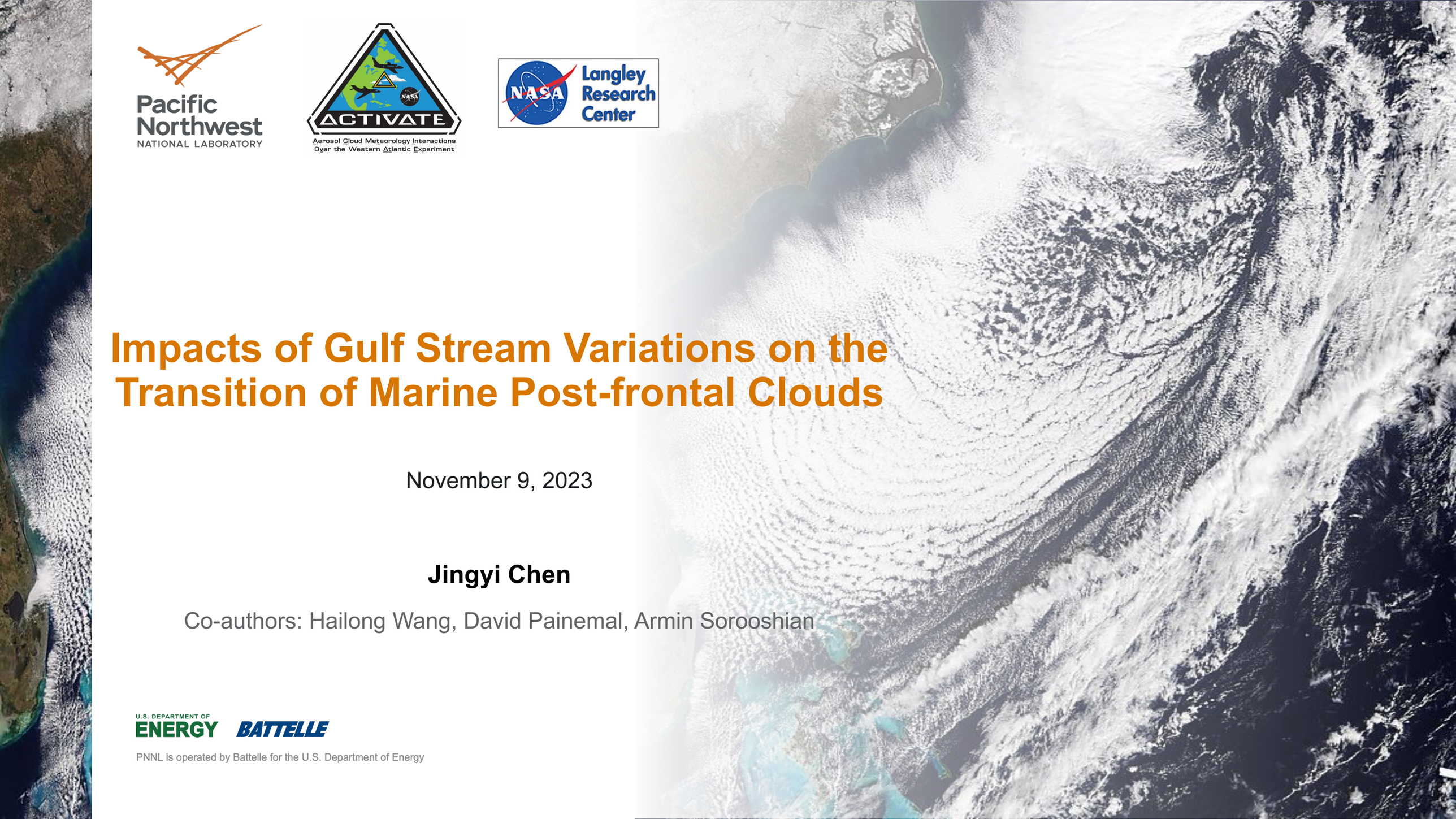


Impacts of Gulf Stream Variations on the Transition of Marine Post-frontal Clouds

