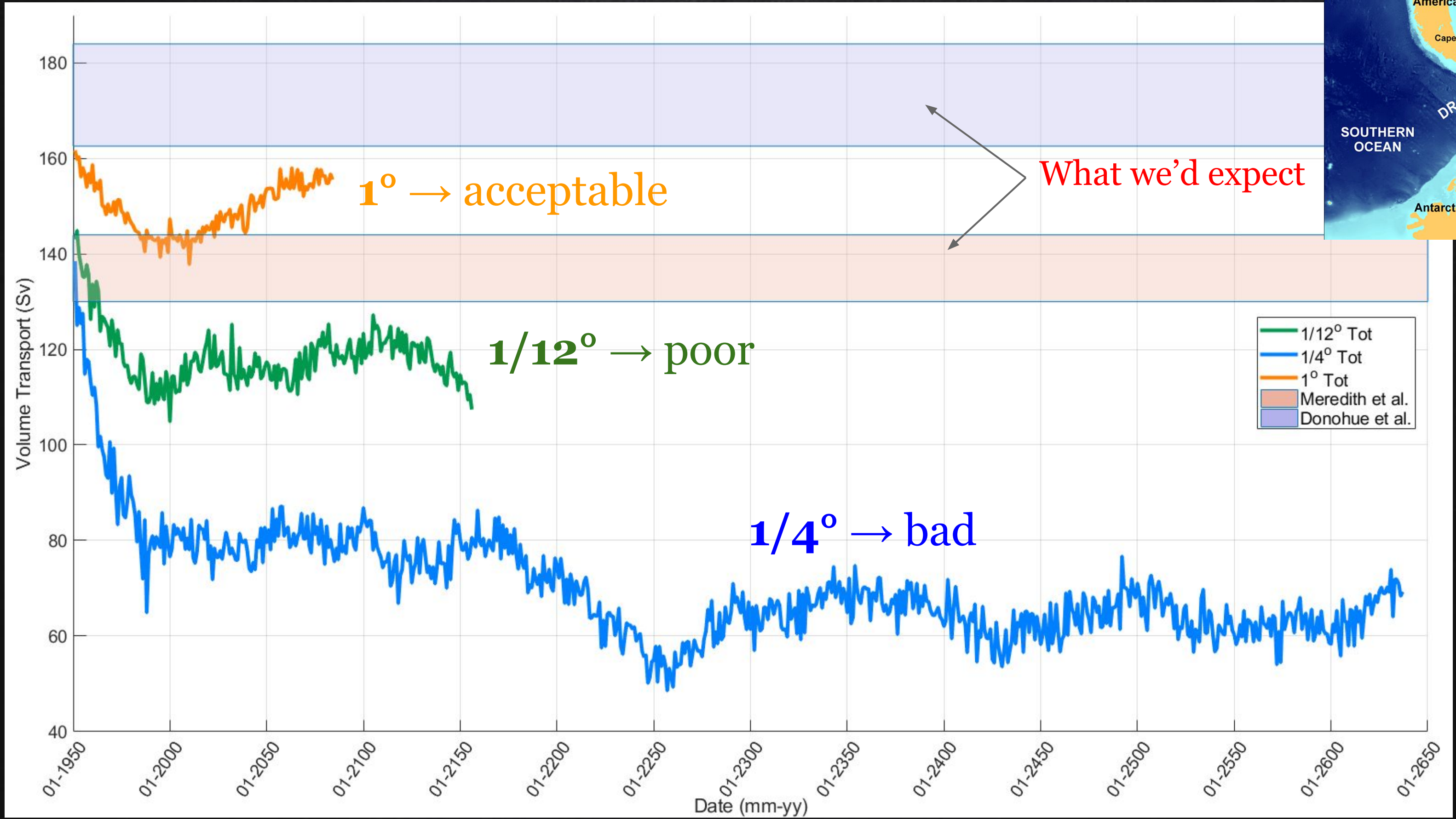
66.5°W

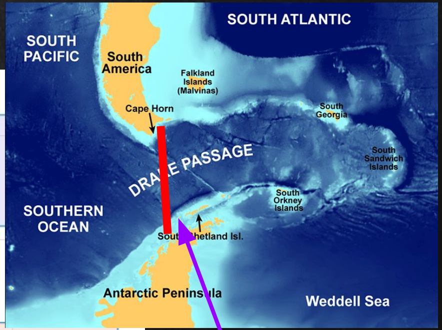
<u>Model:</u>
Prototype
HadGEM3-GC3.1

N216 Atmosphere

Annual-means

Motivation





66.5°W

Model:

