SYMPOSIUM OP'24

ADVANCING OCEAN PREDICTION SCIENCE FOR SOCIETAL BENEFITS

Theme 5.4

Assimilation of Surface Residual Currents from HF Radar in the Jeju Strait

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Introduction

High frequency (HF) radar is an instrument that measures surface currents by emitting short waves from antennas to the sea surface and analyzing the phase difference of the reflected waves from the sea surface. The Jeju Strait, the study area, is heavily influenced by tides, predominantly the M2 semi-diurnal tide, which plays a crucial role in vertical and horizontal mixing due to its seasonal and spatial variability. For effective data assimilation of HF radar currents into an ocean circulation numerical model, the tidal characteristics simulated by the numerical model must be similar to those observed by the HF radar. This study proposes a method to assimilate residual currents, derived by removing tidal components from HF radar surface current data, into the numerical ocean circulation model.

Data and Methods

- Numerical Model

- Based on ROMS
- Model Domain: the Jeju Strait
- Average horizontal grid spacing: 500 m (898 x 834)
- vertically 20 sigma levels
- Initial & Boundary Data from HYCOM (0.04˚x 0.04˚x 40 level grid spacing)
- Atmospheric forcing data: ECMWF era5 (0.25˚x 0.25˚grid spacing)
- 10 tidal constituents along the open boundary (TPXO9)

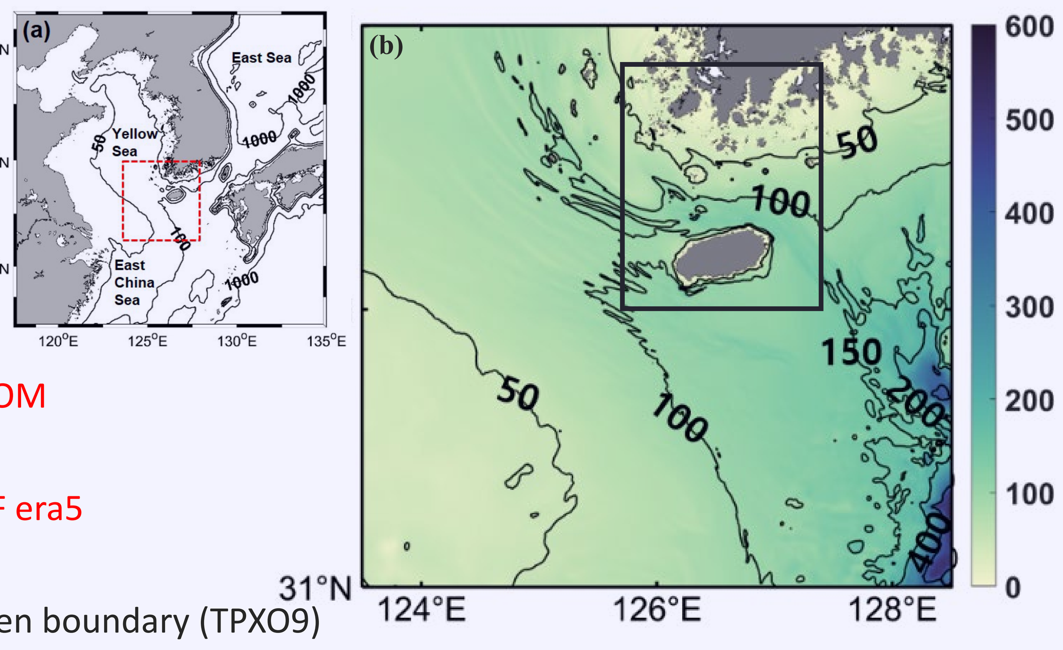
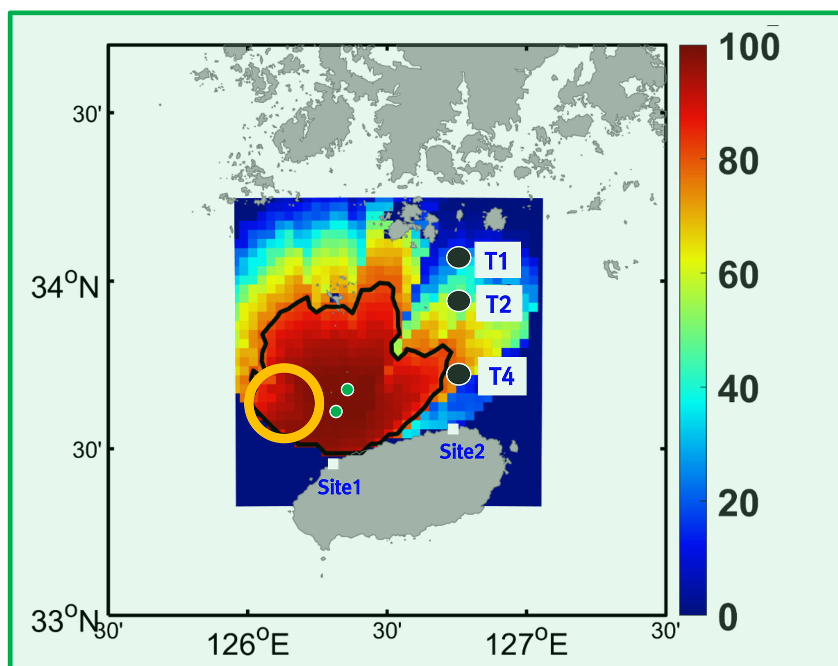