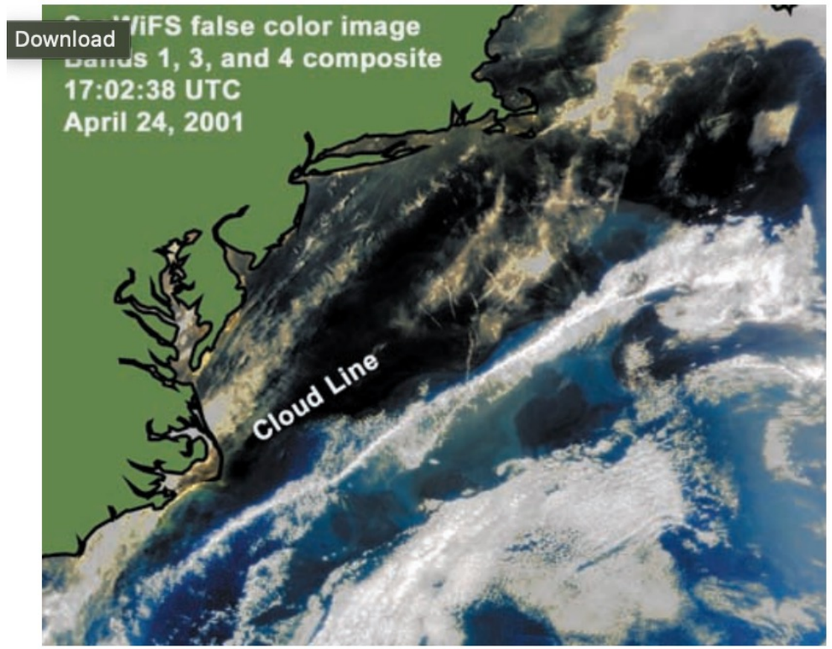
November 9, 2023

Jingyi Chen

Co-authors: Hailong Wang, David Painemal, Armin Sorooshian

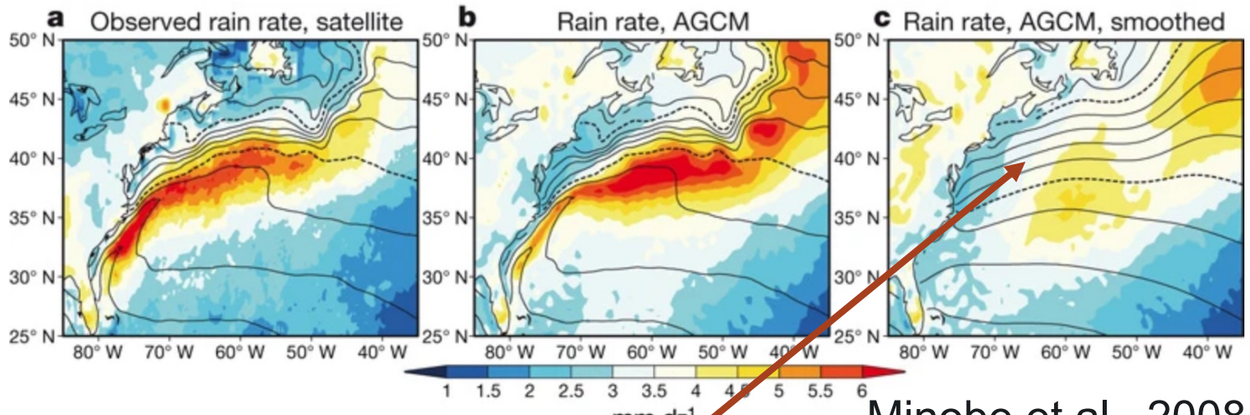
PNNL is operated by Battelle for the U.S. Department of Energy

Gulf Stream in North Atlantic Ocean Region (WNAO)



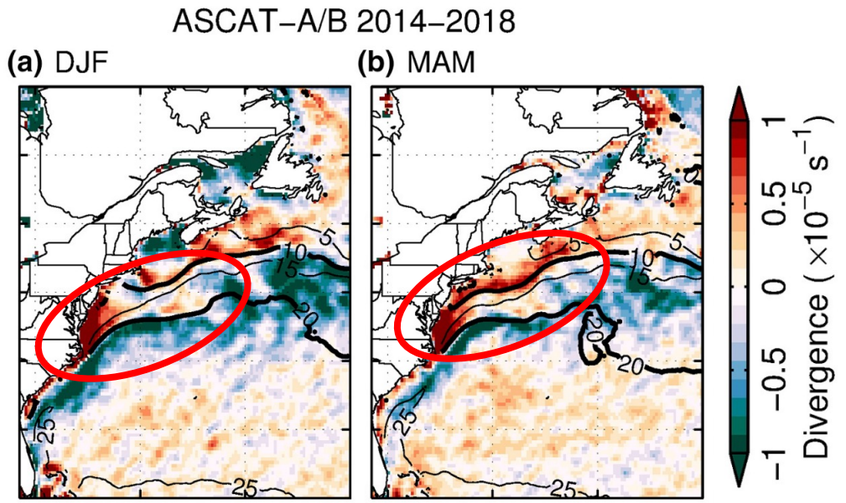
Li et al., 2004, GRL

- 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



Minobe et al., 2008, Nature

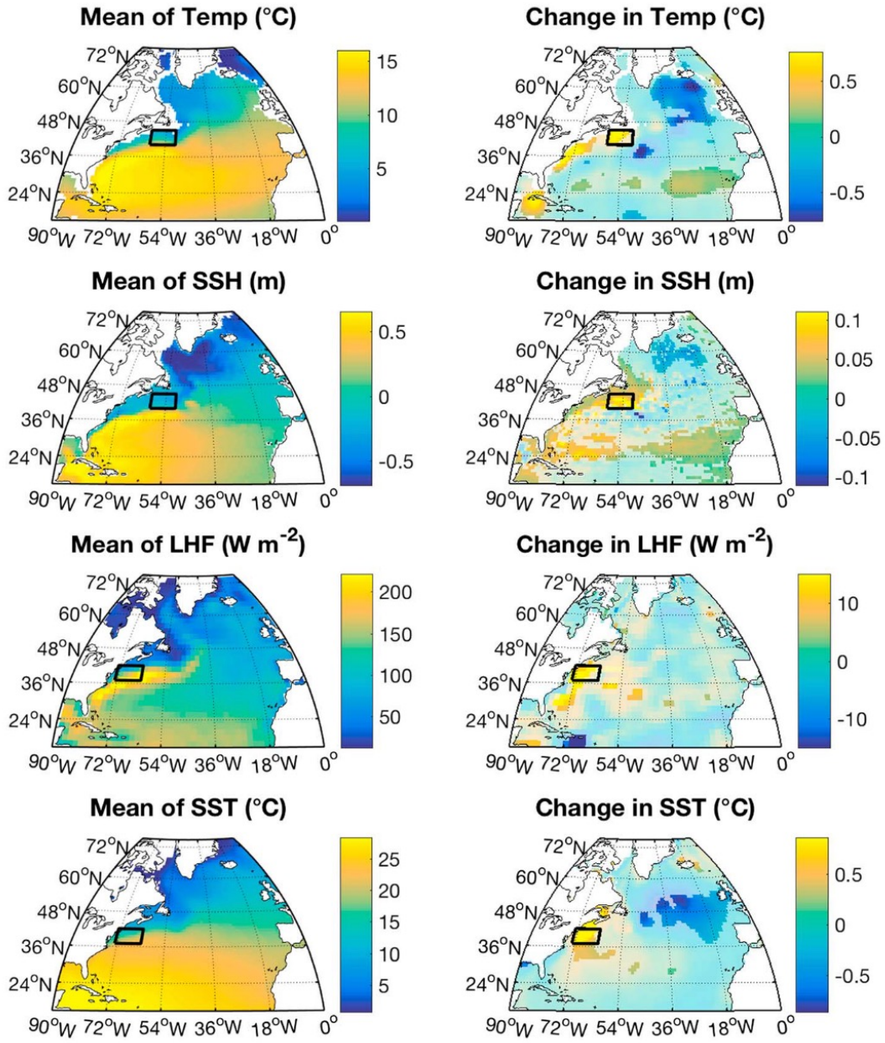
Smoothed SST simulation does not reproduce the rain band.



