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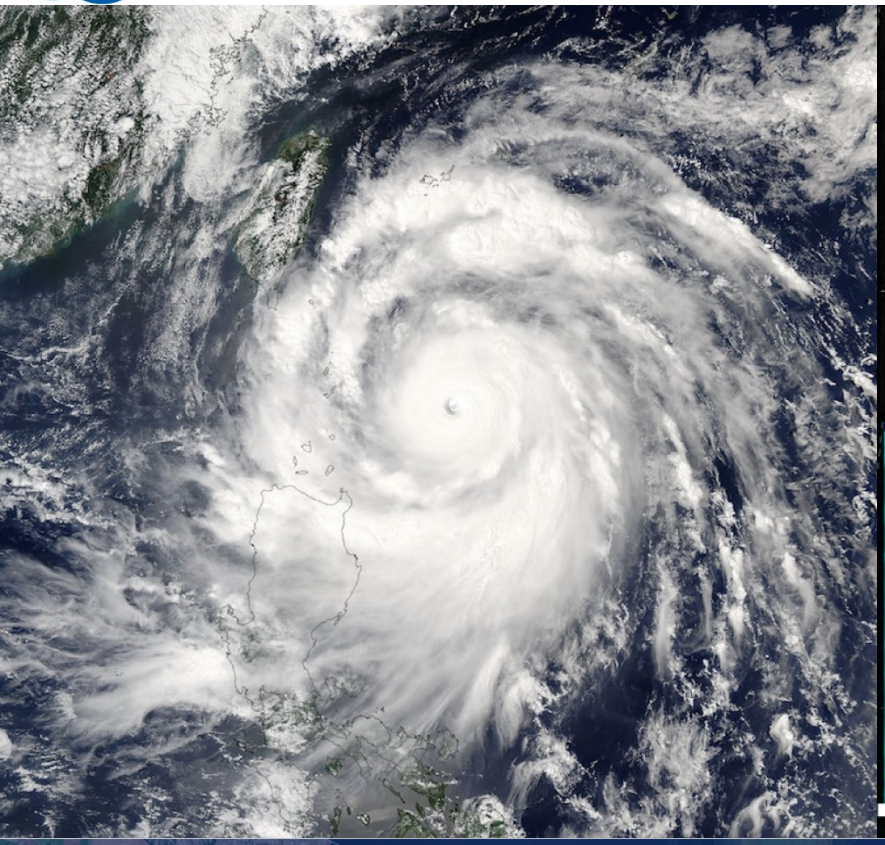
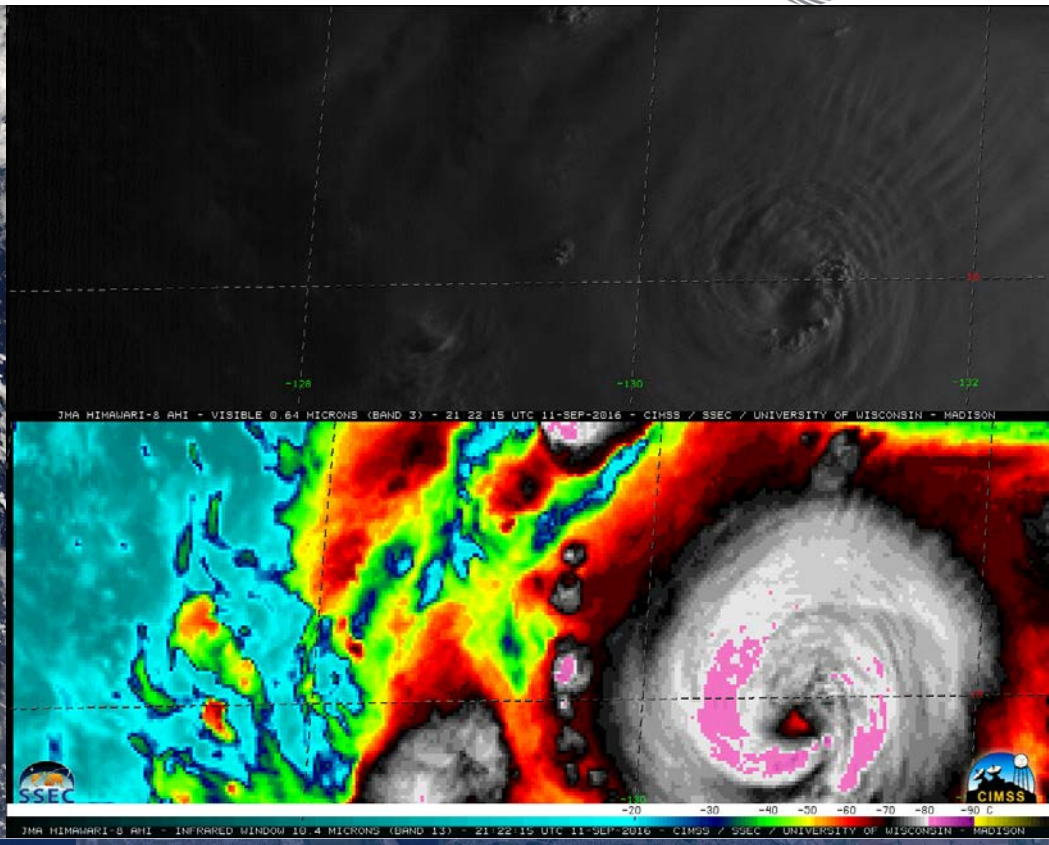
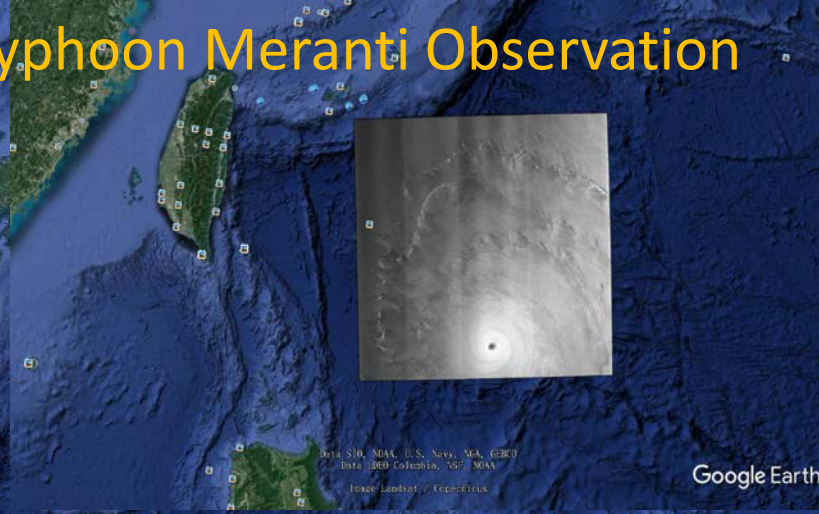
ESA–MOST Dragon Cooperation
中国科技部-欧洲空间局“龙计划”合作
2017 DRAGON 4 SYMPOSIUM
2017年“龙计划”四期学术研讨会
Upper Ocean Response to Typhoon
from multi-sensor observations and numerical simulations
Biao Zhang, Yue Xinxin, Alexis Mouche, Yang Jingsong, Jun Zhang
26–30 June 2017 | Copenhagen, Denmark
2017年6月26-30日，丹麦 哥本哈根

MODIS & HIMAWARI Typhoon Meranti Observations





SAR Typhoon Meranti Observation



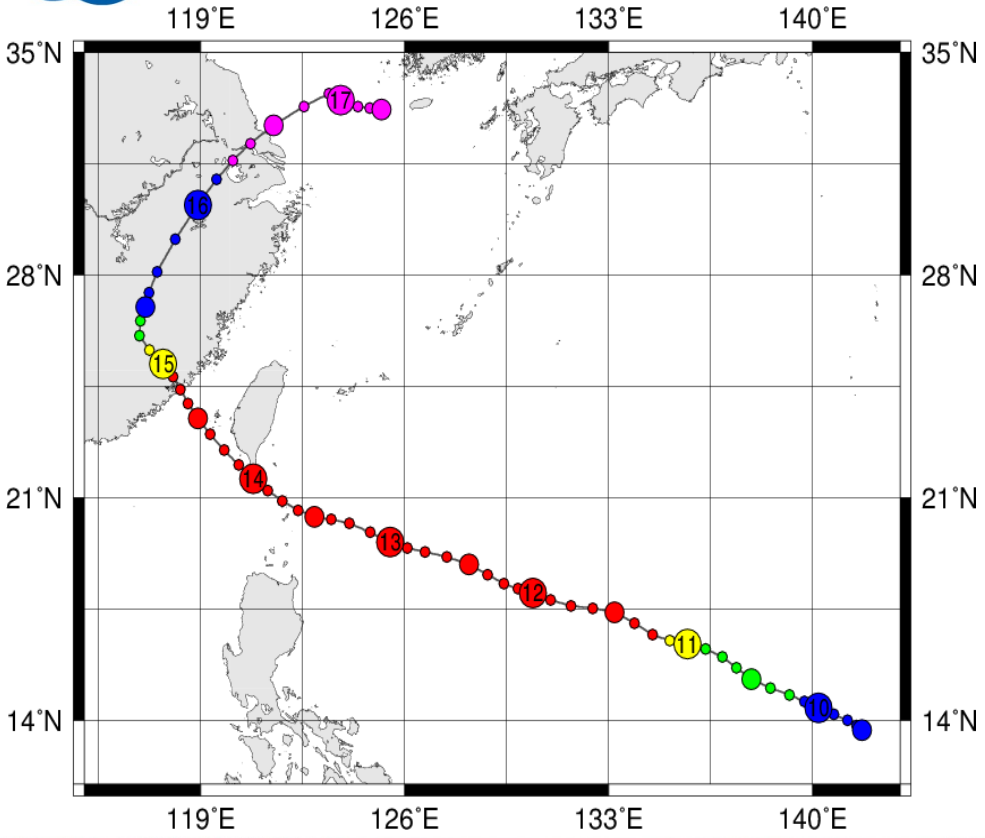
21:28 UTC 12 Sep 2016

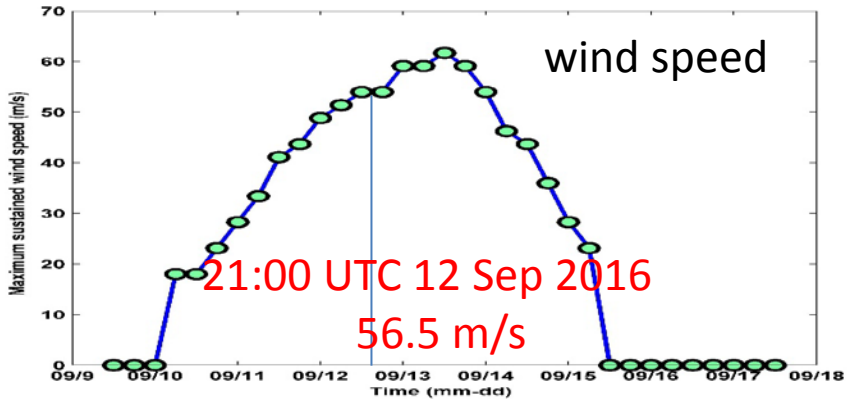
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