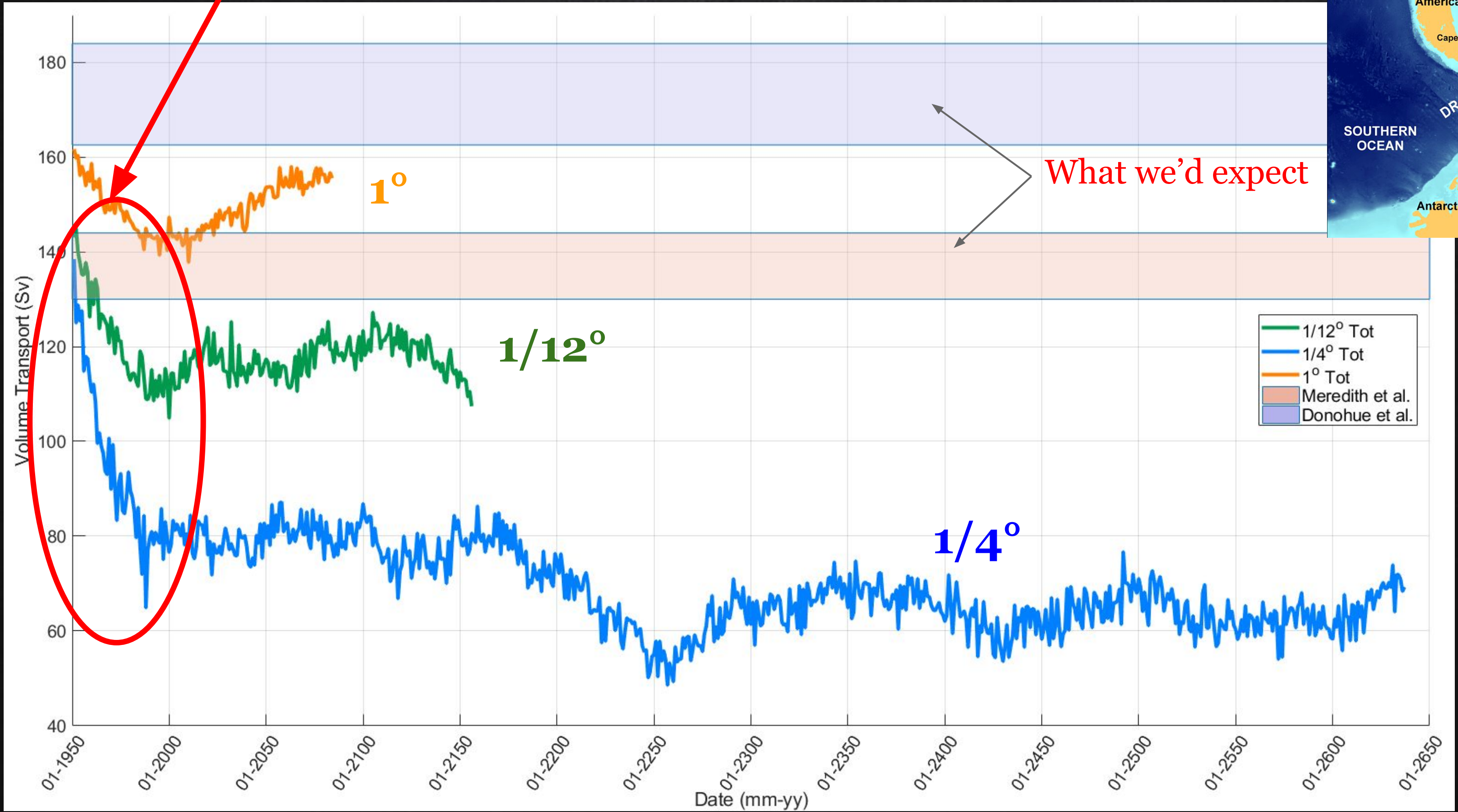
Prototype HadGEM3-GC3.1

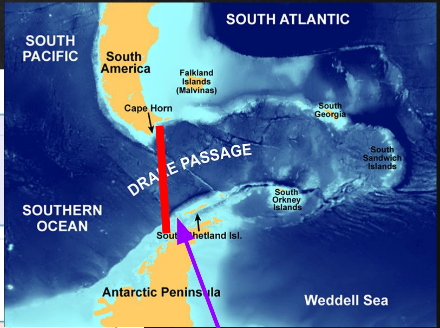
N216 Atmosphere

Annual-mean data

Motivation

Concentrate on spin-up region





66.5°W

Model:

Prototype

HadGEM3-GC3.1

N216 Atmosphere

Annual-means

Want to understand the large variations between resolutions

Investigations:

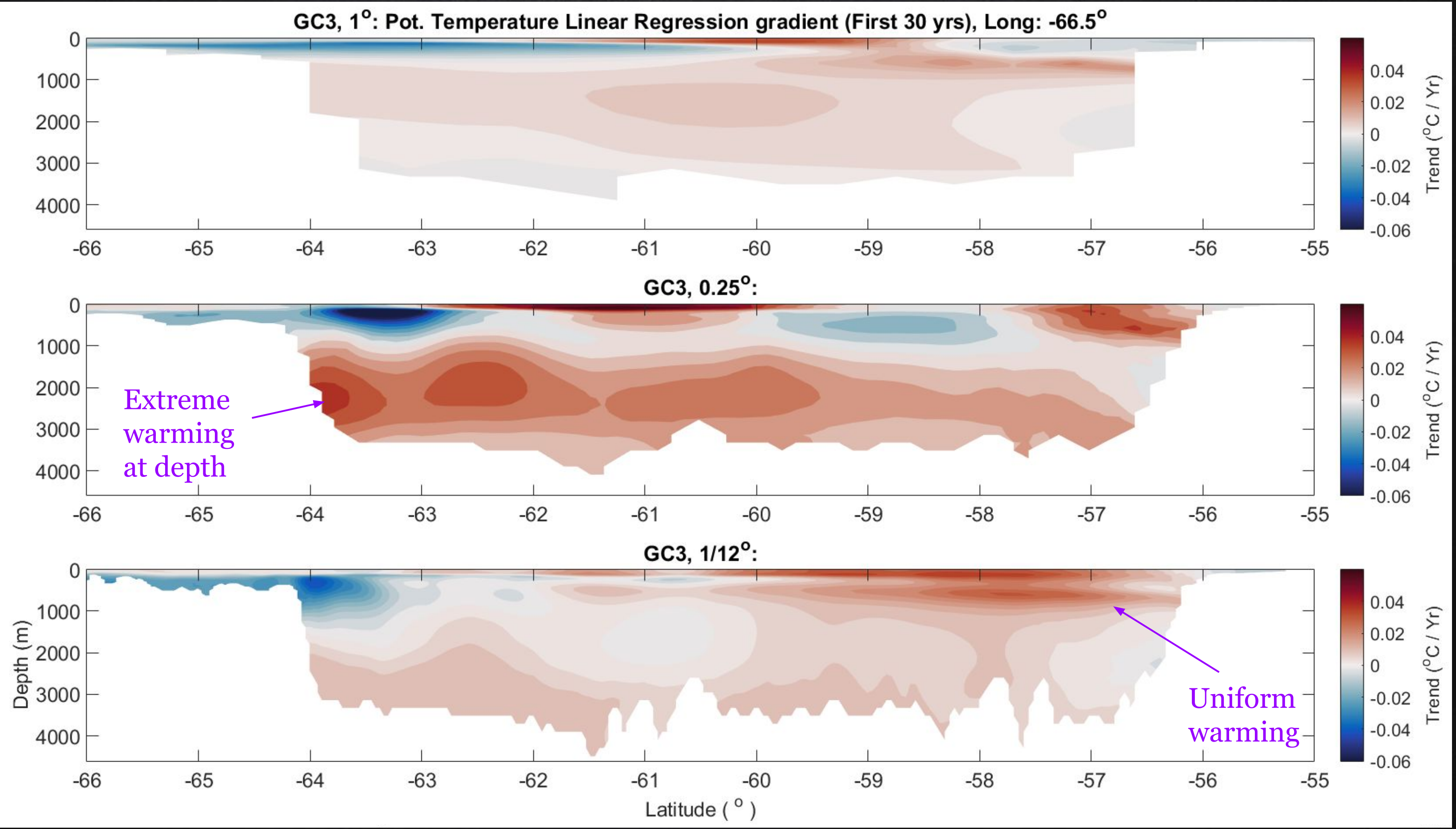
- ➔ Potential Temperature, Salinity, Neutral Density cross-sections at 66.5°W
- ➔ Decompose transport at 66.5°W to analyse boundary contributions
- ➔ The role of Weddell gyre

