Aim of Webinar Series

- Get the most out of TT3!
  - US AMOC Science Team aims to promote AMOC science
  - Facilitate collaborations
  - (bi)-annual meetings may be suboptimal
- Webinars
  - Discuss pressing AMOC-related issues
  - Exchange ideas for collaborative efforts

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- Webinars
  - Discuss pressing AMOC-related issues
  - Exchange ideas for collaborative efforts
- We need volunteers!
  - Otherwise series will end today
  - Let us know if you want to present a webinar

The Salt Advection Feedback in Eddying Models

Wilbert Weijer

Today’s Topic

- Salt advection feedback and the AMOC

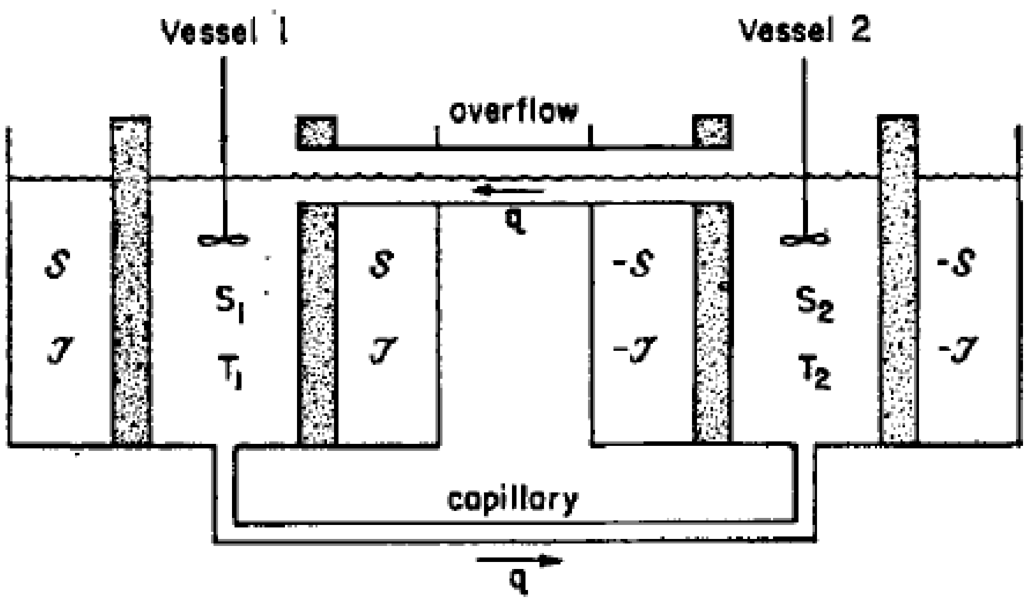
- Theory, low-resolution models:
  – Salt advection feedback critical for AMOC stability
- But:
  – Does the salt advection feedback and its stability implications carry over to an eddying ocean?

Salt Advection Feedback

Stommel 1961

Thermohaline Convection with Two Stable Regimes of Flow

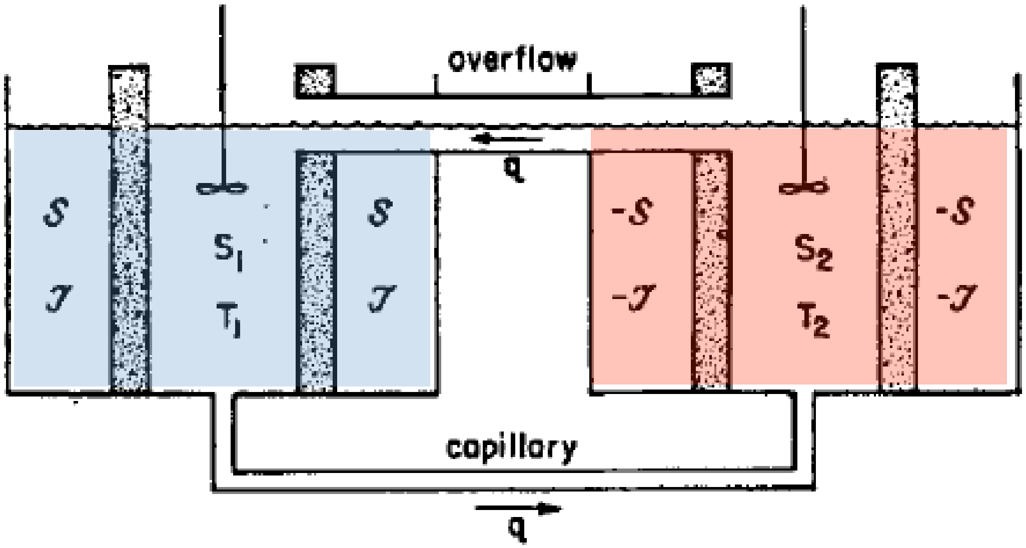
By HENRY STOMMEL, Pierce Hall, Harvard University, Massachusetts



Salt Advection Feedback

Stommel 1961

Cold & Fresh
(subpolar)



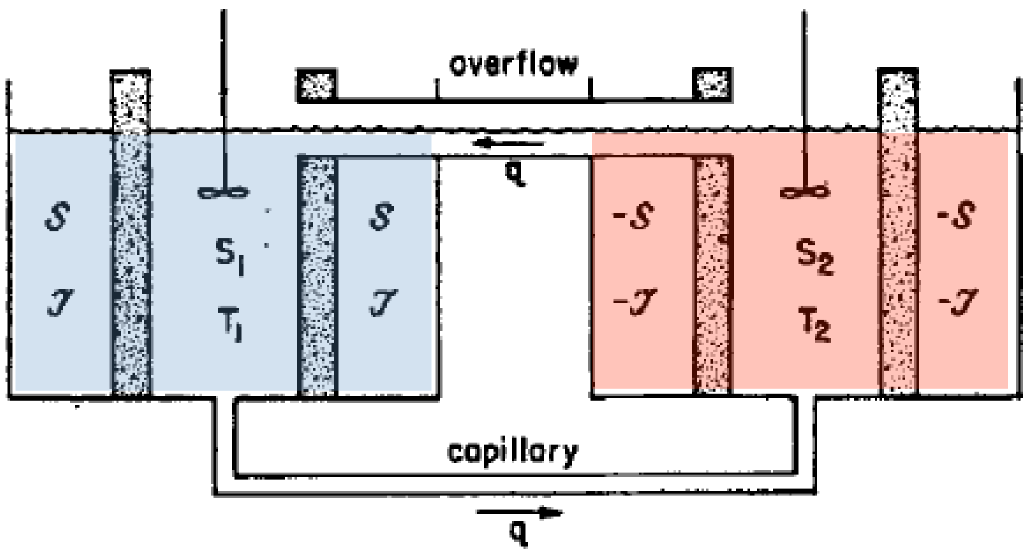
Warm & Salty
(subtropical)

