Air-Sea Interaction Over the Western North Atlantic Ocean

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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

Thermocline depth

TAO  QuikSCAT  NCEP2

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 meridional winds)

During winter midlatitude storms frequently develop near the GS (~3 per week)
The Surface Storm Track

*Surface storm track 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*

F23 STORM
48 hour forecast
Feb 23, 2001 0Z - Feb 25 0Z

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

Pressure minimum

Storms’ paths are nearly identical for different SST values.

Result: warmer SST => stronger storm

SST perturbation per ensemble member: 0.2°C
Storm crosses SST front at hr 16.

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

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

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

Storm crosses SST front at hr 16.

Result: cold side weakening cancels warm side strengthening
Which is more important: latent (LHF) or sensible (SHF)?

Blue: colder  Red: warmer

Result: LHF is mostly responsible for storm sensitivity to SST

LHF only: Large sensitivity

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

QuikSCAT winds February 23, 2007

R/V Knorr

Hurricane force wind speed threshold: 32.5 m/s
CLIMODE Storm Damage

• 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

Photos courtesy Terry Joyce.
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)
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)