Salinity change and the AMOC: Understanding remote influences

Sam Levang, Ray Schmitt

MIT/WHOI

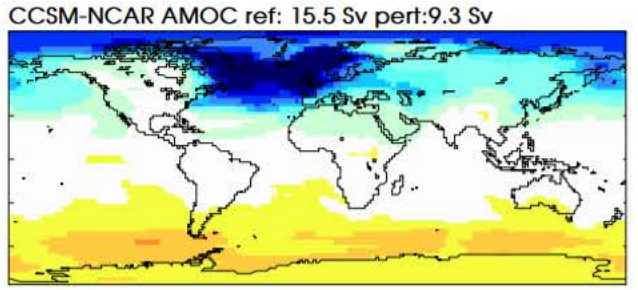
AMOC instability and freshwater

1. Freshwater input to the North Atlantic can cap deep convection sites

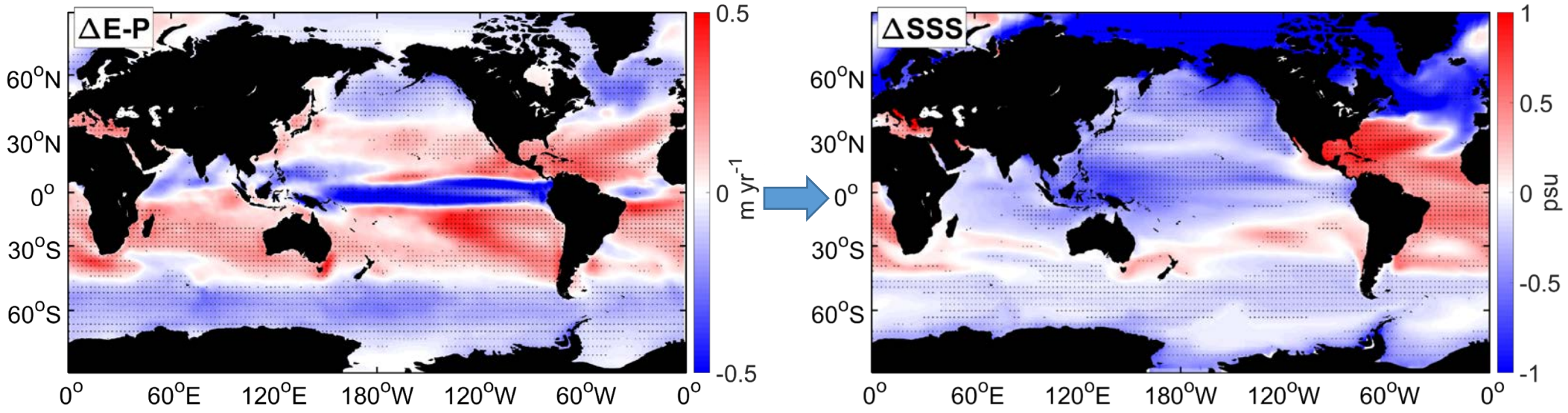
   Under warming scenario:

   - Subpolar precip and ice melt likely to increase
   - Subtropical Atlantic gets saltier

2. Ocean dynamics control the response
   - What is the rate of exchange between subtropical and subpolar waters?
   - Do current climate models get this right?



Motivation: CMIP5 salinity response



Amplification of E-P pattern

RCP8.5 100 year trends (2000-2100), multi-model means

(Levang and Schmitt 2015)

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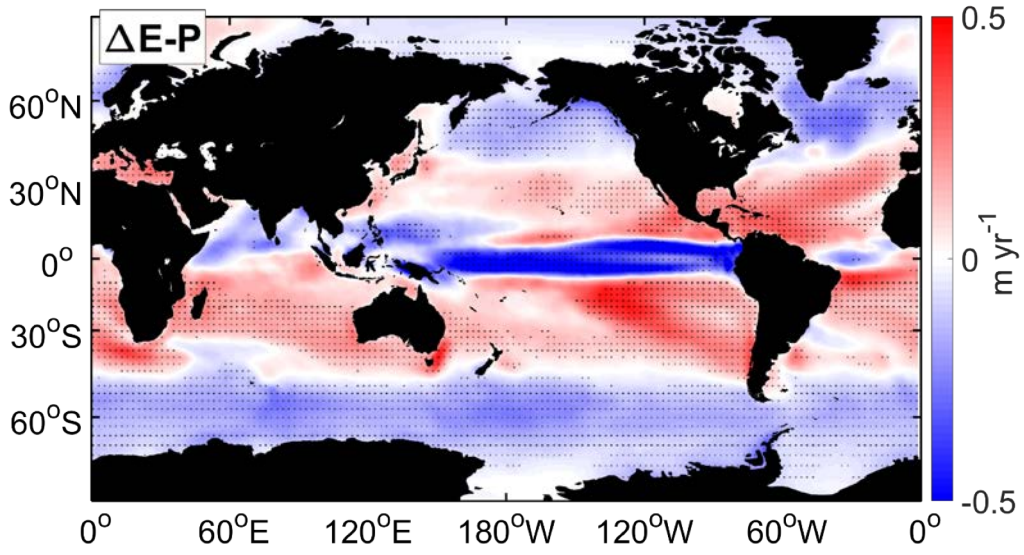
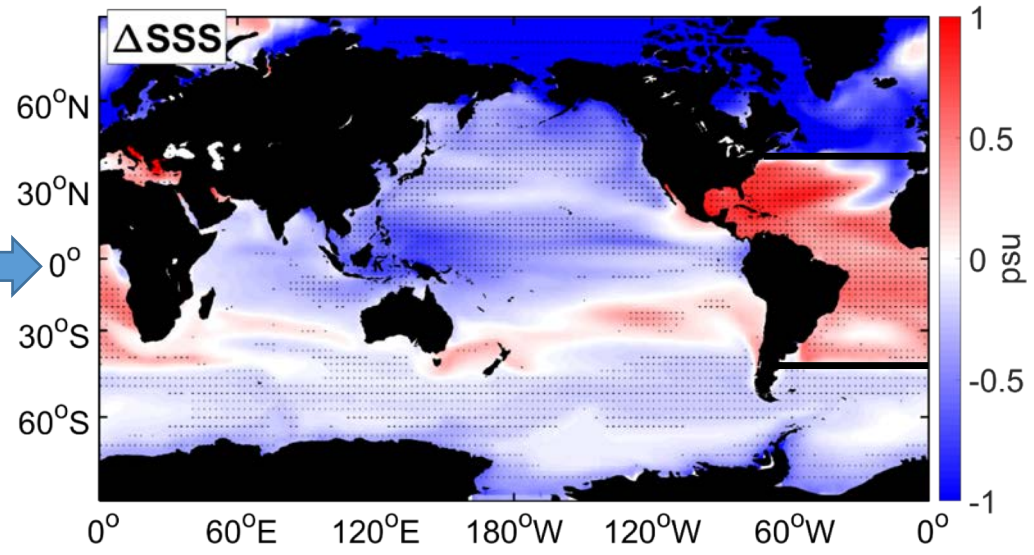
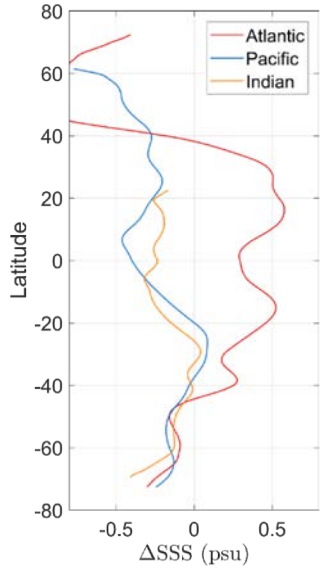


