Impacts of High-Resolution Land and Ocean Surface Initialization on Local Model Predictions of Convection

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Talk Outline

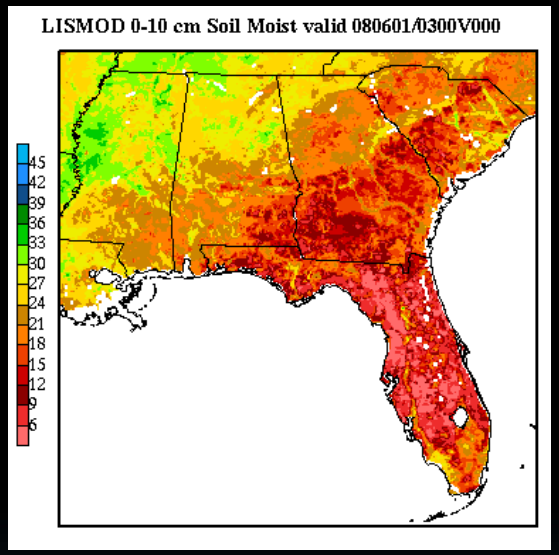
- Experiment objectives
- NASA Data and Tools
  - Goddard's Land Information System (LIS)
  - Moderate Resolution Imaging Spectroradiometer (MODIS)
- Simulation methodology
- Preliminary results
- Future work

Hypothesis and Experiment Objectives

- Hypothesis: High-resolution land and water datasets from NASA utilities can lead to improvements in simulated summertime pulse-type convection over the S.E. U.S.
- Experiment objectives
  - Use NASA LIS to provide high-resolution land surface initializations
  - Incorporate SPoRT MODIS composites for detailed representation of sea surface temperatures (SSTs)
  - Demonstrate proof of concept in using these datasets in local model applications with the Weather Research and Forecasting (WRF) model
  - Quantify possible improvements to WRF simulations

NASA Land Information System (LIS)

- High-performance land surface modeling and data assimilation system
  - Runs a variety of Land Surface Models (LSMs)
  - Integrates satellite, ground, and reanalysis data to force LSMs in offline mode
  - Can run coupled to Advanced Research WRF
  - Data assimilation capability (EnKF) built-in
  - Modular framework enables easy substitution of datasets, LSMs, forcings, etc.
  - Adopted by AFWA for operational use in WRF



- Previous SPoRT work with LIS
  - Case et al. (2008) manuscript in *J. Hydrometeor.*
    - Quantified positive impacts to WRF forecasts over Florida by initializing model with LIS land surface output
    - Focused on verification of primary meteorological variables

Land Surface Modeling with LIS

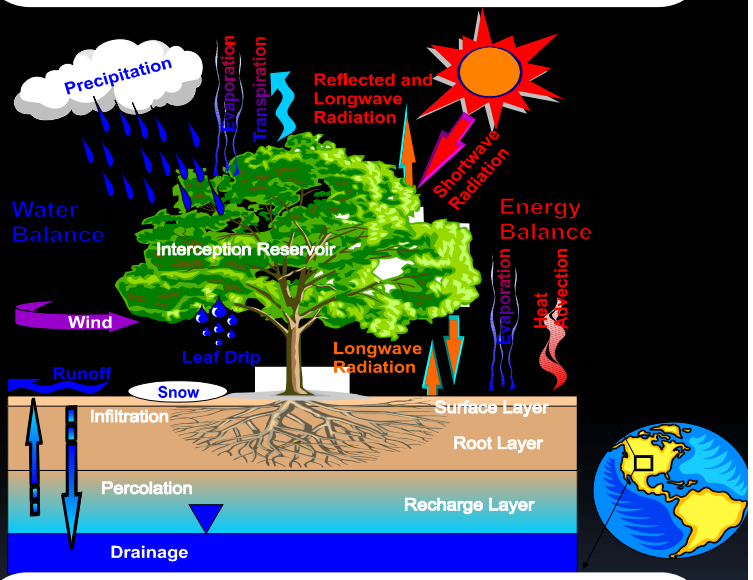
ENSCO, Inc.

Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- Meteorology (Atmospheric Forcing)
- Snow Soil Moisture Temperature

Physics

- Land Surface Models (e.g. Noah, VIC, SIB, SHEELS)
- Data Assimilation Modules



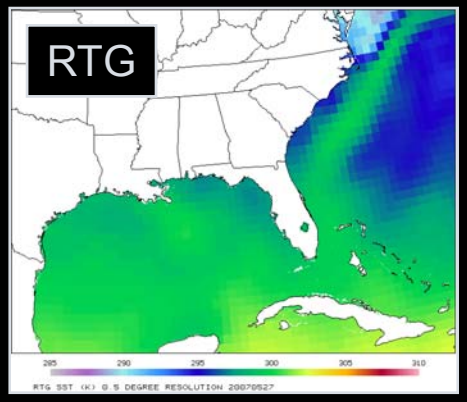
Outputs

- Soil Moisture & Temp
- Evaporation
- Runoff
- Snowpack Properties

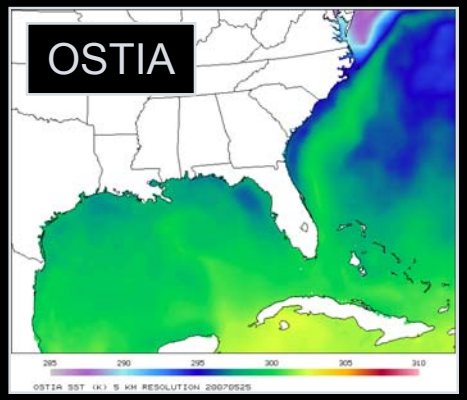
Applications

- Weather/ Climate
- Water Resources
- Homeland Security
- Military Ops
- Natural Hazards

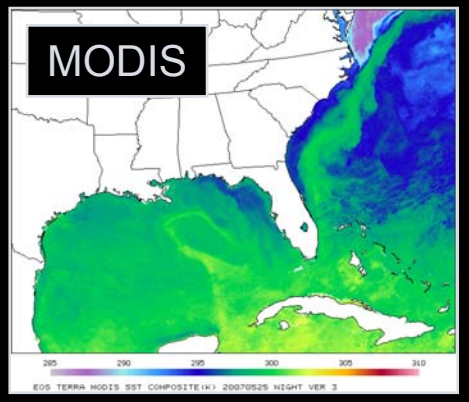
MODIS SST Product



Once daily
1/12 degree resolution

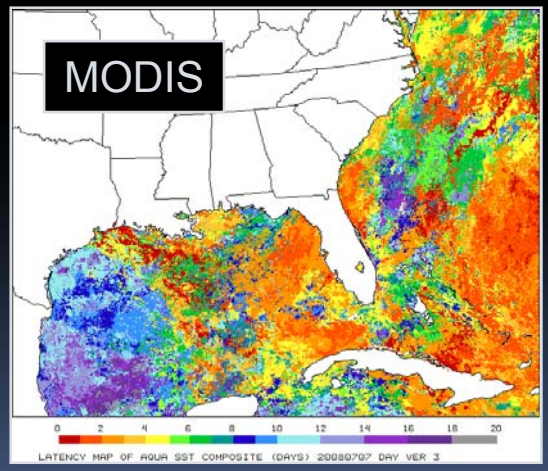


Once daily
5-km resolution



Four times daily
1-km resolution

- MODIS provides superior resolution
- Quality check with the latency product
- Current weakness is high latency in areas with persistent cloud cover
- Collaboration with Jet Propulsion Laboratory to improve product with AMSR-E data

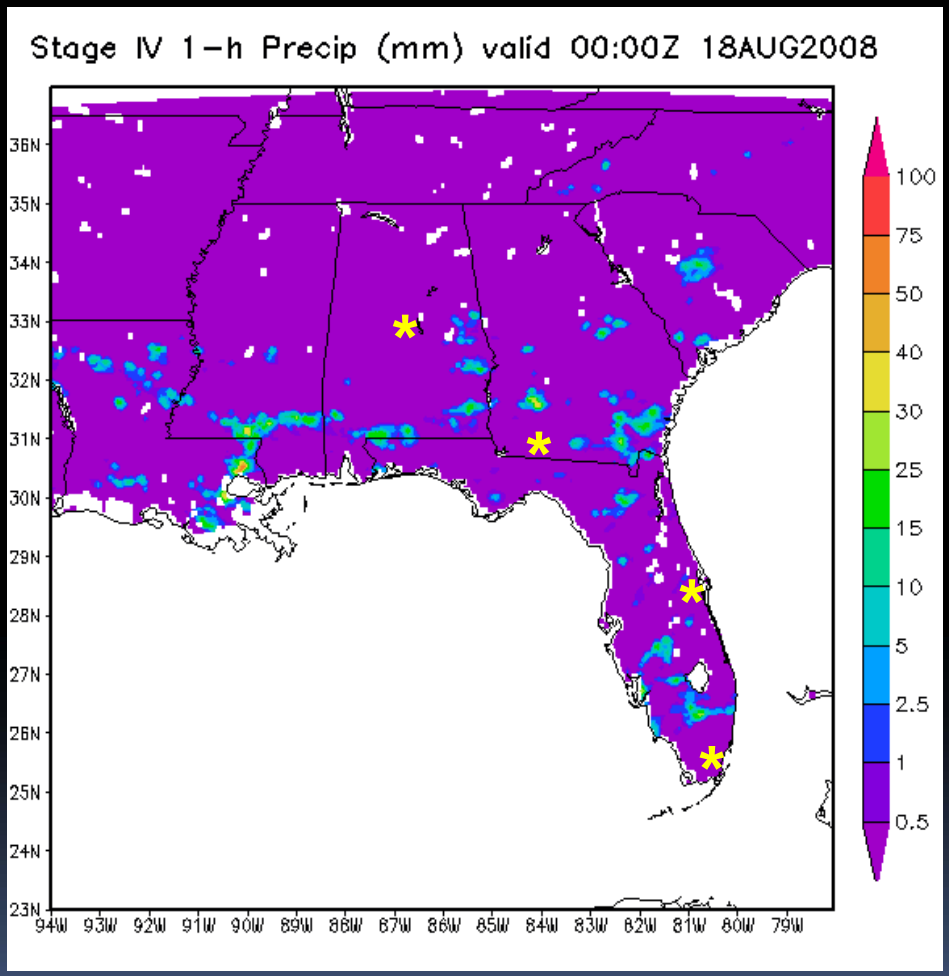


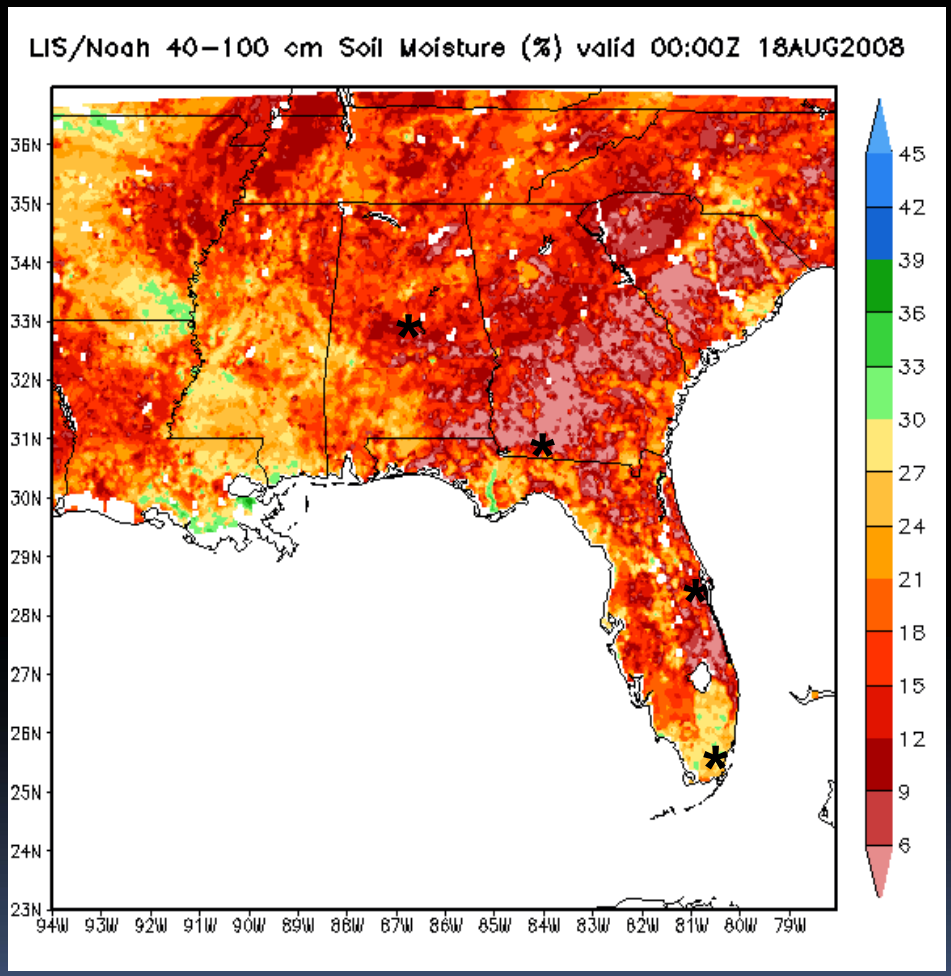
Latency Product

LIS Offline "Spin-up" Run

- LIS/Noah LSM run from 1 Jan 2004 to 1 Sep 2008
  - Same soil and vegetation parameters as in WRF
  - Atmospheric forcing
    - 3-hourly Global Data Assimilation System analyses
    - Hourly Stage IV radar + gauge precipitation products
  - Run long enough to allow soil to reach equilibrium state
  - Output GRIB-1 files to initialize land surface variables for once daily WRF runs from 1 June to 31 Aug 2008
- Incorporation of LIS data into WRF initial condition
  - Slight modifications to WRF Preprocessing System (WPS)
    - Created Vtable.LIS & added LIS fields into METGRID.TBL file
    - Soil moisture/temperature, skin temp, snow-water, land-sea mask
  - LIS data over-write NAM land surface data
  - Similarly, MODIS SSTs over-write NAM / RTG SSTs in WPS

