MODELED UPPER OCEAN RESPONSE TO HURRICANE KATRINA AND TYPHOON KAI-TAK

Yu-heng Tseng
Department of Atmospheric Sciences
National Taiwan University
yhtseng@as.ntu.edu.tw

Collaborators:

McGill University, Quebec, Canada: Peter Yau, Charles Lin, Xingbao Wang

Dalhousie University, Halifax, Nova Scotia, Candada: Jinyu Sheng

AcuSea, Albuquerque, USA David E. Dietrich

National Central University, Taiwan: Sen Jan

National Taiwan University, Taiwan: T. Y. Tang, I-I Lin and Ya-ting Chang

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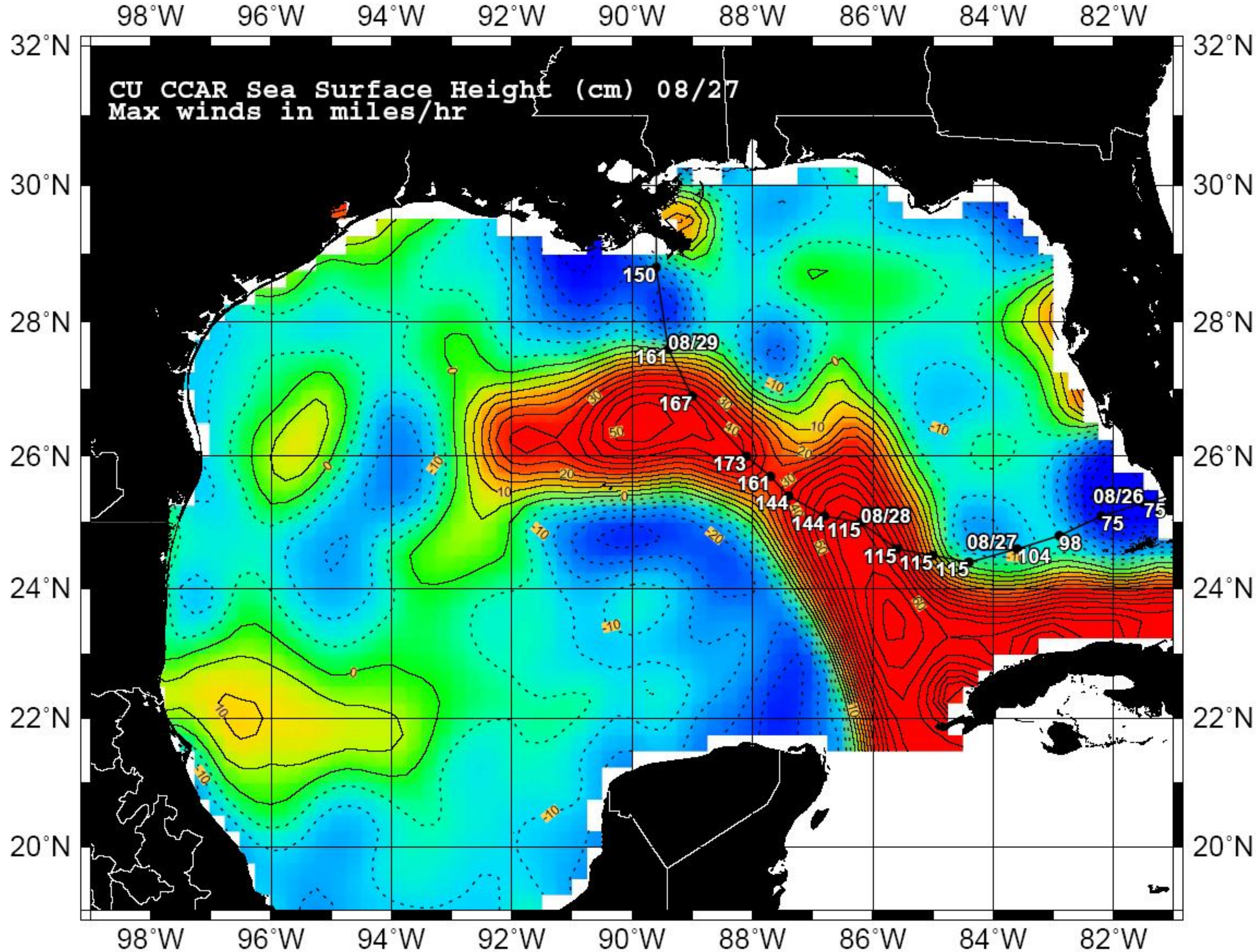
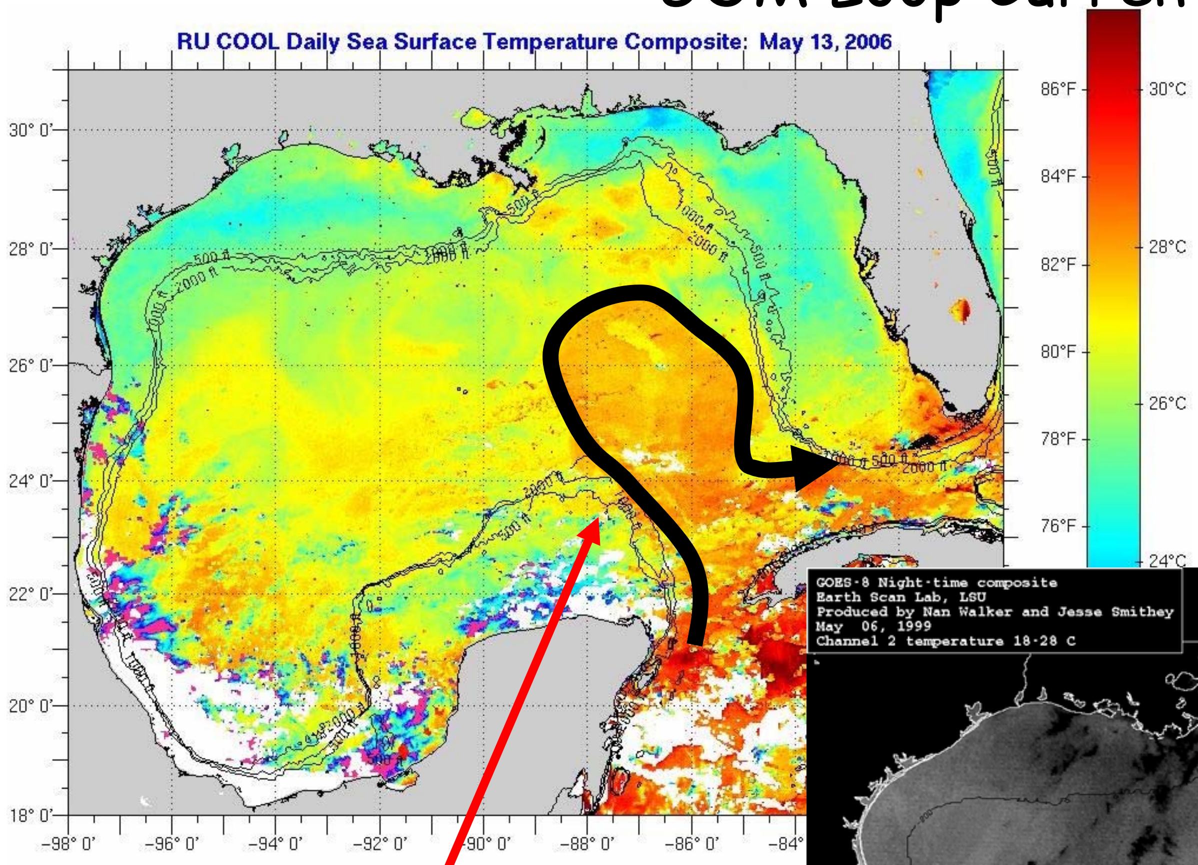
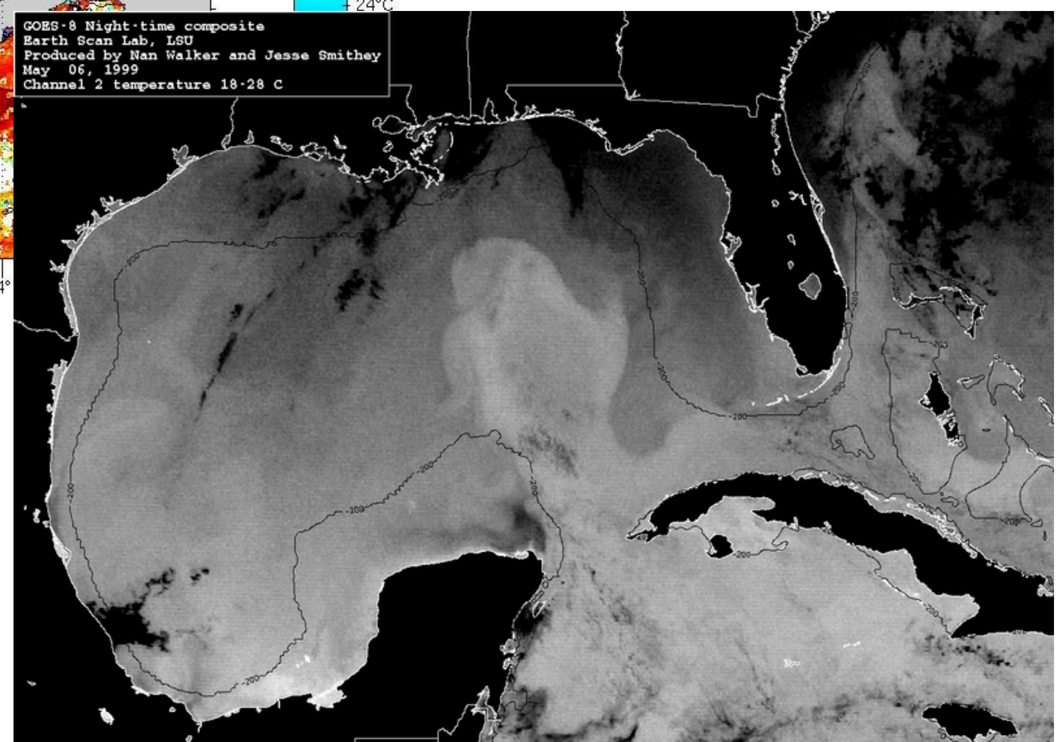
- Model description
- Storm induced circulation in the Gulf of Mexico during Hurricane Katrina
- Storm induced circulation in the South China Sea during Typhoon Kai-tak (validation)
- Summary and conclusion

Observed Sea Surface Height during Katrina



GOM Loop Current





Warm eddy enhances the development of Katrina

Animation

MEDiNA model:

Bathymetry (km) and sub-domains

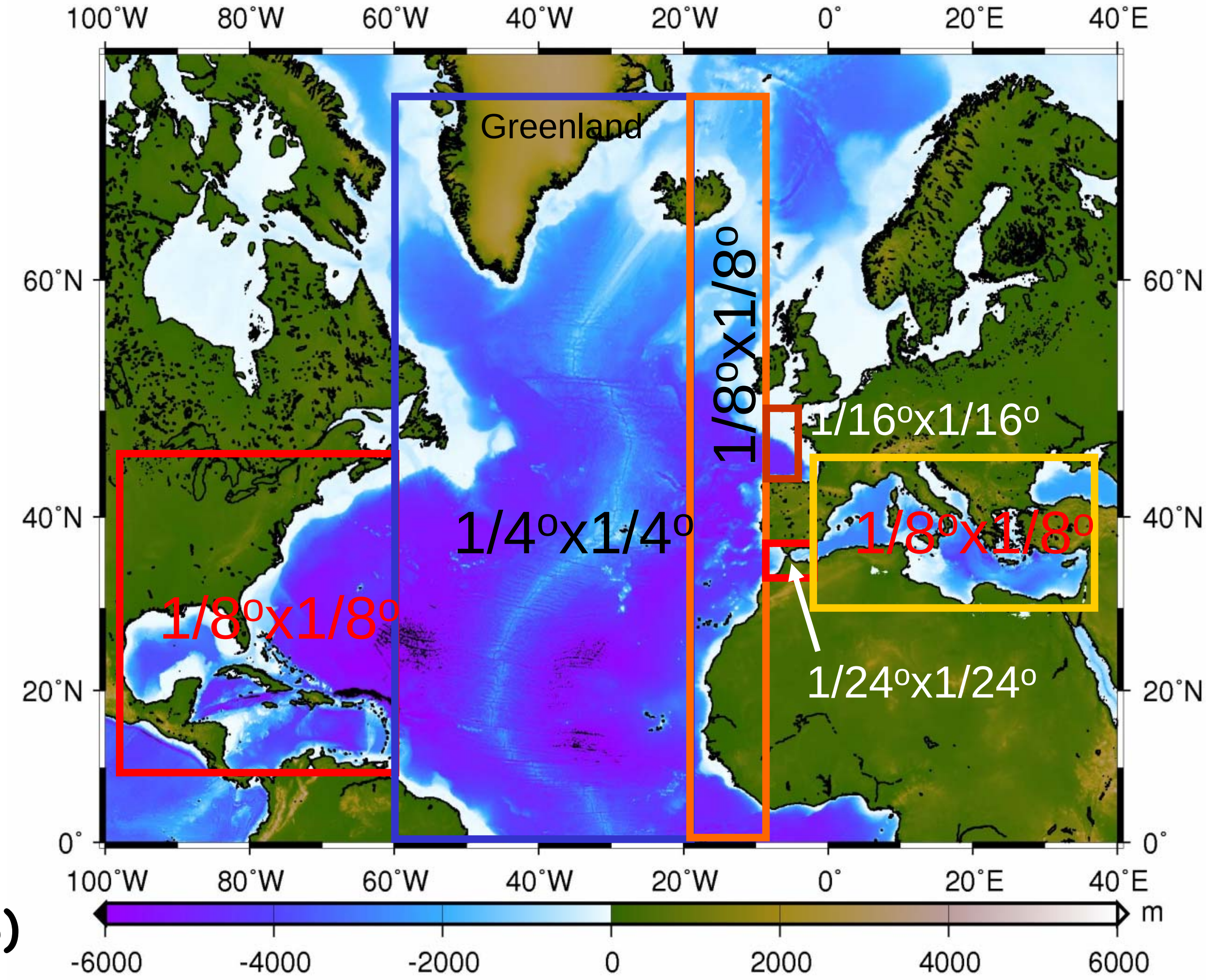
Six domain:

- GOM (1/8°) 304x336
- NAB (1/4°) 162x398
- IBE (1/8°) 100x794
- VIS (1/16°) 60x158
- GIB (1/24°) 125x107
- MED (1/8°) 316x157

30 vertical layers;

top layer 11 m thick;

bottom layer 750 m thick

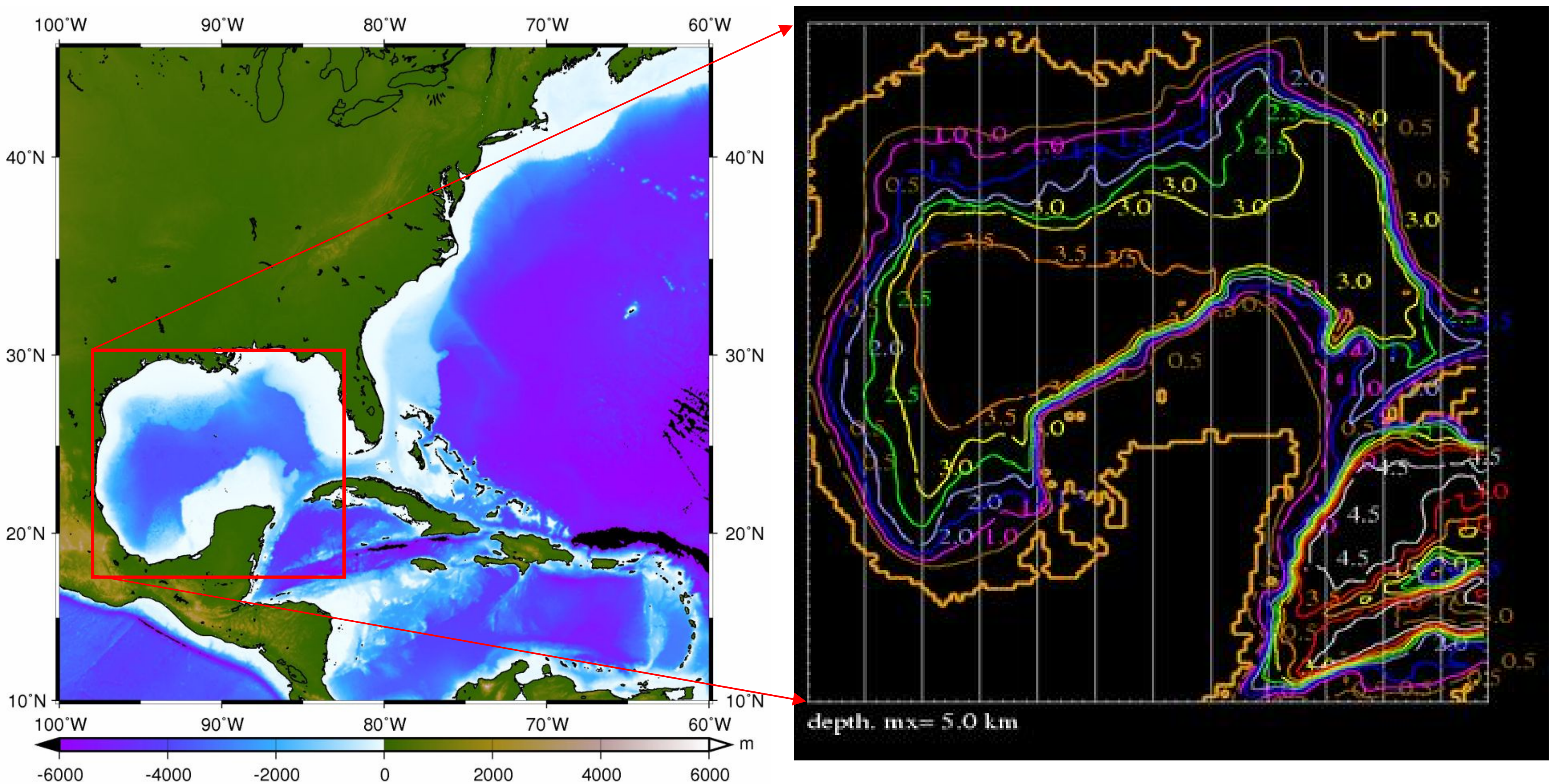


Dietrich et al. (2008)

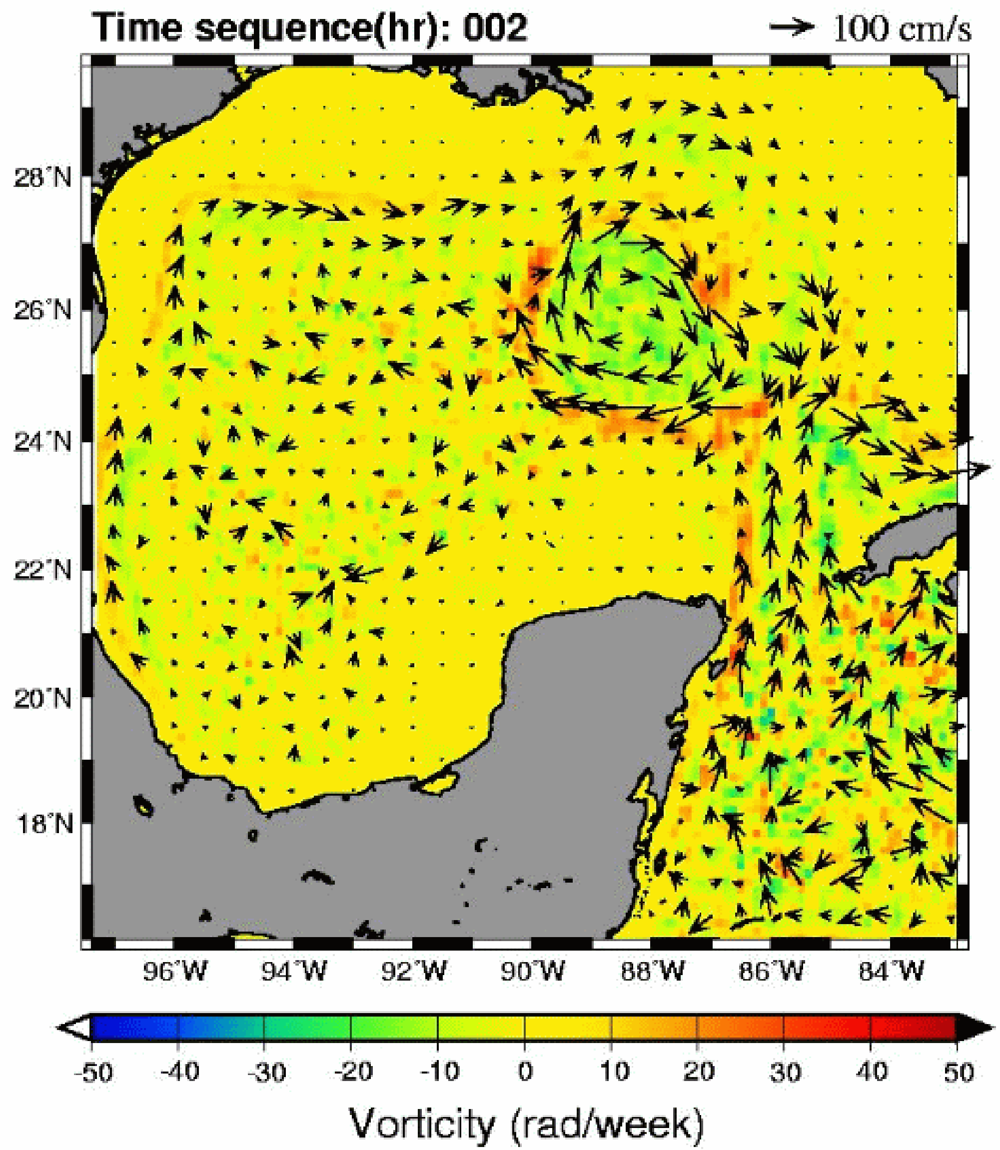
Initialization

- The "initial conditions" (before Katrina winds are applied) are derived from the MEDiNA model using annual cycle climatological wind forcing.
- Surface heat and freshwater fluxes are derived from a non-damping, zero-phase-lag approach that supercedes conventional Haney restoring.
- During model years 15 and 24, the Gulf of Mexico Loop Current is extended far northward into the Gulf of Mexico during August in those two model climatological years. Such deep penetration during August occurs about one year out of ten as expected.
- Both times, the Loop Current flow is similar to the conditions before Katrina. However, the SST is about 2°C cooler than the observed extremely warm conditions just before Katrina.
- To get better initial SST conditions, satellite observed temperature is assimilated for 30 days just before Katrina using a simple projection method to get a more realistic surface mixed layer.

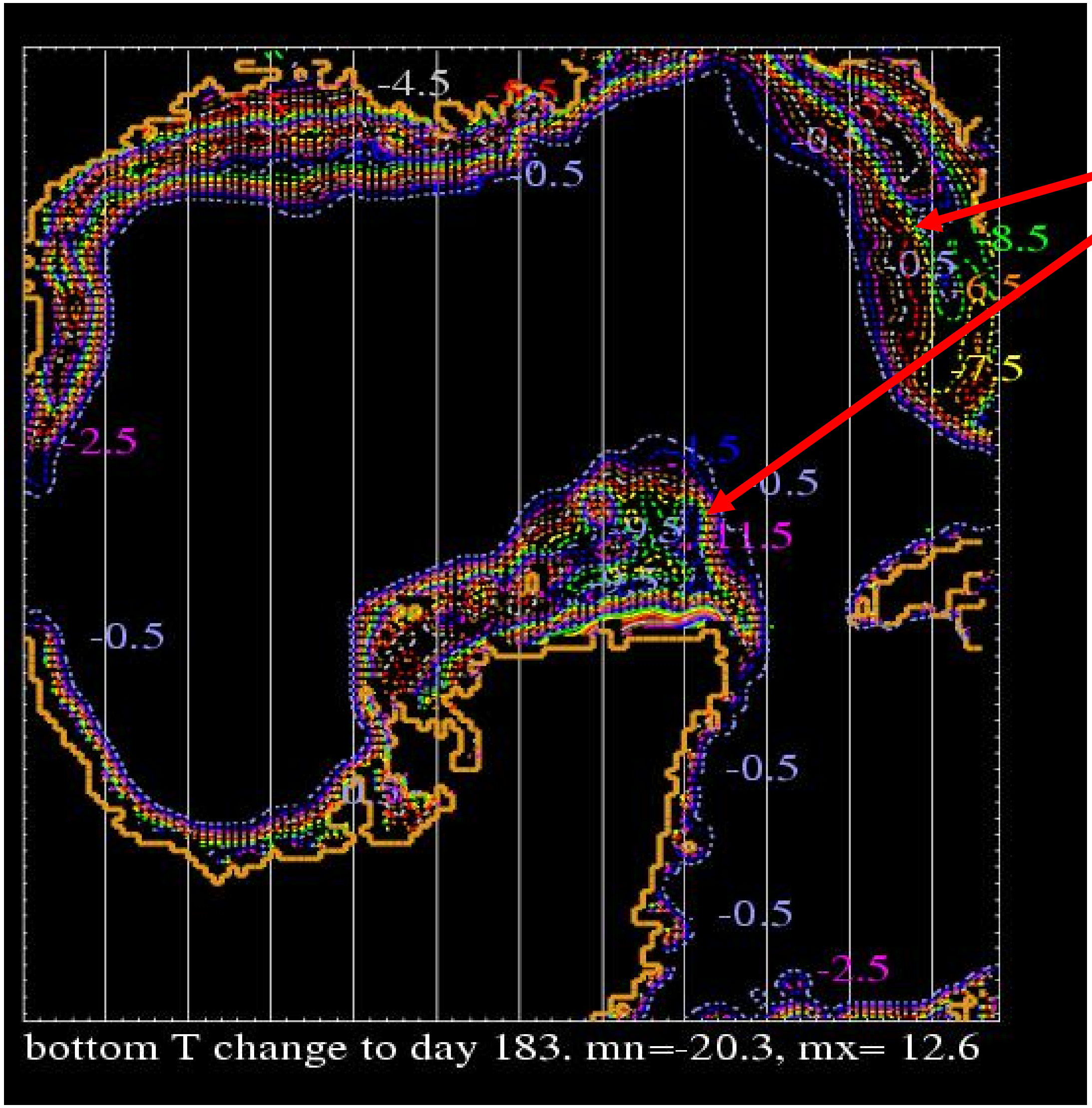
Bathymetry zoom to Gulf of Mexico



Surface layer vorticity and velocity (animation with 2 hour interval between frames)

