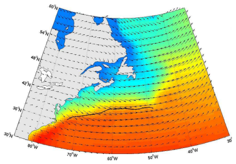
Using Ensemble Sensitivity to Understand the Role of Sea Surface Temperatures in Midlatitude Storm Development in the Gulf Stream Region

Jimmy Booth, Susan Bates,
LuAnne Thompson, Kathie Kelly

University of Washington

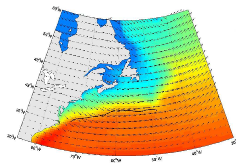
NASA OVWST Meeting

May 18-20 2009, Boulder, CO



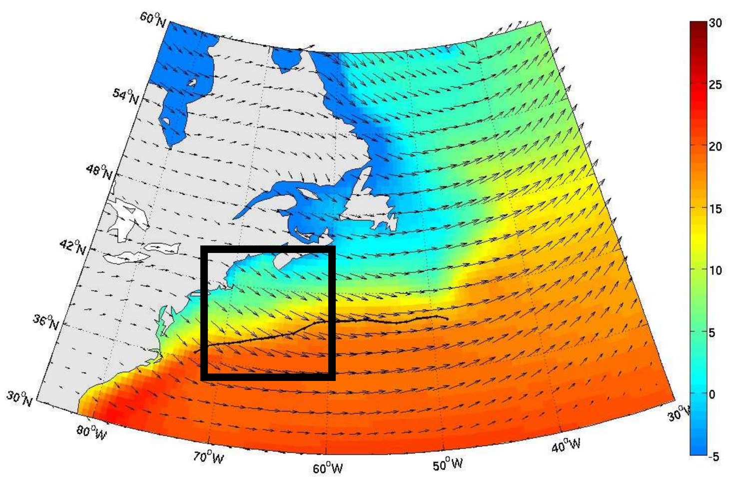
Outline

- Comparison of model (WRF) surface winds with QuikSCAT.
- Show sensitivity of midlatitude storms' central pressure and path to variations in sea surface temperature.
- Explore what physical forcings are responsible for the storm's sensitivity. •

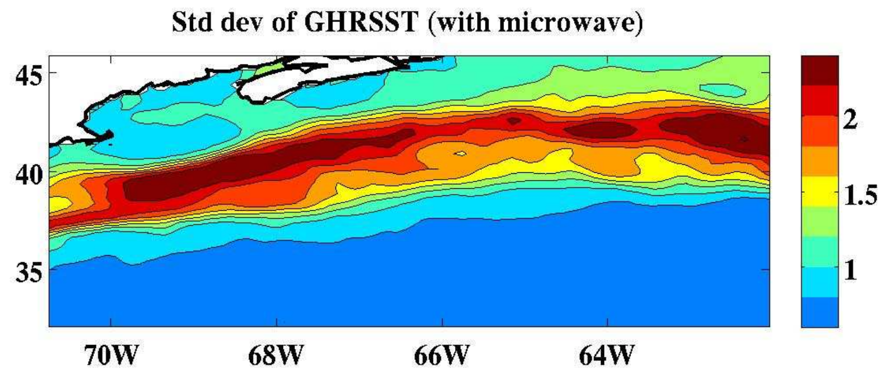


A brief review of winter conditions in the Gulf Stream region

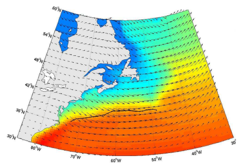
Wintertime Mean Sea Surface Temperature (SST) and 10m winds



Standard deviation of the SST in the Gulf Stream Region



•During winter, midlatitude storms frequently develop in, or near, the GS region (~3 per week).



The State of Things RE: Midlatitude Storms and SST

Known:

-Preconditioning due to latent and sensible heat fluxes are important to storm strength.

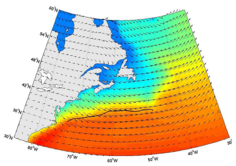
-Sensible heat fluxes affect surface baroclinic zone. *(Kuo, Reed, Low-Nam, MWR, 1993)*

Unknowns:

-Does the SST pattern impact the individual storms' paths?

-Is it the presence of warm water or the strong SST front that matters most?

-Is the water vapor that strengthens the storms from local (moisture fluxes induced by the storm) or remote sources?

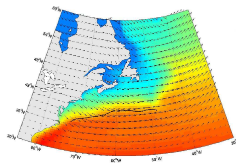


The Sensitivity Analysis Approach

1. Change the sea surface temperature (SST) field
2. Run the model with the new SST
3. Compare the storm path, intensity and intensification for the various SST configurations.

