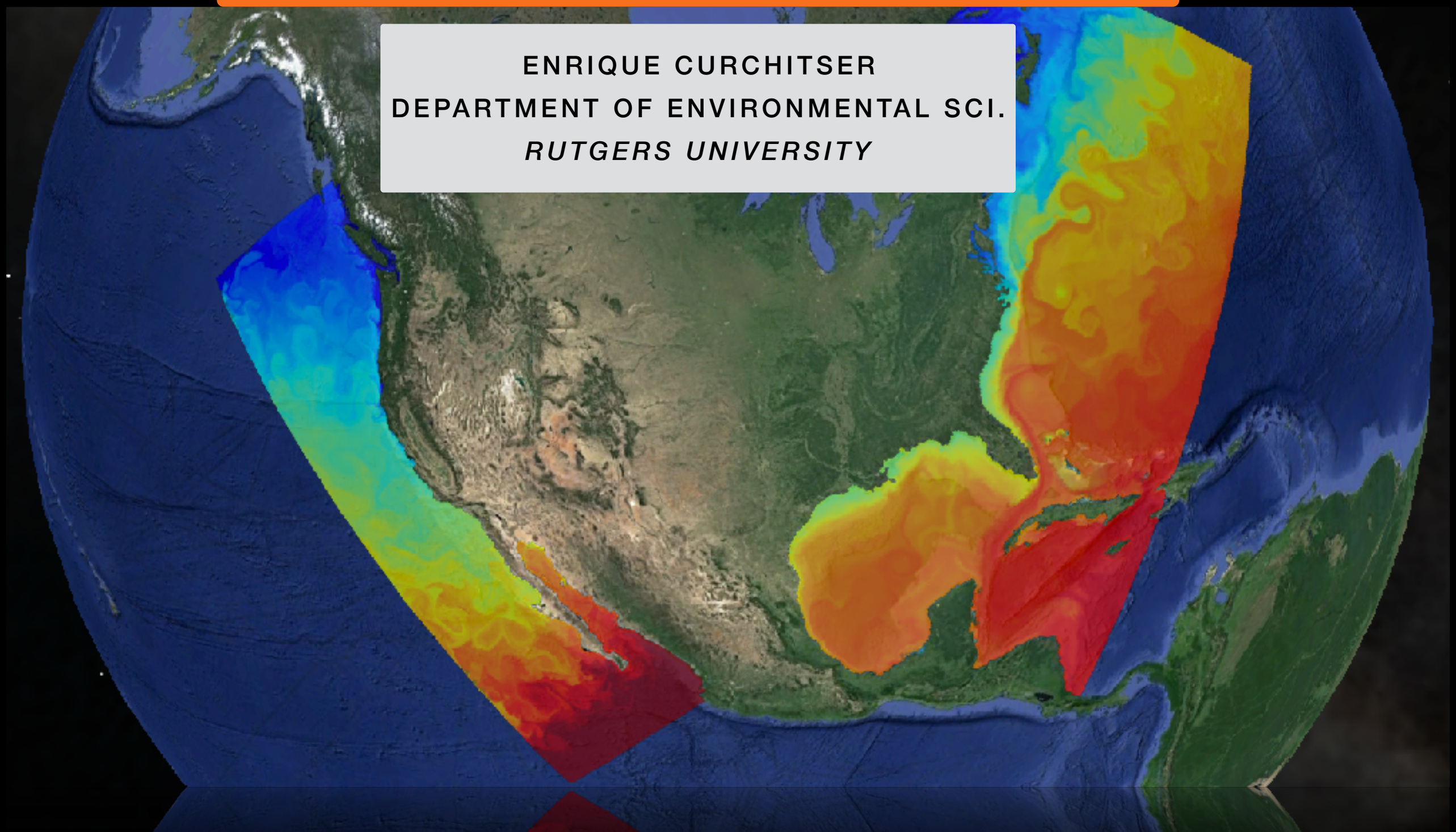
# REGIONAL MODELING WITH MOM6



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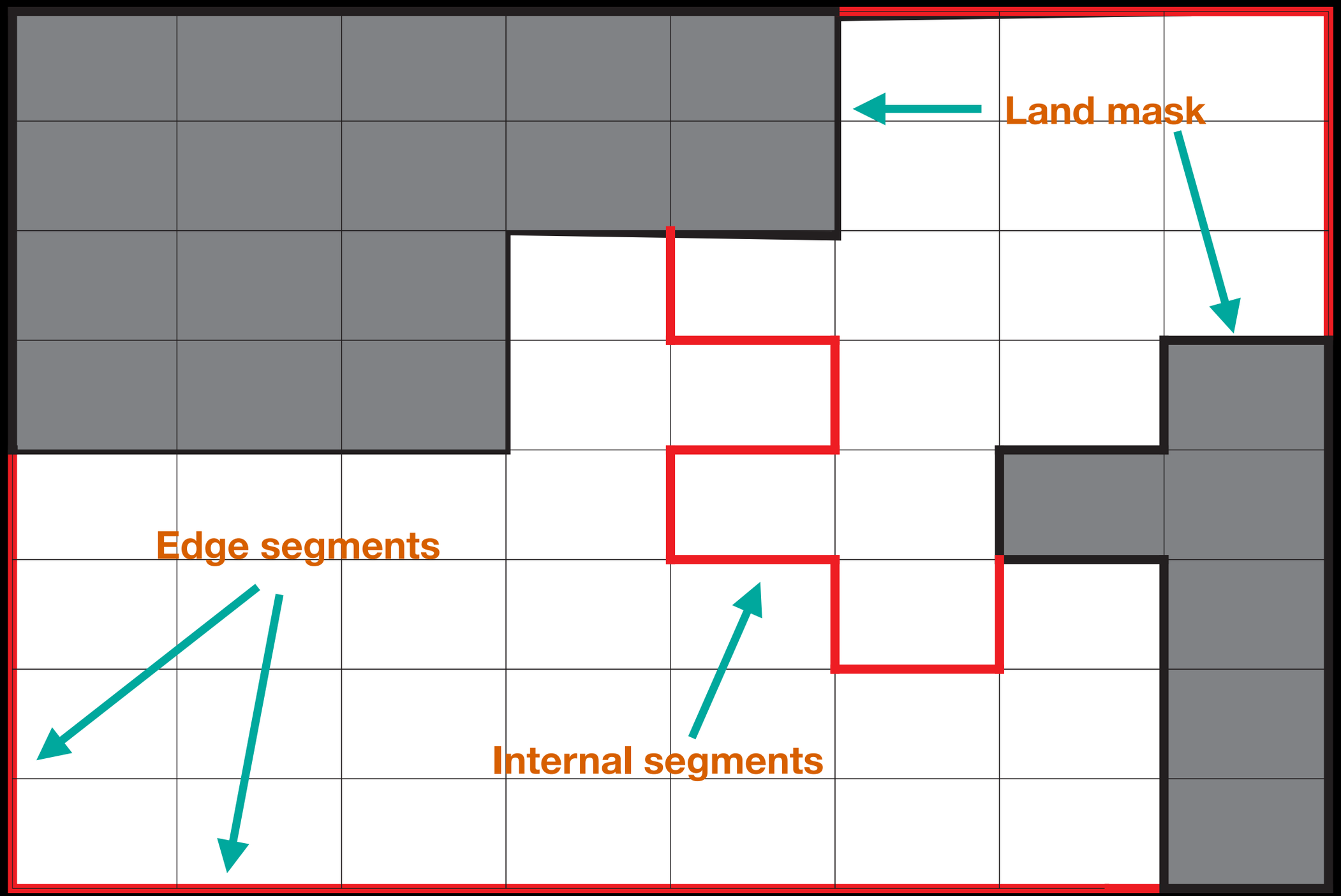
# People involved