Cross-sectional analysis at 66.5°W

For spin-up phase (first 30 years) of run

Temperature trends

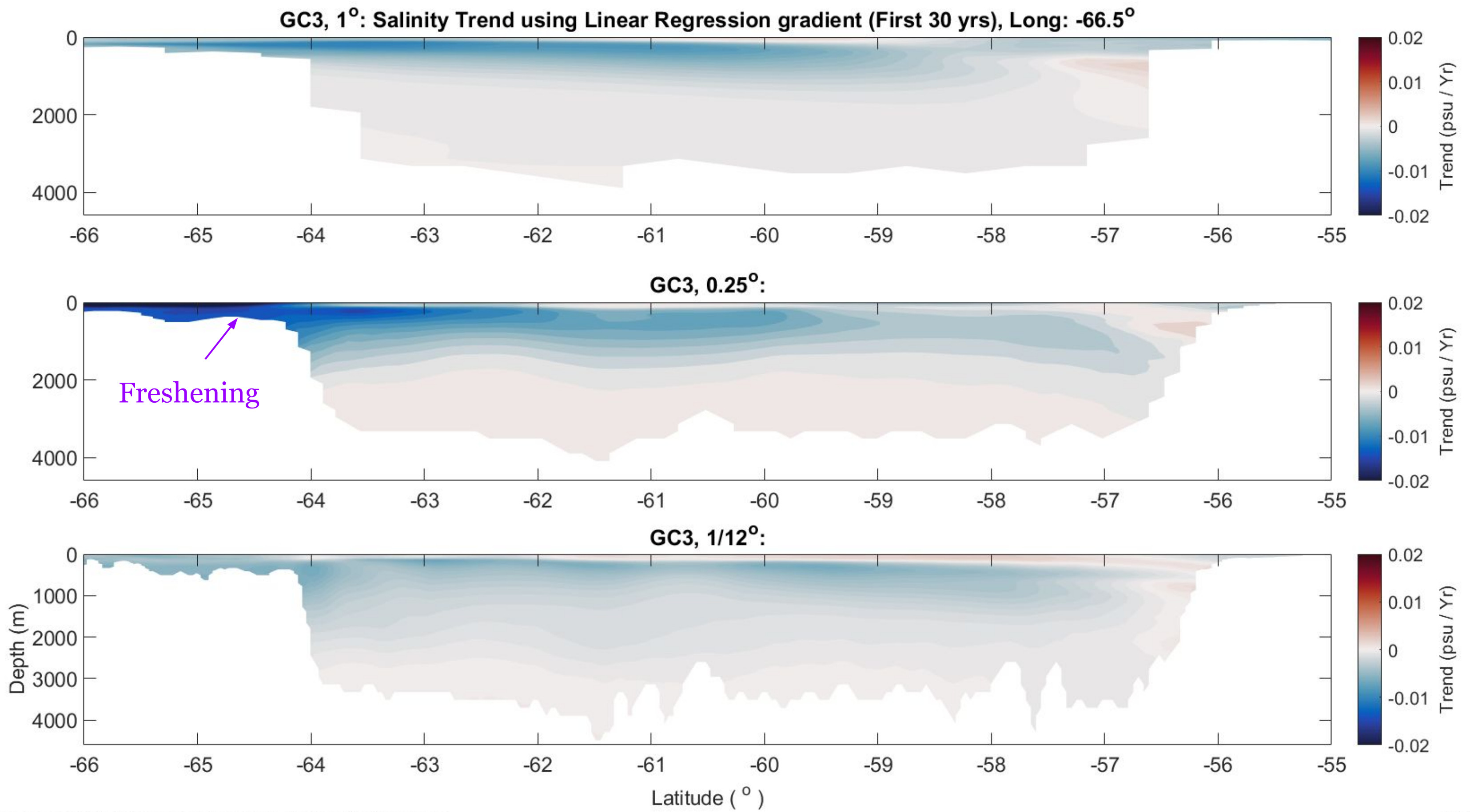
66.5°W



For spin-up phase
(first 30 years) of run

