Coupled COAMPS-LIS-WRF-HYDRO Coastal Flood Applications – Preliminary Results

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Objectives

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To provide a new baseline capability for Naval LIS-hydrological modeling by:

- **quantifying the impact of the water cycle budget on LND dynamics, via the interactive feedback of LIS and WRF-Hydro within the COAMPS ESMF coupling framework**
- **quantifying the impact of enhanced cloud-microphysical to severe flood processes via linkage with COAMPS moist physics parameterizations**
- **quantifying the feasibility of a "generalized" LND and hydrological components within COAMPS**

Outlines

- **Introduction of NRL Coupled Ocean/Atmosphere Mesoscale Prediction System**
- **Approach to couple LIS and WRF Hydro with COAMPS**
- **Preliminary results**
  - **Atmosphere precipitation and surface parameters**
  - **LIS soil temperature, soil moisture fraction**
  - **WRF-HYDRO surface and subsurface runoffs**
- **Summary**
- **Future plans**

Air-Ocean-Wave-ICE-LSM-Hydro Coupled COAMPS Forecast and Data Assimilation System

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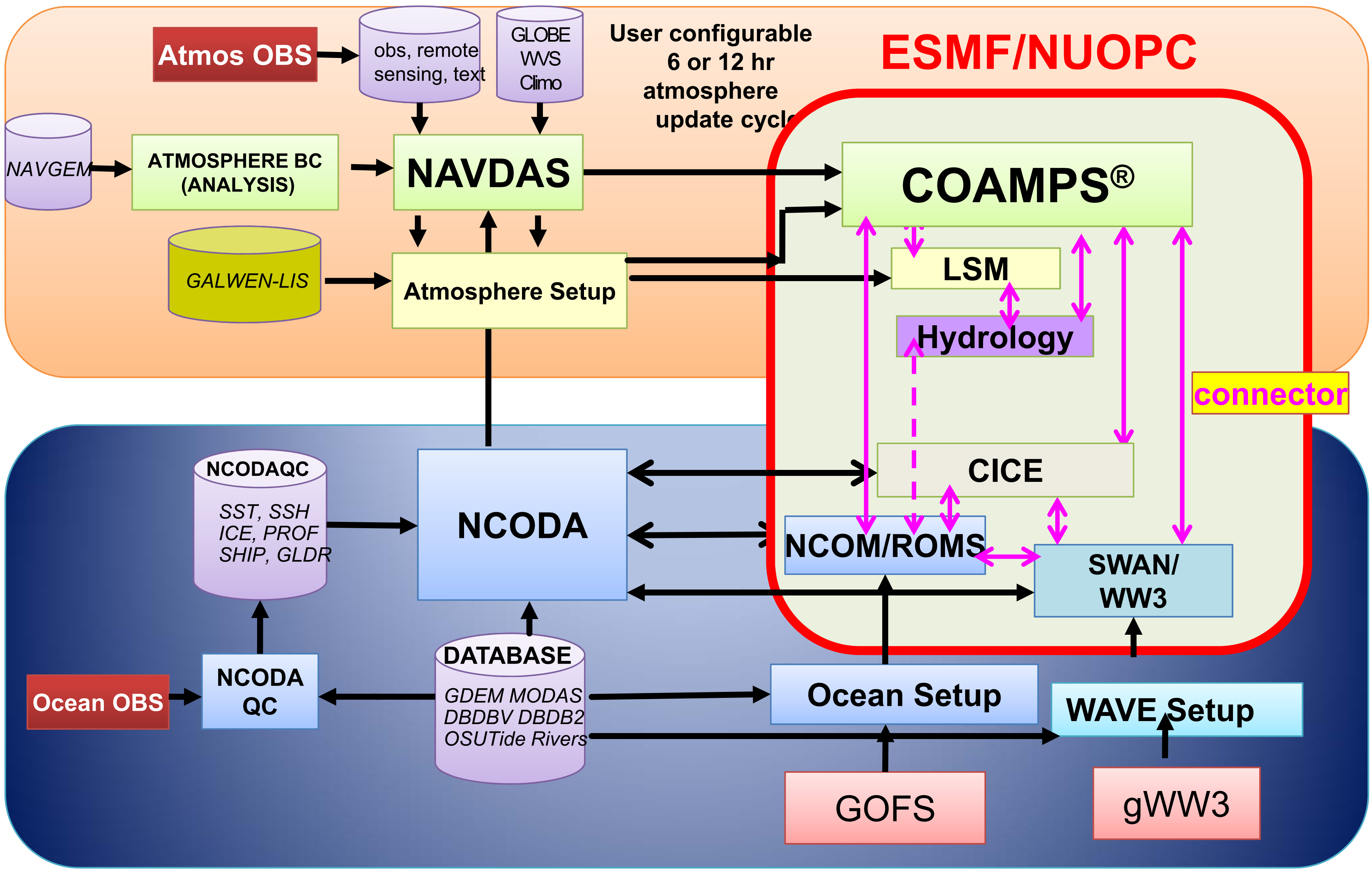
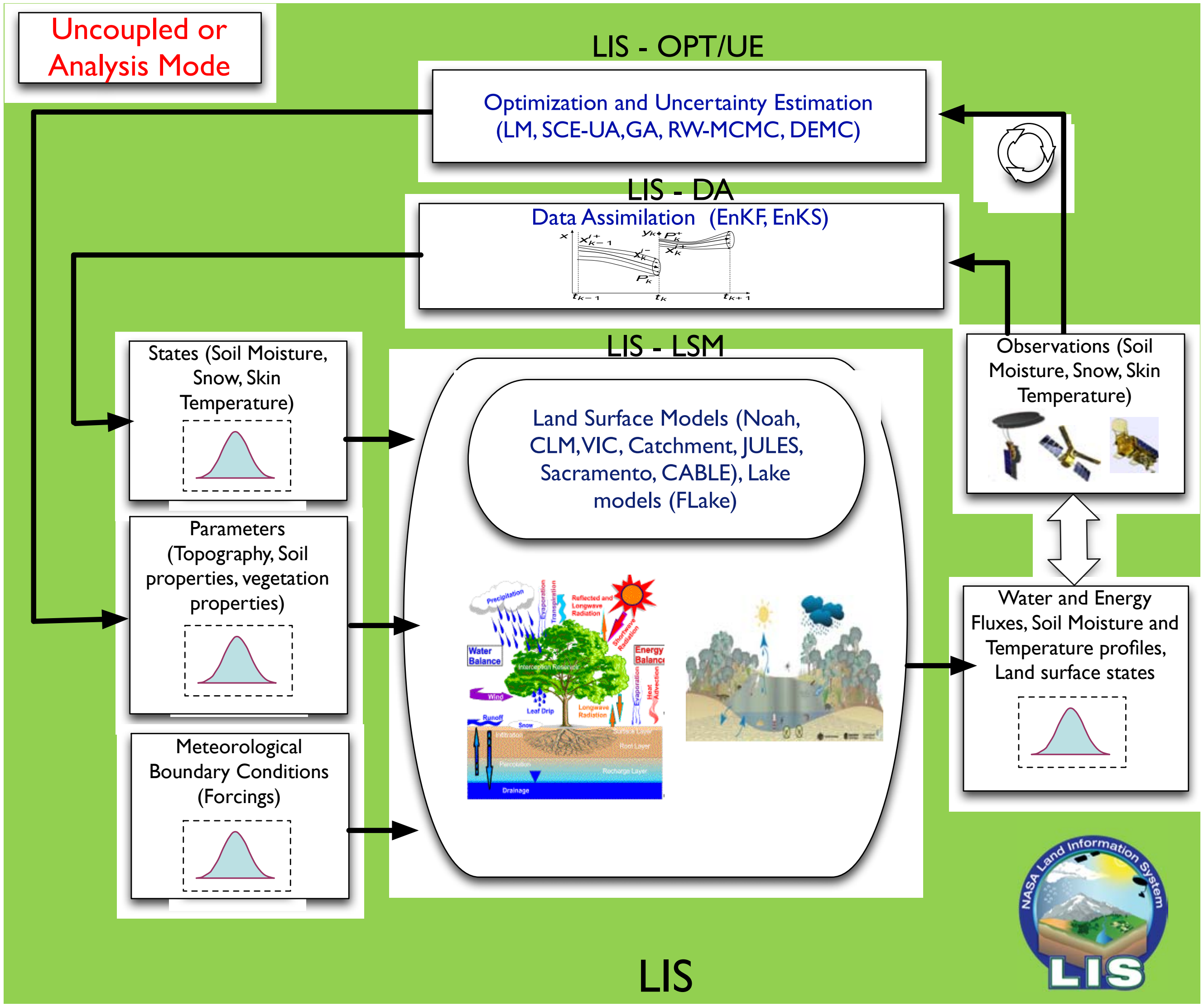
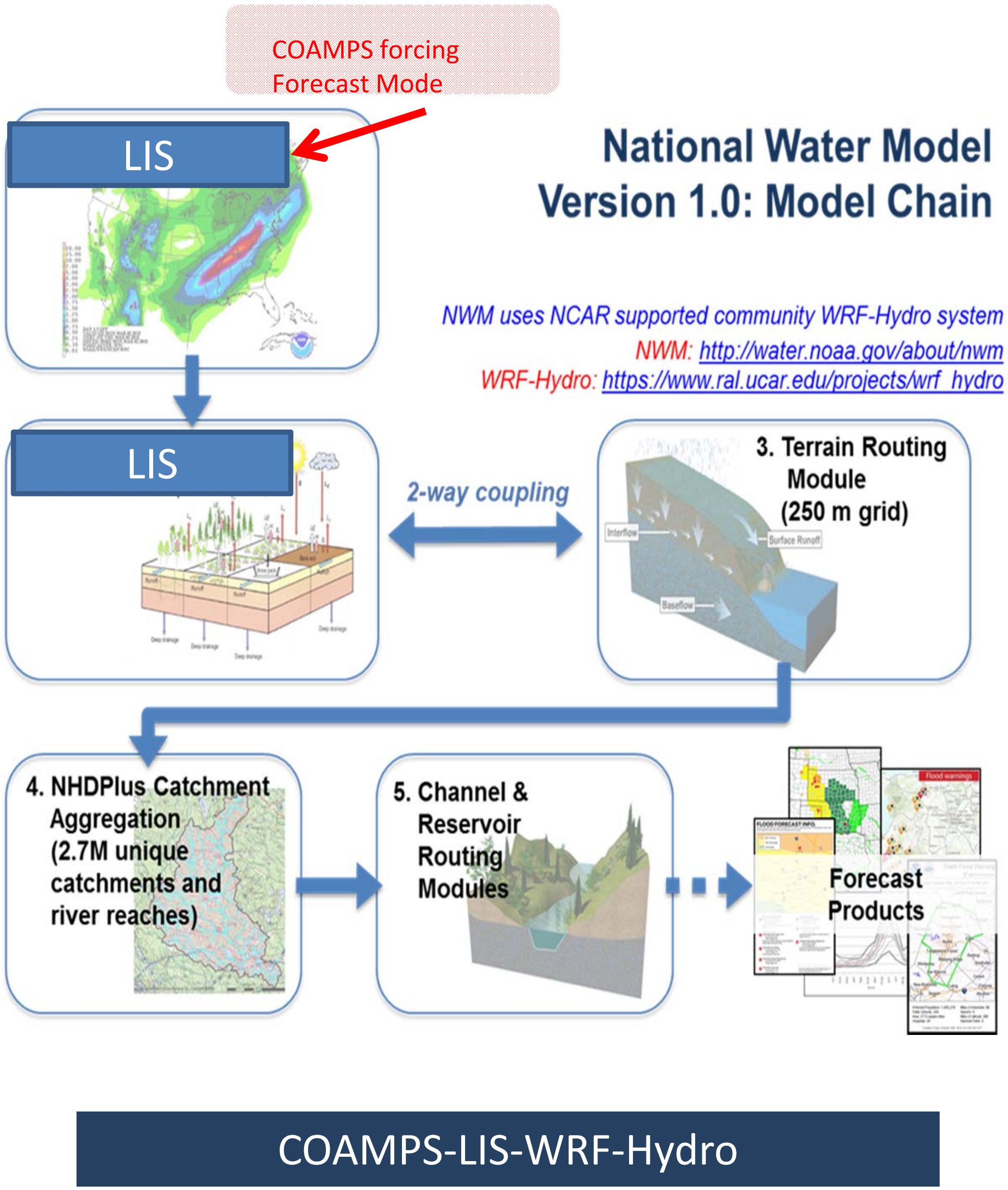


NASA Land Information System (LIS; lis.gsfc.nasa.gov)



- LIS is a comprehensive, interoperable land surface modeling and data assimilation framework
- Includes the support for :
  - A large suite of land surface models (Noah, CLSM, VIC, JULES, CLM, ...)
  - Data assimilation algorithms (EnKF, EnKS)
  - Remote sensing data products (SMAP, SMOS, AMSR2, ASCAT, GRACE, MODIS, VIIRS, ...)
- Includes computational subsystems for optimization, forward modeling and uncertainty estimation

Implementation of WRF-Hydro for Naval Applications



WRF-HYDRO's configuration for COAMPS-LIS-HYDRO is similar to the National Water Model

Coupled Ocean/Atmosphere Mesoscale Convective System (COAMPS®)

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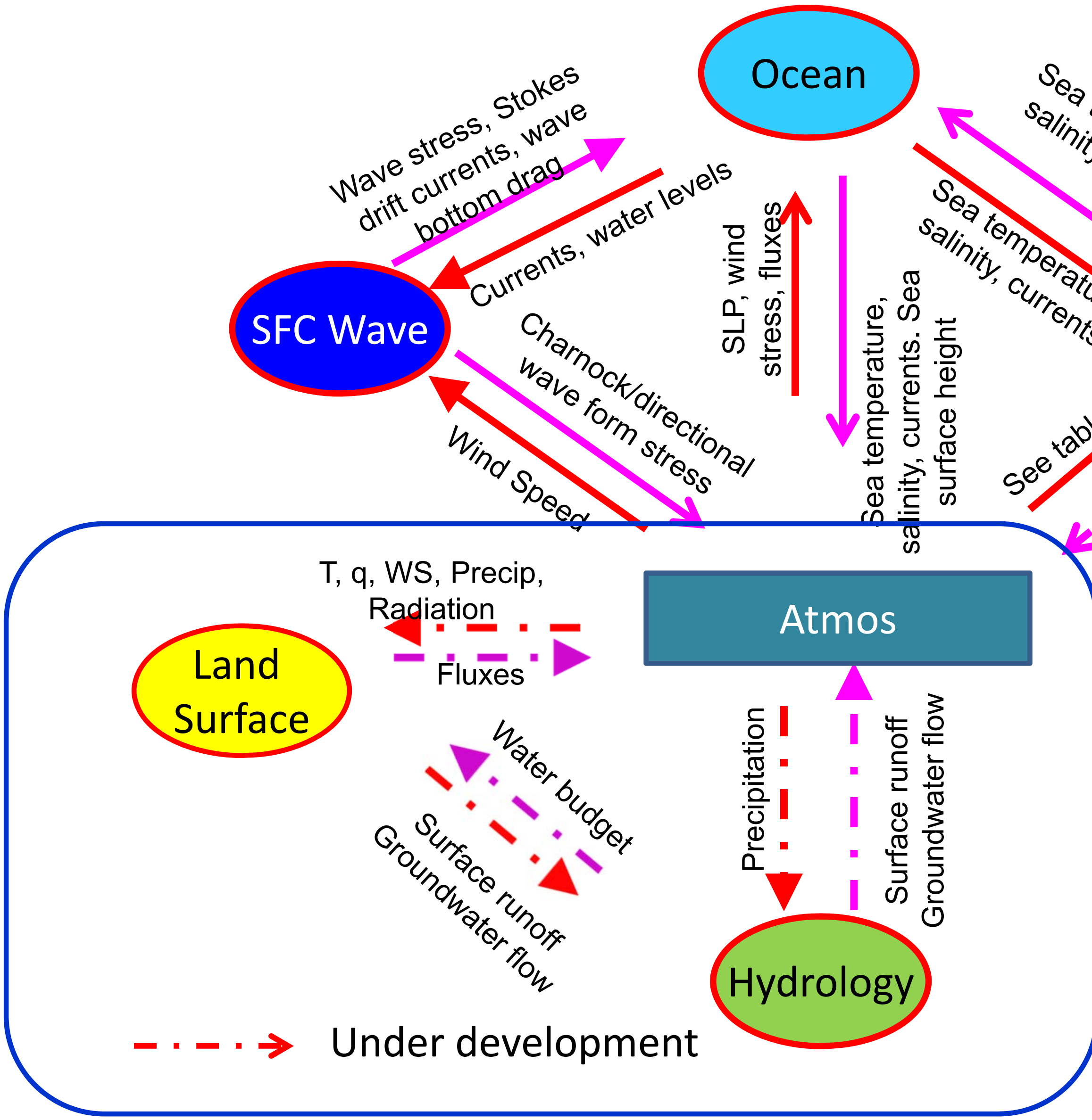


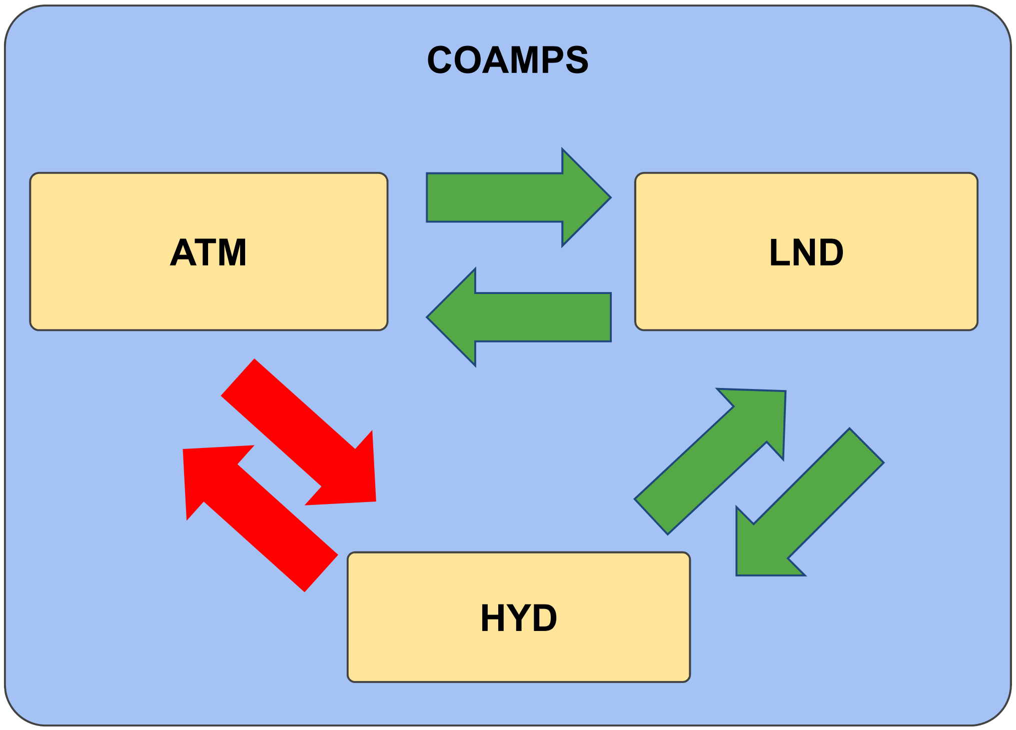
Table 1 atmos-CICE exchange fields

1. Land surface type
2. sea level pressure
3. surface wind U (10m)
4. surface wind V (10m)
5. air temp (2m)
6. Water vapor mixing ratio (2 m)
7. surface downward short wave flux
8. surface downward longwave flux
9. surface total precipitation
10. relative humidity (2m) *
11 surface net shortwave flux *
12. surface net longwave flux *
13. surface albedo *
14. ground surface temperature (i.e., sea surface temperature)*
15. surface latent heat flux *
16. surface sensible heat flux *
17. surface stress *

* variables may not be actually needed, but are included

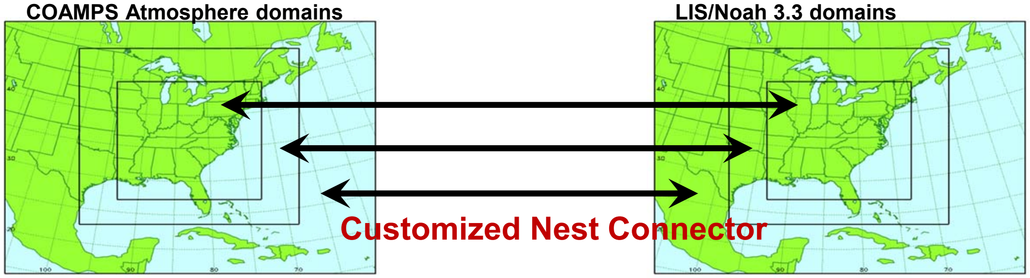
Coupled COAMPS-LIS-HYDRO Forecasting System

ESMF NUOPC Caps for COAMPS, LIS and WRF-HYDRO



COAMPS Atmosphere domains

LIS/Noah 3.3 domains



The land model is typically called as a subroutine of the atmosphere. After introducing LIS as an *external* land component, a customized NUOPC Connector was created to couple nest-to-nest. Supported connector operations (can be applied in series).

