Past to future South Atlantic Meridional Overturning Circulation: pathways and low-frequency variability

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Laboratory of Physical Oceanography, Climate and Cryosphere

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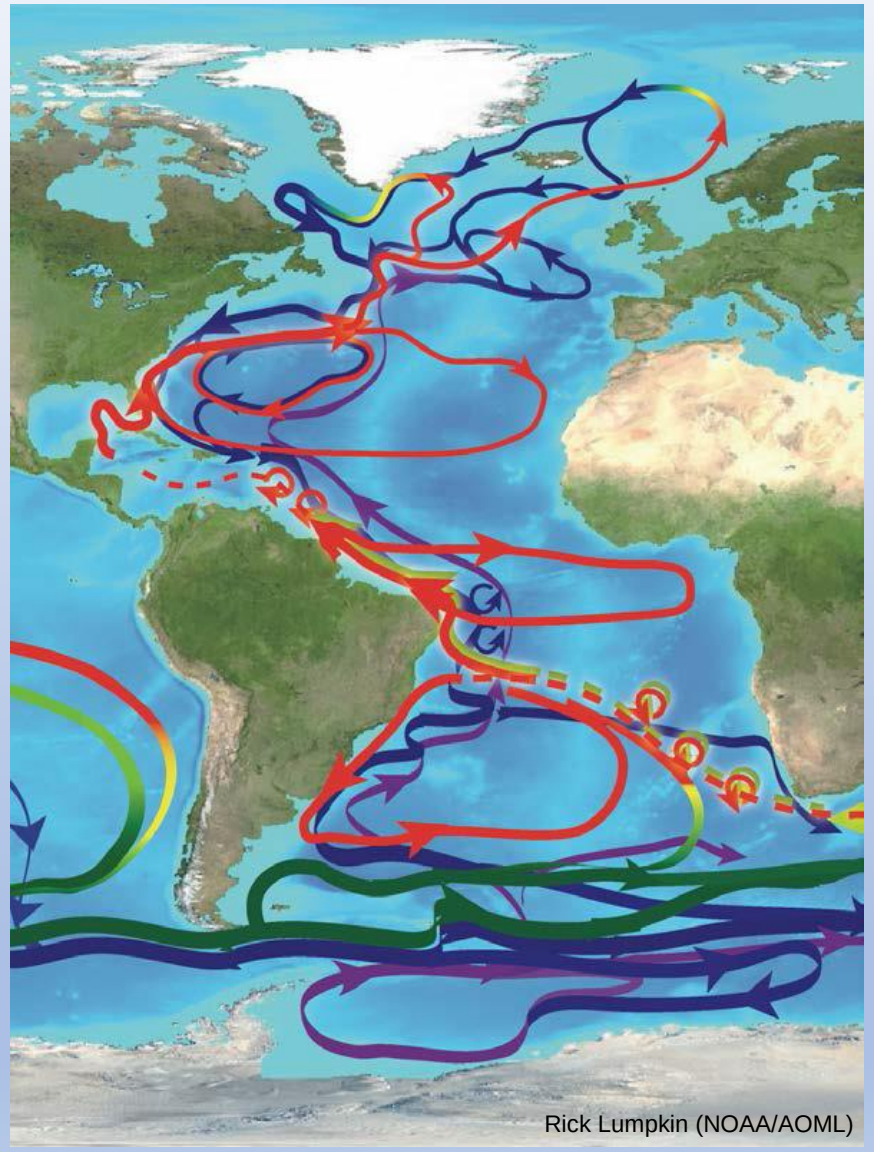
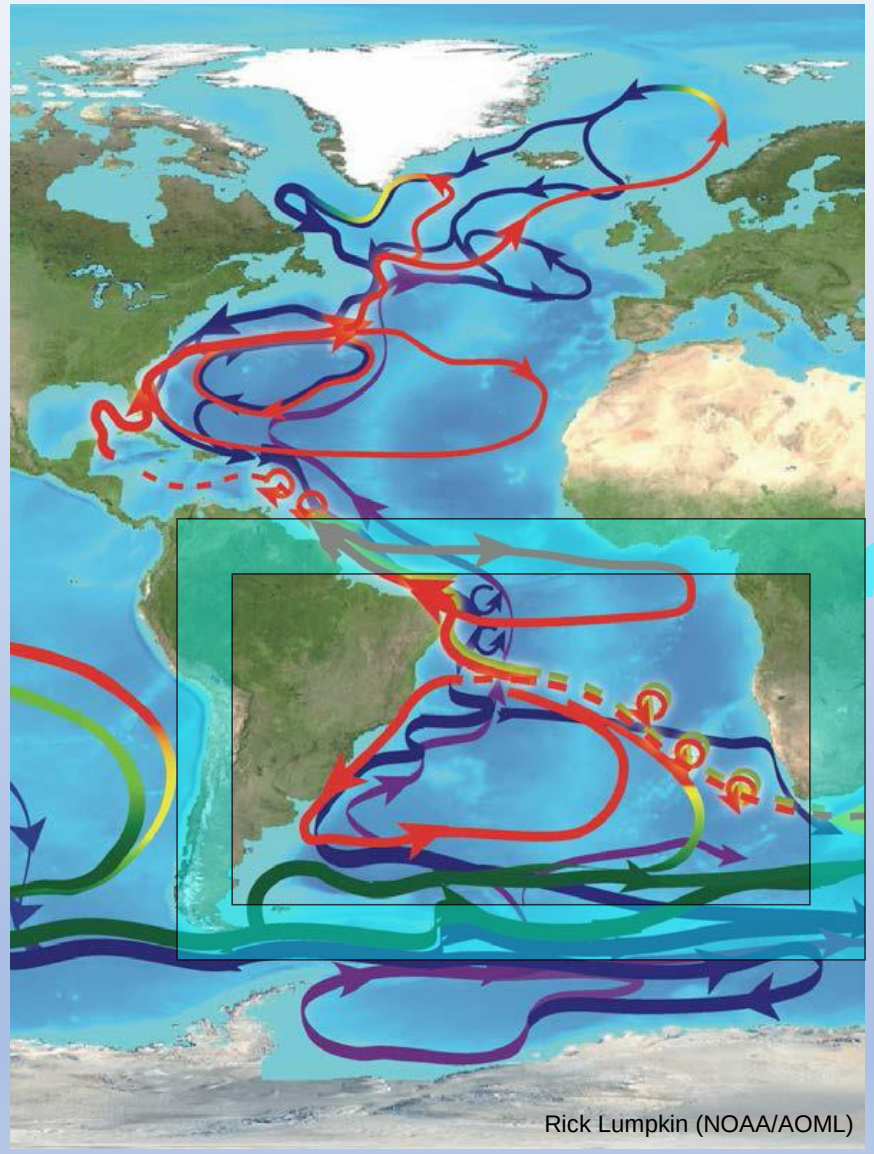
July, 26.



AMOC:

Wind-driven + Thermohaline

- **Near-surface currents are required to close the flow.**
- **Wind-driven gyres can alter the pathways and time scales of AMOC variability.**

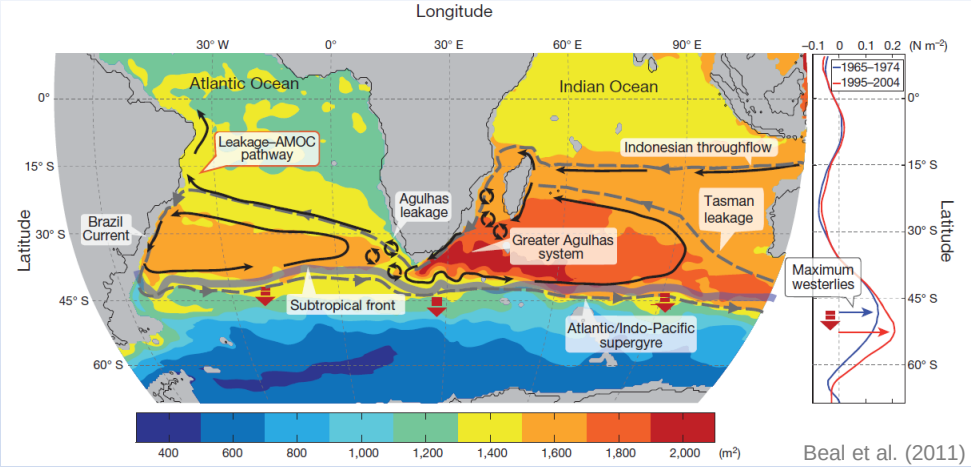


The South Atlantic Ocean:

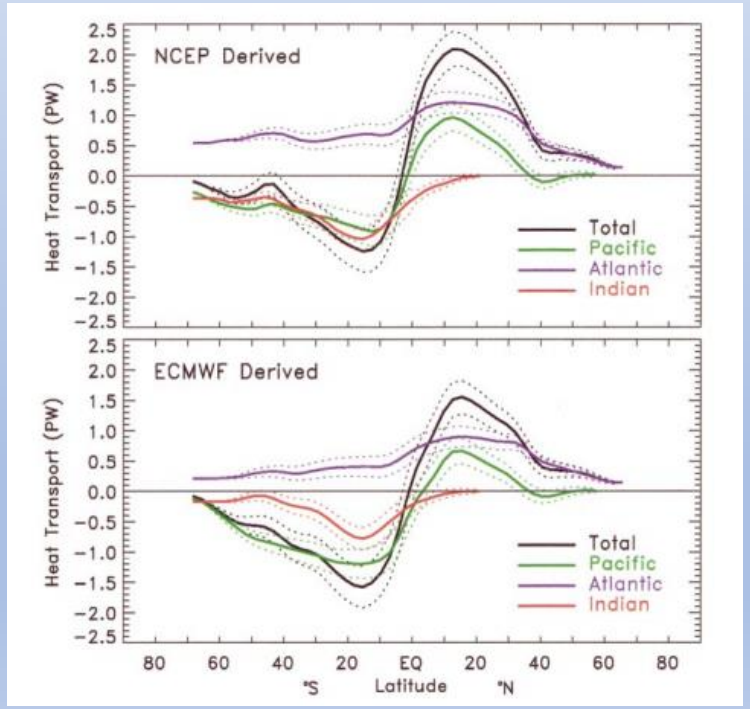
- Upper limb of the AMOC

+

- Subtropical gyre circulation



Beal et al. (2011)



Trenberth and Caron (2001)

The South Atlantic Ocean:

- the only basin which is in direct contact with all the other major oceans;
- it connects the source region of the most abundant deep water found in the global oceans – the NADW – to the rest of the ocean basins;
- intermittent supply of heat and salt received from the Indian Ocean;

The Agulhas leakage pre-conditions the Atlantic as a site of major MOC.

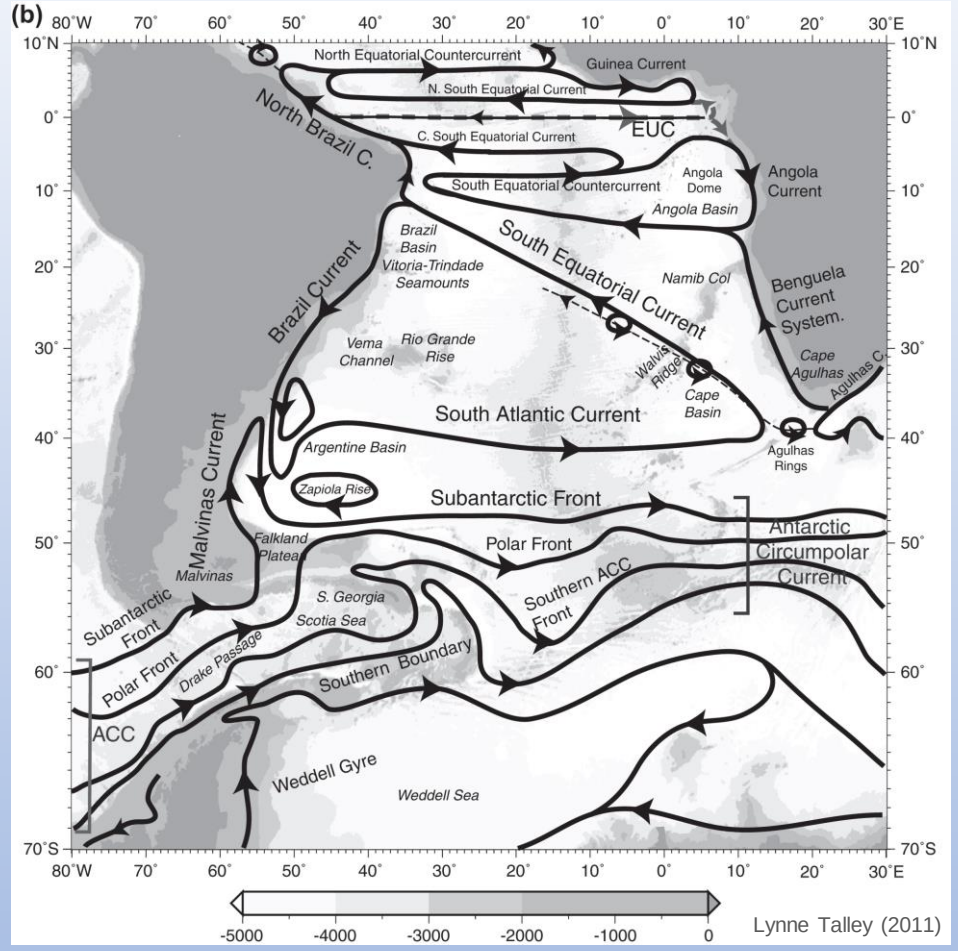
~Arnold Gordon

- the only ocean in which the heat transport is directed from the poles towards the equator;

= strategic location // critical crossroad for the AMOC.

The SAO is not just a passive conduit for the transit of remotely formed water masses, but instead actively participates in their transformation.

Garzoli and Matano (2011)



The South Atlantic Ocean:

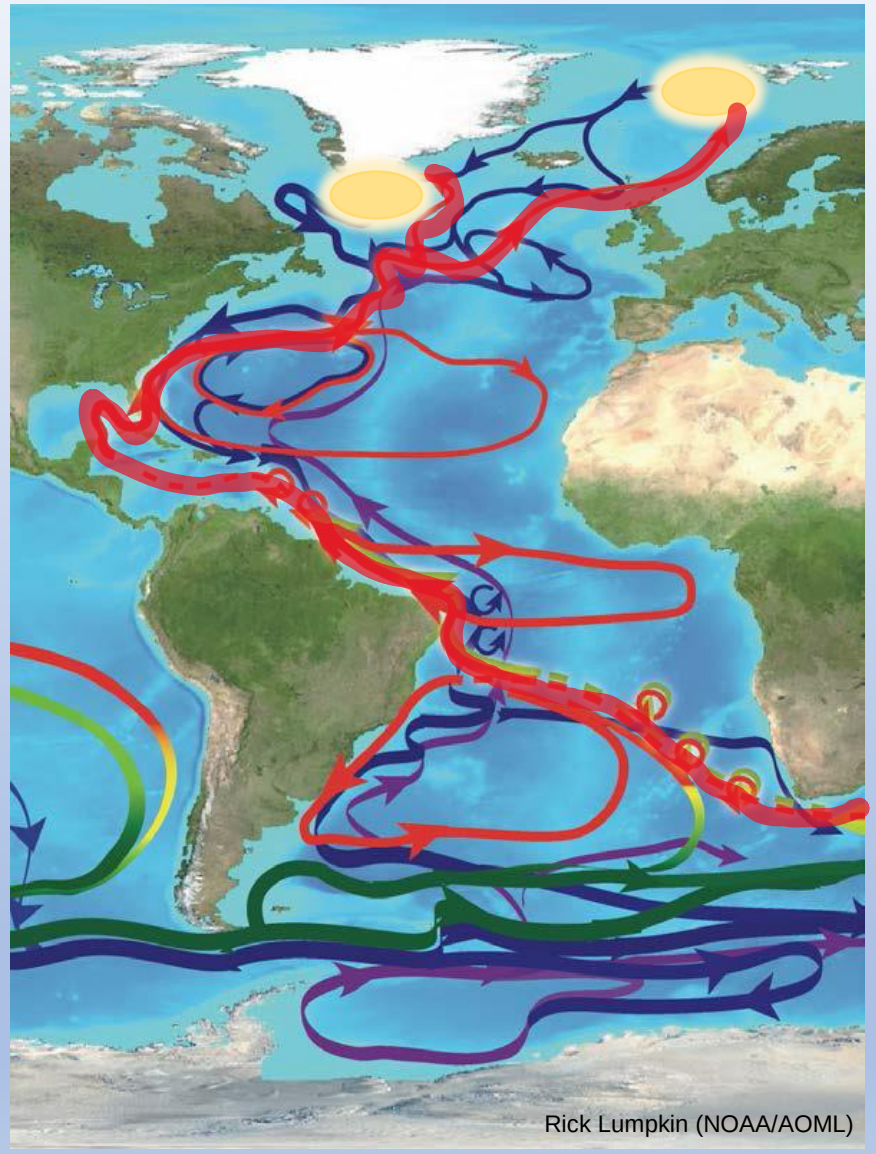
→ Pattern of gyre-scale flow is strongly influenced by interocean connections:

External forcings → **Boundary currents variability** → **Impacts on the SASG**

- Brazil Current → Weak among global WBCs

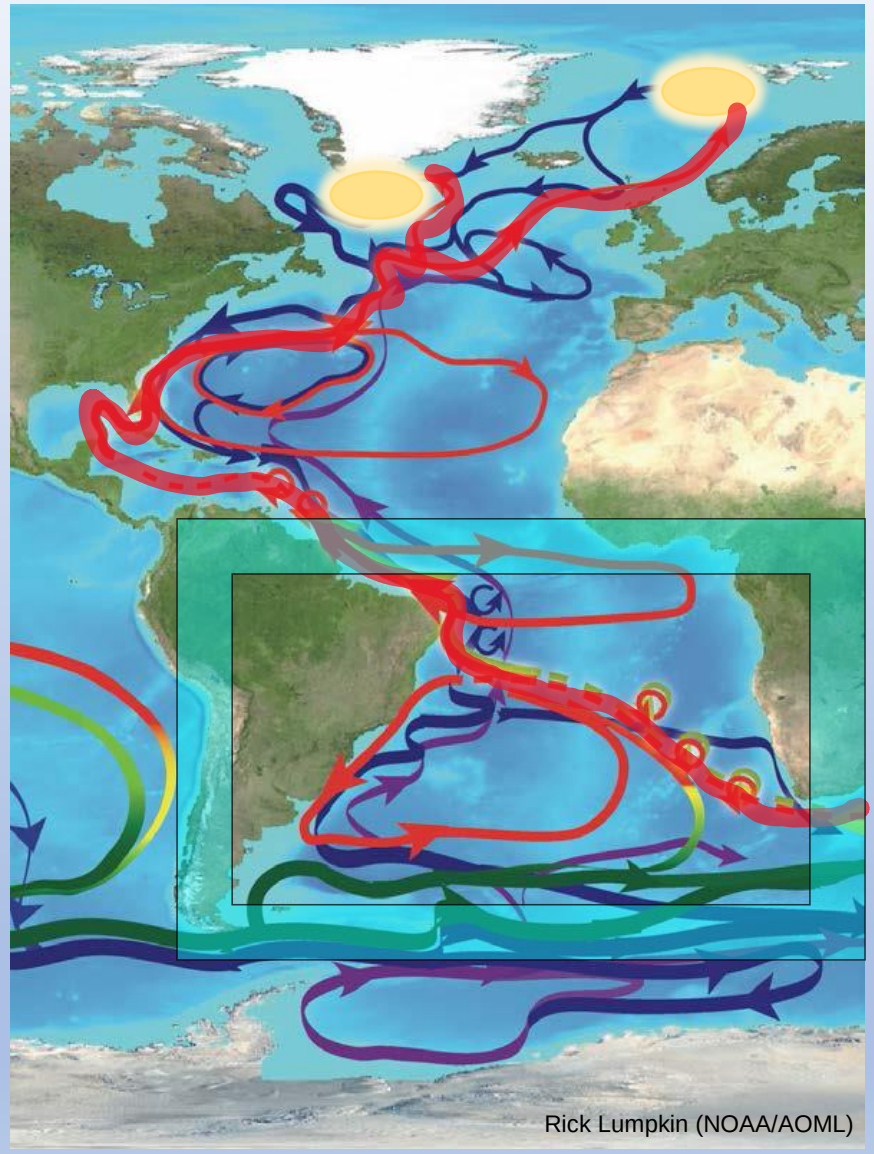
→ Transport is directed northward

Evans & Signorini (1985)
Stramma et al. (1990)
Peterson & Stramma (1999)