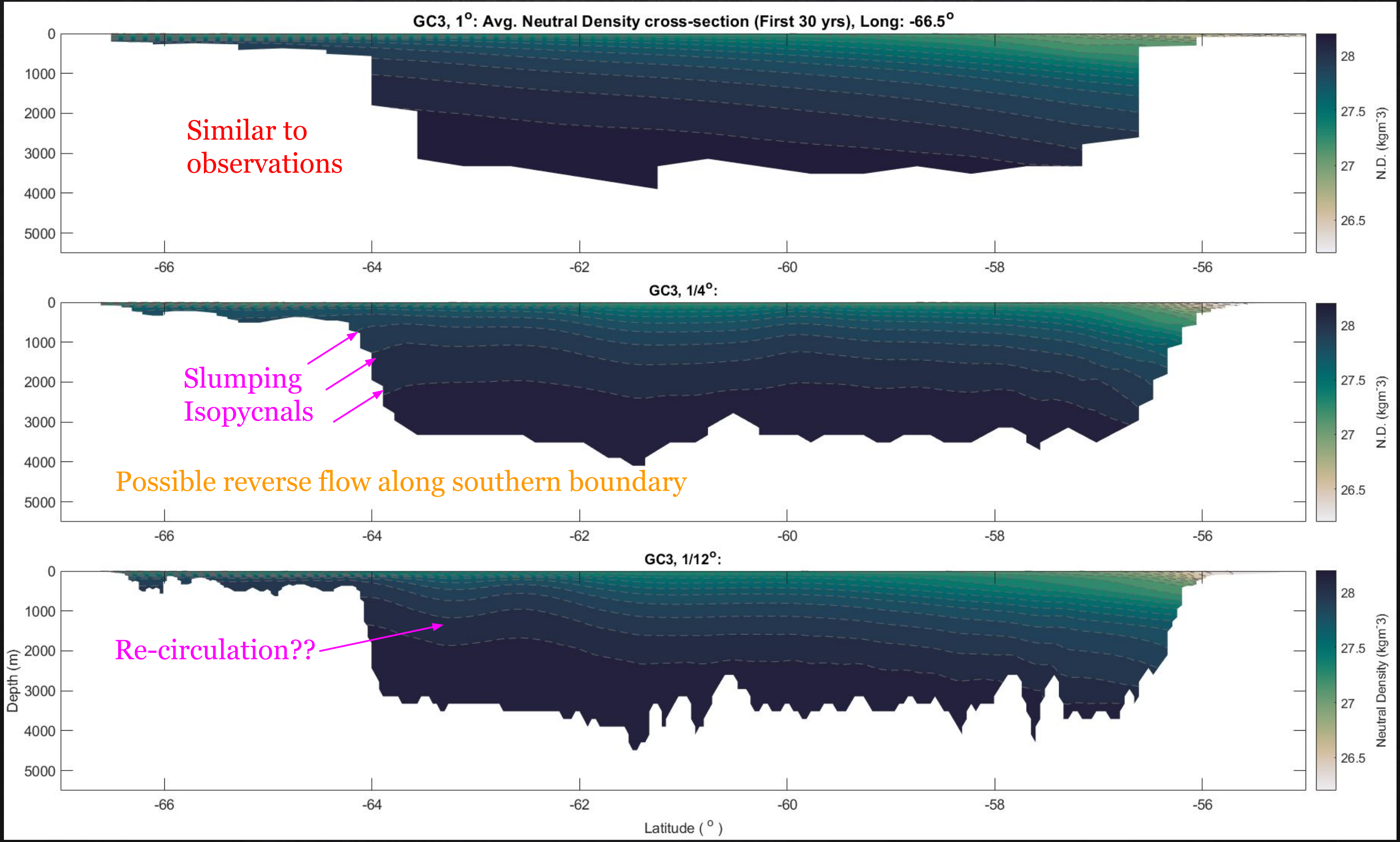
Salinity trends

66.5°W



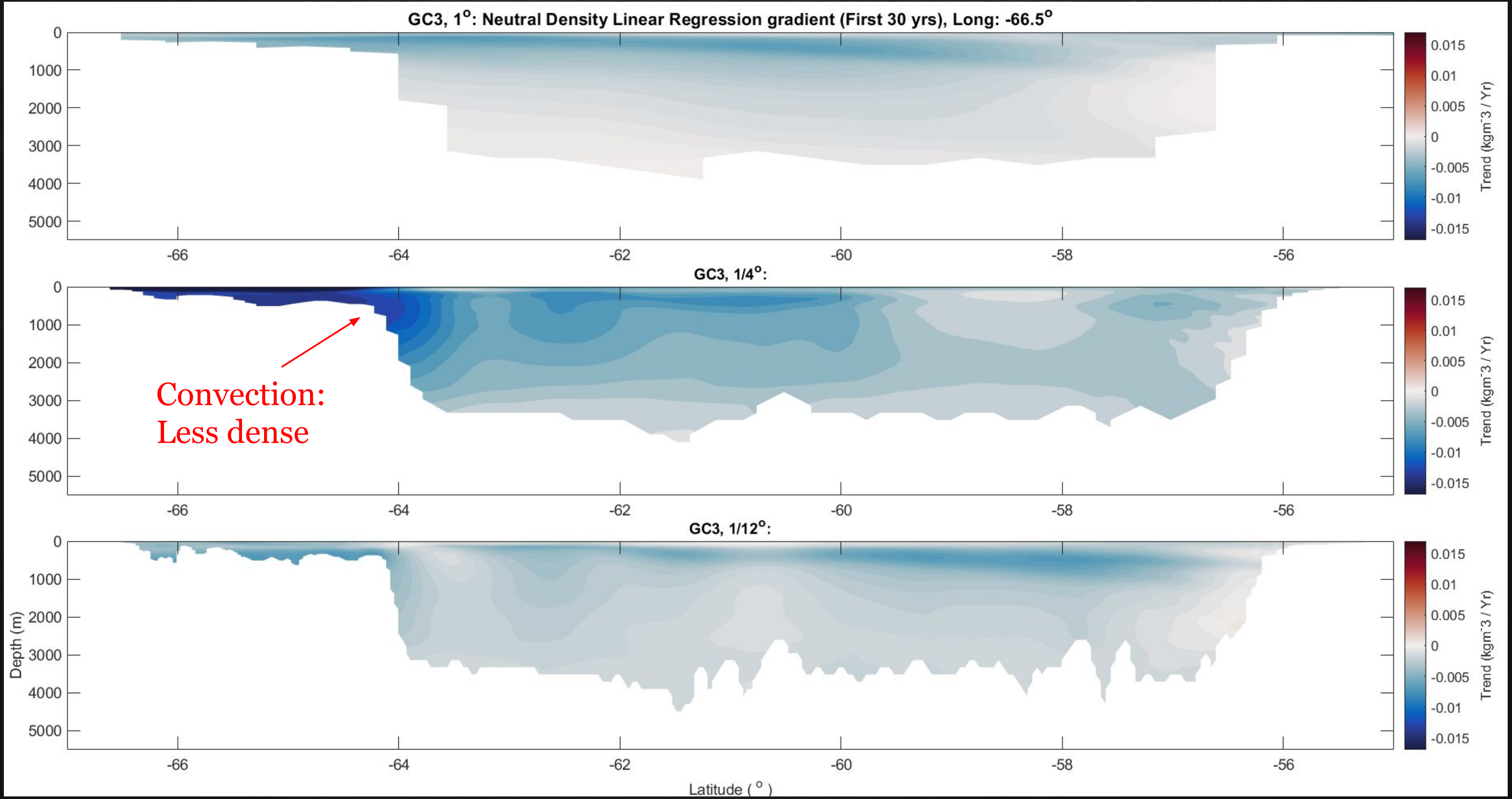
Neutral Density cross-sections

66.5°W



Neutral Density trends (First 30 years)