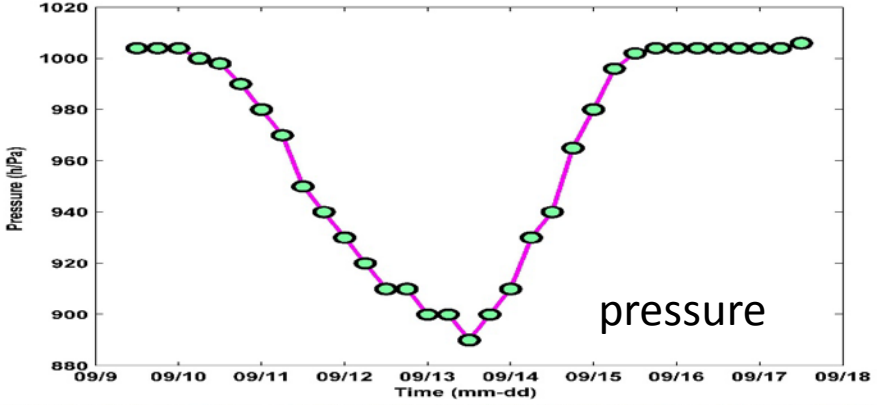
Image Landsat / Copernicus

Google Earth

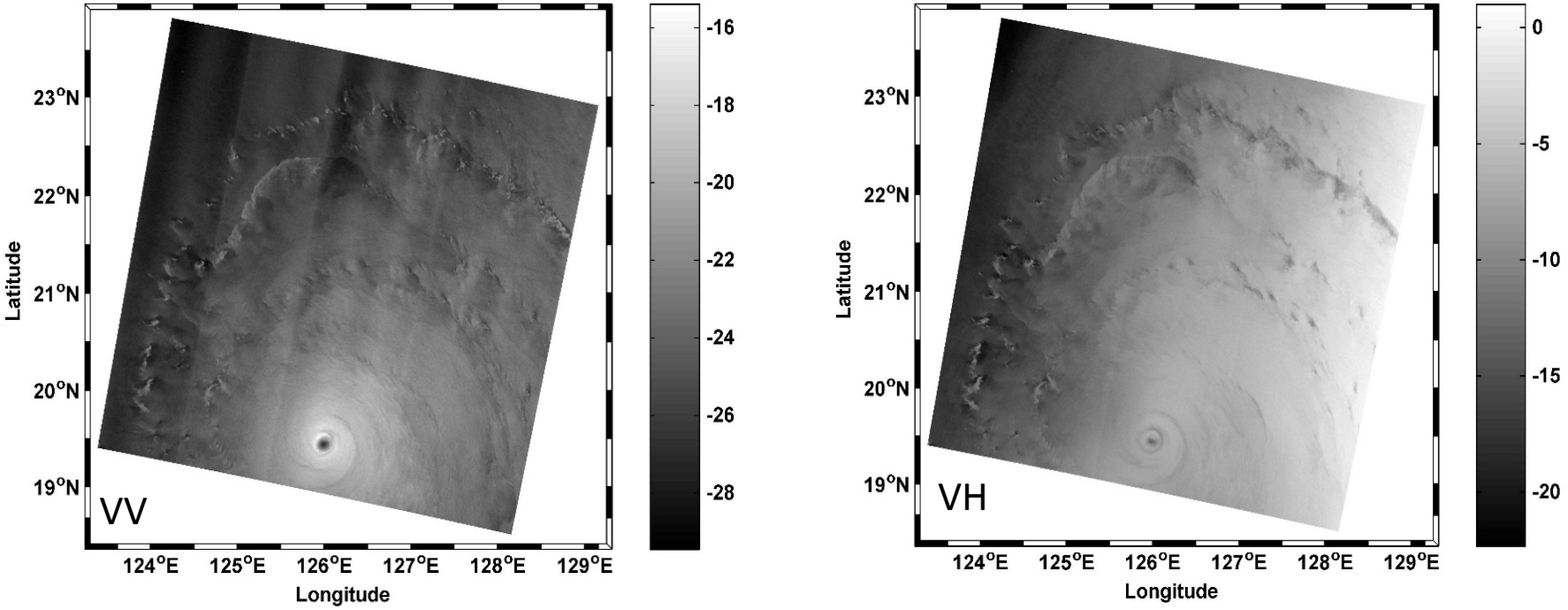
JTWC Typhoon Meranti Best Track







Dual-Pol SAR Typhoon Meranti Observations



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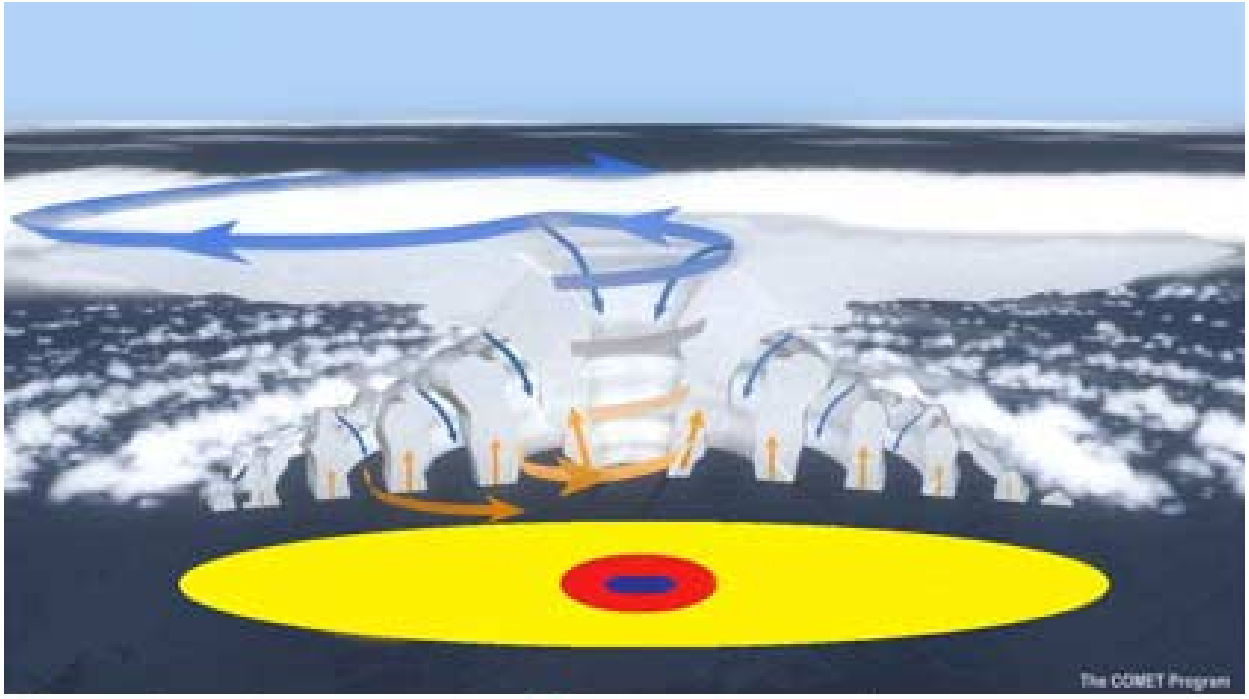
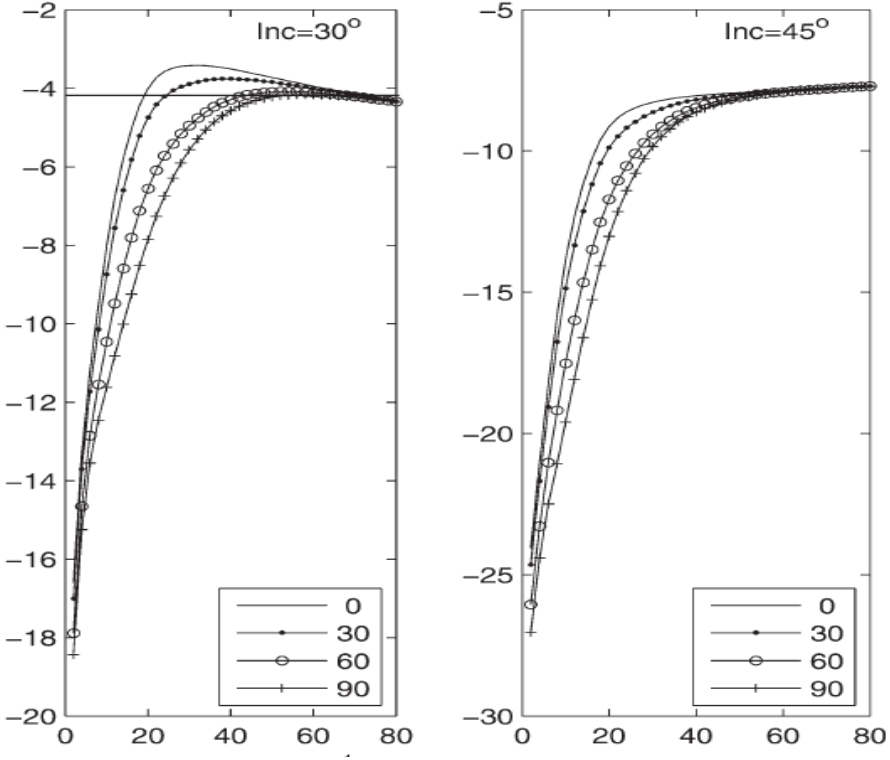


Light Winds

Very Strong Winds

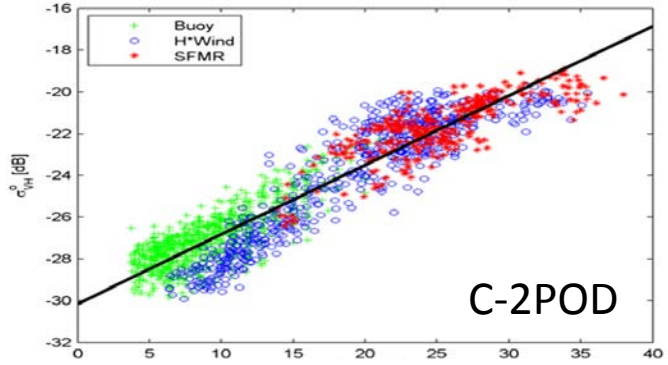
Transition from very strong winds to light winds at the outer edge

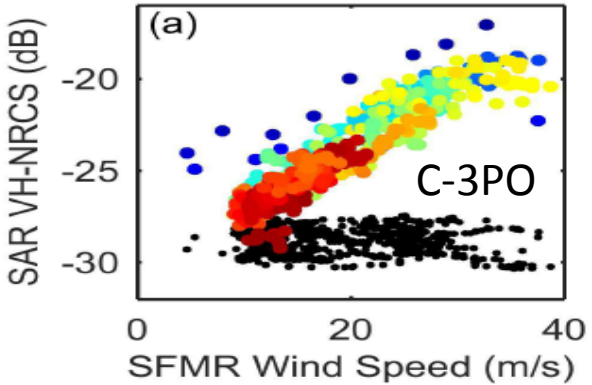
VV-pol SAR wind speeds

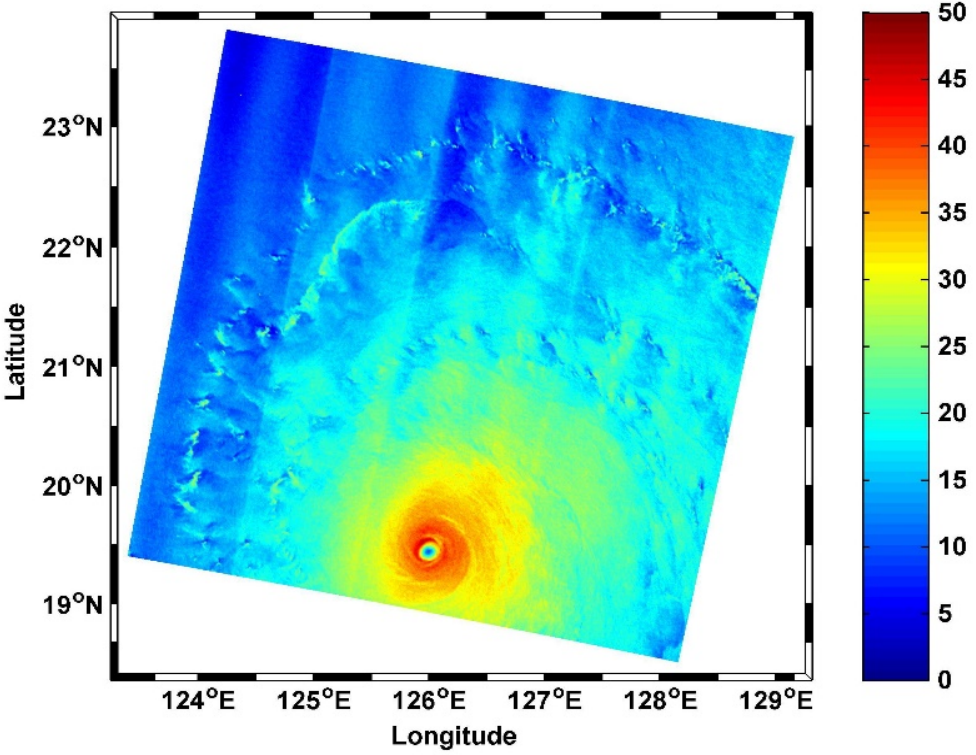


underestimate high winds in the typhoon eyewall region

VH-pol SAR wind speeds







overestimate low and moderate winds outside eyewall region

Dual-Pol SAR Winds ?

$$J(u,v) = \left(\frac{\sigma_{vv}^{o} - \sigma_{vv}^{m}}{\Delta\sigma_{vv}}\right)^2 + \left(\frac{u_{FG} - u}{\Delta u}\right)^2 + \left(\frac{v_{FG} - v}{\Delta v}\right)^2$$

