PRELIMINARY RESULTS OF SCATTEROMETER OF CFOSAT

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Outlines

Brief Introduction

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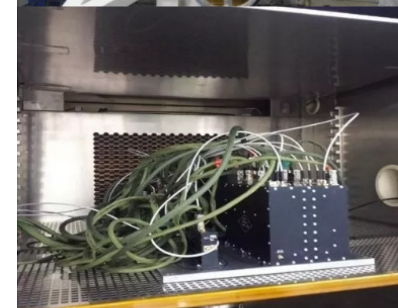
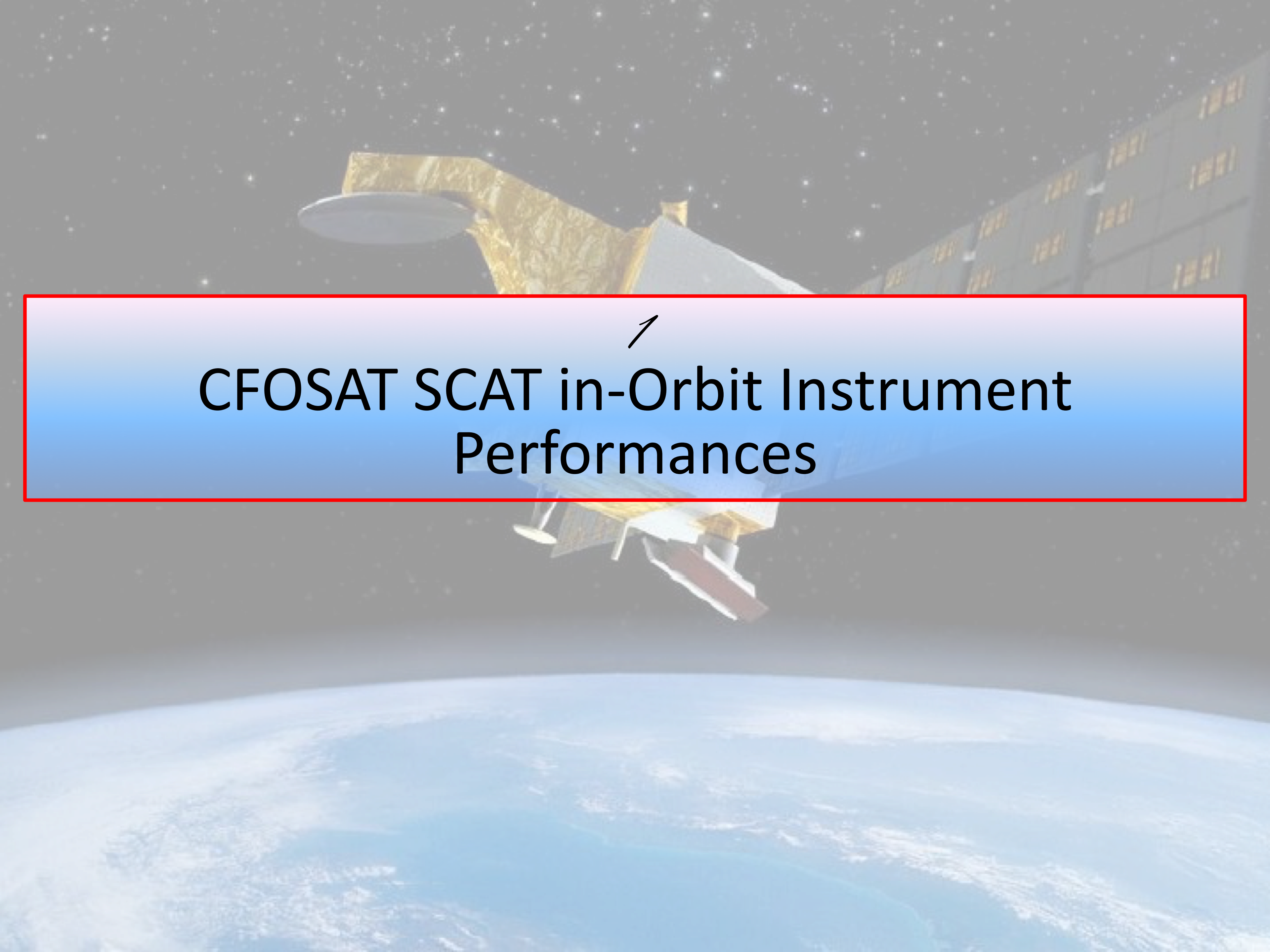
2. CFOSAT SCAT Data L1 Processing and Calibration
3. CFOSAT SCAT Data L2 Processing and Preliminary Validation
4. Summary

Brief Introduction

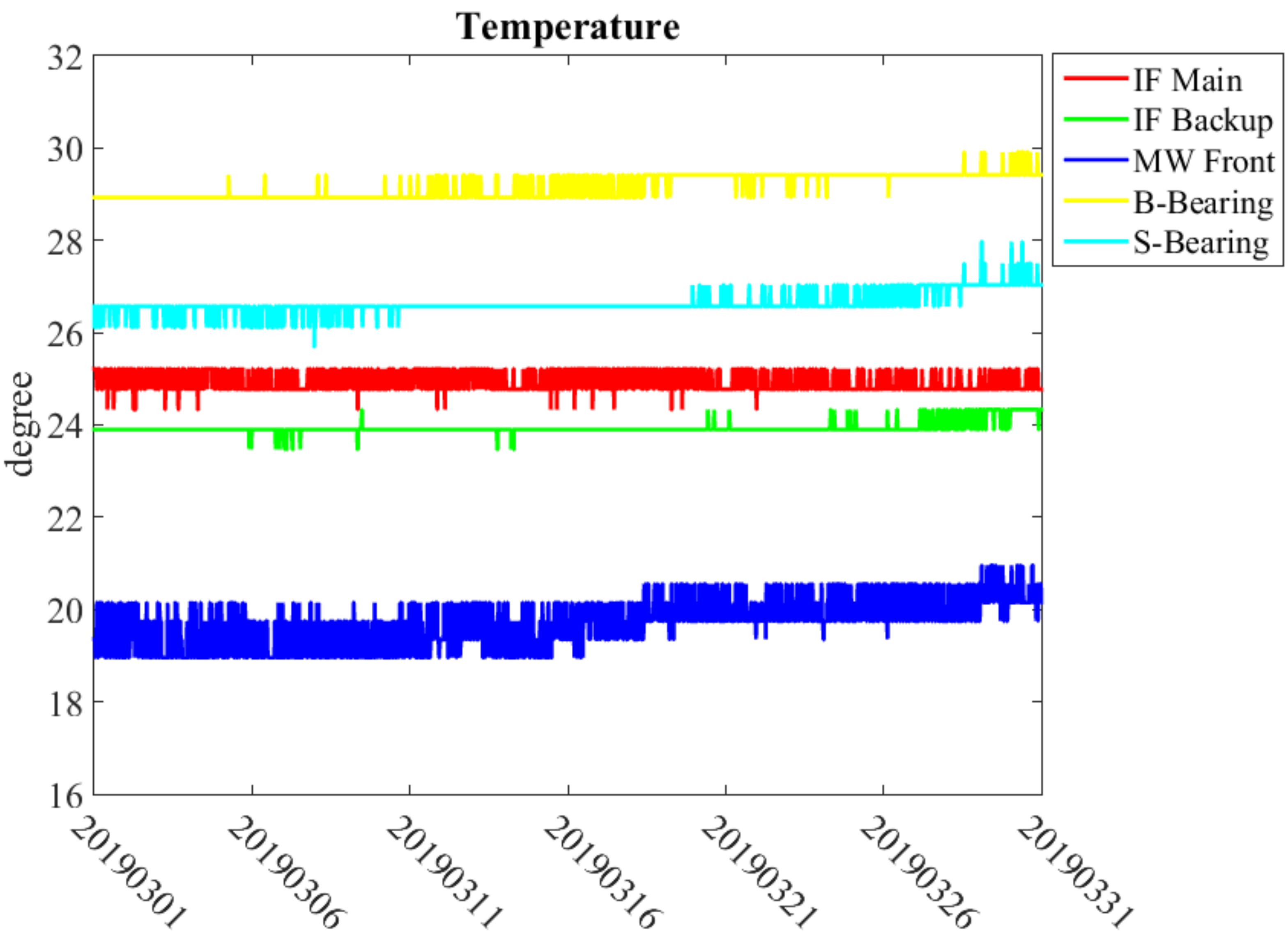




- CFOSAT Scatterometer (CSCAT), a Ku-band (13.256GHz) **rotating fan-beam scatterometer** for ocean surface wind vector.
- CFOSAT was Launched on 29th Oct,2018, from Jiuquan Satellite Launching Center in Inner Mongolina, Northwestern China.
- Scanning servo and receivers switched on 29th Oct, 2018
- TWTA switched on 1st Nov, 2018
- Twice orbit maintenances after launch, when TWTA switched off; scanning never stopped;
- Onboard LUT for regrouping was updated on 18th Dec, 2018; more uniformly distributed range gate at about 10km. (Data before 18th Dec, 2018 needs reprocessing but the range resolution will be 5-15km.)
- SCAT DPU rebooted 52 times to refresh the FPGA and DSP onboard the satellite(automatically reboot every 3.8 days). Every reboot costs 8 seconds scientific data loss.



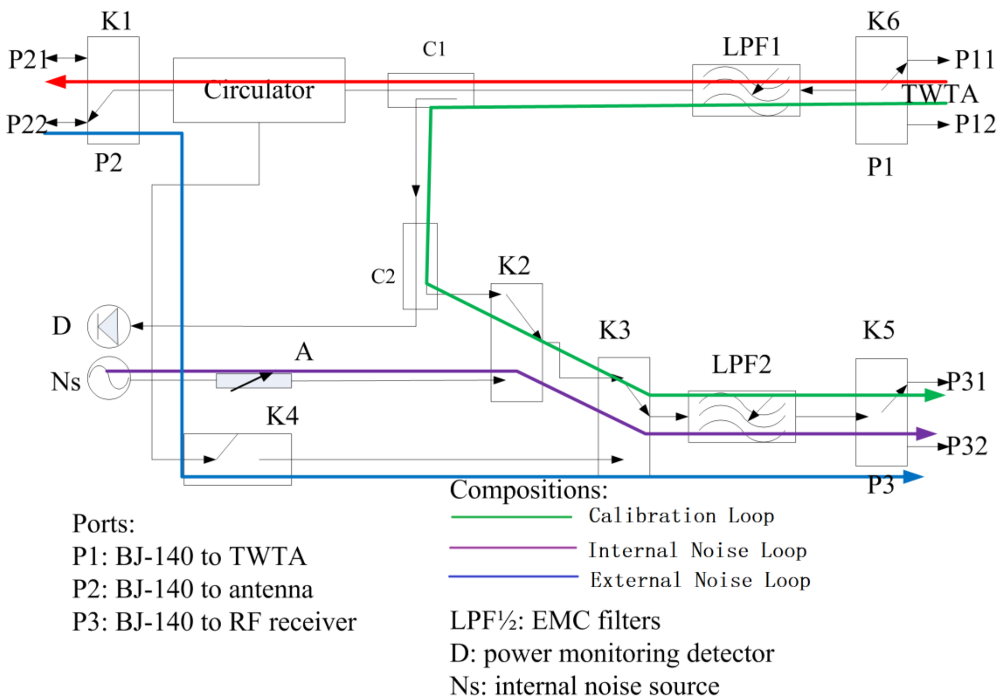
1
CFOSAT SCAT in-Orbit Instrument Performances

Temperatures of SCAT instruments



Calibration and noise measurement

- calibration signal is used to compensate the fluctuations of transmitted power and T/R channel gains.
- Internal and external noise measurements are used to estimate the noise floor of the receiver. Thus the noise can be removed from the radar echoes to get the signal energy.

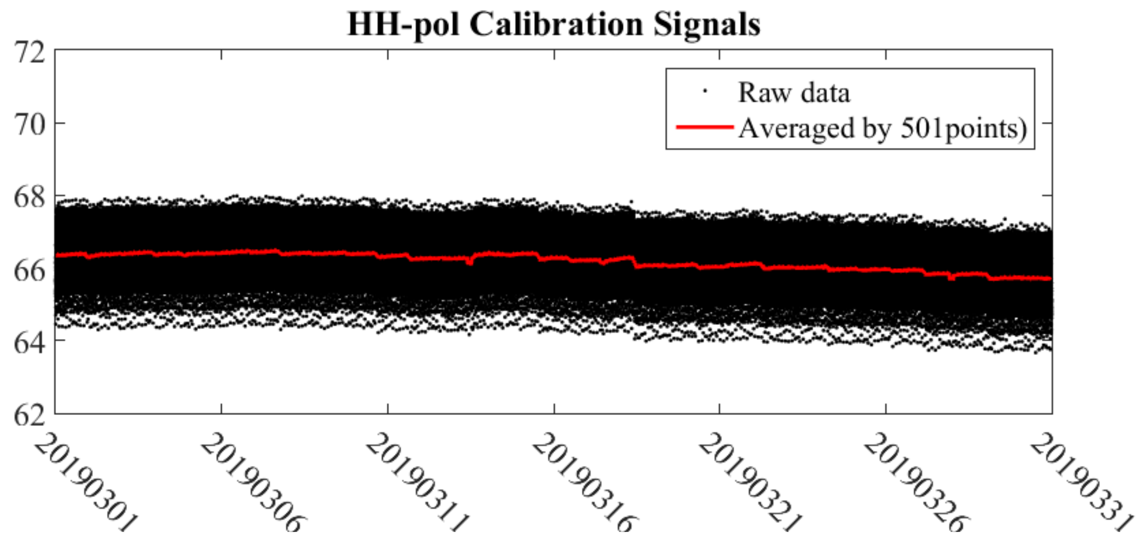


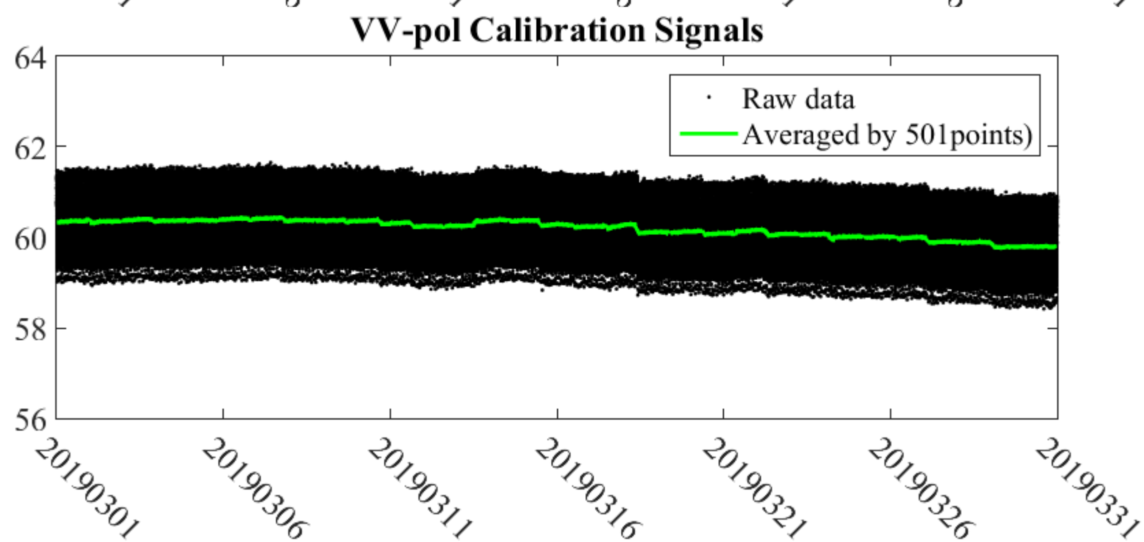
Internal calibration loop

External noise loop

Internal noise loop

Calibration and Noise Signals

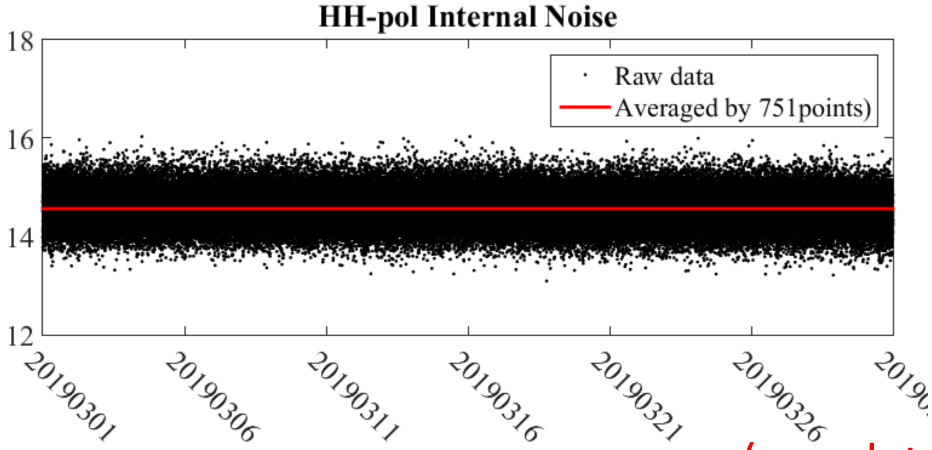


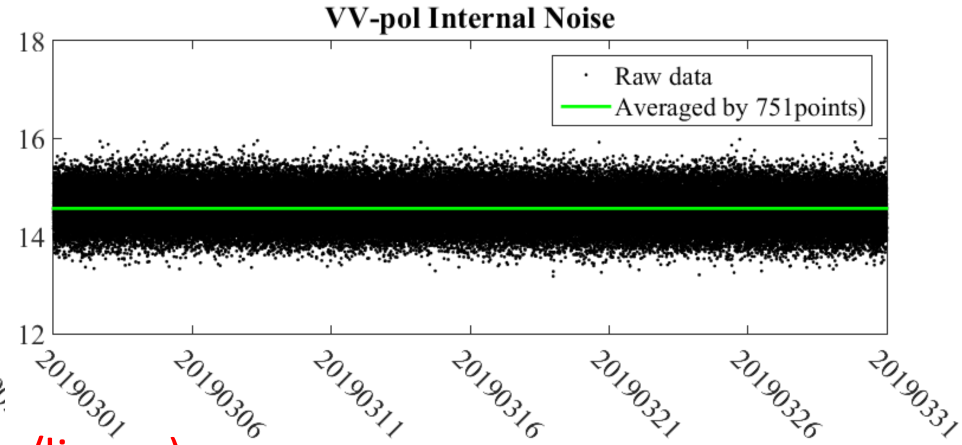


(raw data/linear)

- Steady calibration signals show that both the transmitter and the receiver of the scatterometer work properly.
- The internal calibration signal change slightly with the environment temperature.