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

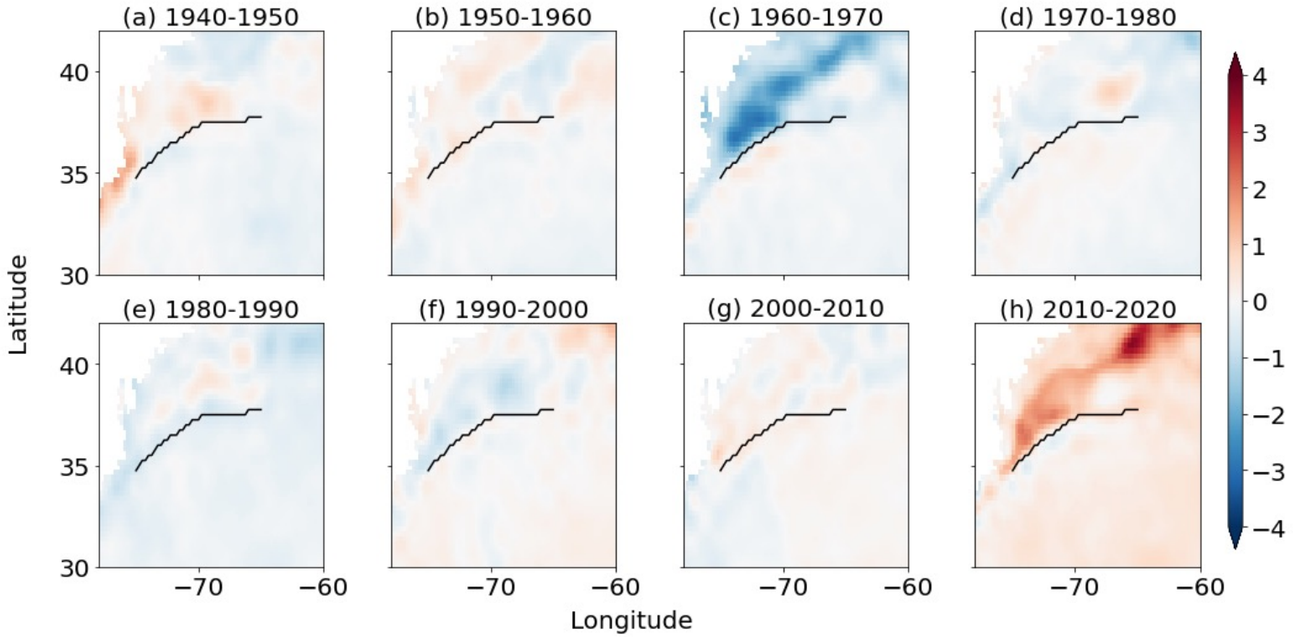
Painemal et al., 2021, JGR

Variations of gulf stream in WNAO region



Smeed et al., 2018., GRL

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



Data source: ERA5-reanalysis

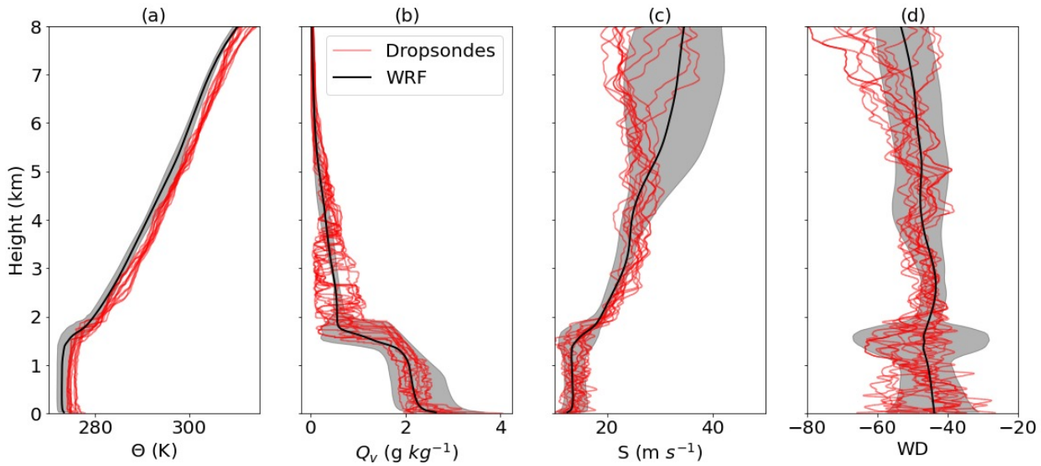
Scientific Question: How does these changes in GS impact the post-frontal clouds morphology?