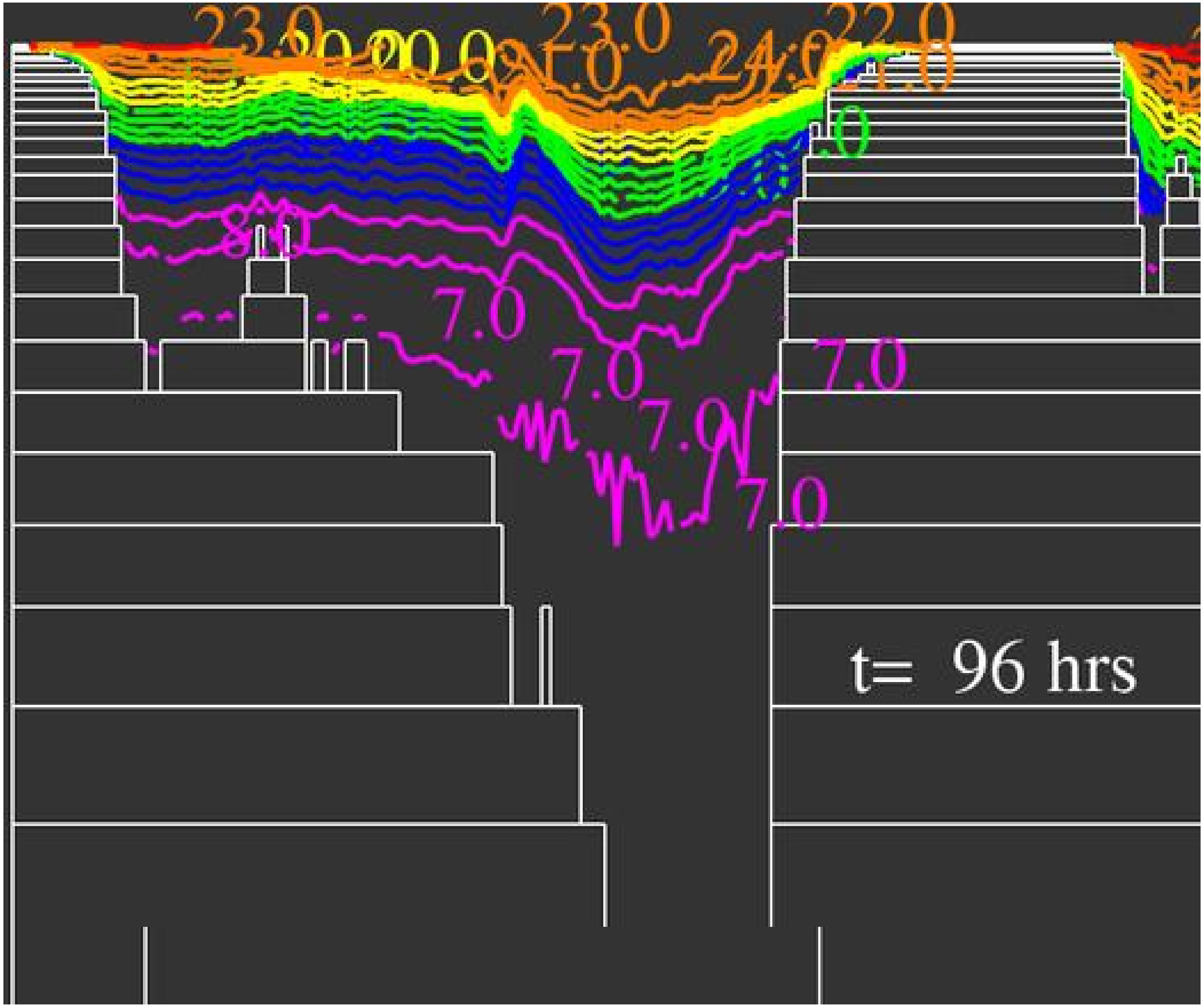


Bottom T change



Upwelling and cooling

Vertical-longitudinal (zonal) section



REMARKS

- The fully coupled MEDINA model is used to simulate the response to Hurricane Katrina winds derived from an MM5 based hurricane model.
- An energetic mesoscale eddy with current speeds larger than 4 m/s and horizontal scale 50-100km. Buoyancy and strong wind forcing appear to play a big role in energizing such an energetic eddy.
- Strong surface and bottom cooling is found resulting from the vertical mixing and topographical upwelling.
- Strong inertial oscillation is also induced.
- big problem! No detailed observation for comparison. Only NDBC buoy 42001, 42003, 42040 (information mostly related to waves)

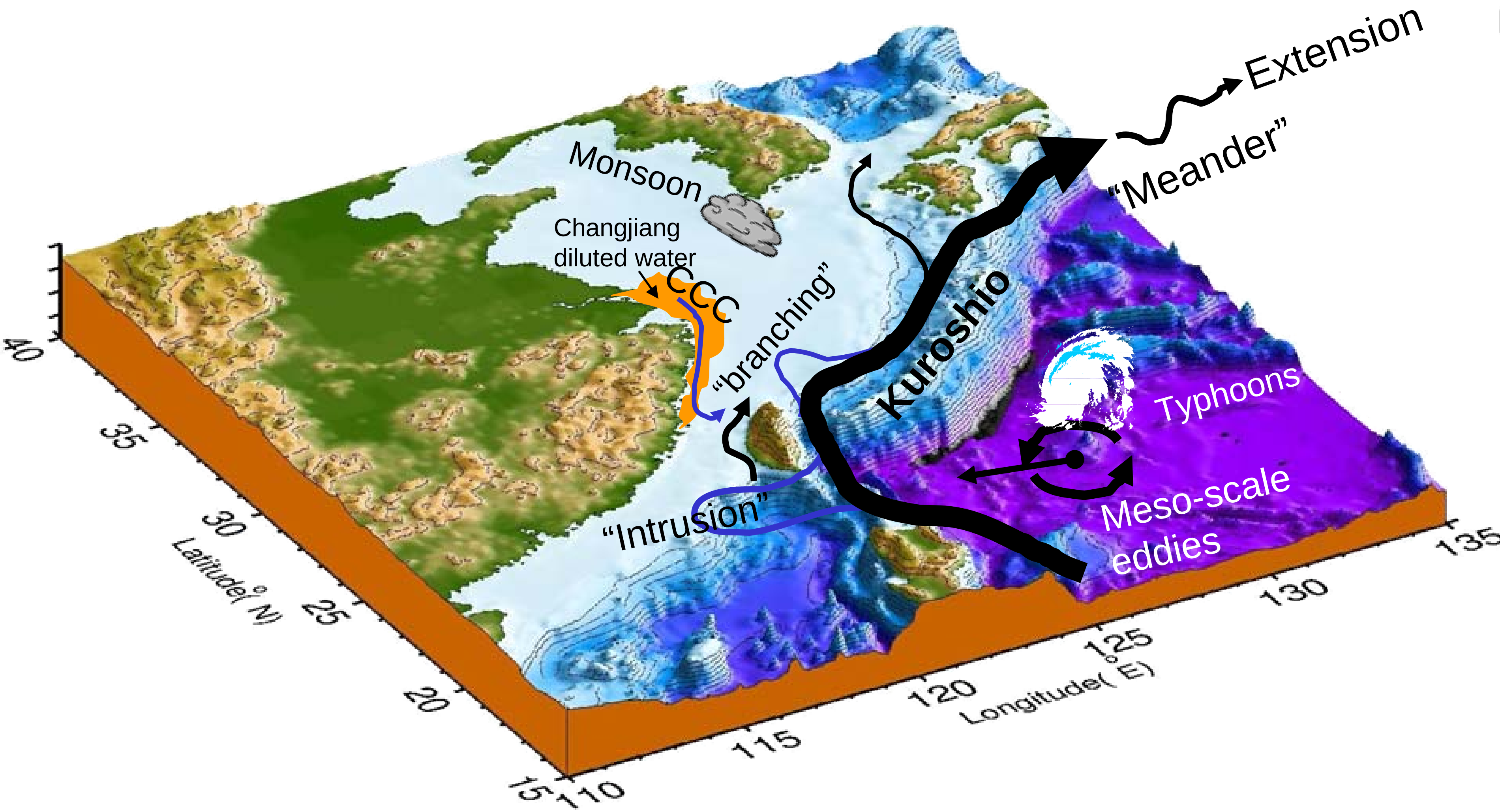
NEED VALIDATIONS

Category	Mph (m/s)
1	74-95 (33-42)
2	96-110 (43-49)
3	111-130 (50-58)
4	131-155 (59-69)
5	156 (70)>

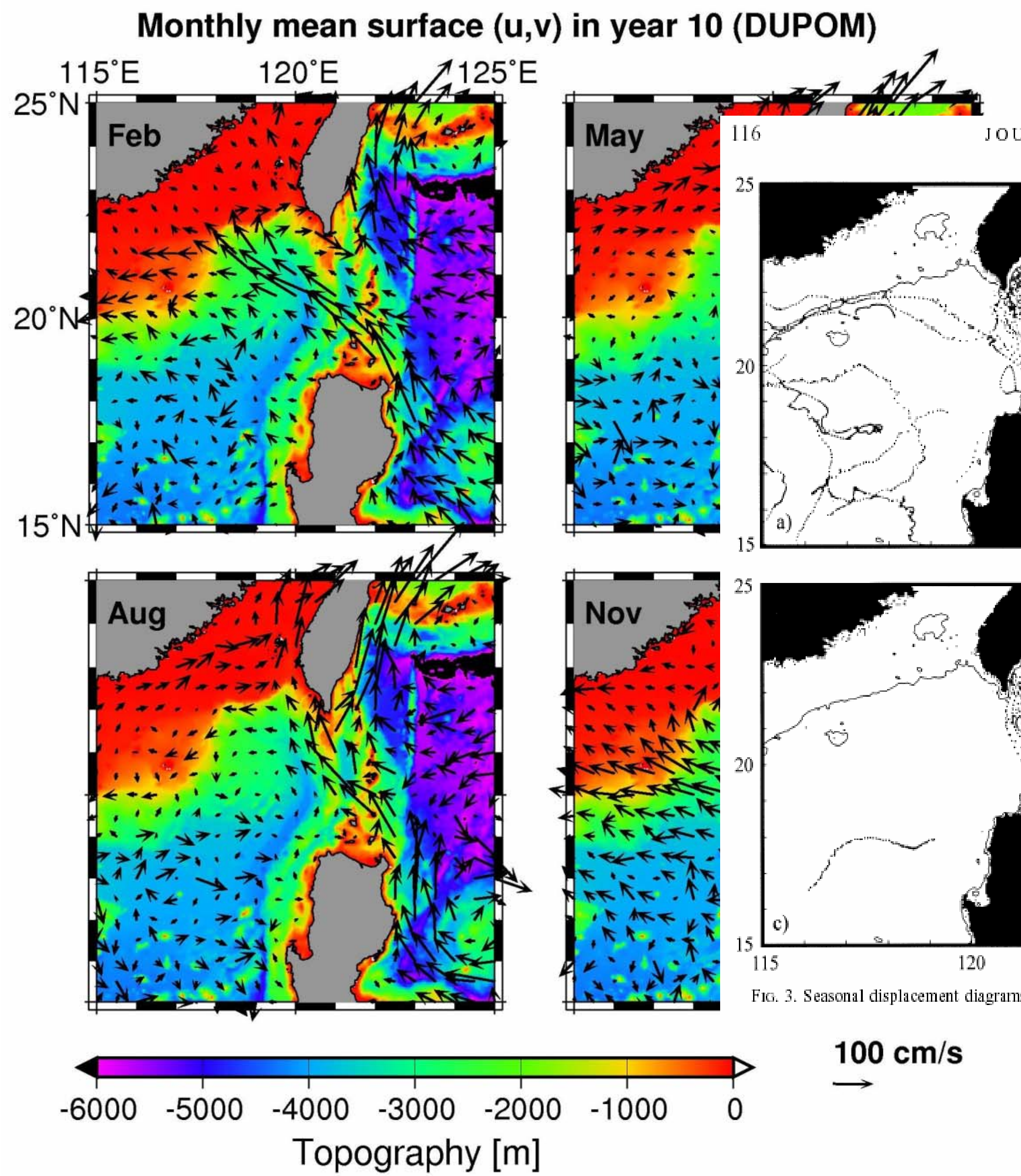
- Hurricane Katrina
  - Cat. 5
  - Most destructive
- Typhoon Kai-Tak
  - Cat. 2
  - Most significant SST drop (8°C>)
  - Question: why the SST drops so significant?

