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Impact of Gulf Stream meanders on atmospheric fronts in a regional high resolution atmospheric model.

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Introduction

Oceanic fronts associated with western boundary current (WBC) vent a vast amount of heat and moisture upward into the atmosphere and anchoring mid-latitude storm tracks (Minobe et al., 2008, Nakamura and Shimpo, 2004, Kwon et al. 2010). The mid-latitude precipitation is sensitive to the mesoscale SST variability (Minobe et al., 2008) associated with Gulf Stream (GS).

The ocean mesoscale variability has a significant effect on the jet streams, large-scale flow, and midlatitude storm tracks.

Better representation of midlatitude mesoscale ocean-atmosphere interactions in the forecast models is considered a potential way to improve the Subseasonal-to-Seasonal prediction (Saravanan & Chang, 2018 ; Roberts et al., 2022).

Motivation

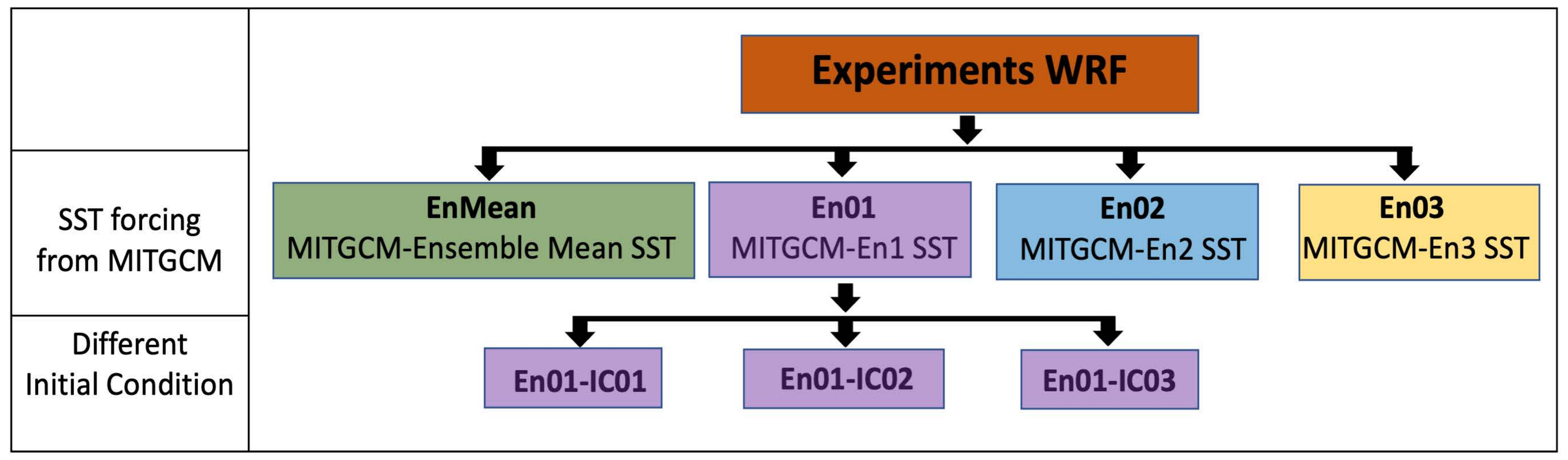
1. **Understand the effect of mesoscale SST variability on local atmospheric dynamics:** It is still not clear whether the mesoscale variability of WBCs impacts the atmospheric means state (e.g., Shimada & Minobe, 2011) or happens on the synoptic/frontal scale (e.g., Hirata et al., 2015, 2018).
2. **Lack of robust response of the atmosphere to mesoscale SST variability:** The unrealistic spatial smoothing of SST-forcing generates different model climatology.
3. **How mesoscale SST variability effect beyond the atmospheric boundary layer?** The mechanism of how mesoscale SST variabilities influence beyond the marine boundary layer is still not clear.

