Airborne experiment of the L-band scatterometer for the Chinese Salinity Observation Mission

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1. Overview of the Experiment

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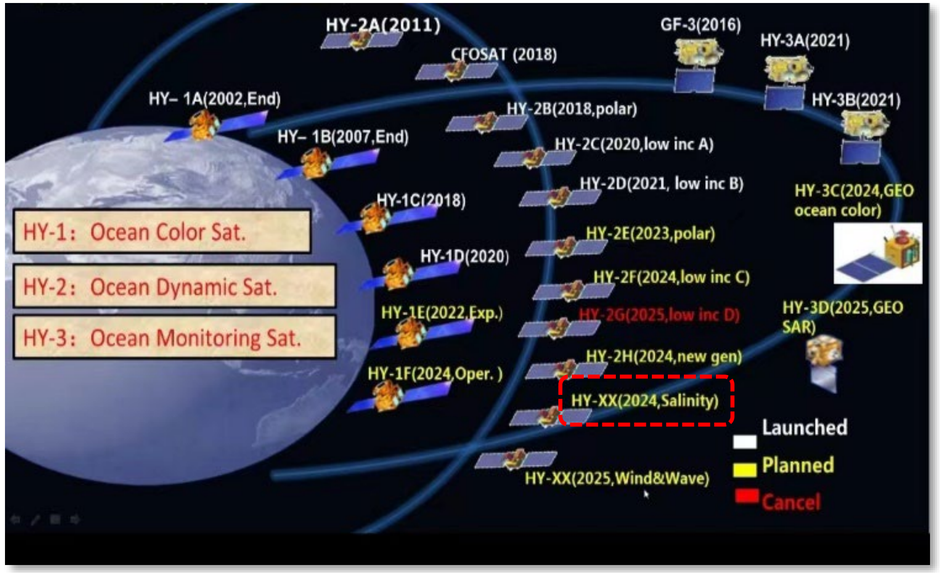
1.1 Experimental Background

Before the Salinity Satellite is deployed for space applications, it is necessary to carry out airborne experiment to effectively validate the instrument detection theory, data preprocessing algorithms, and salinity inversion algorithms.

- Satellite Payloads: an synthetic aperture radiometer and active/passive detection instruments
- Available Physical Parameters： sea surface salinity, sea surface roughness, and sea surface temperature

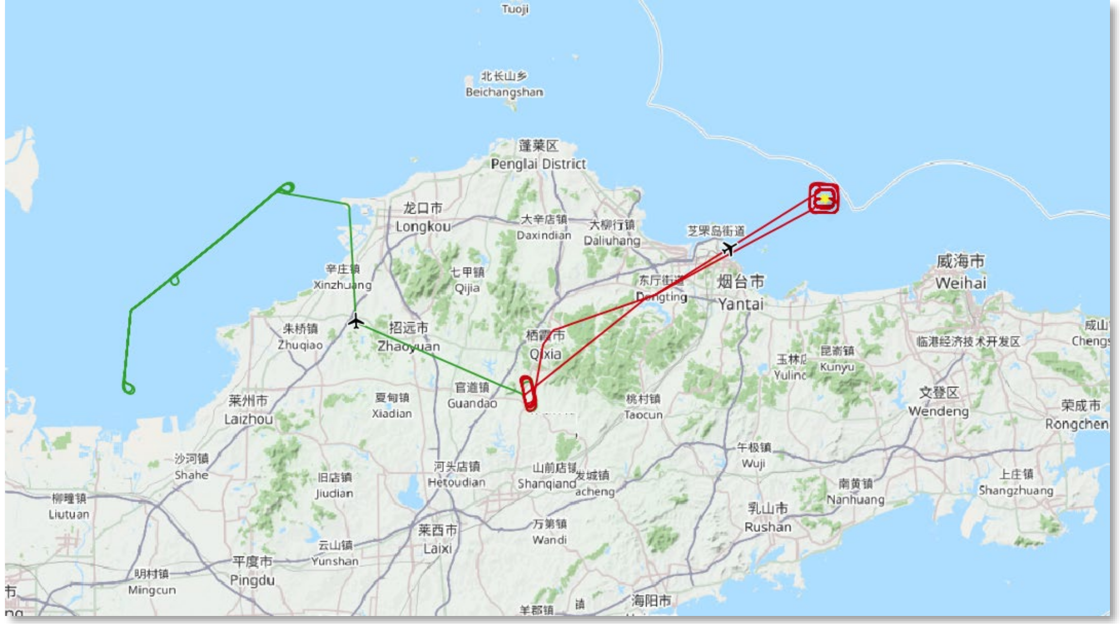


Airborne flight test platform　　Scatterometer antenna array

1. Overview of the Experiment

1.2 Experimental Overview

- Experimental area： Sea area of Yantai City, Shandong Province, China
- Experimental period： 2023.07.12~08.14
- Flight altitude: 3 km
- Flight speed: 200 km/h
- Flight sorties： 8 sorties in total



Flight tracks of of two typical sorties

- Flight mission has carried out around offshore platform during 1st~4th sorties. (Red line in Fig.)
- 5th~8th sorties involve simultaneous observations following the movement of the vessel. (Green line in Fig.)

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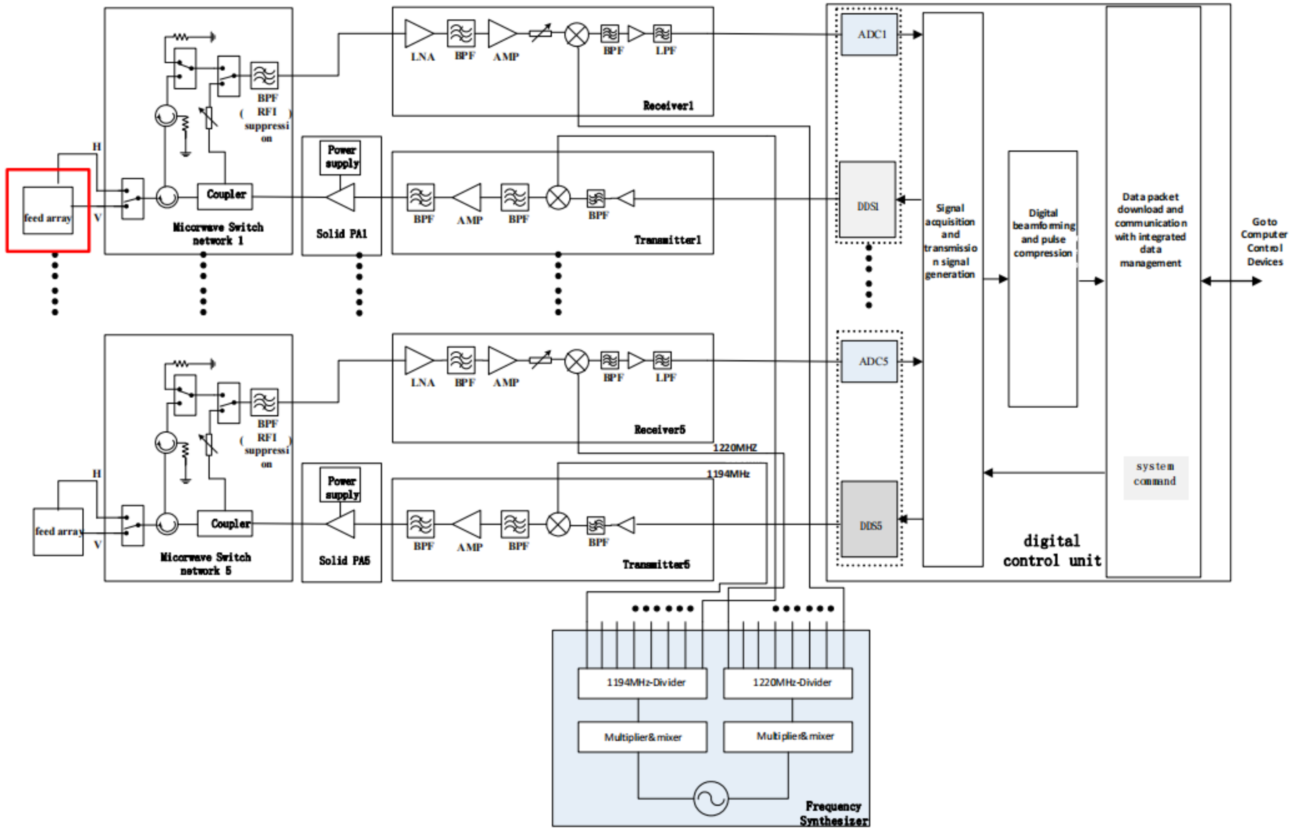
1.3 Airborne Scatterometer System



