Retrieval of ocean surface wind and current using OSCOM airborne campaign dataset

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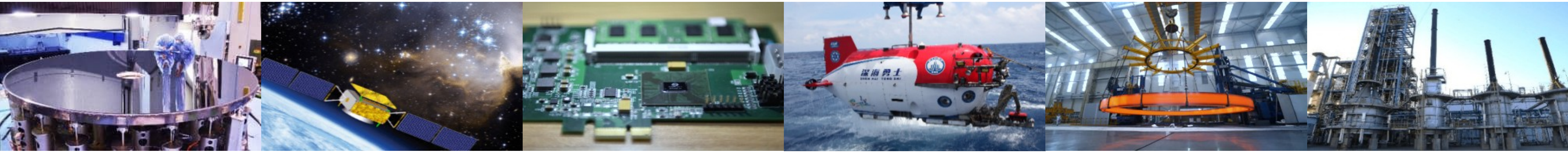

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Wind and current retrievals from Doppler scatterometer data:

Doppler Scatterometer → NRCS (σ_0) → Ocean surface wind

Doppler Scatterometer → Doppler shift (df) → Ocean surface current

1. the wind and currents are retrieved **separately**

- Wind inversion:

$$MLE = \frac{1}{n}\sum_{i=1}^{n}\frac{(\sigma_{mi}^0 - \sigma_{si}^0)^2}{(K_p\sigma_{mi}^0)^2}$$

$$\sigma_{si}^0 = F_\sigma(\mathrm{u}_{10}, \varphi, \theta, pol)$$

- Current inversion:

$$U = U_D - U_{wd} - U_{geo}$$

$$U_{wd} = F_D(u_{10}, \varphi, \theta, pol)$$

2. the wind and currents are retrieved **simultaneously**

$$MLE = \frac{1}{n}\sum_{i=1}^{n}\frac{(\sigma_{mi}^0 - \sigma_{si}^0)^2}{(K_p\sigma_{mi}^0)^2} + \frac{1}{n}\sum_{i=1}^{n}\frac{(f_{mi} - f_{si})^2}{(\Delta f_{mi})^2}$$

The velocity includes 3 components:

$$U_D = U_{geo} + U_{nwd} + U_{wd}$$

U_{geo} : non-geophysical component

U_{nwd} : Currents that are not driven by the instantaneous local wind

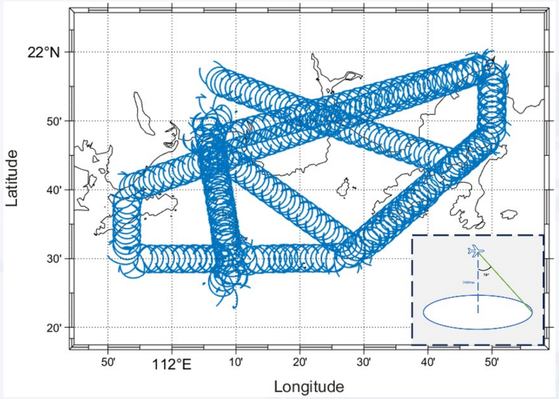
U_{wd} : wind-driven component (Wind-wave-induced Artifact Surface Velocity (WASV))

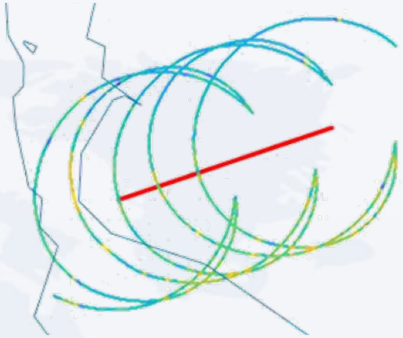
Airborne Doppler scatterometers face many challenges → **calibrate measurements**

- Instrument instability
- Limited dataset
- ……

Ocean Surface Current multiscale Observation Mission (OSCOM) campaign:

Rotating pencil-beam airborne doppler scatterometer





- Ka-band: 35.9 GHz
- Experiment year : 2020

  August 6 14:30pm-17:30pm

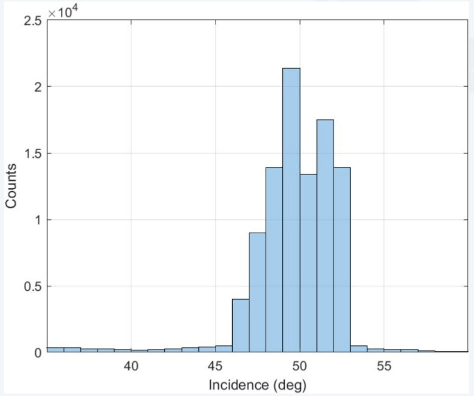
  August 11 14:30pm-17:10pm

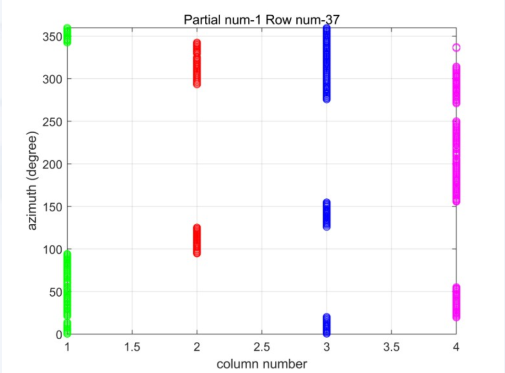
  August 15 14:00pm-18:00pm
- Experiment area: Coastal area in south of Yangjiang River, Guangdong Province, China

  Latitude: from 21°30’N to 22°00’N

  Longitude: from 111°53’E to 112°50’E

- Polarization: VV
- turning angle: ±160°





The main system parameters are shown in Table I.

Table I System Parameters of Airborne Doppler Scatterometer

Incidence Angle	50°
Flight Height	3000m
Carrier Frequency	35.9GHz
Signal Bandwidth	5MHz
Signal Form	Chirp Signal
Pulse Width	4us
Pulse Interval	4us
Central Frequency of IF	14MHz
Sampling Frequency	56MHz
Pulse Period	100us
Antenna Rotation Speed	40°/s

Others:

- Ka-band GMF: KaDPMod, KaDOP
- ECMWF winds

L1B Measurements → L2

- NRCS (σ_0)
- Doppler shift

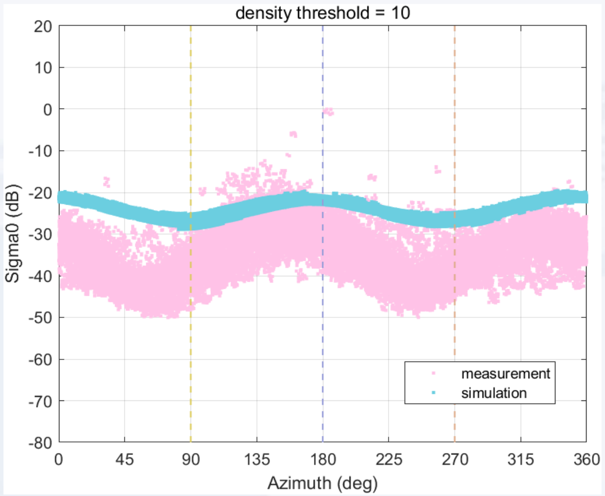
- Cell size: 2 km
- Swath width: 8 km

3. Methodology: calibration and inversion for winds

B. Calibration and Inversion：

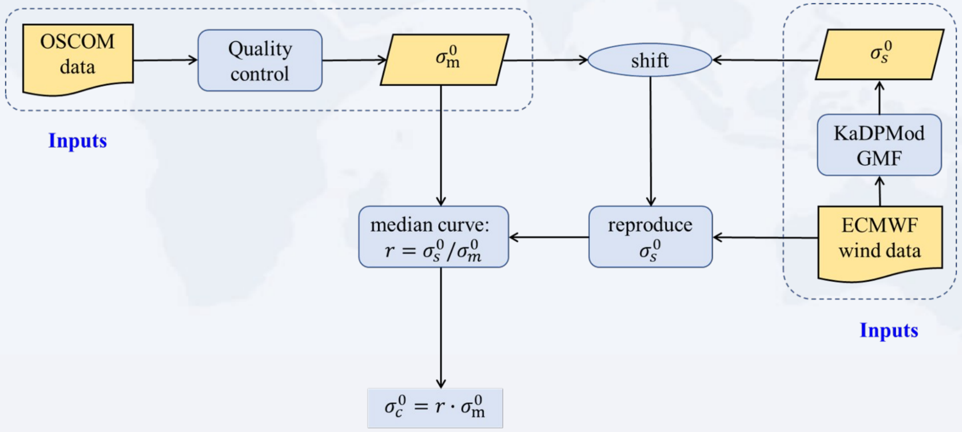
Calculate the ‘true’ wind directions (azimuthal shift)

