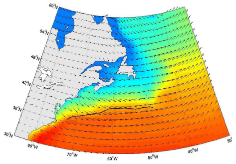


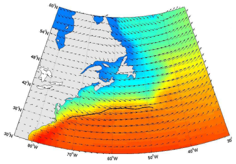
Air-Sea Interaction Over the Western North Atlantic Ocean

Jimmy Booth, Susan Bates, Jessica Kleiss,
Suzanne Dickinson,
LuAnne Thompson, *Kathryn Kelly*

University of Washington

NASA OVWST Meeting

August 19-21 2009, Arlington, VA



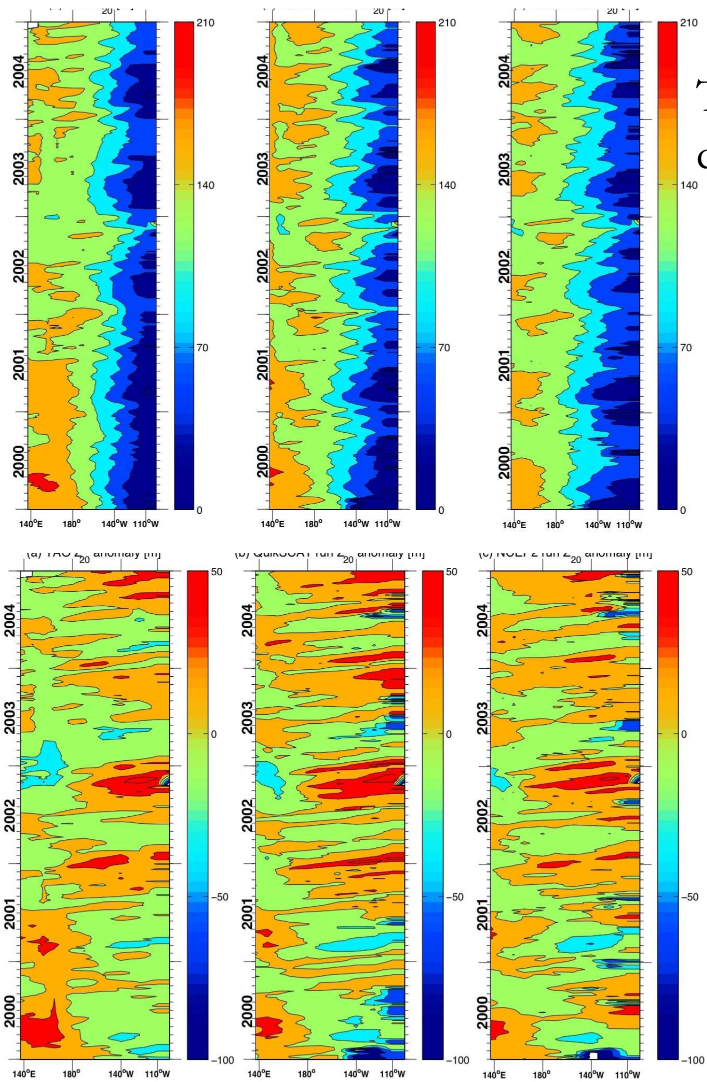
Outline

- Wind-forced ocean circulation
- Extratropical storm track
- Sensitivity of storms to SST
- Comparison of model (WRF) surface winds with QuikSCAT
- Wind speed validation • (ship, mooring)
- Air-sea fluxes in CLIMODE

Wind-forced Ocean Circulation:

Model response to QuikSCAT vs. NCEP winds

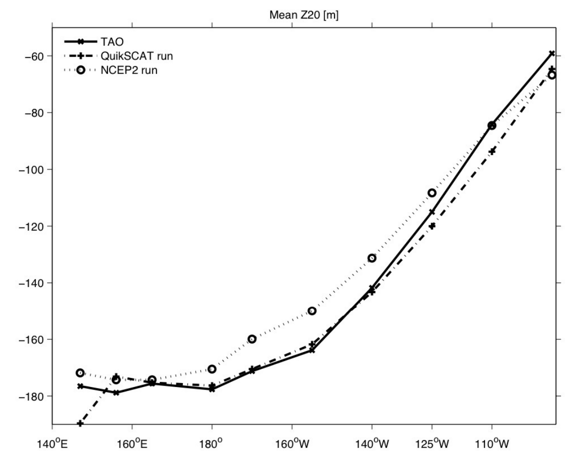
TAO QuikSCAT NCEP2



Thermocline depth

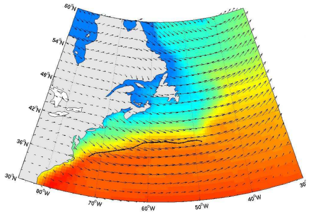
Thermocline anomaly

HIM in Tropical Pacific Ocean



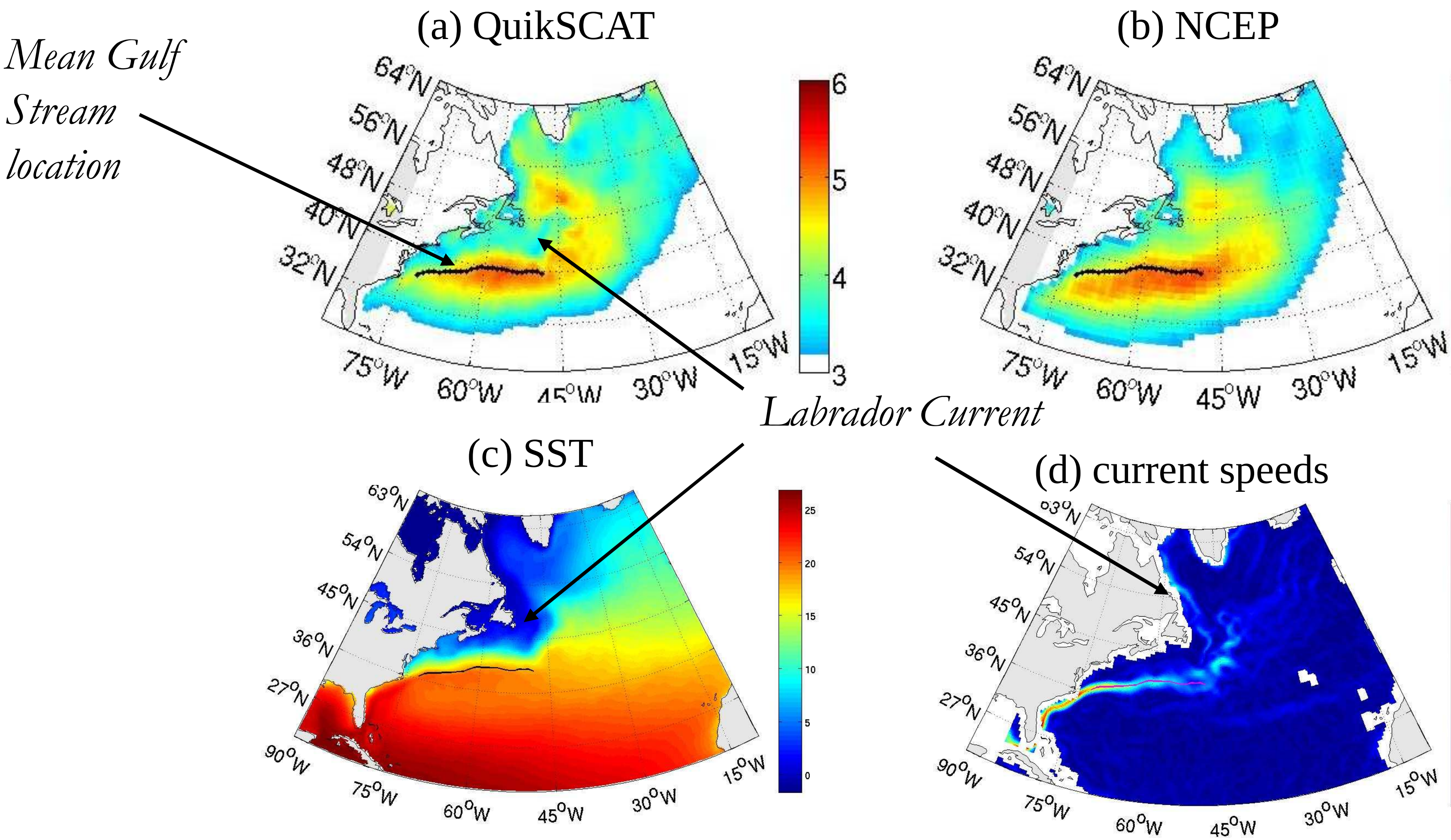
QuikSCAT (dash)gives more accurate thermocline depth than NCEP2 winds (dotted)