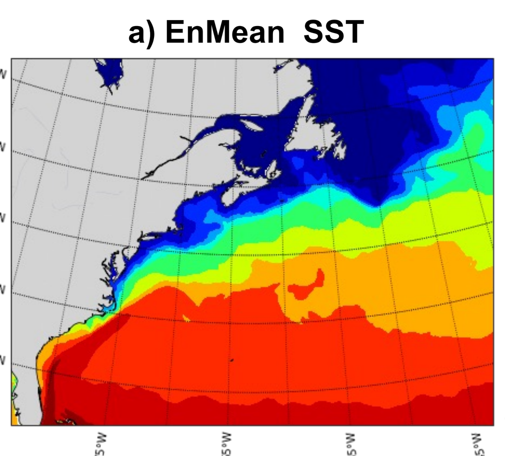
Models and Experimental setup

High Resolution WRF (with 10 Km horizontal resolution) Run (15-Feb-2010 to 17-Mar-2010). I forced the model with SST from high-resolution "eddy-resolving" MITGCM (Dewar et al., 2022) output. 24-member ensemble simulation of MITGCM runs at an "eddy-resolving" horizontal resolution of (1/12)°.

Three types of experiments:

1. **Forced with mean SST of 24 ensemble members:** No mesoscale SST meanders structure.
2. **Forced with SST from individual ensemble members:** With mesoscale SST meanders structures.
3. **Forced with En1 MITGCM SST but different Initial Condition:** With mesoscale SST meanders structures.





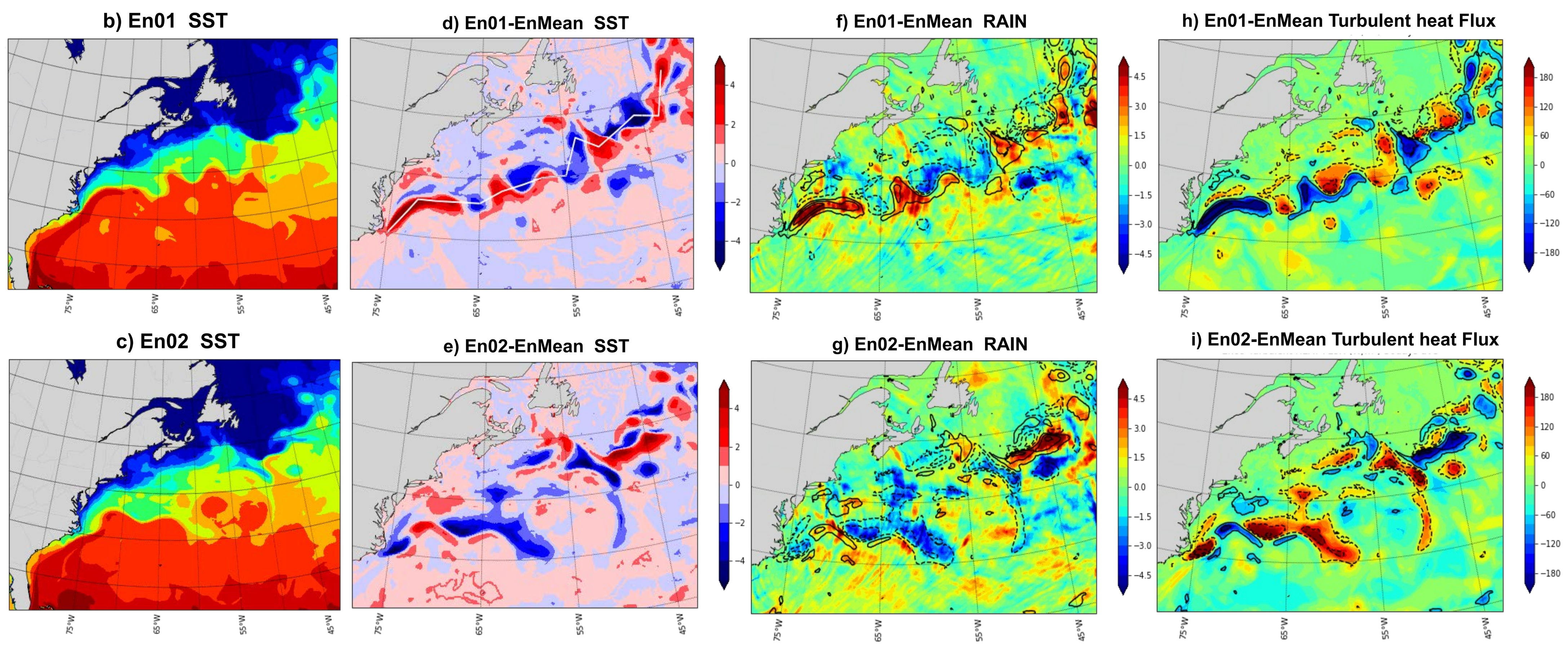
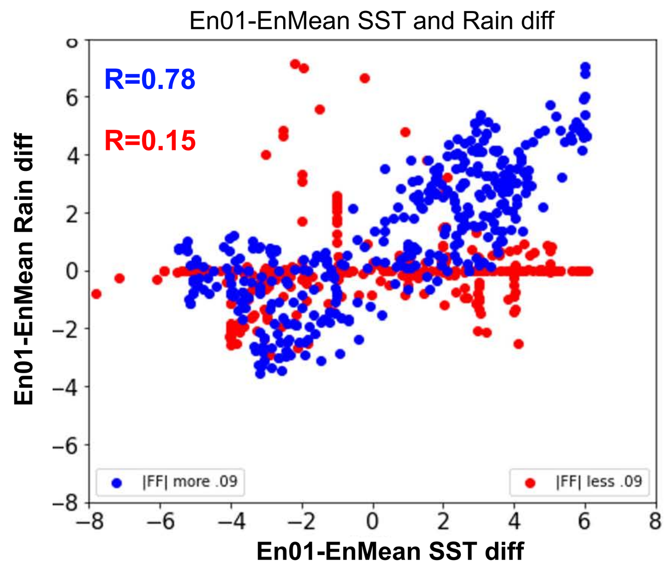


