HWRF Ocean: The Princeton Ocean Model (POM-TC)

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WRF for Hurricanes Tutorial
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What is the Princeton Ocean Model?

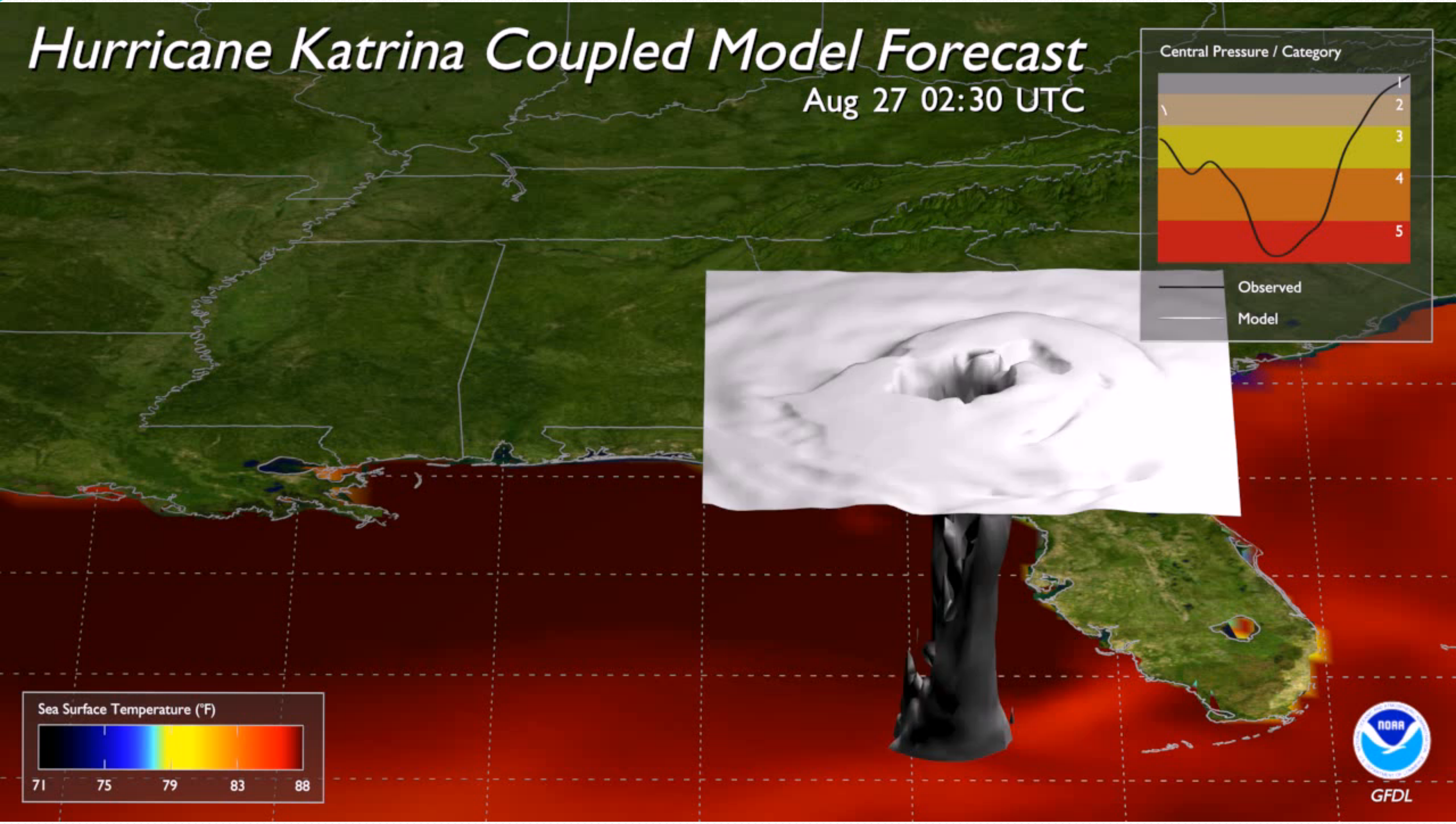
- Three-dimensional, primitive equation, numerical ocean model (commonly known as POM; Mellor 2004)
- Originally developed by Alan Blumberg and George Mellor in the late 1970's
- Initially used for coastal ocean circulation applications Open to the community during the 1990's and 2000's
- Many user-generated changes incorporated into "official" code version housed at Princeton University

Developing HWRF Ocean (POM-TC)

- Available POM code version transferred to University of Rhode Island (URI) in mid-1990's
- POM code changes made at URI specifically to address ocean response to hurricane wind forcing
- This POM version coupled to GFDL hurricane model at URI
- Coupled GFDL/POM model operational at NCEP in 2001
- Additional POM upgrades made at URI during 2000's (e.g. initialization) and implemented in operational GFDL/POM
- Same version of POM coupled to operational HWRF in 2007
- This POM version is now designated "POM-TC"
- Some further POM-TC upgrades made at URI since 2007

Why Couple POM-TC to HWRF?

- To create accurate SST field for input into the HWRF
- Evaporation (moisture flux) from sea surface provides heat energy to drive a hurricane
- Available energy decreases if storm-core SST decreases
- Uncoupled hurricane models with static SST neglect SST cooling during integration → high intensity bias
- One-dimensional (vertical-only) ocean models neglect upwelling and horizontal advection, both of which can impact SST during integration (e.g. Yablonsky and Ginis 2009, 2013, Monthly Weather Review)



Hurricane Katrina Coupled Model Forecast
Aug 27 02:30 UTC
Central Pressure / Category
1
2
3
4
5
Observed
Model
Sea Surface Temperature (°F)
71
75
79
83
88
GFDL

Physics of Storm-Core SST Change

1) Vertical mixing/entrainment (Slide 7)

2) Upwelling (Slide 8)

3) Horizontal advection (Slide 9)

4) Heat flux to the atmosphere (small by comparison)

1) Vertical mixing/entrainment

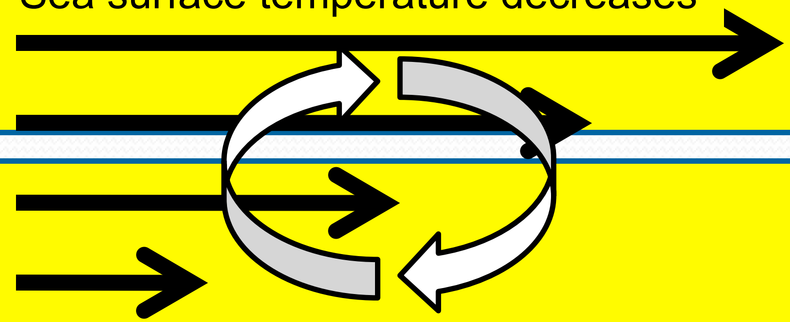
Wind stress → surface layer currents

Current shear → turbulence

Turbulent mixing → entrainment of cooler water

POM-TC uses the Mellor-Yamada 2.5 turbulence closure submodel to parameterize vertical mixing

