Impacts of a Weakened Atlantic Meridional Overturning Circulation on Tropical Cyclone Activity in a Warming Climate

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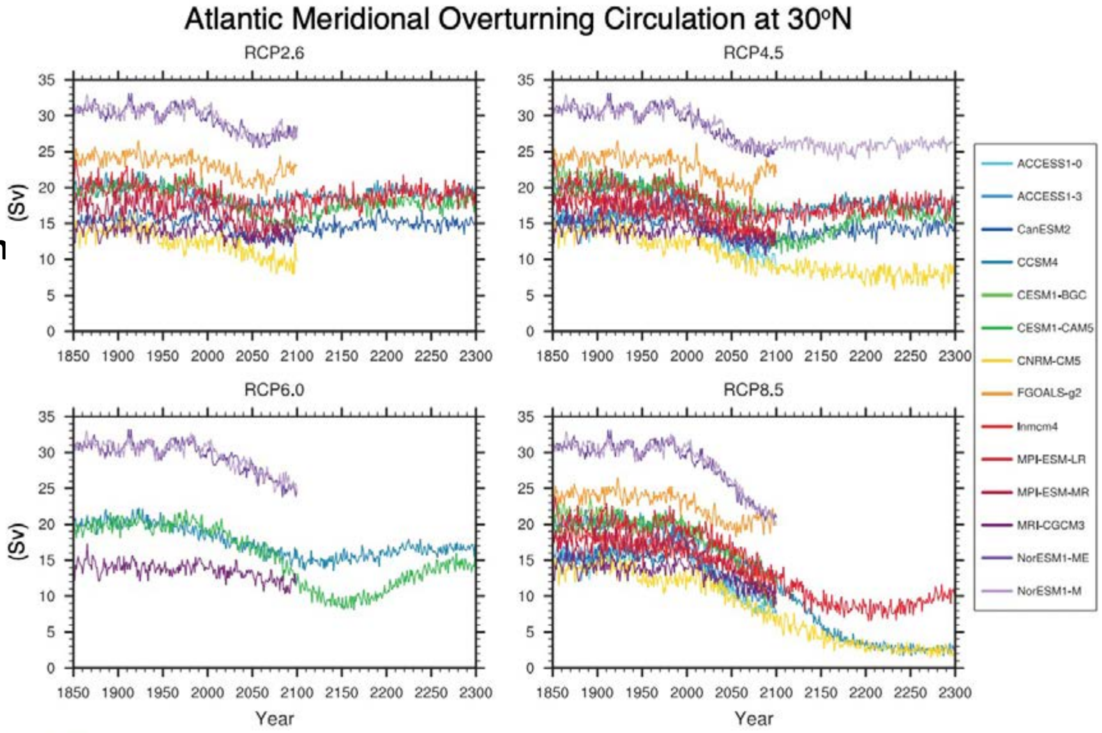
Background

- It remains **uncertain** how **global TC frequencies** will be affected by a **warmer climate**.
- The Atlantic Meridional Overturning Circulation (**AMOC**) is expected to **slow down with increased anthropogenic forcing** (Liu et al. 2020).
- But, there is a large **uncertainty in the projected slowdown rate** (Yin and Stouffer, 2007; Liu and Liu, 2015; Jackson and Wood, 2018).
- Understanding the **role of AMOC slowdown in TC genesis** helps constrain future TC changes.