Salt Advection Feedback

Stommel 1961

1) Flow rate proportional to meridional density difference
    - $q \sim \Delta\rho_{NS} \sim -\alpha\,\Delta T_{NS} + \beta\,\Delta S_{NS}$
    - For $q > 0$, temperature drives the flow, salinity provides a brake

Cold & Fresh (subpolar)



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Salt Advection Feedback

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   - $q \sim \Delta\rho_{NS} \sim -\alpha\,\Delta T_{NS} + \beta\,\Delta S_{NS}$
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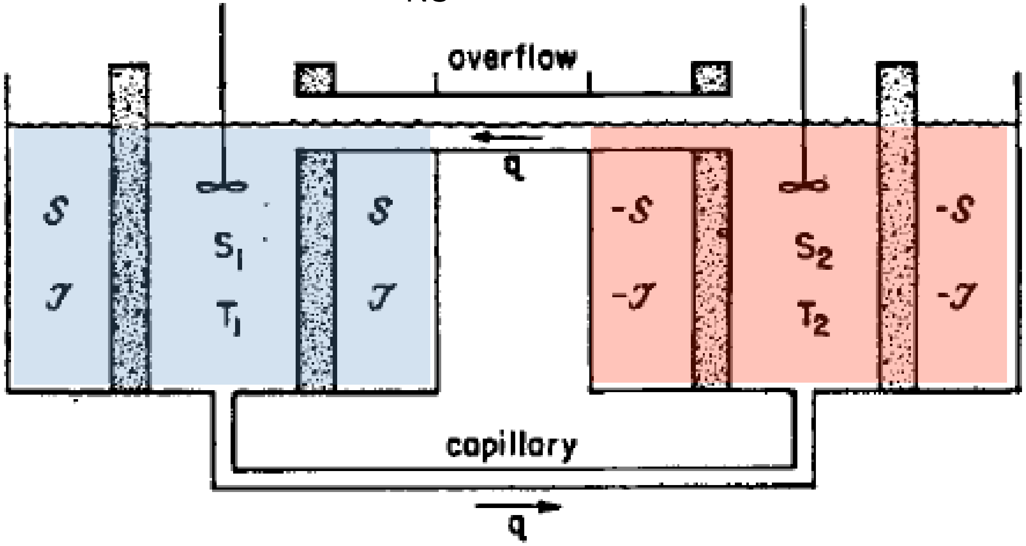
2) Meridional density difference depends on advection between boxes
   - Stronger flow reduces ΔT_{NS}, tends to reduce q (negative feedback)
   - Stronger flow reduces ΔS_{NS}, tends to enhance q (positive feedback)

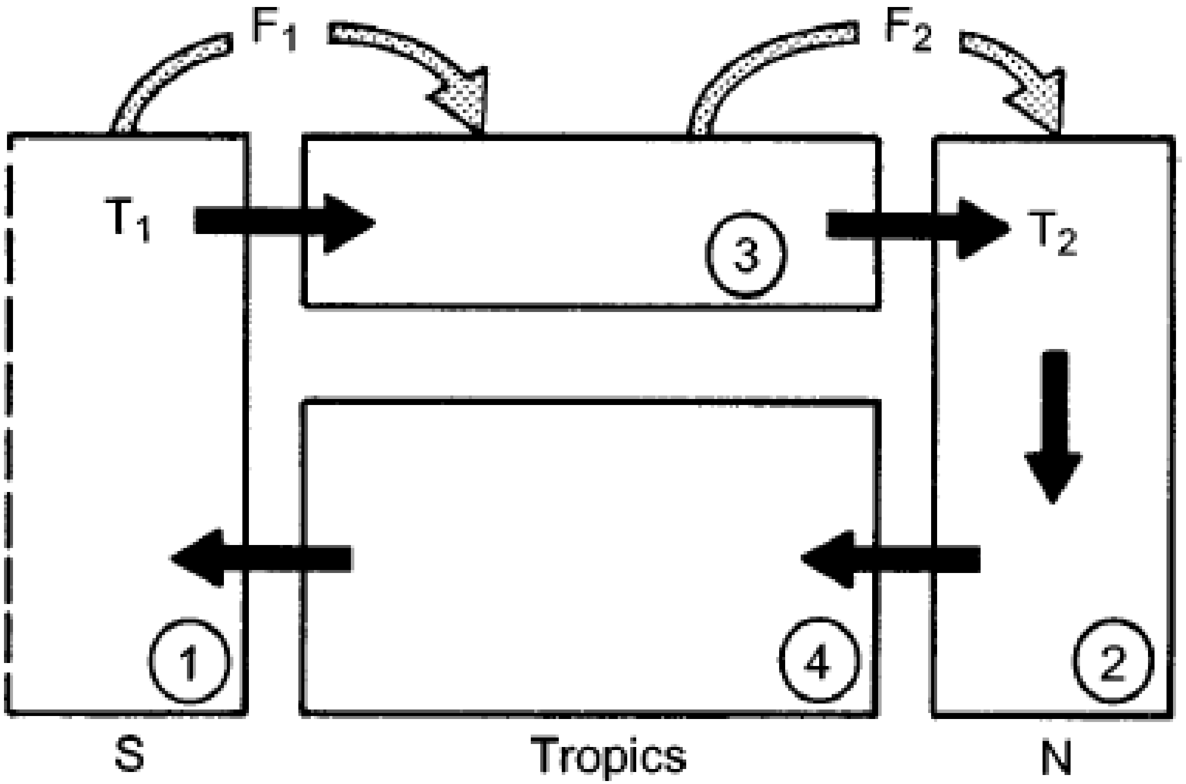
Cold & Fresh (subpolar)



Warm & Salty (subtropical)