Paradise of physical oceanography

Complicated circulation patterns in the East Asian seas



Seasonal variation of Kuroshio intrusion through the Luzon Strait



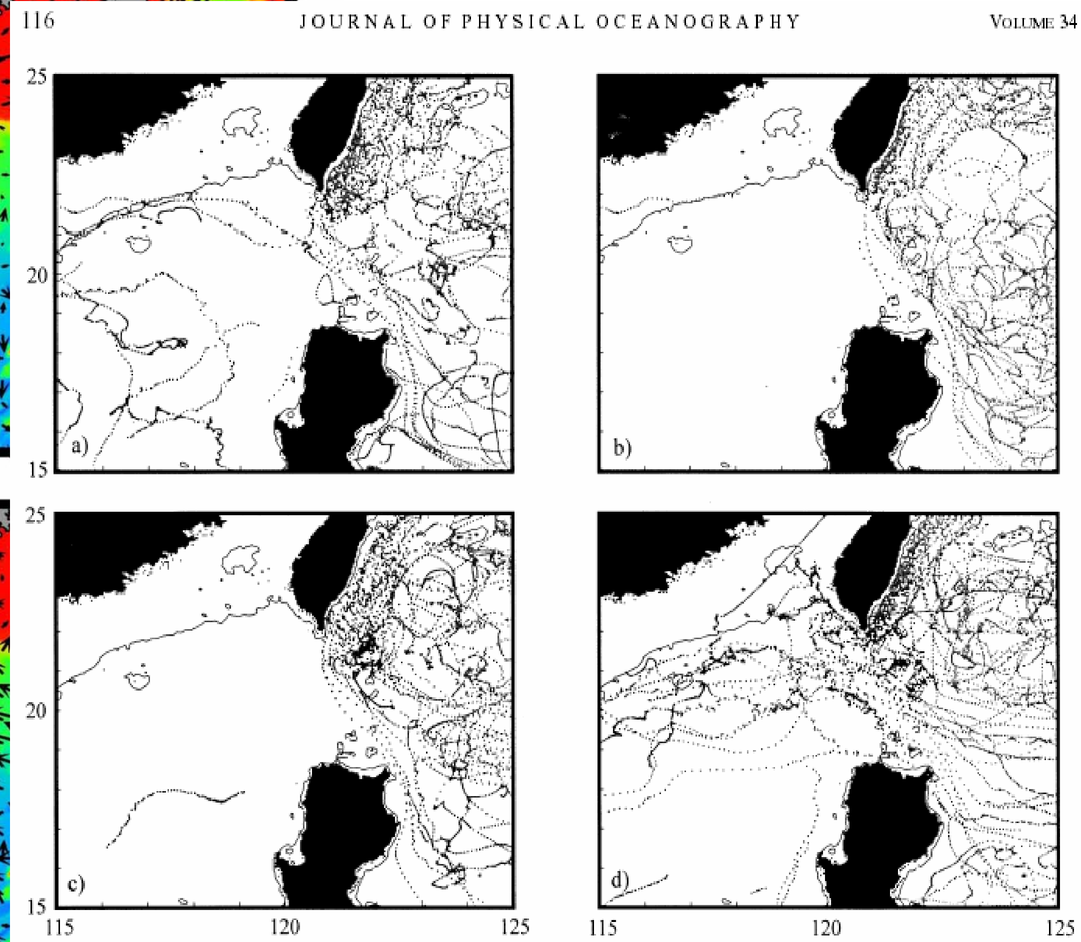
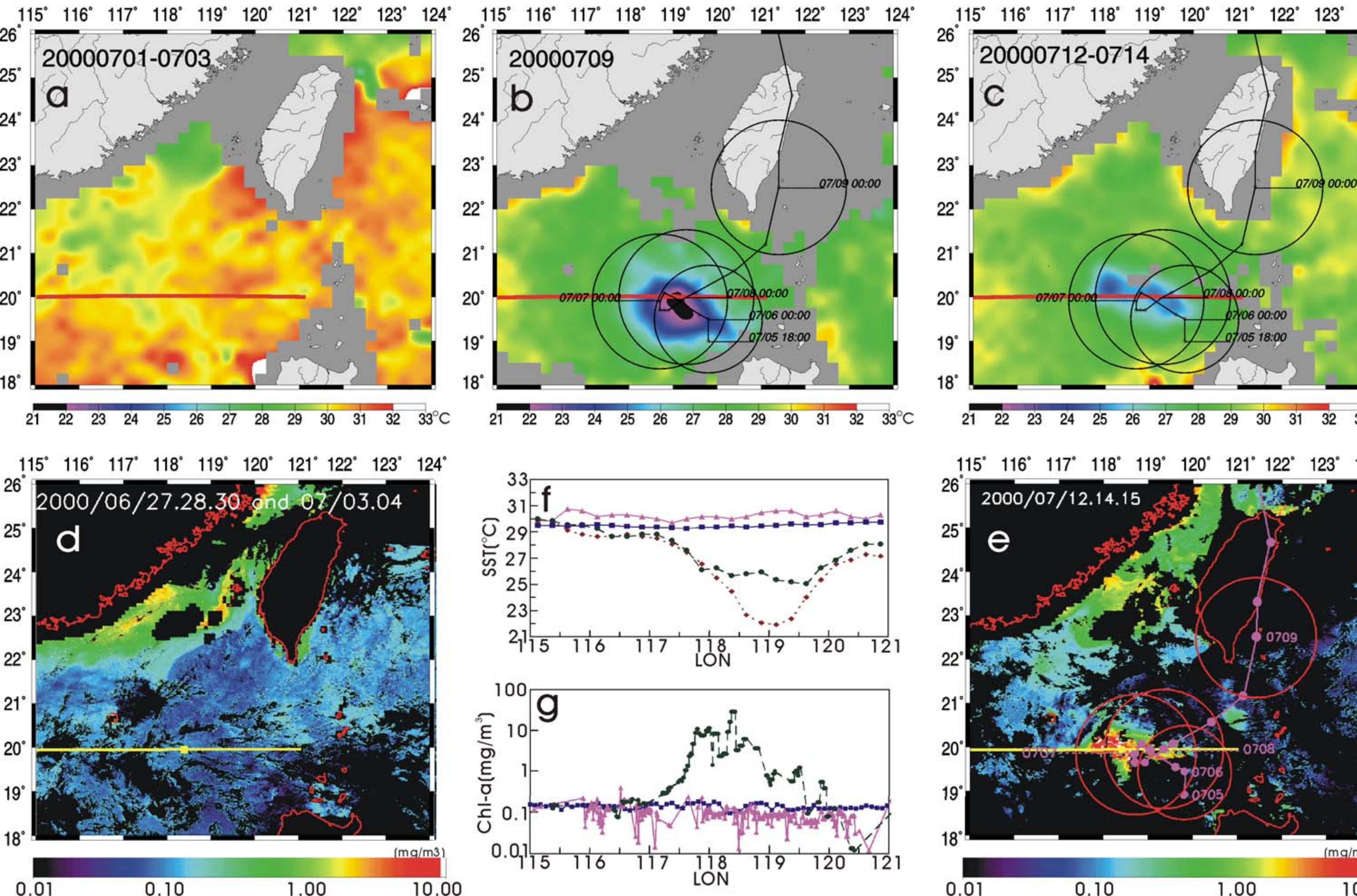
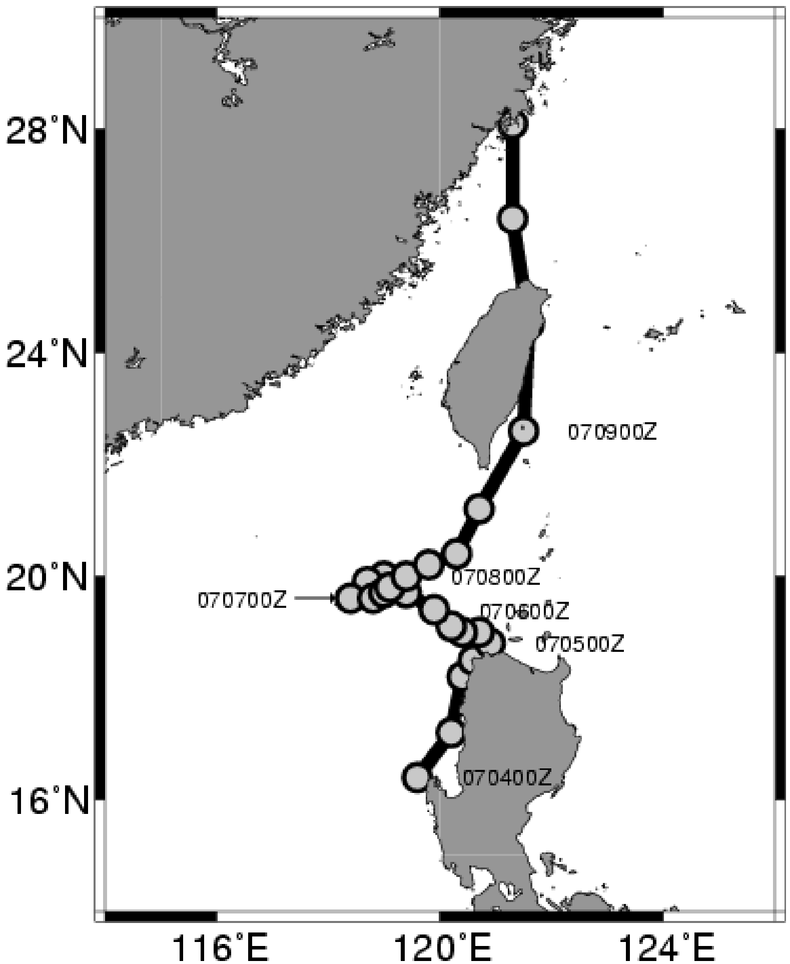


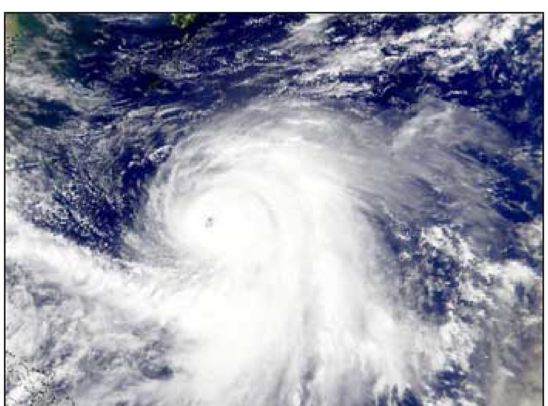
FIG. 3. Seasonal displacement diagrams of the drifters: (a) Jan–Mar, (b) Apr–Jun, (c) Jul–Sep, and (d) Oct–Dec. Contours of bottom depth are 200 m.

(Centurioni et al., 2004)

New Evidence for Enhanced Ocean Primary Production Triggered by Tropical Cyclone (Lin et al., 2003c; *GRL)*