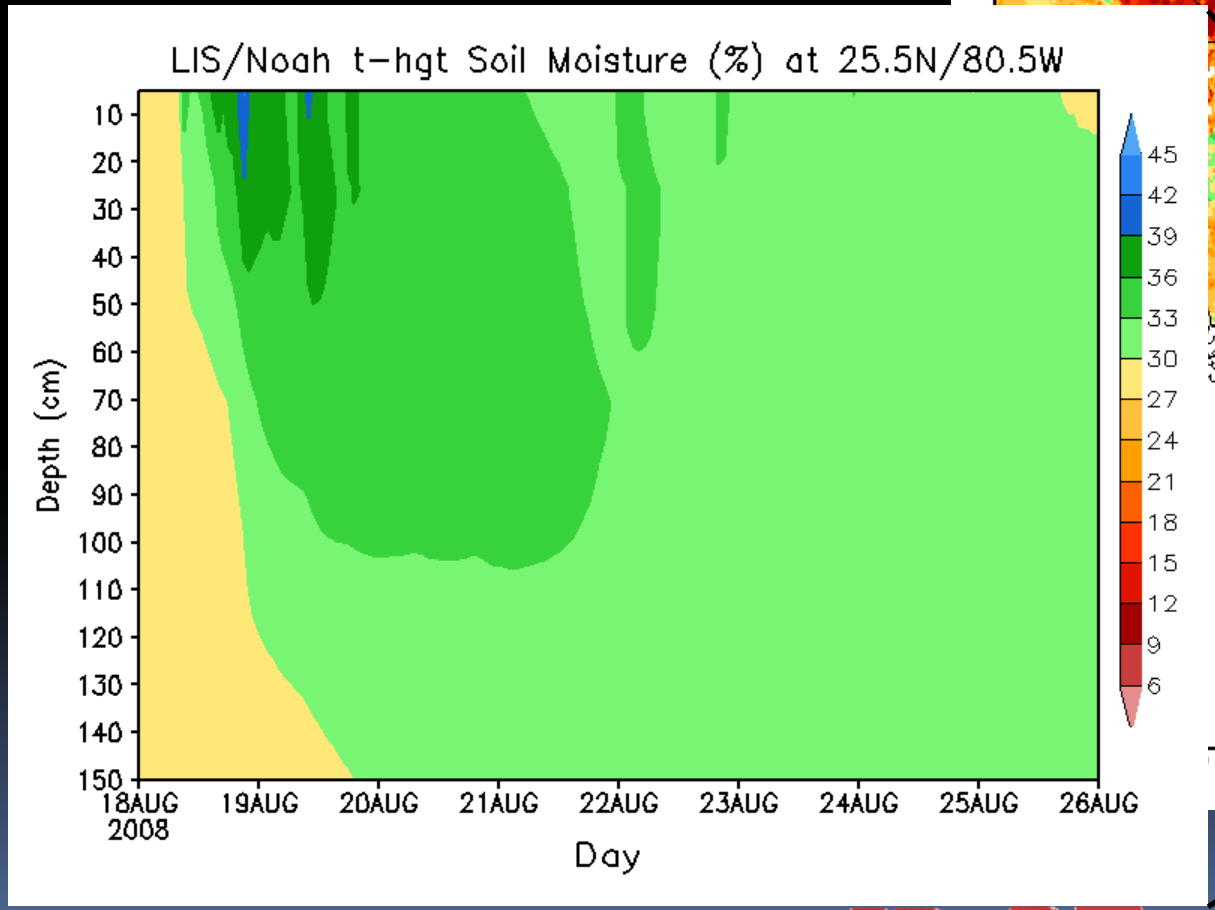
Tropical Storm Fay: Rainfall and Dramatic Soil Moistening