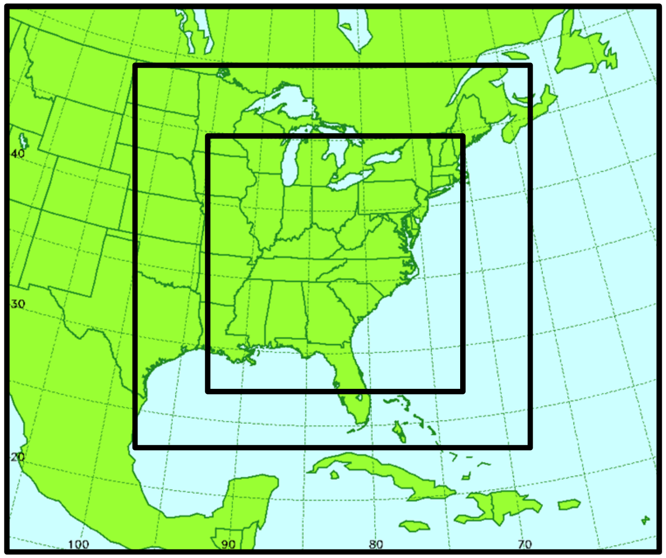
Complete milestones

- V0.3 – one-way coupled ATM-LND-HYD
- V0.4 - two-way coupled ATM-LND w/ one-way coupled LND-HYD
- V0.5 - two-way coupled ATM-LND w/ two-way coupled LND-HYD
- V0.6 - all six feedbacks turned on, allowing direct interactions between WRF-Hydro and atmosphere
- V0.7 – Integrate with generalized microphysics & LND ensemble perturbations

Near Future Plan

- Evaluate water cycle budget diagnostics for high-resolution coupled experiments
- Refine linkage of hydrology-microphysics within COAMPS/WRF-Hydro framework
- Prototype testing and evaluation of generalized re-locatable COAMPS-OS capability
  - second OCONUS test case – Luzon (Philippine) flood case
- Leverage land and hydrology community advancemen**ts (upgrades of LIS and WRF-Hydro in COAMPS-Hydro coupled system)**

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)



COAMPS grid 1: 27-km (180x150)
grid 2:   9-km (319x313)
grid 3:   3-km (628x628)

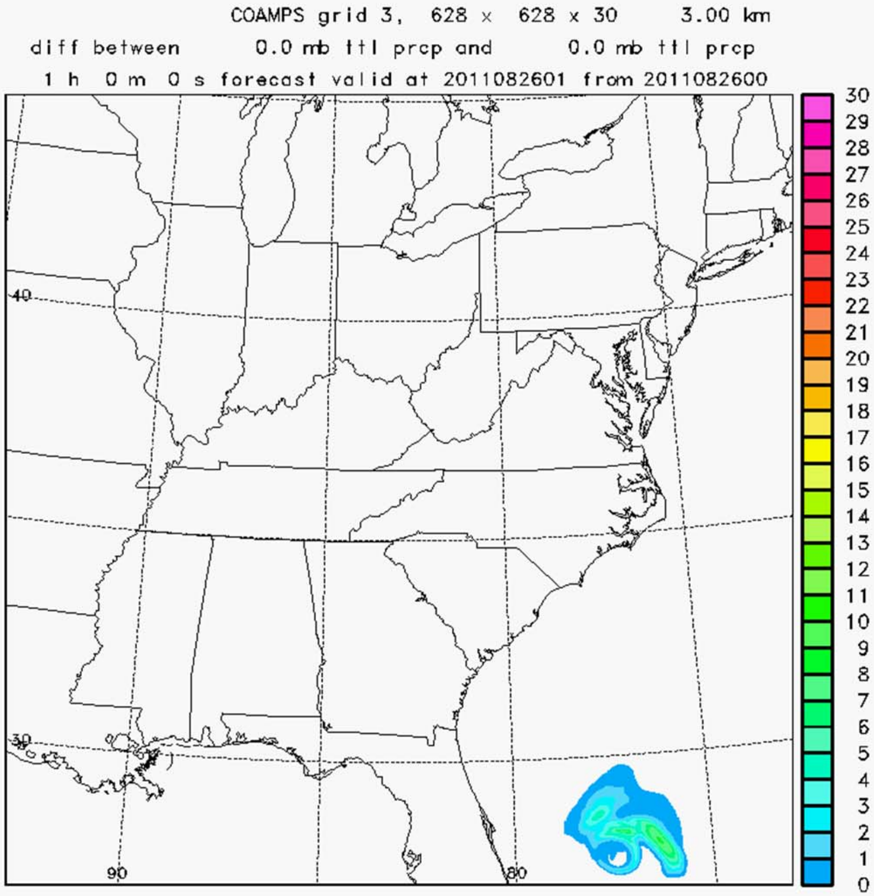
- Cold start 72-h forecast (from 2011082600)
- 3-nests (27-km; 9-km; 3-km)
- LSM: NOAH v3.4
- Two experiments:
  1. "lis" :
     - Initial soil state= Global ~47-km AFWA LIS fields interpolated to COAMPS grid
     - Surface parameters (e.g., soil, vegetation types, terrain, etc.) from COAMPS initialization (USGS-based)
  2. "ldt" :
     - Initial soil state= *LIS_HIST* file (From Sujay Kumar, NASA-GSFC)
     - Surface parameters (e.g., soil, vegetation types, terrain, etc.) from LDT *lis_input* file (MODIFIED_IGBP_MODIS_NOAH-based) (from Kumar, NASA-GSFC)
- Validation using NRL *verify* against radiosonde and surface (land, ship, buoy) observations
- ~2h CPU for 72-h fcst on DSRC *haise* (240 proc)

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

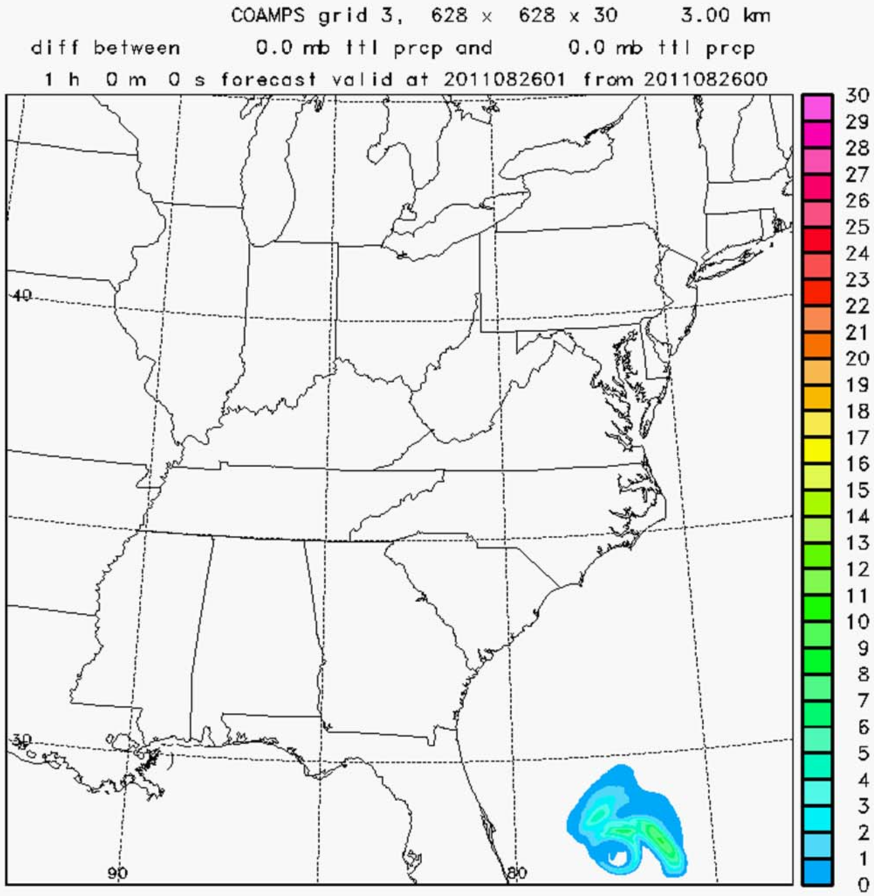
72-h forecasts from 2011082600 for nest 3 (3-km)

Hourly precipitation (mm h^{-1})

LIS



LDT

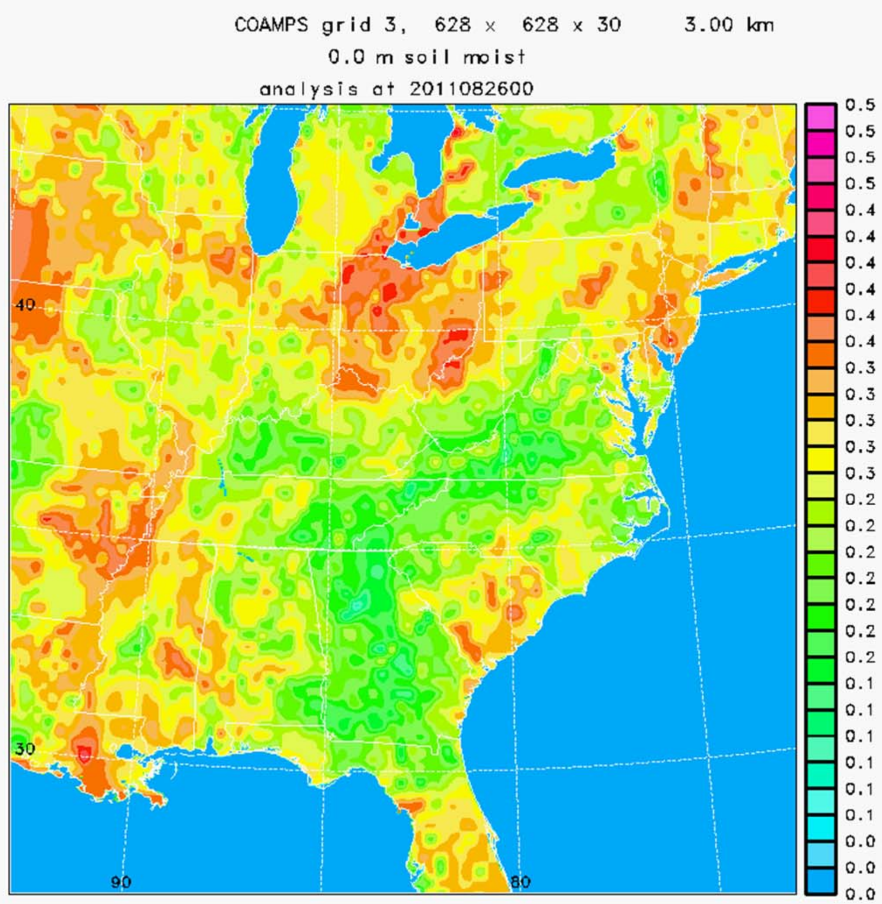


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

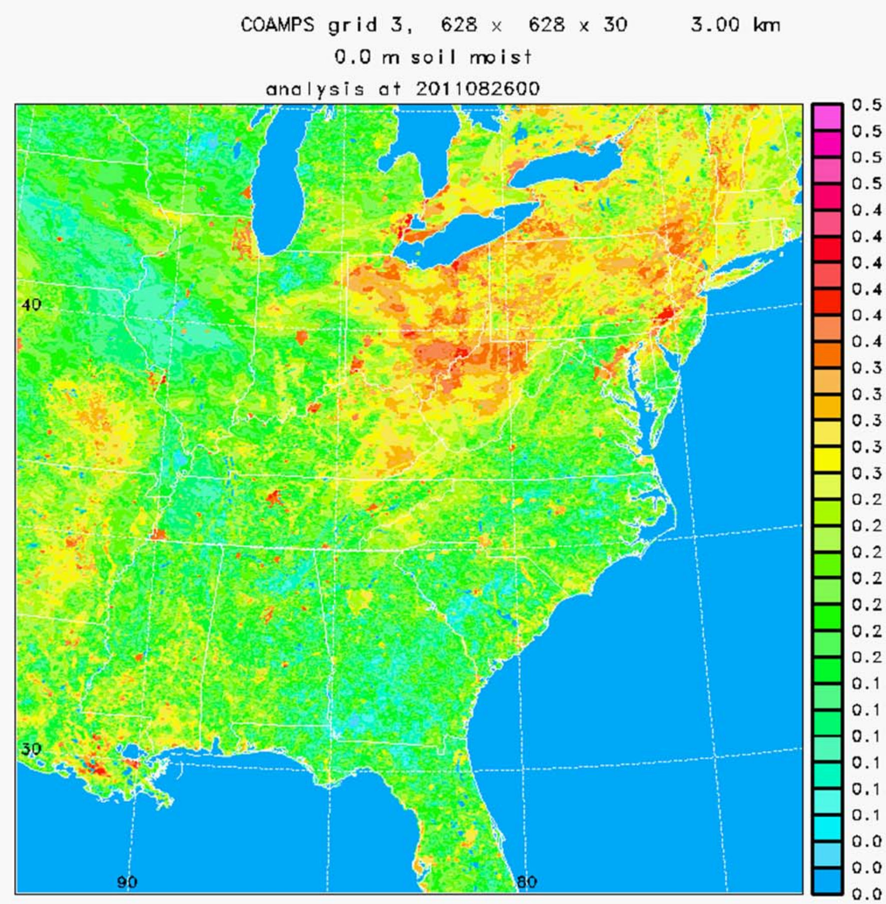
72-h forecasts from 2011082600 for nest 3 (3-km)

10-cm soil moisture (vol fr)

LIS



LDT

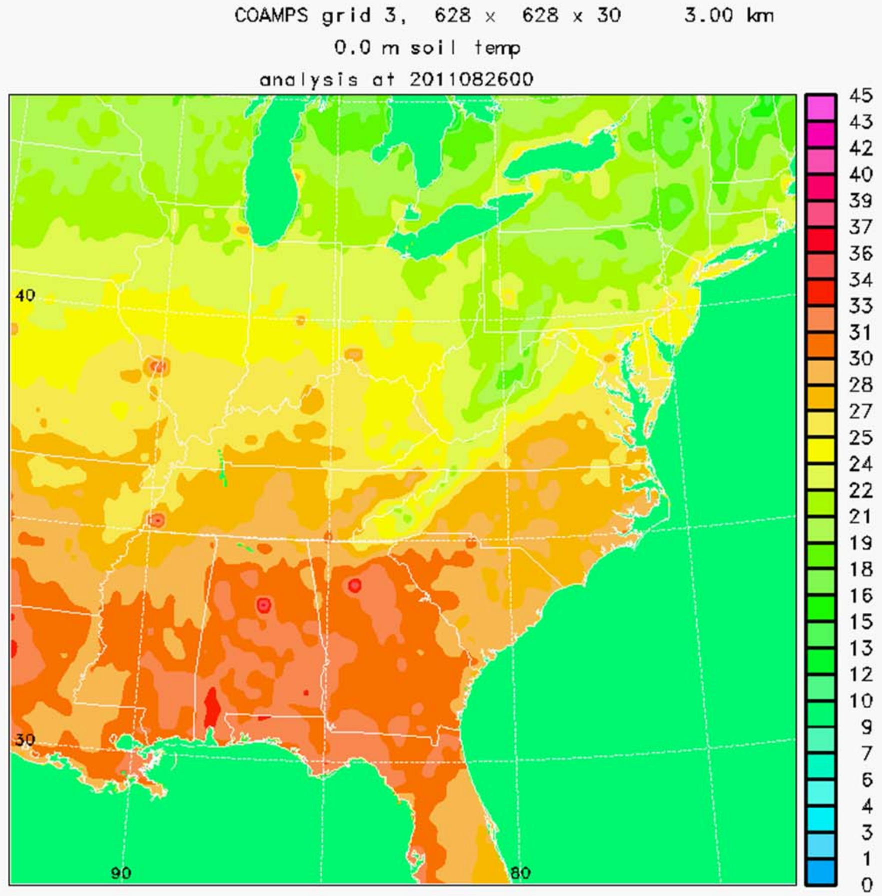


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

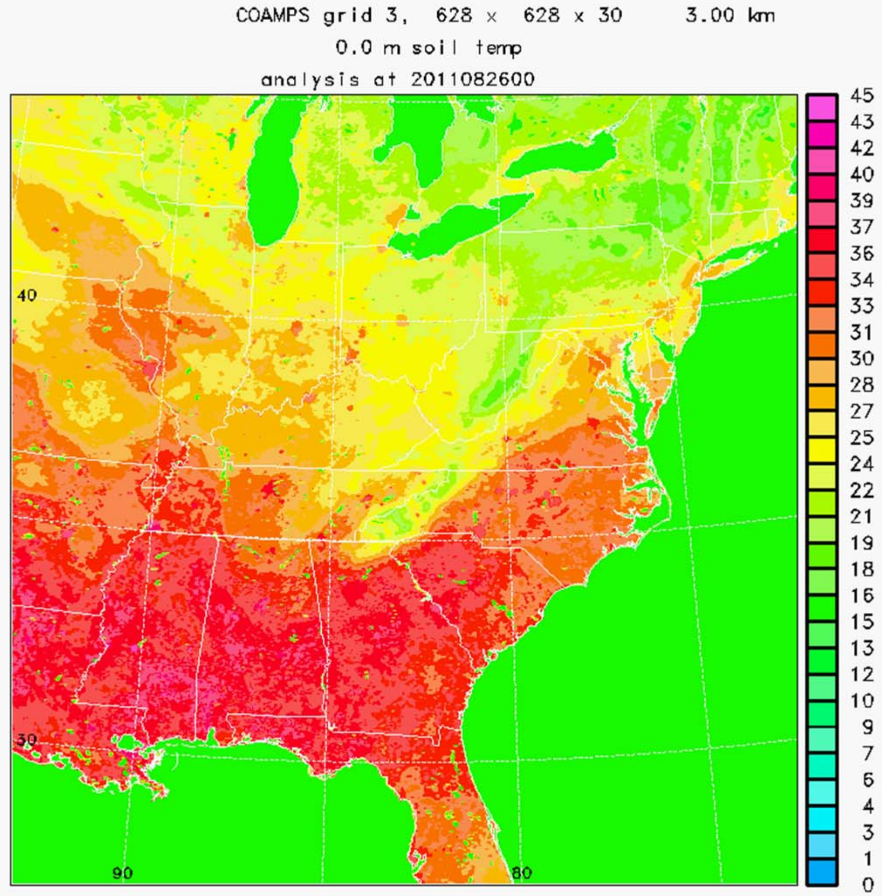
72-h forecasts from 2011082600 for nest 3 (3-km)