Schematic diagram of the airborne scatterometer system

List of the main system parameters

Parameters	Values
Frequency	1.25 GHz
Pulse duration	8 μs
Bandwidth of transmitted signal	2 MHz
Pulse repetition frequency	6.67 kHz
Forward looking beam elevation angle	38.4°
Polarization	HH,VV,HV,VH
Number of array elements	5
Number of beam positions	11
Peak power	100 W
Noise figure	3.5 dB

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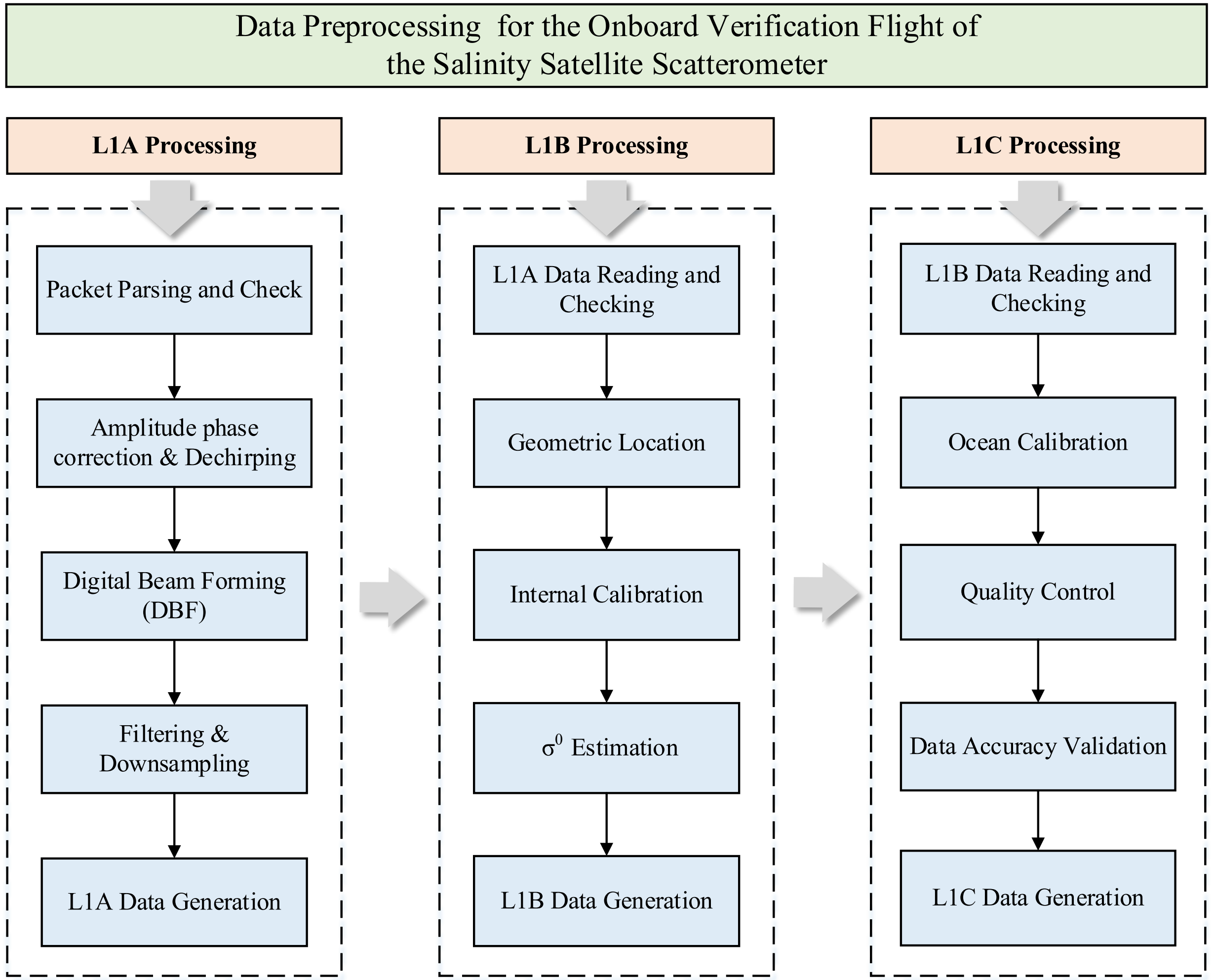
2. Data Preprocessing Methods

2.1 Technological Route



Data preprocessing flowchart

2. Data Preprocessing Methods

2.2 Key steps in L1A processing

- **Signal Dechirping**

Mix the received signal with the reference signal, and perform amplitude-phase correction and doppler compensation during the process.

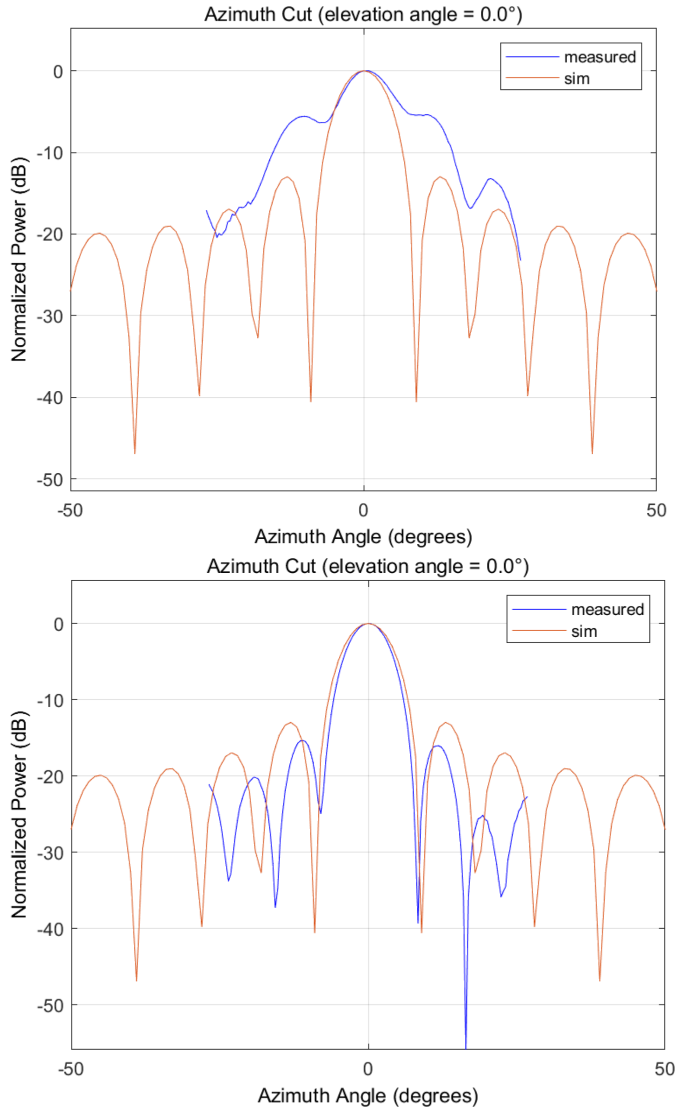
$$\begin{cases} S_{\mathrm{ref}}^{mn} = \Delta A_{\mathrm{r}}^{m} \cdot A_{\mathrm{ref}} \cdot \mathrm{rect}\left(\dfrac{t-\tau_0^j}{T_{\mathrm{ref}}^j}\right) \\ \quad \cdot \exp\left[j2\pi\left(f_{\mathrm{ref}}(t-\tau_0^n) + \dfrac{1}{2}\mu(t-\tau_0^n)^2 \right) + j\phi_{ref} + j\phi_{\mathrm{r}}^{mn} + j\Delta\phi_{\mathrm{r}}^{m} \right] \\ S_{\mathrm{dechp}}^{mn}(t) = S_{\mathrm{IF}}^{mn}(t) \cdot S_{\mathrm{ref}}^{mn}(t), \quad m = 1,2,\cdots,5;\ n = 1,2,\cdots,11 \end{cases}$$