Jiang et al, Ocean Modelling, 2008

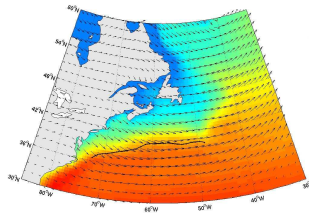


Wintertime Conditions in North Atlantic

Wintertime (DJFM) surface stormtrack (2-8 day meridonal winds)

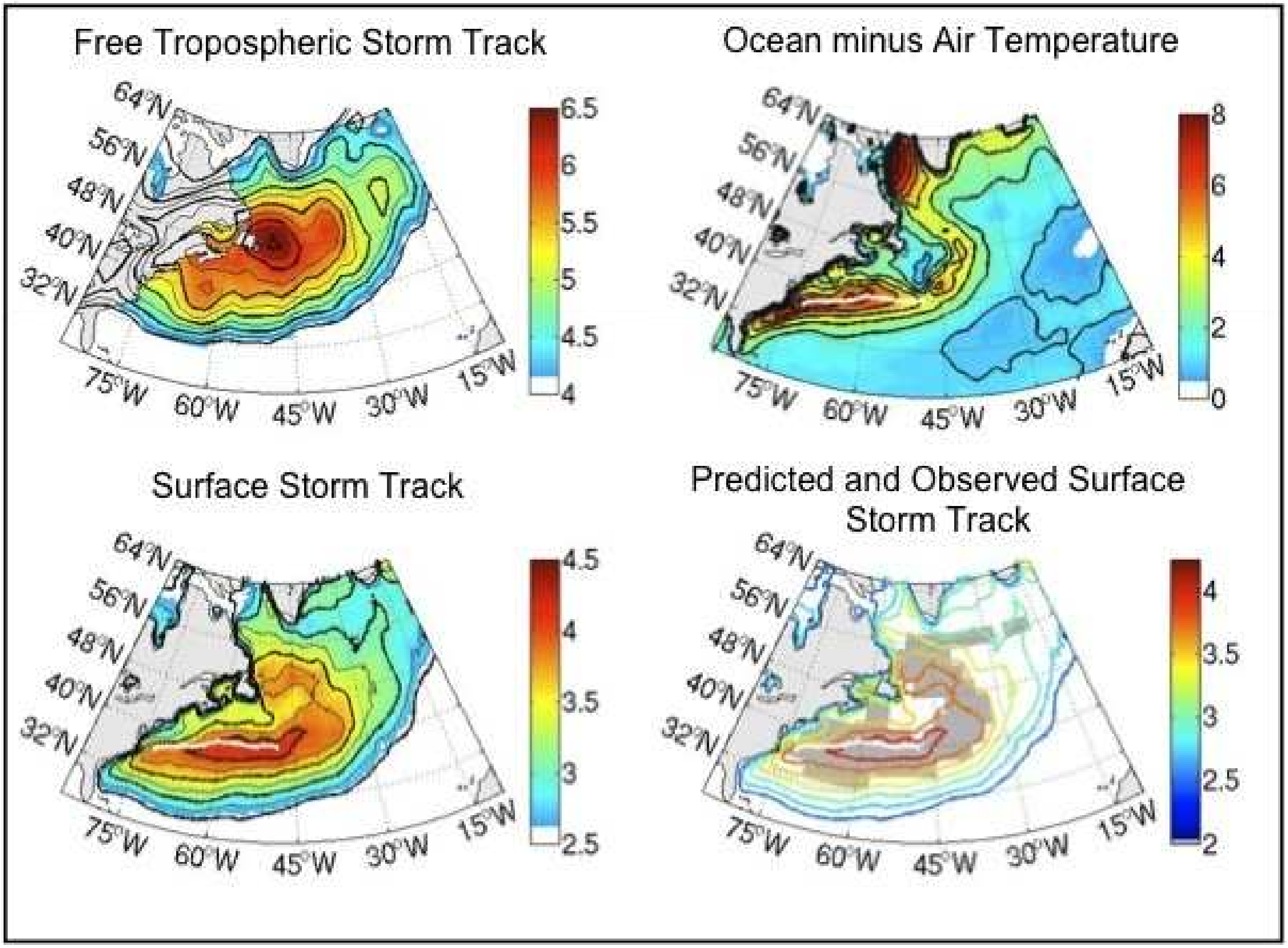


During winter midlatitude storms frequently develop near the GS (~3 per week)



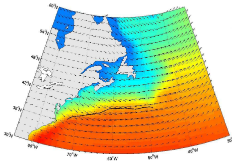
The Surface Storm Track

Surface stormtrack from QuikSCAT reflects influence of storm track aloft and stability of the atmospheric boundary layer (from strong SST gradients)



Gray shading: regions in which amplitudes of tropospheric track and instability are in the top quartile

Booth et al., 2009, revised for J Climate



Storm Sensitivity Study

Sensitivity of midlatitude storm intensification to Gulf Stream SST in the weather forecasting model (NCAR's WRF)

Questions:

Does the SST pattern impact the individual storm paths?

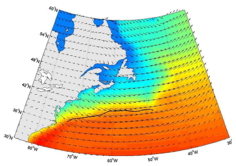
Does the SST affect storm intensification?

Is it warm water or SST gradient that matters most?

Model Setup:

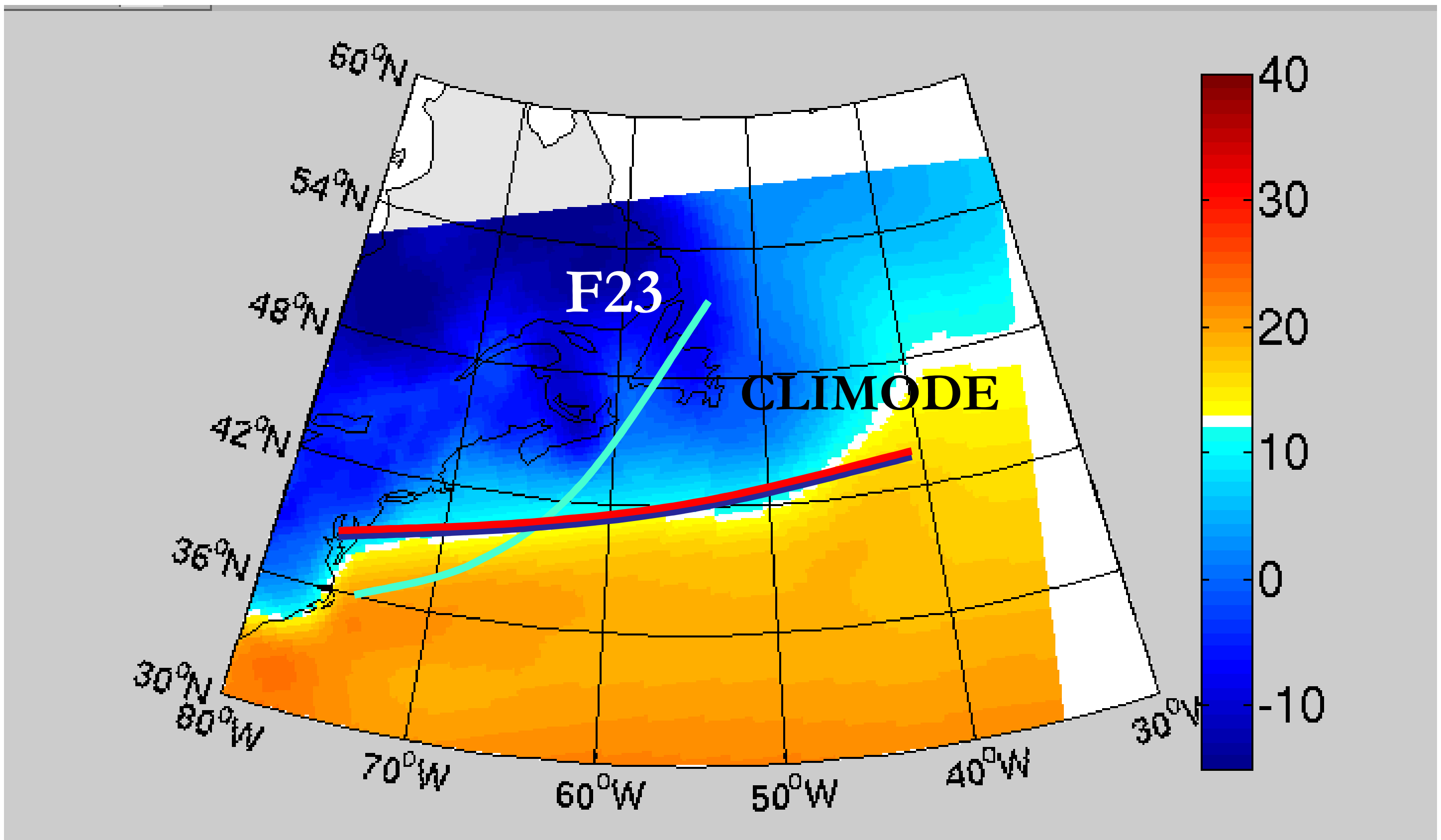
- Horizontal Resolution: 36 km.
- Vertical: Staggered, 38 levels.
- Boundary and initial conditions, including SST: ERA-40 Interim Reanalysis (6 hourly, 1.25 degree)

