High-Resolution MODIS /AMSR-E Composite SST for Regional Weather Prediction

Gary Jedlovec[1], Frank LaFontaine[2], Jaclyn Shafer[3], Jorge Vazquez[4], Edward Armstrong[4], Mike Chin[4]

A presentation at the Joint Center for Satellite Data Assimilation
June 17, 2009

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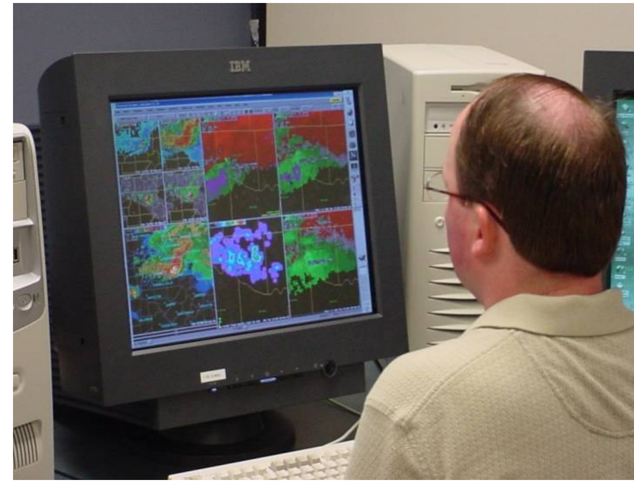
The SPoRT Center
Infusing NASA Technology Into NWS WFOs

Mission of the SPoRT Center: Apply ***NASA measurement systems and unique Earth science research*** to improve the accuracy of short-term (0-24 hr) weather prediction at the regional and local scale

- conduct focused research
- evaluate in "testbed" mode
- transition priority products to WFOs



External Partners
NWS (SR, HQs), NESDIS (STAR, NDE), NCEP, JCSDA, JPL, GSFC/GMAO

End users:
12 WFOs in Southern Region, other Govt organizations, and numerous private sector weather partners

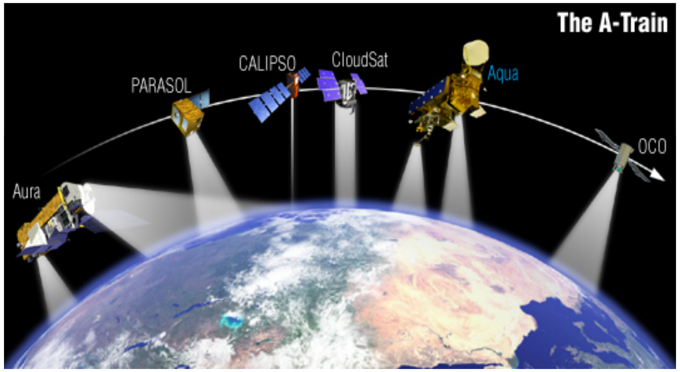
Keys to success

- ***link data / products to forecast problems***
- ***Integrate capabilities into AWIPS***
- ***Provide training / forecaster interaction & feedback***

Focused Research and its Transition

Exploit use of satellite observations for diagnostic analysis and nowcasting (MODIS, AMSR-E, and AIRS, special GOES products)

- timing and location of thunderstorms, severe weather, and precipitation
- diagnostic analysis of current conditions, cloud cover, visibility, fog, etc. (esp. at night), morning minimum temperatures (and its local variations)
- coastal weather processes (sea breeze convection / temperatures), off-shore precipitation processes
- weather in data void regions



Data assimilation studies

- AIRS radiances in GSI / WRF NAM (McCarty)
- AIRS profiles in WRF / Var (Zavodsky)

Unique modeling configurations

- coupled WRF / LIS (satellite data to improve surface parameterizations) (Case 5/20)
- use of high resolution SST in regional models WRF, WRF NMM (EMS), and for validation studies (Jedlovec 6/17)

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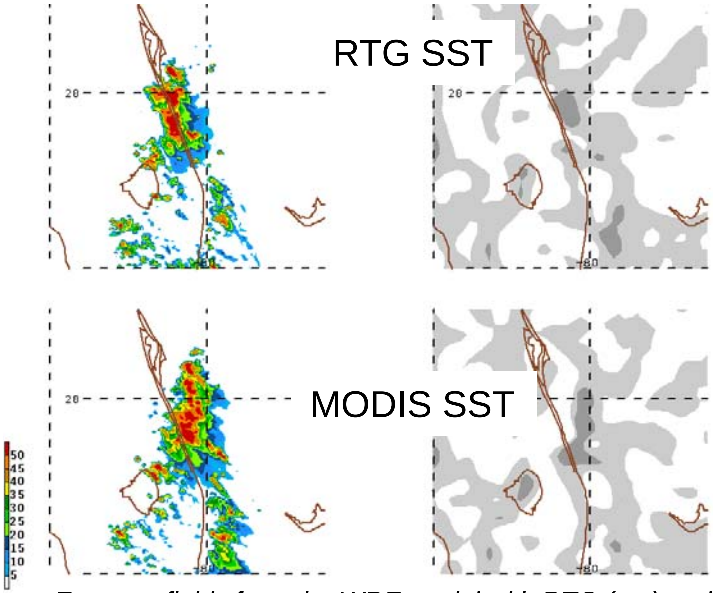
High-Resolution MODIS /AMSR-E Composite SST

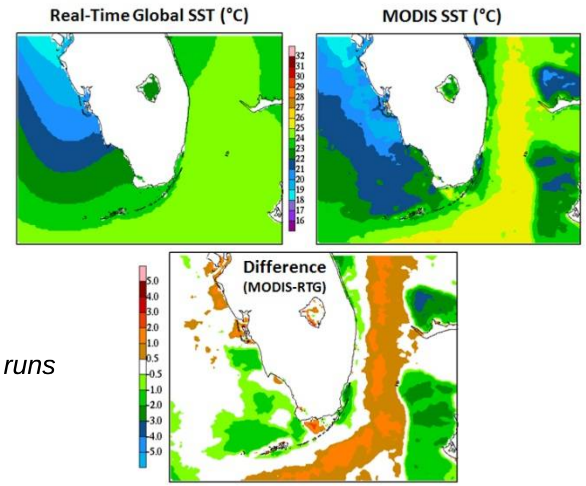
Motivation

- Accurate high resolution specification of sea surface temperature (SST) is important for regional weather forecasting studies
  - coastal ocean / land applications
  - tropical storms
- Diurnal SST mapping important for validation of ocean models and air-sea interaction studies
- Most SST products are
  - a daily average
  - generated from nighttime data (void of diurnal influences)
  - relatively course resolution
  - few are available operationally



Forecast fields from the WRF model with RTG (top) and MODIS (bottom) SST data. The left panels are simulated reflectivity, the right panels show low-level convergence.

from LaCasse et al. (2008) – Mon Wea. Rev.