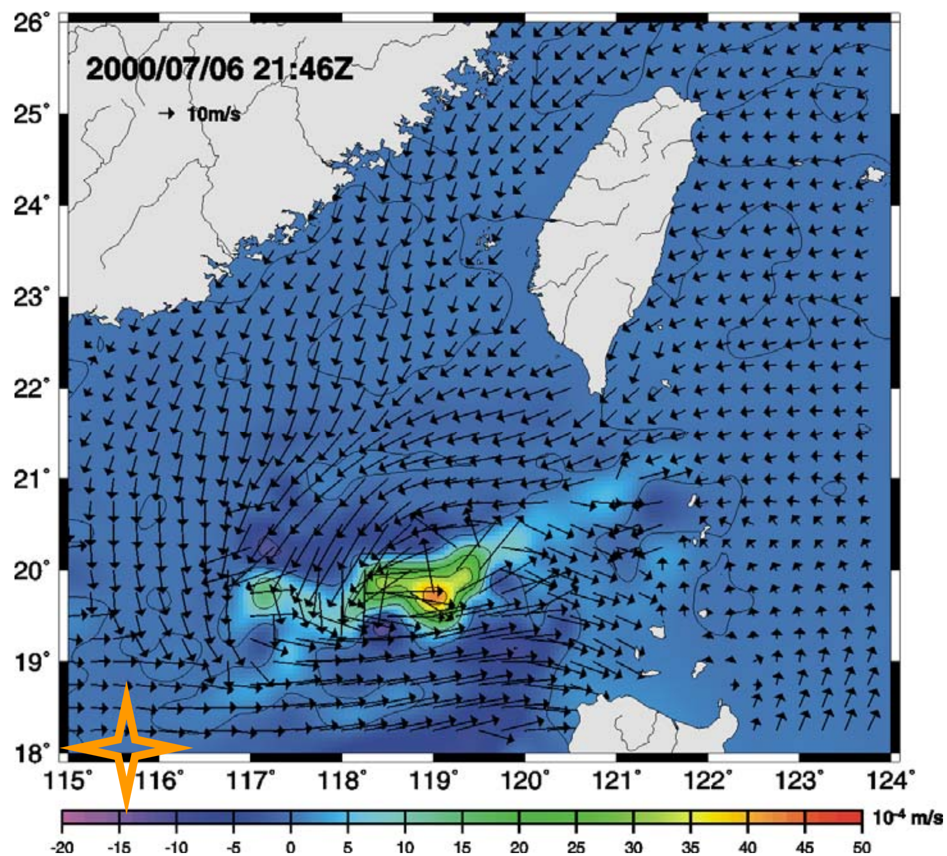


1. *Entrianment Depth (PWP model, Price et al., 86) : 90m*

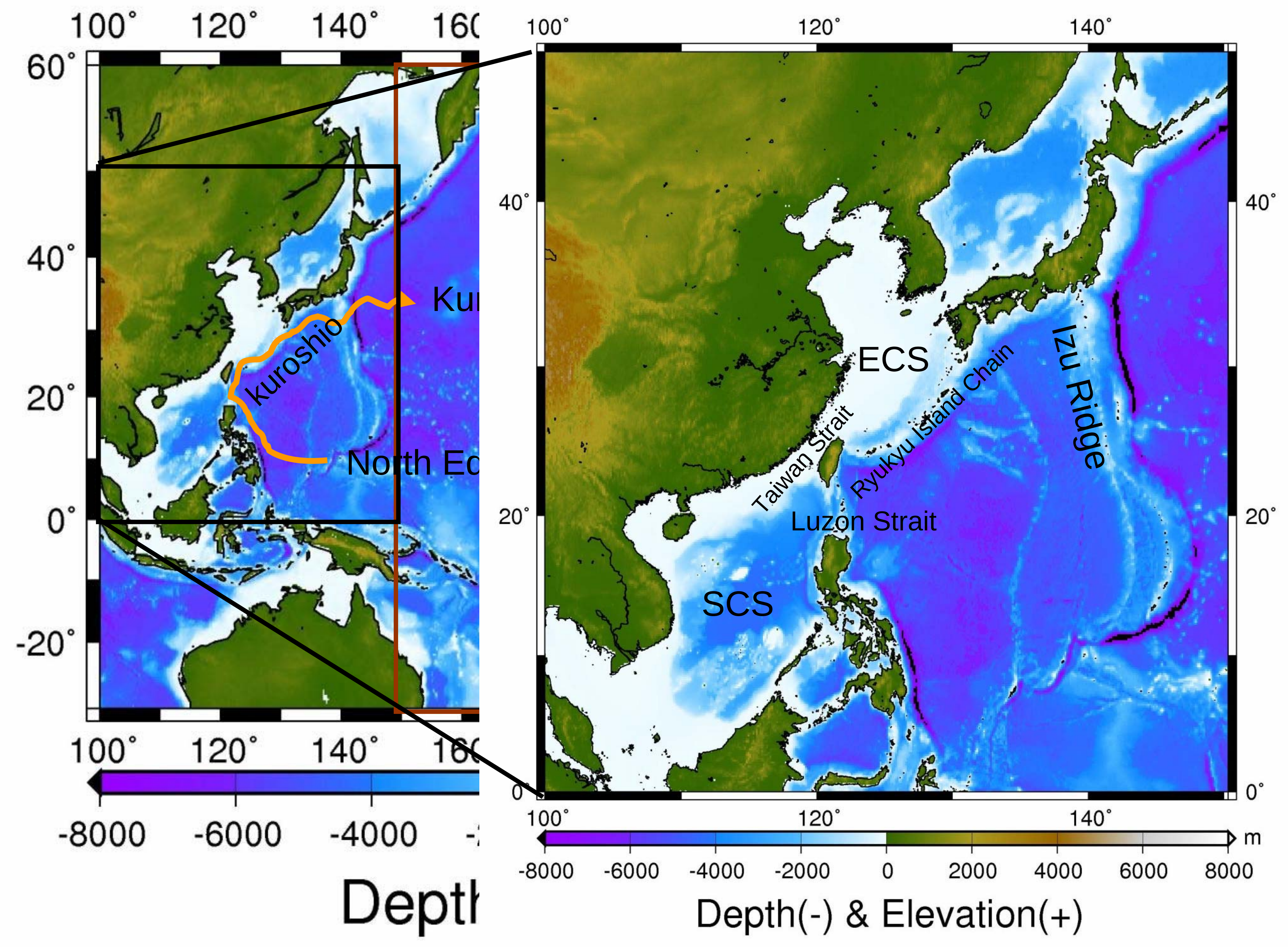
2. *Uh < 4m/s, Upwelling:*

$20 * 10^{-4}$ m/s

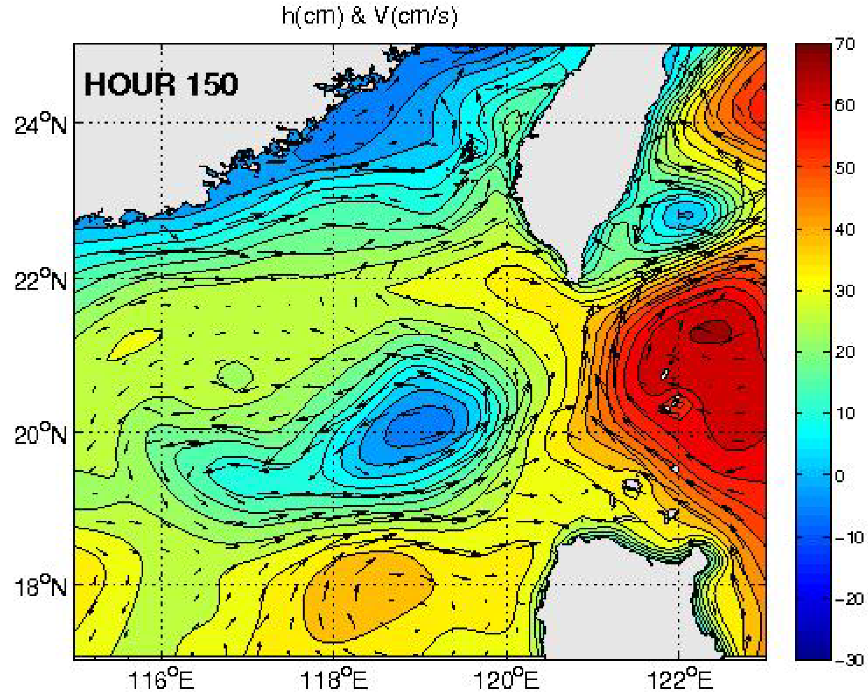
(100m for half inertial period)

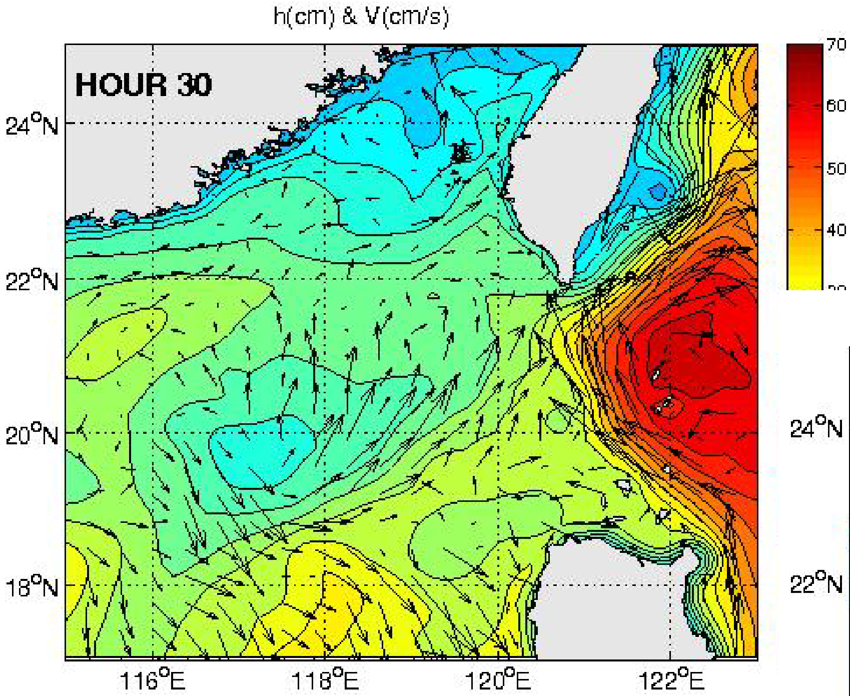


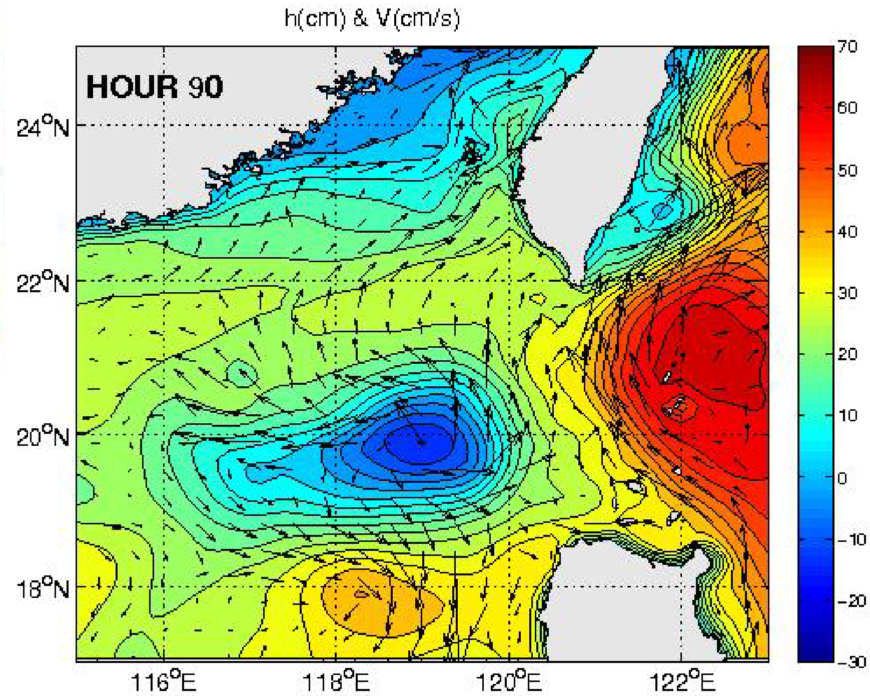
Duo Grid Pacific Ocean Model (DUPOM)