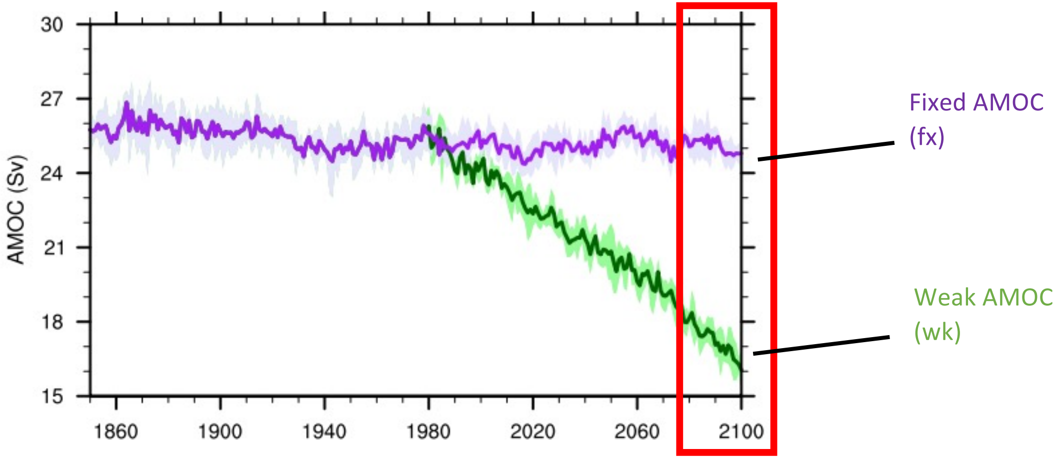


IPCC AR5, 2018

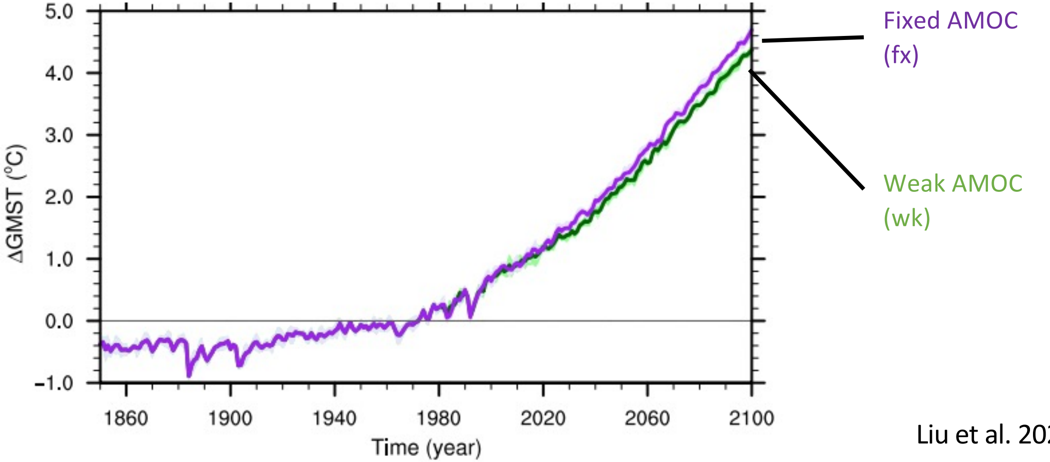
Approach

- **Weak (wk) AMOC**: RCP8.5 CCSM4 model simulation
- **Fixed (fx) AMOC**: RCP8.5 CCSM4 model simulation
    - From Liu et al. 2020
    - Artificially fix AMOC strength by removing freshwater in the NA (dehosing)
- Both simulations are **global warming scenarios** (2075-2100)
- ~1° resolution

AMOC strength



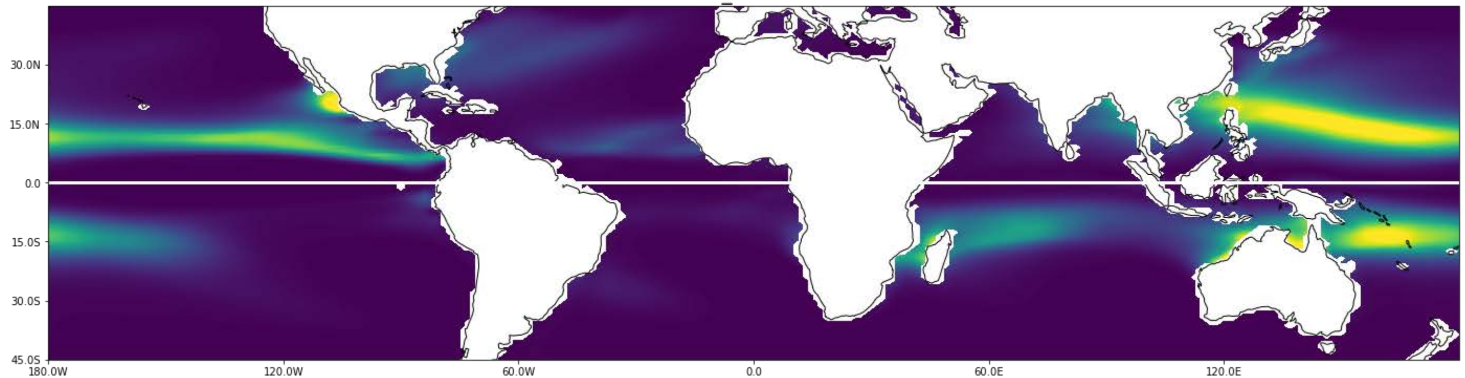
Global mean surface air temp. anomalies relative to 1961-1980