- **Digital Beam Forming (DBF)**

Amplitude-phase-corrected signals of each channel are summed up.

$$S_{\mathrm{r}}^{n}(t) = \sum_{m=1}^{5} S_{\mathrm{dechp}}^{mn}(t)$$

Antenna pattern



Without amplitude and phase correction

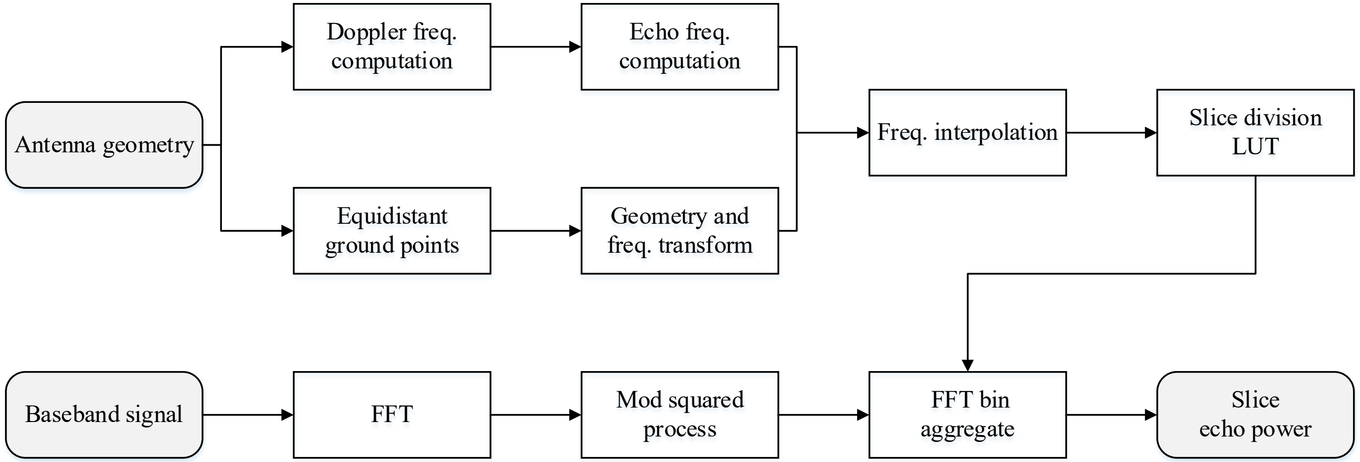
With amplitude and phase correction

2. Data Preprocessing Methods

2.3 Key steps in L1B processing

- **Geometric Location**

Locate the center of the ground footprint and its slices by applying coordinate transformation relationships.



- **X-factor Computation**

$$X^q = \frac{P_t G_p^2 G_r \lambda^2}{(4\pi)^3 L} \sum_{i\in F} \left\{ \left(\frac{\Delta A_i g_i^2}{r_i^4}\right) \sum_{k=k_s}^{k_e} \left[\frac{\sin^2\left[\pi N_i \left(f_{b,i} T_s - \frac{k}{N}\right)\right]}{\sin^2\left[\pi \left(f_{b,i} T_s - \frac{k}{N}\right)\right]} \right] \right\}$$

- **σ^0 Estimation**

$$\sigma^0 = K_s \frac{E_{s,q}}{N \cdot E_c \cdot \left(X^q / P_t\right)}$$

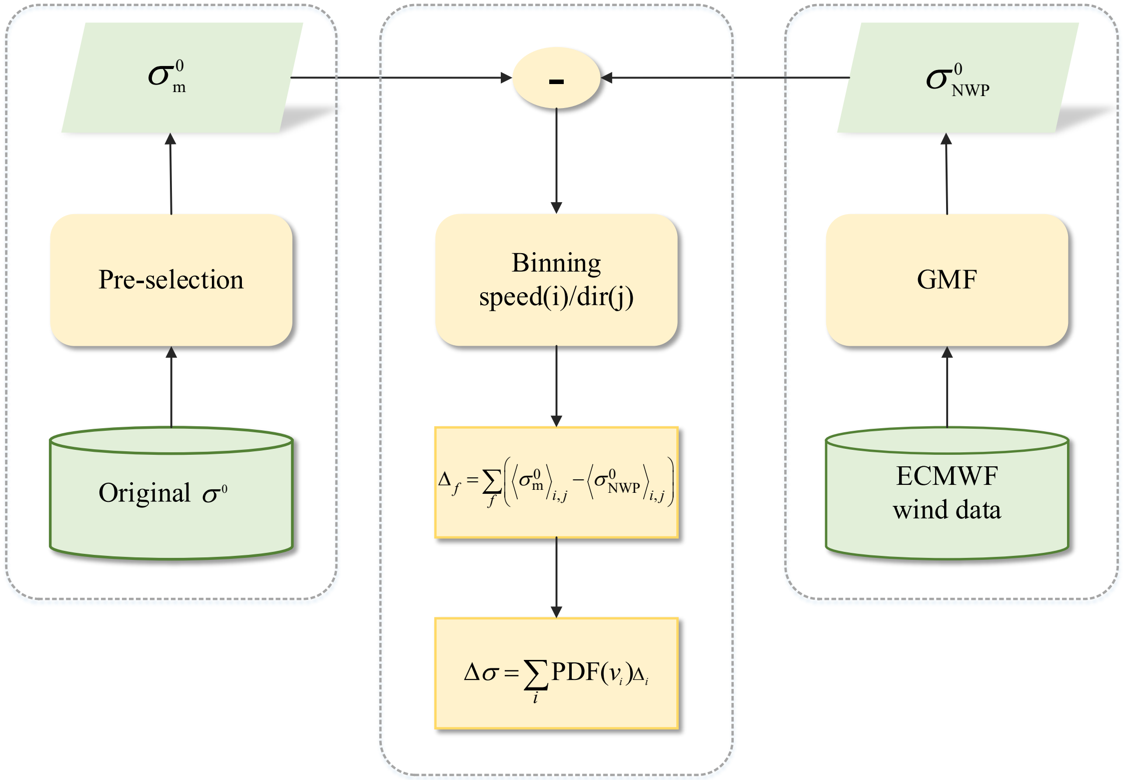
$E_{s+n,q} \Rightarrow$ The qth slice backscattering total energy

$E_{n,q} \Rightarrow$ External thermal noise (radiometer)

$E_c \Rightarrow$ Internal calibration signal

2. Data Preprocessing Methods

2.4 Key steps in L1C processing



Flow chart of the NWP ocean calibration

Look Up Table (L1B to L1C):