Salt Advection Feedback

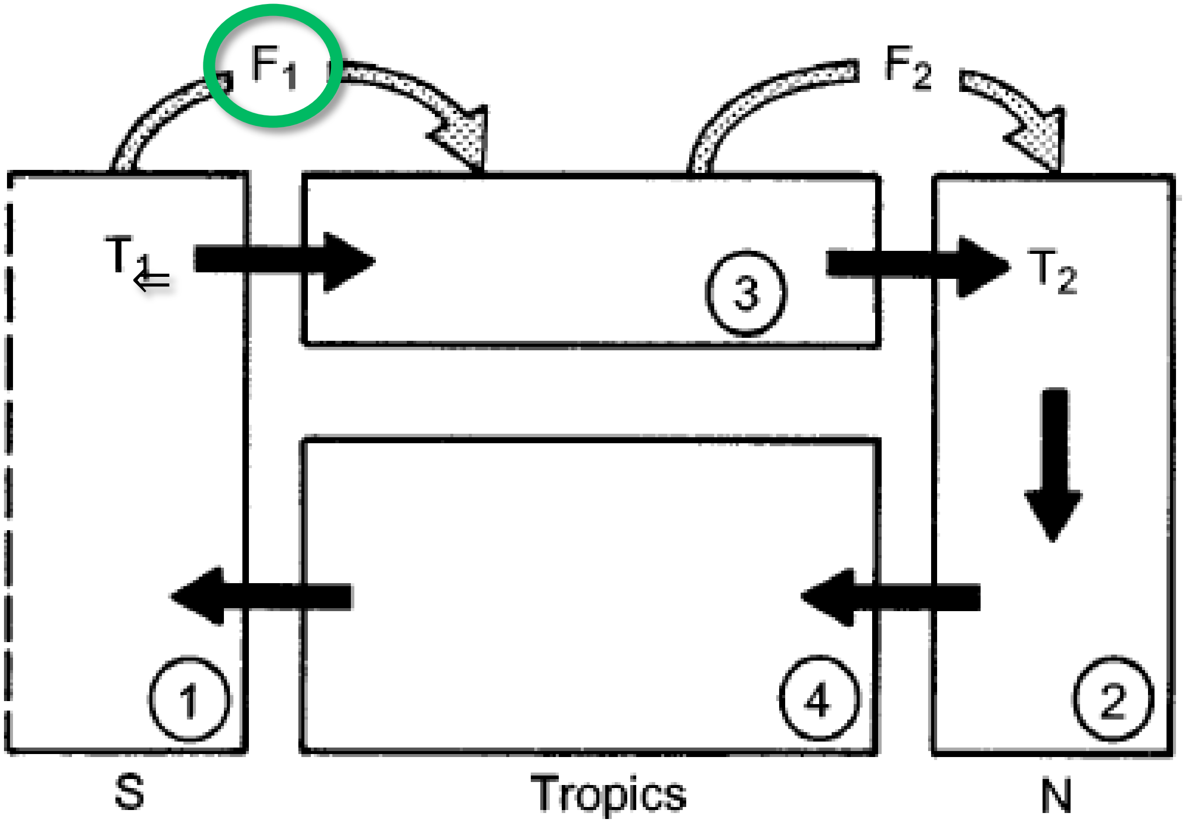
Rahmstorf 1996



Salt Advection Feedback

Rahmstorf 1996

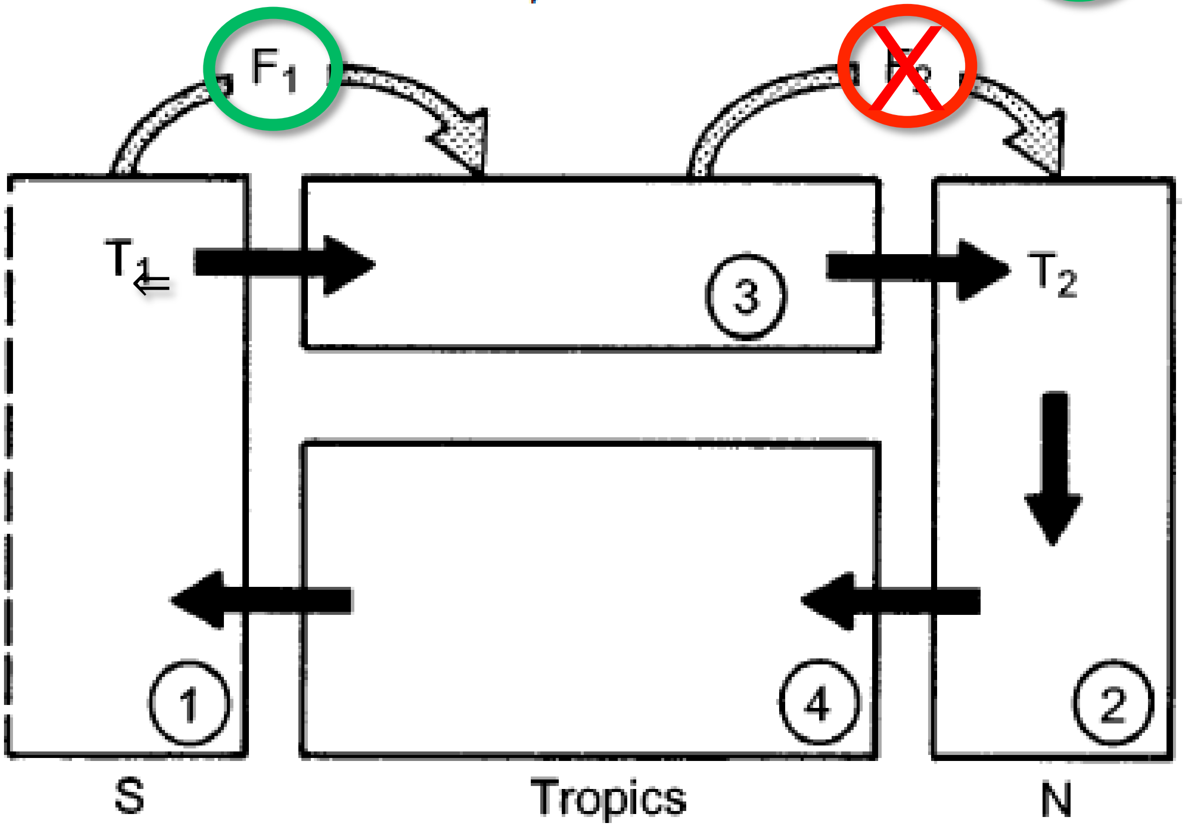
F_1 is freshwater imported into the Atlantic
Or rather, freshwater *exported* by the AMOC