Sea surface temperature decreases



Subsurface temperature increases

This is a 1-D (vertical) process

ATMOSPHERE

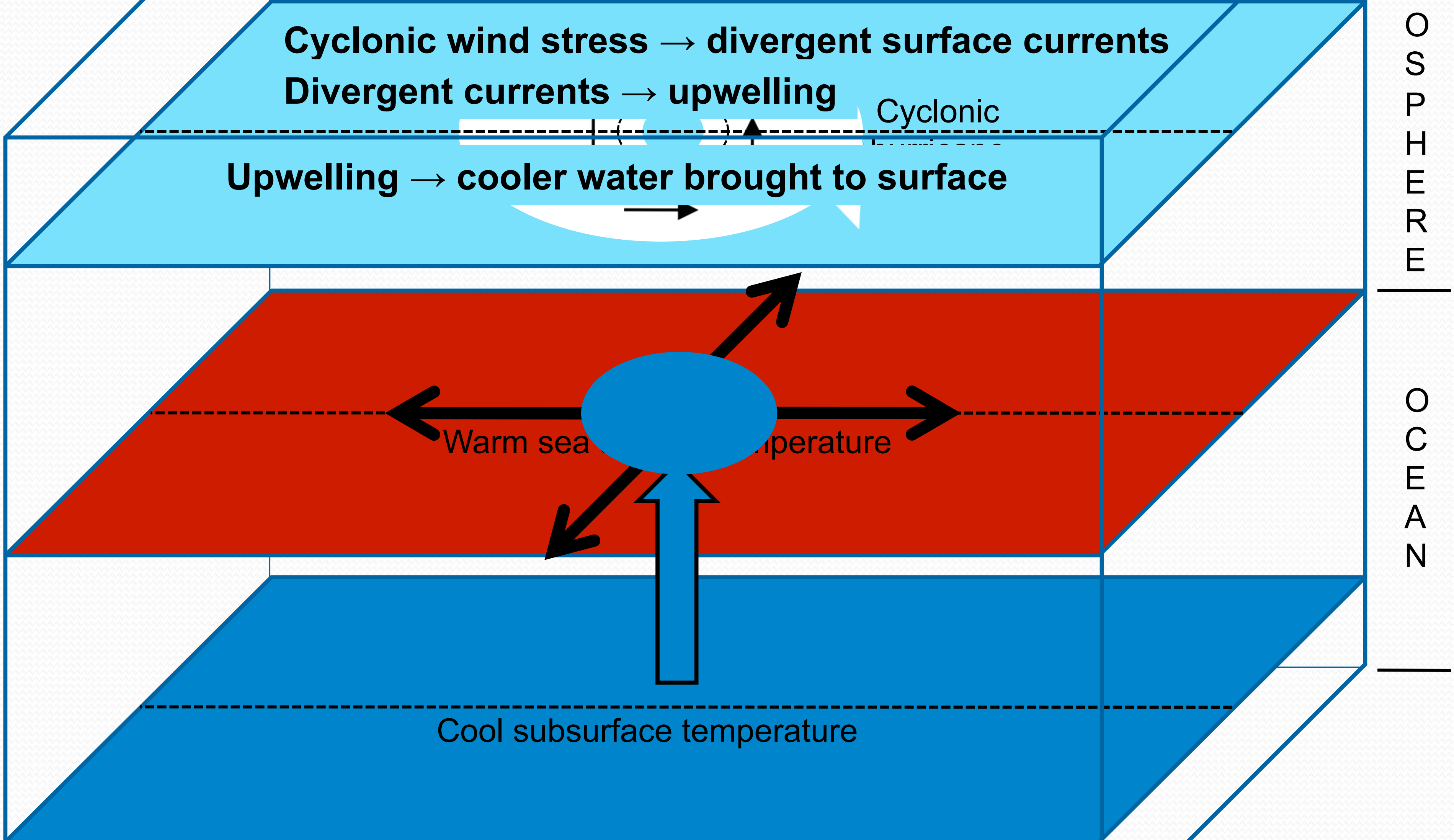
OCEAN

2) Upwelling

Cyclonic wind stress → divergent surface currents

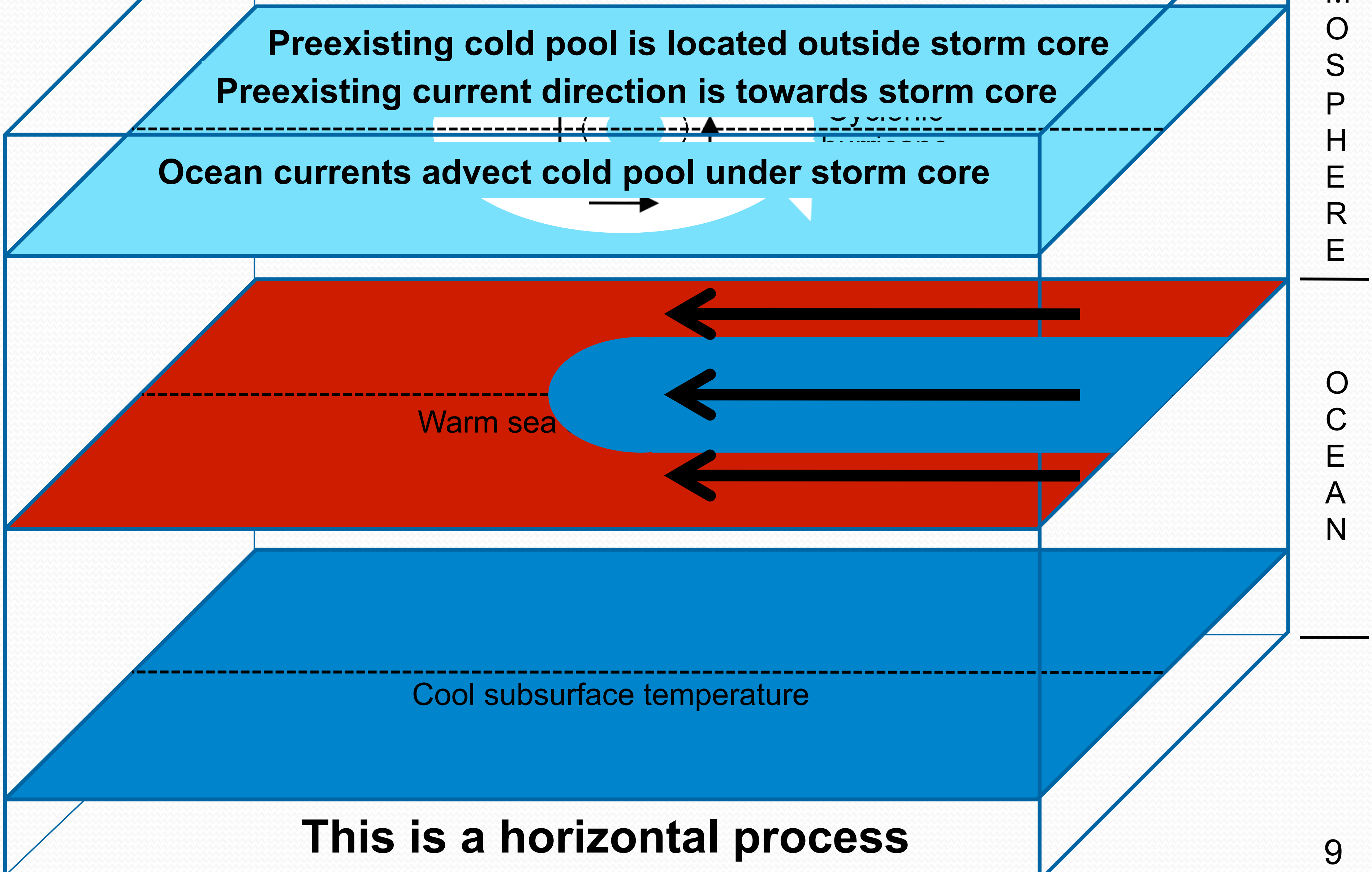
Divergent currents → upwelling

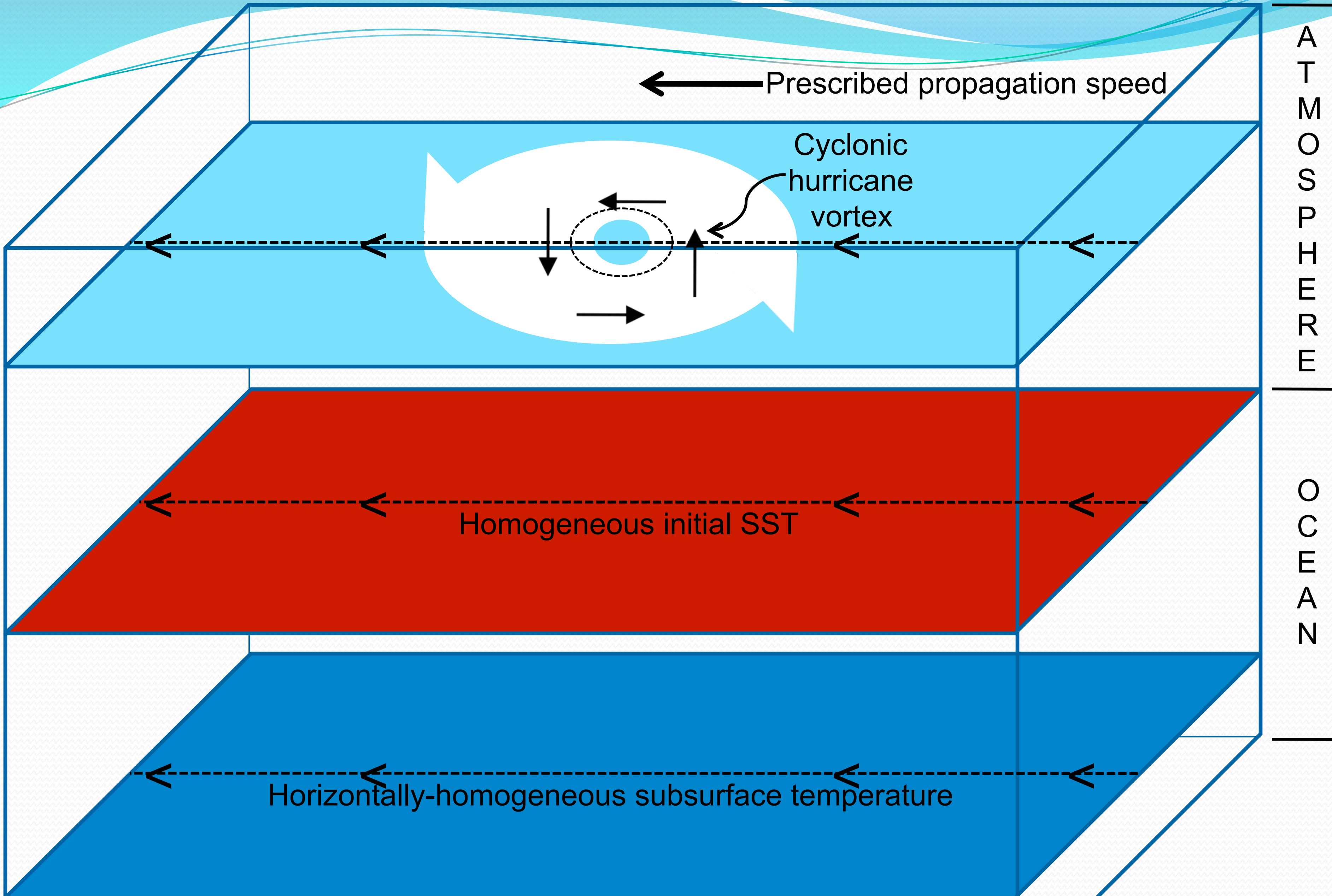
Upwelling → cooler water brought to surface



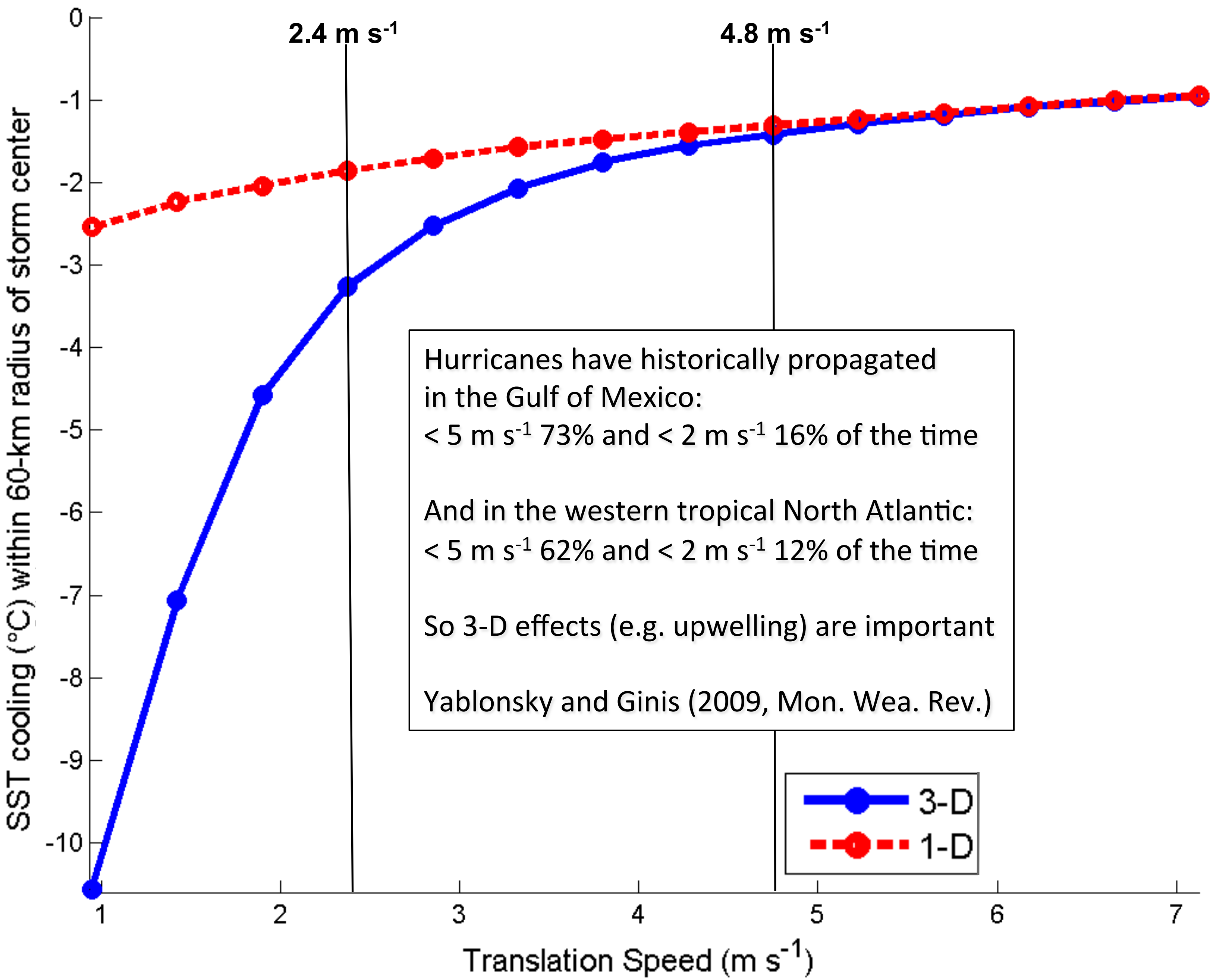
This is a 3-D process

3) Horizontal advection

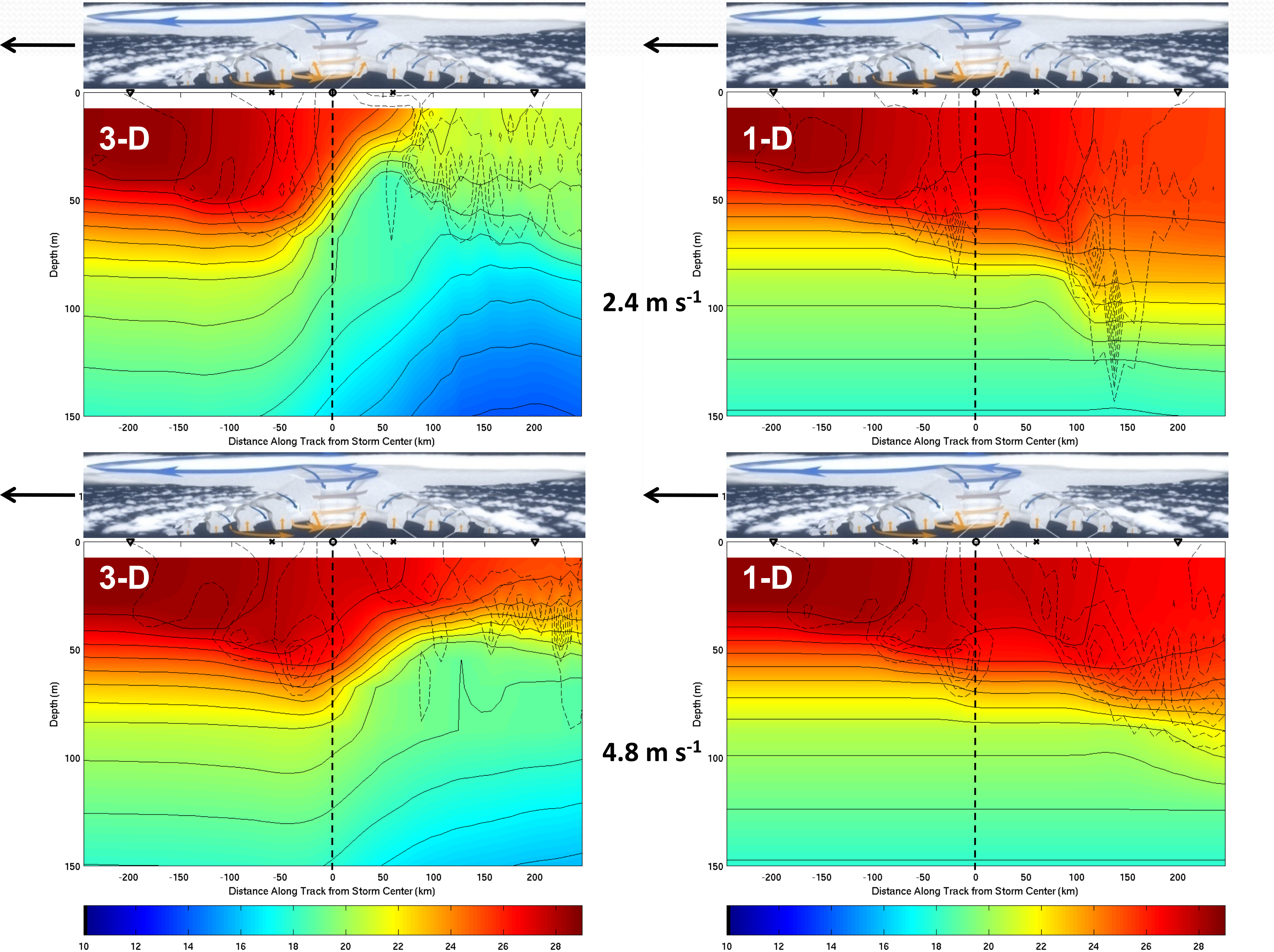




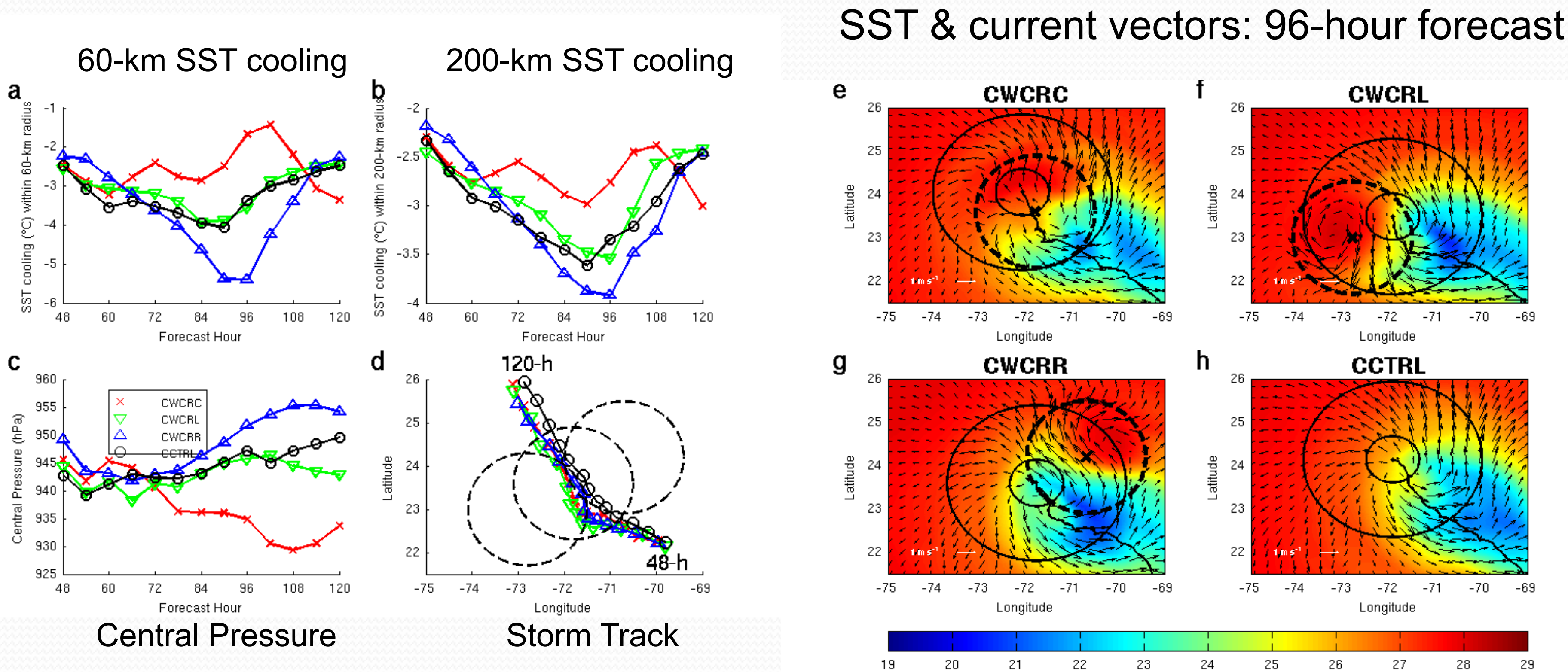
What is the impact of varying storm translation speed?