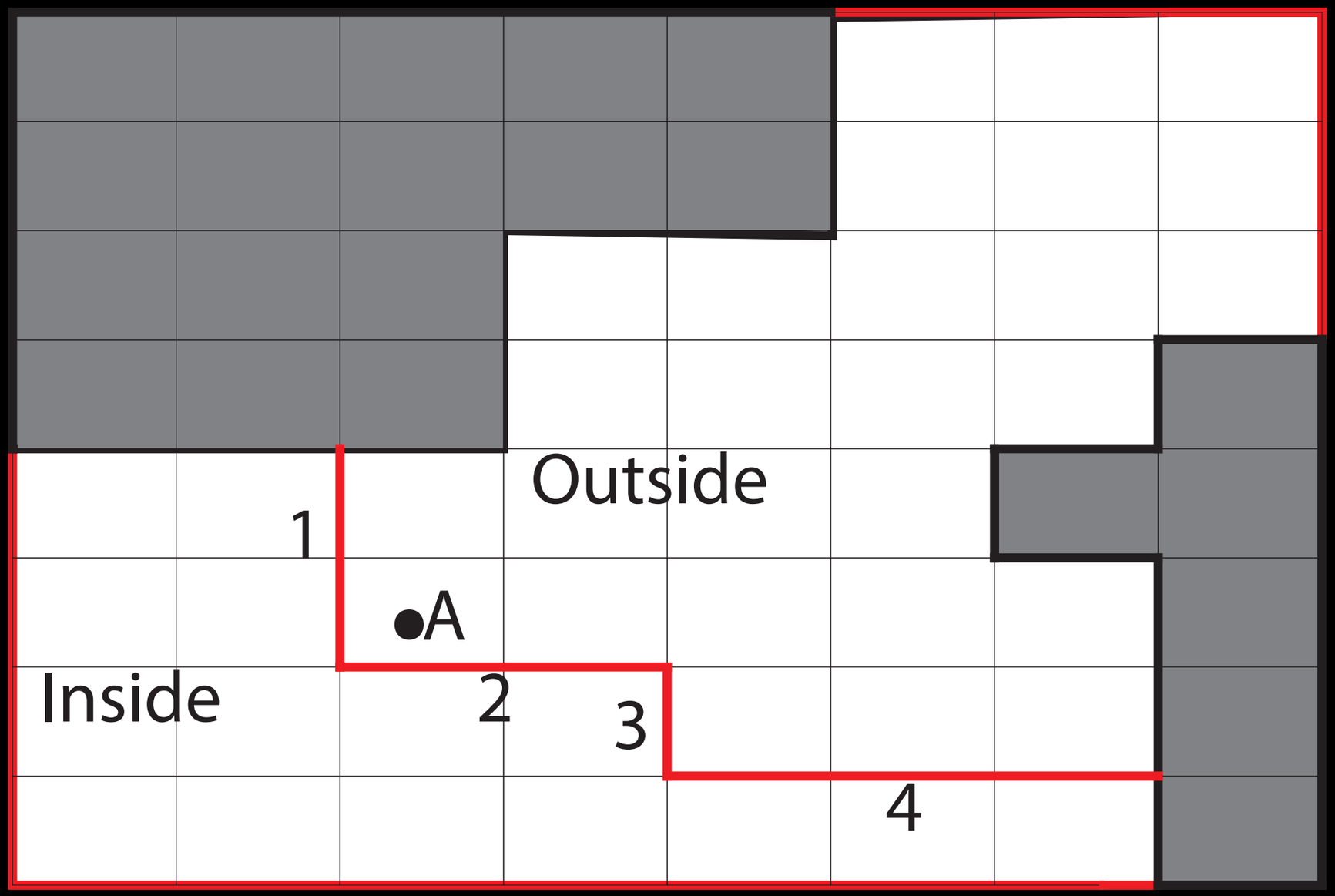
- Bob Hallberg (GFDL)
- Alistair Adcroft (Princeton/GFDL)
- Matt Harrison (GFDL)
- Raphael Dussin (GFDL)
- Andrew Ross (GFDL)
- Liz Drenkard (GFDL)
- Charlie Stock (GFDL)
- Kate Hedstrom (UAF)
- Dujuan Kang (Rutgers)
- Alan Wallcraft (FSU)
- Eric Chassignet (FSU)
- Gustavo Marques (NCAR)
- Scott Bachman (NCAR)
- Alper Altuntas (NCAR)
- A few others working on implementations (Indian Ocean, Nordic Seas, …)

# Design philosophy:  Put OBCs anywhere



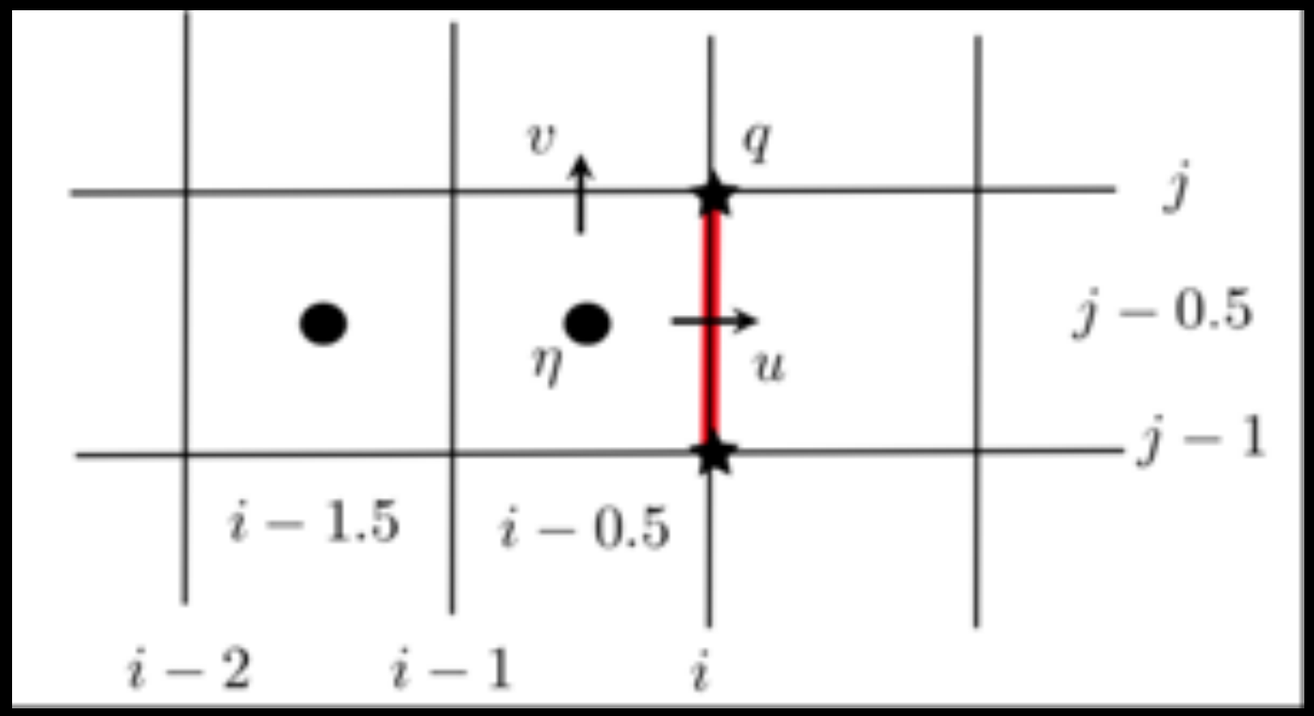
# Design:  OBC segments

- Point A is outside for segments 1 and 2
- BC cannot depend on outside value



# Arakawa C-grid

- Free surface
- Normal velocity
- Tangential velocity
- Tracers
- Layer thickness… would be nice but messy?



# Boundary conditions:  Barotropic mode

- Flather (needs boundary information for both $U_{barotropic}$ and free surface $\eta$

$$\bar{u} = \bar{u}_{ext} + \sqrt{\frac{g}{H}}(\eta - \eta_{ext})$$

# Boundary conditions:  Baroclinic

- Baroclinic Mode:
  - Orlanski or oblique radiation (Raymond & Kuo):  Compute local normal phase speed ( also used for tangential velocity if needed)

$$\frac{\partial \phi}{\partial t} = - \left( \phi_\xi \frac{\partial \phi}{\partial \xi} + \phi_\eta \frac{\partial \phi}{\partial \eta} \right)$$

where $\phi_{\xi,\eta}$ are the phase speeds

- On inflow, either zero gradient nudged to external value (Marchesiello)

# Boundary conditions:  Tangential velocity

- Strain/Vorticity (Lateral viscosity/Coriolis):
  - Free slip (zero gradient)
  - Specified dv/dx or du/dy from file or radiation condition
  - Computed using velocities from file or radiation condition
  - Zero

# Boundary conditions

- Tracers
  - A reservoir has memory of fluid that has left the domain out of each boundary
  - Can also mix in external values of tracers on inflow
  - Mixing lengths set relative contributions of each tracer

