Report from National Space Science Center, CAS

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Outline

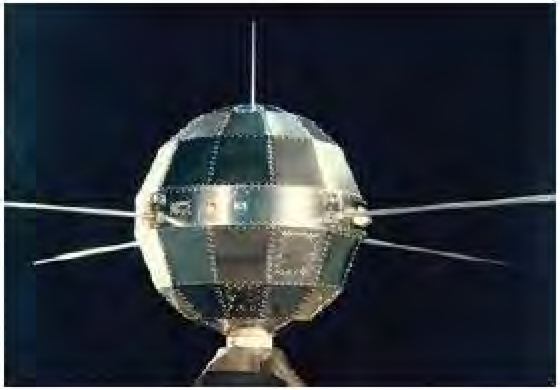
- **Introduction to NSSC and MiRS**
- **EO satellite missions contributed**
- **CAL/VAL activities in NSSC**

NSSC (National Space Science Center, CAS), Since 1958

Oct. 1958, set up by CAS, dedicated to the development of the first Chinese artificial satellite

8.26 in

The first Chinese artificial satellite DFH-1 was launched on April 24, 1970



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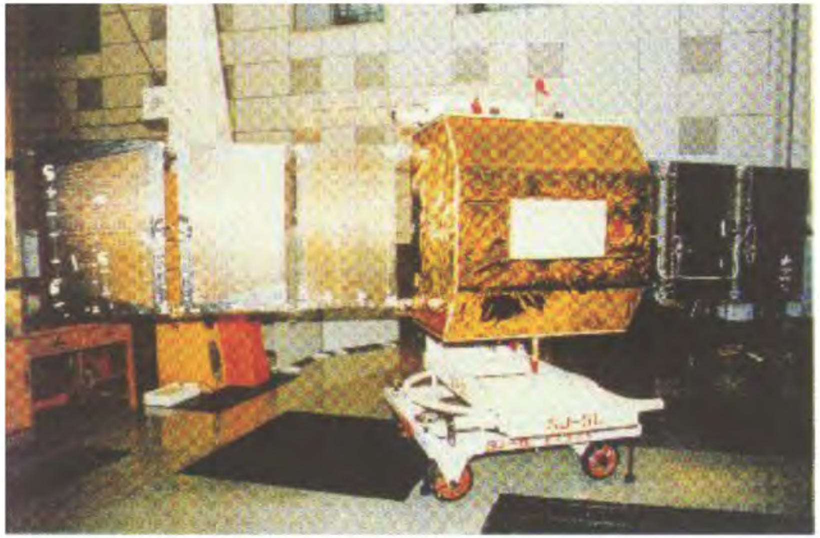
1980-90s, SJ series satellites, pioneered the space environment exploration in China



1990-2000, major player of China's manned space flight program

In 2011, CSSAR→NSSC

Center for Space Science and Applied research
== > National Space Science Center

- **Institute in CAS for planning, selection, management, development, launching and operations of China's space science satellite missions;**
- **Taking leading role in China in space physics, space environment, microwave remote sensing.**
- **Also the Space Science Remote Sensing Department of NRSCC.**

NSSC

- **Institute in CAS for planning, selection, management, development, launching and operations of China's space science satellite missions;**
- **Taking leading role in China in space physics, space environment, microwave remote sensing.**

Main research directions of NSSC

- ✧ **Fundamental research in**
  - ➢ **space plasma physics,**
  - ➢ **space weather study and forecasting,**
  - ➢ **space-borne and ground-based space environment monitoring and detection,**
  - ➢ **special effects of the space environment,**
  - ➢ **and the related study of experimental technology.**
- ✧ **integrated electronics on complex spacecraft system and the related information technology,**
- ✧ **space mission simulation,**
- ✧ **microwave remote sensing and information technology.**