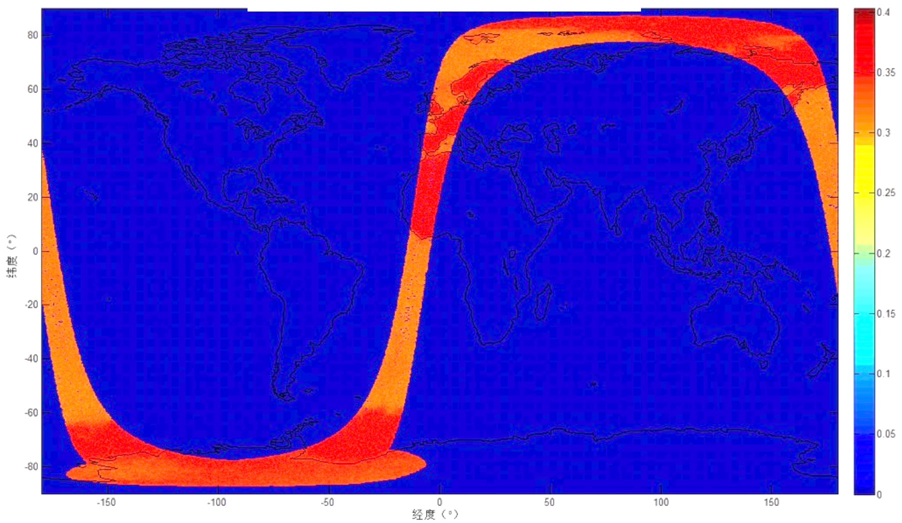
Calibration and Noise Signals



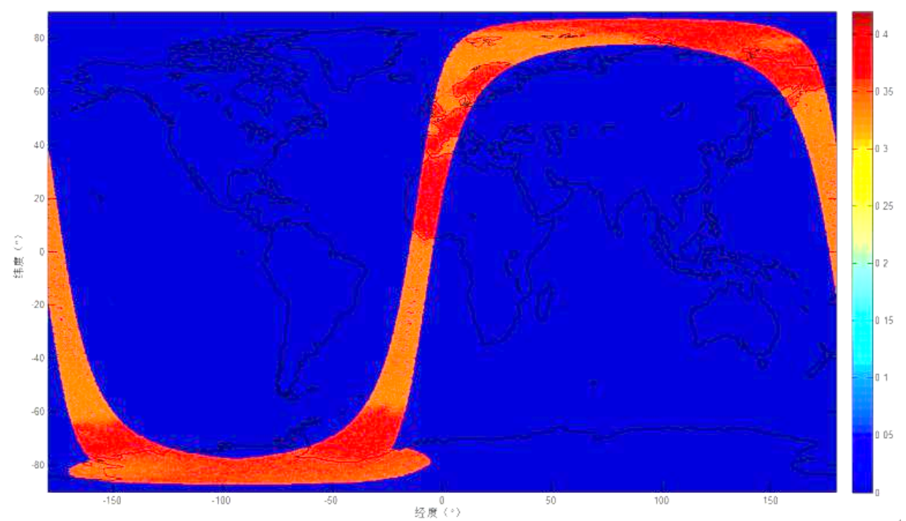


(raw data/linear)

HH-pol External Noise



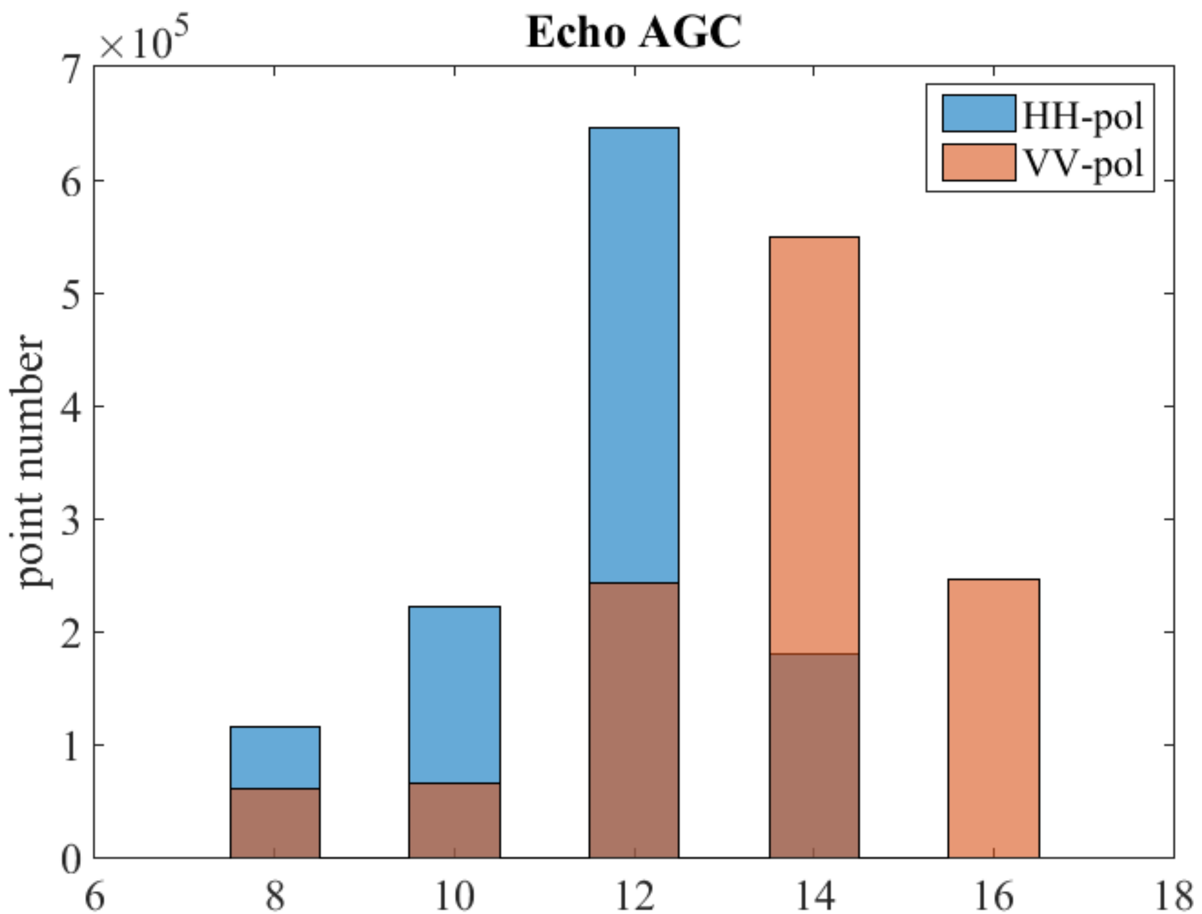
VV-pol External Noise



- ➢ The internal noise is stable, because the internal noise source is from a matched load inside the temperature-controlled cabinet of the satellite
- ➢ The external noise energy changes with the land-sea alternating and variation of surface emission

SCAT on-board Hardware test

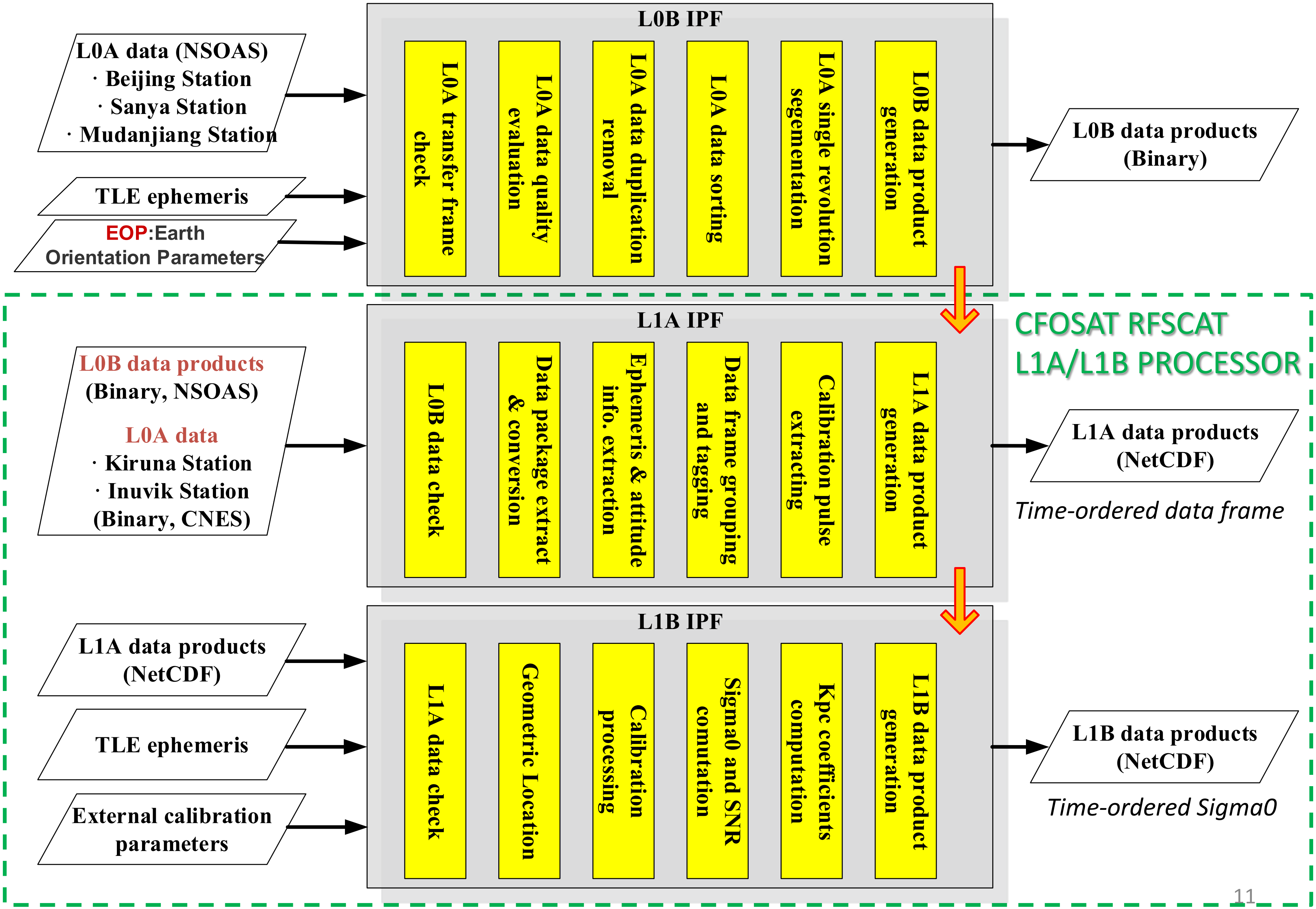
- AGC adjustment of SCAT
  - From 1st Mar. to 31st Mar.



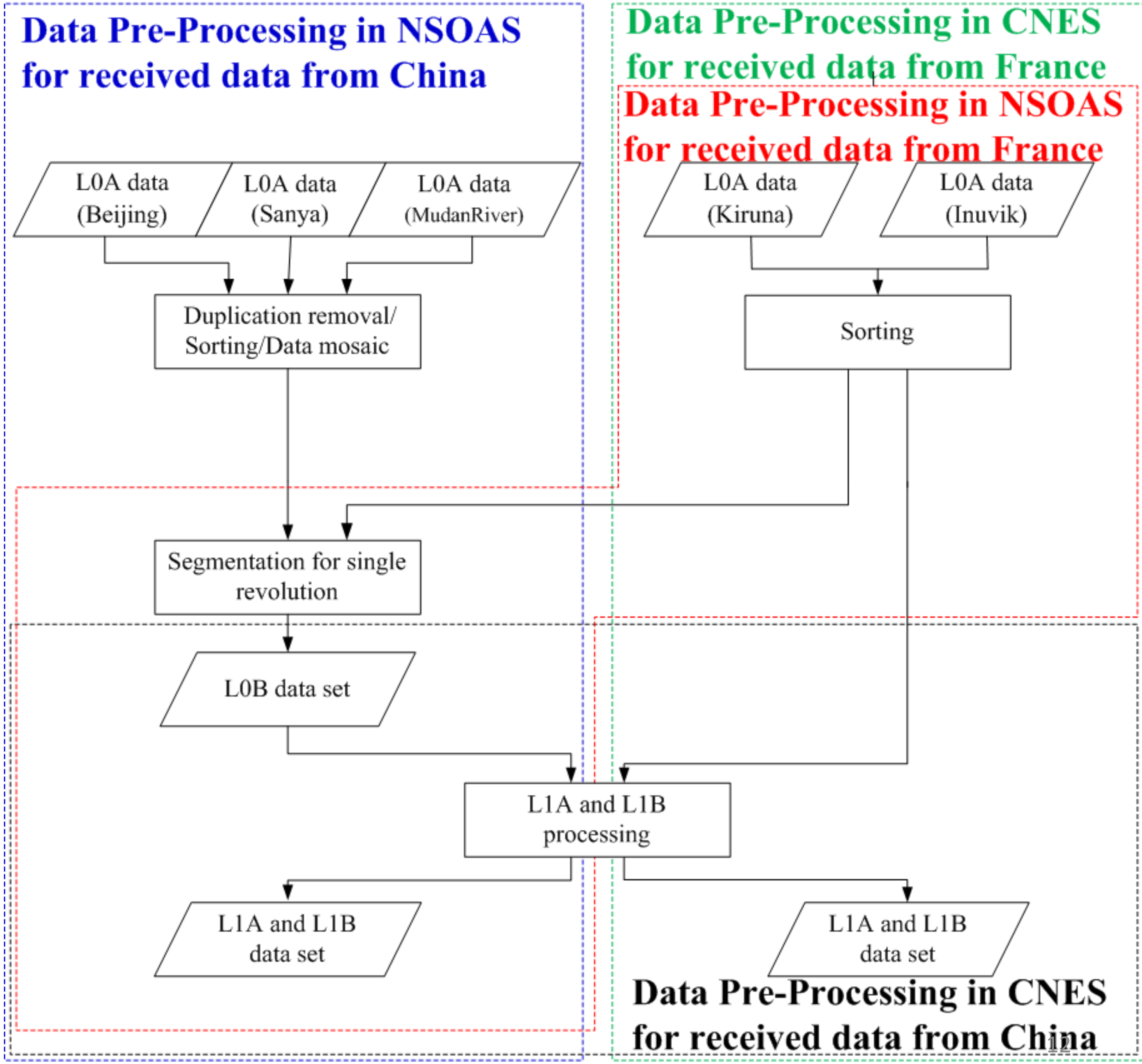
2

CFOSAT SCAT Data L1 Processing and Calibration

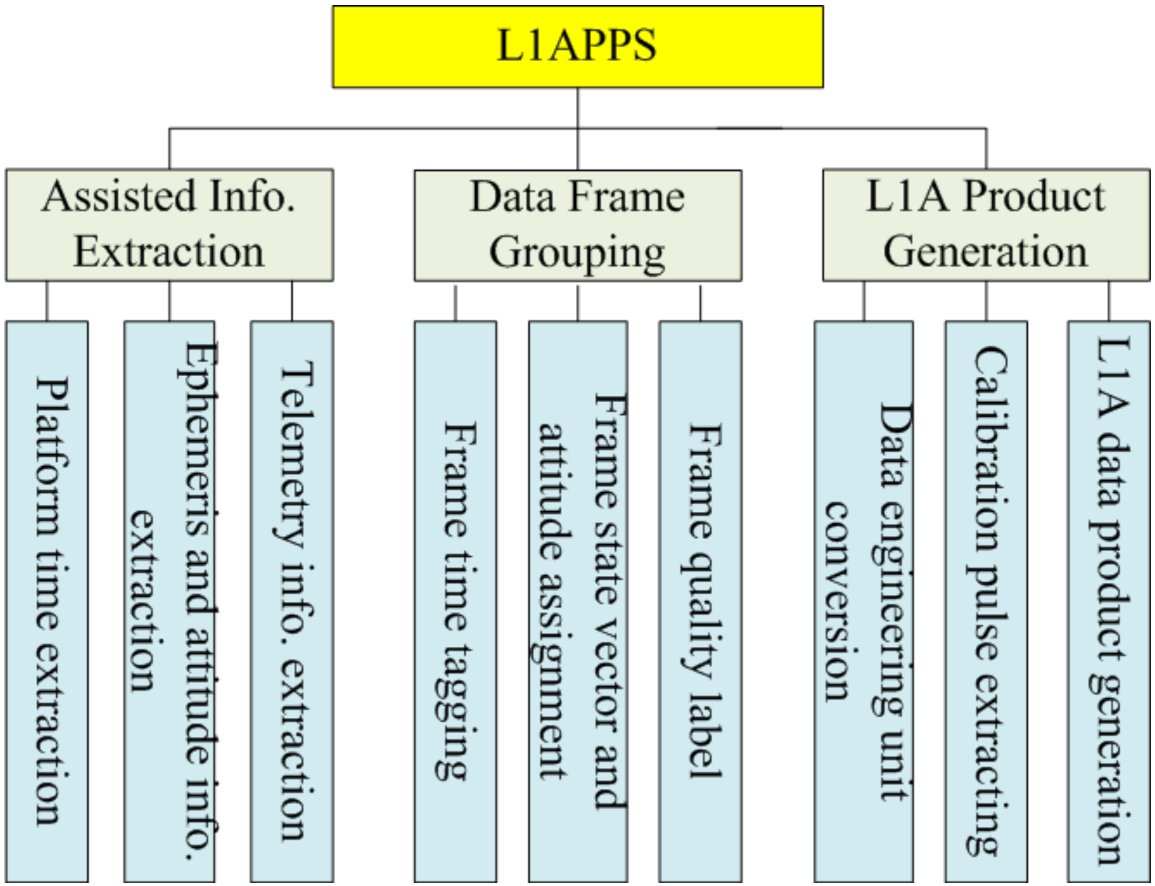
CFOSAT SCAT Data Pre-Processing System



CFOSAT SCAT Data Pre-processing Strategy in NSOAS and CNES

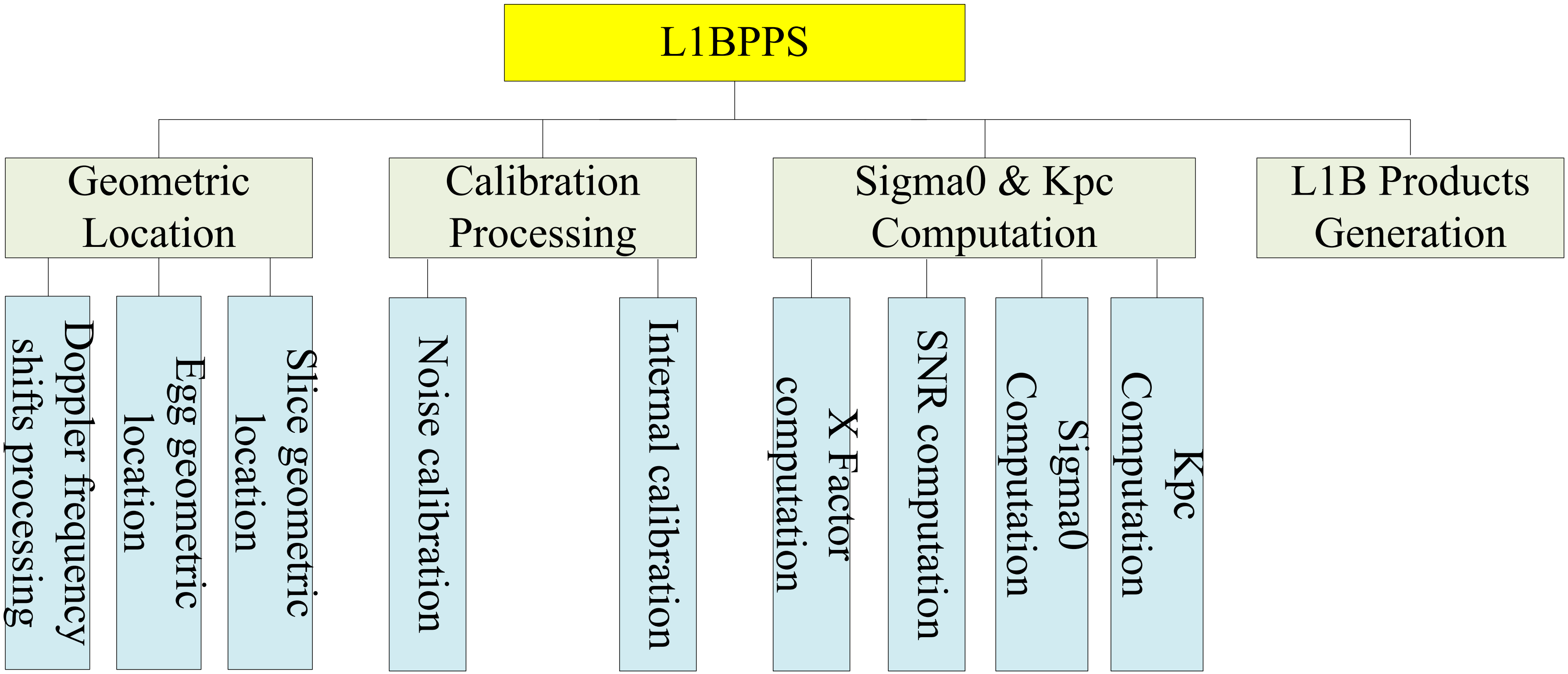


CFOSAT SCAT L1A Processing



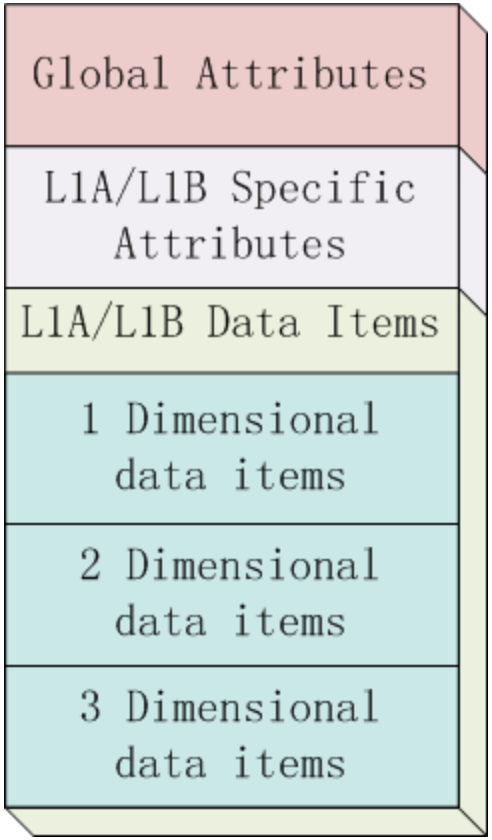
- Pulse time determination
- Ephemeris extraction and interpolation
  - Cubic spline interpolation
- Attitude extraction and interpolation
- Data frame grouping
  - Extract data package from raw VCDU frame
  - data package check
  - Grouping 75 pulses into 1 L1A data frame
- Calibration pulse extraction
- Engineering unit conversion
- L1A product generation
  - NetCDF 4.0 format