NOC_coefficient_VV

NOC_coefficient_HH

NOC_coefficient_VH

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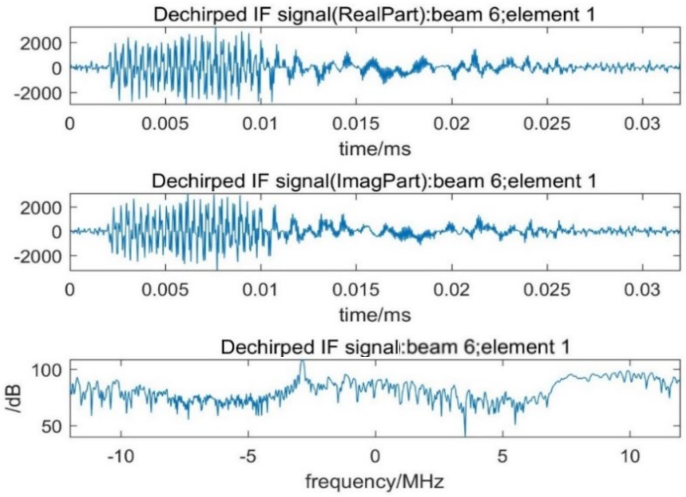
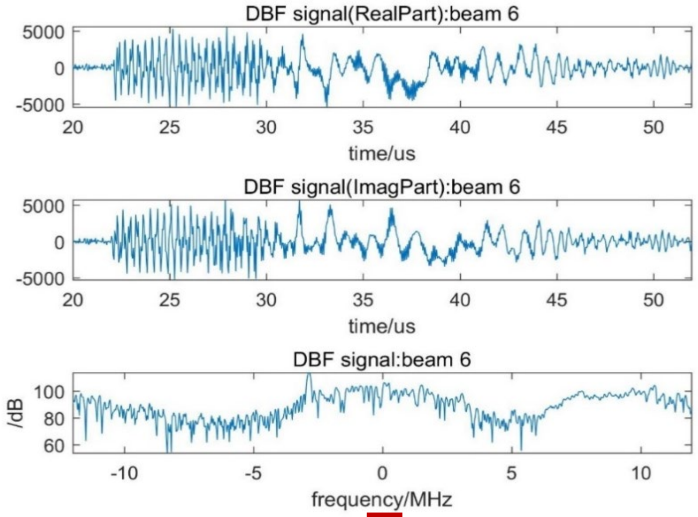
3. Preprocessing Results

3.1 L1A processing results

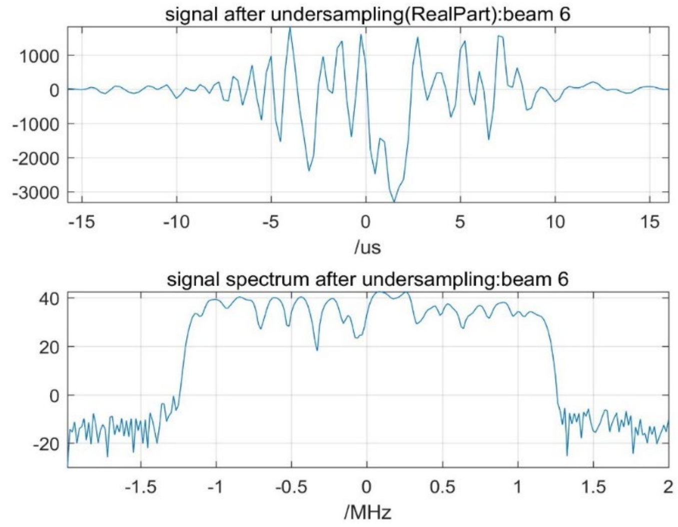
Dechirped IF signal



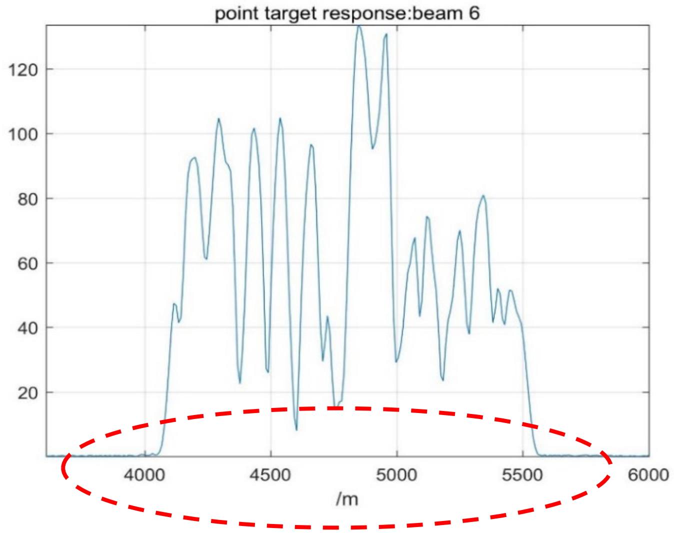
5 channels DBF signal



Filtered & downsampled signal



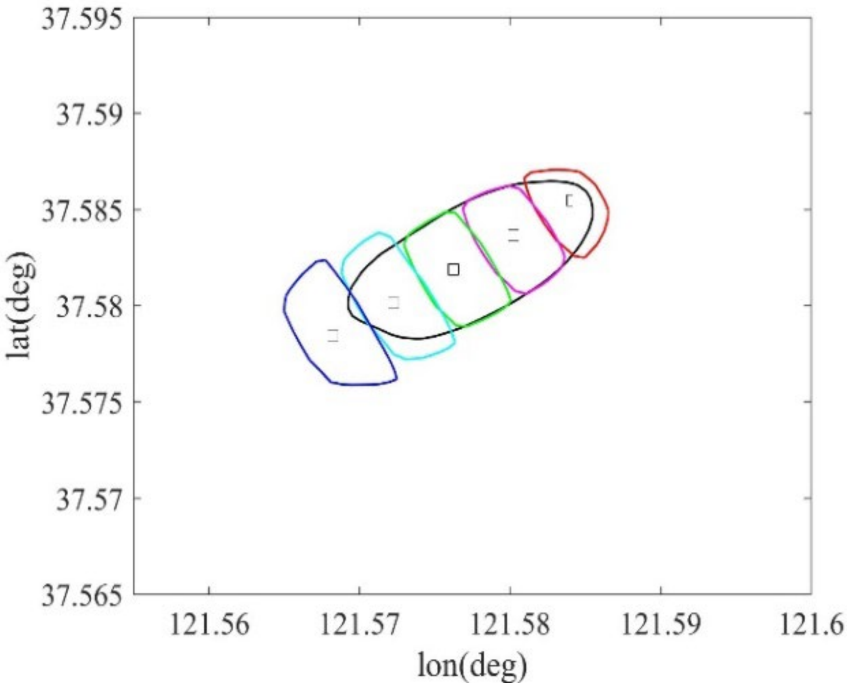
Surface target echo response

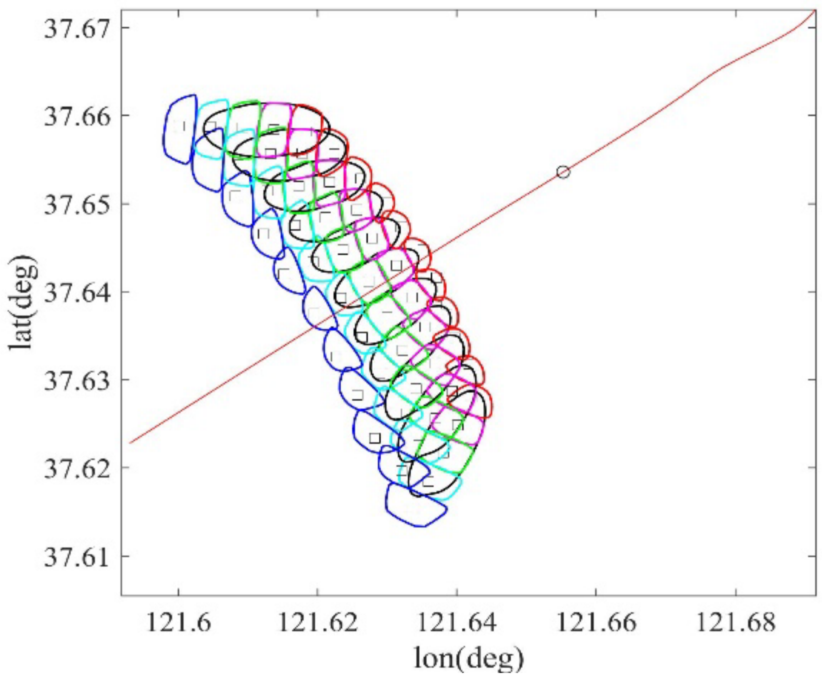


3. Preprocessing Results

3.2 L1B processing results

After geometric localization and X-factor calculation, each footprint can be further divided into five slices.