Major Projects

- Strategic Pioneer Program on Space Science
- Double Star Program
- Meridian Project
- Manned Space Flight and Lunar Exploration Program
- Applied and Operational Satellites (FY, HY)

key labs and affiliated organizations

- State Key Laboratory of Space Weather
- CAS Key Laboratory of Microwave Remote Sensing (MiRS)
- CAS Key Laboratory of Complex Space Electronic Systems
- Hainan National Field Observation Station of Space Weather
- CAS Center for Space Environment Research and Forecast
- Chinese Society on Space Research (CSSR)
- Chinese National committee for Committee on Space Research (COSPAR)

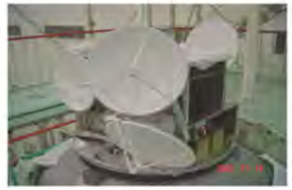
MiRS, CAS

- Founded in 1958, as electronics group participated in the development of China's 1st satellite (DFH-1) in early 1970s.
- NMRS developed the telemetry receiver for DFH-1.
- From 1973, focuses turned to microwave remote sensing technology.

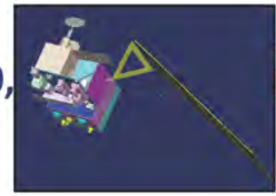
- Research and development priorities:
  - Theory and techniques of microwave sounding and imaging;
  - Development of microwave remote sensing payloads
    - microwave radiometer,
    - radar altimeter,
    - radar scatterometer
  - Calibration, and information techniques for microwave remote sensing.

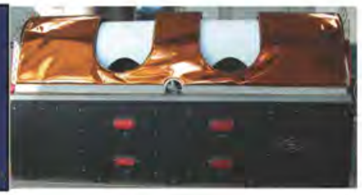
EO Satellite Missions NSSC and MiRS Contributed

- **Multi-Mode Microwave Remote Sensors (M3RS) on SZ-4 Unmanned Spaceship (2002.12-2003.4)**
  - **Ku-band scatterometer, altimeter**
  - **Multi-band microwave radiometer (C~Ka)**

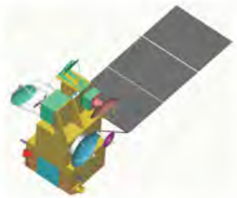


- **FY-3 Polar Orbit Meteorological Satellite**
  - **Microwave Humidity Sounder (FY-3A 2008, FY-3B 2010): 150, 183GHz (5 channels)**
  - **Microwave Humidity Sounder-II (FY-3C 2013): 89, 118, 150, 183GHz (15 Channels)**

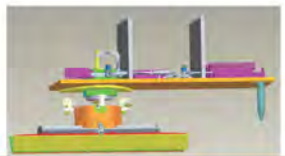




- **HY-2 Ocean Dynamic Environment Missions (A, 2011)**
  - **Radar altimeter (Ku, C)**
  - **Atmospheric Correction Microwave Radiometer**
  - **Radar Scatterometer (Ku, Rotation pencil beam, participated)**



- **CFOSAT (Chinese-French Oceanography Satellite, 2015)**
  - **Radar scatterometer (Ku, rotation fan-beam)**



CAL/VAL activities in NSSC

- **Calibration of radar altimeter with transponders**
- **Calibration of radar scatterometer with global oceans**
- **Calibration techniques for rotation fan-beam scatterometer**
- **Calibration of full-polarized microwave radiometer**
- **Calbration of spaceborne radiometers without rotation mechanism (SARad and Nadir looking radiometer)**

Calibration of radar altimeter with transponders (W Guo and C Y Wang)

- **Calibration of HY-2A radar scatterometer with transponders**
- **Estimation and correction of system offset**