10-cm soil temperature (^oC)

LIS

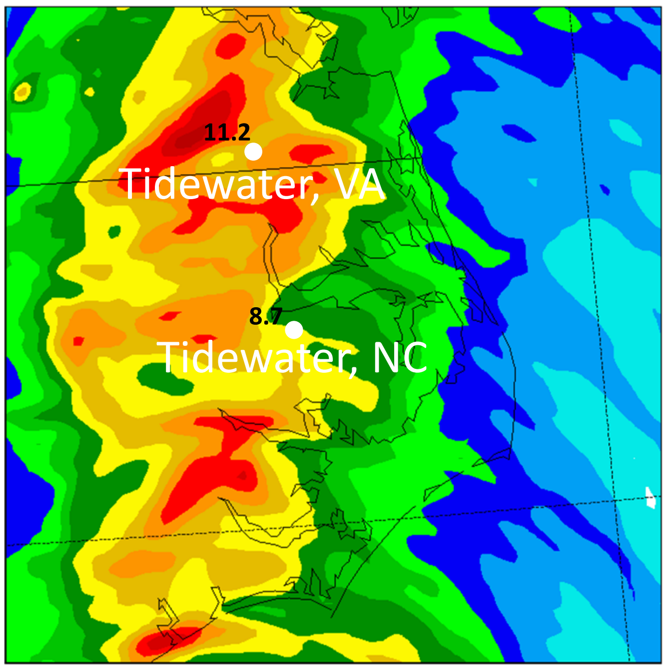


LDT

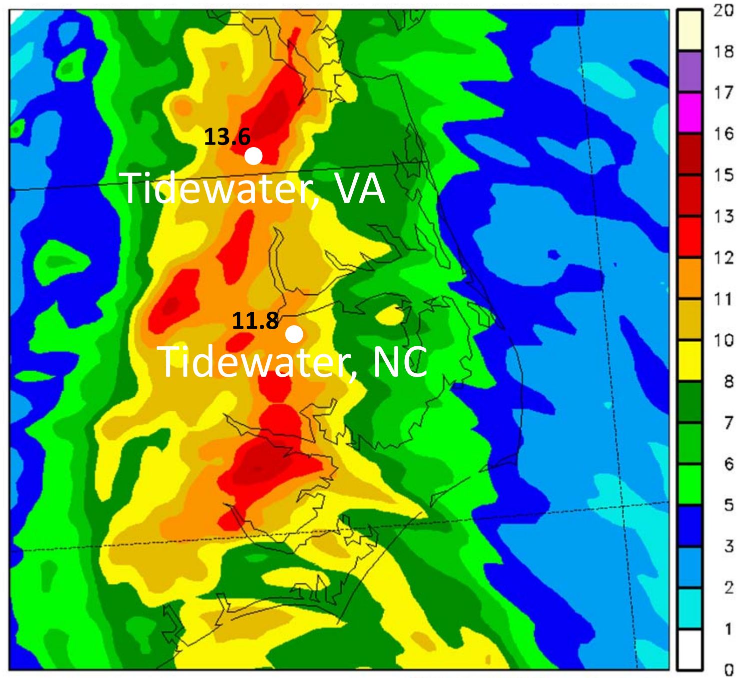


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

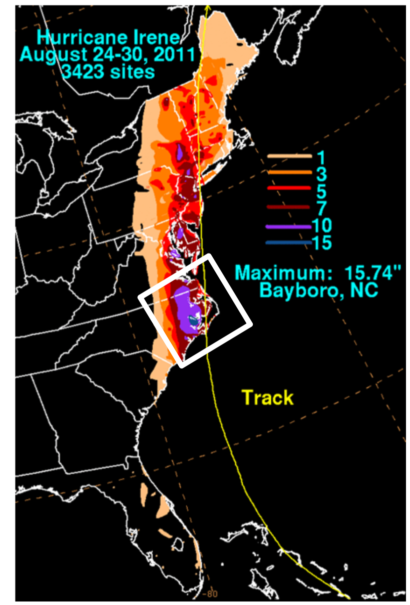
Nest 3 subset (3-km) LIS experiment
72-h accumulated precipitation (in)

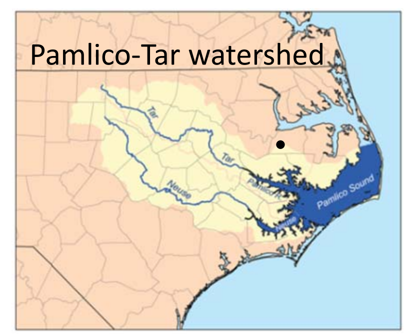


Nest 3 subset (3-km) LDT experiment
72-h accumulated precipitation (in)



Observed

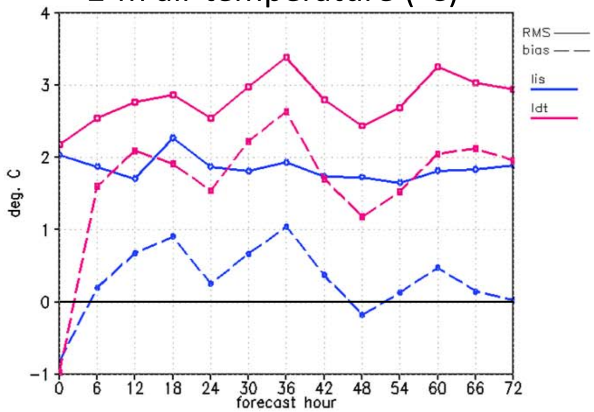




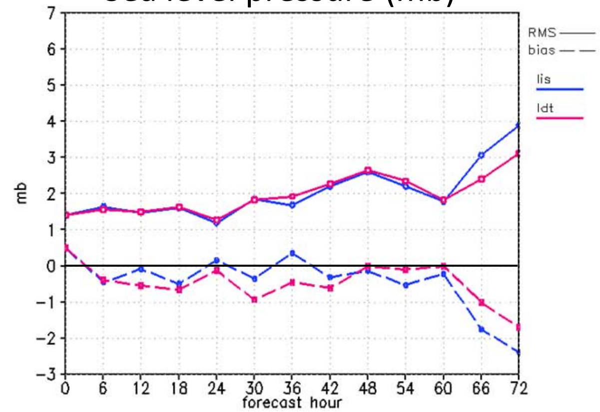
COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) near-surface statistics (against land, ship, buoy data)

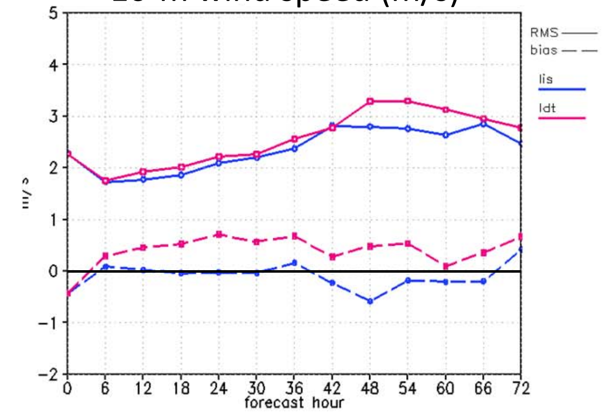
2-m air temperature (°C)



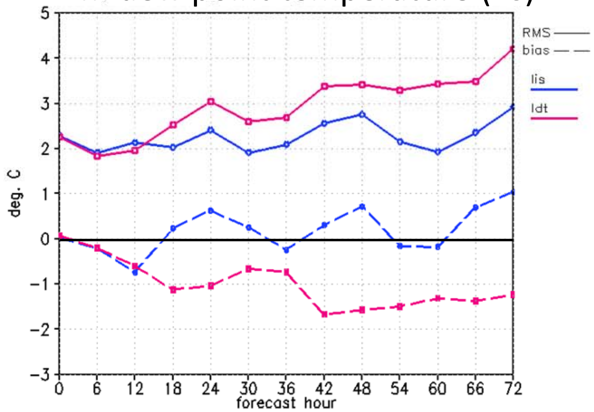
Sea level pressure (mb)



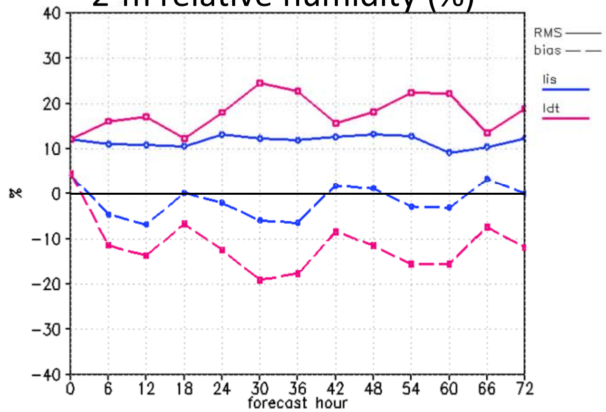
10-m wind speed (m/s)



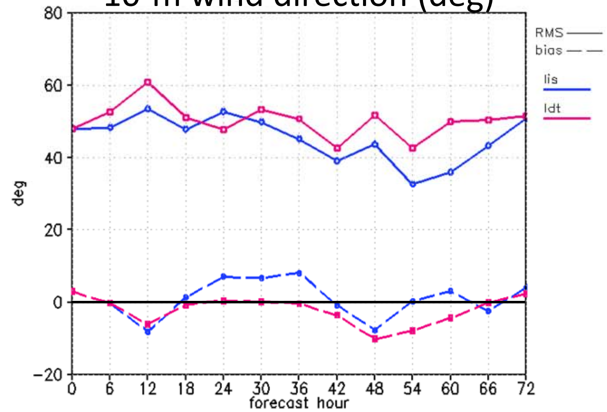
2-m dew point temperature (°C)



2-m relative humidity (%)



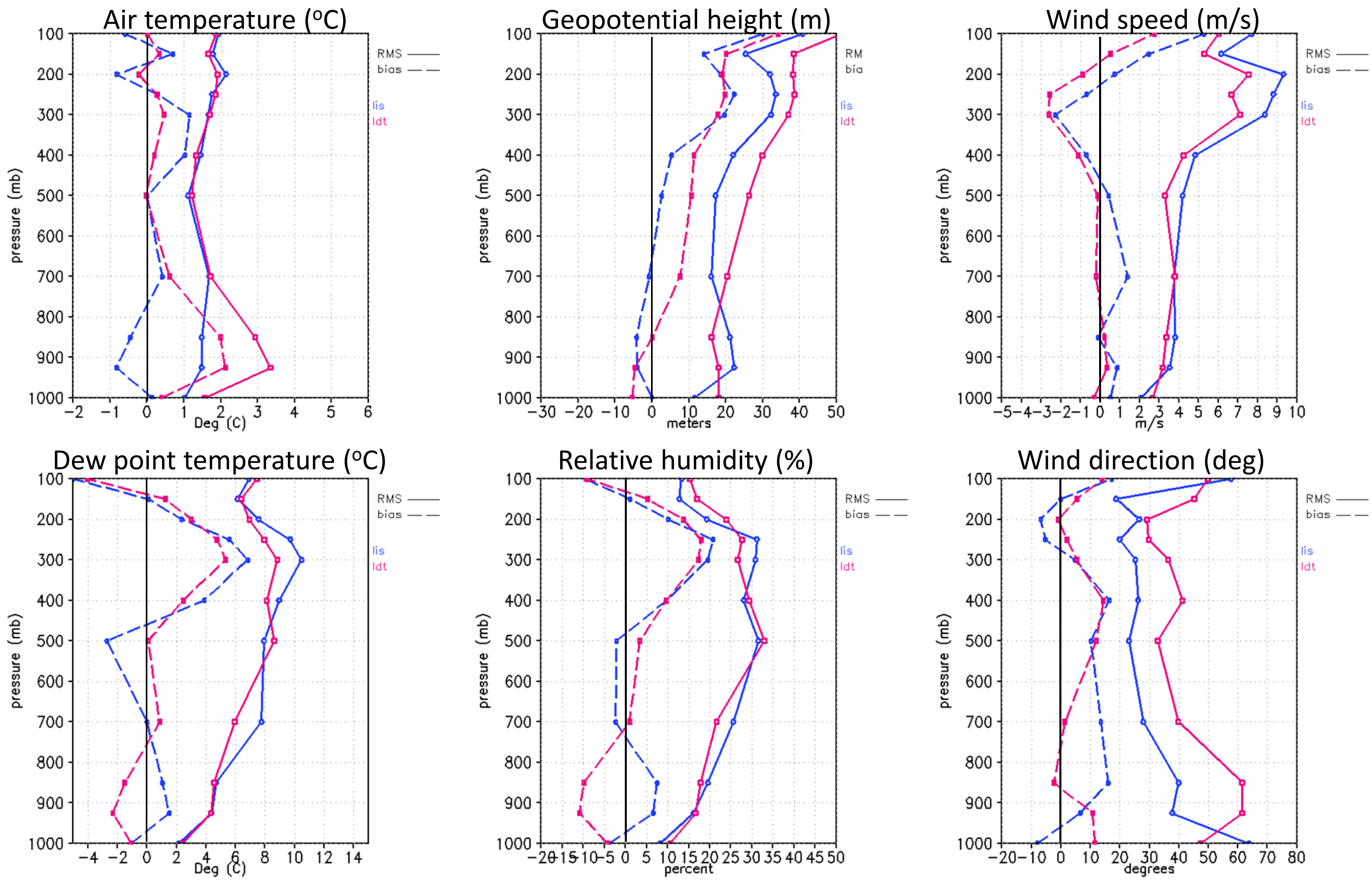
10-m wind direction (deg)



"LDT" is generally too warm and dry.

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

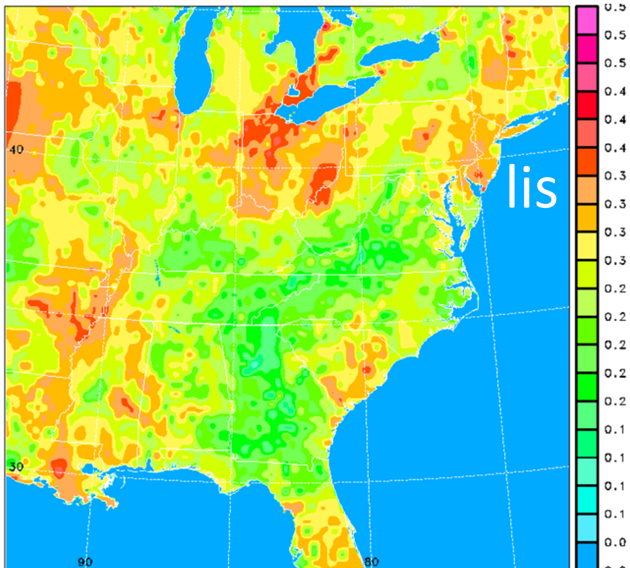
COAMPS Nest-3 (3-km) 72-h forecast vertical statistics (against radiosonde data)

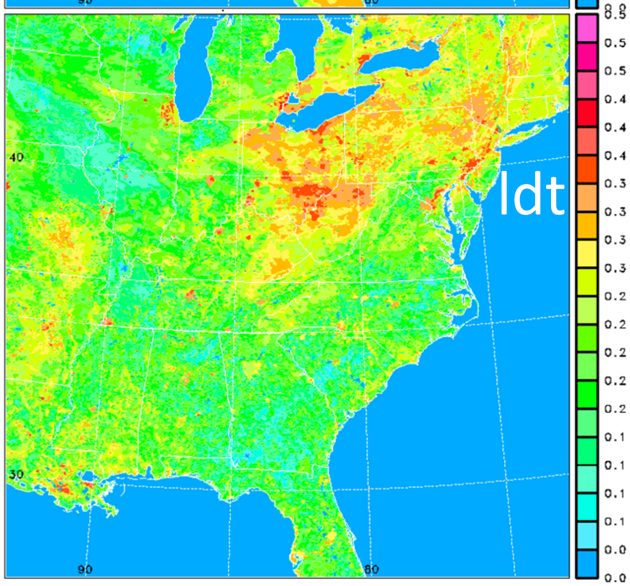


“LDT” is generally too warm and dry in boundary layer.