Methodology: for a single storm examine evolution of the storm's central pressure



Storms Used in Modeling Study

Storm paths shown over SST



JB1

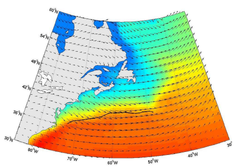
F23 STORM
48 hour forecast
Feb 23, 2001 0Z -Feb25 0Z

CLIMODE STORM
48 hour forecast
Feb 22, 2007 0Z-F24 0Z

Slide 7

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.

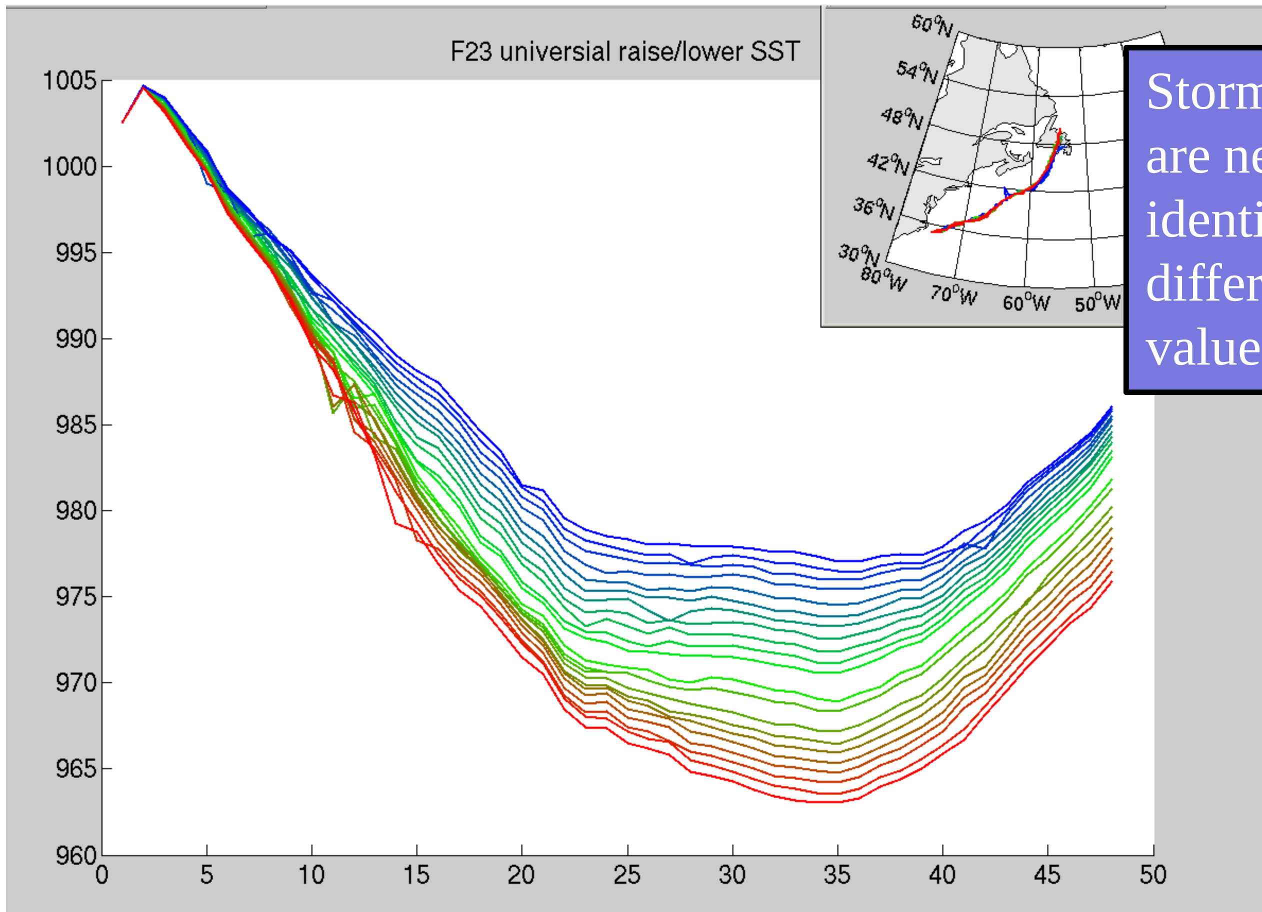
CLIMODE observing ship was at sea during the CLIMODESTORM; it probably contained hurricane force winds.
James Booth, 5/13/2009



Uniform Increase in SST

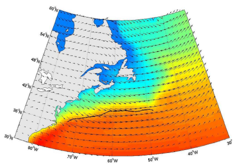
Red corresponds to warmer temperature and blue to colder.

SST perturbation per ensemble member: 0.2C



Storms' paths are nearly identical for different SST values.

