WIND ANALYSIS DOWNSCALING

(COASTAL-Act Project)

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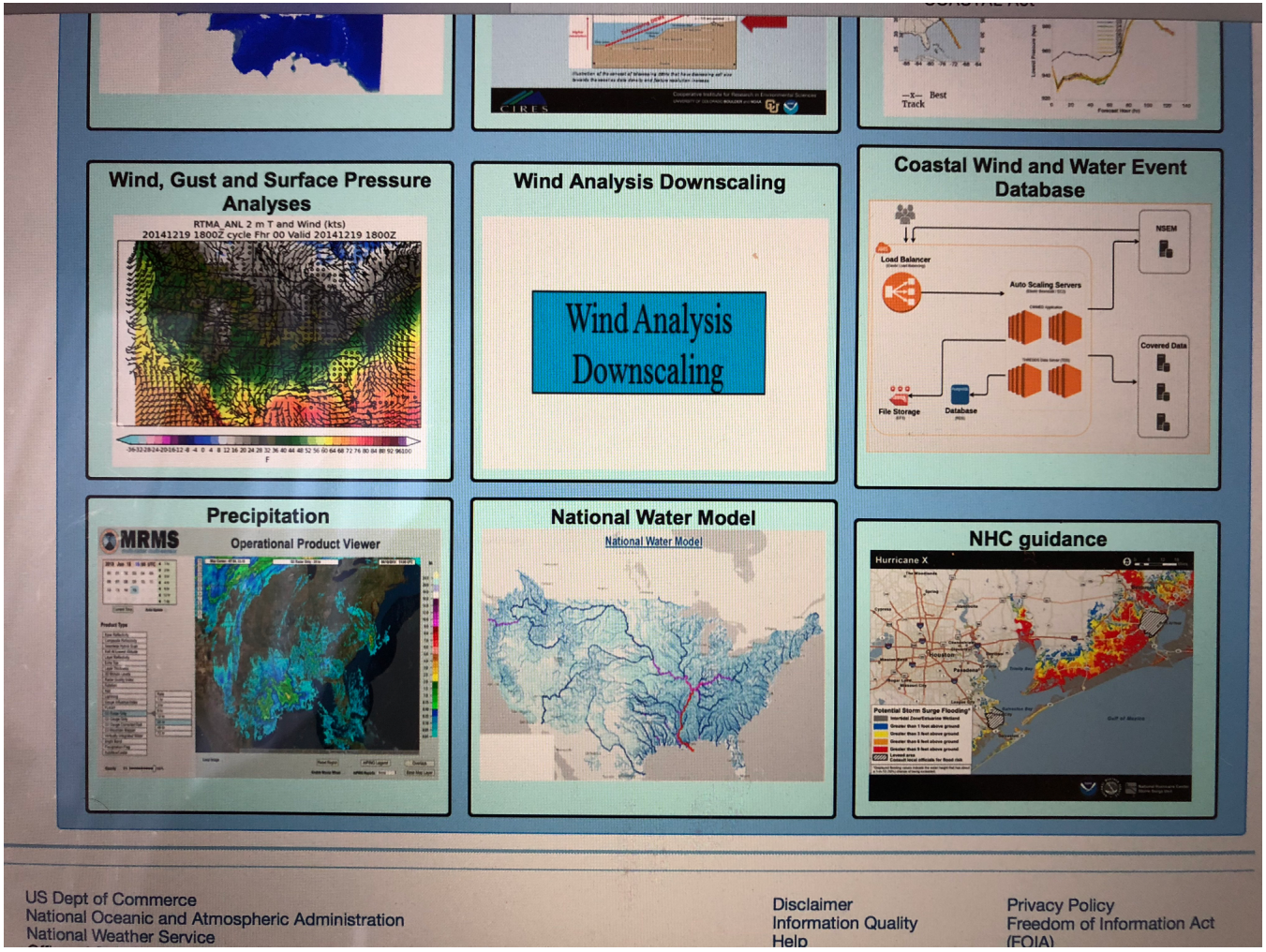
WIND ANALYSIS DOWNSCALING COMPONENT

(COASTAL) Act requires a wind analysis and to estimate the strength and timing of damaging winds at a given, "parcel-scale (10-30 meters)" over-land location in the area impacted by the tropical cyclone and to drive surge and wave models for estimating the water damage. And this can be done using LES.

The Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act 22

COASTAL-Act : Overview

- The Consumer Option for an Alternative System to Allocate Losses (COASTAL) Act was signed into law on July 6, 2012. The purpose of the COASTAL Act is to lower costs to FEMA's National Flood Insurance Program (NFIP) by better discerning wind versus water damage in the case of "indeterminate losses;" that is, where little tangible evidence beyond a building's foundation ("slab") remains for the proper adjustment of insurance claims for homes totally destroyed by a tropical cyclone.
- The COASTAL Act requires NOAA to produce detailed "post-storm assessments" in the aftermath of a damaging tropical cyclone that strikes the U.S. or its territories. Using output from a hindcast model (termed the "Named Storm Event Model" (NSEM) by the Act), the assessments will indicate the strength and timing of damaging winds and water at a given location in the area impacted by the tropical cyclone. If the assessment results for the location of a specific "slab" case can be certified by NOAA as being greater than 90 percent accurate, those results will be input into a FEMA-managed formula that considers a variety of factors that may have contributed to structural damage. Based on this formula, FEMA will determine the appropriate loss allocation between wind and water.


Wind, Gust and Surface Pressure Analyses
RTMA_ANL 2 m T and Wind (kts)
20141219 1800Z cycle Fhr 00 Valid 20141219 1800Z
Wind Analysis Downscaling
Wind Analysis Downscaling
Coastal Wind and Water Event Database
NSEM
Load Balancer
Auto Scaling Servers
Covered Data
File Storage
Database
Precipitation
MRMS
Operational Product Viewer
National Water Model
National Water Model
NHC guidance
Hurricane X
Potential Storm Surge Flooding
US Dept of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Disclaimer
Information Quality
Help
Privacy Policy
Freedom of Information Act (FOIA)

What is LES mode?

Running the WRF at high resolutions with the PBL scheme turned off and full diffusion turned on. The effects of sub-grid scale turbulence on the state variables is no longer parameterized.

Why Run in LES mode?

1. Capture a very turbulent or small scale phenomena
2. Capture all scales of turbulence >= model grid and their effects implicitly instead of parameterizing them with a PBL scheme
3. Run a high resolution run (<500m)
4. Loss of faith in the current WRF PBL parameterizations

Resolved winds at 10 to 30 meters spatial scale and at higher temporal resolution

The detailed structure and change of surface winds during landfall, which is controlled by the multi-scale interactions among the storm-scale circulation, meso-vortices, turbulence-scale eddies, and the underlying surface, cannot be obtained from operational numerical simulations (Ping Zhu 2008)

WRF Physics (Turbulence/Diffusion (diff_opt, km_opt))

High-resolution real-data cases (~100 m grid or less)

- No PBL
- diff_opt=2; km_opt=2,3 (tke or Smagorinsky scheme)
- diff_opt=2 Horizontal diffusion acts along model levels Numerical method includes vertical correction term using more grid points

km_opt selects method to compute K (km_opt=2)

1: constant (khdif and kvdif used)

2: 1.5-order TKE prediction

3: Smagorinsky (deformation/stability based K)

4: 2D Smagorinsky (deformation based onhorizontal wind for horizontal diffusion only)

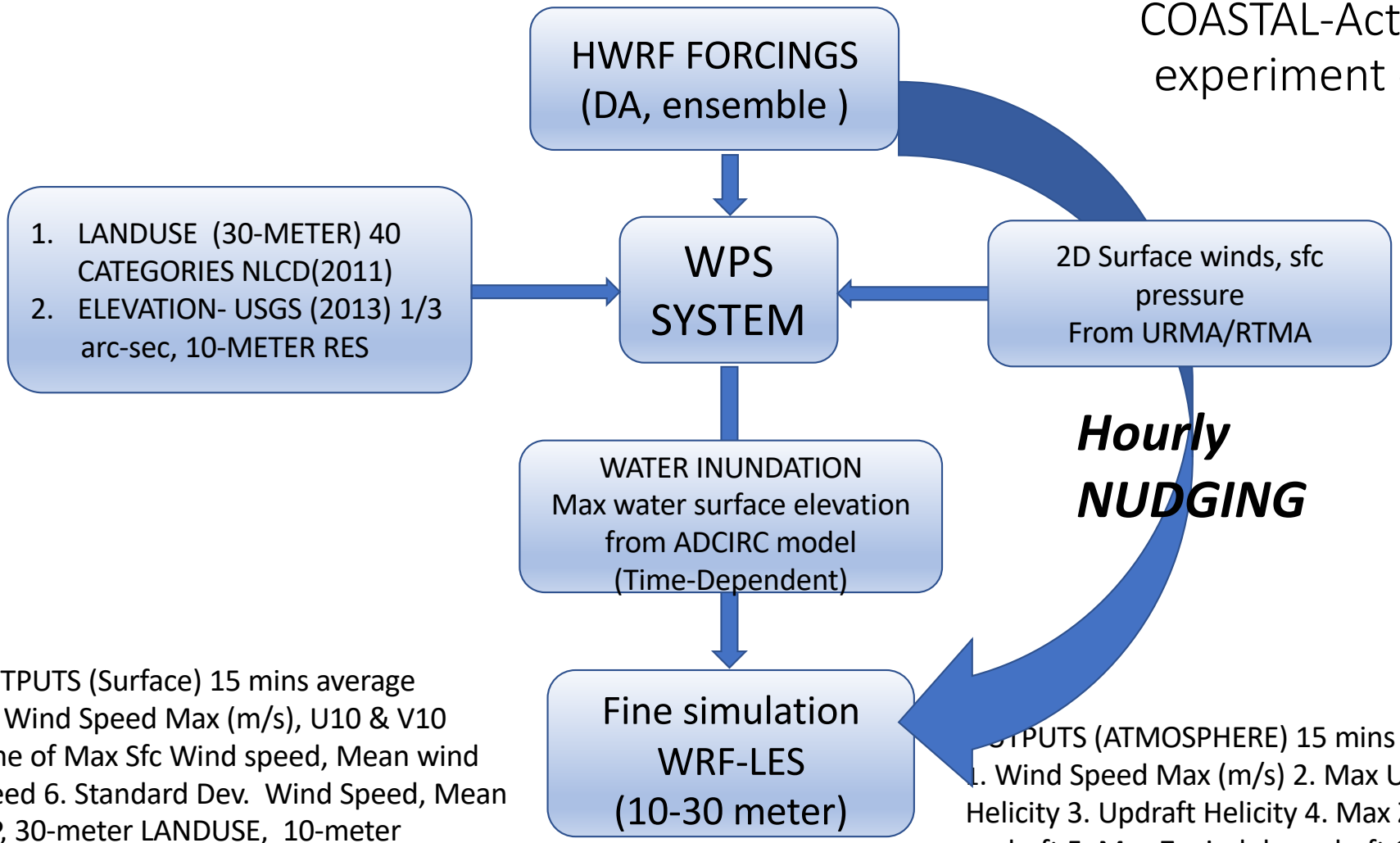
LES schemes in V3.2

bl_pbl_physics	diff_opt	km_opt	Scheme	Cores	sf_sfclay_physics	isfflx	Prognostic variables
0	2	2	tke	ARW	0,1,2	0,1,2	tke
0	2	3	3d Smagorinsky	ARW	0,1,2	0,1,2	

Namelist isfflx controls surface flux methods

isfflx	sf_sfclay_physics	Heat flux	Drag	Real/Ideal
0	0	From namelist tke_heat_flux	From namelist tke_drag_coefficient	Ideal
1	1,2	From LSM/sfclay physics (HFX, QFX)	From sfclay physics (UST)	Real
2	1,2	From namelist tke_heat_flux	From sfclay physics (UST)	Ideal