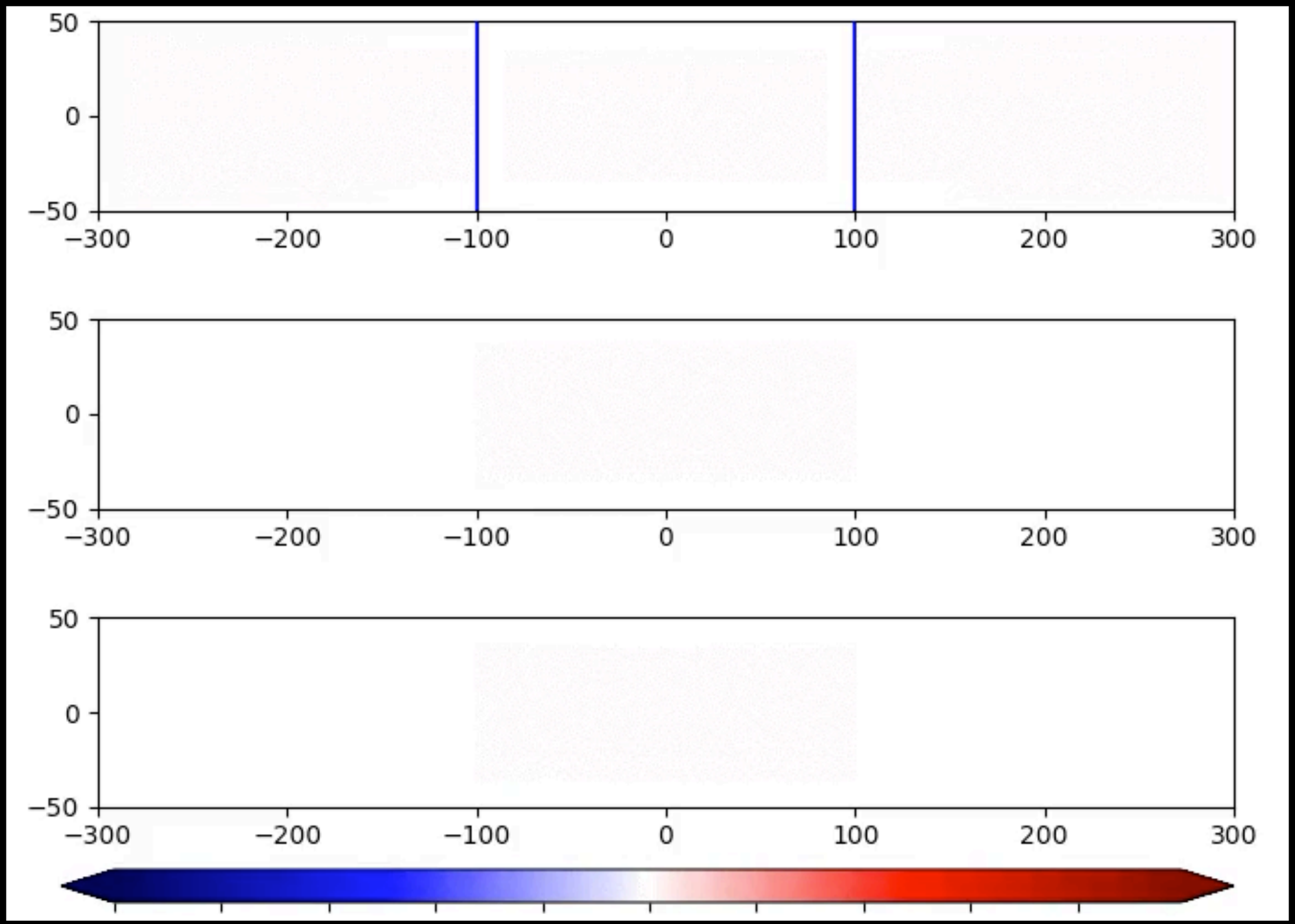
- Layer thickness (used in continuity and Coriolis computations)
  - Set to no-gradient
  - With ALE, may be difficult to implement other options

# OBC Types currently in MOM6

- SIMPLE (aka clamped), needs user code
- GRADIENT (zero gradient)
- FLATHER - barotropic mode
- ORLANSKI - radiation
- OBLIQUE - another radiation
- NUDGED - modifier to radiation

The above are normal velocity options, mostly

# Test cases:  Dumbbell



# MOM6 Implementations: NW Atlantic

## MOM6-NWA Setup

- **Regional MOM6 simulation of Northwest Atlantic (NWA)**

  - **Grid** (converted from ROMS grid of Kang & Curchitser, 2013)

    - **Horizontal**: ~7 km resolution, 720 x 360 grid points
    - **Vertical**: { Geopotential (z*) NK=75 & NK=50; Hybrid Hycom1 (z* & $\rho$) NK=75

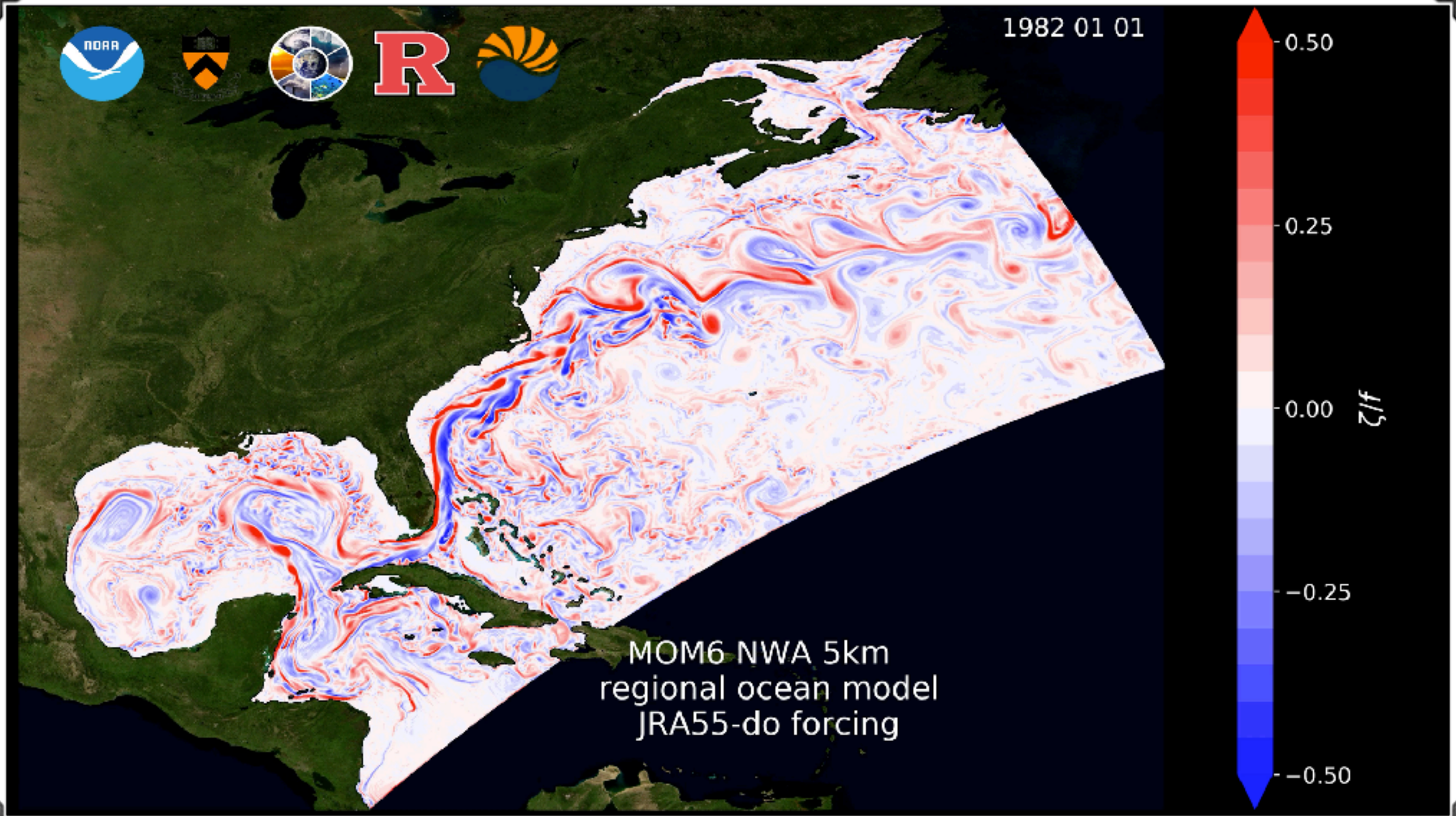
- **Forcing**

  - **Ocean BC & IC**: SODA3
  - **Atmospheric forcing**: JRA55-do
  - **Runoff**: Dai & Trenberth river discharge