CFOSAT SCAT L1B Processing



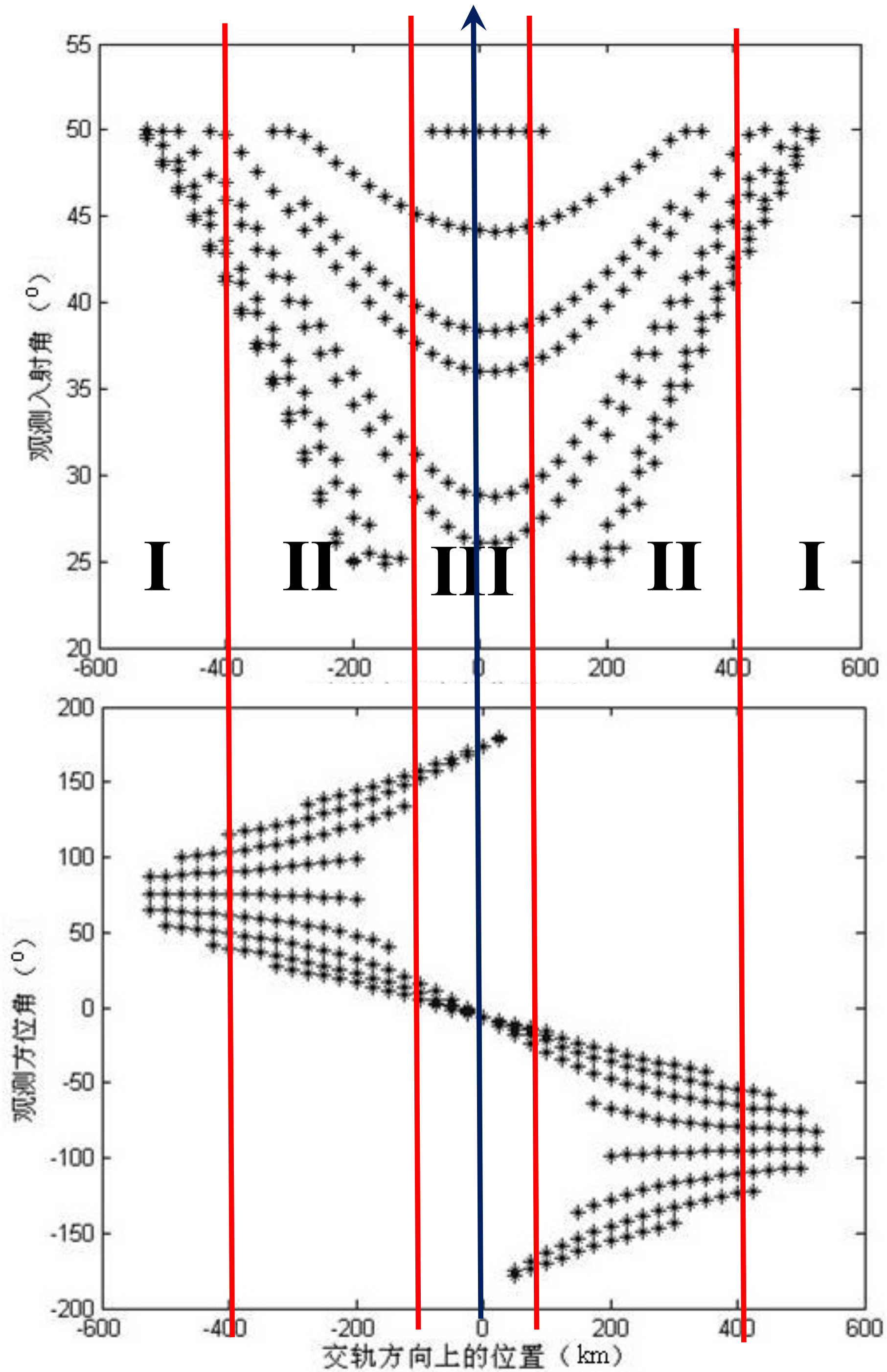
CFOSAT SCAT L1A/L1B Data Product File Structure

- L1A/L1B data products include attribute items and data items in single NetCDF product file
- L1A/L1B data products produced by NSOAS are single revolution data refer to Southernmost
- L1A/L1B data products produced by NSOAS are overlapped by about 240s data for continuous data products



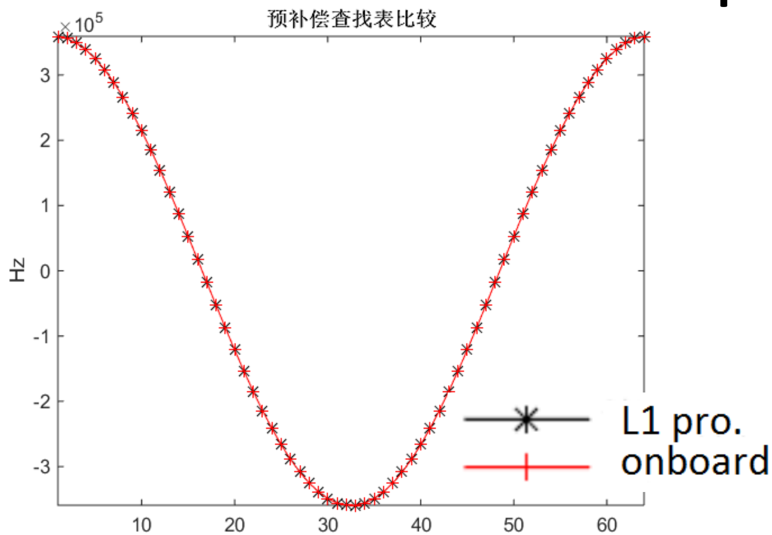
CFOSAT SCAT L1B Data

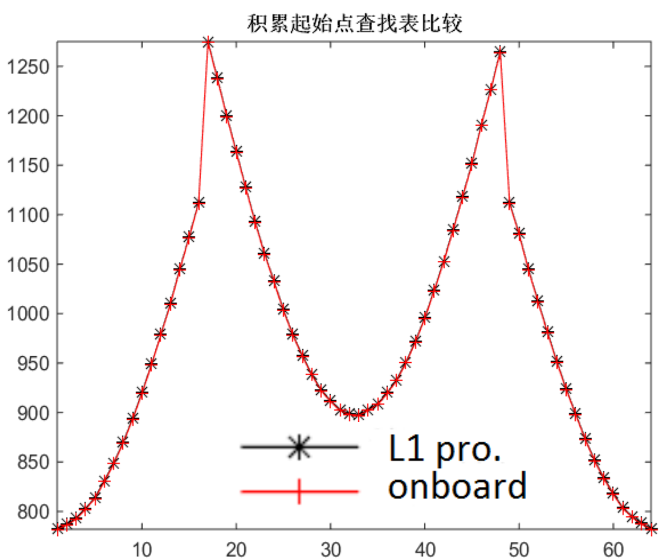
- Incident angle: 26~46deg
- Azimuth looks: 2~9
- Resolution
  - Azimuth: ~8-12km
  - Range: ~10.5km

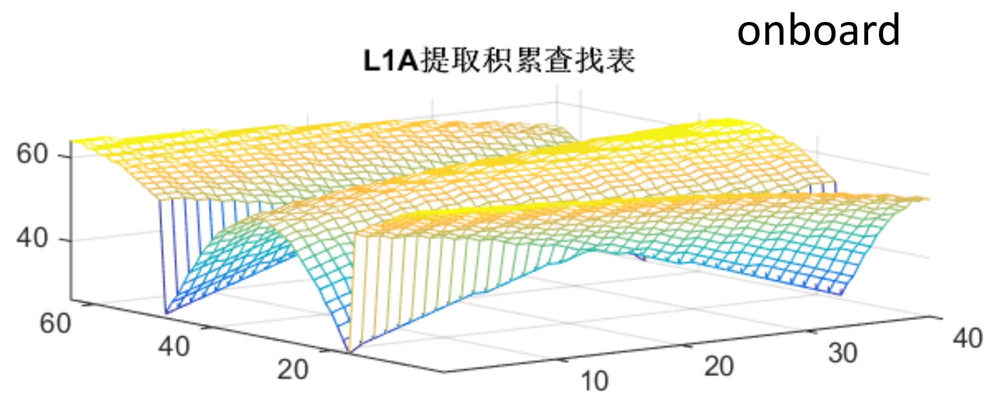


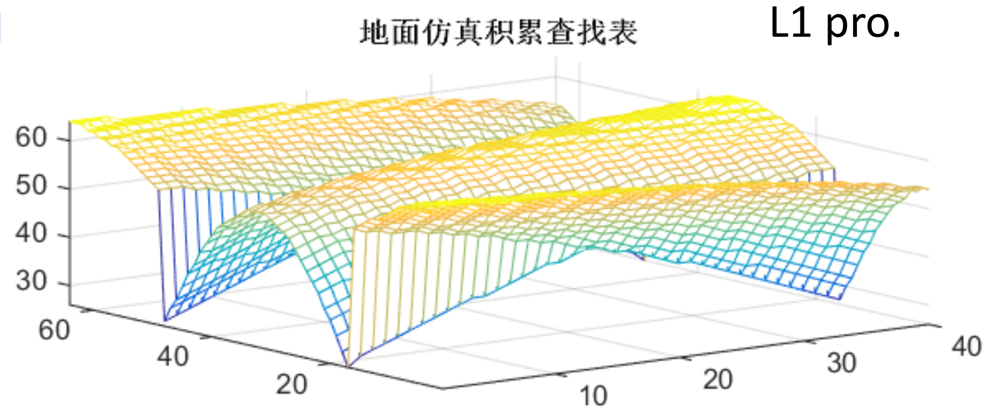
CFOSAT SCAT Instrument Test by L1 Processor

- Onboard and L1 processing LUT

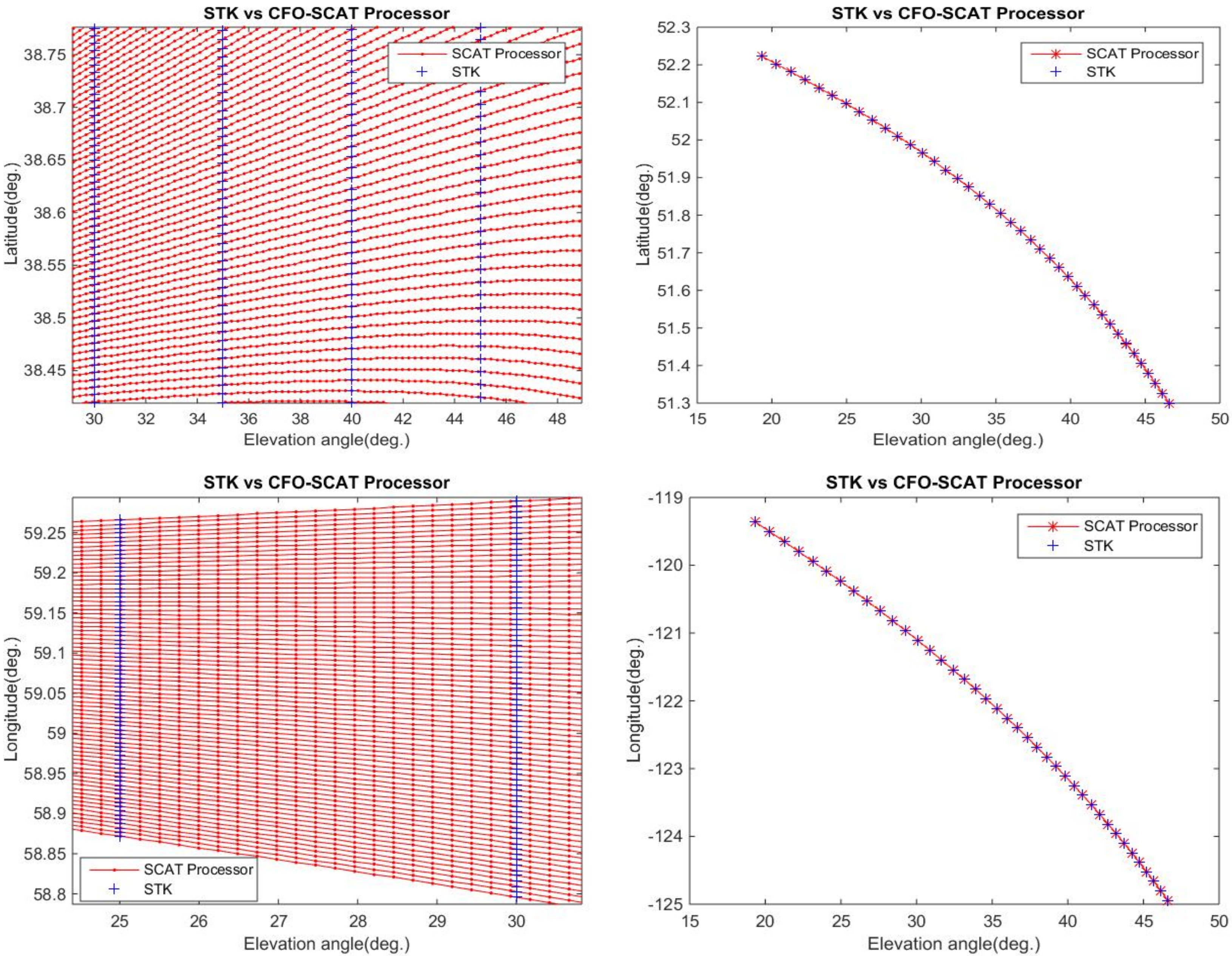


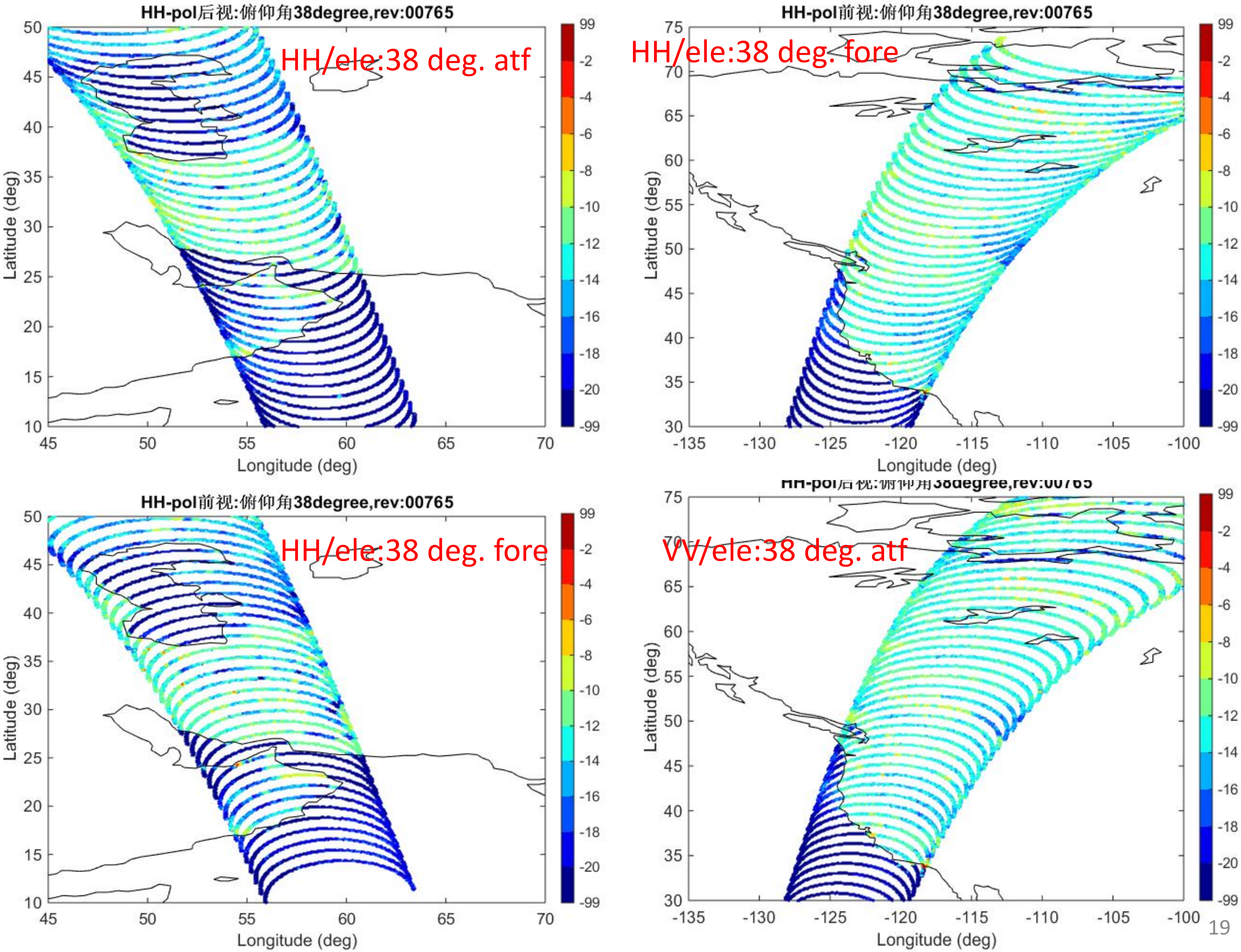






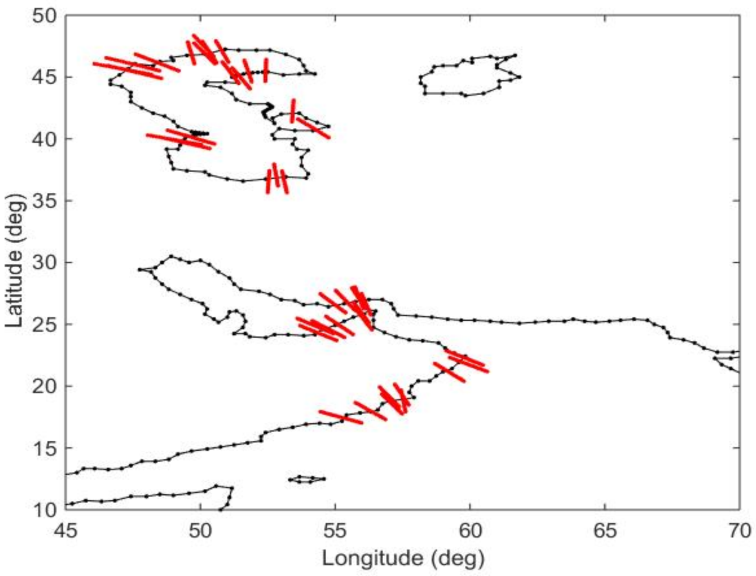
CFOSAT SCAT Geometric Locating

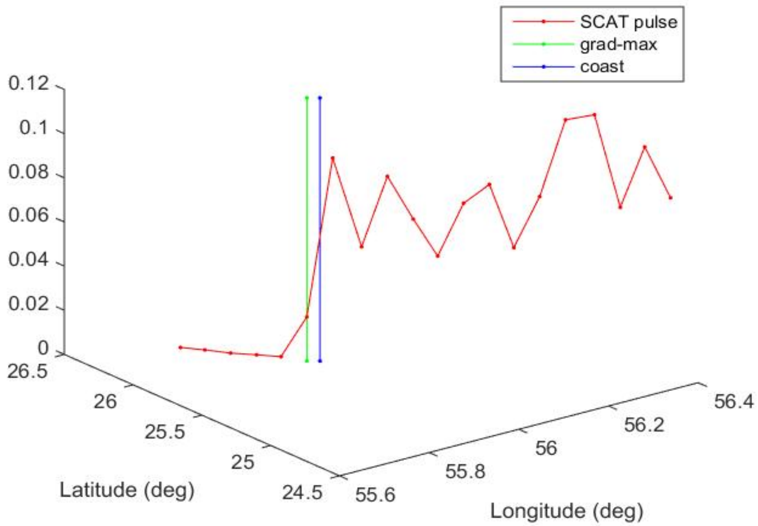




HH-pol后视:俯仰角38degree,rev:00765
HH/ele:38 deg. atf
HH-pol前视:俯仰角38degree,rev:00765
HH/ele:38 deg. fore
HH-pol前视:俯仰角38degree,rev:00765
HH/ele:38 deg. fore
VV/ele:38 deg. atf
Latitude (deg)
Longitude (deg)

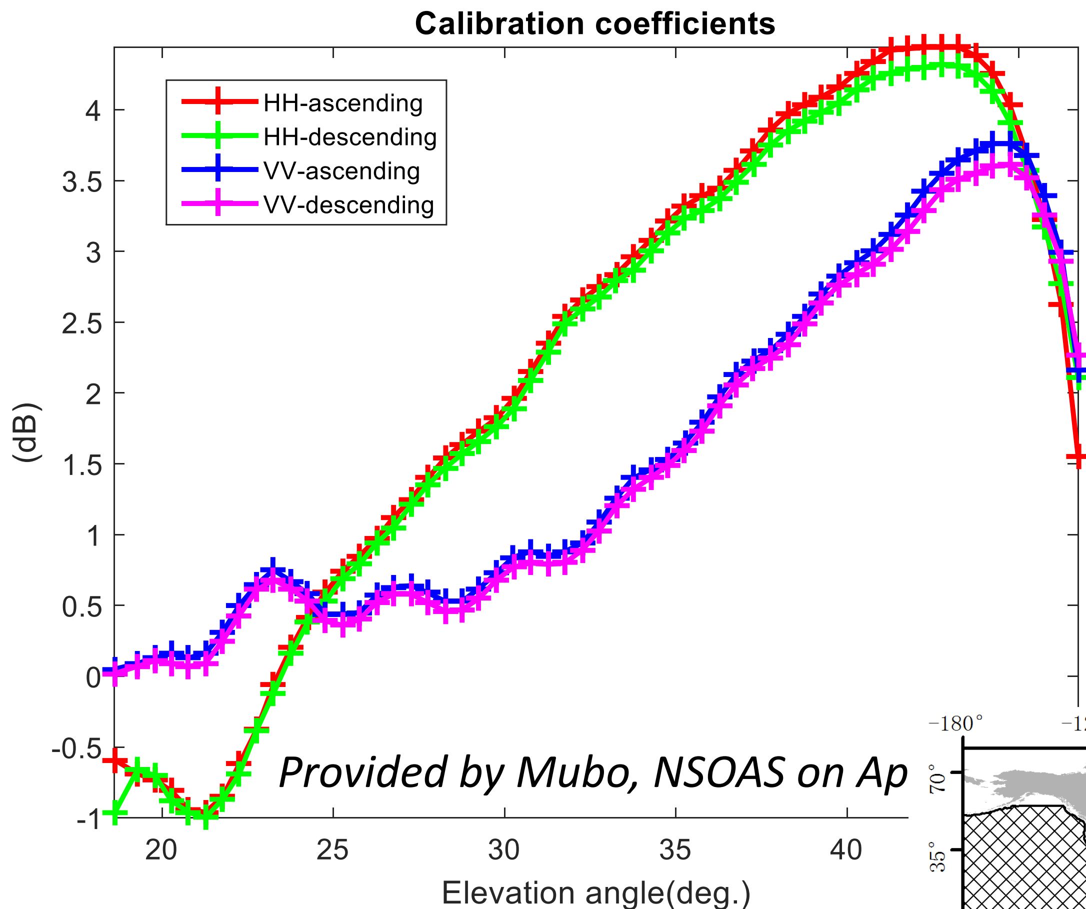
CFOSAT SCAT Geometric Locating



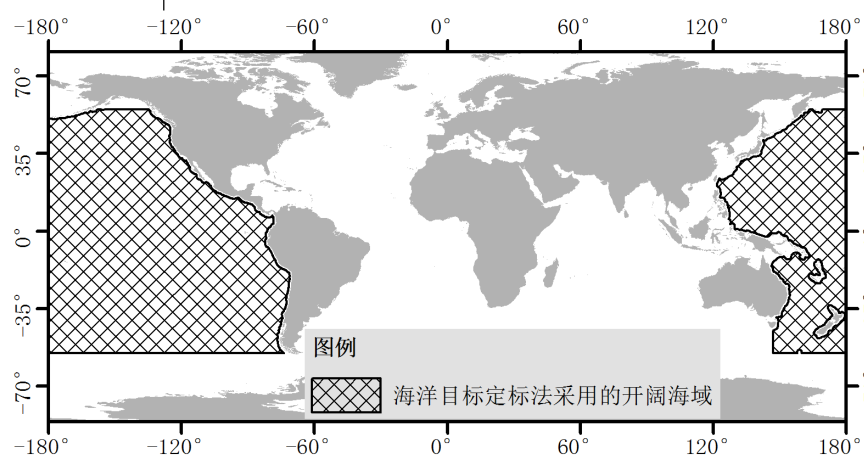


- Using STK, the accuracy of geometric locating algorithms are verified
- Using the coastline data, the geometric locating performance is estimated preliminarily
- At present, the geometric locating accuracy of L1 processor is less than 10km
- Improving the geometric locating performance and assessment method will be done continuously