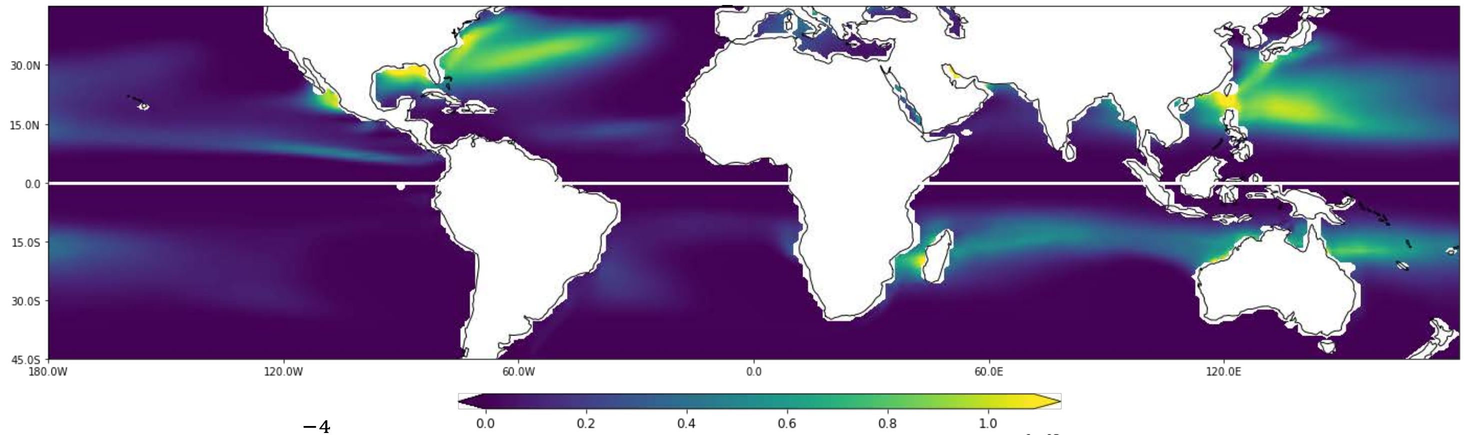
Liu et al. 2020

Genesis Potential Index (GPI) climatology

a. GPI_wk 1980-2005



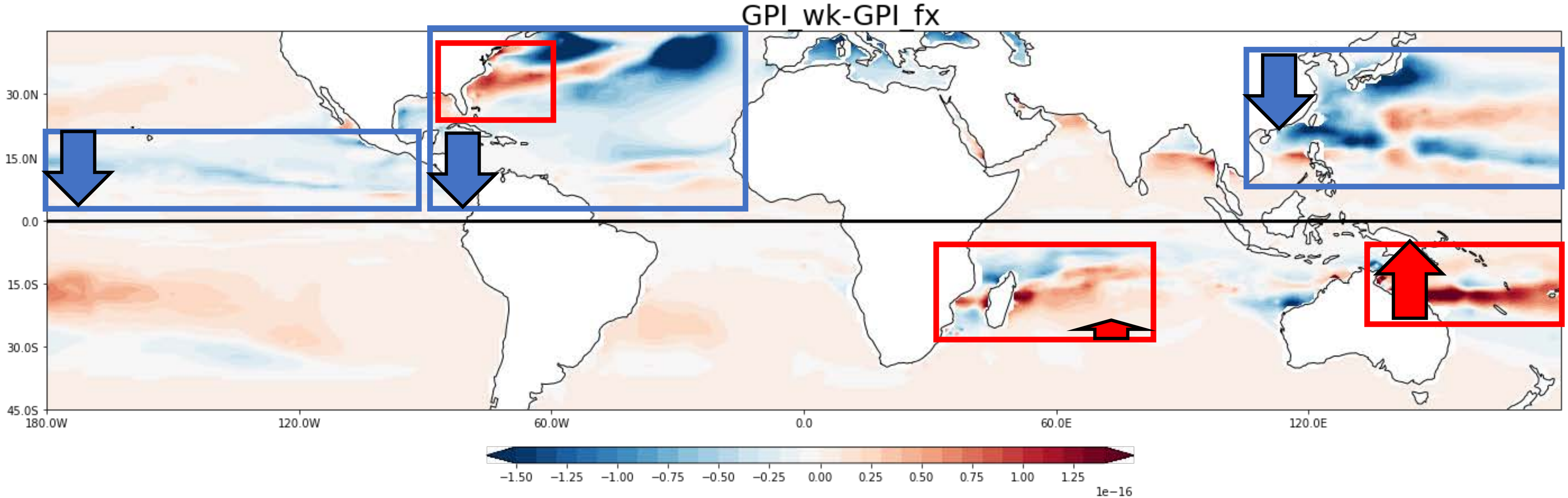
b. GPI_wk 2075-2100



$$GPI = |vort|^3 \times \chi^{\frac{-4}{3}} \times MAX[(PI - 35\, ms^{-1}), 0]^2 \times [25\, ms^{-1} + shear]^{-4}$$

Emanuel, 2010

Changes in 2075-2100 GPI with a Weakened AMOC



Overall: patterns across different GPIs appear *qualitatively* similar, but vary slightly *quantitatively.*

North Atlantic: Increase in GPI near the Southeastern U.S.

Western North Pacific: Equatorial shift in ITCZ, decrease in GPI.

Eastern North Pacific: Equatorial shift in ITCZ, decrease in GPI.

Western South Pacific: Equatorial shift in GPI, and an overall increase in GPI.

Western South Indian: Poleward shift in GPI.

Log Decomposition of GPI Change (wk-fx)

$$[GPI\_term]_{wk} - [GPI\_term]_{fx} = ([vort\_term]_{wk} - [vort\_term]_{fx})$$
$$- ([chi\_m\_term]_{wk} - [chi\_m\_term]_{fx})$$
$$+ ([PI\_term]_{wk} - [PI\_term]_{fx})$$
$$- ([shear\_term]_{wk} - [shear\_term]_{fx})$$

