Impacts of the Atlantic Multidecadal Variability on the tropical climate and tropical cyclone activity

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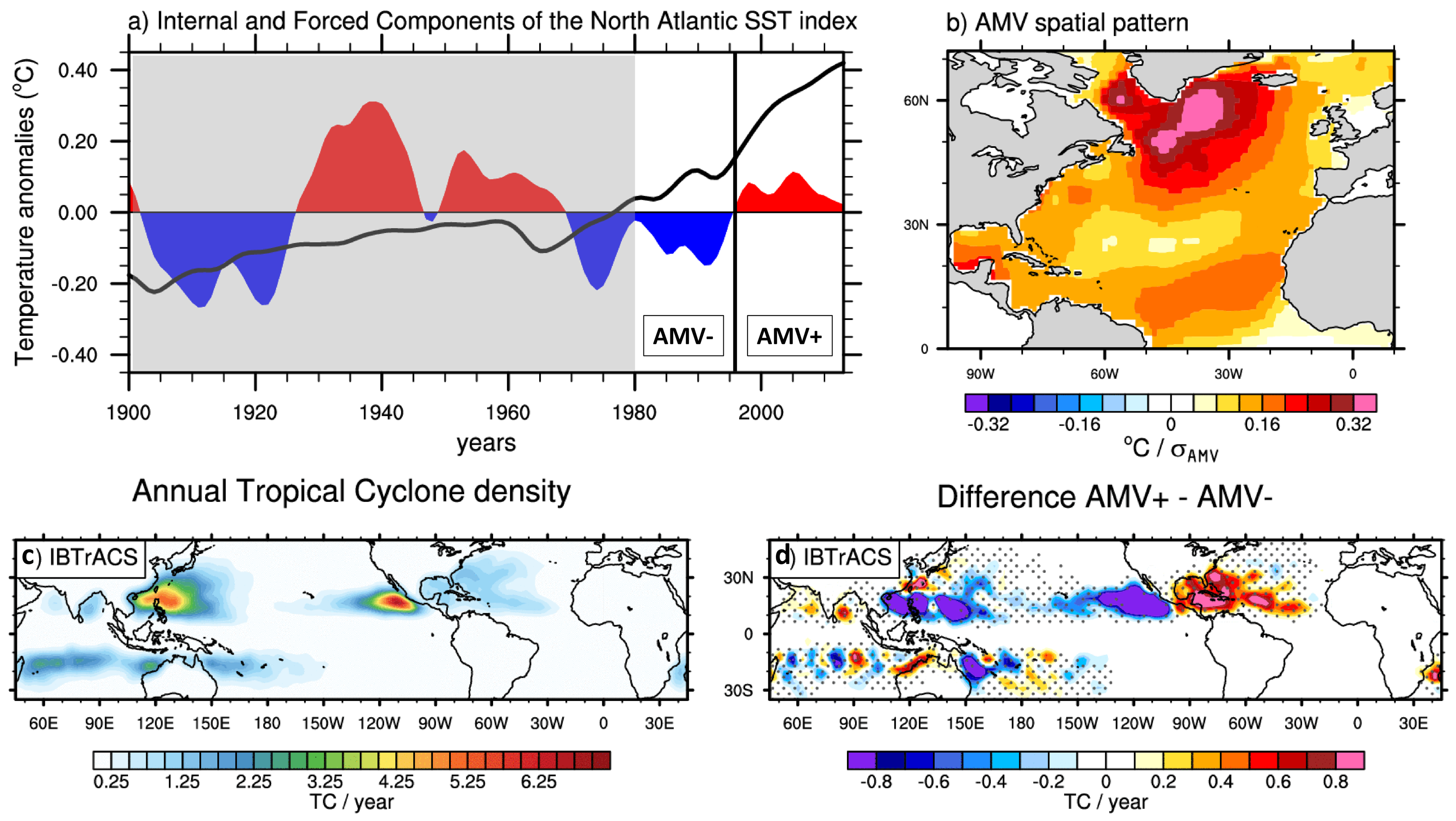
Introduction: The impacts of the **Atlantic Multidecadal Variability** (**AMV**) on the tropical climate and tropical cyclones are investigated using observation datasets and the **GFDL-FLOR** Coupled Global Climate Model (FLOR) in which the North Atlantic sea surface temperature (SST) is restored to observed AMV anomalies. In response to an **AMV warming**, the model simulates a **Walker Circulation decrease** and a **cooling** over **Tropical Pacific**, which are driving an **increase of the Atlantic Tropical Cyclone activity** and a **decrease of the Pacific Tropical Cyclone activity of about 30%** compared to an AMV cooling.