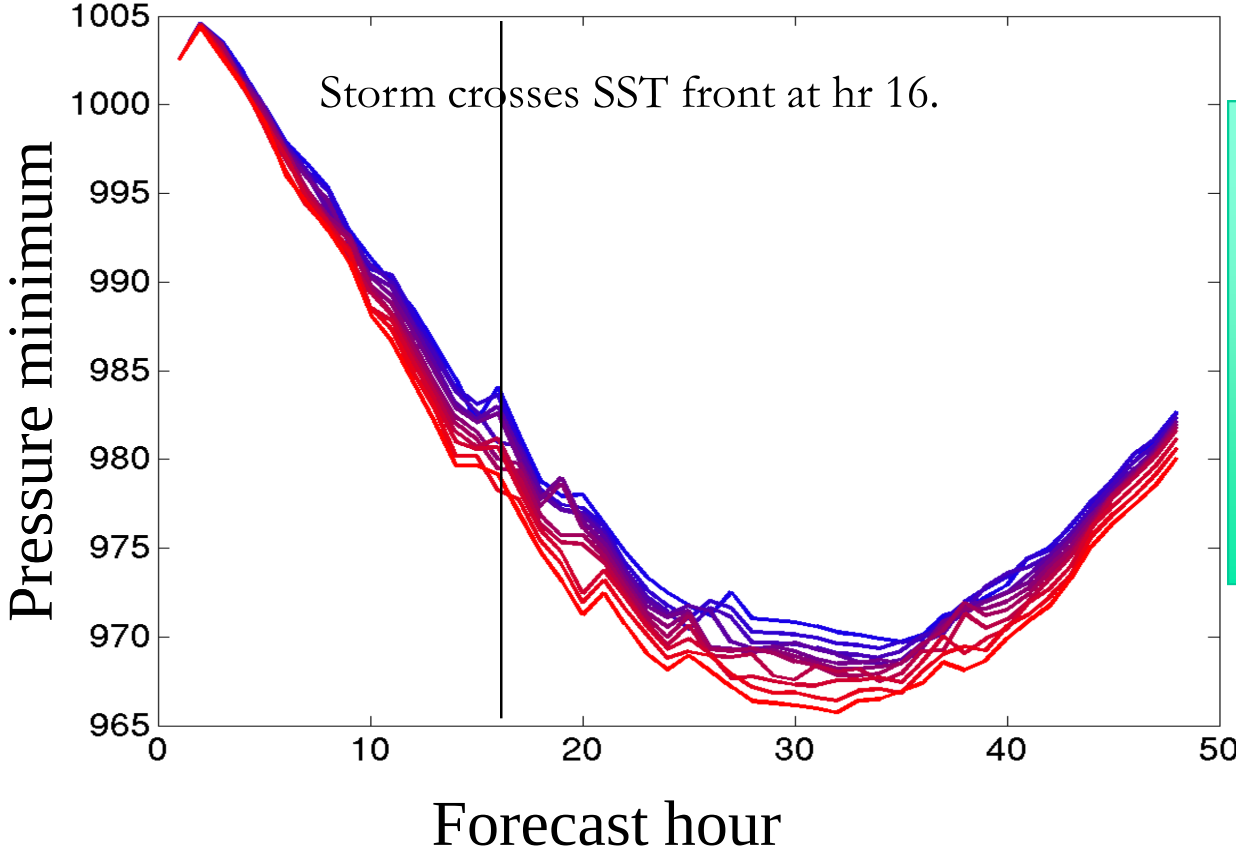
Result: warmer SST => stronger storm



Increase SST Gradient

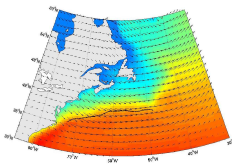
maintain the meridional mean SST
(warm the warmside and cool the coldside)

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



Blue = weakest gradient amplification.
Red = strongest gradient amplification

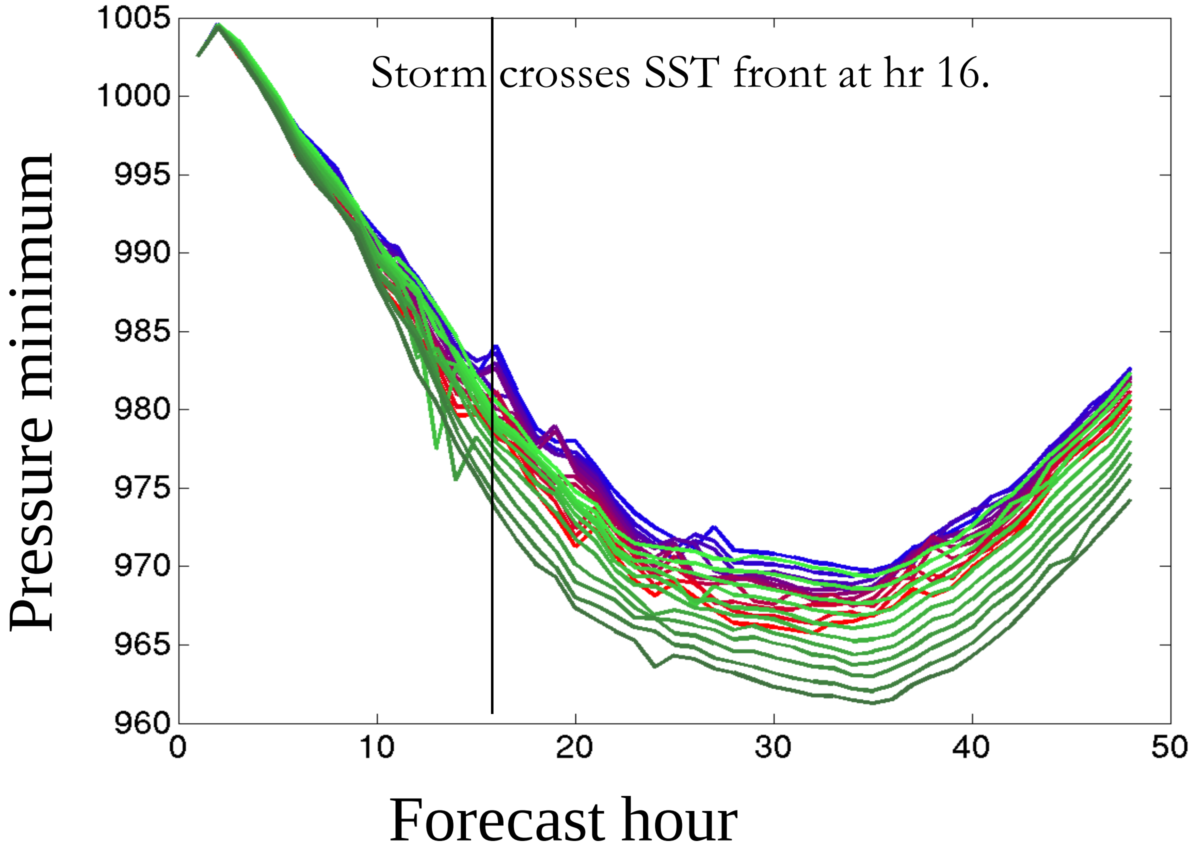
Result: stronger SST gradient => little effect



Warming Vs. Gradient

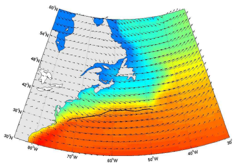
warm the warm side vs.
warm the warm side and cool the cold side

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



Additional cooling of cold side causes strong SHF that damps the storm.

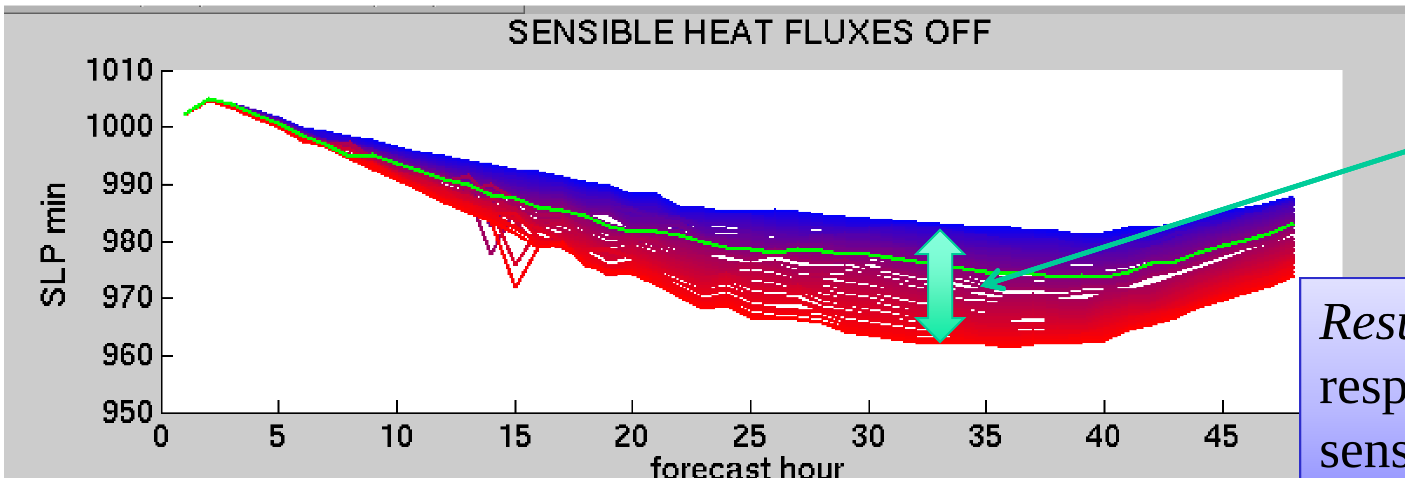
Result: cold side weakening cancels warm side strengthening