COASTAL-Act Model experiment design

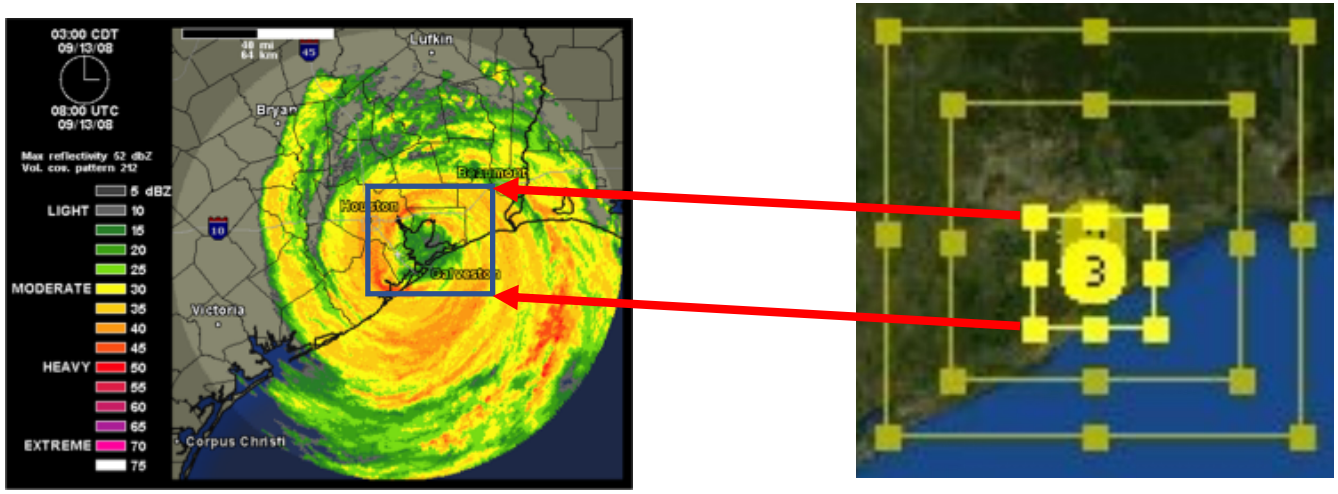


OUTPUTS (Surface) 15 mins average
Sfc Wind Speed Max (m/s), U10 & V10 Time of Max Sfc Wind speed, Mean wind speed 6. Standard Dev. Wind Speed, Mean SLP, 30-meter LANDUSE, 10-meter ELEVATION TERRAIN, Water Inundation mark

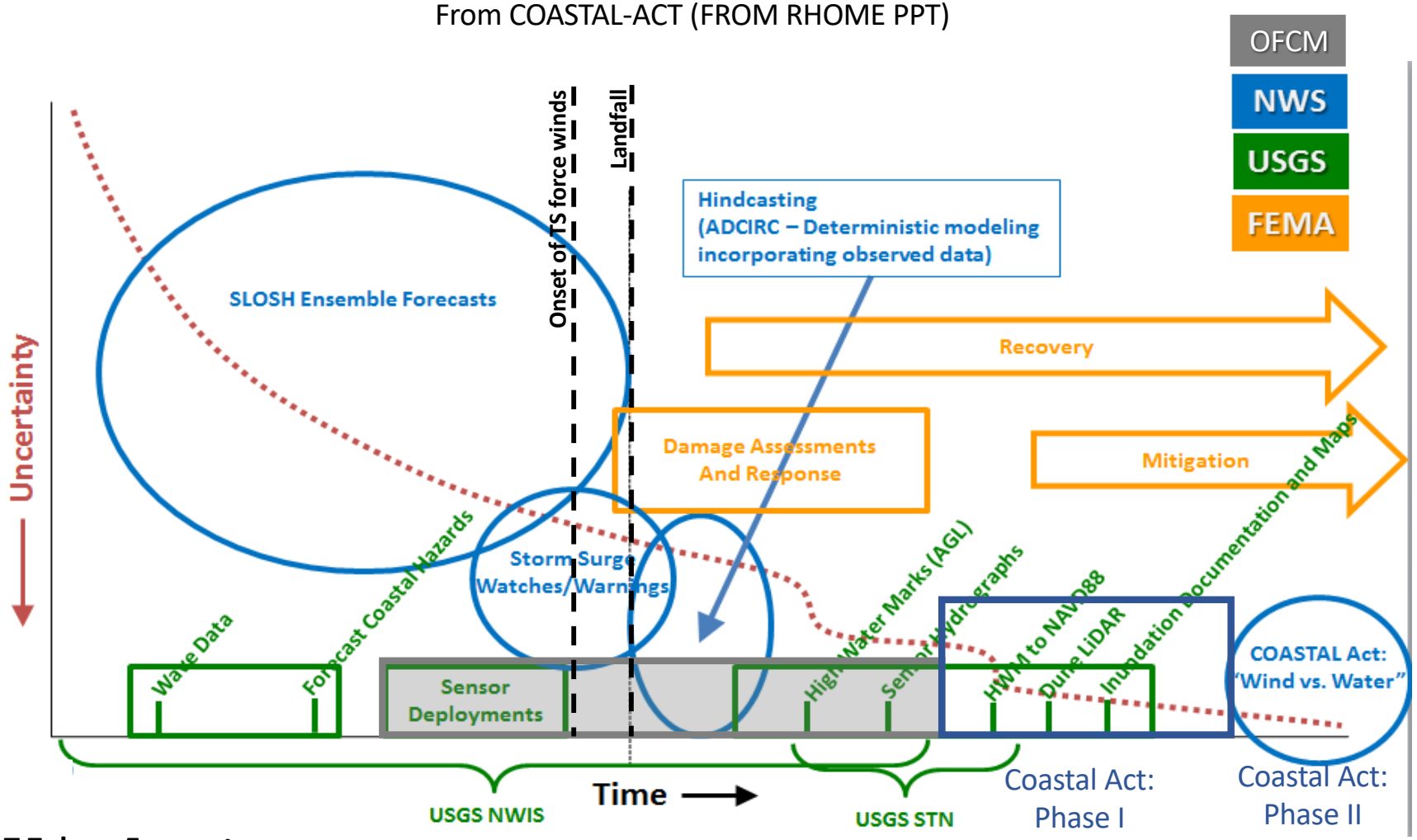
OUTPUTS (ATMOSPHERE) 15 mins average
1. Wind Speed Max (m/s) 2. Max Updraft Helicity 3. Updraft Helicity 4. Max Z-wind updraft 5. Max Z-wind downdraft 6. Mean Z-wind 7. Max col integrated Graupel

Fine simulation WRF-LES (10-30 meter) For Hurricane Ike 2008

Simulation type	PBL treatment	dx, dy (meters)	Grid Points	
D1-mesoscale	YSU	500	500 x 400	
D2- microscale	LES	100	1000 x 900	
D3-microscale	LES	33	1500 x 1200	
D4-microscale	LES	10	1500 x 1000	



From COASTAL-ACT (FROM RHOME PPT)



Implementation of very High-Resolution Landuse and Terrain data

Required for LES real time nested domains

Implementation of High-res Landuse and Terrain data in the LES simulations

Currently available Topography and Landuse in WRF

- LANDUSE : USGS Based 30S (1Km) Data (24-category USGS landuse) & MODIS 30S (21-Category)
- TOPOGRAPHY: GMTED2010 30 arc-second (1-km) topography height (USGS Based)

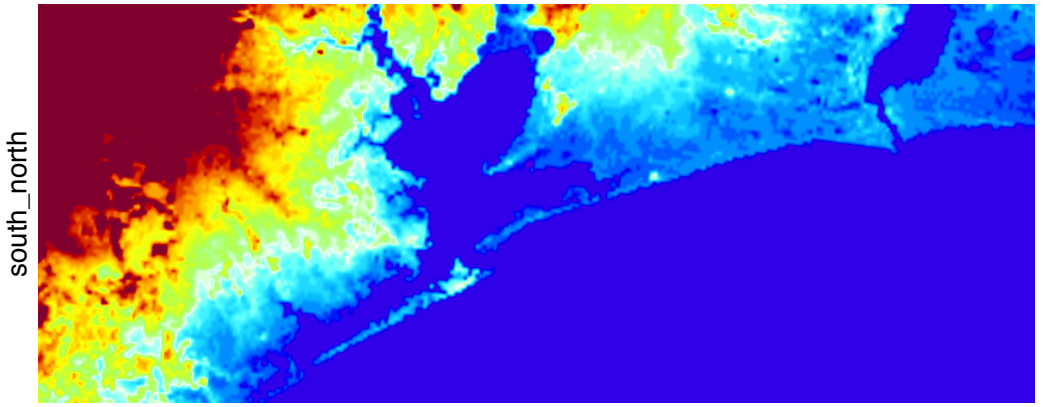
Replace with (For LES domains)

- LANDUSE : NLCD (2011) 1 Arc-second (30-meter) USGS Based (40-category USGS)
- TOPOGRAPHY: USGS (2013) 1/3 Arc-second (10-meters) topography height

LES Domain 1
(Terrain data comparision)

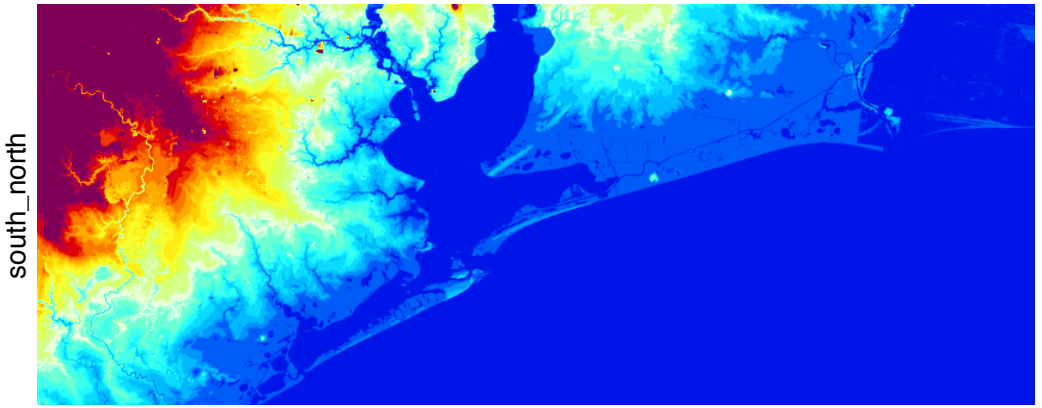
GMTED2010 30-arc-second (1-Km resolution) topography height. The Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010). By USGS and National Geospatial-Intelligence Agency (NGA).

Terrain data: 1-Km Resolution



U.S. Geological Survey (USGS), 2013, USGS National Elevation Data (NED) 1/3 arc-second (10-meter resolution)

Terrain Data : 10-meter resolution



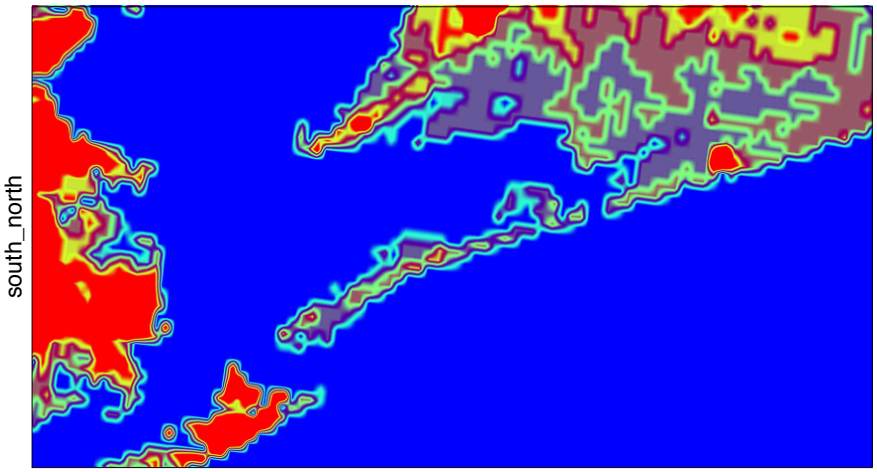
LES Domain 2 (Terrain data)

GMTED2010 30-arc-second (1-Km resolution) topography height. The Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010). By USGS and National Geospatial-Intelligence Agency (NGA).