Fig. 1. (a) Numerical model domain, outlined by a red dashed box, are enclosed by the Yellow and East China Sea, (b) contour line represents bathymetry within the model domain and black rectangle indicates the area of interest , Jeju Strait, for further analysis



- Data Assimilation

- Method: Ensemble Kalman filter (EnKF)
- Data: HF-Radar **Total Vector**
- Depth: Surface
- Period: July 2020 (1 month)
- Assimilation Cycle: 3 hour
- Number of Ensemble member: 30

- Independent Data for validation

- 2 buoys, 3 ADCPs, 7 Drifters

Fig. 2. Distribution of HF radar total vector data coverage (%) for July 2020 at Sites 1 and 2. The black contour line represents the 80% data coverage threshold. Green circles indicate the locations of ocean buoy observations, blue circles denote ADCP observation sites, and the orange circle marks the positions of seven drifter observations

$$\overrightarrow{X_m} = \widetilde{X_m} + X_m' \qquad \text{- (1)}$$

$$\overrightarrow{X_o} = \widetilde{X_o} - X_o' + X_m' \qquad \text{- (2)}$$

$\overrightarrow{X_m}$: Model surface current

$\overrightarrow{X_o}$: HF Radar surface current

$\widetilde{X_m}$: Model residual current

$\widetilde{X_o}$: HF Radar residual current

X_m': Model tidal current

X_o': HF Radar tidal current

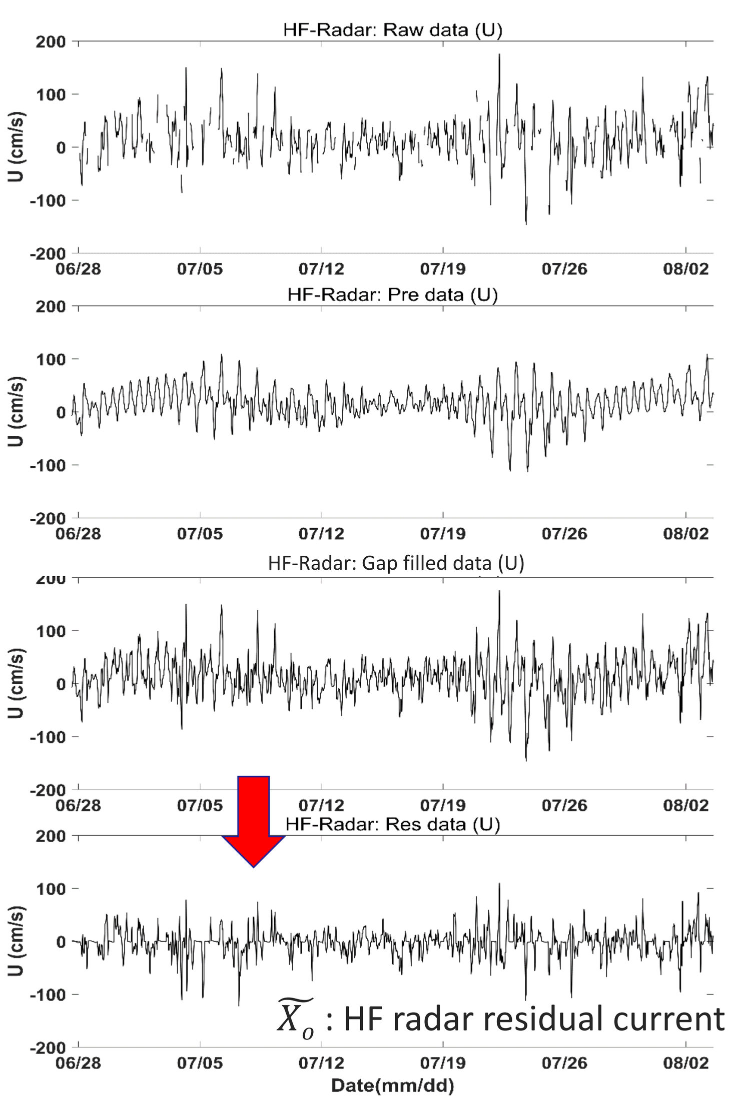


Fig. 3. The process of obtaining HF radar residual currents by performing harmonic analysis on raw HF radar data to fill gaps and applying harmonic analysis three times. The residual current from HF radar is then combined with the tidal current from the numerical model to be used in data assimilation

Results

Comparison of Surface Currents

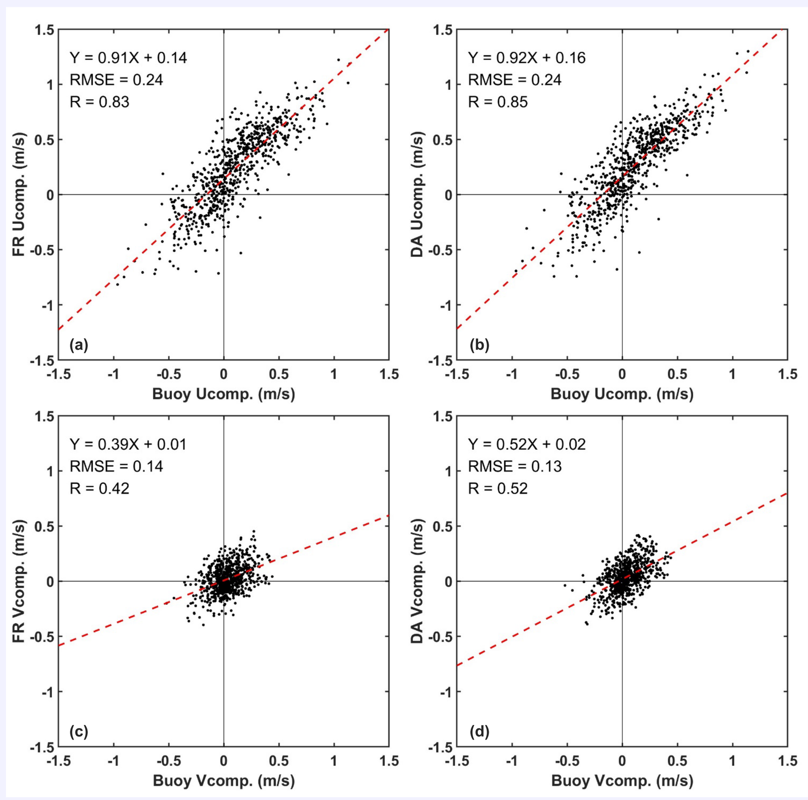


Fig. 4. Comparison of model surface currents with observations from ocean buoys for both u- and v-components in FR (a, c) and DA (b, d)