2.4 m s-1
4.8 m s-1
Hurricanes have historically propagated in the Gulf of Mexico:
< 5 m s-1 73% and < 2 m s-1 16% of the time
And in the western tropical North Atlantic:
< 5 m s-1 62% and < 2 m s-1 12% of the time
So 3-D effects (e.g. upwelling) are important
Yablonsky and Ginis (2009, Mon. Wea. Rev.)
3-D
1-D
SST cooling (°C) within 60-km radius of storm center
Translation Speed (m s-1)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
1
2
3
4
5
6
7

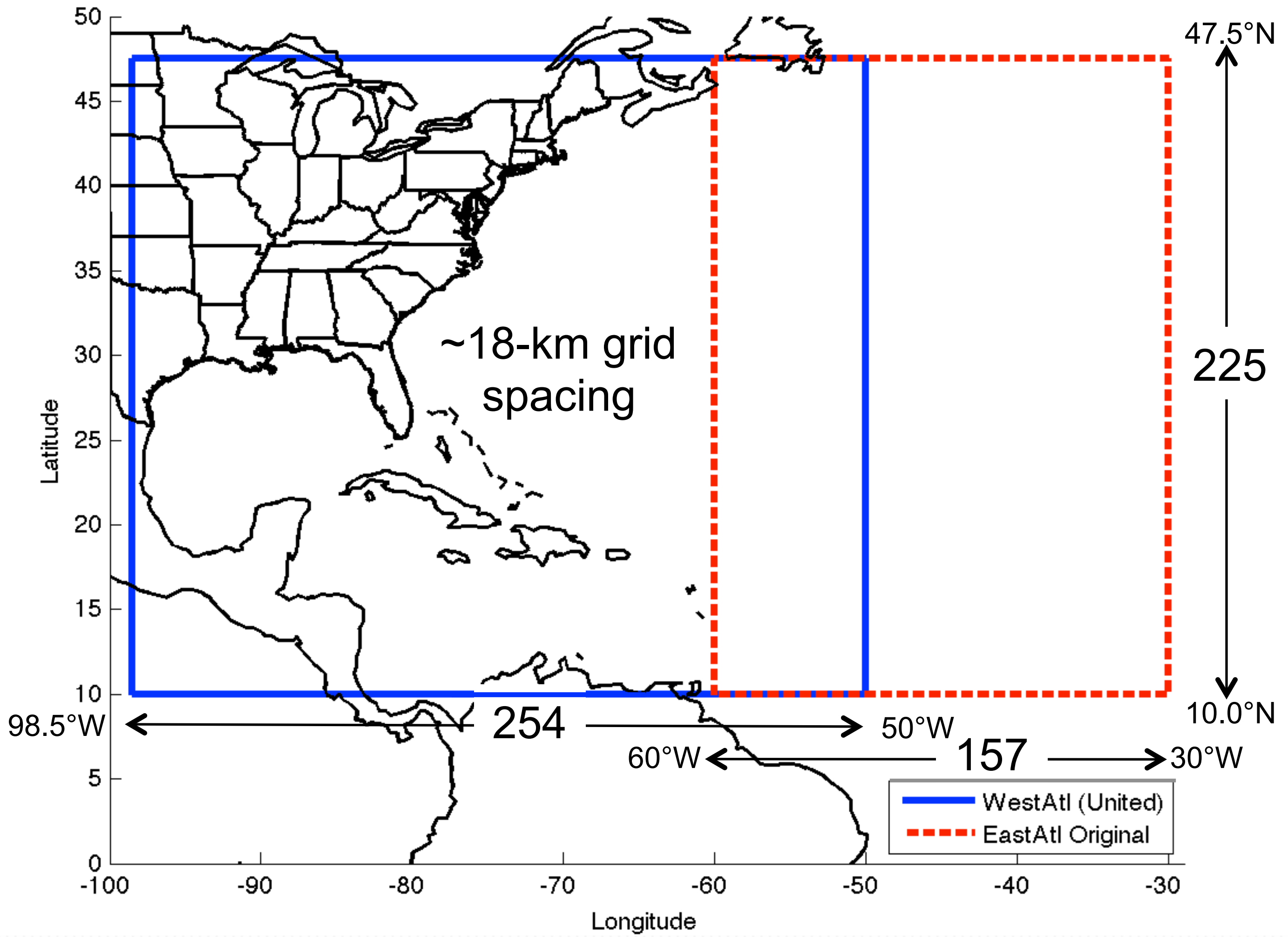

3-D
1-D
3-D
1-D
2.4 m s-1
4.8 m s-1
Depth (m)
Distance Along Track from Storm Center (km)
0
50
100
150
-200
-150
-100
-50
0
50
100
150
200
10
12
14
16
18
20
22
24
26
28

Impact of Horizontal Advection: Example with a Warm Ocean Eddy

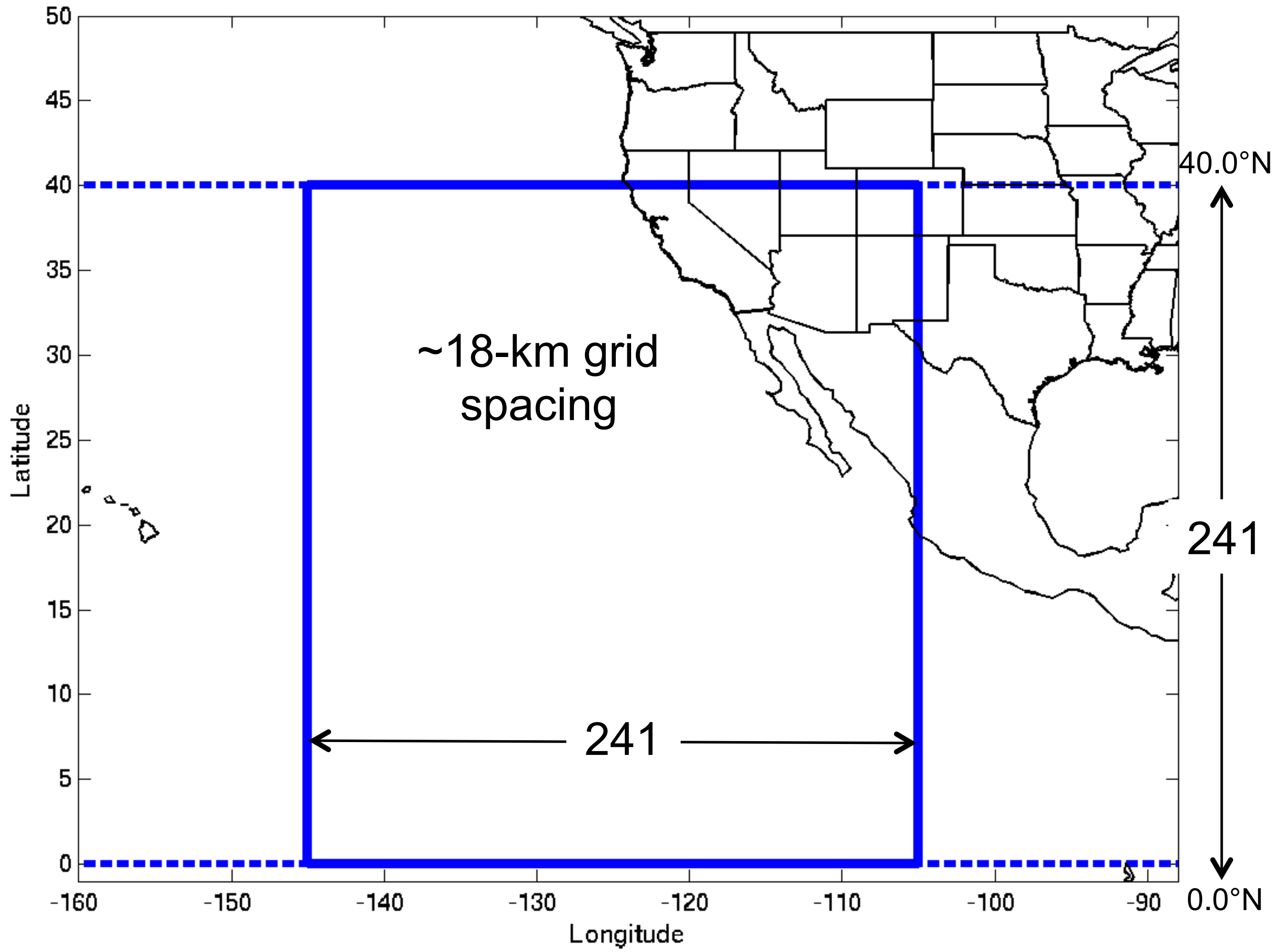


Yablonsky and Ginis (2013, Mon. Wea. Rev.)

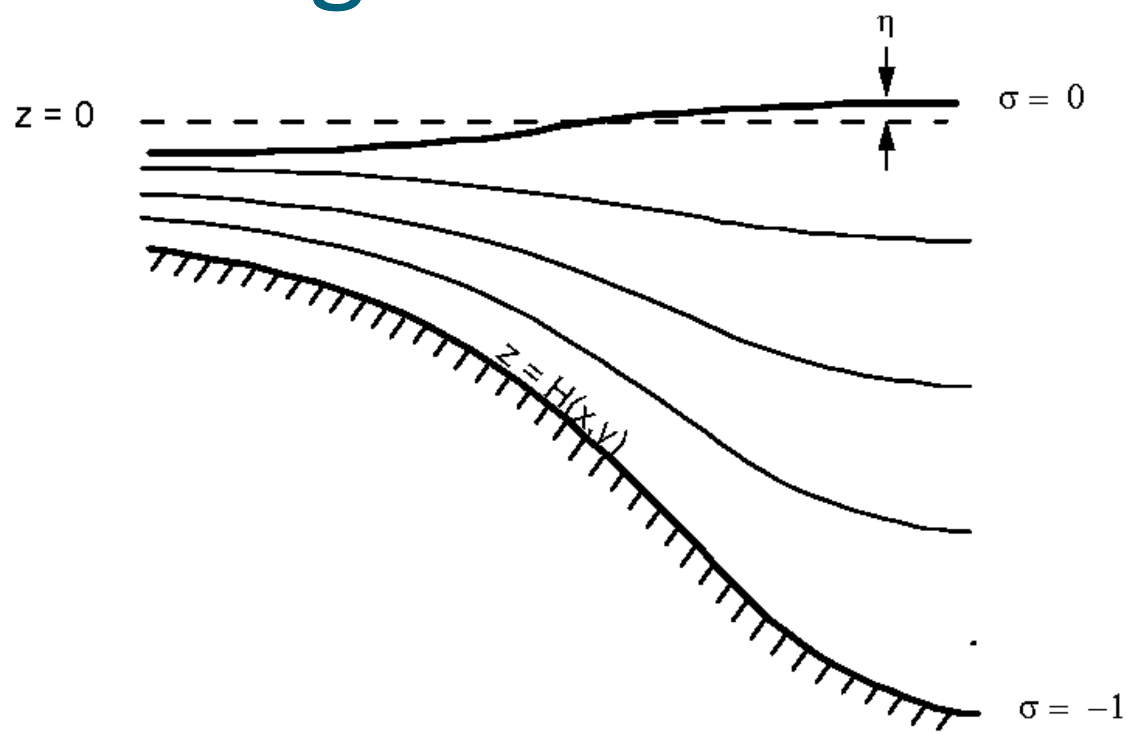
POM-TC Atlantic Domains: "United" and "East Atlantic"



POM-TC 1D E-W Relocatable "East Pacific" Domain

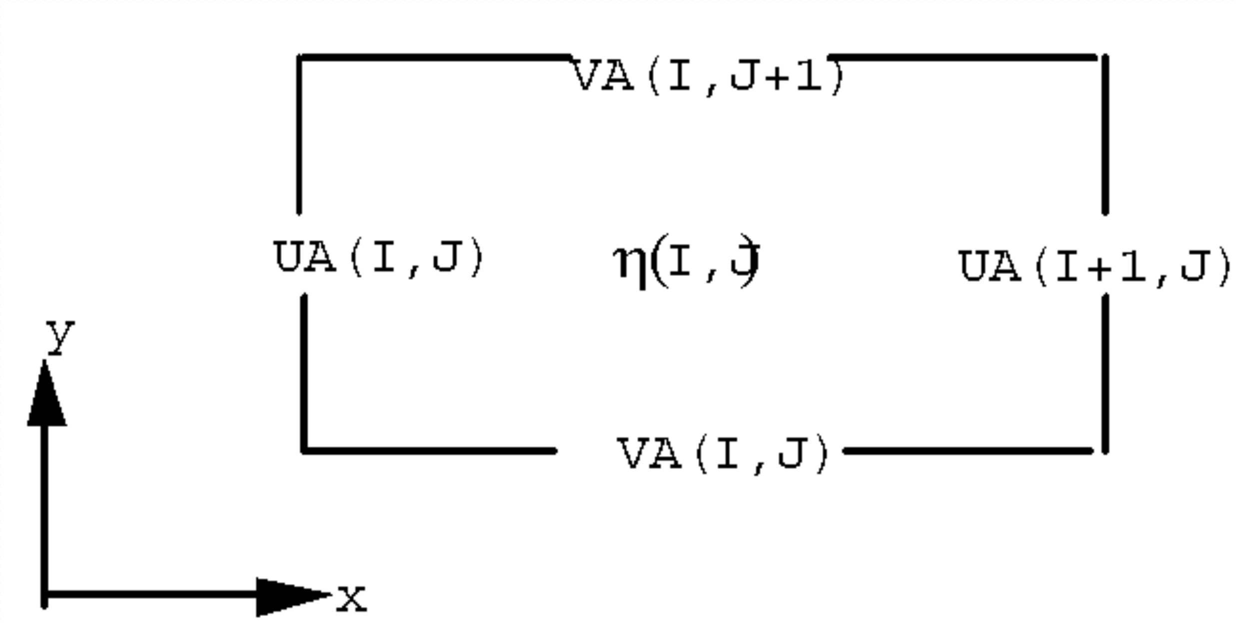


POM-TC Sigma Vertical Coordinate



- 23 vertical sigma levels; free surface (η)
- Level placement scaled based on ocean bathymetry
- Largest vertical spacing occurs where ocean depth is 5500 m
- Location of 23 half-sigma levels when ocean depth is 5500 m:
  5, 15, 25, 35, 45, 55, 65, 77.5, 92.5, 110, 135, 175, 250, 375, 550, 775, 1100, 1550, 2100, 2800, 3700, 4850, and 5500 m