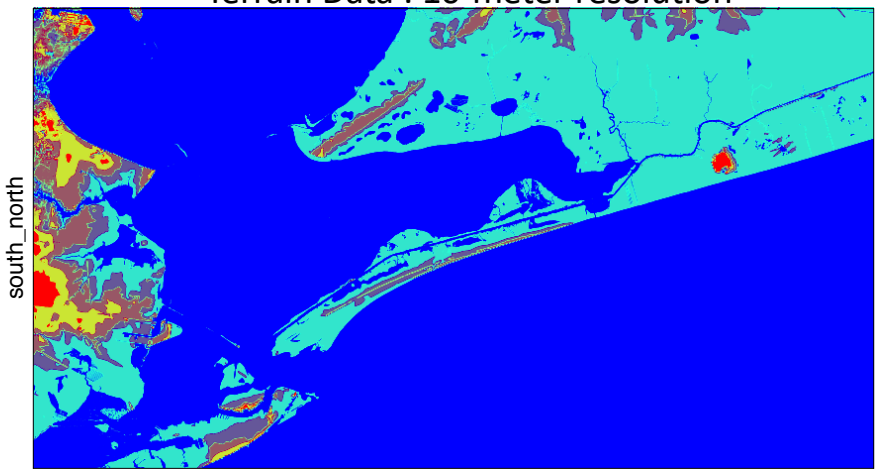
U.S. Geological Survey (USGS), 2013, USGS National Elevation Data (NED) 1/3 arc-second (10-meter resolution)

For our LES nested domains over Hurricane Ike landfall location, 10-meters resolution binary files are created & implemented using geogrid process in the WRF Preprocessing System (WPS).

Terrain data: 1-Km Resolution
HGT_M (meters MSL)



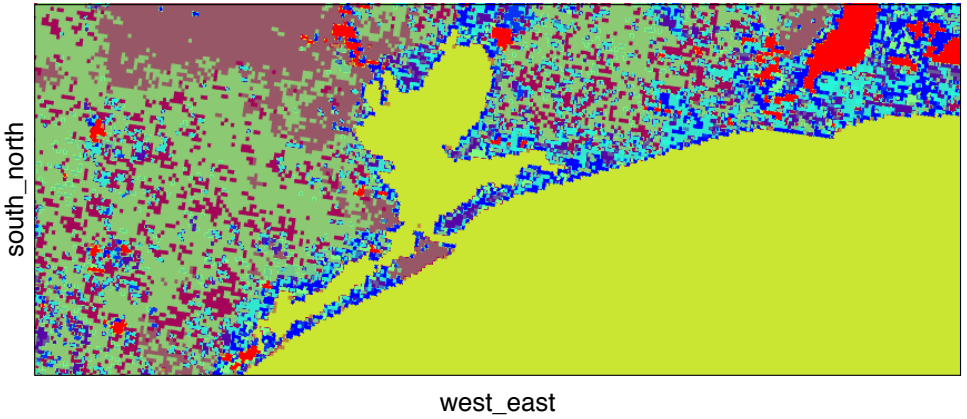
Terrain Data : 10-meter resolution



LES Domain 1
(Landuse Comparison)

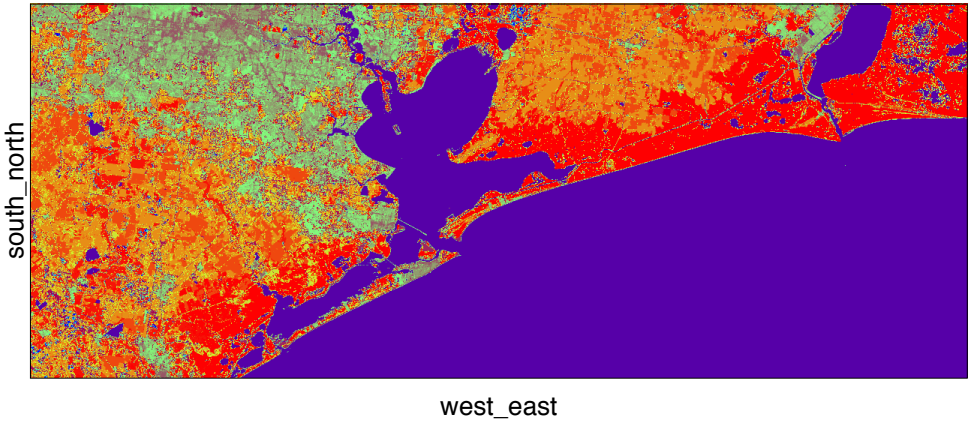
MODIS based (1-Km resolution) Landuse map.
21 landuse categories. Only one class of urban landuse.

MODIS based Landuse: 1-Km Resolution



USGS NLCD 1 arc-second (30-meter resolution)
40 landuse categories
It has urban classifications
Developed Open space (23)
Developed Low Intensity (24)
Developed Medium Intensity (25)
Developed High Intensity (26)

NLCD : 30-meter resolution



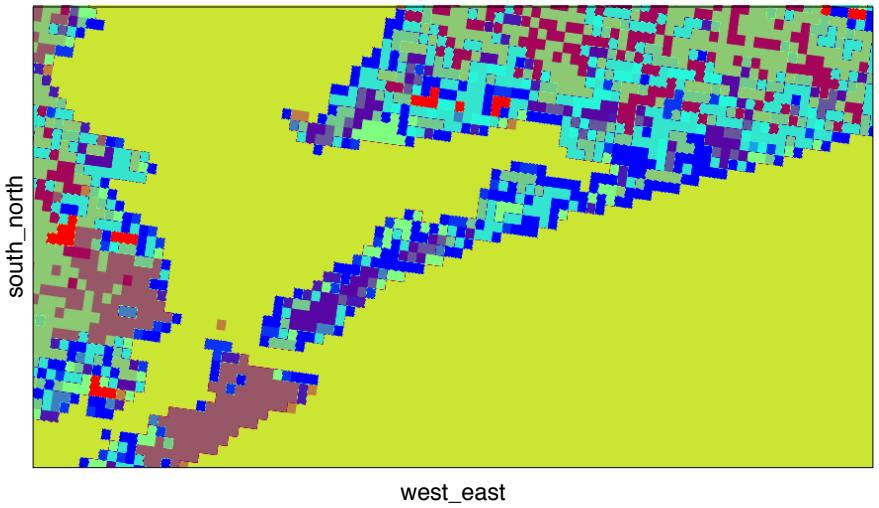
LES Domain 2

MODIS based (1-Km resolution) Landuse map.
21 landuse categories. Only one class of urban landuse.

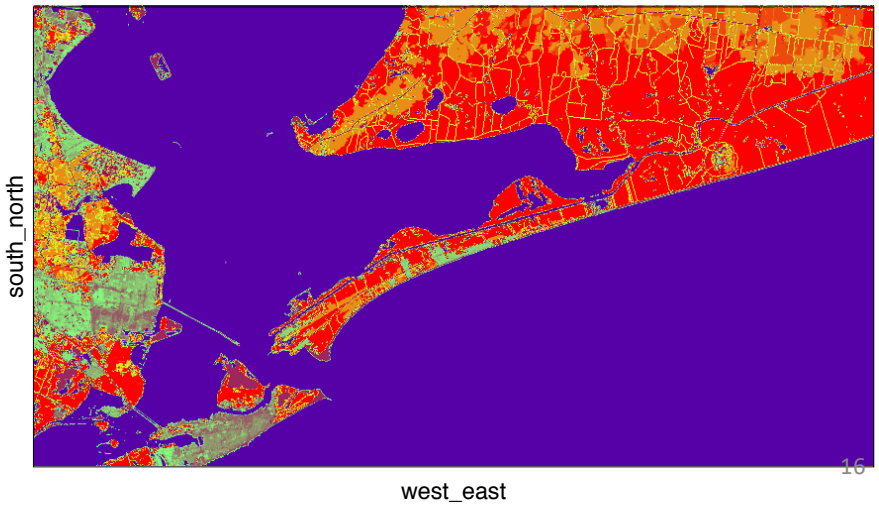
USGS NLCD 1 arc-second (30-meter resolution)
40 landuse categories
It has urban classifications
Developed Open space (23)
Developed Low Intensity (24)
Developed Medium Intensity (25)
Developed High Intensity (26)

For our LES domain selected region- Hurricane Ike landfall location, 10-meters binary files created & implemented using geogrid process in WPS.