66.5°W

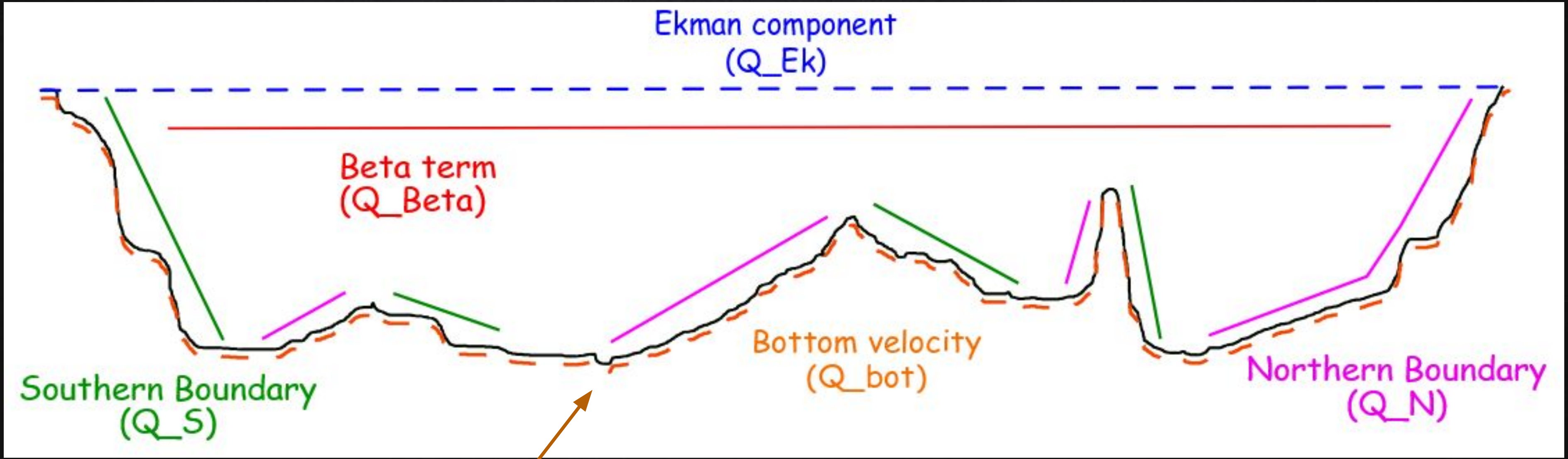


Decomposition of transport at 66.5°W

Decomposition of volume transport

$$Q(z;x,t) = \int_S^N \int_{-H}^z u_E(x,y,z',t)dz'dy$$

$$Q_{Est} = Q_N + Q_S + Q_{Beta} + Q_{Ek} + Q_{bot}$$



Q_S and Q_N referenced to the neutral density at deepest point

$$\sigma(y,z\,;\,t) = \rho(y,z\,;\,t) - \rho_{dp}(y\,;\,t=0)$$

Decomposition specifics

$$Q_{North}(z) = \frac{g}{\rho_0} \int_{-H(N(z))}^{z} (z - z') \left(\frac{\sigma_N(z')}{f_N(z')} \right) \mathrm{d}z'$$

$$Q_{South}(z) = -\frac{g}{\rho_0} \int_{-H(S(z))}^{z} (z - z') \left(\frac{\sigma_S(z')}{f_S(z')} \right) \mathrm{d}z'$$

$$Q_{Beta}(z) = \int_{S(z)}^{N(z)} \frac{\beta(y)}{f^2(y)} \int_{-H(y)}^{z} (z - z')\, \sigma(y, z')\, \mathrm{d}z'\, \mathrm{d}y$$

$$Q_{Bot}(z) = \int_{S(z)}^{N(z)} \int_{-H(y)}^{z} u_{bot}(y)\, \mathrm{d}z'\, \mathrm{d}y$$

$$Q_{Ekm}(z) = \frac{1}{\rho_0} \int_{S(z)}^{N(z)} \frac{1}{h(y) f(y)} \int_{-h(y)}^{z} \tau_S^y(y, z') \mathrm{d}z' \mathrm{d}y$$

Density terms

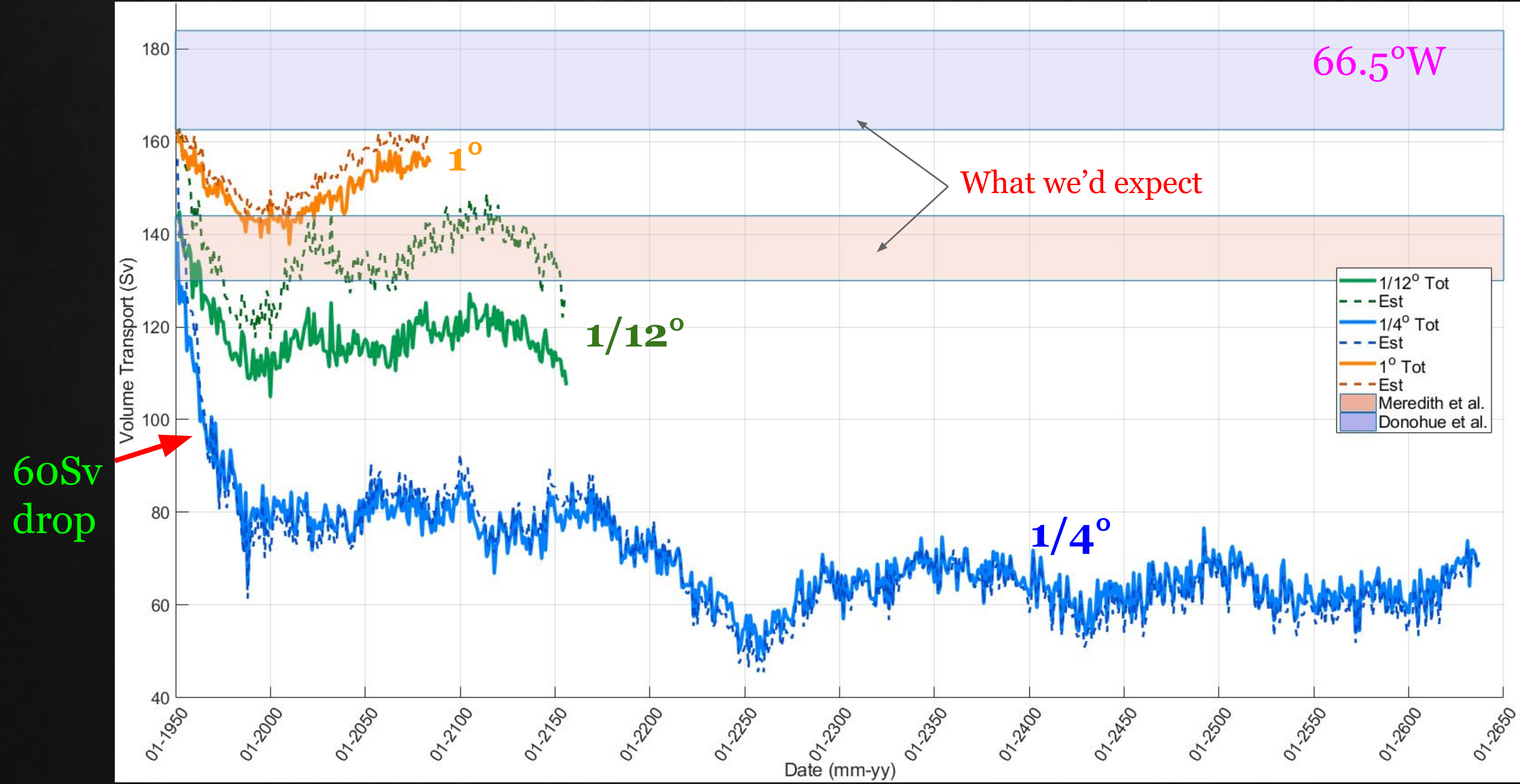
Use density from first full cell along sloping boundary