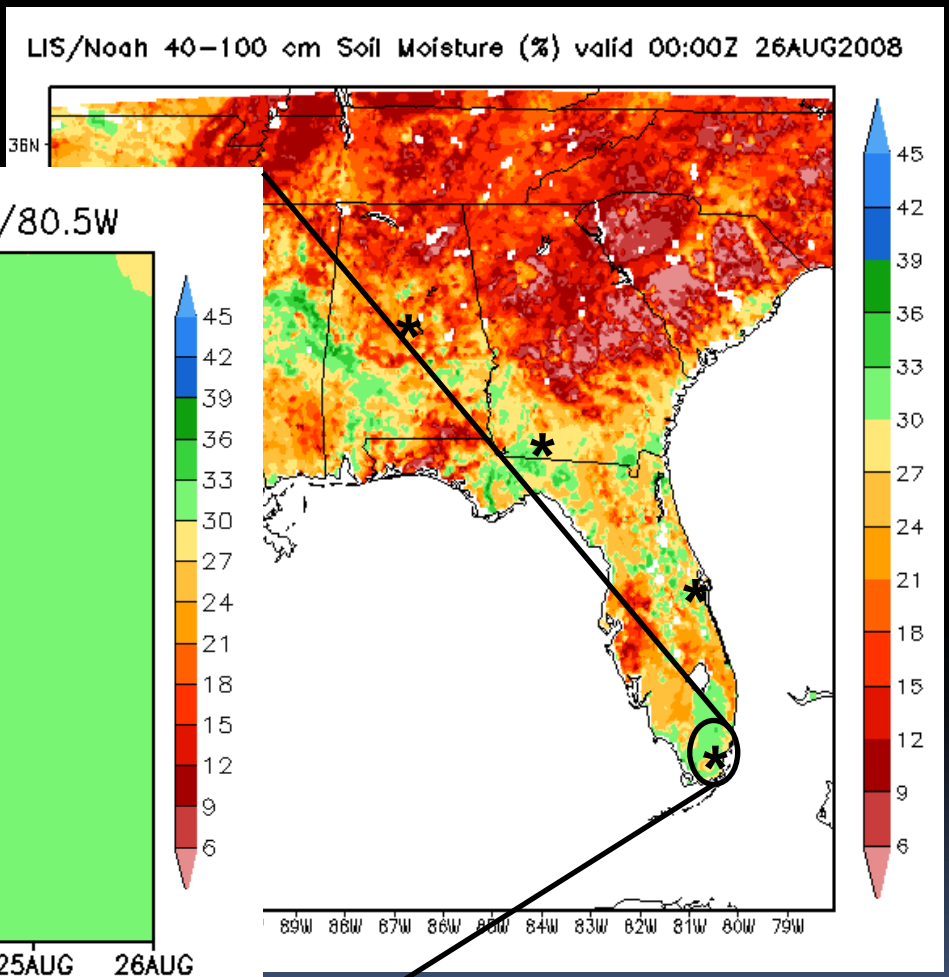




Tropical Storm Fay: Rainfall and Dramatic Soil Moistening

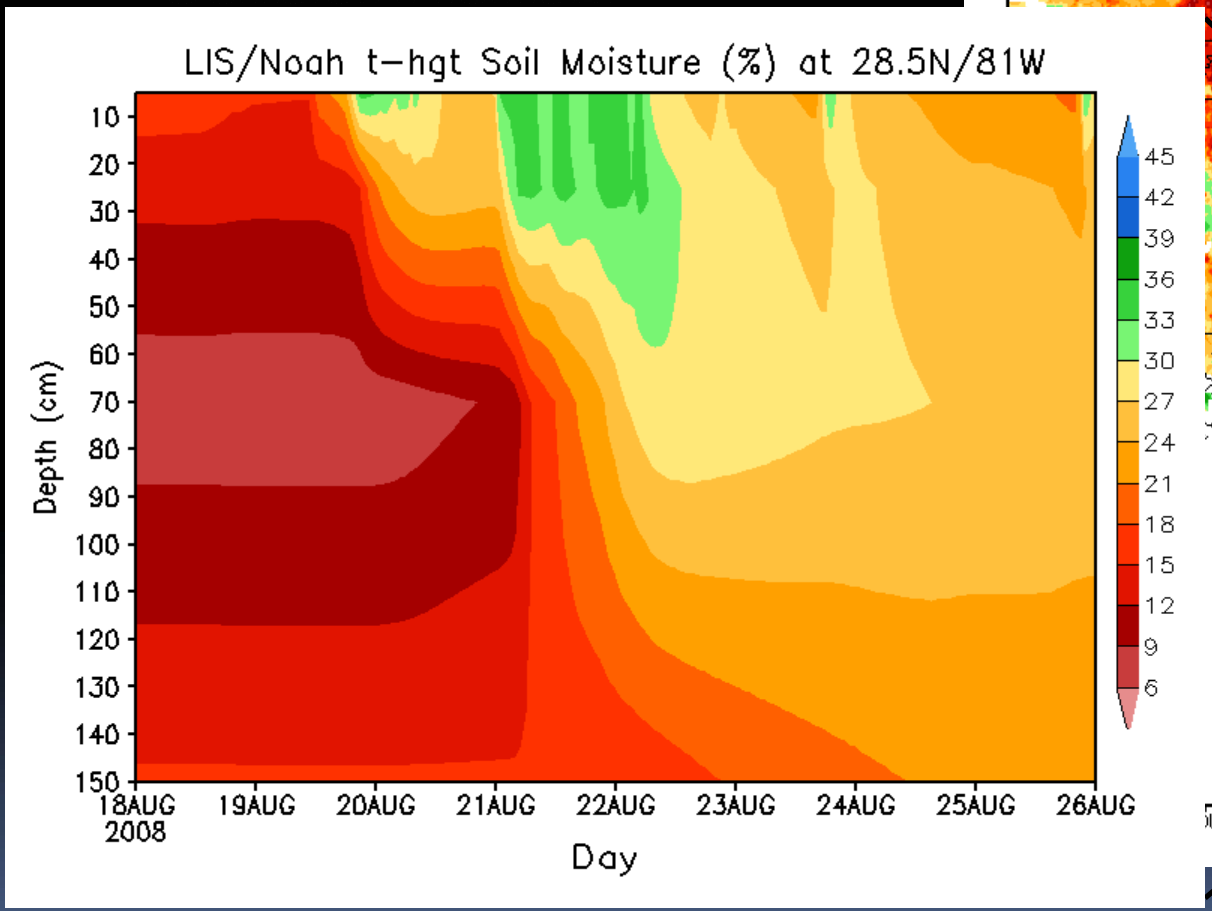
South Florida

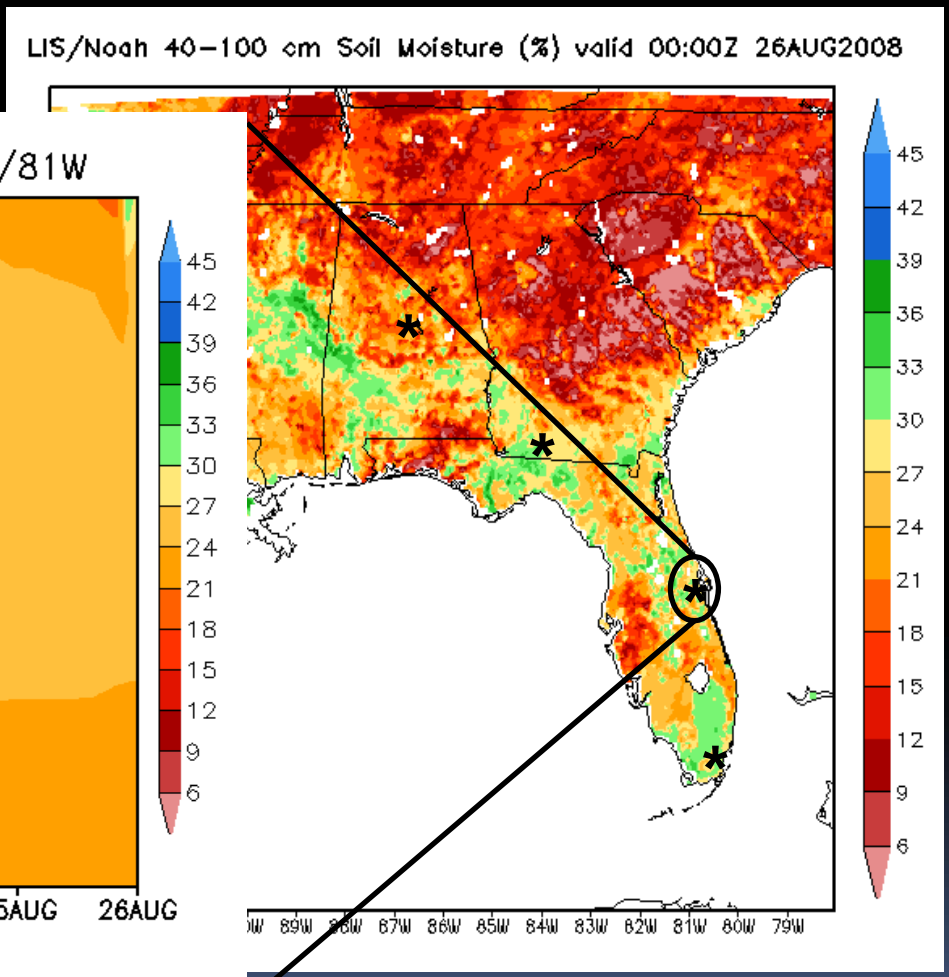




Tropical Storm Fay: Rainfall and Dramatic Soil Moistening

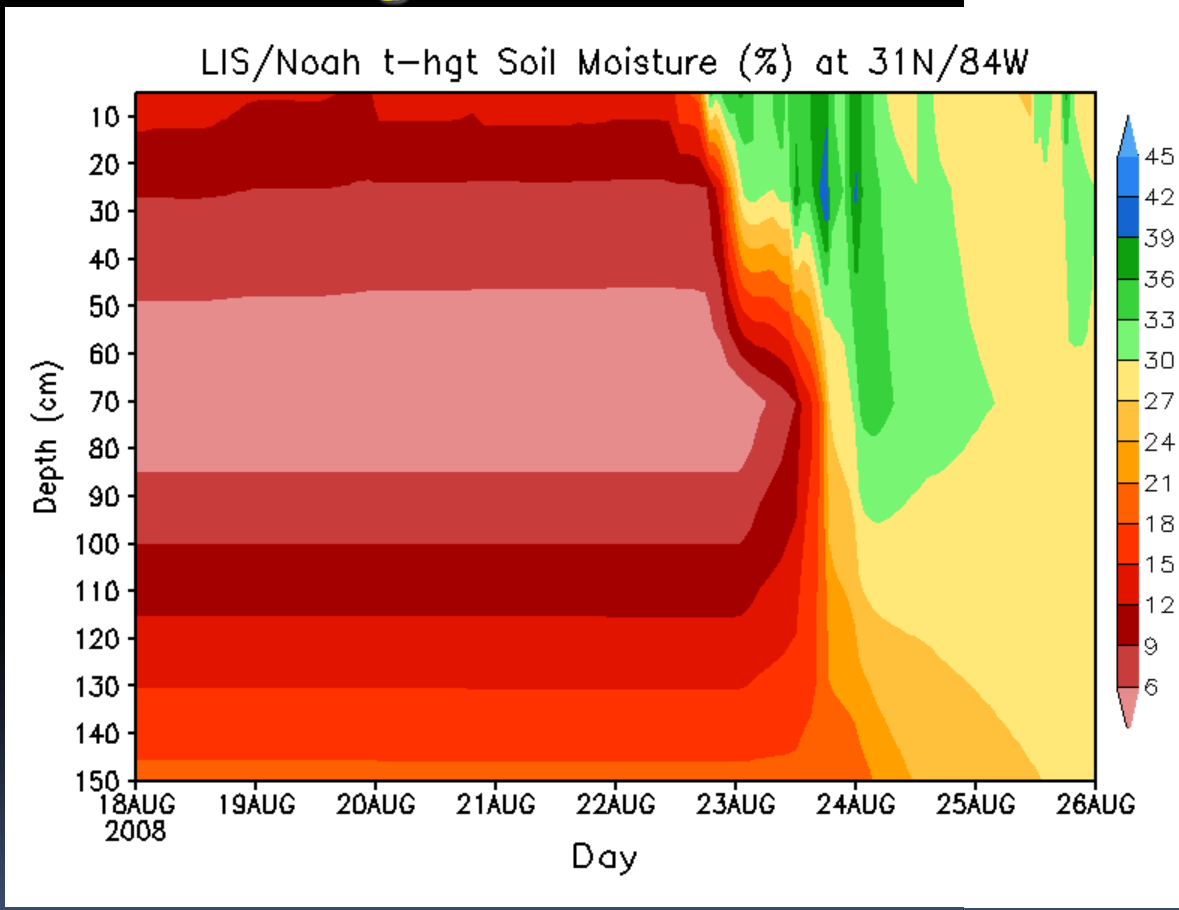
Central Florida

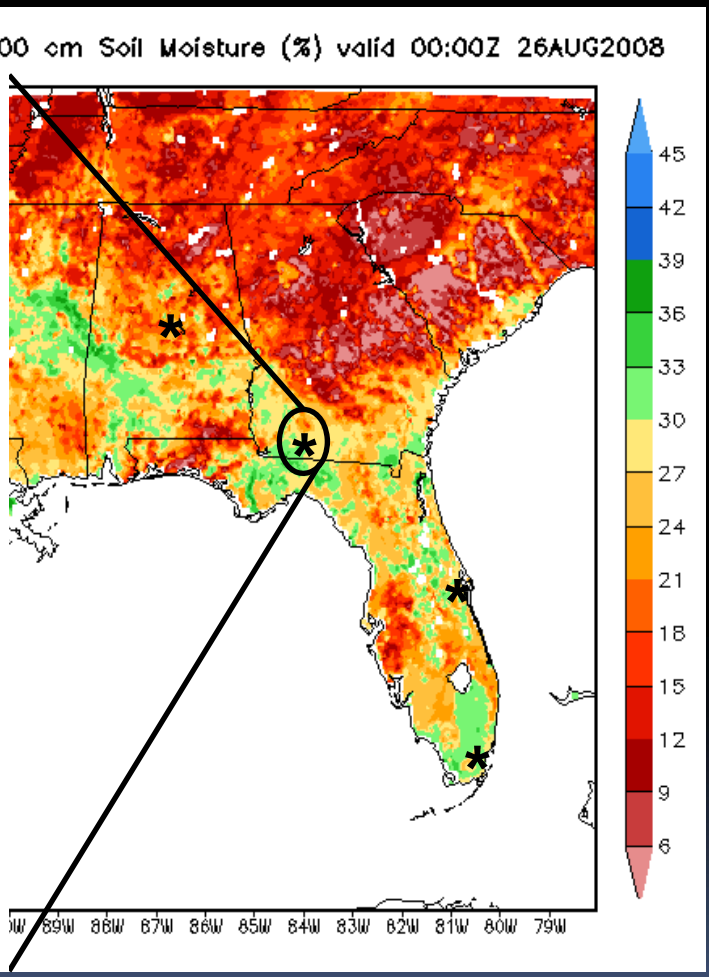




Tropical Storm Fay: Rainfall and Dramatic Soil Moistening

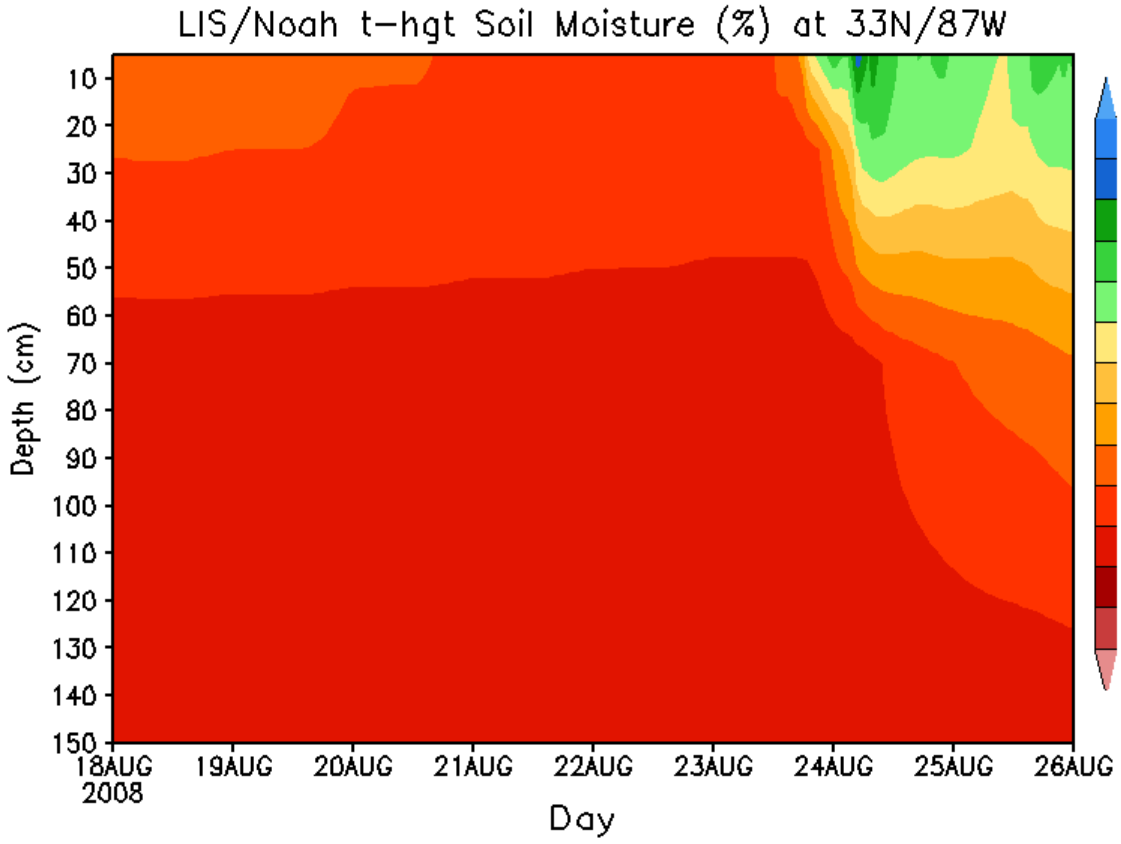
SW Georgia

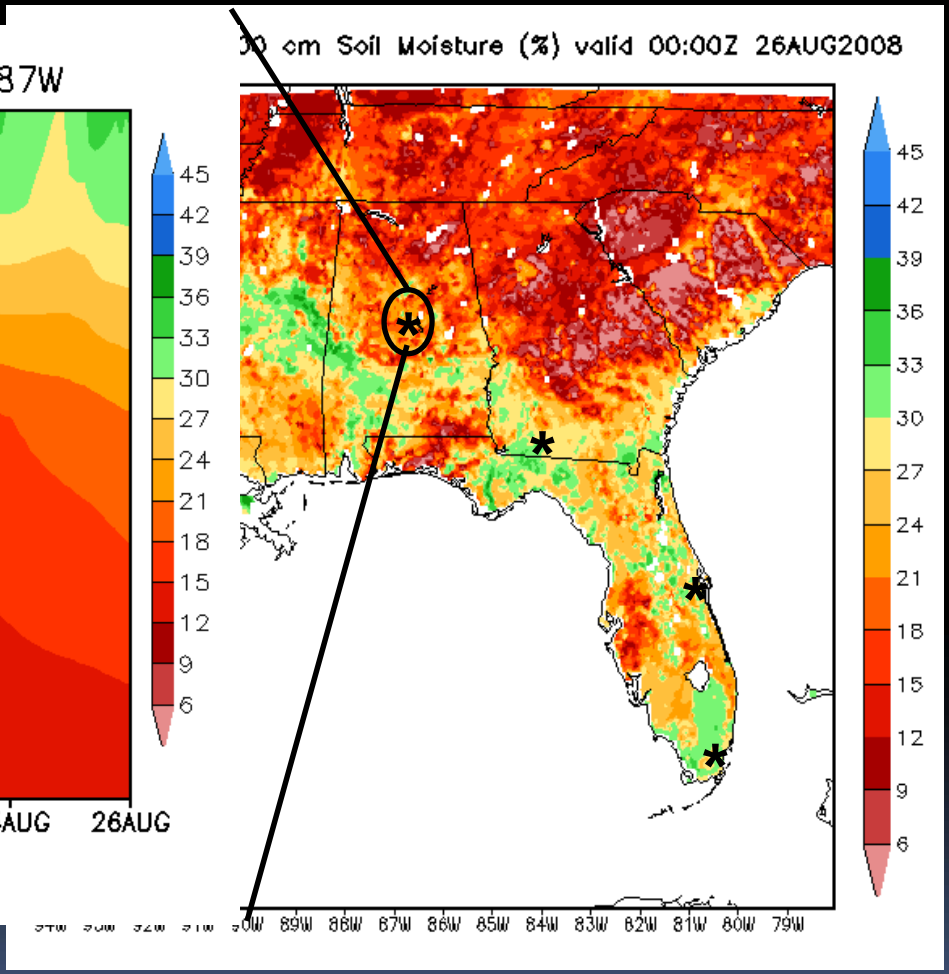




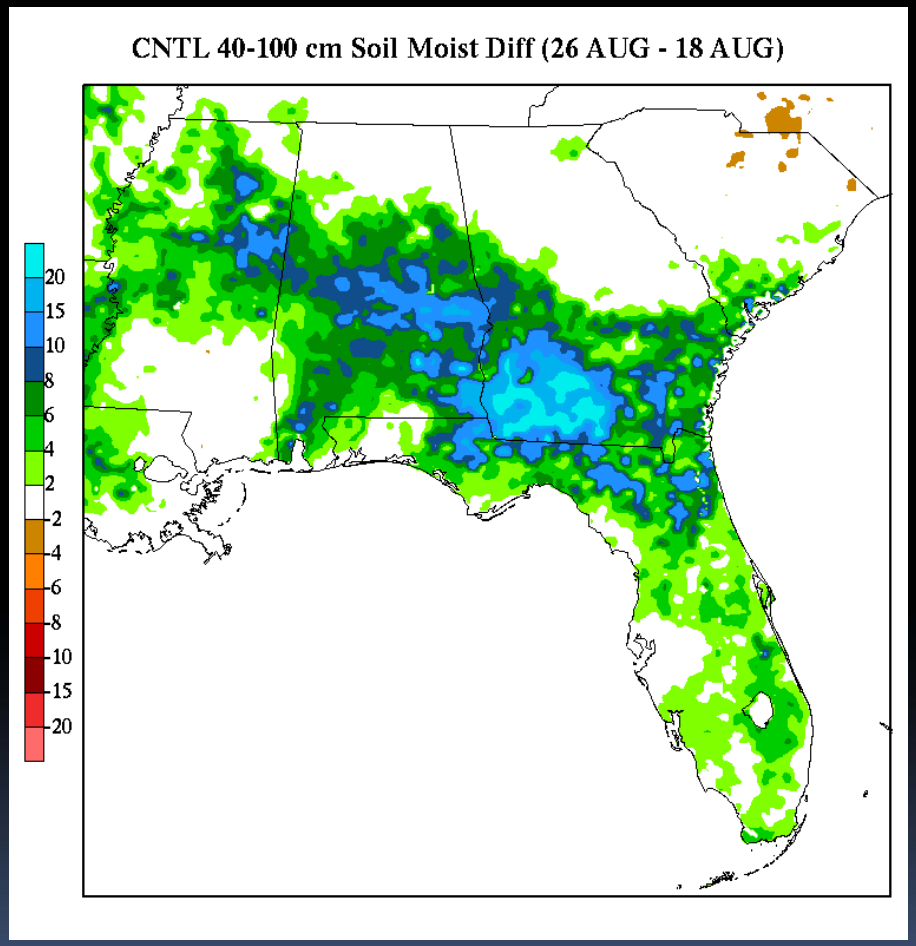
Tropical Storm Fay: Rainfall and Dramatic Soil Moistening