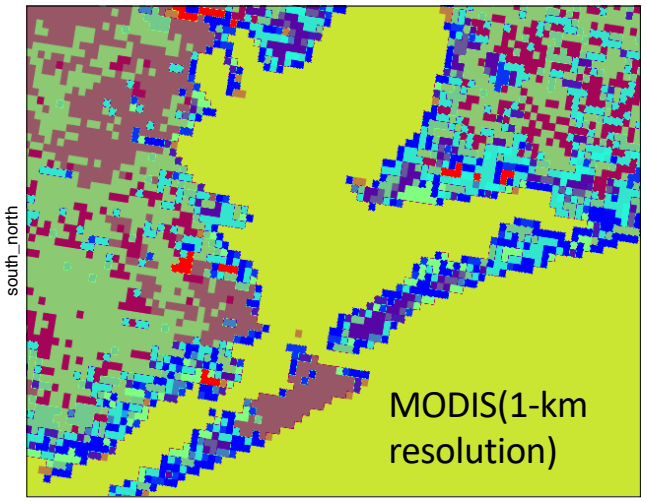
Landuse: 1-Km Resolution



Landuse : 30-meter resolution

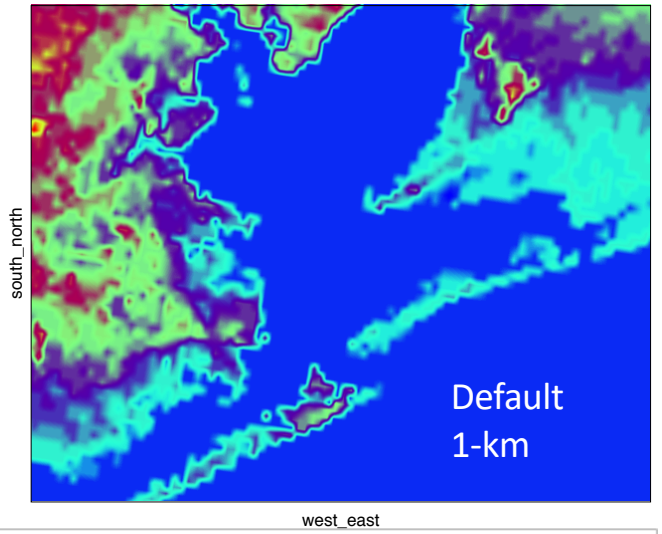


LANDUSE MAP

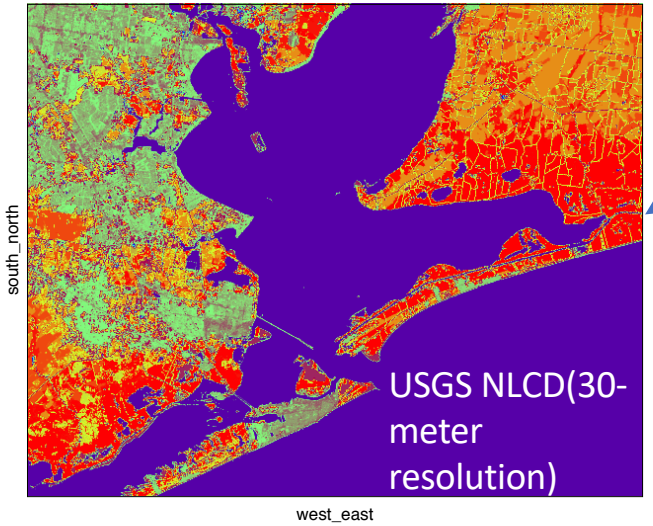


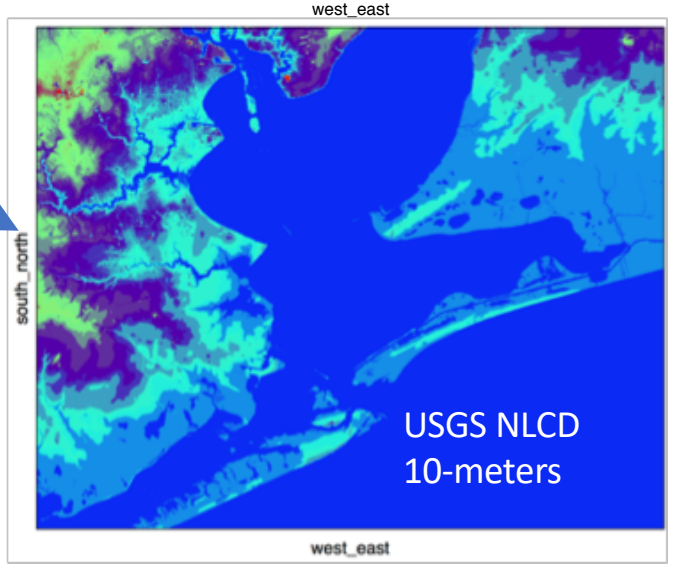
COARSER DATASETS

TERRAIN DATA



FOR LES SIMULATIONS





Implementation of Water Inundation (High Water Mark) in the LES simulations

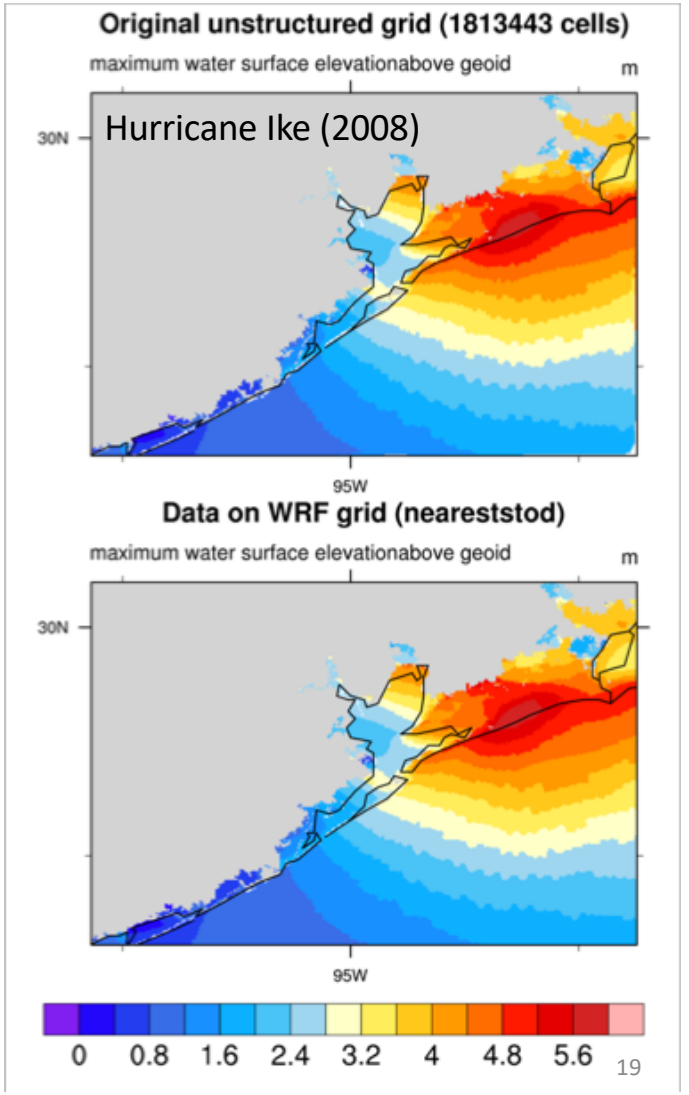
Implementation of Max Water surface elevation in the WPS –WRF System for LES (Hurricane Ike-2008)

1. Maximum water surface elevation(zeta_max) data is available in unstructured grid format from ADCIRC model.
2. First step is to regrid zeta_max variable on WRF grid.
3. ESMF_regrid is used to transform data from unstructured to WRF grid, using ESMF software. ESMF_regrid is part of as suite of regridding routines based on the Earth System Modeling Framework (ESMF) software.

This function is an "all-in-one" function that performs all of these steps:
1. Writes the description of the source grid to a SCRIP or ESMF description NetCDF file.
2. Writes the description of the destination grid to a SCRIP or ESMF description NetCDF file.
3. Generates the weights and writes them to a NetCDF file.
4. Regrids the data by applying the weights.
5. Copies metadata (attributes and coordinate arrays) where possible.

Interpolation Method: nearest neighbor method

We have done this using NCL V6.4.0 (or higher)

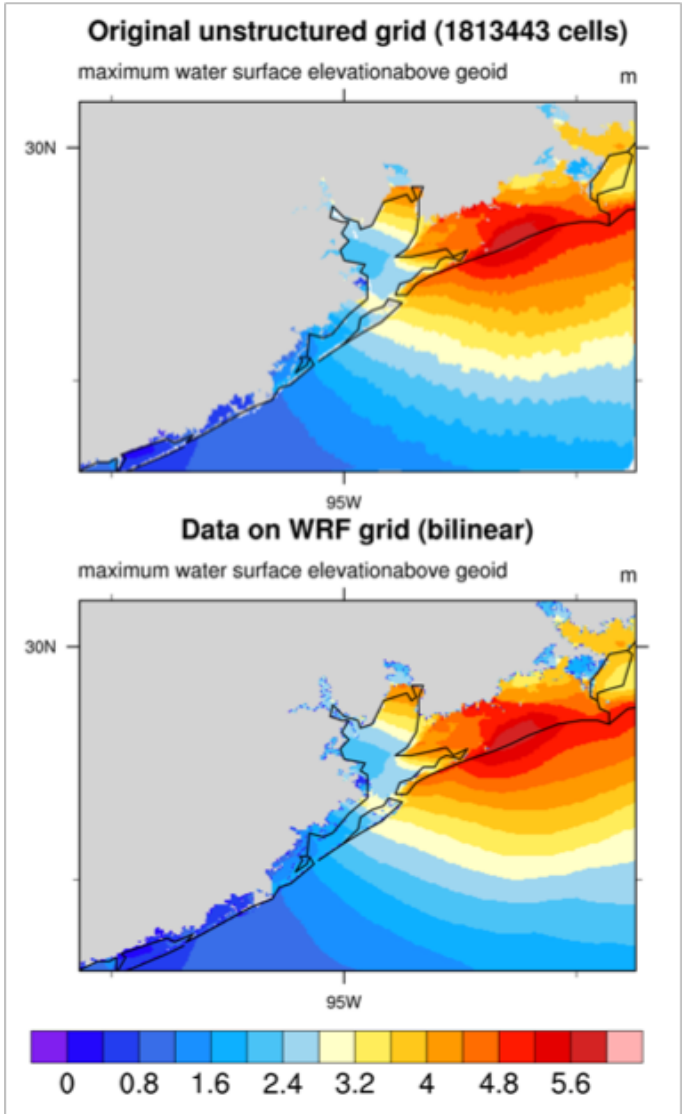


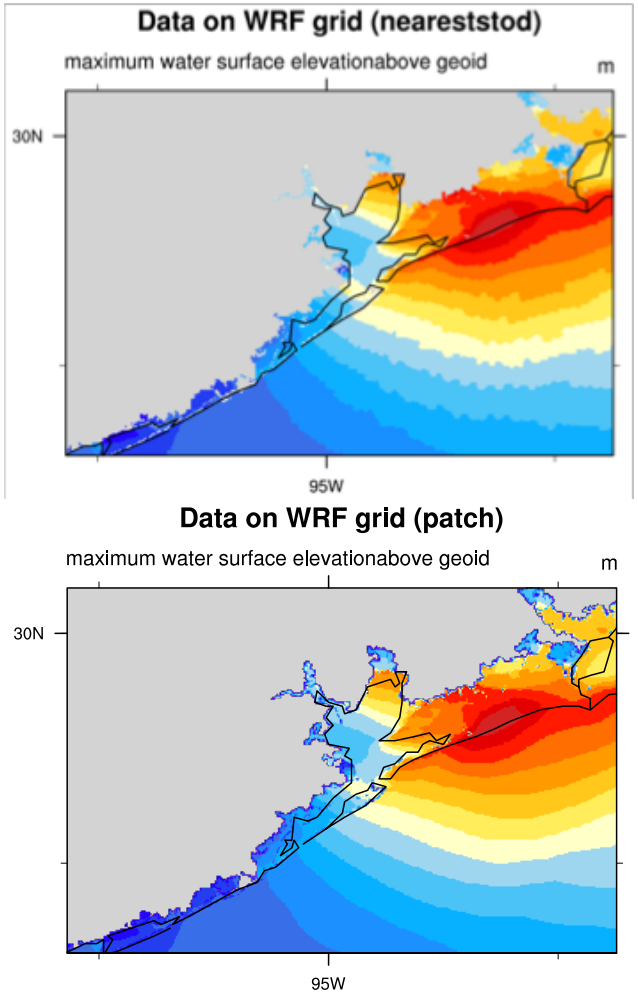
Interpolation Methods

Nearest Point interpolation method looks better than bilinear and patch methods in comparison with original data.

"patch" - this method is the ESMF version of a technique called "patch recovery" commonly used in finite element modeling. It typically results in better approximations to values and derivatives when compared to bilinear interpolation.

Using nearest point method
In our analysis.

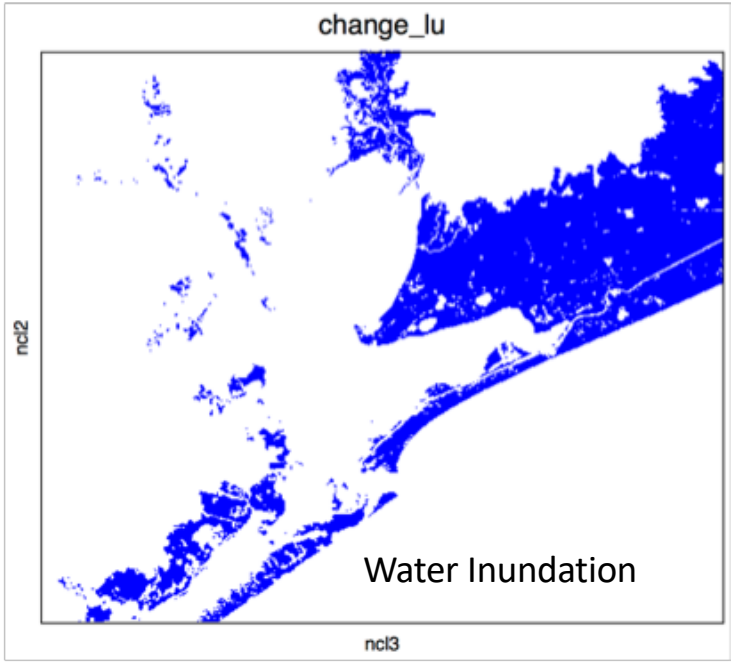




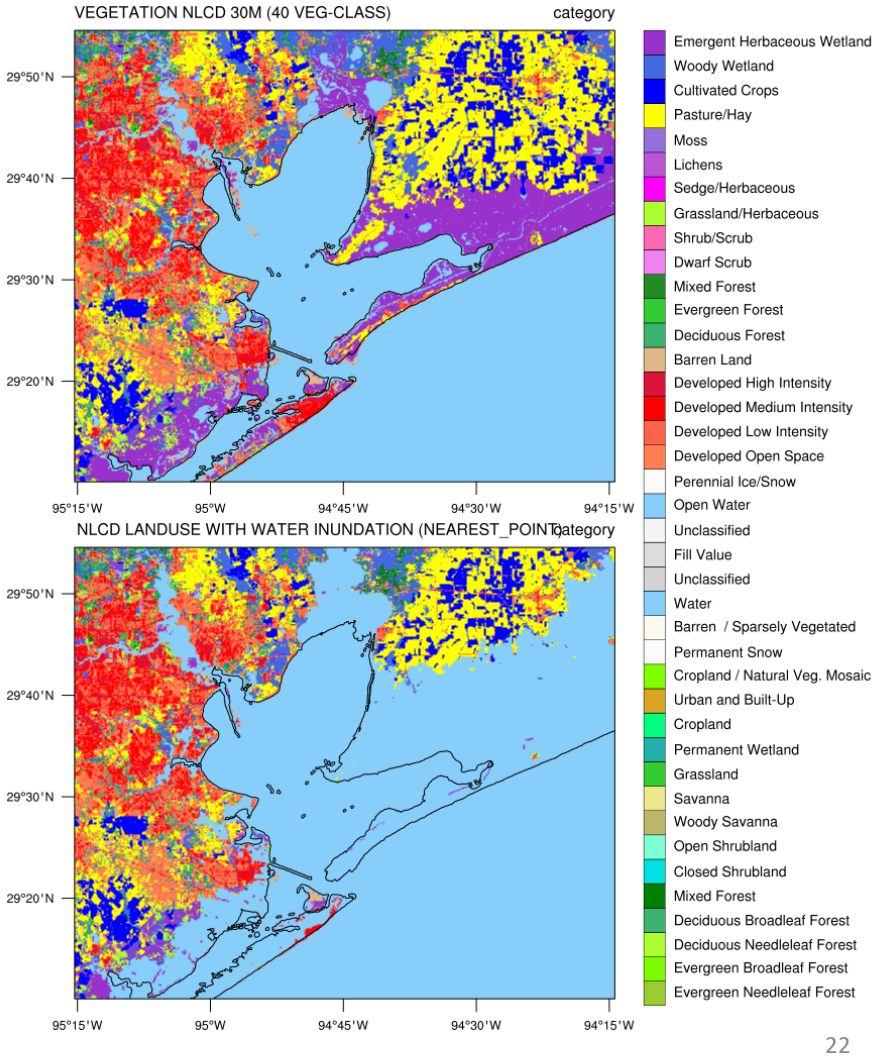
Water Inundation – Summary Points

- 1. mapping the high water level [aka inundation] data from is unstructured grid to the WRF-ARW grid
- 2. where Maximum water surface greater than the model's terrain, we set landuse to open water.
- 3. not changing the land-sea mask nor the terrain height or sfc-pressure in the model.