Amplification of E-P pattern



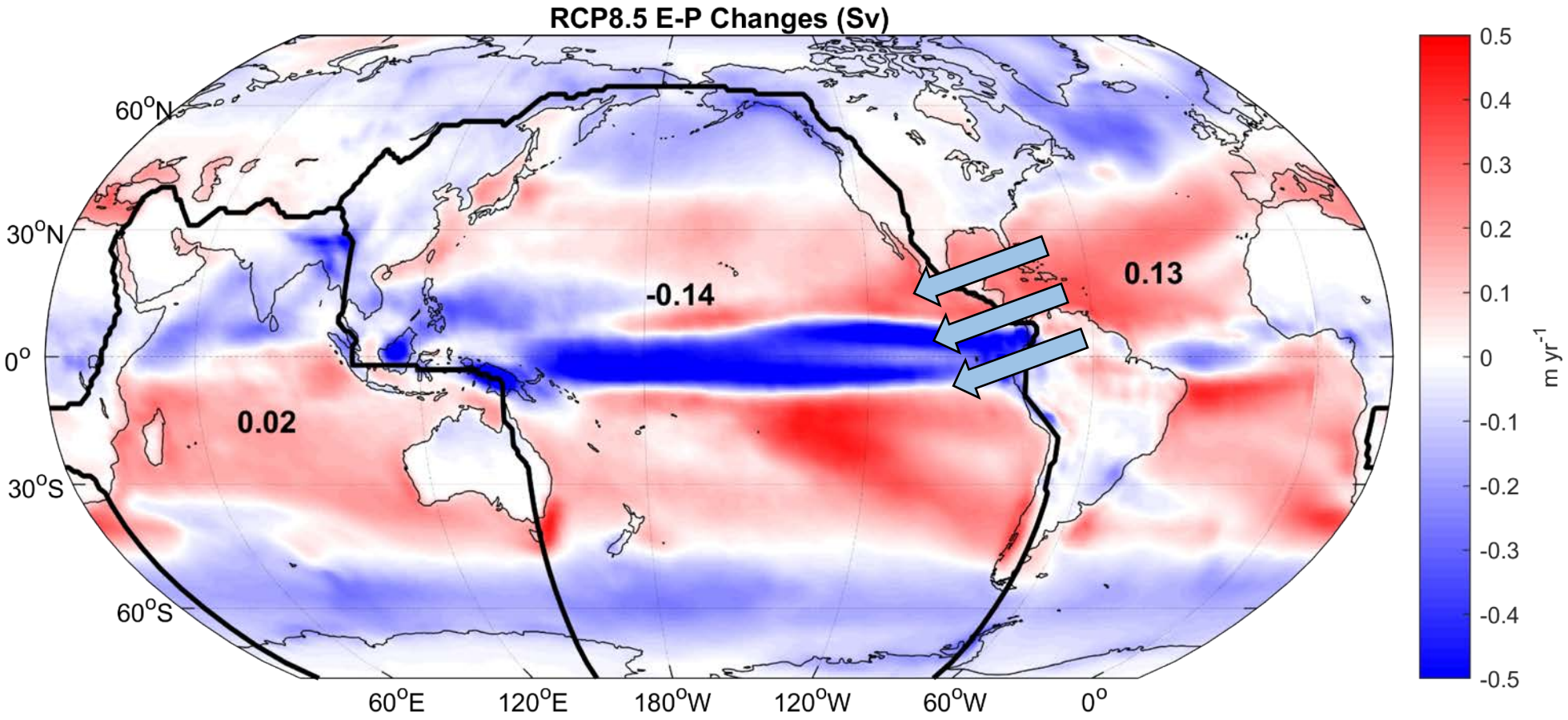
Ocean integrates basin-wide forcing



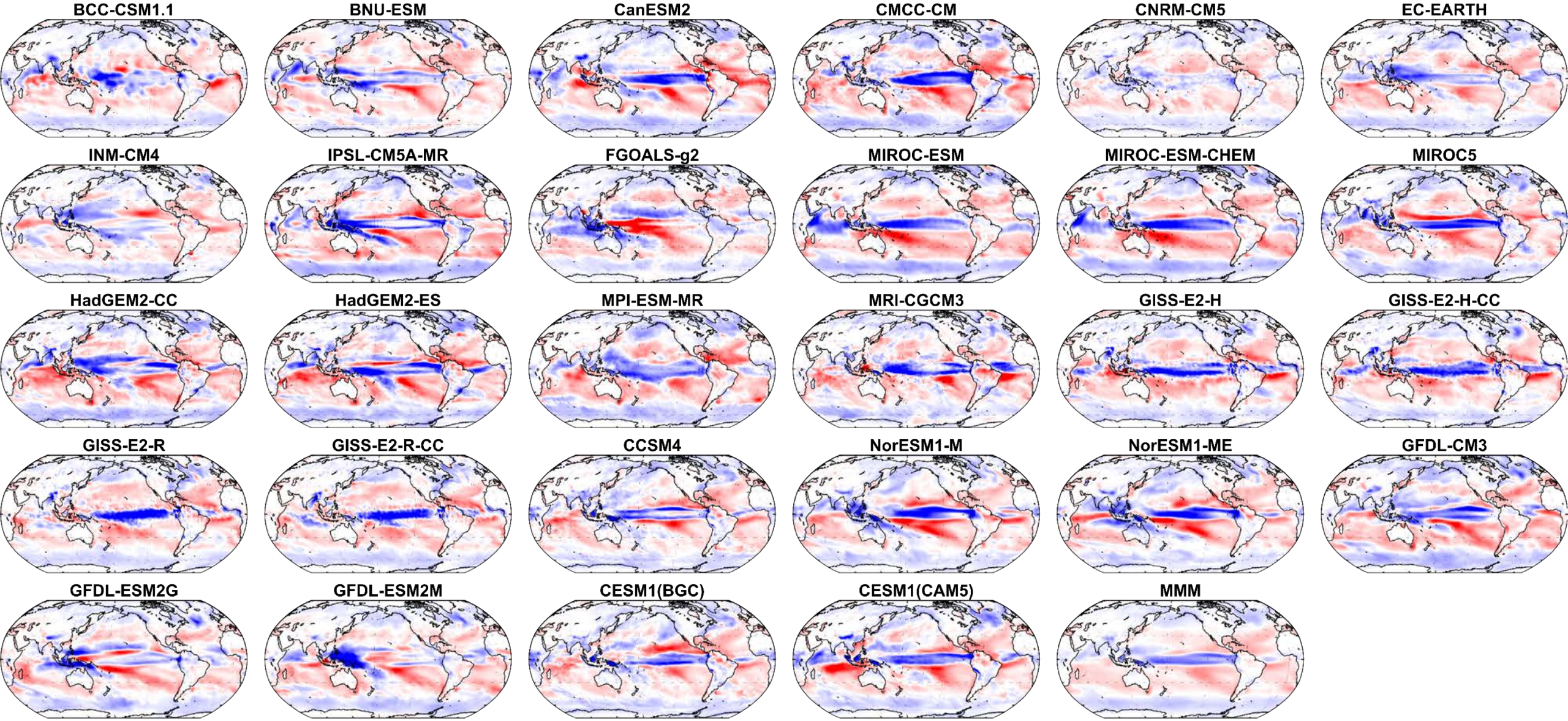
RCP8.5 100 year trends (2000-2100)

(Levang and Schmitt 2015)