Salt Advection Feedback

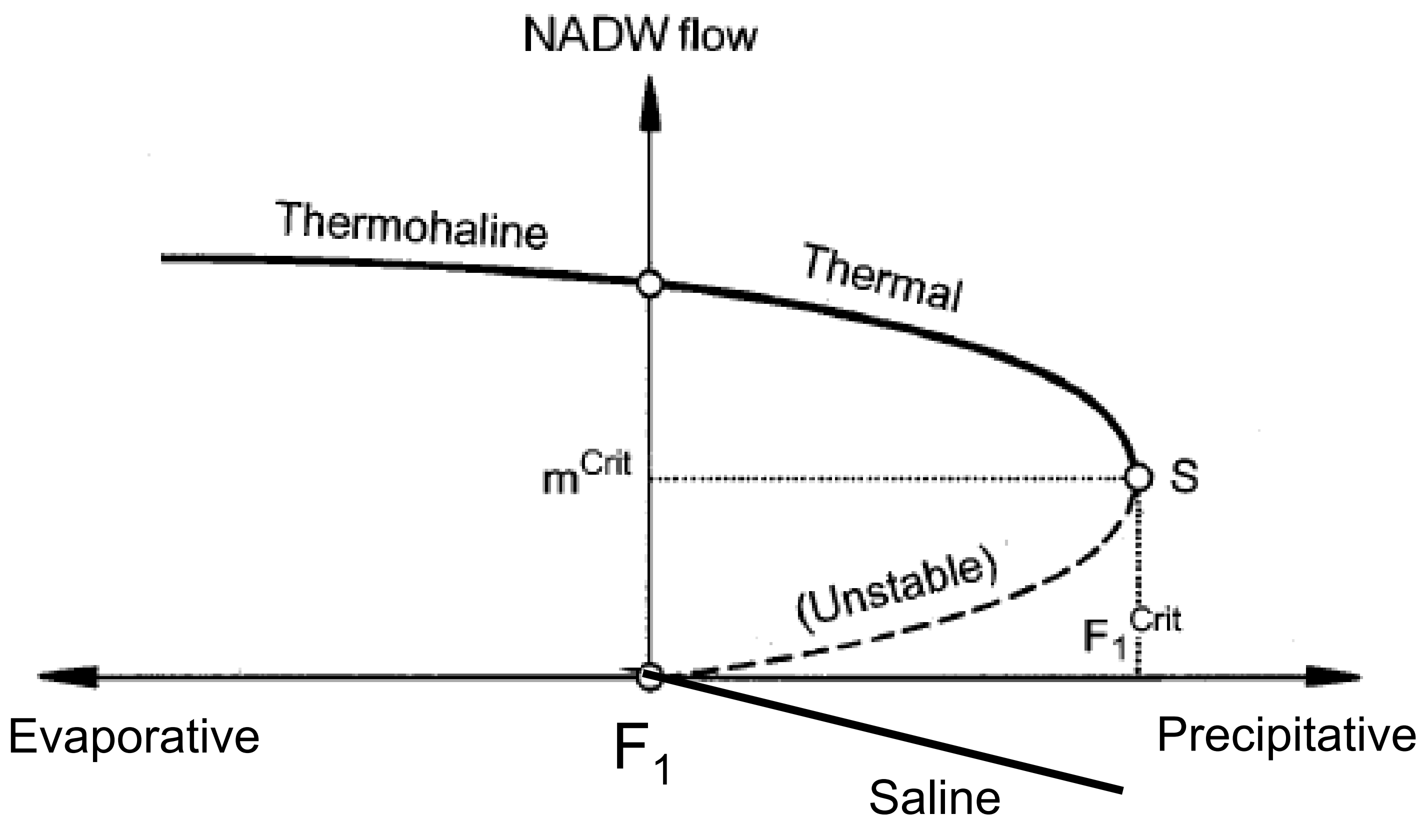
Rahmstorf 1996

$$m = -\frac{1}{2}k\alpha(T_2 - T_1) \pm \sqrt{\frac{1}{4}[k\alpha(T_2 - T_1)]^2 - k\beta S_0 F_1}$$