U_{FG} : first guess wind speed from cross-pol model

$$\sigma_{vh}^{o} = C3PO(U_{FG}, \theta)$$

u_{FG} : wind speed components

v_{FG}

$$u_{FG} = U_{FG}\cos(\varphi_u)$$
$$v_{FG} = U_{FG}\sin(\varphi_u)$$
$$\varphi_u = 90^o - \Phi$$

Φ : wind direction from improved local gradient method

$$\sigma_{vv}^{m} = CMOD5.N(\theta, U_{FG}, \varphi)$$

VH-pol SAR wind direction derivation

Local gradient estimation

$$D_x = \frac{1}{32}\begin{bmatrix} 3 & 0 & -3 \\ 10 & 0 & -10 \\ 3 & 0 & 3 \end{bmatrix}$$

$$D_y = D_x^T$$

$$G = (D_x + iD_y) * (A)$$

$$\beta = arctan\left(\frac{G_x}{G_y}\right)$$

Interpolation operation

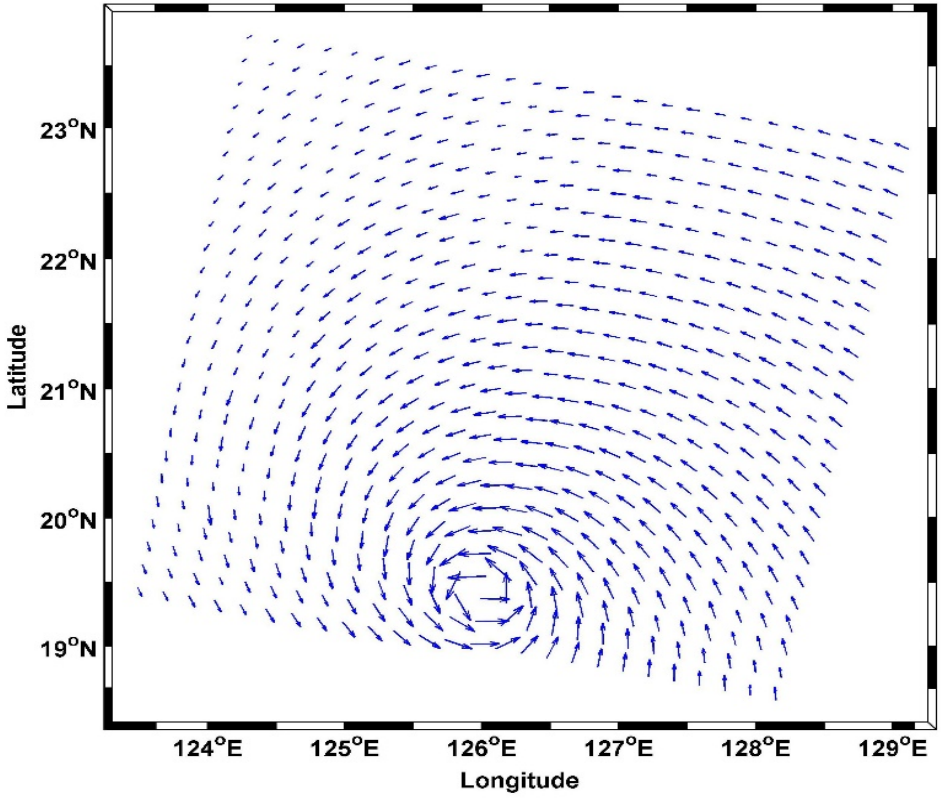
$$sin\Phi(x,y) = a_0^{sin} + a_x^{sin}x + a_y^{sin}y + \sum_i^N a_i^{sin} exp\left(-\frac{(x-x_i)^2 - (y-y_i)^2}{\sigma_\omega^2}\right)$$

$$cos\Phi(x,y) = a_0^{cos} + a_x^{cos}x + a_y^{cos}y + \sum_i^N a_i^{cos} exp\left(-\frac{(x-x_i)^2 - (y-y_i)^2}{\sigma_\omega^2}\right)$$

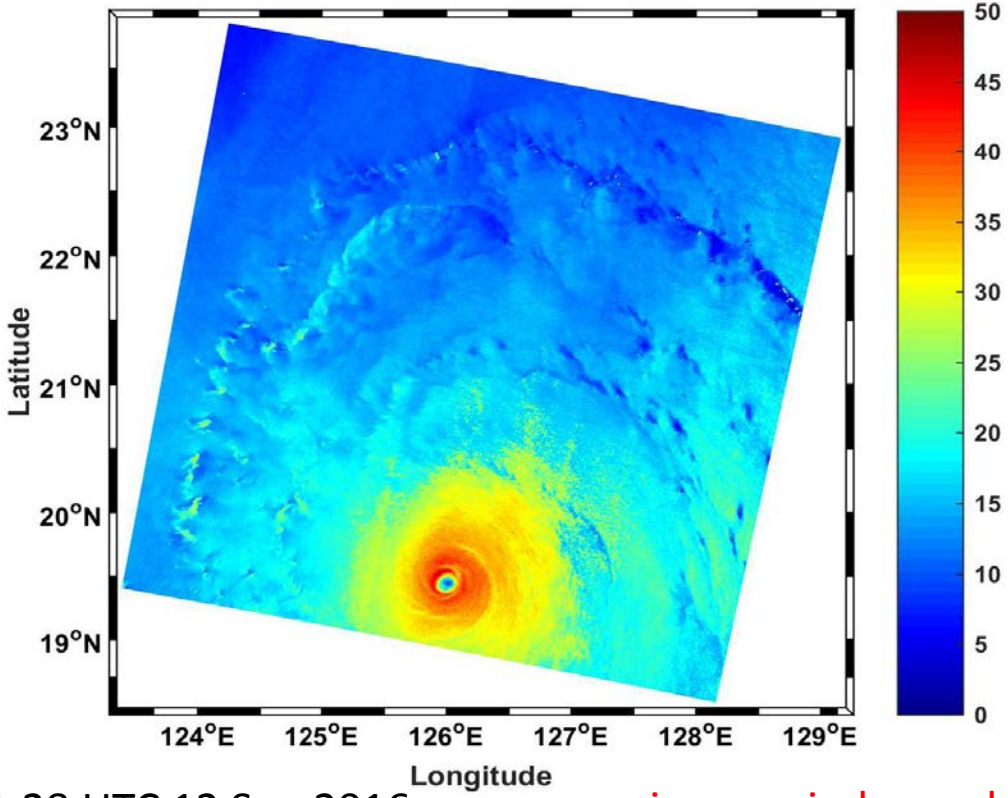
$$J^{sin} = \sum_{i=1}^{N}\left(sin\Phi_i - a_0^{sin} - a_x^{sin}x_i - a_y^{sin}y_i\right)$$

$$J^{cos} = \sum_{i=1}^{N}\left(cos\Phi_i - a_0^{cos} - a_x^{cos}x_i - a_y^{cos}y_i\right)$$

VH-pol SAR wind direction derivation



Dual-Pol SAR wind field



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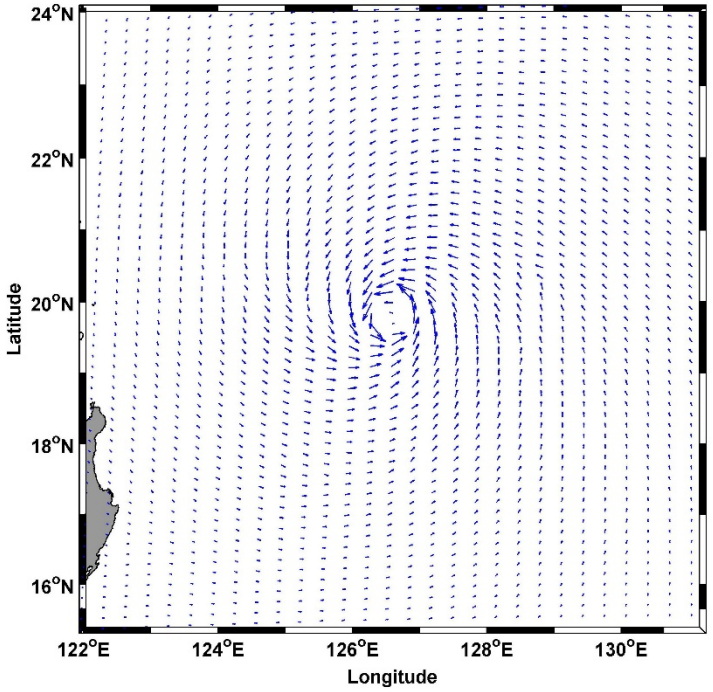
maximum wind speed is 47.4 m/s

HWRF-simulated wind field



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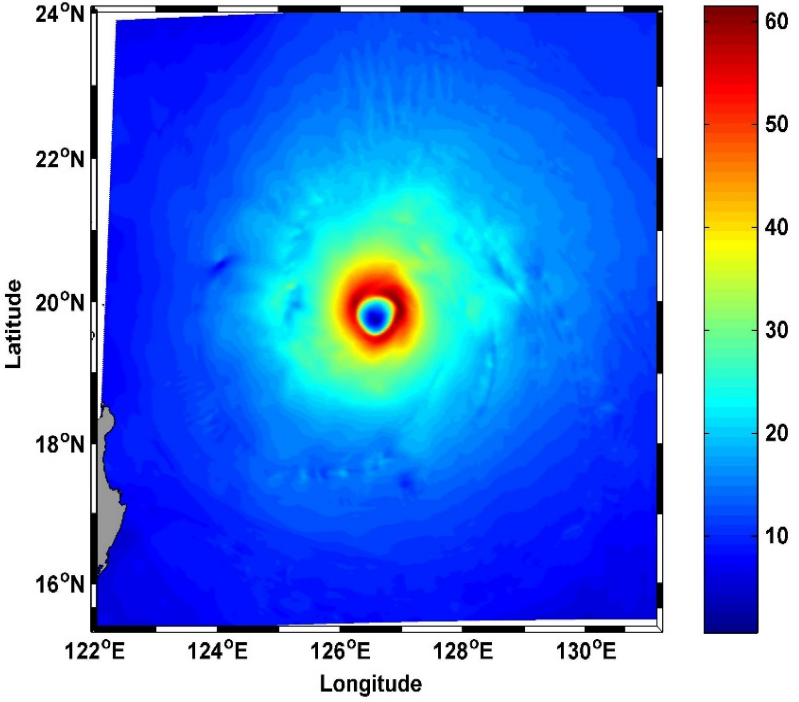
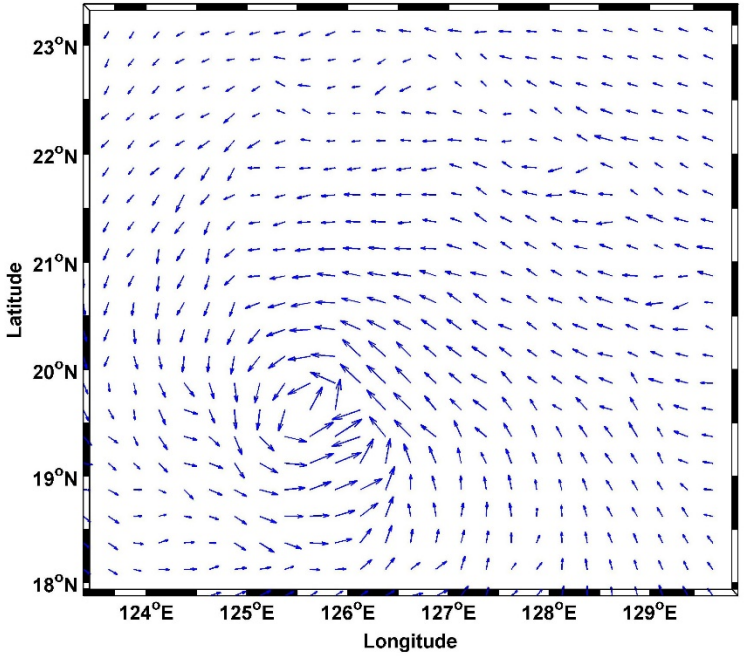