Active radar calibrator

- SUV-carried
- Mobility
- Automated

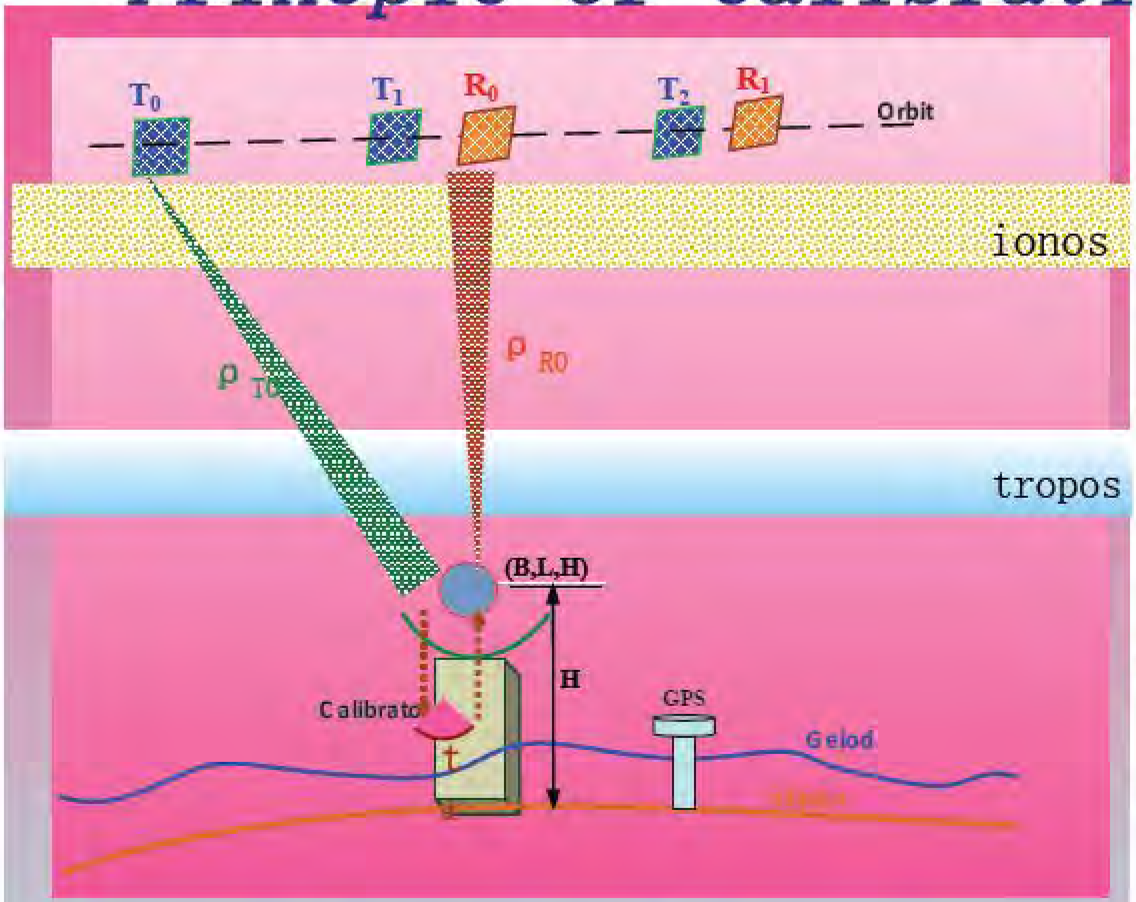
Accessories: ***D-GPS for precise locationing***