- the median curves of σ^0

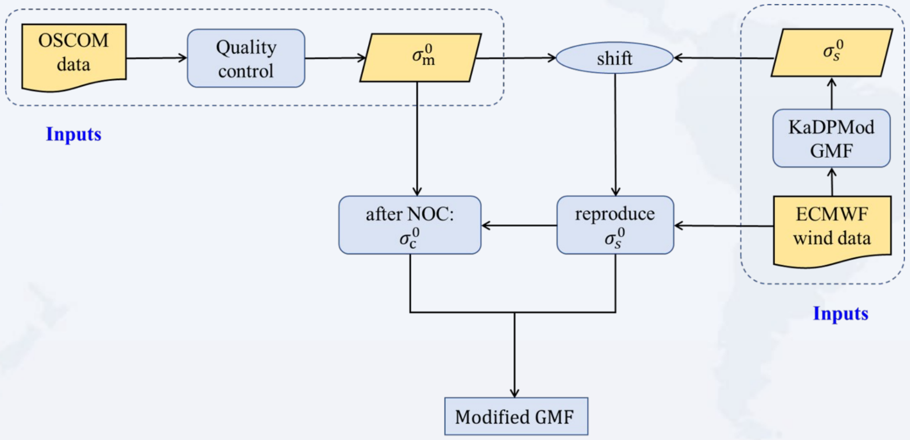


Compared with simulated data:

- larger azimuthal shift → an error in the ECMWF wind direction
- approximately 10 dB smaller → needs NOC calibration
- greater wind direction modulation → **2 different calibration methods**



Method 1: azimuth dependent



Method 2: based on modification of the GMF

4. Results: calibration and inversion for winds

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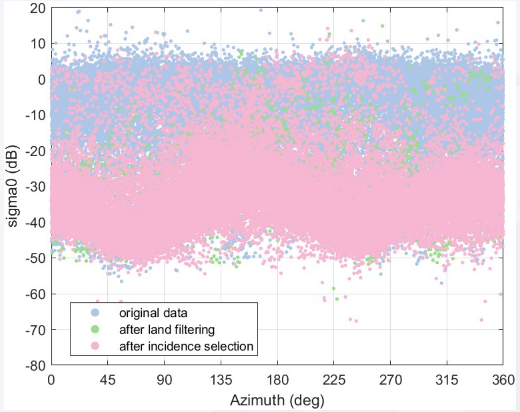
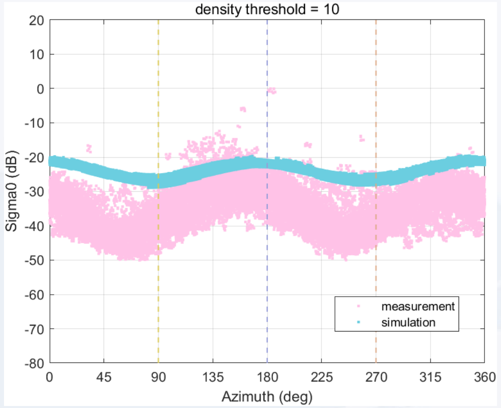
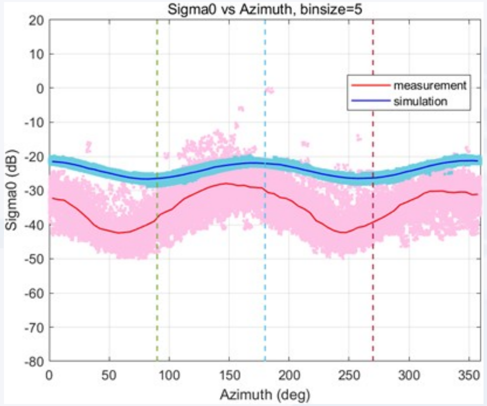
A. Quality control results：



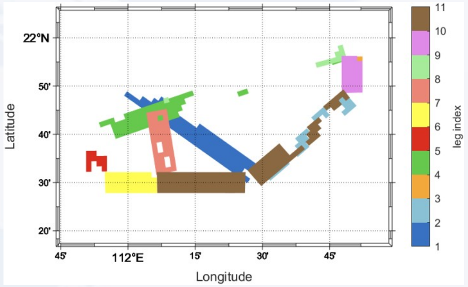


B. Calibration results： ‘True’ wind direction



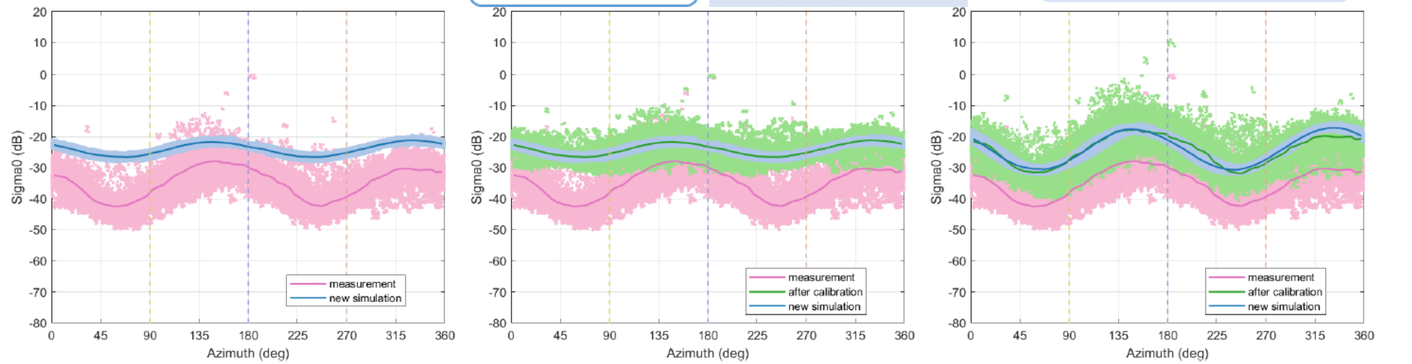
Shift: **‘True’ wind direction**

- measurement = 155°
- Simulation = 175°



C. Calibration results： with azimuth-dependent calibration and modified GMF calibration

$r = \sigma_s^0 / \sigma_m^0$ $\quad$ $\sigma_c^0 = r \cdot \sigma_m^0$ $\quad$ σ_c^0 with new GMF



(a) measured and simulated σ^0 (b) azimuth-dependent calibration (c) modified GMF calibration

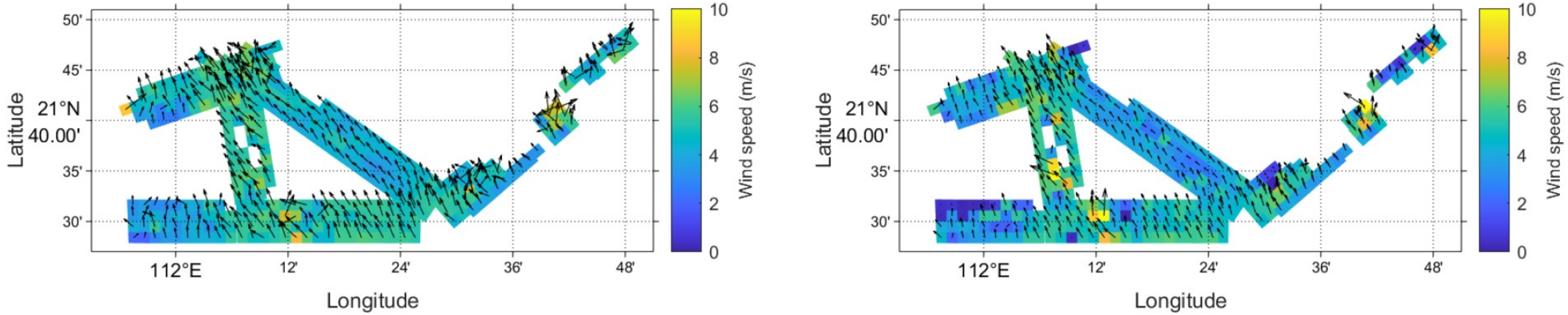
Fig. 8. Backscatter data as a function of azimuth angle for: a) measured (after quality control) and simulated backscatter data, where the wind directions (curve peak shifts w.r.t. 180°) are 155° and 175° (w.r.t. North), respectively; b) measured (pink), newly simulated (blue) and azimuth-dependent calibrated (green) σ^0; and c) measured (pink), modified GMF calibrated (green) and newly simulated (blue) σ^0.