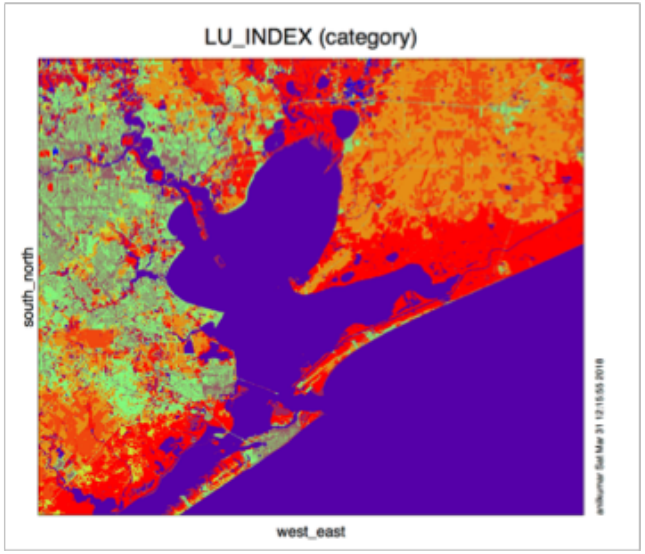
Domain 2 (Outer Domain 90 meter)

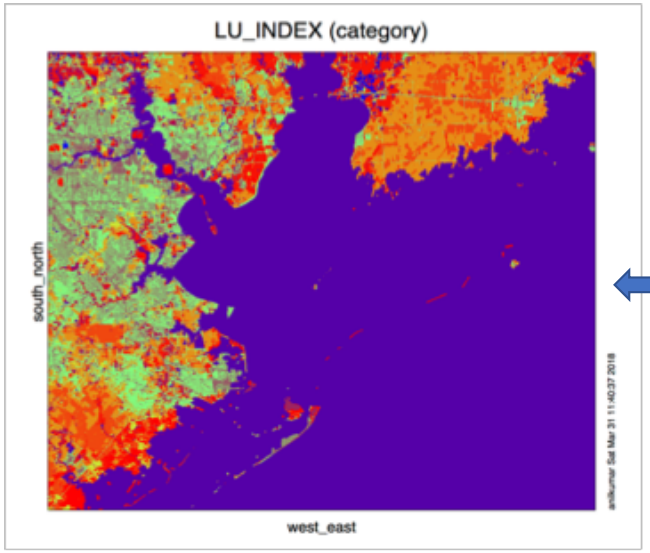


Update the Landuse (LU_INDEX geo_em.d02.nc) in WPS



Domain-2
90-m resolution

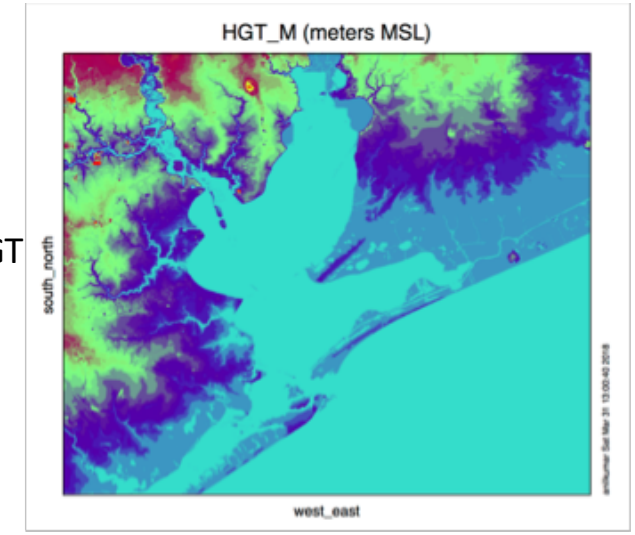


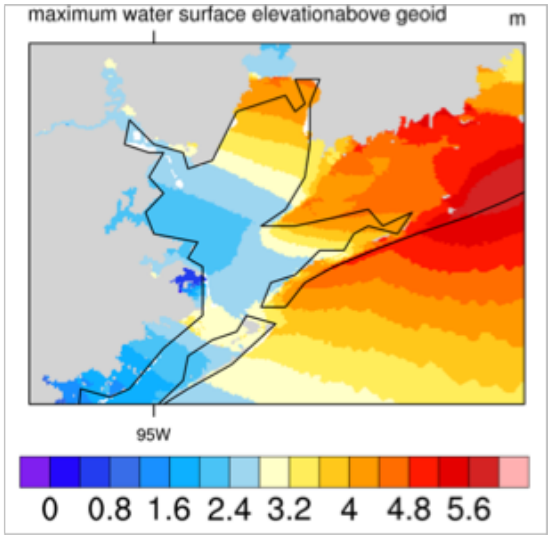


Snapshot from WPS geogrid file (from ncview)