Lifting-jack

GPS **base receiver**

GPS mobile **receiver**

Princple of calibration by ARC



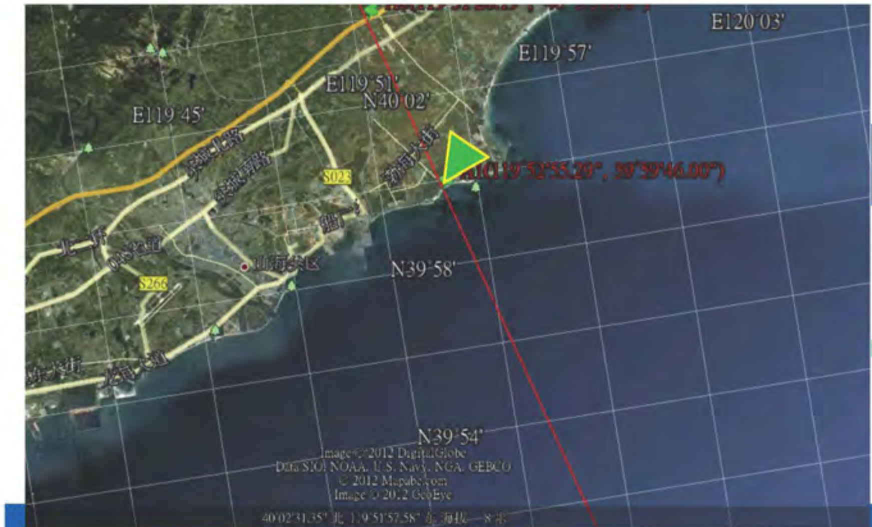
Troposphere	h_{tropos}
Ionosphere	h_{ionos}
Solid tide	h_{solid}
Pole tide	h_{pole}
clock difference	h_{clk}
ARC delay	h_{ARC}
Altimeter *instrum delay*	***?***

$$InstrumDelay = (R_n - T_n) * C - \rho_{Tn} - \rho_{Rn} - h_{trops} - h_{iono} - h_{tide} - h_{clk} - h_{ARC}$$