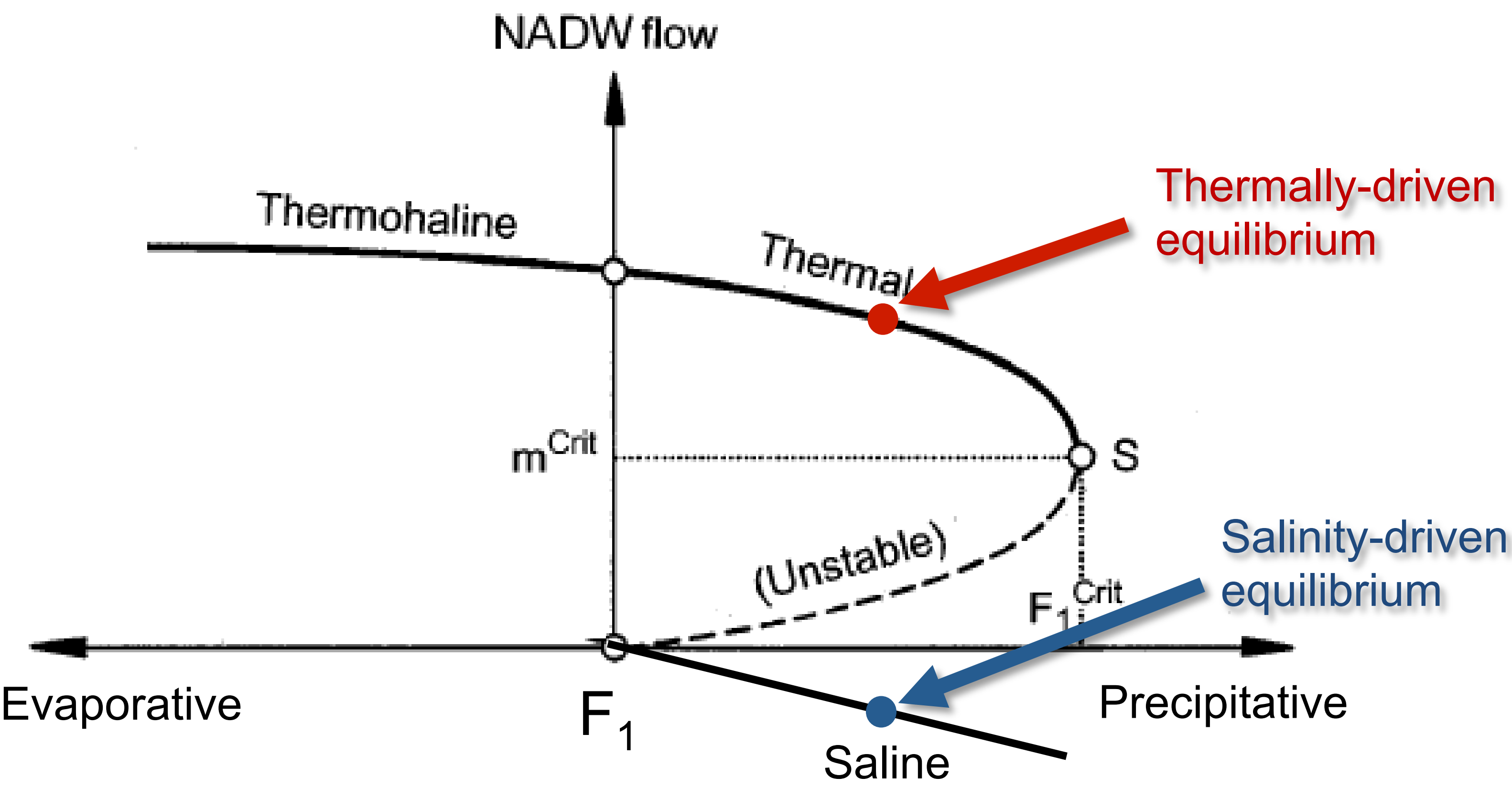
Salt Advection Feedback

Role in Multiple Equilibria



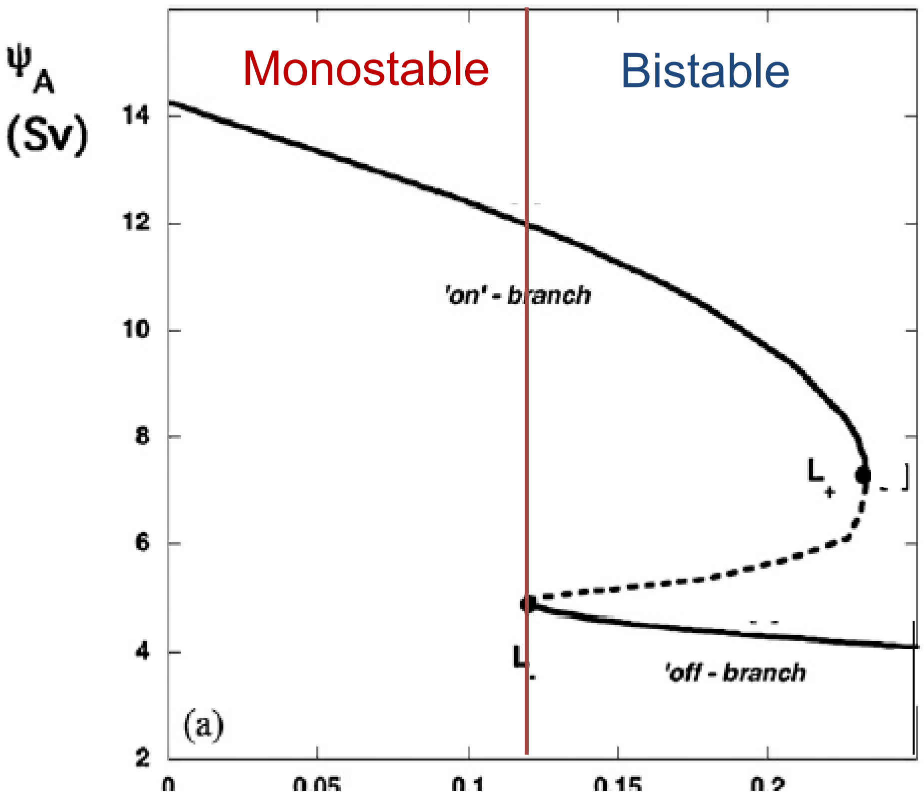
Salt Advection Feedback

Role in Multiple Equilibria



Salt Advection Feedback

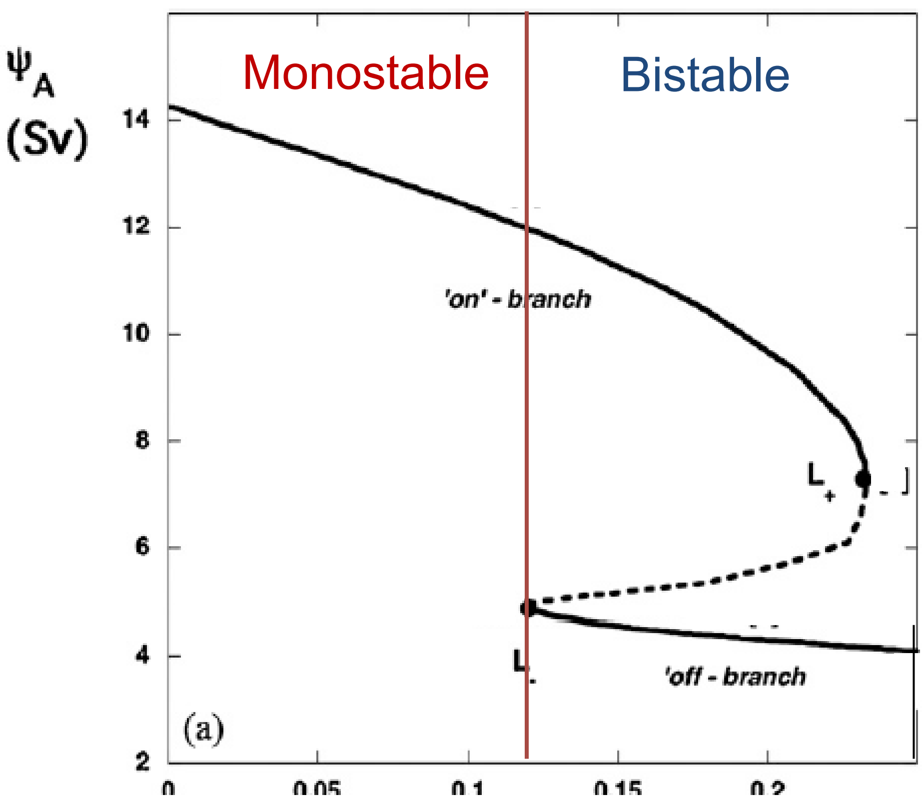
Role in Multiple Equilibria

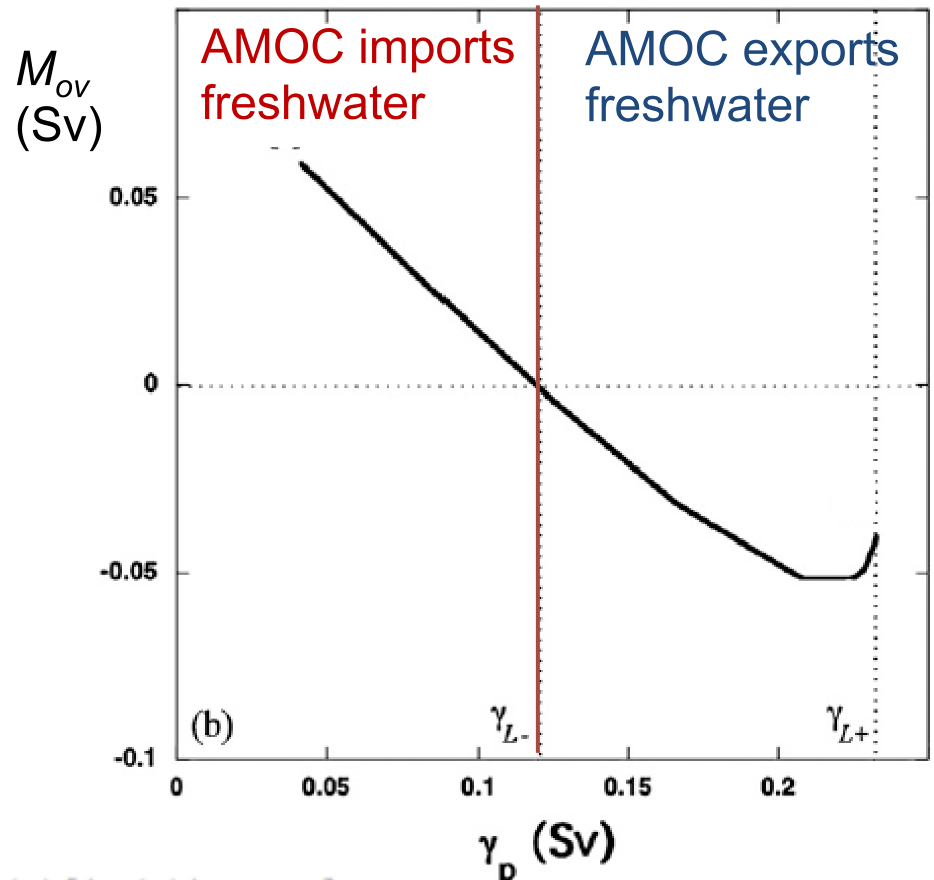


Dijkstra (2007)

Salt Advection Feedback

Role in Multiple Equilibria





$$M_{\mathrm{ov}} = -\frac{1}{S_0}\int dz\,\overline{v}(z)[\langle S(z)\rangle - S_0],$$

Dijkstra (2007)

Salt Advection Feedback

Role in Multiple Equilibria

- So:
  - if AMOC *exports* freshwater → Bistable regime
    - Salt advection feedback is *positive*