Model: **FLOR** is a coupled climate model of **~1° oceanic** resolution and **~50km atmospheric** resolution. In addition of the freely integrated version of FLOR, a surface flux adjusted version is used, called **FLOR-FA**. In the latter, surface fluxes of fresh water, momentum, and heat strongly reduced the SST model biases.

1) Observed AMV and Tropical Cyclones modulation



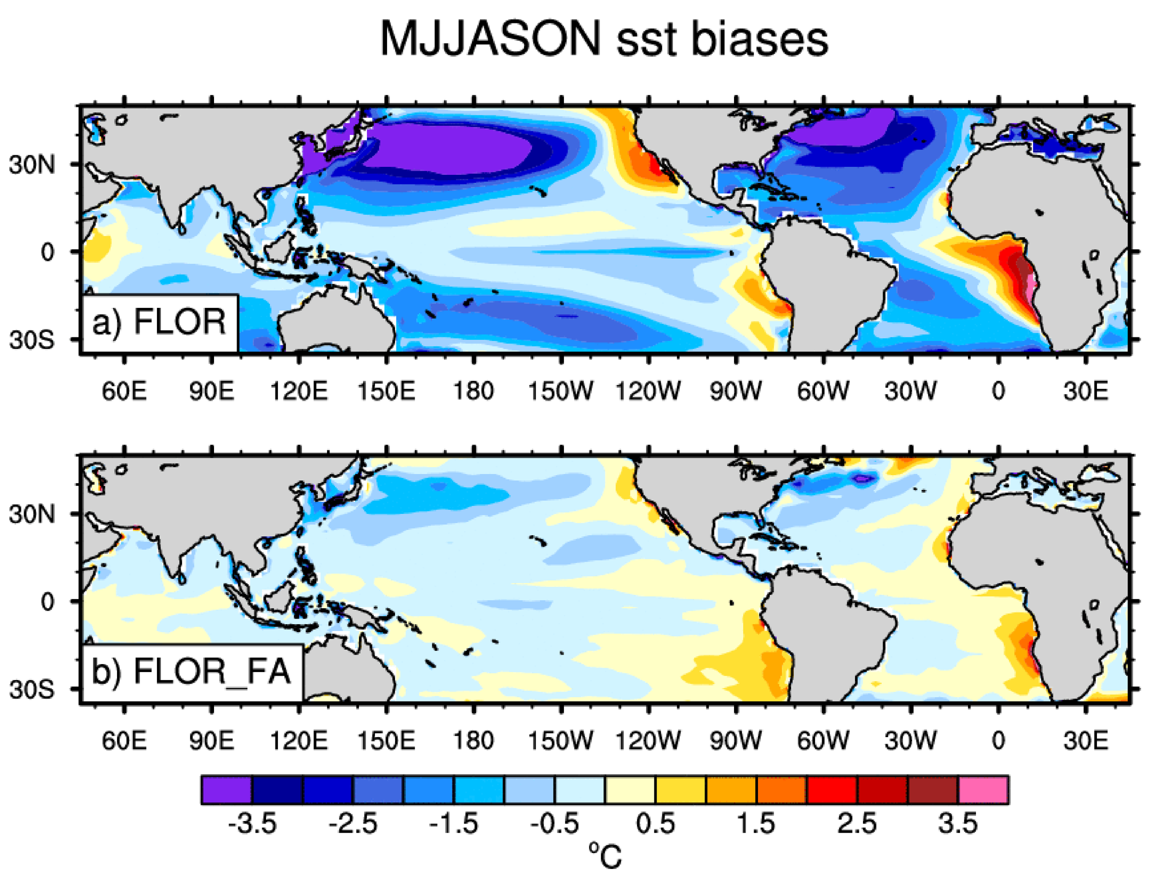
(**a**) Internal (red and blue) versus external (black) components of the observed North Atlantic SST decadal variability following Ting et al. (2009) definition. (**b**) Regression map of the observed annual mean SST (ERSSTv3; Smith et al. 2008) on the internal component of the North Atlantic SST index (i.e., the AMV index). (**c**) Annual climatology of Tropical Cyclone density from IBTrACS (Knapp et al. 2010) computed over the 1980-2011 period. (**d**) Tropical Cyclone density difference between the AMV+ and AMV- periods shown on (a). Stippling indicate non-significant differences.

Question: What is the role of AMV in the observed Tropical Cyclone modulation?