Calibration sites

Beijing

E: 116. 4392°
N: 39. 8151°

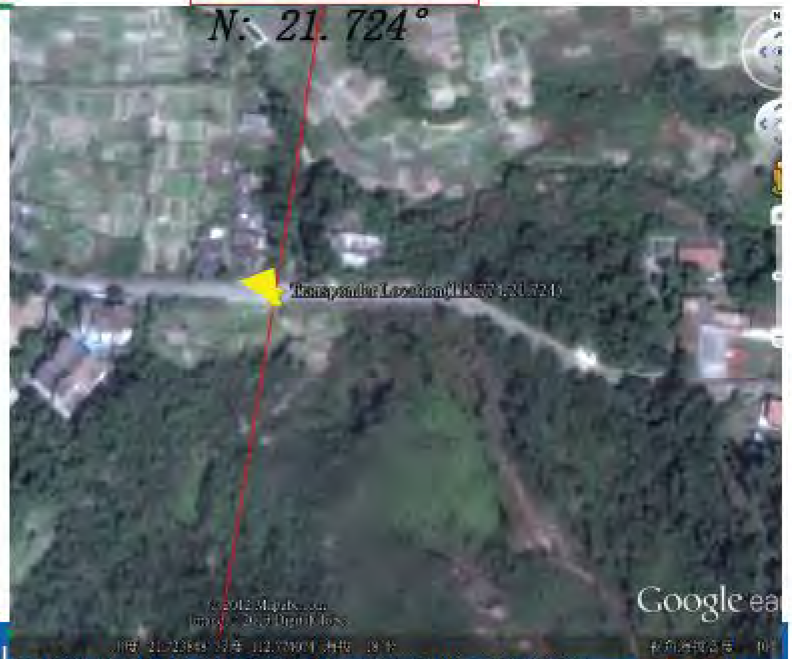


Suizhong

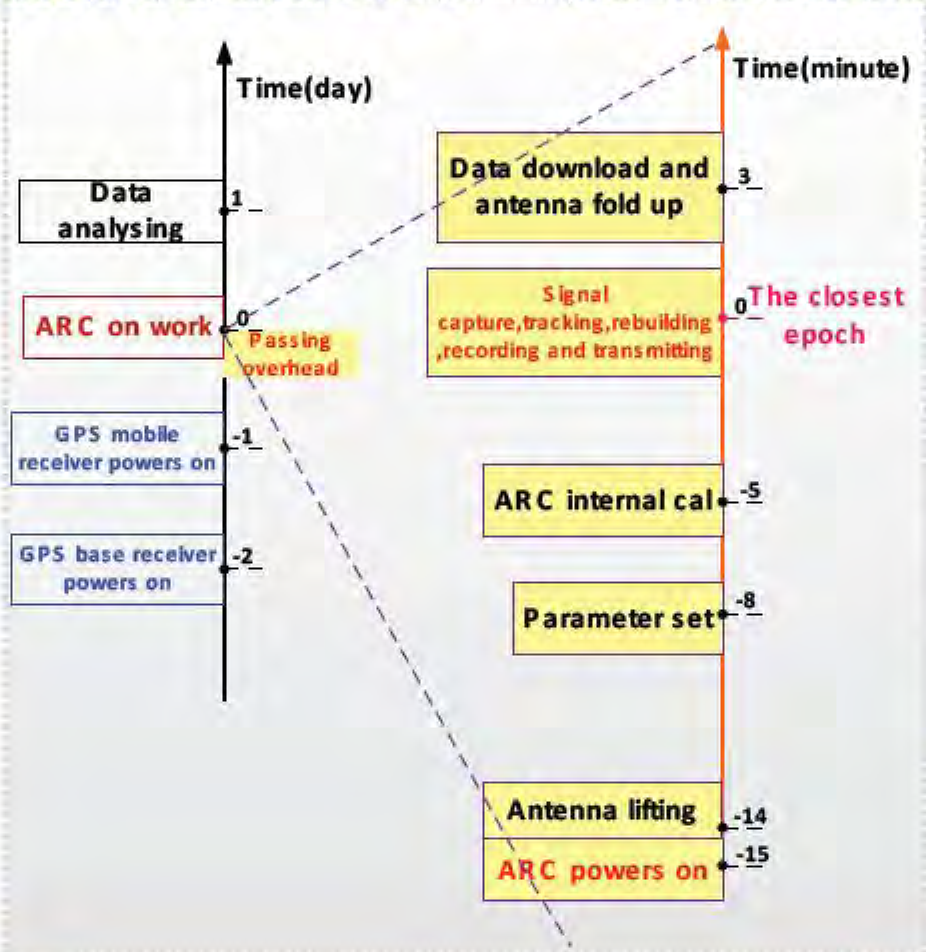
E: 119. 8798°
N: 40. 0007°

ShangChuan Island,
Guangdong Province, ***China***

Calibration sites



Experiment procedure



Before the passing day:

- ✓Charge the batteries and UPS;
- ✓Predict the orbit height at the closest aproach time;
- ✓Power on GPS receiver ;

On the passing day:

- ✓Lift the jeep and antenna;
- ✓Power on ARC and set parameters;
- ✓Record the demodulated I/Q data.

After the passing day:

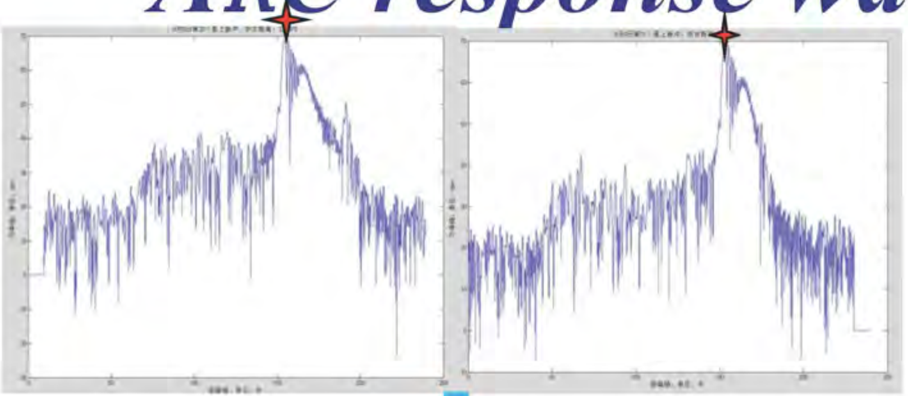
- ✓Data analysing......