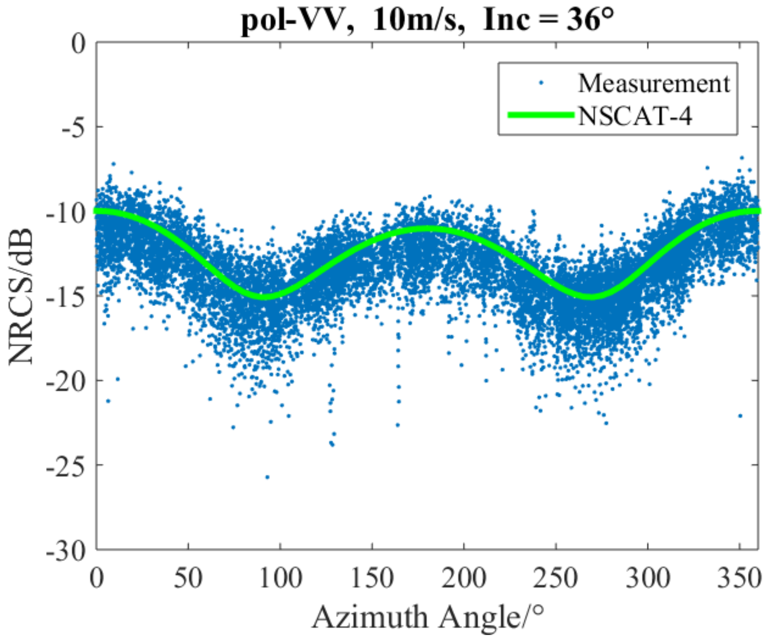
CFOSAT SCAT Sigma0 Calibration

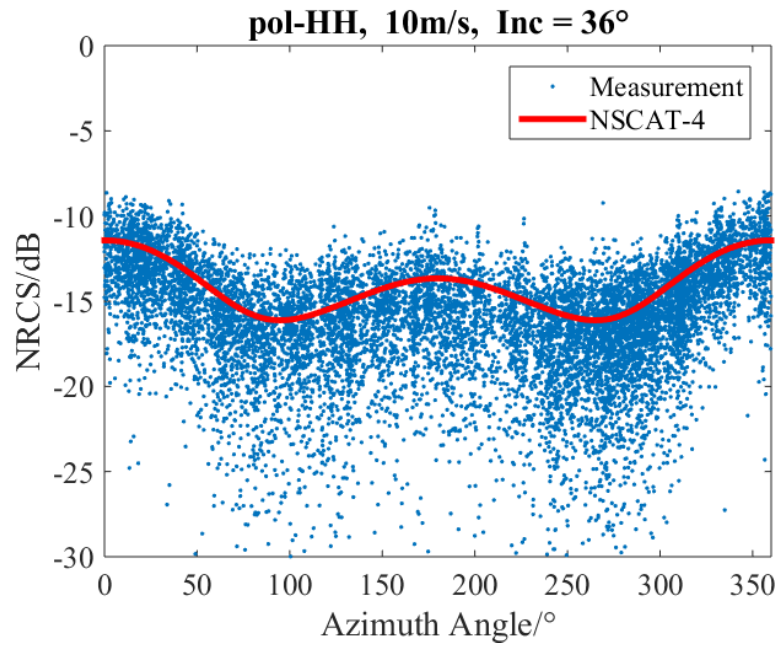


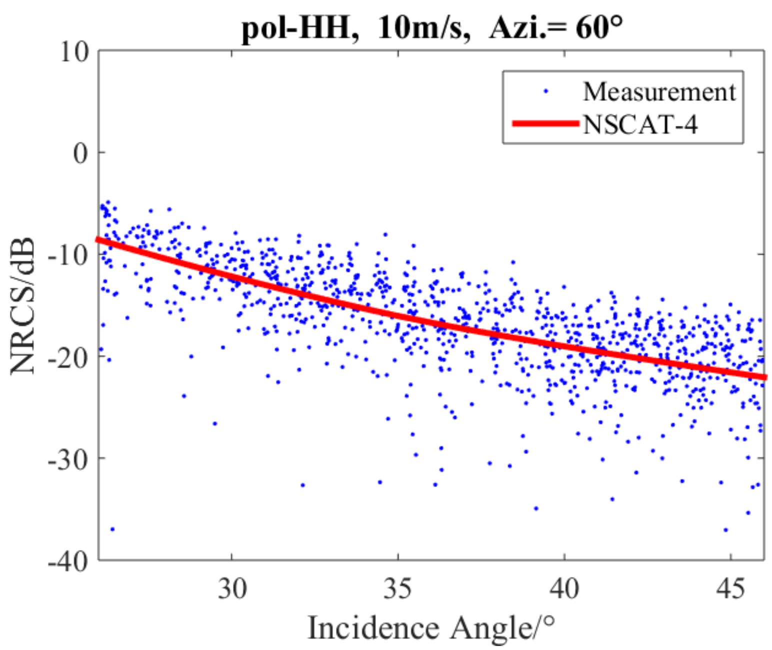
- The ocean calibration method utilizes the simulated sigma0 by GMF and the CFOSAT SCAT wind data in open ocean.
- GMF: NSCAT-4 model. This was correspondingly chosed for the L2B wind inversion.

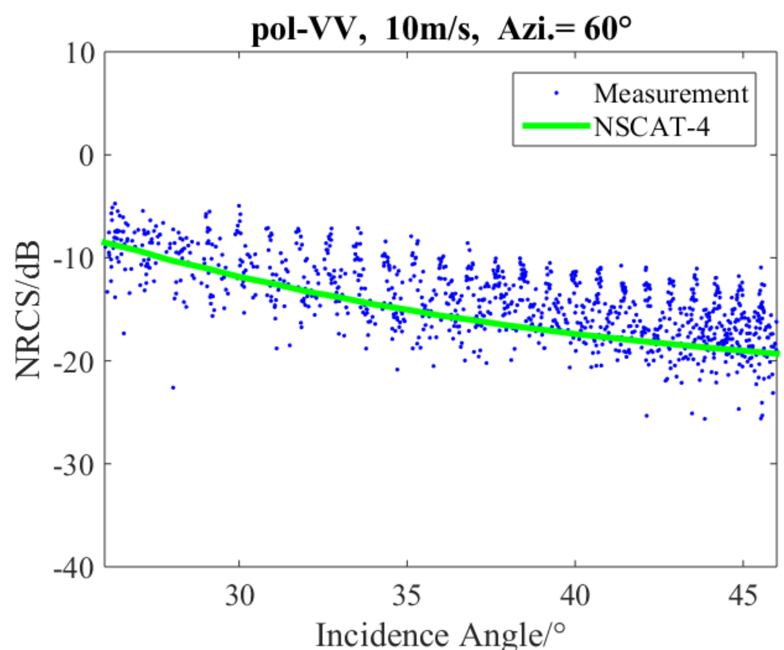


CFOSAT SCAT Sigma0



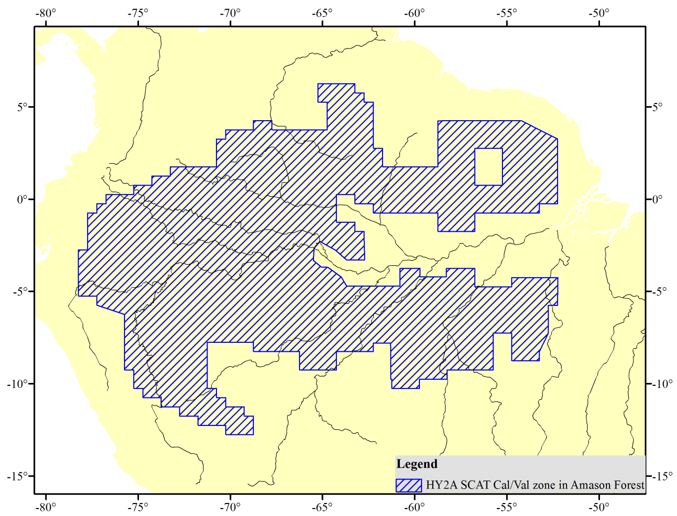




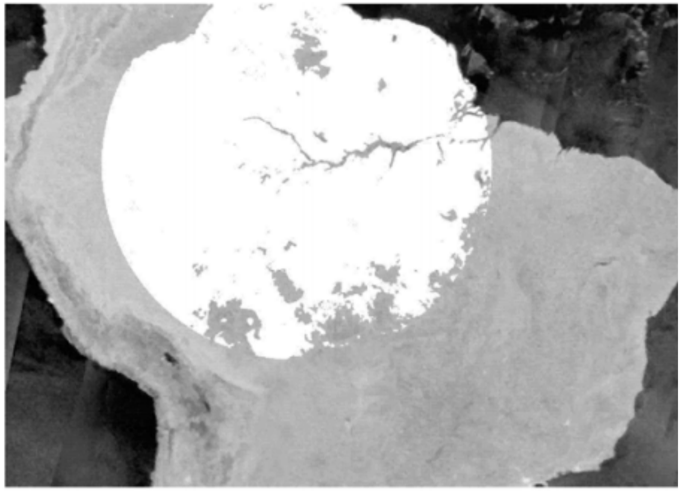


Sigma0 Validation with Amazon Forest

- Measurement noise: by monitoring the width of the sigma0 histogram.
- Azimuth response of sigma0: by monitoring the sigma0 in azimuth angle.
- Long-term stability of sigma0: by monitoring the mean value of the sigma0 histogram.



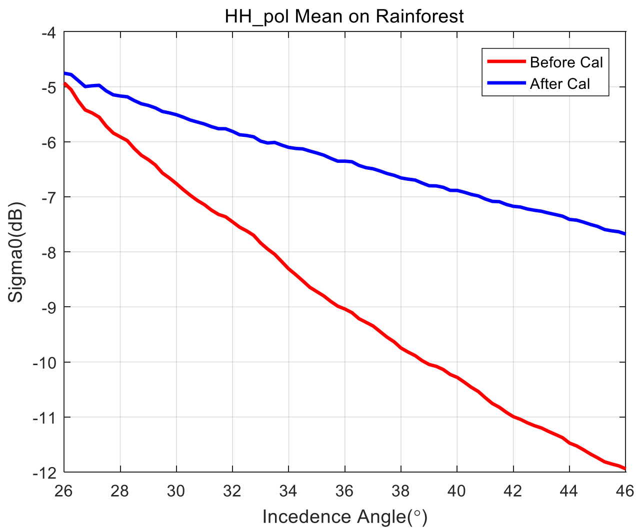
The selected zone for HY-2 and CFOSAT scatterometers

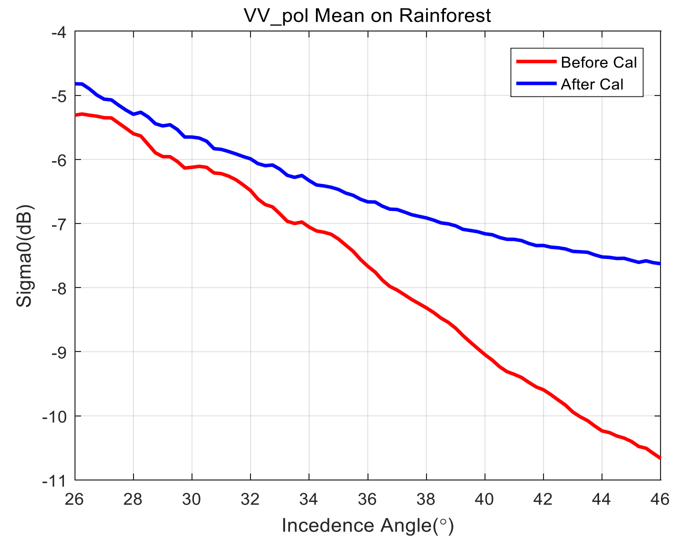


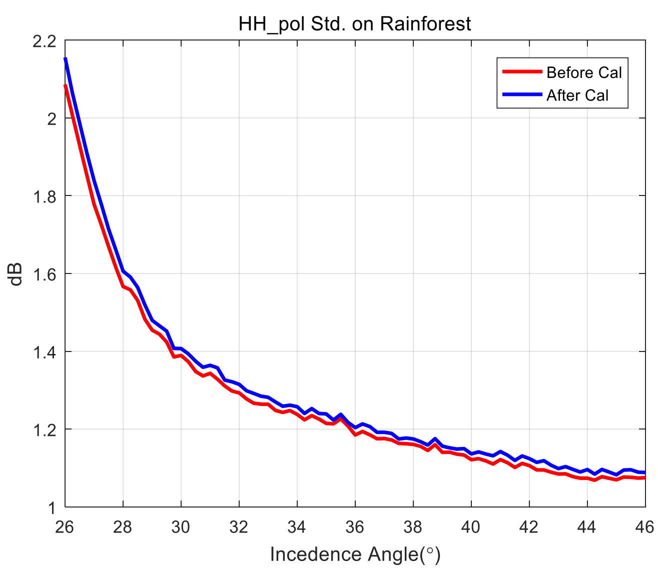
[Kunz and Long, 2005]