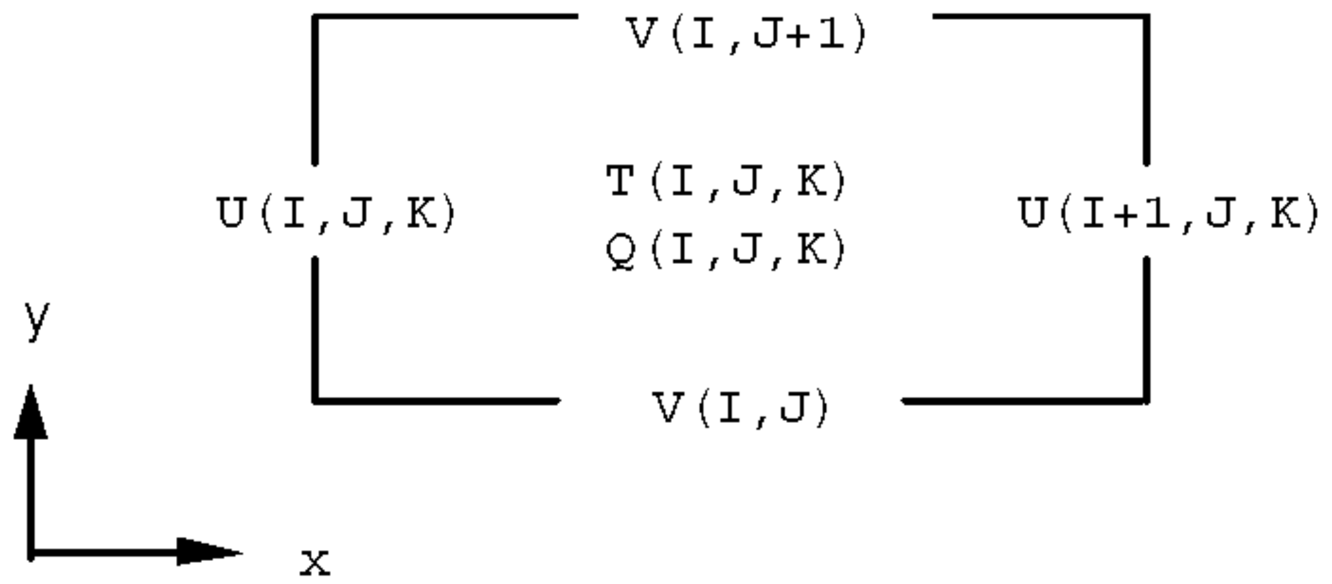
Arakawa-C Grid: External Mode



Plan View

- Horizontal spatial differencing occurs on staggered Arakawa-C grid
- 2-D variables "UA" and "VA" are calculated at shifted location from "η"

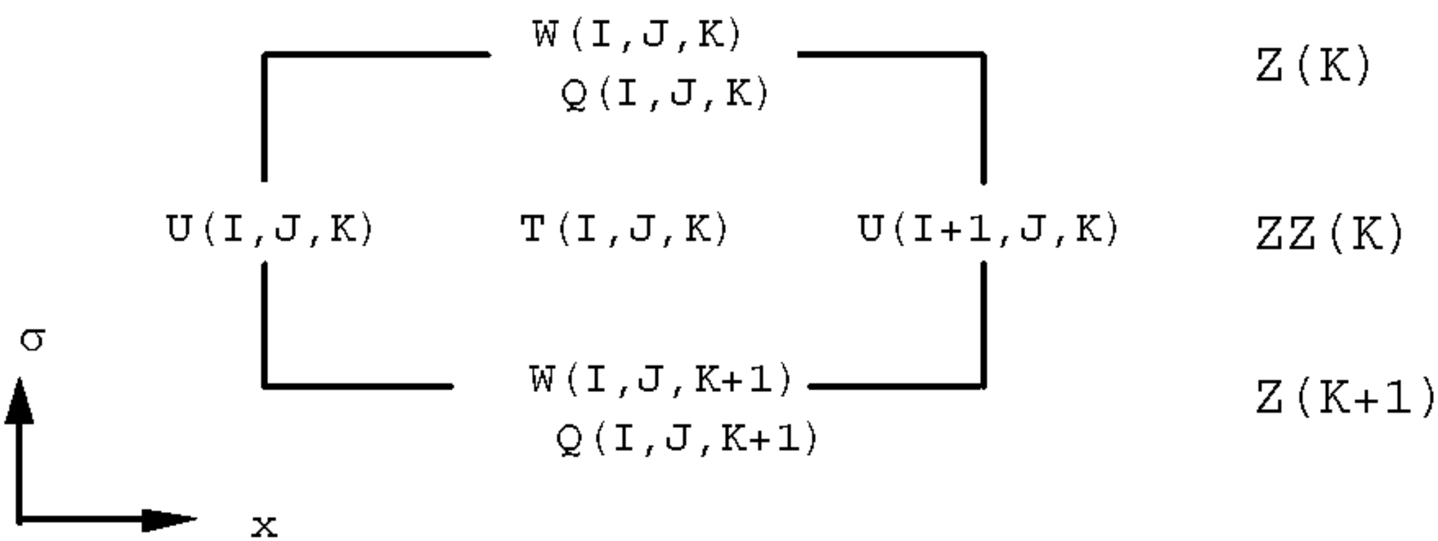
Arakawa-C Grid: Internal Mode



Plan View

- Horizontal spatial differencing occurs on staggered Arakawa-C grid
- 3-D variables "U" and "V" are calculated at shifted location from "T" and "Q"
- "T" here represents variables "T", "S", and "RHO"
- "Q" here represents variables "Km", "Kh", "Q2", and "Q2l"

Vertical Grid: Internal Mode



Elevation View

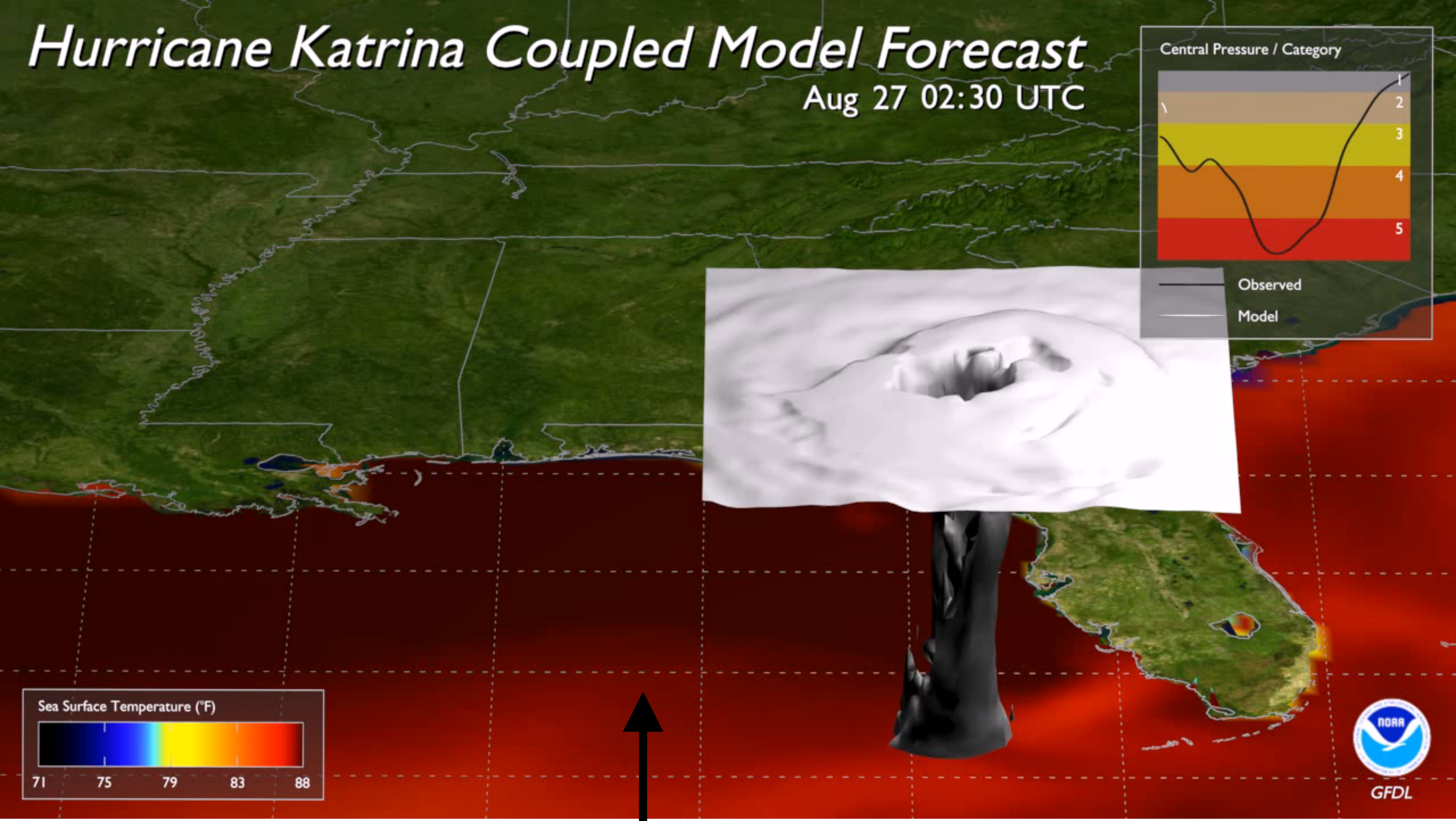
- Vertical spatial differencing also occurs on staggered grid
- 3-D variables "W" and "Q" are calculated at shifted depth from "T" and "U"
- "T" here represents variables "T", "S", and "RHO"
- "Q" here represents variables "Km", "Kh", "Q2", and "Q2l"

Time Stepping

- POM-TC has a split time step
- External (two-dimensional) mode uses short time step:
  - 22.5 seconds during pre-coupled POM-TC initialization
  - 13.5 seconds during coupled POM-TC integration
- Internal (three-dimensional) mode uses long time step:
  - 15 minutes during pre-coupled POM-TC initialization
  - 9 minutes during coupled POM-TC integration
- Horizontal time differencing is explicit
- Vertical time differencing is implicit

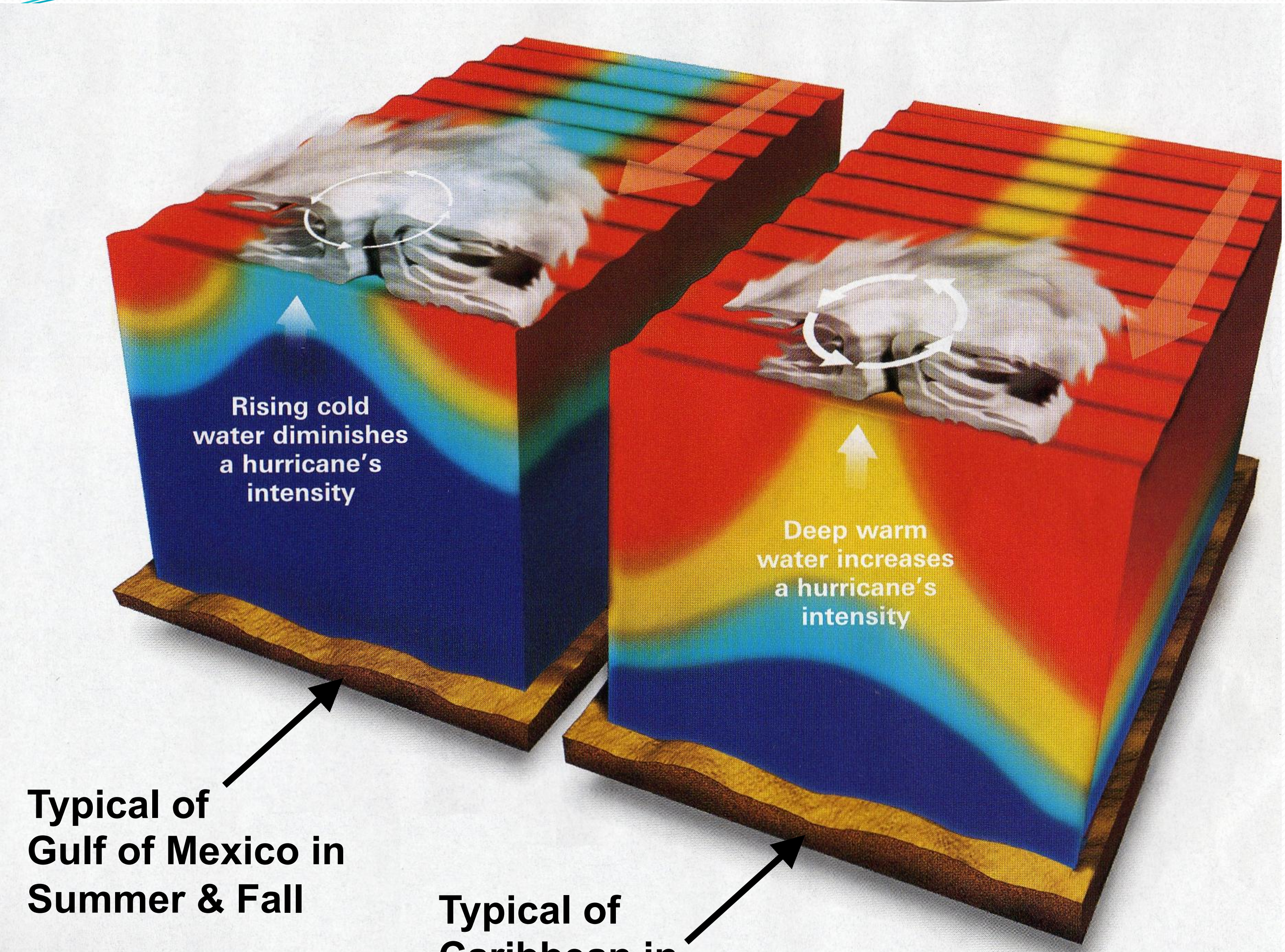
POM-TC initialization

- Prior to coupled model integration of HWRF/POM-TC, POM-TC must be initialized with a realistic, 3-D temperature (T) and salinity (S) field
- This T & S field must then be used to generate realistic ocean currents via geostrophic adjustment
- The "spun-up" ocean must then incorporate the preexisting hurricane-generated cold wake by applying TC's wind stress using the NHC hurricane message file



Why is the cold wake "not as cold" here?