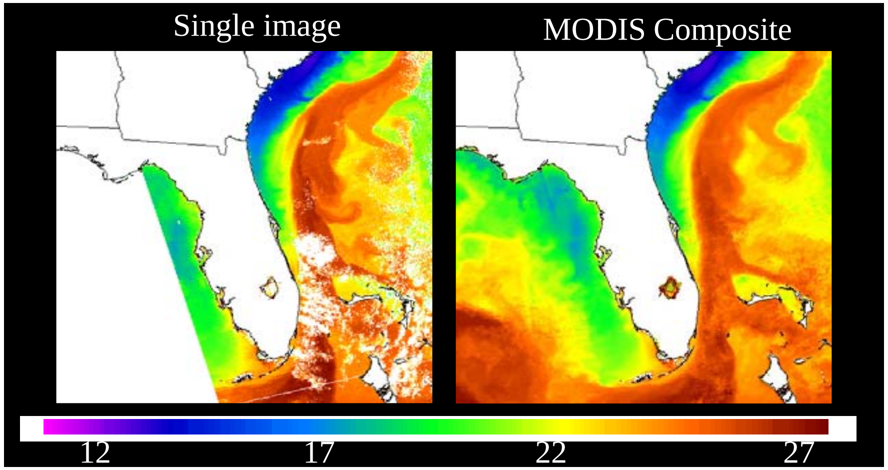
SST data used in limited area WRF runs at Miami WFO.

- Need to develop high resolution SST product and study its impact on weather forecasting
- Demonstrate capability with NASA data, then transition to NPOESS /GOES-R
- Show applicability to operational community – Centers and WFOs

Application of MODIS SST

Haines et al. (2007) developed a compositing approach for MODIS SST data

- assume day-to-day changes in SST at a given time are small
- use previous days' data to fill in gaps and cloudy regions in current day's SST field – average available data at each pixel
- track latency on a pixel basis



Strengths:

- regional coverage
- available in near real-time
- multiple times a day – captures portion of diurnal cycle @ MODIS overpass times
- high resolution – 1km

Weaknesses:

- continuous day-to day cloud cover increases latency and reduces accuracy
- some cloud contamination

- Used in Miami and Mobile WFOs for local forecasting applications
- Available to the WRF EMS community
- Being evaluated at NSSL – run operationally to support Spring Program

Enhanced SST Composite

Partnered with the physical oceanography team at JPL in a ROSES07 proposal to develop an enhanced composite – MODIS and AMSR-E, CONUS coverage, bias correction and error weighting

MODIS data source

- switch from ground station ingest to L2P data stream
  - more passes
  - expand product coverage - beyond direct broadcast
  - pixel by pixel quality estimates
  - slight additional delay in data access – tolerable
  - different (better?) cloud detection

AMSR-E data source

- Use AMSR-E SST data to reduce latency due to clouds – L2P data stream
  - spatial resolution differences from MODIS
  - only on Aqua
  - bias w.r.t MODIS
  - no data near coast

Algorithm changes - latency, error, and resolution weighted product

Enhanced Approach

Use GHRSST L2P data stream for both MODIS and AMSR-E data

- use confidence flags - “mask” bad, cloud, rain contaminated pixels
- create a collection of SST values (for a given location i,j) for a given MODIS/AMSR-E local overpass time based on the previous 7 days of cloud-free / rain-free values
- a different collection of data is created for each x,y location

For each point (some x,y location) in a 1km product image, the composite SST ($SST^C_{x,y}$) value is determined by the following

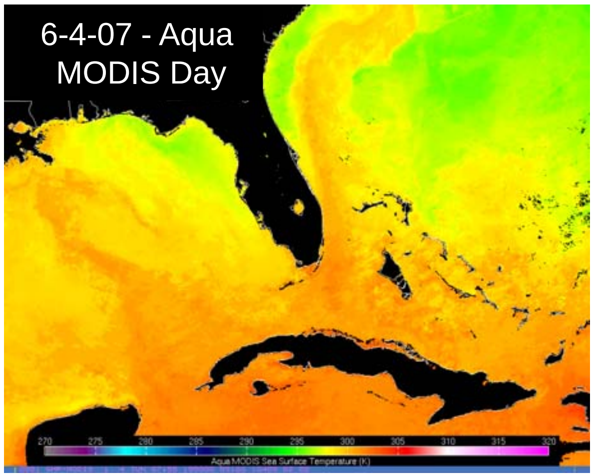
$$SST^C_{x,y} = \frac{\sum_{t=1}^{N} \left[SST(t)_{x,y} - \beta_k\right] * [((1 / (DL(t) + 1)) * RC_k]}{\sum_{t=1}^{N} [((1 / (DL(t) + 1)) * RC_k]}$$

where

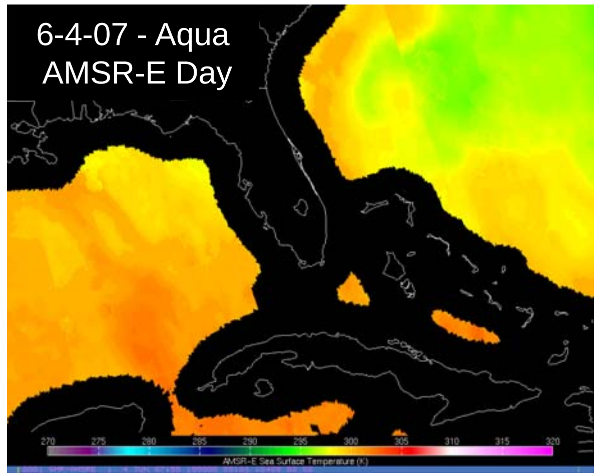
- N is the number of values in the collect at each pixel location,
- t is the t-th most recent value in the collection,
- β is the SST bias (w.r.t. MODIS),
- k is the sensor or data type,
- RC is the “resolution confidence” in the SST value (=1 for MODIS; <1 for AMSR-E)