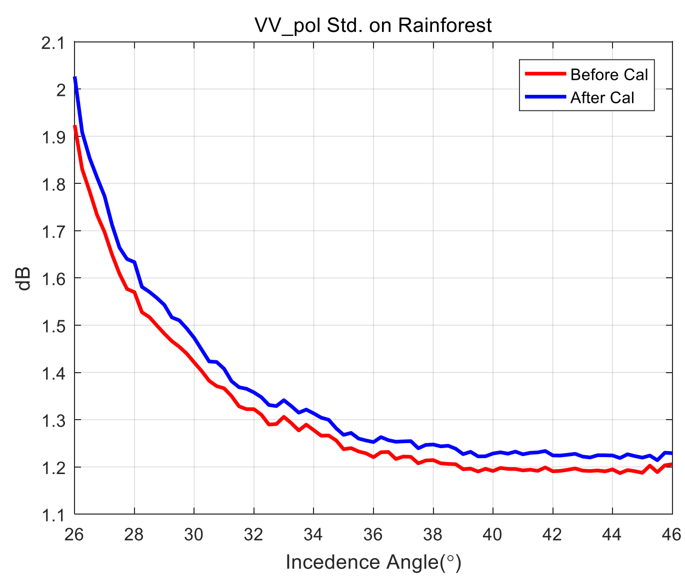
Sigma0 Validation with Amazon Forest

- Computed on 10km*12.5km slices



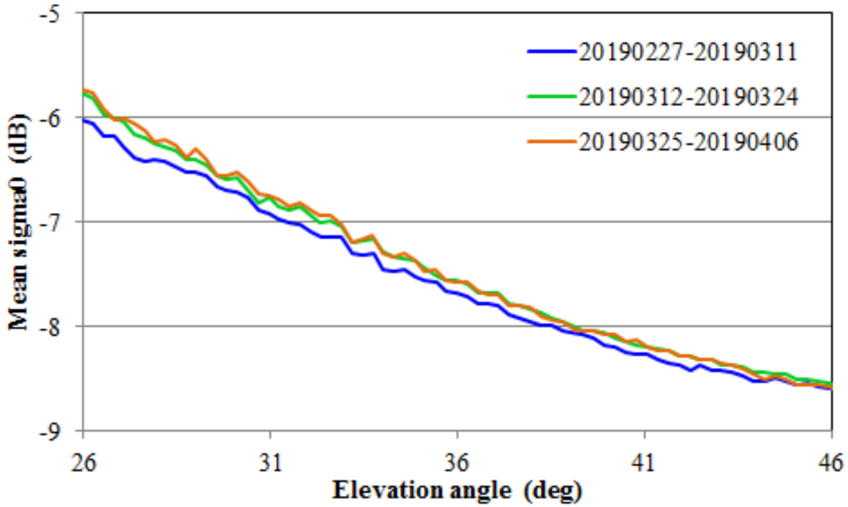


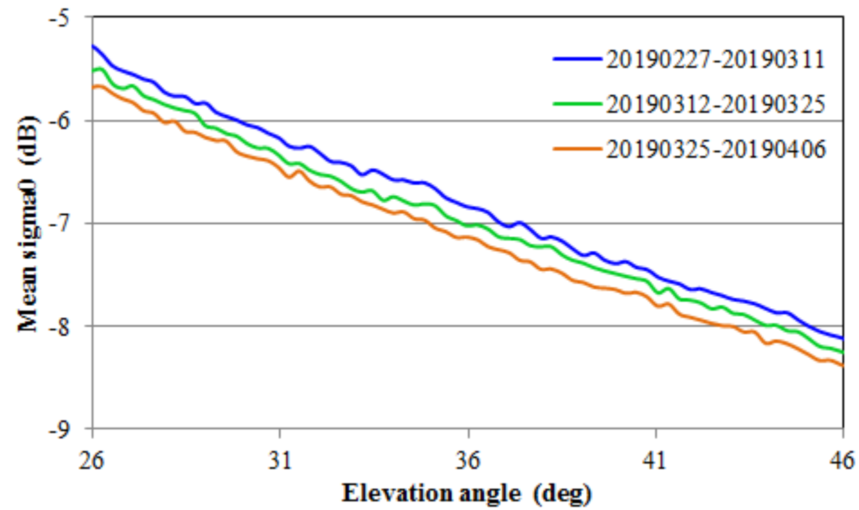


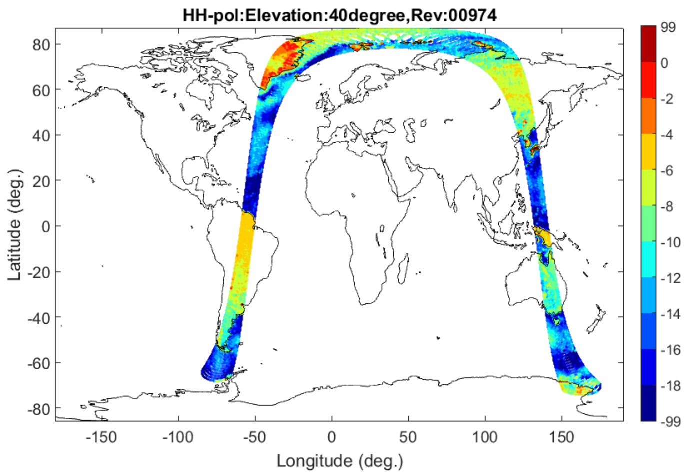


Sigma0 Validation with Amazon Forest

➢ Long-term stability of sigma0



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Longitude (deg.)
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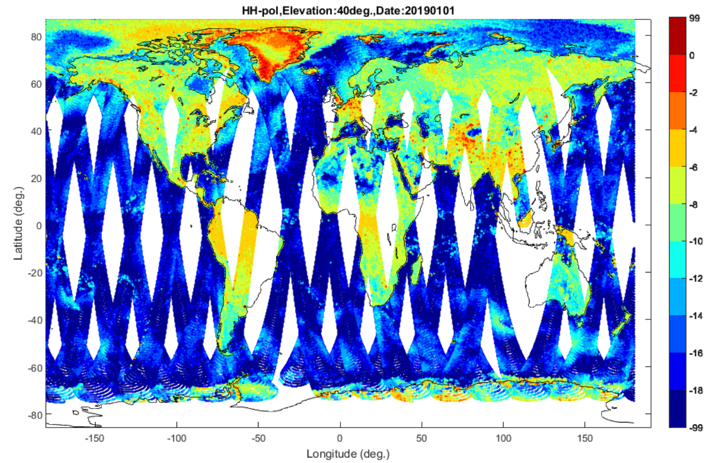
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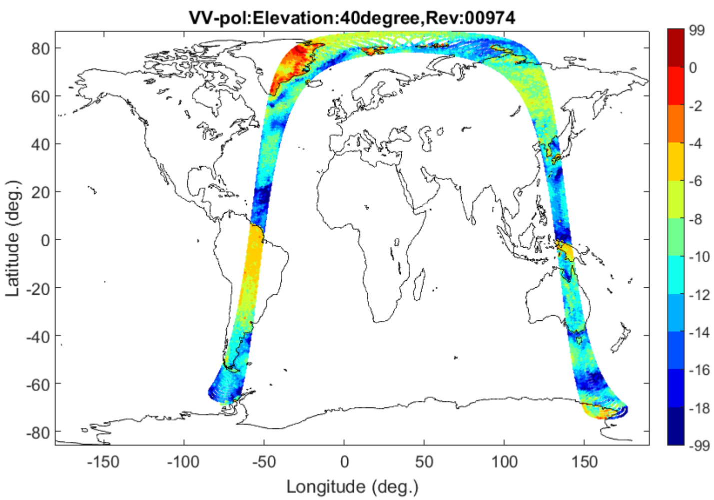
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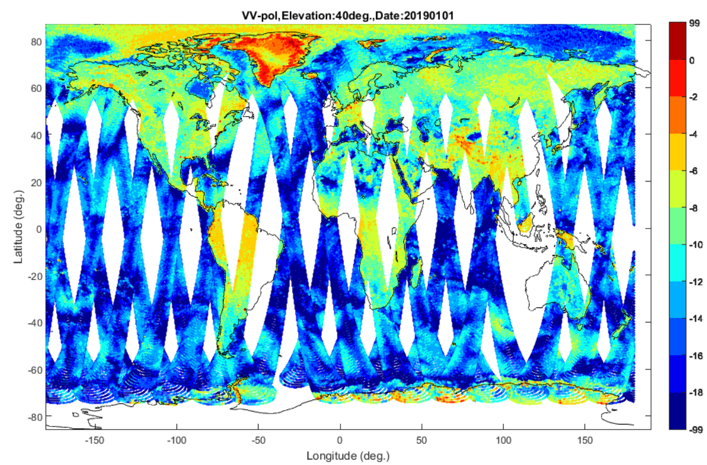
VV-pol,Elevation:40deg.,Date:20190101
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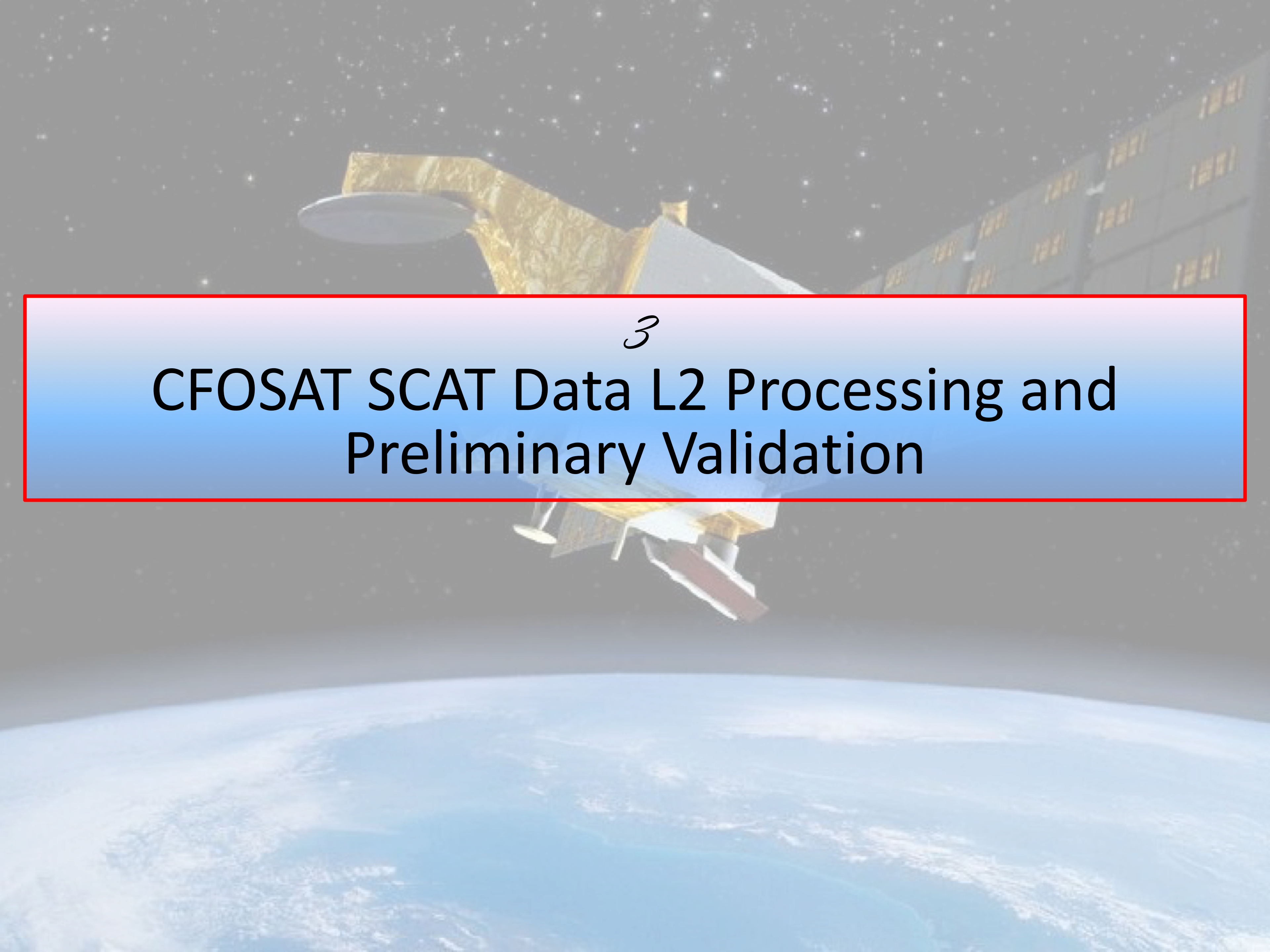
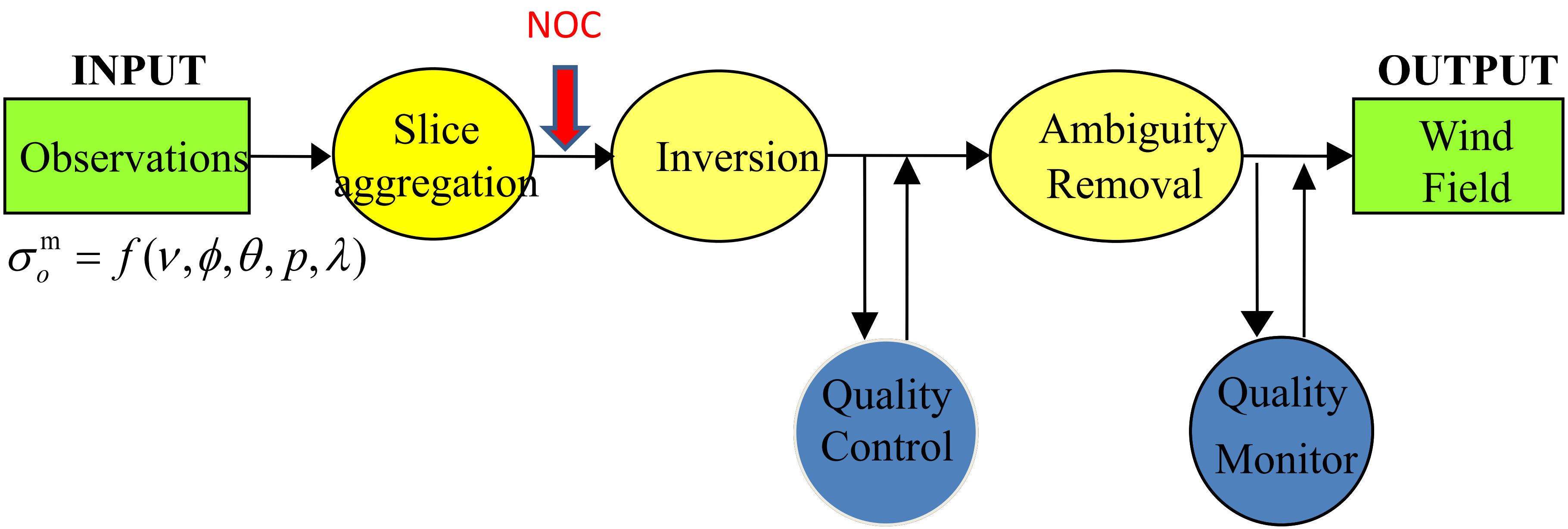


3

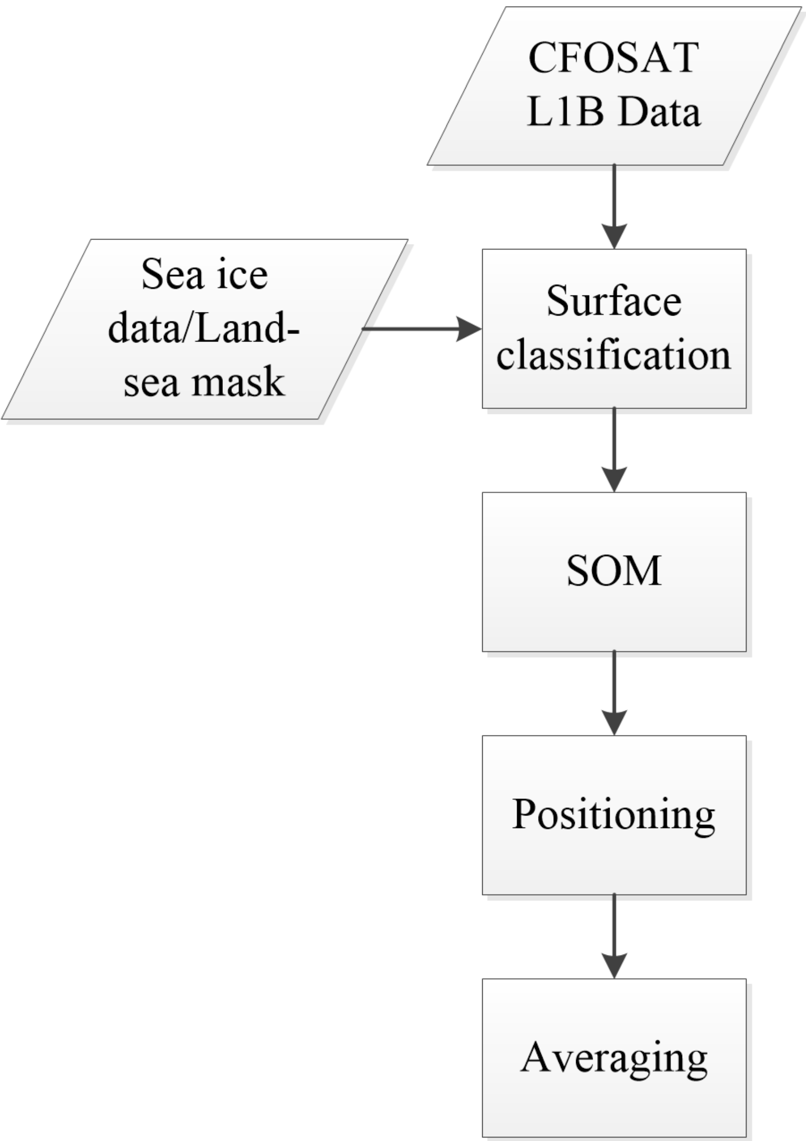
CFOSAT SCAT Data L2 Processing and Preliminary Validation

L2 processing



Similar to the conventional scatterometer wind retrieval, the L2 processing of CFOSAT scatterometer includes 1) slice aggregation, 2) wind inversion, 3) ambiguity removal, and 4) quality control.

L2 processing



Slice aggregation

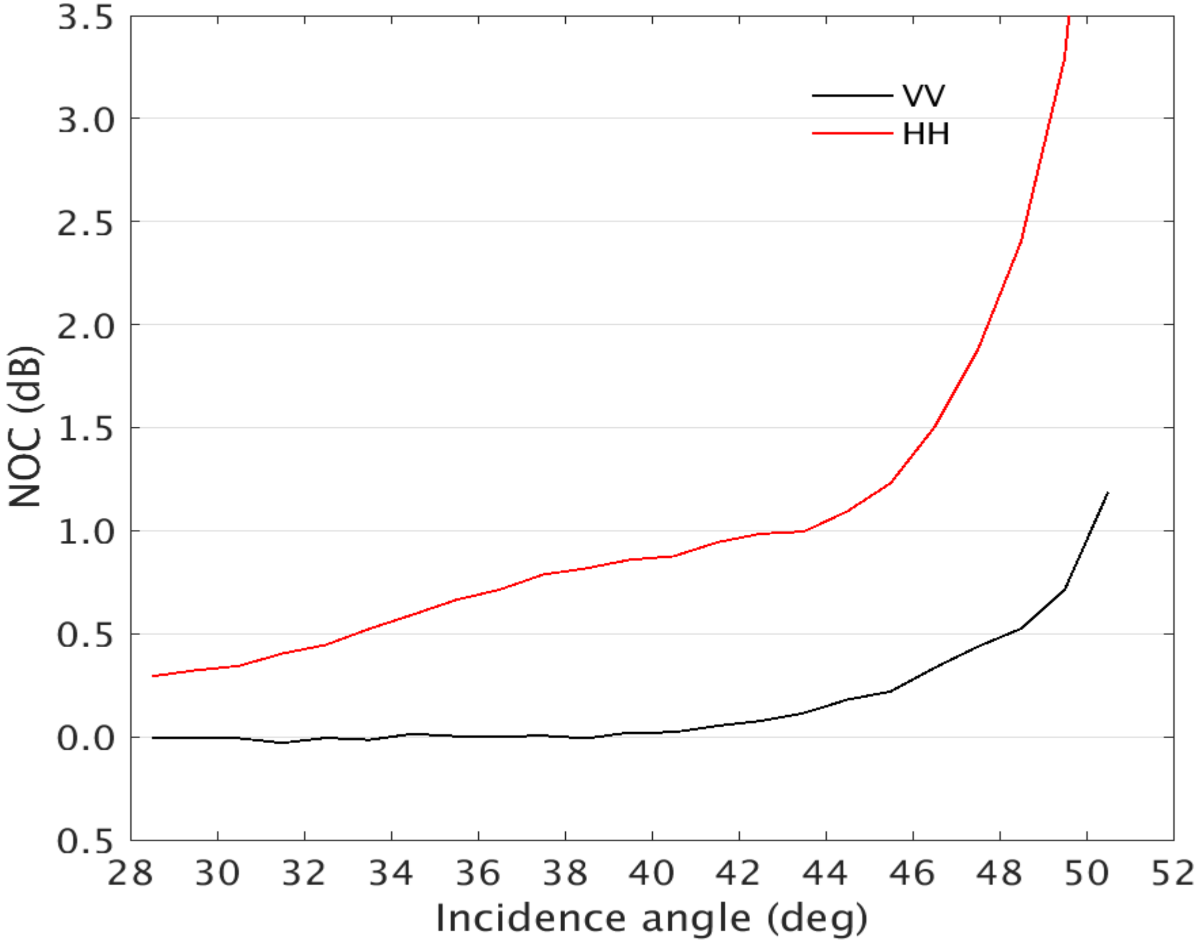
① Surface classification: this is done by collocating sea ice data and land-sea mask with the L1B data, and then classifying the surface as land, ice or sea surface.

② Conversion of coordinates: the geographic positions of the measurements over the ocean are converted to a Cartesian coordinate using the so-called space oblique Mercator (SOM) projection.

③ Positioning: in the new coordinate, the slice position is simply scaled to derive the WVC row and column numbers, and then slices with similar incidence and azimuth angles are aggregated into a specific WVC view.

④ Averaging: the WVC position is acquired by averaging the geographic positions of all sea-surface slices within the same WVC. While the backscatter measurements that belong to the same WVC and correspond to the same antenna revolution are averaged into a particular WVC view.

L2 processing-NOC calibration



CFOSCAT NOC coefficients based on the L2A products

L2 processing-Quality control/monitoring

Quality Control

- ✓ Ice flag from the ancillary data;
- ✓ Land flag from the land-sea mask;
- ✓ QC flag based on the inversion residual (MLE);
- ✓ QC flag based on singularity exponent;

Quality Monitor

- ✓ Rain probability;
- ✓ Estimated wind errors based on triple collocation;

Red contents to be updated using ONE year of data

Methodologies

1) The sea surface winds are retrieved by minimizing the MLE cost function below,

$$MLE = \frac{1}{N}\sum_{i}^{N}\frac{\left(\sigma_{mi}^{0}-\sigma_{si}^{0}\right)^{2}}{\left(K_{pi}\cdot\sigma_{ti}^{0}\right)^{2}}$$

Geophysical Model Function – NSCAT-4

2) Ambiguity removal – 2DVAR developed by KNMI

$$J\left(\mathbf{x}_{o}^{k},\mathbf{x},\mathbf{x}_{b}\right)=J_{o}\left(\mathbf{x}_{o}^{k},\mathbf{x}\right)+J_{b}\left(\mathbf{x}\right)$$

3) Quality control

Scatterometers provide good quality sea surface winds except for:

- Sea ice or land contamination
- Large spatial and temporal variability (e.g., vicinity of fronts and low-pressure centres)
- Rain (especially in Ku-band systems)

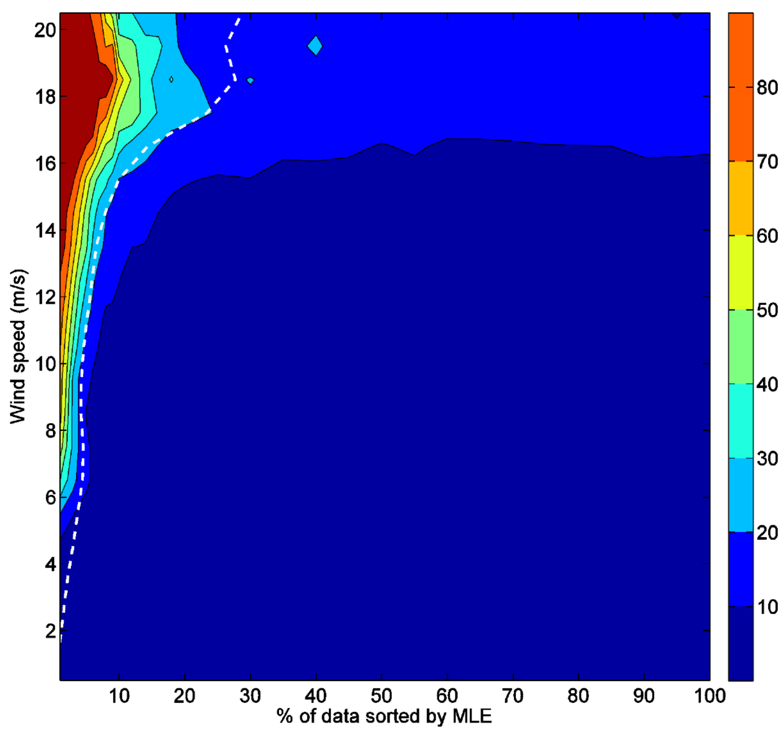
(see Wenming Lin et al, presentation on Thursday)