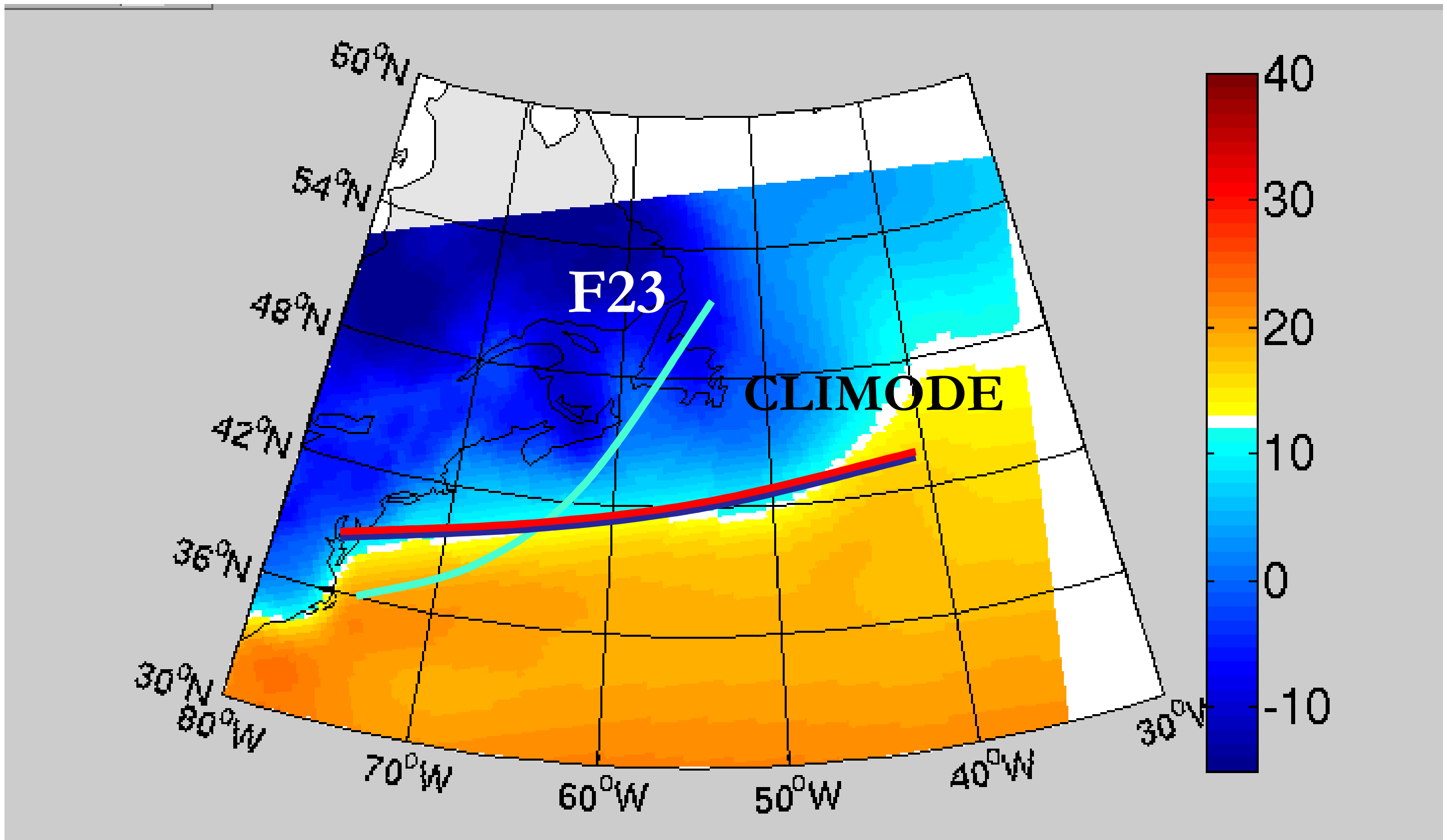
NOTES:

- SST is fixed thru-out the forecast.
- Model used:
  - NCAR's Weather Research Forecasting (WRF) Model.
  - Horizontal Resolution: 36Km. Vertical: Staggered, 38 levels.
  - Lateral and Initial Conditions, including SST: ERA-40 Interim Reanalysis (6 hourly, 1.25 degree horiz. resolution).