GPI_term: $log(GPI)$

shear_term: $4log(25\ ms^{-1} + shear)$

PI_term: $2log\{MAX[(PI - 35\ ms^{-1}), 1]\}$

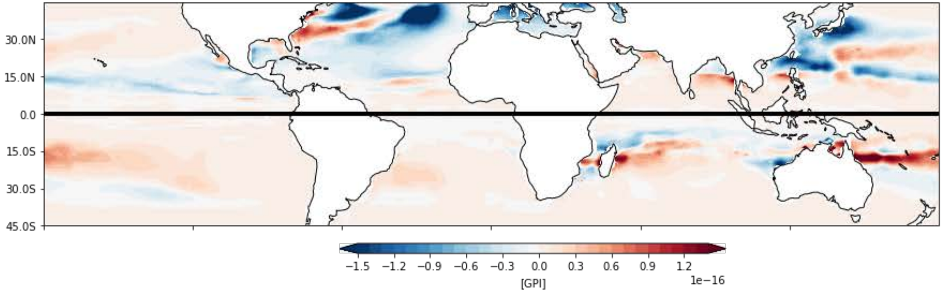
chi_m_term: $\frac{4}{3}log(\chi)$

vort_term: $3\log(|vort|)$

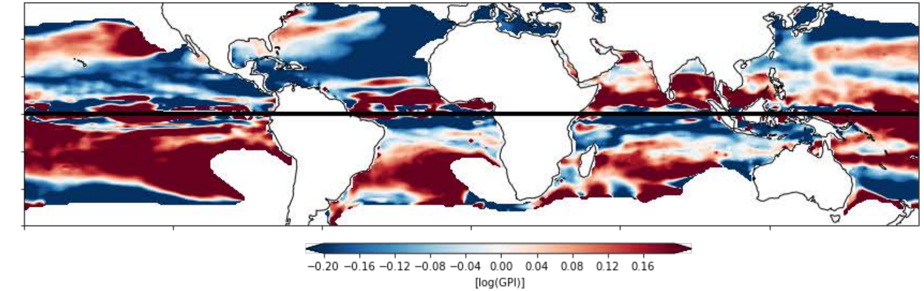
This allows us to understand the relative contribution of each term to the overall change in GPI.
From Emanuel, 2010