ACTIVATE post-frontal cloud case during CAOs

WRF (v4.2) Domain Setups

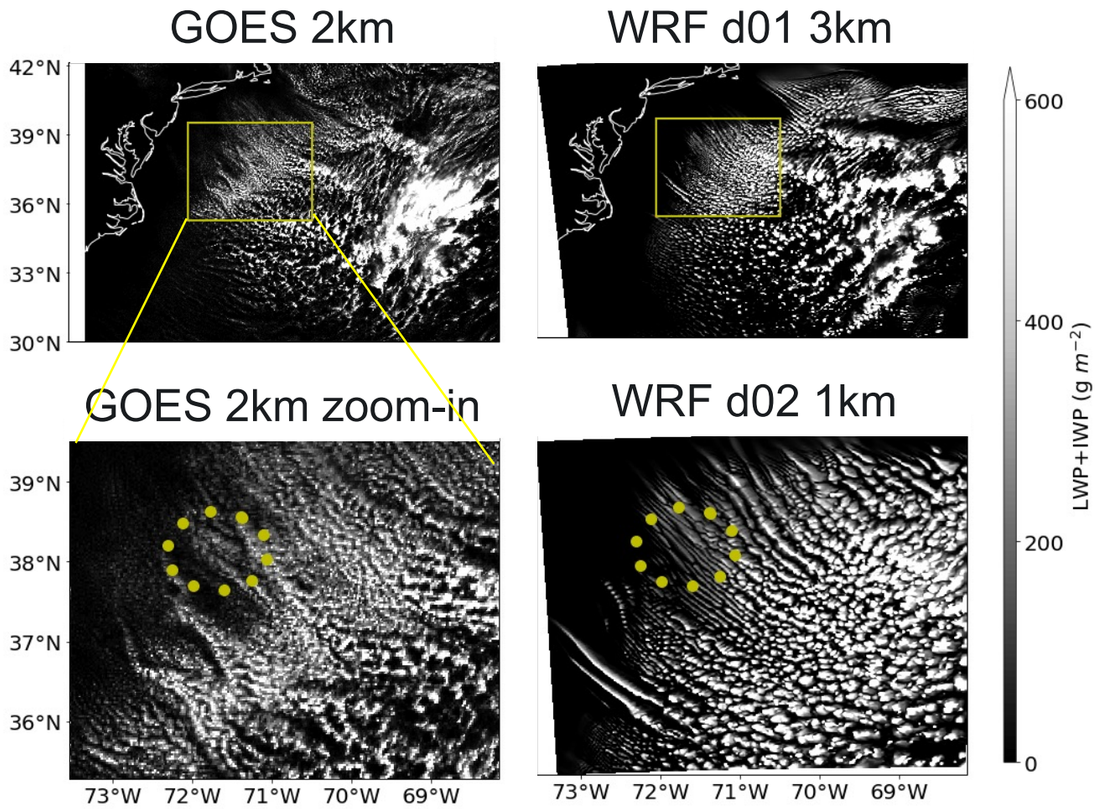
- Domain Size (square): 1650km, 450km
- Resolution: 3km, 1km