The storms used in the modeling study

Storm Paths shown over SST



JB1

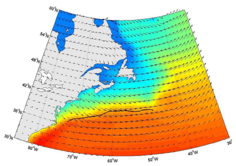
F23STORM
48 hour forecast
Feb 23, 2001 0Z -Feb25 0Z

CLIMODESTORM
48 hour forecast
Feb 22, 2007 0Z-F24 0Z

Slide 6

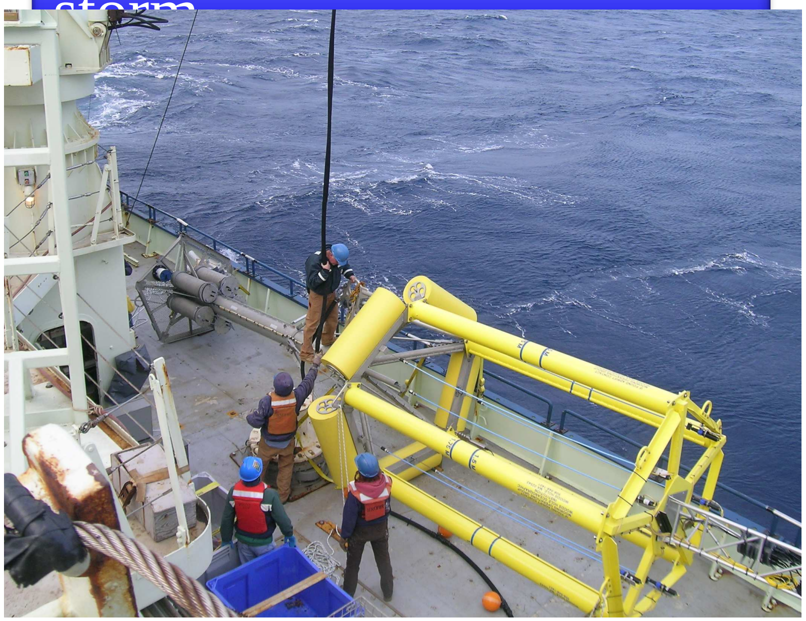
JB1 Reasons for choosing these storms:
F23: The storm has a meridional path across the Gulf Stream region, with intensification maximum over the SST gradient maximum.

CLIMODE observing ship was at sea during the CLIMODESTORM; it probably contained hurricane force winds.
James Booth, 5/13/2009



Damage to the CLIMODE buoy caused by the storm.