  - If AMOC *imports* freshwater → Monostable regime
    - Salt advection feedback is *negative*
- Observations: AMOC *exports* freshwater
- Climate models: AMOC *imports* freshwater
  - Do they overestimate AMOC stability?

So…

- Do these concepts carry over to an eddying ocean?

Eddy-Resolving Model

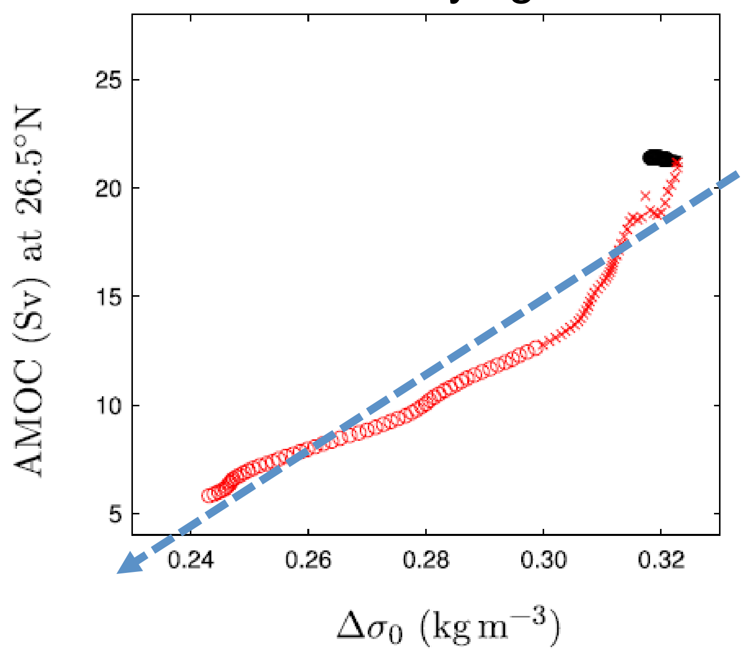
den Toom et al. (2014)

- Approach
  - Run global eddy-resolving (0.1°) ocean model for 50 years
  - Compare
    - Control experiment
    - Perturbation experiment, forced with Greenland freshwater fluxes
    - Non-eddying configurations

Eddy-Resolving Model
den Toom et al. (2014)