Figure1: MITGCM SST a)EnMean, b)En01, c)En02. SST difference between d)En01, e)En02 and EnMean. Rain (30-day ave) difference between f)En01, g)En02 and EnMean. Turbulent Heat-Flux (30-day ave) difference between h)En01, i)En02 and EnMean.

Main Result:

- ❑The mesoscale SST variability generates strong turbulent flux anomalies along the Gulf Stream. Though the radiative heat fluxes show no significant signal.
- ❑Positive SST variability generates strong positive precipitation anomalies and vice versa. Thus, highly correlated with each other.
- ❑The SST meanders are persistence. But precipitation anomalies mainly follow the atmospheric frontal activity. The SST and precipitation relation is only valid in the presence of atmospheric frontal activity.



$F^* = \xi_{900} |\nabla T_{900}|$

$|\nabla T_{900}|$ = temperature gradient on the 900mb surface

ξ_{900} = curl of the wind vector normal 900mb surface

(Parfitt et al., 2016)

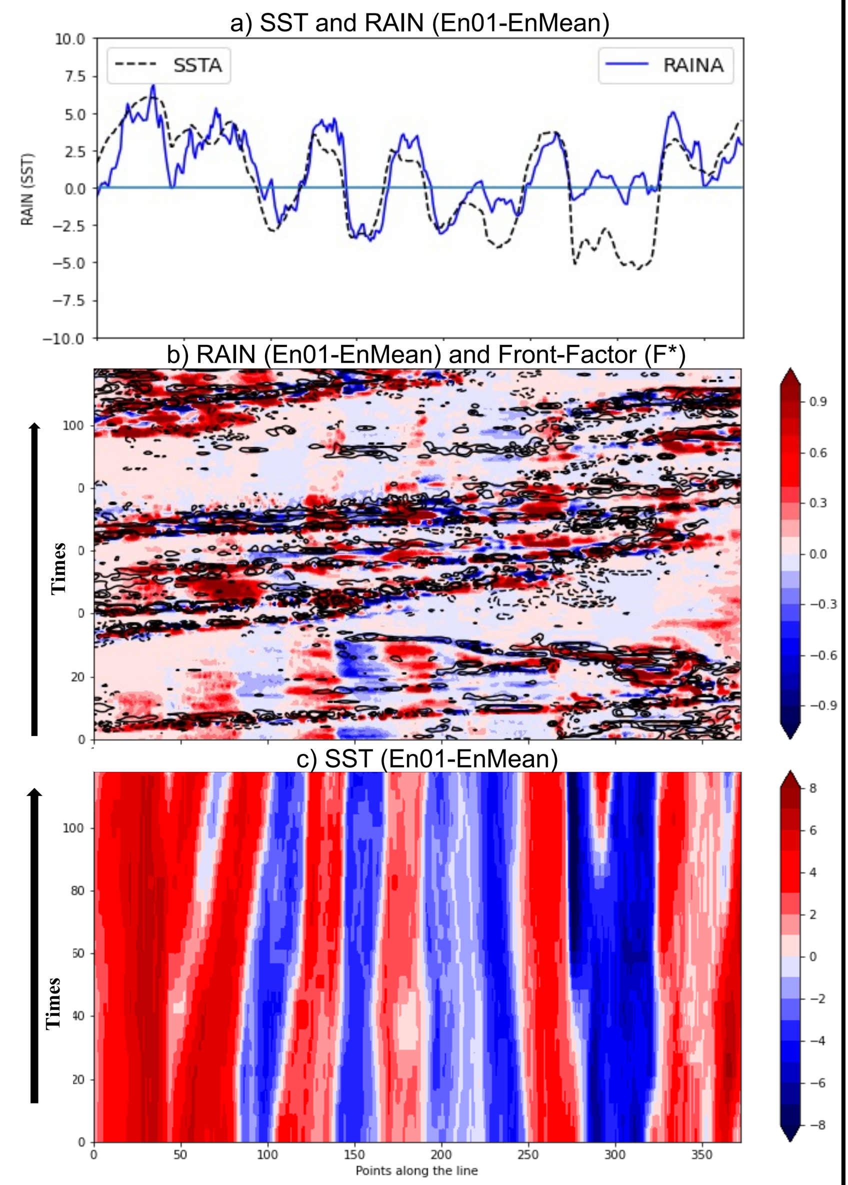


Figure2: a) Difference of Rain (mm/day) and SST along the white line (Fig1) between En02 and EnMean simulations. Time evolution (30 day 6hourly data) of difference of b) Rain and F-factor and c) SST along the white between En02 and EnMean simulations.