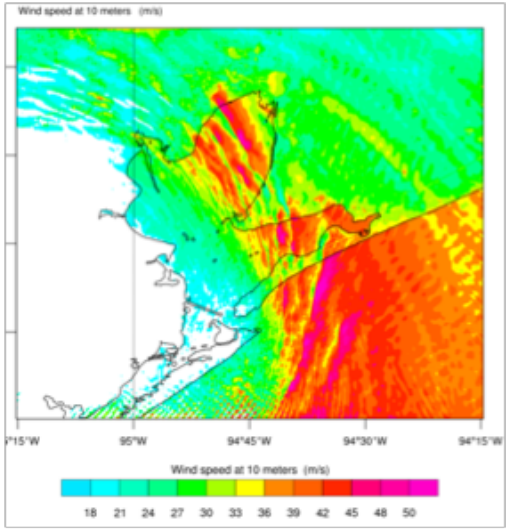
Updated Landuse In WPS

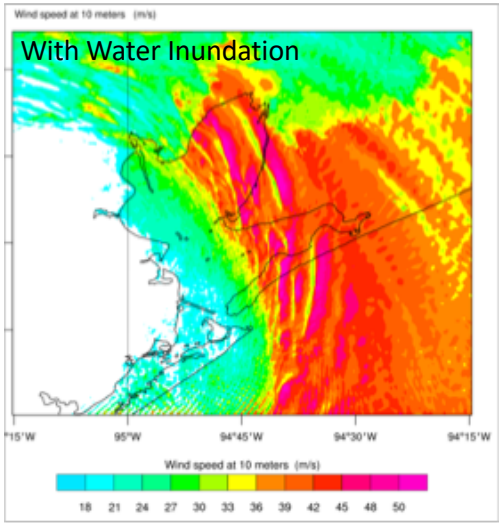
Terrain HGT



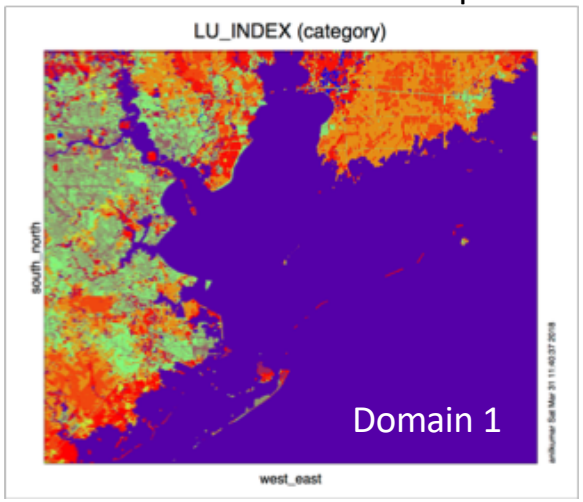


Domain 1 = 90 meter

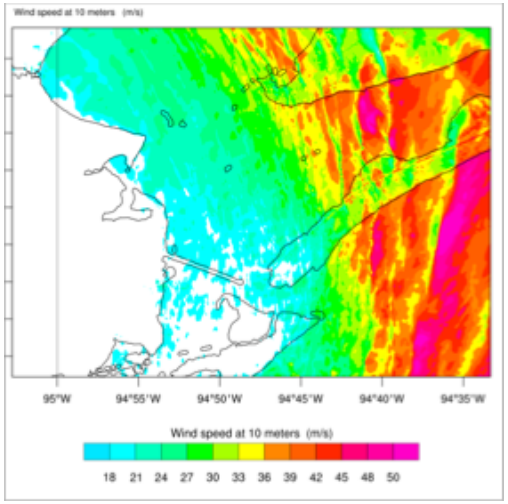


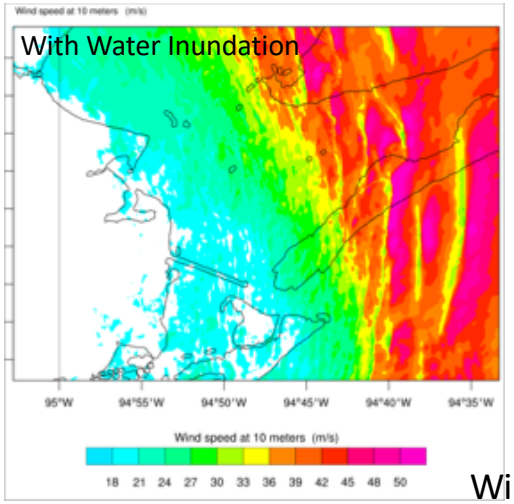


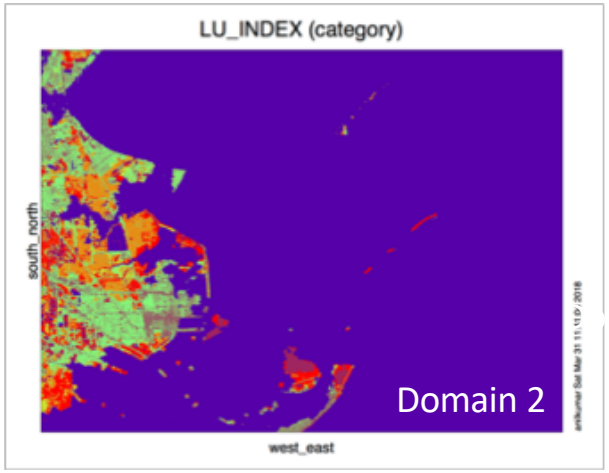
Water Inundation map



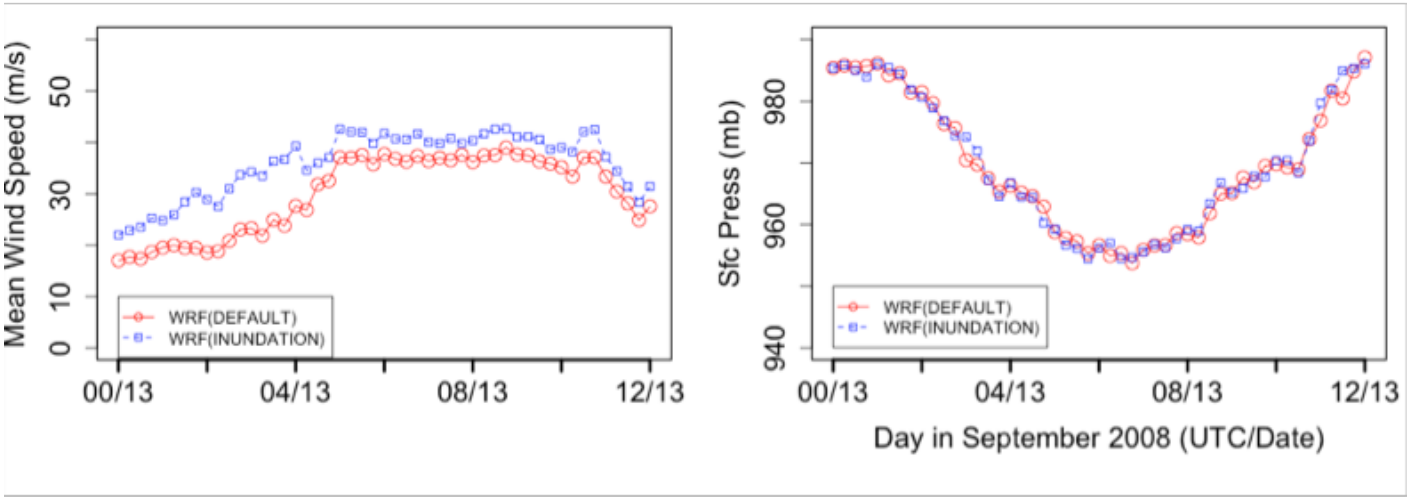
Domain 2 = 30 meter







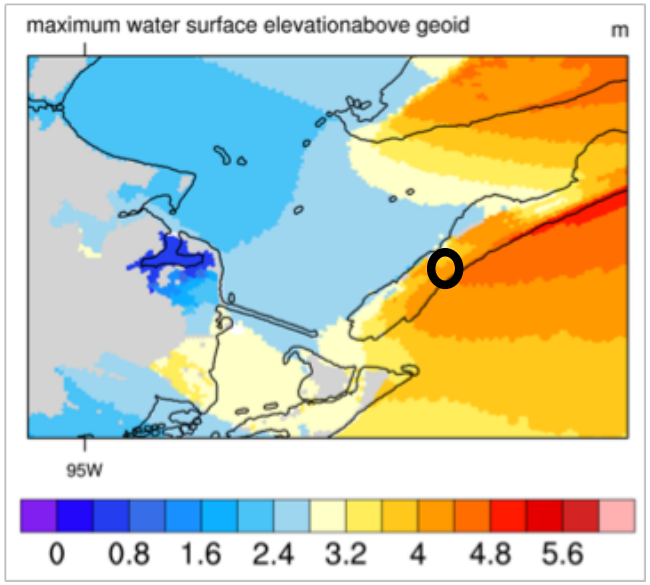
Wind Speed 10-meters (0800 UTC 13 Sep 2008)



No Observation at this location

5-10 m/s higher wind speed (at 10-meters) over inundation nearly 3 to 4 meters

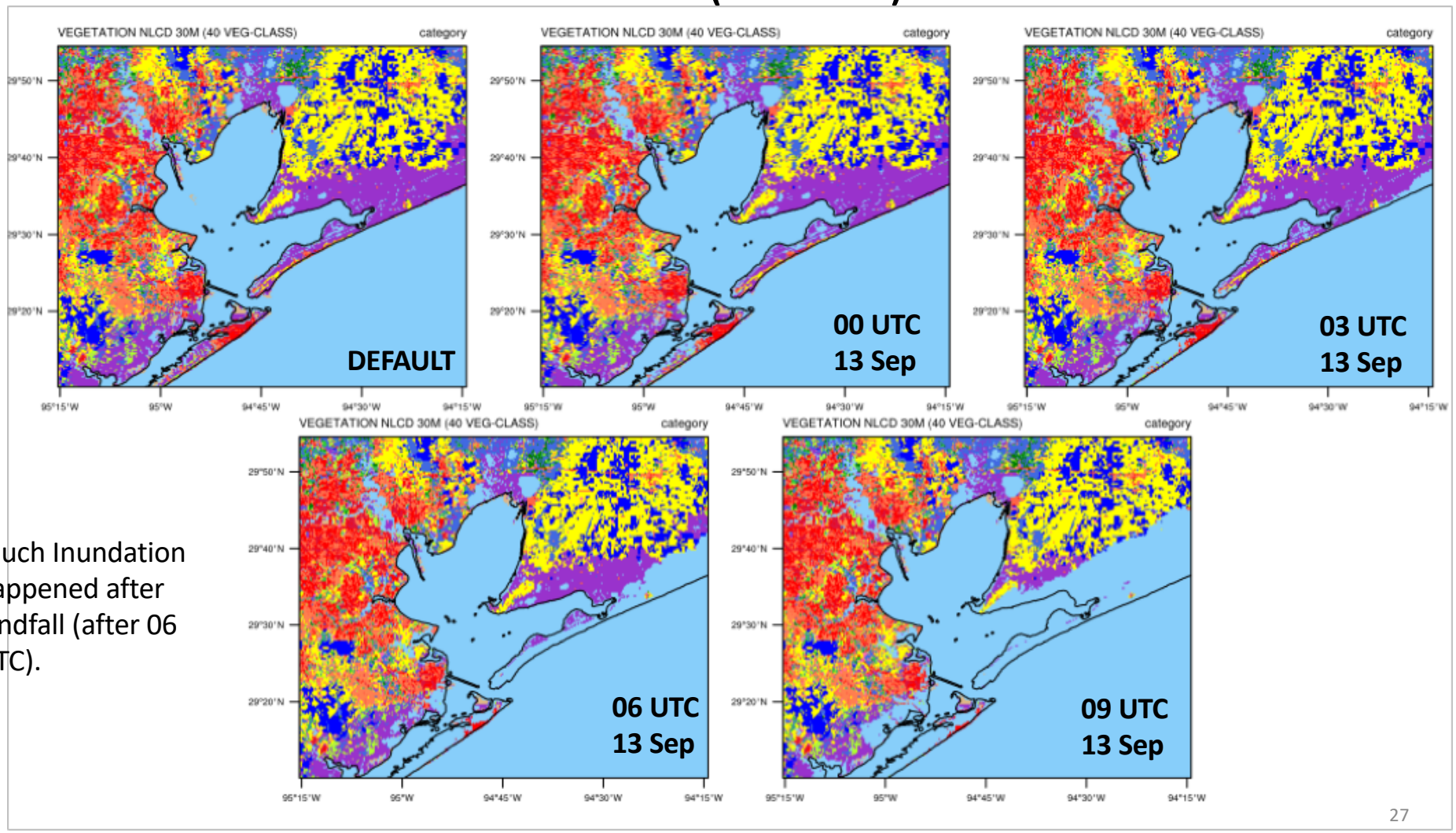
Time–dependent Inundation will be much more realistic to capture accurate near surface winds?



Time-Dependent Inundation

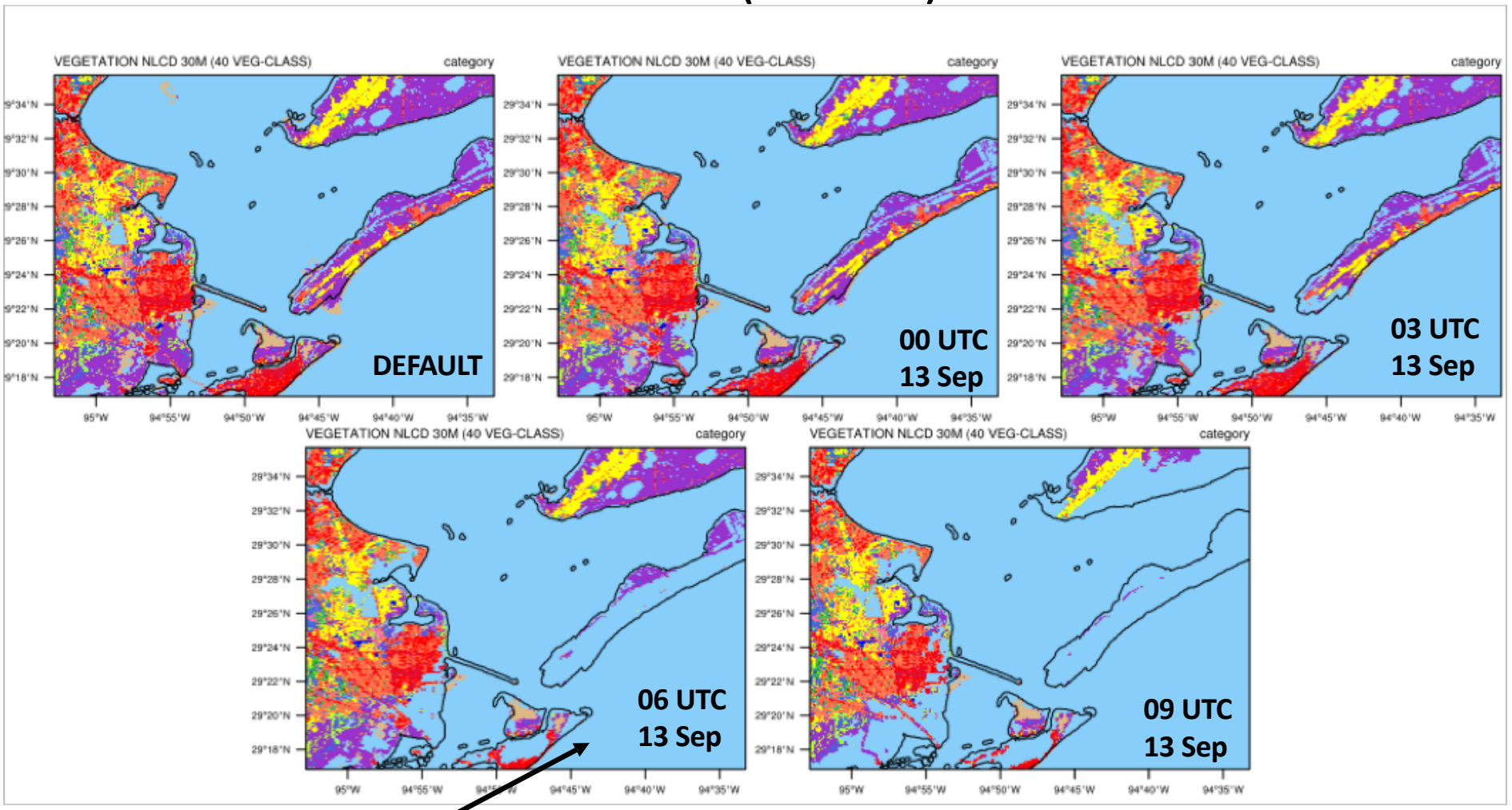
- One hourly Inundation from ADCRIC model
- Uses 3-hourly inundation information for Hurricane Ike case
- Changing landuse (LU_INDEX, vegetation type (IVGTYP) and soil type (ISLTYP))
- All these changes are made in wrfinput files and wrf-restart files.