Procedure Example

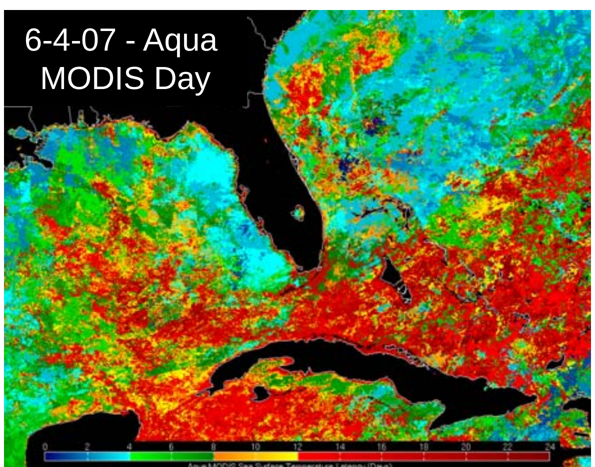
Enhanced approach combines MODIS and AMSR-E data in a latency – weighted compositing scheme



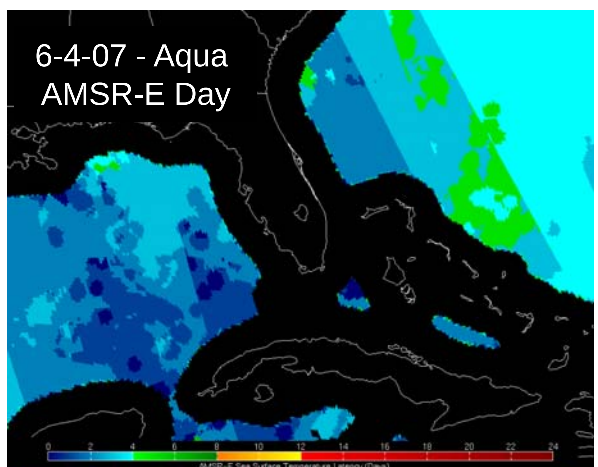
MODIS Composite SST



AMSR-E Composite SST



MODIS Latency

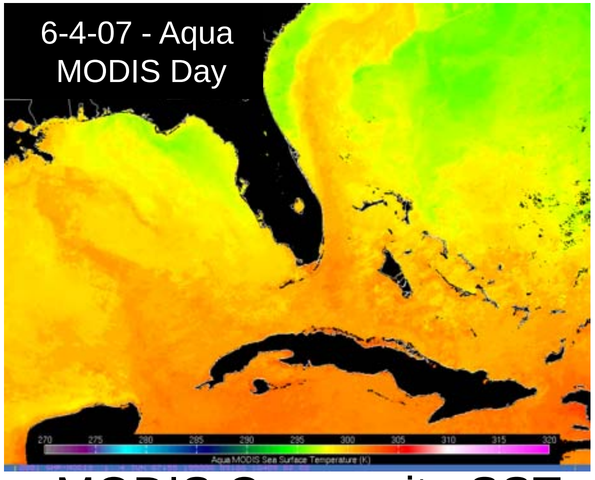


AMSR-E Latency

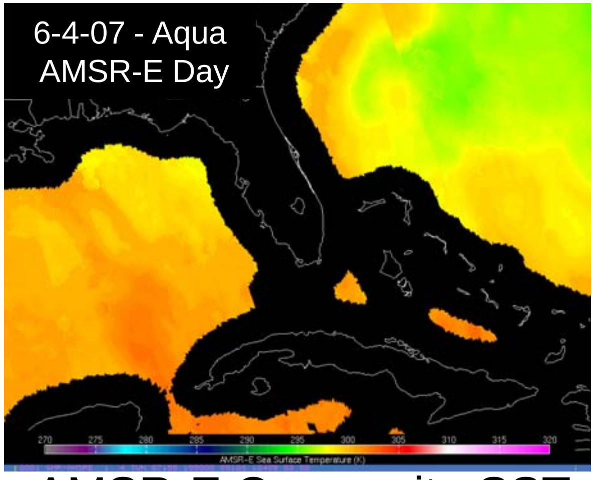
- MODIS only 30-day SST composite (upper left) and latency image (lower left)
  - lot of structure
  - still some missing data – “clouds”
  - Much data older than 14 days - 7 day product just come from blue green – shows need for AMSR-E data
- No AMSR-E SST data within 125 km of land
  - 7 day composite provides course resolution, but good coverage within 2-3 days
  - no AMSR-E data in MODIS SST gap regions
  - problem in coastal regions

Procedure Example

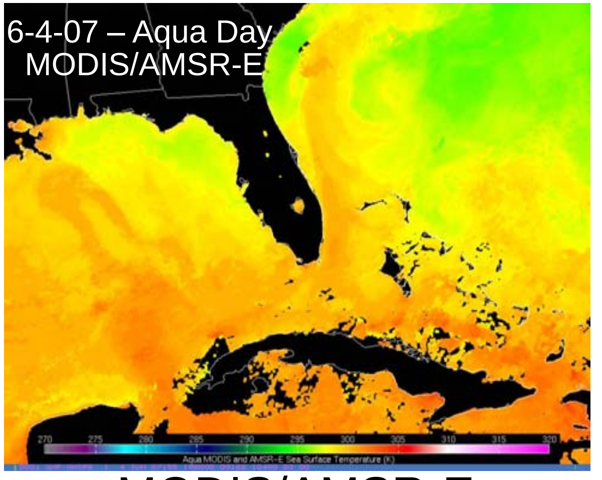
Enhanced approach combines MODIS and AMSR-E data for the previous week in a latency –weighted compositing scheme