Term due to varying Coriolis parameter

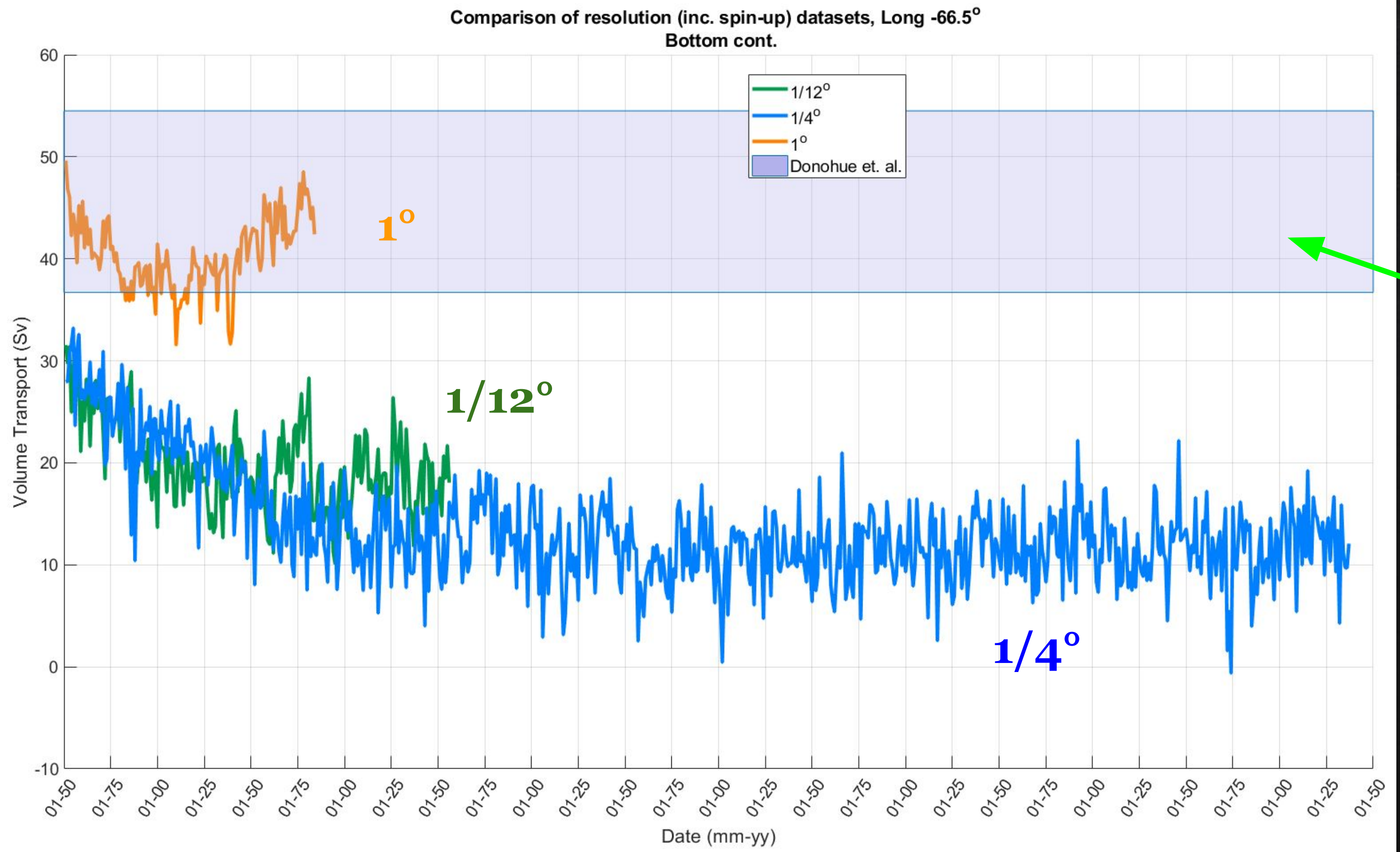
Depth-independent term using eastward bottom velocities

Wind stress term

Our estimate: $Q_{Est} = Q_N + Q_S + Q_{Beta} + Q_{Ek} + Q_{bot}$



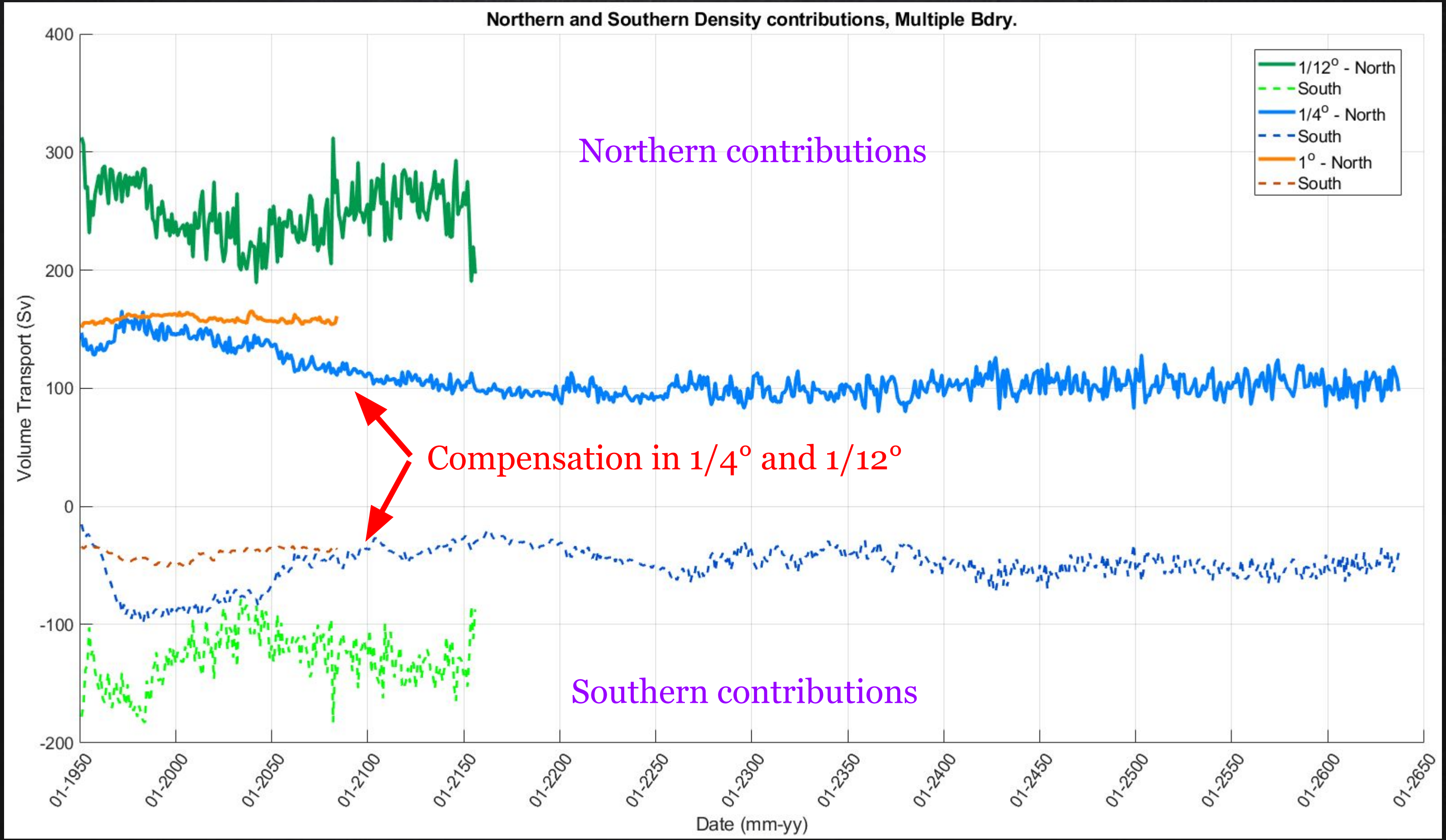
Depth-independent (bottom) component



Donohue et al. 2016 estimate.