Methodologies

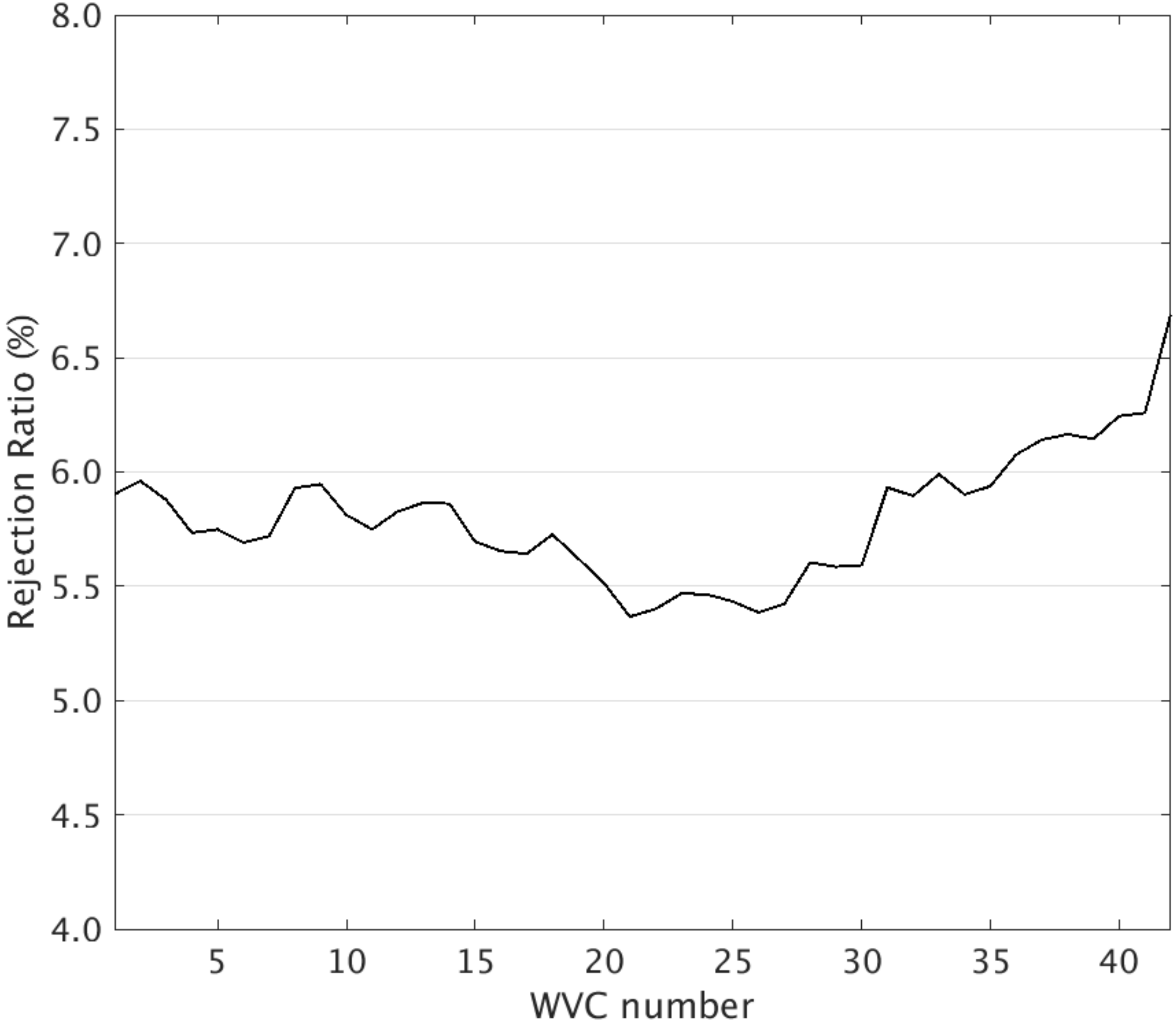
3) Quality control – two indicators

$$MLE = \frac{1}{N}\sum_{i}^{N}\frac{\left(\sigma_{mi}^{0}-\sigma_{si}^{0}\right)^{2}}{\left(K_{pi}\cdot\sigma_{ti}^{0}\right)^{2}}$$

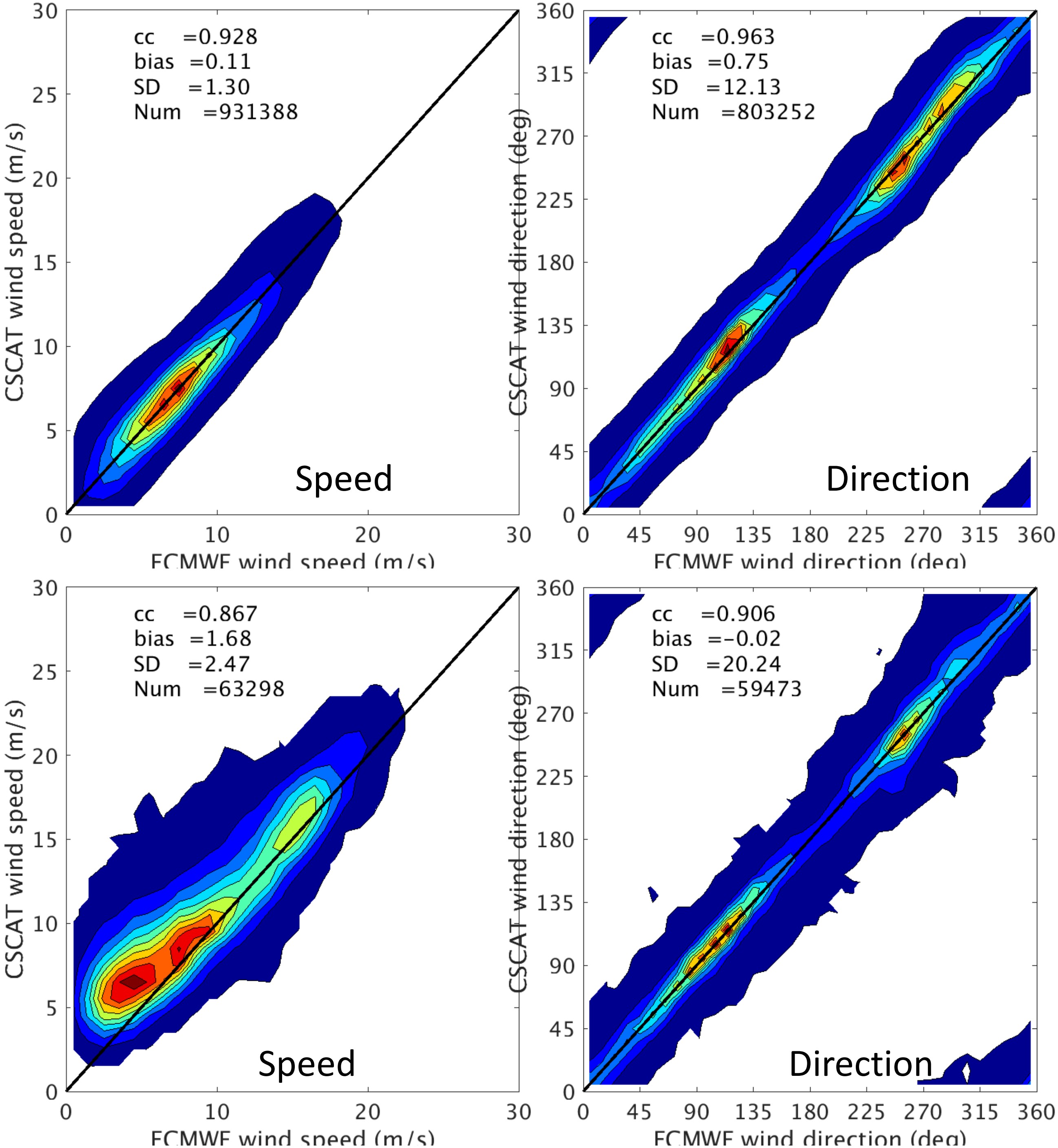
$$h(\mathbf{x}) = \frac{\log\left[\mathrm{T}_{\psi}\left\|\nabla s\right\|(\mathbf{x},r)/\mathrm{T}_{\psi}^{0}\right]}{\log r_0} + o\left(\frac{1}{\log r_0}\right)$$



Setting a set of MLE/SE threshold, such that the rain rate contour aligns well with the white curve (rejection ratio), and most the rejected data are indeed affected by rain.