2) Experimental protocol

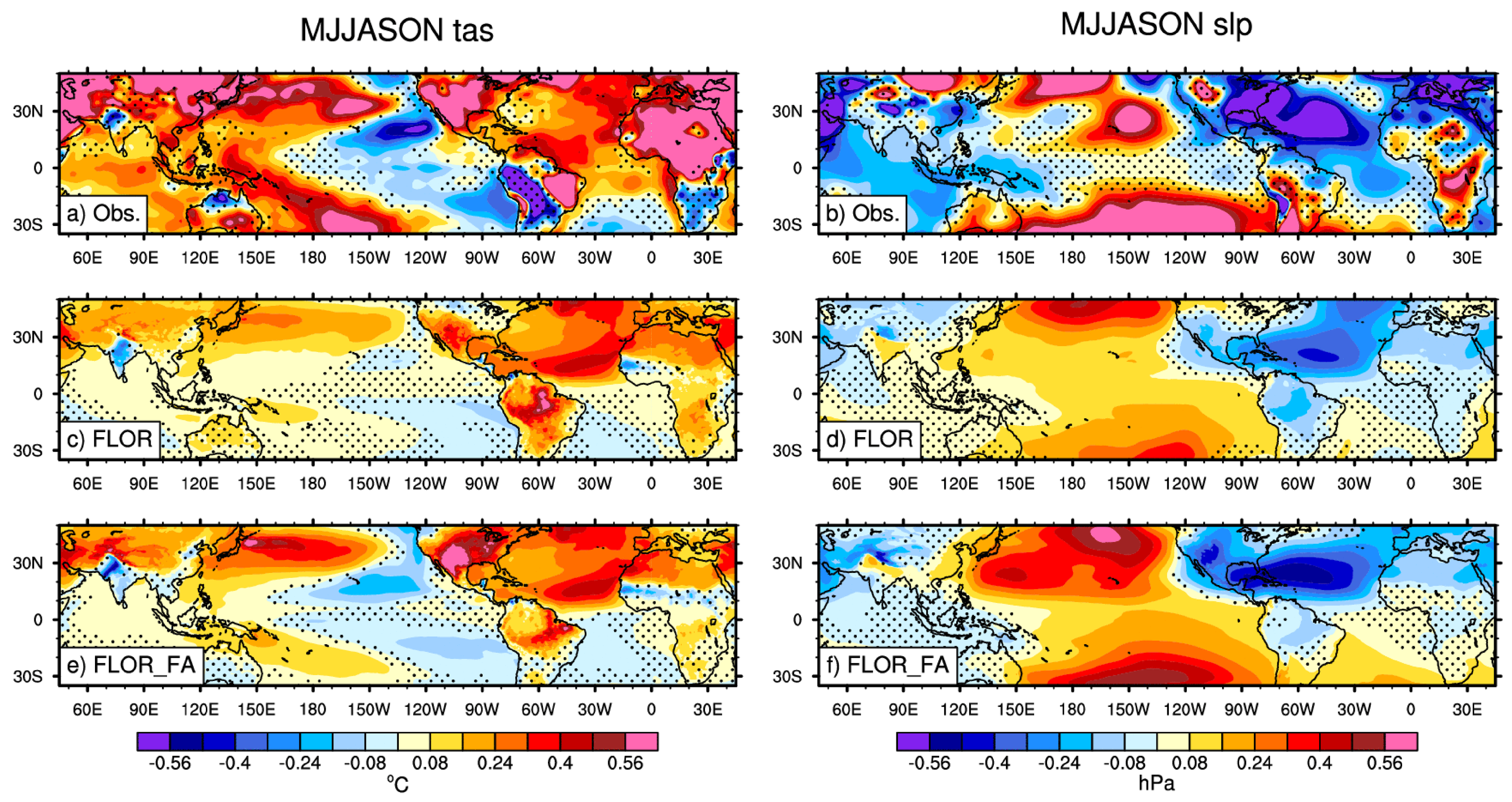
- FLOR's North Atlantic SSTs restored to the fixed **observed AMV anomalies**: AMV+ and AMV-
- 10yr long ensemble experiments of 50 members
- Free ocean-atmosphere interactions outside North Atlantic ➔ allows Pacific adjustment