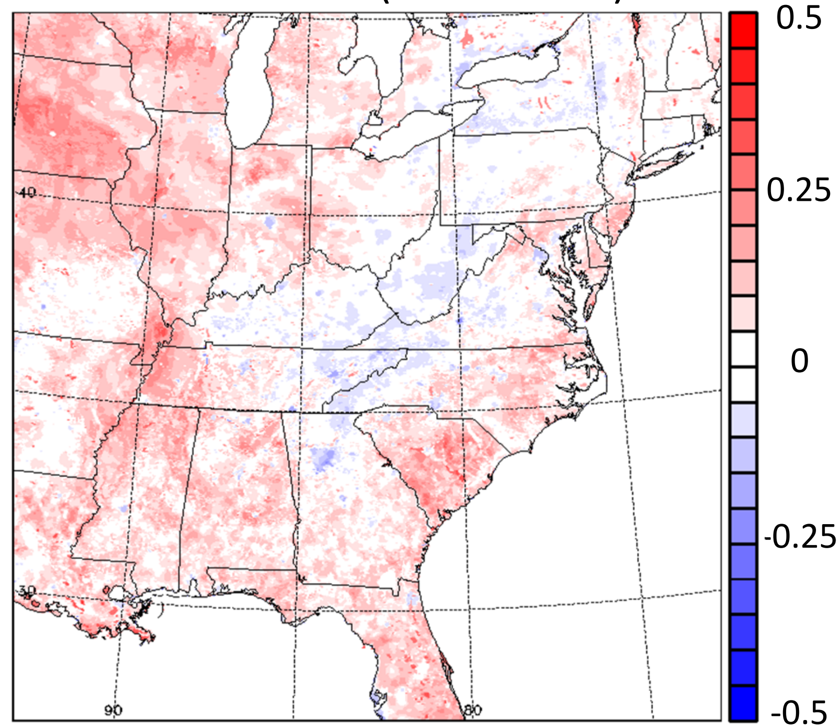
COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) 10-cm soil moisture (vol frac): Analysis valid 2011082600





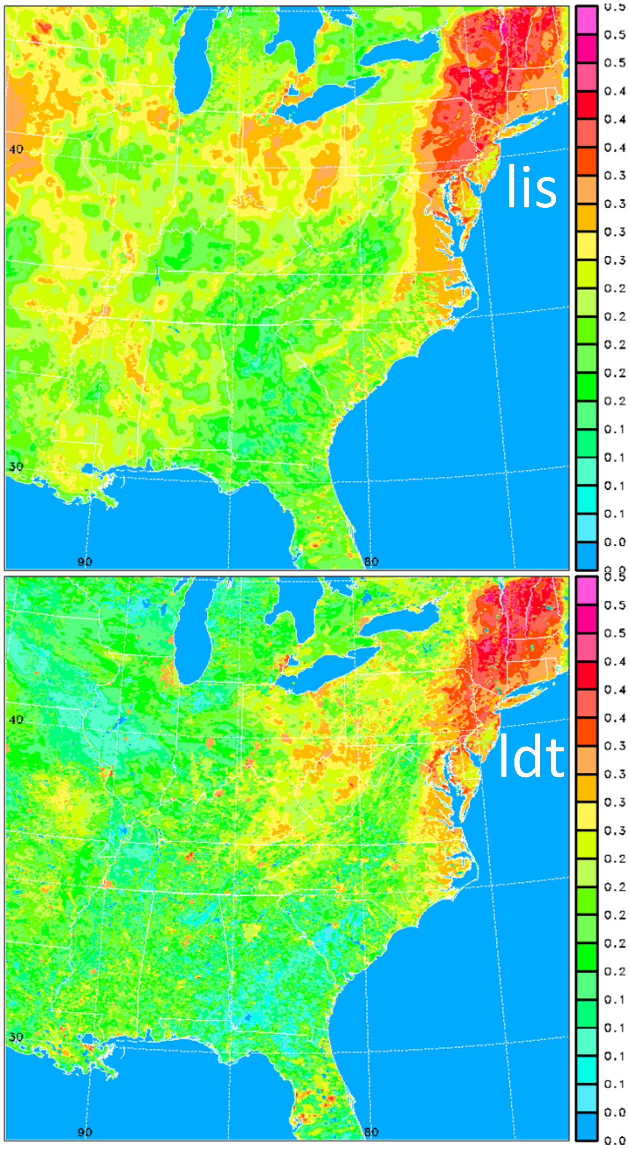
Difference (“lis” – “ldt”)



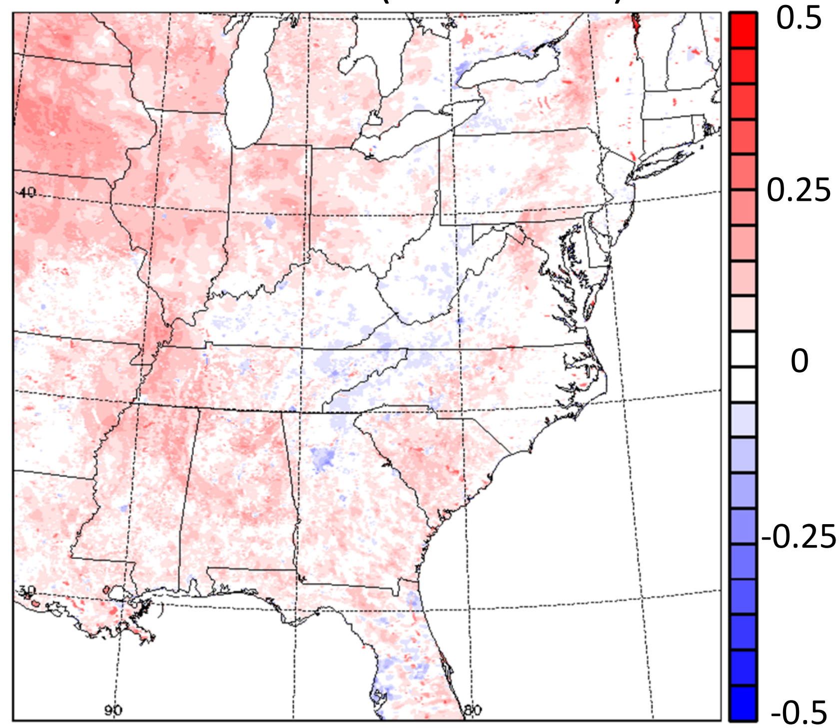
- Soil generally drier domain-wide for “ldt”, as compared to “lis”.

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) 10-cm soil moisture (vol frac): 72-h fcst valid 2011082900



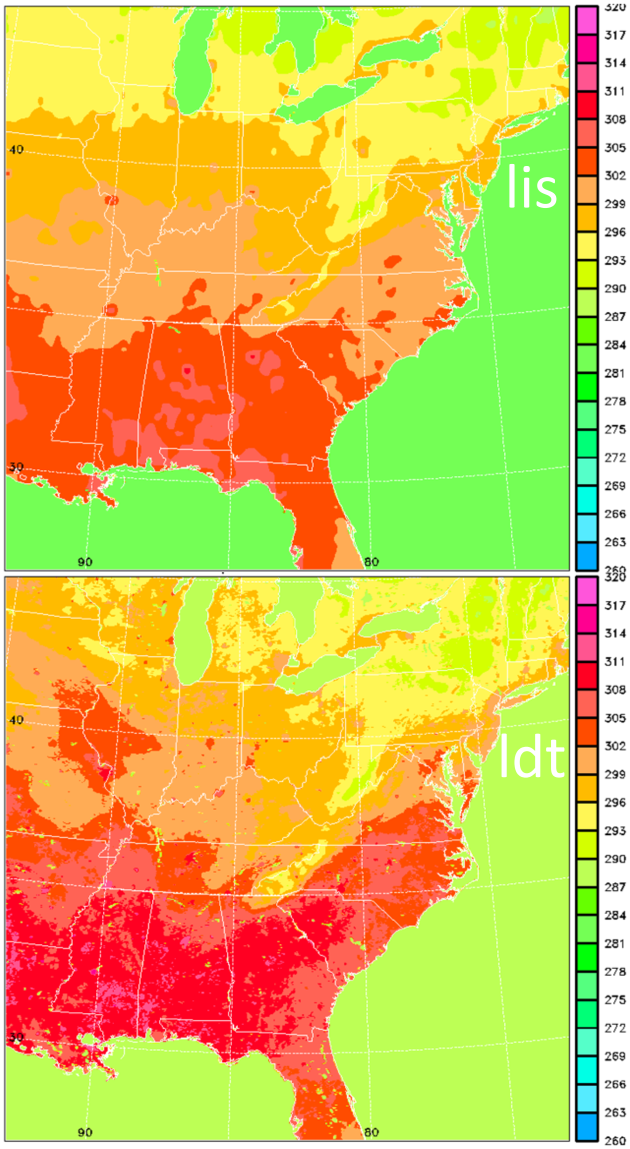
Difference ("lis" – "ldt")



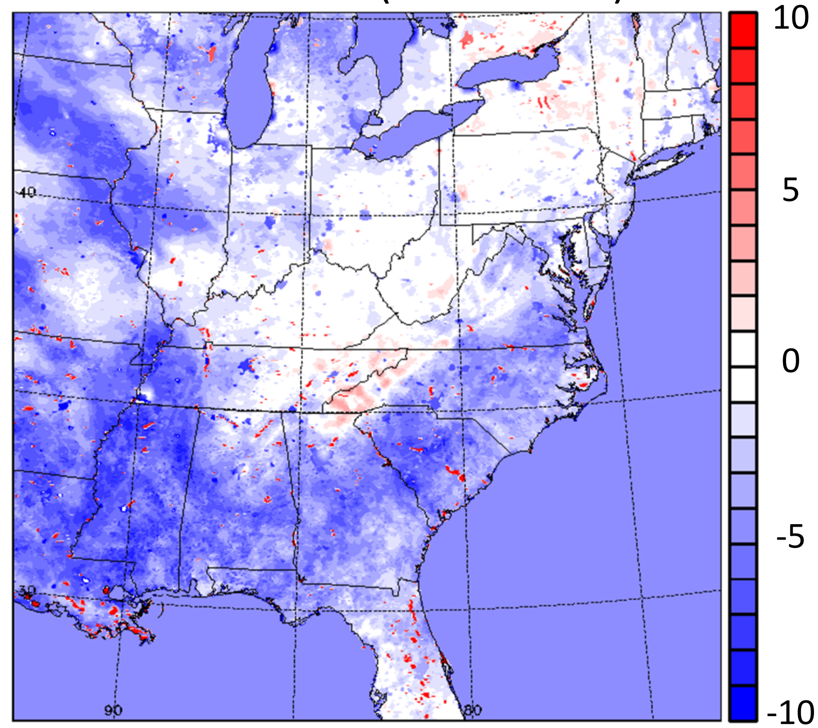
- Soil generally drier domain-wide for "ldt", as compared to "lis".

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) 10-cm soil temperature (K): Analysis valid 2011082600



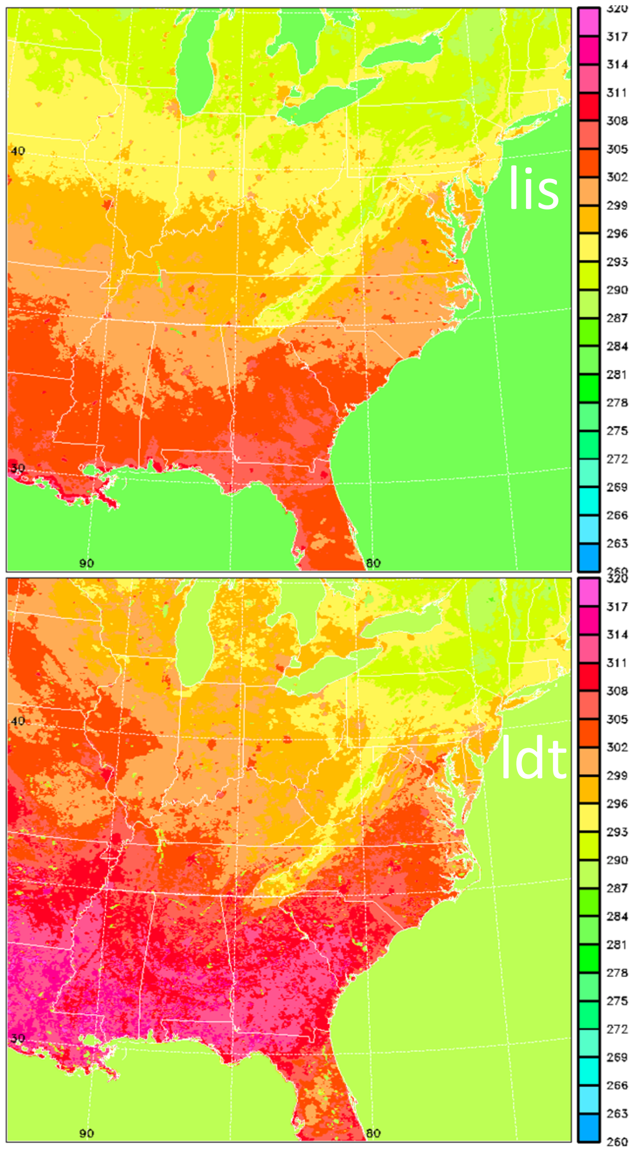
Difference ("lis" – "ldt")



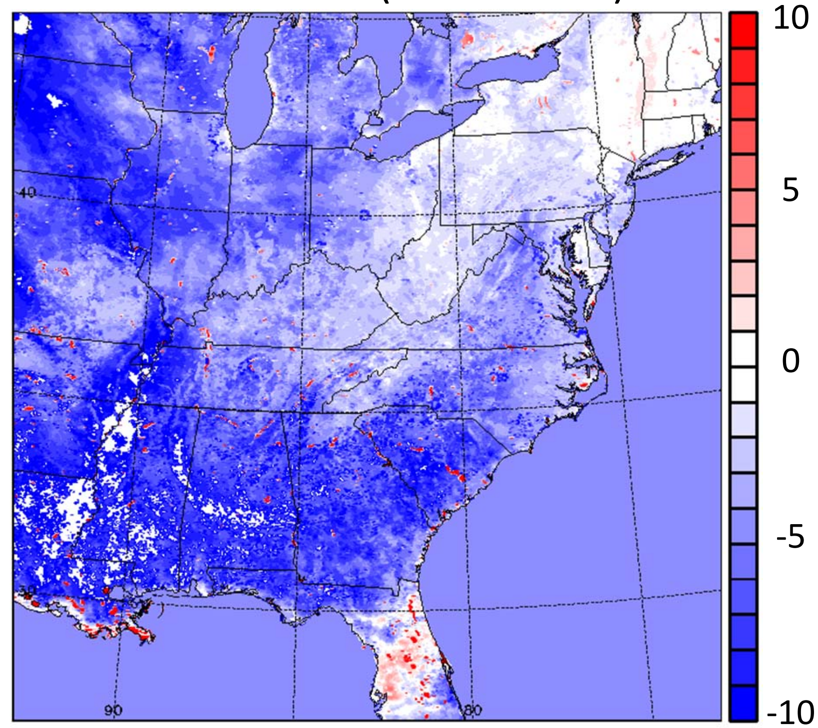
- Soil generally warmer domain-wide for "ldt", as compared to "lis".

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) 10-cm soil temperature (K): 72-h fcst valid 2011082900



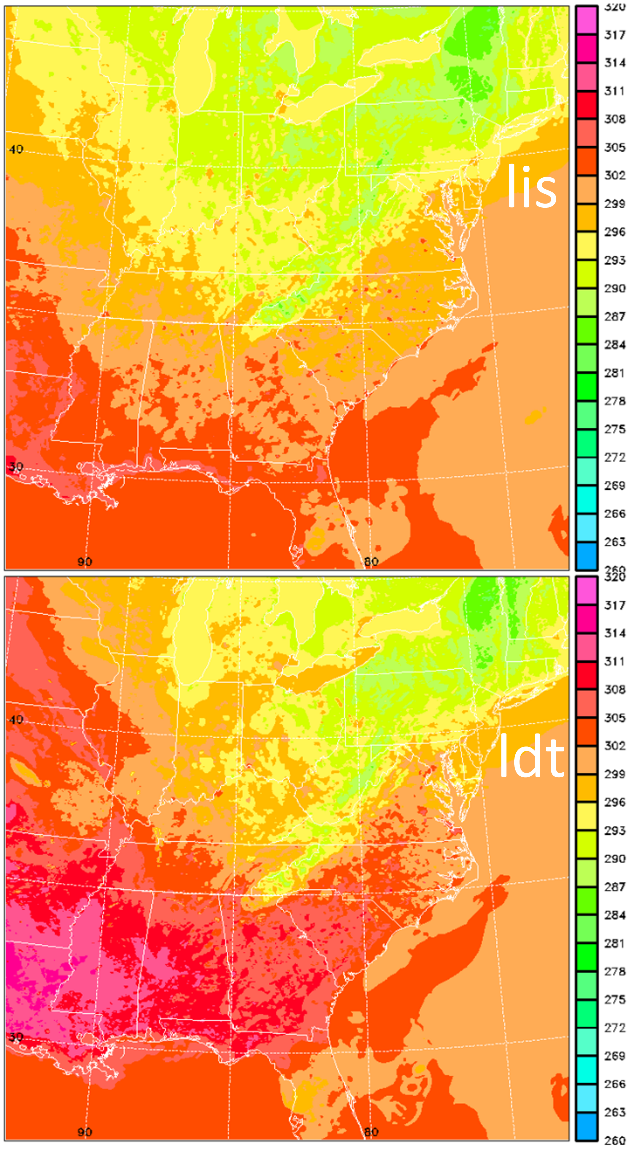
Difference (“lis” – “ldt”)



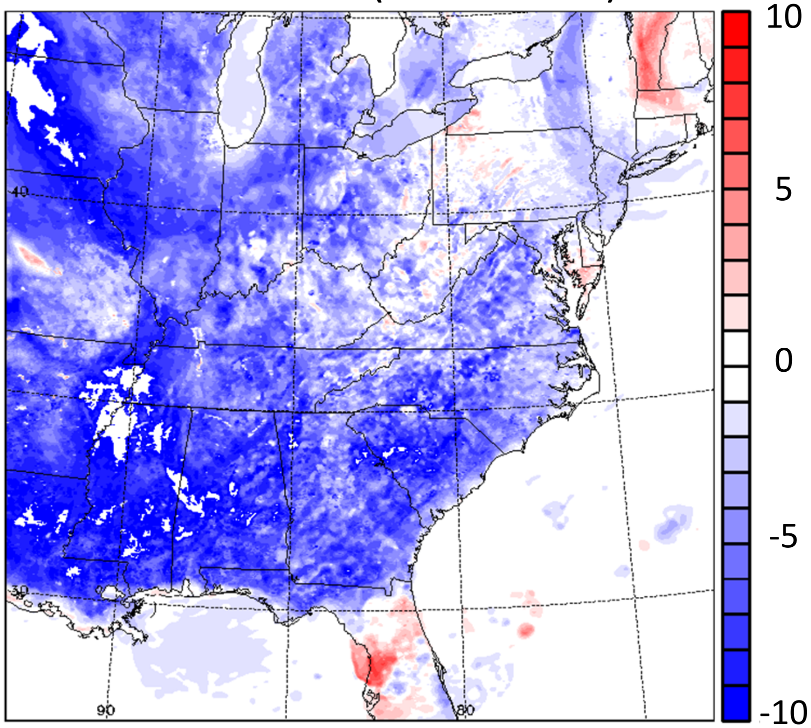
- Soil generally warmer domain-wide for “ldt”, as compared to “lis”.

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) 2-m air temperature (K): 72-h fcst valid 2011082900



Difference ("lis" – "ldt")

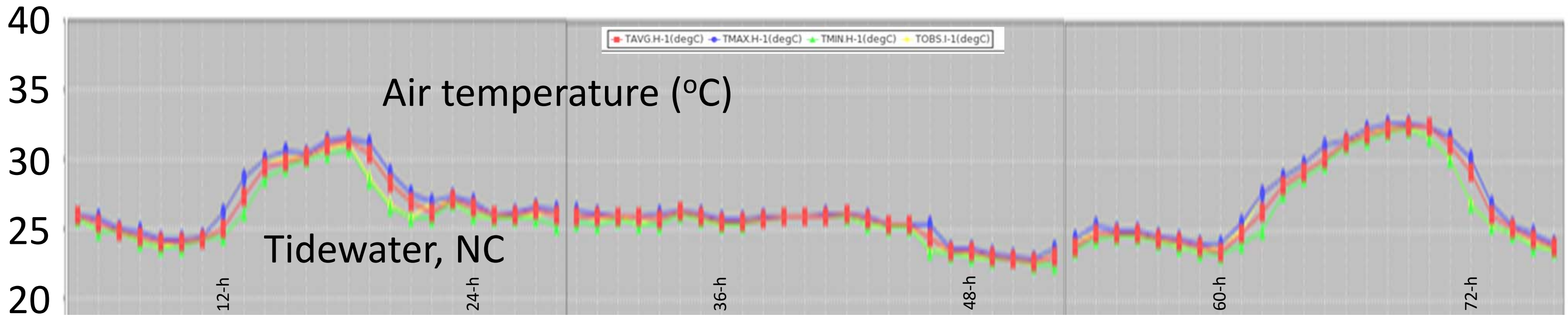


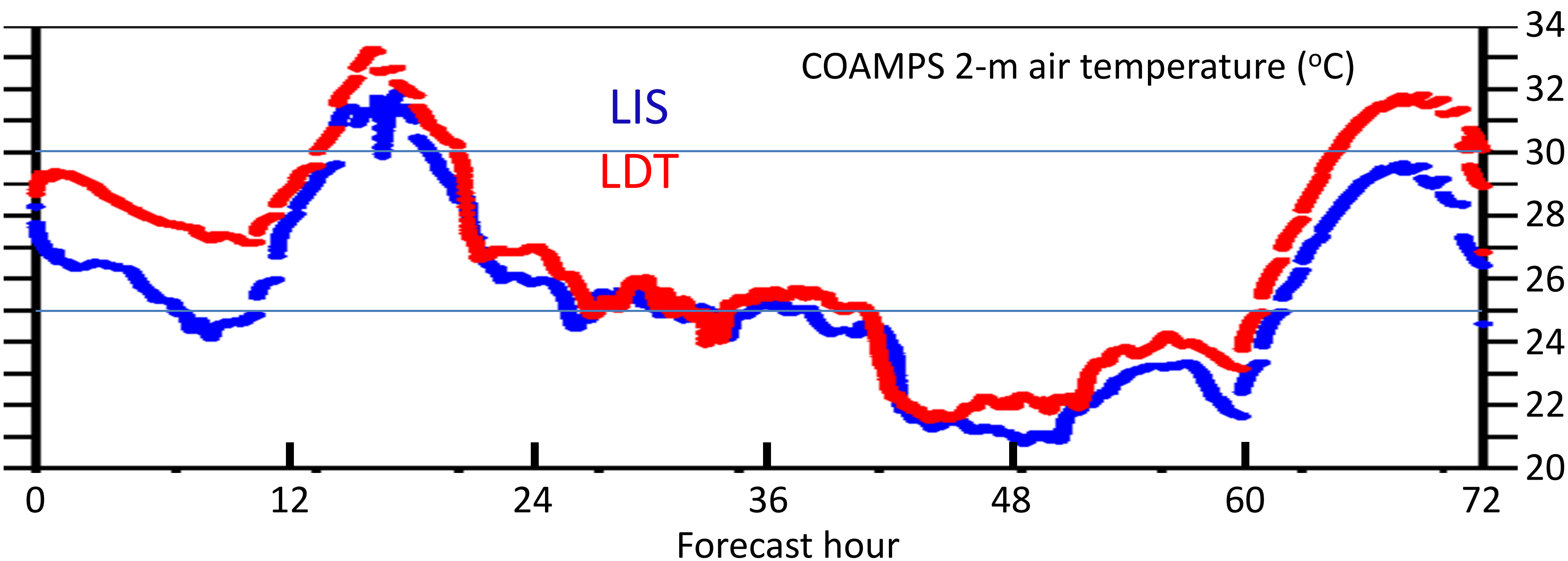
- Air temperature bias similar to soil temperature.