- **Computation** (1 simulation year)

| z* (NK=50) | z* (NK=75) | hycom1 (NK=75) |
|---|---|---|
| 15x160 = 2400 CPU hrs | 19x240 = 4560 CPU hrs | 21x240 = 5040 CUP hrs |

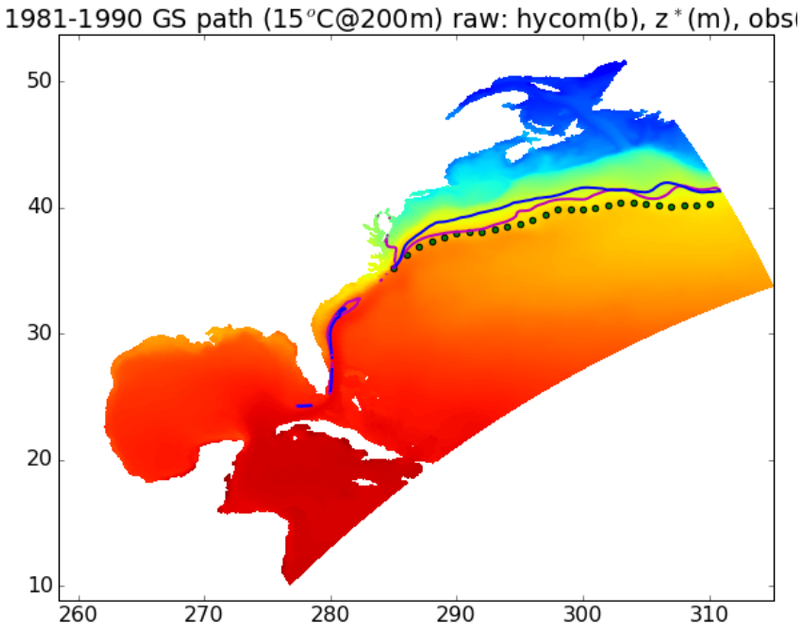
# Regional Modeling with MOM6



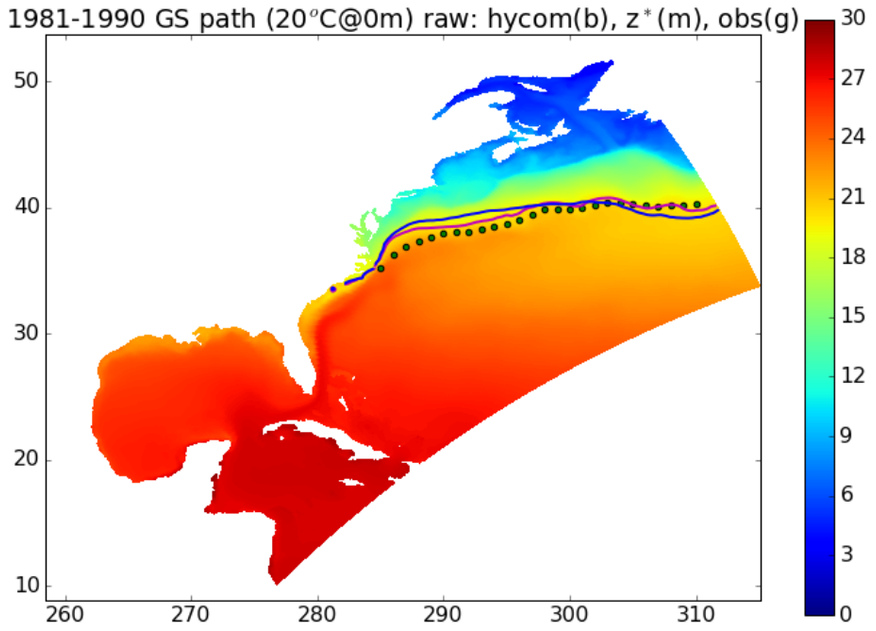
# MOM6 Implementations: NW Atlantic

## Raw Bathy: Gulf Stream Mean Path of 1981-1990

**15° C @ 200m**

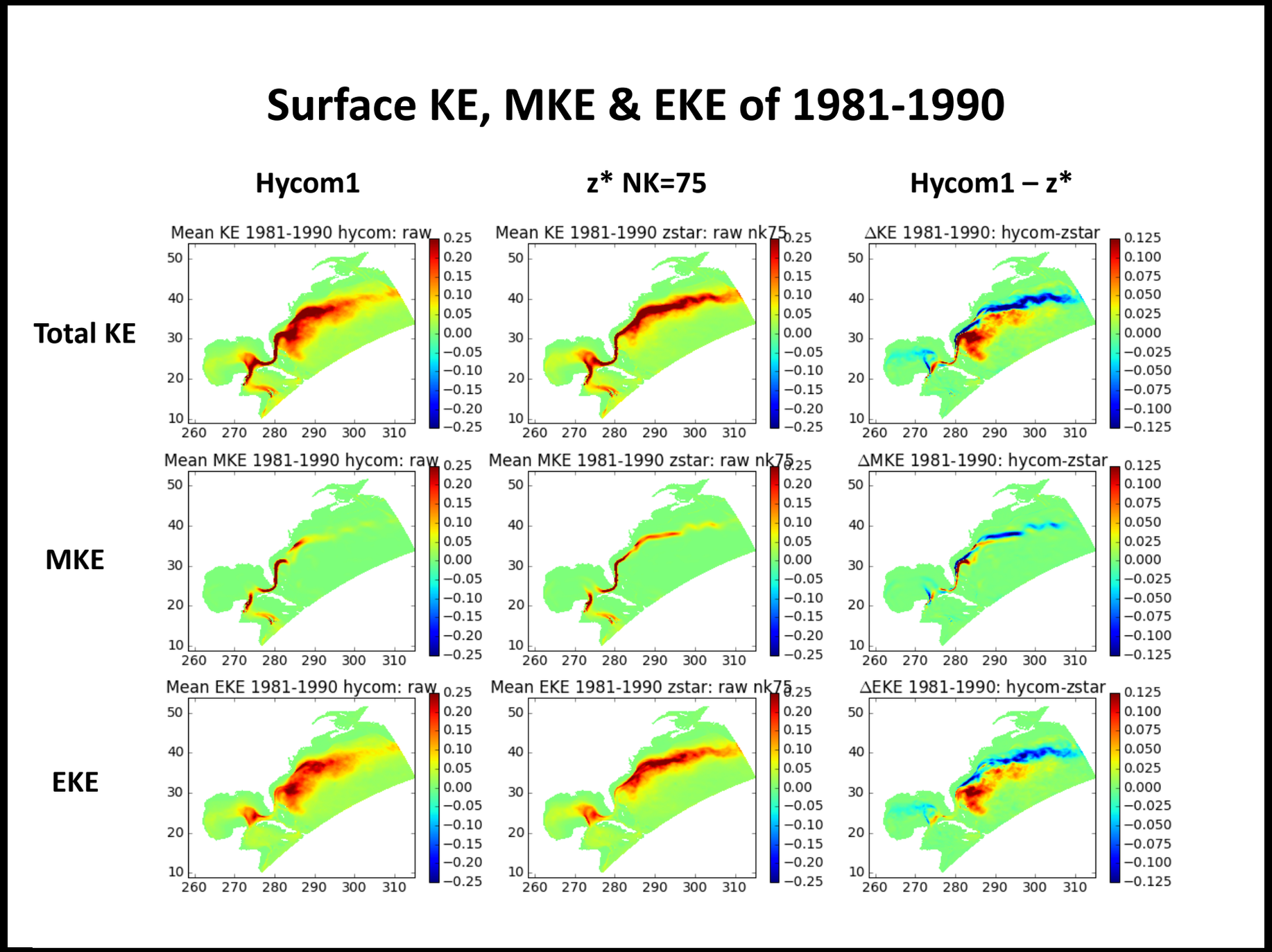