3) Model mean biases



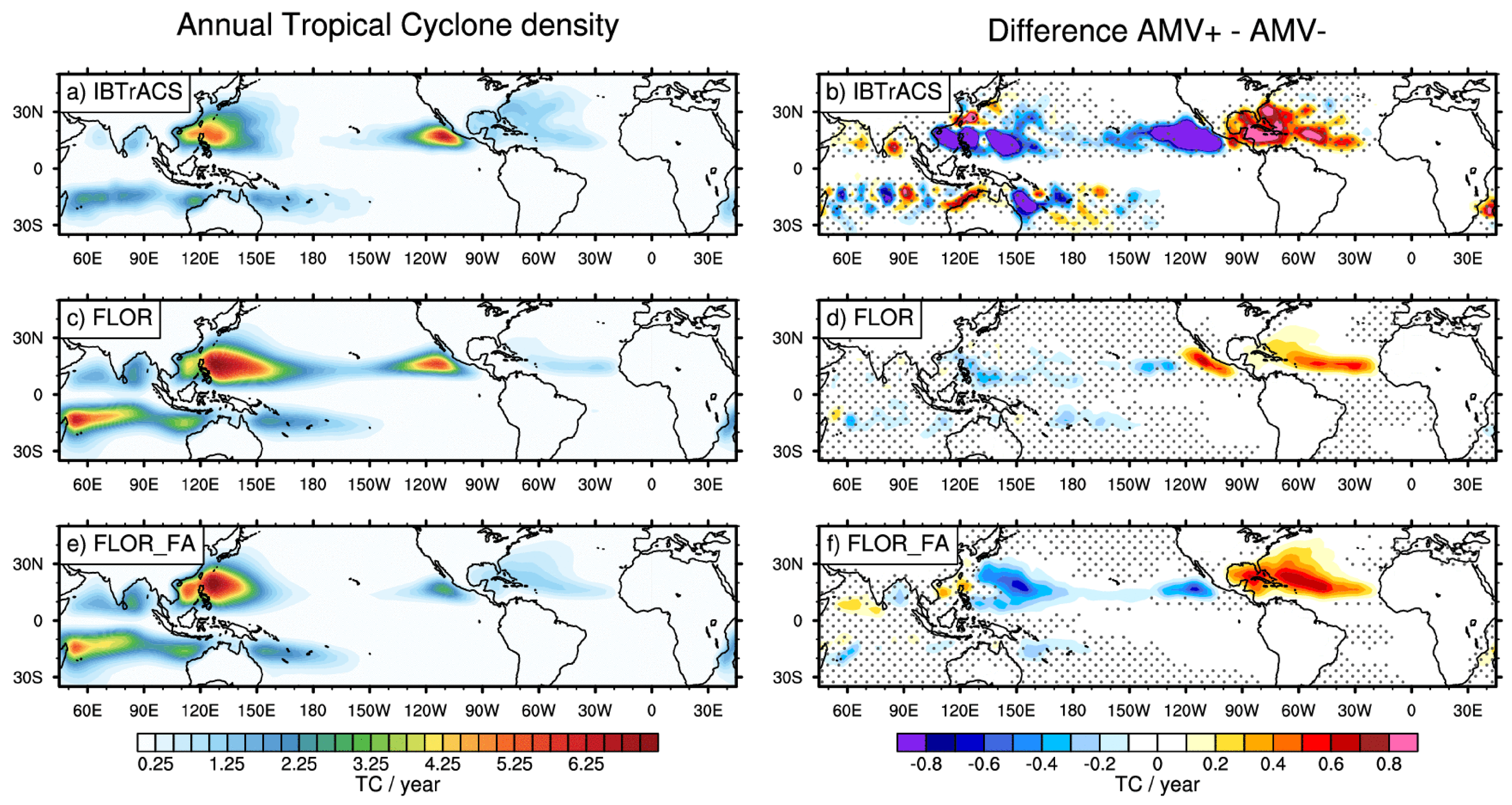
Climatological SST differences between (**a**) FLOR and ERSSTv3 and (**b**) FLOR-FA and ERSSTV3 for the May to November season (MJJASON). As expected, the surface flux adjustment in FLOR-FA strongly reduces the mean SST bias of FLOR.