maximum wind speed is 61.5 m/s

WindSat-derived wind field



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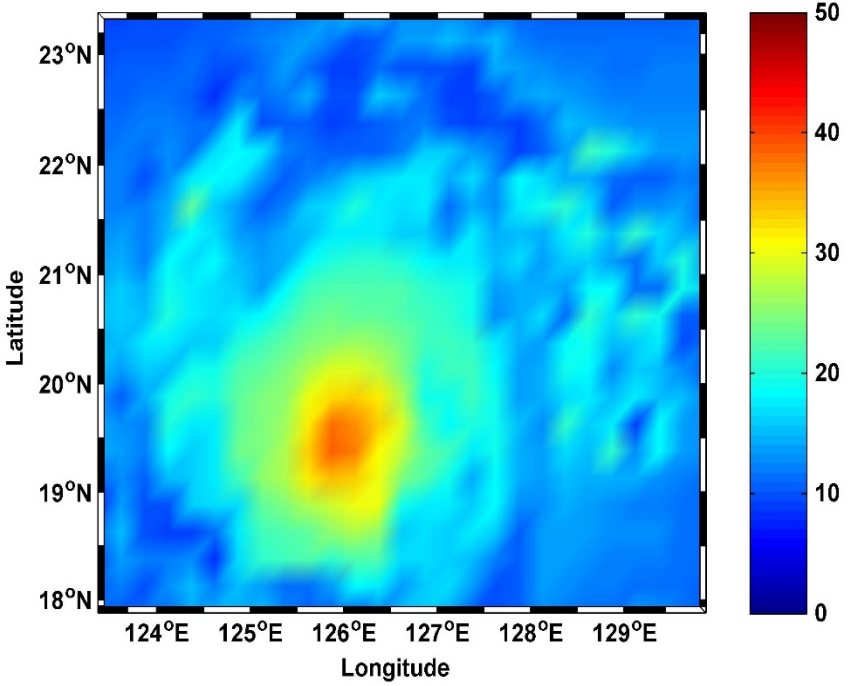
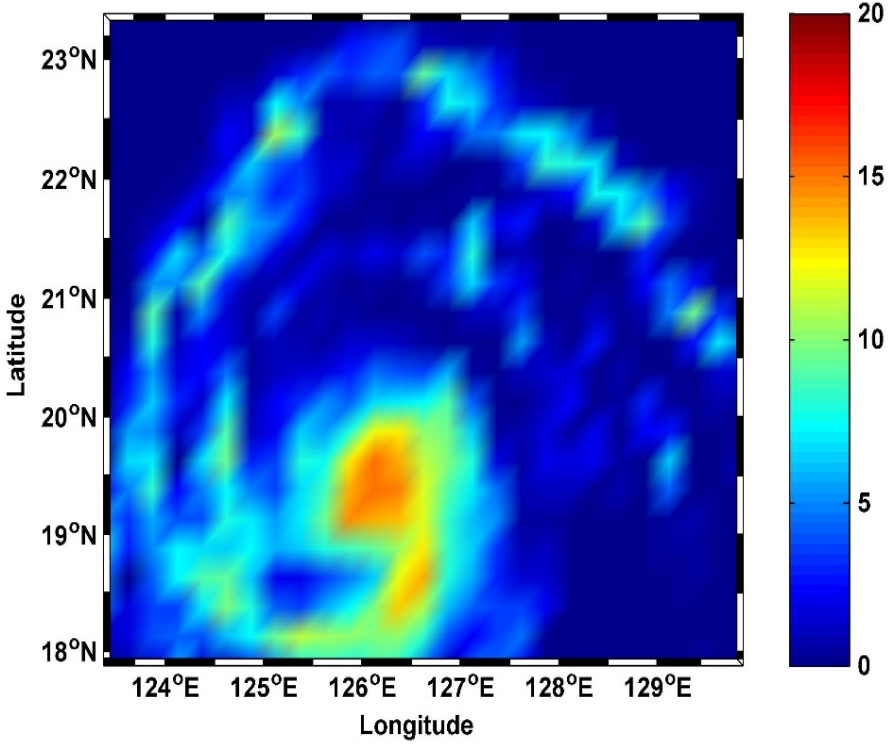
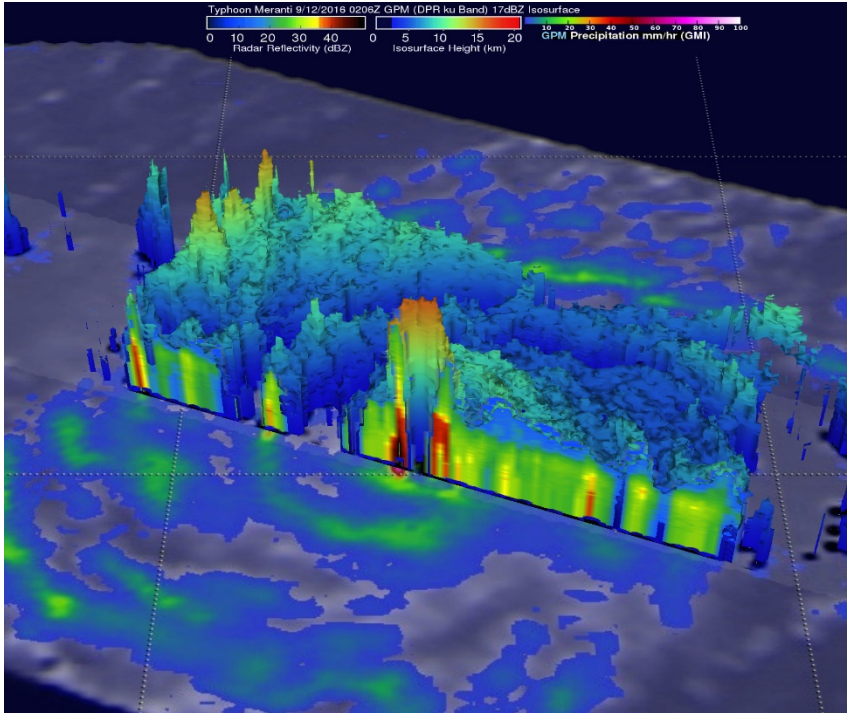


maximum wind speed is 38.6 m/s

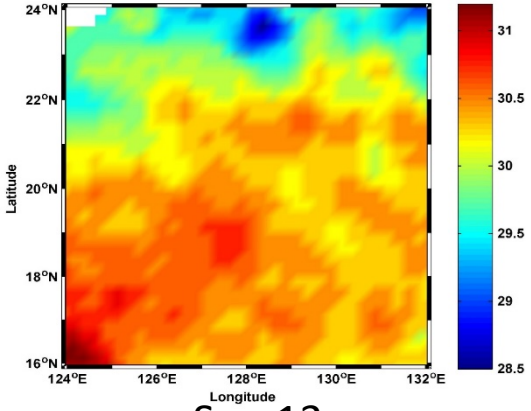
WindSat & GPM rain





Microwave optimally-interpolated SST

Sep 10



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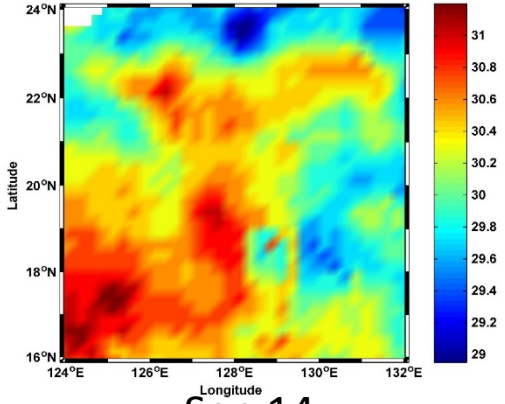

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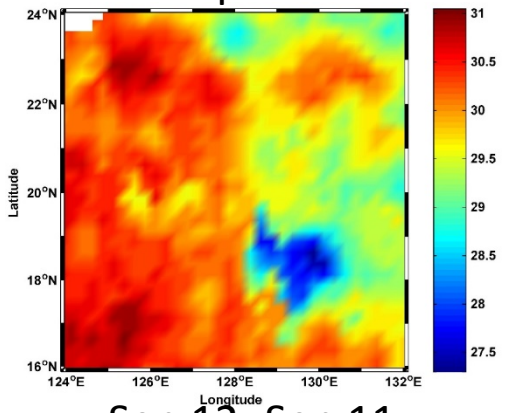

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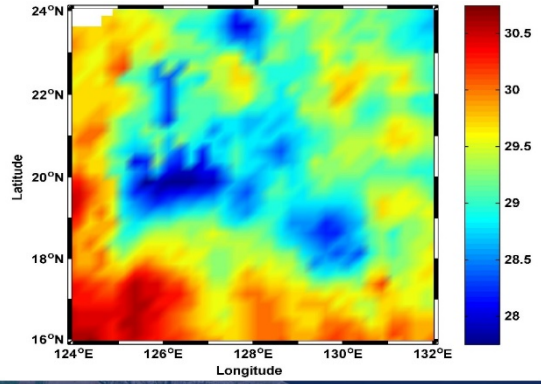

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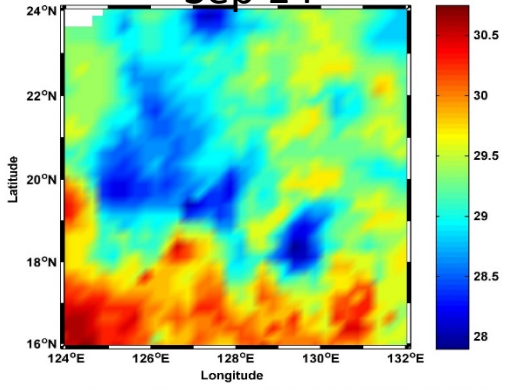
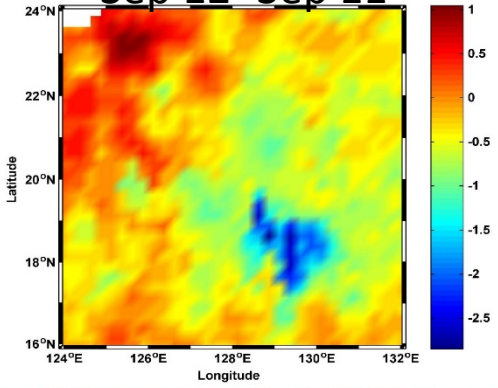
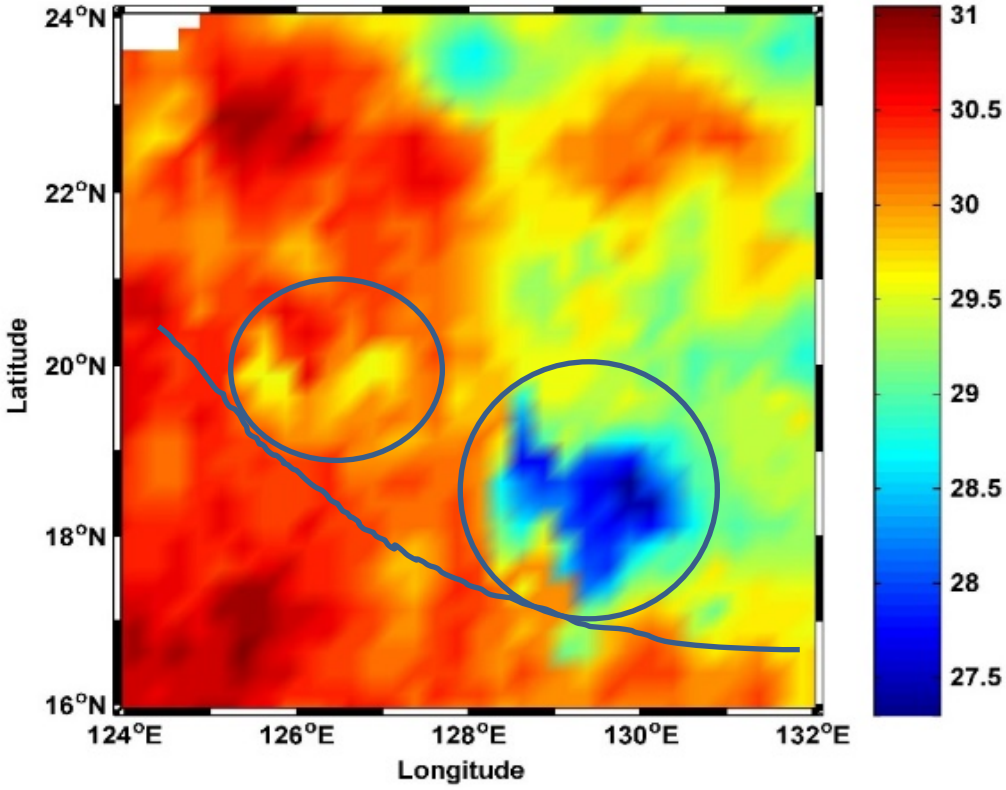