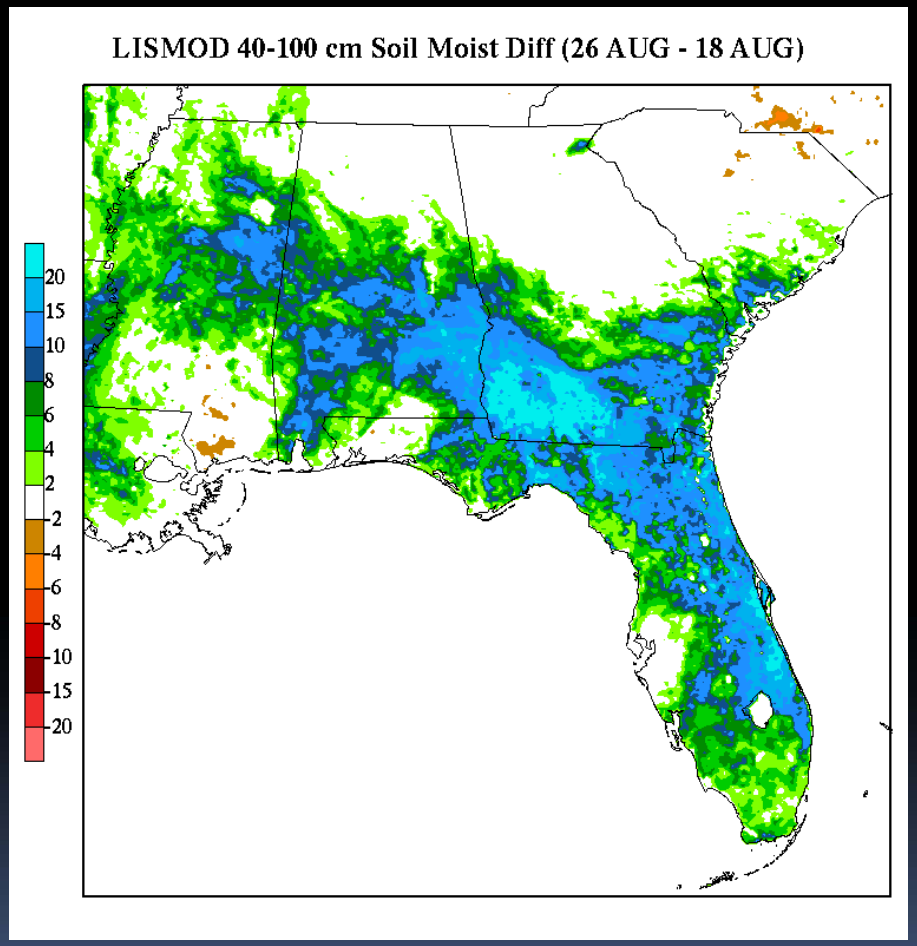
Central Alabama





Tropical Storm Fay: Rainfall and Dramatic Soil Moistening





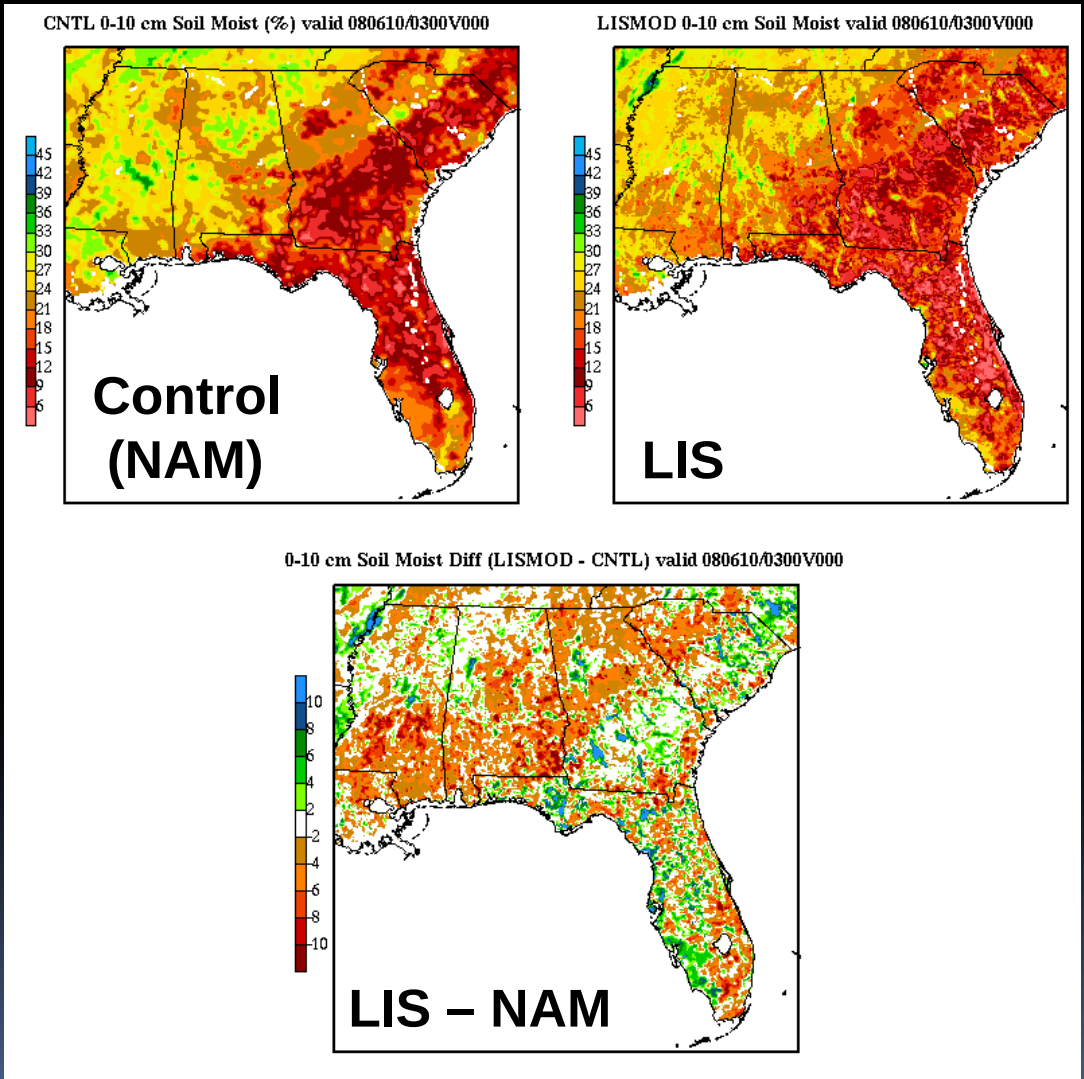
Experiment Design

- Run parallel WRF simulations
  - Once daily 27-h simulations, initialized at 0300 UTC
    - 81 total forecasts (Jun – Aug 2008)
    - 11 missing dates due to missing/corrupted MODIS SST data
  - Control: Initial / boundary conditions from NCEP 12-km NAM model
  - Experimental: Same as Control, except
    - Replace land surface data with LIS output fields
    - Replace SSTs with SPoRT MODIS composites
- Evaluation and Verification
  - Graphical and subjective comparisons
  - Verification using Meteorological Evaluation Tools (MET) package
    - Developed by WRF Development Testbed Center
    - Standard point / grid verification statistics
    - Method for Object-Based Diagnostic Evaluation (MODE)
      - Object-oriented, non-traditional verification method

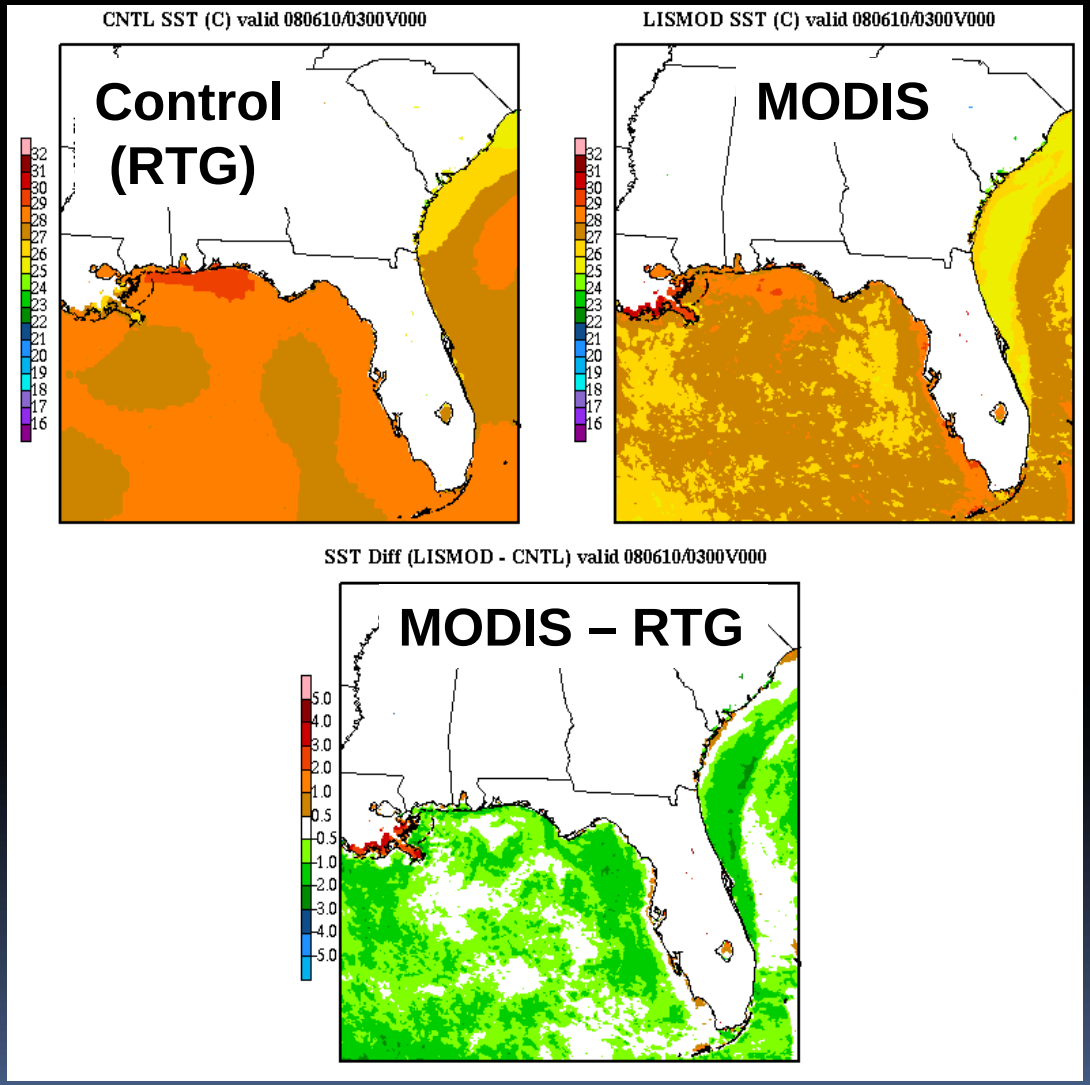
WRF Model Configuration

- Model domain over Southeastern U.S.
  - Advanced Research WRF v3.0.1.1
  - 4-km horizontal grid spacing
  - 39 sigma-p levels from surface to 50 mb
    - Min. spacing near surface of 0.004 sigma
    - Max. spacing of 0.034 sigma
  - Positive definite advection of scalars
  - Model physics options
    - Radiation: Dudhia SW and RRTM LW
    - Microphysics: WSM6
    - Land Surface: Noah LSM (same as LIS)
    - PBL: MYJ scheme
    - Cumulus parameterization: None

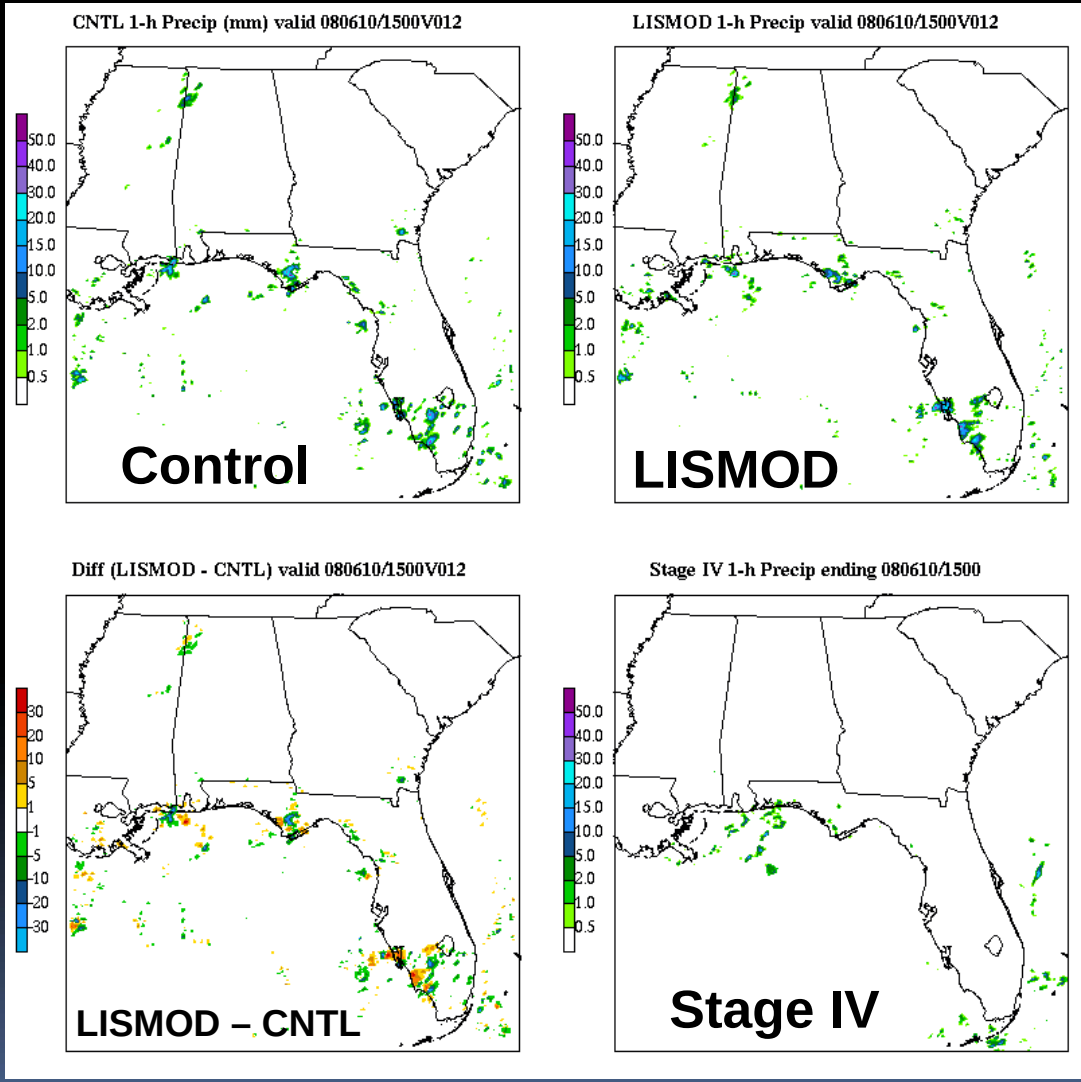
10 June 2008 Sensitivity Example:
0–10 cm Soil Moisture Differences