- Δσ → AMOC

Non-eddying



Eddy-Resolving Model

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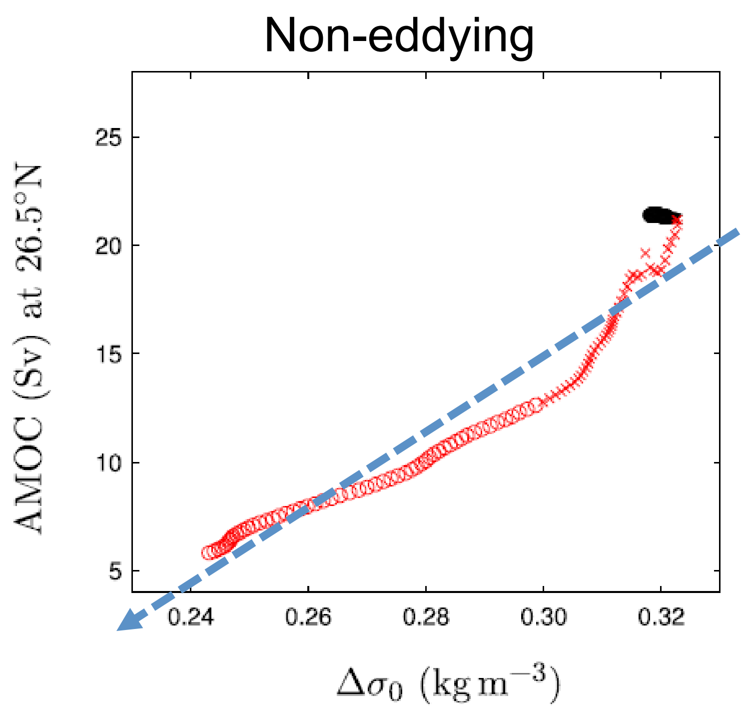
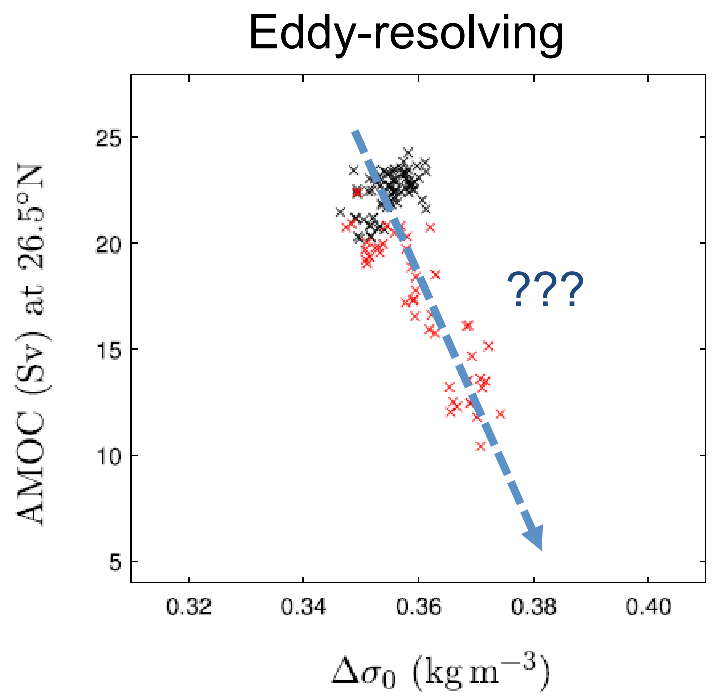
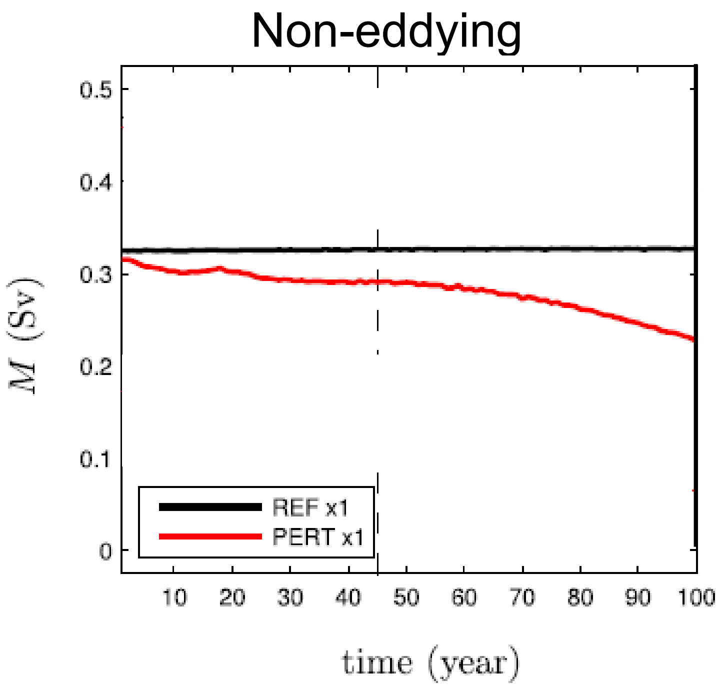




Eddy-Resolving Model

den Toom et al. (2014)

- AMOC → M_{ov}

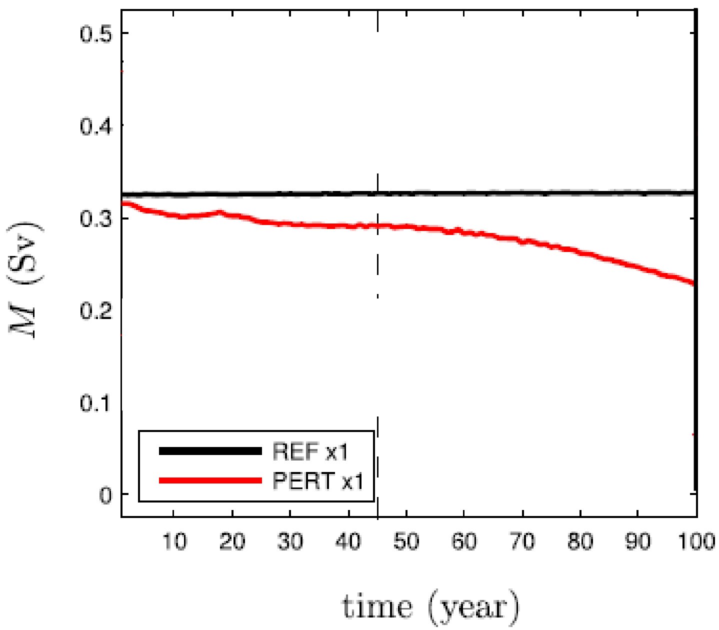


→ AMOC imports freshwater
→ Reduced AMOC reduces FW import
Negative salt advection feedback in action!

Eddy-Resolving Model
den Toom et al. (2014)