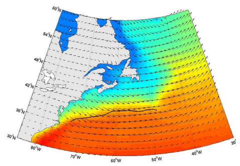
ASIS buoy before storm



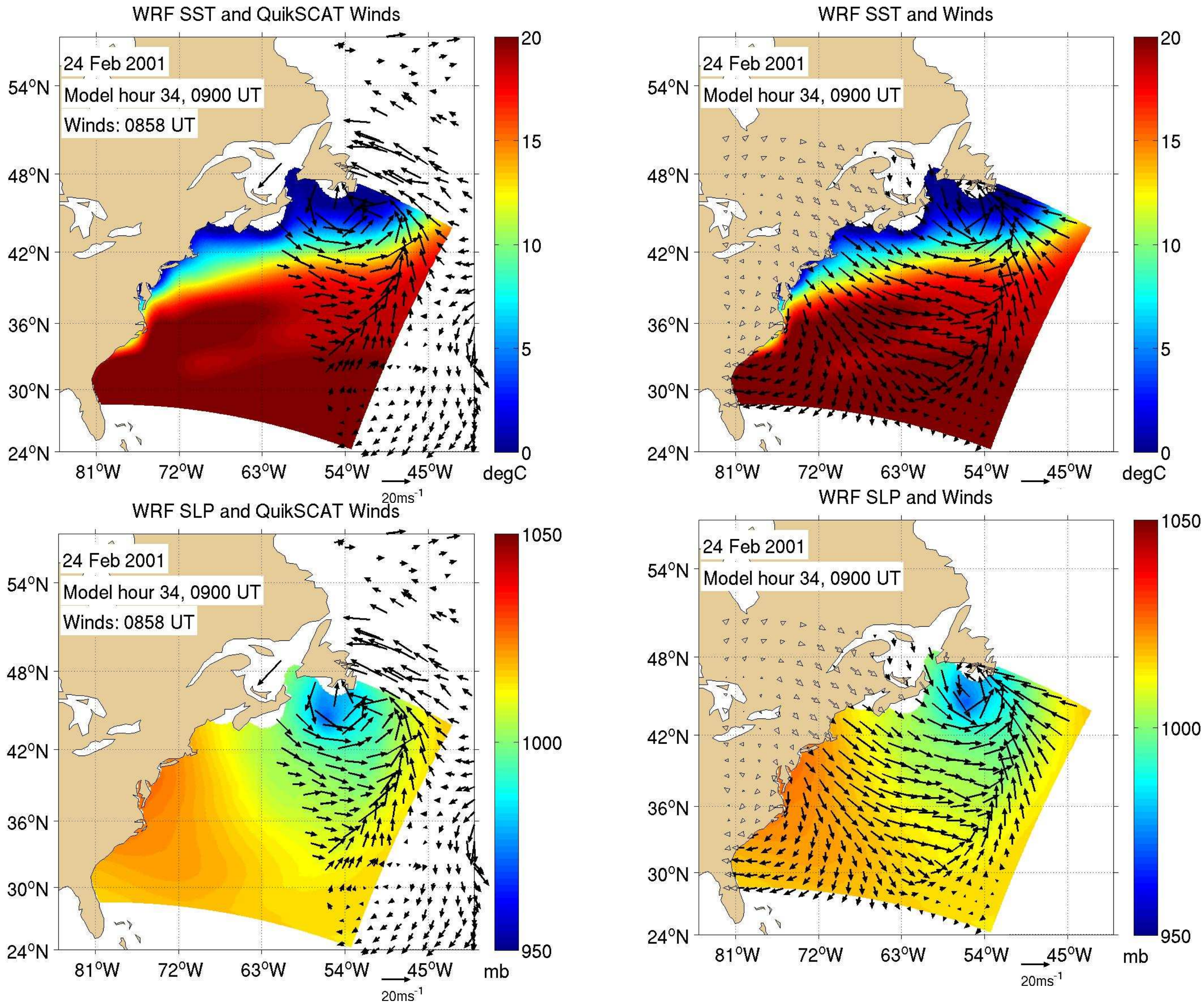
ASIS after the storm

In situ air-sea fluxes available from CLIMODE buoy.
Ship anemometer sometimes overtopped by waves.

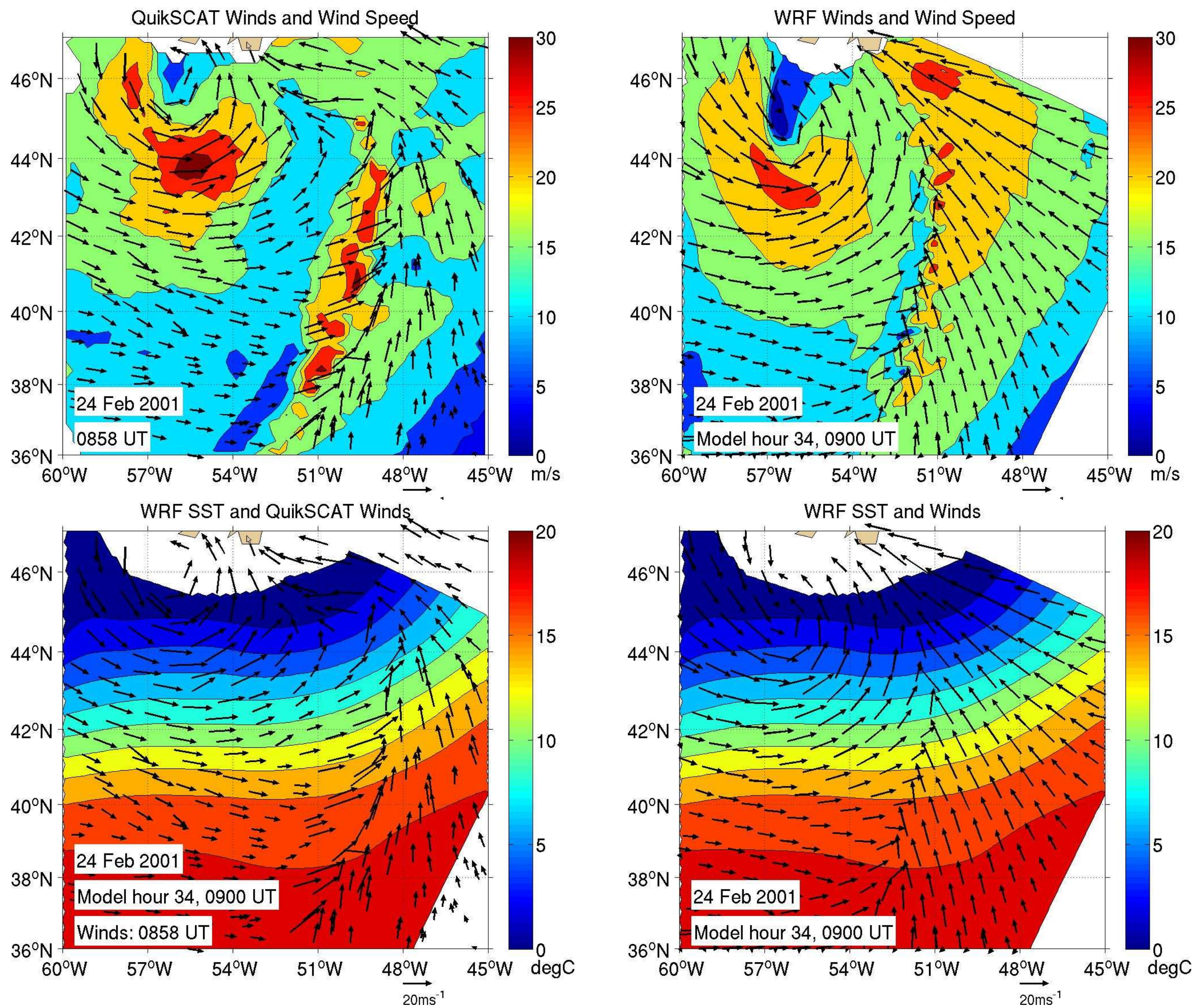
Photos courtesy Terry Joyce.