10 June 2008 Sensitivity Example:
SST Differences

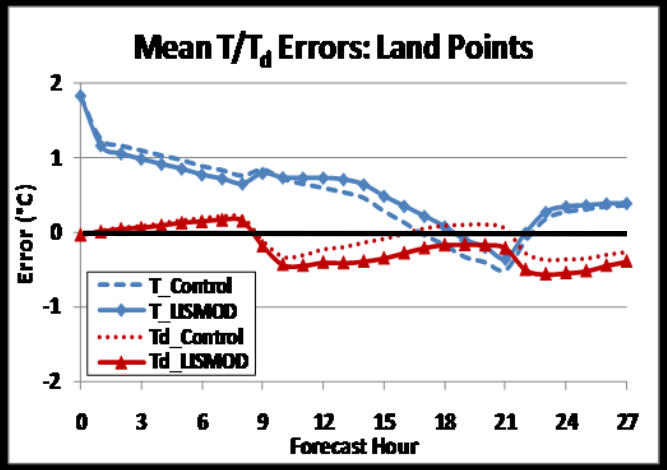


10 June 2008 Sensitivity Example:
WRF 1-h Precip Diffs (15z to 03z)

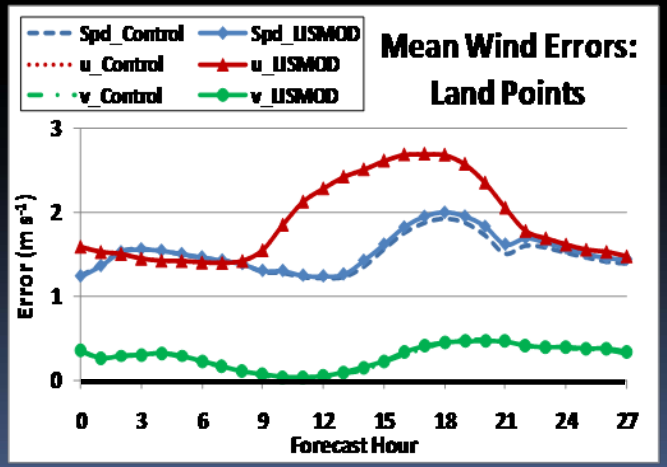


Obligatory Point Verification

2-m/10-m Bias

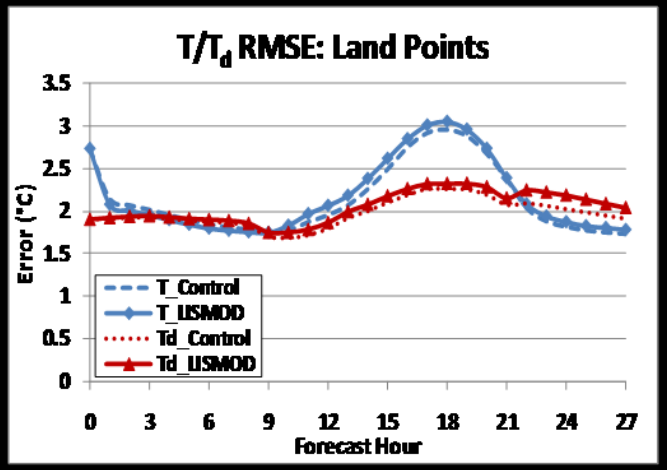


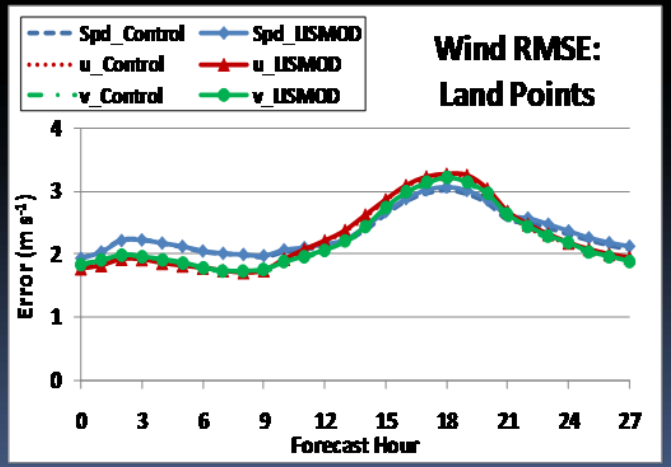
- LISMOD is slightly warmer/drier than the Control during the day
- Marginally larger RMSE



- Little to no differences in wind errors and MSLP (not shown)

2-m/10-m RMSE

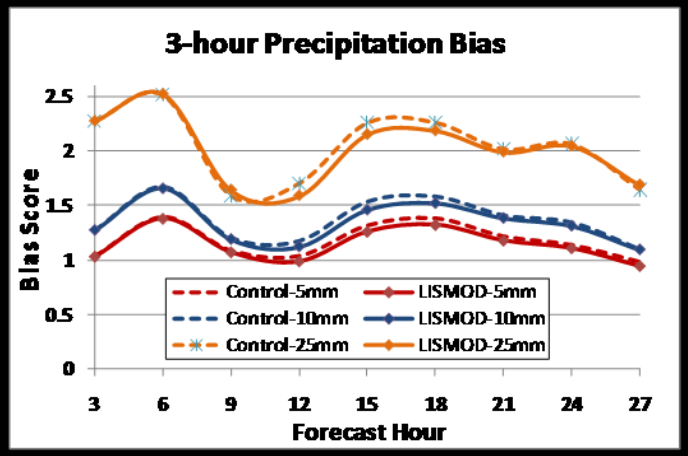




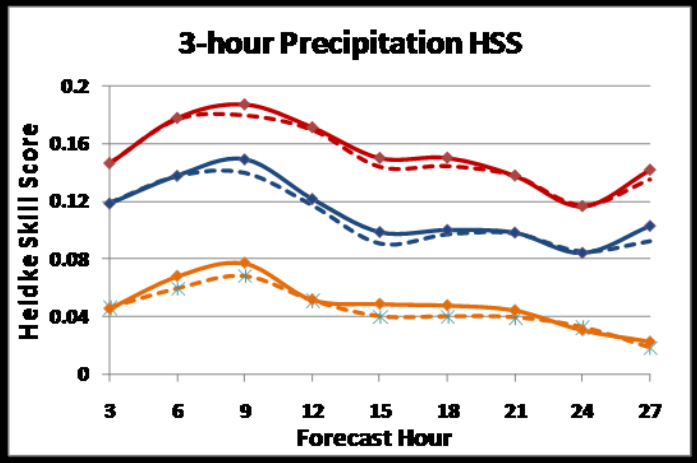
Precip Verification with MET / MODE

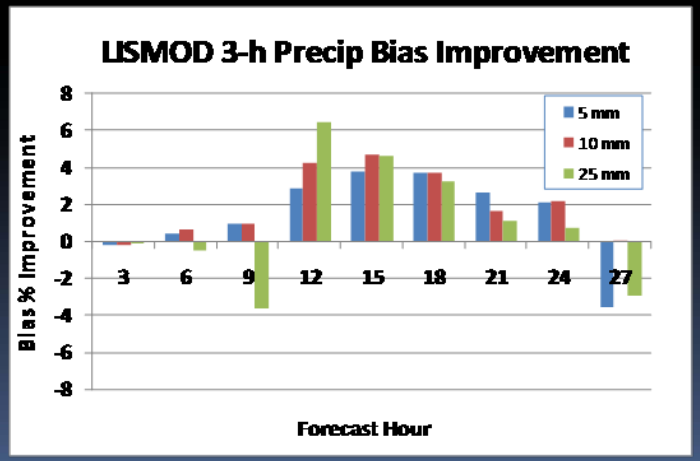
- Stage IV grid as validation for traditional stats and MODE
- Traditional grid point verification
  - Bias, Threat Score, Heidke Skill Score (HSS)
    - 1-h / 3-h accumulation intervals
    - 5, 10, and 25 mm thresholds
  - Neighborhood precipitation verification
    - Occurrence of precipitation threshold in a “box” surrounding a grid point
    - Relaxes stringency and determines model skill at distance thresholds
- MODE object classification
  - Resolves objects through convolution thresholding:
    - Filter function applied to raw data using a tunable radius of influence
    - Filtered field thresholded (tunable parameter) to create mask field
    - Raw data restored to objects where mask meets/exceeds threshold
  - Several attributes computed for “matching” objects

3-h Traditional Precip Verification:
(3–27 hours; Jun-Aug 2008)

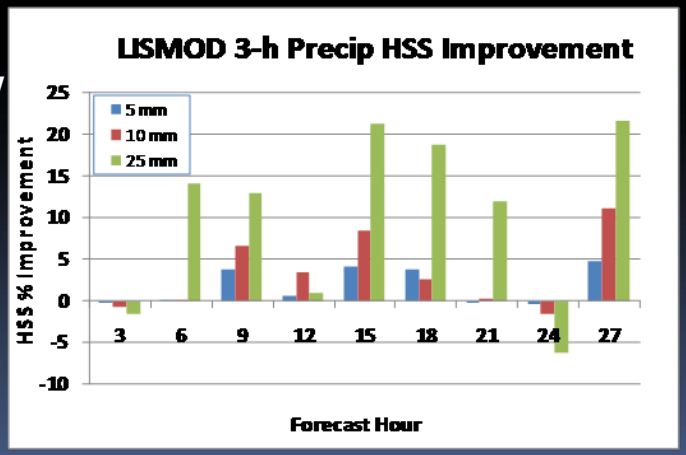


- WRF has an overall high bias
- LISMOD reduces bias some, esp. during daylight hours (12-24 h)

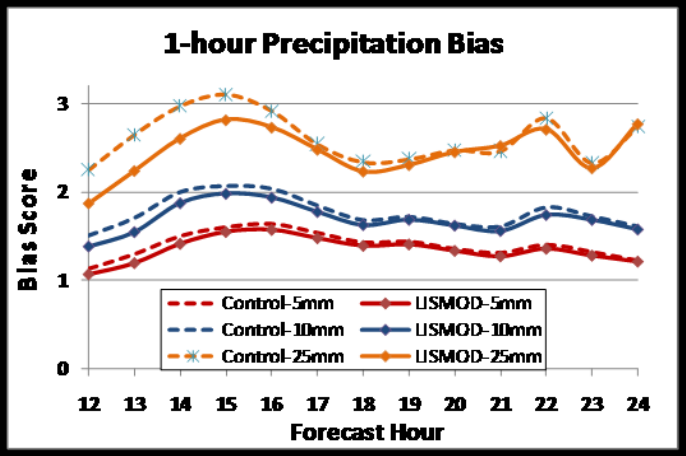




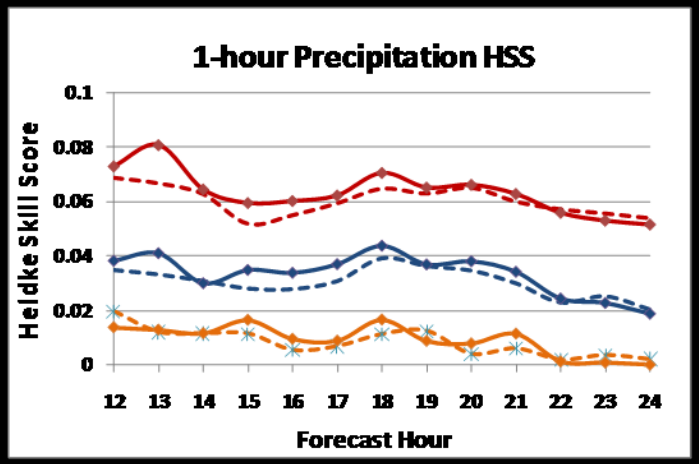
- WRF generally has low skill (Heidke SS, right)
- LISMOD incrementally improves skill

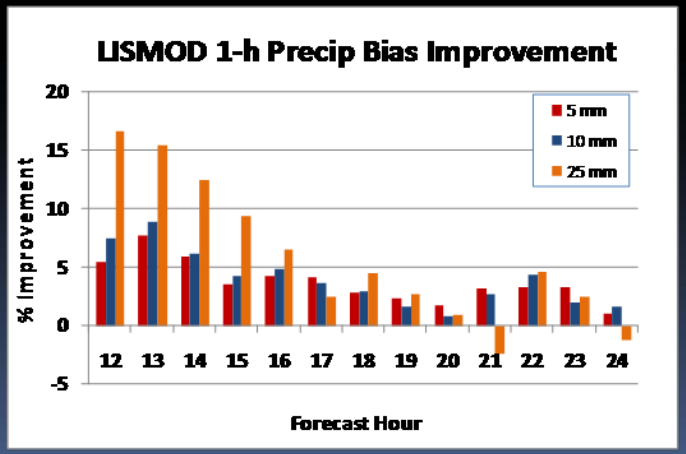


1-h Traditional Precip Verification:
(12–24 hours; Jun-Aug 2008)

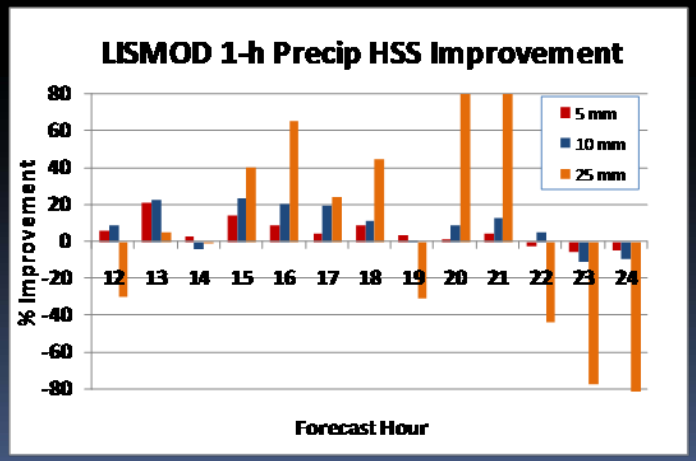


- WRF has an overall high bias
- LISMOD reduces bias some, esp. mid-AM to early-PM (12-18 h; 15-21z)