Sep 12- Sep 11



SST cooling

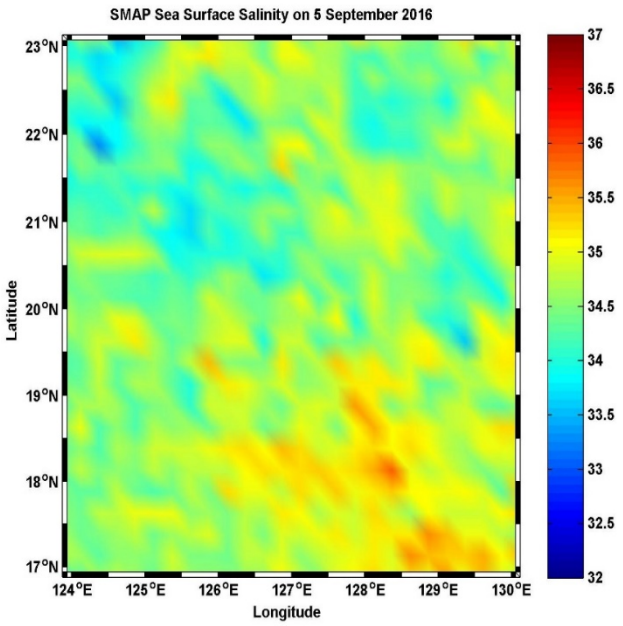


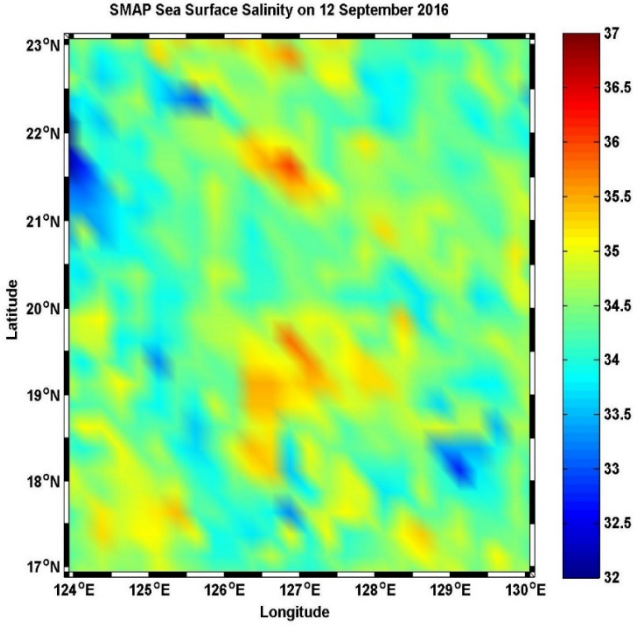
The typhoon wind-stress vector turns clockwise with time on the right side of the track and is roughly resonant with the wind-driven near-inertial currents in the mixed layer, which cause strong entrainment and thus a strong SST response.

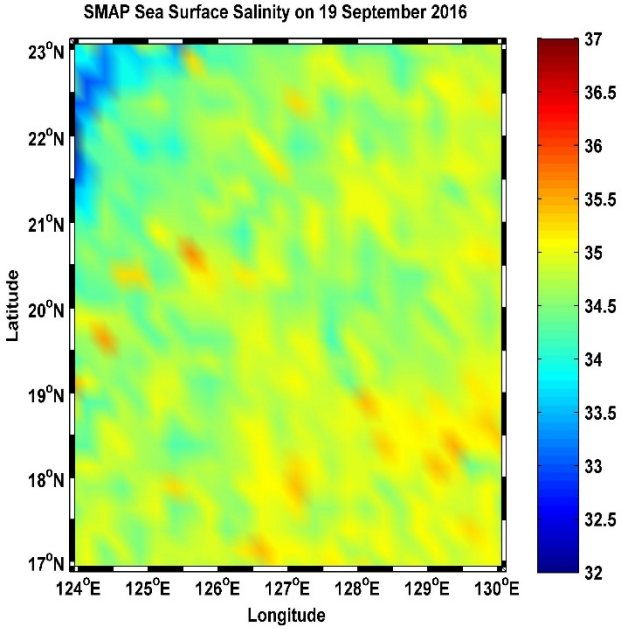
The SST response is large for strong, slowly moving typhoons, because entrainment dominates the ML heat balance, the SST response is large when there is cold water Near sea surface, when the initial ML layer is shallow and temperature gradient beneath The ML is sharp.

SMAP sea surface salinity

Level 3 8-day running maps



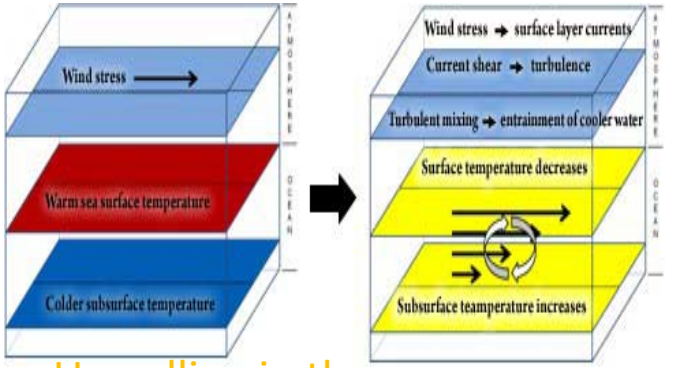




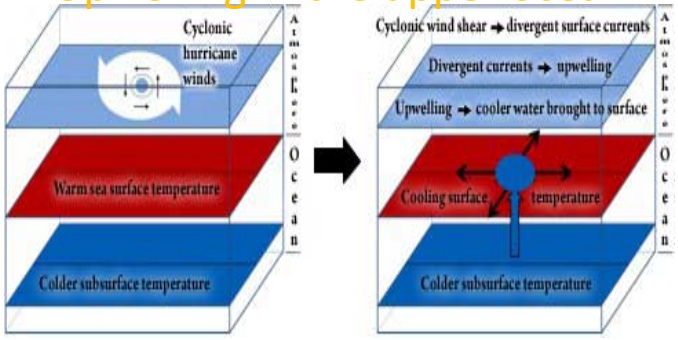
SSS increase about 1 psu

Upper Ocean response to Typhoon

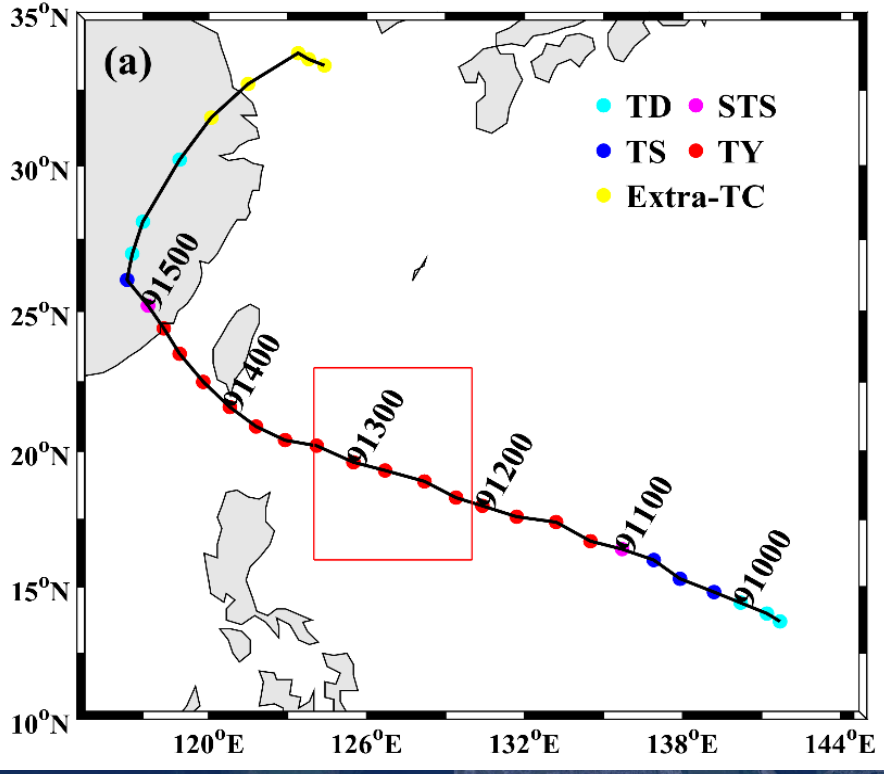
Vertical mixing in the upper ocean



Upwelling in the upper ocean



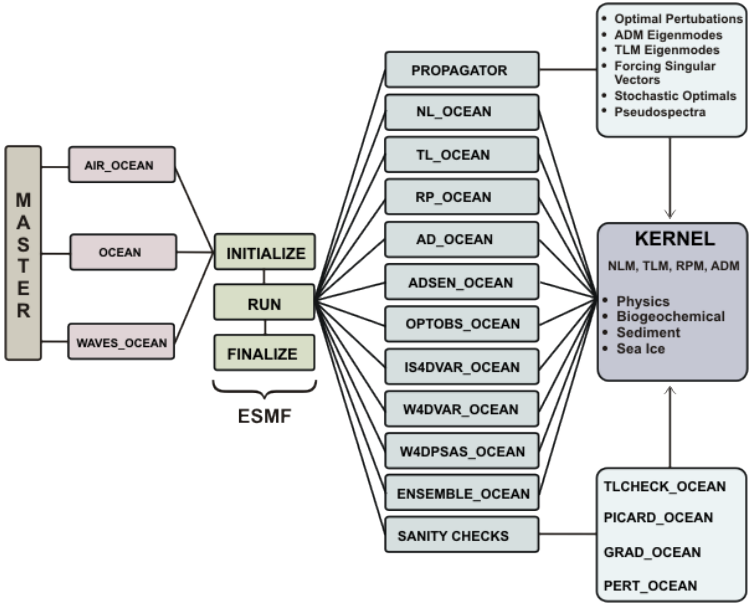
Numerical Simulation of Upper Ocean response to Typhoon



Regional Oceanic Modeling System (ROMS)

ROMS is a three-dimensional numerical oceanic model intended for simulating current, Ecosystems, biogeochemical cycles, and sediment movement in various coastal regions.

vertical sigma-coordinate grid, horizontal curvilinear orthogonal grid



lateral boundary conditions

surface forcing

bottom boundary conditions

ROMS model Setup

✓ Grid

- Horizontal resolution of the grid was 1/32° (≈3 km);
- Vertical coordinate was discretized with 72 vertical sigma layers;
- The grid dimensions (latitude, longitude, and depth) were (191×237×72).

✓ Open Boundaries/Initial Conditions

- The mesoscale temperature, salinity, and velocity values were derived from HYCOM (1/12°) and the data are stored at daily time steps.

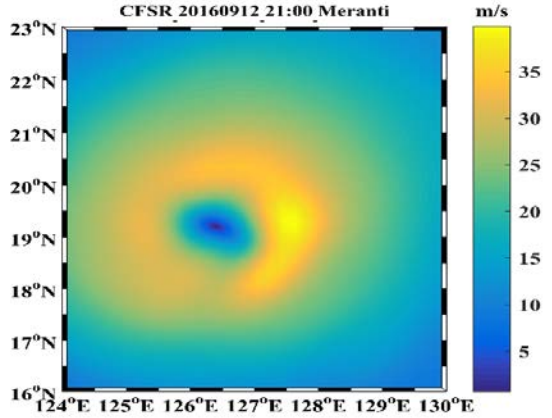
✓ Atmospheric Forcing

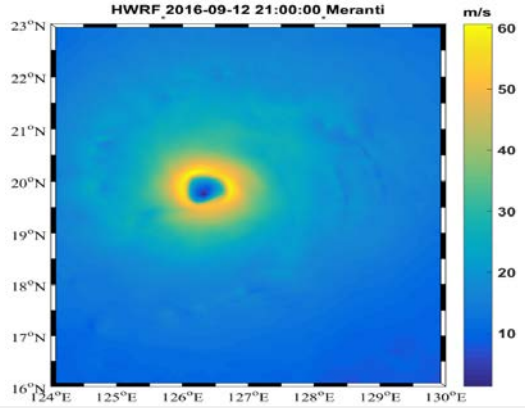
- The forcing for the ocean model was derived from CFSR (1/25°) and the data are stored at hourly time steps.