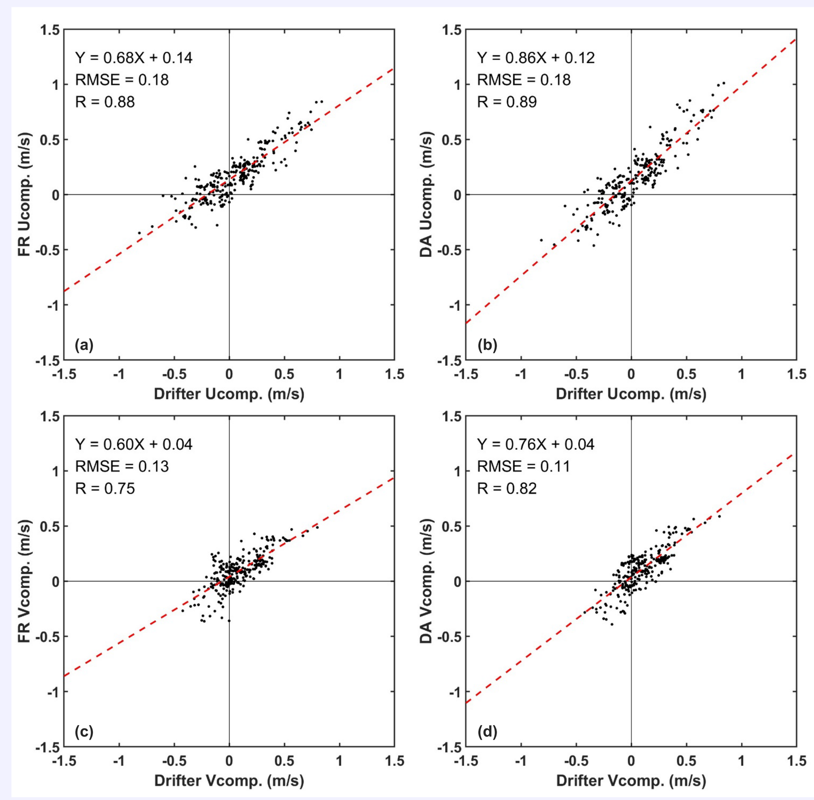


Fig. 5. Comparison with surface currents from drifters. Root mean square error (RMSE) and correlation coefficient (R) were used for assessment

- u-component improved: Buoy R 0.83 → 0.85, Drifter R 0.88 → 0.89
- v-component improved: Buoy R 0.42 → 0.52, Drifter R 0.75 → 0.82
- RMSE reductions indicate improved accuracy in surface current predictions

Impact on Vertical Currents Distribution

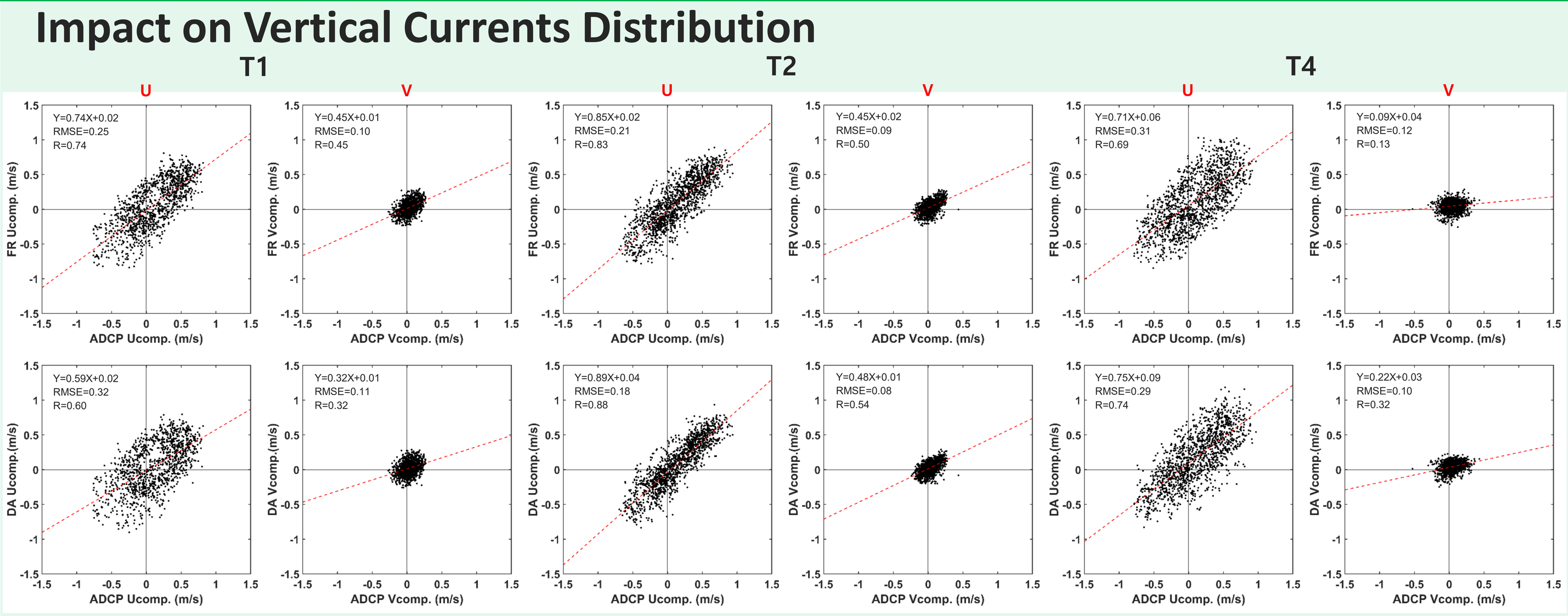


Fig. 6. Comparison of model surface currents with ADCP observations at locations T1, T2, and T4 for the u-component (left) and v-component (right), with FR (upper panels) and DA (lower panels). Each panel provides the linear regression equation, RMSE, and R for both FR and DA results