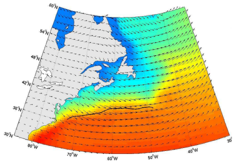


10M winds: WRF vs. QuikSCAT



Wind speed: WRF vs. QuikSCAT





The Ensembles and Analysis Technique

<u>Four separate ensembles for each storm:</u>

•Raise/Lower all SSTs

•Strengthen the gradient by:

-change SST on warm side only

-change SST on cold side only

-change SST on warm and cold side, maintaining mean SST.

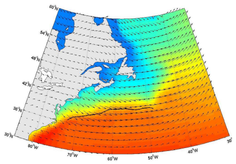
<u>Analysis</u>

•Track SLPmin position for each member

•Plot tracks for all ensemble members.

•Plot intensity vs. time for all members.

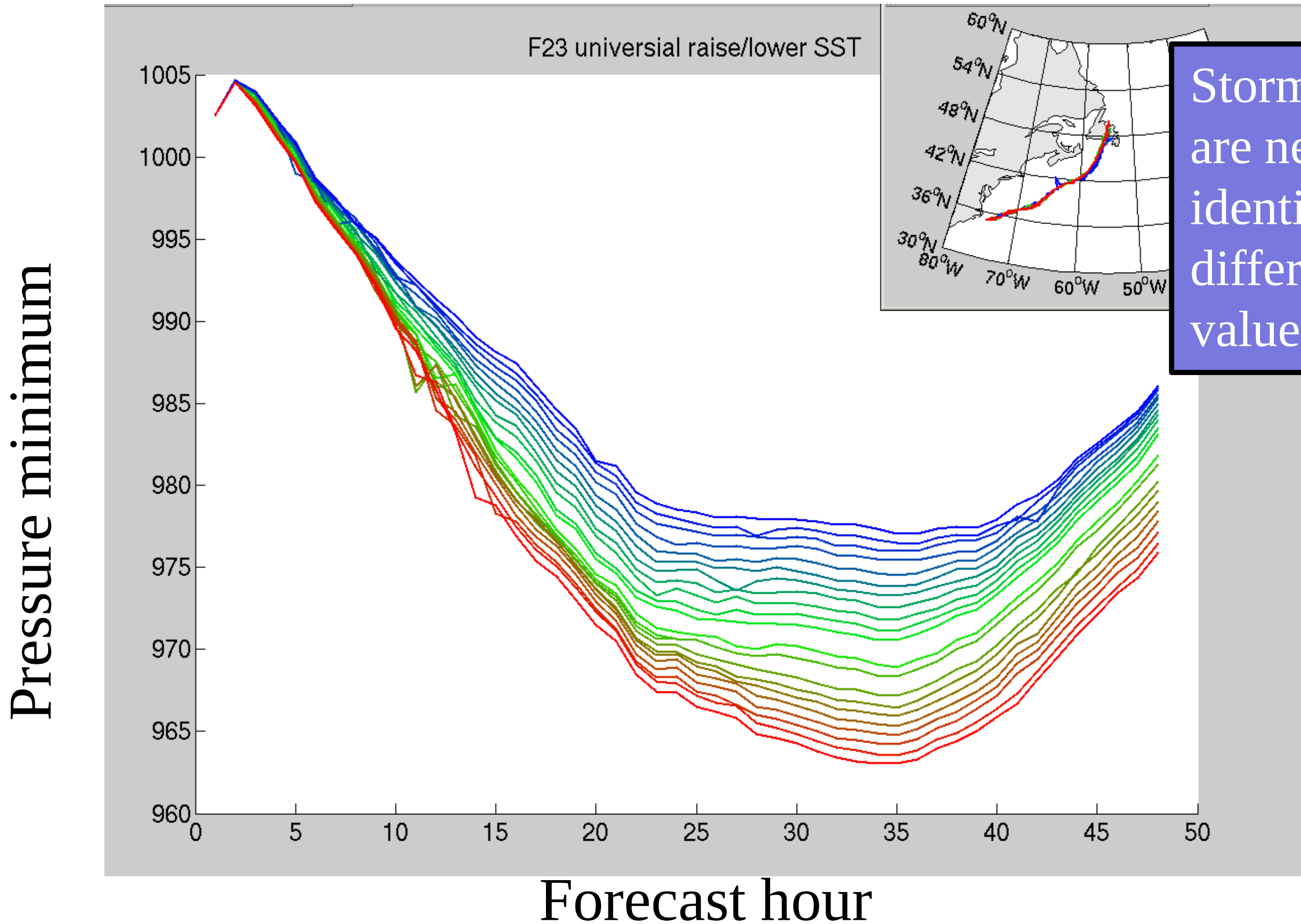
•Calculate regression statistics from ensembles.