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) near-surface time series: Tidewater, NC

Observations: NRCS National Water and Climate Center

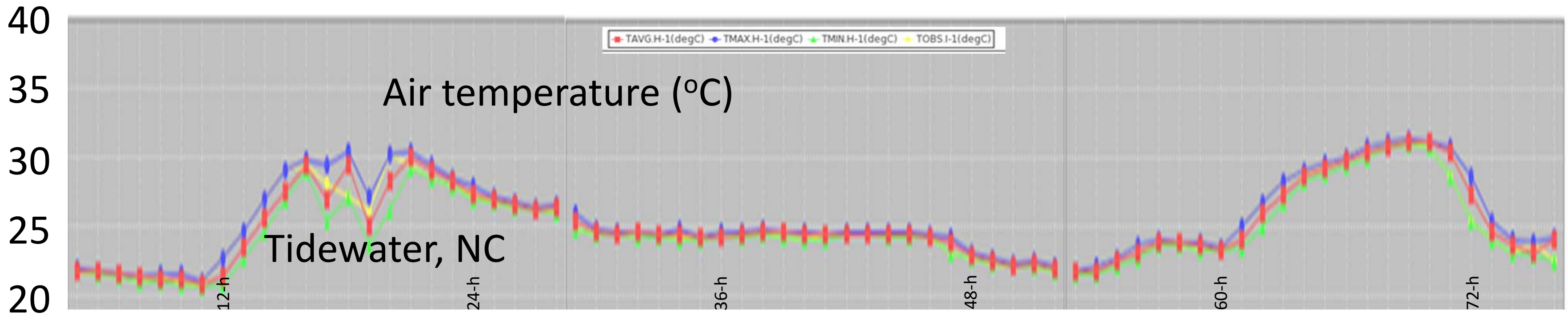


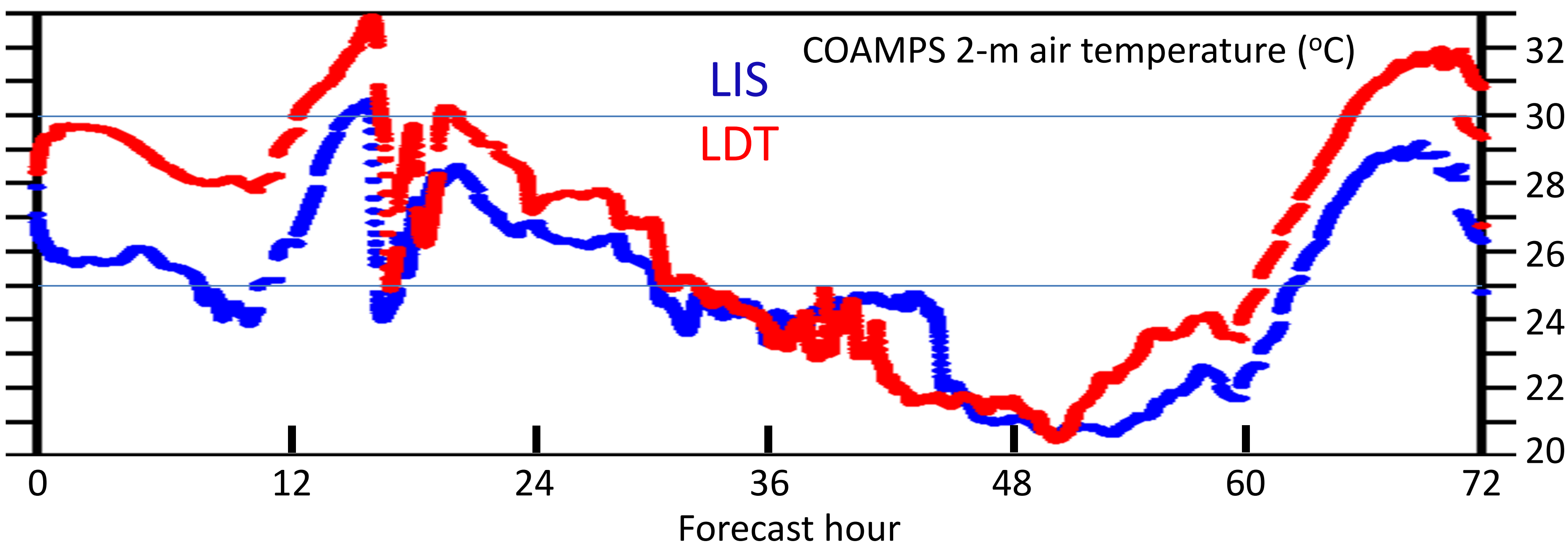


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

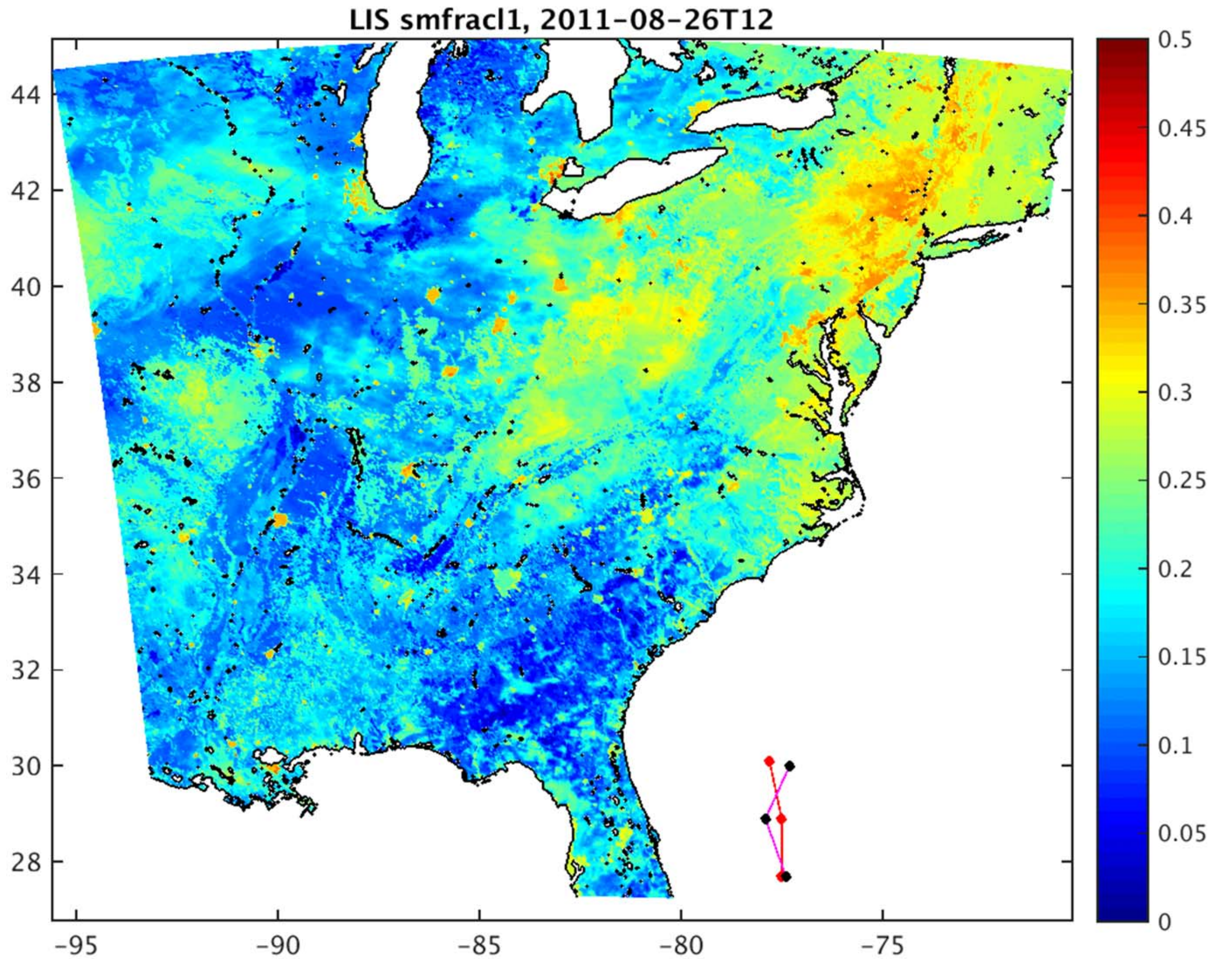
COAMPS Nest-3 (3-km) near-surface time series: Tidewater, VA

Observations: NRCS National Water and Climate Center





COAMPS-LIS Soil Moisture Forecast Movie



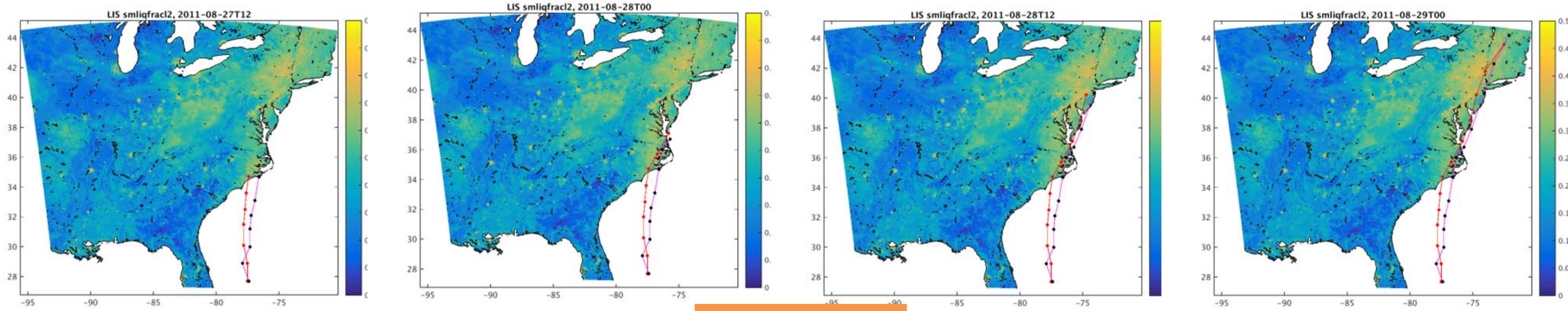
Large change of soil moisture fraction following the Hurricane Irene forecast track

Red line: COAMPS forecast track

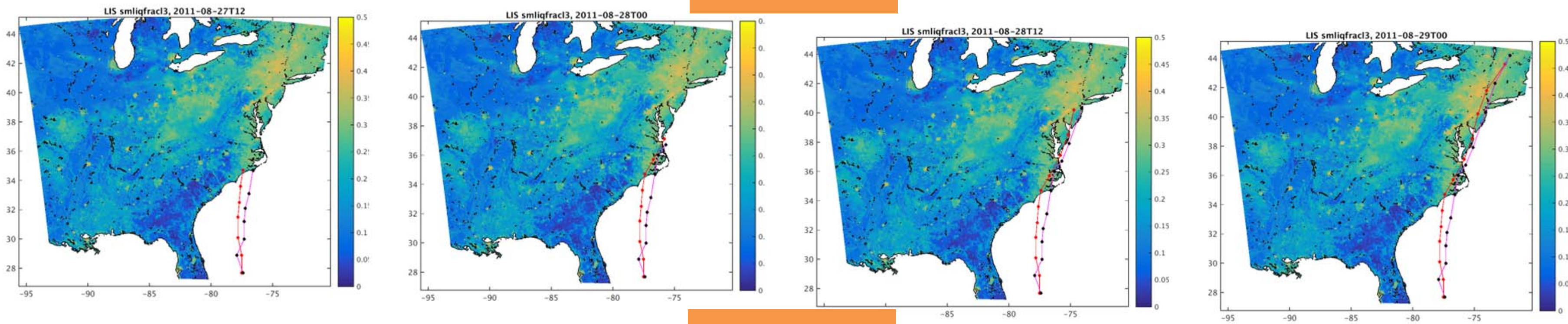
Magenta line: Best track

Day 2-3 COAMPS-LIS 20 – 100 m Soil Liquid Fraction Forecast

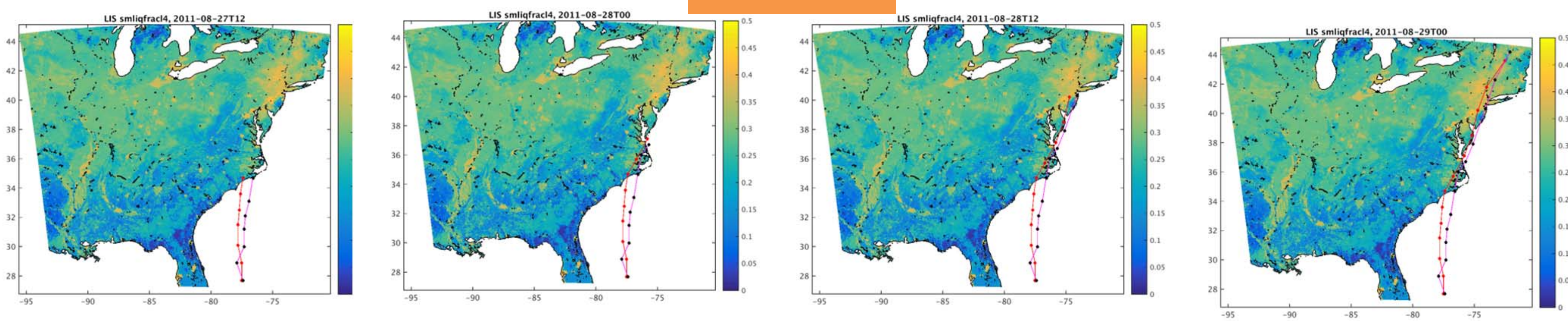
20 m



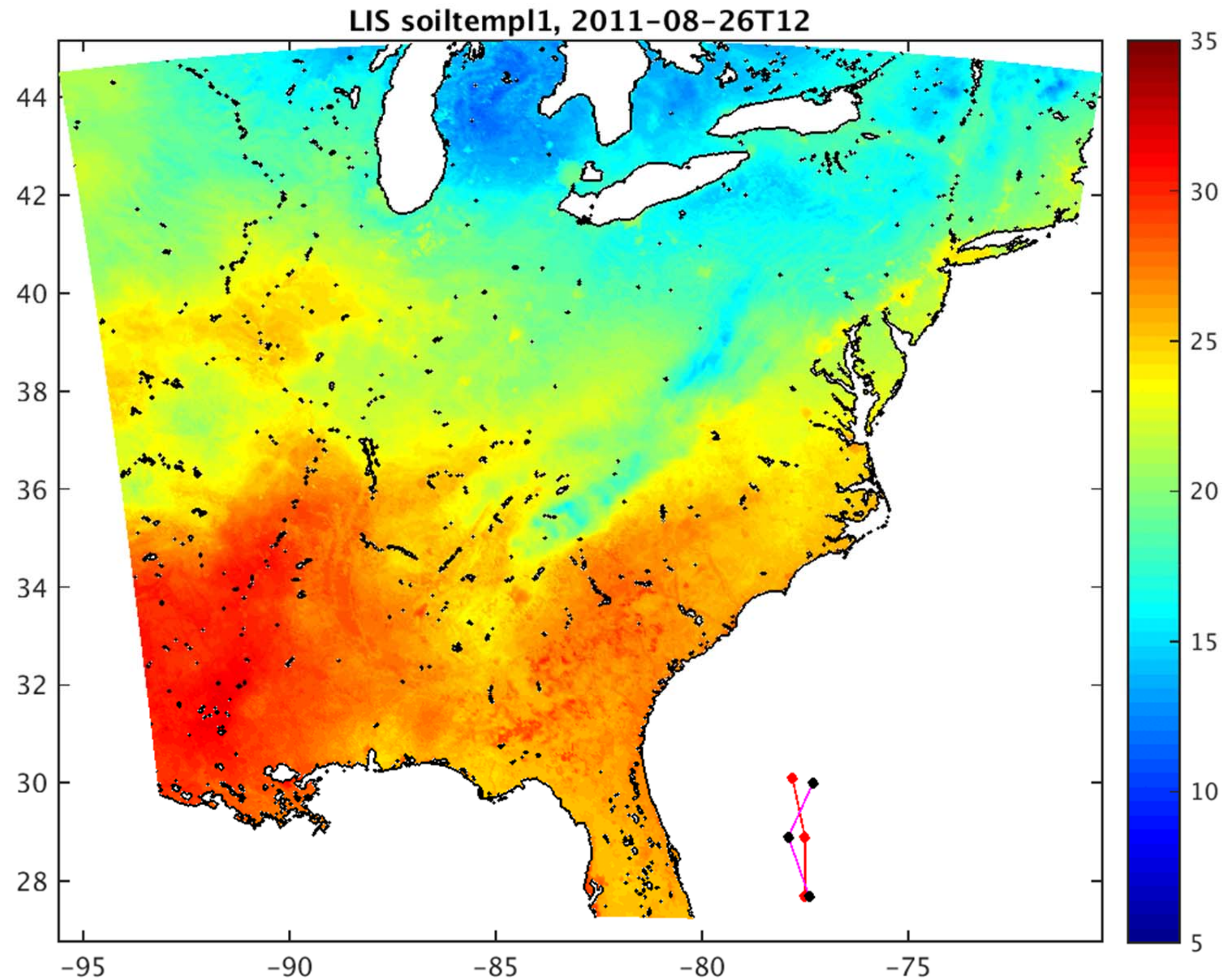
40 m



100 m



COAMPS-LIS Soil Temperature Forecast Movie



Day 2-3 COAMPS-LIS 20 m – 100 m Soil Temperature Forecast

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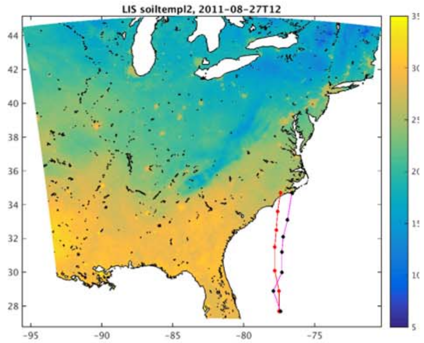
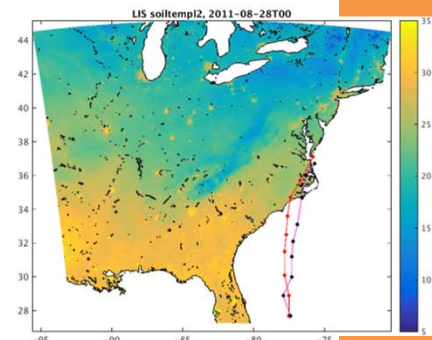
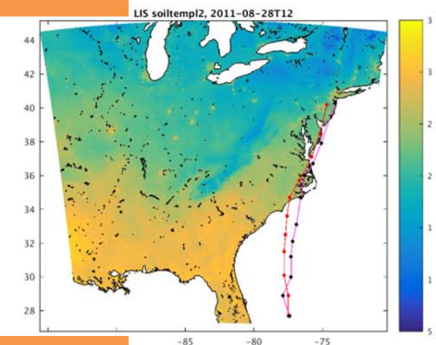
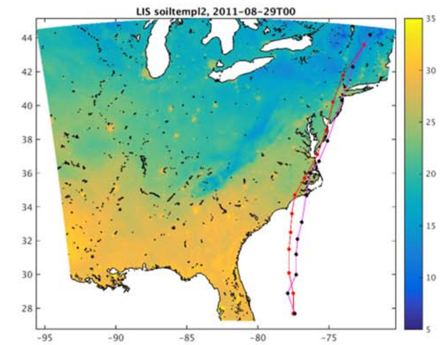
20 m