Effect of Heat Fluxes

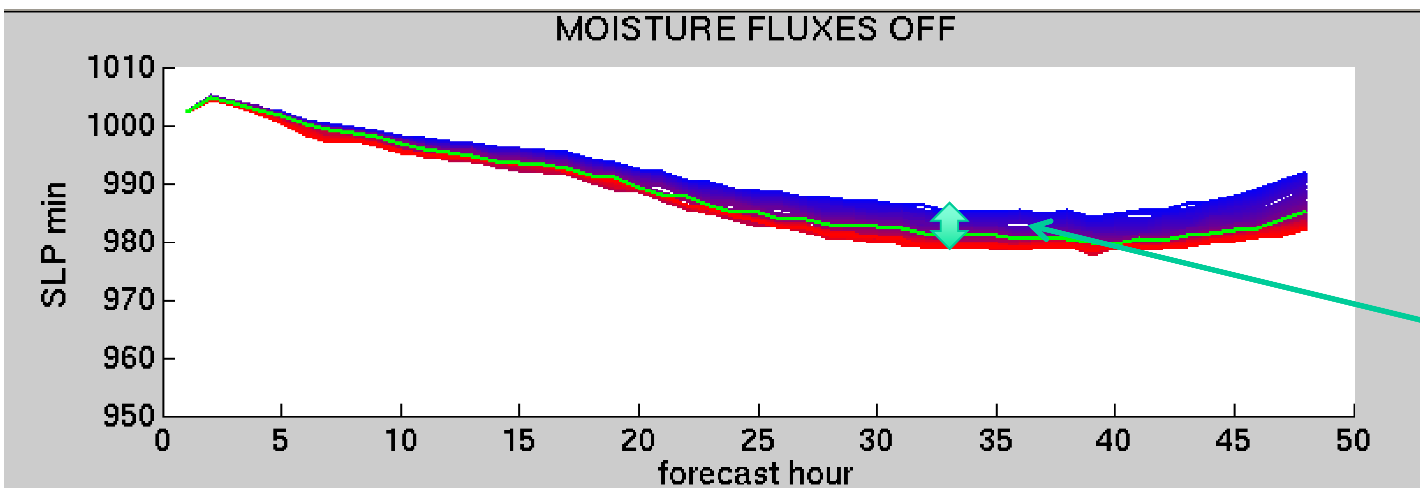
Which is more important: latent (LHF) or sensible (SHF)?

Blue:colder Red: warmer

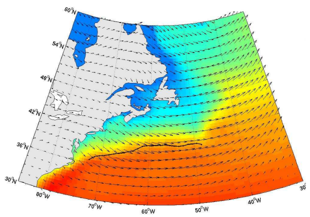


LHF only: Large sensitivity

Result: LHF is mostly responsible for storm sensitivity to SST



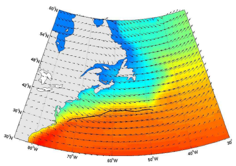
SHF only: Small sensitivity



Conclusions from WRF Experiments

- Storms are stronger when water is warmer
- Storms are more sensitive to warming in their early development
- Storm intensification is more sensitive to a warmer GS region than to the SST gradient.
- Storm path does not respond to SST or SST gradient changes
- Storm intensification is mostly driven by LHF (diabatic heating from condensation)

Caveat: Storm intensification from warmer SSTs may be offset by climate change in the troposphere from global warming *(O'Gorman and Schneider, J. Climate 2008)*

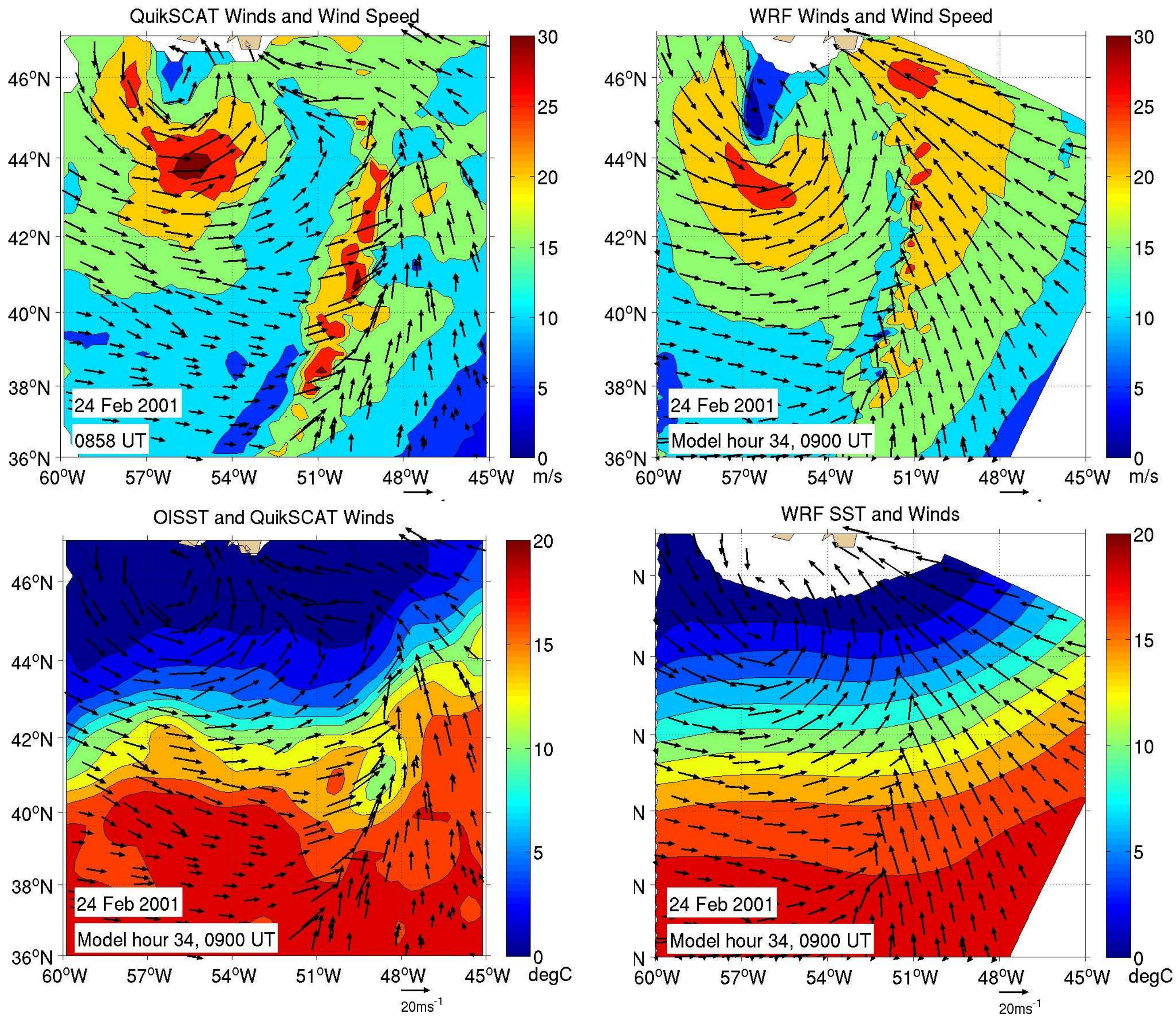


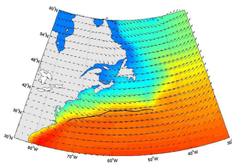
Model validation:

Observations (left) WRF (right)