**20° C @ Surface**

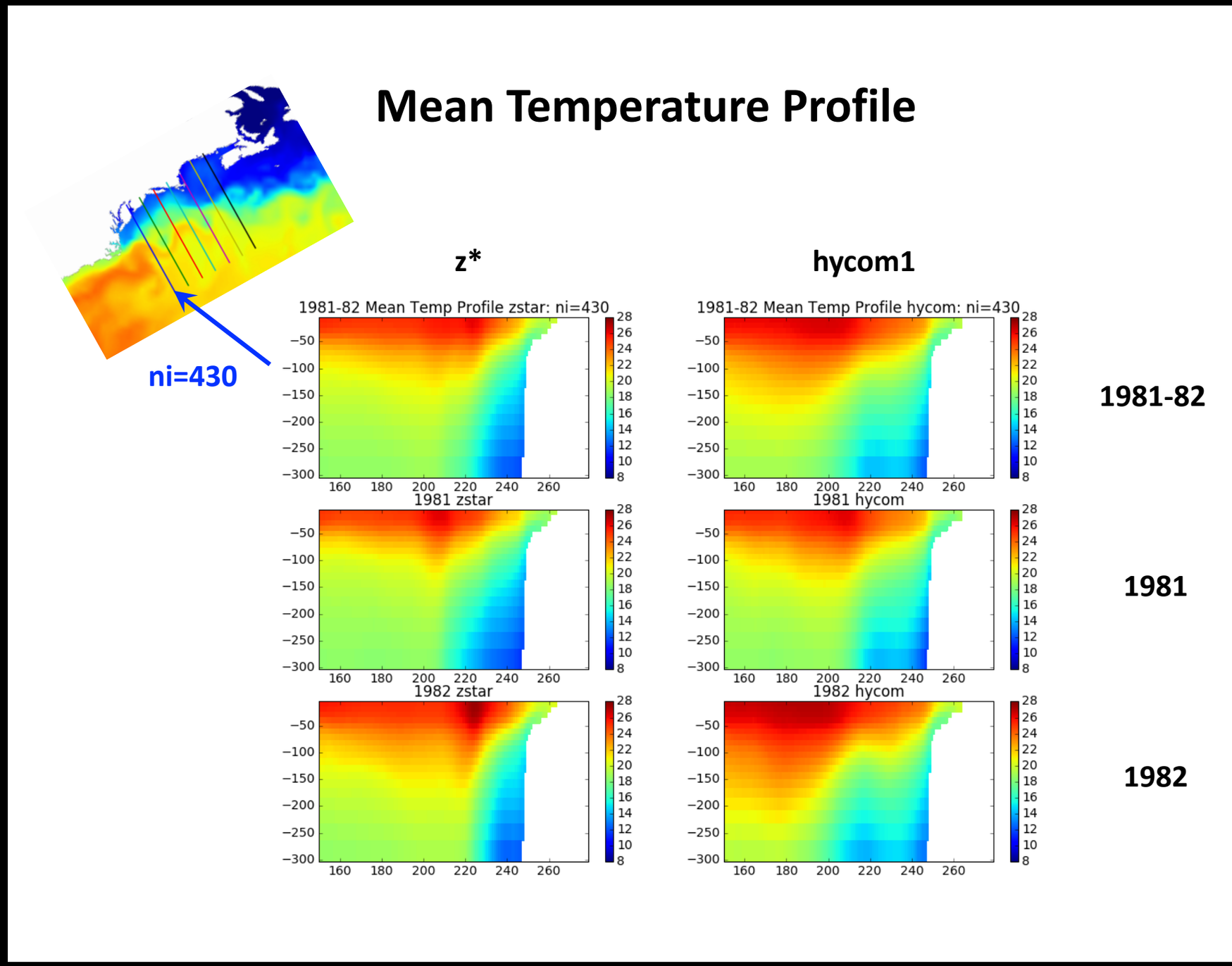



**Hycom1** **z* NK=75** **Observation**

# MOM6 Implementations:  NW Atlantic



# MOM6 Implementations:
# NW Atlantic temperature transects



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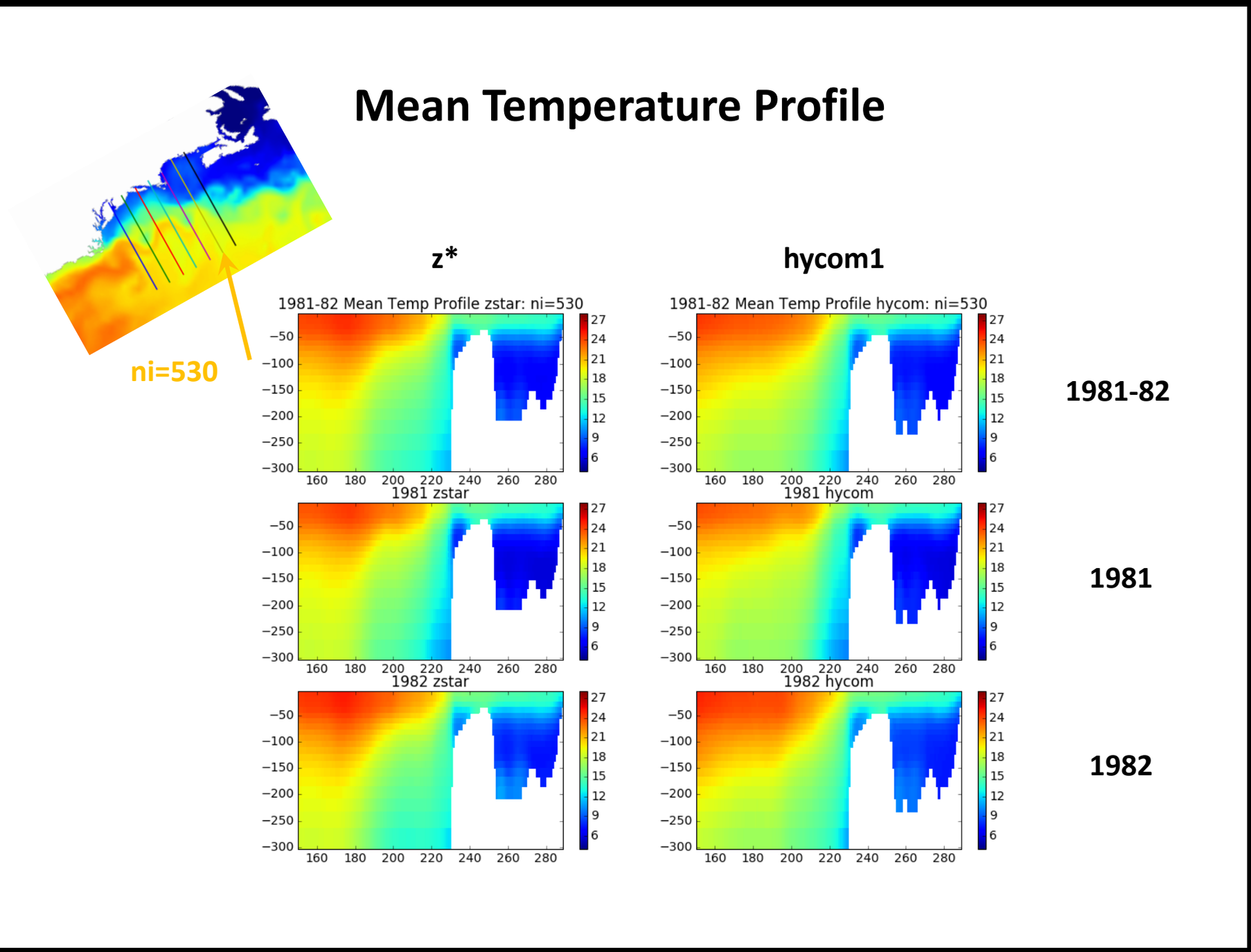
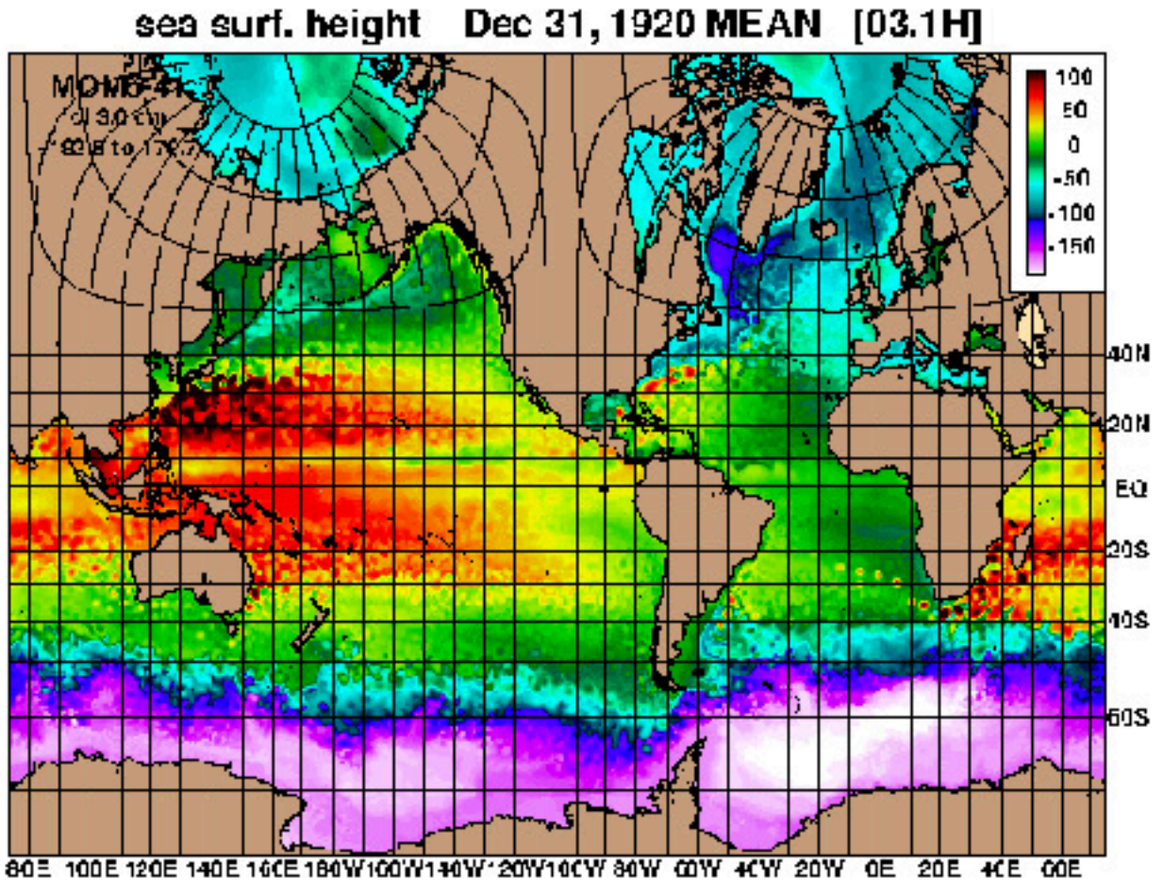