F23 Increase/Decrease All SST: Storms' Path and Intensity

Red corresponds to warmer temperature and blue to colder.

SST perturbation per ensemble member: 0.2C

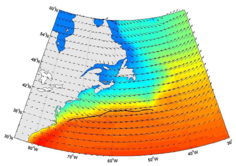


Storms' paths are nearly identical for different SST values.

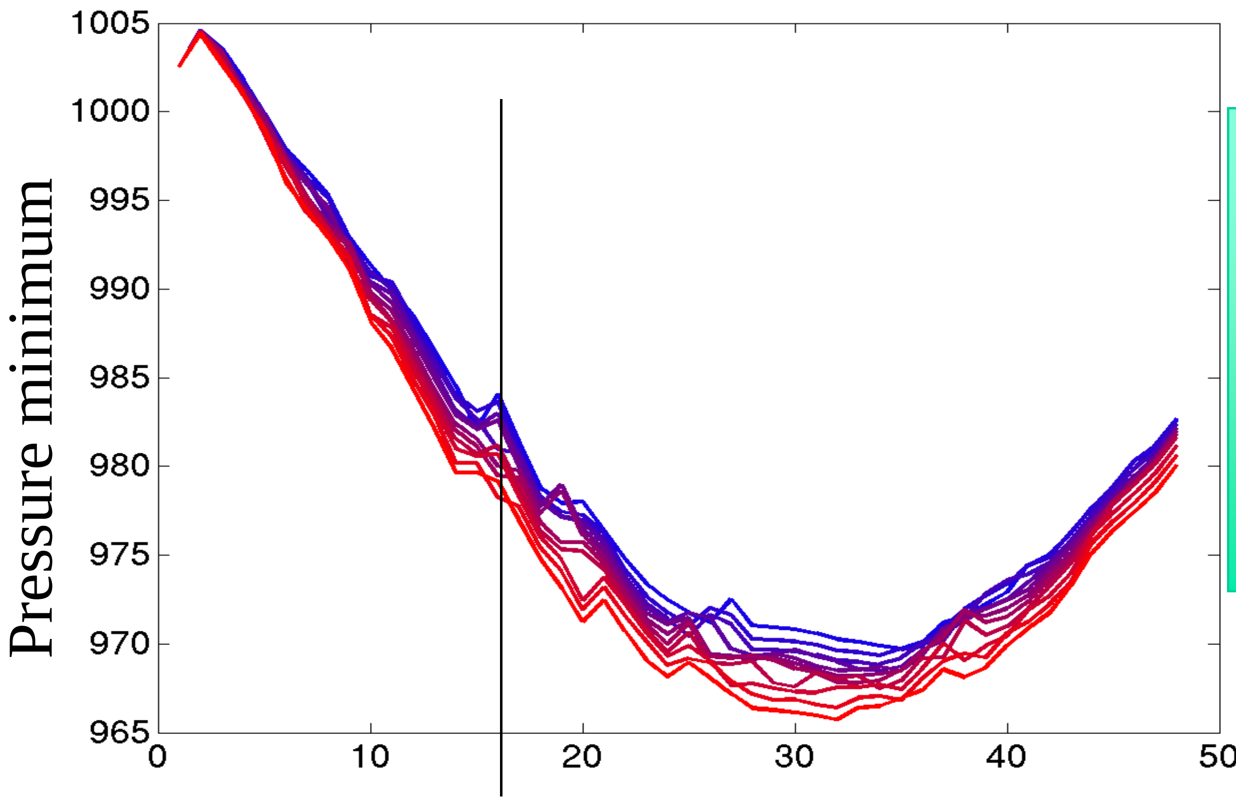
Result: The relationship between the uniform SST change and SLPmin is linear: ***warmer SST = stronger storm***