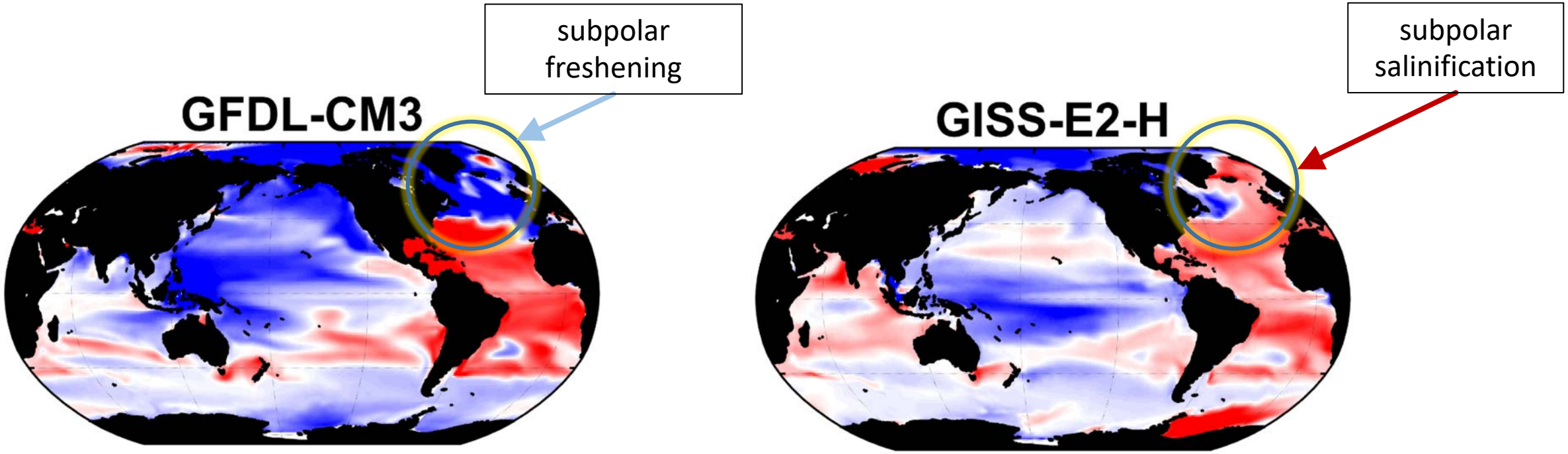
Moisture budget



Atmospheric response very robust



Different salinity responses in the Subpolar Atlantic

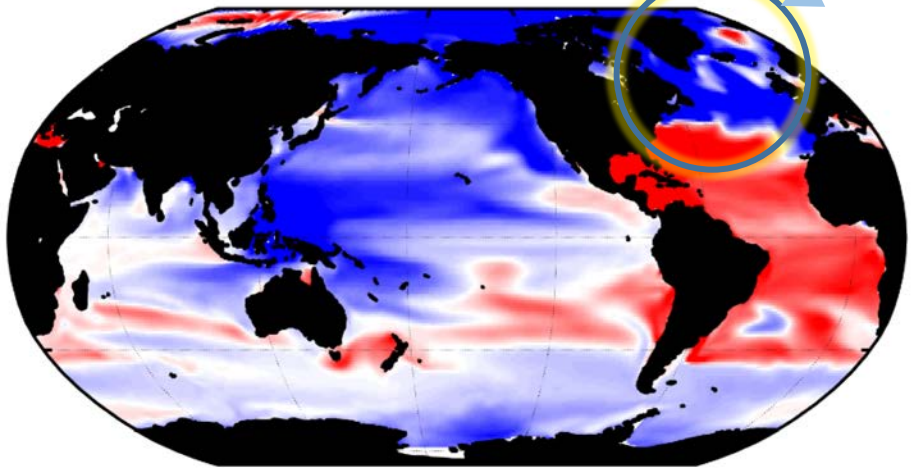


Different salinity responses in the Subpolar Atlantic

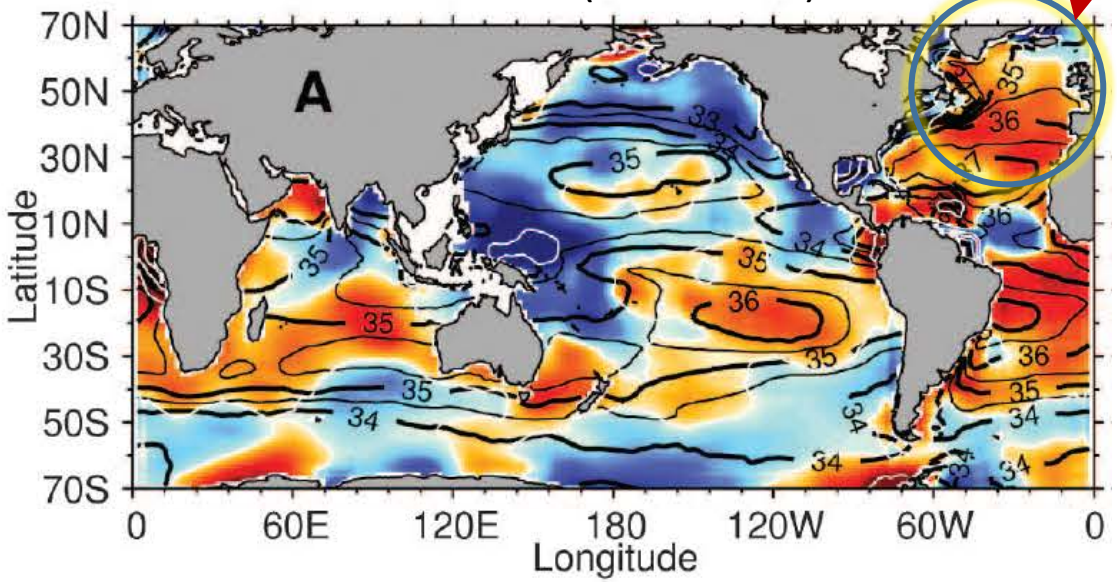
subpolar freshening

subpolar salinification

GFDL-CM3



Observations (1950-2000)



(Durack et al. 2012)

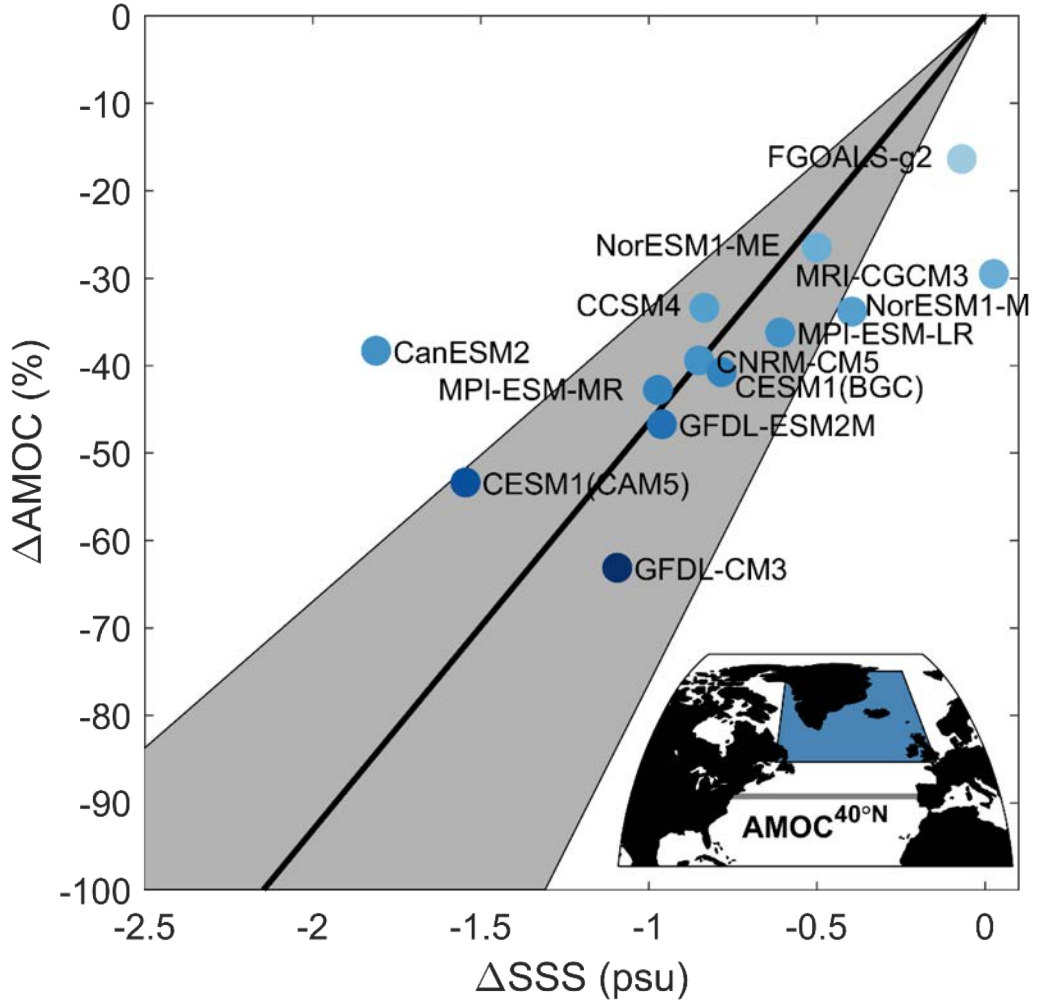
Which is realistic?

AMOC and density: cause or effect?

- **More freshening**
  - ↳ Buoyancy increase
    - ↳ Weaker AMOC
- **Weaker AMOC**
  - ↳ Decreased northwards heat flux
    - ↳ Less warming

Also: β~8·α for NADW (2°C, 35psu)

Need big ΔT to affect density



AMOC and density: cause or effect?

It's salinity!

- **More freshening**
  - ↳ Buoyancy increase
    - ↳ Weaker AMOC
- ~~**Weaker AMOC**~~
  - ~~↳ Decreased northwards heat flux~~
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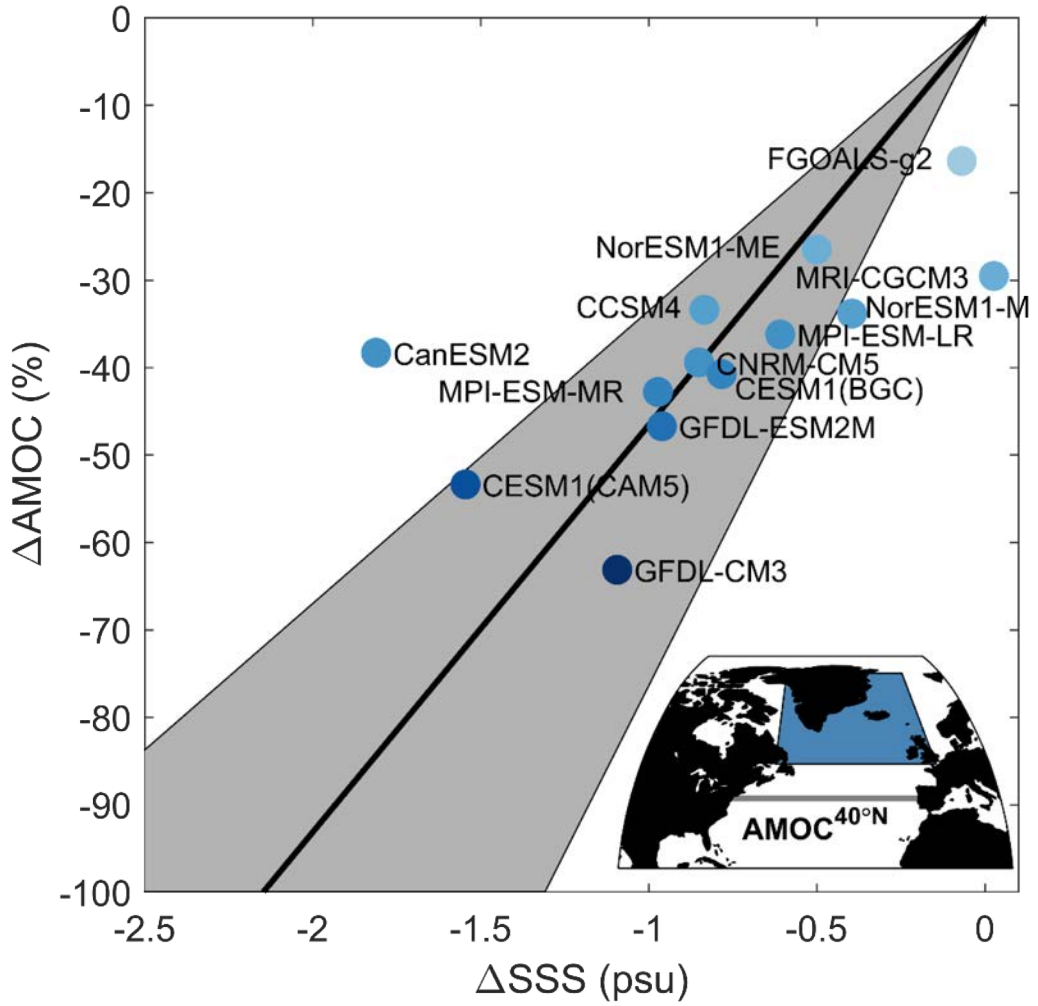