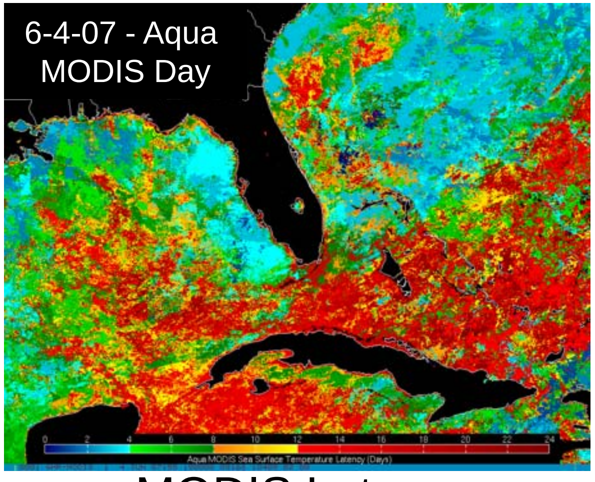
MODIS Composite SST



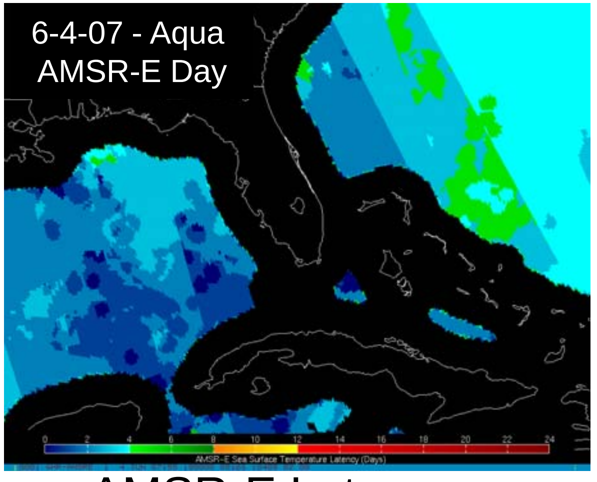
AMSR-E Composite SST



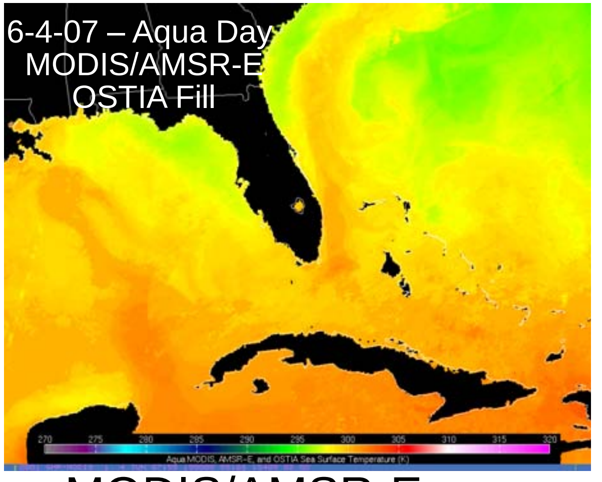
MODIS/AMSR-E



MODIS Latency



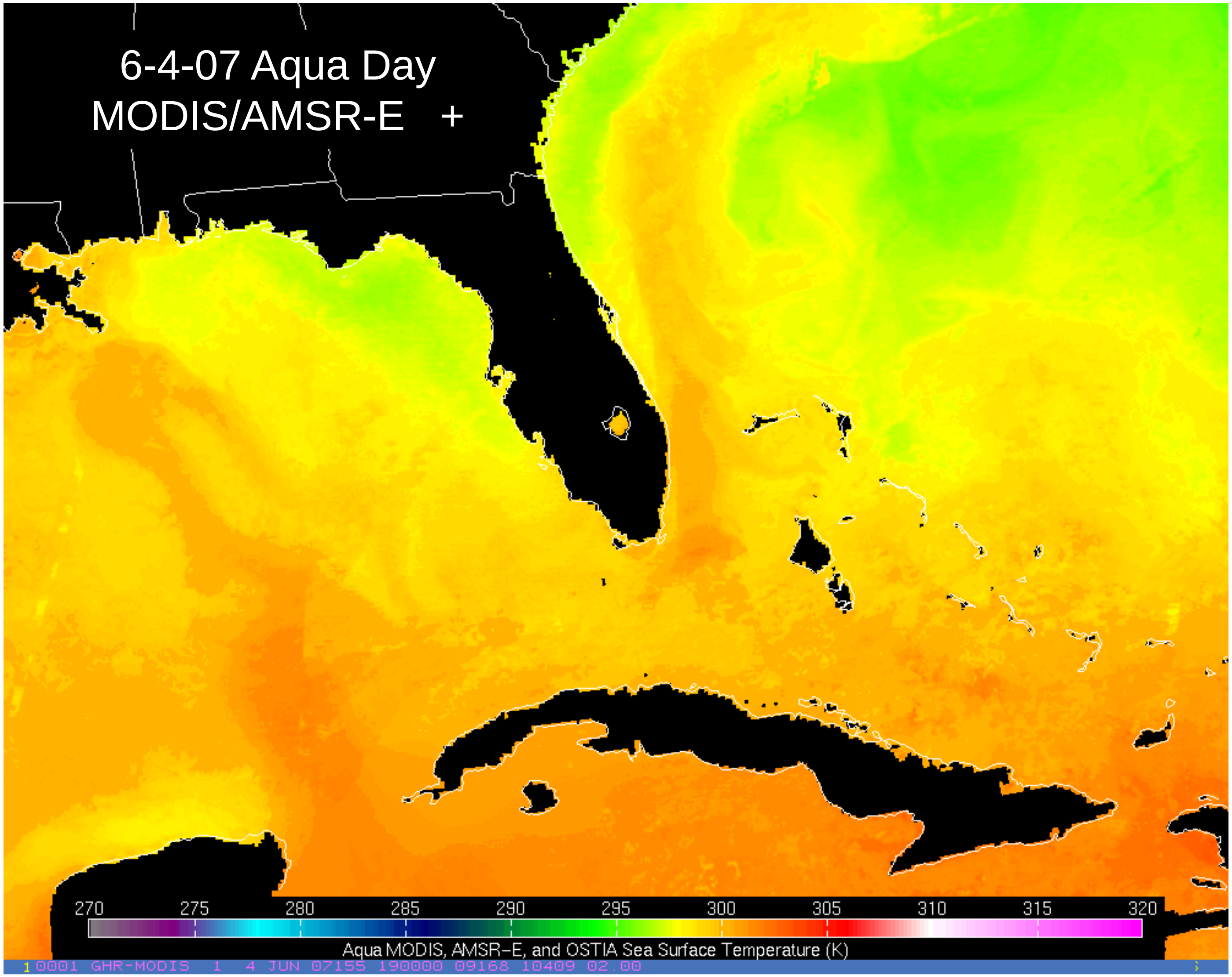
AMSR-E Latency



MODIS/AMSR-E +

Procedure Example

Enhanced approach combines MODIS and AMSR-E data for the previous week in a latency –weighted compositing scheme