Vertical Profiles of Boundary Layer Properties



Vertically Integrated Hydrometer Mixing Ratio

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



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

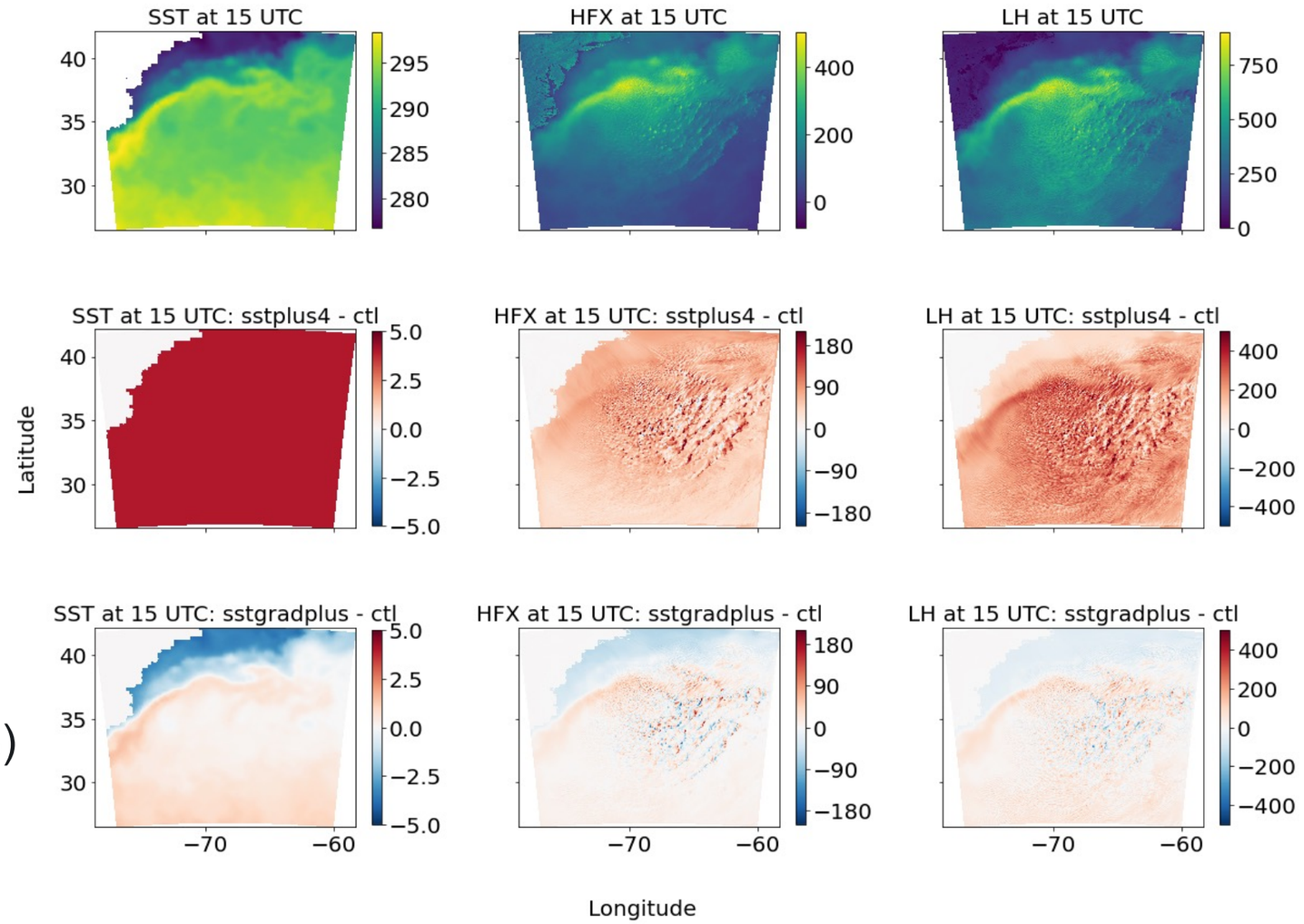
Chen et al., JAS, 2022

Sensitivities of SST gradient experiments

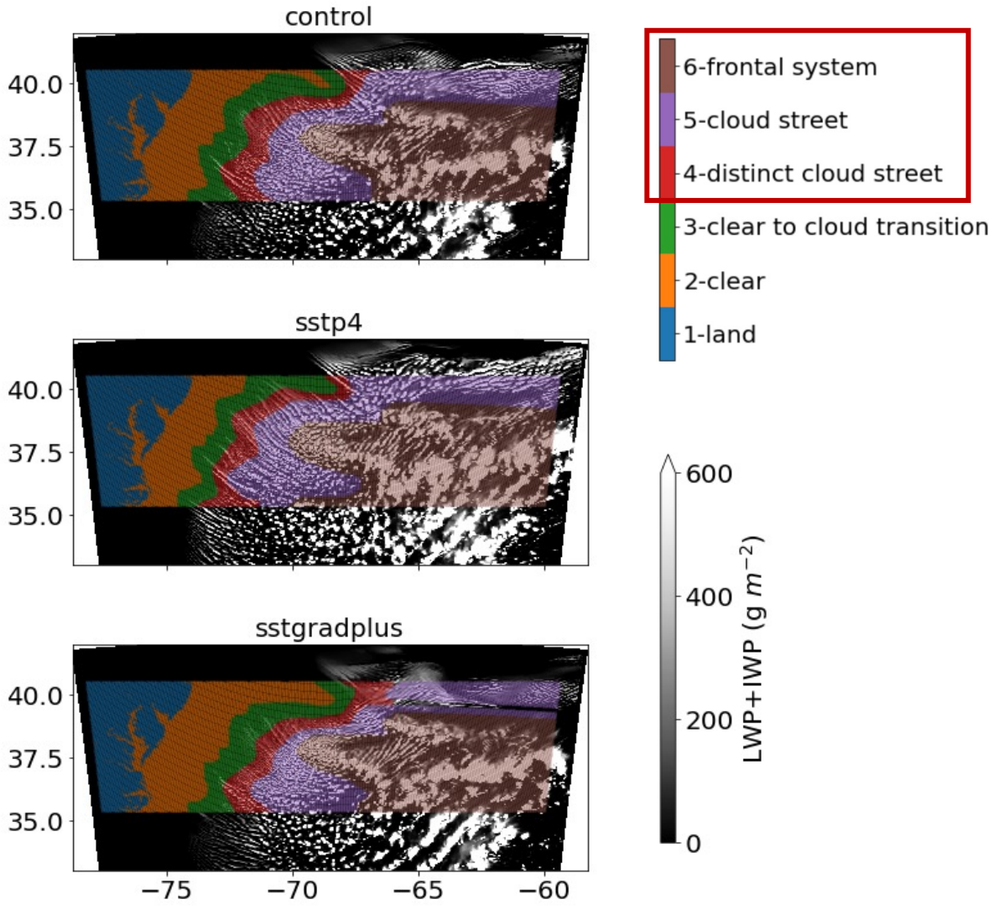
Control Simulation
(Default SST)

Plus4
(increase SST by 4 K)

Gradplus
(increase SST anomalies by 25%)