Pink: measurement
Blue: simulation
Green: calibration

4. Results

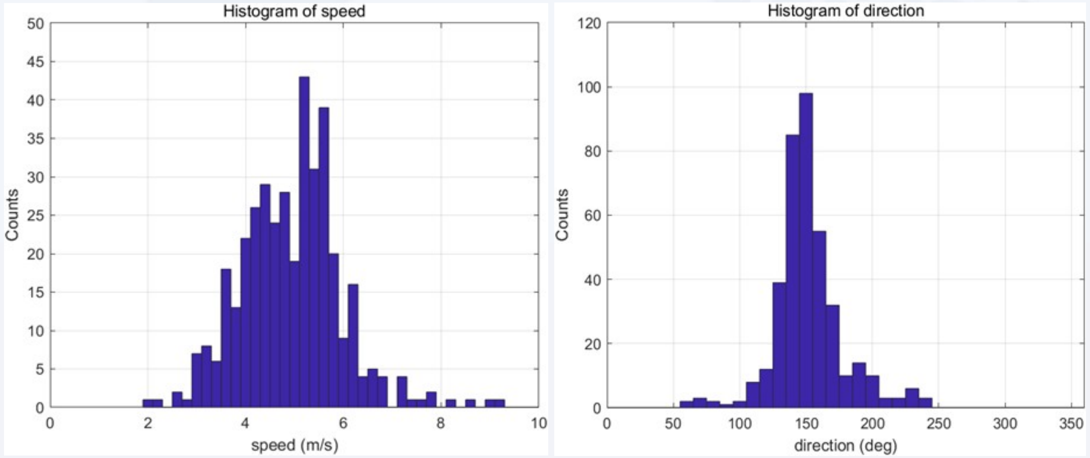
D. Wind inversion results

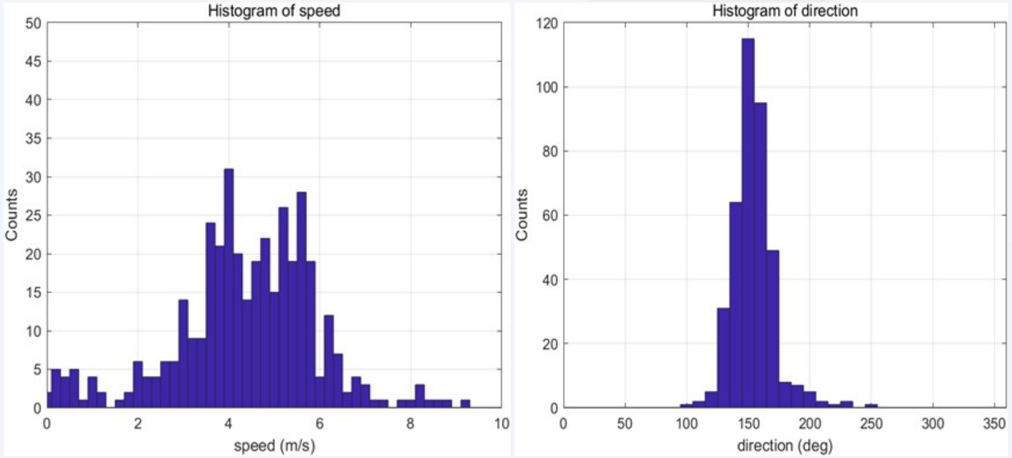
Wind field:



(a) azimuth-dependent method (b) with modified GMF

Fig. 13. Wind field retrieved using calibration method: a) using azimuth-dependent method (with the overall ratio); b) using the method with modified GMF (using dual correction factors). The data are shown with a 2 km × 2 km grid spacing.

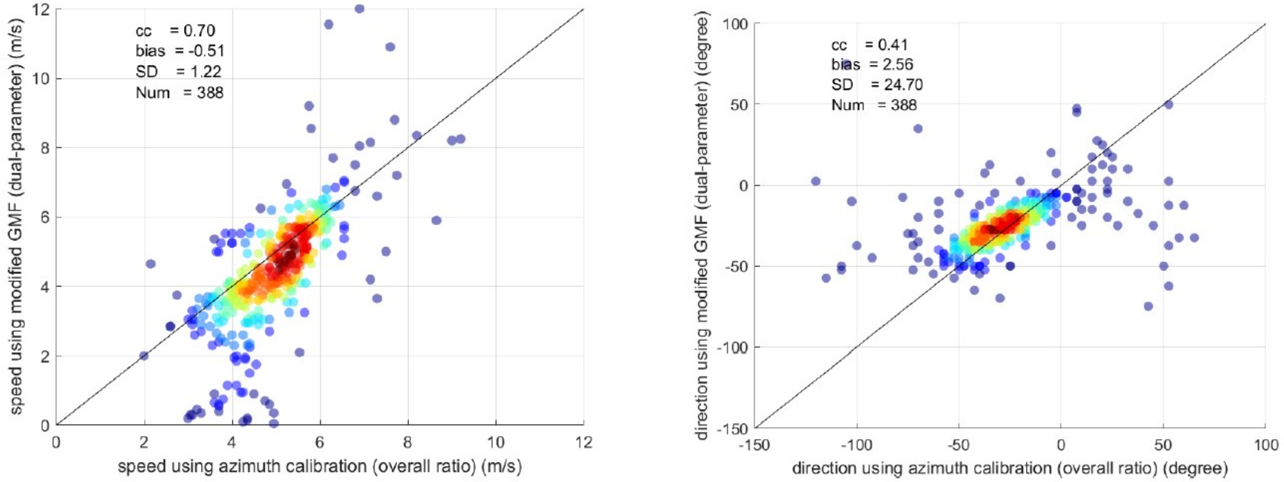




4. Results

D. Wind inversion results

Comparison between azimuth calibration and modified GMF winds:



(a) speed (b) direction

Fig. 14. Comparison between wind field retrieved using two calibration methods: a) for wind speed; b) for wind direction.

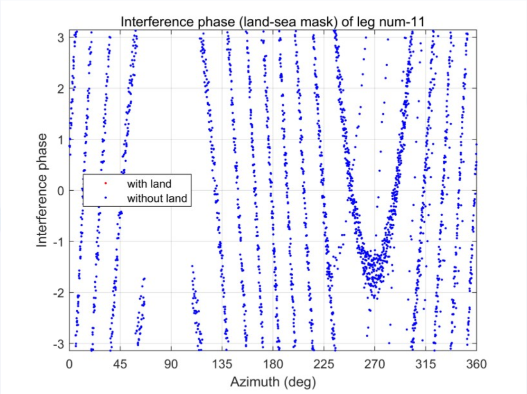
Comparison against ECMWF winds:

TABLE I
The mean bias and the mean standard deviation (SD) of residuals of four methods.

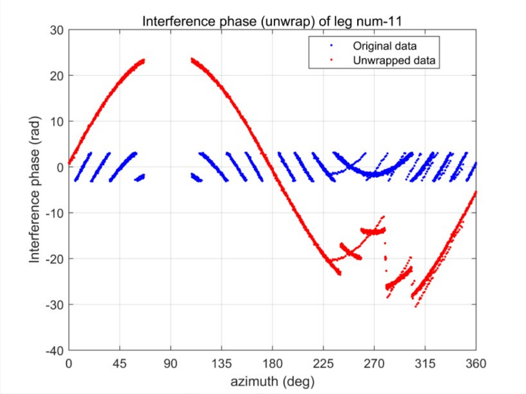
	speed bias (m/s)	speed SD (m/s)	direction SD (deg)	U SD (m/s)	V SD (m/s)
with azimuth calibration (overall ratio)	-0.28	0.65	8.97	0.78	0.60
with azimuth calibration (each leg's ratio)	-0.17	0.20	4.56	0.33	0.27
with modified GMF (a_{1coef} and a_{2coef})	-0.80	0.84	5.86	0.58	0.70
with modified GMF (only a_{2coef})	-0.84	0.76	3.67	0.3	0.70