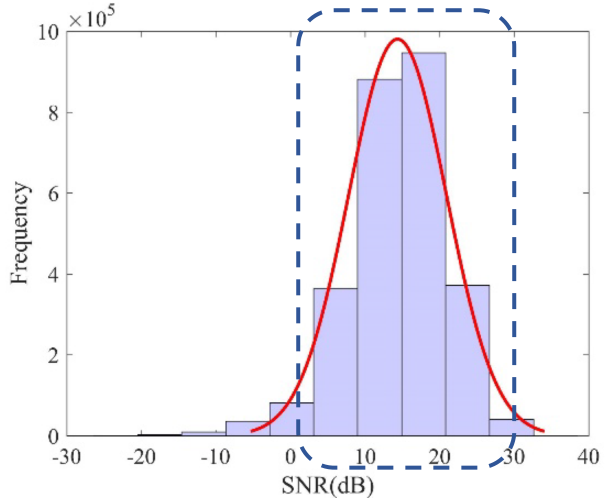
Schematic diagram of antenna footprint and slice division

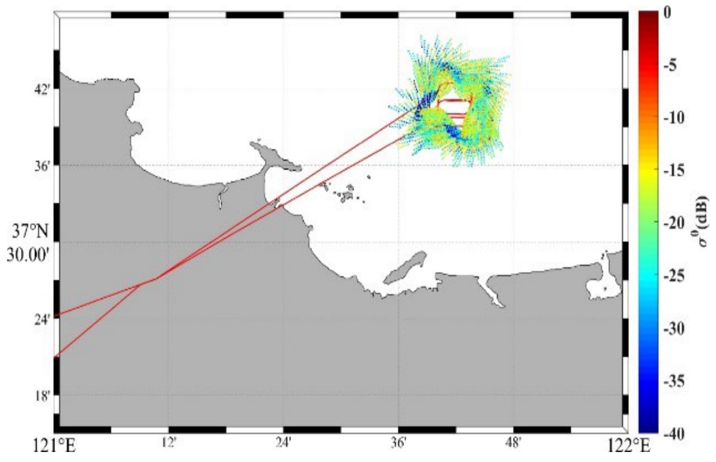
3.2 L1B processing results

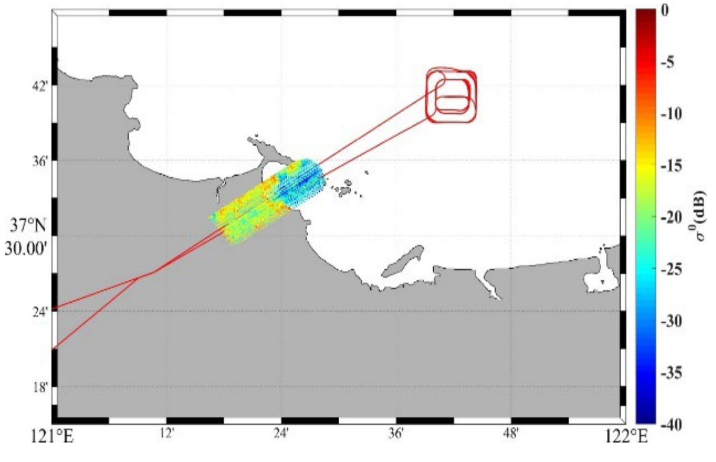
SNR statistics

Distribution of backscatter coefficient in observation area

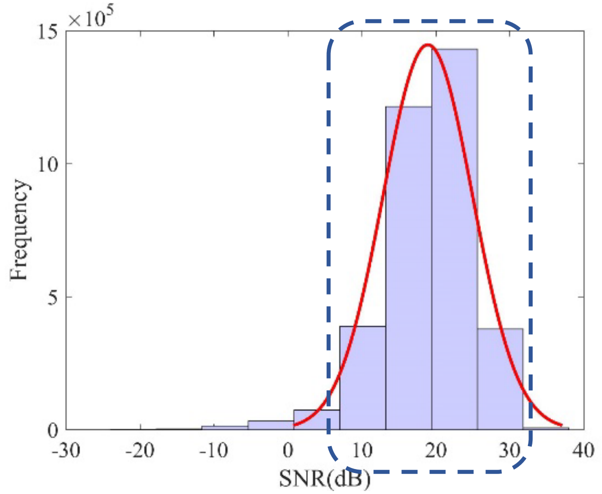
3rd flight

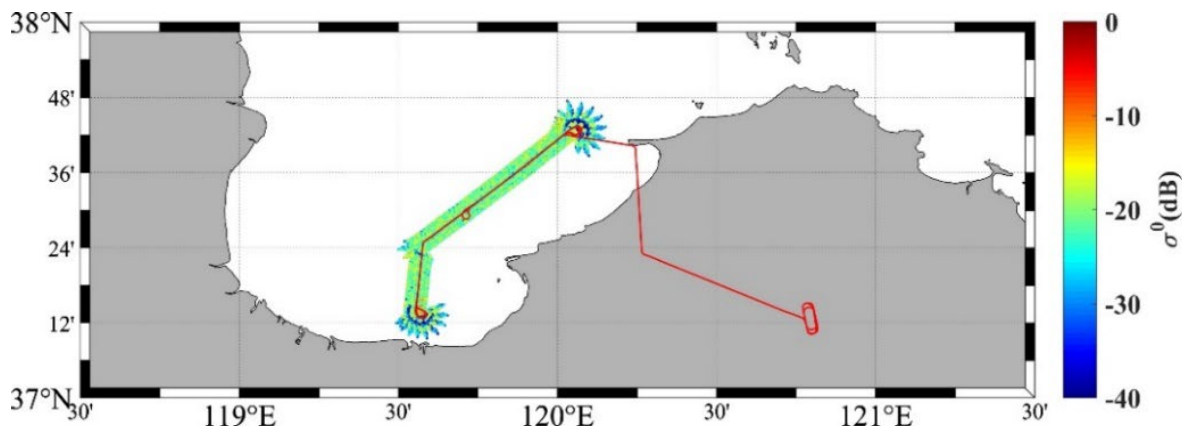






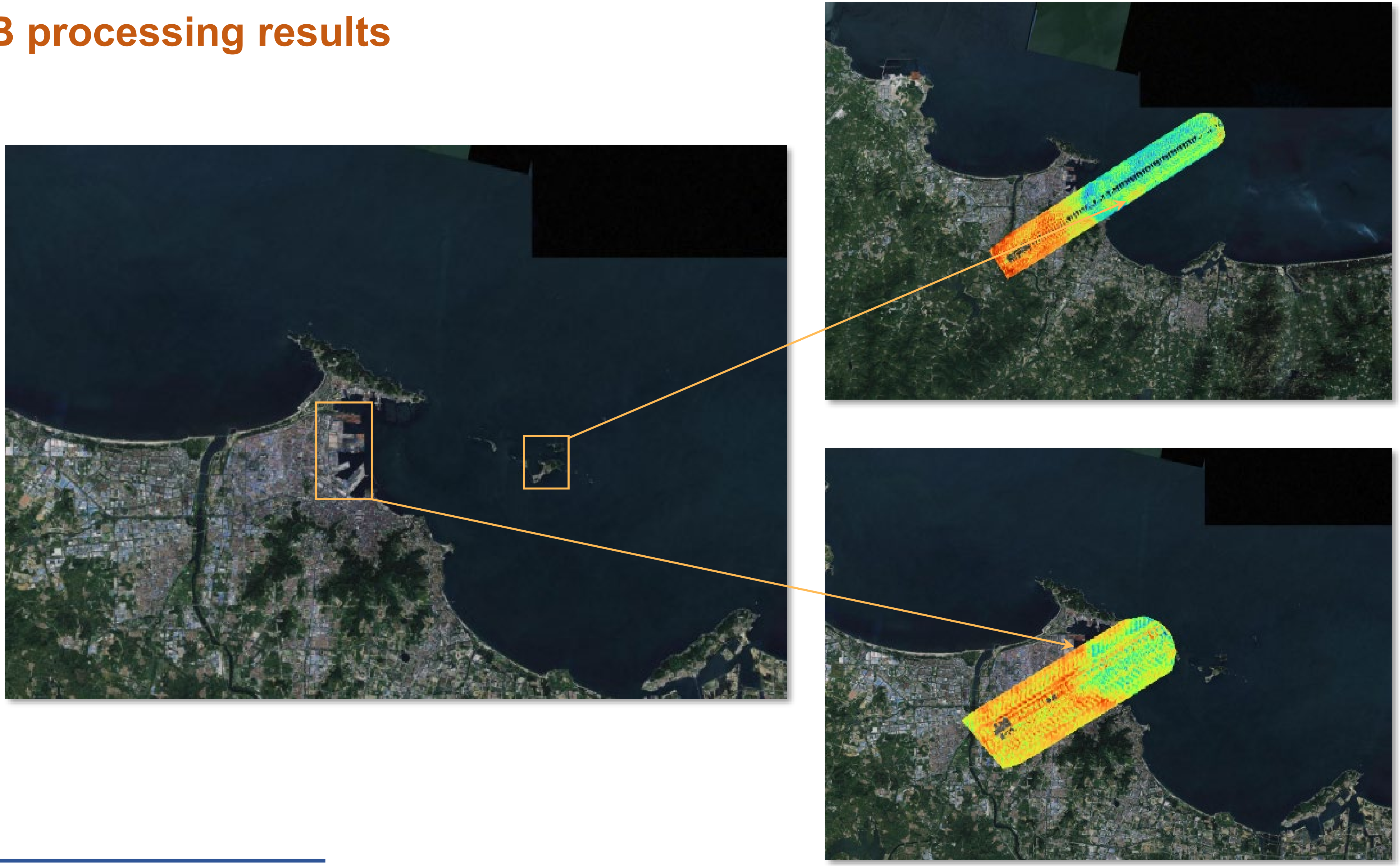
5th flight





3. Preprocessing Results

3.2 L1B processing results



3. Preprocessing Results

3.3 L1C processing results

Setting up backscattering coefficient flag for data QC:

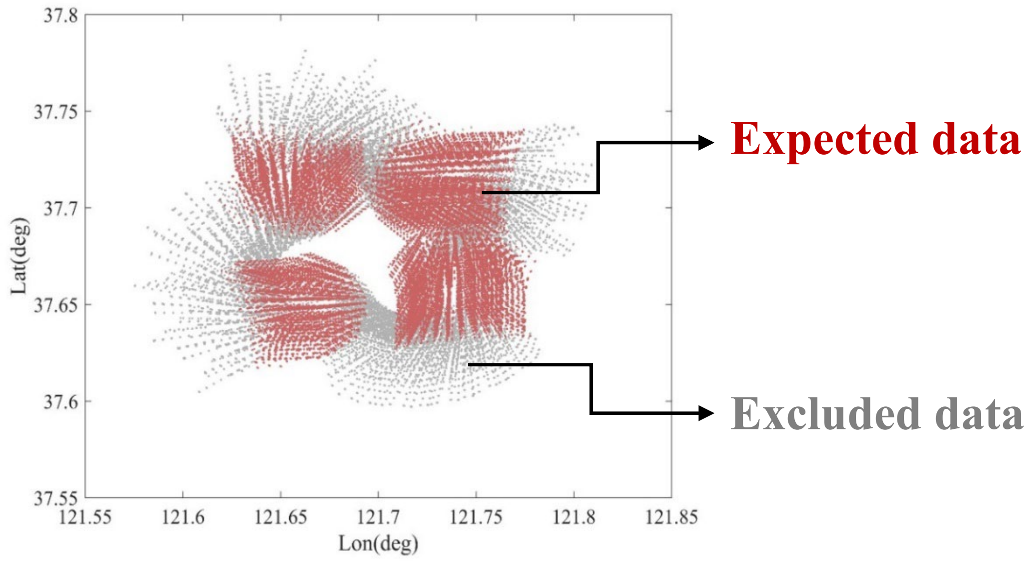
a) Invalid value;