Log Decomposition Results

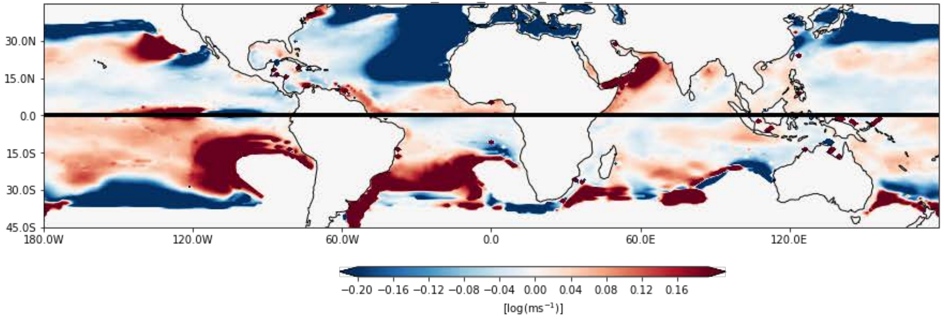
a. GPI_wk – GPI_fx absolute



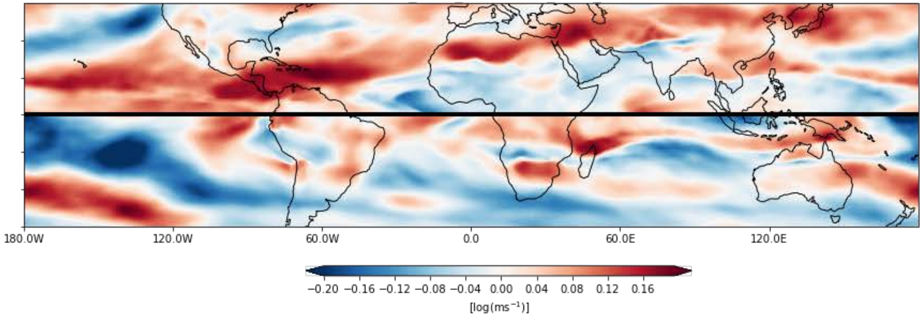
b. GPI_wk – GPI_fx log scale



c. PI_wk – PI_fx log scale