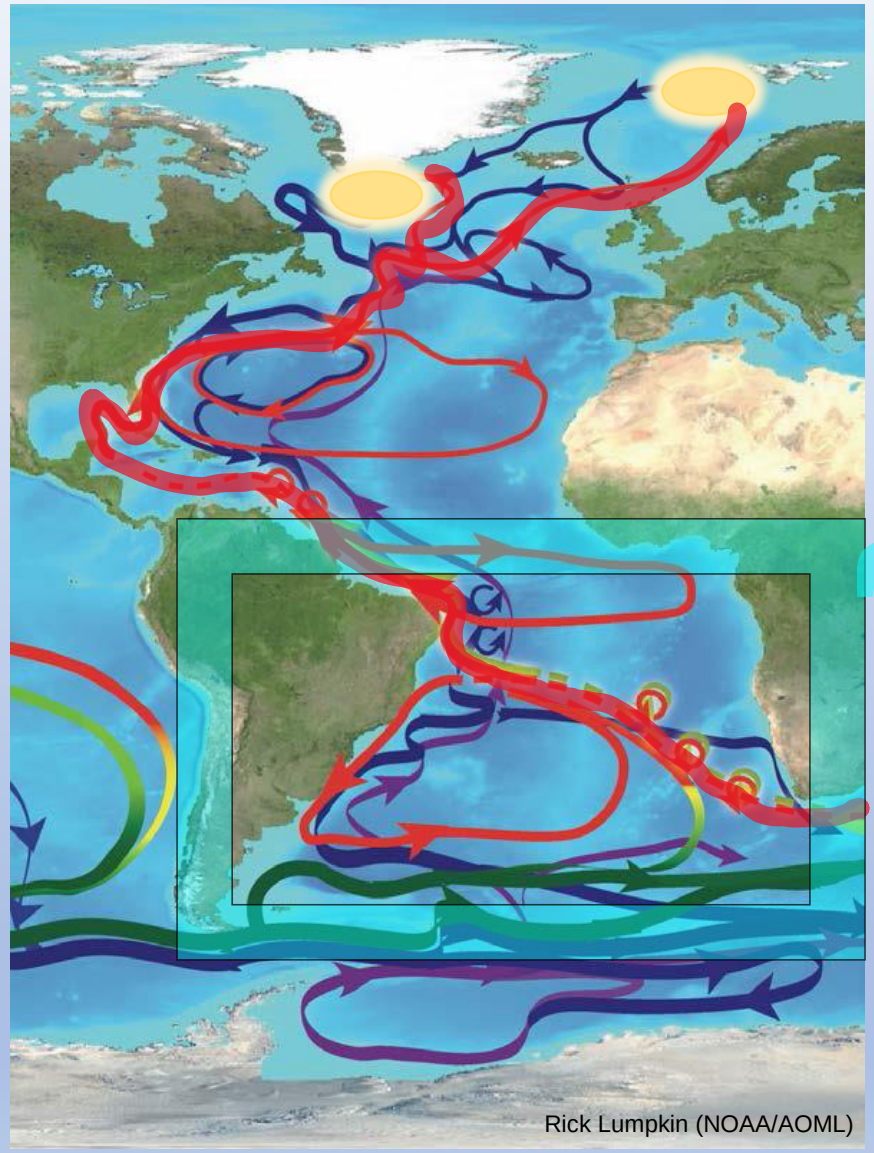
The South Atlantic Ocean:

- DWF ⇔ upper limb inflow



The South Atlantic Ocean:

- DWF ⇔ upper limb inflow
- SASG circulation ⇔ AMOC variations
  + boundary currents



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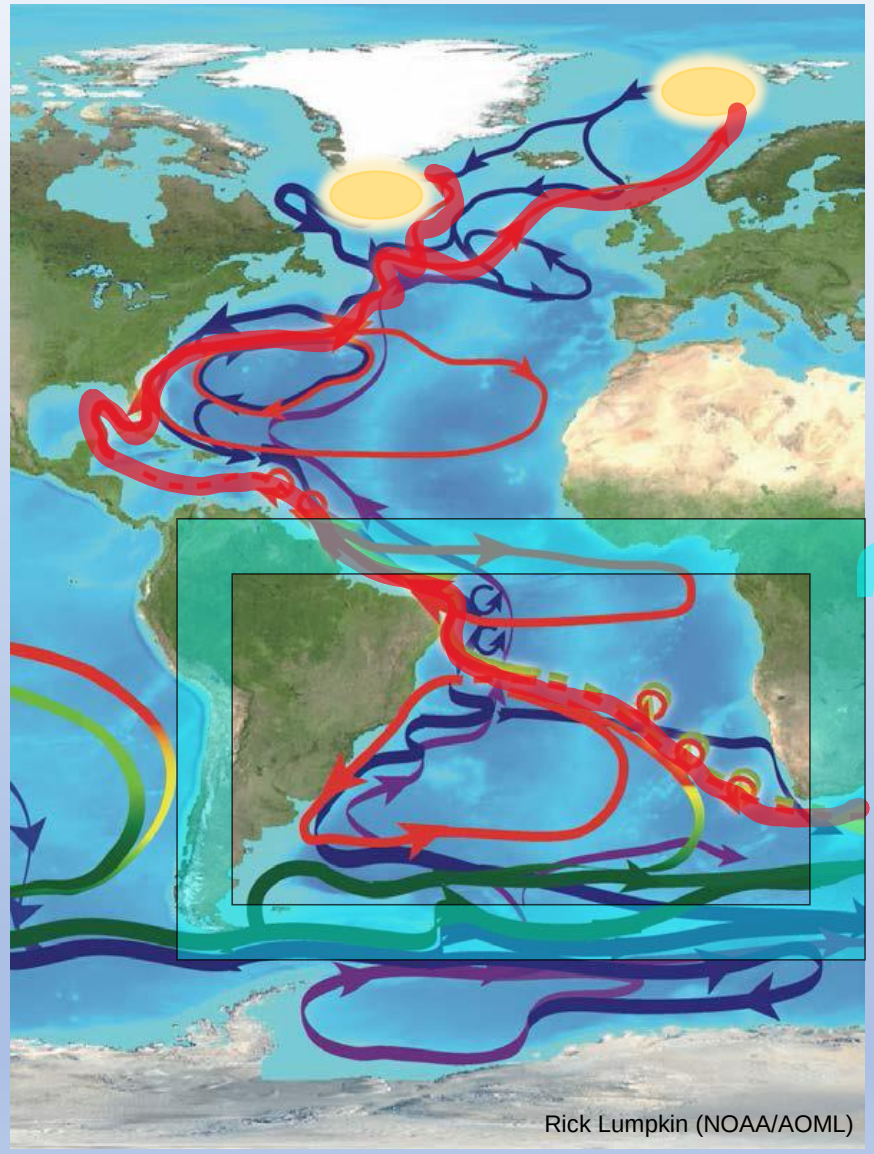

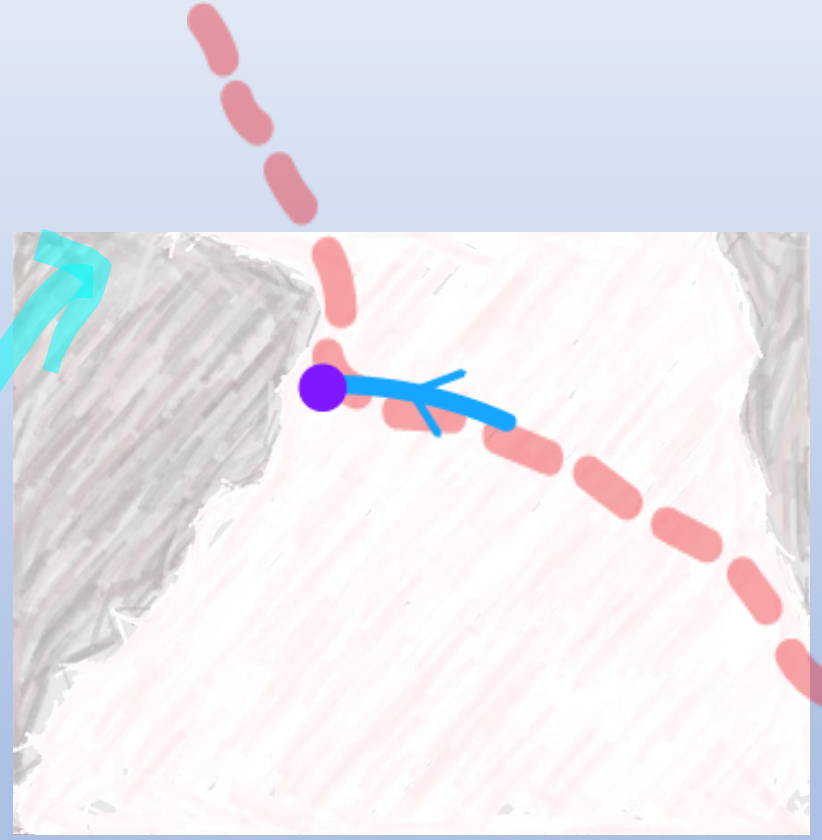

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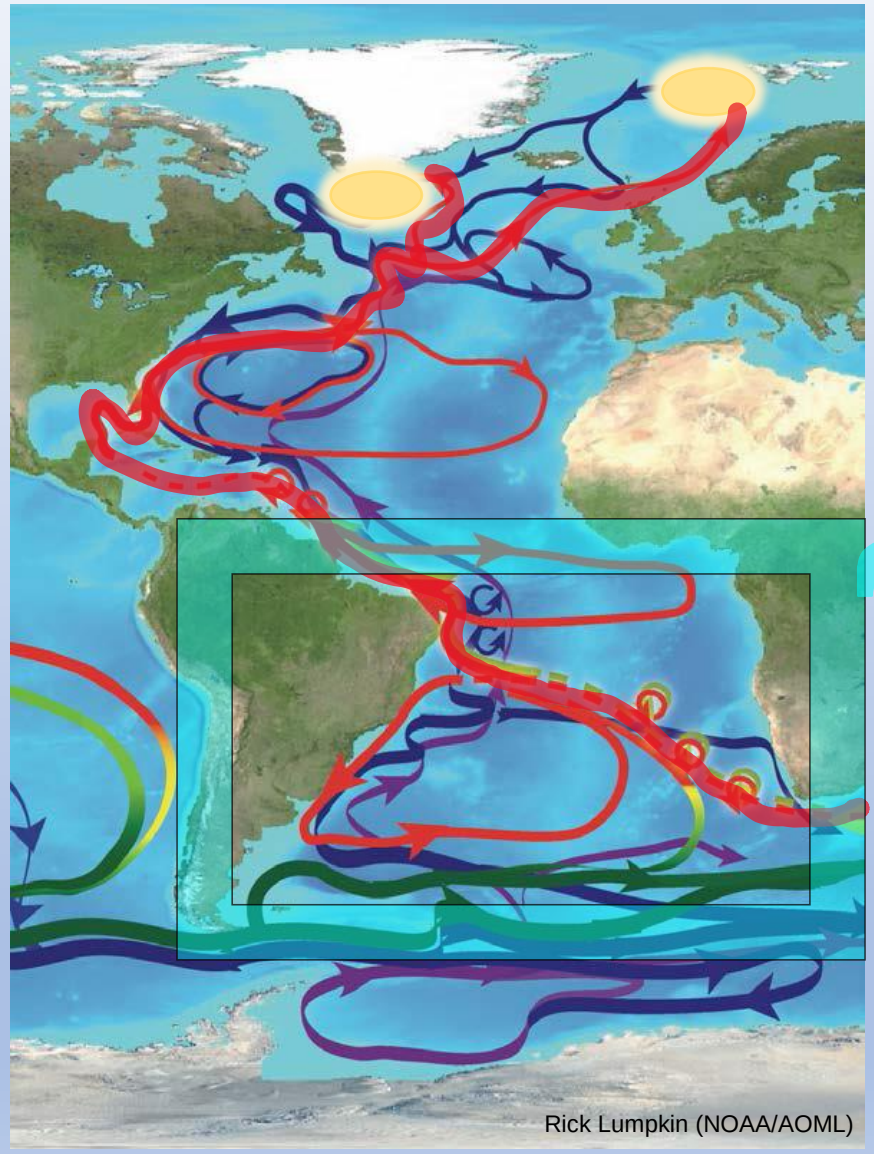

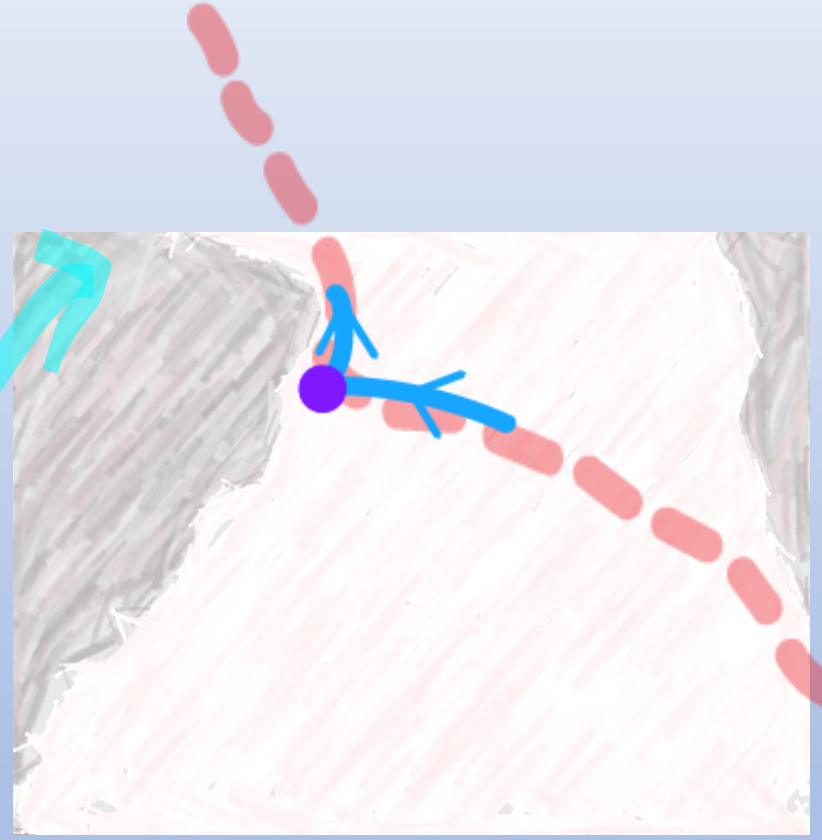

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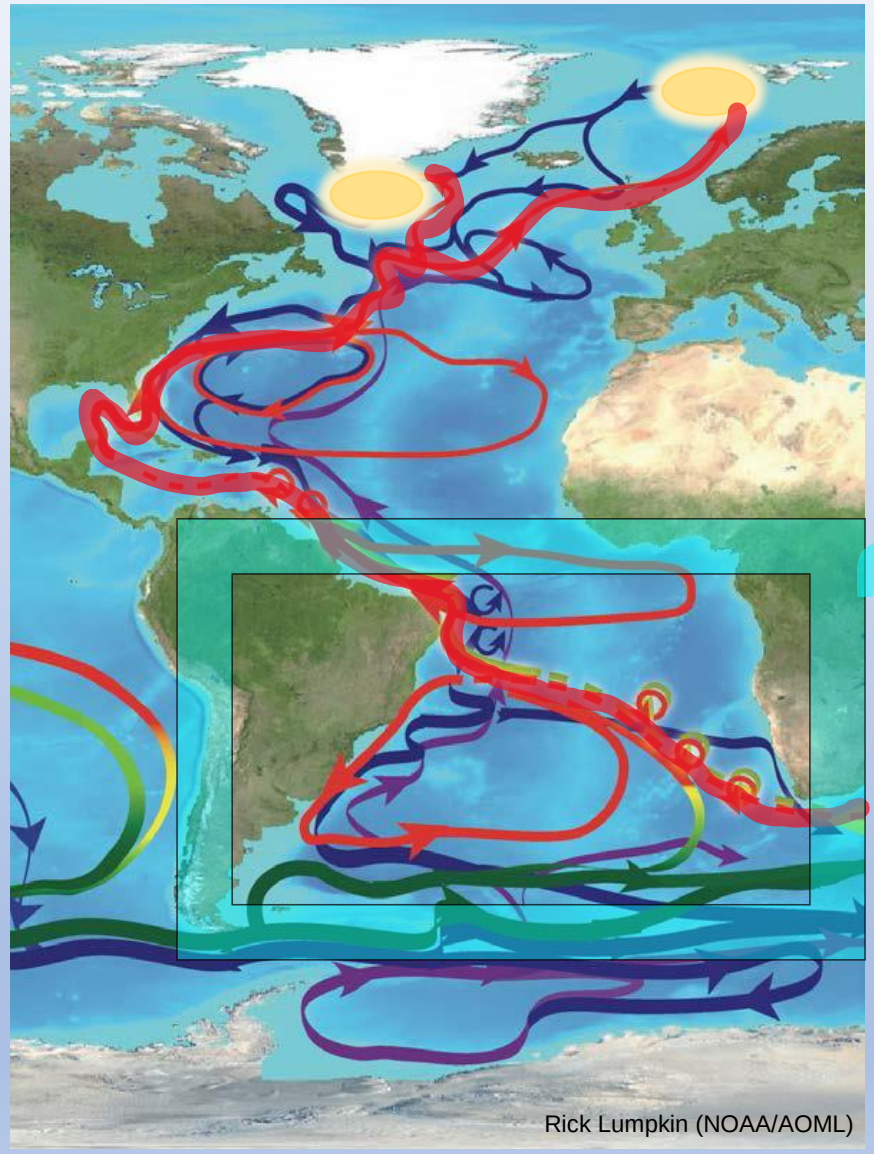

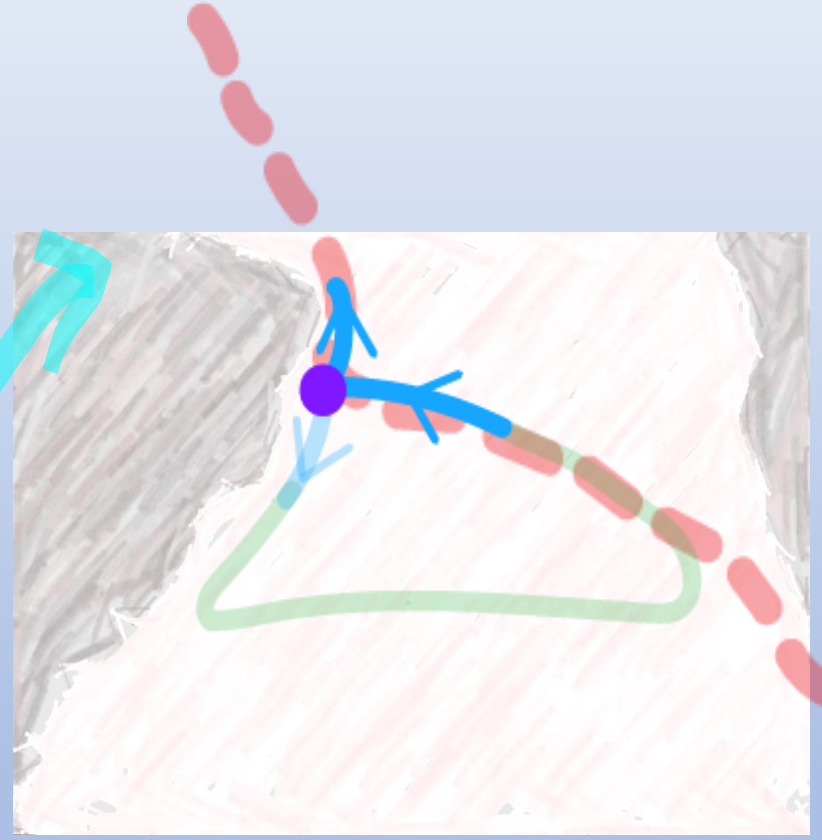

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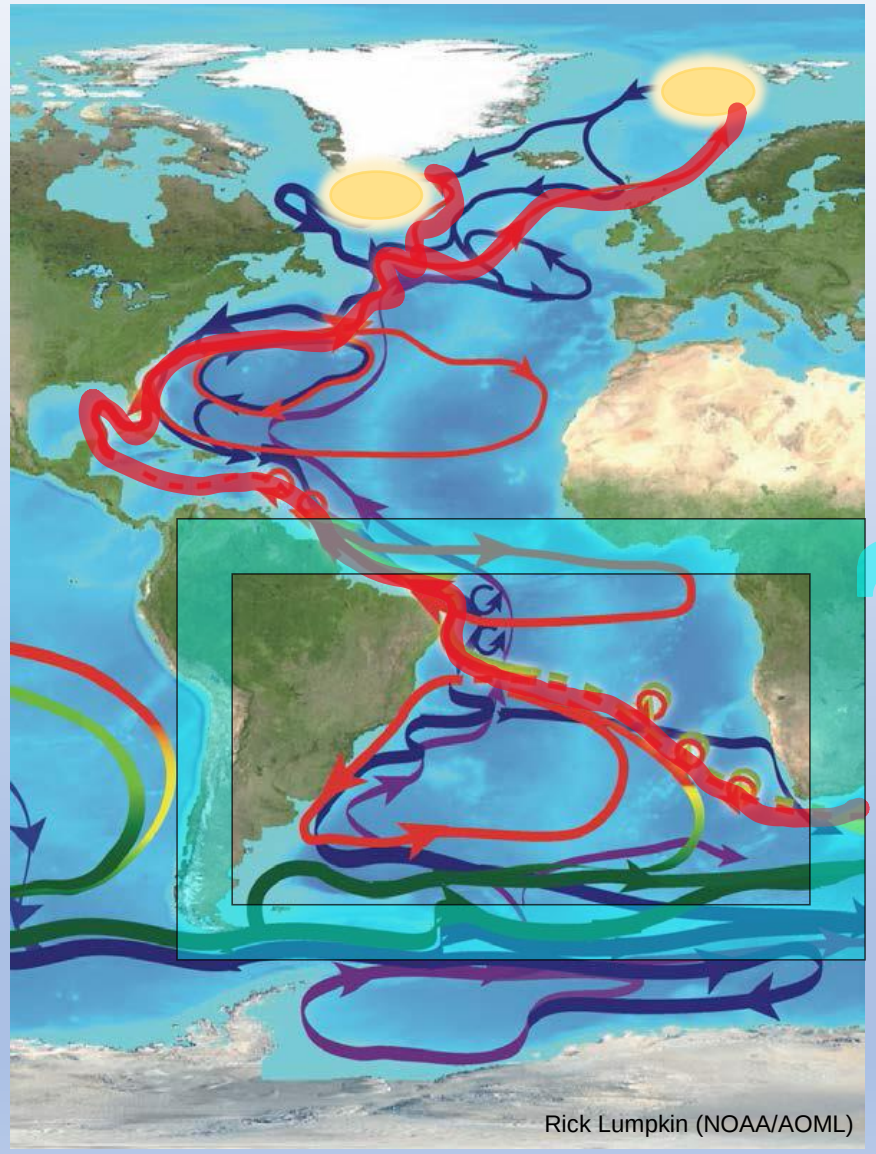
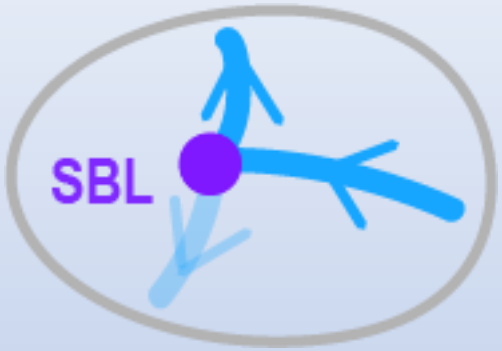
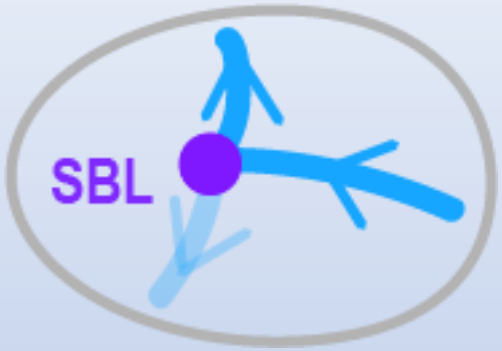