Outline

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   Under warming scenario:

   - Subpolar precip and ice melt likely to increase
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2. **Ocean dynamics control the response**

   - What is the rate of exchange between subtropical and subpolar waters?
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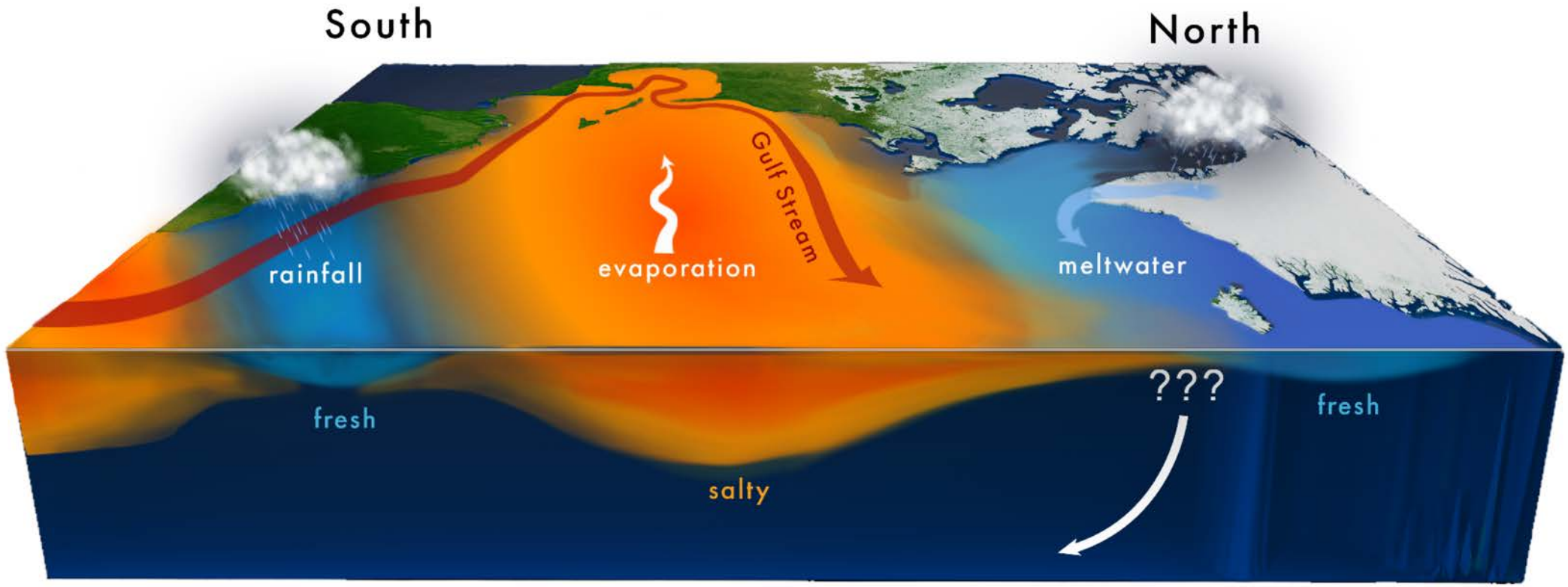

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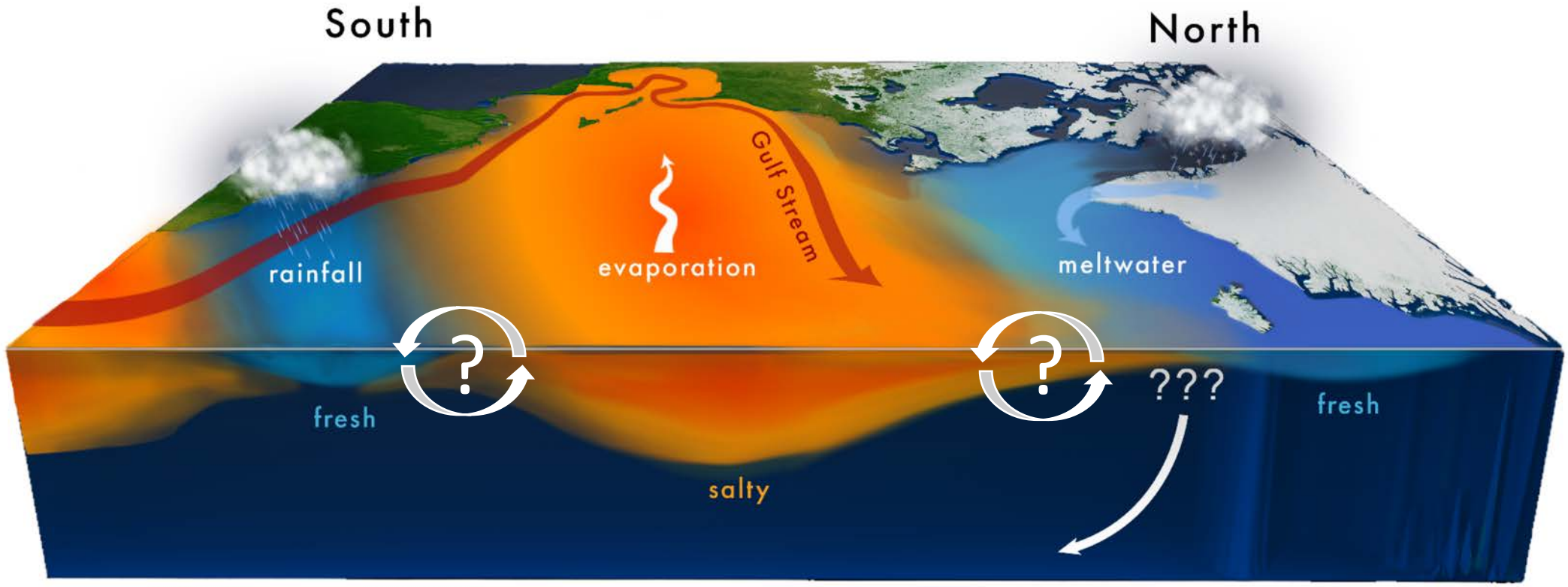
1) What are the relevant circulations and exchange timescales between these regions?

2) How do these timescales control the salinity (density) response in the NADW convection sites?



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Working hypothesis:

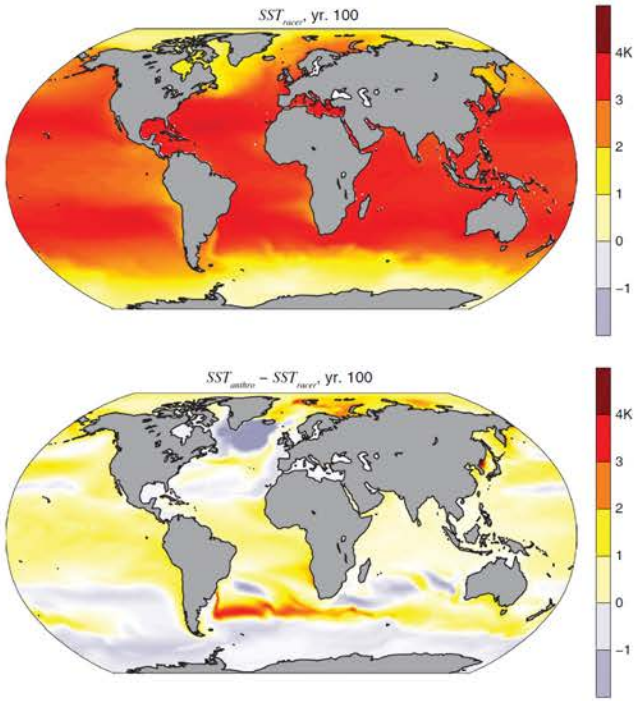
Treat freshwater anomaly as a passive tracer

- Assume that anomalies persist indefinitely along circulation pathways
- Ignore density-advection feedbacks

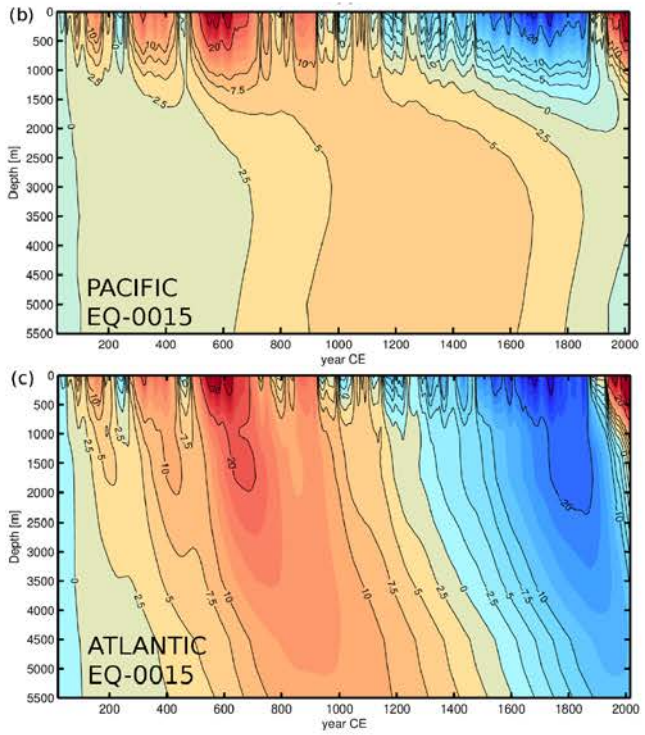
- Advect salinity anomalies along “present-day” circulation
- Make use of data assimilated reanalyses
  - SODA3: <1/4° GFDL CM2.5, 1980-2016
    - Use 5-day outputs, and climatology (eddies removed)
  - ECCOv4.3: 1° MITgcm, 1992-2015
    - Proxy for CMIP5-type models