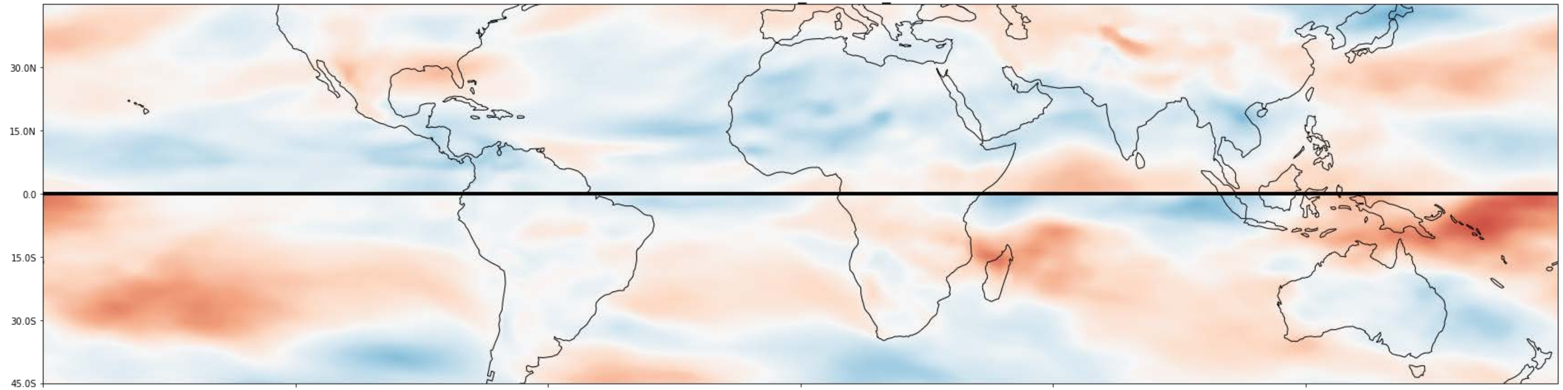


d. shear_wk – shear_fx log scale

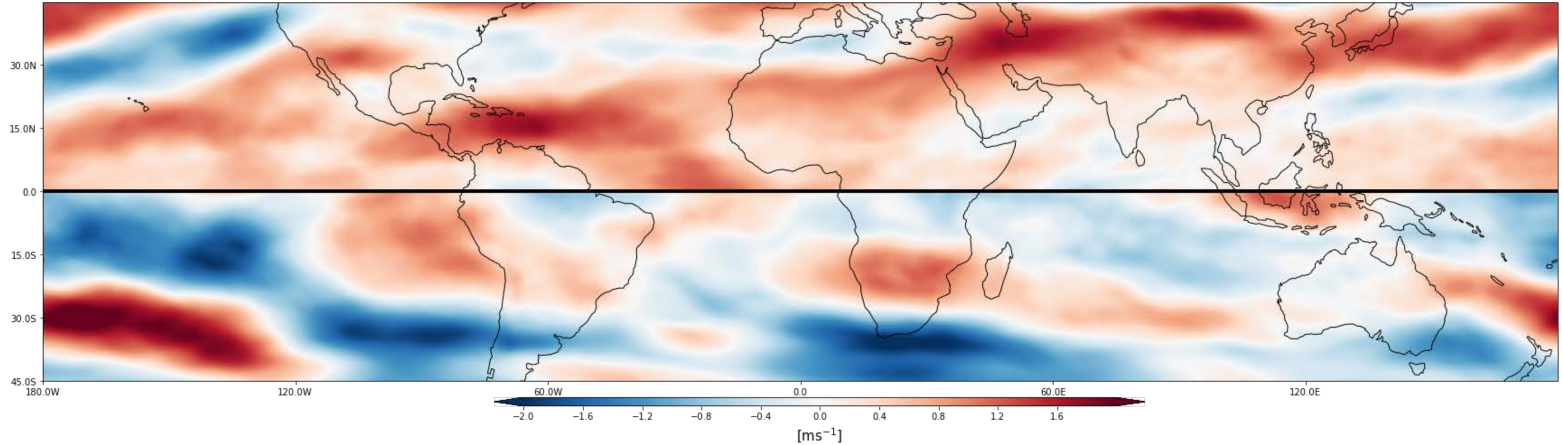


Changes in U850 and U250 Winds with a Weakened AMOC

a. U850_wk – U850_fx

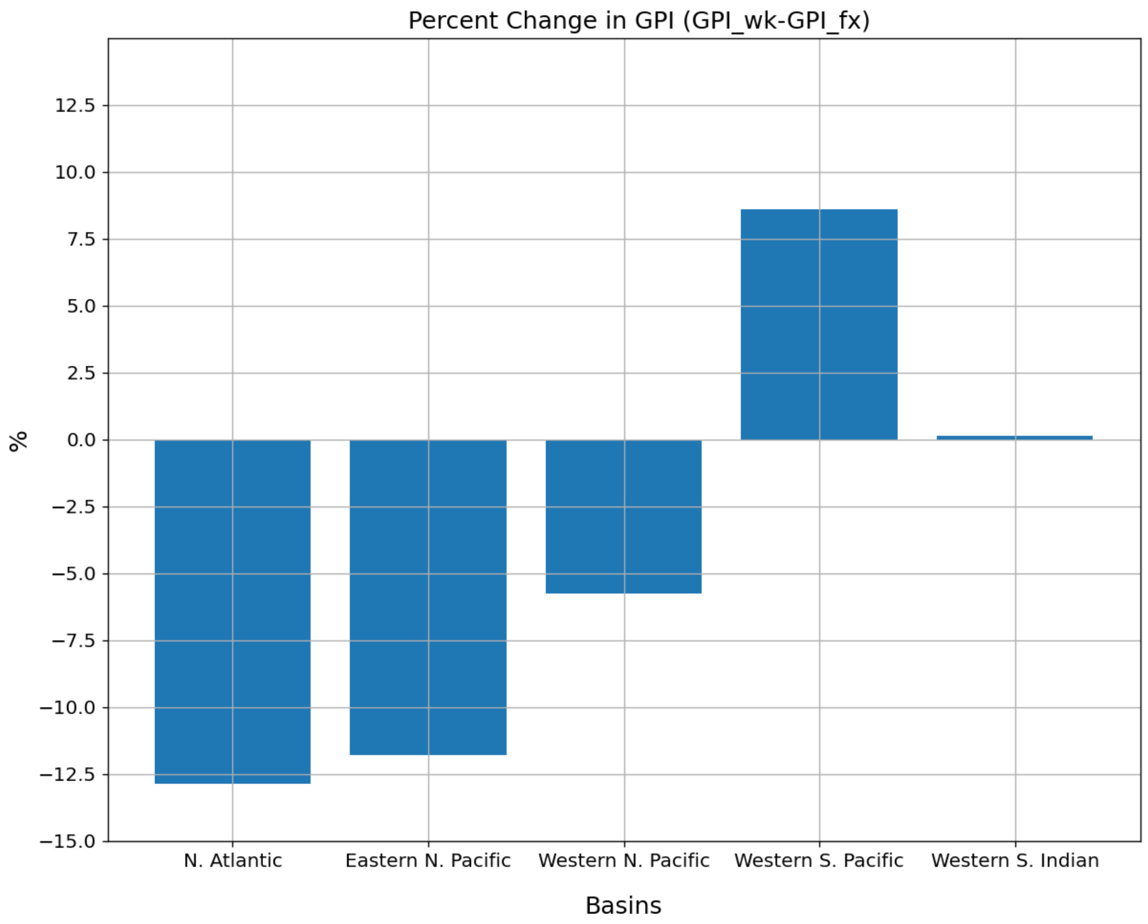


b. U250_wk – U250_fx



Significant changes in **upper level winds** drive changes in **shear**.

Average Basin GPI Changes with a Weakened AMOC



North Atlantic: Overall pronounced decrease in GPI.