3. Methodology: inversion for currents

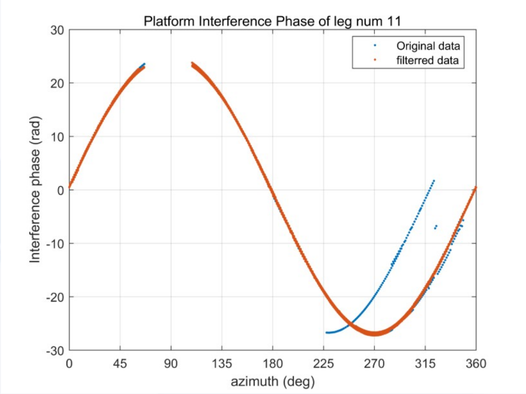
Phase processing：



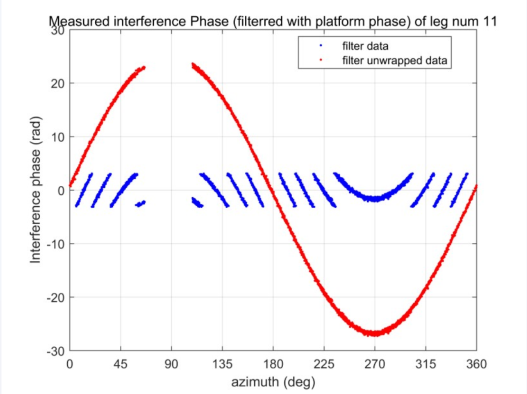
Measured interference phase in one leg



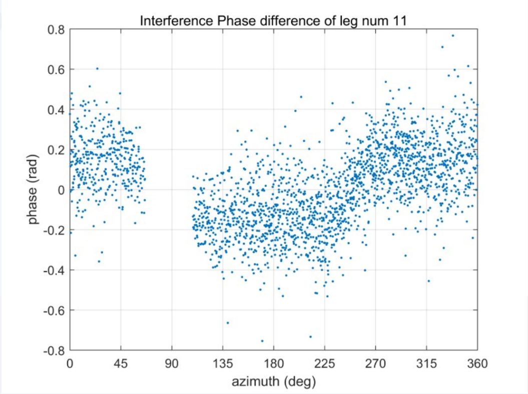
Unwrap measured interference phase (red)



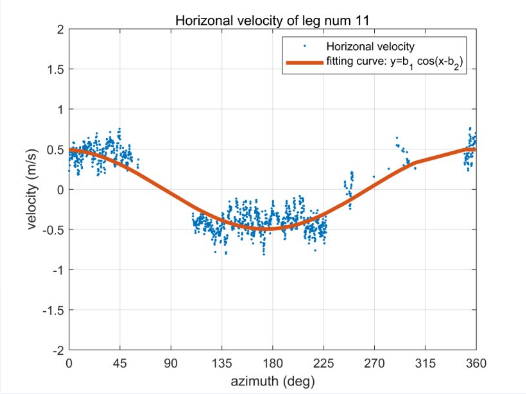
Platform interference phase (red: after filtering)



Measured interference phase after filtering



Measured interference phase **minus** Platform interference phase



Apply mean filter

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A. the wind and currents are retrieved separately:

The wind-correlated Doppler shift is simulated using the KaDOP GMF.

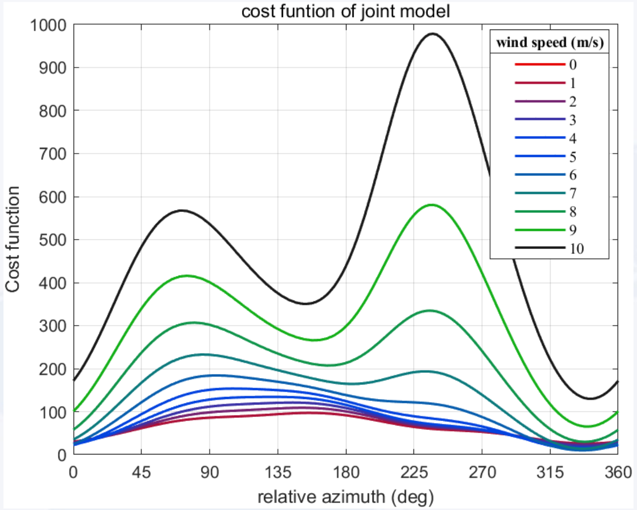
$$U_{current} = U_D - U_{wd} - U_{geo}$$

$$U_{wd} = F_D(u_{10}, \varphi, \theta, pol)$$

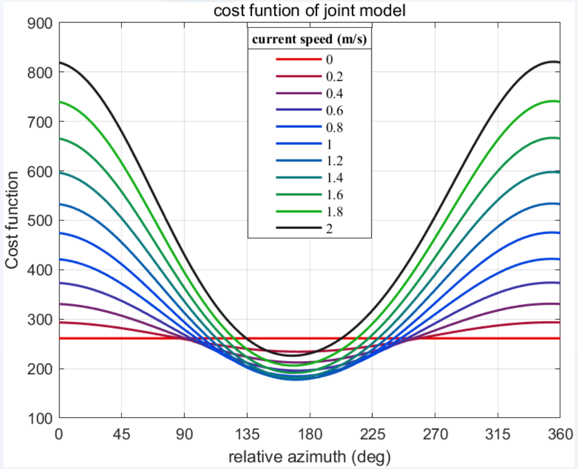
$$U_D = \frac{\pi}{k_e \sin\theta} f_D$$

B. the wind and currents are retrieved simultaneously

$$MLE = \frac{1}{n}\sum_{i=1}^{n}\frac{(\sigma_{mi}^0 - \sigma_{si}^0)^2}{(K_p\sigma_{mi}^0)^2} + \frac{1}{n}\sum_{i=1}^{n}\frac{(f_{mi} - f_{si})^2}{(\Delta f_{mi})^2}$$



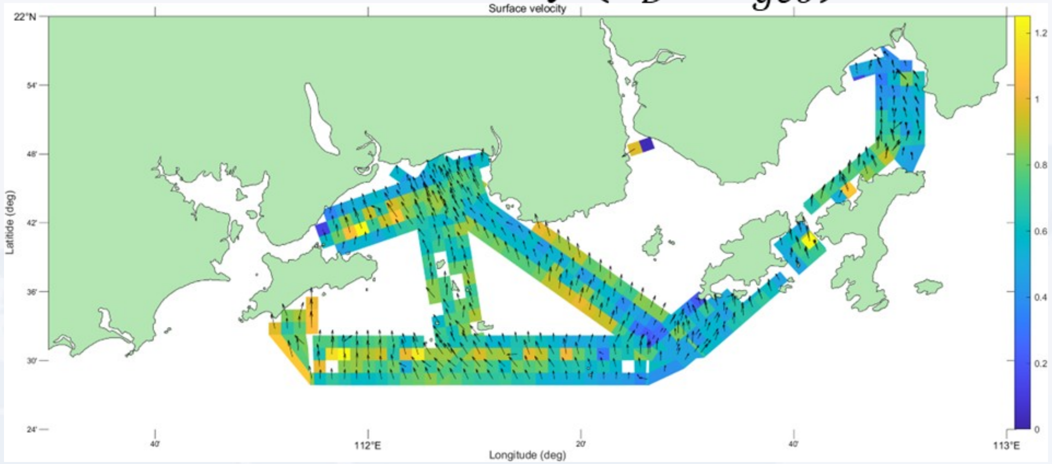
Cost function when the current is fixed (0.18m/s, 1.51°) two and flat minima



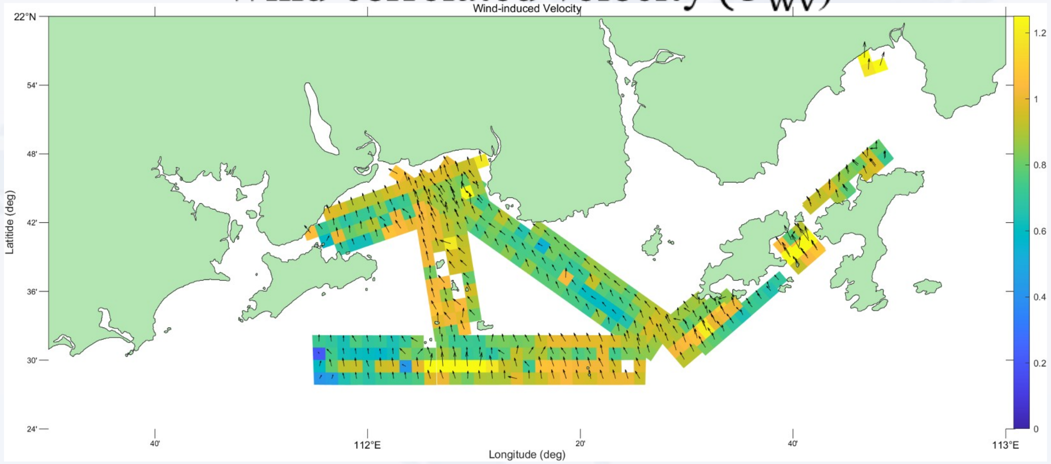
Cost function when the wind is fixed (6.08m/s, 6.64°) one minima