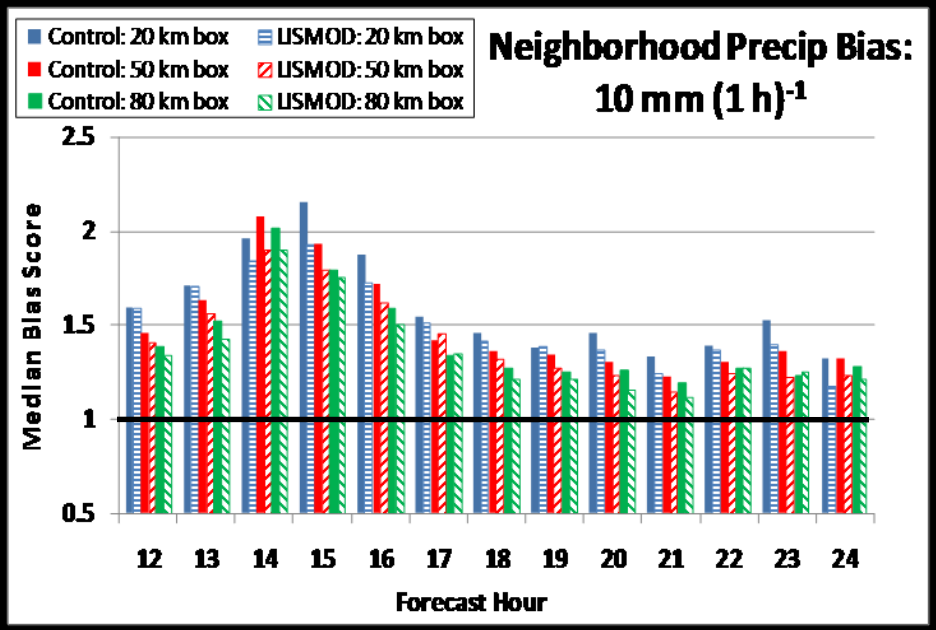


- WRF generally has very low skill (right)
- LISMOD incrementally improves skill

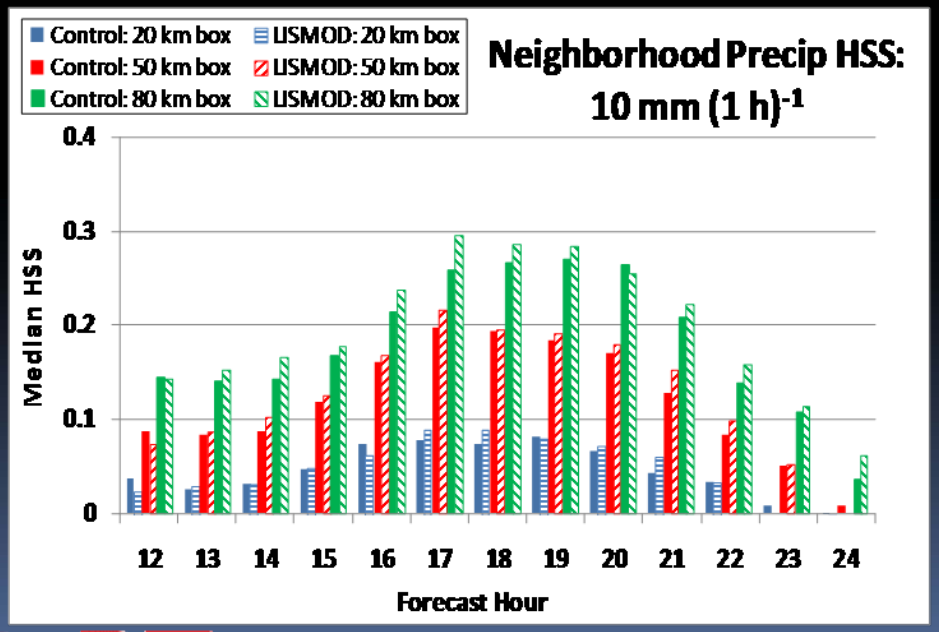


1-h Neighborhood Precip Verification

(12-24 hours; Median of 81 individual forecasts)



- Three neighborhood "boxes" examined
  - 20, 50, 80 km on a side
  - A hit is defined as ANY occurrence of precip at specified threshold within box surrounding the grid point



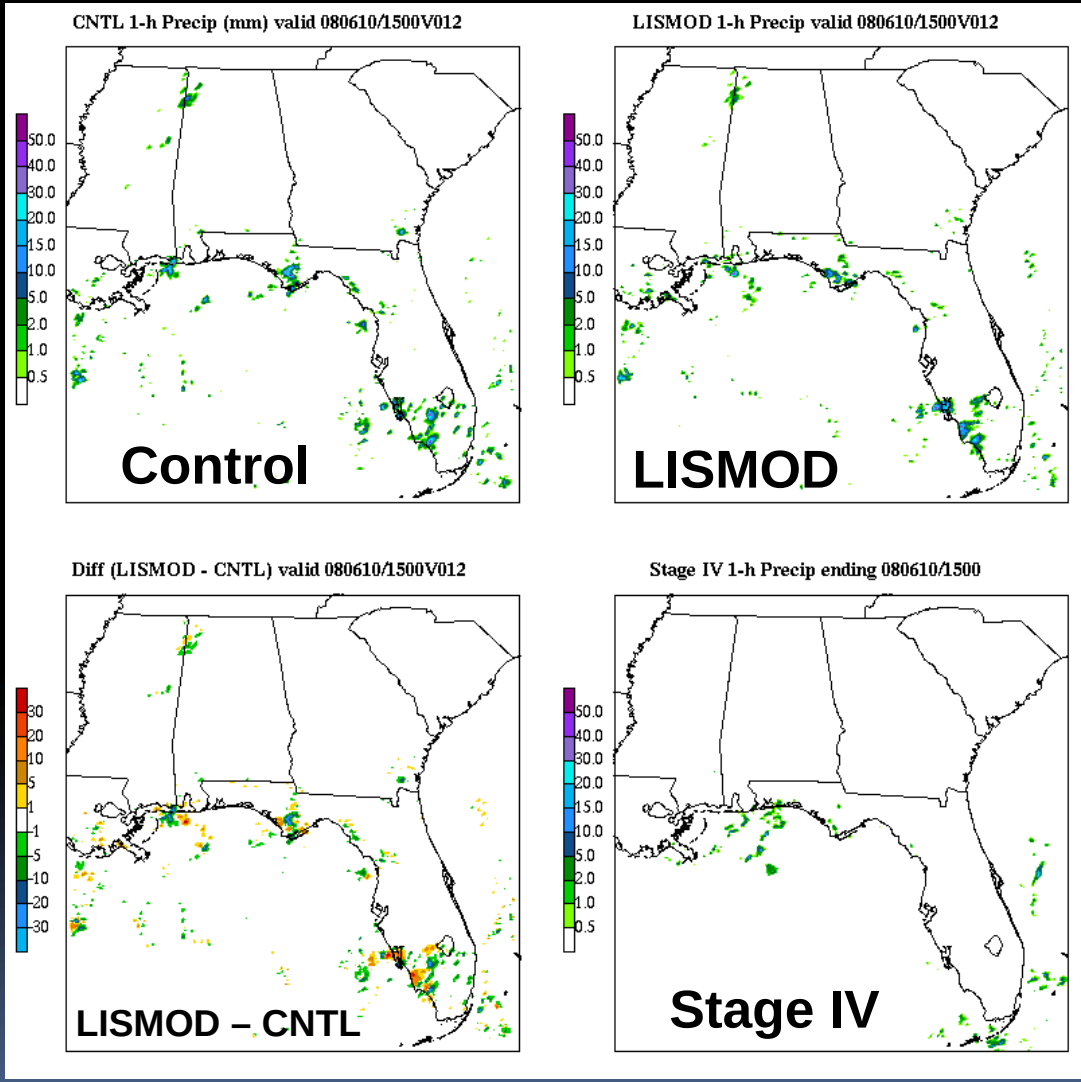
- Consistent over-prediction prevalent
- LISMOD reduces high bias, and increases skill at most day/evening forecast hours during the day

MODE Configuration Parameters

Fuzzy engine weights applied to object attributes to compute "total interest" field	
Object Attribute	**Weight**
Centroid Distance	20%
Minimum Boundary Distance	40%
Orientation Angle Difference	10%
Ratio of Object Areas	10%
Intersection Area Ratio	20%

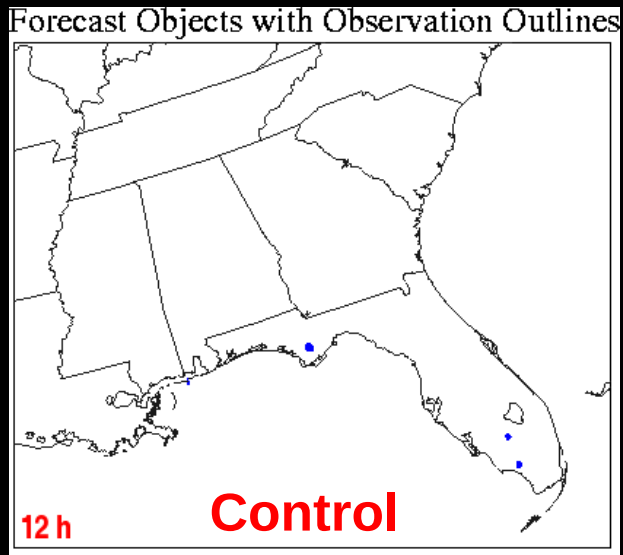
- **MODE is run with:**
  - 1-h/3-h accumulated precipitation
  - 5, 10, and 25 mm thresholds
  - Circular convolution radius of 12 km (produced best objects)
- **Fcst/Obs objects match if:**
  - Centroid distance ≤ 80 km
  - Total interest ≥ 60%

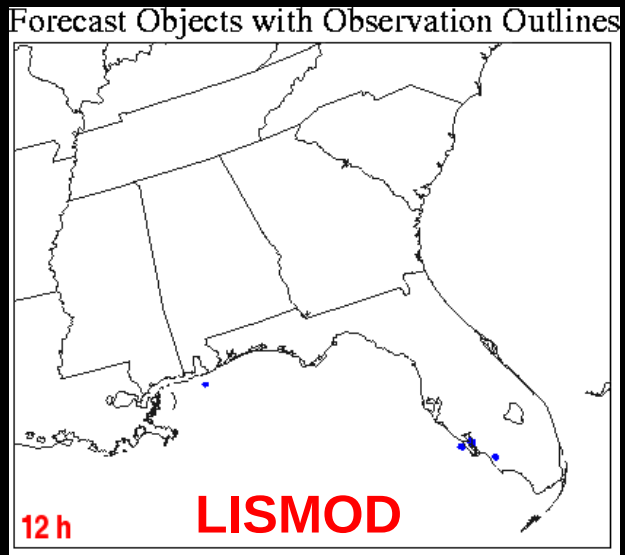
10 June 2008 Sensitivity Example:
WRF 1-h Precip Diffs (12z to 03z)

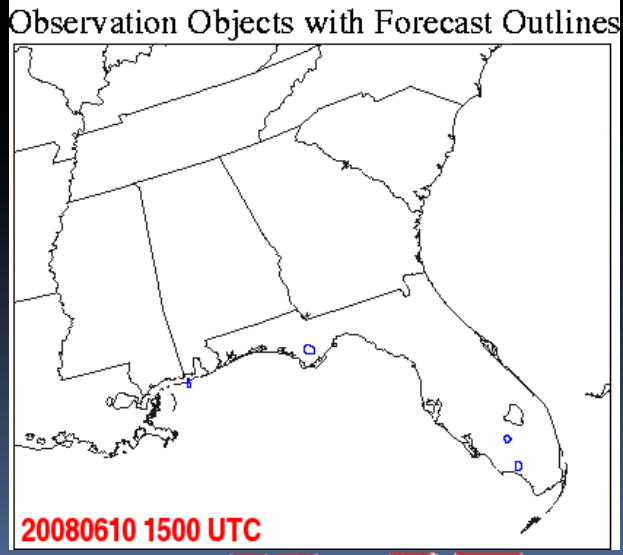


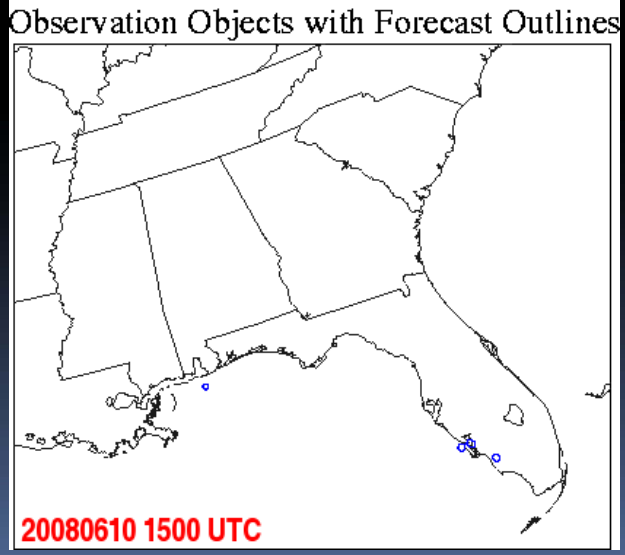
10 June 2008 Sensitivity Example:
MODE 10-mm / 1-h precip "Objects"

	Control		LISMOD	
Fcst hour	Grid Area Match	Grid Area Un-match	Grid Area Match	Grid Area Un-match
12	0	115	0	115
13	0	93	0	64
14	0	222	0	108
15	0	492	0	474
16	0	802	232	587
17	388	544	606	653
18	419	1039	470	711
19	108	1122	186	916
20	318	680	271	674
21	394	301	382	646
22	0	596	110	424
23	28	632	30	501
24	0	328	0	417