4) Mean Tropical Climate response to AMV



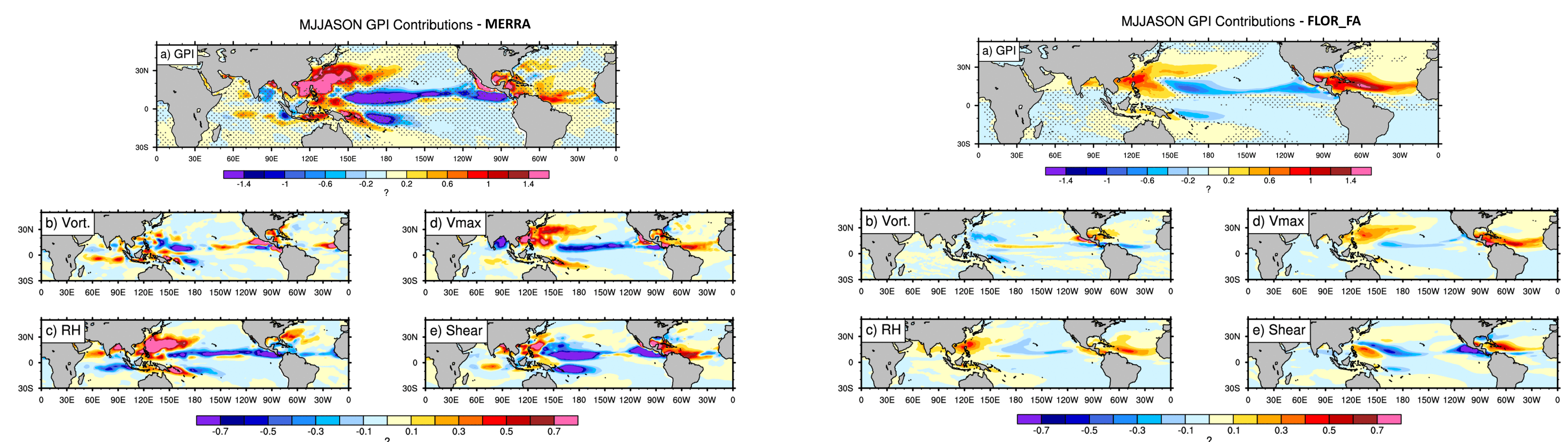
Observed 2-meter air temperature (**a**) and sea level pressure (**b**) differences between the AMV+ and AMV- period (cf. Figure 1a) over the May to November season. Observation are an averaged of 3 datasets: ERA-Interim (Dee et al. 2011), MERRA (Rienecker et al. 2011), and JRA (Kobayashi et al. 2015).
Differences of 2-meter air temperature (**c**) and sea level pressure (**d**) between the 10-year averaged ensemble mean of the AMV+ and AMV- experiments of FLOR.
(**e, f**) same as (c, d) but for FLOR-FA.

5) Tropical Cyclone response to AMV



(**a**) Annual climatology of Tropical Cyclone density from IBTrACS computed over the 1980-2011 period.
(**b**) Observed Tropical Cyclone density difference between the AMV+ and AMV- periods.
(**c**) Annual climatology of Tropical Cyclone density from FLOR. (**d**) 10-year averaged ensemble mean Tropical Cyclone density differences between the AMV+ and AMV- experiments of FLOR.
(**e, f**) same as (c, d) but for FLOR-FA.

6) Mechanisms



Observed (**top left**) and simulated by FLOR-FA (**top right**) Genesis Potential Index difference between AMV+ and AMV-, along with the respective contributions from low-troposphere vorticity, relative humidity, wind maximal potential, and vertical wind shear. (GPI units is arbitrary, it should be scaled with the Tropical Cyclone Genesis number estimated through a tracking algorithm).

GPI = Genesis Potential Index (e.g., Camargo et al. 2007)
➔ empirical formula to estimate large scale background impacts on TC formation

$$GPI = \left|10^5 \eta\right|^{3/2} \left(\frac{\mathcal{H}}{50}\right)^3 \left(\frac{V_{pot}}{70}\right)^3 (1 + 0.1 V_{shear})^{-2}$$

Vorticity (850hPa) — Relative Humidity (700hPa) — Wind Max f(SST, Atmo. Stability) — Vertical Wind Shear

In conclusion, an AMV warming:

- **decreases the Walker Circulation and cools the Tropical Pacific**
- **favors TCs over Atlantic due to warmer SST and decreased wind shear**
- **inhibits TCs over Pacific due to increased wind shear and decreased vorticity**

Needs to correct the mean SST bias to simulate the observed signal

Related studies: - Ruprich-Robert, Y., T. Delworth, R. Msadek, F. Castruccio, S. Yeager, and G. Danabasoglu (2018) Impacts of the Atlantic Multidecadal Variability on North American Summer Climate and Heat Wave. J. Clim., doi:10.1175/JCLI-D-17-0270.1
- Ruprich-Robert, Y., R. Msadek, F. Castruccio, S. Yeager, and D. Danabasoglu (2017) Assessing the climate impacts of the observed Atlantic Multidecadal Variability using the GFDL CM2.1 and NCAR CESM1 Global Coupled Models. J. Clim., doi: 10.1175/JCLI-D-16-0127.1
- Ruprich-Robert, Y. and R. Msadek (2017) Global impacts of the Atlantic Multidecadal Variability during the boreal winter. Pages Magazine, doi: 10.22498/pages.25.1.7