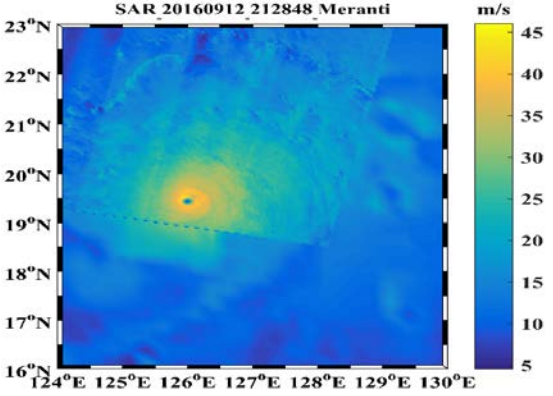
✓ ROMS Parameterization Scheme

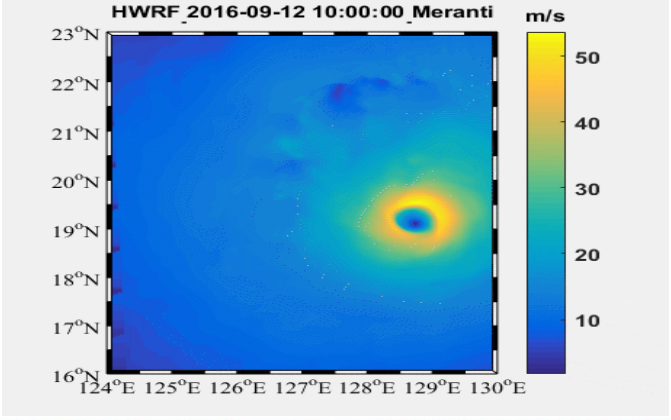
- Using the COARE3.0 bulk-flux formulation for parameterizing momentum and buoyancy fluxes.
- Vertical mixing was parameterized using the KPP formulation.