SBL = sSEC bifurcation latitude → **division between both large-scale regimes**

* sSEC = southern branch of the South Equatorial Current



NBUC → Equator → NH



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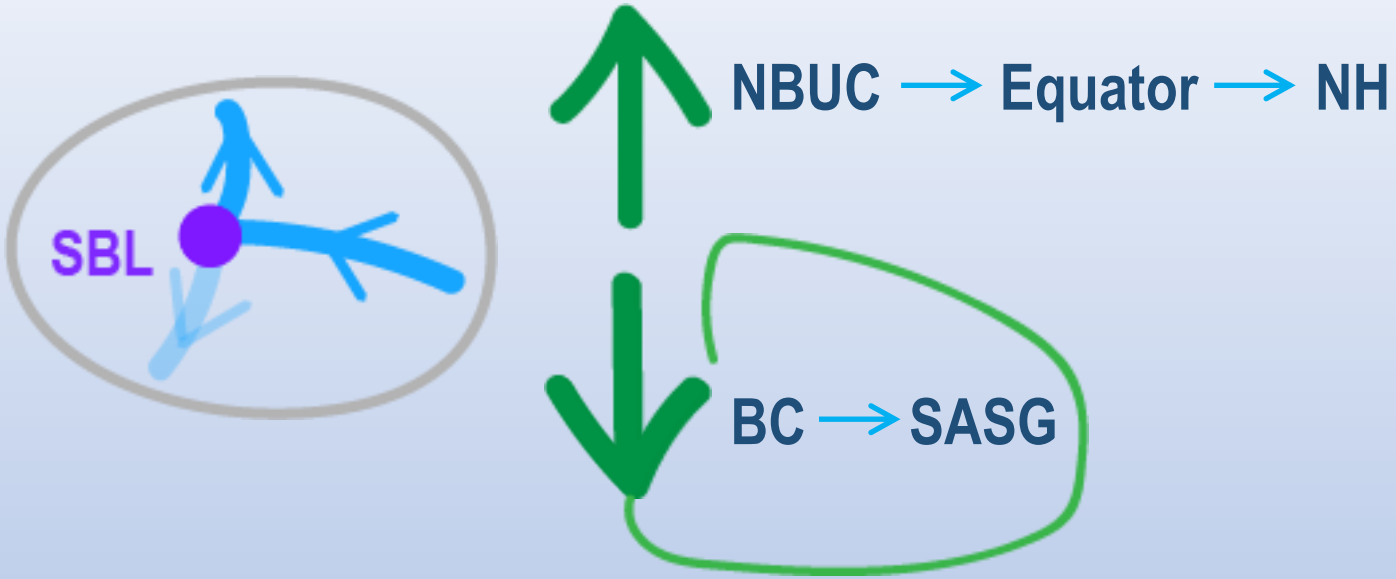
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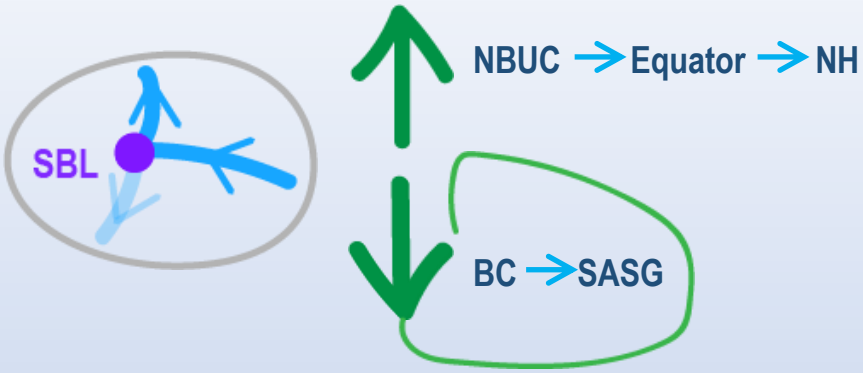
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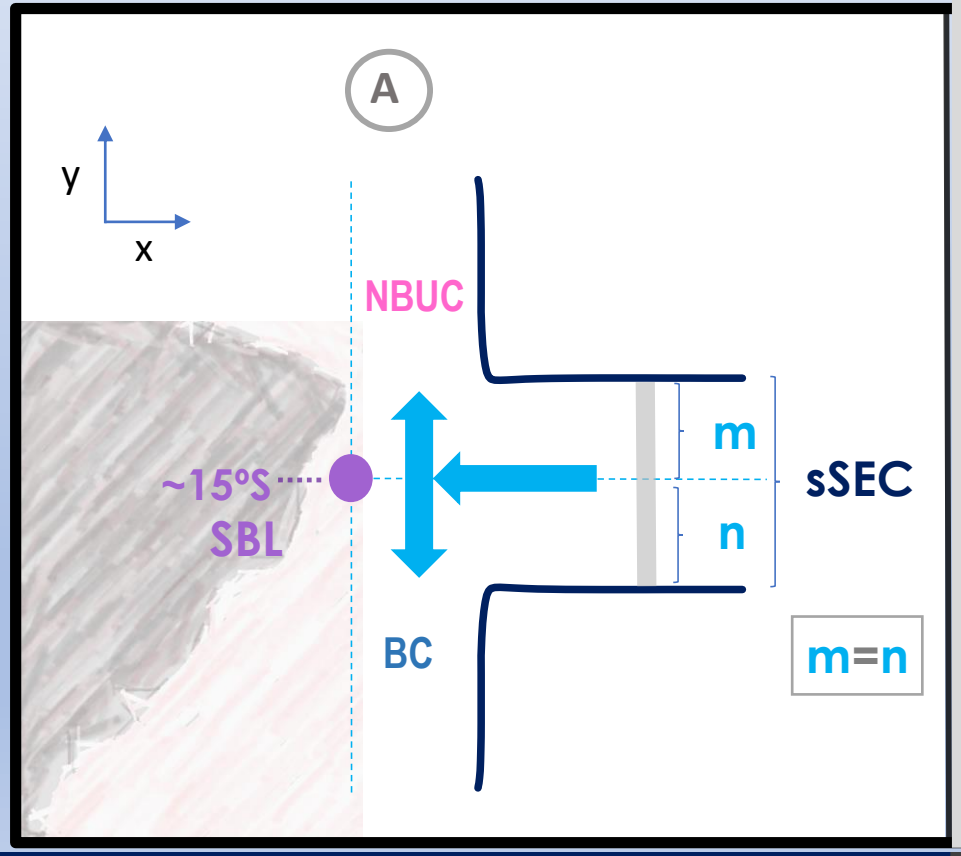
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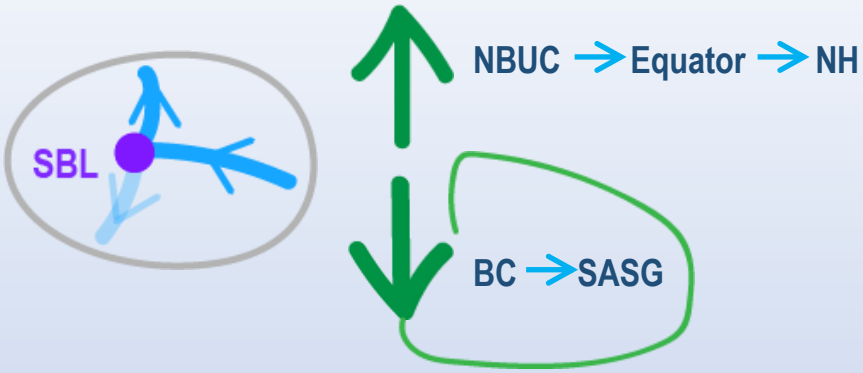
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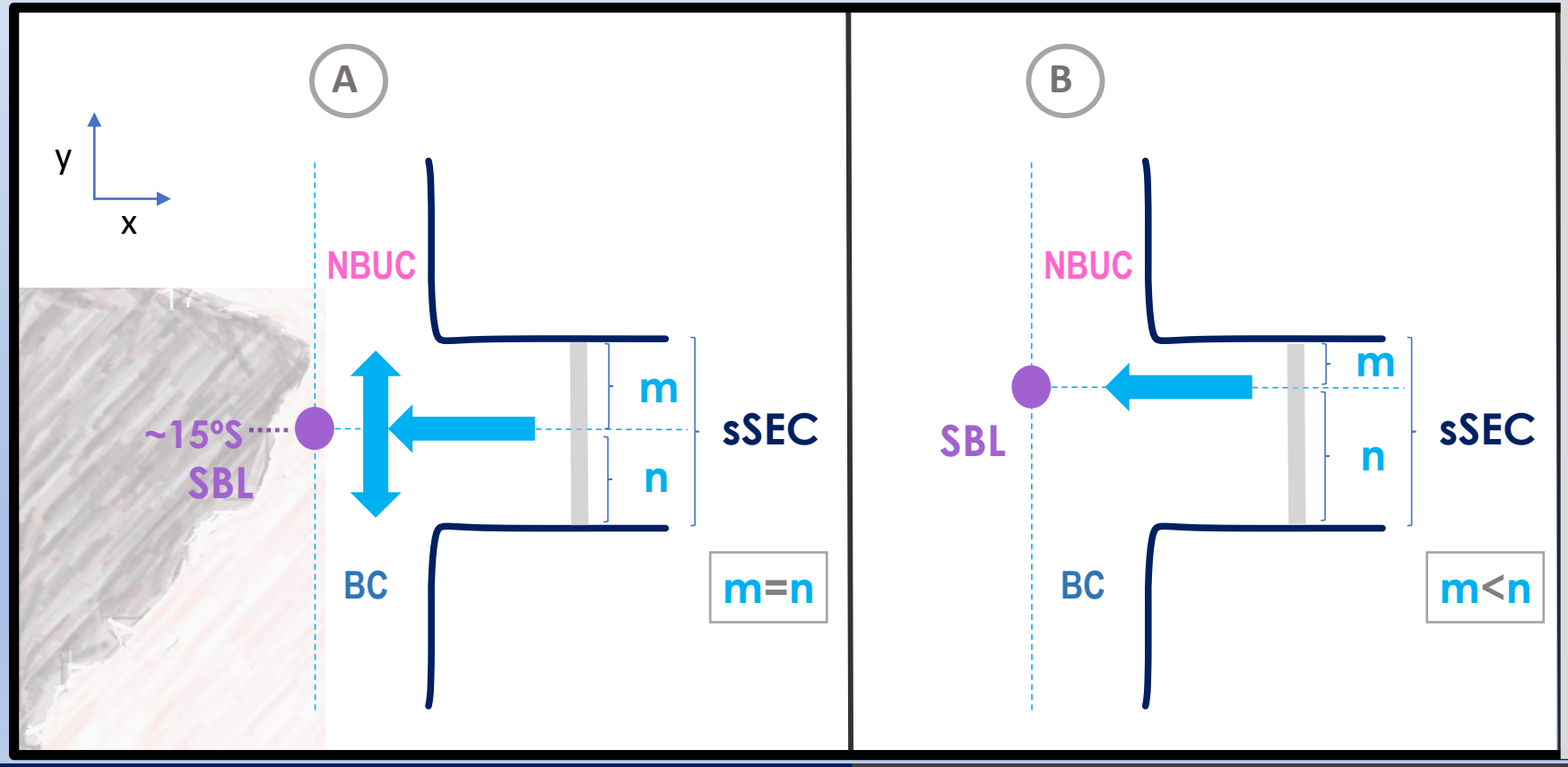
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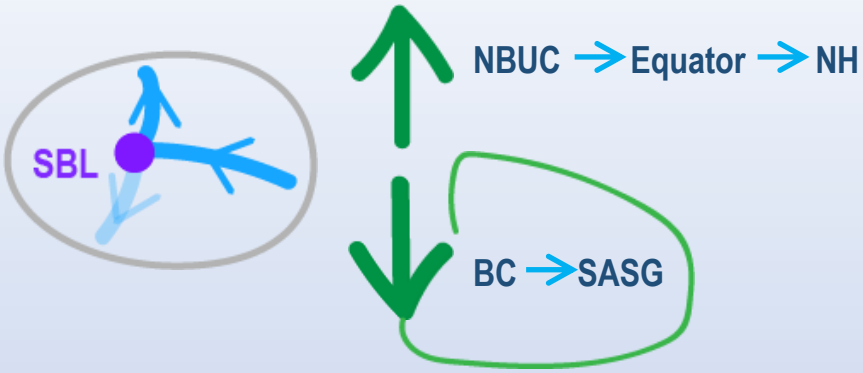
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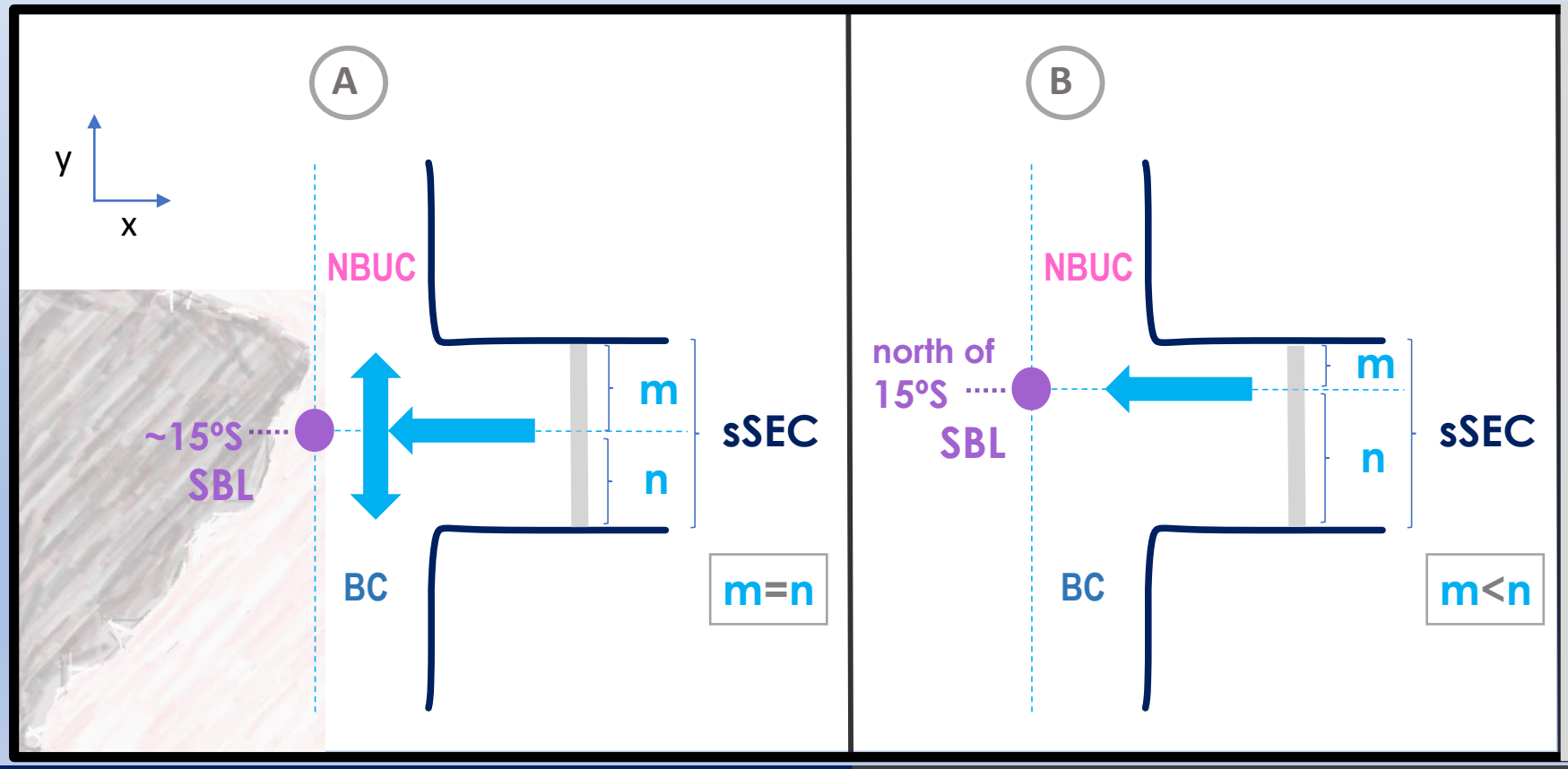
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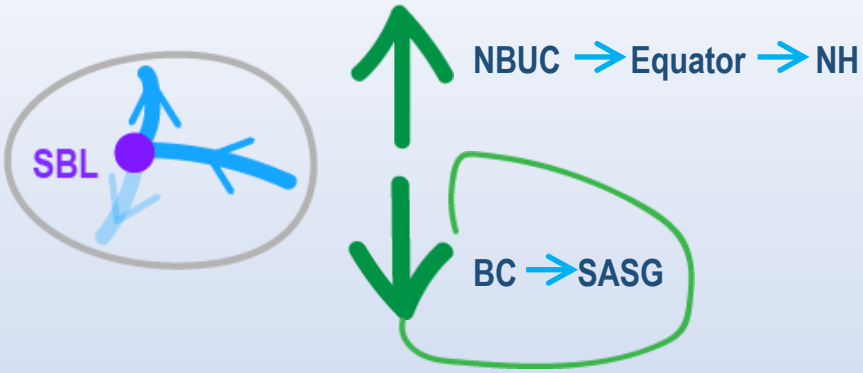
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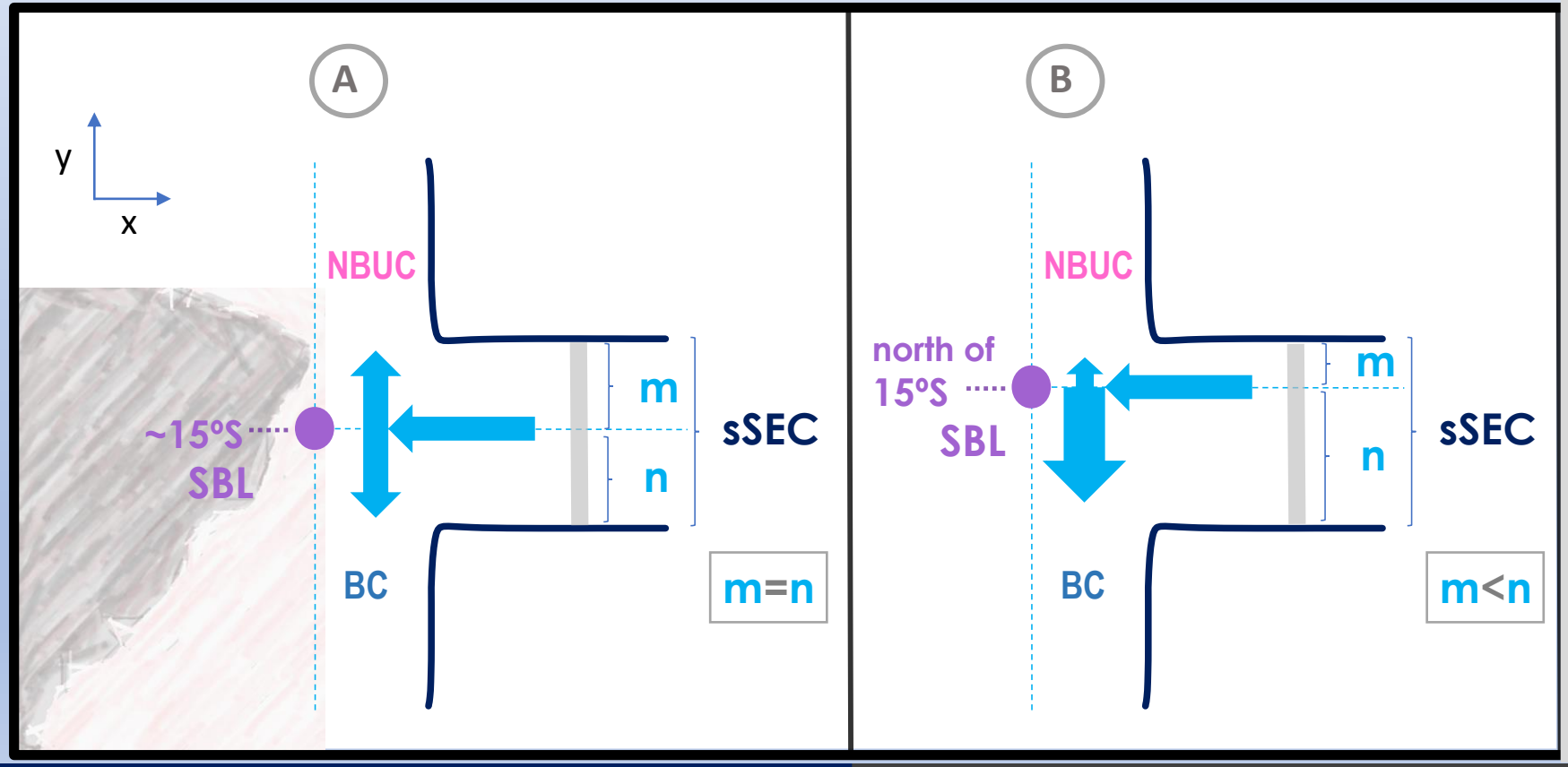
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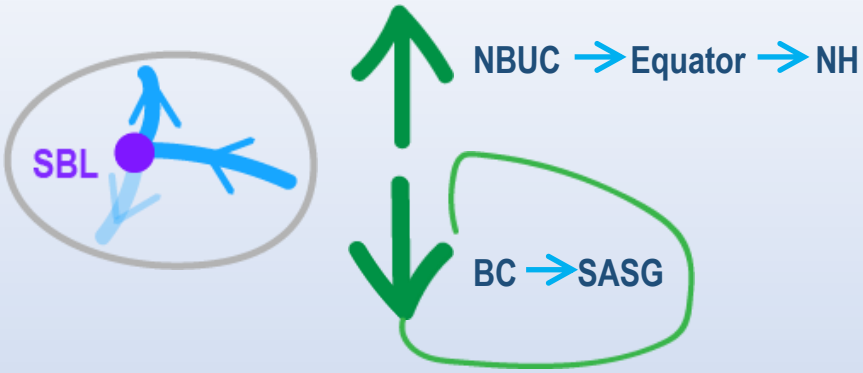
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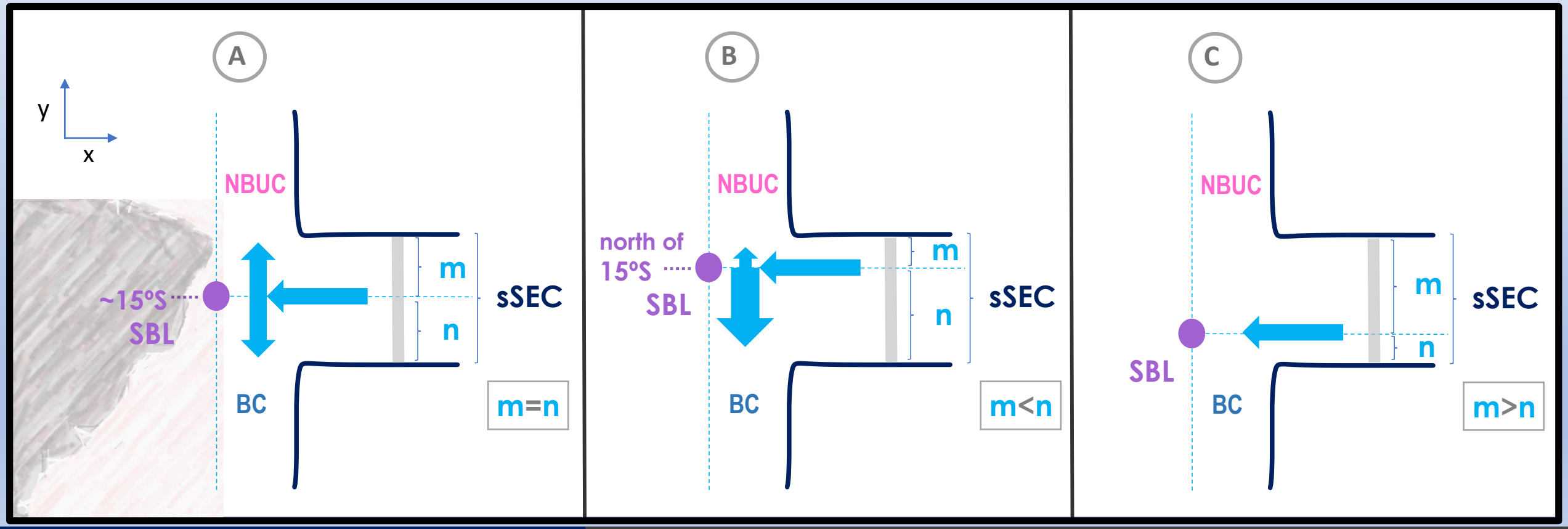
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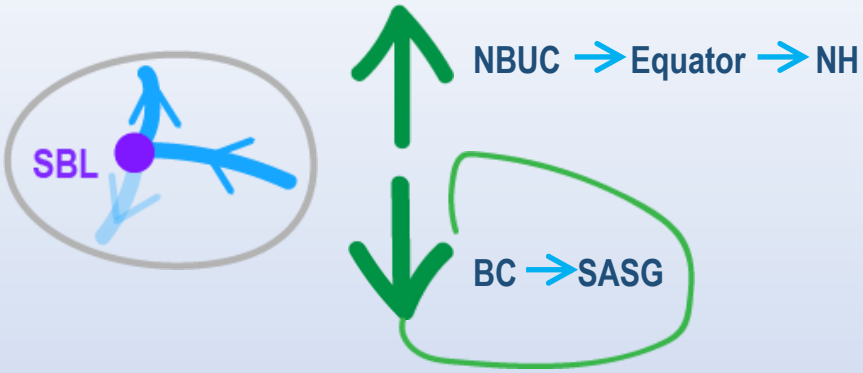
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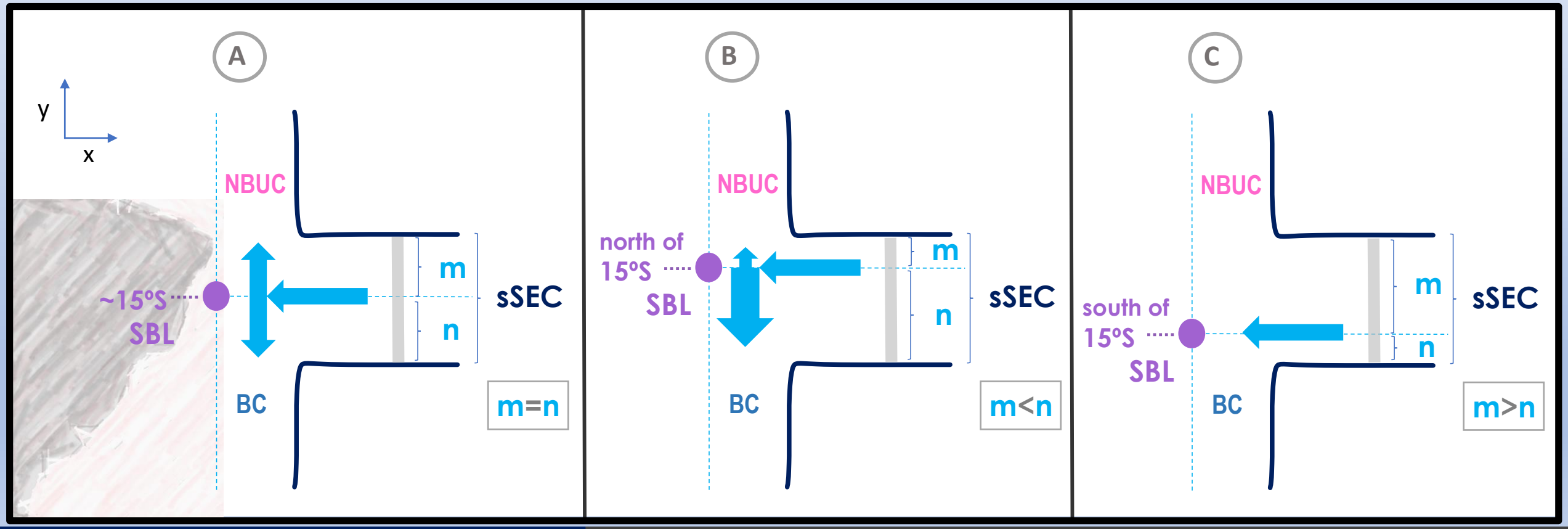
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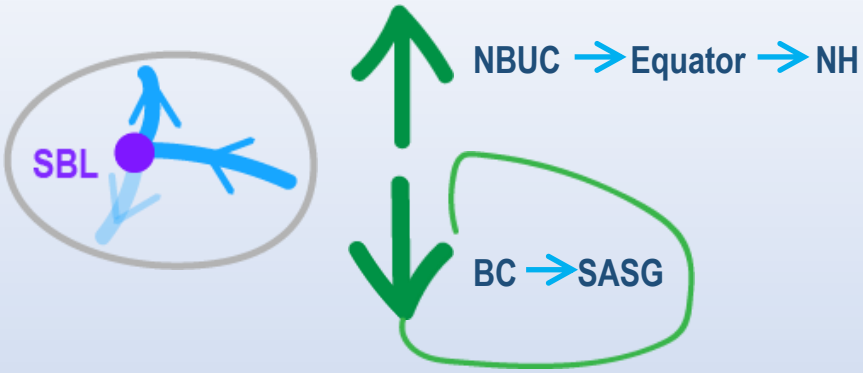
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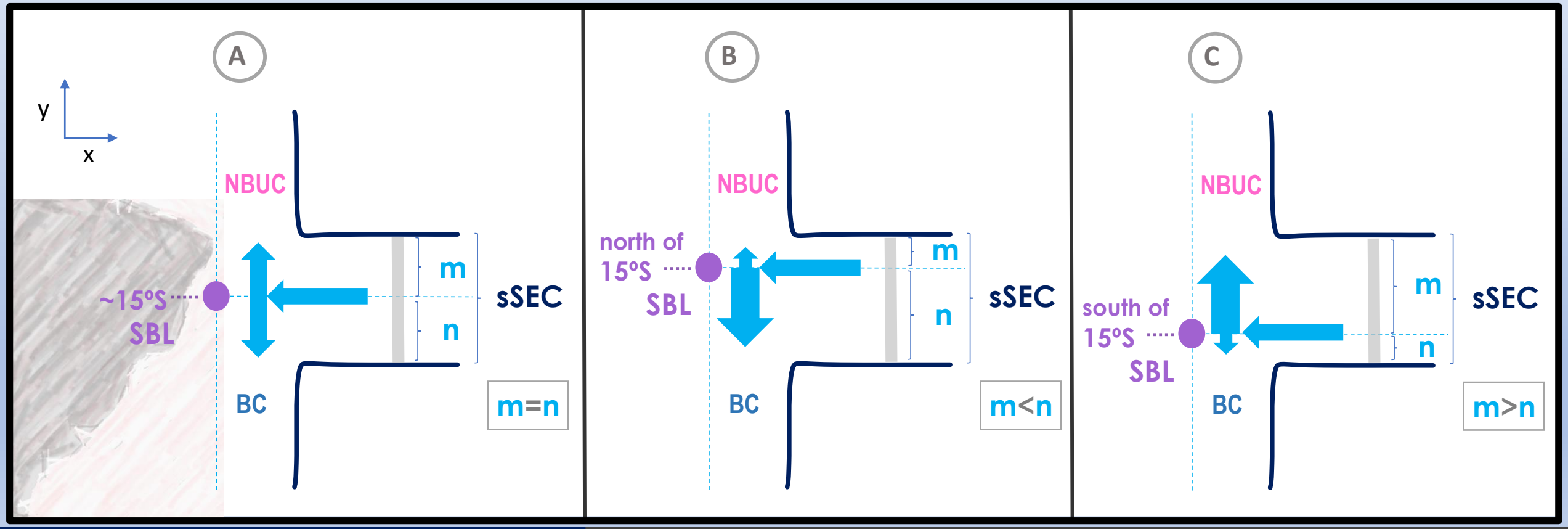
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Model simulation results:

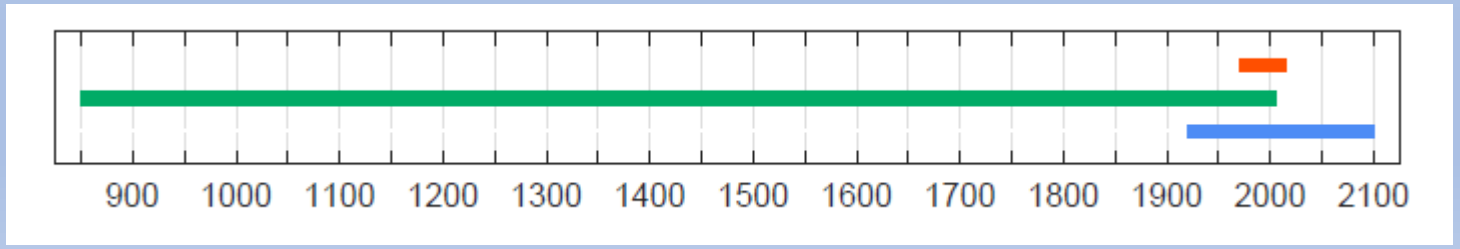
The *Community Earth System Model*:

I) single-realization	-- the ocean component (**CESM-POP2**)	------> **1970-2015**
II) 10-member ensemble	-- the *Last Millennium* experiment (**CESM-LME**)	------> **850-2005**
III) 33-member ensemble	-- the *Large Ensemble* project (**CESM-LEns**)	------> **1920-2100**

((coupled ocean-atmosphere realizations))

((single-model ensemble approaches))

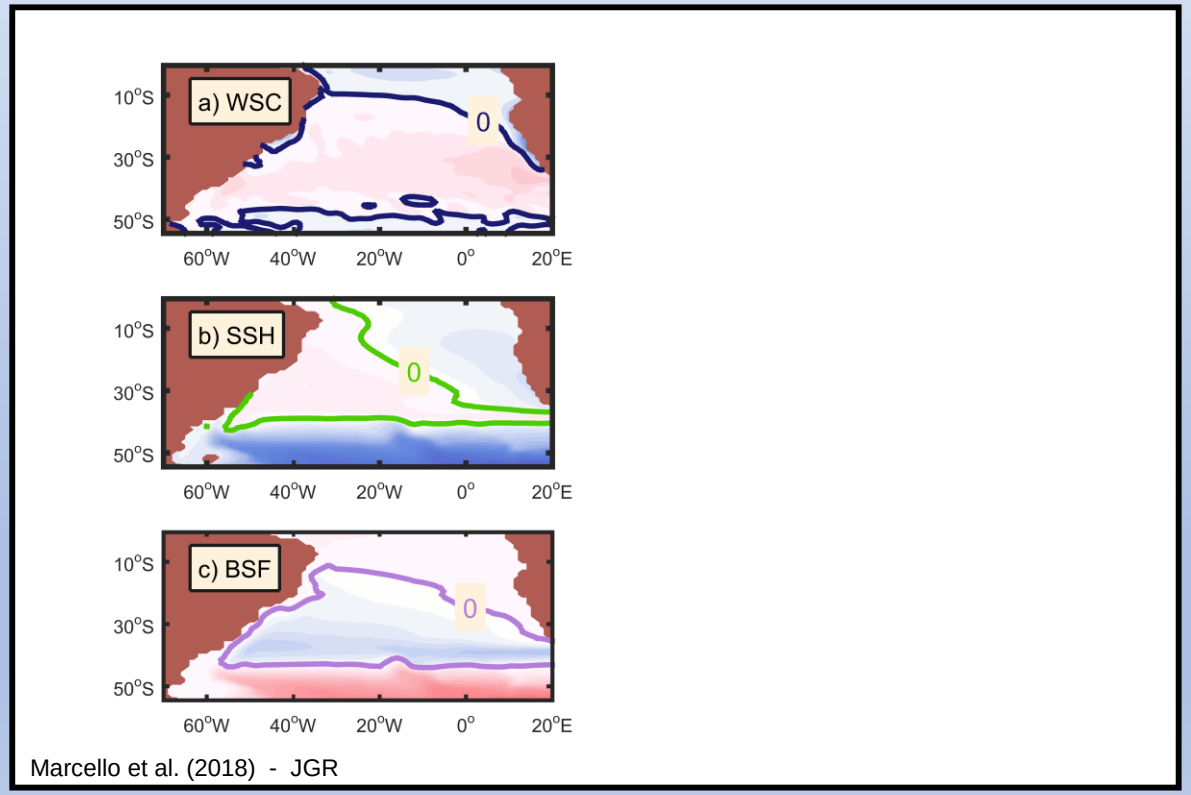
** with small random round-off (order 10^{-14} K) differences in the air temperature field at the start of each ensemble member



Model simulation results:

- The ocean component of the *Community Earth System Model*: **POP2** Danabasoglu et al. (2012) [1970 -- 2015]

  forced with *Coordinated Ocean-Ice Reference Experiments* (CORE-II)
  (interannually varying atmospheric data set) Large and Yeager (2009)



Marcello et al. (2018) - JGR

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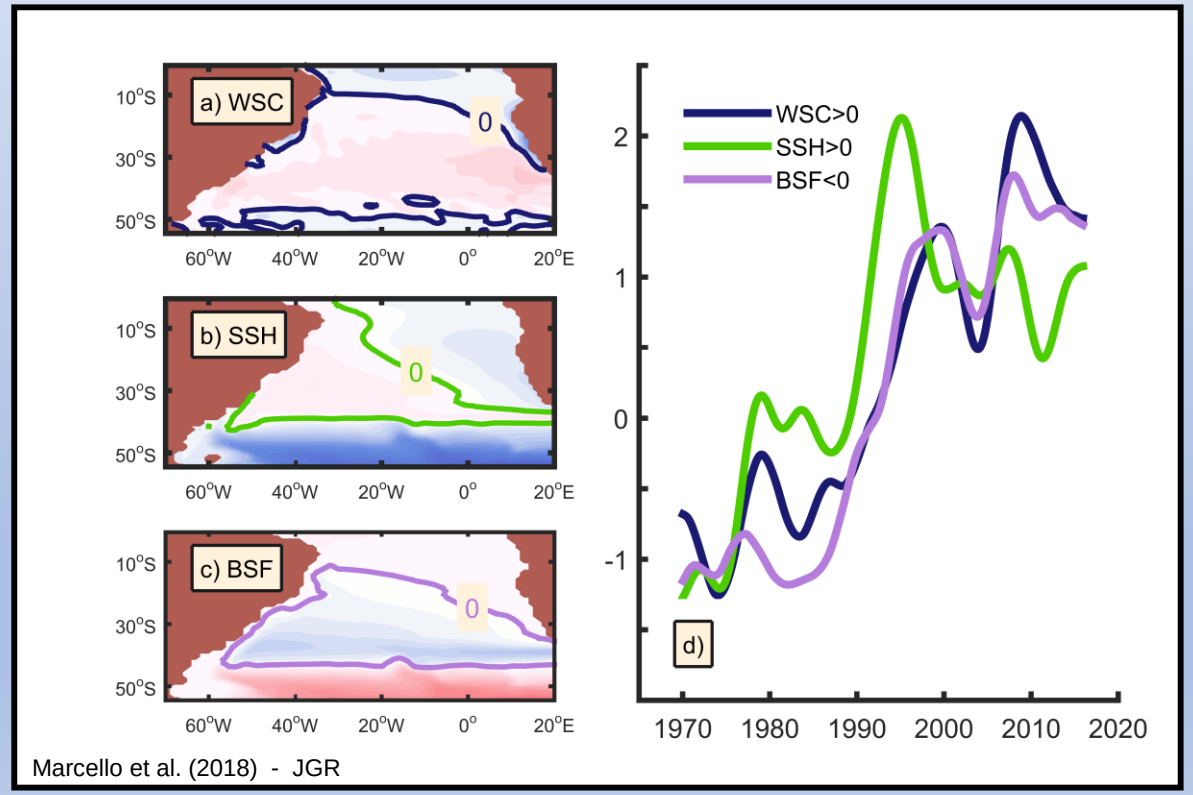