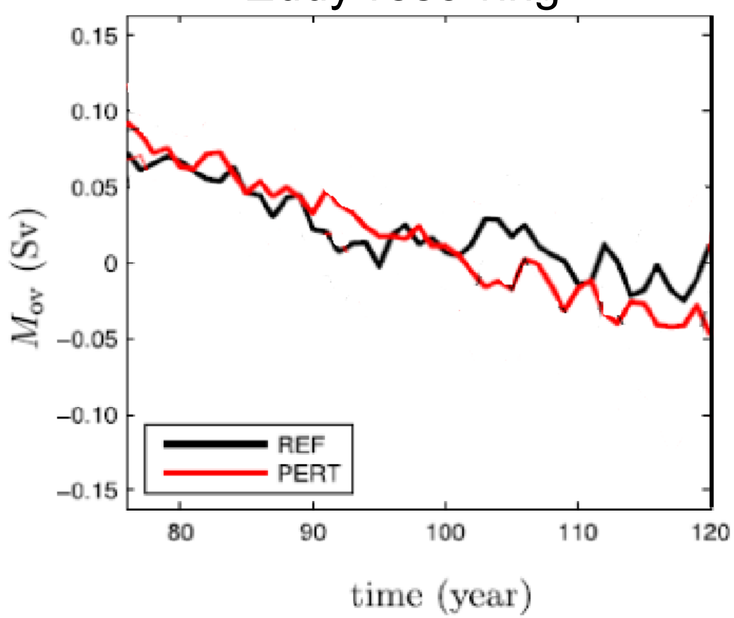
- AMOC → M_{ov}

Non-eddying



Decline due to reduced AMOC

Eddy-resolving

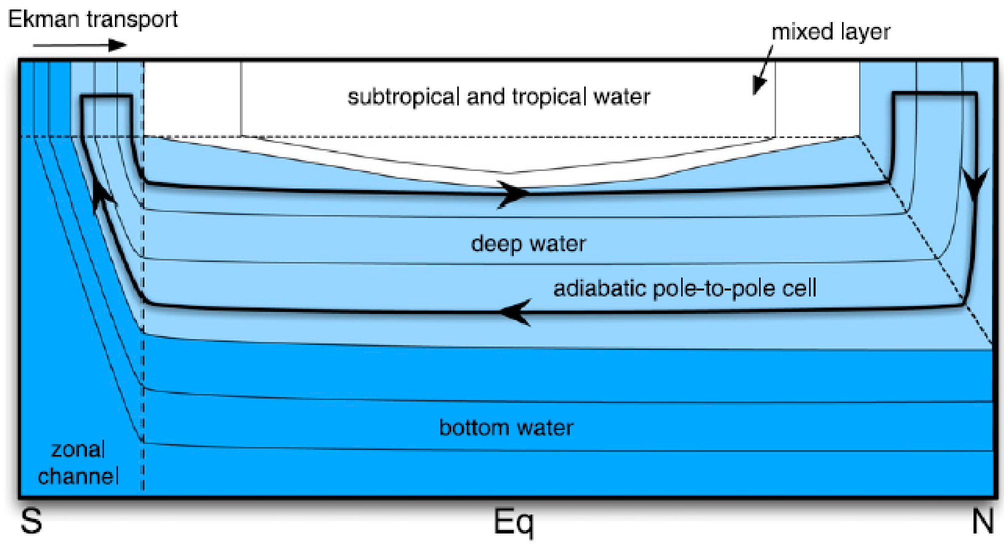


Decline due to drift in salinity at 34°S

Quasi-Adiabatic Models

Wolfe & Cessi (2014)

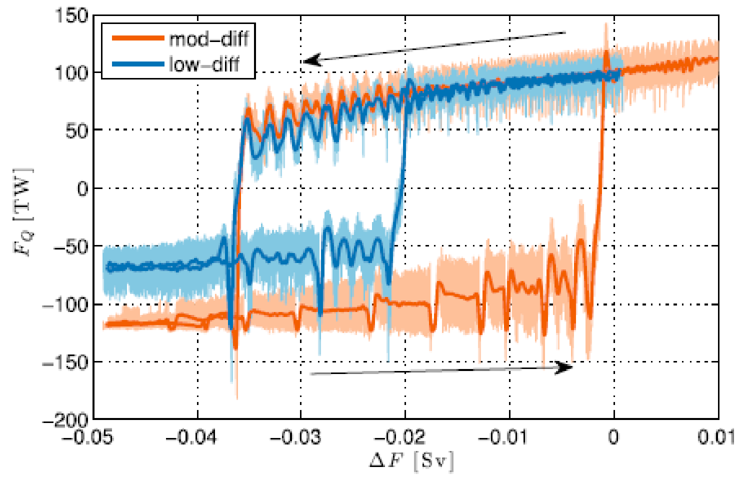
- Adiabatic pole-to-pole circulation
  - Driven by wind-driven upwelling in Southern Ocean
  - Enabled by joint buoyancy outcrops in NH and SH
  - Assumes NH is *lighter* than SH
  - Salt advection feedback *reduces* N-S buoyancy difference

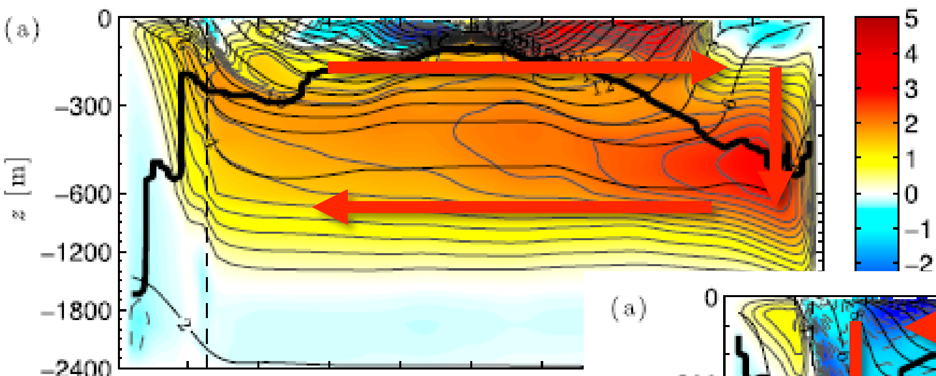


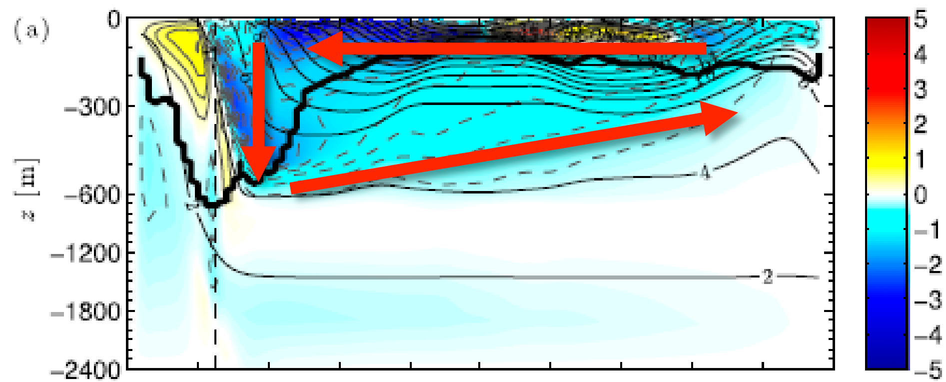
Quasi-Adiabatic Models

Wolfe & Cessi (2015)

- Multiple Equilibria possible
  - Direct circulation is *adiabatic*
  - Reverse circulation is *diabatic*







Summary

- Diabatic paradigm
  - AMOC proportional to *positive* $\Delta\rho_{NS}$
    - Salt advection feedback positive if $M_{ov} < 0$
    - Salt advection feedback negative if $M_{ov} > 0$
  - M_{ov} indicates bistability
- Adiabatic paradigm
  - AMOC strongest for weak $\Delta\rho_{NS}$ (for *negative* $\Delta\rho_{NS}$)
    - Salt advection feedback is positive
  - What determines bistability regime?

Questions

- How can we reconcile our diabatic intuition with the adiabatic paradigm?
- Is M_{ov} metric still relevant as stability indicator?
- How can we tackle this problem systematically?
  - Hierarchy of models?