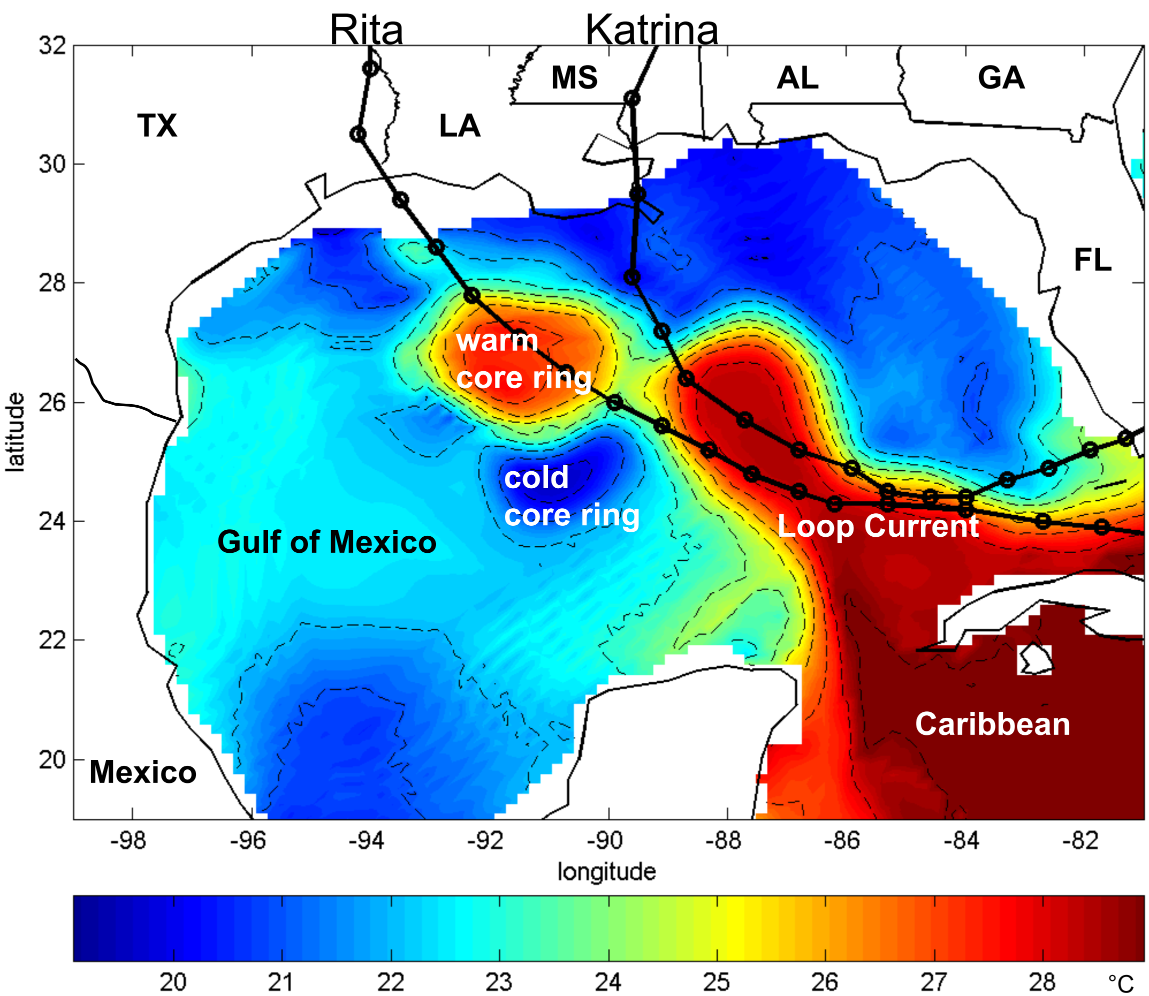
Answer: We must look **under** the ocean surface!



Typical of Gulf of Mexico in Summer & Fall

Typical of Caribbean in Summer & Fall

Approximate Locations of Oceanic Features During Hurricanes Katrina and Rita (2005)



Subsurface (75-m) ocean temperature during Katrina & Rita

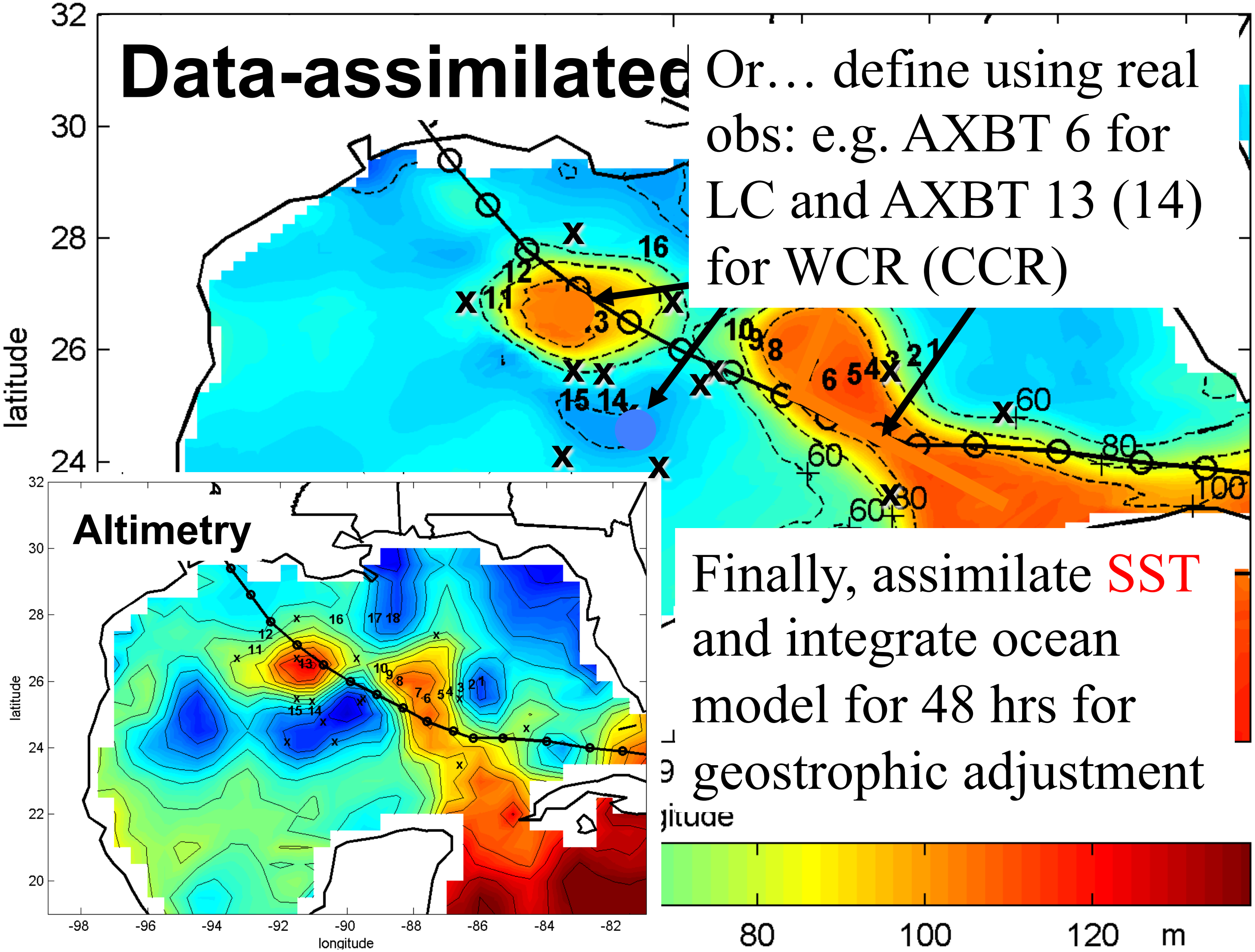
Warm Loop Current water and a warm core ring extend far into the Gulf of Mexico from the Caribbean…

Directly under Rita's & Katrina's track…

But… how do we know the locations of (& how do we assimilate) these features in real-time?

Feature-based modeling in POM-TC

Yablonsky and Ginis (2008, Mon. Wea. Rev.)



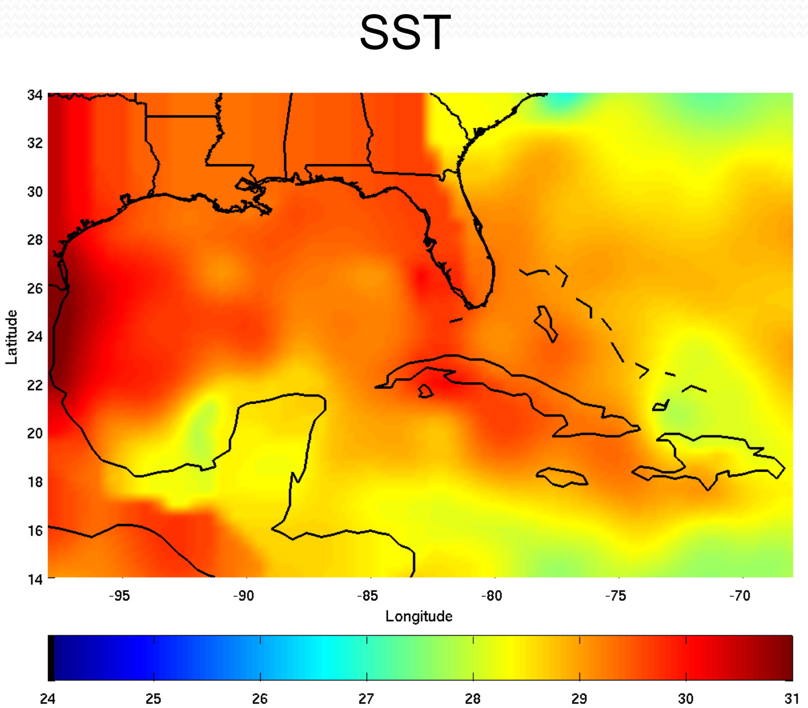
Or… define using real obs: e.g. AXBT 6 for LC and AXBT 13 (14) for WCR (CCR)

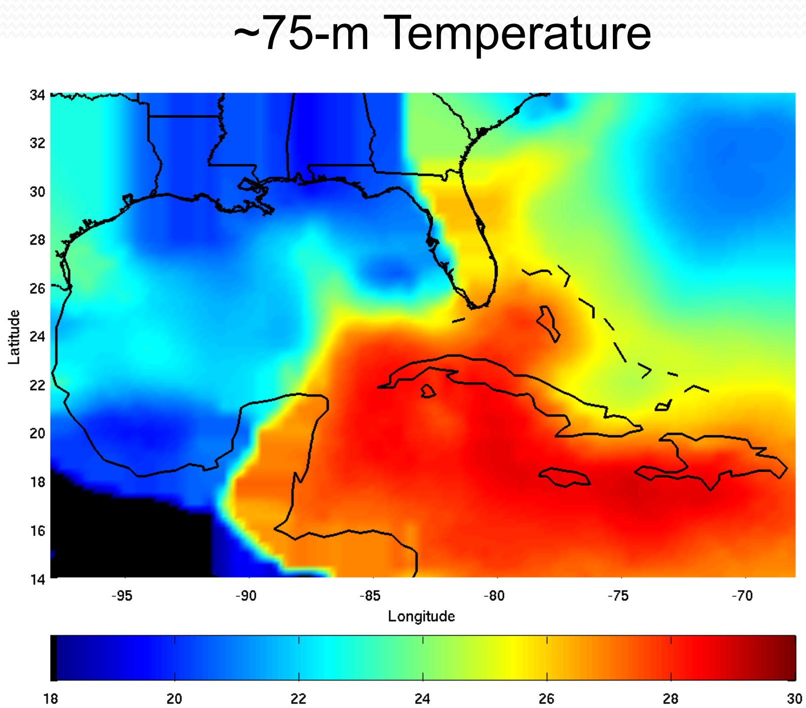
Finally, assimilate SST and integrate ocean model for 48 hrs for geostrophic adjustment

- Start with GDEM T/S
- Look at altimetry/obs
- Define LC & ring positions
- Use Caribbean water along LC axis & in WCR center
- Make CCR center colder than environ.
- Blend features w/ env. & sharpen fronts

Gustav 2008082800 Example: Ocean Initialization & Response (Next 6 Slides)

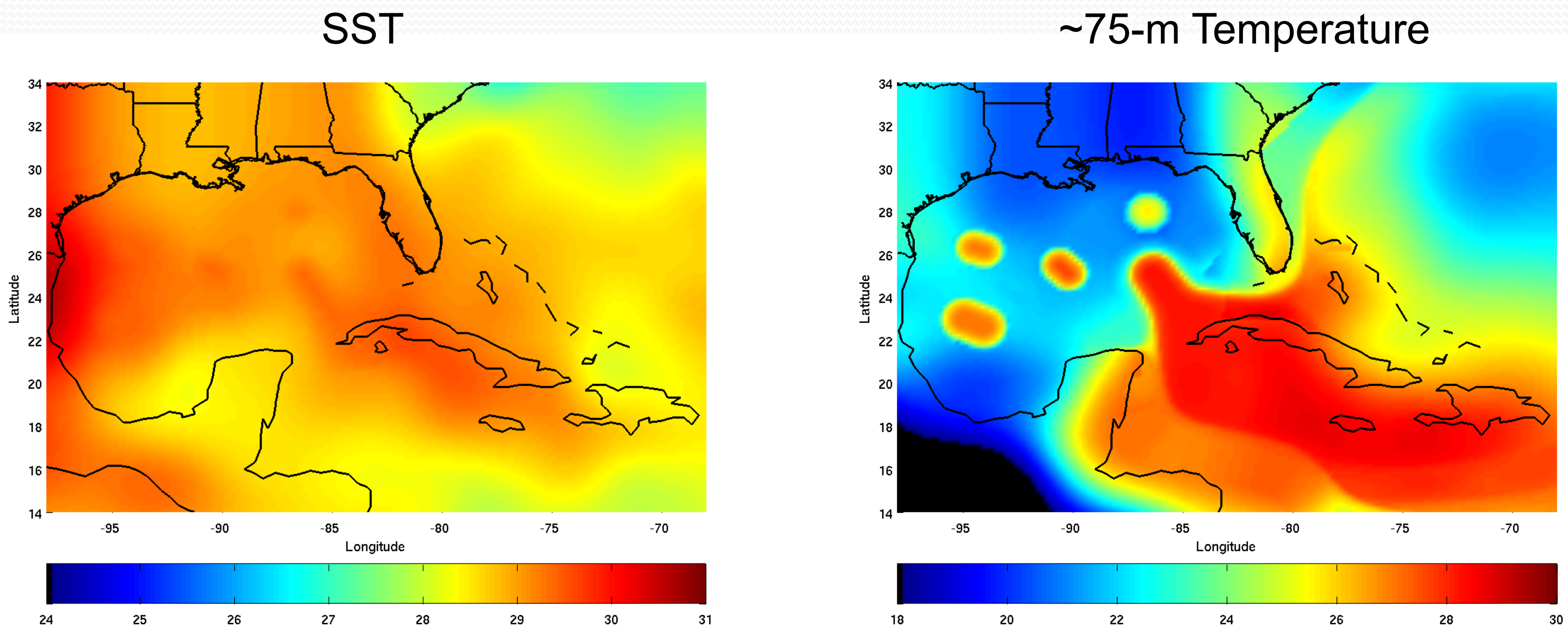
August GDEM T/S Climatology





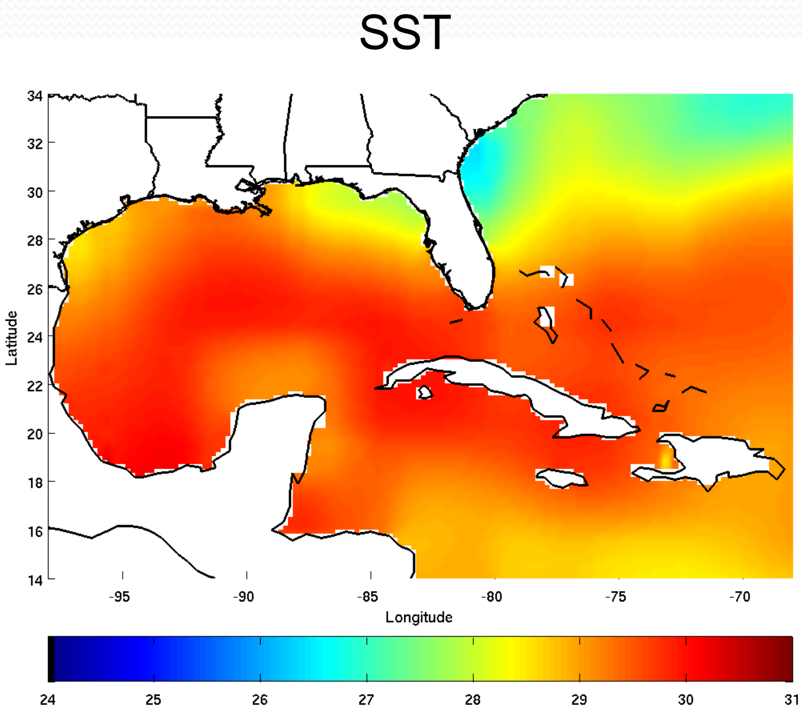
- Starting point is August GDEM T/S climatology
- August GDEM is then interpolated in time to start date by blending with September GDEM