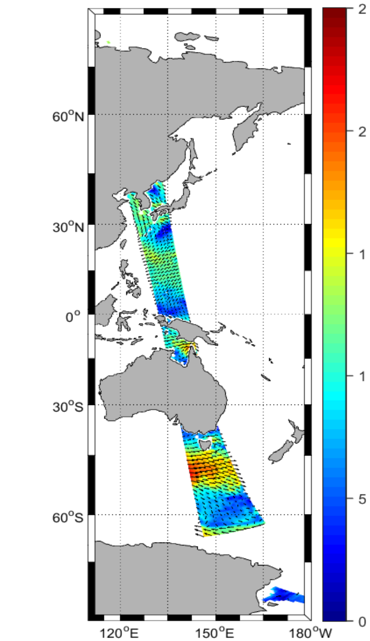


QC rejection ratio vs WVC number

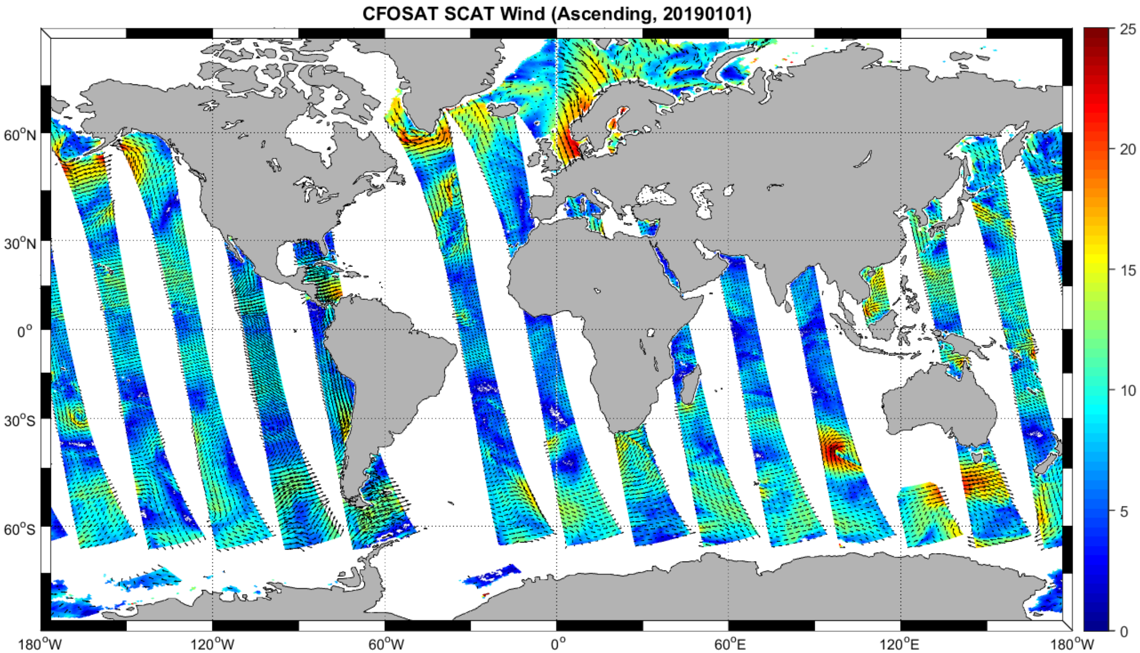


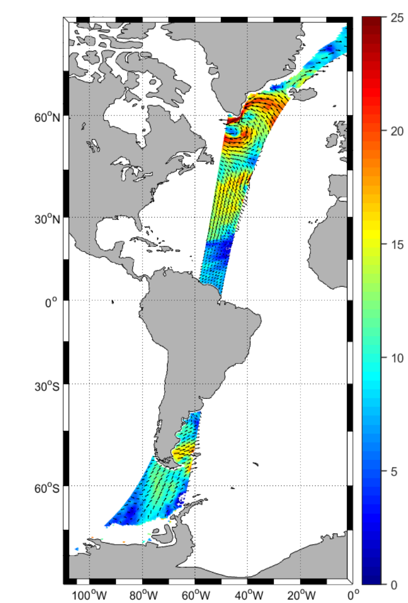
QC-accepted

QC-rejected

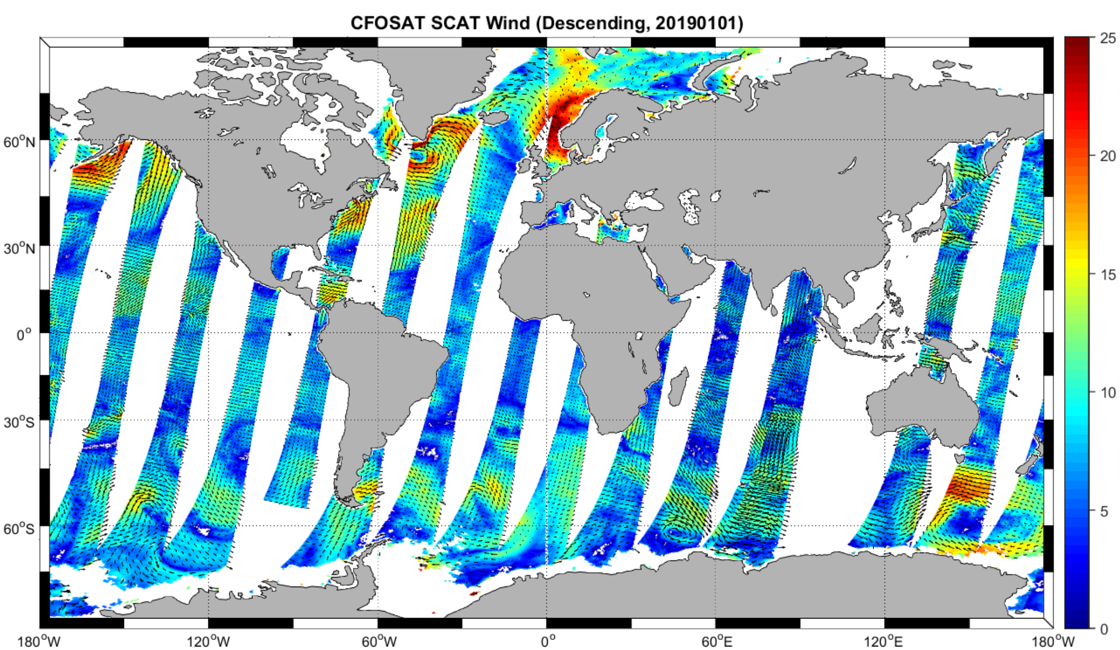


Ascending, 20190101, Rev.00974

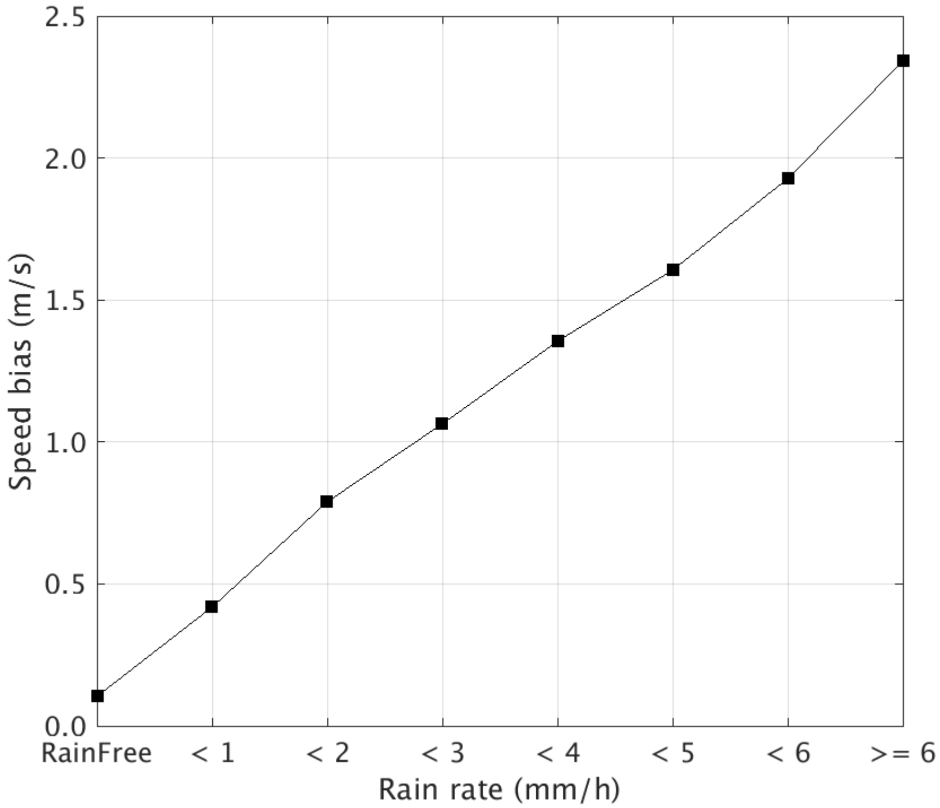


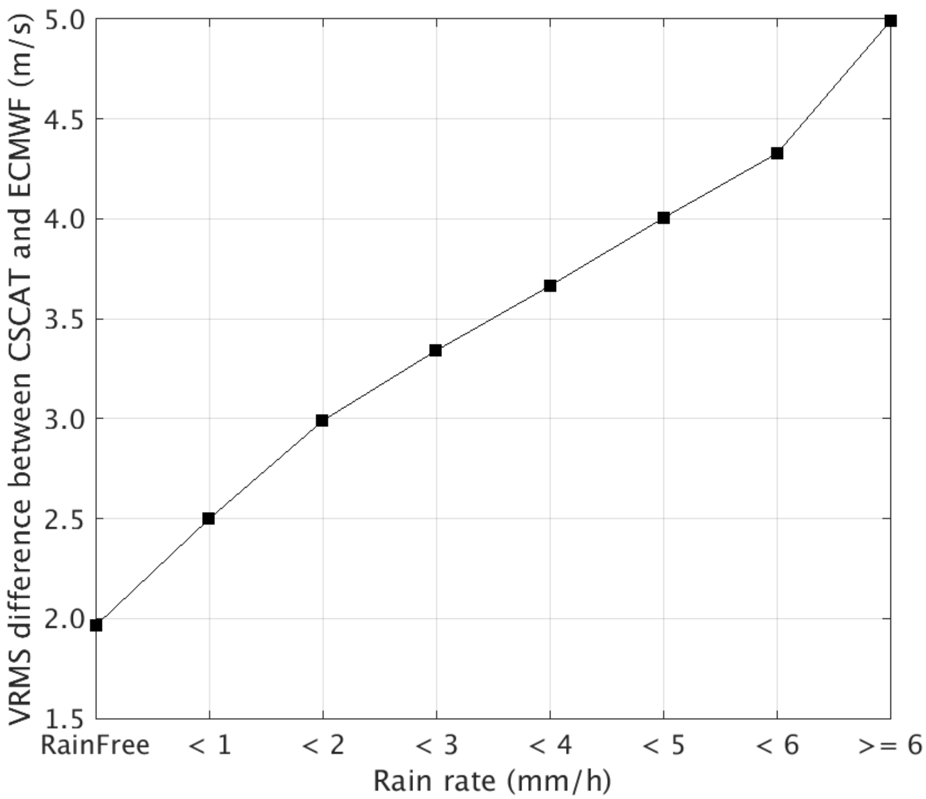


Descending, 20190101, Rev. 00974



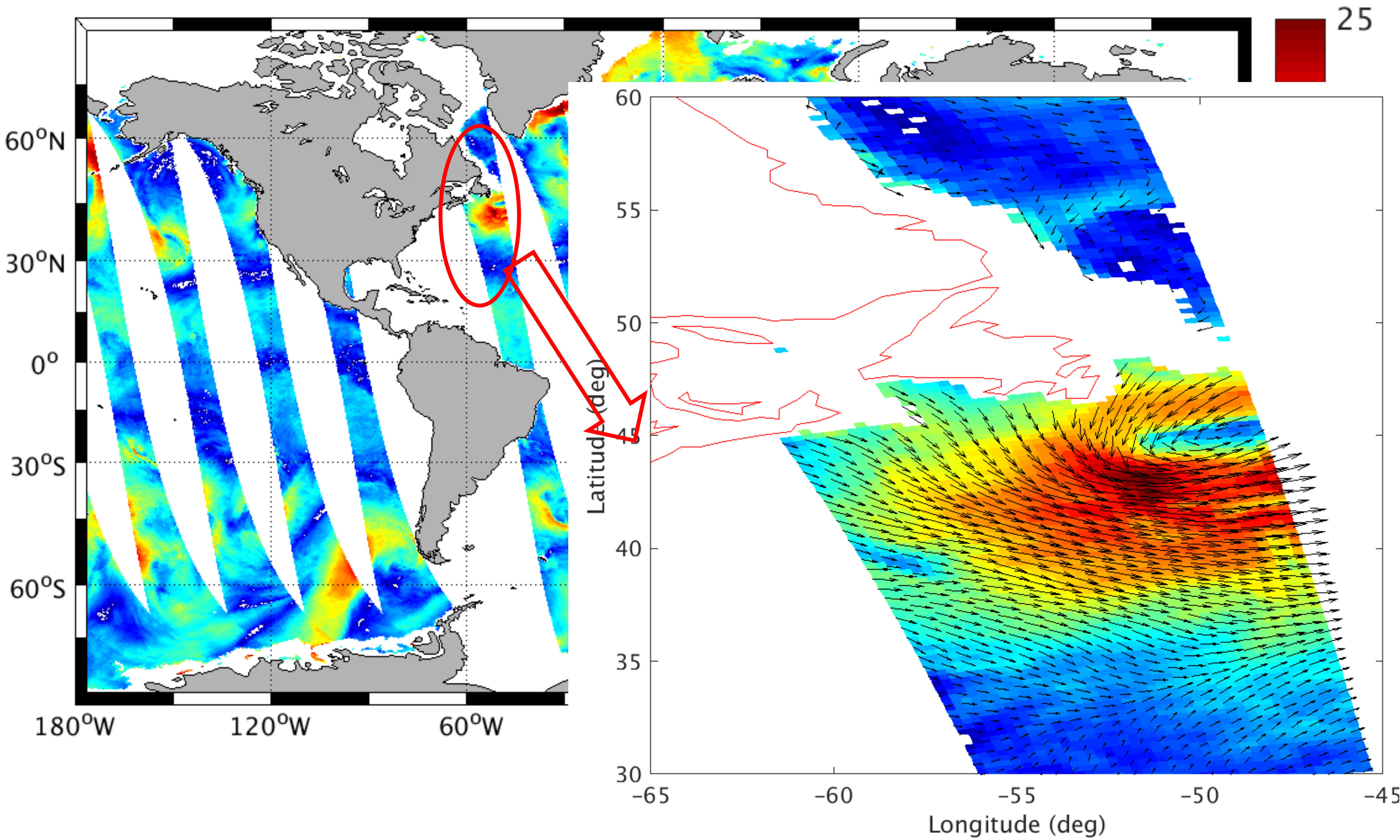
Results and Verifications – Rain Impact

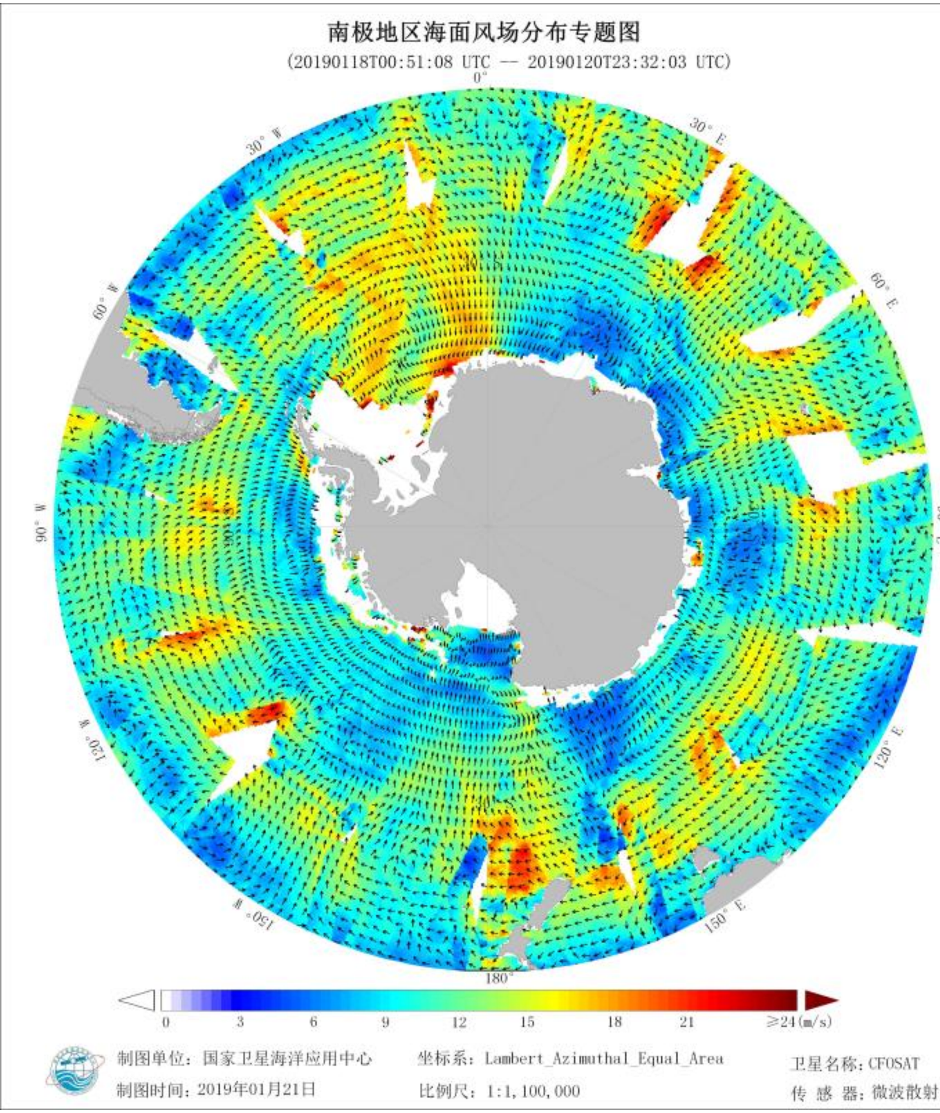


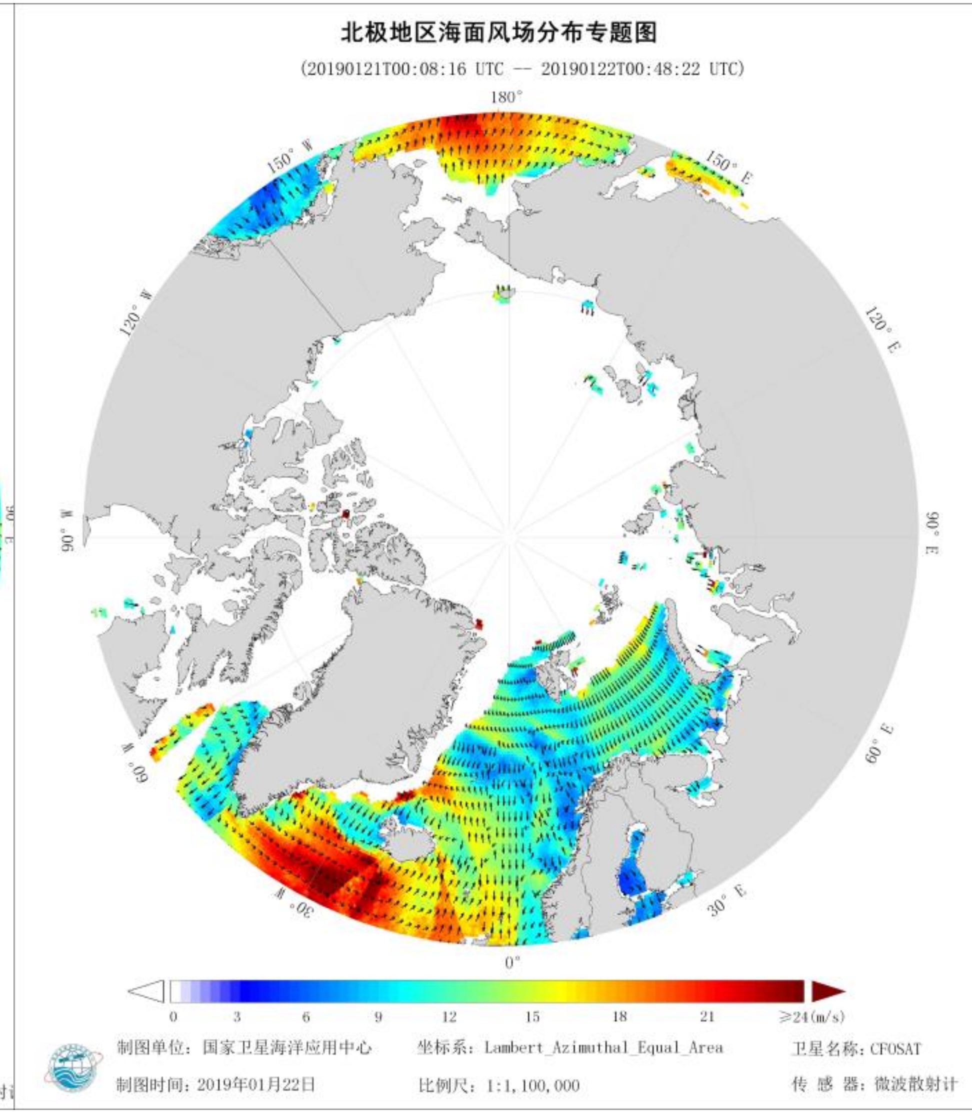


Wind quality degrades as the rain rate increases

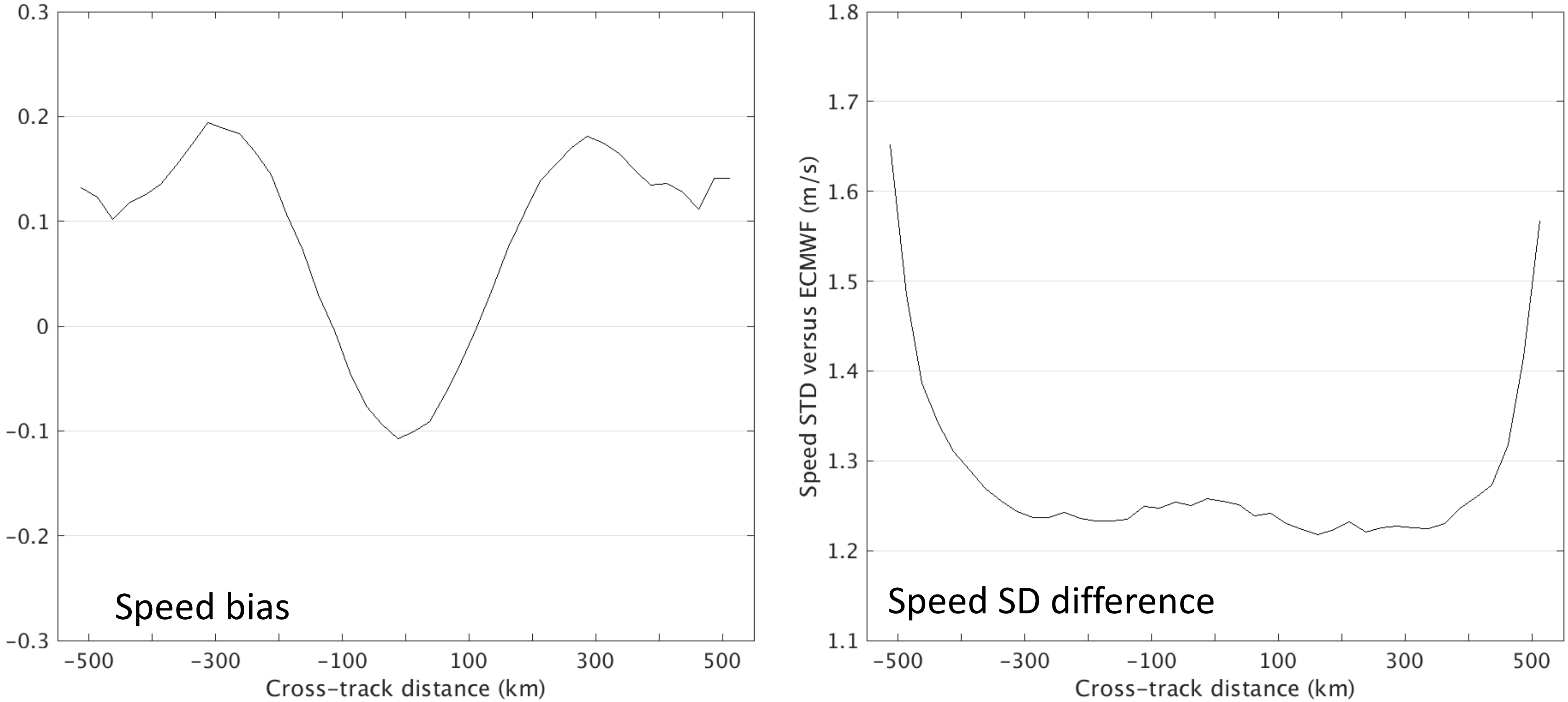
CSCAT wind speed in one day




南极地区海面风场分布专题图
(20190118T00:51:08 UTC -- 20190120T23:32:03 UTC)
0°
30° E
60° E
90° E
120° E
150° E
180°
150° W
120° W
90° W
60° W
30° W
0
3
6
9
12
15
18
21
≥24(m/s)
制图单位：国家卫星海洋应用中心
制图时间：2019年01月21日
坐标系：Lambert_Azimuthal_Equal_Area
比例尺：1:1,100,000
卫星名称：CFOSAT
传 感 器：微波散射计

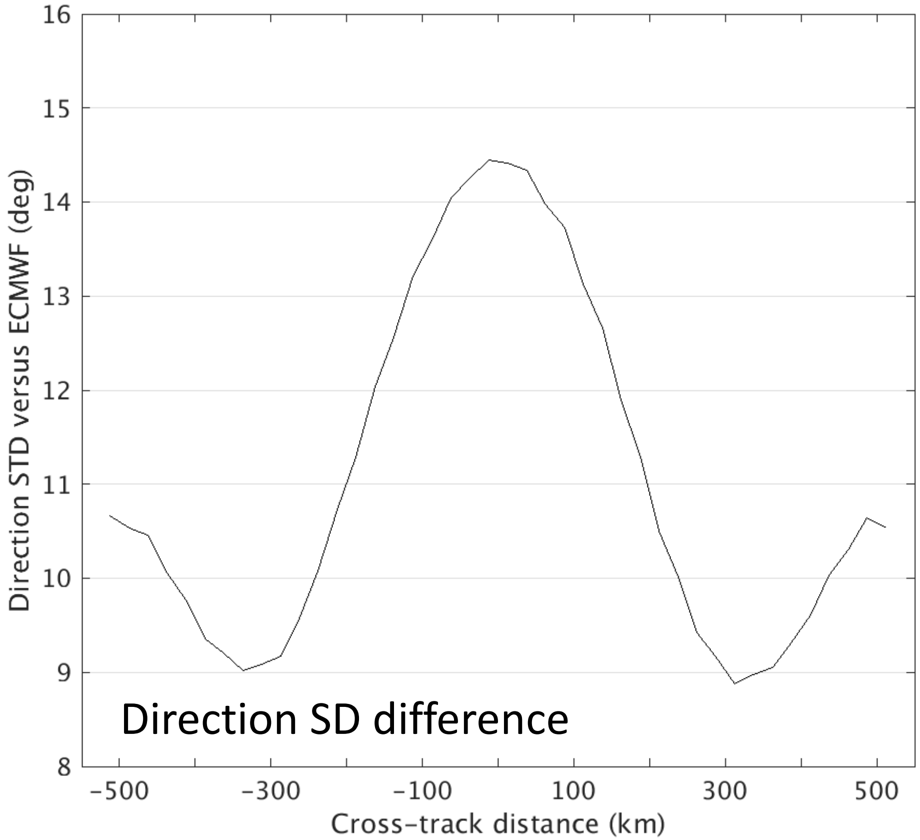

北极地区海面风场分布专题图
(20190121T00:08:16 UTC -- 20190122T00:48:22 UTC)
180°
150° E
120° E
90° E
60° E
30° E
0°
30° W
60° W
90° W
120° W
150° W
0
3
6
9
12
15
18
21
≥24(m/s)
制图单位：国家卫星海洋应用中心
制图时间：2019年01月22日
坐标系：Lambert_Azimuthal_Equal_Area
比例尺：1:1,100,000
卫星名称：CFOSAT
传 感 器：微波散射计