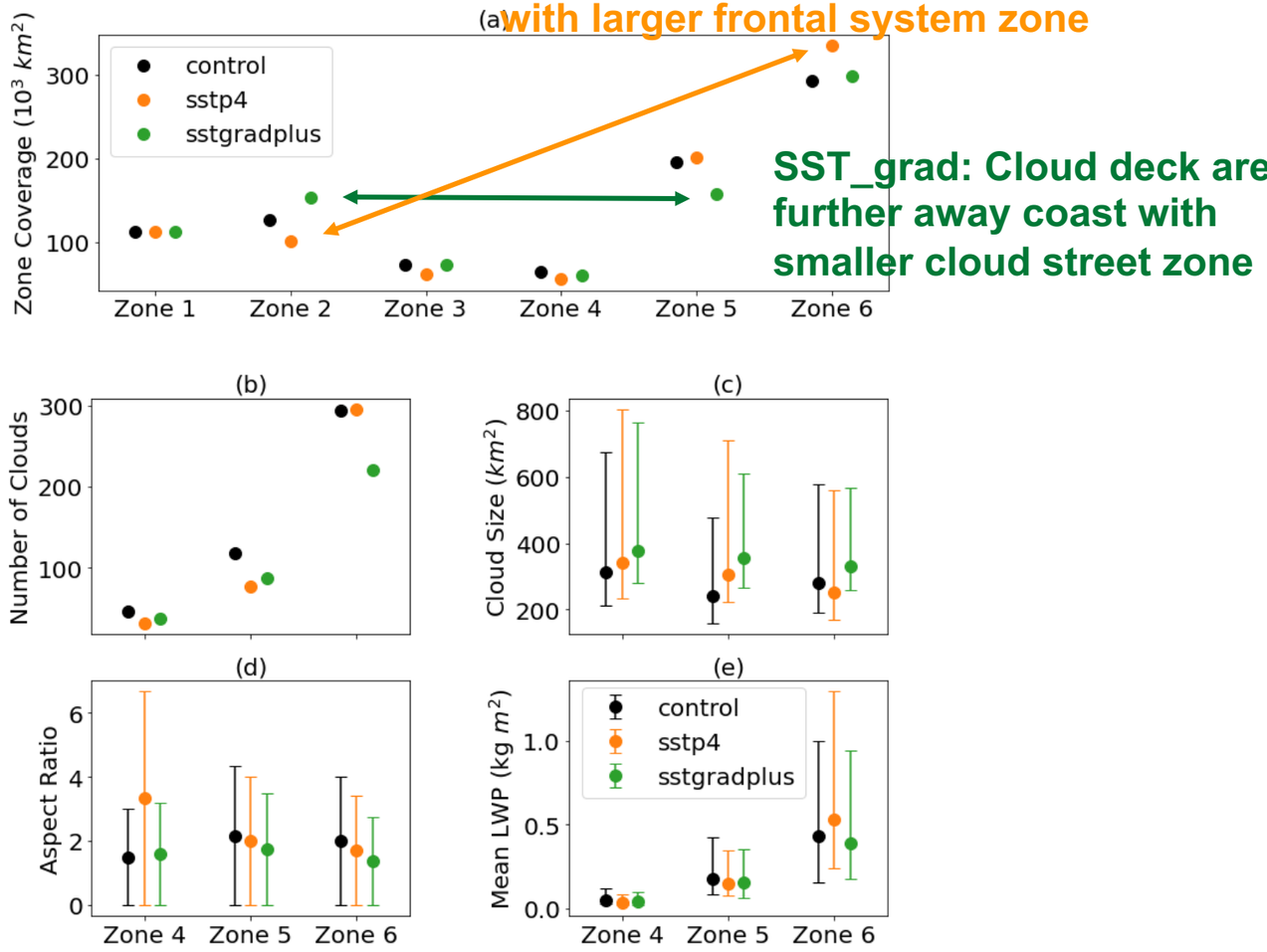


SST impacts zone classification and cloud mask morphology in post-frontal region



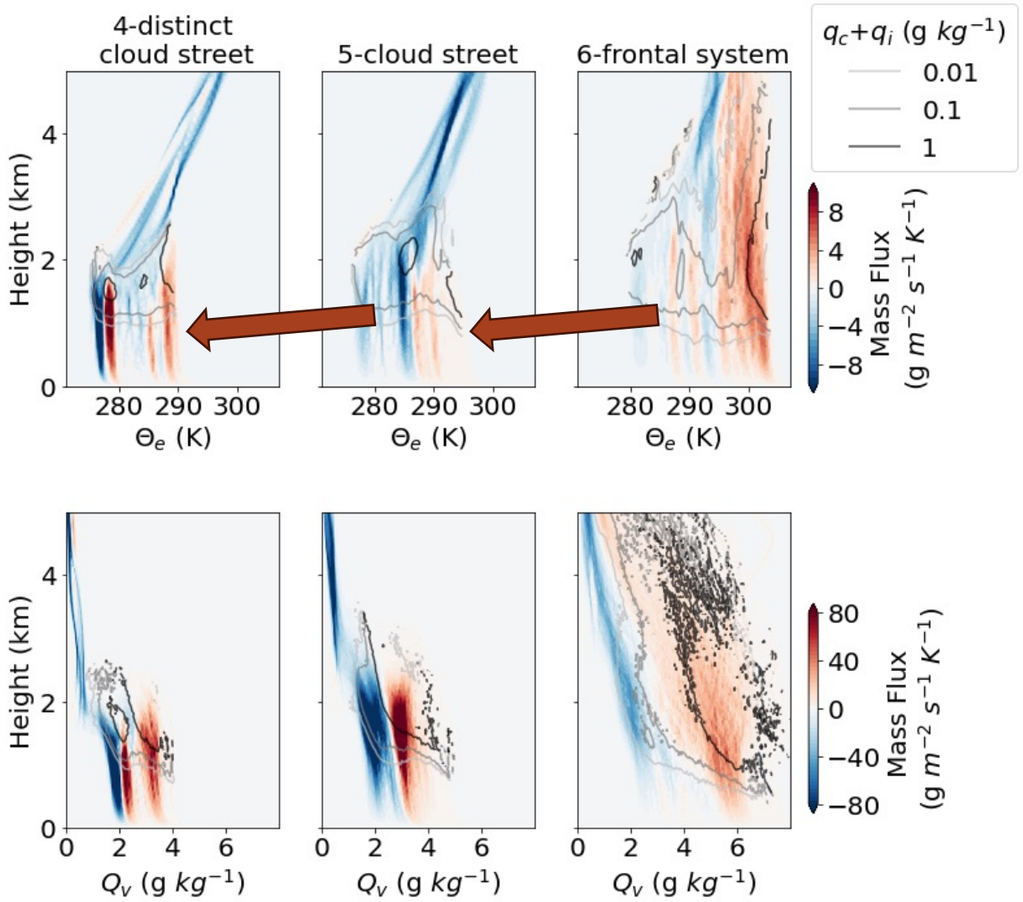
SST+4: Cloud deck is closer to coast with larger frontal system zone