Others that have used this technique:

Anthropogenic temperature signal (Marshall et al. 2015)



Little ice age and deep Pacific cooling (Gebbie and Huybers 2018)



Persistent observed salt anomalies (Dickson et al. 1988)

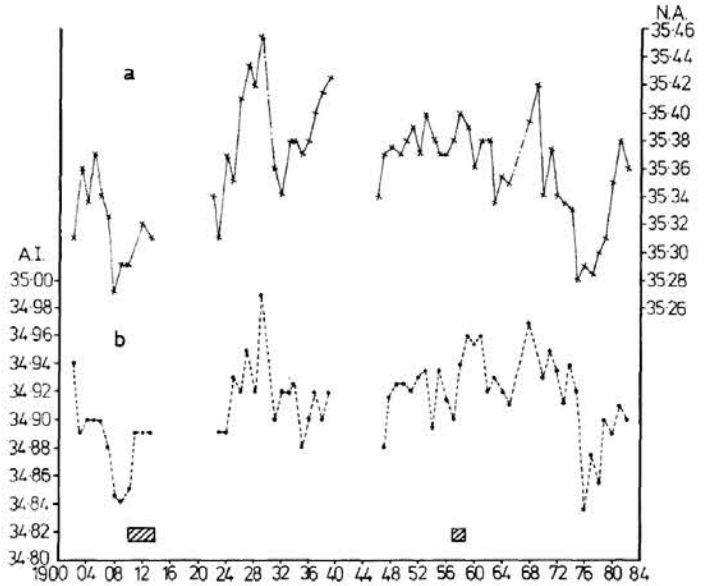
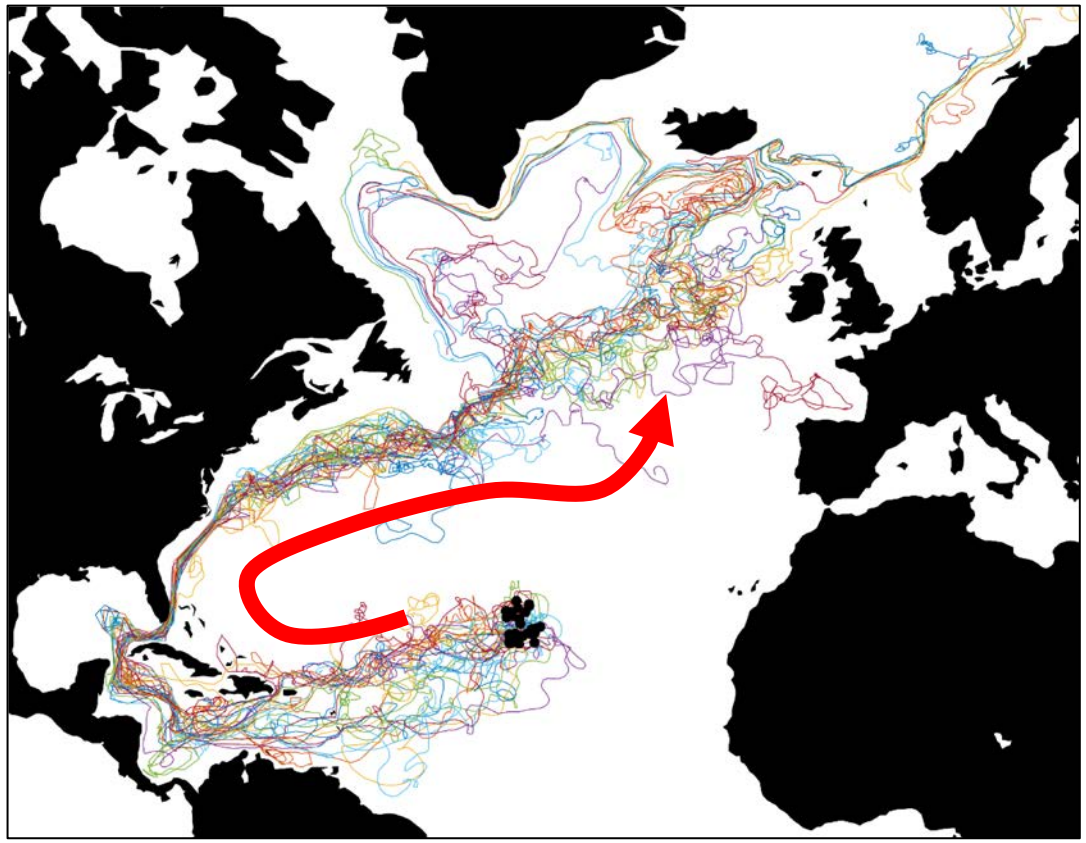


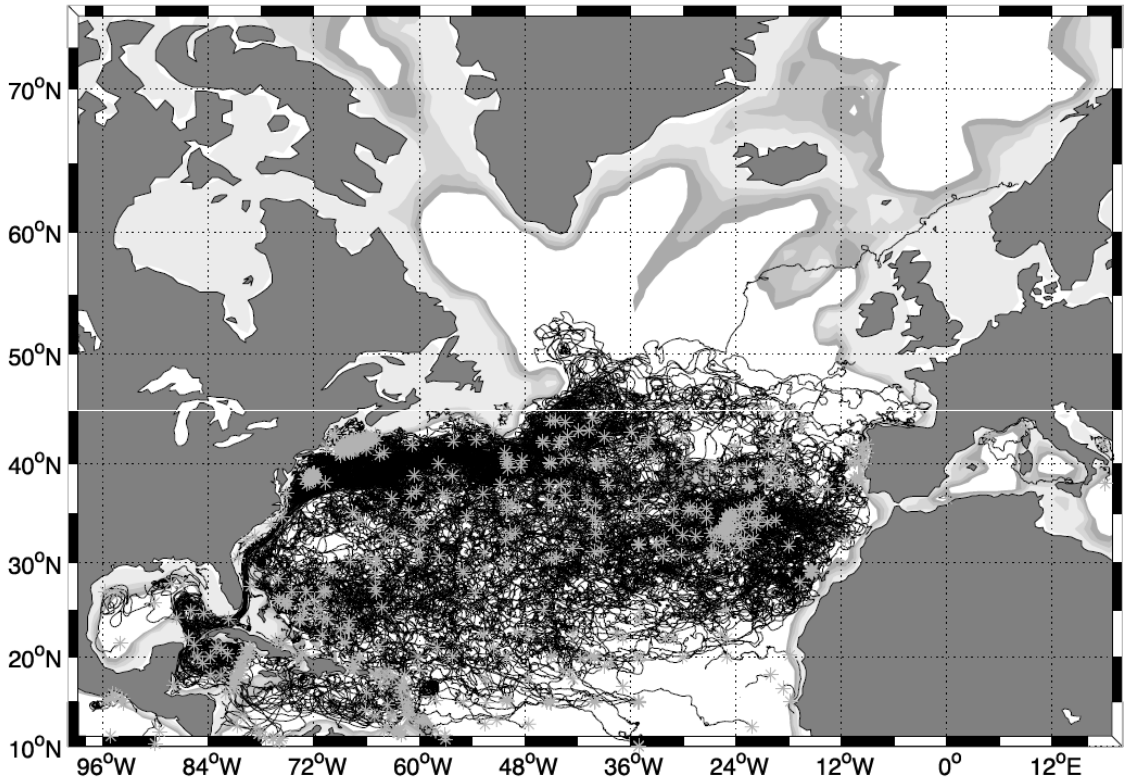
FIG.1. Salinity time-series for North Atlantic and Arctic Intermediate Watermasses in the Faroe-Shetland Channel, 1902-1982. From DOOLEY, MARTIN, and ELLETT (1984)

Why use the Lagrangian frame?