B. Current inversion results (with modified GMF, single parameter)

Sea Surface Velocity $(U_D - U_{geo})$

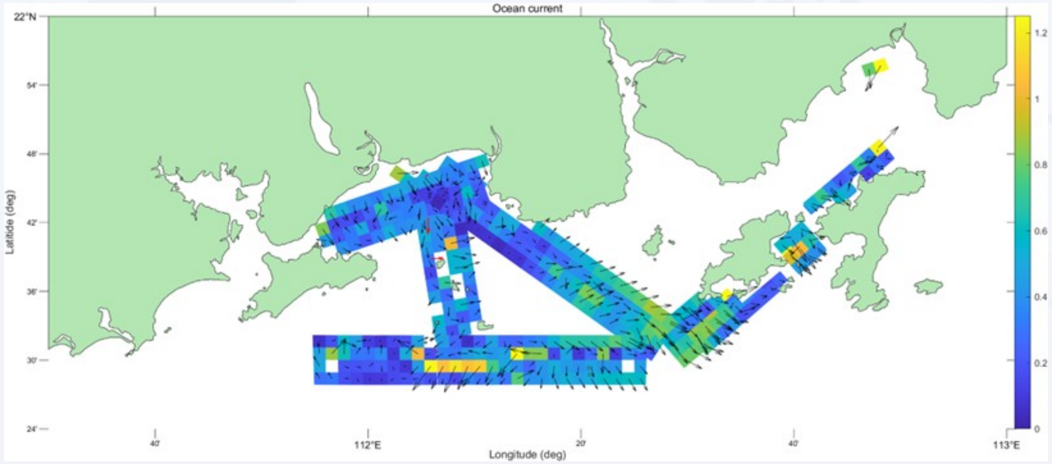


Wind-correlated Velocity (U_{wv})



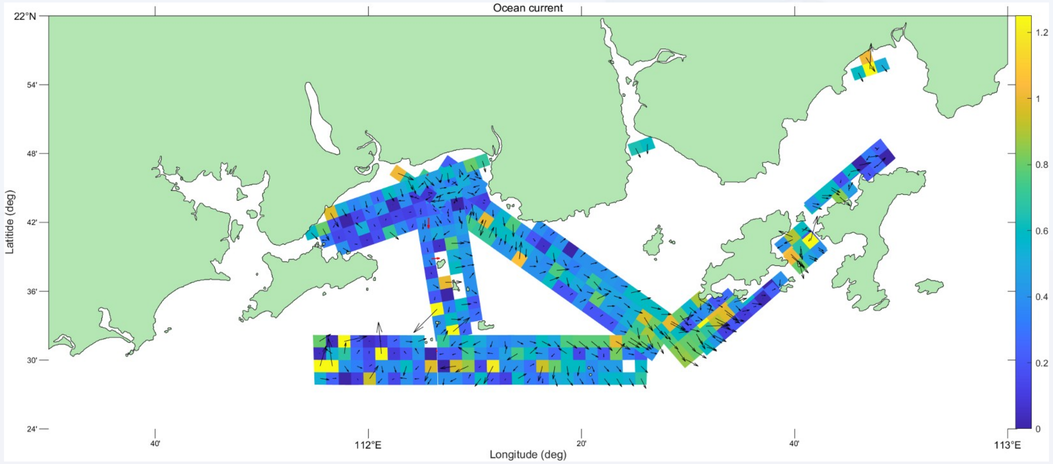
Sea Surface Current (retrieved separately)

$U_{current}$



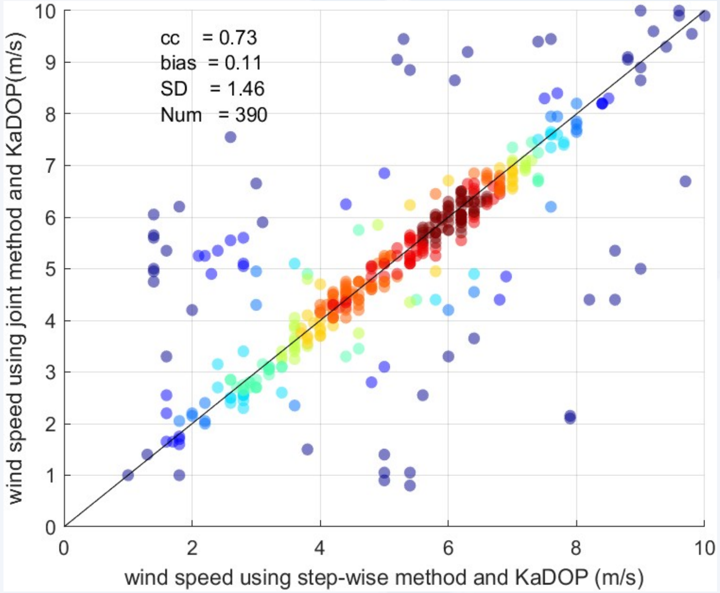
Sea Surface Current (retrieved simultaneously)