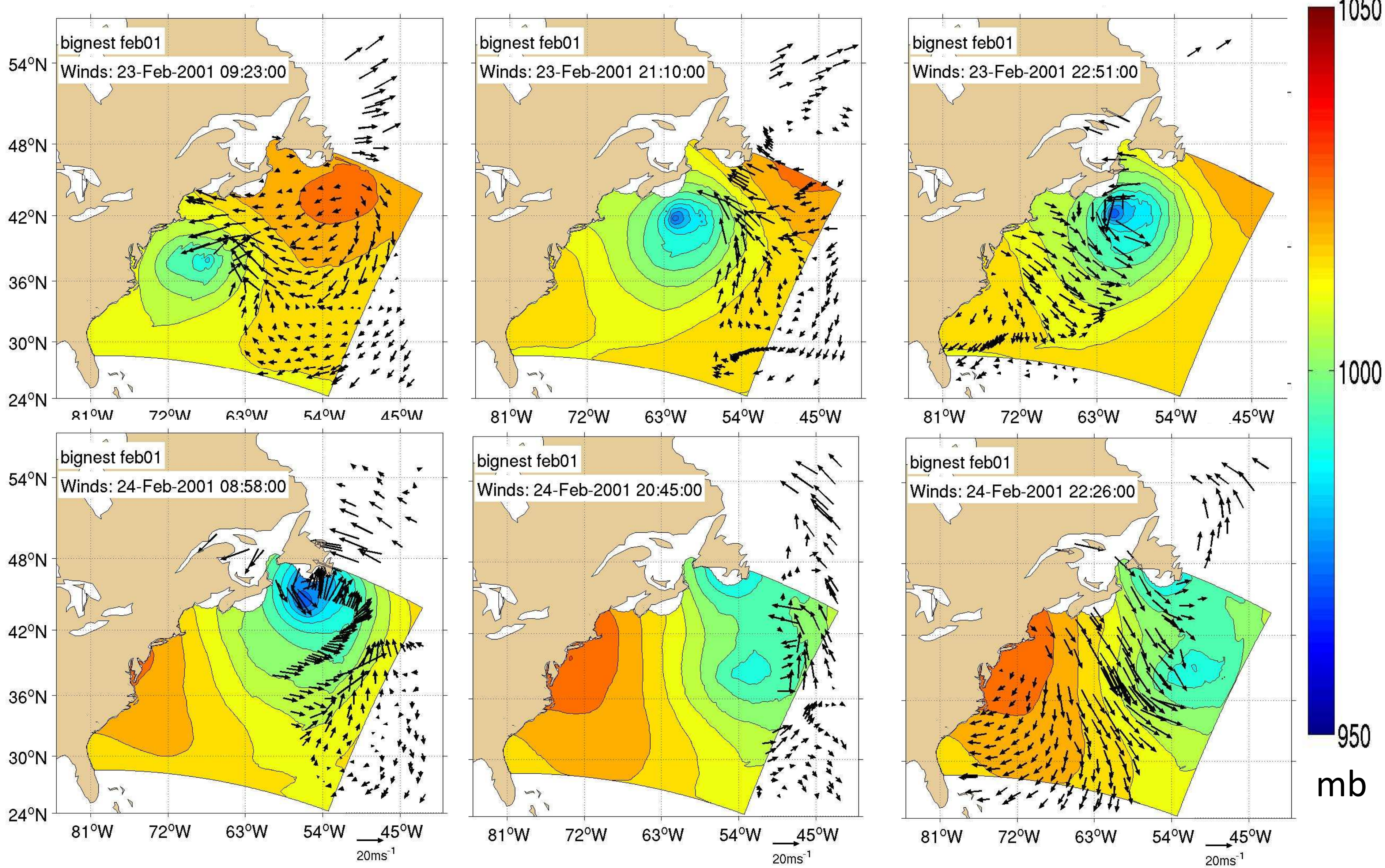
Wind speed too high over cold water, too low over warm water(unstable)

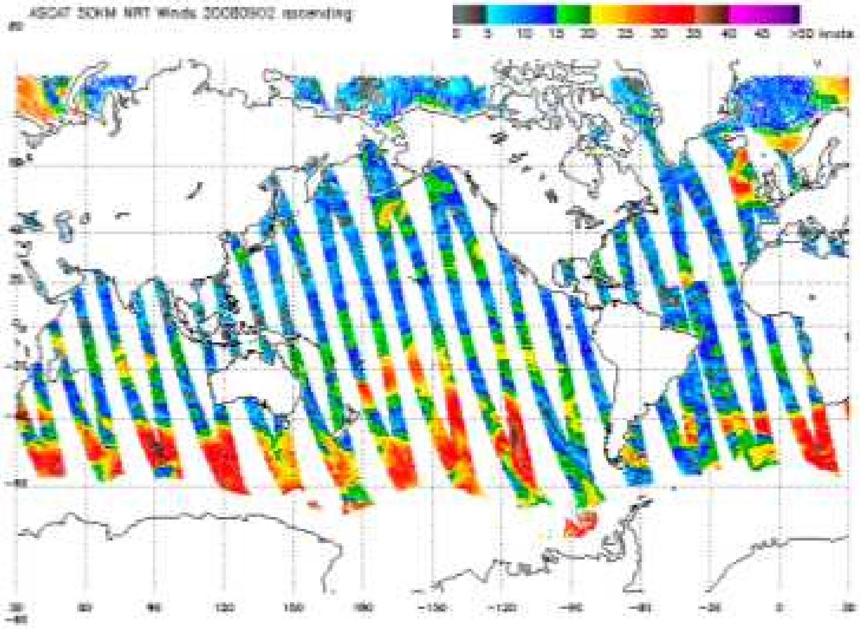
SST: WRF uses smoothed fields, less frontal structure