b) Internal noise exceeds the threshold;

c) Measured values at aircraft turns (Roll>±3°);

d) Incidence angle out of range (30°~60°);

e) data quality （MLE）



Data filtering situation

	Num of σ^0_{VV} (filtered)	Num of σ^0_{HH} (filtered)	Total num of σ^0 (unfiltered)
2nd flight	405224	1040655	4108625
3rd flight	240414	611166	2735530
4th flight	387446	986203	3932290
5th flight	460536	1160176	3546600
6th flight	581543	1464408	4675315
7th flight	297275	748170	2550620

3. Preprocessing Results

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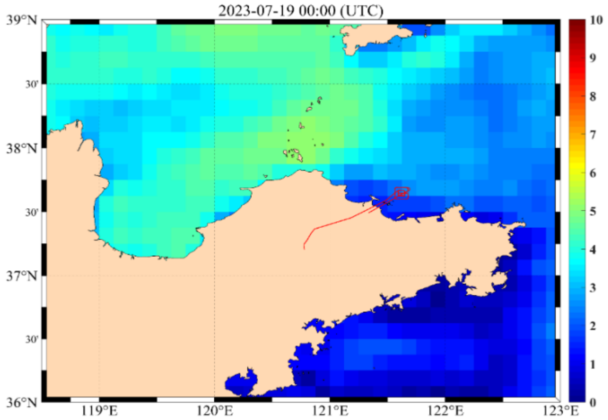
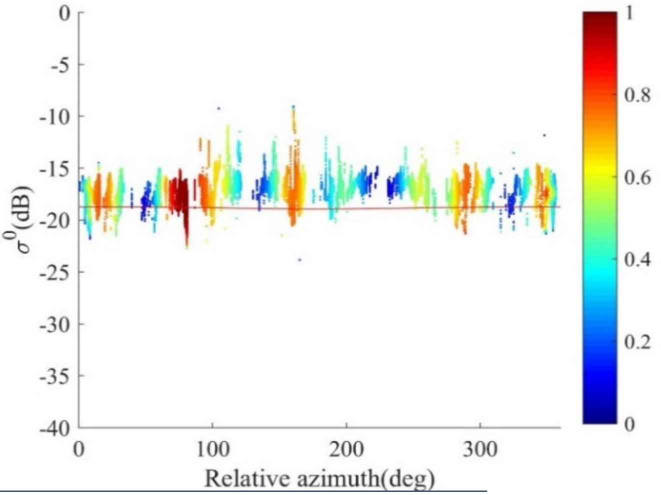
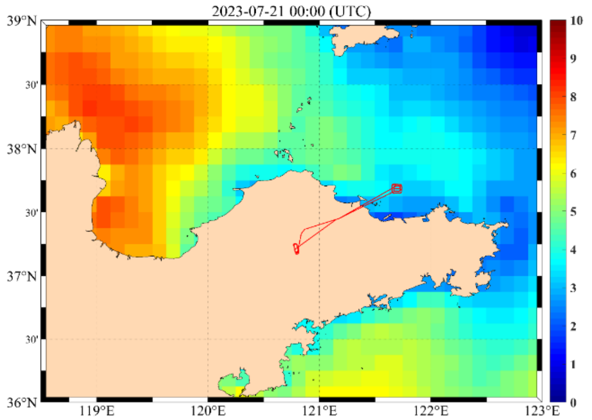
3.3 L1C processing results