Table 1. Comparison of the slope, RMSE, and R values between the FR and DA results at the T1, T2, and T4 ADCP stations. The percentage values represent the relative improvement or deterioration from FR to DA, with blue indicating improvement and red indicating deterioration

Sta.	Comp.	Slope FR	Slope DA	RMSE FR	RMSE DA	R FR	R DA
T1	u	0.74	0.59 (20%)	0.25	0.32 (28%)	0.74	0.60 (19%)
	v	0.45	0.32 (29%)	0.10	0.11 (10%)	0.45	0.32 (29%)
T2	u	0.85	0.89 (4.7%)	0.21	0.18 (14%)	0.83	0.88 (6.0%)
	v	0.45	0.48 (6.7%)	0.09	0.08 (11%)	0.50	0.54 (8.0%)
T4	u	0.71	0.75 (5.6%)	0.31	0.29 (6.5%)	0.69	0.74 (7.2%)
	v	0.09	0.22 (144%)	0.12	0.10 (16.7%)	0.13	0.32 (146%)

Effects on Surface Temperature and Currents

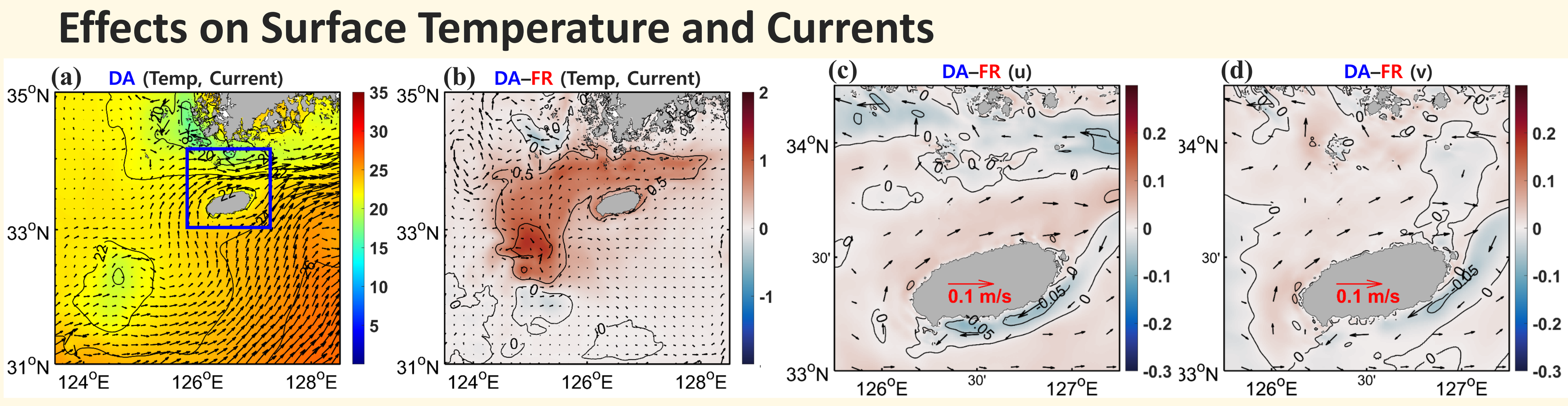


Fig. 7. (a) Horizontal distribution of surface temperature and currents in the DA. (b) Difference in surface temperature and currents between DA and FR. (c) Surface u-component difference and (d) surface v-component difference between DA and FR, with (c) and (d) showing the enlarged view of the blue box region in (a)

- After data assimilation, increased turbulent inflow results in elevated sea surface temperature within the Jeju Strait, likely due to the strengthened representation of turbulent inflow in the assimilated fields
- Intensified warm current inflow is thought to enhance the northeastward flow and increase current speeds to the north of Jeju Island, whereas the northeastward currents to the southeast of Jeju Island were weakened

Conclusions

A method for assimilating residual currents was developed to address discrepancies between numerical model and HF radar tidal currents in regions with strong tidal influence. Assimilative model results demonstrated improvements in surface current accuracy, with the influence on both surface currents and vertical current profiles. The assimilation further intensified warm current inflow, raising surface temperatures in the Jeju Strait. This process is thought to strengthen the northeastward flow in the northern region of Jeju, while relatively weakening the northeastward flow in the southern region.