Impacts of Gulf Stream Variations on the Transition of Marine Post-frontal Clouds

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Gulf Stream in North Atlantic Ocean Region (WNAO)

- A cloud-line is formed along with GS region.
- Upward motion of the air is caused by mesoscale solenoidal circulation induced by the large surface thermal gradient.

Smoothed SST simulation does not reproduce the rain band.

Minobe et al., 2008, Nature

Li et al., 2004, GRL

This convergence zone closely follows the meandering path of the GS and the area with the strongest SST gradient.

Painemal et al., 2021, JGR
Variations of gulf stream in WNAO region

Decadal Variations of SST Anomalies (Feb.–Mar.) over the western North Atlantic Ocean region (WNAO)

Data source: ERA5-reanalysis

Scientific Question: How does these changes in GS impact the post-frontal clouds morphology?

Smeed et al., 2018., GRL
**ACTIVATE post-frontal cloud case during CAOs**

**WRF (v4.2) Domain Setups**
- Domain Size (square): 1650km, 450km
- Resolution: 3km, 1km

**Vertical Profiles of Boundary Layer Properties**

Vertically Integrated Hydrometer Mixing Ratio

March 1st, 15:00 UTC (10:00 EST)

- GOES 2km zoom-in
- WRF d02 1km

Dropsondes at 15-16 UTC (10-11 EST)

Chen et al., JAS, 2022
Sensitivities of SST gradient experiments

Control Simulation
(Default SST)

Plus4
(increase SST by 4 K)

Gradplus
(increase SST anomalies by 25%)
SST impacts zone classification and cloud mask morphology in post-frontal region

SST+4: Cloud deck is closer to coast with larger frontal system zone

SST_\text{grad}: Cloud deck are further away coast with smaller cloud street zone
Boundary layer energy transport: isentropic analysis

Control Simulation

Averaging by height between 200 m and 2 km

Identify the circulation that vertically transport energy.

Circulation of energy transport occurs at higher $\theta_e$ and $q_v$ in “SST+4” simulation, and weaker in “SST_grad” simulation with increased SST gradient.
Contrast variabilities in the north and south region of the GS

Control simulation: two $\theta_e$ peaks

Inner domain
Time evolution of post-frontal clouds

sstgrad: Upwind low $\theta$ impacts the down-wind ones.
Summary

• SST+4:
  1. warmer and moister BL
  2. less but larger clouds
  3. less liquid and more ice phase hydrometeor
  4. More long cloud lines at the edge of PFCs.

• Increased SST gradient
  1. Impacts are larger in the upwind negative SST anomalies region.
  2. Colder and drier BL
  3. Less but larger clouds
  4. A little more liquid but less ice phase hydrometeor
  5. Weaker massflux for energy circulation
Thank you

Questions?
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