Impact of Variable SST on Simulated Warm Season Precipitation

Stephen M. Saleeby and William R. Cotton
Department of Atmospheric Science, Colorado State University

Introduction

What are the impacts of variability in SSTs on RAMS model simulations of the North American Monsoon on seasonal and surge timescales and at coarse and high resolutions?

The Colorado State University – Regional Atmospheric Modeling System (RAMS) was recently upgraded with the capability of ingesting more modern and higher resolution Sea Surface Temperature (SST) datasets for ocean surface initialization and forcing. Prior model versions were limited to use of climatological data or Reynold's 1°x1° datasets. Within the past year we have added the capability of ingesting the AVHRR 18km data as well as the MODIS 36km and 4.63km data from both the Terra and Aqua platforms.

The North American warm season moisture transport and precipitation, including moisture surges from the Gulf of California, are strongly influenced by the ocean temperature and gradients in SST. Thus, simulations of monsoon-related precipitation may vary dramatically if the SST forcing is varied due to the data source alone. This may indicate the need to determine the most accurate and best resolution source of SSTs as well as the necessary model resolution for simulating the fine scale features of the monsoon.

RAMS Model Setup

1. SIMULATIONS: Run from June 1 – Aug 31 for the 2002, 2003, 2004 warm seasons.
2. GRID SETUP: a. Single grid, 30km grid spacing covering the U.S., southern Canada, and Mexico for full seasonal simulations.
   b. Parent grid above + nested 7.5km grid spacing covering extreme southwest U.S. and most of Mexico for the July 13-15, 2004 surge event.
3. INITIALIZATION: NCEP 2.5° reanalysis.
4. PHYSICS: a. Single moment microphysics for liquid and ice hydrometeors on both grids.
   b. Kain-Fritsch cumulus parameterization within the coarse parent grid.
5. SST FORCING: Weekly averaged, and updated over the coarse of the simulation.
   a. Climatology (CLIMO), b. Reynold's Version-2 (REYV2)
   c. AVHRR 18km (AVHRR), d. MODIS 4.63km Terra (MODIS)

*****Only the 2004 SST sensitivity simulations are presented here.*****

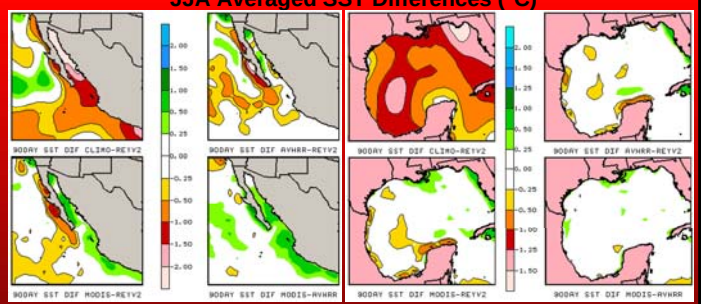
CLIMO – REVY2	AVHRR - REYV2
MODIS - REYV2	MODIS - AVHRR

NOTATION: The 4-panel figures display difference fields and are labeled such as "MODIS-REYV2". This indicates the field using the REYV2 data was subtracted from the field using the MODIS data. Each 4-panel plot is setup in a similar manner to the example on the left.

EXAMPLE: In the JJA average SST plots below, the lower left panel displays the difference in the 90-day averaged SSTs between the MODIS and REYV2 datasets taken as the MODIS field minus the REYV2 field. Thus we see that the MODIS data shows warmer SSTs, relative to REYV2, along the west coast of Mexico during 2004.

SST Dataset Variability

JJA Averaged SST Differences (°C)



The CLIMO SSTs vary most dramatically and are much cooler along the Gulf of California than in the other datasets. The MODIS and AVHRR are most similar, but still offer SST differences up to 1° C along the west coast of Mexico.