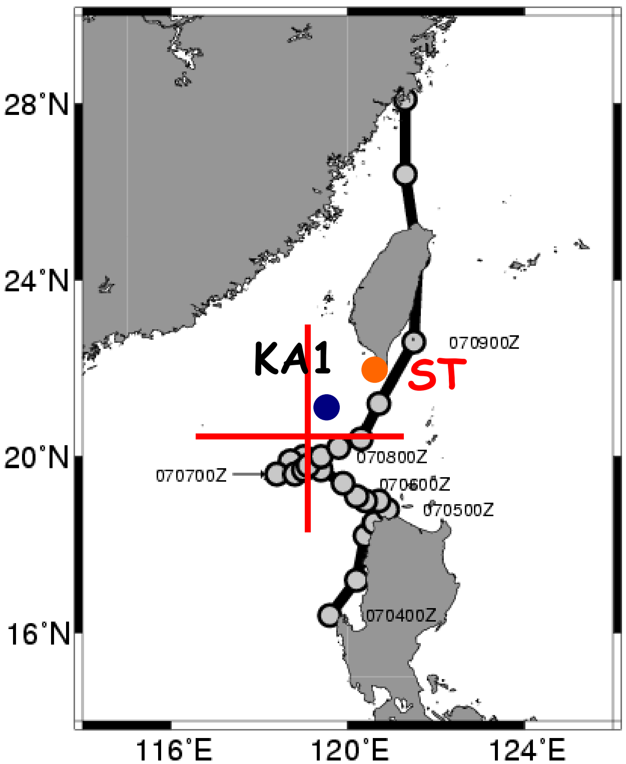
Surface pressure and velocity vectors



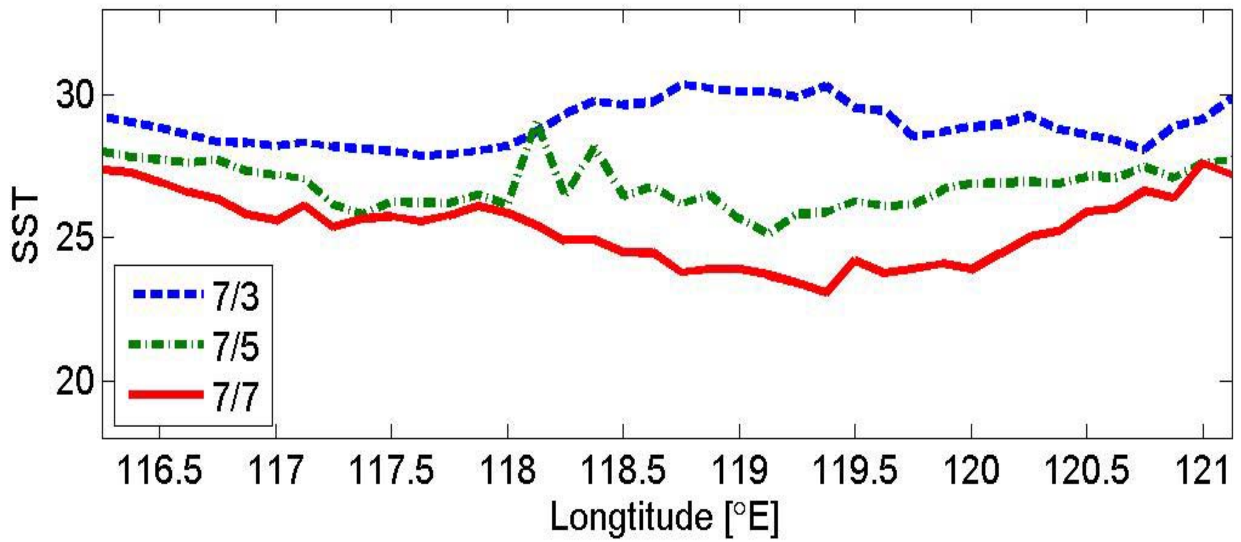


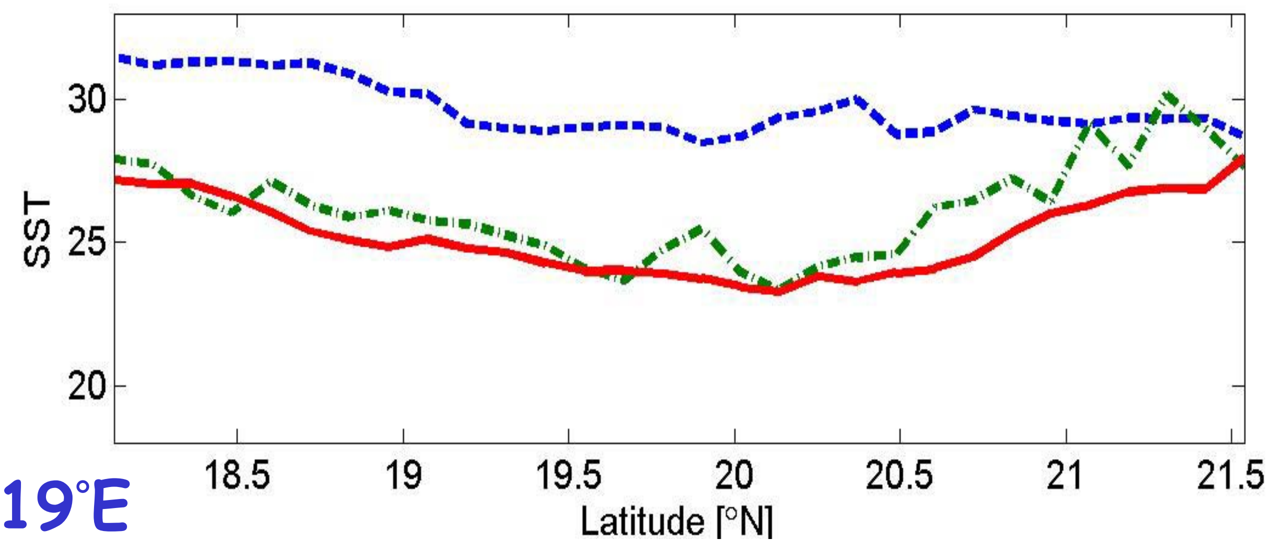


Modeled SSTs on different days



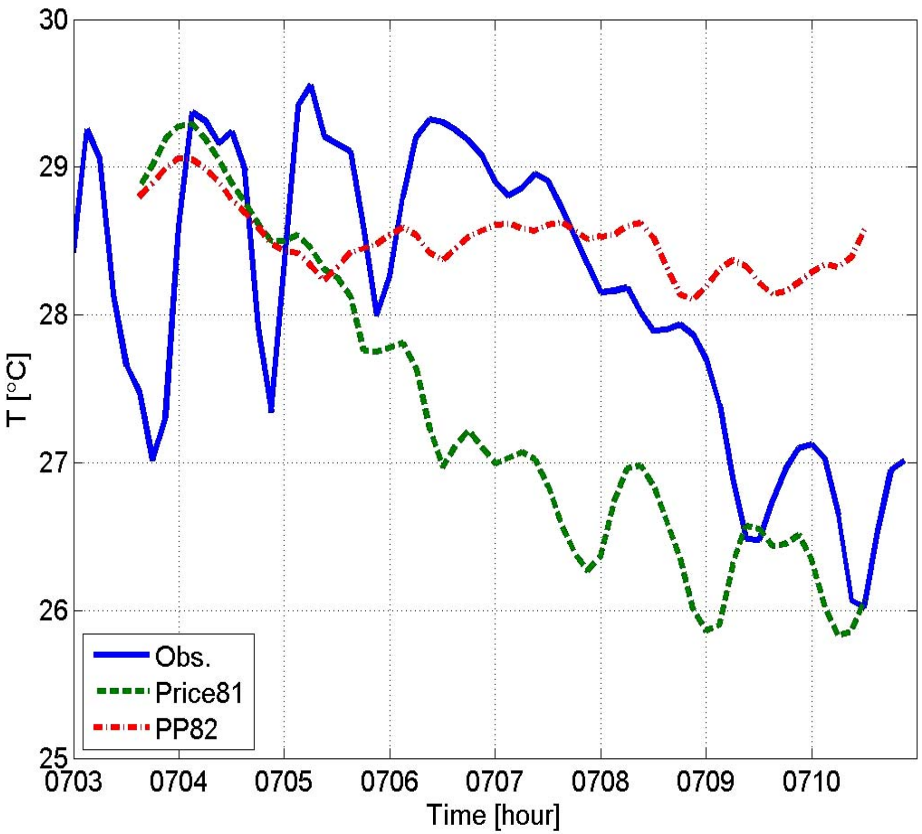
Along latitude 20.5°N





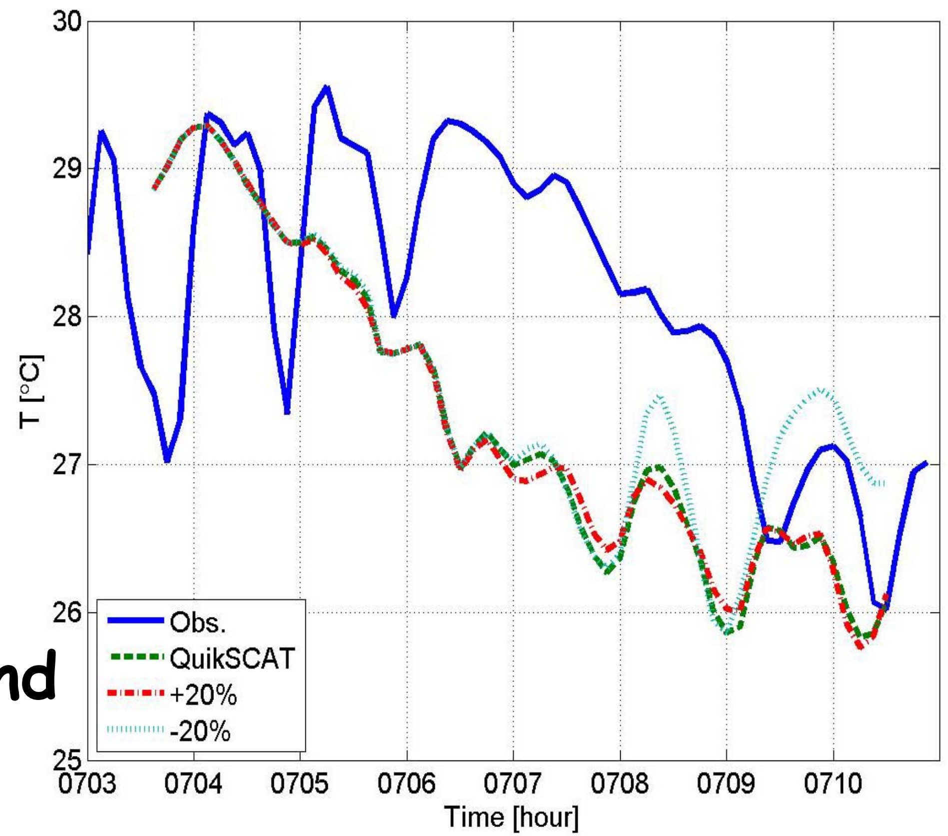
Along longitude 119°E

Comparisons with observation (station: ST)