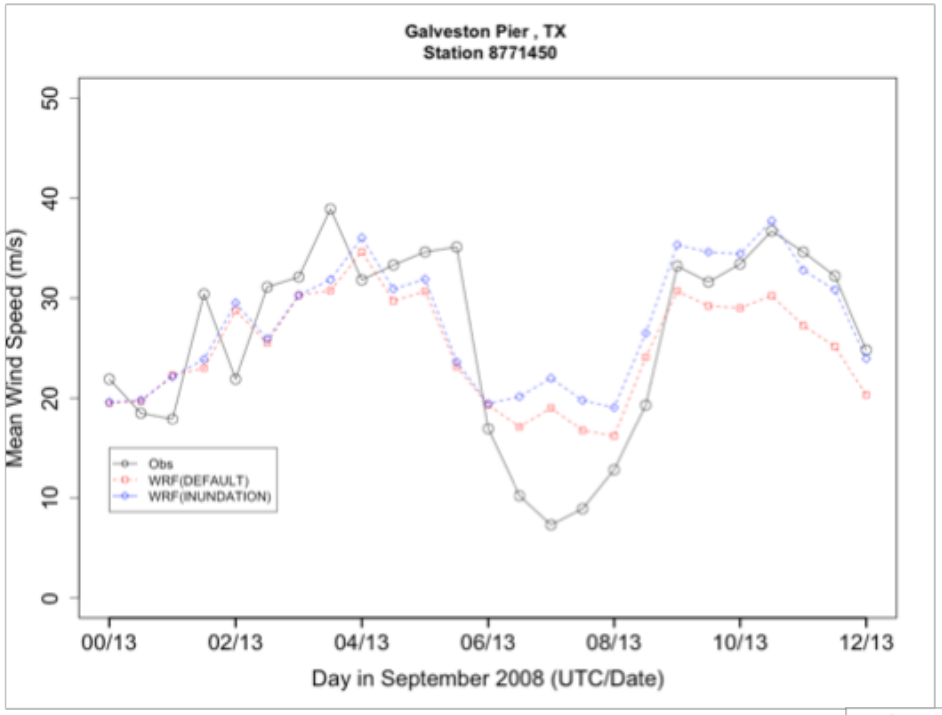
Domain 1 (90-meters)

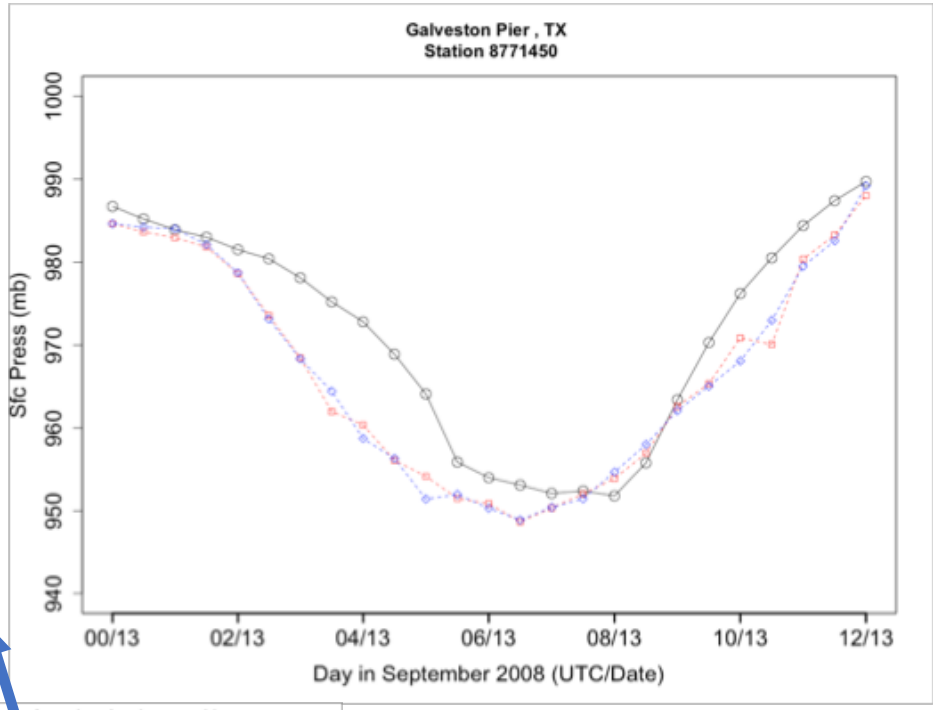


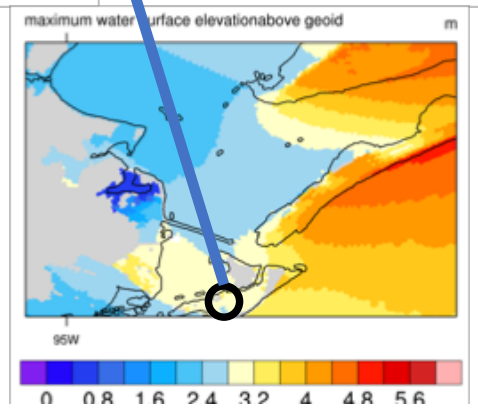
Much Inundation happened after landfall (after 06 UTC).

Domain 2 (30-meters)

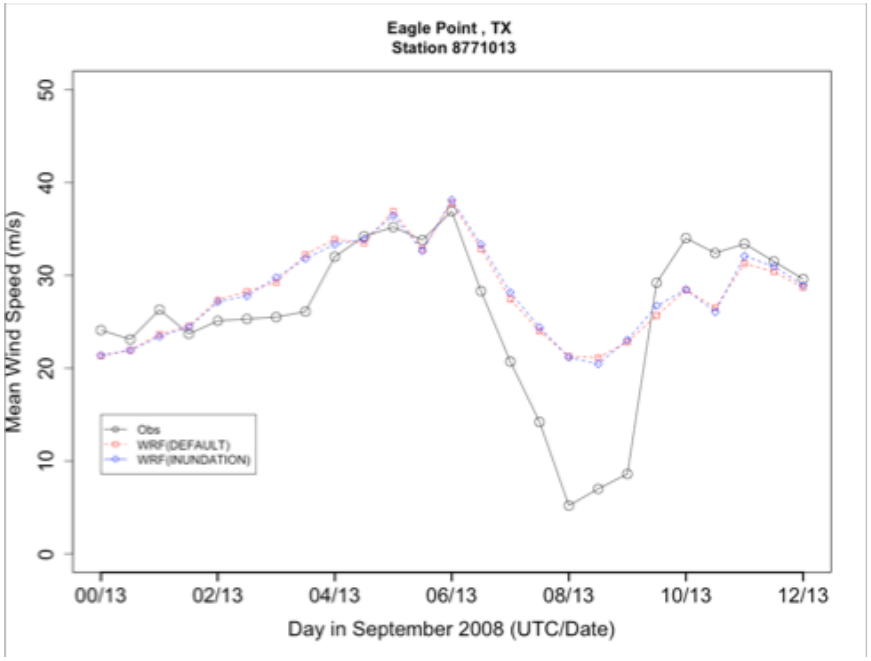


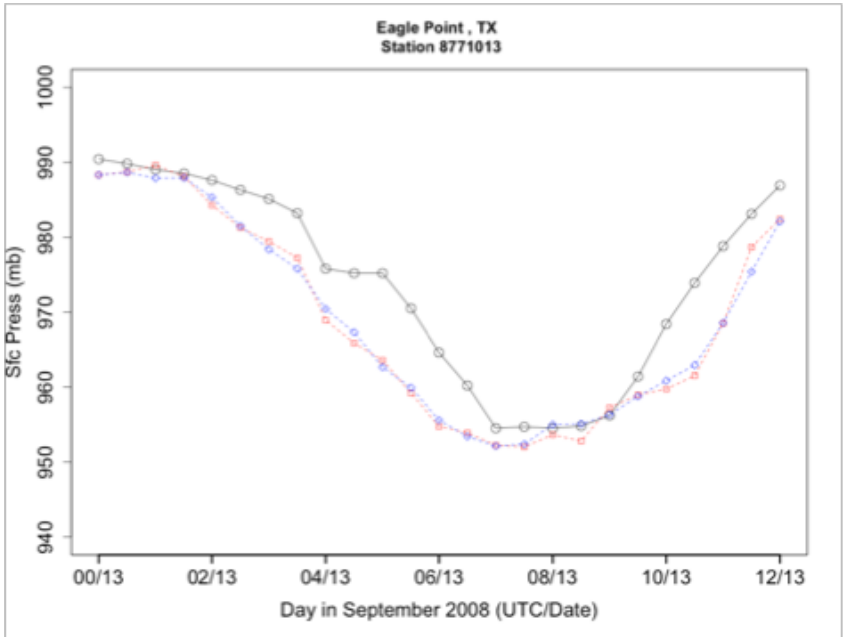


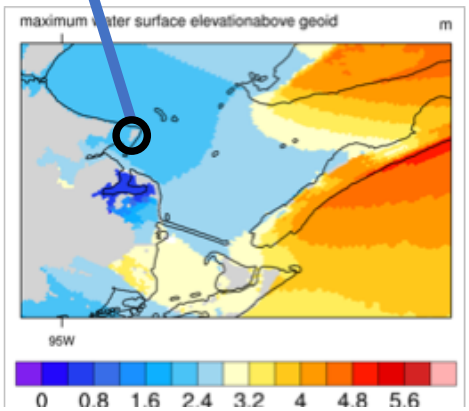




Galveston Pier TX station

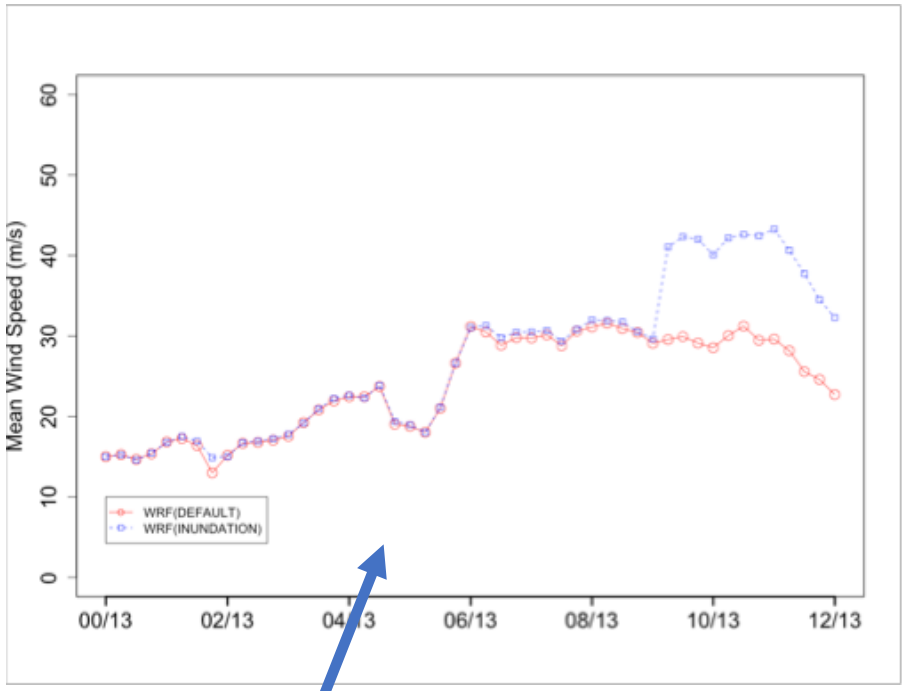


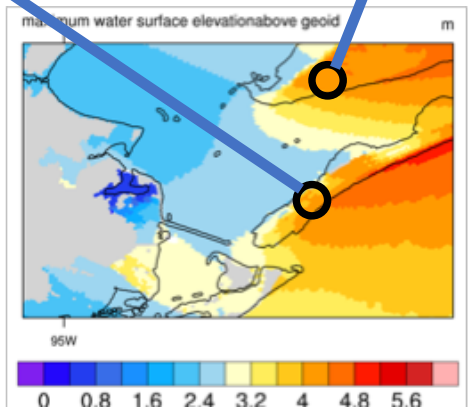




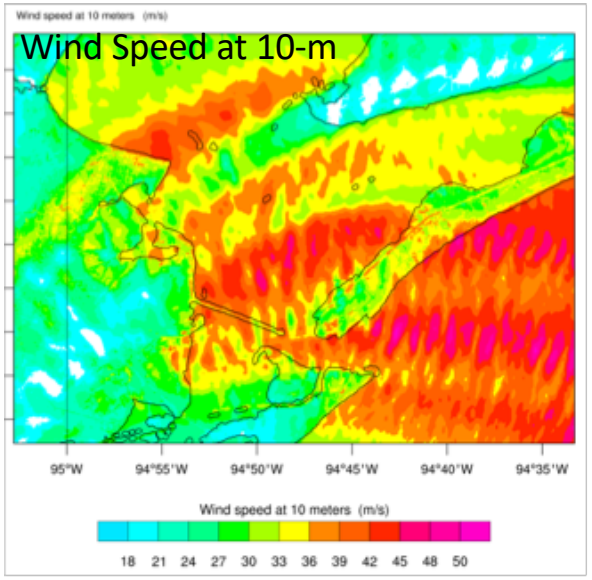
Eagle Point TX station

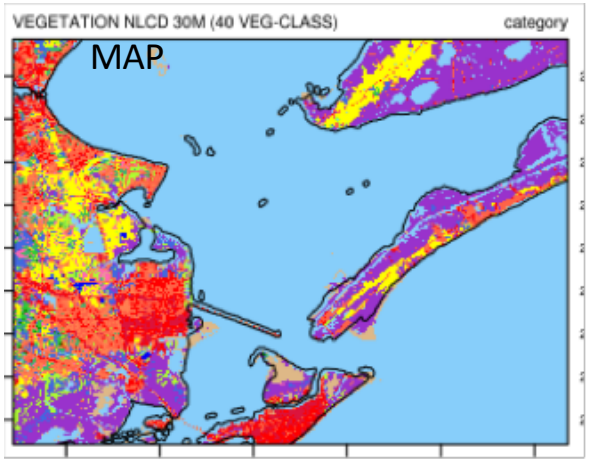

Mean Wind Speed (m/s)
0
10
20
30
40
50
60
00/13
02/13
04/13
06/13
08/13
10/13
12/13
WRF(DEFAULT)
WRF(INUNDATION)