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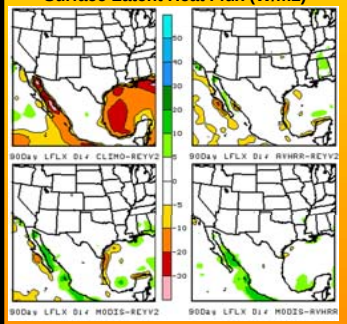
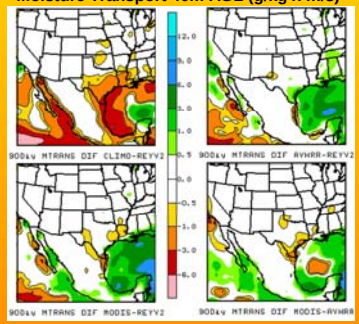
30km Grid - 2004 Full Warm Season Impact

30km grid plots are difference fields of the June, July, August averages

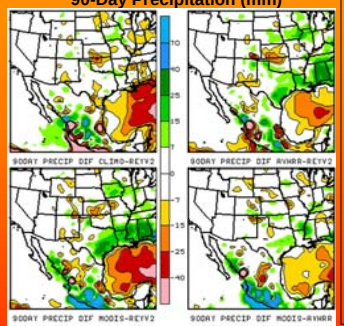
Surface Latent Heat Flux (W/m2)



Moisture Transport 40m AGL (g/kg x m/s)



90-Day Precipitation (mm)



1. Variations in surface latent heat flux are directly linked to differences in SST. Regions with cooler (warmer) SST have decreased (increased) moisture flux from the ocean which is in proportion to the magnitude of the SST difference.

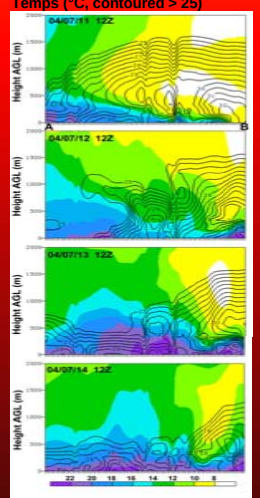
2. Over the eastern Pacific, differences in low-level horizontal moisture flux show a general trend toward reduced fluxes over cooler waters and very little inland impact. Over the Gulf of Mexico, however, there is substantial variability for each dataset comparison, despite having only limited variability among the REYV2, AVHRR, and MODIS SSTs. Causes of this unexpected variability are not straight-forward.

3. Precipitation impacts are greatest near the southern coast of Mexico and along the Sierra Madres. The variability over the CONUS is rather chaotic, but is limited to areas impacted by the Gulf of Mexico or monsoon convection. Again, the variations over the Gulf of Mexico are puzzling. Another unexpected outcome is the lack of variability in areas near the northern Gulf of California where SST and latent heat flux variability is maximized.

7.5km Spacing Surge Cross-Section

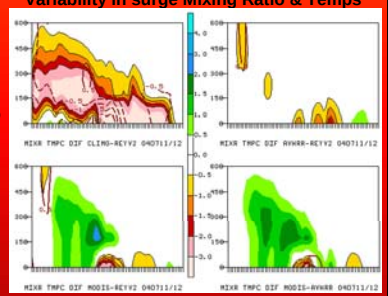
Time progression of surge using MODIS SST.

Mixing ratio (g/kg, shaded)
Temps (°C, contoured > 25)

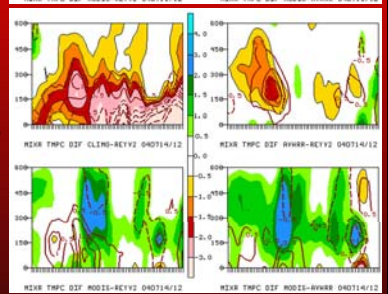


Variability in surge Mixing Ratio & Temps

Pre-surge



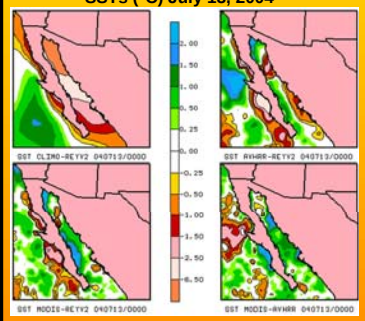
Mid-surge



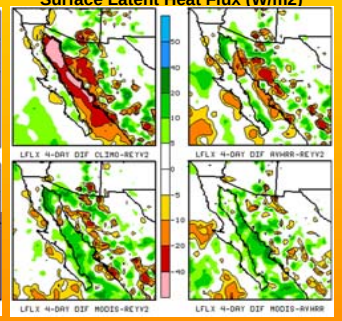
7.5 km Grid - July 12-16, 2004 Gulf Surge Episode