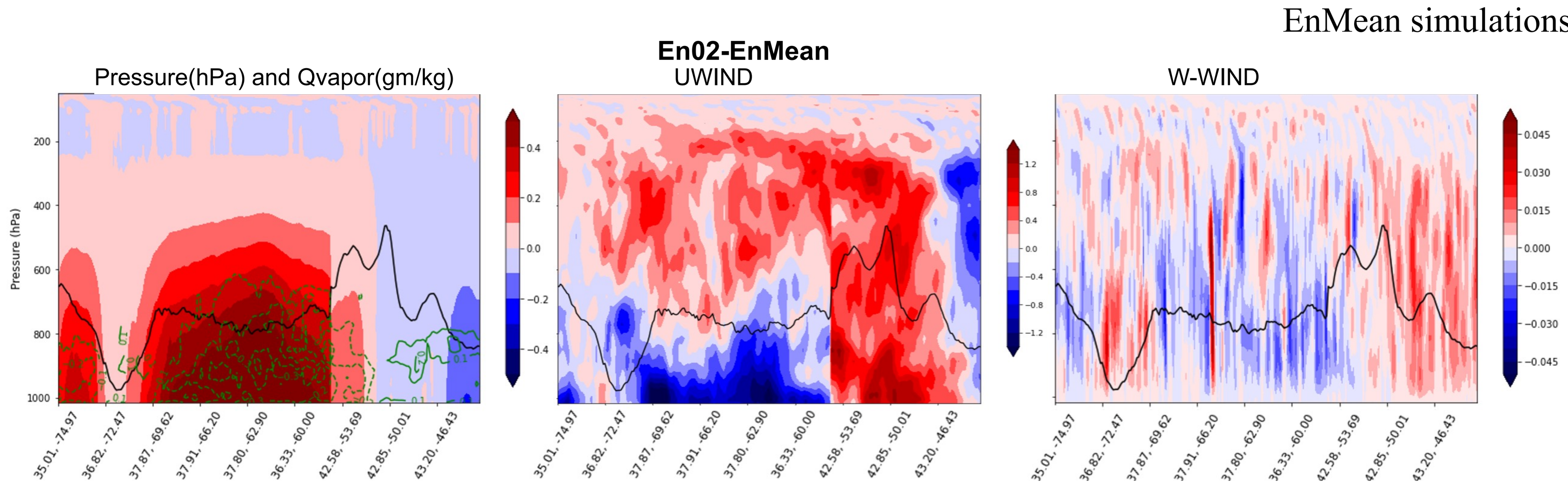
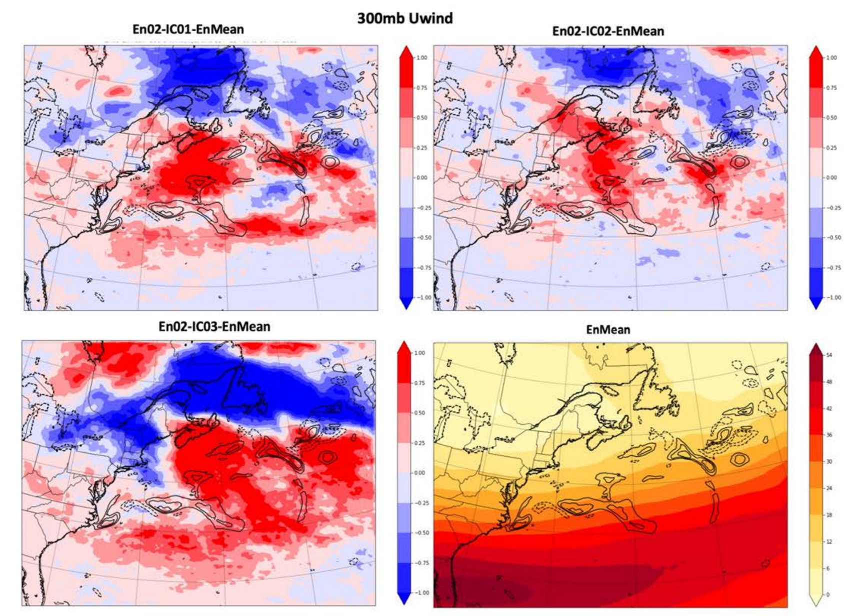


Figure3: The vertical profile of 30-day average Pressure(hPa), Qvap(gm/kg), zonal-wind(m/s) and vertical-wind difference between En02 and EnMean simulations.

- ❑Strong moisture anomalies are trapped in the lower atmosphere.
- ❑But the pressure and vertical velocity variability associated with SST meanders influence the deep atmosphere. Also, strong zonal wind anomalies are noticeable in the upper troposphere. The imprint of the meanders on the dynamical fields is found to reach beyond the marine boundary layer (MABL) and it perturbs the upper troposphere.

Figure4: The effect of ocean mesoscale variability on the jet streams. 30-day average zonal wind component at 300 hPa (m/s) difference between three different MITGCM-En02 SST forced simulation with different initial condition. Mean zonal wind component in EnMean.



- ❑ The shift of the North Atlantic jet observed in the experiments due to the mesoscale SST variability. The effect of ocean mesoscale variability significantly effect the jet streams, large-scale flow, and midlatitude storm tracks in all the En02 ensemble members consistently.

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