Sensitivity of turbulent parameterization

Temperature drops due to vertical mixing and topographical upwelling

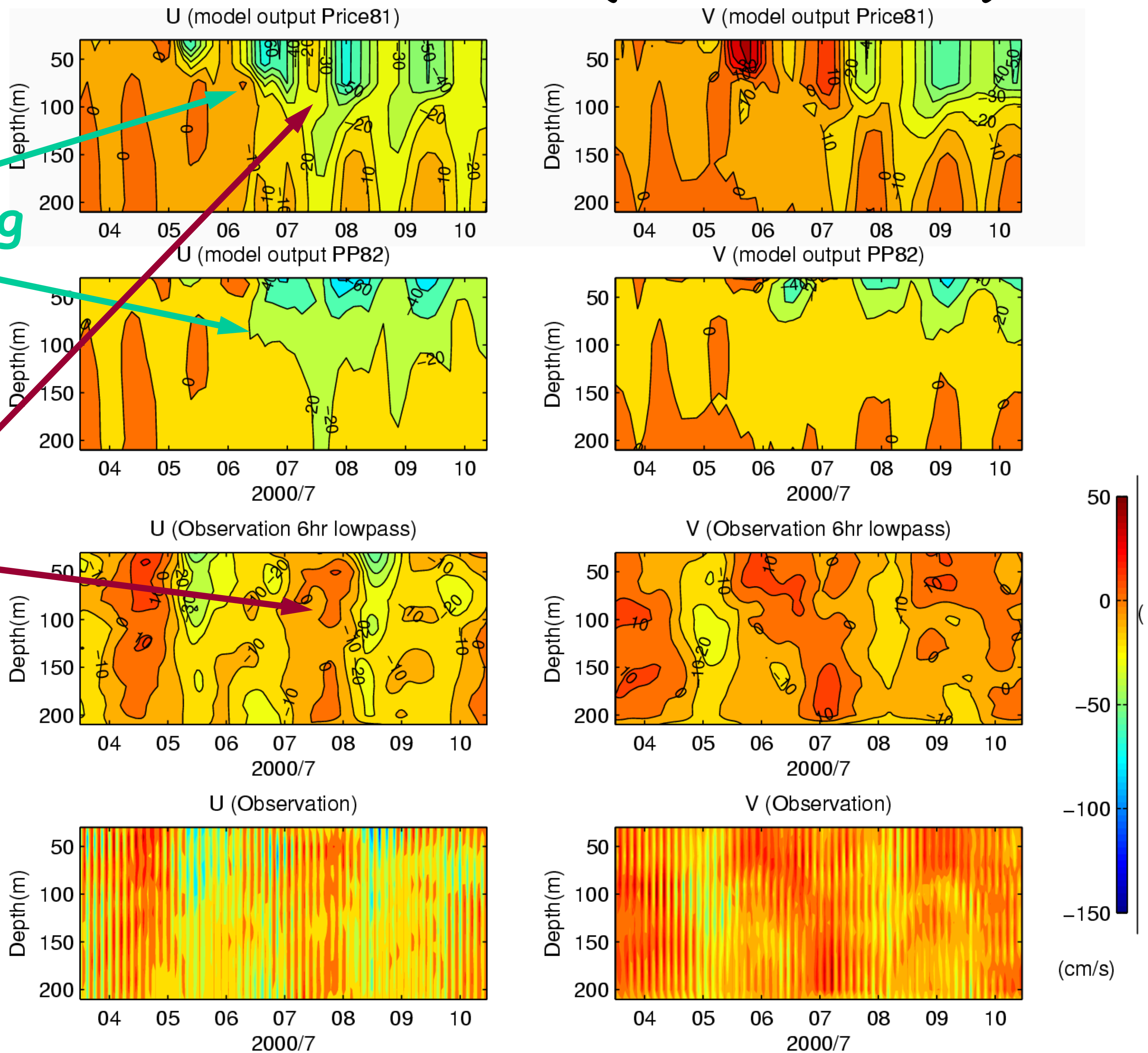


Sensitivity of wind stress strength

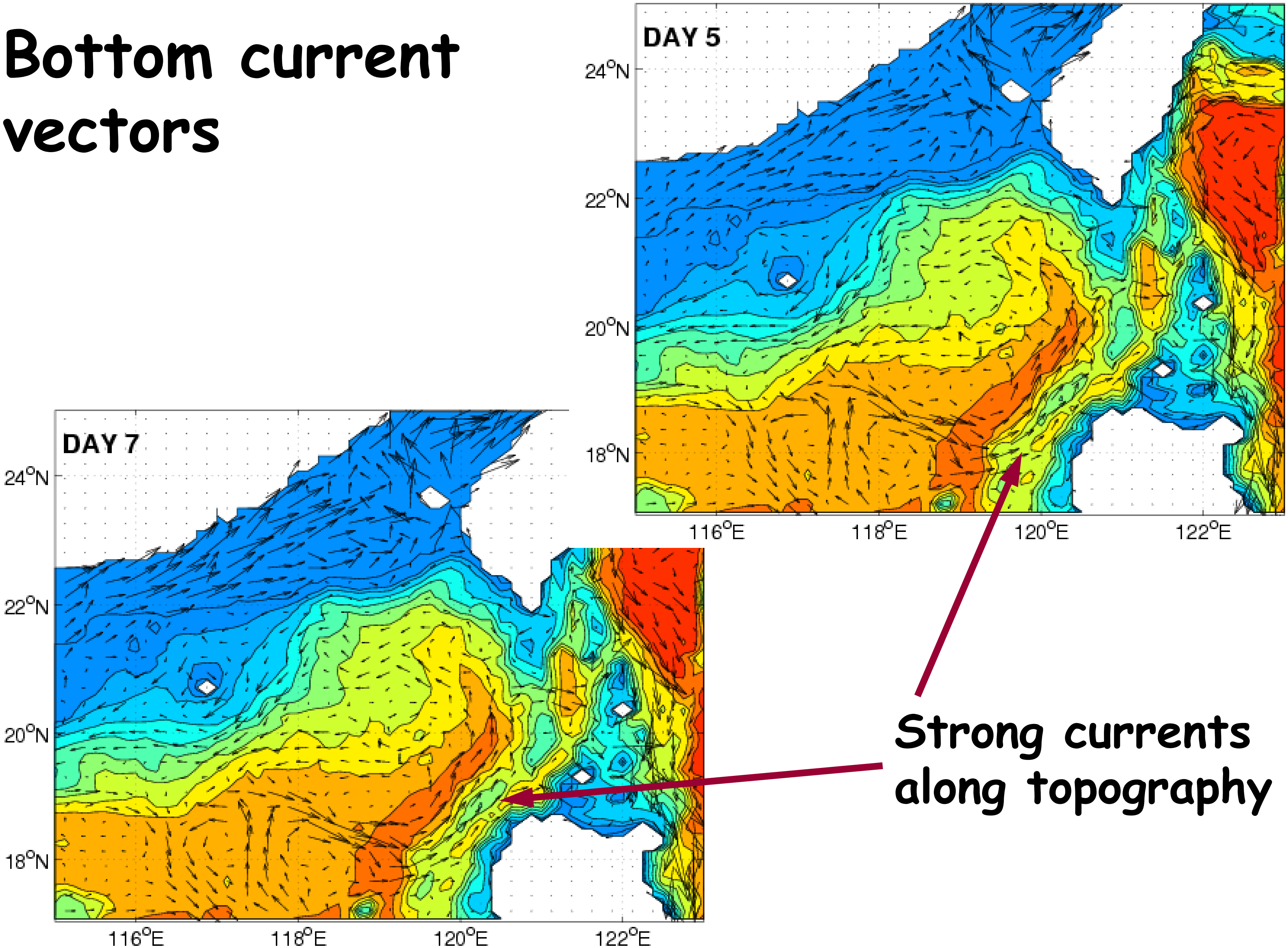
Comparisons with observation (station: KA1)

Vertical mixing matters

Inertial oscillations (~32hr)



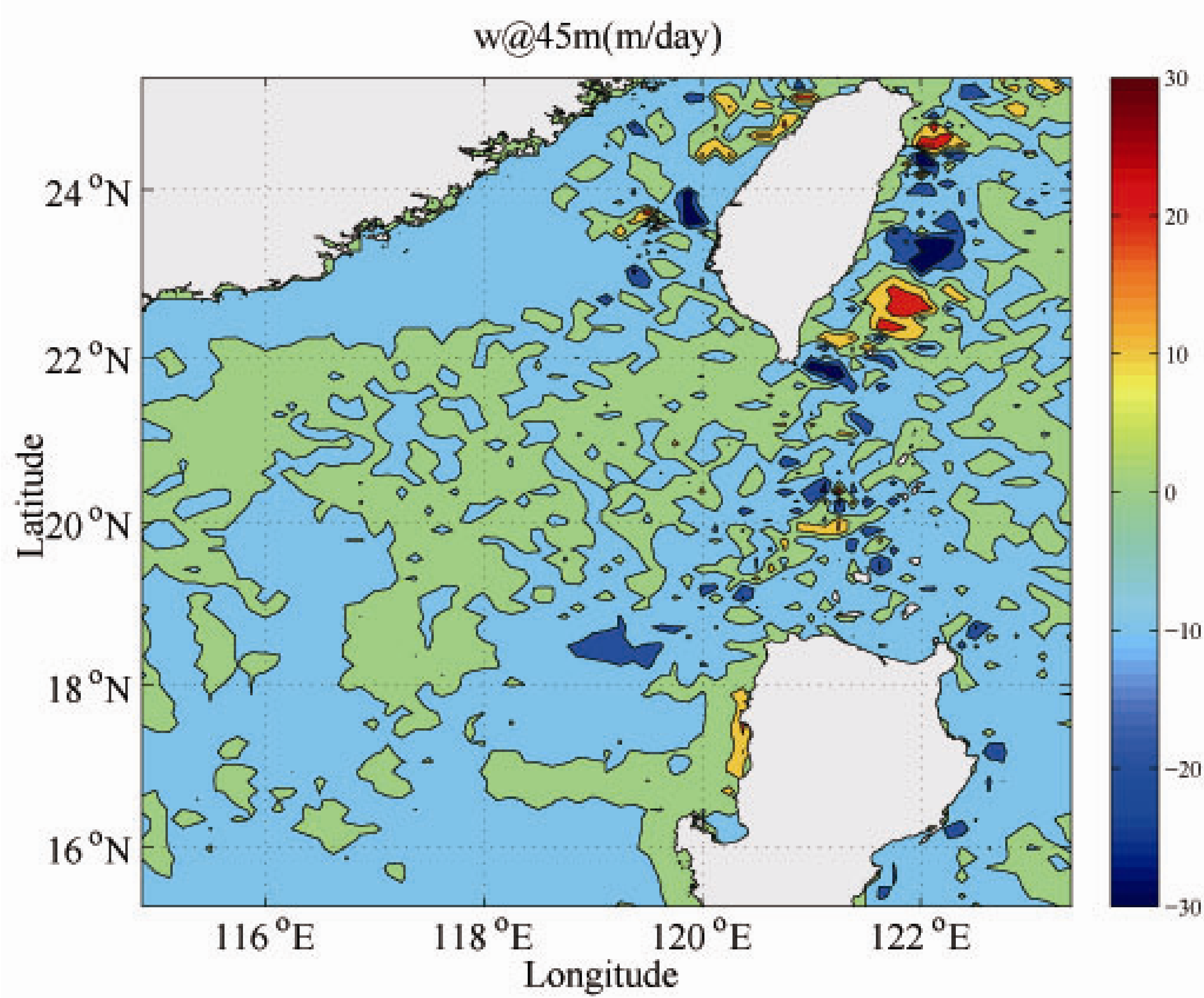
Bottom current vectors



Strong currents along topography

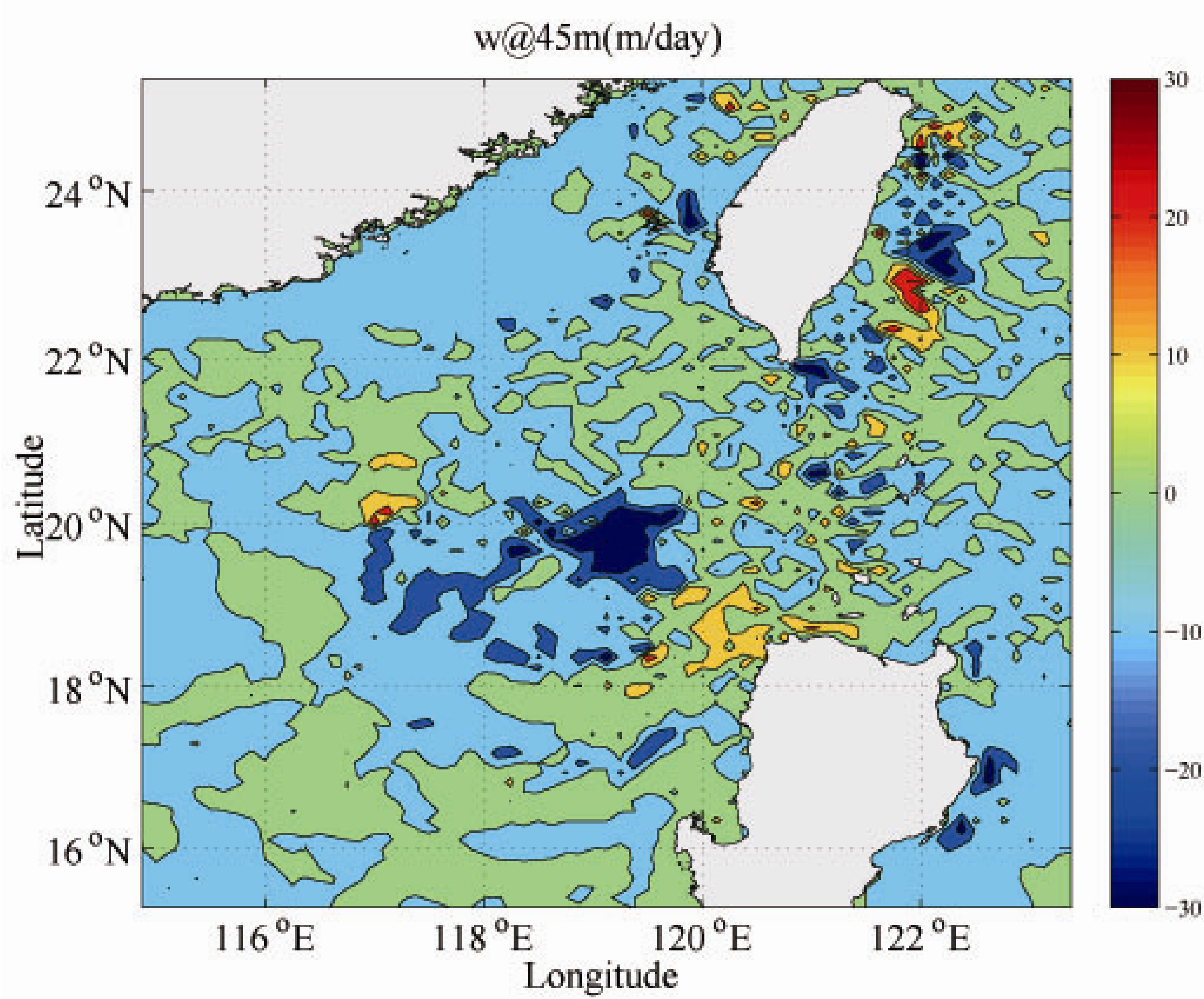
Daily-averaged vertical velocity

Day 1
(7/4)



Daily-averaged vertical velocity

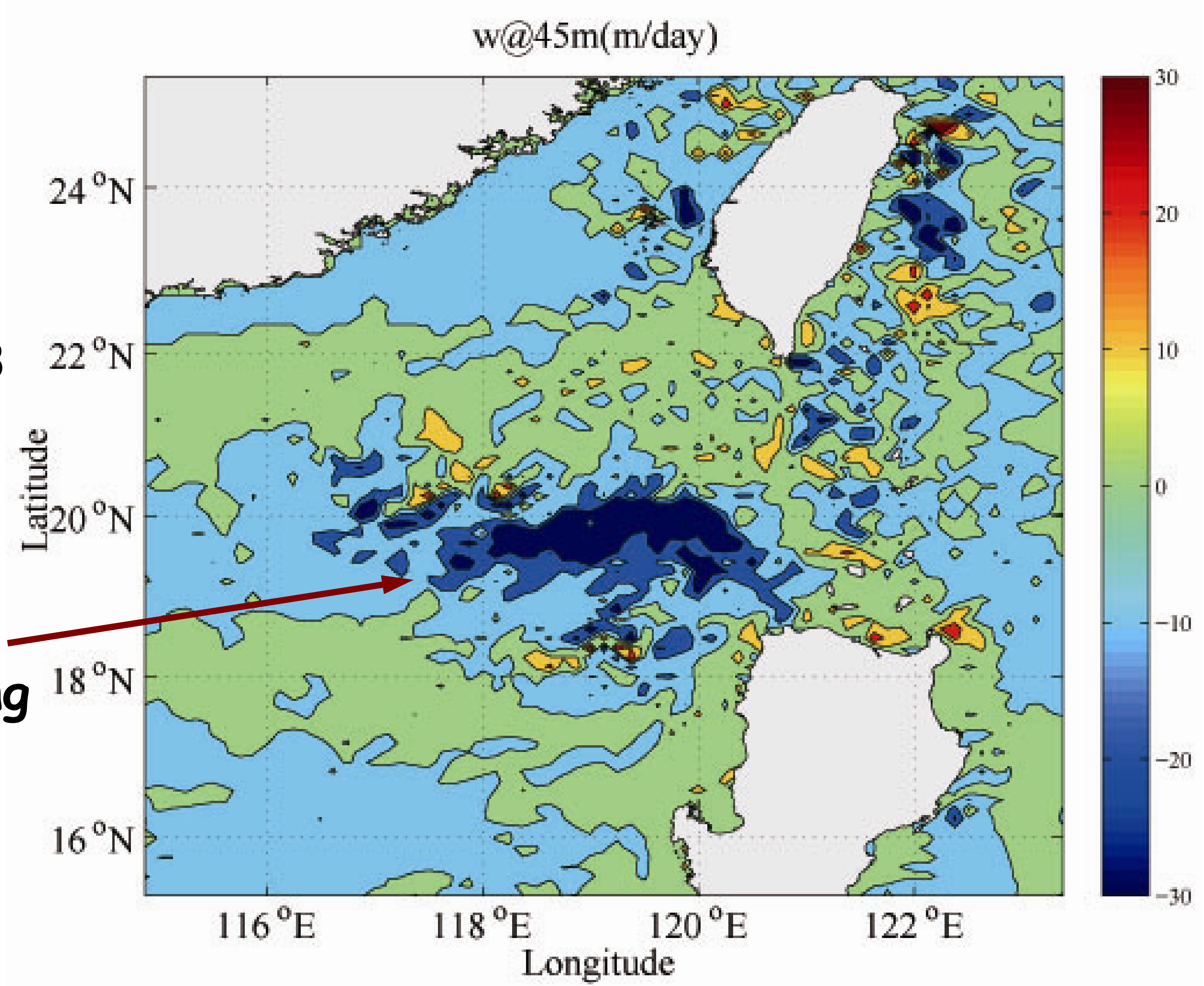
Day 2
(7/5)