2nd flight

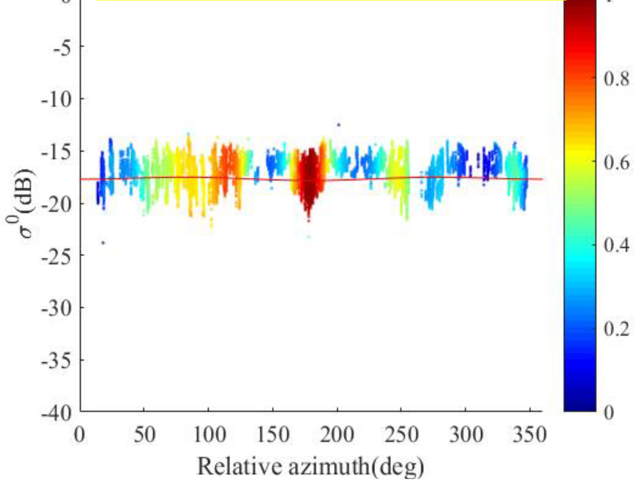




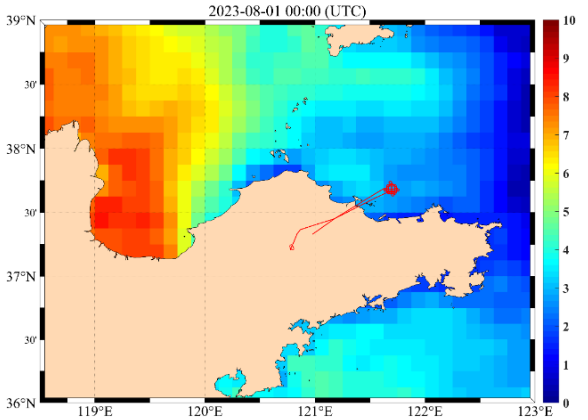
3rd flight

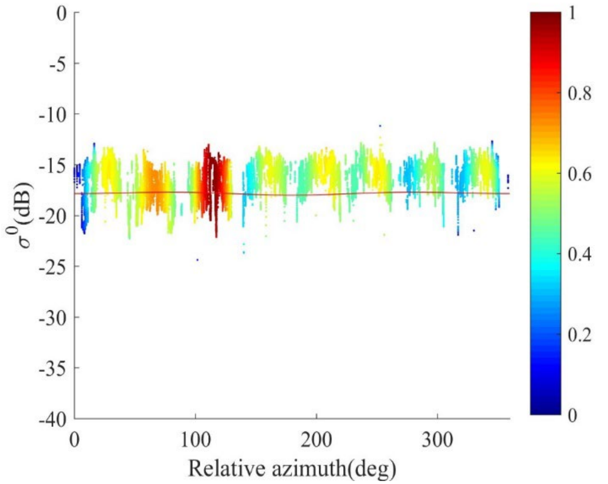


Low winds speed conditions



4th flight





The distribution of measured and simulated values is essentially identical.

3. Preprocessing Results

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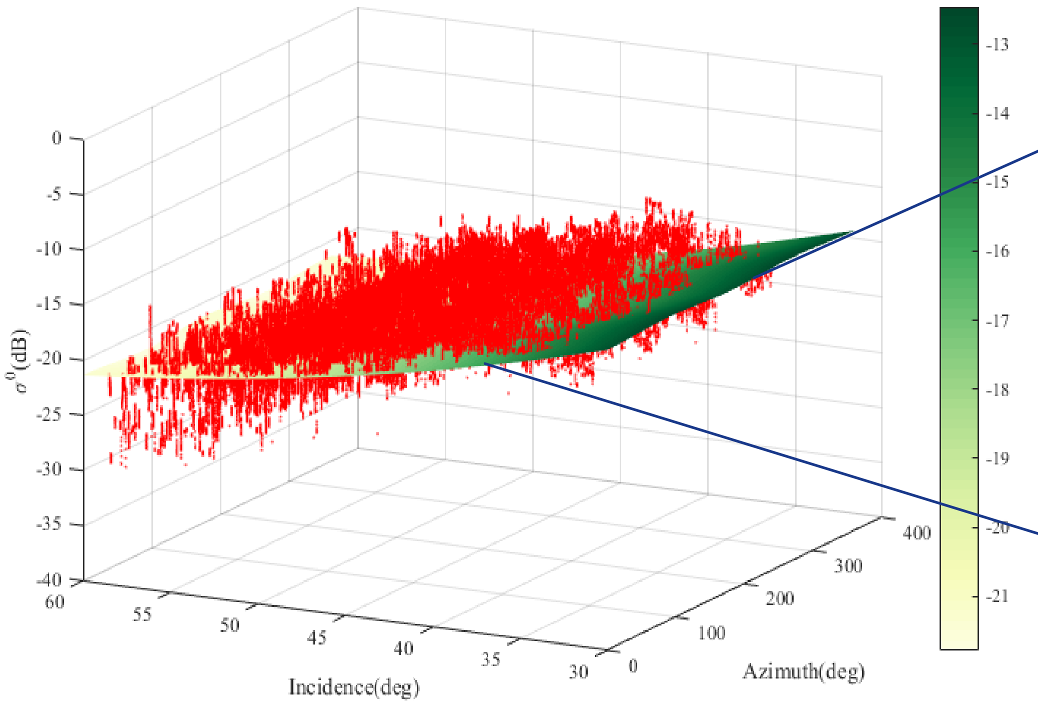
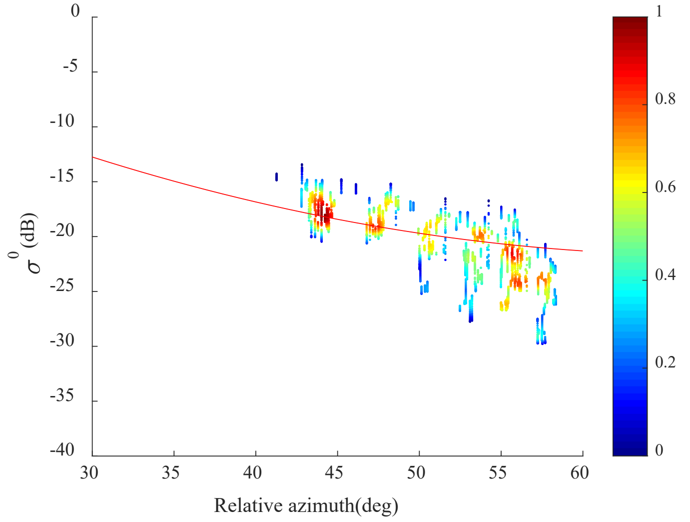
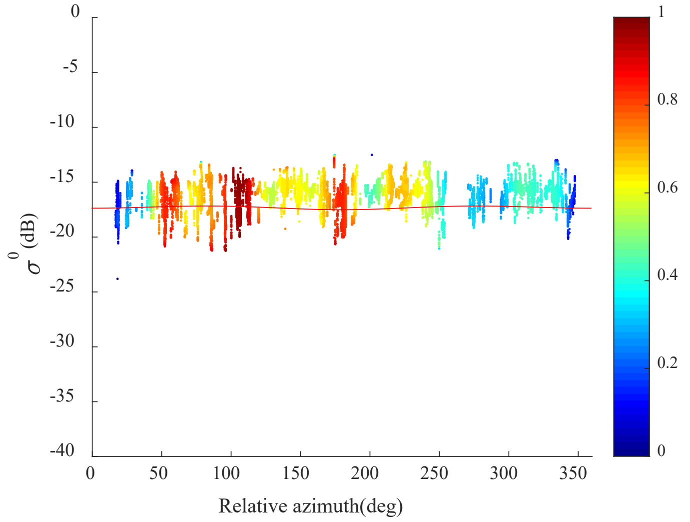
3.3 L1C processing results