F23 SST GRADIENT AMPLIFICATION, but maintain the meridional mean (for storm local region) temperature

(i.e. warm the warmside and cool the coldside)



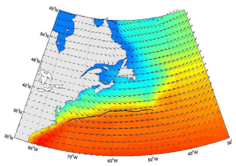
SST perturbation per ensemble member:
Warmside: +.4
Coldside: -.4



Blue = weakest gradient amplification.
Red = strongest gradient amplification

Storm crosses SST front at frct hr 16.

Forecast hour

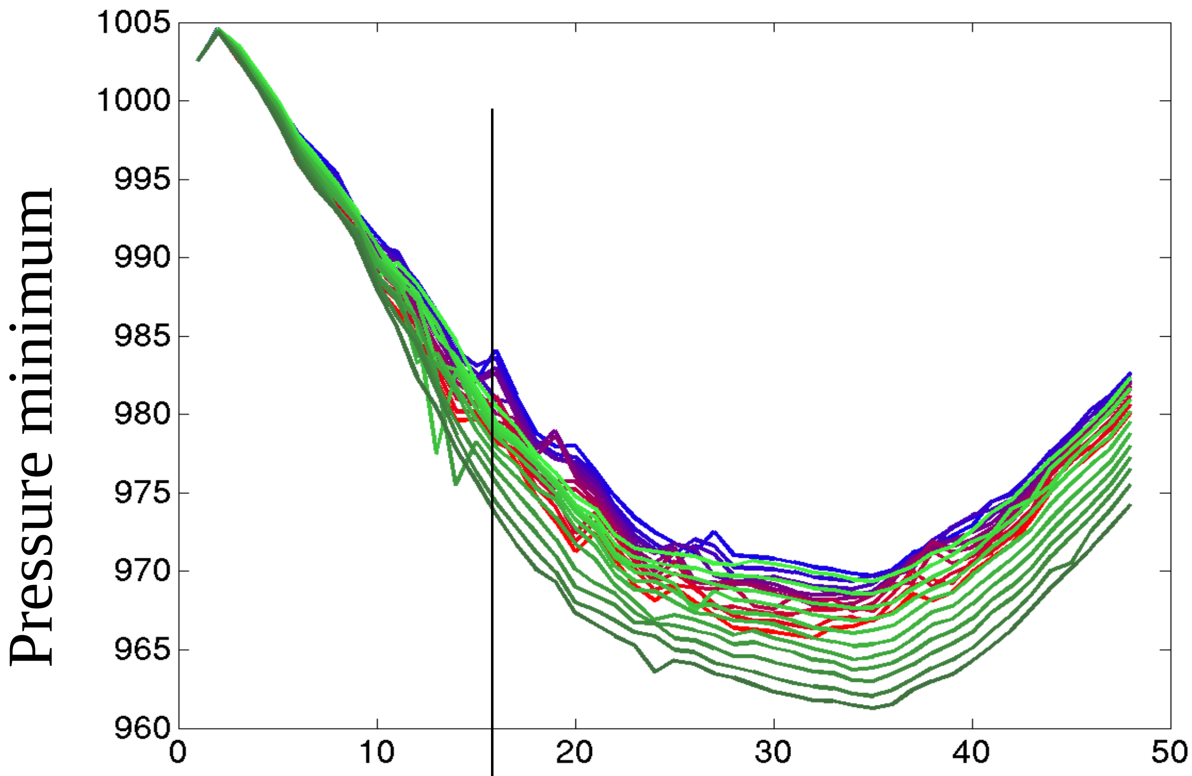


warm the warmside

VS.

warm the warmside and cool the coldside

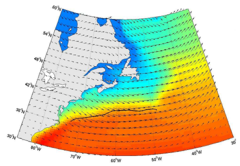
SST perturbation per ensemble member:
Warmside: +.4
Coldside: -.4



Storm crosses SST front at frct hr 16.

Forecast hour

Additional cooling of coldside causes strong SHLFX that damp the storm.



What type of surface fluxes are more important: latent (QFX) or sensible (SFX)?