Atmospheric forcing



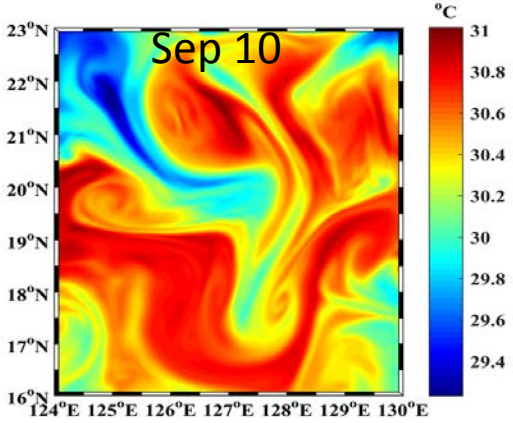


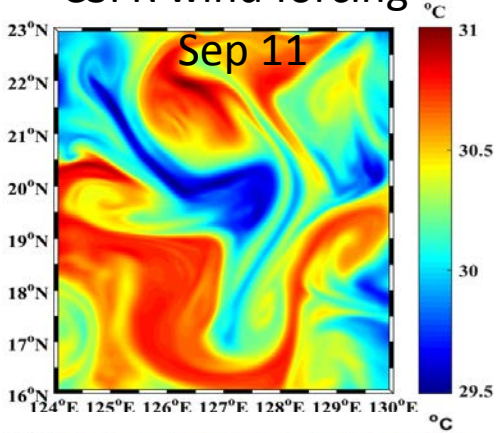


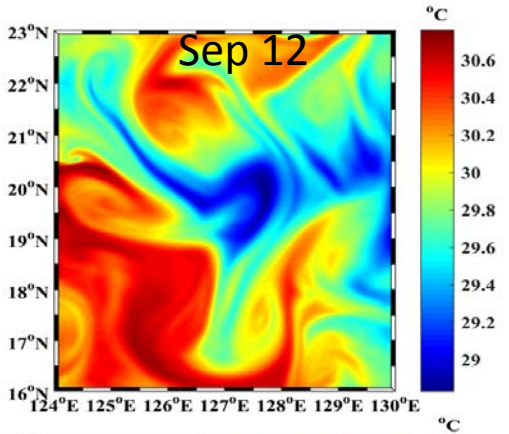


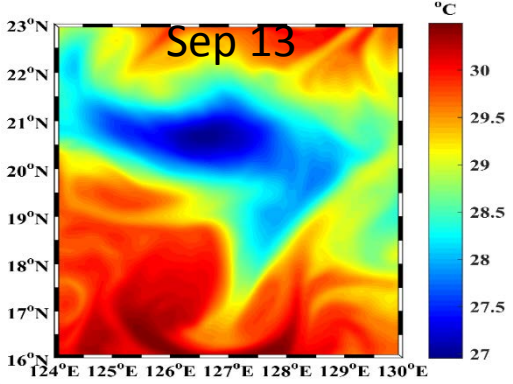
Sea surface temperature response

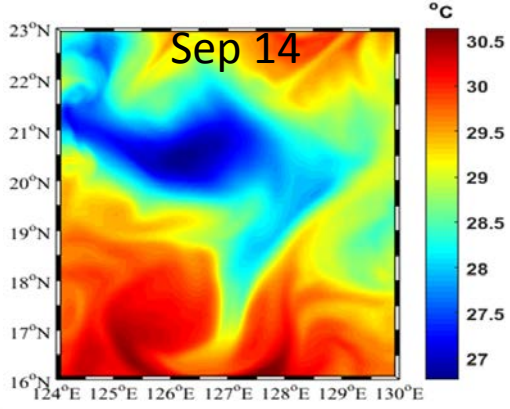
CSFR wind forcing

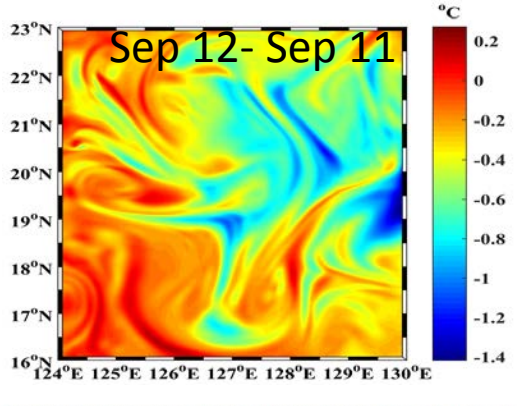






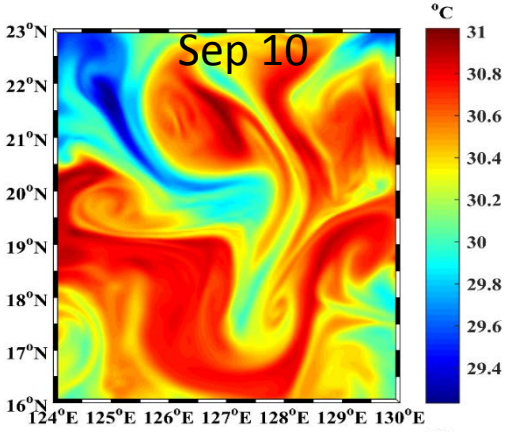


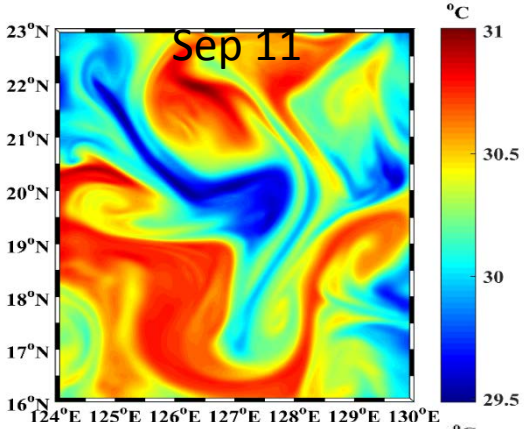


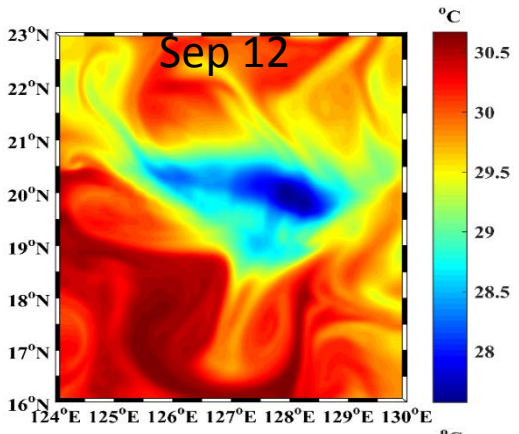


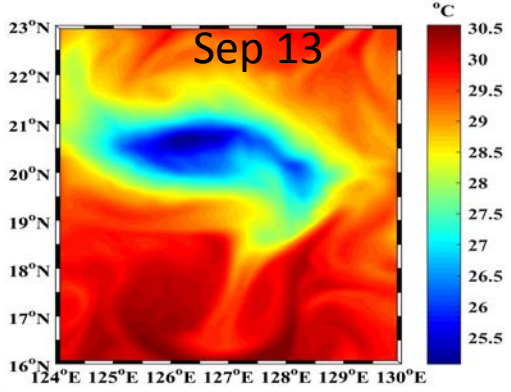
Sea surface temperature response

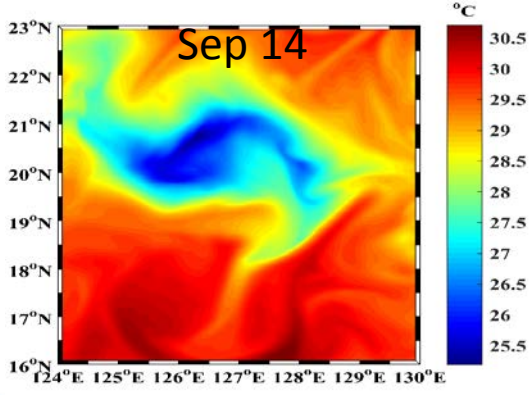
HWRF wind forcing

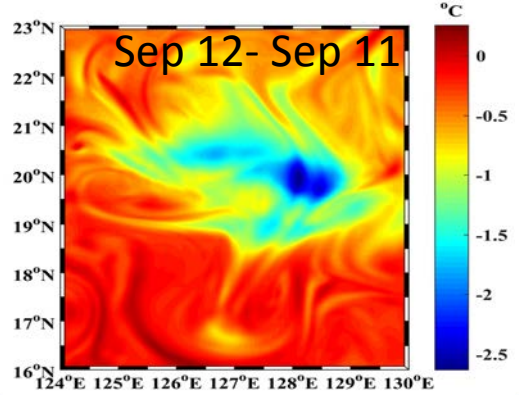






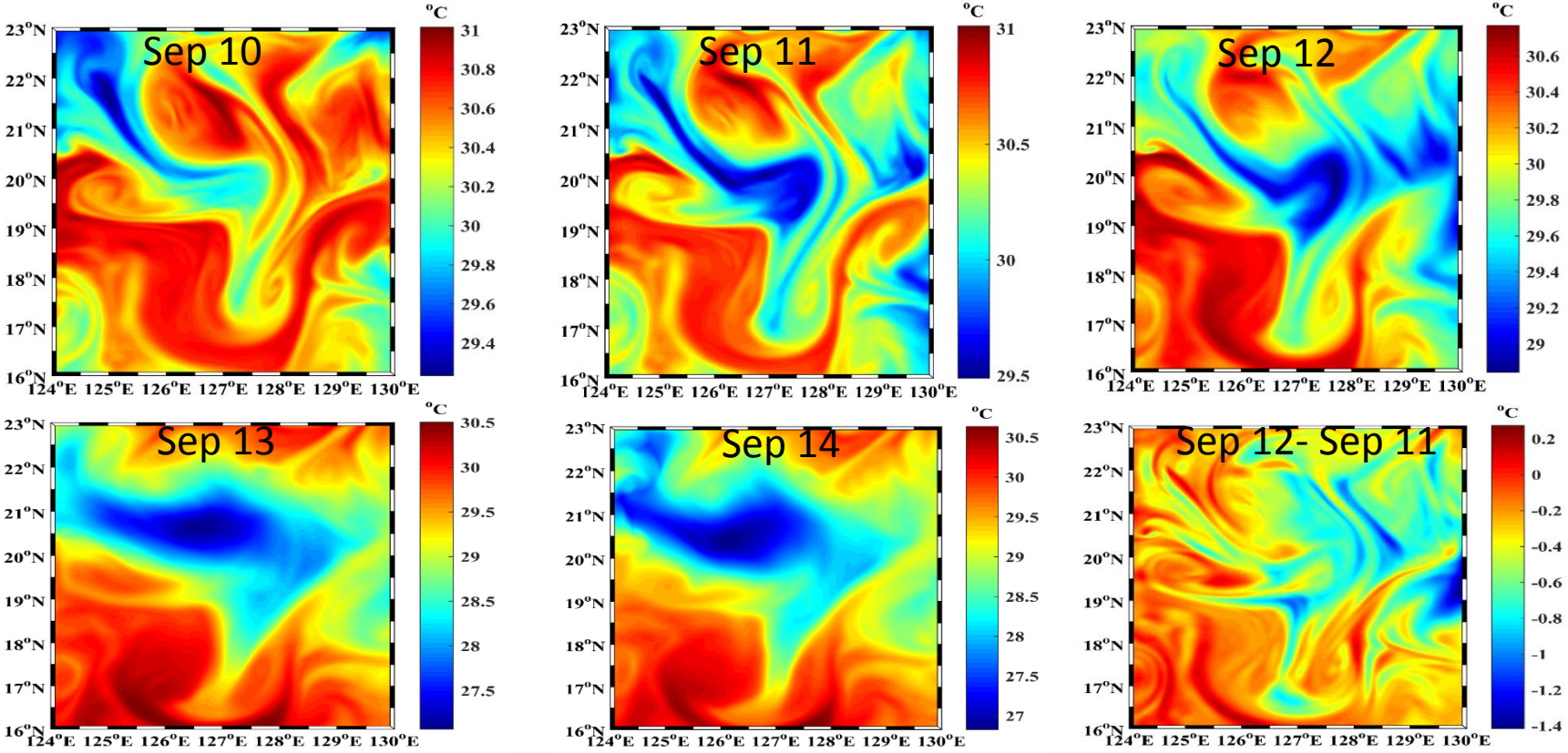




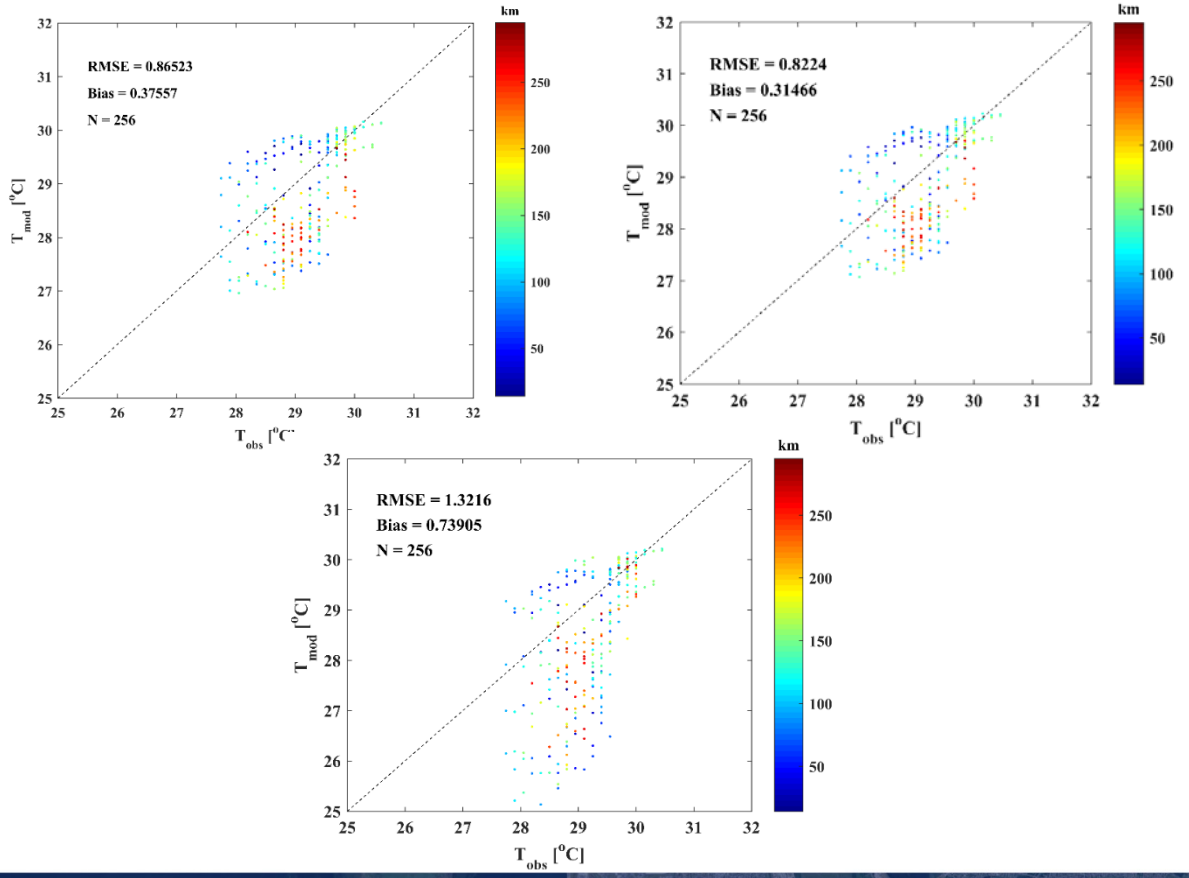


Sea surface temperature response

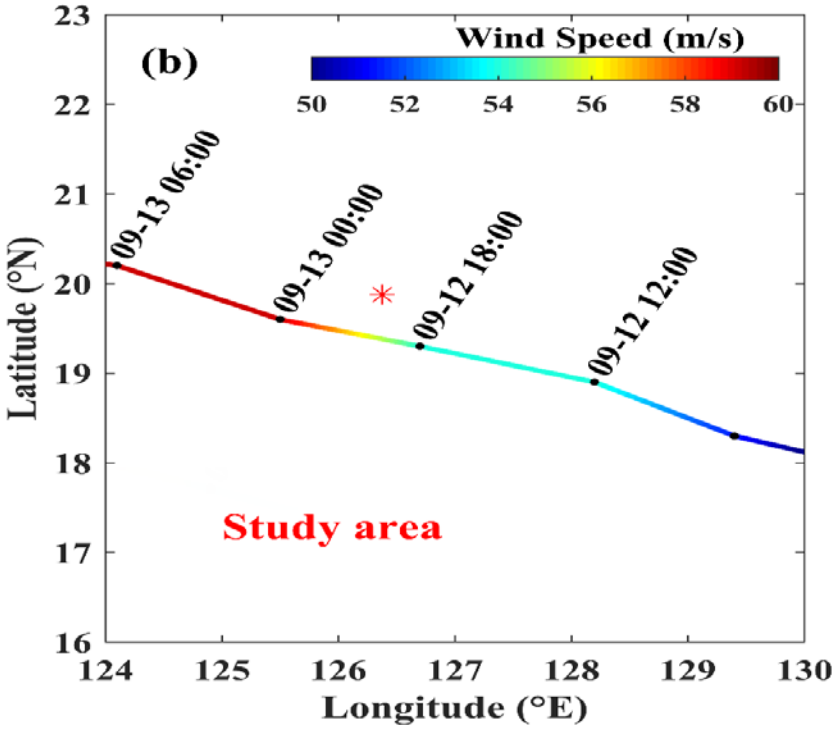
SAR wind forcing

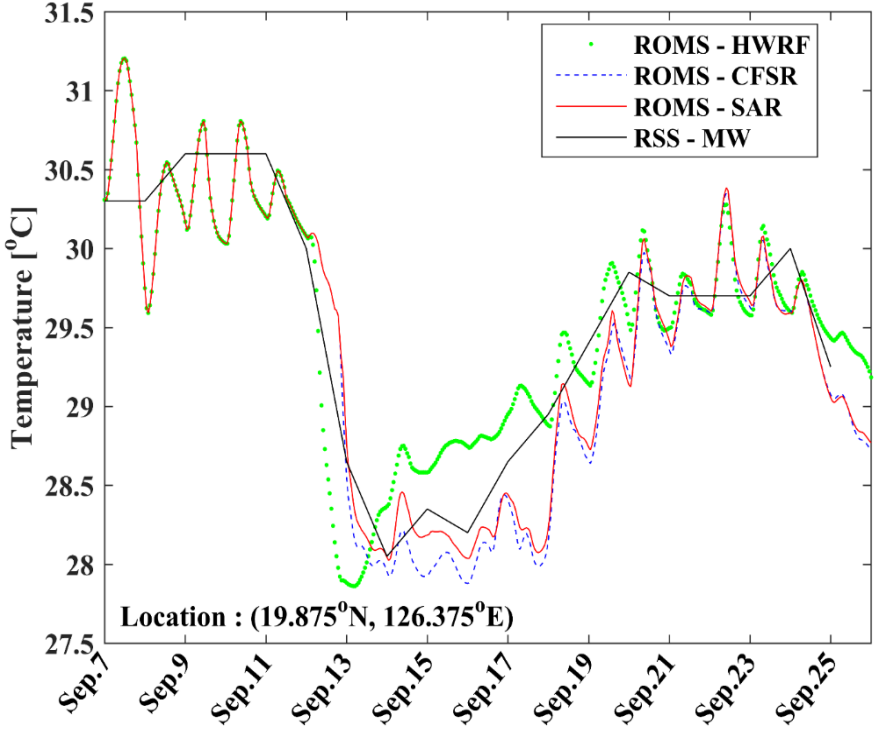


SST comparison between observations and simulations



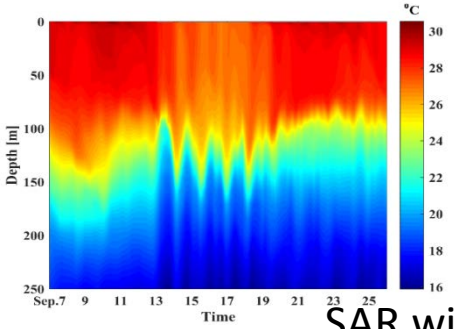
SST comparison between observations and simulations



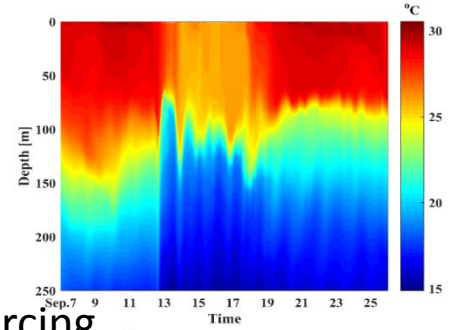


Sub-surface temperature response

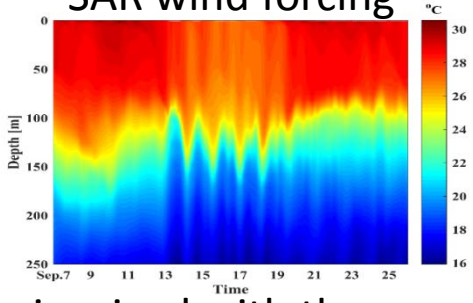
CSFR wind forcing



HWRF wind forcing

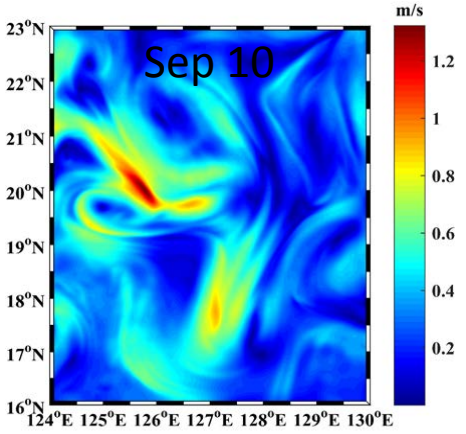


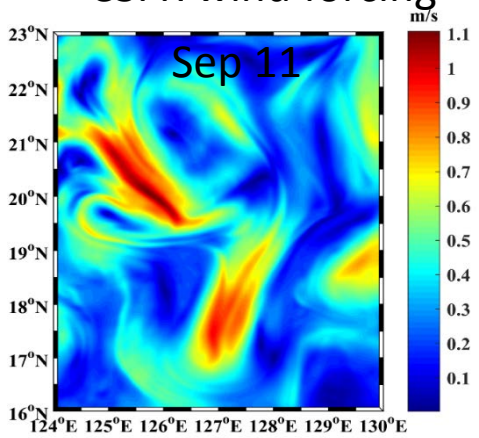
SAR wind forcing

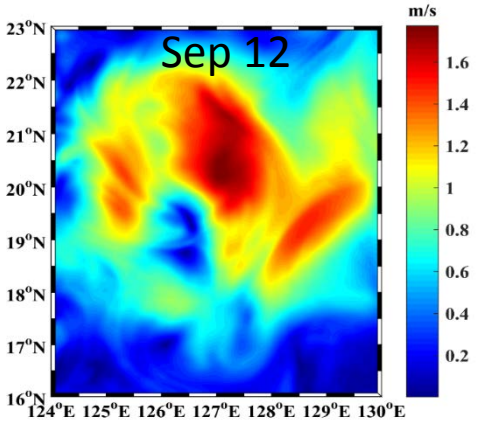


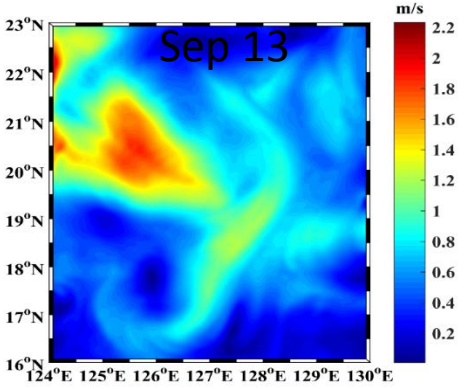
A cooler thermocline layer water is mixed with the warmer water from the mixed layer by entrainment mixing, the SST decrease. This entrainment is generated either by vertical shear of the horizontal current or by surface-generated turbulence within mixed layer.