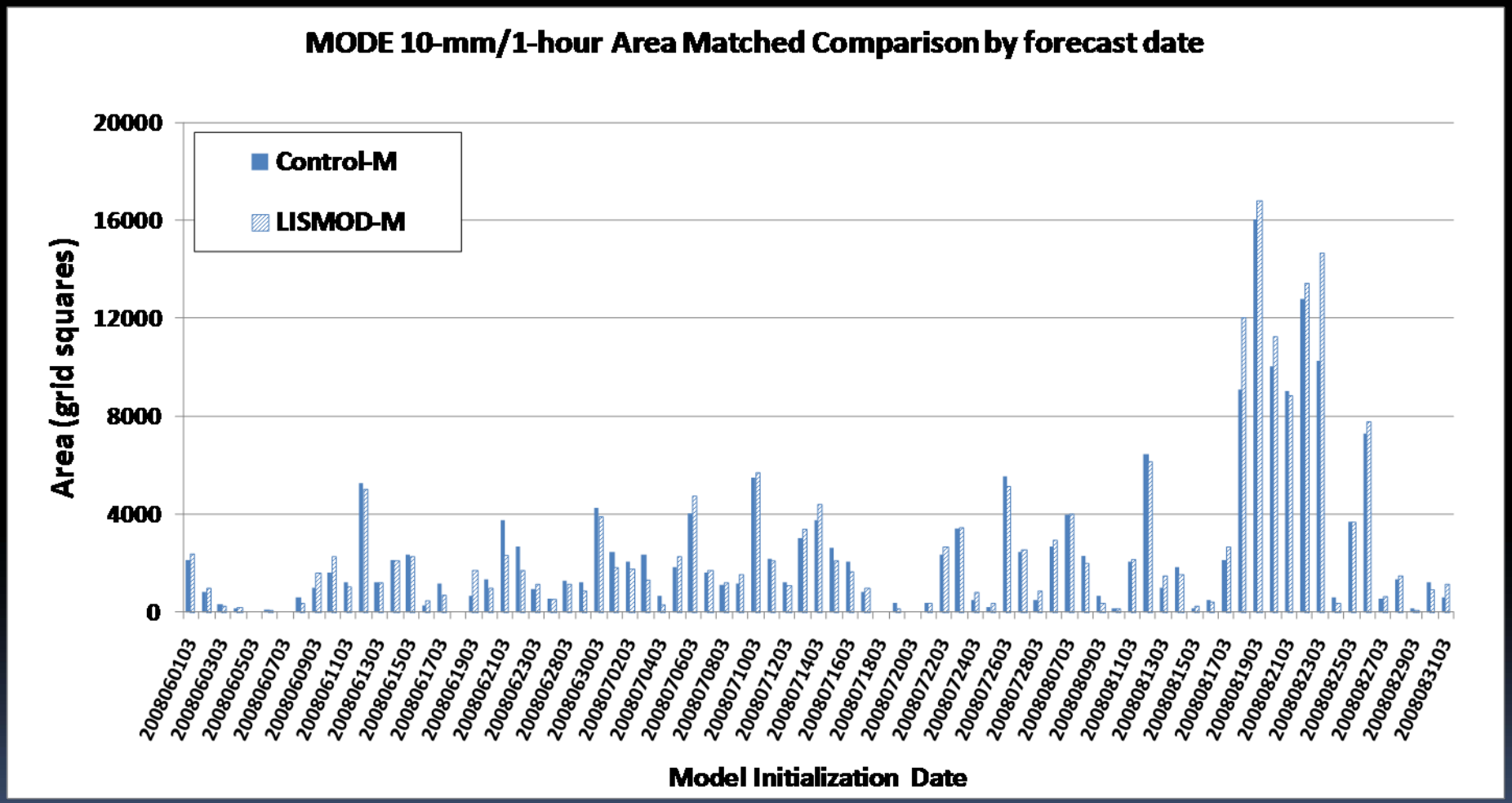




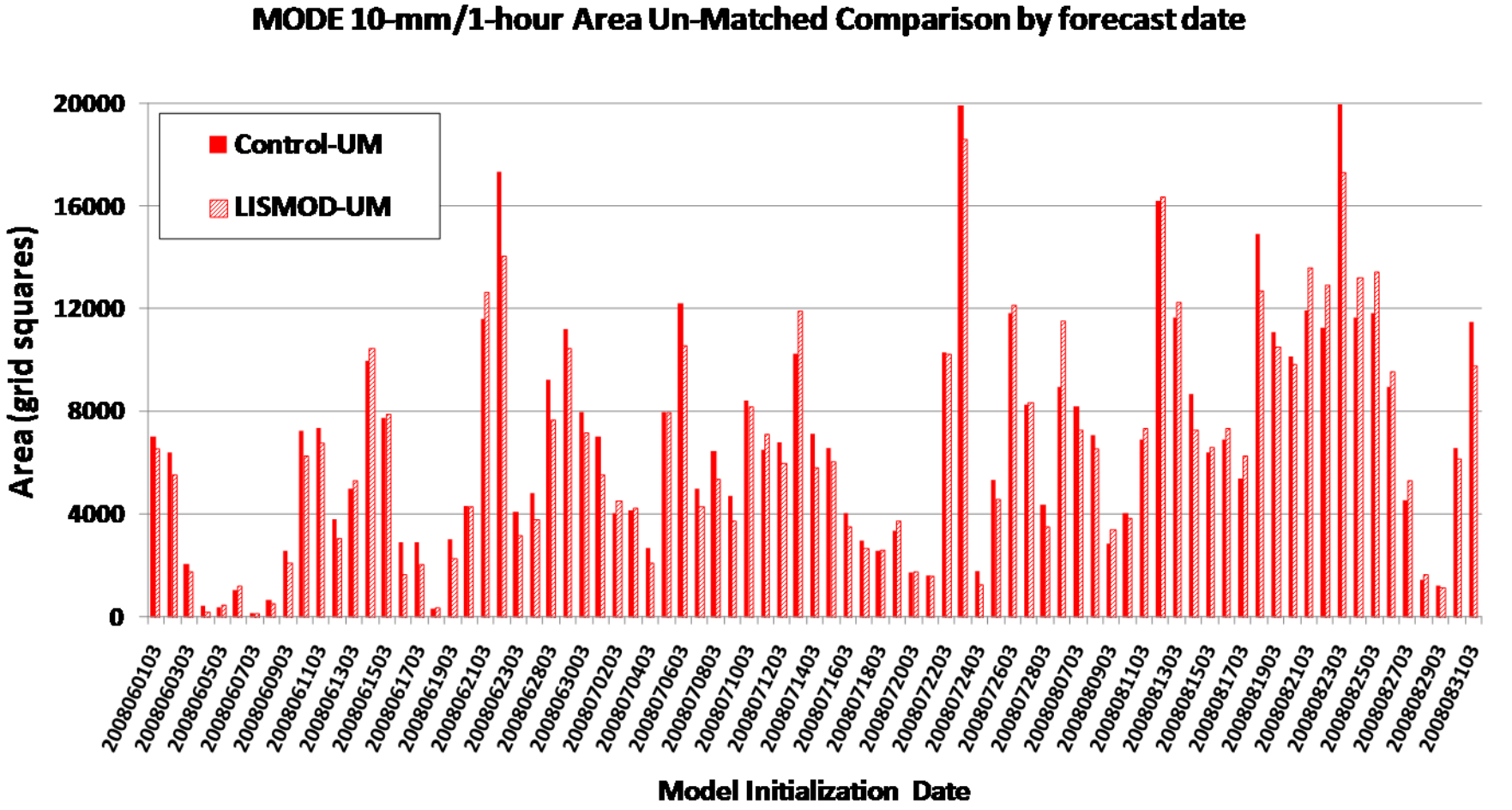




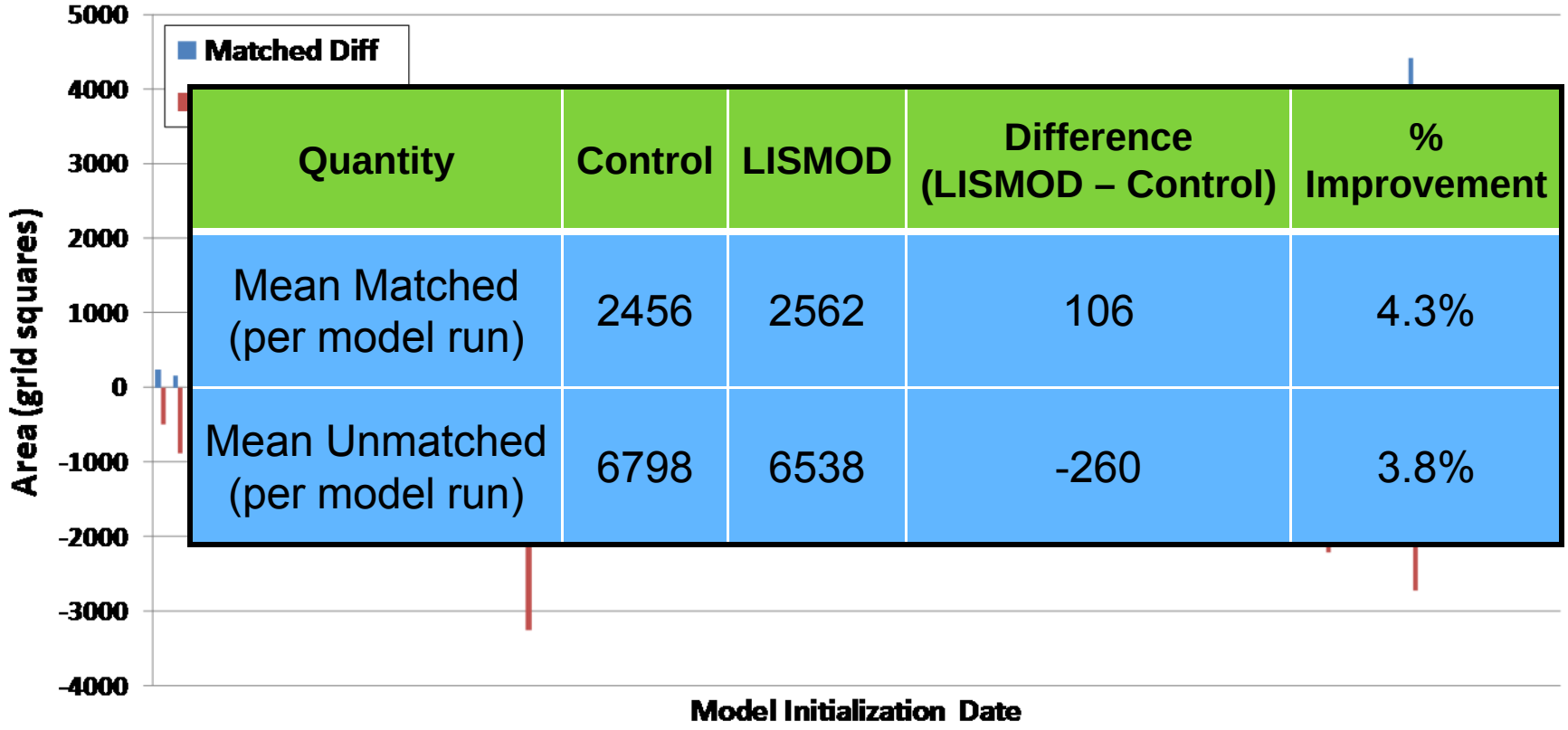
1-h MODE Precip Object Verification:
Area Matched by Model Run: 12-24 h Combined



1-h MODE Precip Object Verification:
Area Un-matched by Model Run: 12-24 h Combined



1-h MODE Precip Object Verification:
(Un-)Matched Differences by Model Run

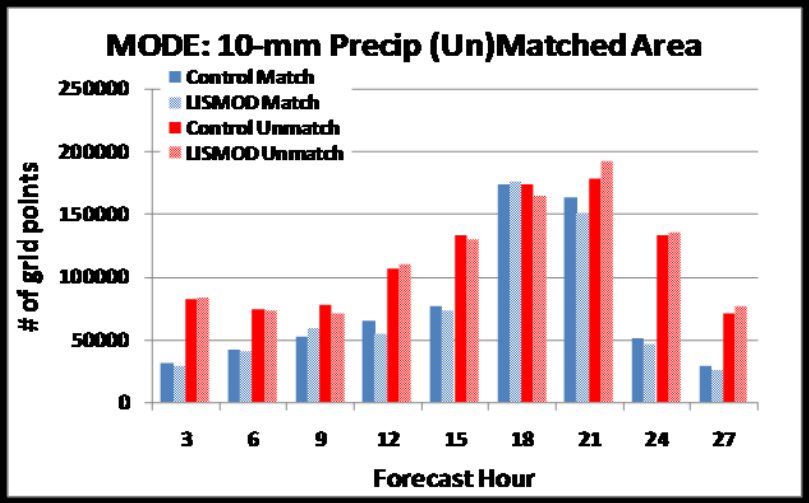


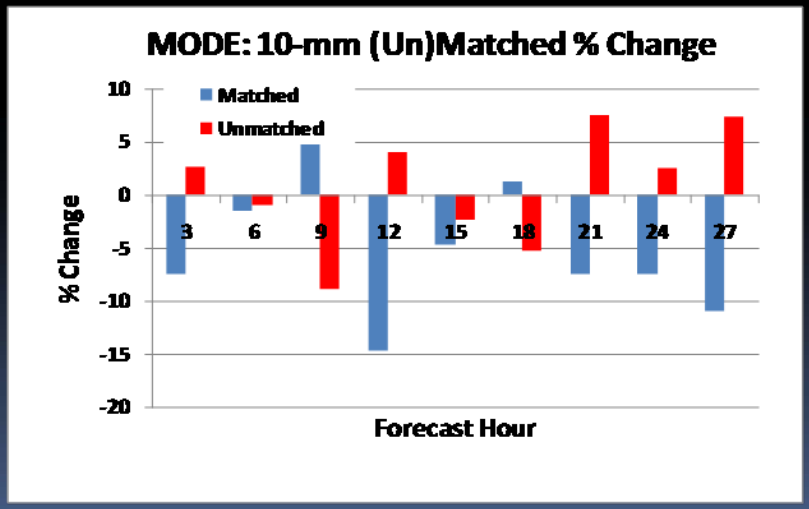
Quantity	Control	LISMOD	Difference (LISMOD – Control)	% Improvement
Mean Matched (per model run)	2456	2562	106	4.3%
Mean Unmatched (per model run)	6798	6538	-260	3.8%

MODE Precip Object Verification:

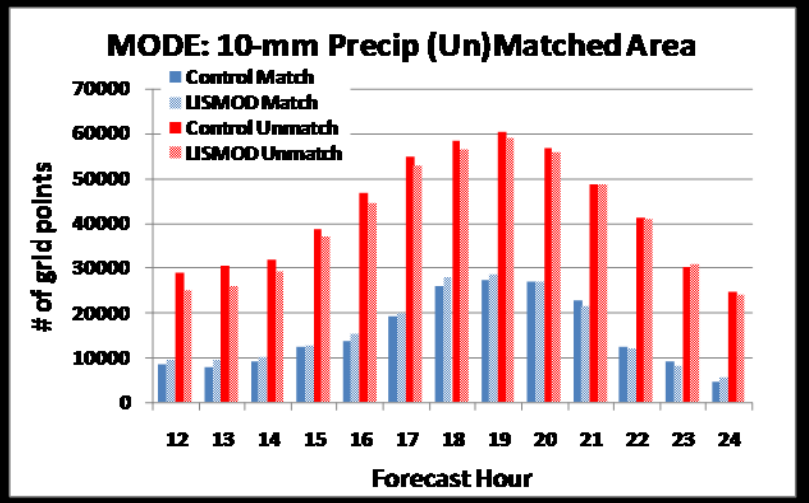
Area Matched vs. Area Un-matched: All 81 forecasts

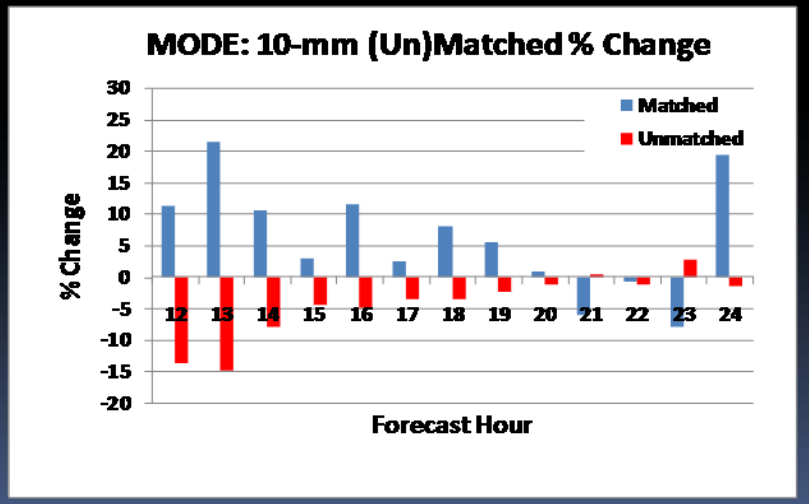
3-h Accumulated Precip Objects





1-h Accumulated Precip Objects

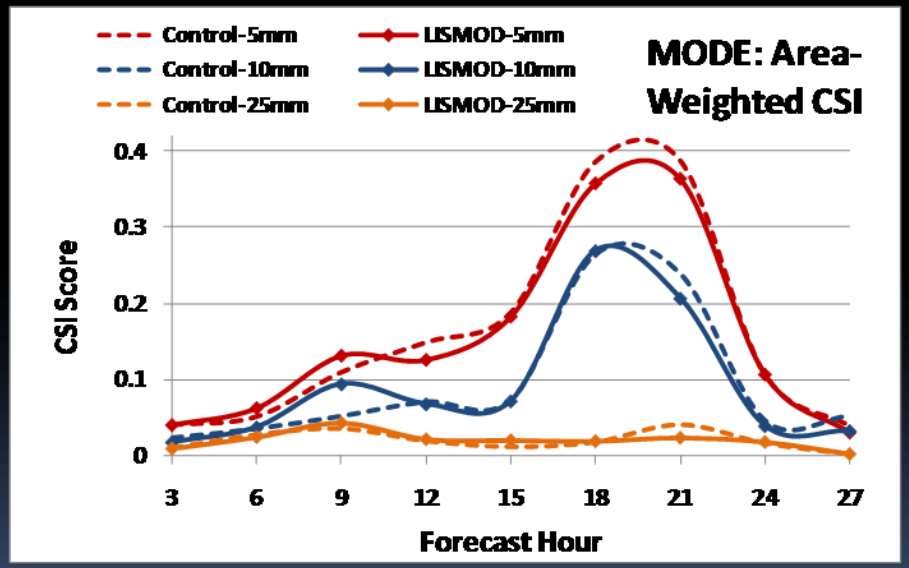




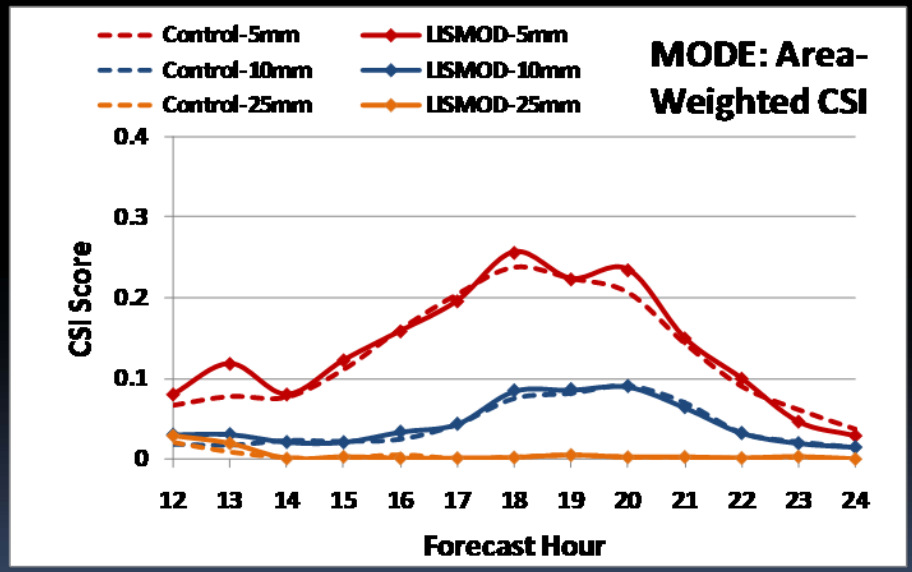
MODE Precip Object Verification:
Area Weighted Critical Success Index

$$AWCSI = \frac{(HitArea/TotalArea)*n_{HitArea}}{[(HitArea/TotalArea)*n_{HitArea} + (MissArea/TotalArea)*n_{MissArea} + (FalseAlarmArea/TotalArea)*n_{FalseAlarmArea}]}$$

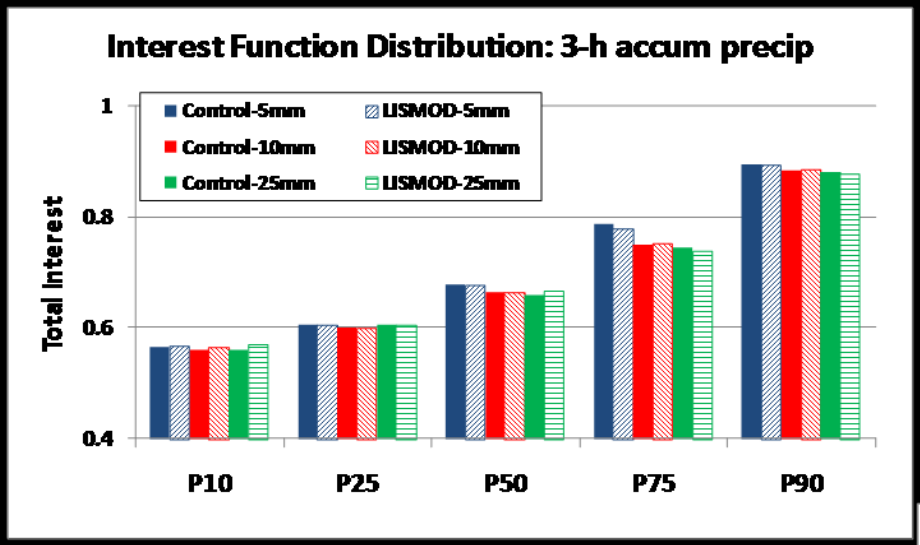
3-h Accumulated Precip Objects



1-h Accumulated Precip Objects

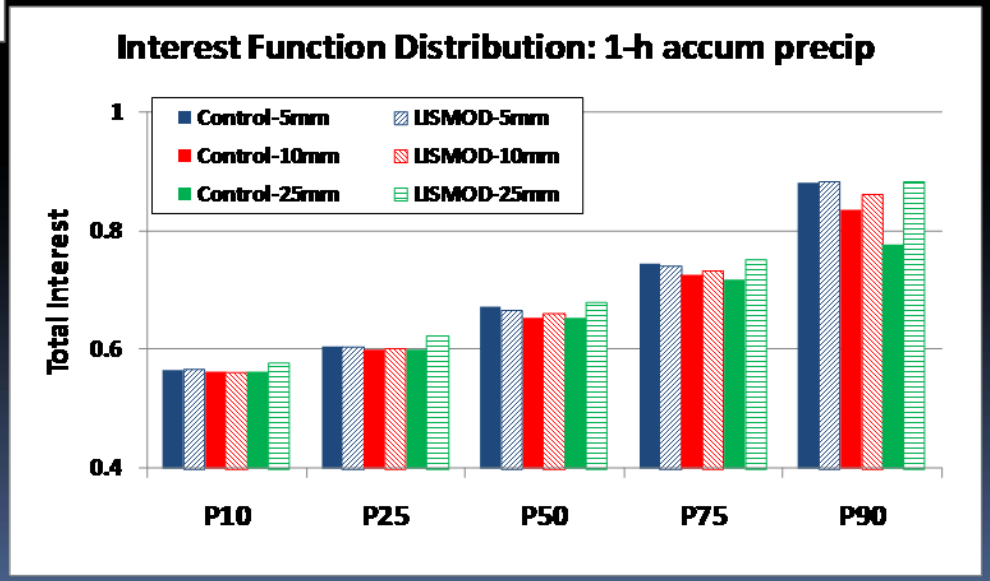


MODE Precip Object Verification:
Distribution of Total Interest Field



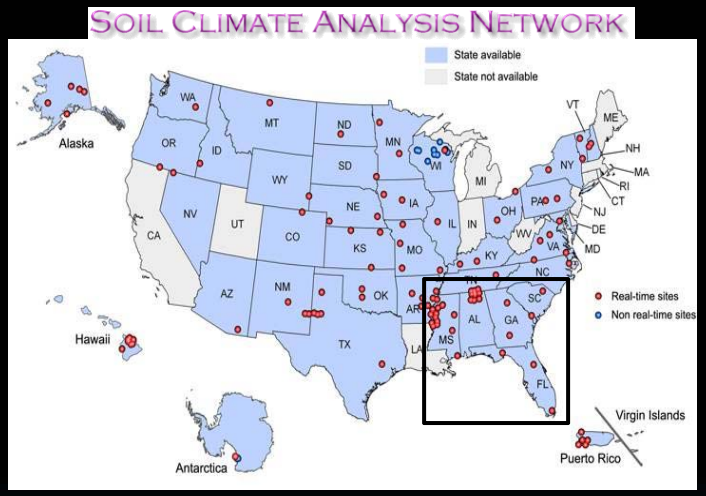
- Interest field take into account all weighted object attributes from slide 23
- Weighted heavily towards distance between objects (60%)

- 3-hour accumulated precip interest fields show few trends
- 1-hour accumulated precip interest tends to be greater in LISMOD at higher precipitation thresholds and percentiles (i.e. LISMOD objects tend to be more similar to observed objects than the Control objects)



Summary / Future Work

- Presented a simulation methodology using NASA data and tools
  - LIS land surface + MODIS SST composites
  - Provides high-resolution representation of land/water surface, consistent with local & regional modeling resolution
  - Incremental improvements to 1-hour WRF convective precipitation forecasts



- Ongoing / Future efforts
  - Validate LIS output at SCAN sites
  - Develop real-time LIS at SPoRT for local modeling applications
  - Assimilate AMSR-E and/or SCAN data into real-time LIS
  - Develop MODIS vegetation fraction database for LIS/Noah
- NASA / SPoRT website: http://weather.msfc.nasa.gov/sport/

Backups

LIS High-Level Overview

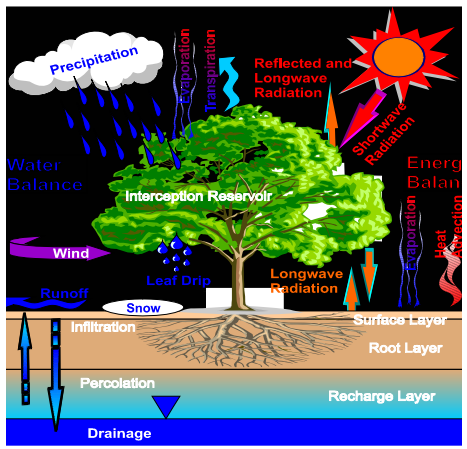
Uncoupled or Analysis Mode

Coupled or Forecast Mode

Station Data

Global, Regional Forecasts and (Re-) Analyses

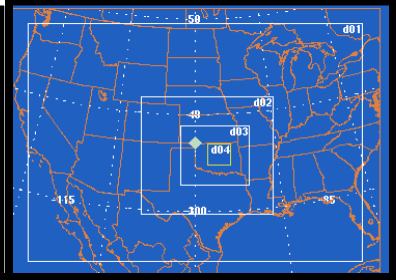
Satellite Products

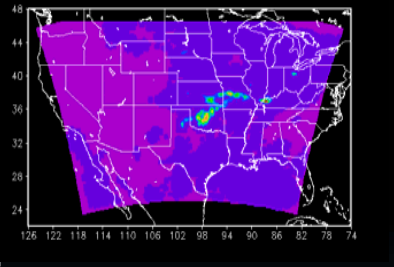


LSM Physics (e.g. Noah, VIC, SIB, **SHEELS**)

ESMF

WRF





Data Assimilation
- Soil moisture
- LST, Snow cover

LSM First Guess / Initial Conditions

SPoRT MODIS SST Composites

- Real-time, 1-km SST product
  - Composites available up to four times per day
    - 0400, 0700, 1600, and 1900 UTC
  - Primarily over Gulf of Mexico, western Atlantic waters, and larger lakes (e.g. Florida's Lake Okeechobee)
  - GRIB-1 files posted to publicly available ftp site
    - Sub-sampled to 2-km spacing for model applications
- Compositing technique
  - Build complete SST composite with multiple Earth Observing System satellite passes (both Aqua and Terra)
  - At each pixel, examine 5 most recent readings:
    - Take average of 3 warmest readings
    - This method helps to eliminate cloud contamination