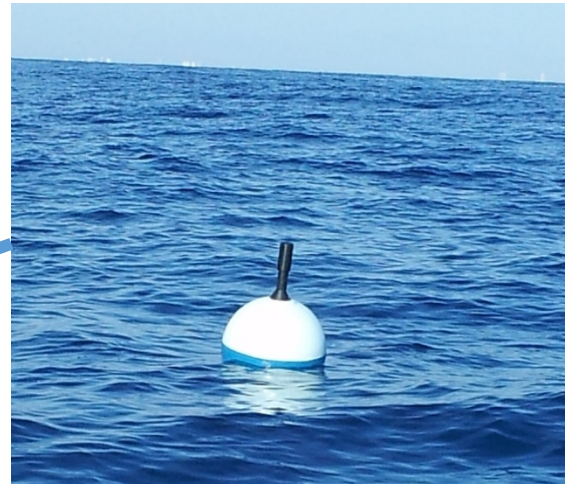
- Focus on what the circulation is doing in terms of connectivity
  - Not possible in Eulerian perspective
- Pathways are 3D and chaotic
  - Need many datapoints to understand the circulation statistically

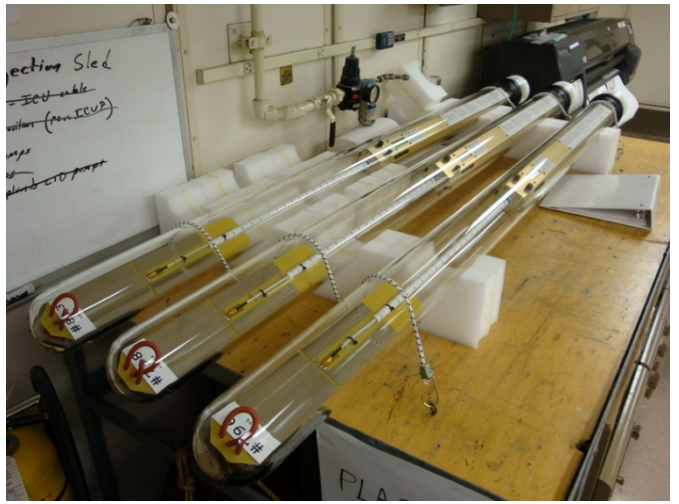


Insufficient Observations



(Brambilla and Talley 2006)

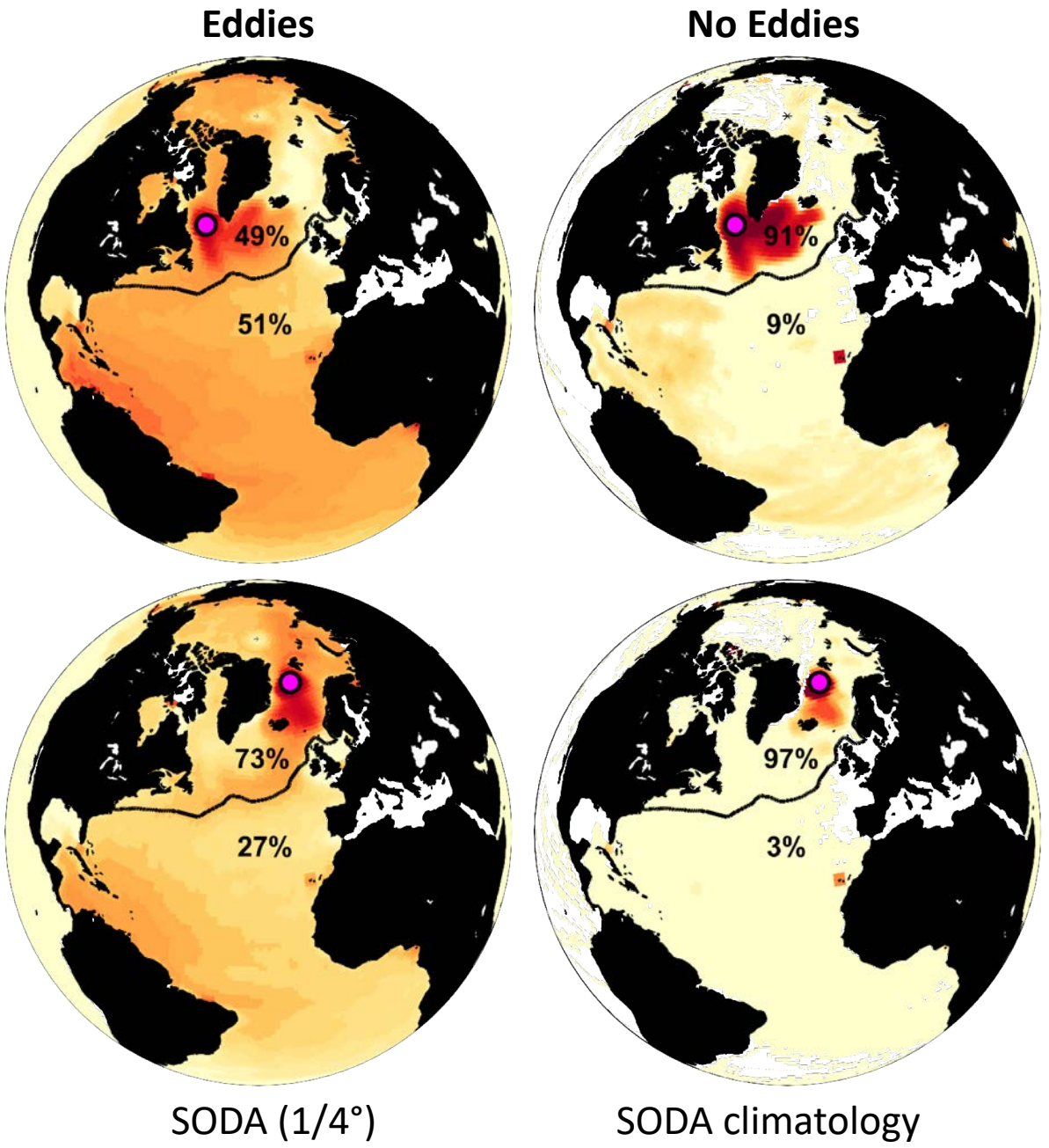




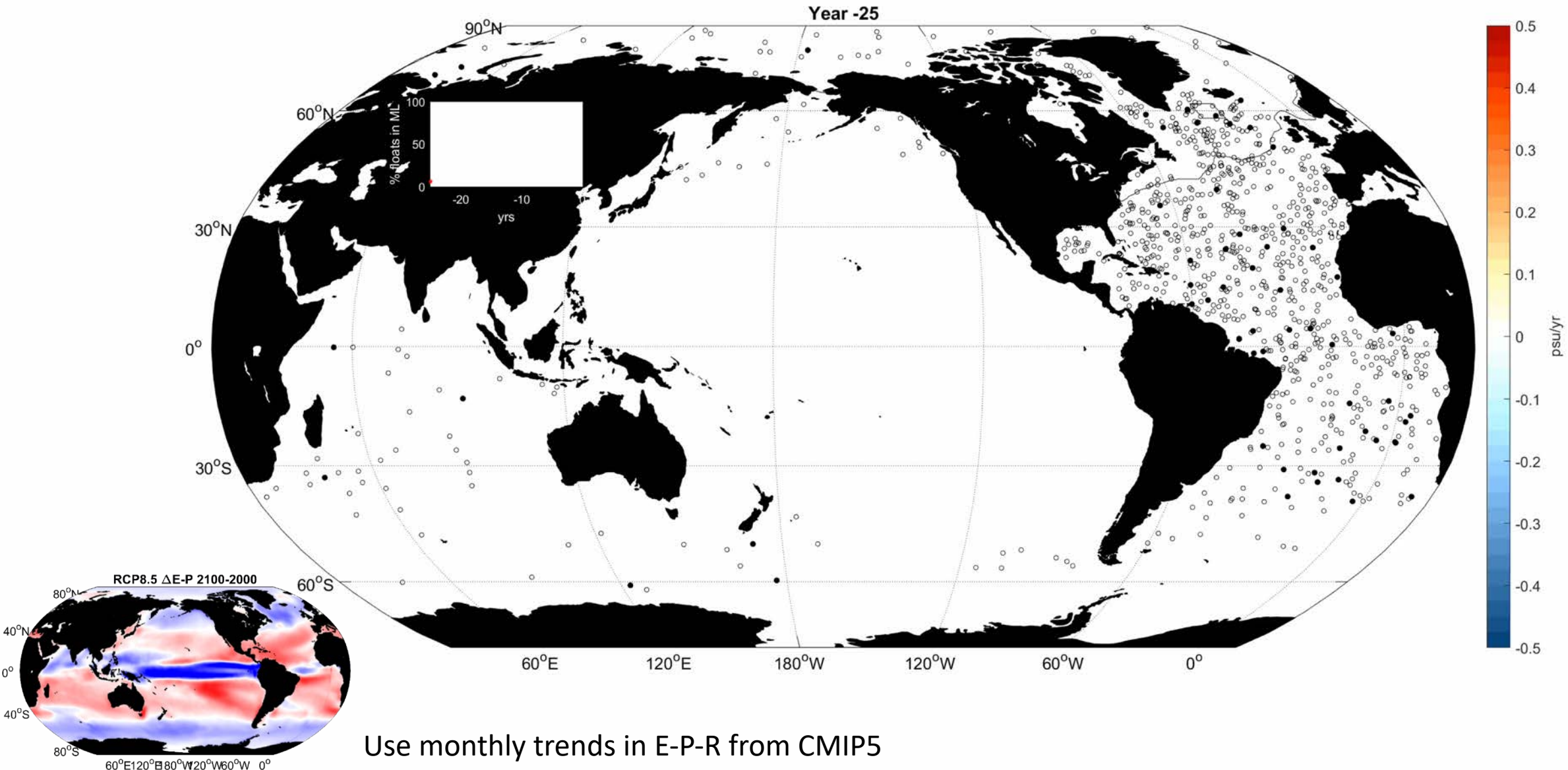
Remote influences:

- What is the pathway history of water masses in the subpolar?
- Where do they contact the mixed layer? Anomalous surface fluxes absorbed here

$$\overline{\oint \frac{1}{MLD} dt}$$



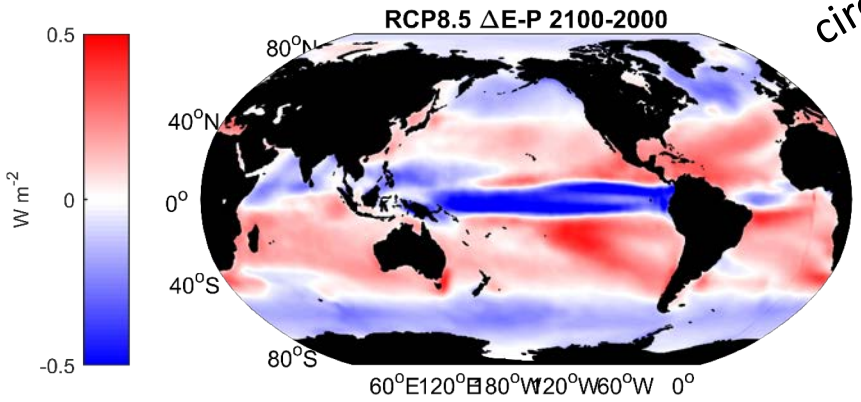
Accumulate forcing to predict SSS changes



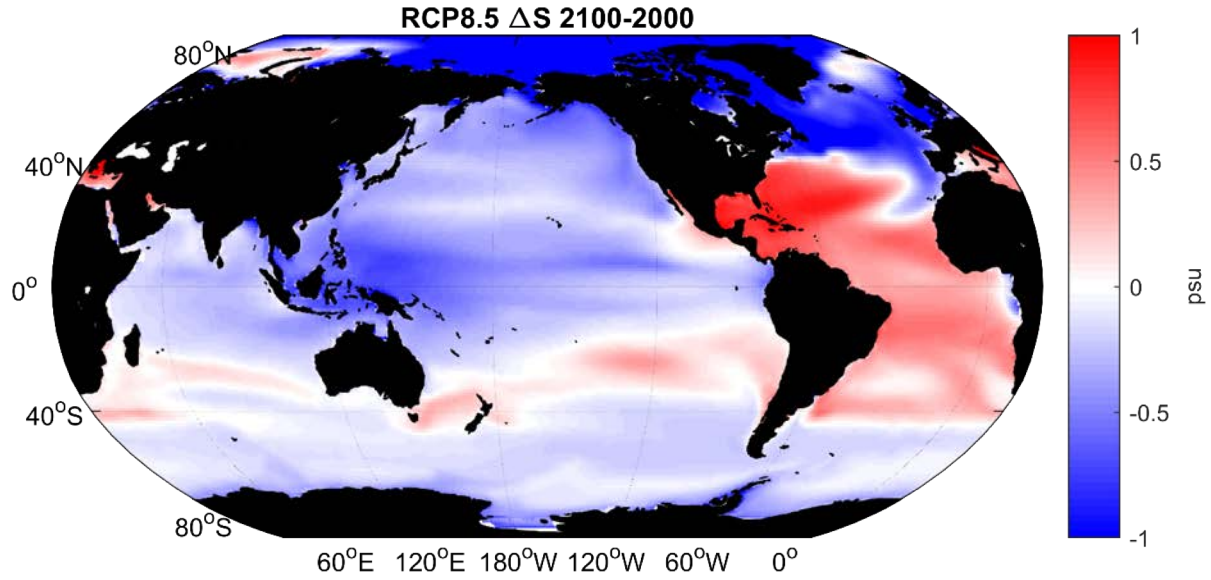
Use monthly trends in E-P-R from CMIP5

Proof of concept:

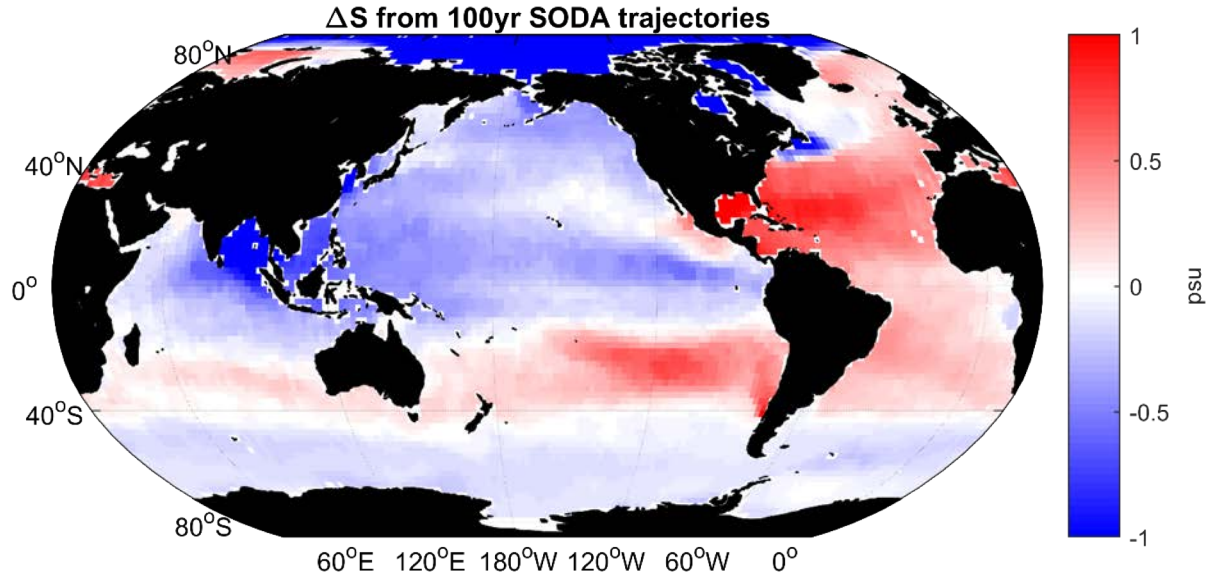
Accumulate anomalous freshwater forcing along reverse trajectories