# 1/12° GLOBAL COMPARISON OF HYCOM AND MOM6

- The Navy's Global Ocean Prediction System (GOFS) 3.1 runs every day
  - https://www.hycom.org/dataserver/gofs-3pt1/analysis
    - HYCOM+CICE on a 1/12° global tripole grid
    - HYCOM has 41 hybrid layers in the vertical
- Use the Navy's GOFS 3.1 configuration for MOM6+SIS2
- Repeat CFSR 2003 atmospheric forcing for 10 model years

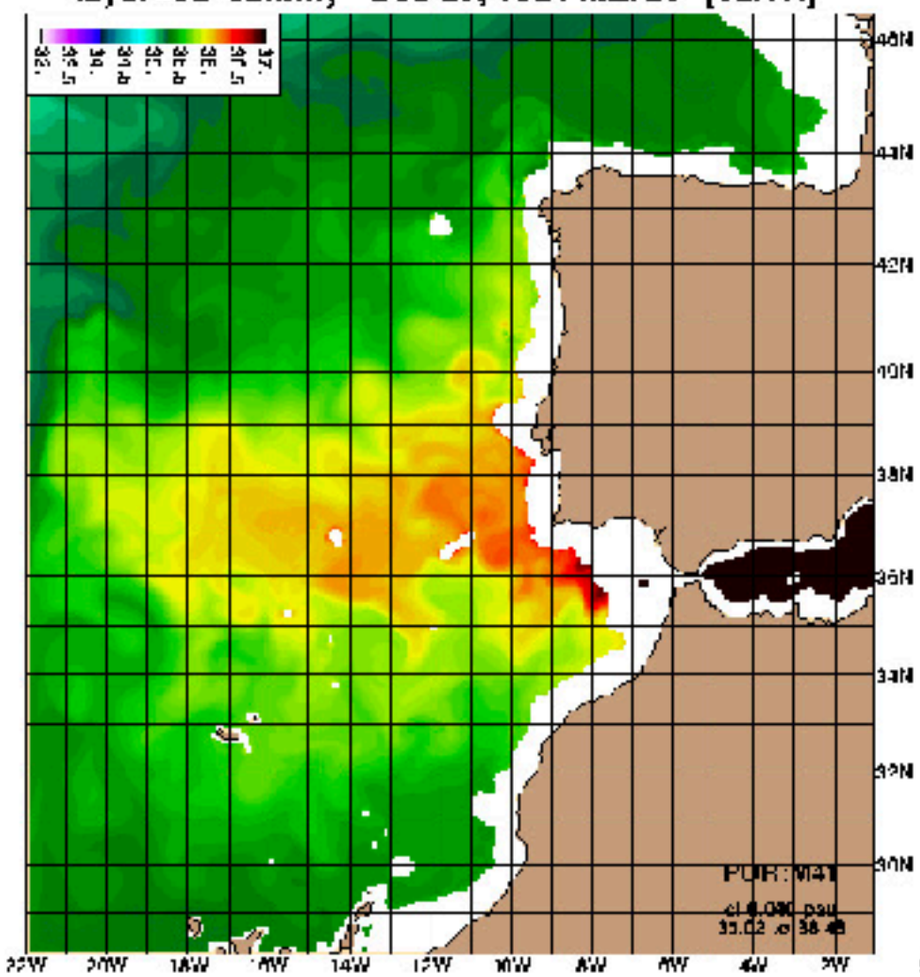



**Courtesy of A. Wallcraft and E. Chassignet**

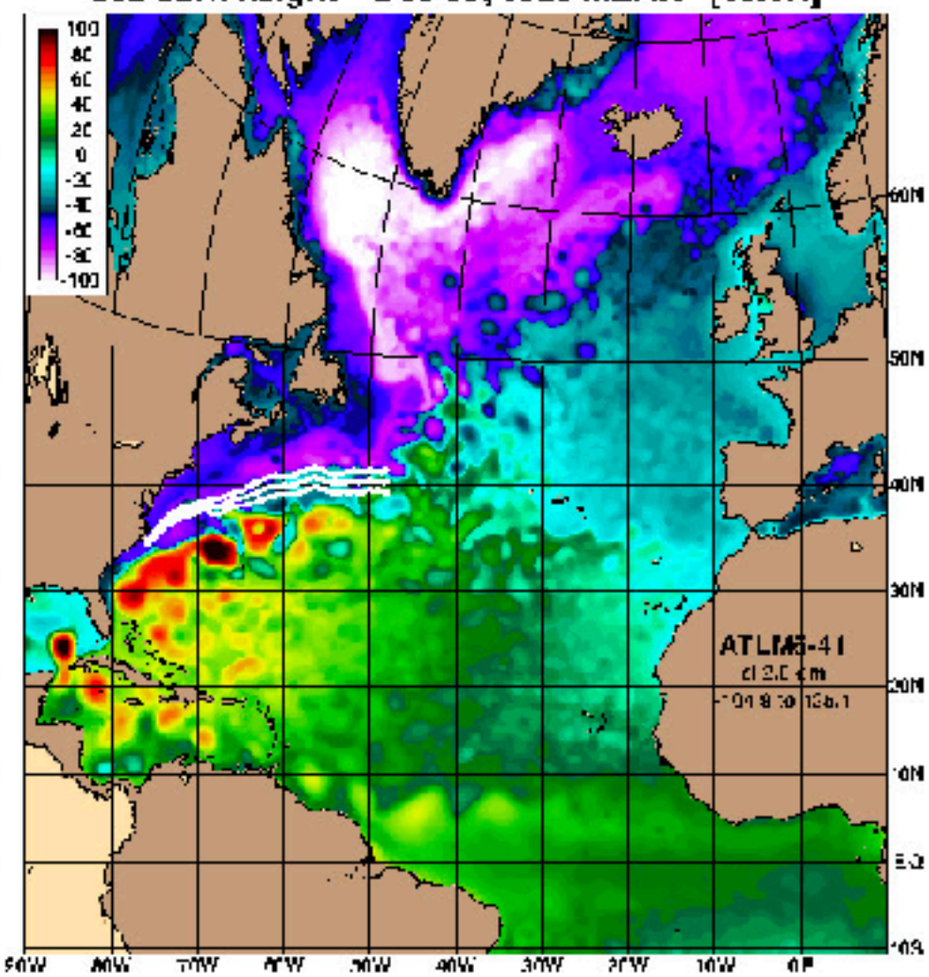
# REGIONAL MOM6 DOMAINS SUBSETTING 1/12° GLOBAL (I)