Azimuth angle：173°



Incidence angle：43°

Distribution of backscatter coefficient with incidence and azimuth angle(VV-pol)

3. Preprocessing Results

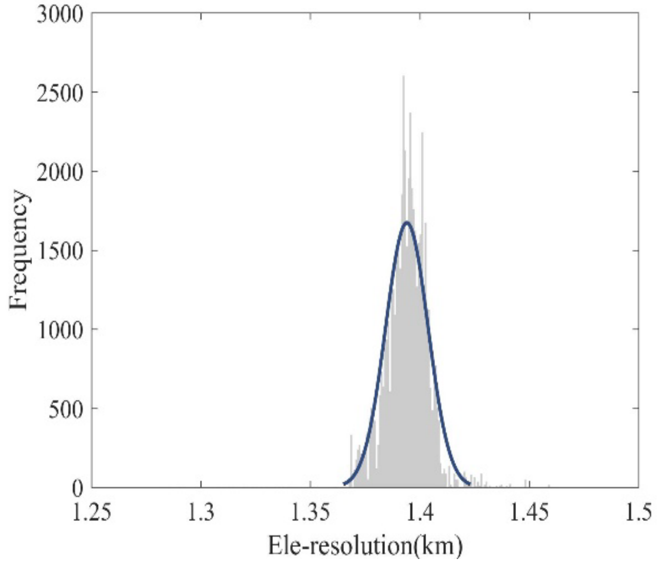
3.4 Performance analysis

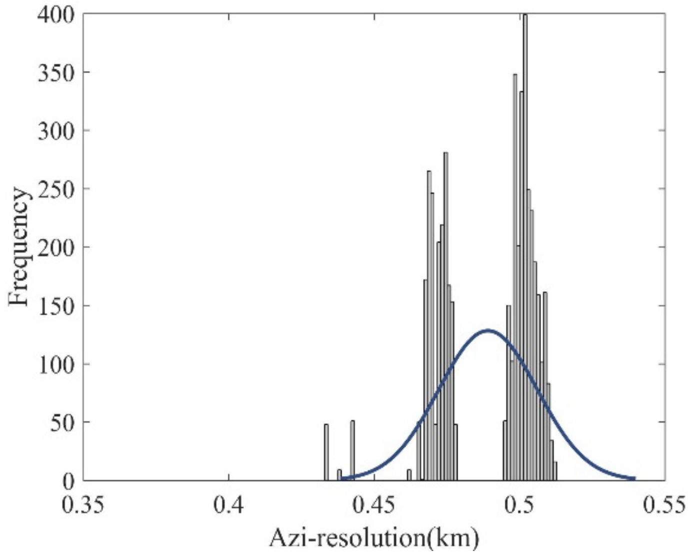
- **Spatial resolution**

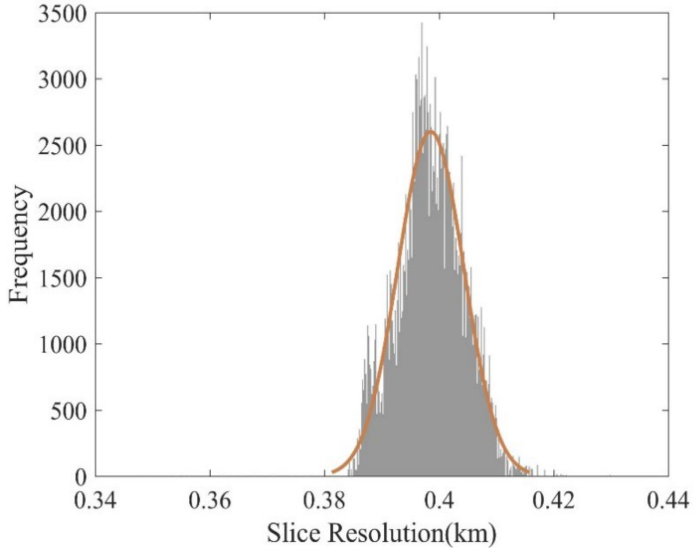
Ele-dimension footprint size : ≈ 1.38 km

Azi-dimension footprint size : ≈ 0.50 km

→ Slice width: ≈ 0.40 km





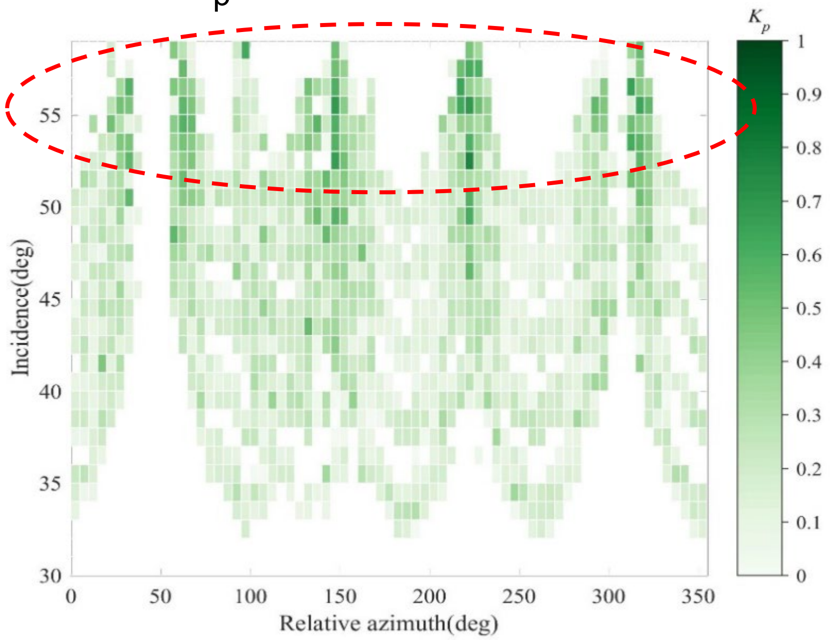


3. Preprocessing Results

3.4 Performance analysis

□ Backscatter measurement accuracy

Variation of K_p with incidence and azimuth angle



Comparison of measured and simulated values

	VV-pol			HH-pol		
	cc	Bias(dB)	std(dB)	cc	bias(dB)	std(dB)
2nd flight	0.64	1.87	1.90	0.81	1.42	2.53
3rd flight	0.74	0.57	1.99	0.85	0.26	2.43
4th flight	0.68	1.54	1.76	0.81	1.07	2.41
5th flight	0.69	-0.01	1.53	0.79	0.23	2.34
6th flight	0.65	-0.60	2.06	0.85	-1.32	2.43
7th flight	0.71	0.31	1.43	0.82	0.05	2.32

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4. Conclusions

1. A salinity satellite scatterometer flight experiment data preprocessing system has been developed, including L1A, L1B and L1C data processing.
2. The spatial distribution of backscatter coefficients clearly reveals the difference between the ocean and land, providing a validation of the data accuracy.
3. A preliminary validation of the results was carried out, which showed that the measured values were close to the simulated.

4. Issues

1. Due to the presence of more interference sources during airborne measurements, further analysis is required to eliminate abnormal signals and improve data quality.
2. The currently used GMF is based on scatterometer data from the Aquarius satellite, which only provides measurements at three incidence angles. It would be beneficial to explore more suitable data verification methods.

Thank you for your attention