SST_grad: Cloud deck are further away coast with smaller cloud street zone



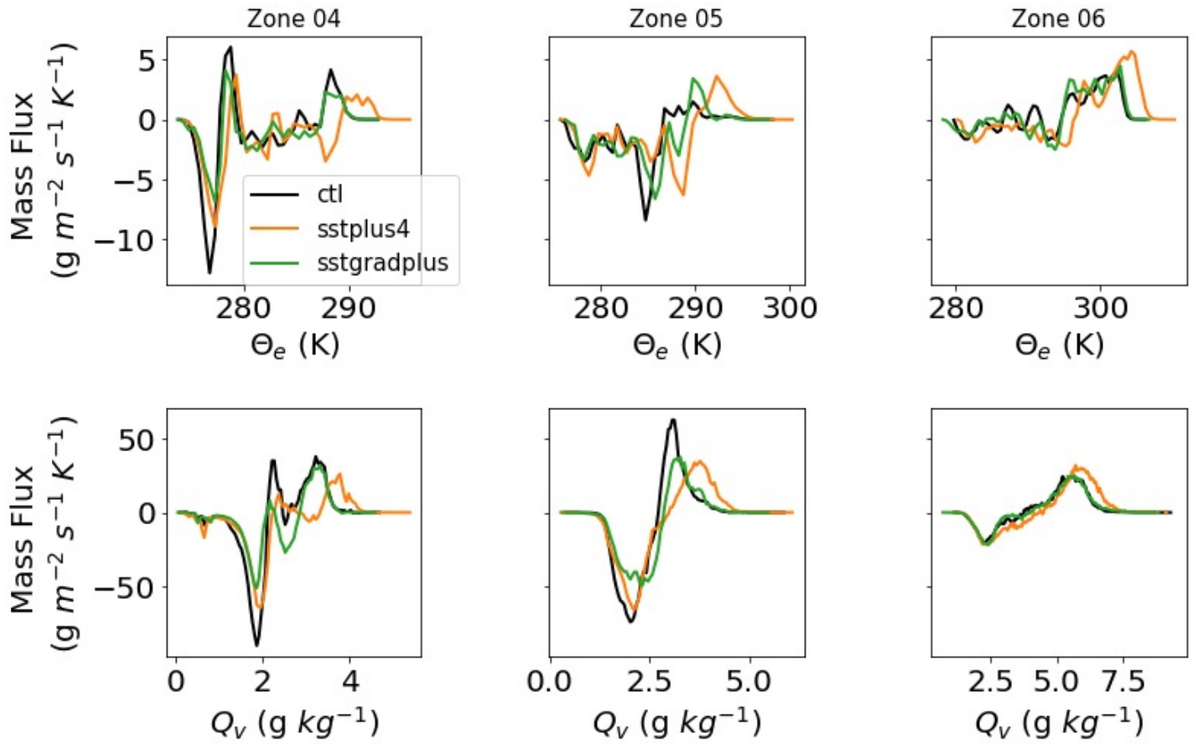
Boundary layer energy transport: isentropic analysis

Control Simulation



Identify the circulation that vertically transport energy.

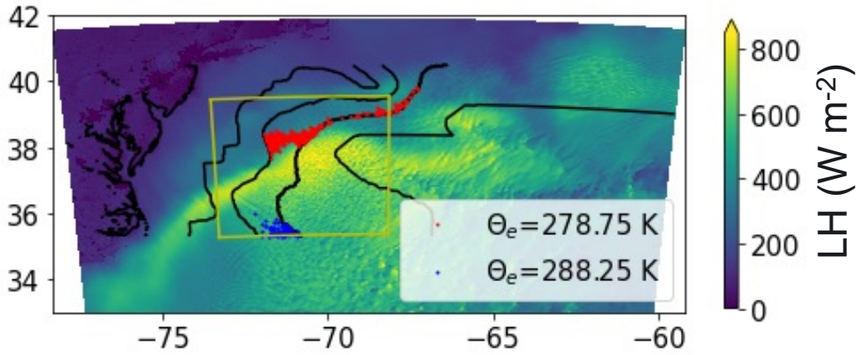
Averaging by height between 200 m and 2 km

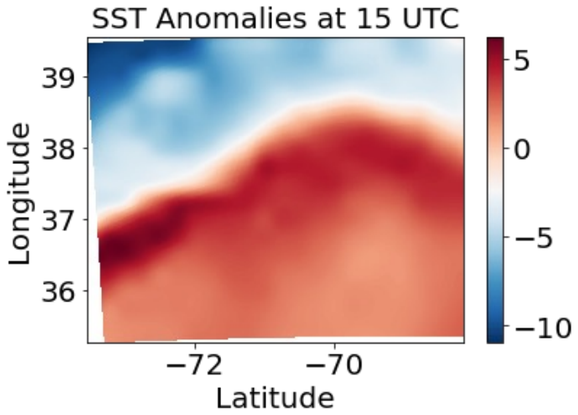


Circulation of energy transport occurs at higher θ_e and q_v in "SST+4" simulation, and weaker in "SST_grad" simulation with increased SST gradient.

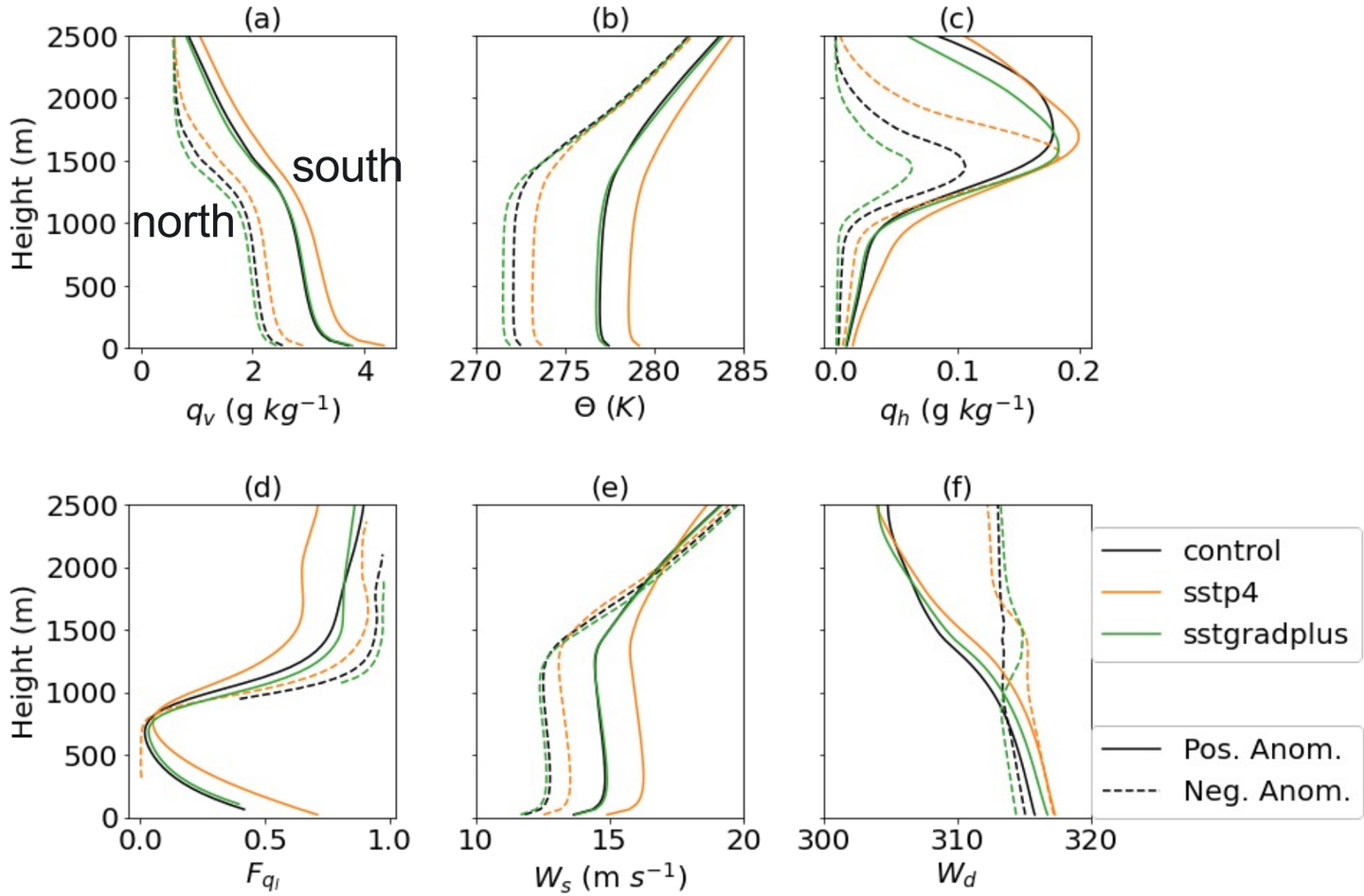
Contrast variabilities in the north and south region of the GS