Ekman and Beta contributions negligible

Northern and Southern Density components



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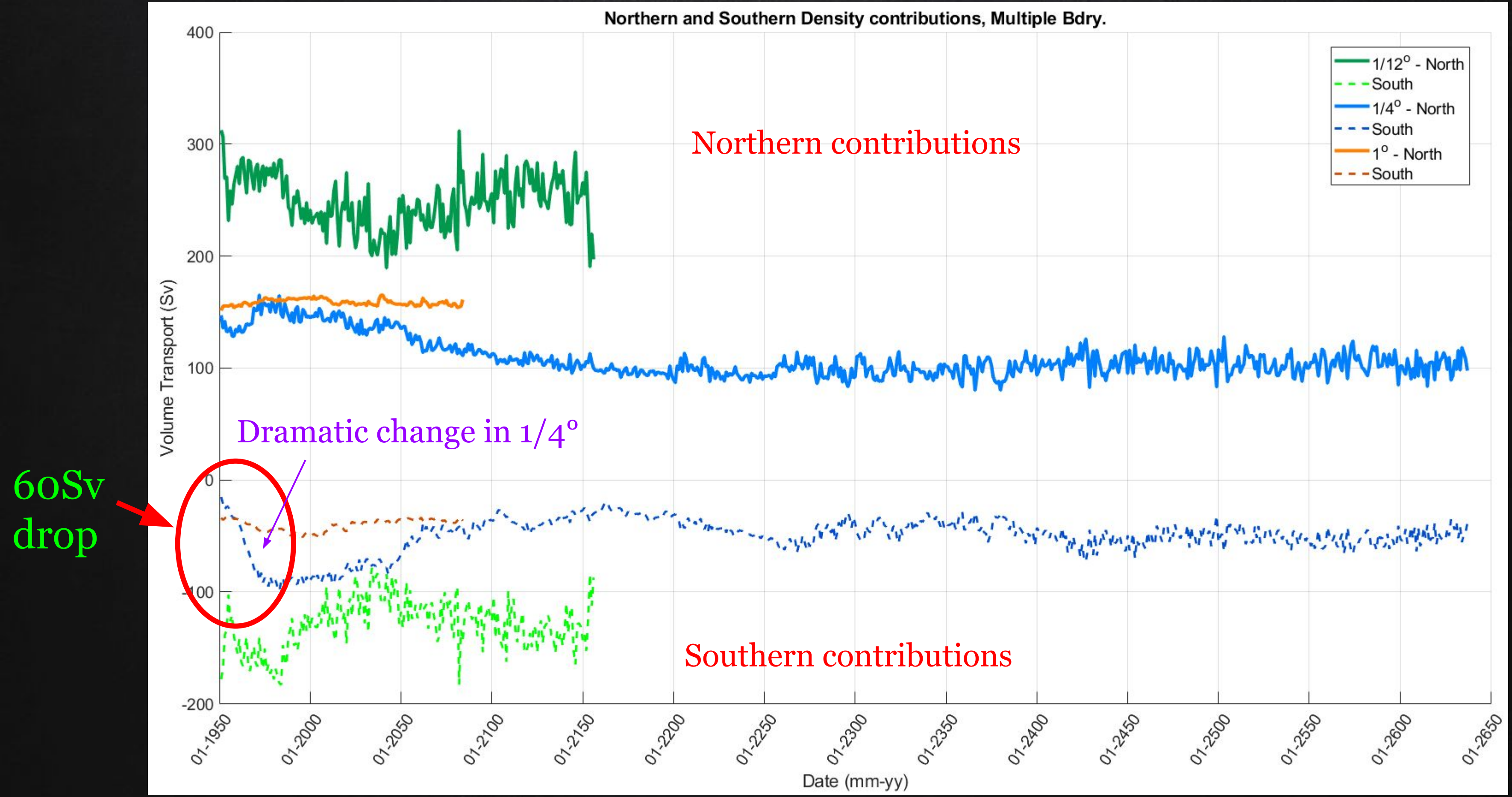
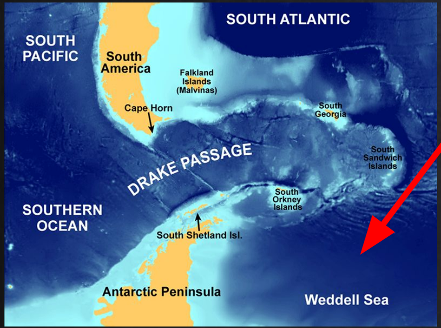