Mean Wind Speed (m/s)
0
10
20
30
40
50
60
00/13
02/13
04/13
06/13
08/13
10/13
12/13
WRF(DEFAULT)
WRF(INUNDATION)

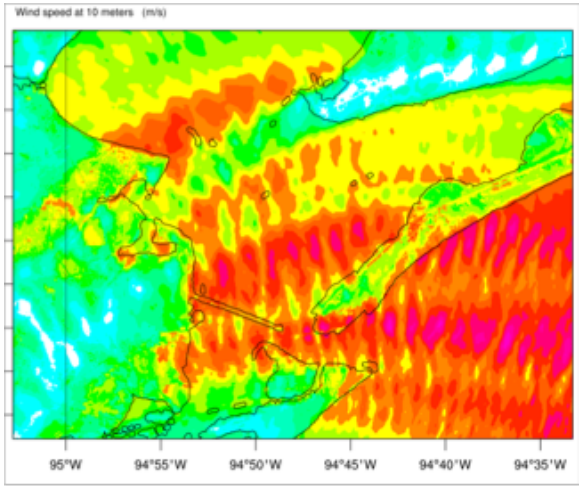

m
95W
0
0.8
1.6
2.4
3.2
4
4.8
5.6

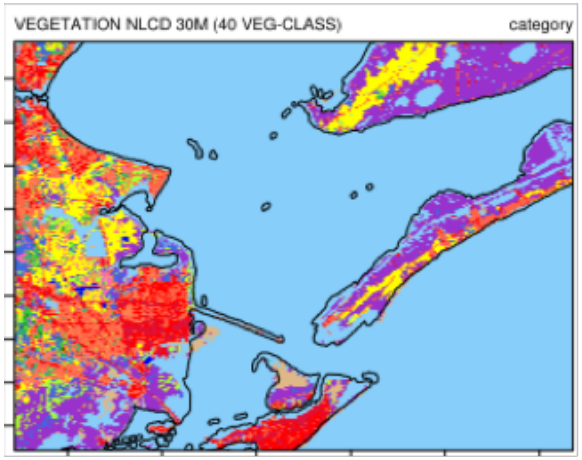
0500 UTC 13 Sep 2008 (Before landfall)





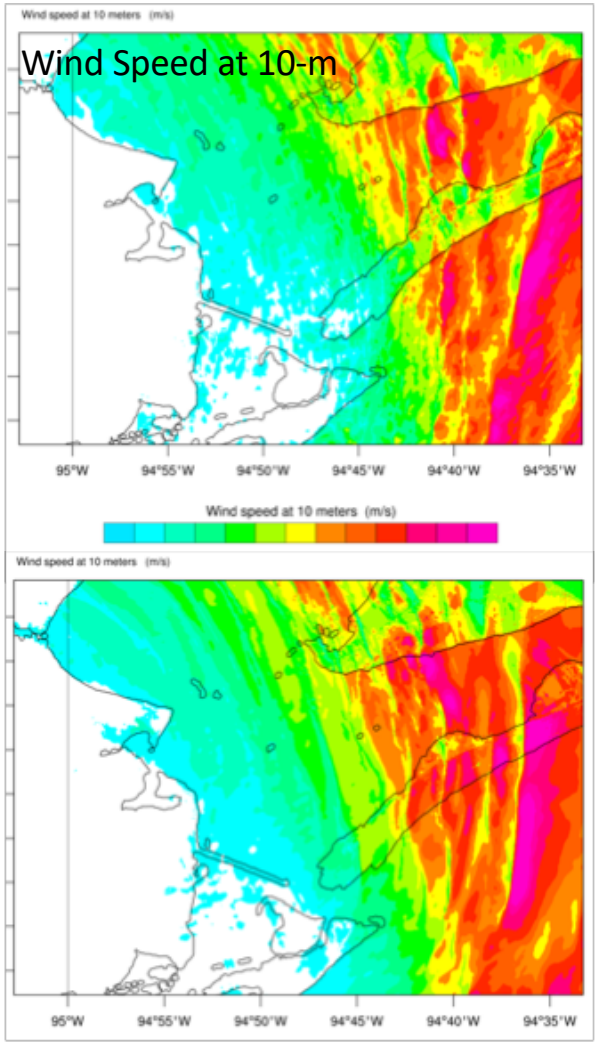
Default expt

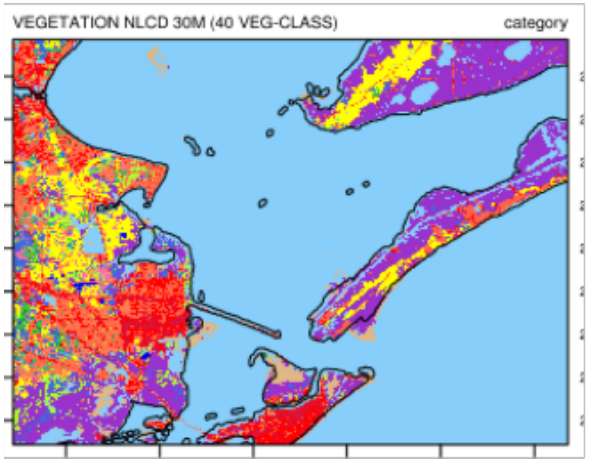




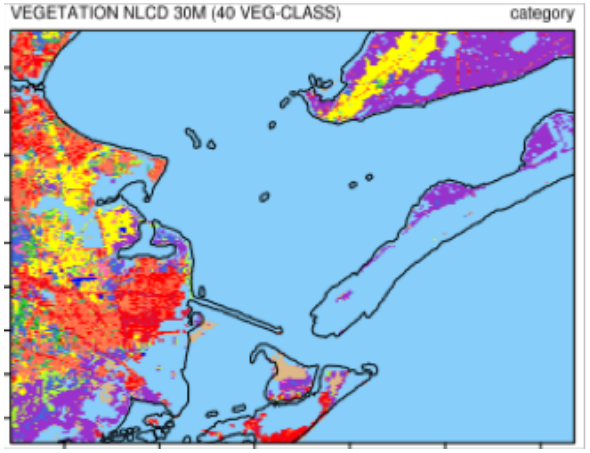
Inundation expt

0800 UTC 13 Sep 2008 (at landfall)





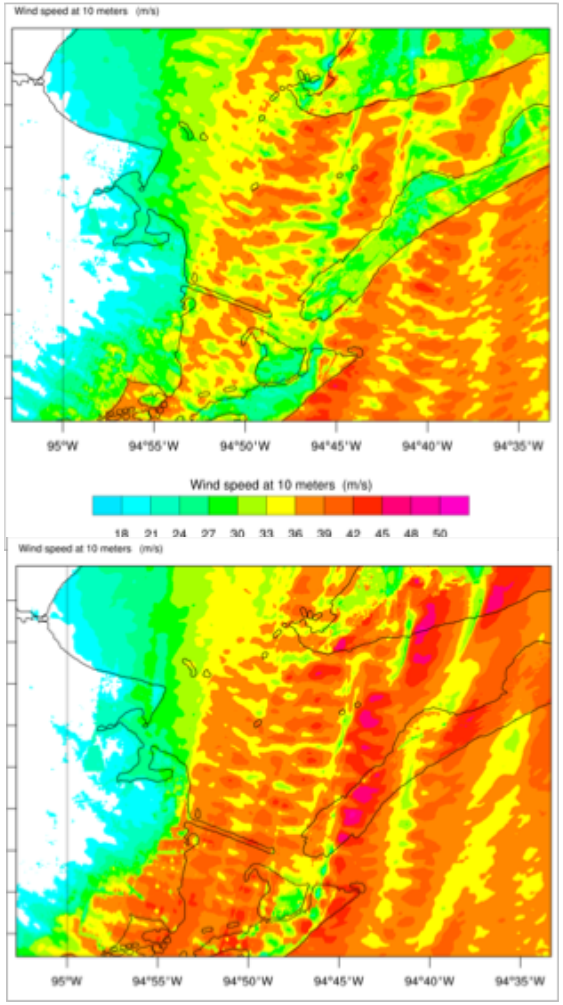
Default expt

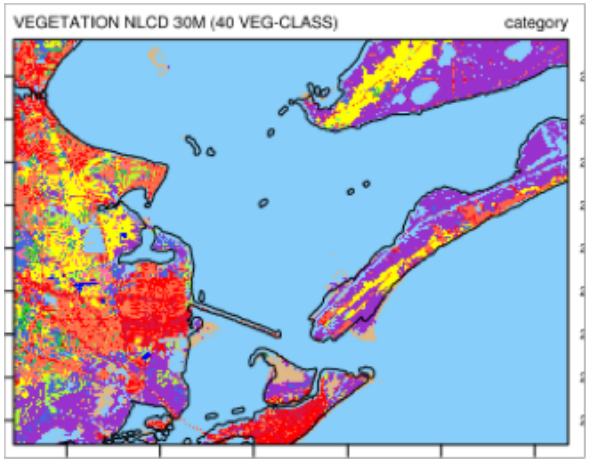


Inundation expt

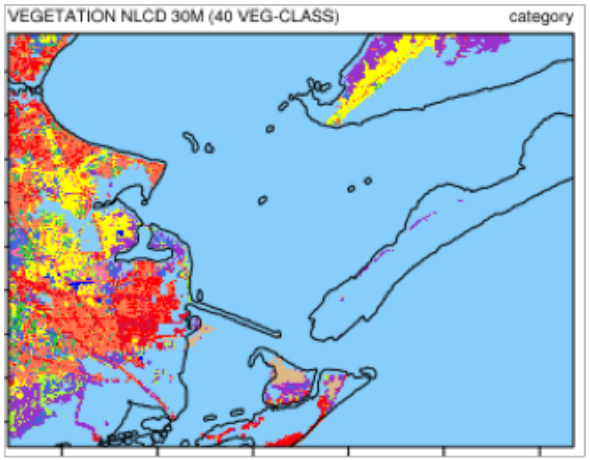
1000 UTC 13 Sep 2008 (after landfall)

Wind Speed at 10-m





Default expt



Inundation expt

FINAL POINTS

- Refine wind downscaling component if needed. (all hurricane cases needs to be completed, 2018-2019 year)
- Testing on next three hurricanes: Irma(2017), Sandy(2012), Michael (2018) – expect to see better results in recent storms (because of more observational data)
- Develop NSEM CONOPS (Concept of Operations) - HWRF, Wave/Surge, URMA, LES etc in some operational framework.
- Future Plans: Integration with national water model. (With NWM Team -Brian Cosgrove). NWM is complex model with lakes and rivers & WRF-LES is fine downscale atmospheric-land model.

THANK YOU!