Control simulation: two θ_e peaks



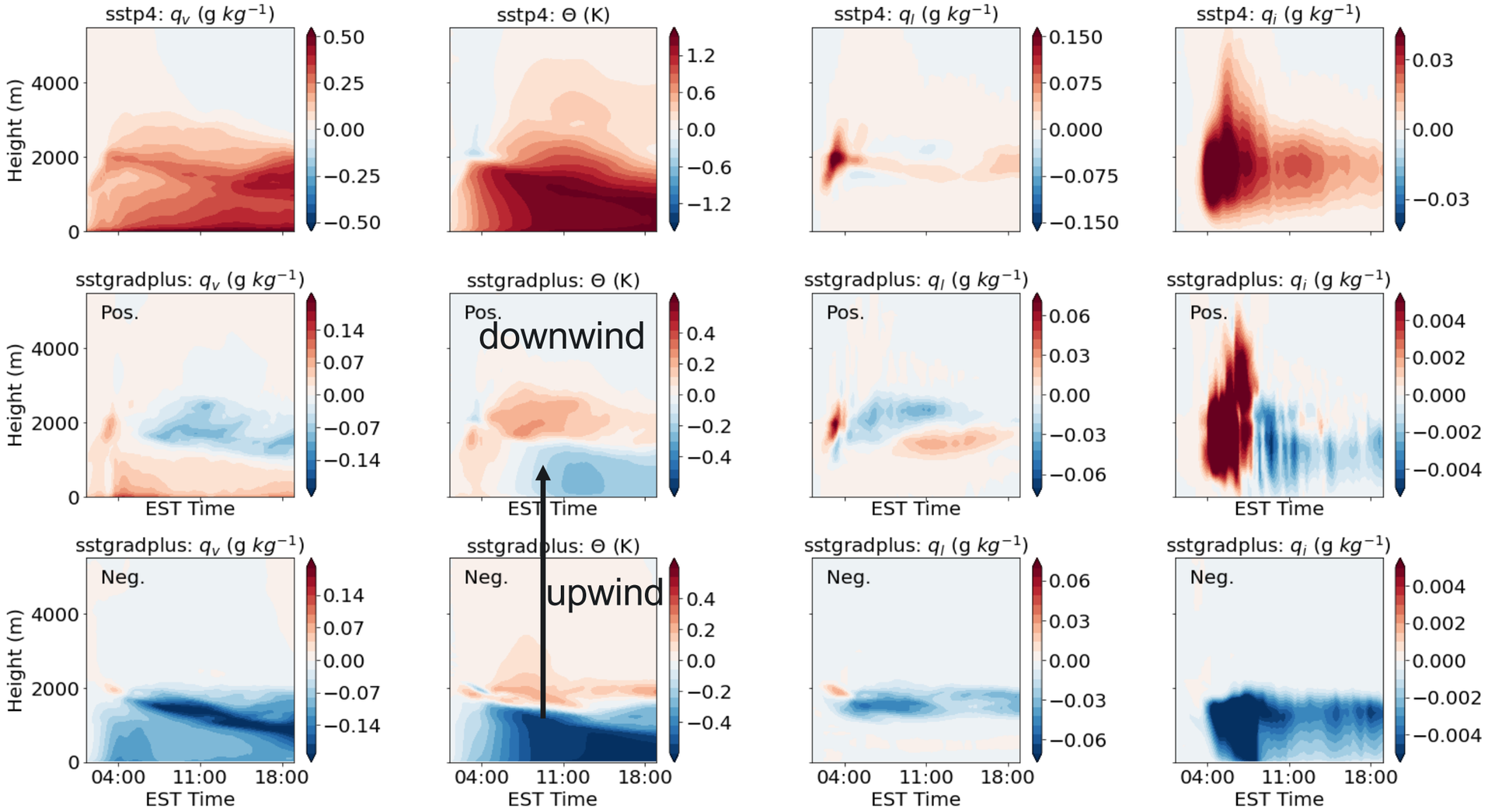


Inner domain



Time evolution of post-frontal clouds

Inner domain



sstgrad: Upwind low θ impacts the down-wind ones.

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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

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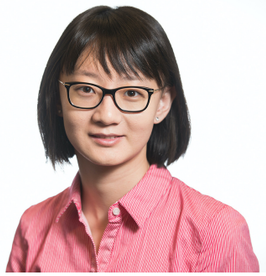
Thank you



Questions?
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