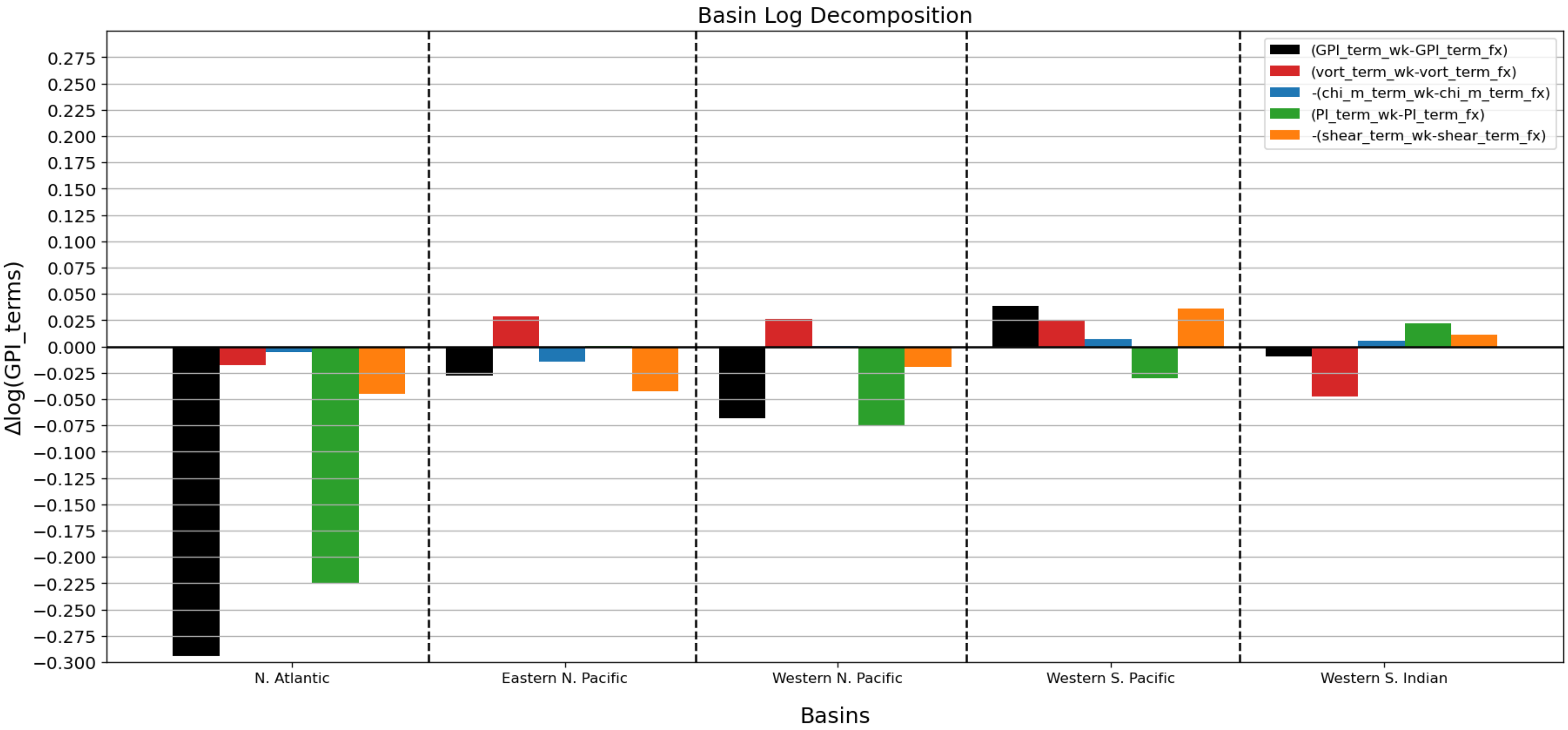
Eastern North Pacific: Overall decrease in GPI; large relative decrease.

Western North Pacific: Overall decrease in GPI; smaller relative decrease than Eastern North Pacific.

Western South Pacific: Only basin with an absolute and relative increase in GPI.

Western South Indian: Overall negligible change in GPI.

Net Impact of Log Decomposition



Summary

In a warming climate, with a weakened AMOC in comparison to a fixed AMOC …

- **TC genesis is reduced** in the Northern Hemisphere.
- **TC genesis is spatially shifted** in all basins.
    - A notable coastal **increase in TC genesis** is near the **Southeastern US**.
- **Changes in Potential Intensity contribute** to the overall decrease in TC genesis, while **changes in wind shear** (especially upper-atmosphere winds) contribute to the GPI spatial shifting.

AMOC weakening is an important factor for future TC projections!

Thank you!

Questions/comments?

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Additional slides

$$GPI = \left|10^5 vort\right|^3 \times \left(\frac{\mathcal{H}}{50}\right)^3 \times \left(\frac{PI}{70}\right)^3 \times (1 + 0.1 shear)^{-2}$$

Emanuel and Nolan, 2004