Daily-averaged vertical velocity

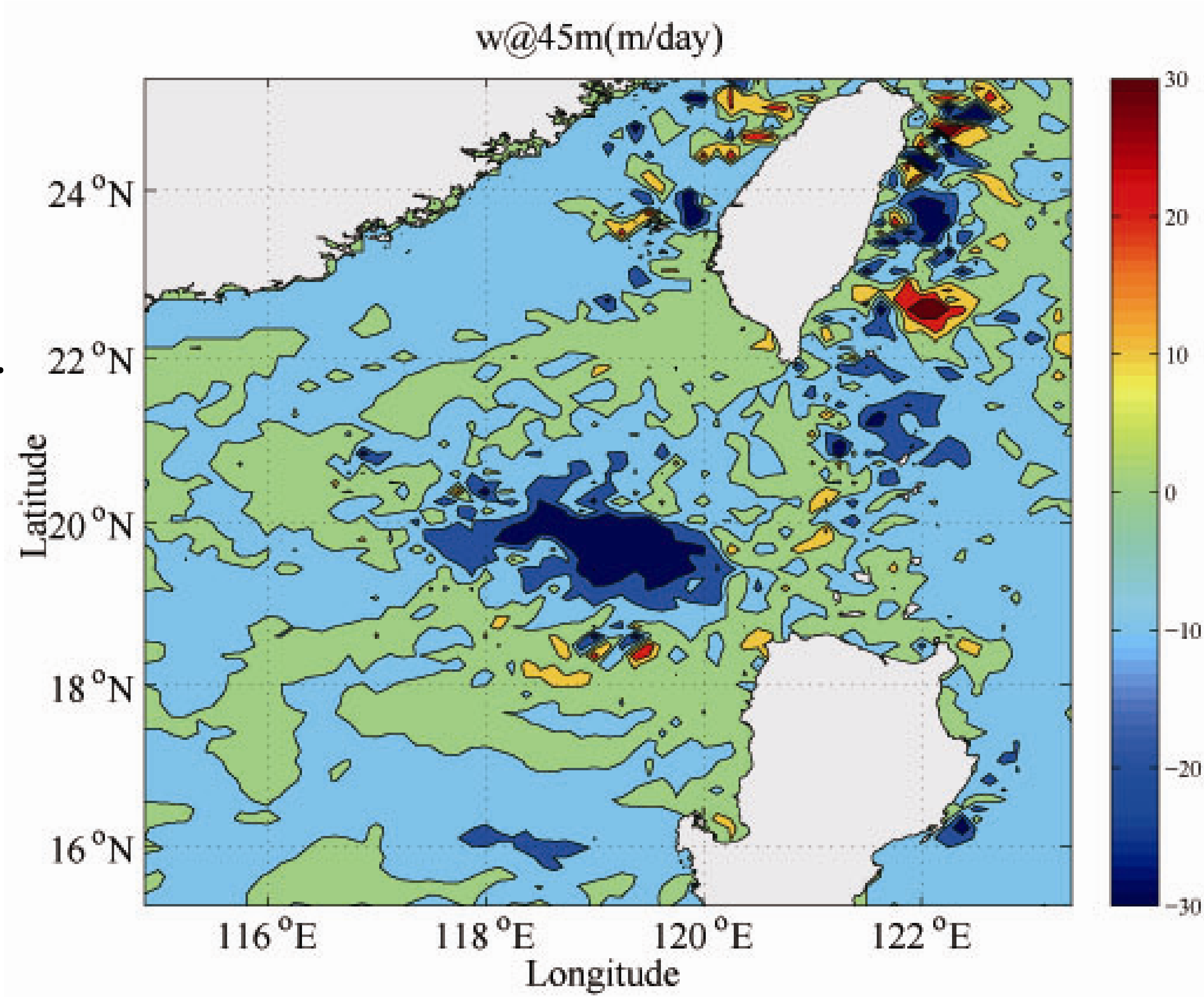
Day 3
(7/6)

Strong upwelling



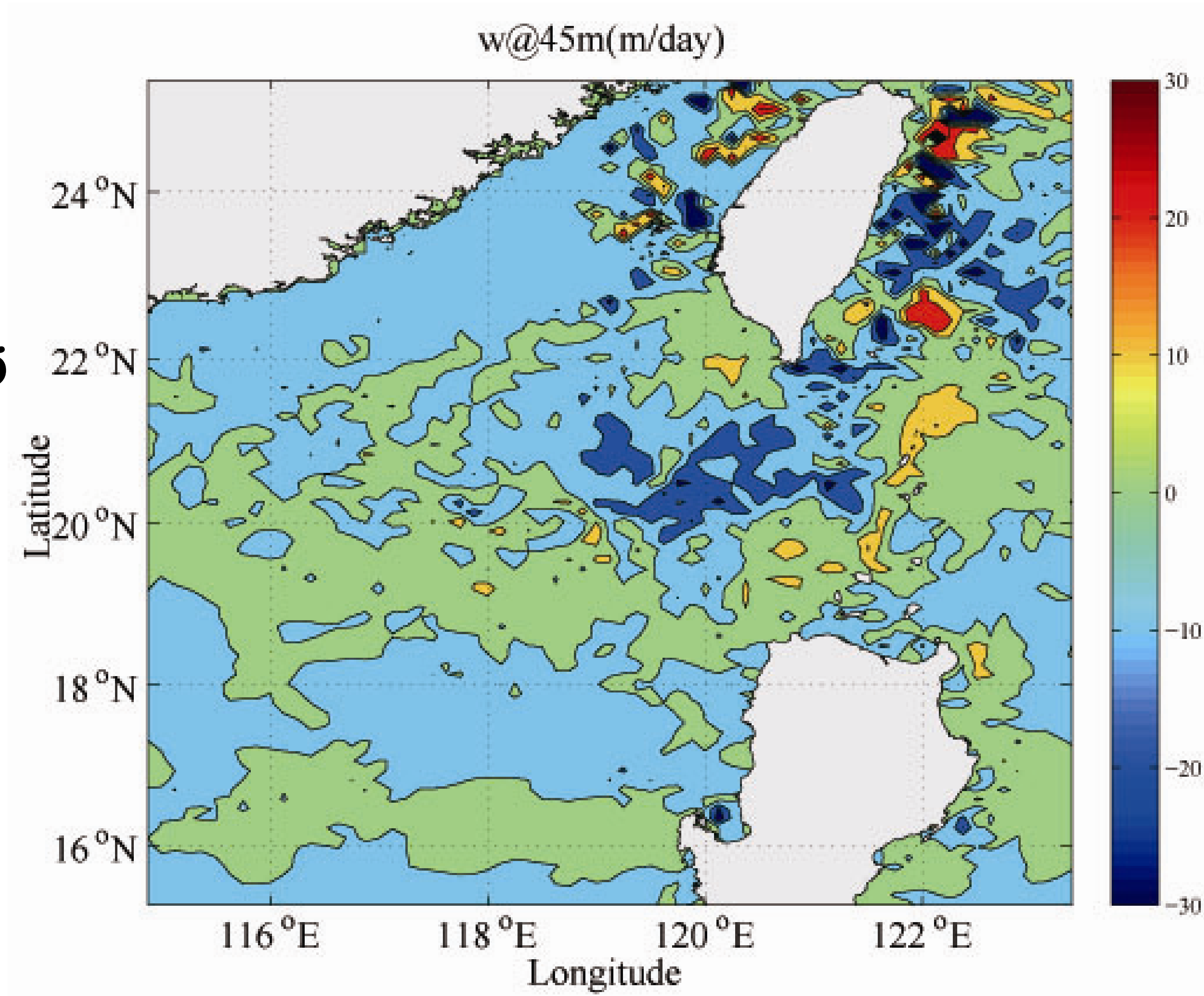
Daily-averaged vertical velocity

Day 4 (7/7)



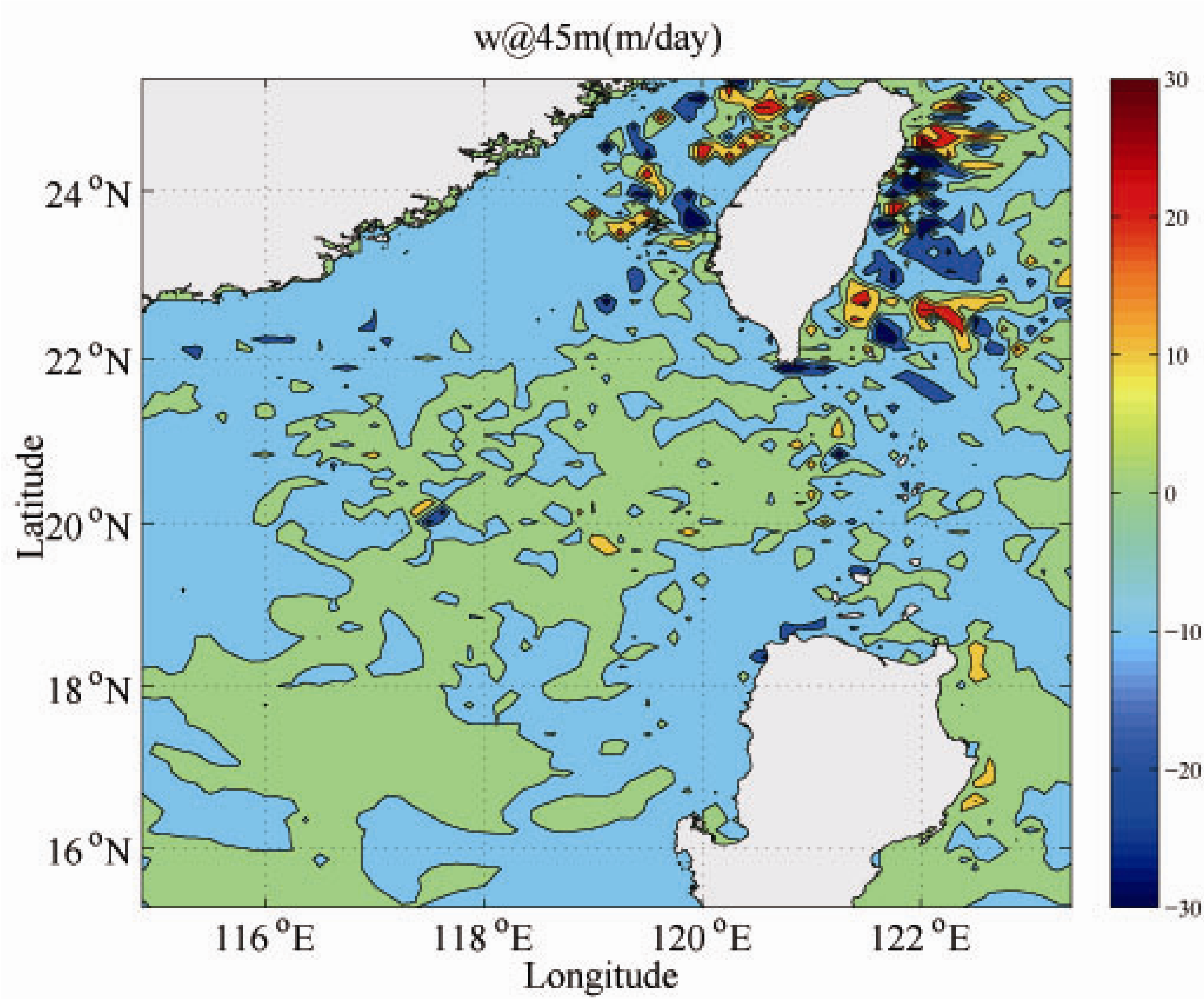
Daily-averaged vertical velocity

Day 5 (7/8)



Daily-averaged vertical velocity

**Day 6
(7/9)**



Summary and conclusion

- Strong inertial motions (oscillations) due to hurricanes/typhoons. Impacts on the climate system?
- Cold wake (compare well with the observed SST change)
- SST cooling biases-vertical mixing, Ekman pumping, vertical convection and others?
- Storm induced currents
- Strong surface and bottom cooling due to the vertical mixing and topographical upwelling
- Better vertical mixing schemes for hurricanes/typhoons? Better surface forcing parameterization/mechanisms (breaking waves)?