Case Studies – Demonstration & Validation

Testing and evaluating enhanced approach for varying regions / seasons - see Vazquez et al. 2009 for additional evaluation and validation work

<u>Evaluation Periods</u>

<u>Pacific coast U.S.</u>:

June and July 2009

<u>Florida</u>:

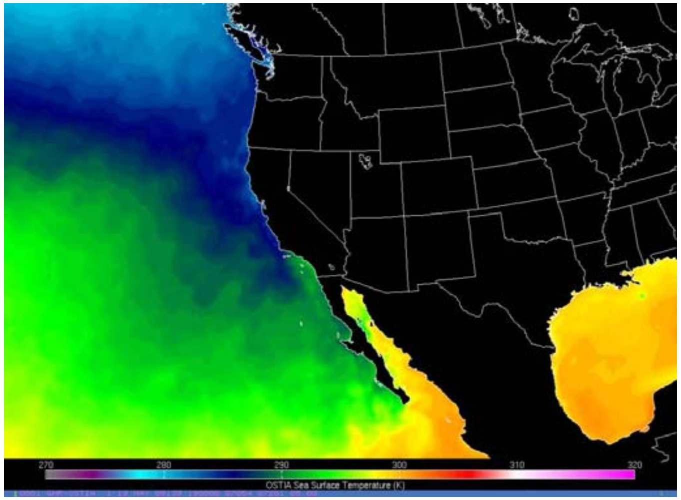
June & July 2007

<u>Hurricane</u>:

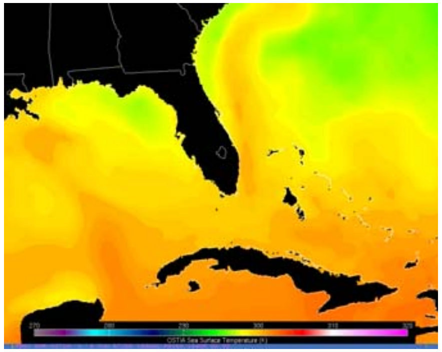
Aug.15 - Sept. 15, 2008

<u>Atlantic</u>:

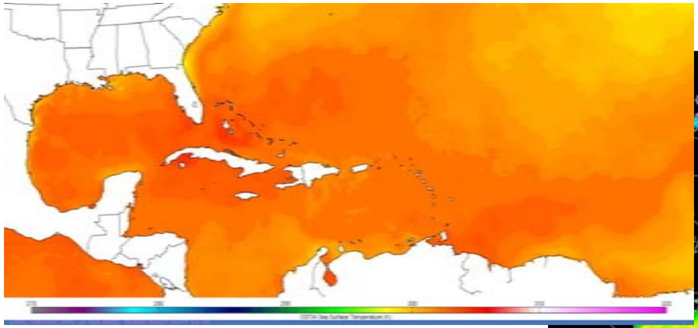
December 2008



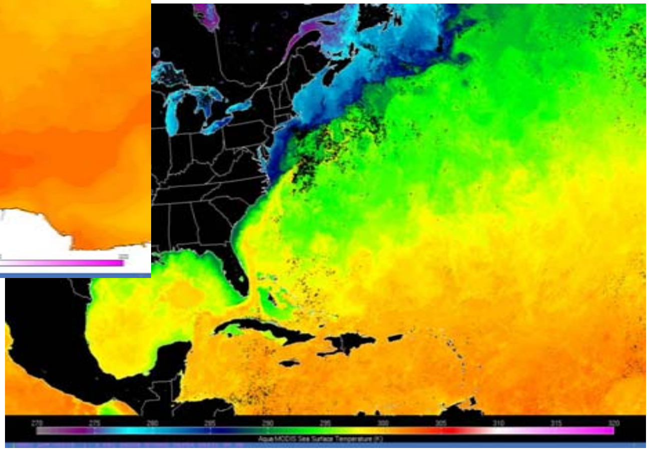
Pacific Ocean



Florida



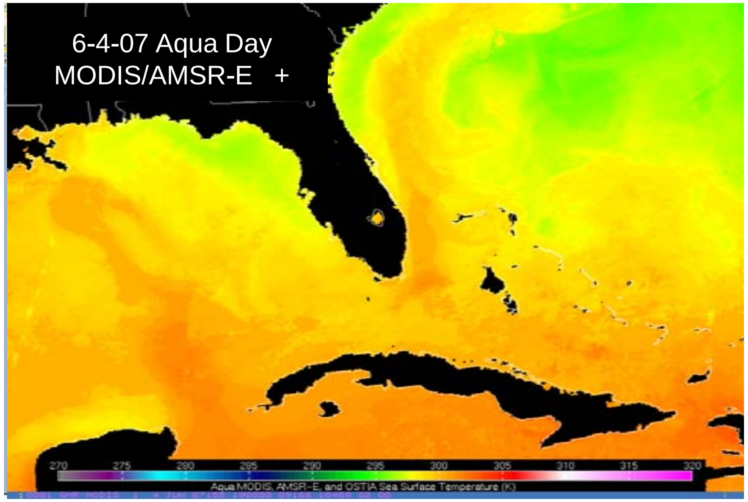
Hurricane

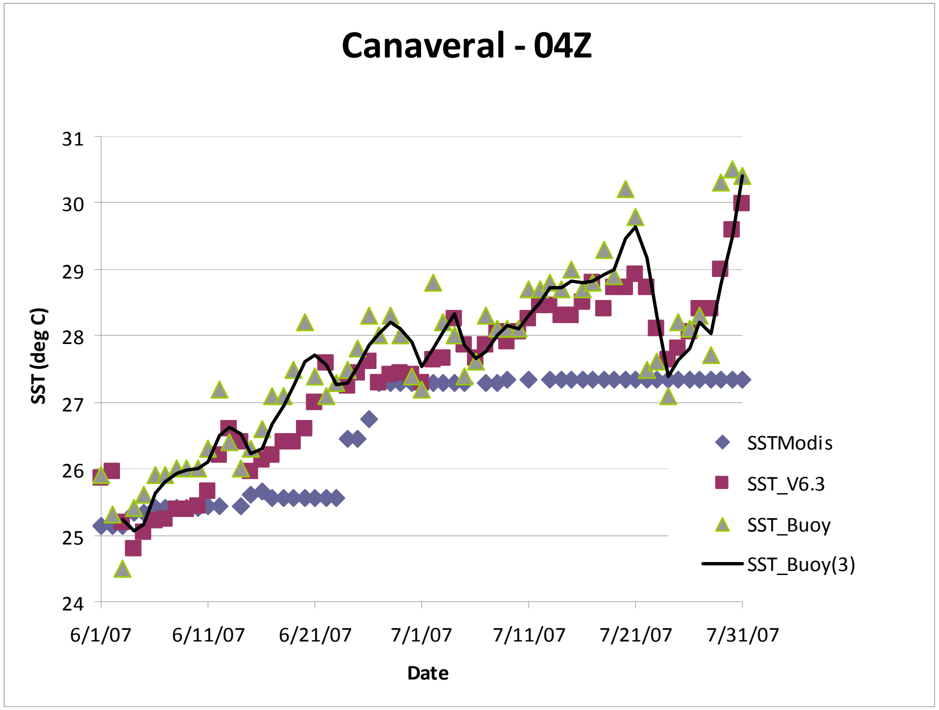


Atlantic Ocean

Validation of the Enhanced Technique

- Validation underway for case studies
  - regions surrounding CONUS
  - variance of composites against buoy data is reduced by >50% compared to original method





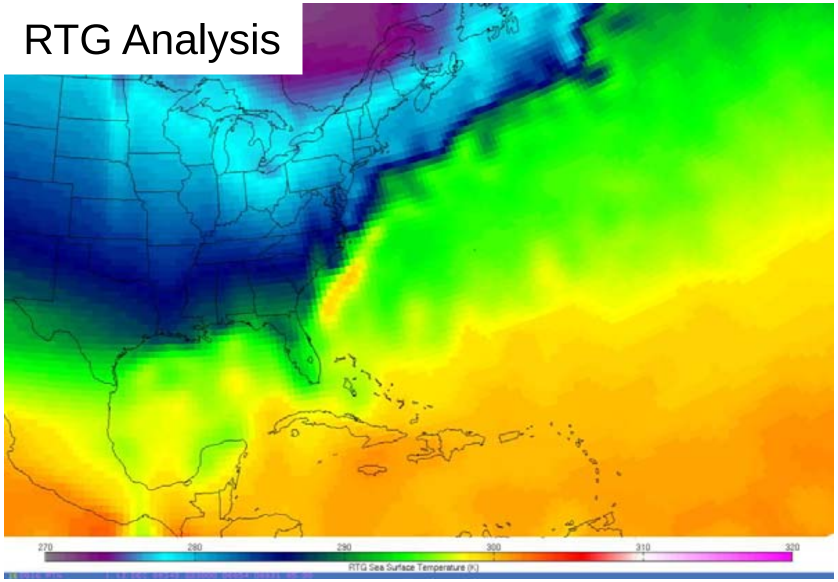
Graph above shows comparison of enhanced (red) and old (blue) compositing method to buoy data (green) for June – July 2007. Black line indicates the trend in the buoy data during the period. The comparison is for the 0400UTC composite time.

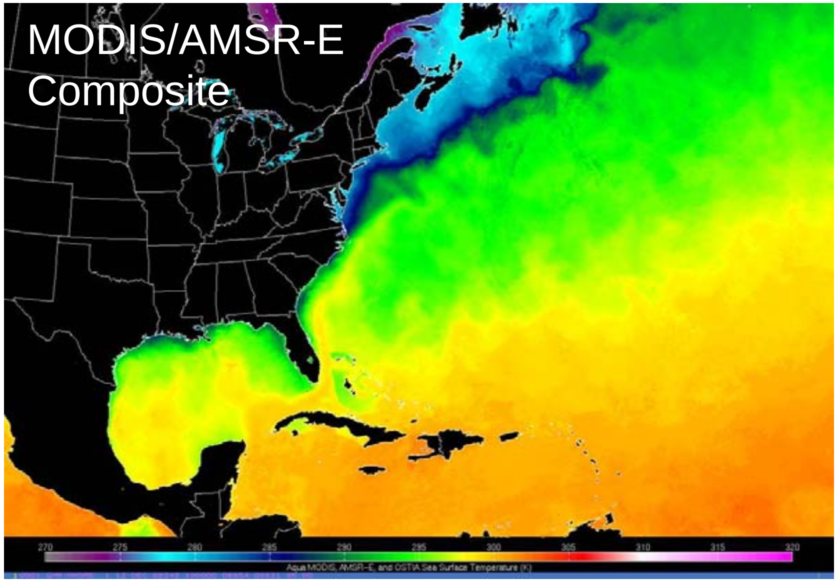
  - comparison against AASTR

Regional Applications of the SST Composite

Matching resolution of SST product to model grid spacing seems intuitive, but:

- Does the higher resolution data add value at the larger scales?
- Does initializing with "daily" values (vs SSTs valid at initialization time) constrain the forecasts?
- Is there a need to couple a diurnal cycle model for SST with the forecast model?