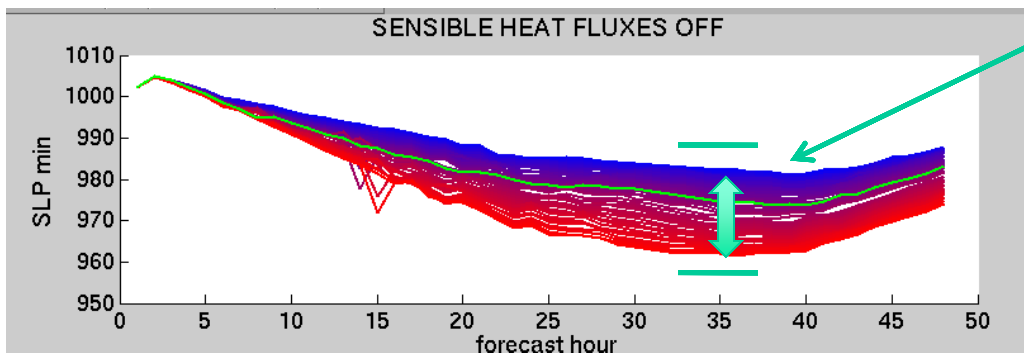
Change SST → Changes QFX and SFX.

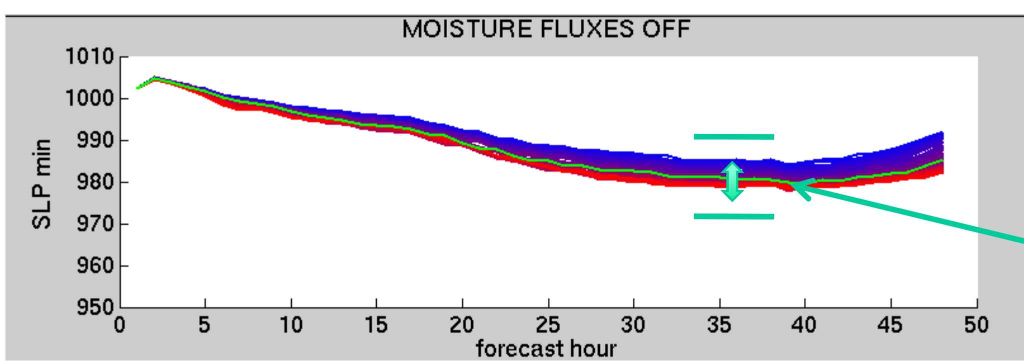
Which is more important?

2 more ensembles, SST AMP

1. QFX turned off in the model.
2. SFX turned off in the model.

Large sensitivity

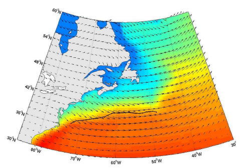




small sensitivity

Blue: SST is colder.
Red: SST is warmer.

RESULT:
When QFX is turned off, storms' SLPmin sensitivity to changes in SST is diminished.



Quantifying the Sensitivity

SLP’ : anomaly relative to Ensemble mean.

SST’ : anomaly relative to Ensemble mean.

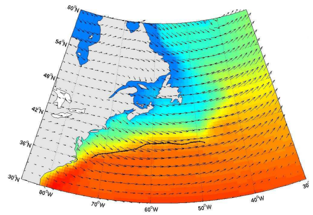
$$\tilde{s} = sensitivity = \frac{\sum SLP' SST'}{\sqrt{\left(\sum SST'^2\right)}} = \frac{\mathrm{cov}(SLP', SST')}{\sigma(SST)}$$

$$\tilde{s}_{DEFAULT} = -7.8$$

$$\tilde{s}_{NO-SHFX} = -6.1$$

$$\tilde{s}_{NO-QFX} = -2.1$$

Turning off the moisture flux → smaller sensitivity.



Conclusions from SST vs. SLP and Path.

- The storms are stronger when there is more warm water present.
- The storms are more sensitive to the SST warming in the regions of their early development.
- For equal warming of the warm side, the storms do not intensify more due to a stronger SST gradient.
- Storm path does not respond to SST amplification, nor SST gradient amplification.
- The storms intensification is mostly driven by increased diabatic heating caused by condensation.
- Water vapor added to the atmosphere from storm-local moisture fluxes does make its way into the storm and aid intensification.

Next:

1) Increase SST gradient to compensate for weak response to SST
2) Modify PBL, if possible (Song & Chelton)
3) Compare fluxes with CLIMODE mooring

***Final comment*:**

These results do not prove that storms will become stronger in a warmer climate. GCM studies show that *there may be compensating changes to the troposphere that will limit* the importance of any storm intensification related to stronger moisture fluxes (related to warmer SSTs) from strengthening storms, e.g. **O'Gorman and Schneider, J. Clim, 2008.**