- Used to inexpensively explore model issues
- Sponge zone at "open" boundaries
  - Relax to monthly climatology in layer space

**Strait of Gibralter Overflow**




**Atlantic North of 28S**

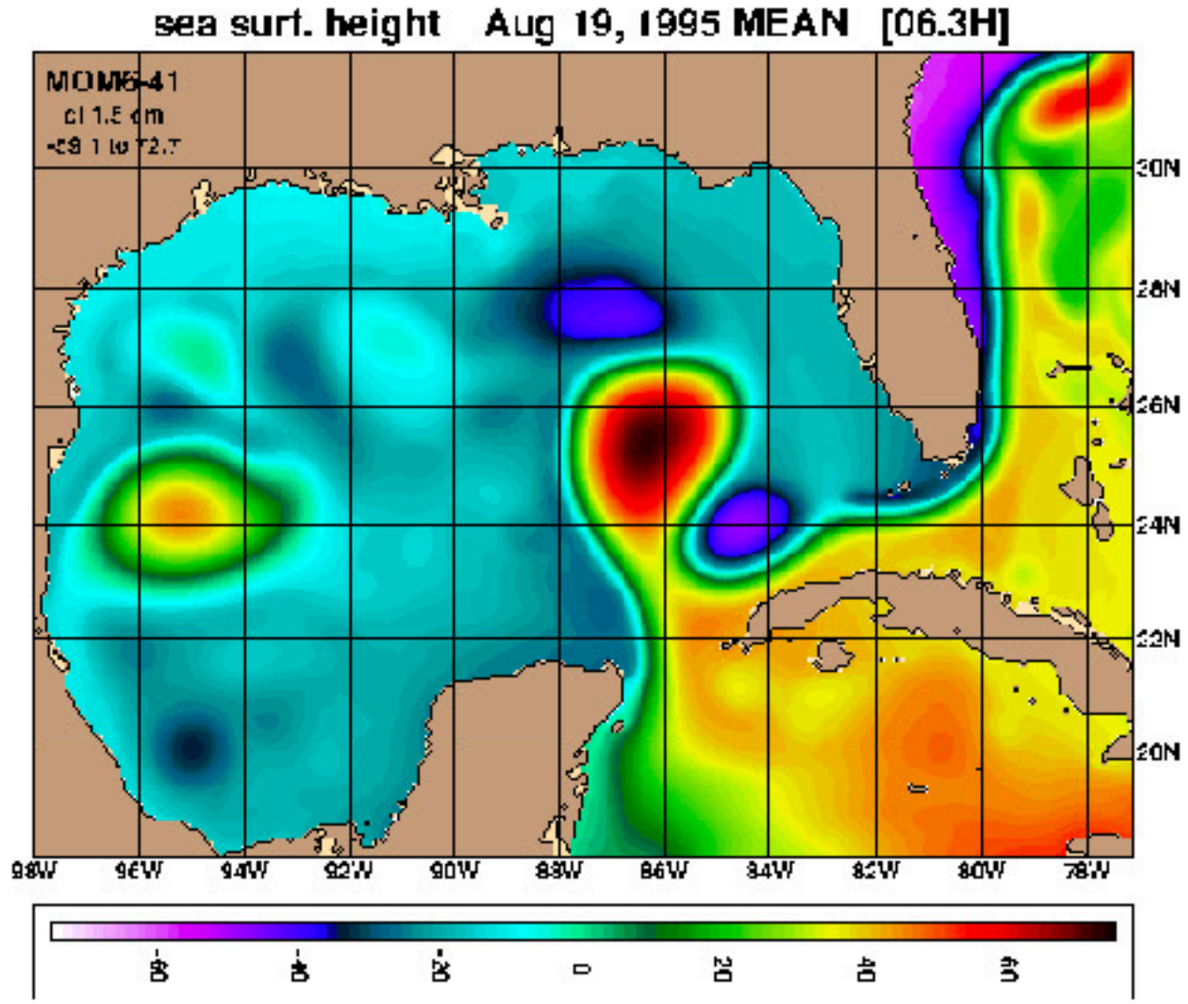



Courtesy of A. Wallcraft and E. Chassignet

# REGIONAL MOM6 DOMAINS SUBSETTING 1/12° GLOBAL (II)

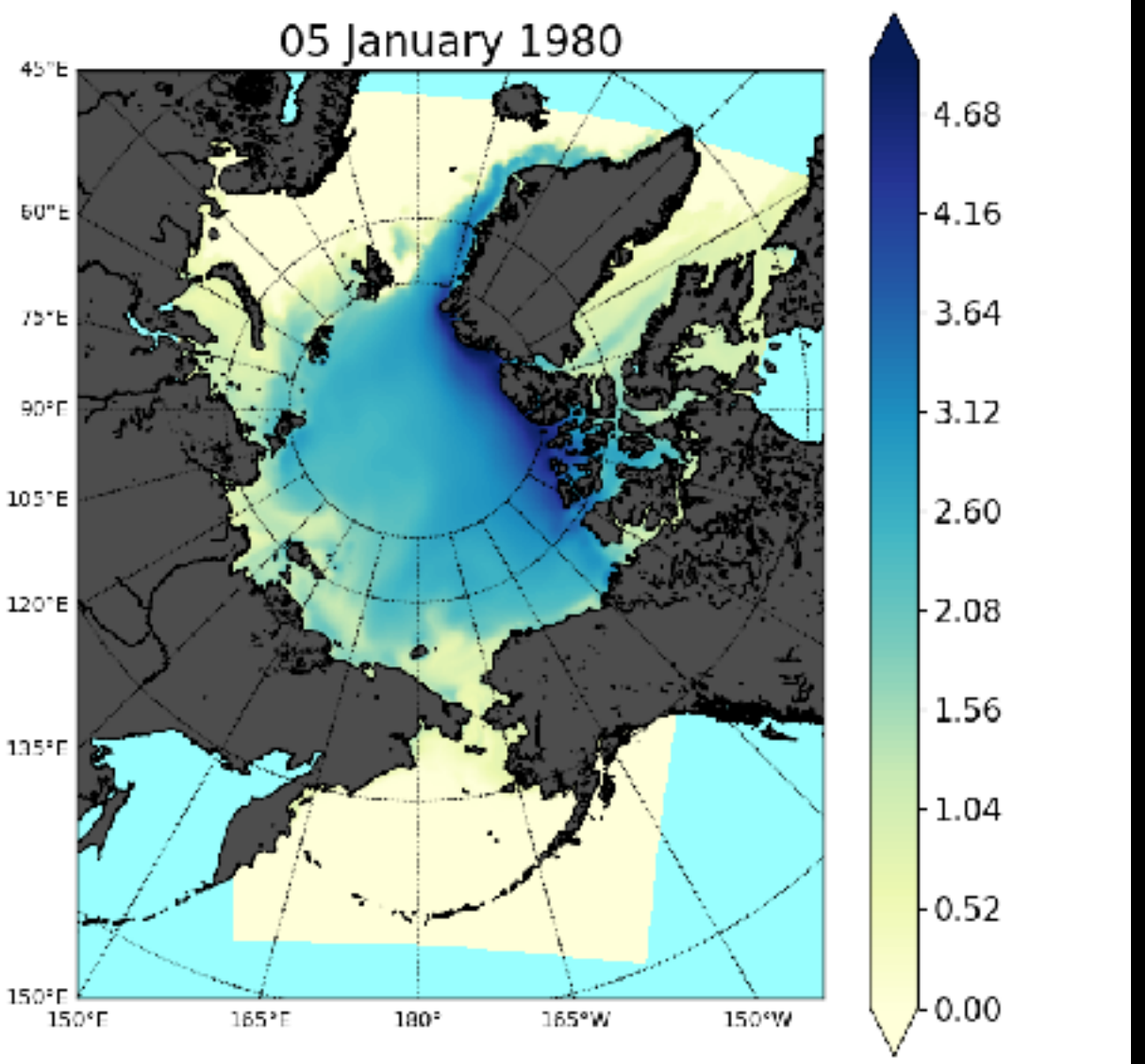
- Gulf of Mexico
  - open boundaries: FLATHER,ORLANSKI,NUDGED