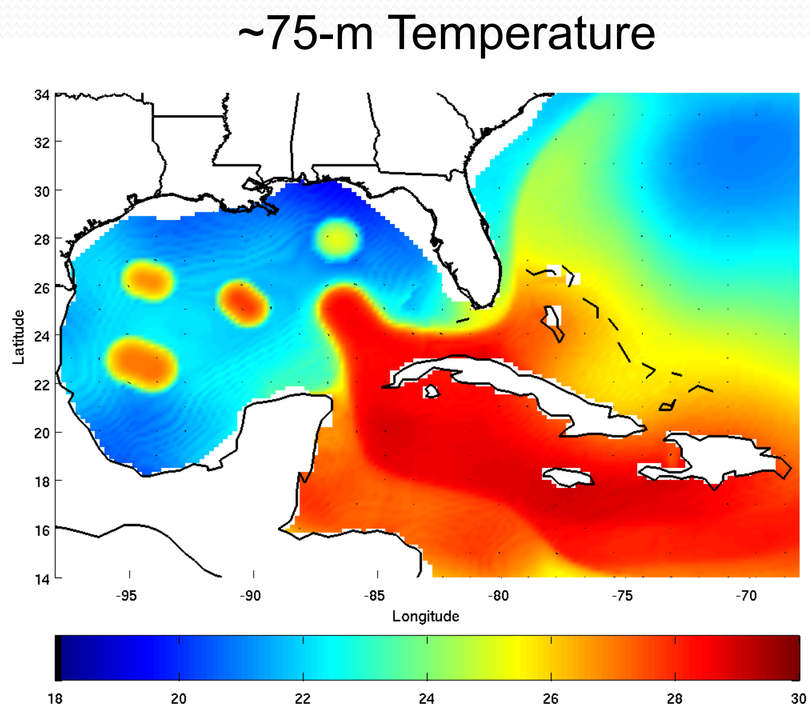
Including Features & Sharpening



- GDEM T/S climatology is modified using the feature-based model (see slide 25)
- This includes cross-frontal sharpening

00-hr Phase 1: GFS SST Assimilated



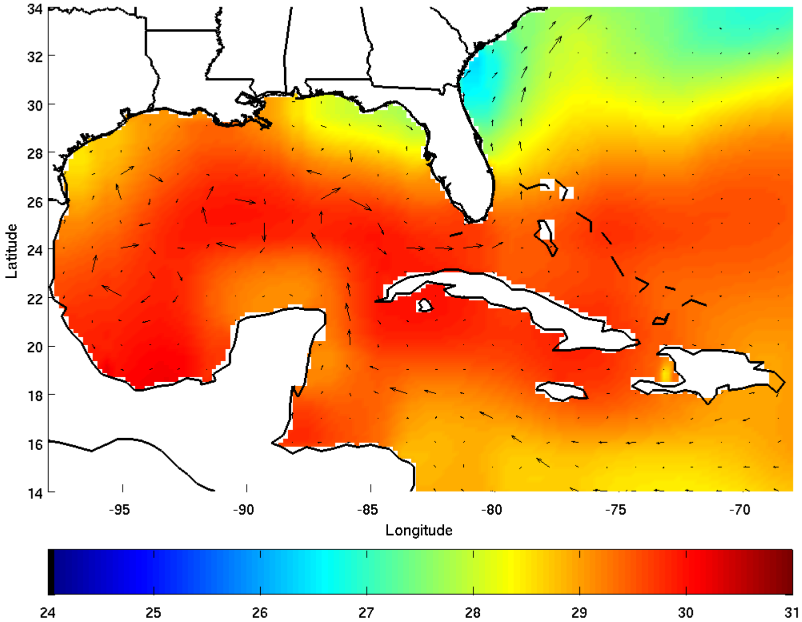


(Land/sea mask applied)

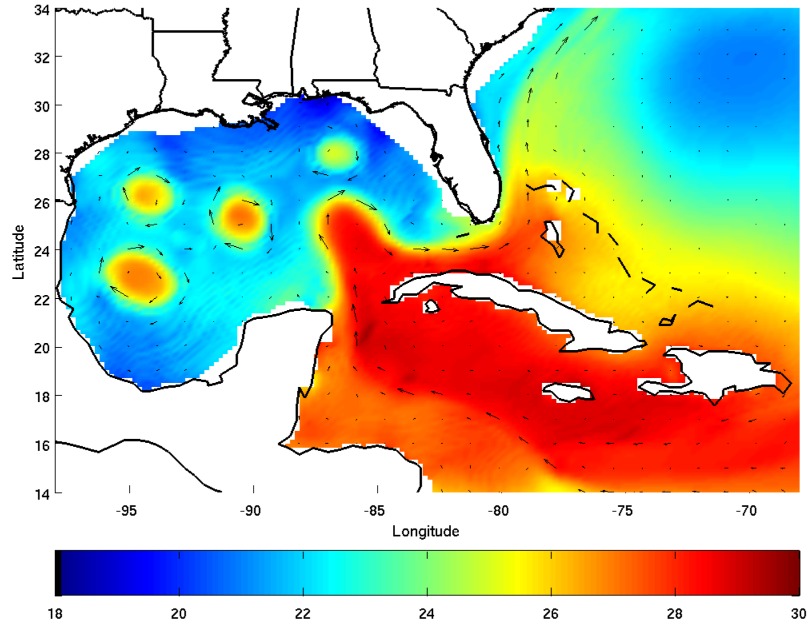
- At 00-hr phase 1, daily NCEP SST is assimilated into the upper ocean mixed layer
- T/S fields vertically-interpolated to POM σ-levels

48-hr Phase 1 / 00-hr Phase 2

SST and Surface Current Vectors



~75-m Temperature and Current Vectors

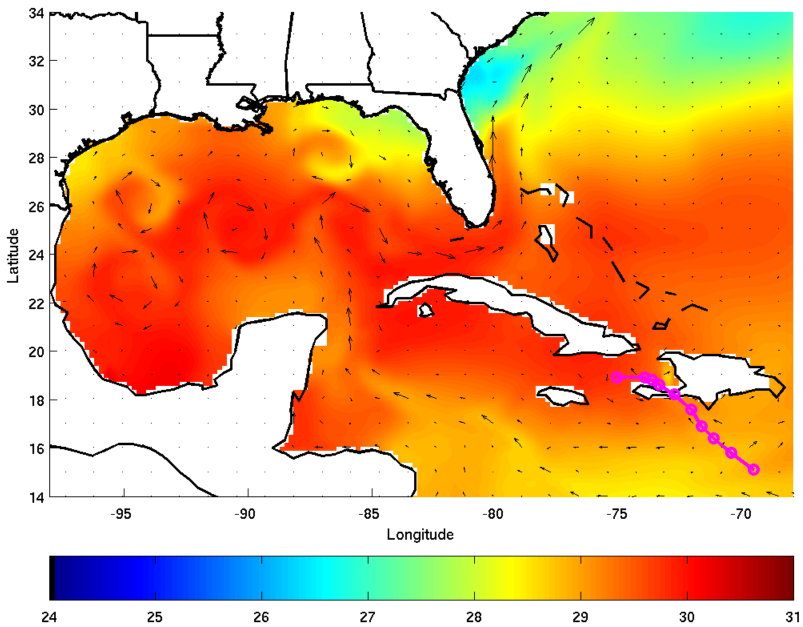


(Land/sea mask applied)

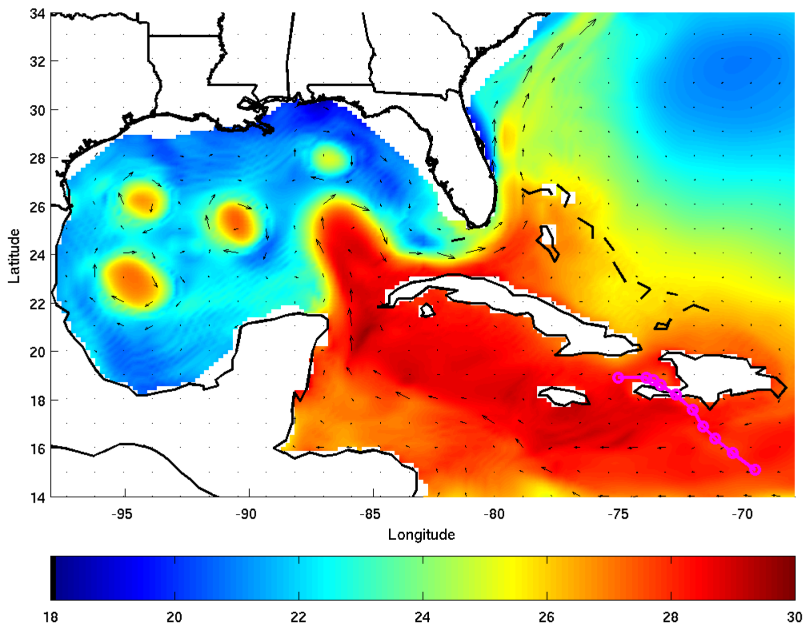
- During 48-hr of phase 1 integration, SST is held constant while currents geostrophically adjust
- 48-hr phase 1 = 00-hour phase 2

72-hr Phase 2 / 00-hr Coupled

SST and Surface Current Vectors



~75-m Temperature and Current Vectors

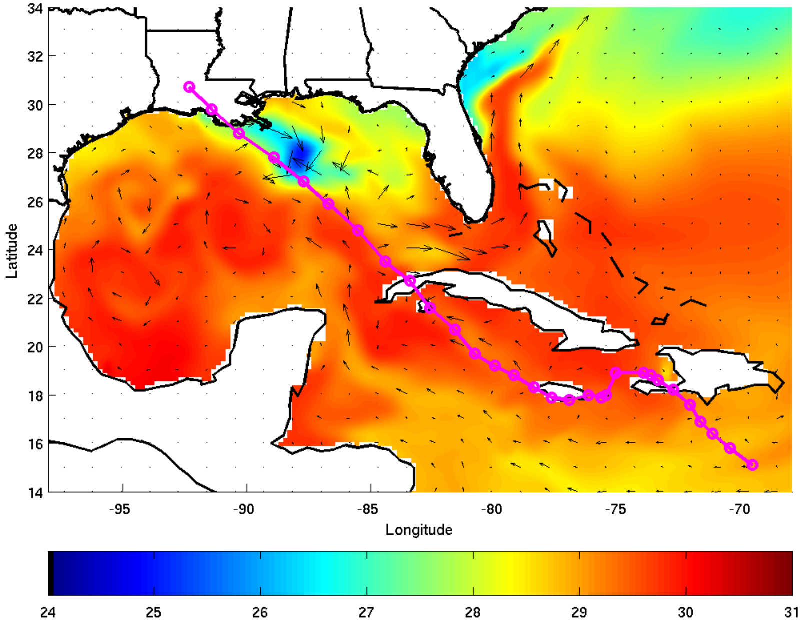


(Land/sea mask applied)

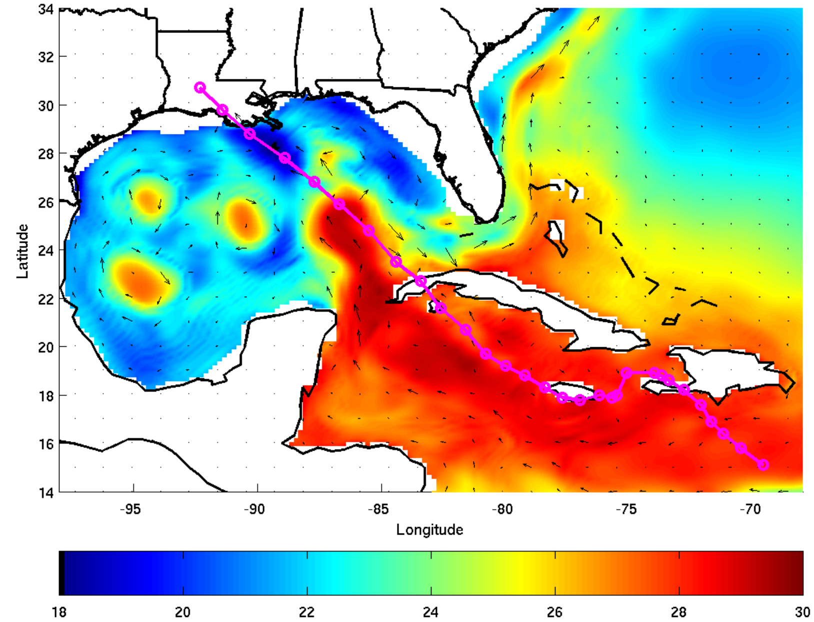
- During 72-hr of phase 2 integration, cold wake is generated by applying NHC message file wind
- 72-hr phase 2 = 00-hour coupled HWRF/POM-TC

192-hr Phase 2 (like 120-hr Coupled)

SST and Surface Current Vectors



~75-m Temperature and Current Vectors



(Land/sea mask applied)

- During 120-hr of coupled HWRF/POM-TC run, cold wake is generated by HWRF wind + thermal forcing
- Cold wake is generated here by extending phase 2

HWRF/POM-TC Coupling

Hurricane Model

Wind speed (U_a)
Temperature (T_a)
Humidity (q_a)

Momentum flux (τ)
Sensible heat flux (Q_H)
Latent heat flux (Q_E)

Air-Sea Interface

Momentum flux (τ)
Temperature flux
Shortwave radiation

SST (T_s)

Ocean Model

$$\tau = \rho_a C_D U_a U_a \qquad Q_H = C_H U_a (T_a - T_s) \qquad Q_E = \frac{L_V}{C_P} C_E U_a (q_a - q_s)$$

How to Run the POM-TC Ocean Initialization: Technical Details (Next 20 Slides)

Using the Wrapper Script

- Wrapper scripts can be found in directory:
  ${HWRF_SRC_DIR}/hwrf-utilities/wrapper_scripts
- For the tutorial, HWRF_SRC_DIR =
  /glade/scratch/$USER/HWRFV3.5a/sorc
  where $USER is your user name for the tutorial
- Go to the wrapper scripts directory
- Check global_vars.ksh to make sure the required environmental variables are correctly defined
- Required environmental variables are on the next slide
- Once global_vars.ksh is OK, run the wrapper script:
  ./pom_init_wrapper

Required Variables in global_vars.ksh

- DOMAIN_DATA
- POMTC_ROOT
- START_TIME
- BASIN
- SID
- TCVITALS
- LOOP_CURRENT_DIR
- GFS_SPECTRAL_DIR
- use_extended_eastatl
- HWRF_SCRIPTS
- OCEAN_FIXED_DIR