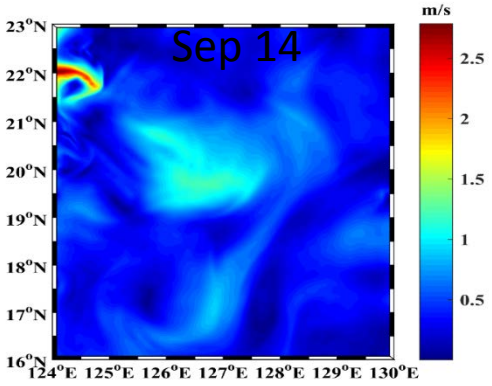
Surface current response
CSFR wind forcing

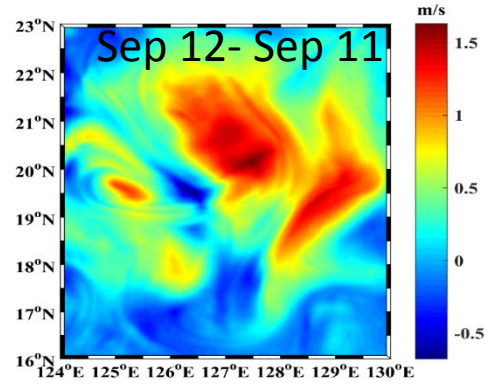






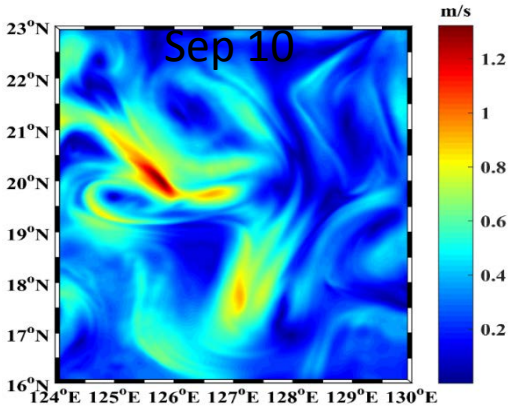


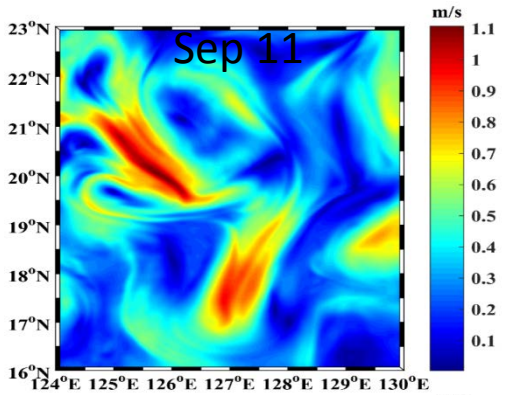


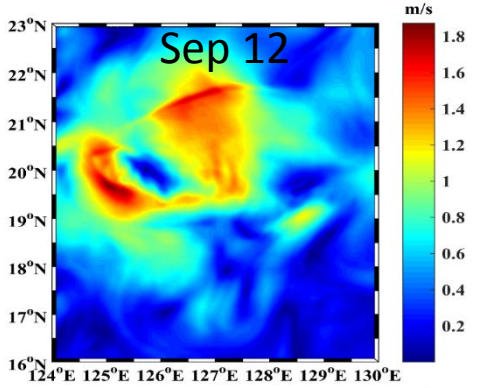


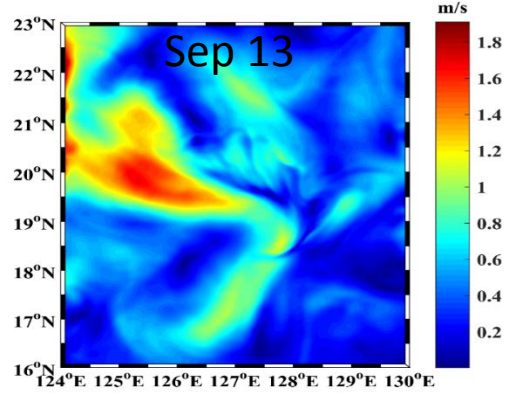
Surface current response

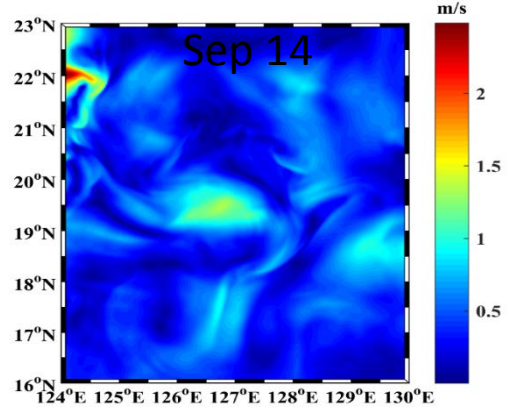
HWRF wind forcing

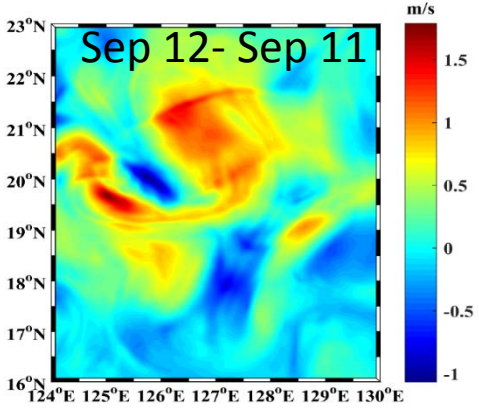




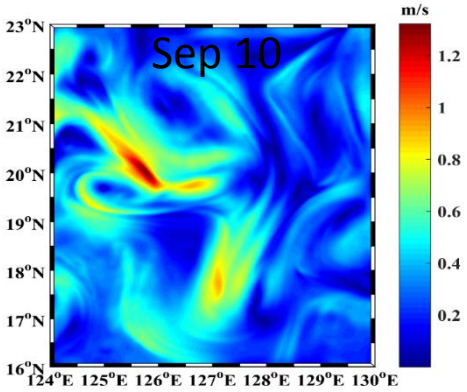


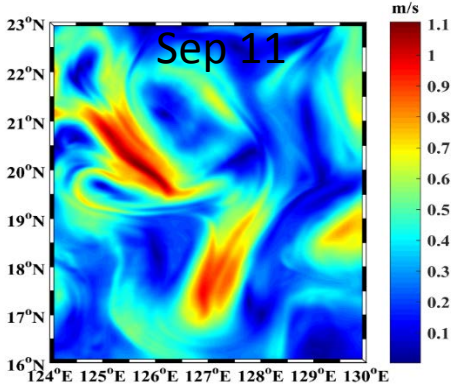


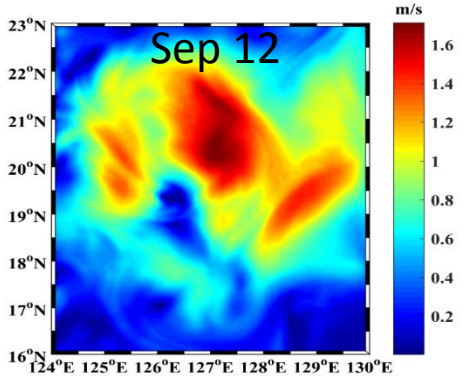


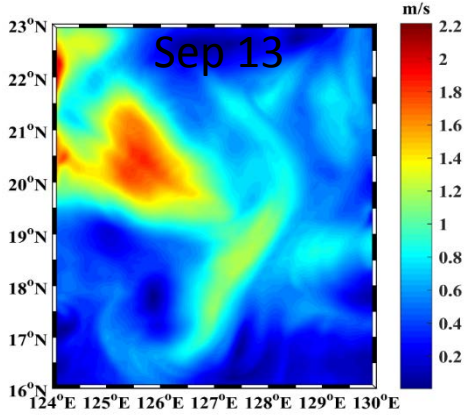


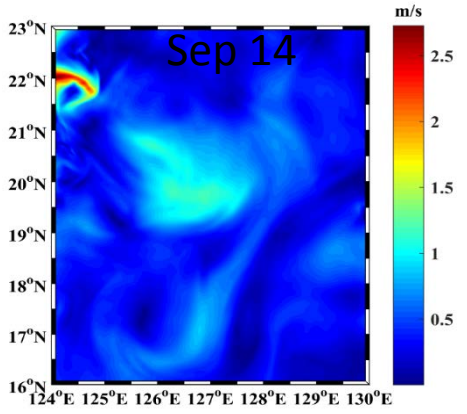
Surface current response
SAR wind forcing

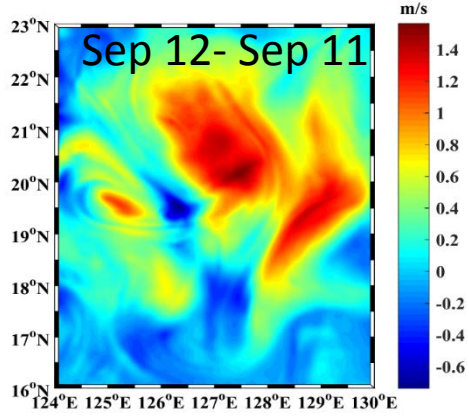




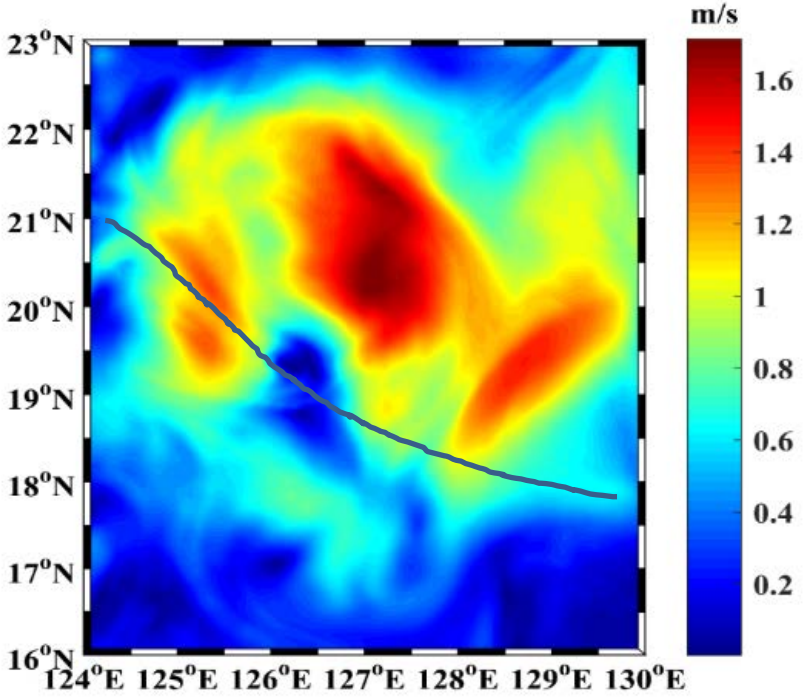








Surface current response



The asymmetry in the velocity pattern is a result of effective coupling of clockwise rotating wind stress vectors on the right side of the track and inertially rotating wind-driven currents.

Summary

1: The reasonable typhoon wind fields are obtained via combination of co- and cross-pol SAR measurements .

2: Dual-polarized SAR wind field is a good candidate surface forcing for oceanic numerical model. Synergy of SAR winds and model simulations has potential to better understanding the response of upper ocean to typhoon.

3: High temporal RCM SAR along with scatterometer and radiometer observations will provide a unique opportunity for monitoring typhoon and improving its forecast accuracy.

Thanks for your attention ！