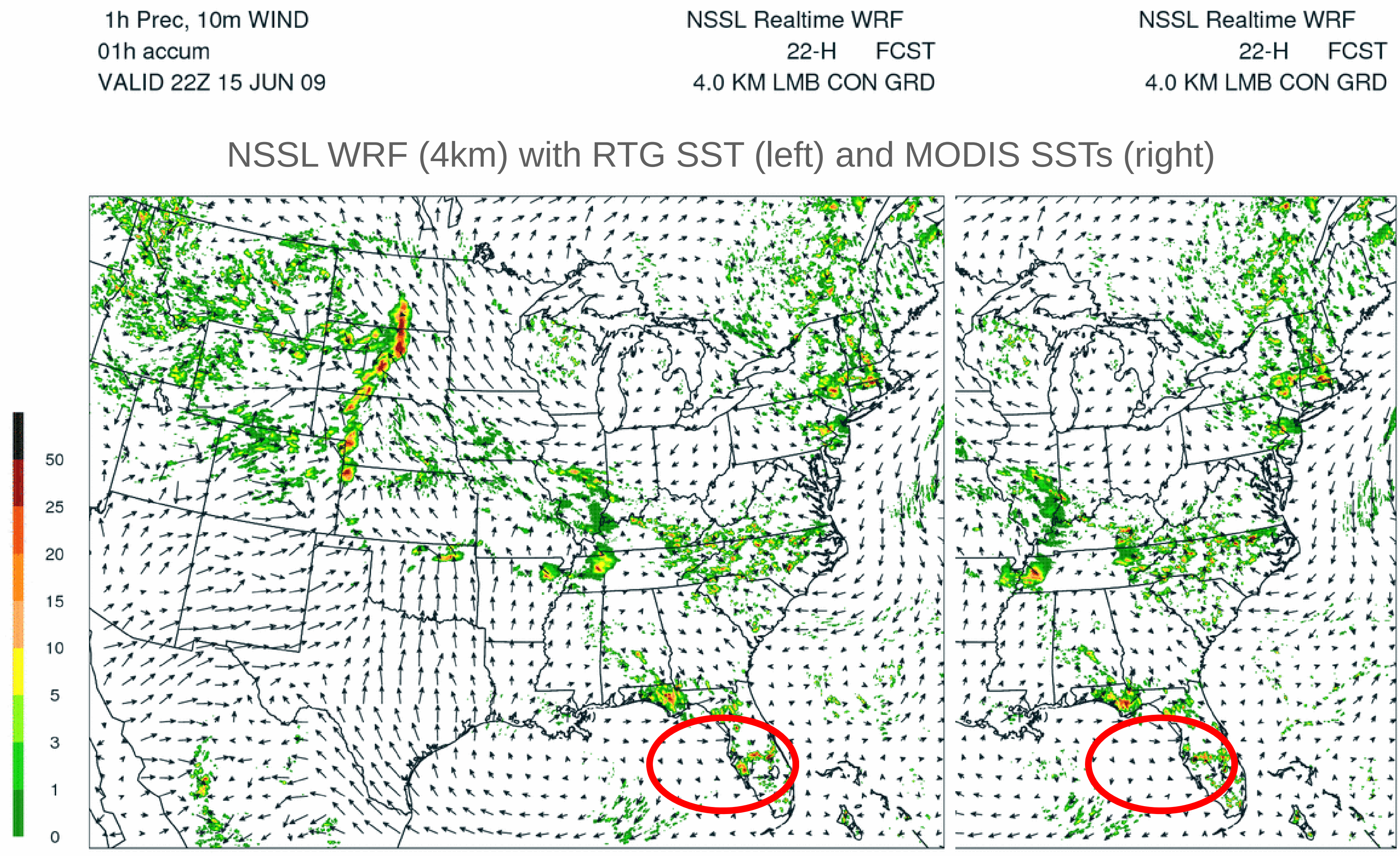




Resolution differences between the RTG and MODIS/AMSR-E SST composite product for December 13, 2008.

Higher Resolution SSTs in Larger Scale Models

MODIS SST composite being run in 4km version of WRF over CONUS at NSSL in support of Spring Program