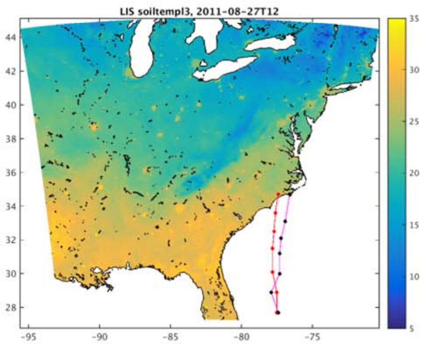


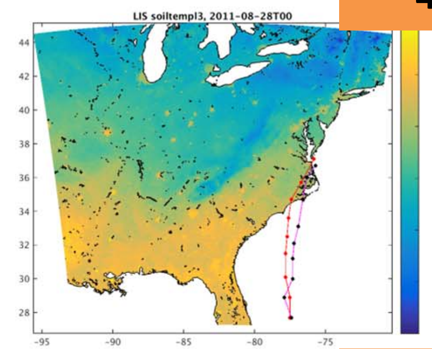


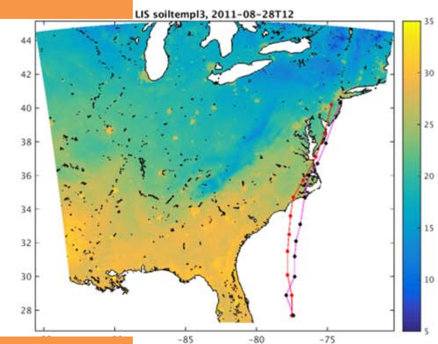


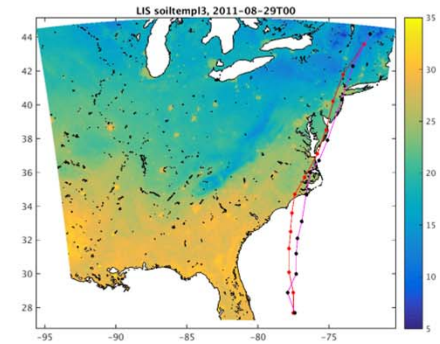


40 m

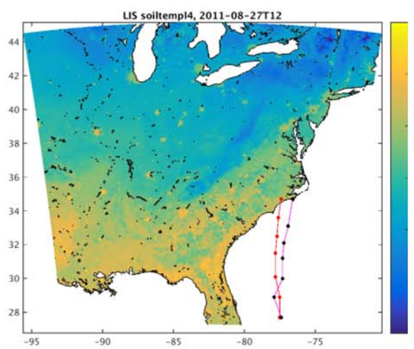


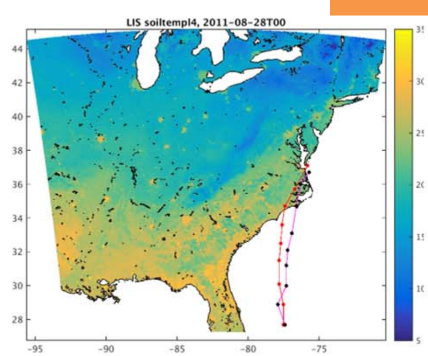


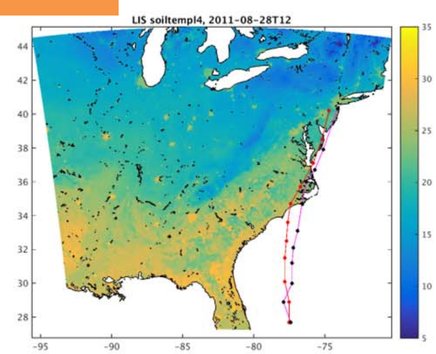


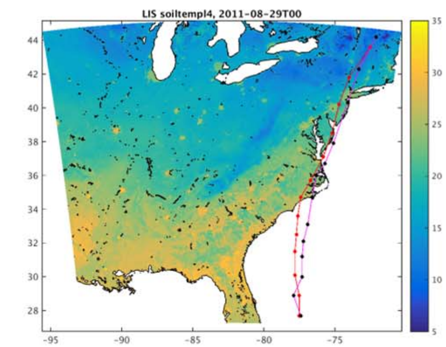


100 m









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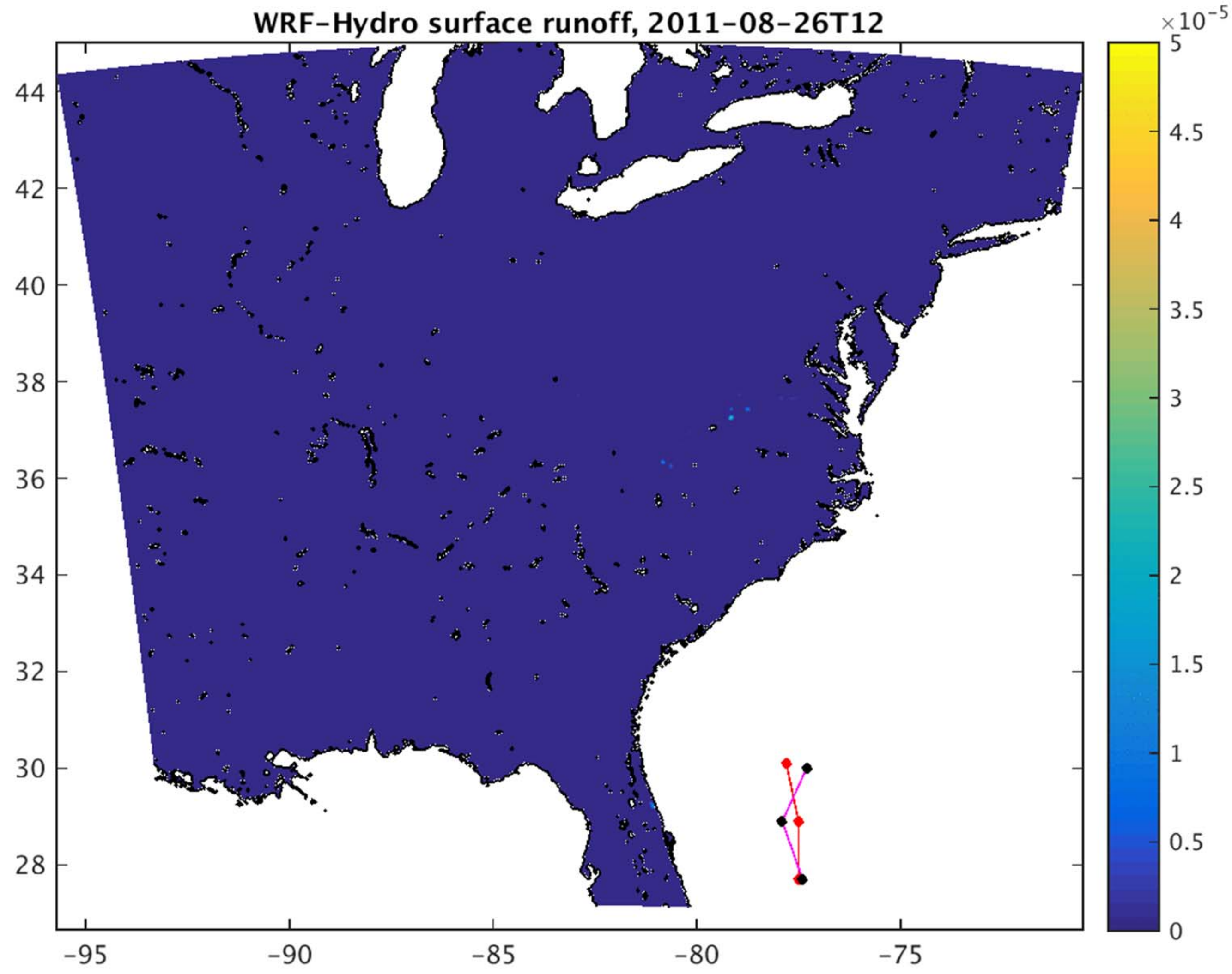
Implementation of WRF-Hydro for Naval Applications

- one-way coupling of COAMPS-LIS-WRF-Hydro
- Initiated setup of hurricane Irene test case
- Initiated setup of Luzon Island

Surface Runoff Movie

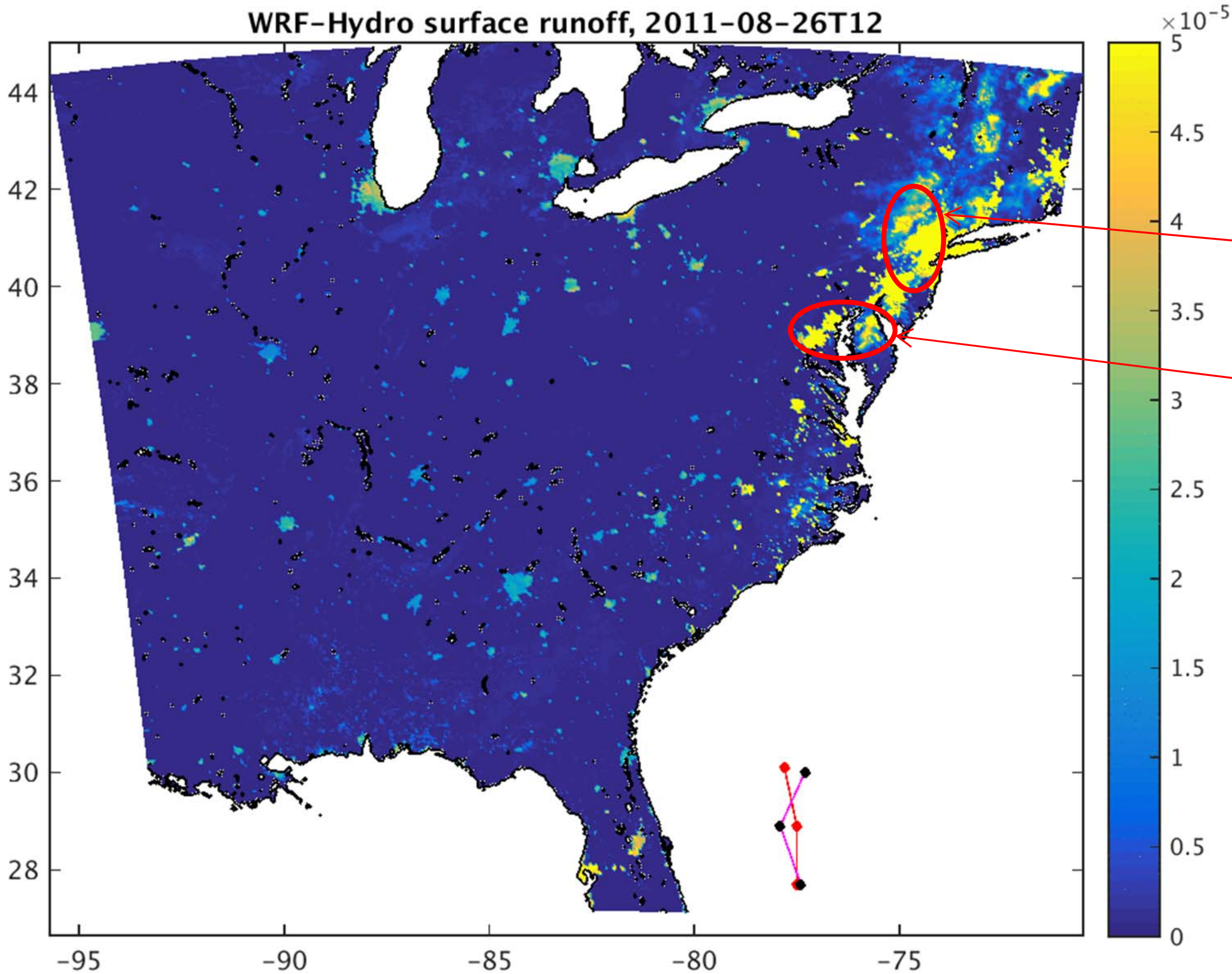


Large surface water runoff following the Hurricane Irene forecast track

Red line: COAMPS forecast track

Magenta line: Best track

Subsurface Runoff Movie



Increased subsurface runoff in the Cape Cod and Delaware Estuary Watersheds

Summary

Key Findings

- To couple LIS and WRF-Hydro with COAMPS via the ESMF NUOPC connectors at every nest time step require us to:
  - move the coupling of the land surface to the end of physics loop
  - develop customized NUOPC nest-to-nest connectors
  - modify COAMPS surface variables to use a much higher-resolution LIS inland water mask (LIS includes lake models)
- COAMPS precipitation is sensitive to the microphysical collection and aerosol concentration in the new generalized microphysics
- The COAMPS-LIS-WRF HYDRO preliminary results are encouraging

Expected Broader Implications

- Provides new capability of hydrology forecast – new battlespace information for coastal Marine Operation
- Improvement of the atmosphere land surface prediction and its feedback to the atmosphere BL

Future Plan

- Refine linkage of hydrology-microphysics within COAMPS/WRF-Hydro framework
- Evaluate water cycle budget diagnostics for high-resolution coupled experiments
- Prototype testing and evaluation of generalized re-locatable capability
  - second flood test case over Luzon, Philippine
- Leverage land and hydrology community advancements **(upgrades of LIS and WRF-Hydro in COAMPS-Hydro coupled system)**

Idealized two-moment COAMPS® Hurricane Prediction

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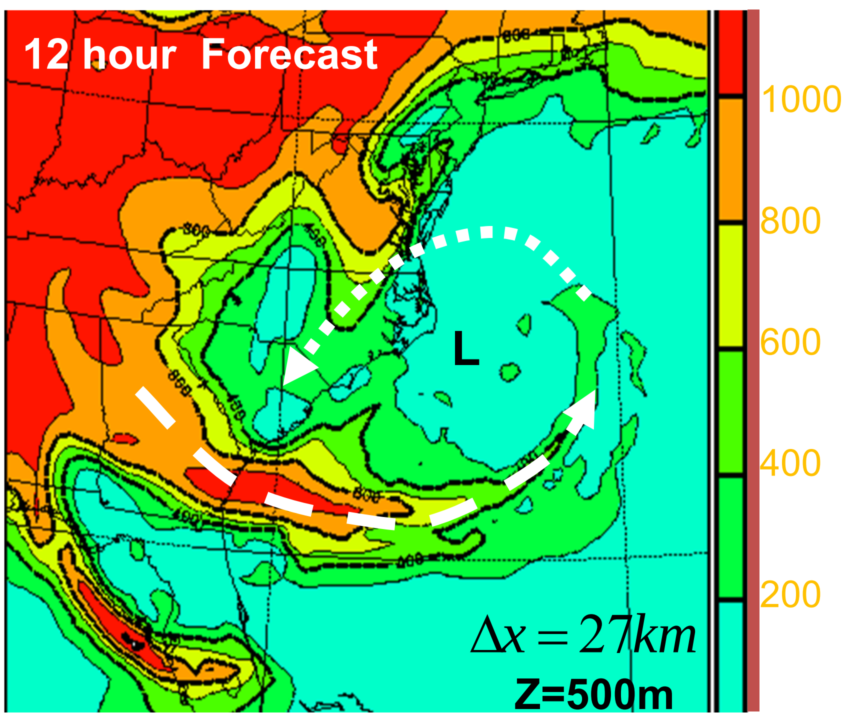
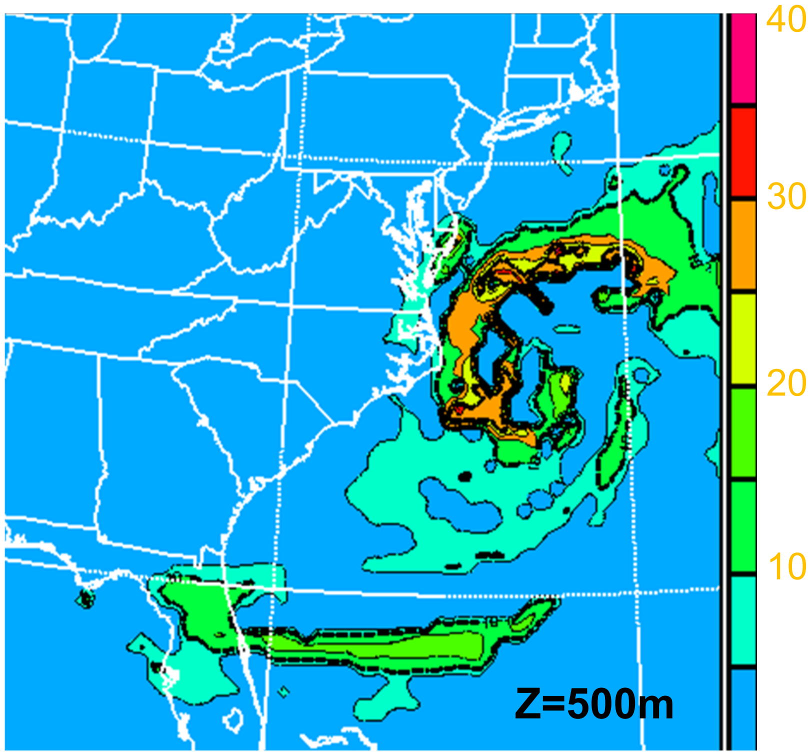
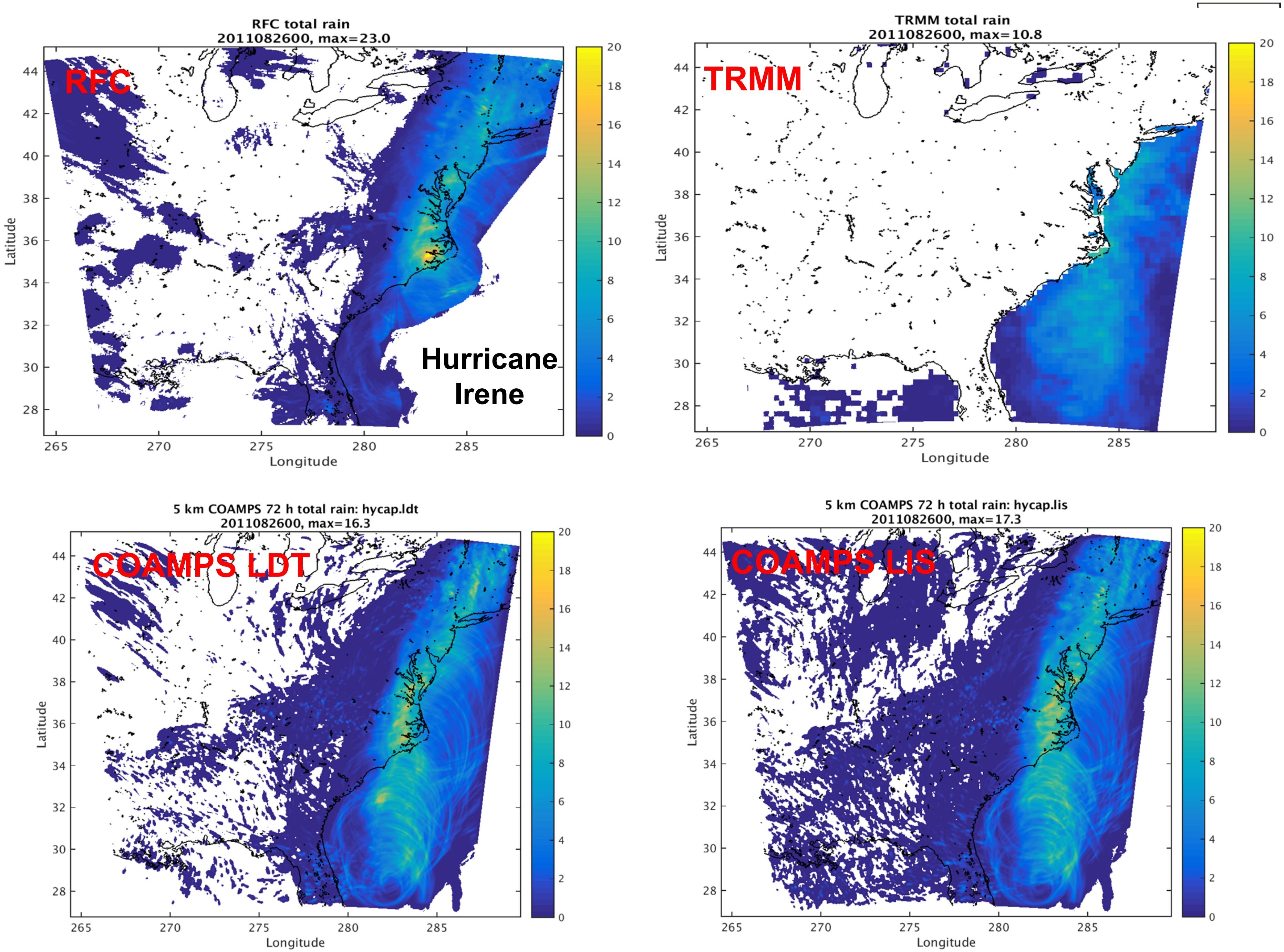
Hurricanes appear to pre-condition the orographic rainfall environment prior to landfall through aerosol transport.