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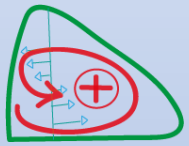
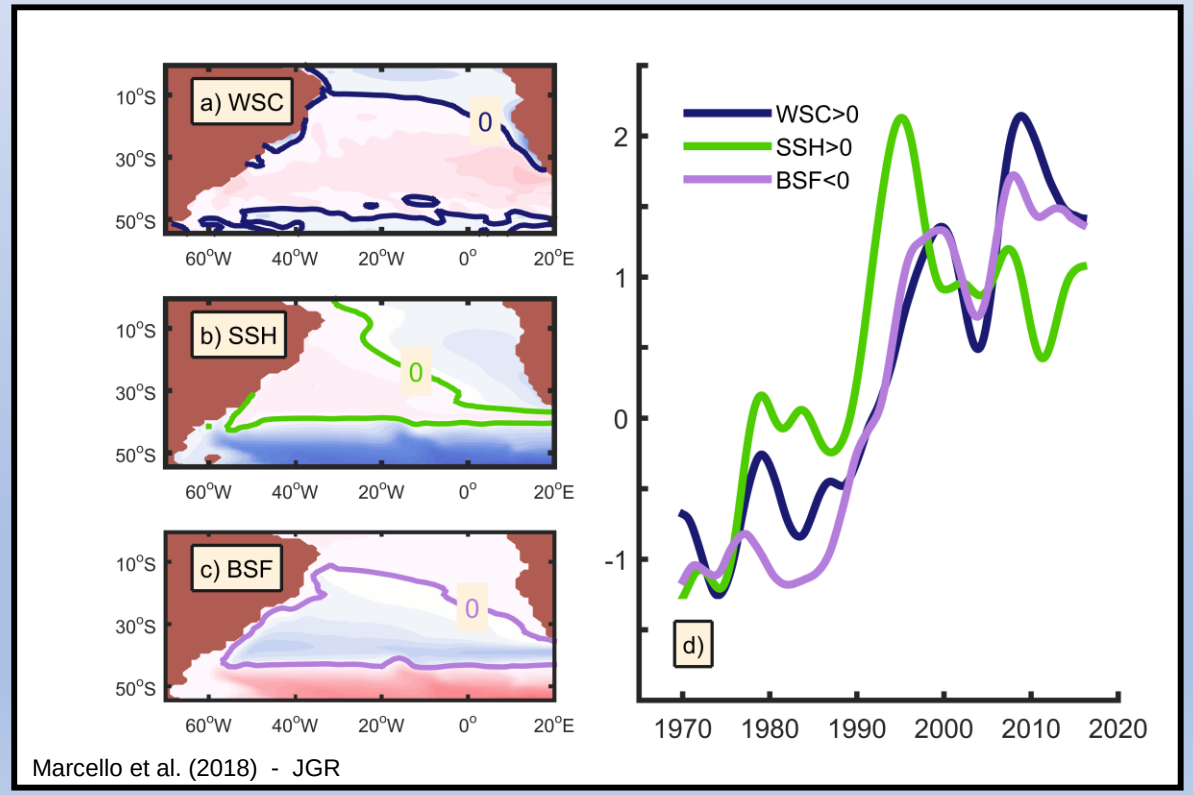
Increased:

Wind stress curl,





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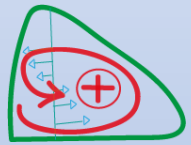
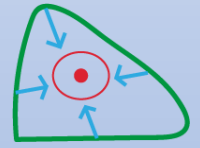
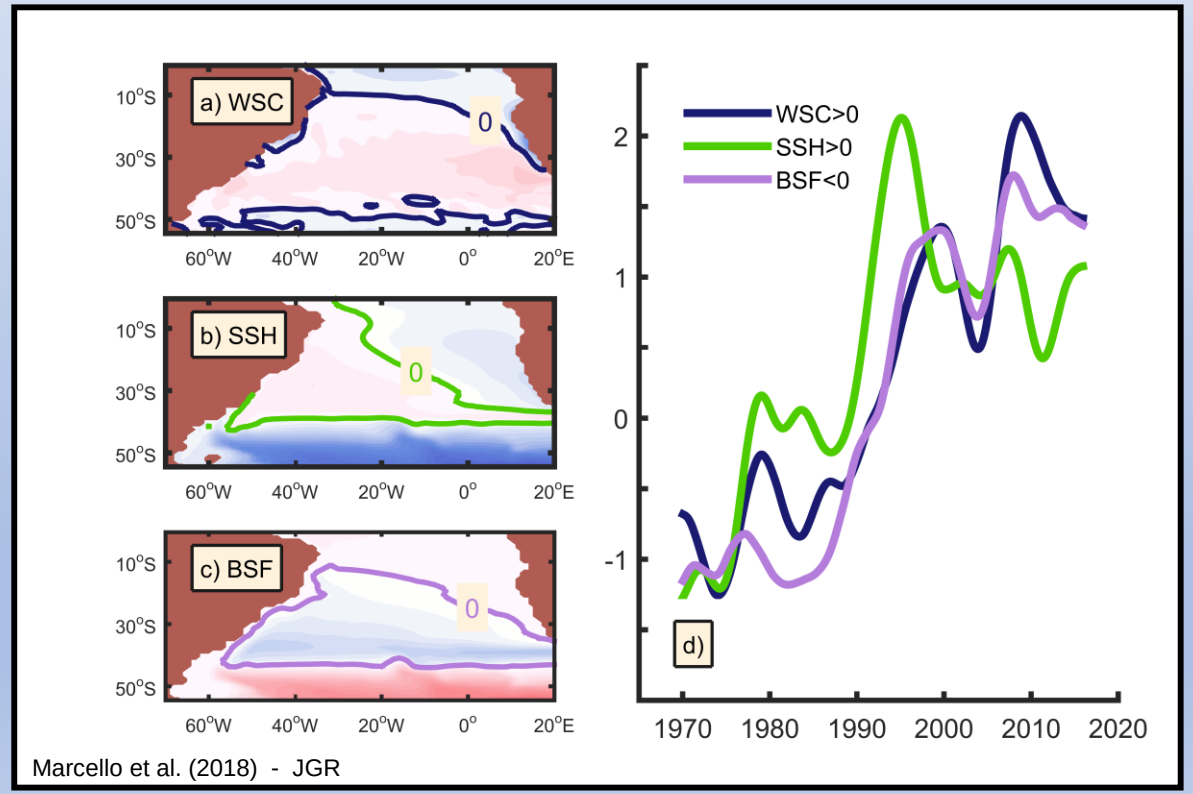


Sea surface height and





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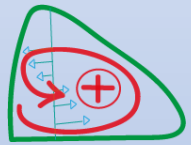

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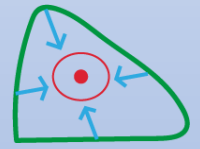
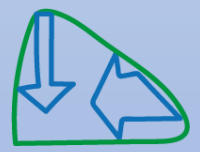
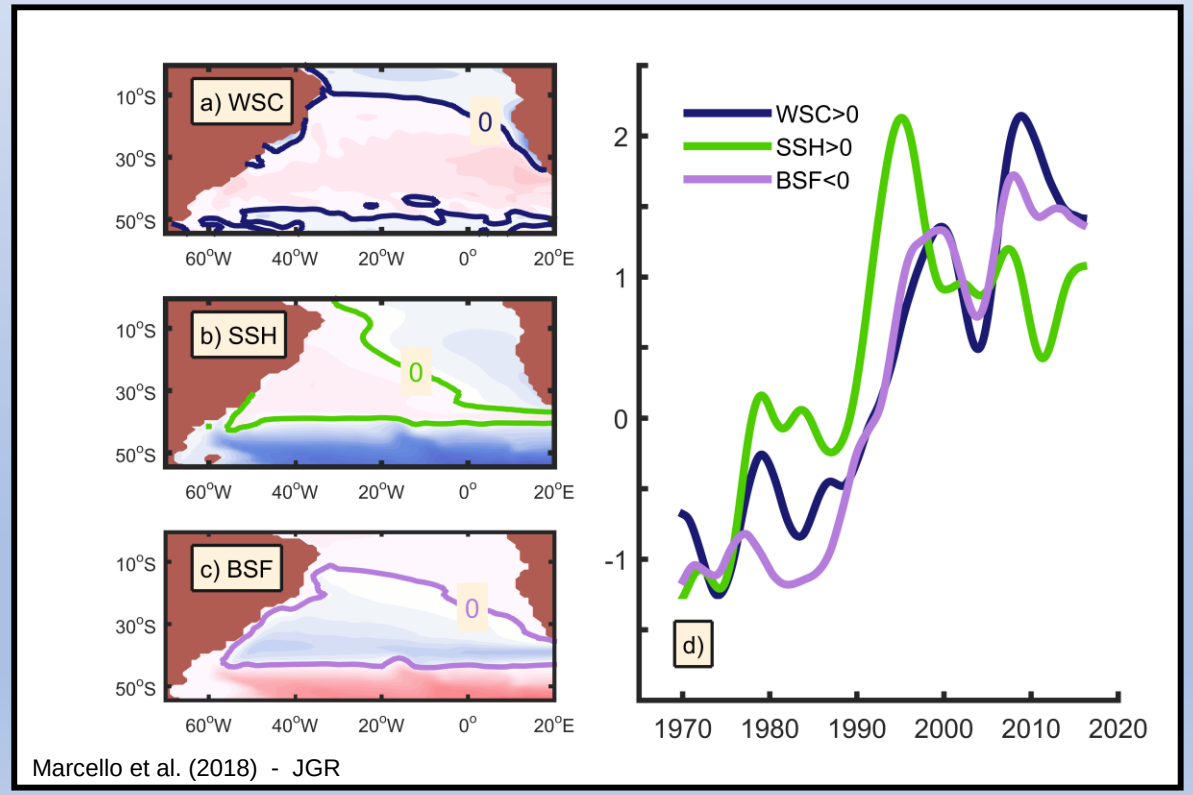


Barotropic stream function



within the limits of the gyre.



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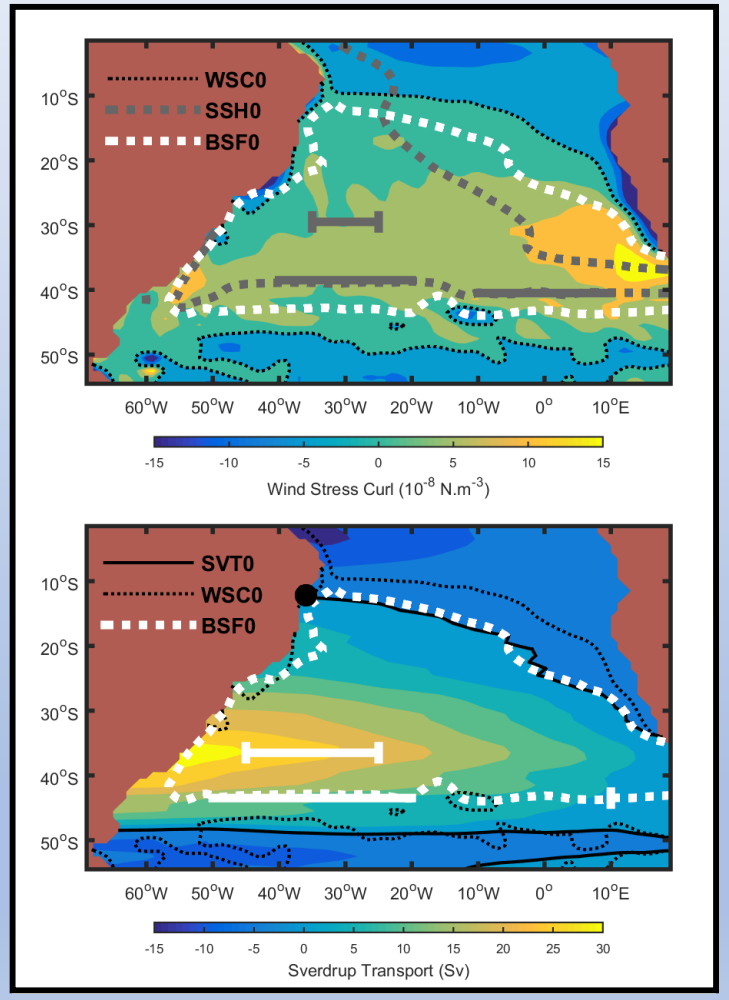
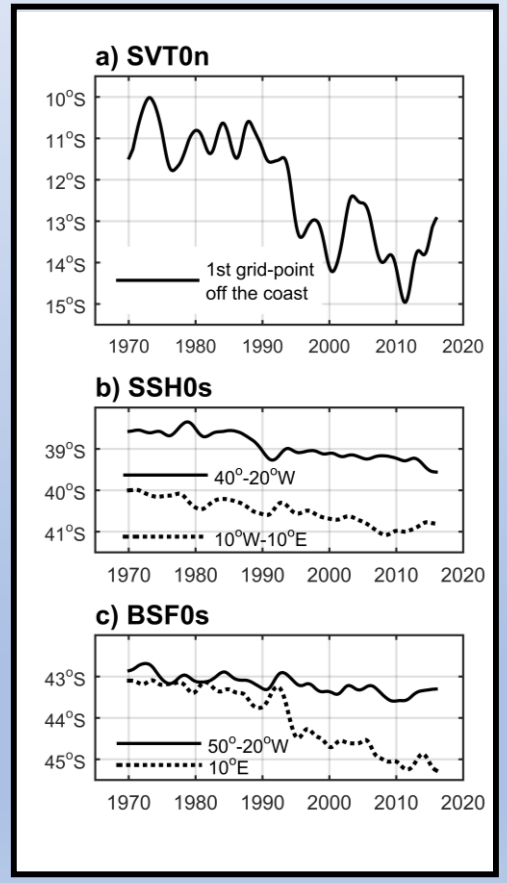
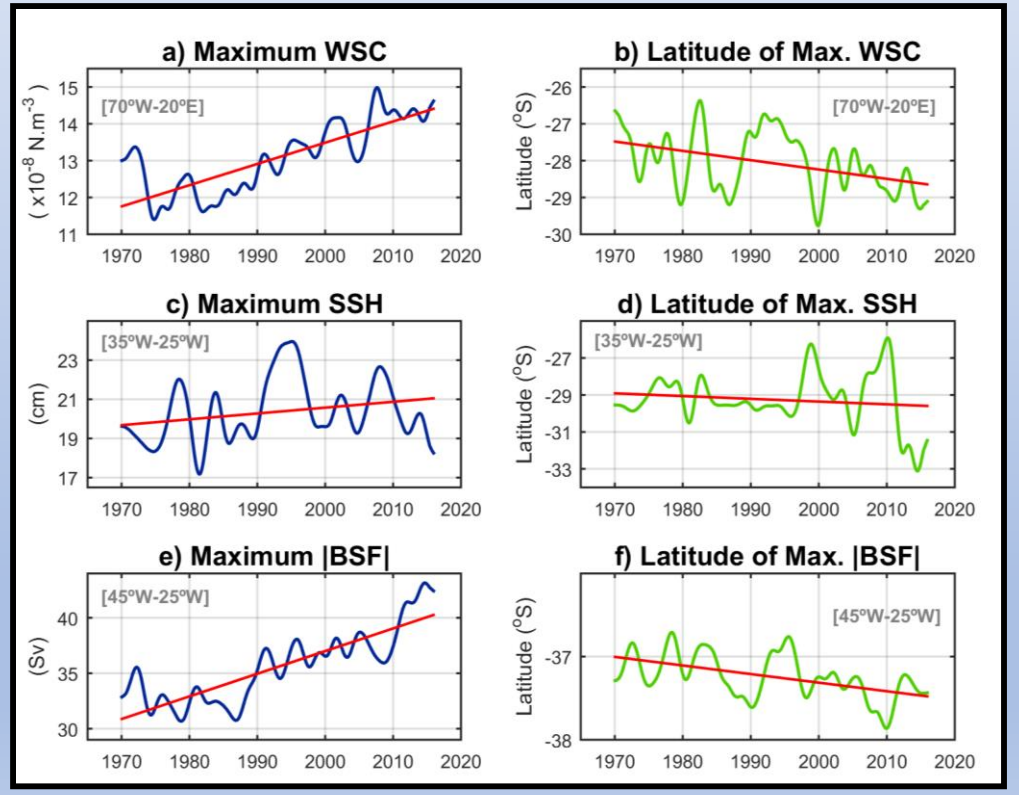


- SASG boundaries shift southward:

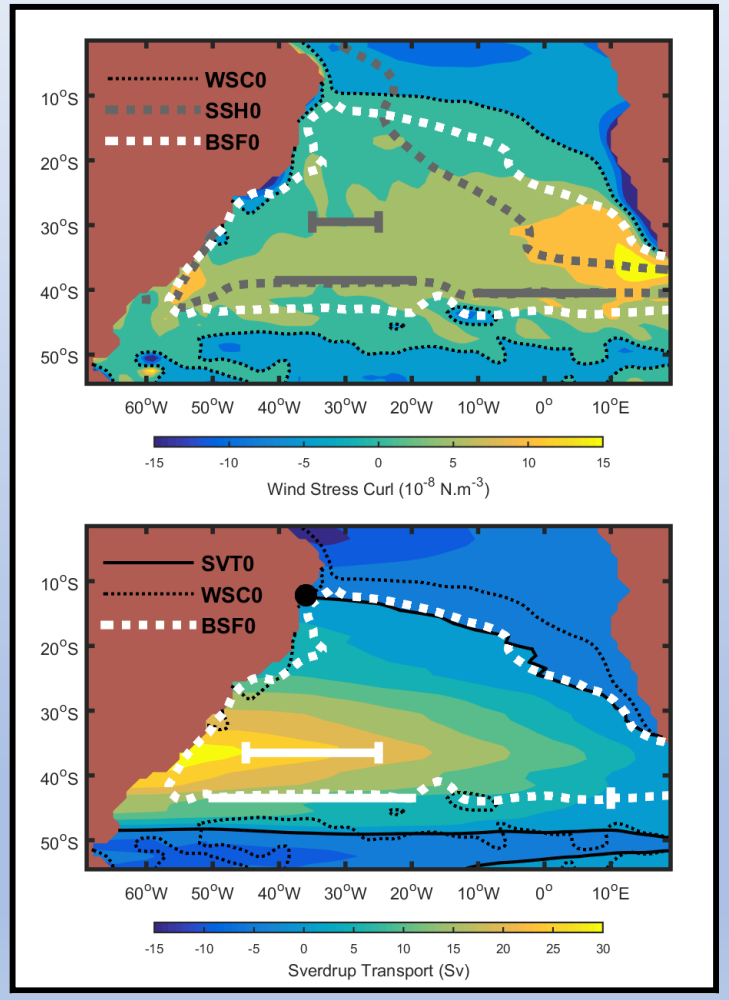


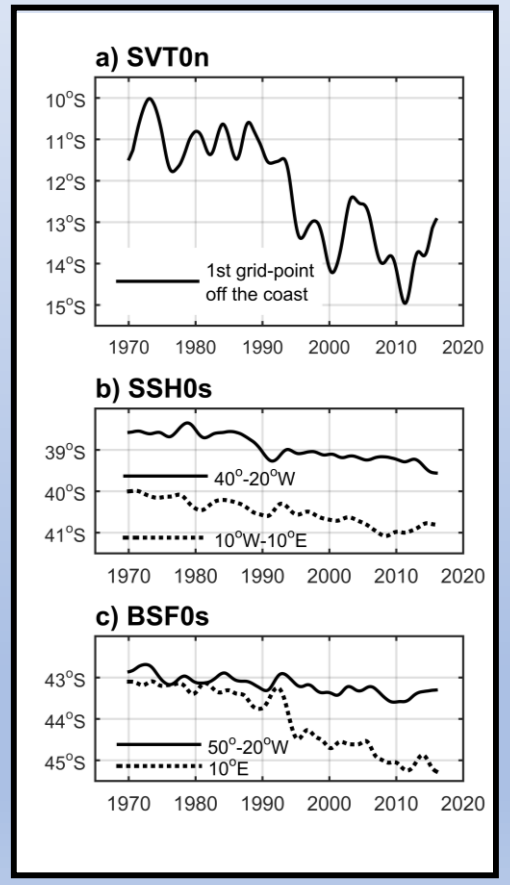
- Zonally averaged maximums increase:
- Zonally averaged maximums shift southward:

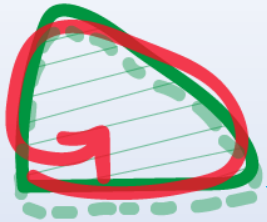


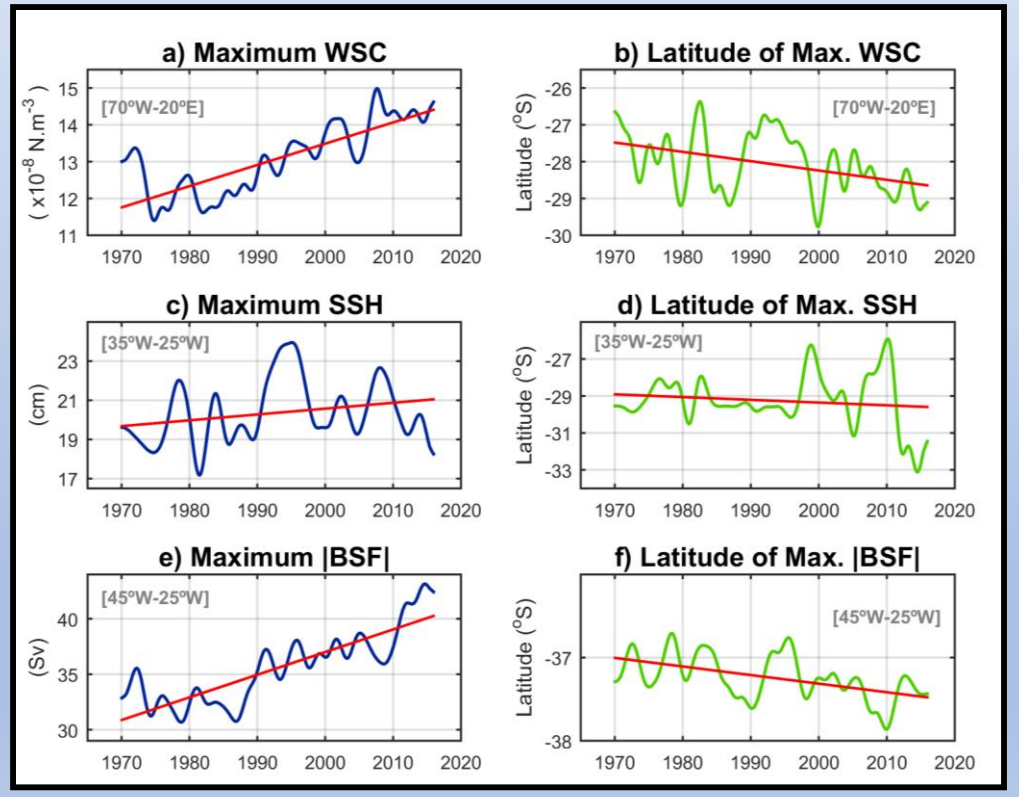
Marcello et al. (2018) - JGR

Model simulation results:





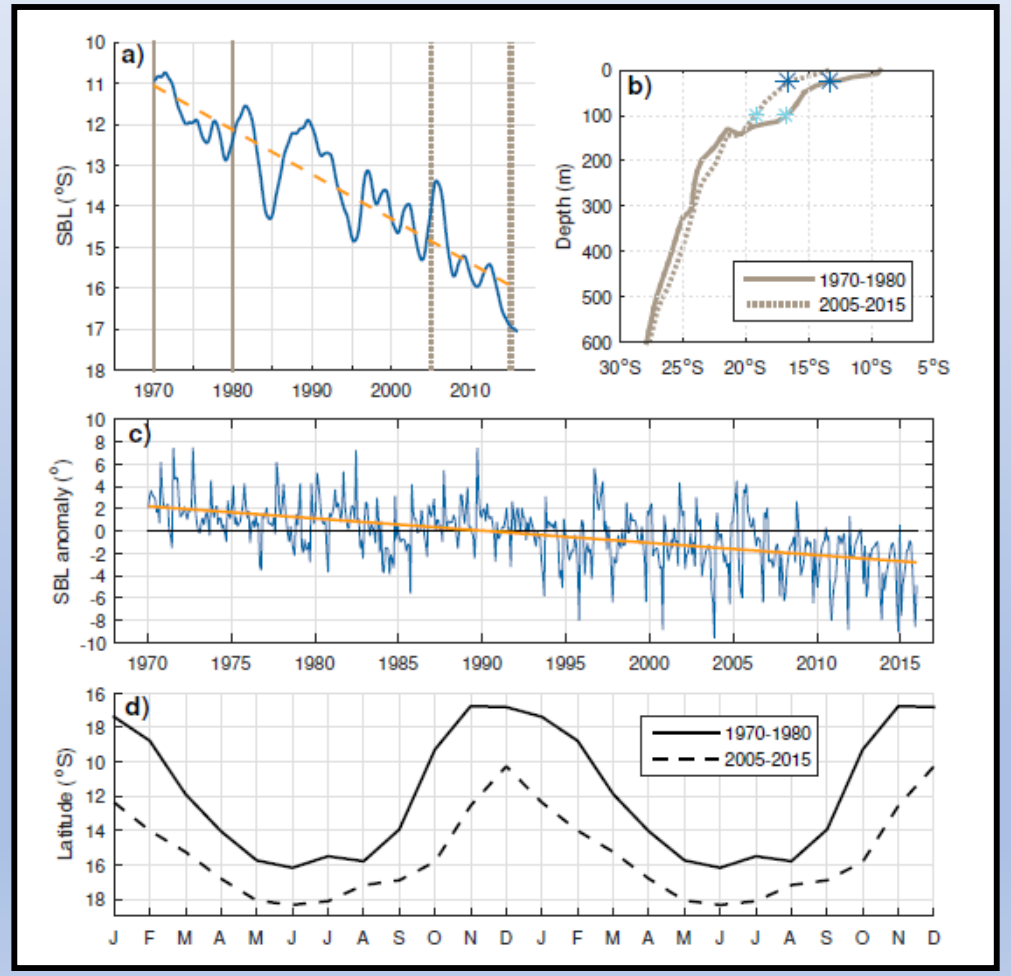




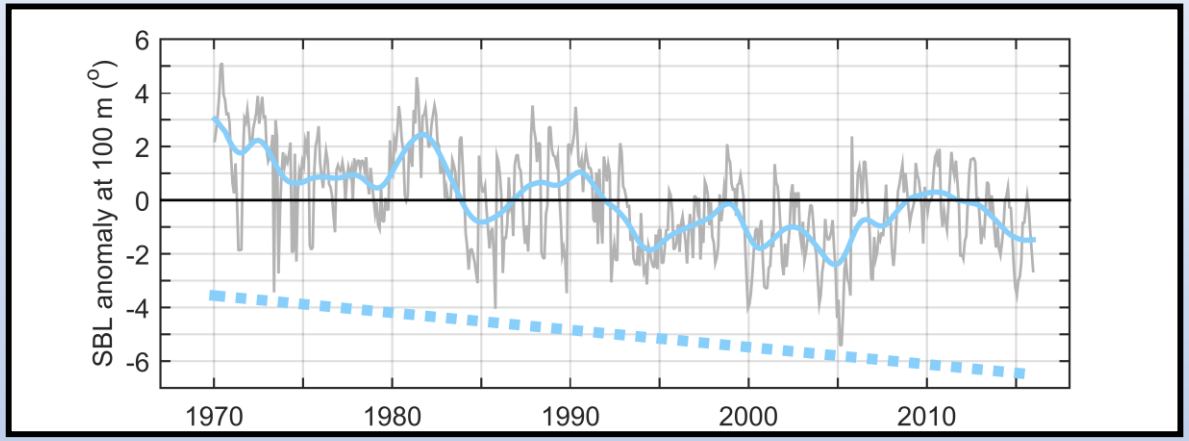
Marcello et al. (2018) - JGR

Model simulation results:

- **sSEC bifurcation latitude at 25 m:**



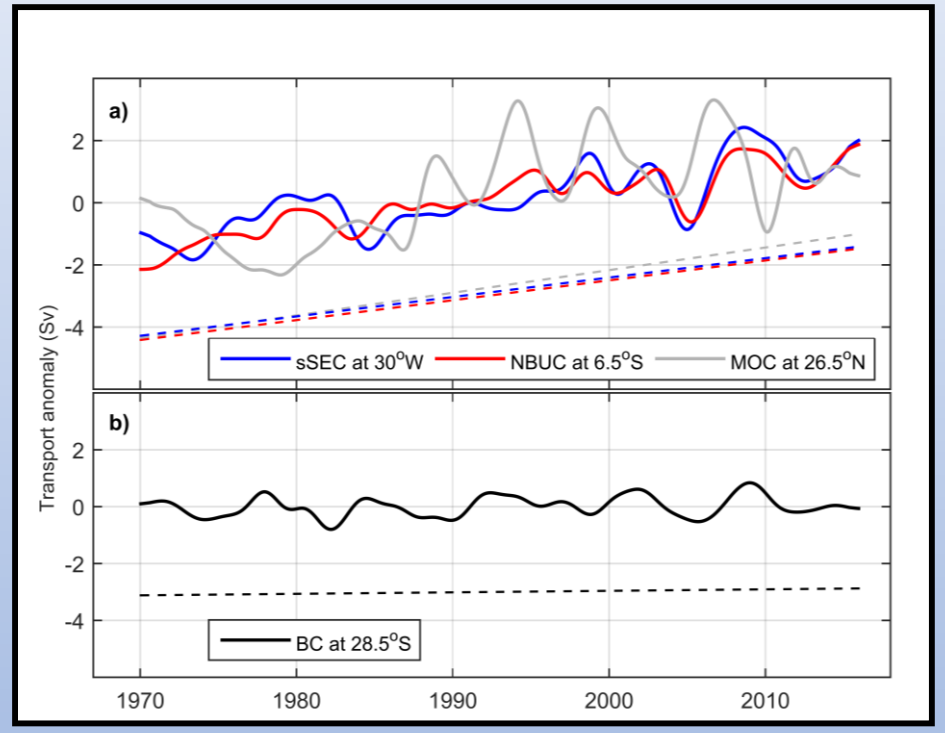
- **sSEC bifurcation latitude at 100 m:**

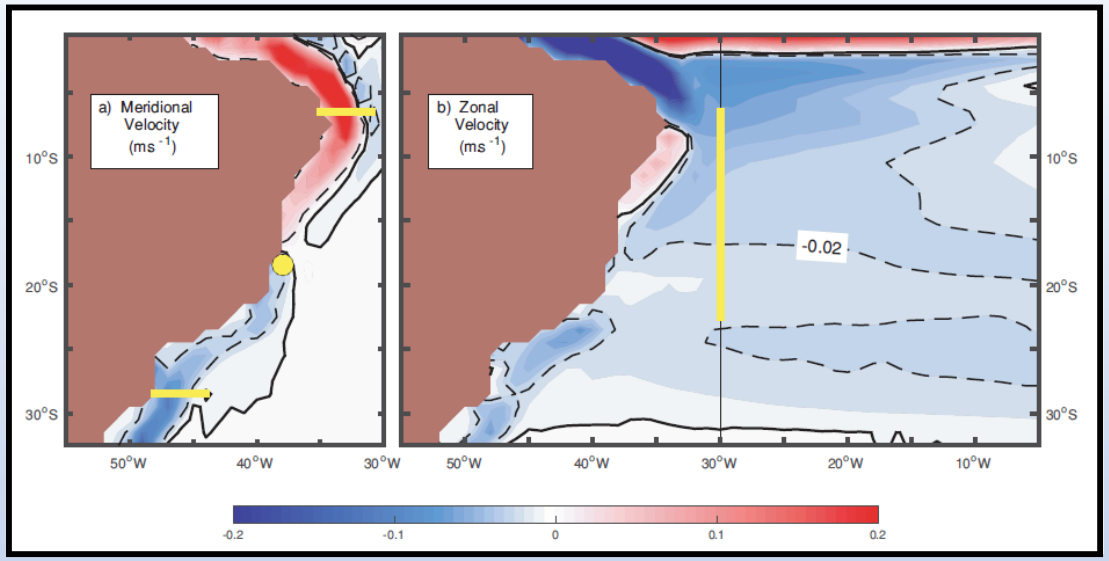


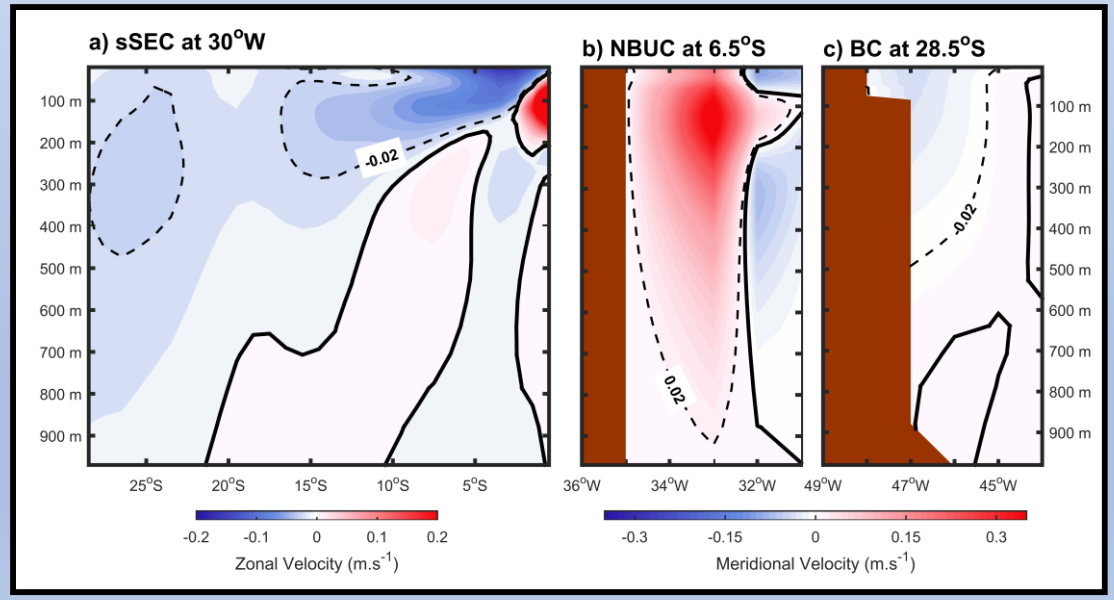
- **Southward migration**

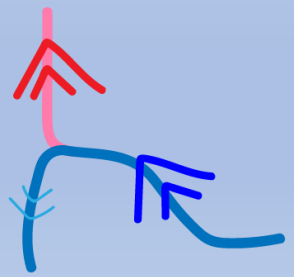
Marcello et al. (2018) - JGR

Model simulation results:







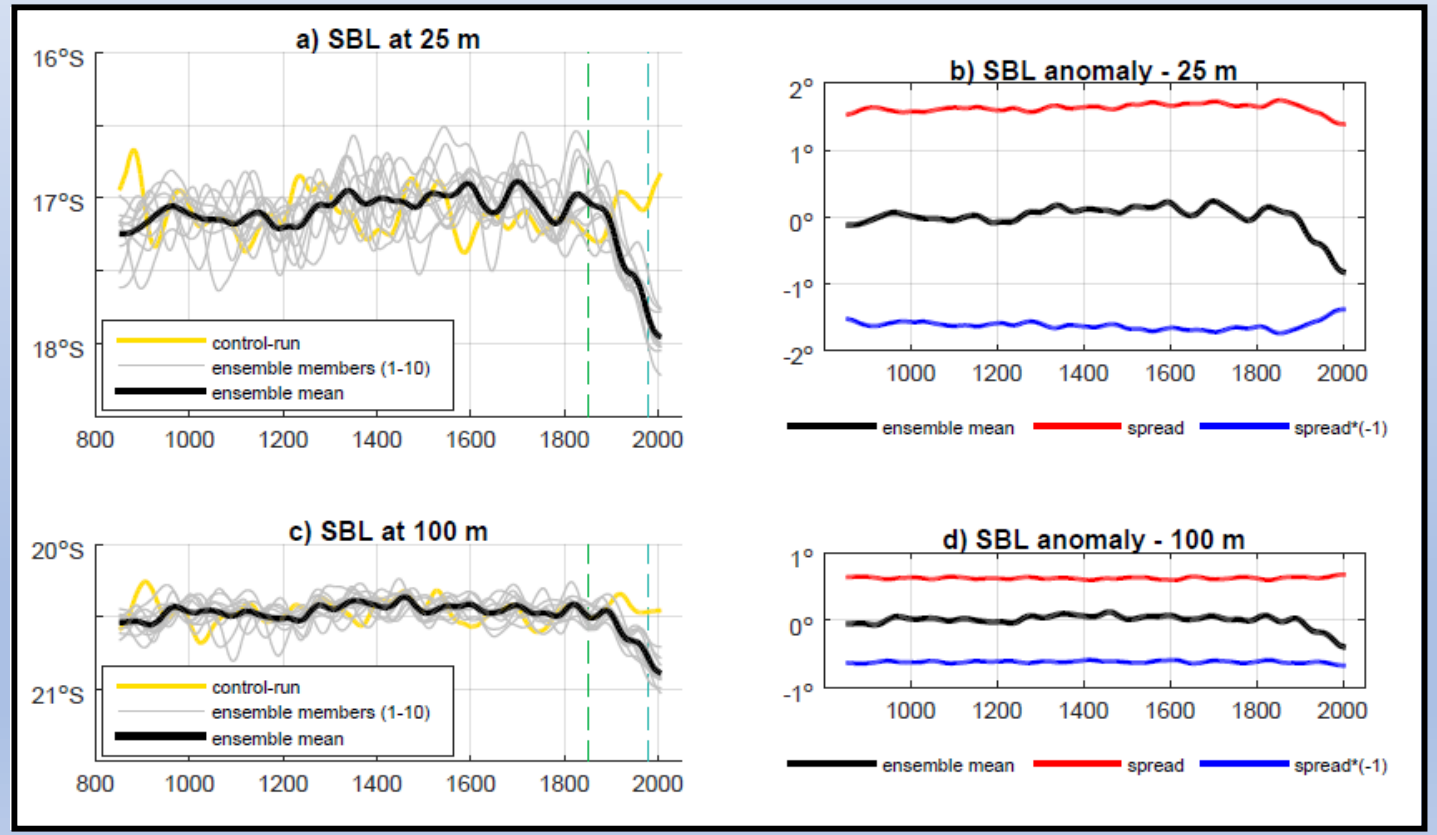


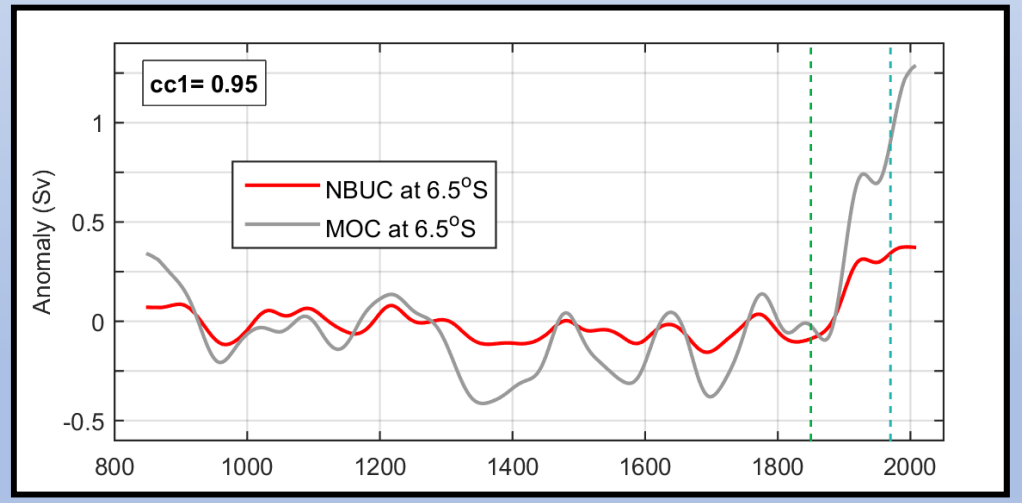
Marcello et al. (2018) - JGR

Model simulation results:

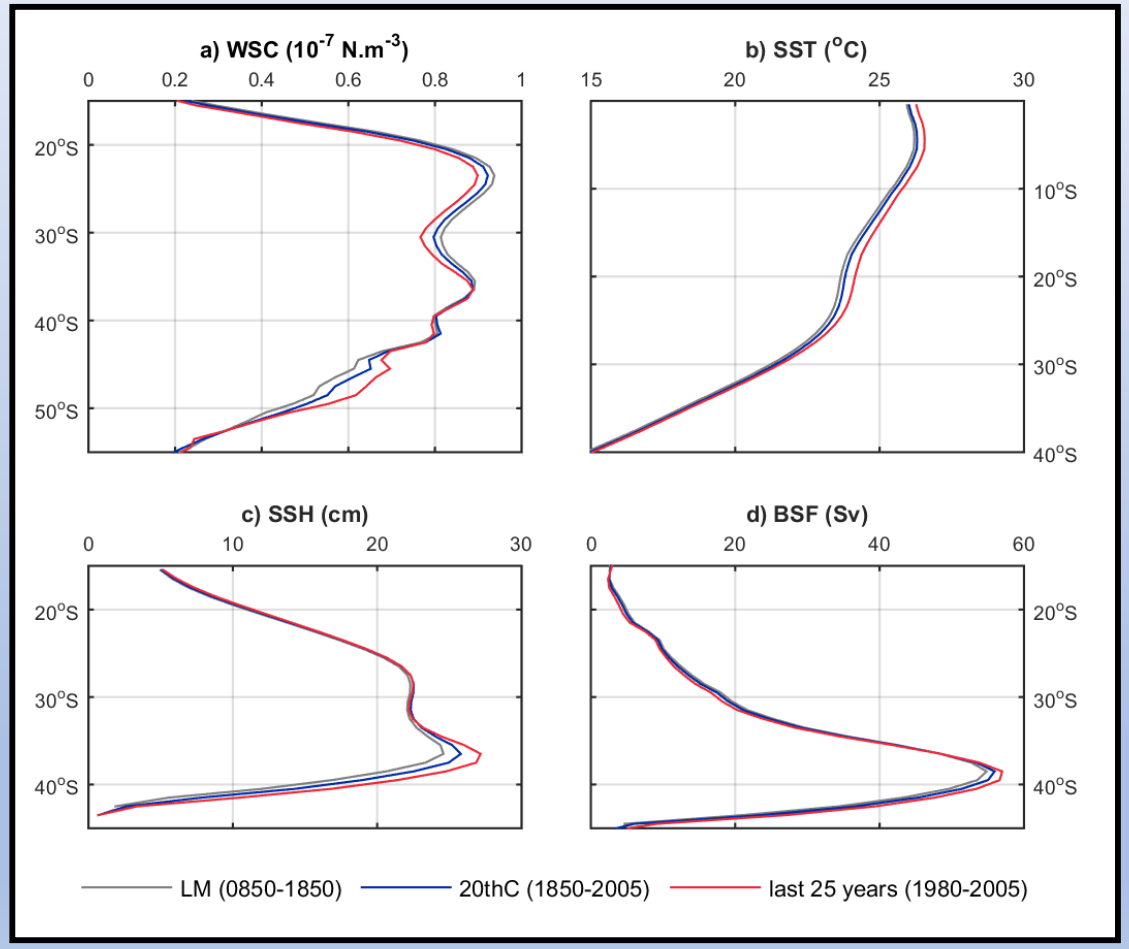
- The *Community Earth System Model* – ***Last Millennium Experiment*** (**CESM-LME**) [850 -- 1850] Otto-Bliesner et al. (2016)

  > 10 ensemble members with the full-set of external forcings

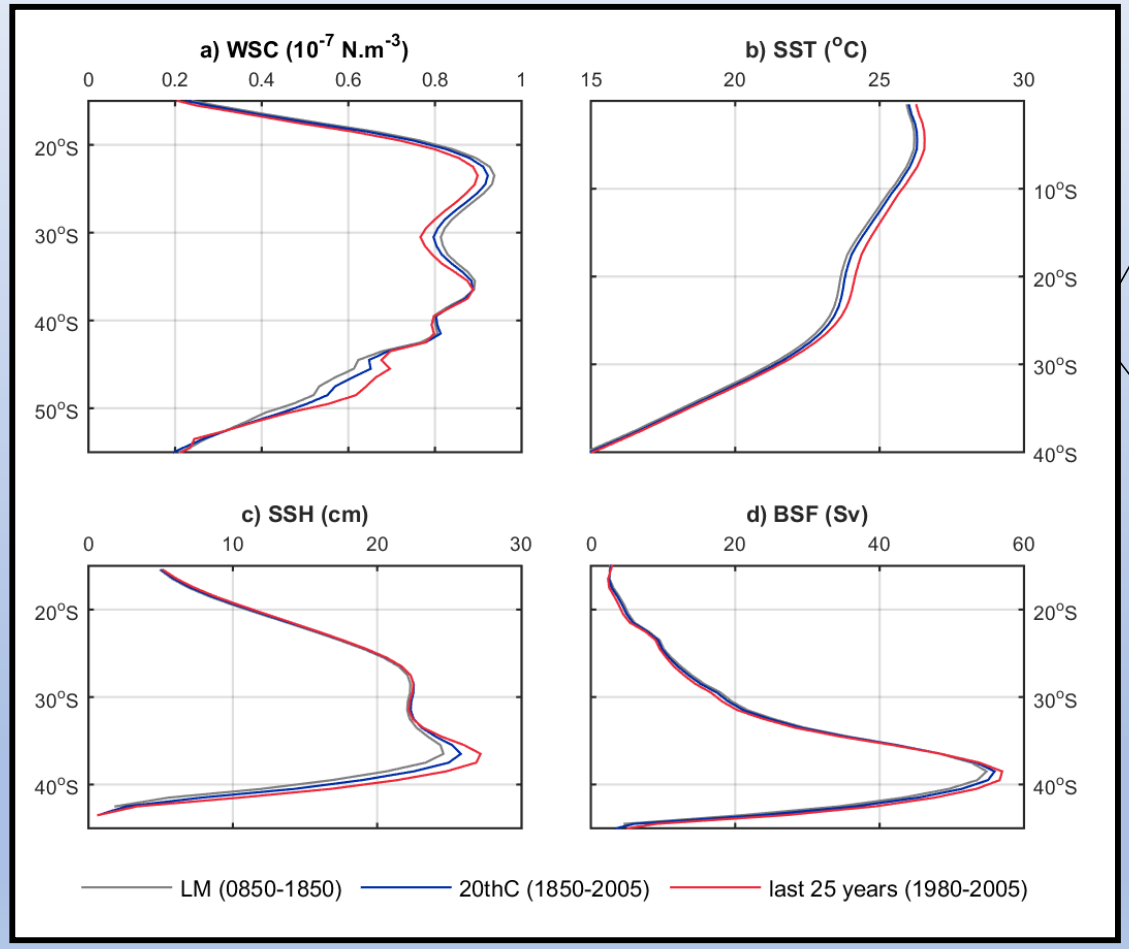


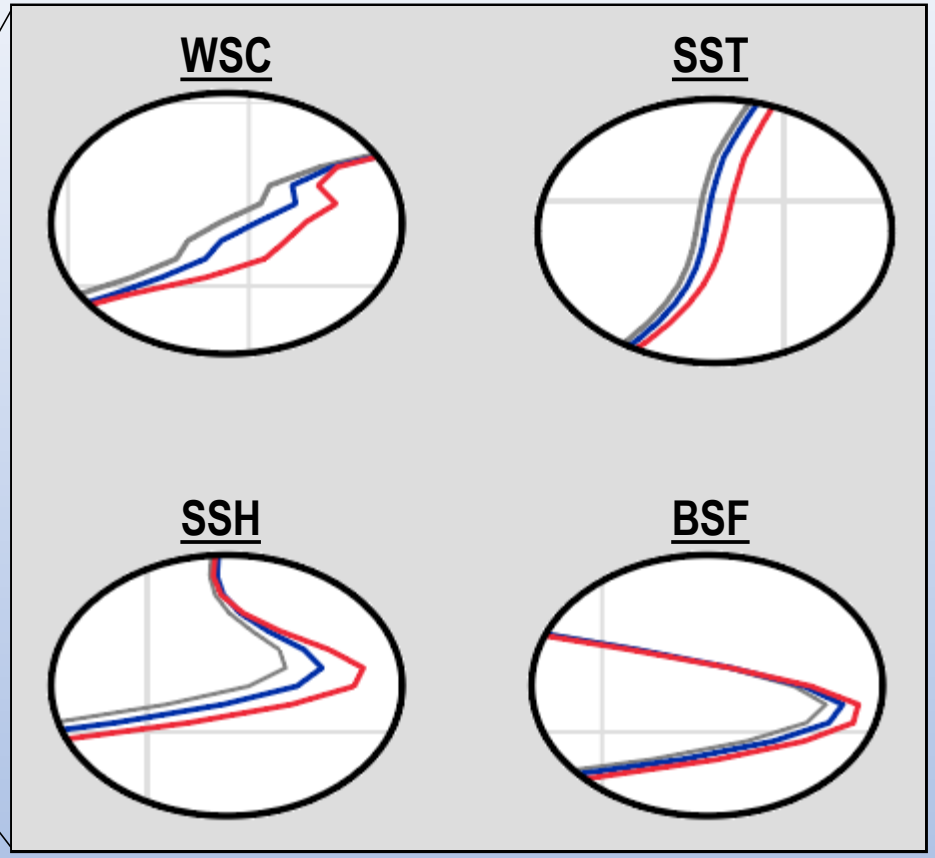


Model simulation results:



Model simulation results:



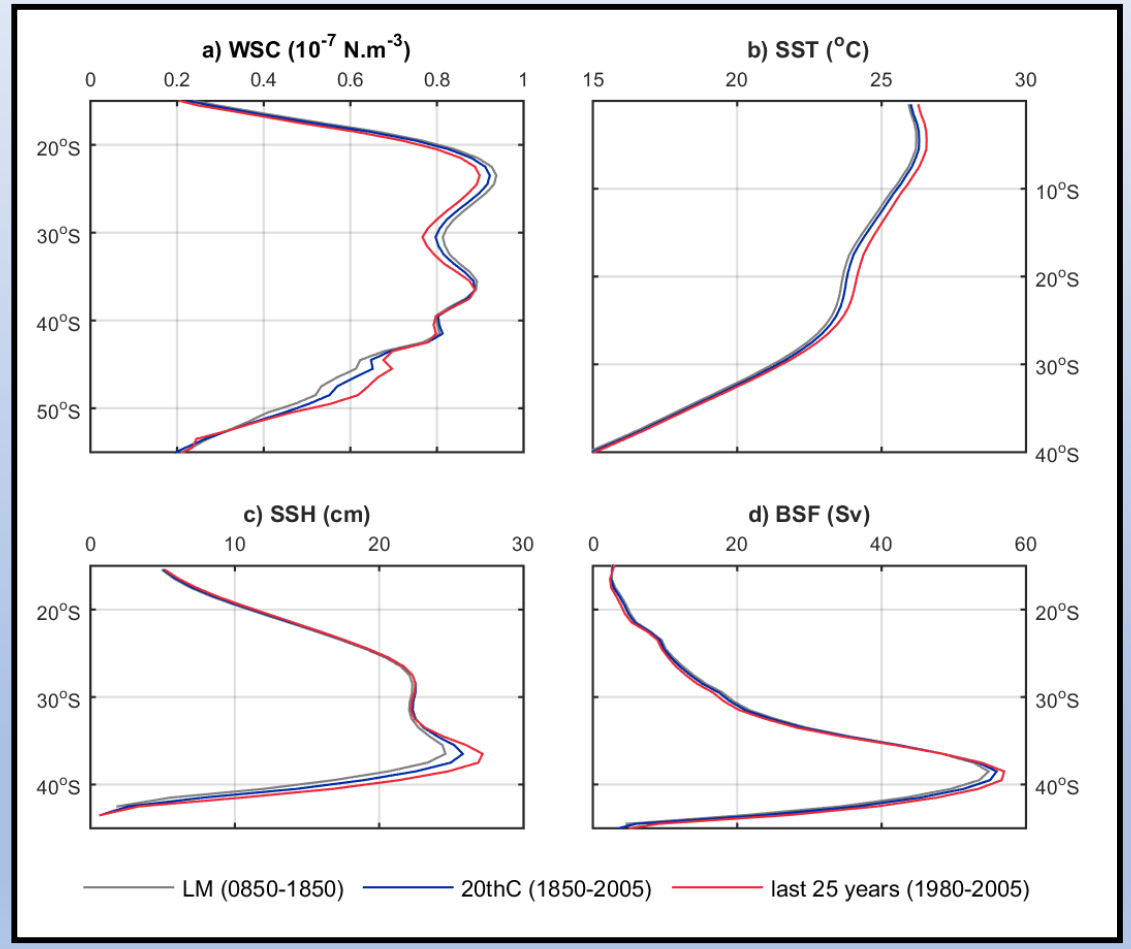


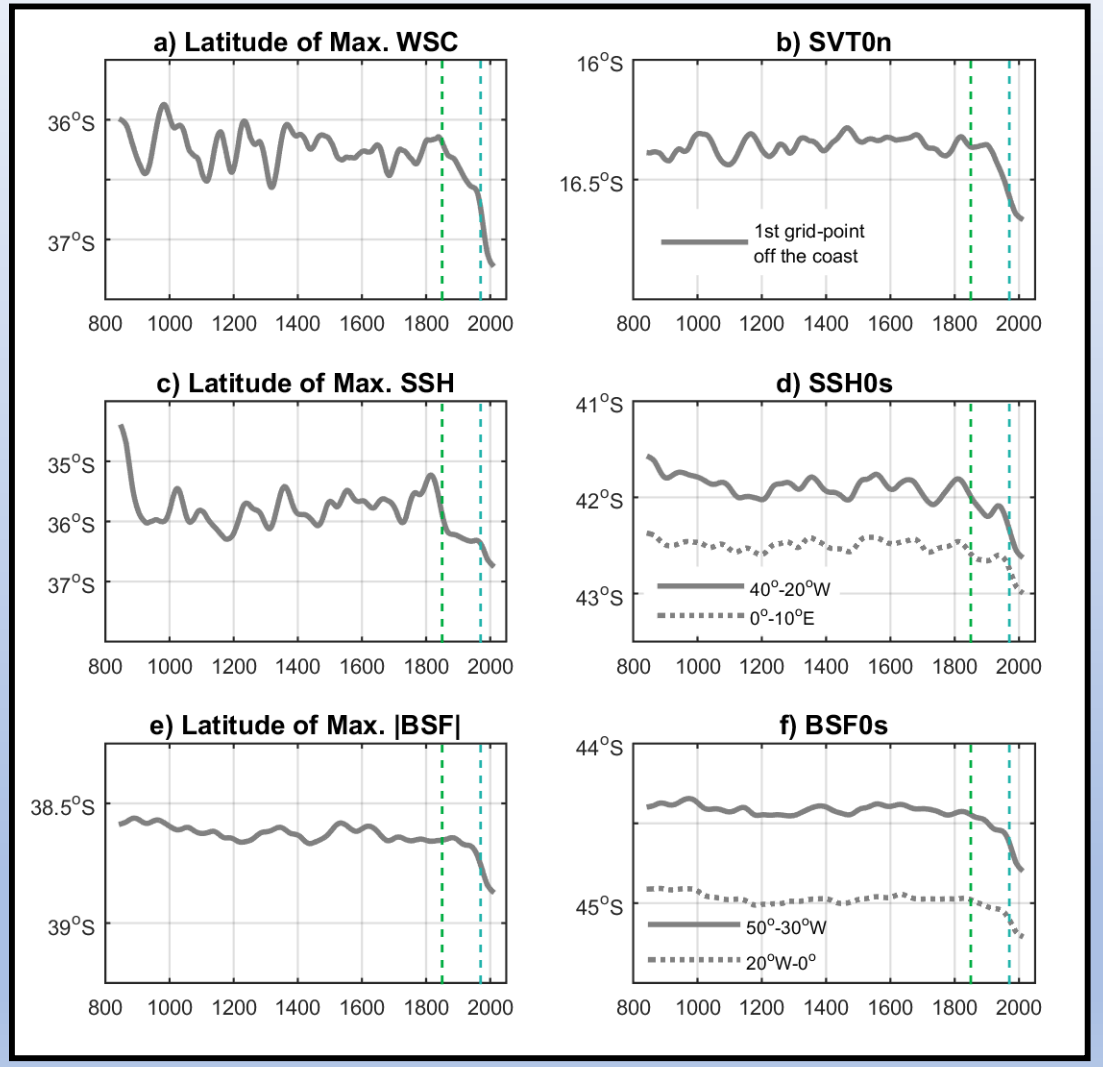
850-1850 = 1000 years

1850-2005 = 155 years

1980-2005 = 25 years

Model simulation results:





Model simulation results:

- The *Community Earth System Model* – ***Large Ensemble*** project

  (**CESM-LEns**) [1920 – 2100] Kay et al. (2015)

  > 33 ensemble members with the full-set of external forcings

- 1920-2005 = historical simulations (postindustrial era)

- 2006-2100 = climate change simulations (RCP8.5)

Model simulation results:

- The *Community Earth System Model* – ***Large Ensemble*** project

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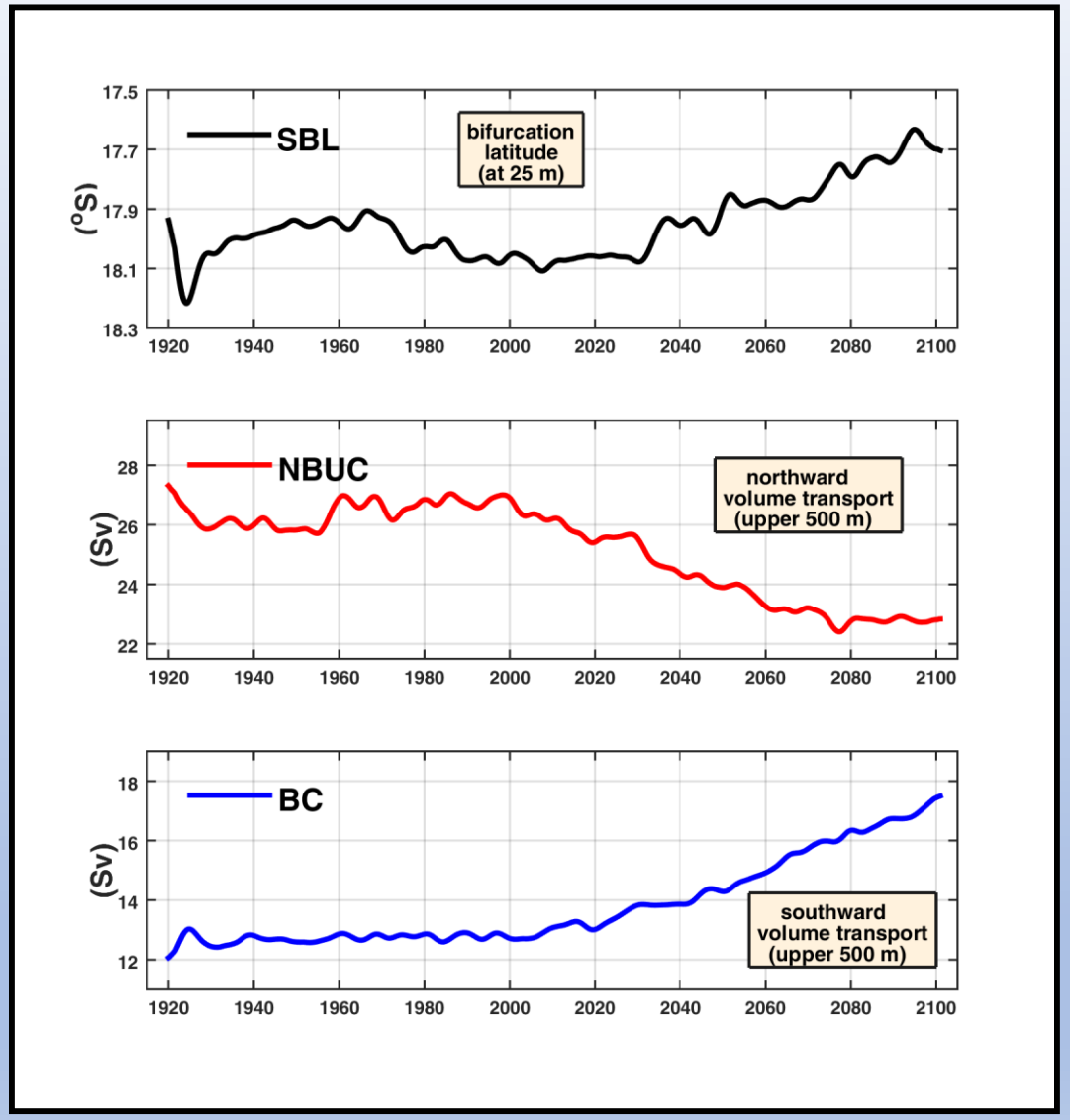

Model simulation results:

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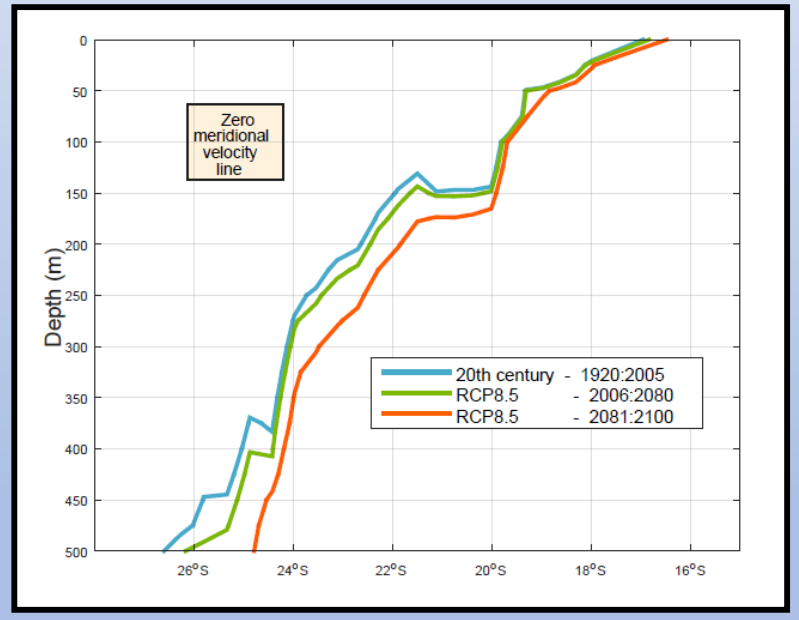
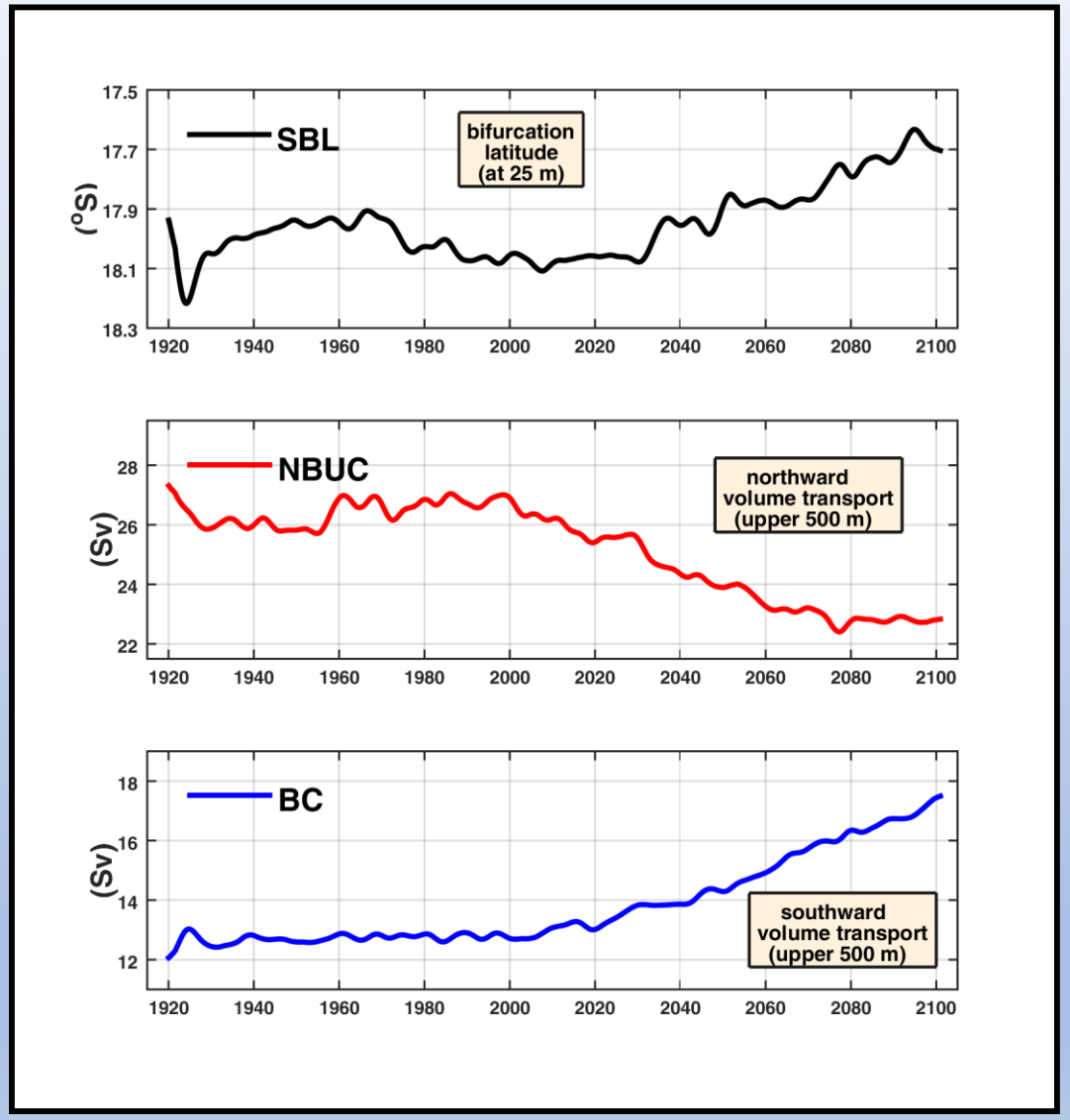
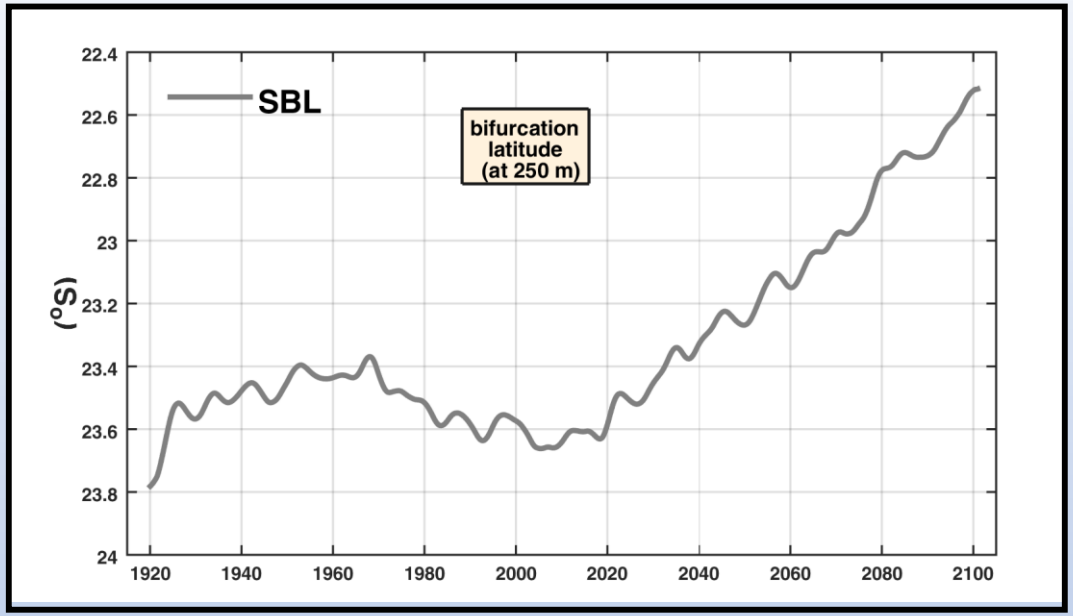
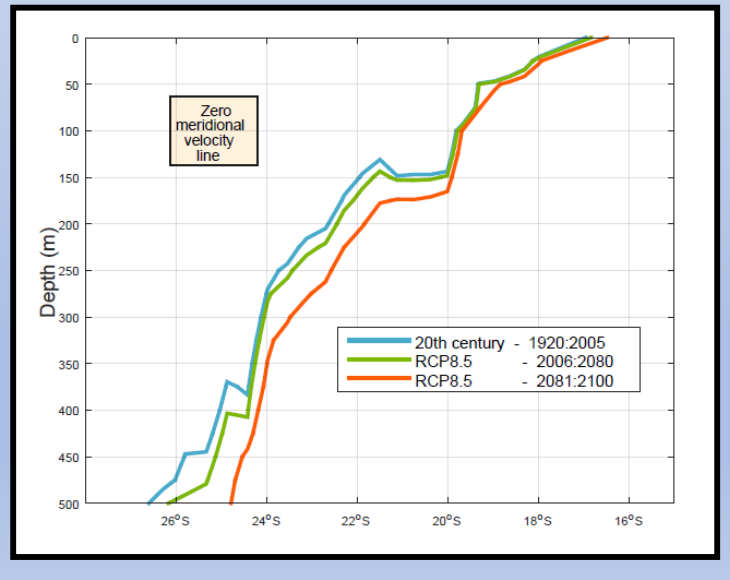
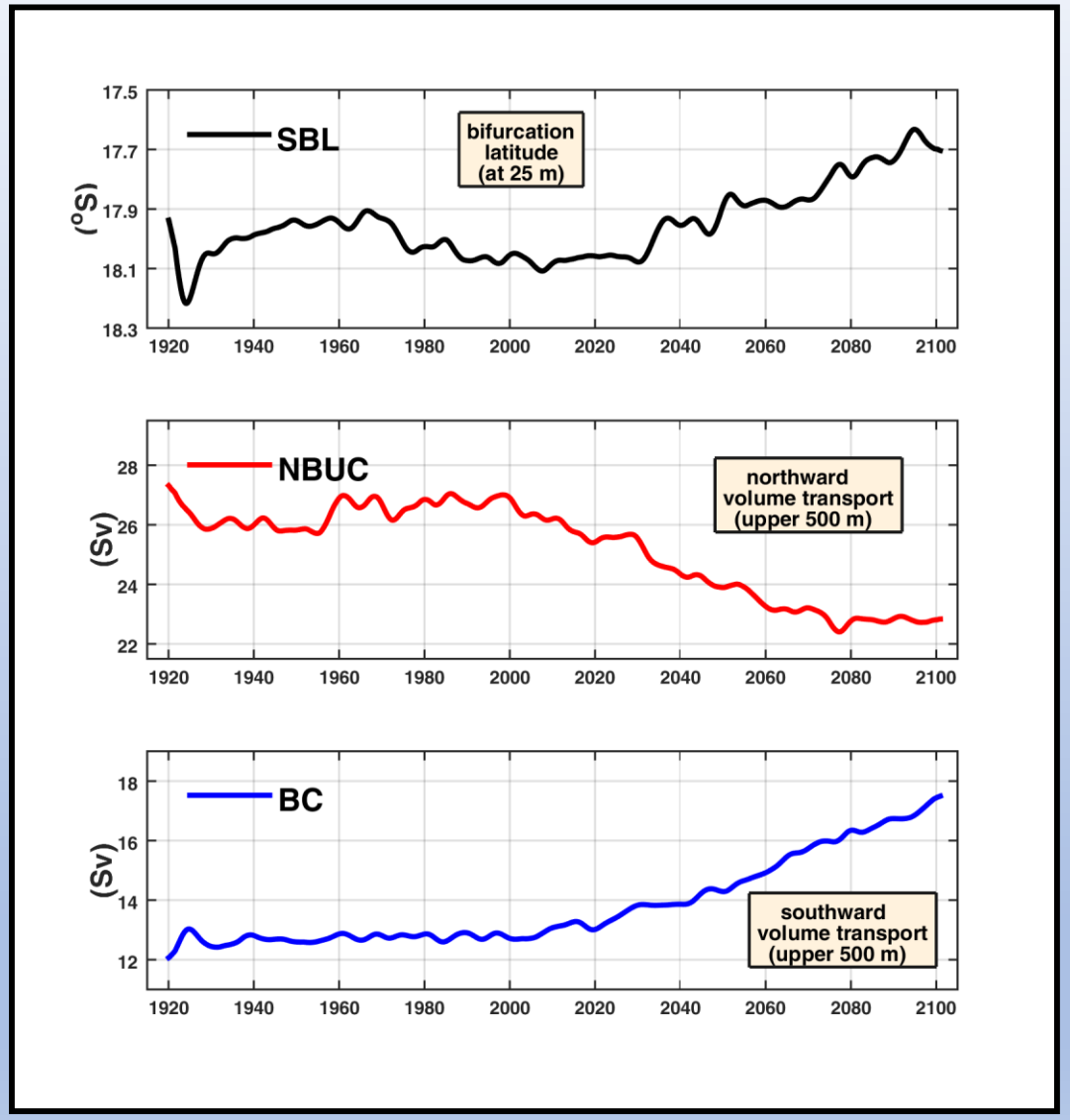
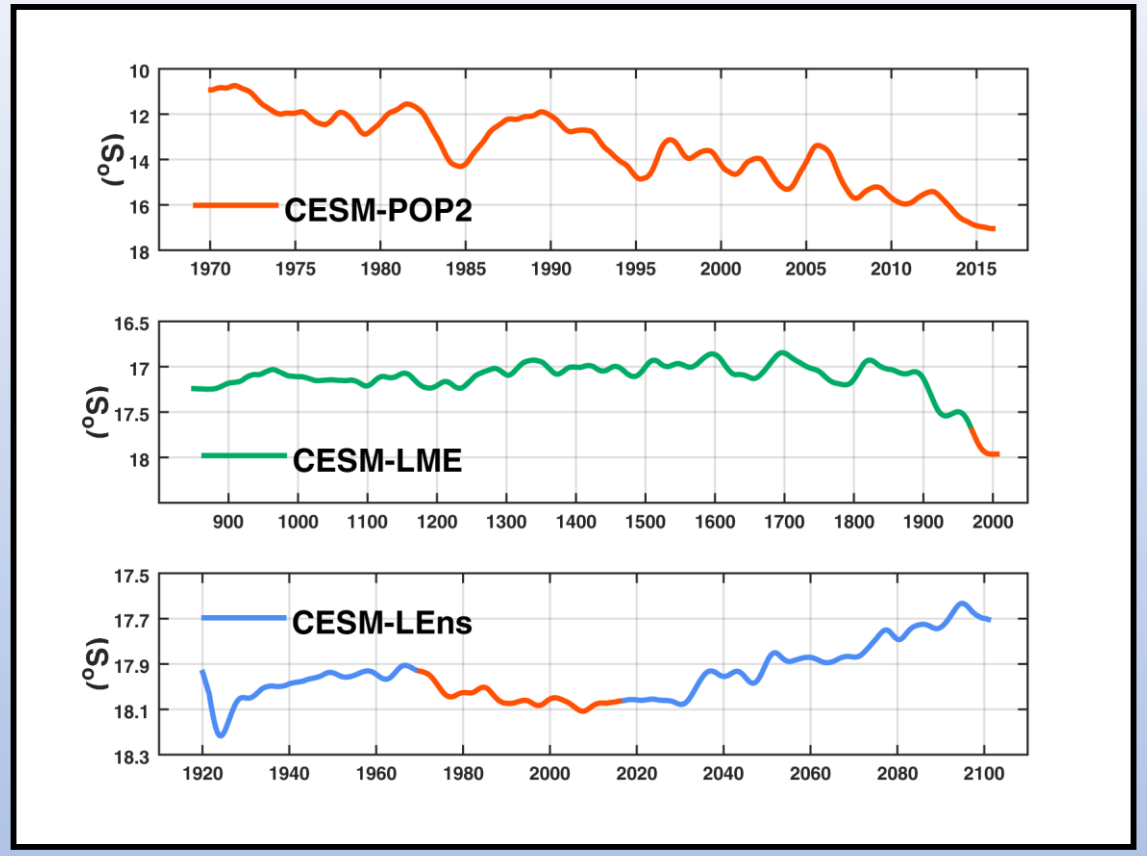


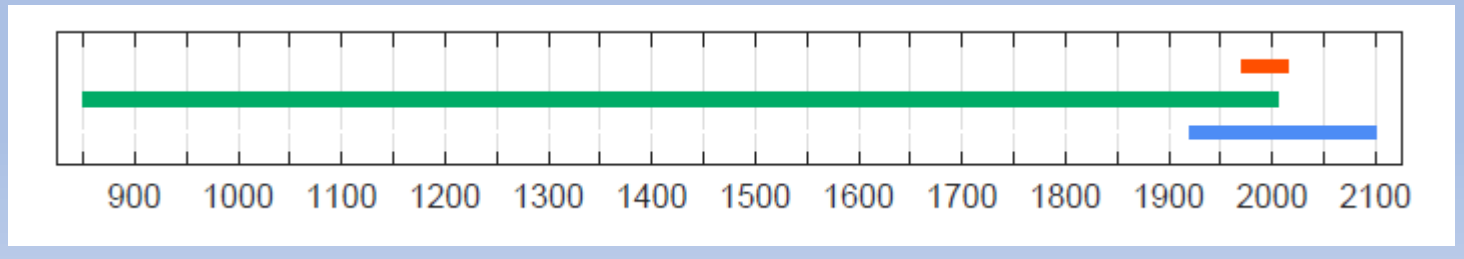



SBL
bifurcation latitude (at 250 m)
(°S)
22.4
22.6
22.8
23
23.2
23.4
23.6
23.8
24
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100


Zero meridional velocity line
Depth (m)
0
50
100
150
200
250
300
350
400
450
500
26°S
24°S
22°S
20°S
18°S
16°S
20th century - 1920:2005
RCP8.5 - 2006:2080
RCP8.5 - 2081:2100


SBL
bifurcation latitude (at 25 m)
(°S)
17.5
17.7
17.9
18.1
18.3
NBUC
northward volume transport (upper 500 m)
(Sv)
28
26
24
22
BC
southward volume transport (upper 500 m)
(Sv)
18
16
14
12
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100

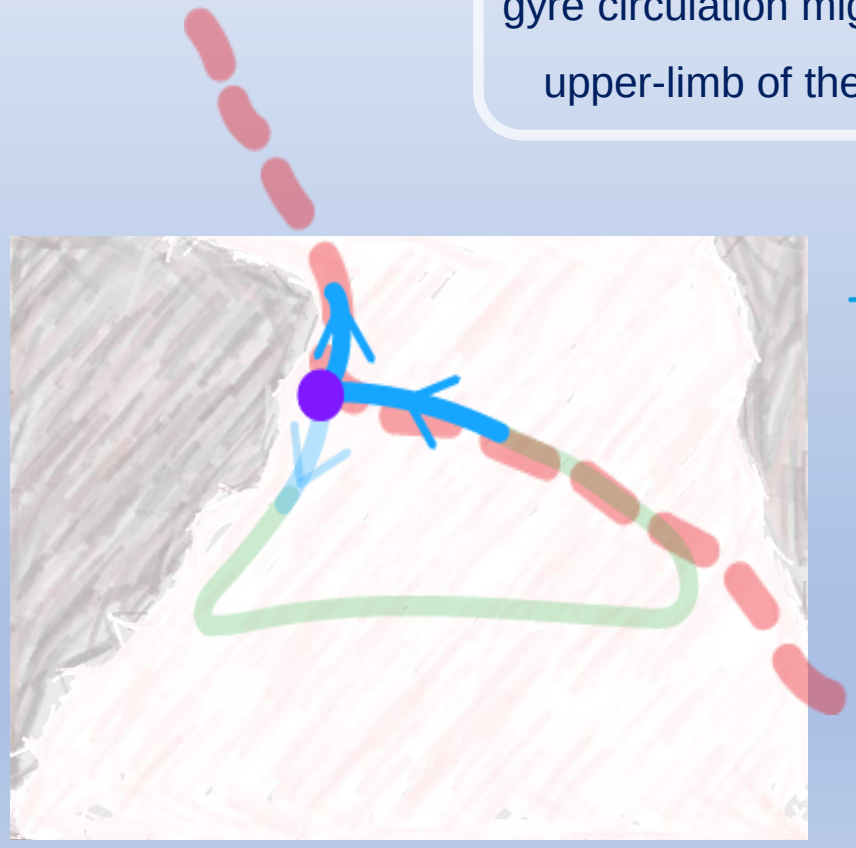

(°S)
CESM-POP2
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
CESM-LME
900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000
CESM-LEns
1920 1940 1960 1980 2000 2020 2040 2060 2080 2100


900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100

Conclusions // The take-home message:

Variations in the South Atlantic subtropical gyre circulation might reflect variations in the upper-limb of the AMOC and vice-versa;

→ ***Coupled large-scale features***



Subtropical gyre circulation

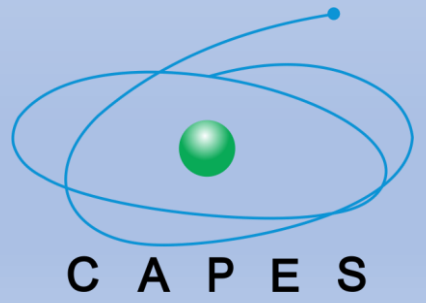
→ ***Insights on the upstream flow***

warm + cold routes ⇔ DWF region

sSEC bifurcation latitude

→ ***how much waters veering north/southward??***

Thank you! ☺



Oceanographic Institute of the University of São Paulo