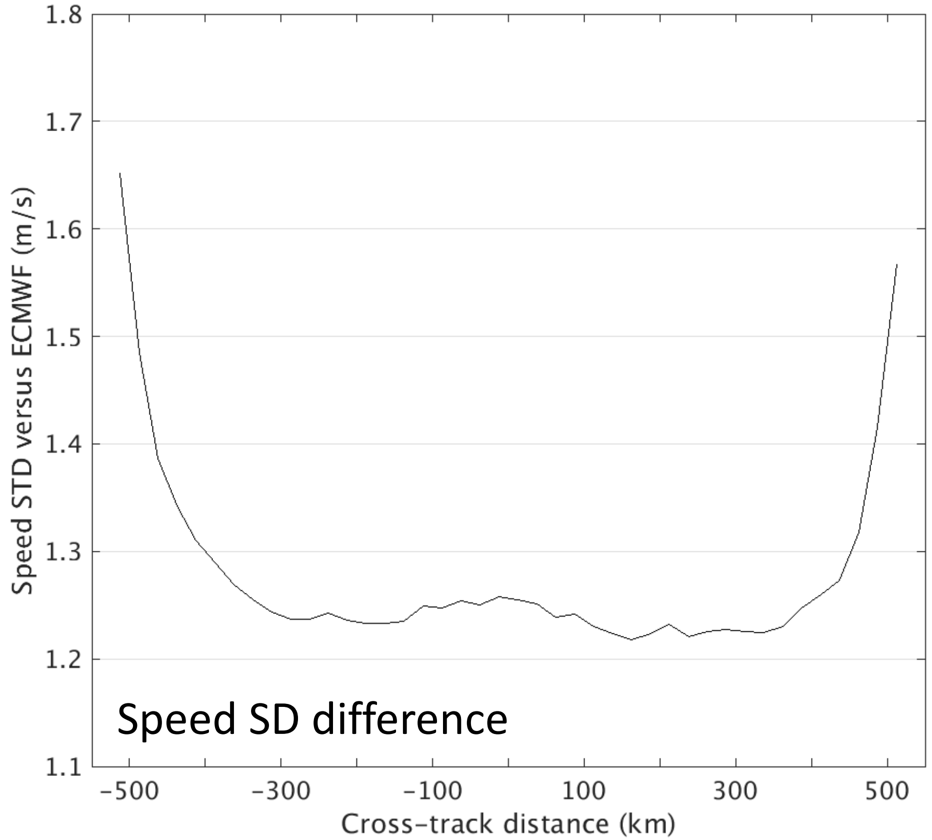
Results and Verifications -- ECMWF



Statistical scores versus ECMWF winds

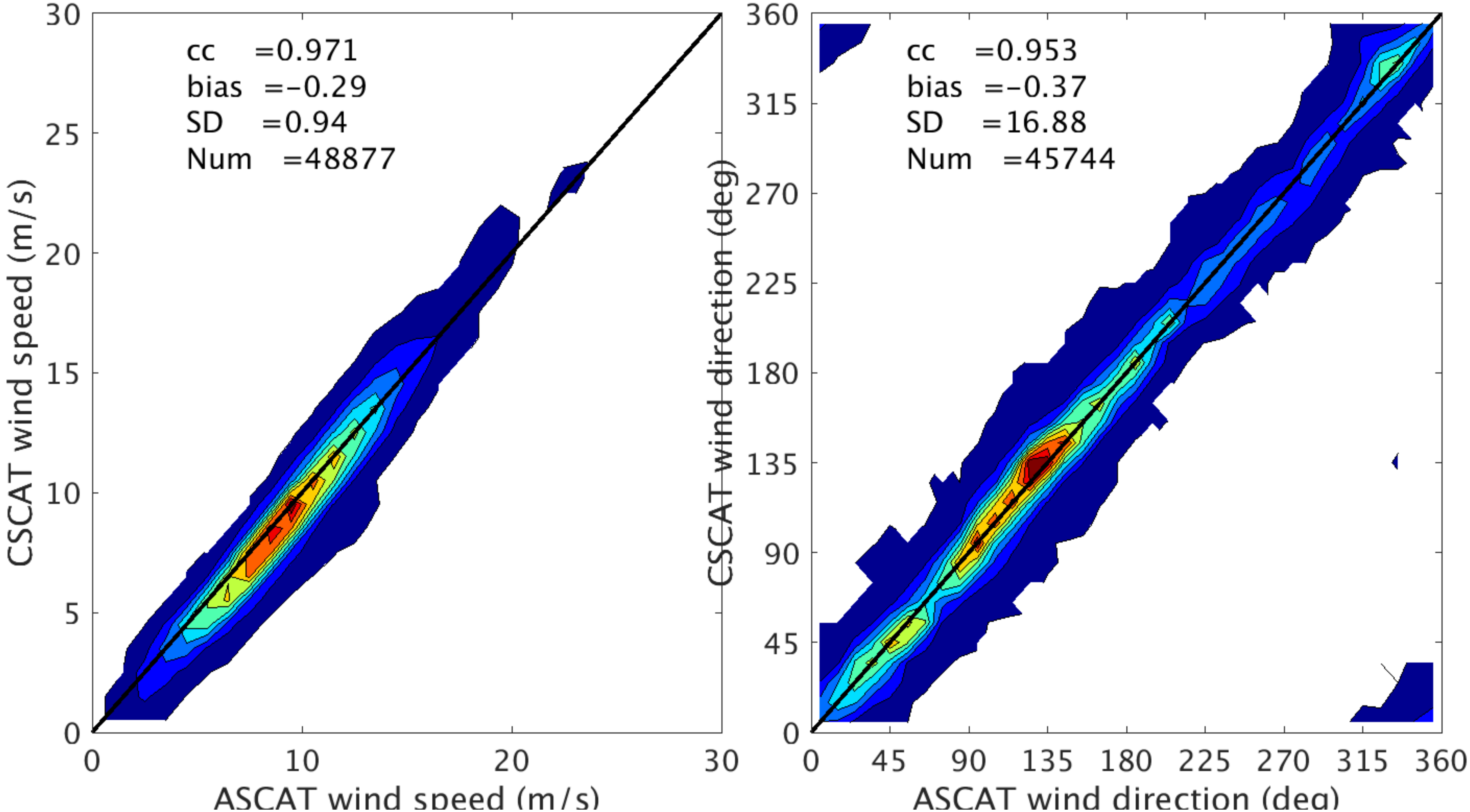
Results and Verifications -- ECMWF

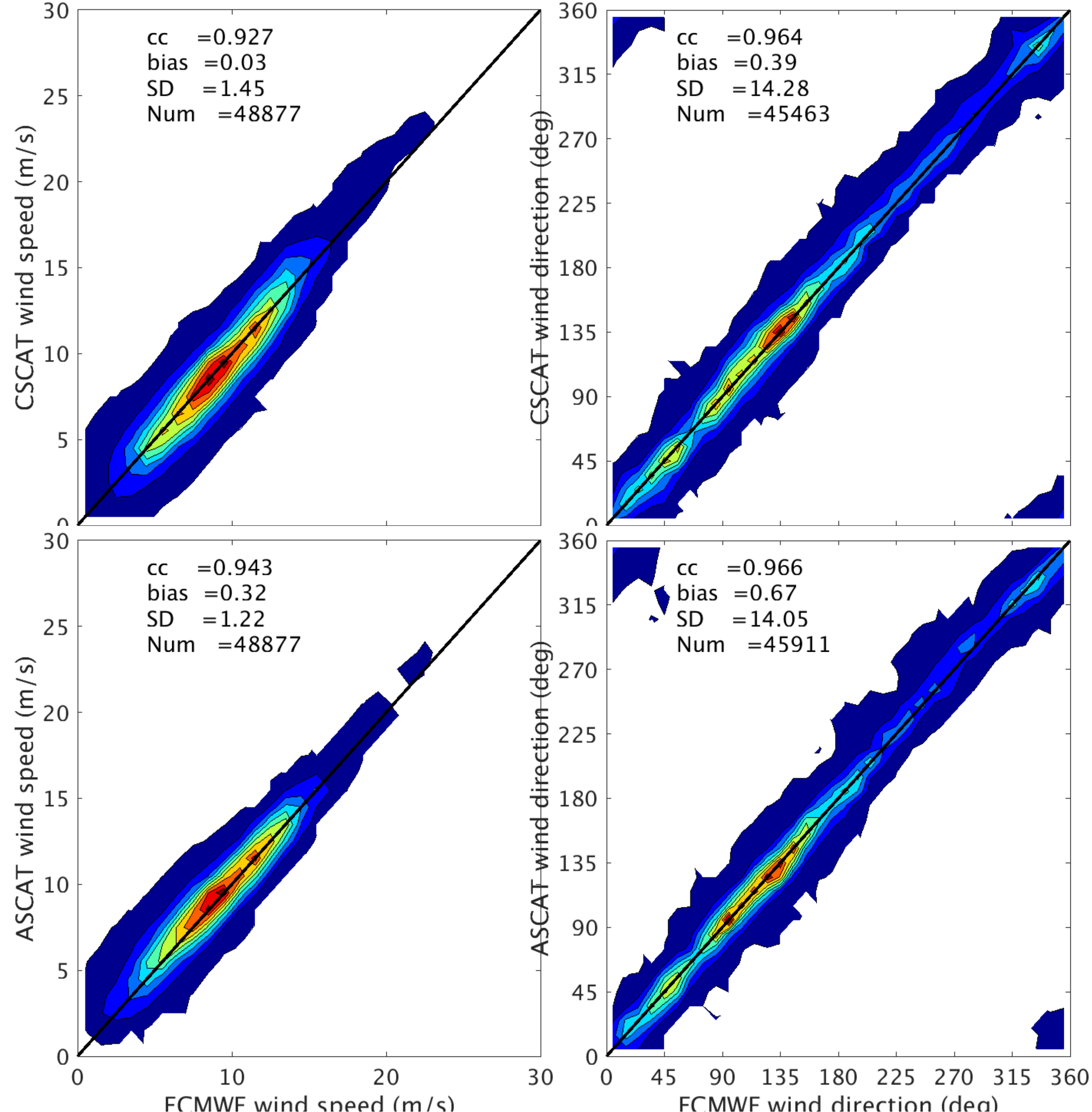




Statistical scores versus ECMWF winds

Results and Verifications -- ASCAT

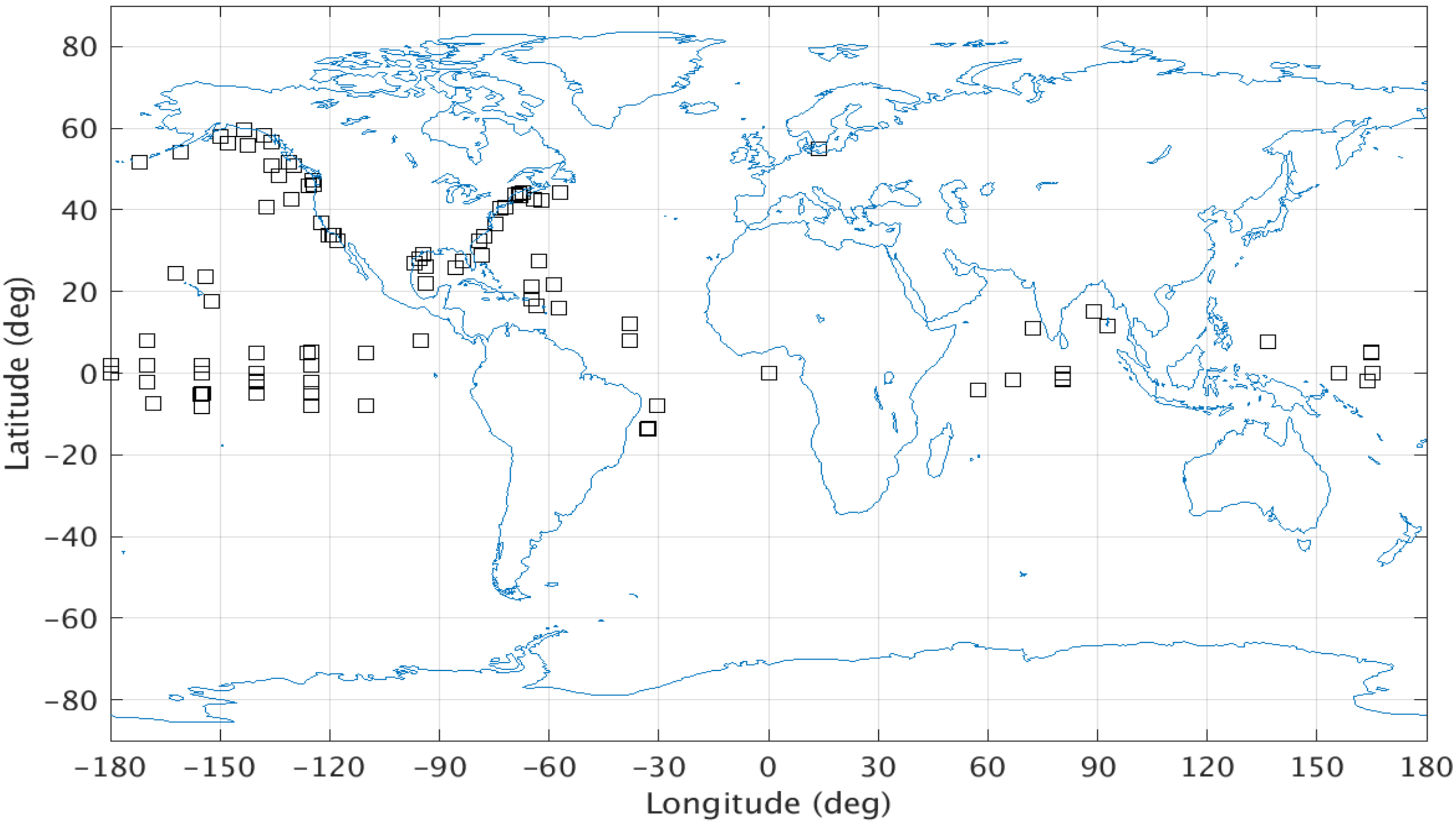




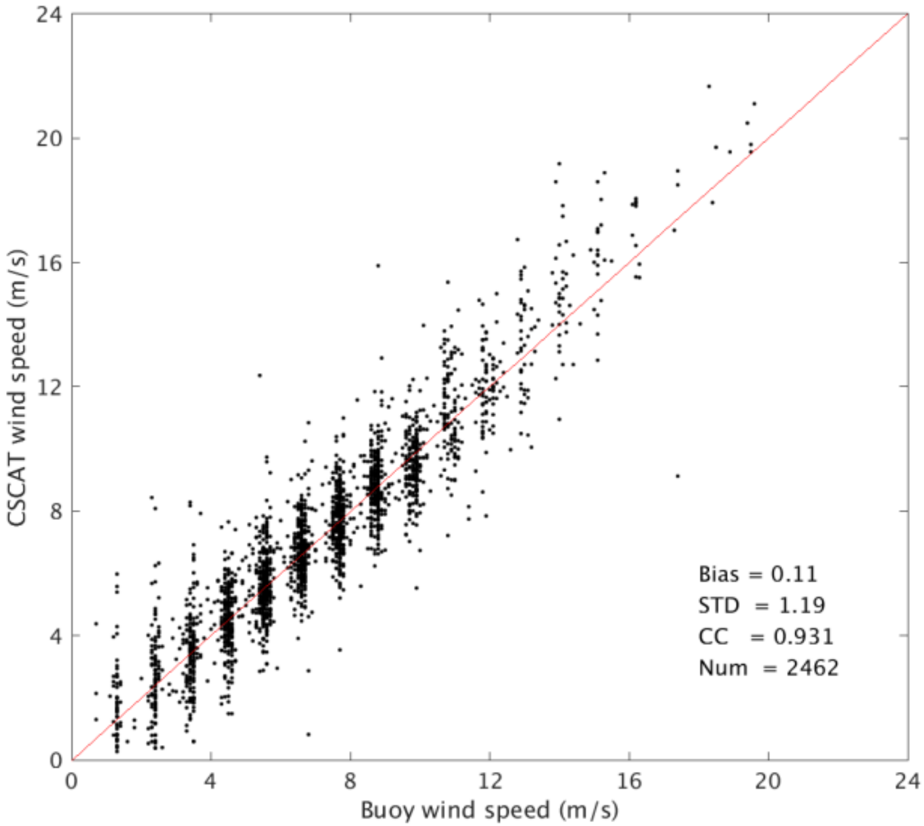
CSCAT versus ECMWF

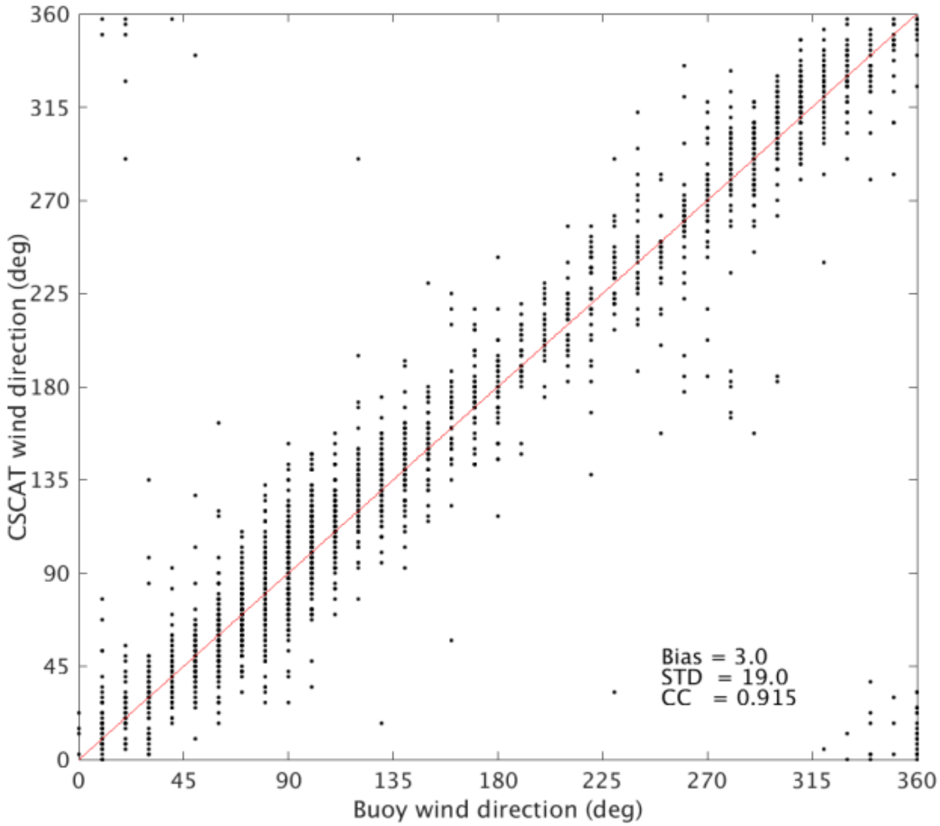
ASCAT versus ECMWF

Results and Verifications – Buoys



Results and Verifications – Buoys





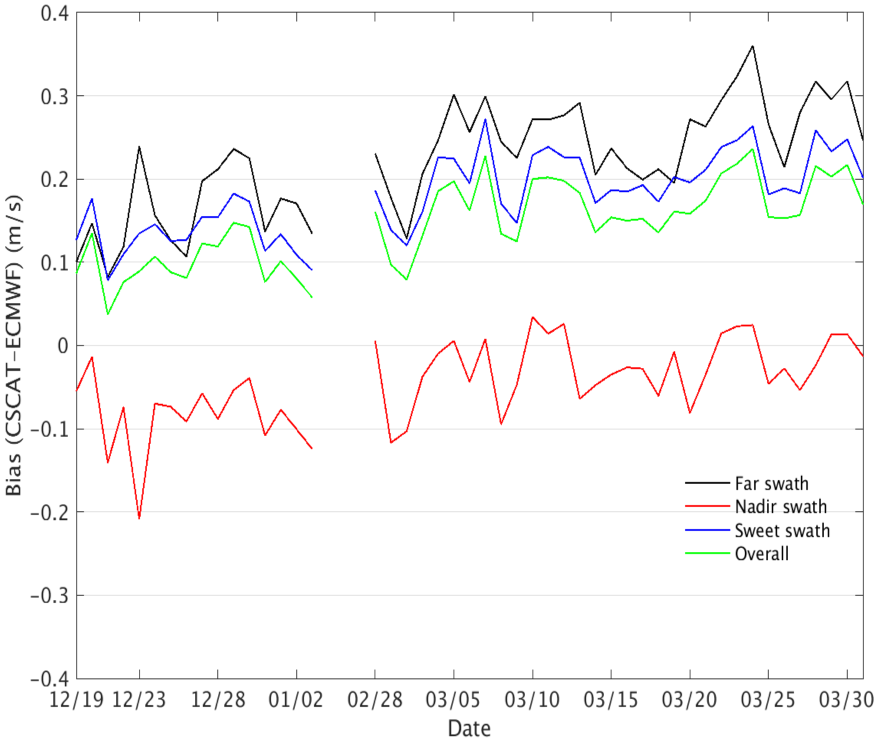
CFOSCAT versus Moored buoy wind vectors

- ✓ Spatial distance < 25 km;
- ✓ Time difference < 30 minutes

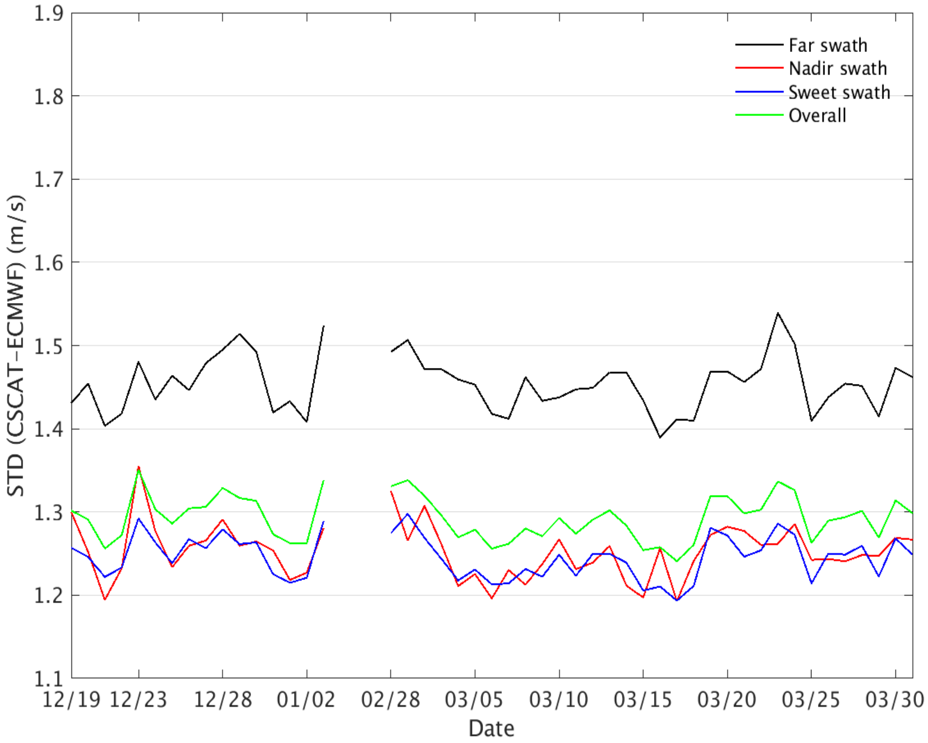
Triple collocation analysis

Sources	Buoy		CSCAT		ECMWF	
	u	v	u	v	u	v
Errors （m/s）	1.46	1.55	0.97	0.78	1.07	1.12

$$\begin{cases} \langle\delta_1\rangle^2 + \langle\delta_2\rangle^2 = \langle(w_1 - w_2)^2\rangle \\ \langle\delta_1\rangle^2 + \langle\delta_3\rangle^2 = \langle(w_1 - w_3)^2\rangle \\ \langle\delta_2\rangle^2 + \langle\delta_3\rangle^2 = \langle(w_2 - w_3)^2\rangle \end{cases}$$

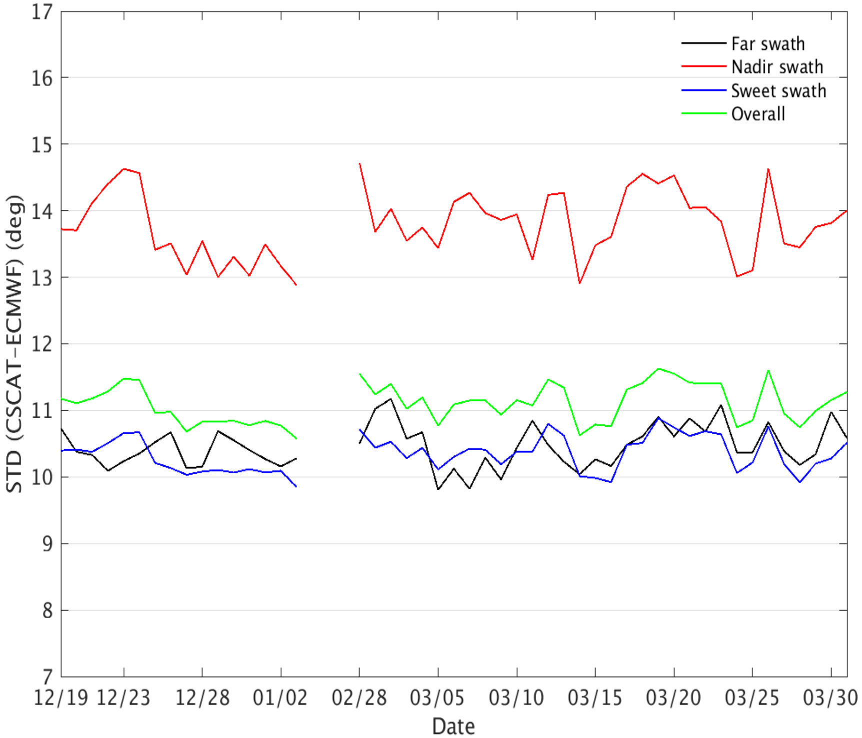


Wind speed bias

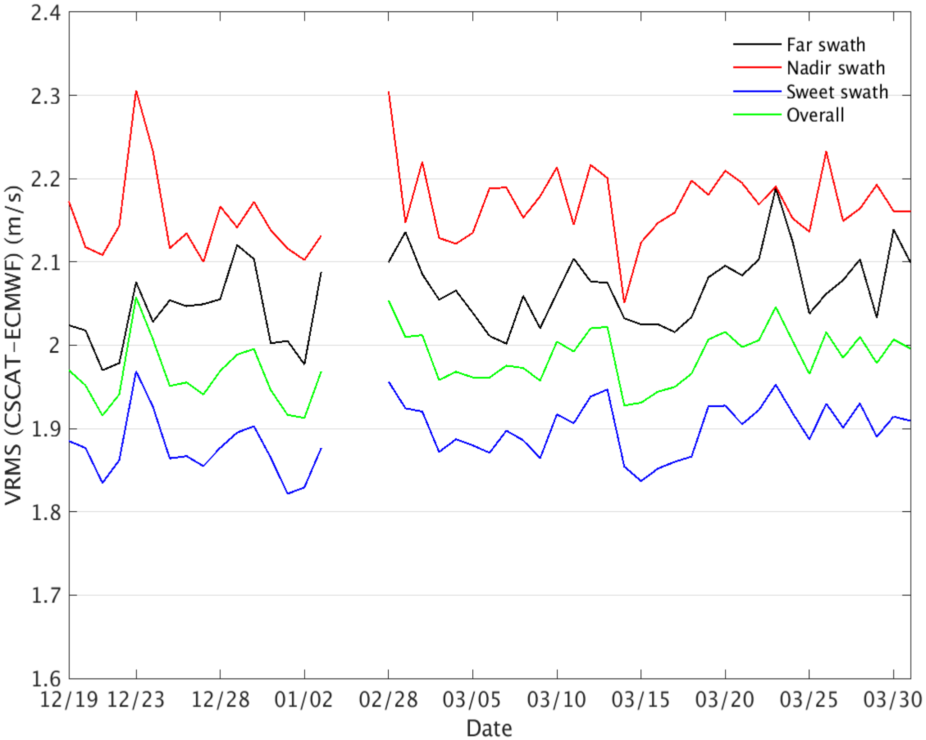


Wind speed SD

Daily monitoring



Wind direction SD



VRMS

Daily monitoring

SUMMARY

- In orbit testing results show that SCAT works properly and has a good performance in wind retrieval;
- The geometric locating accuracy is better 10km, improving the geometric locating performance will be continued;
- External calibration is applied to Sigma0, the sigma0 accuracy is about 0.5dB(on 25km*25km grid)
- The consistency and accuracy of Sigma0 are verified; Improving the Sigma0 performance and calibration processing will be done continuously;
- Calibration needs to be improved over nadir and far swath;
- Rain is the key factor in degrading CFOSCAT wind quality, particularly for the medium-low wind conditions.