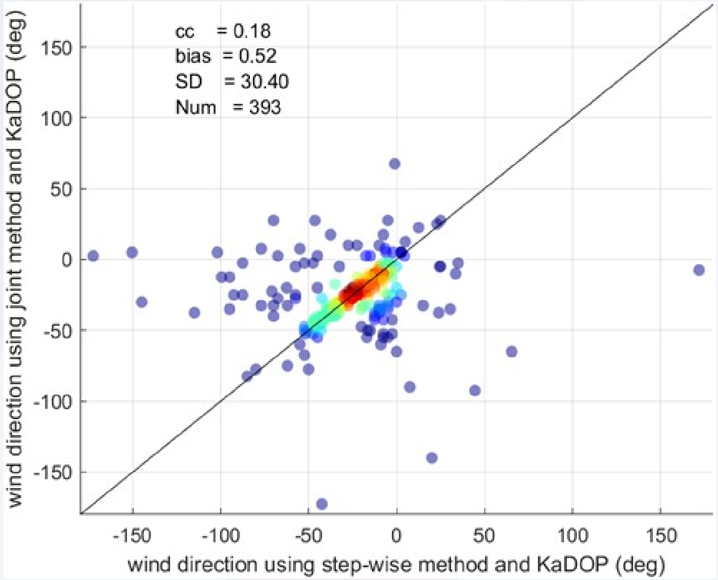
$U_{current}$



A. Wind inversion results (with modified GMF, single parameter)

Comparison between step-wise method and joint method

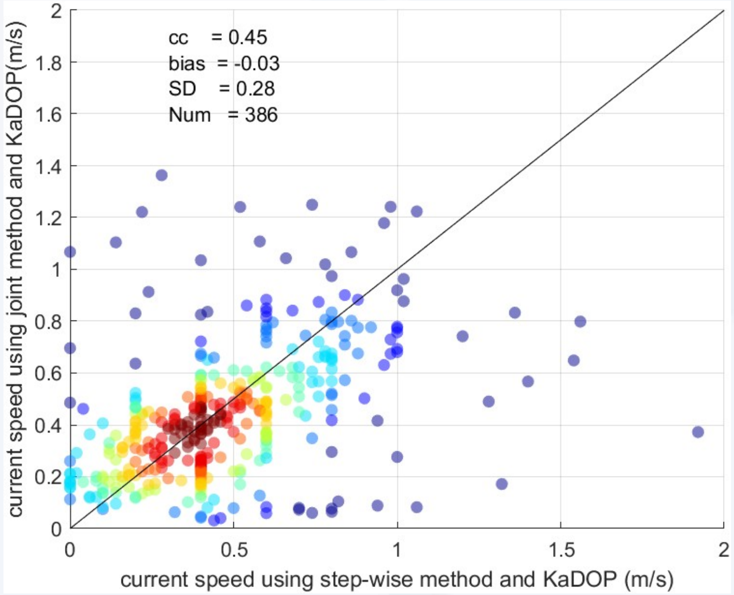


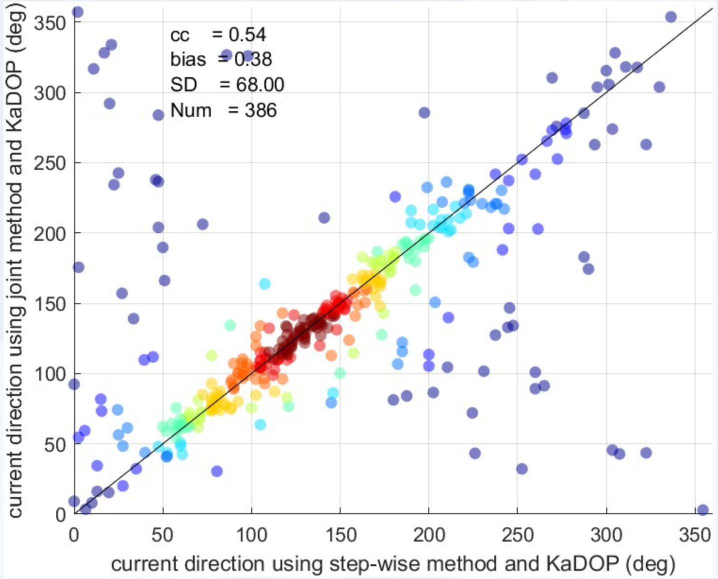


4. Results

A. Current inversion results (with modified GMF, single parameter)

Comparison between step-wise method and joint method





Comparison with in-situ data (current meter)

	Step-wise method	Joint method
Speed (m/s)	0.14	0.16
Direction (°)	18.00	14.59

Comparison with OSCAR data (0.25°, per day)

	Step-wise method	Joint method
Speed bias (m/s)	0.35	0.36
Speed std(°)	0.38	0.31
Direction bias(°)	18.94	8.27
Direction std(°)	54.04	71.71

5. Summary

- Two calibration methods are applied to NRCS, one using azimuth-dependent calibration and the other using a modified GMF. Two inversion methods are used to retrieve ocean surface winds: step-wise method and simultaneous method.

- In comparison with ECMWF winds, the retrieved winds obtained using azimuth-dependent calibration present lower wind speed bias. The wind directions obtained with the modified GMF calibration show lower scatter with respect to ECMWF wind directions.

- Compared to in situ data, the stepwise inversion shows smaller differences in current speed and direction, indicating better agreement with buoy readings. In contrast, the joint inversion method results in larger discrepancies, suggesting its performance may be impacted by data quality and azimuthal diversity.

- A comprehensive reference dataset with coincident in situ wind measurements is needed.

- Offer quantitative support for future research.

6. Future: CFOSAT-NG

CFOSAT (The China France Oceanography SATtellite)

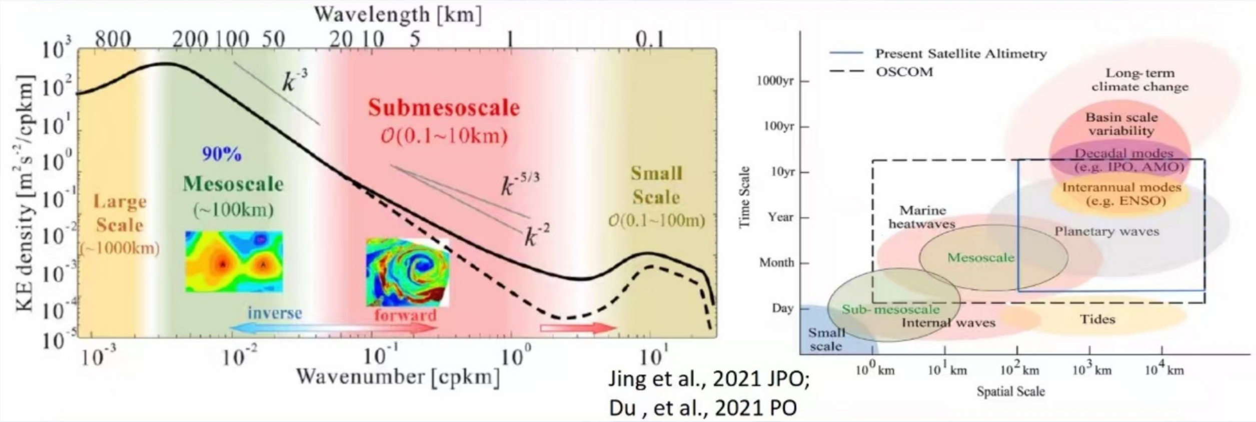
China: SCAT-NG   Doppler Scatterometer, DOPS

France: SWIM-NG

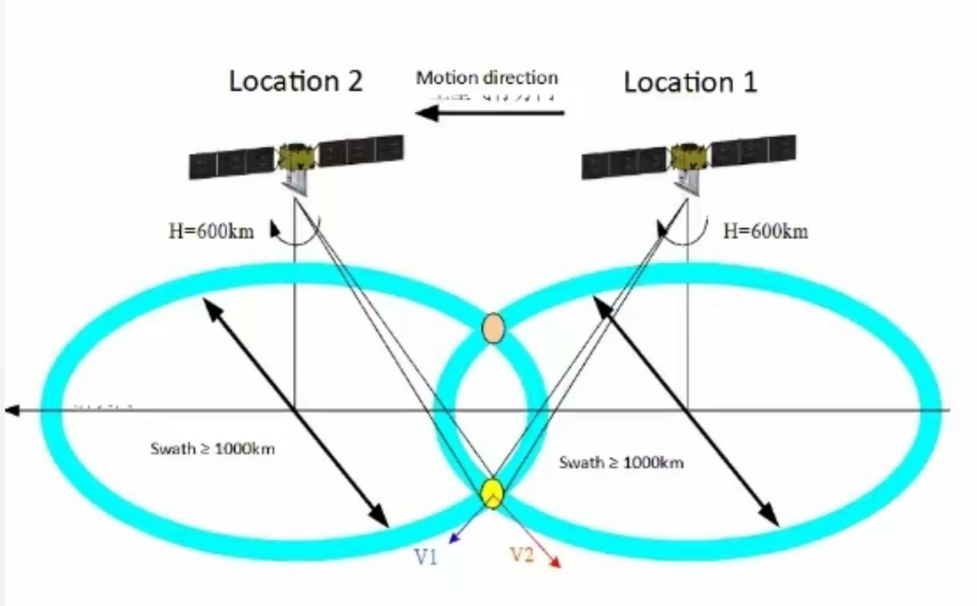
DOPS is based on OSCOM, operated in Ka + Ku band.

- Ocean current (5 km, 0.1 m/s)
- Ocean wind (5 km, 1.5 m/s)
- Ocean wave (10 km 、 50-500 m wavelength)

Swath: ≥ 1000 km



Jing et al., 2021 JPO;
Du , et al., 2021 PO



Thank you!

Simultaneous wind and current retrievals from Doppler scatterometer data: calibration of OSCOM backscatter measurements

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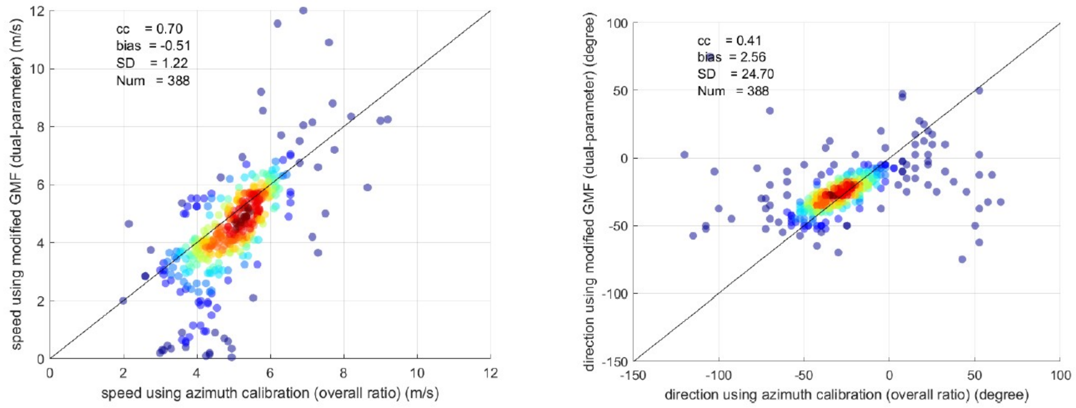
Qingliu Bao (baoqingliu@piesat.cn)