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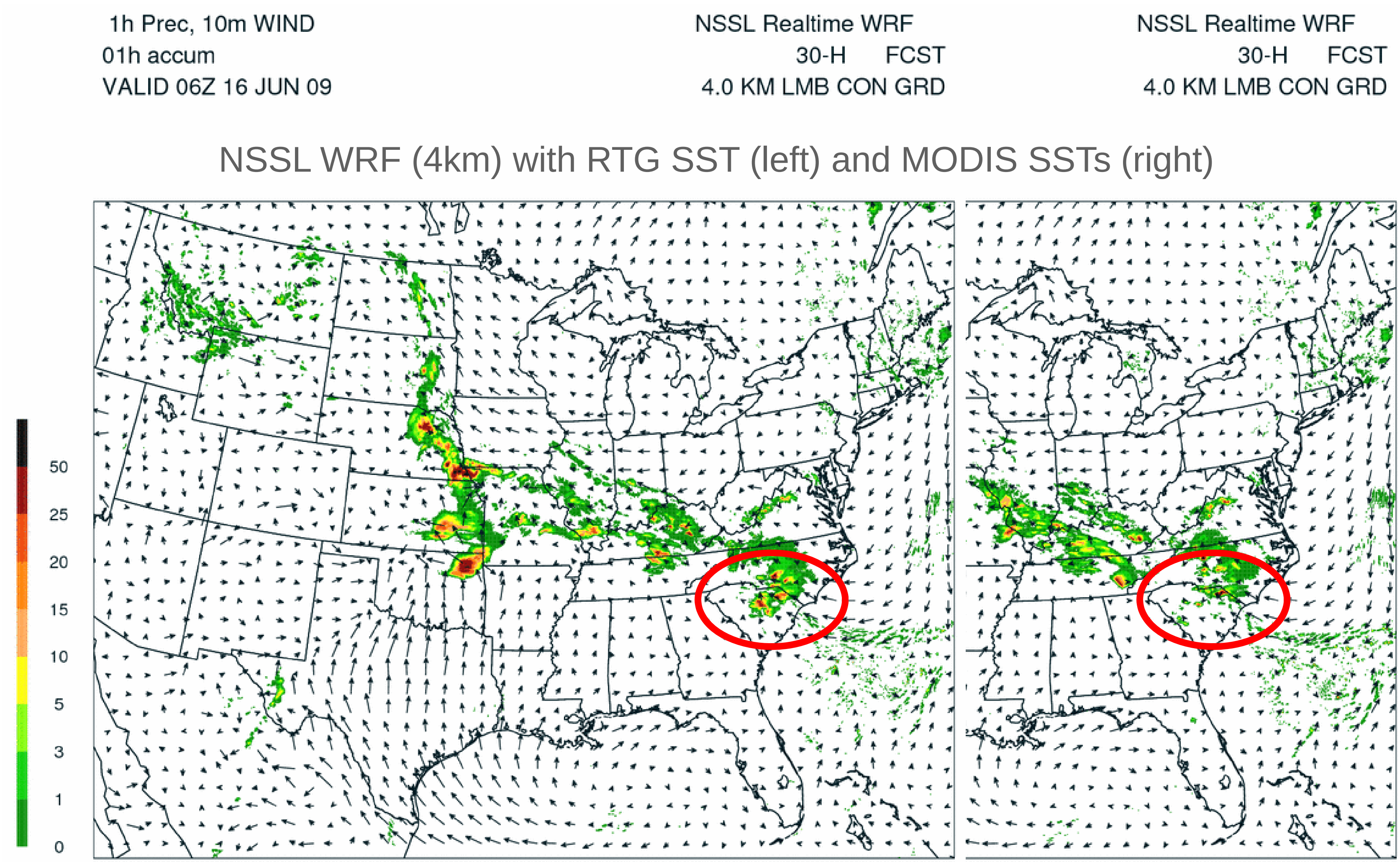
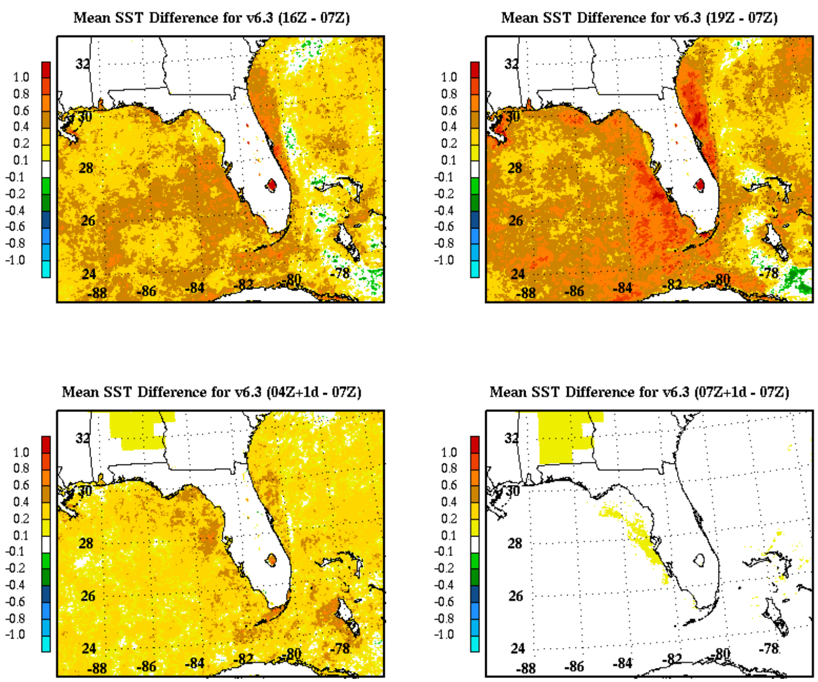
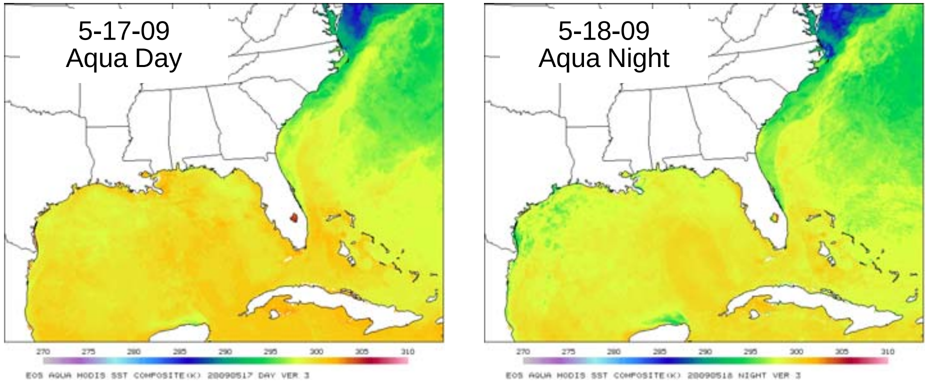


Capturing the Diurnal Cycle in SSTs

The 4x / day MODIS/AMSR-E SST composites capture diurnal cycle in SST



Mean of difference images for the MODIS/AMSR-E SST composites for the months of June-July 2007 corresponding to (clockwise from upper left)16-07Z , 19-07Z, 04-07Z, and 07-07Z (to consecutive days). The 19-07Z captures the amplitude of the diurnal cycle.



Regional weather forecasts benefit from model initialization with data that captures the diurnal cycle of SSTs, rather than a single "daily" average.

Diurnal cycle of SST controlled by

- insolation
- surface wind speed
- other variables

Preliminary WRF runs show significant differences between forecast initialized with SST from different times

Summary

- High resolution SSTs provide a valuable data source for regional weather forecast models and validation studies
- Current work improves on previous technique to generate composite SST product
- Enhancements include use of GHRSST L2P data stream
  - access to all EOS passes for MODIS and AMSR-E
  - cloud masking / confidence flags / bias correction
  - latency / error / resolution weighted compositing algorithm
- Near real-time CONUS product available in Fall 2009
- 4x / day product captures major component of the diurnal cycle of SST – use may add value to subsequent forecasts
- Consider coupling SST diurnal cycle model to WRF for improved forecasts