7.5km grid plots are difference fields of the July 12-16 Averages

SSTs (°C) July 13, 2004

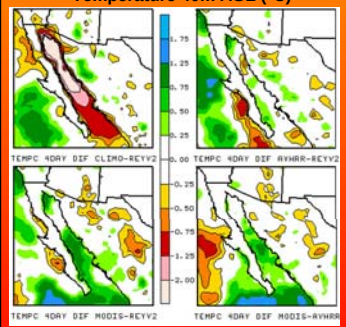


Surface Latent Heat Flux (W/m2)

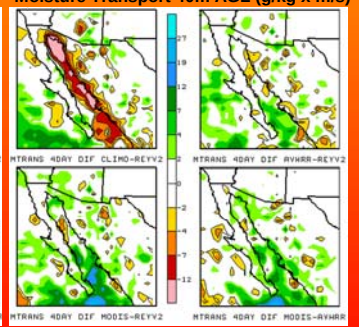


1. The plot of SST differences on the higher resolution nested grid reveals fine scale variability that is otherwise smoothed out on the parent grid.
2. Similar to the coarse grid simulations, the latent heat flux differences over the ocean areas are a direct response to SSTs with cooler SSTs exhibiting reduced latent heat flux.
3. Unlike the coarse grid, the latent heat flux differences here on the fine grid reveal an inland impact. This is likely due to fine scale variability in onshore moisture transport and sea-breeze circulations which may alter monsoonal convection and precipitation.

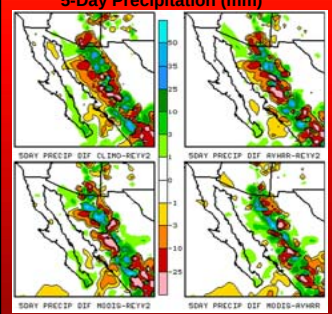
Temperature 40m AGL (°C)



Moisture Transport 40m AGL (g/kg x m/s)



5-Day Precipitation (mm)



1. Primary low-level temperature variations tend to correlate with SST variability. An inland influence does exist along the SMO, but it is quite chaotic with no clear pattern.

2. Variability in moisture transport also appears quite chaotic over inland areas with substantial small-scale features. Only the largest SST differences (spatially and in magnitude) tend to invoke large, coherent responses in moisture flux.

3. The SST variability on the fine grid produces relatively large differences in precipitation that are focused along the slopes of the SMO, with a tendency toward greater variability along the western slope adjacent to the coast. This also invokes precipitation changes over AZ/NM that are not resolved on the coarse grid.

4. The precipitation differences are of fine resolution and are chaotic, with variability of +/- 30 mm (over 5 days) along the length of the SMO.

Conclusions

1. Variability in SST forcing from different datasets impacts simulations in both predictable and unpredictable ways. The low-level temperature, latent heat flux, and mixing ratio are directly impacted by warmer or cooler SSTs. However, the resulting sea-breeze influence, moisture transport, and precipitation differences are more irregular and less predictable; as such, there is difficulty discerning spatial pattern and magnitude changes, as well as determining direct causal mechanisms of the variability.

2. Variability in SSTs produces a more dramatic impact in higher resolution simulations. In these tests, the coarse grid, season-long simulations produce very little precipitation difference over AZ/NM, while the fine-scale nested grid displays a strong impact over AZ/NM from varying the SSTs over the duration of a single monsoon surge event. This suggests a need for both accurate SST forcing and higher resolution regional climate model simulations of the North American Monsoon.