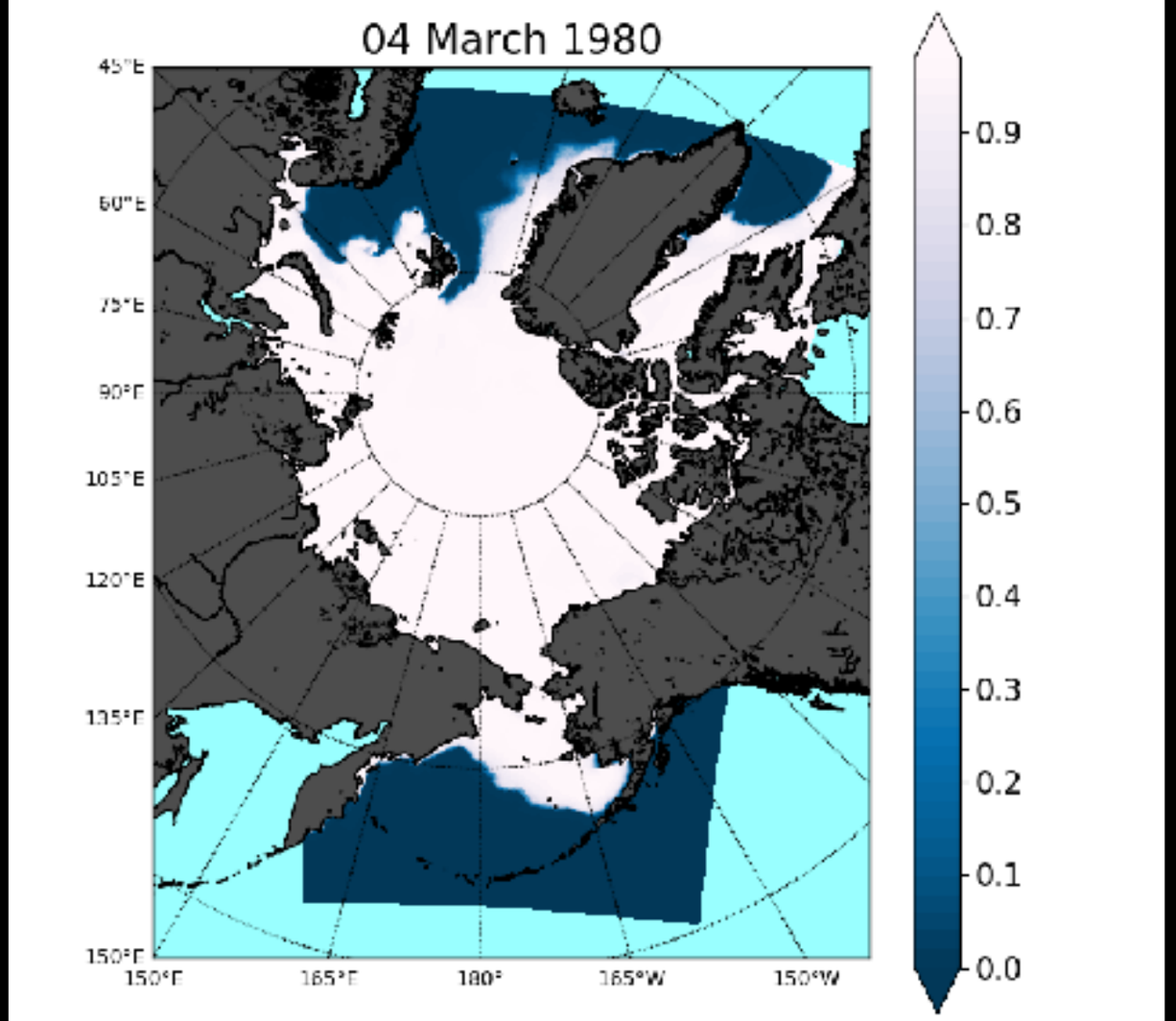
    daily boundary conditions from
    - Global MOM6 simulation or GOFS 3.1 reanalysis



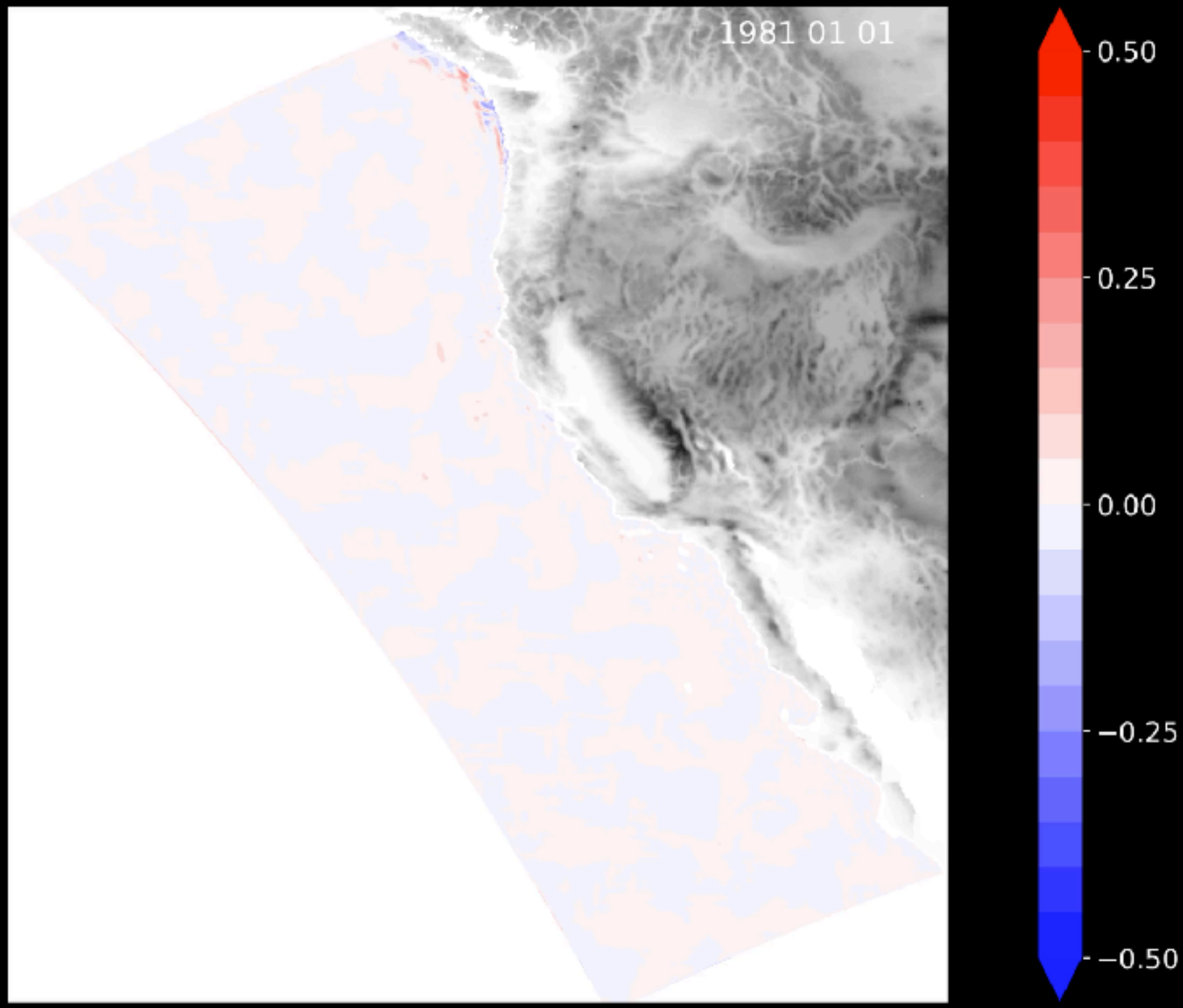

Courtesy of A. Wallcraft and E. Chassignet

# MOM6 Implementations:  Arctic



# MOM6 Implementations:  California Current Vorticity



# Summary

- A community is rapidly building for Regional MOM6 for weather to climate applications
- Imminent developments:
  - Explicit tides at the boundary (A. Ross @GFDL)
  - Tracer and BGC boundary conditions (N. Zadeh @GFDL)
  - Improved sponge layers (S. Bachman+ @NCAR)
- Wish list:
  - Two-way nesting
  - Fully embedded in coupled model
  - Improved OBC dynamics?