Tutorial definitions in global_vars.ksh

- DOMAIN_DATA = ${HWRF_OUTPUT_DIR}/${SID}/${START_TIME}
  where HWRF_OUTPUT_DIR = ${HWRF_SRC_DIR}/../results
- POMTC_ROOT = ${HWRF_SRC_DIR}/pomtc
- START_TIME = 2012102806
- BASIN = AL
- SID = 18L
- TCVITALS = ${HWRF_DATA_DIR}/Tcvitals
  where HWRF_DATA_DIR = /glade/p/ral/jnt/HWRF/datasets
- LOOP_CURRENT_DIR = ${HWRF_DATA_DIR}/loop_current
- GFS_SPECTRAL_DIR = ${HWRF_DATA_DIR}/GFS/spectral
- use_extended_eastatl = F
- HWRF_SCRIPTS = ${HWRF_SRC_DIR}/hwrf-utilities/scripts
- OCEAN_FIXED_DIR = ${HWRF_DATA_DIR}/datasets/fix/ocean

How pom_init_wrapper Works

- Wrapper script pom_init_wrapper first calls global_vars.ksh to define the environmental variables
- pom_init wrapper then calls low-level script pom_init.ksh to run the ocean initializaiton
- Another script, gfdl_pre_ocean_sortvit.sh, is called from within pom_init.ksh
- pom_init.ksh is composed of seven functions (next slide)
- Output files from pom_init_wrapper will be in:
  ${DOMAIN_DATA}/oceanprd
- Scripts to plot the POM-TC ocean output are in:
  ${POMTC_ROOT}/ocean_plot

Seven functions in pom_init.ksh

- function *main* (slide 40)
- function *get_tracks* (slide 41)
- function *get_region* (slide 42)
- function *get_sst* (slide 43)
- function *sharpen* (slide 44)
- function *phase_3* (slide 45)
- function *phase_4* (slide 46)

pom_init.ksh: function *main*

- Initialize the function library.
- Check to see if all the variables are set.
- Alias the executables/scripts.
- Check to see if all the executables/scripts exist.
- Set the stack size.
- Create a working directory and *cd* into it.
- Get the existing storm track information using function *get_tracks*.
- Find the ocean region using function *get_region* and set it accordingly.
- Get the GFS SST using function *get_sst*.
- Run the feature-based sharpening program using function *sharpen*.
- Run POM-TC phase 1 (a.k.a. phase 3) using function *phase_3*.
- Run POM-TC phase 2 (a.k.a. phase 4) using function *phase_4*.

pom_init.ksh: function *get_tracks*

- Get the entire existing storm track record from the *syndat_tcvitals* file using script *gfdl_pre_ocean_sortvit.sh* and store it in file *track.allhours*.
- File *track.allhours* is created in directory ${DOMAIN_DATA}/oceanprd
- Add a blank record at the end of the storm track in file *track.allhours*.
- Remove all cycles after the current cycle from the storm track record and store it in file *track.shortened* in directory ${DOMAIN_DATA}/oceanprd.
- Use *track.shortened* as track file; if it is empty, use *track.allhours* instead.
- Extract various storm statistics from the last record in the track file to generate a 72-hour projected track that assumes storm direction and speed remain constant; save this projected track in file *shortstats*.

pom_init.ksh: function *get_region*

- Run find region code, which selects the ocean region based on projected track points in file *shortstats*; the region is east_atlantic or west_united.
- Store ocean region from the find region code in file *ocean_region_info.txt*.
- If the ocean basin is East Pacific, reset the ocean region to east_pacific.
- Set region variable to eastpac, eastatl, or united; run uncoupled if storm is not in one of these three regions.
- Store region variable in file ${DOMAIN_DATA}/oceanprd/*pom_region.txt*.

pom_init.ksh: function *get_sst*

- Create the directory for the GFS SST, mask, and lon/lat files.
- Create symbolic links for the GFS spectral input files.
- Run the *getsst* code.
- Rename the GFS SST, mask, and lon/lat files for POM-TC phase 3.
- Output files lonlat.gfs, mask.gfs.dat, and sst.gfs.dat will be in directory:

  ${DOMAIN_DATA}/oceanprd/getsst

pom_init.ksh: function *sharpen*

- Prepare symbolic links for most of the input files for the sharpening program.
- Continue with function *sharpen* only if the region variable is set as united.
- Create the directory for the sharpening program output files.
- Continue with function *sharpen* only if the Loop Current and ring files exist.
- Use backup GDEM monthly climatological temperature and salinity files if they exist but the Loop Current and ring files do not exist; warn the user accordingly.
- Exit the ocean initialization with an error if neither the Loop Current and ring files nor the backup climatological temperature and salinity files exist.
- Assuming the Loop Current and ring files exist, use the simulation start date to select the second of two temperature and salinity climatology months to use for time interpolation to the simulation start date.
- Choose the climatological input based on *input_sharp* (hardwired to GDEM).
- Create symbolic links for all input files for the sharpening program.
- Run the sharpening code.
- Rename the sharpened climatology file as ${DOMAIN_DATA}/oceanprd/sharpn/gfdl_initdata.${region}.${mm} for POM-TC phase 3.

pom_init.ksh: function *phase_3*

- Create the directory for the POM-TC phase 3 output files.
- Prepare symbolic links for some of the input files for POM-TC phase 3.
- Modify the phases 3 parameter file by including the simulation start date.
- Prepare symbolic links for the sharpened (or unsharpened) temperature and salinity input file, and for the topography and land/sea mask file, based on whether the region variable is united, eastatl, or eastpac.
- If the region variable is eastatl, choose whether or not to use the extended east Atlantic domain based on whether or not the value of variable *use_extended_eastatl* is set to true.
- Create symbolic links for all input files from POM-TC phase 3. These links include extra input files for defining the domain center and the land/sea mask if the region variable is eastpac.
- Run the POM-TC code for phase 3.
- Rename the phase 3 restart file as ${DOMAIN_DATA}/oceanprd/phase3/RST.phase3.${region} for POM-TC phase 4.

pom_init.ksh: function *phase_4*

- Create the directory for the POM-TC phase 4 output files.
- Prepare symbolic links for some of the input files for POM-TC phase 4.
- If the track file has less than three lines in it, skip POM-TC phase 4 and use *RST.phase3* for initializing the coupled HWRF simulation.
- Back up three days to end phase 4 at the coupled HWRF start date.
- Modify the phase 4 parameter file by including the simulation start date, the track file, and *RST.phase3*.
- Prepare symbolic links for sharpened/unsharpened temperature and salinity input file and topography and land/sea mask file, based on region variable.
- If the region variable is eastatl, choose whether to use extended east Atlantic domain based on whether *use_extended_eastatl* is set to true.
- Create symbolic links for all input files from POM-TC phase 4 (including track).
- Run the POM-TC code for phase 4.
- Rename the phase 4 restart file as ${DOMAIN_DATA}/oceanprd/phase4/RST.final for the coupled HWRF simulation.

Executables

- There are seven executable files associated with POM-TC ocean initialization, which can be found in directory:

  ${POMTC_ROOT}/ocean_exec

- The following slides list the function, input(s), output(s), and usage of each of these seven executable files:
  - gfdl_find_region.exe (slide 48)
  - gfdl_getsst.exe (slide 49)
  - gfdl_sharp_mcs_rf_l2m_rmy5.exe (slide 50)
  - gfdl_ocean_united.exe (slide 51)
  - gfdl_ocean_eastatl.exe (slide 52)
  - gfdl_ocean_ext_eastatl.exe (slide 53)
  - gfdl_ocean_eastpac.exe (slide 54)

gfdl_find_region.exe

- **Function:** Select the POM-TC ocean region based on the projected track points in the *shortstats* file; this region is east_atlantic or west_united

- **Input(s):** shortstats

- **Output(s):** fort.61 (ocean_region_info.txt)

- **Usage:** ${POMTC_ROOT}/ocean_exec/gfdl_find_region.exe < shortstats

gfdl_getsst.exe

- **Function:** Extract SST, land-sea mask, and lon/lat data from the GFS spectral files

- **Input(s):** for11 (gfs.${start_date}.t${cyc}z.sfcanl)
  fort.11 (gfs.${start_date}.t${cyc}z.sfcanl)
  fort.12 (gfs.${start_date}.t${cyc}z.sanl)

- **Output(s):** fort.23 (lonlat.gfs)
  fort.74 (sst.gfs.dat)
  fort.77 (mask.gfs.dat)
  getsst.out

- **Usage:** ${POMTC_ROOT}/ocean_exec/gfdl_getsst.exe > getsst.out

gfdl_sharp_mcs_rf_l2m_rmy5.exe

- **Function:** Run the sharpening program, which takes the T/S climatology, horizontally-interpolates it onto the POM-TC grid for the United region domain, assimilates a land/sea mask and bathymetry, and employs the diagnostic, feature-based modeling procedure.
- **Input(s):** input_sharp
  fort.66 (gfdl_ocean_topo_and_mask.${region})
  fort.8 (gfdl_gdem.${mm}.ascii)
  fort.90 (gfdl_gdem.${mmm2}.ascii)
  fort.24 (gfdl_ocean_readu.dat.${mm})
  fort.82 (gfdl_ocean_spinup_gdem3.dat.${mm})
  fort.50 (gfdl_ocean_spinup_gspath.${mm})
  fort.55 (gfdl_ocean_spinup.BAYuf)
  fort.65 (gfdl_ocean_spinup.FSgsuf)
  fort.75 (gfdl_ocean_spinup.SGYREuf)
  fort.91 (mmdd.dat)
  fort.31 (hwrf_gfdl_loop_current_rmy5.dat.${yyyymmdd})
  fort.32 (hwrf_gfdl_loop_current_wc_ring_rmy5.dat.${yyyymmdd})
- **Output(s):** fort.13 (gfdl_initdata.${region}.${mm})
  sharpn.out
- **Usage:** ${POMTC_ROOT}/ocean_exec/gfdl_sharp_mcs_rf_l2m_rmy5.exe < input_sharp > sharpn.out

gfdl_ocean_united.exe

- **Function:** Run POM-TC ocean phase 1 or phase 2 (also known historically as ocean phase 3 and phase 4, respectively, as in the model code) in the United region.

- **Input(s):** fort.10 (parameters.inp)
  fort.15 (empty if phase 1; track if phase 2)
  fort.21 (sst.gfs.dat)
  fort.22 (mask.gfs.dat)
  fort.23 (lonlat.gfs)
  fort.13 (gfdl_initdata.united.${mm})
  fort.66 (gfdl_ocean_topo_and_mask.united)
  fort.14 (not used if phase 1; RST.phase3.united if phase 2)

- **Output(s):** RST.phase3.united if phase 1; RST.final if phase 2
  phase3.out if phase 1; phase4.out if phase 2

- **Usage:** Phase 1: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_united.exe > phase3.out
  Phase 2: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_united.exe > phase4.out

gfdl_ocean_eastatl.exe

- **Function:** Run POM-TC ocean phase 1 or phase 2 (also known historically as ocean phase 3 and phase 4, respectively, as in the model code) in the East Atlantic region.

- **Input(s):** fort.10 (parameters.inp)
  fort.15 (empty if phase 1; track if phase 2)
  fort.21 (sst.gfs.dat)
  fort.22 (mask.gfs.dat)
  fort.23 (lonlat.gfs)
  fort.12 (gfdl_initdata.gdem.united.${mm})
  fort.13 (gfdl_initdata.eastatl.${mm})
  fort.66 (gfdl_ocean_topo_and_mask.eastatl)
  fort.14 (not used if phase 1; RST.phase3.eastatl if phase 2)

- **Output(s):** RST.phase3.eastatl if phase 1; RST.final if phase 2
  phase3.out if phase 1; phase4.out if phase 2

- **Usage:** Phase 1: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_eastatl.exe > phase3.out
  Phase 2: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_eastatl.exe > phase4.out

gfdl_ocean_ext_eastatl.exe

- **Function:** Run POM-TC ocean phase 1 or phase 2 (also known historically as ocean phase 3 and phase 4, respectively, as in the model code) in the extended East Atlantic region. This executable is not used in the operational HWRF configuration.

- **Input(s):** fort.10 (parameters.inp)
  fort.15 (empty if phase 1; track if phase 2)
  fort.21 (sst.gfs.dat)
  fort.22 (mask.gfs.dat)
  fort.23 (lonlat.gfs)
  fort.12 (gfdl_initdata.gdem.united.${mm})
  fort.13 (gfdl_initdata.eastatl.${mm})
  fort.66 (gfdl_ocean_topo_and_mask.eastatl_extn)
  fort.14 (not used if phase 1; RST.phase3.eastatl if phase 2)

- **Output(s):** RST.phase3.eastatl if phase 1; RST.final if phase 2
  phase3.out if phase 1; phase4.out if phase 2

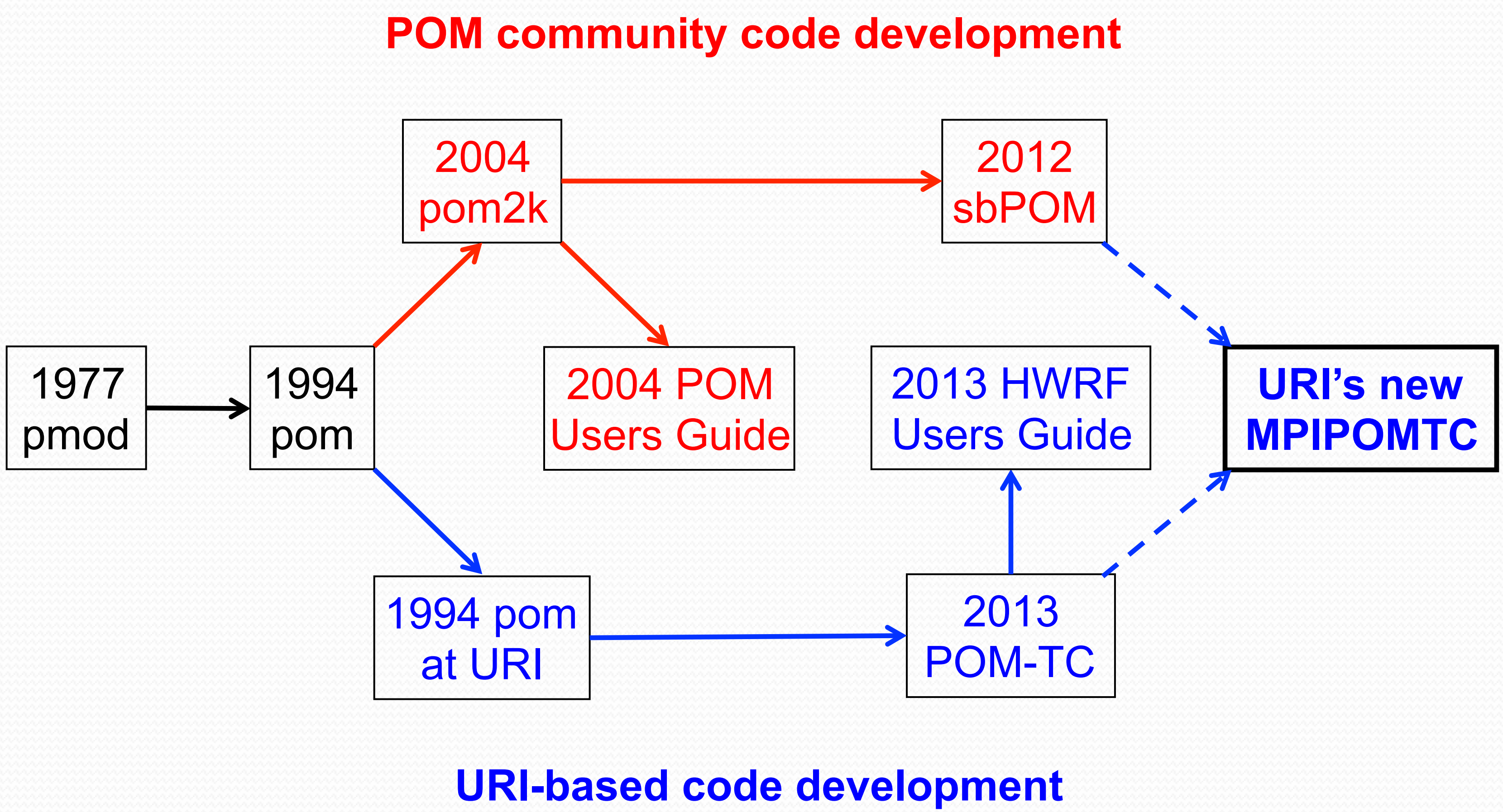
- **Usage:** Phase 1: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_ext_eastatl.exe > phase3.out
  Phase 2: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_ext_eastatl.exe > phase4.out