4. Results

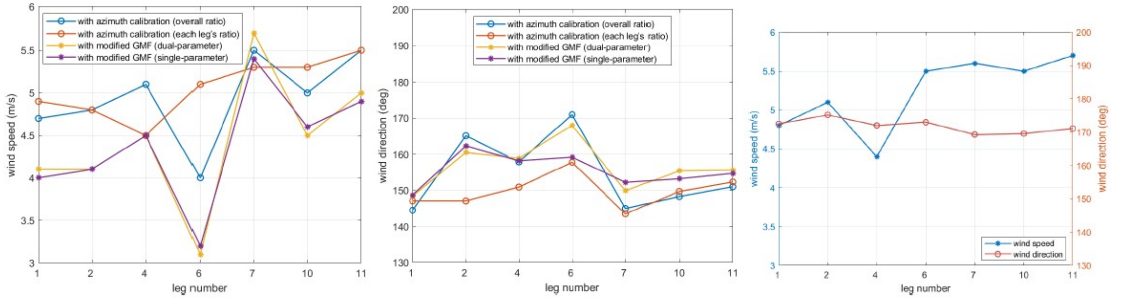
D. Wind inversion results

Comparison:



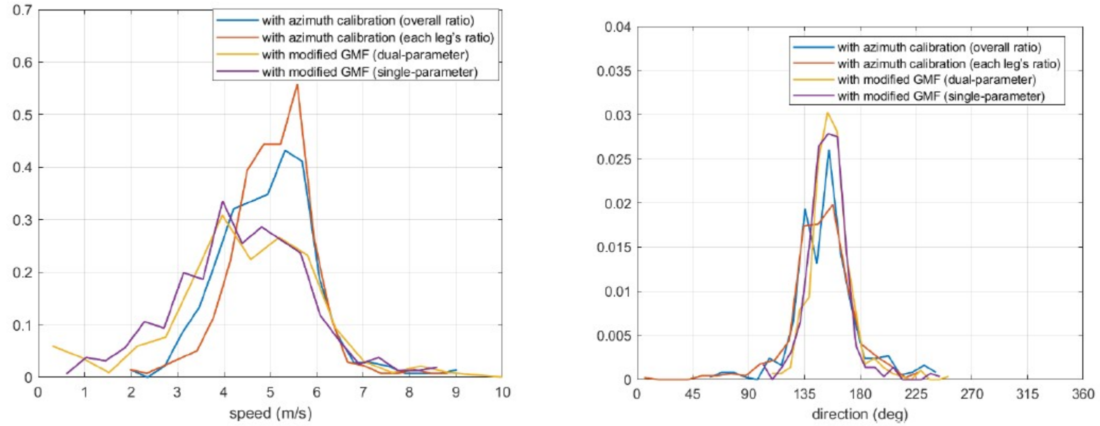
(a) speed (b) direction

Fig. 14. Comparison between wind field retrieved using two calibration methods: a) for wind speed; b) for wind direction.



(a) speed (b) direction (c) ECMWF

Fig. 16. Comparison between mean wind retrieved using four calibration methods and ECMWF: a) retrieved wind speed; b) retrieved wind direction; c) ECMWF.



(a) speed (b) direction

Fig. 15. Comparison between histogram of wind retrieved using four calibration methods: a) for wind speed; b) for wind direction.

TABLE I
The mean bias and the mean standard deviation (SD) of residuals of four methods.

	speed bias (m/s)	speed SD (m/s)	direction SD (deg)	U SD (m/s)	V SD (m/s)
with azimuth calibration (overall ratio)	-0.28	0.65	8.97	0.78	0.60
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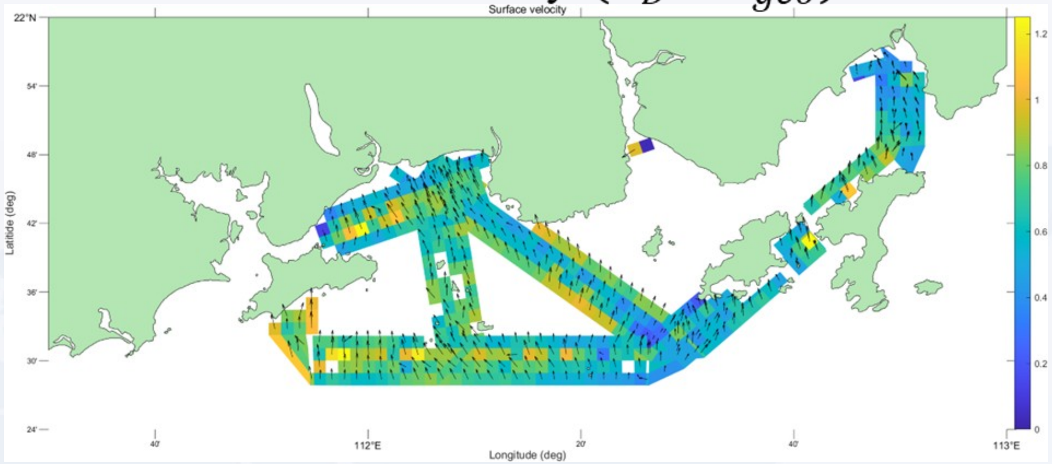
with modified GMF (a_{1coef} and a_{2coef})	-0.80	0.84	5.86	0.58	0.70
with modified GMF (only a_{2coef})	-0.84	0.76	3.67	0.3	0.70