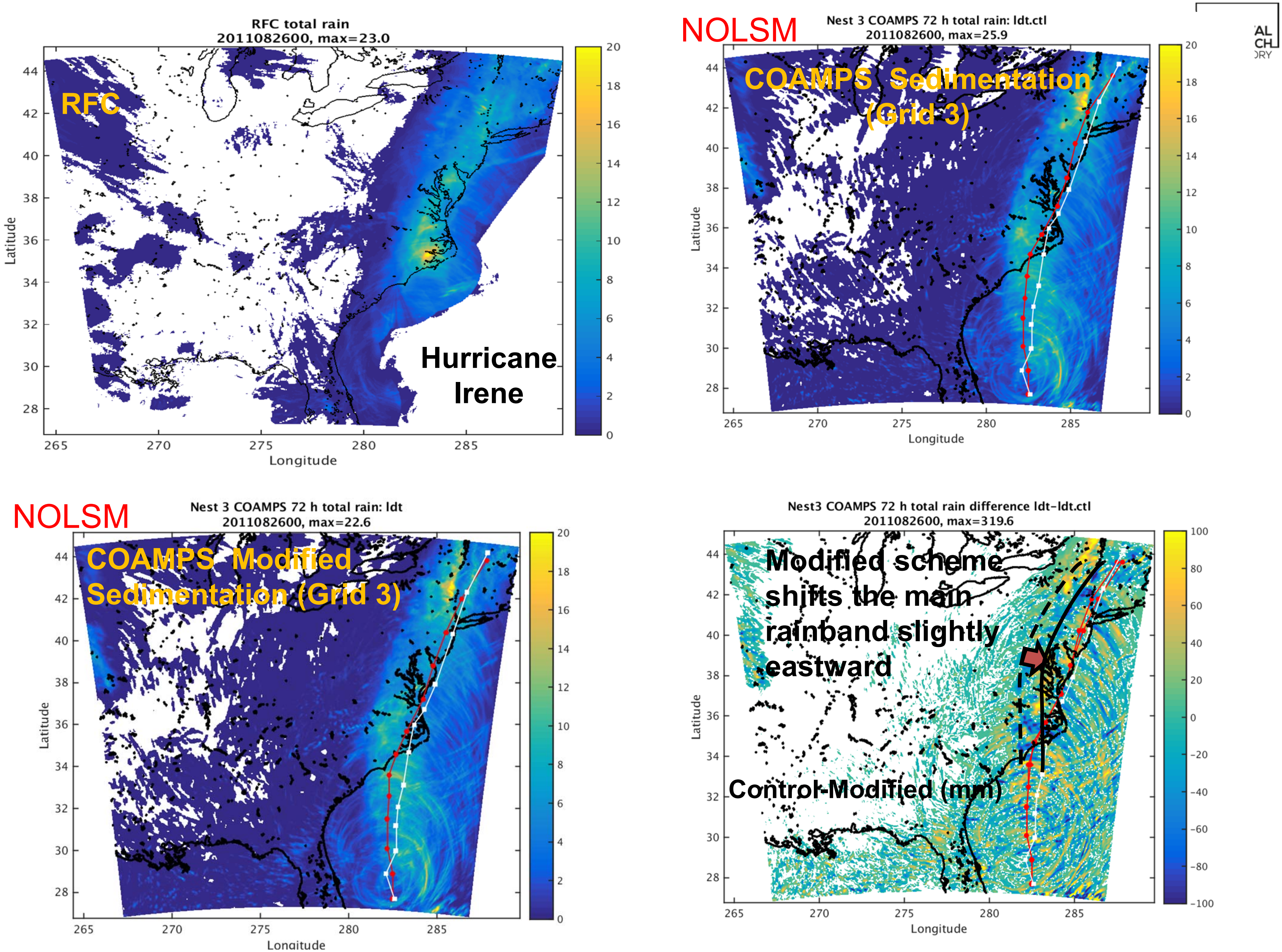


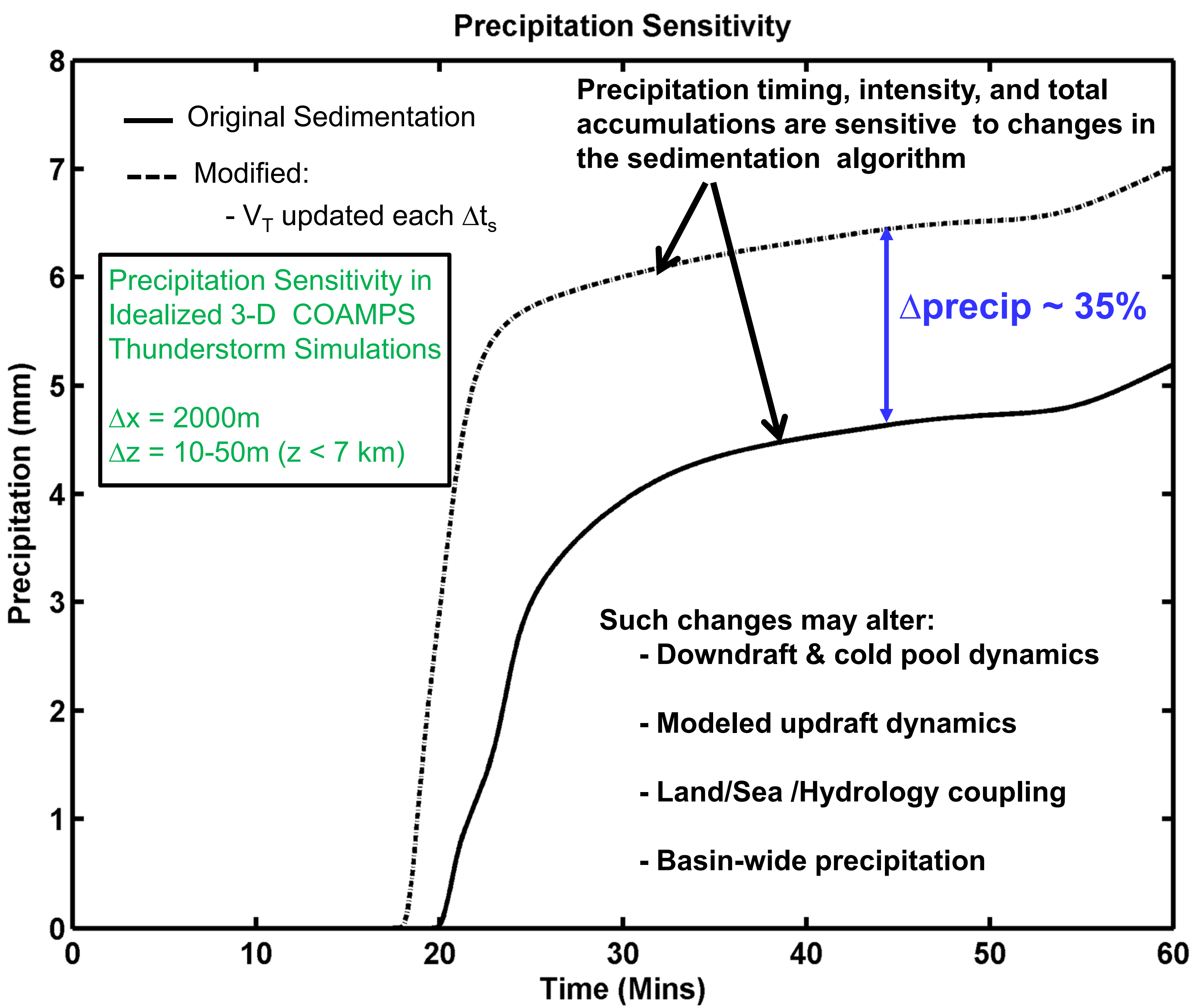


The challenge will be to reliably predict these conditions or other cloud/aerosol interactions in complex mesoscale situations:

- **Account for source/sink terms**
- **Include 3-D initialization (NAAPS)**


RFC total rain
2011082600, max=23.0
RFC
Hurricane
Irene
Latitude
Longitude
TRMM total rain
2011082600, max=10.8
TRMM
5 km COAMPS 72 h total rain: hycap.ldt
2011082600, max=16.3
COAMPS LDT
5 km COAMPS 72 h total rain: hycap.lis
2011082600, max=17.3
COAMPS LIS


RFC total rain
2011082600, max=23.0
RFC
Hurricane Irene
Latitude
Longitude
NOLSM
Nest 3 COAMPS 72 h total rain: ldt.ctl
2011082600, max=25.9
COAMPS Sedimentation (Grid 3)
NOLSM
Nest 3 COAMPS 72 h total rain: ldt
2011082600, max=22.6
COAMPS Modified Sedimentation (Grid 3)
Nest3 COAMPS 72 h total rain difference ldt-ldt.ctl
2011082600, max=319.6
Modified scheme shifts the main rainband slightly eastward
Control-Modified (mm)

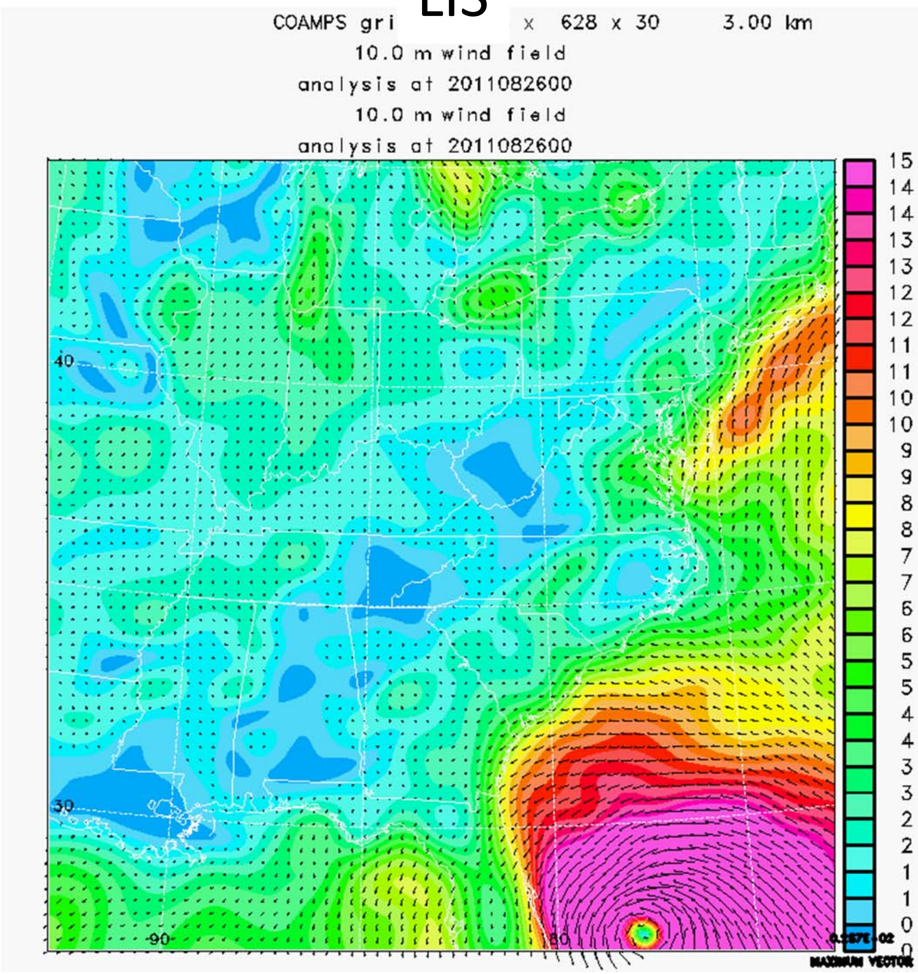

Precipitation Sensitivity
Original Sedimentation
Modified:
- V_T updated each Δt_s
Precipitation Sensitivity in Idealized 3-D COAMPS Thunderstorm Simulations
Δx = 2000m
Δz = 10-50m (z < 7 km)
Precipitation timing, intensity, and total accumulations are sensitive to changes in the sedimentation algorithm
Δprecip ~ 35%
Such changes may alter:
- Downdraft & cold pool dynamics
- Modeled updraft dynamics
- Land/Sea /Hydrology coupling
- Basin-wide precipitation
Precipitation (mm)
Time (Mins)
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60

COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

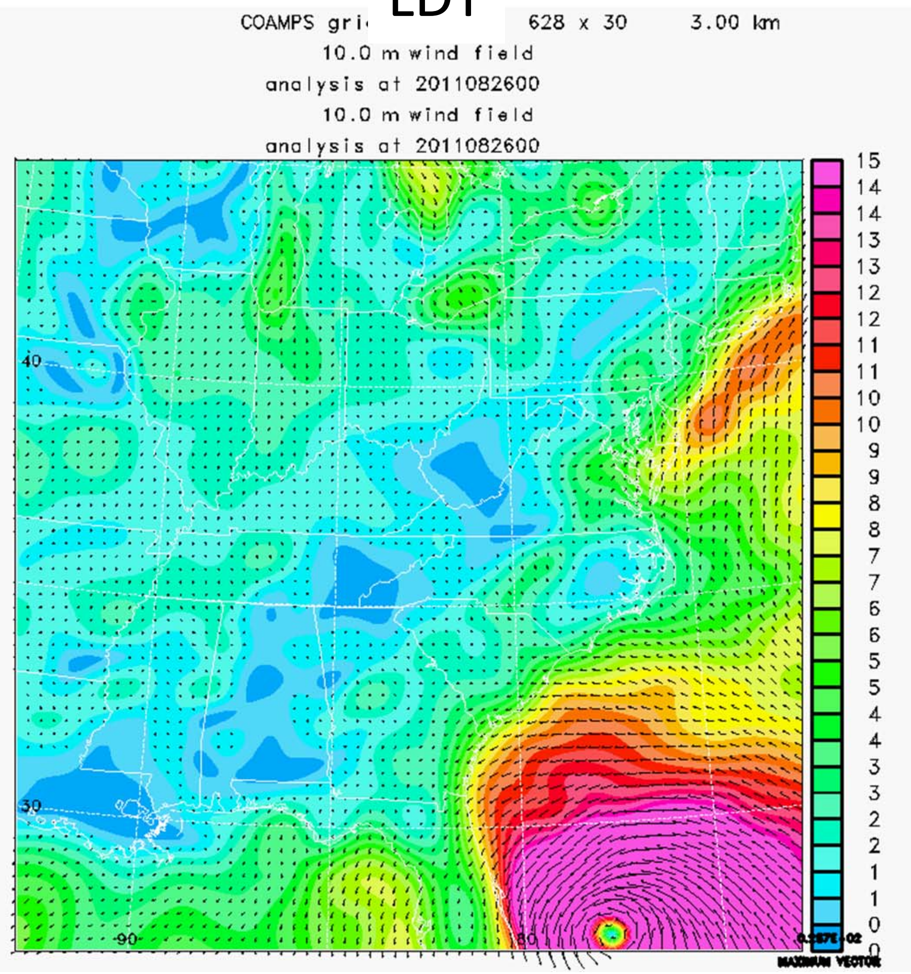
72-h forecasts from 2011082600 for nest 3 (3-km)

10-m winds (m s^{-1})