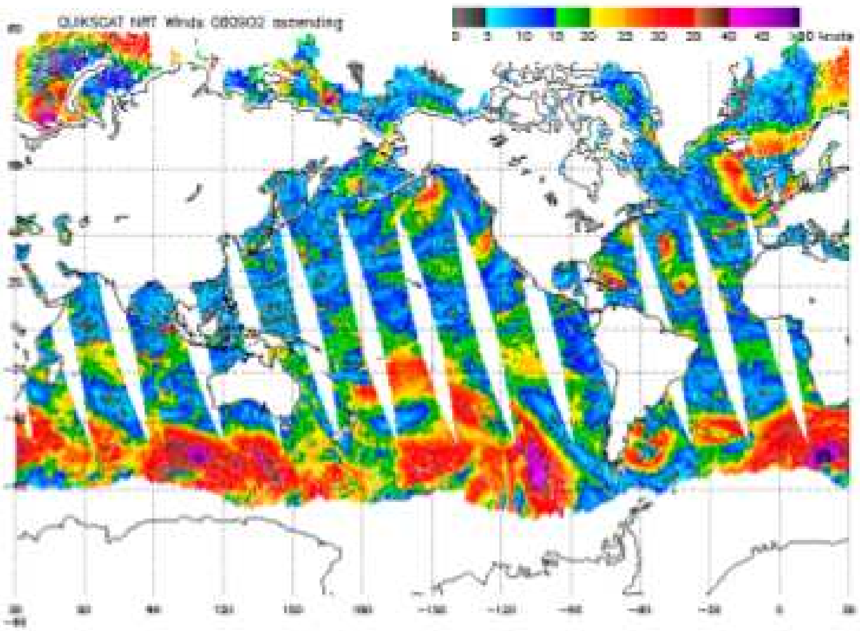




Storm Coverage by QuikSCAT:
the best swaths over 2 days





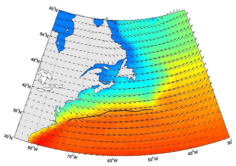


Model Storm Validation

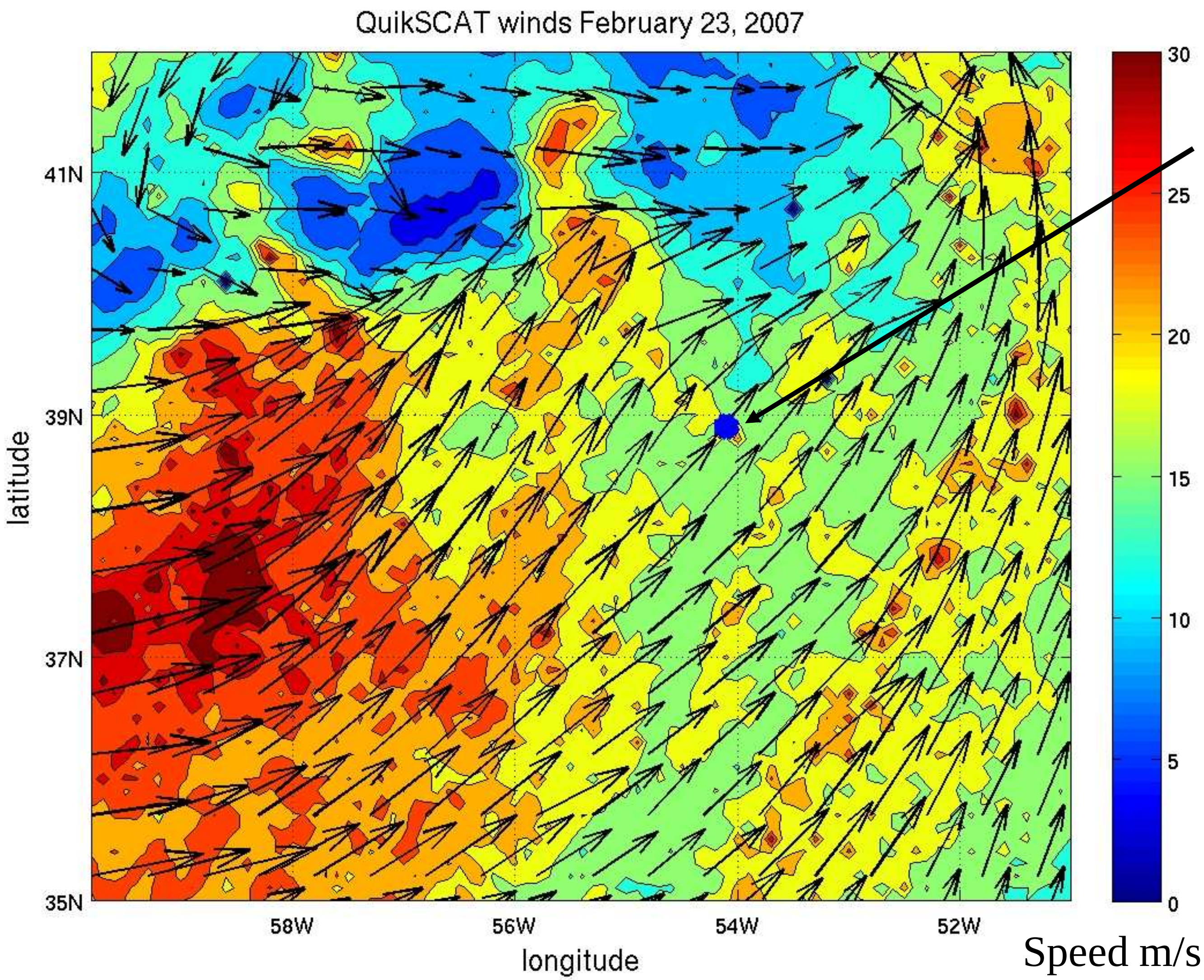
ASCAT vs. QuikSCAT coverage

Daily coverage of ascending passes from ASCAT (top) and QuikSCAT (bottom) from 02 September 2008

(Ahmad, Sienkiewicz, Jelenak, and Chang)

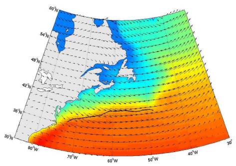


CLIMODE Storm Validation:
23 February 2007 Storm



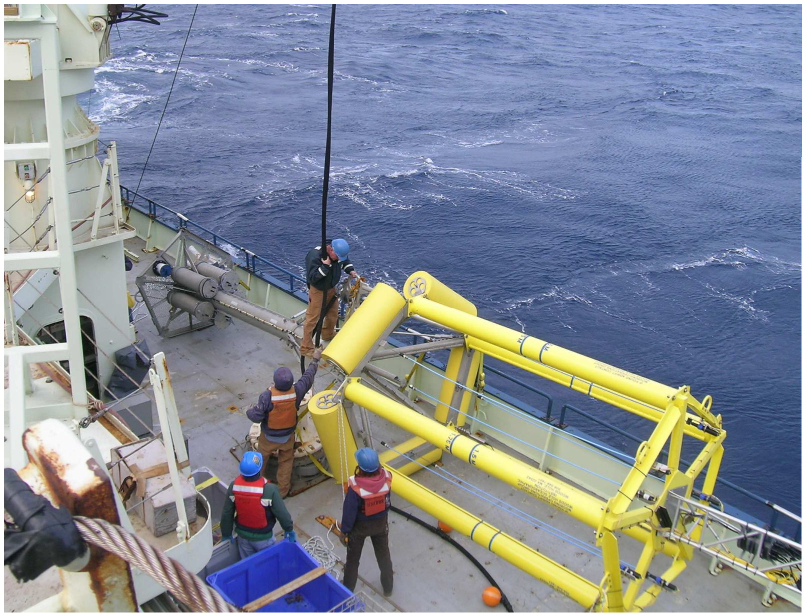
R/V Knorr

Hurricane force wind speed threshold: 32.5 m/s



CLIMODE Storm Damage

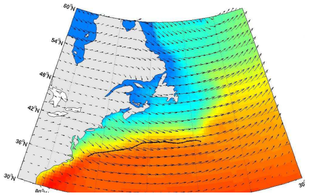
ASIS buoy before storm



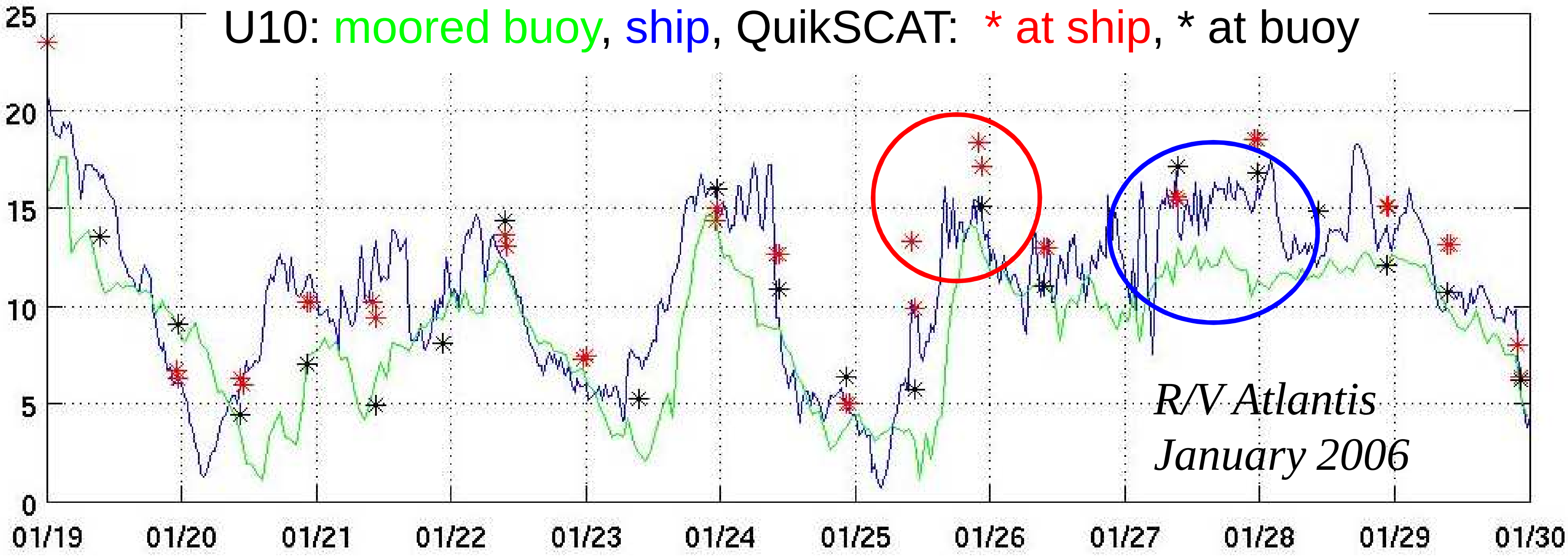
ASIS after the storm

Photos courtesy Terry Joyce.