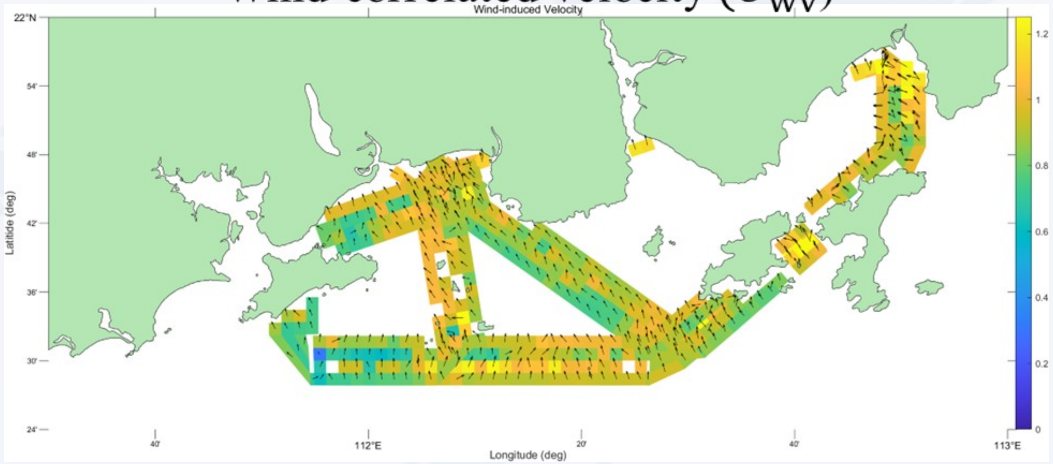
4. Results

A. Current inversion results (with azimuth calibration)

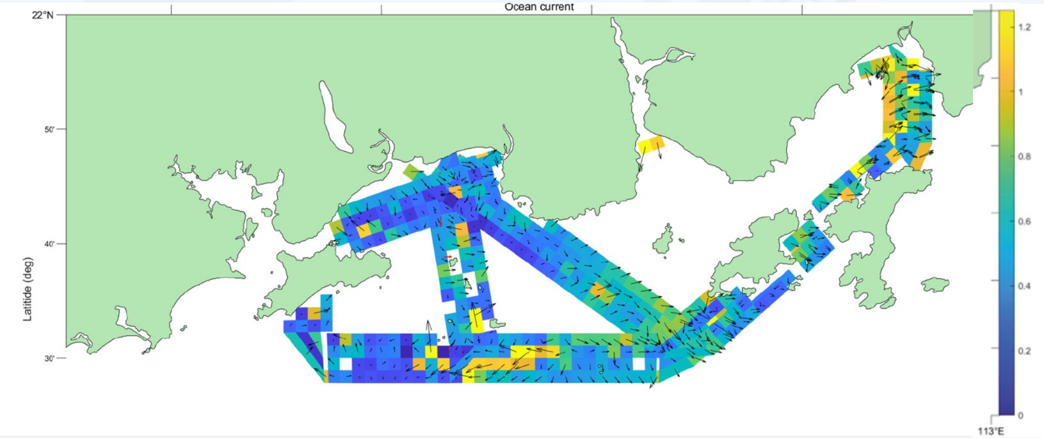
Sea Surface Velocity $(U_D - U_{geo})$



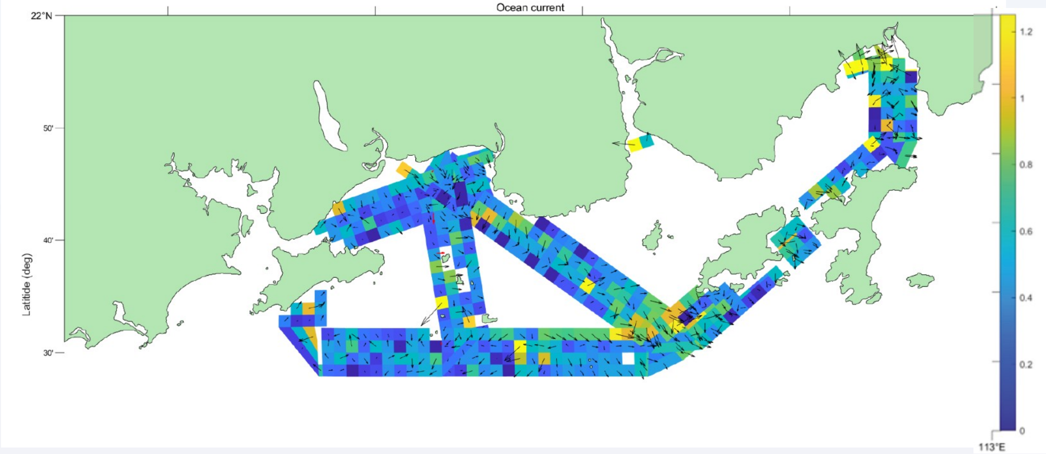
Wind-correlated Velocity (U_{wv})



Sea Surface Current (retrieved separately) $U_{current}$

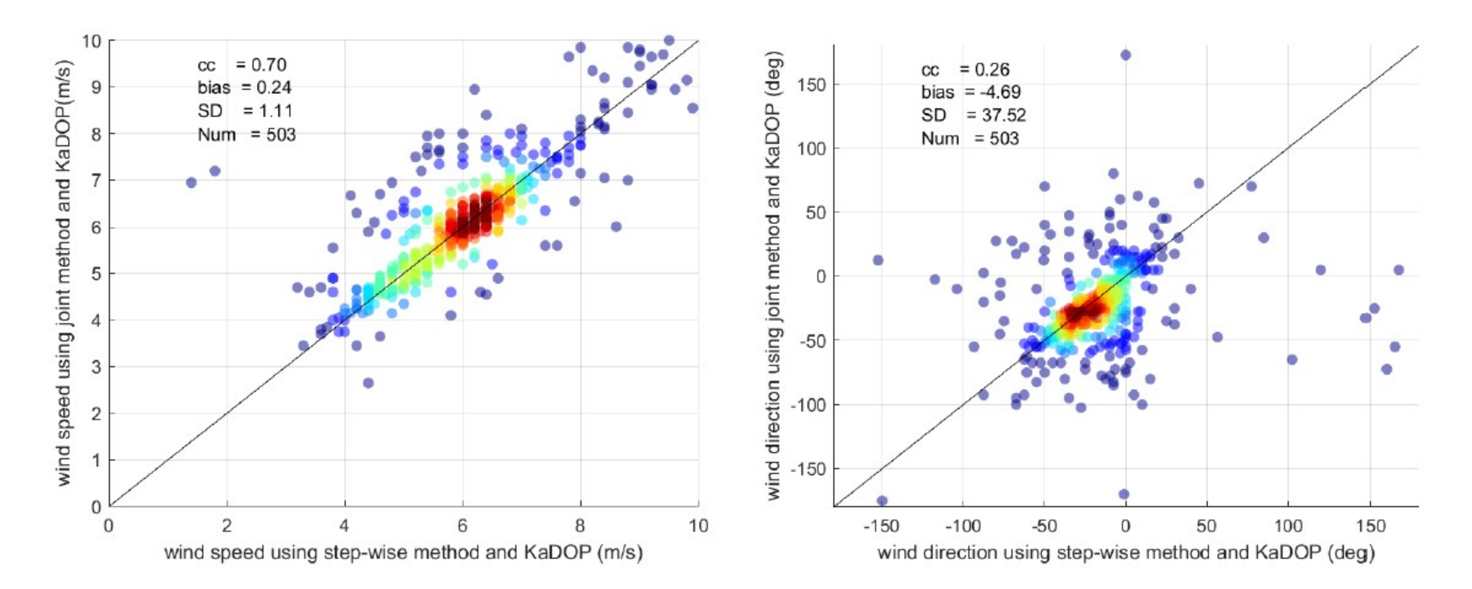


Sea Surface Current (retrieved simultaneously) $U_{current}$



A. Wind inversion results (with modified GMF, single parameter)

Comparison between step-wise method and joint method



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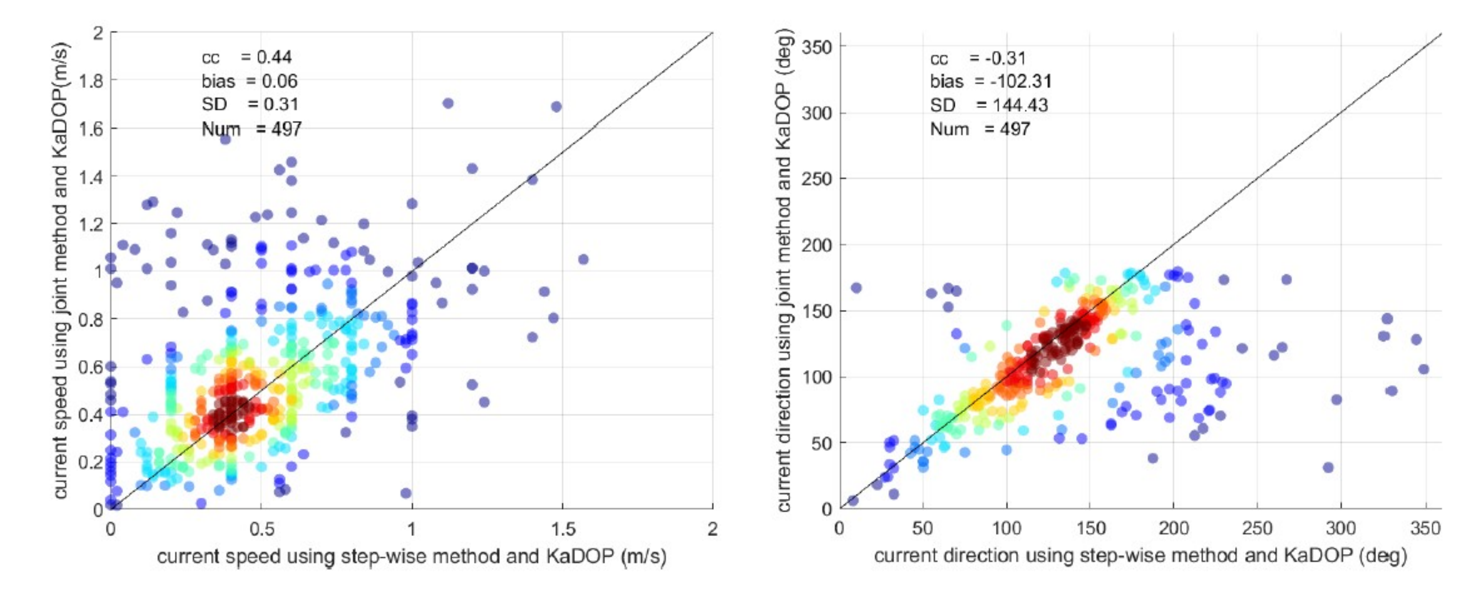
A. Current inversion results (with modified GMF, single parameter)

Comparison between step-wise method and joint method



Comparison with in-situ data (current meter)

	Step-wise method	Joint method
Speed (m/s)	0.28	0.58
Direction (°)	26.96	45

Comparison with OSCAR data (0.25°, per day)

	Step-wise method	Joint method
Speed bias (m/s)	0.54	0.29
Speed std(°)	0.41	0.23
Direction bias(°)	40.77	-3
Direction std(°)	49.17	74.35