LIS



LDT

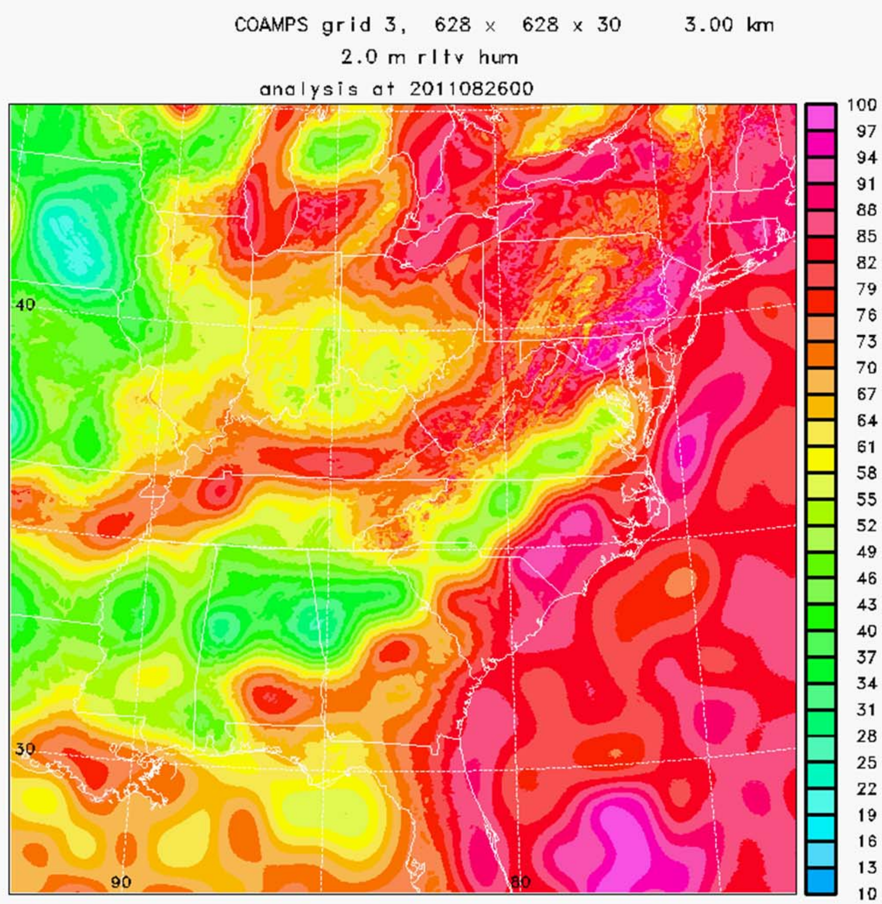


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

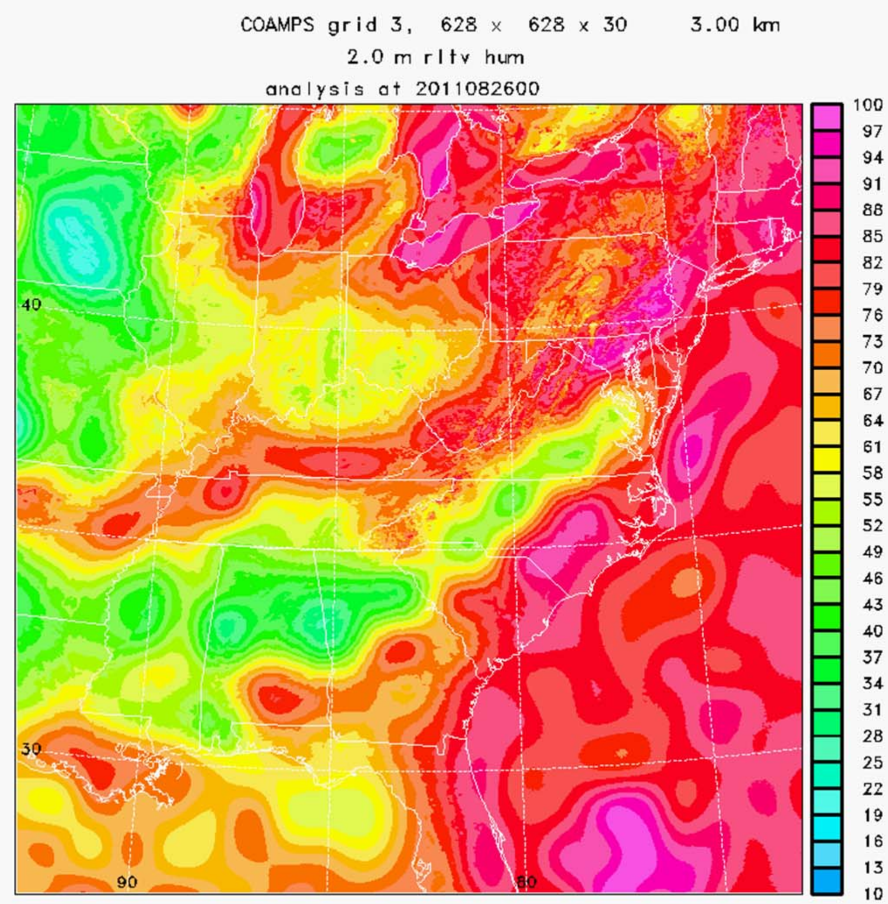
72-h forecasts from 2011082600 for nest 3 (3-km)

2-m relative humidity (%)

LIS



LDT

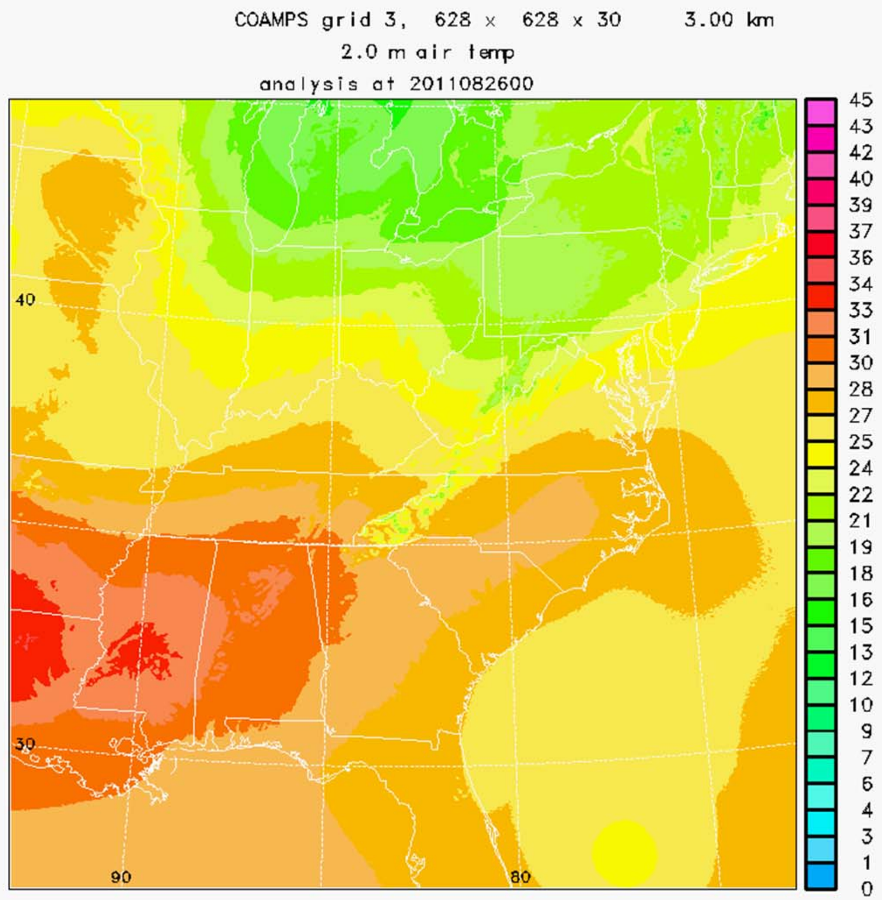


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

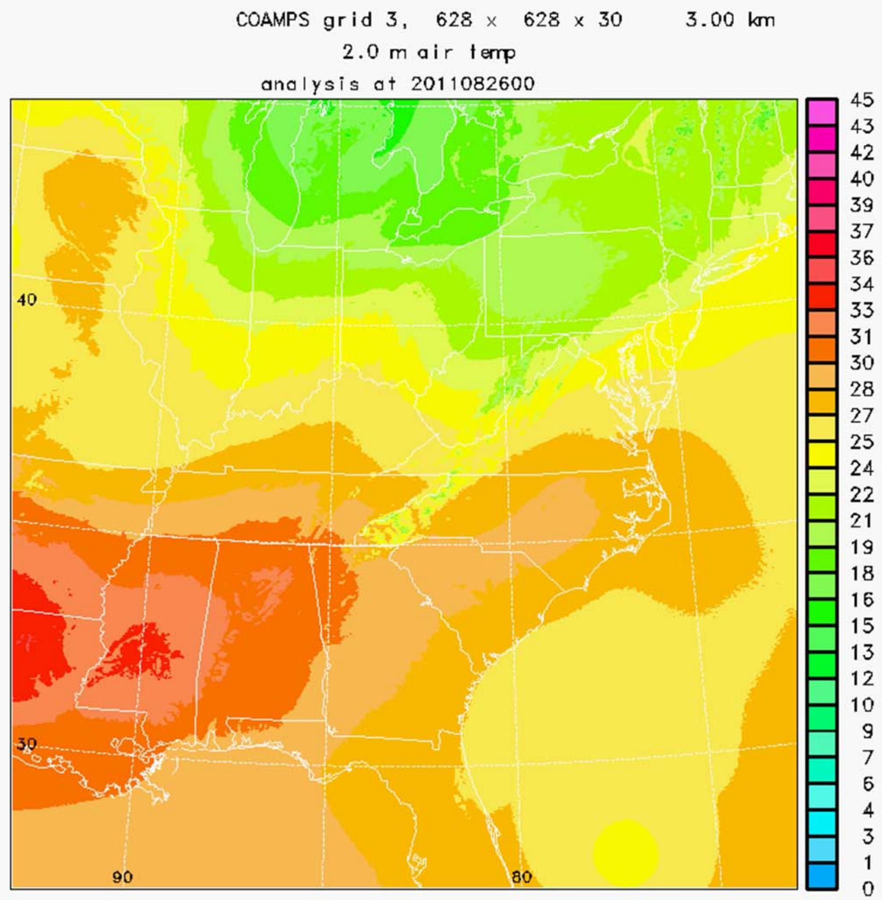
72-h forecasts from 2011082600 for nest 3 (3-km)

2-m air temperature (^{o}C)

LIS



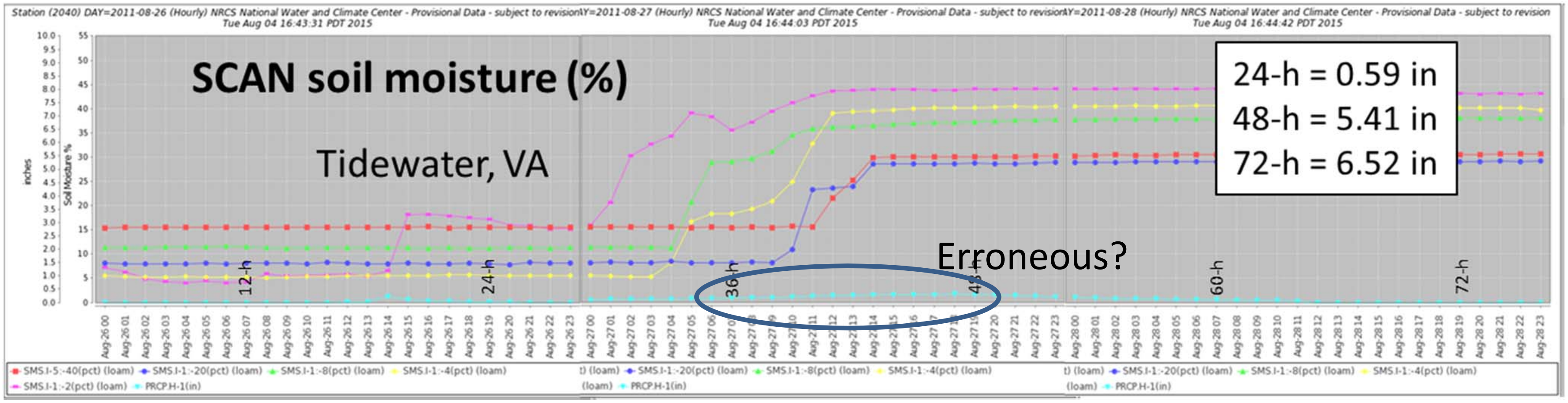
LDT

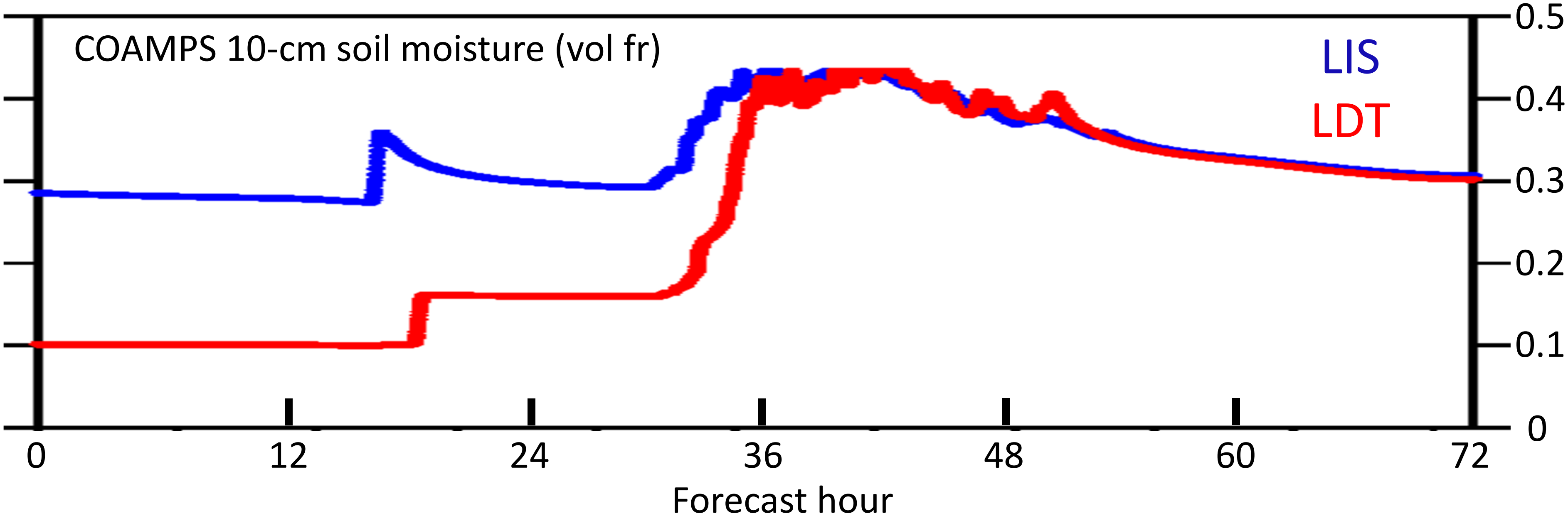


COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

COAMPS Nest-3 (3-km) near-surface time series: Tidewater, VA

Observations: NRCS National Water and Climate Center





COAMPS HYCCAP Case Study: Hurricane Irene (Aug 2011)

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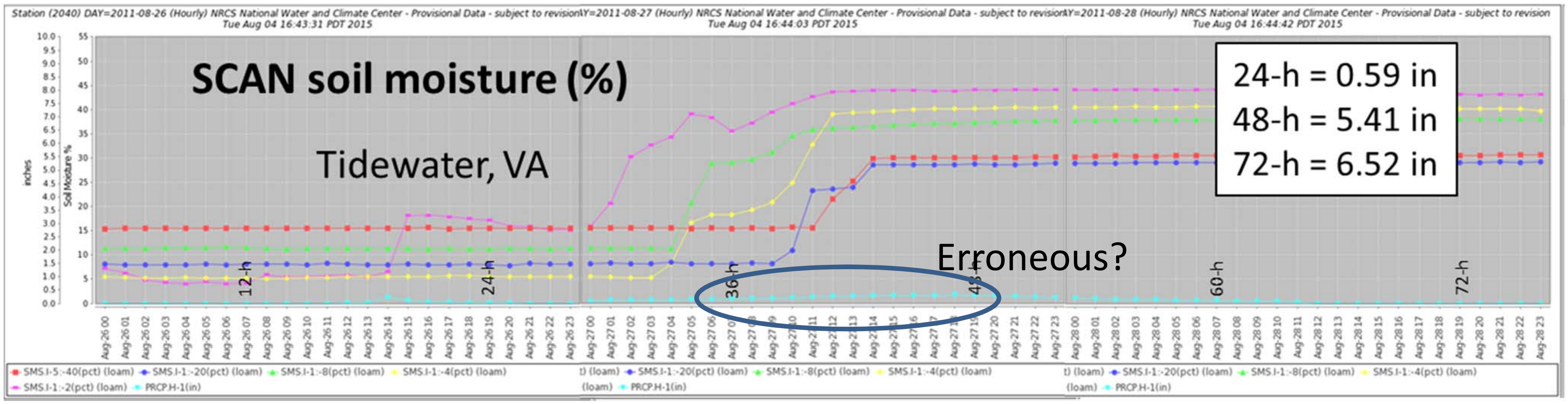

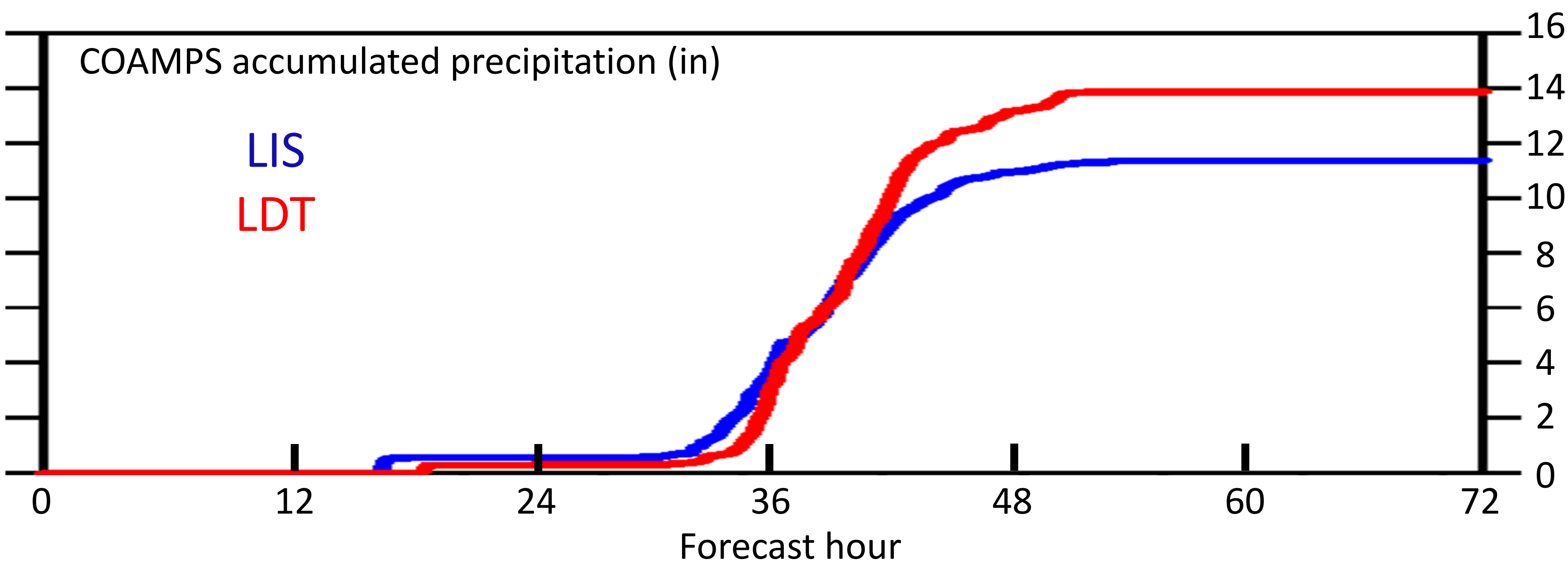

Implementation of LIS for Naval Applications

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- COAMPS-LIS simulations were conducted to generate initial conditions for Hurricane Irene (Aug 2011) case study.
- Noah LSM (v 3.3) was configured over a 3-nested domain, using high resolution vegetation (MODIS) and soils (STATSGO; 1km) parameters
- The COAMPS and NLDAS2 meteorology was used to drive the LSMs
- The test domain and initial condition data are used to test/validate a two-way coupled COAMPS-LIS.

NLDAS2-LIS soil moisture forecast