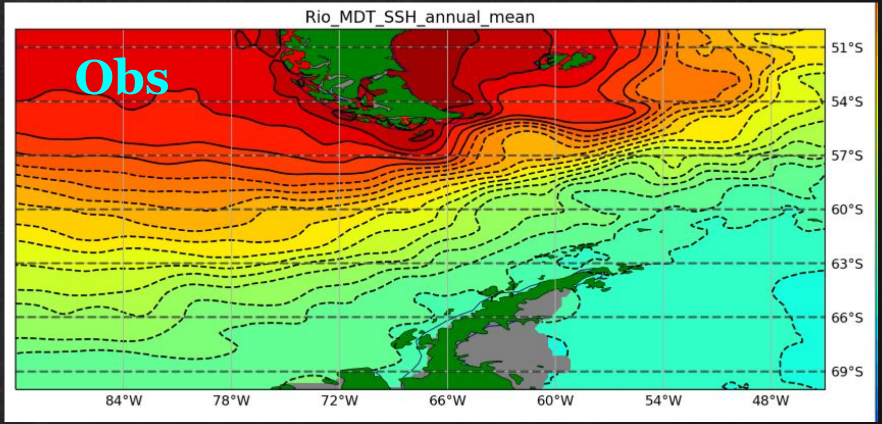
The role of Weddell gyre

Physical interpretation

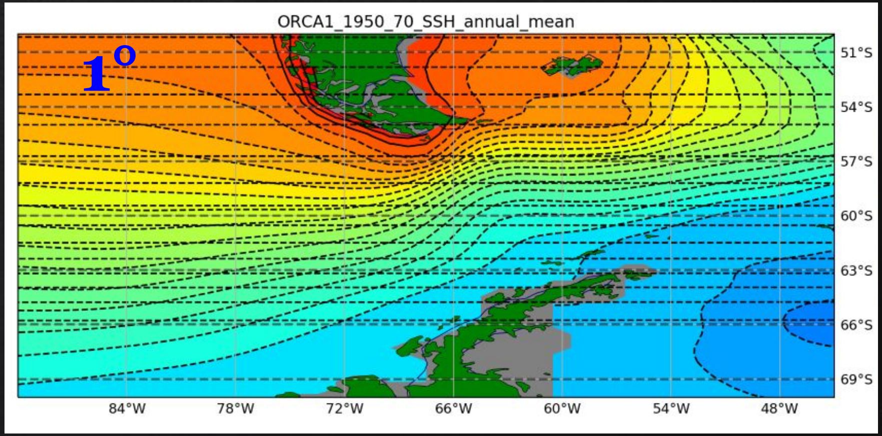


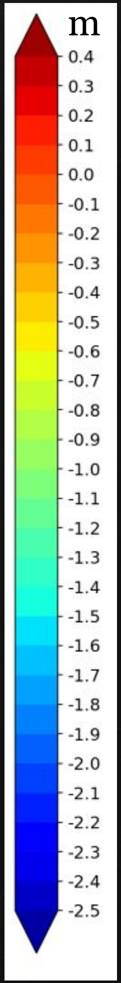
Weddell Gyre

- ➔ For 1/4°, 1/12° model Weddell Gyre expands
- ➔ Drives convection of bottom water
- ➔ Slumps isopycnals, return flow induced
- ➔ Use SSH to investigate

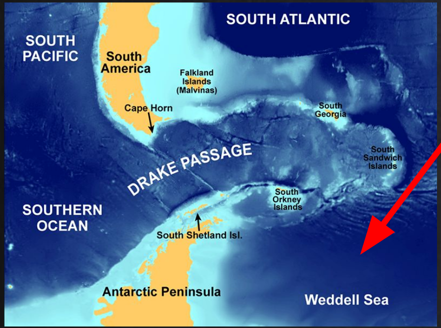


Sea Surface Height
(annual-mean)

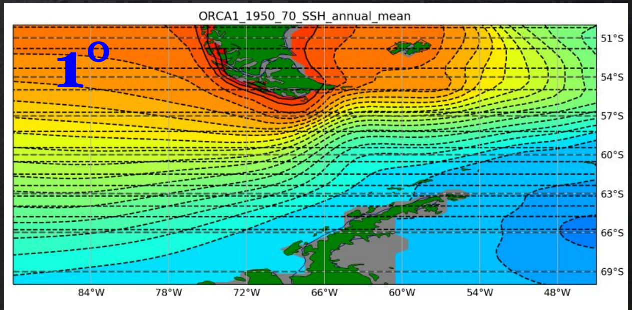




Physical interpretation



Weddell Gyre



- For 1/4°, 1/12° model Weddell Gyre expands
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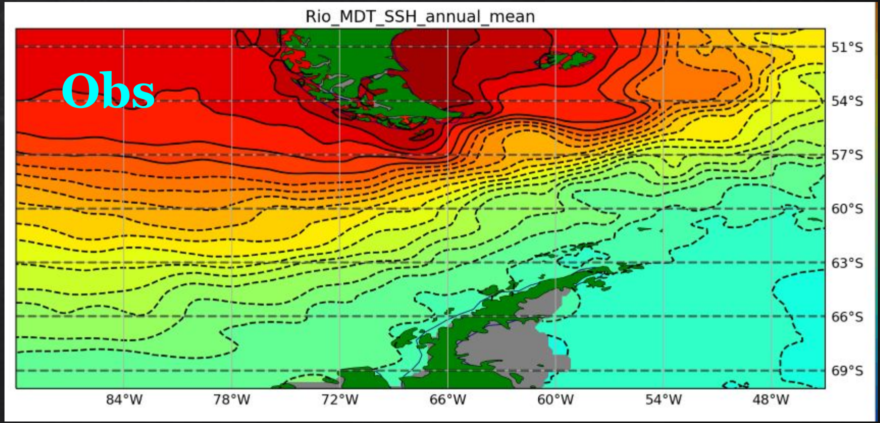
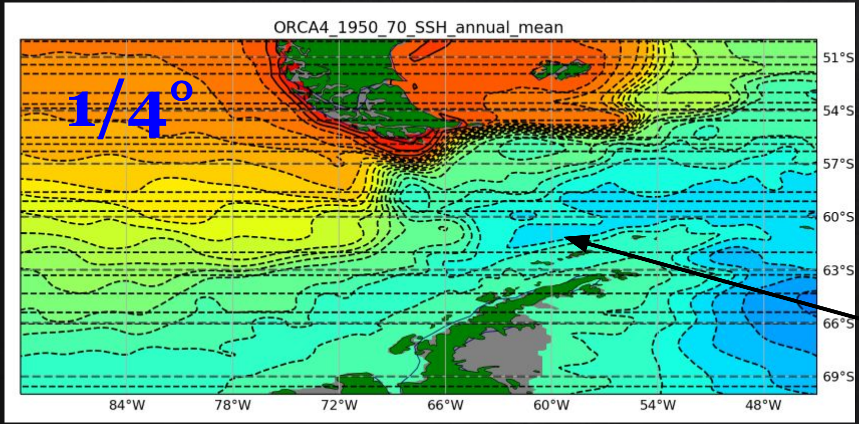
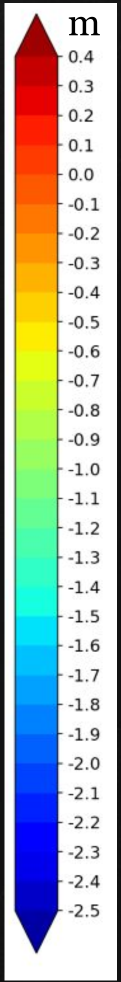




Gyre appears to expand into passage



Apologies, preliminary plots... With thanks to Pat.

Future Work

- ➔ Improve 1/12° estimate
  - ◆ Influence of trenches (overestimate transport)
  - ◆ Using momentum diagnostics
  - ◆ Influence of time-averaging fields
- ➔ Understand sensitivity of 1/4°
- ➔ Investigating other sections of the ACC (in progress)
- ➔ Volume budget in different regions of Southern Ocean
- ➔ Variability of SSH and role of wind stress

Summary

- ➔ Strong resolution dependence of the ACC in UK-CMIP6 model (NEMO)
- ➔ ACC through the Drake Passage weakens significantly in 1/4° and 1/12° resolution models
- ➔ Higher resolution models suggest an initial localised return flow along Antarctic coast, indicated by:
  - ◆ Lightening of southern density component contribution
  - ◆ Slumping of isopycnals near southern boundary
- ➔ Strengthening of Weddell gyre


Thanks for reading
I'll be available on live chat!
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Beta and Ekman terms