gfdl_ocean_eastpac.exe

- **Function:** Run POM-TC ocean phase 1 or phase 2 (also known historically as ocean phase 3 and phase 4, respectively, as in the model code) in the East Pacific region.
- **Input(s):** domain.center (used if phase 1; not used if phase 2)
  gfdl_pctwat (used if phase 1; not used if phase 2)
  fort.10 (parameters.inp)
  fort.15 (empty if phase 1; track if phase 2)
  fort.21 (sst.gfs.dat)
  fort.22 (mask.gfs.dat)
  fort.23 (lonlat.gfs)
  fort.45 (gfdl_raw_temp_salin.eastpac.${mm} if phase 1; not used if phase 2)
  fort.13 (output if phase 1; temp_salin_levitus.eastpac if phase 2)
  fort.66 (output if phase 1; eastpac_ocean_model_info if phase 2)
  fort.14 (not used if phase 1; RST.phase3.eastpac if phase 2)
- **Output(s):** RST.phase3.eastpac if phase 1; RST.final if phase 2
  phase3.out if phase 1; phase4.out if phase 2
  fort.13 (temp_salin_levitus.eastpac) if phase 1 only
  fort.66 (eastpac_ocean_model_info) if phase 1 only
- **Usage:** Phase 1: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_eastpac.exe > phase3.out
  Phase 2: ${POMTC_ROOT}/ocean_exec/gfdl_ocean_eastpac.exe > phase4.out

Big change for 2014 HWRF?

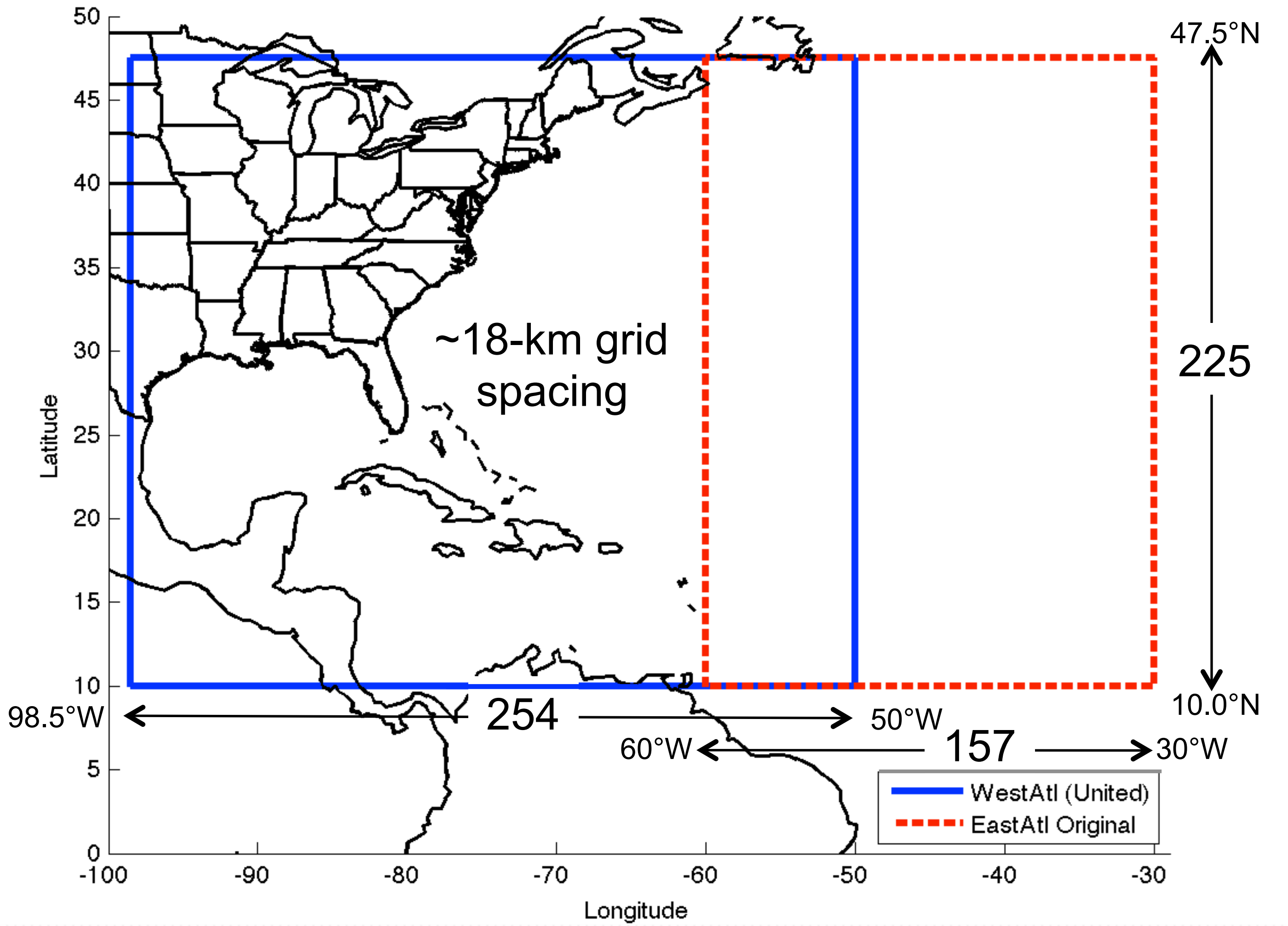
Developing a new MPIPOMTC at URI



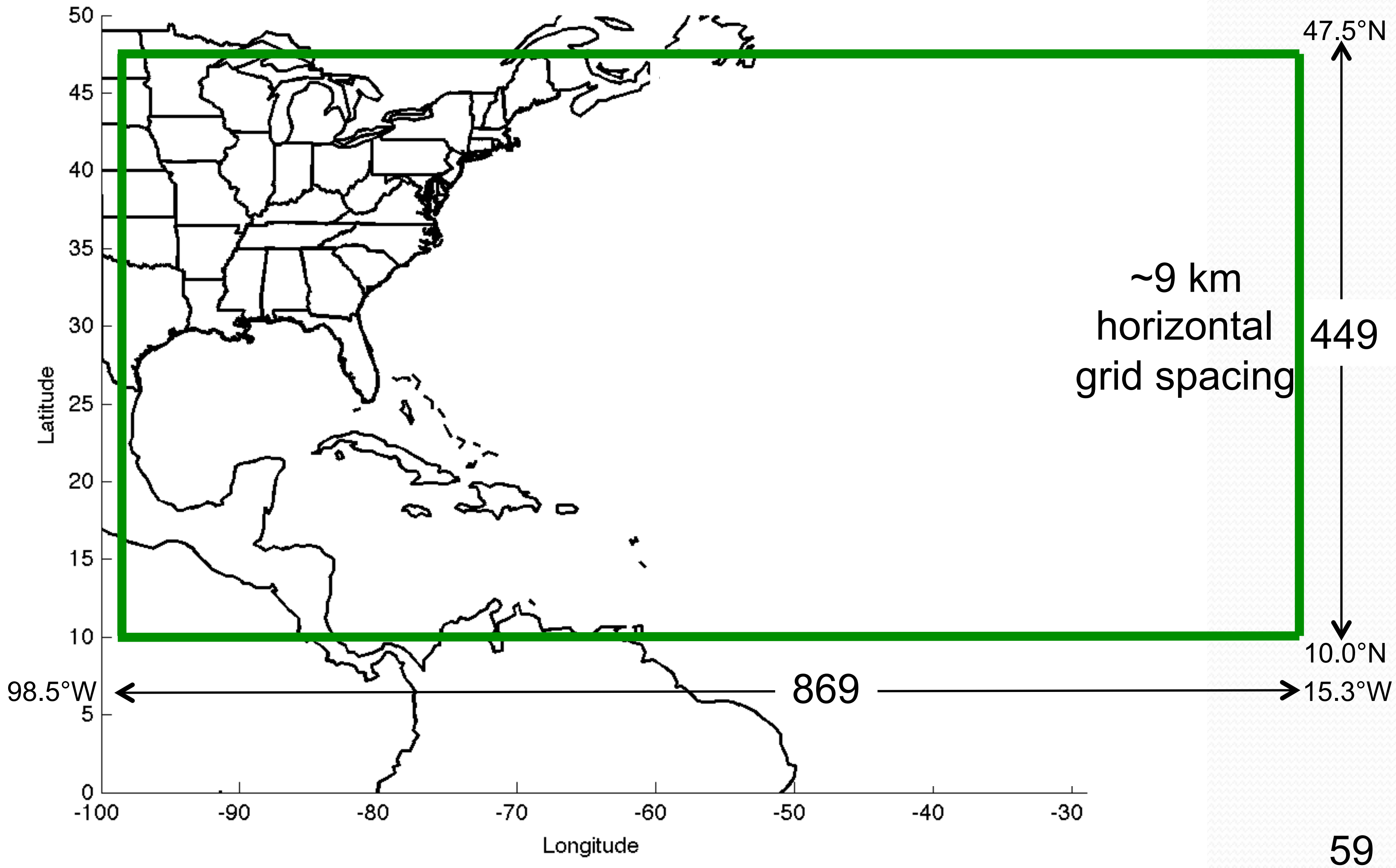
Why create a new MPIPOMTC?

- MPIPOMTC uses MPI software to run on efficiently on multiple processors, allowing for both higher grid resolution and a larger ocean domain than POM-TC
- MPIPOMTC accepts flexible initialization options
- MPIPOMTC is an adaptation of sbPOM, which has community support and includes 18 years of physics updates and bug fixes
- MPIPOMTC is a modernized code with NetCDF I/O

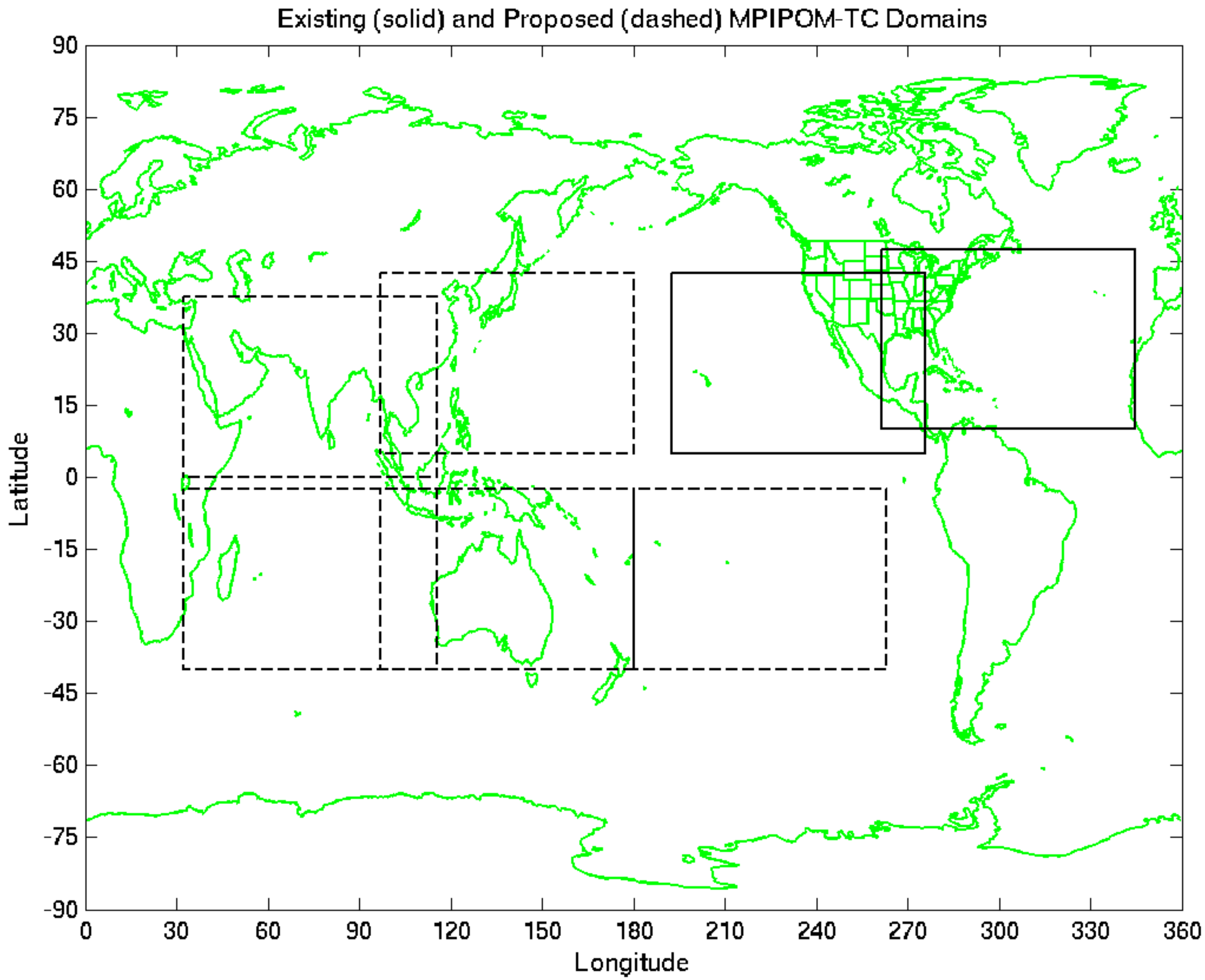
POM-TC Atlantic Domains: "United" and "East Atlantic"



URI's MPIPOMTC transatlantic domain



URI's Proposed Worldwide MPIPOMTC domains



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