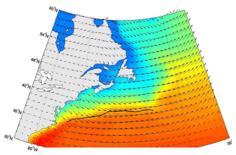
- Ship anemometer overtopped by waves at times
- Winds near Gulf Stream reached hurricane force
- In situ winds & air-sea fluxes available from mooring, buoy & ships



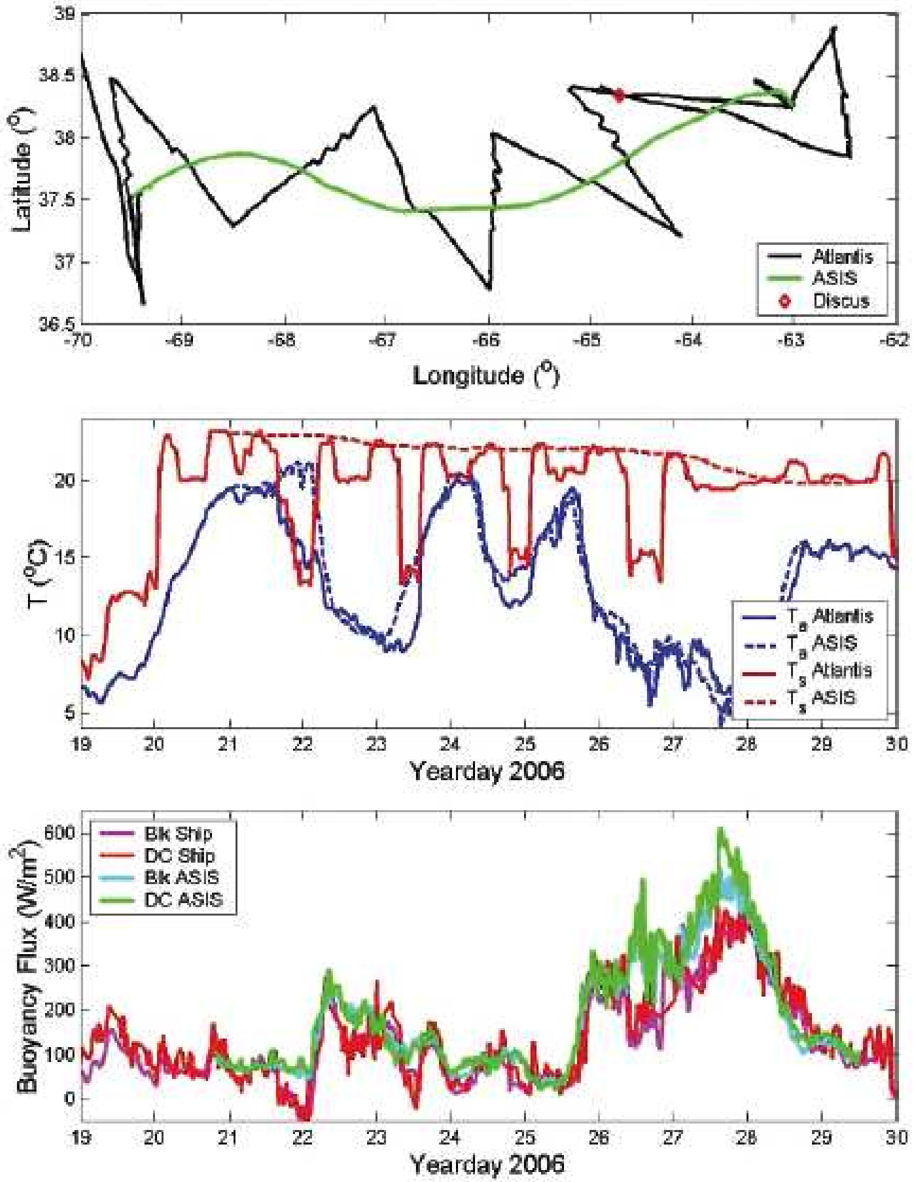
Wind Speed Comparisons in CLIMODE



- QuikSCAT 2-3 m/s high at times
- Neutral winds ~0.5 m/s bias
- Ship winds ~2-3 m/s higher than buoy (wave sheltering?)

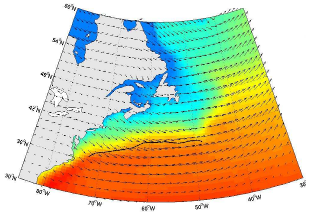


CLIMODE Field Program: heat fluxes



- (top) Ship track criss-crossing the Gulf Stream & ASIS (green)
- (middle) Air temp. (blue) and SST (red) for ship and ASIS buoy
- (bottom) Buoyancy fluxes: bulk and direct covariance for ship and ASIS (ship fluxes smaller)

The CLIMODE Group, submitted to BAMS



Air-Sea Heat Fluxes in CLIMODE

Taylor diagram shows *correlation* and *relative magnitudes*

LHF from mooring/COARE = "truth" (red dot)

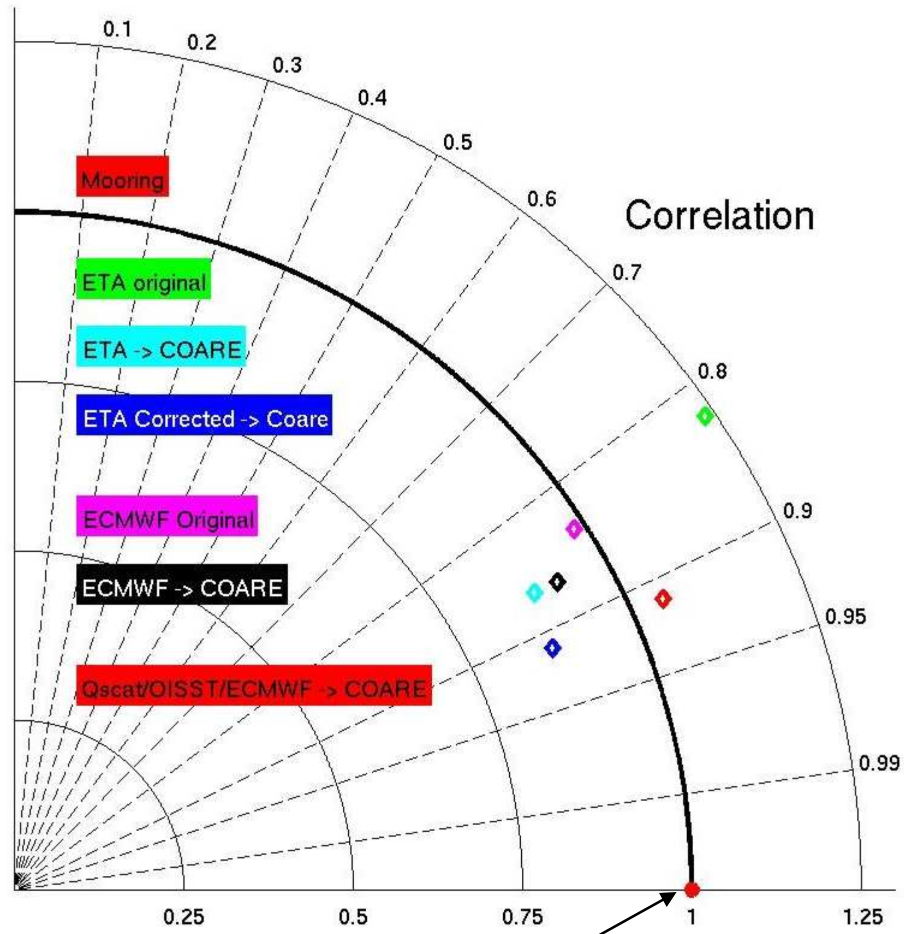
ETA/NAM fluxes too energetic

COARE bulk formula reduces magnitudes

OISST + air temp. correction improves ETA

ECMWF/COARE comparable to ETA

QuikSCAT/OISST improves ECWMF *(advantage over ETA: global)*



LHF from mooring

Conclusions

WRF/QuikSCAT comparisons:

• Model wind speeds insufficiently sensitive to stability

• QuikSCAT coverage (at least) needed for model storm evaluation

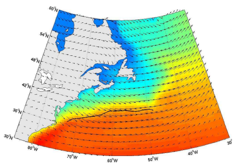
CLIMODE Comparisons:

• Wintertime Gulf Stream tests extremes of wind & fluxes

• QuikSCAT wind speed biased high relative to buoy & ship (wave sheltering, neutral)

• SST + QuikSCAT give improved turbulent fluxes

• Better humidity and air temp. needed



WRF Wind Speeds:

too high over cold water (stable), too low over warm water (unstable)