Individual model mixing schemes, circulation feedbacks



Simple passive tracer along 'present day' trajectories

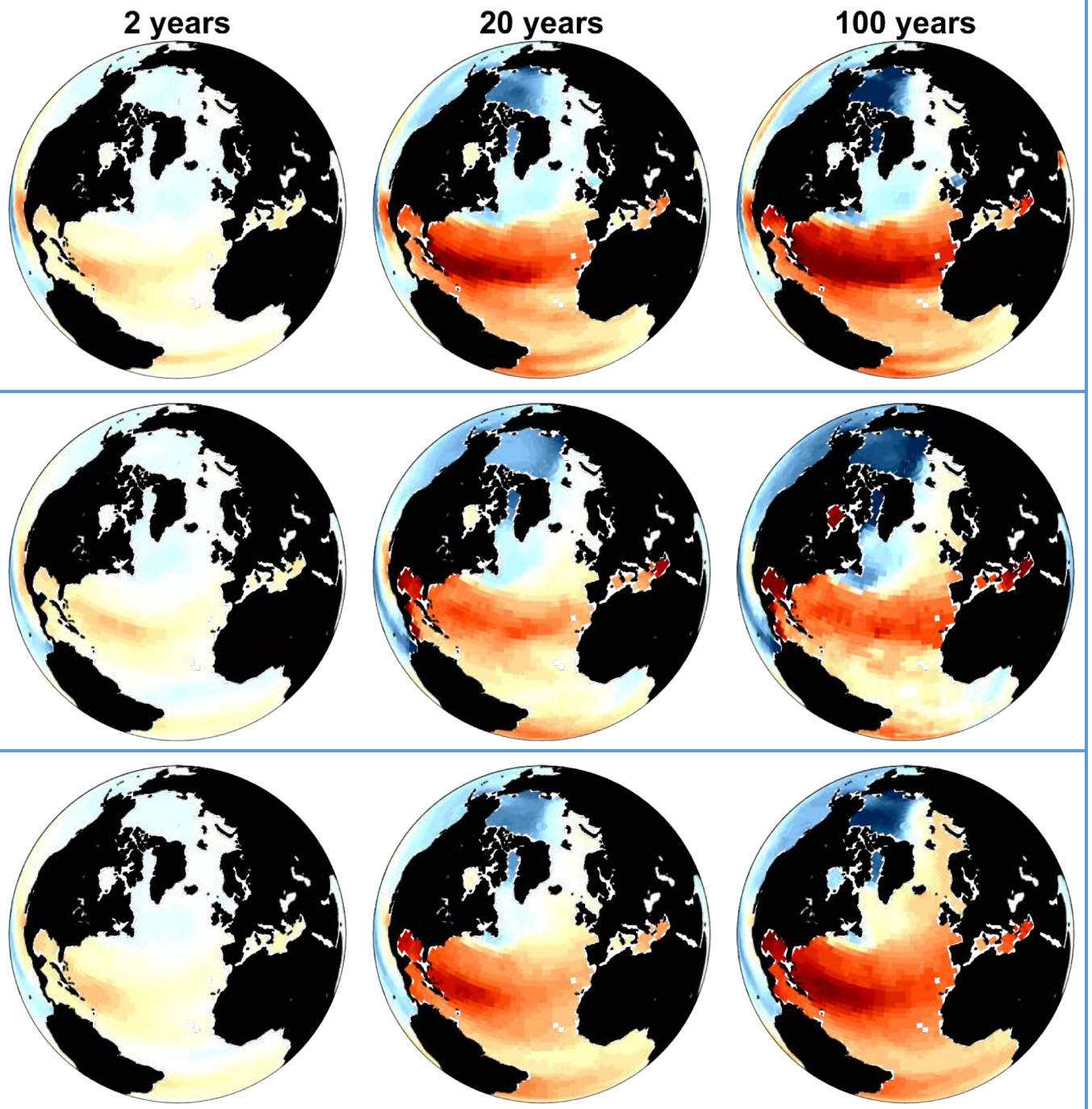


$$\Delta S = \overline{\oint \frac{S \cdot \Delta(E-P)}{MLD} dt}$$

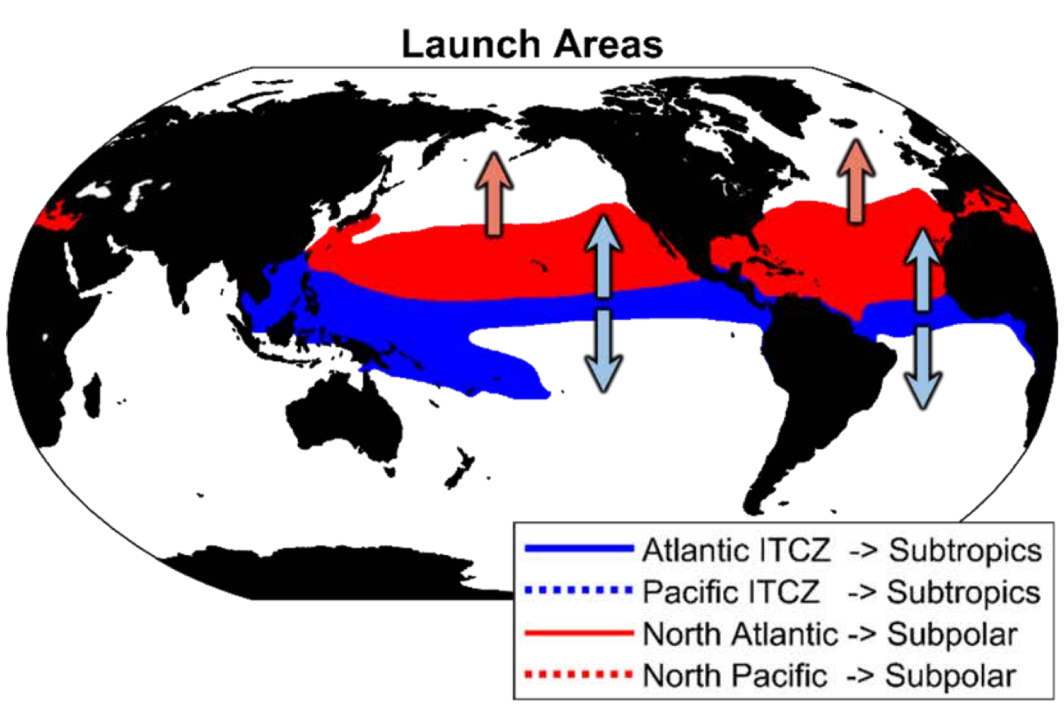
SODA3
(no eddies)

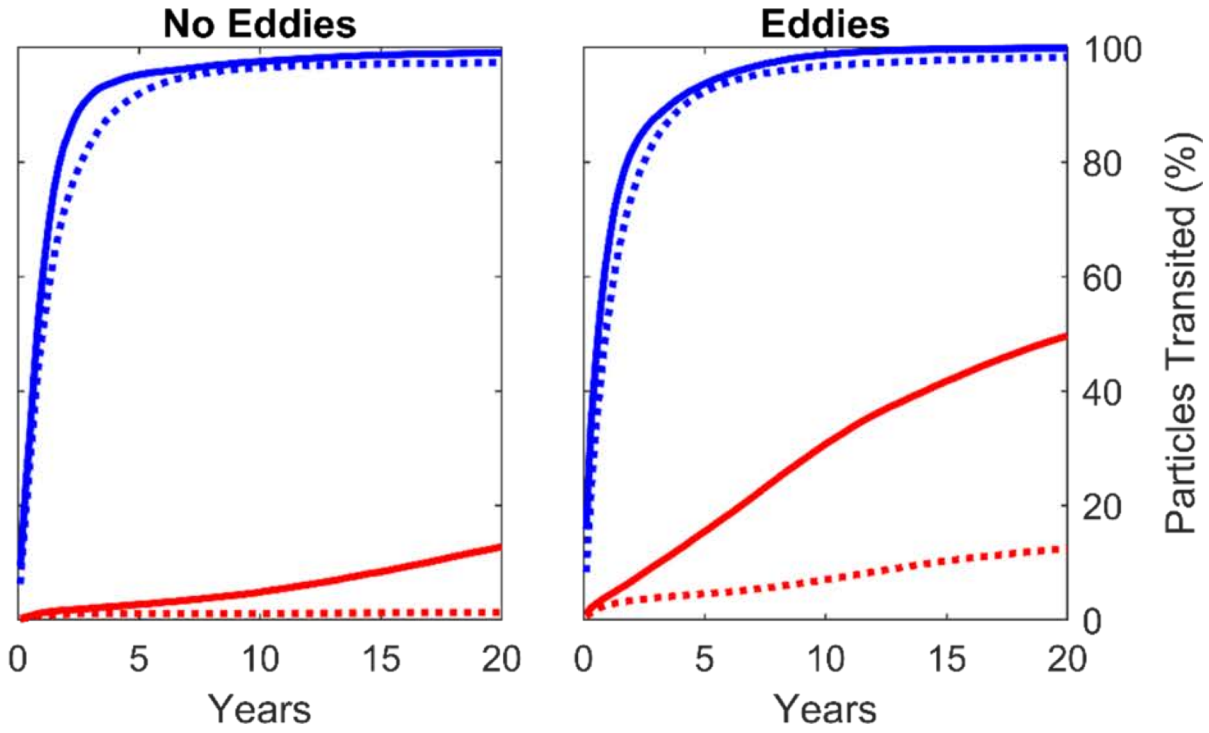
ECCOv4
(GM) 1°

SODA3
(eddies)<1/4°



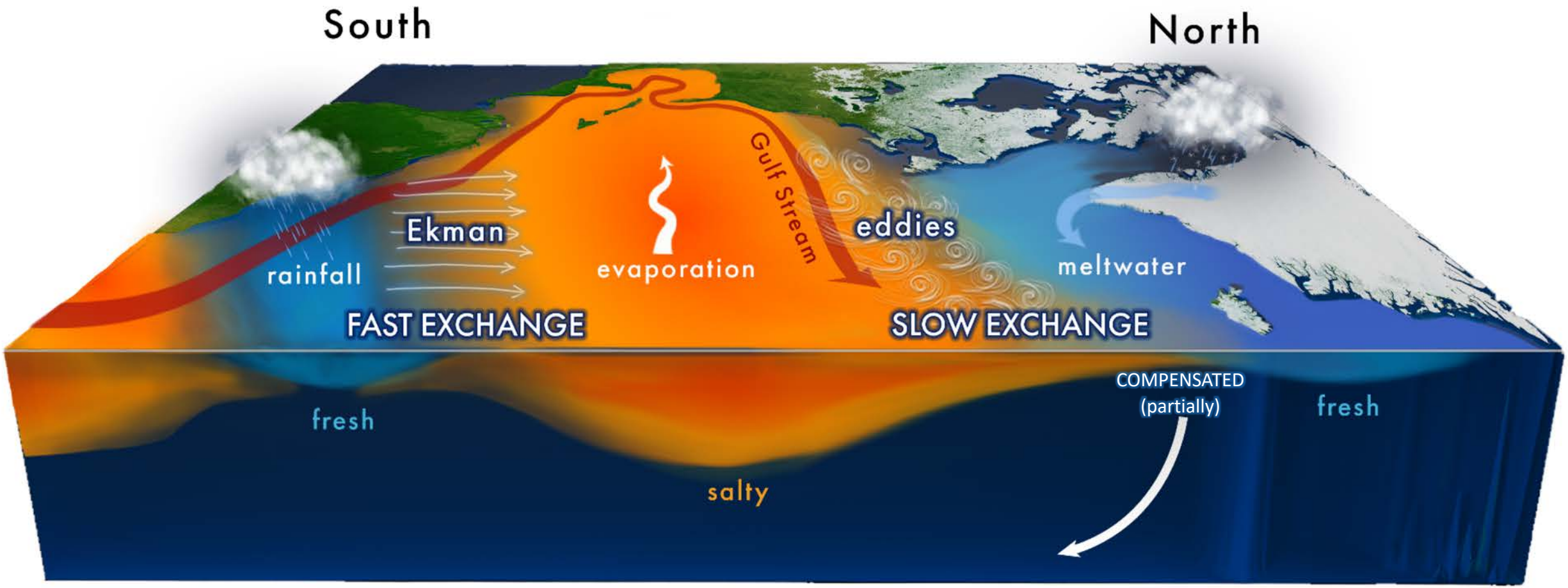
Forward spreading experiment





Summary:

- Increasing CO2 forces regular pattern of freshwater flux anomalies
- Fast exchange between tropics/subtropics
- Slower exchange between subtropics/subpolar – eddy driven
- Subtropical waters spreading to subpolar stabilizes the AMOC – poorly represented in coarse models



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