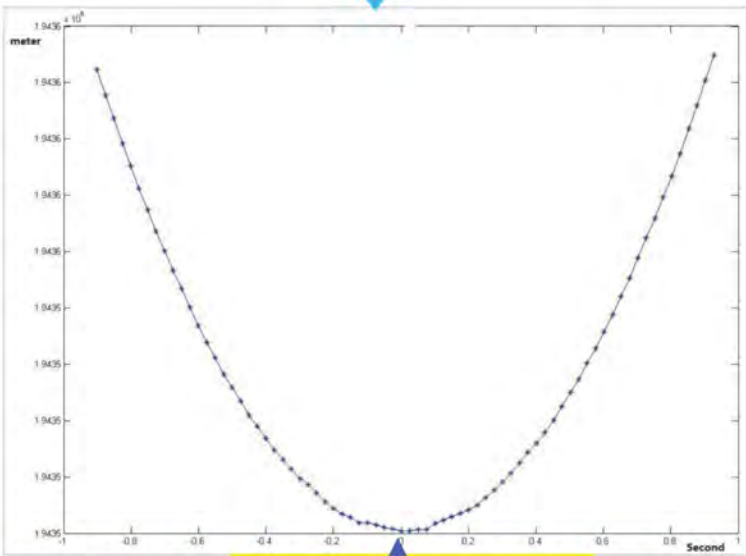
Calibration data available

date	Site	Status
2012-08-09	SuiZhong	OK
2012-08-19	BeiJing	OK
2012-09-02	BeiJing	OK
2012-09-06	SuiZhong	OK
2012-11-01	SuiZhong	OK
2012-11-15	SuiZhong	OK
2013-01-20	BeiJing	OK
2013-03-03	BeiJing	OK
2013-03-17	BeiJing	OK
2013-03-31	Beijing	OK

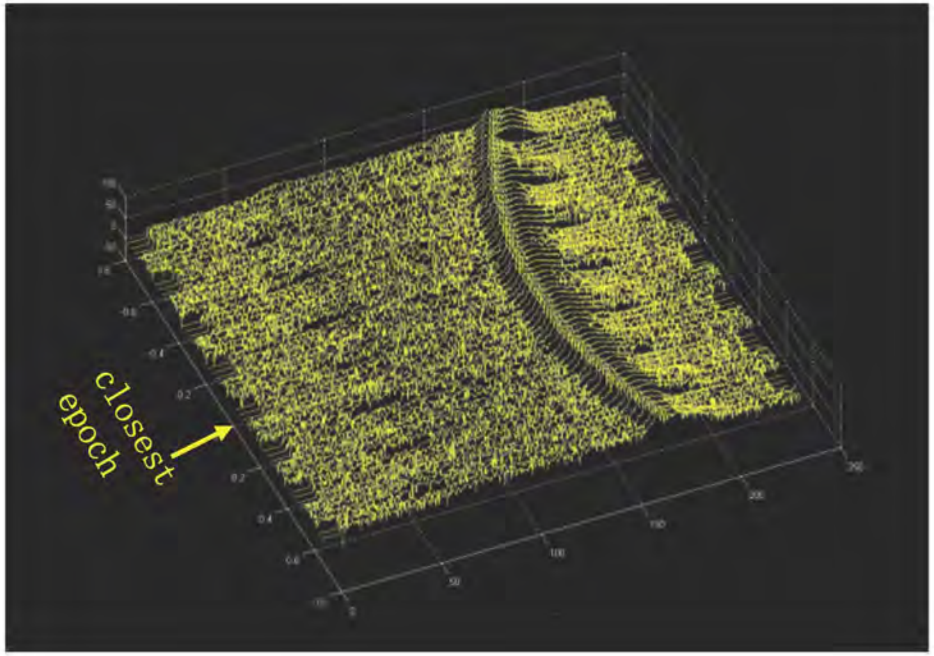
- *HY-2 altimeter transmits bursts at constant interval*
- ***Unprocessed I/Q data, not averaged 20Hz power spectrum***
- ***The ephemeris data and orbit data** are obtained **from DORIS***
- *The geophysical data are obtained **from** GPS **& IGS***

ARC response waveform

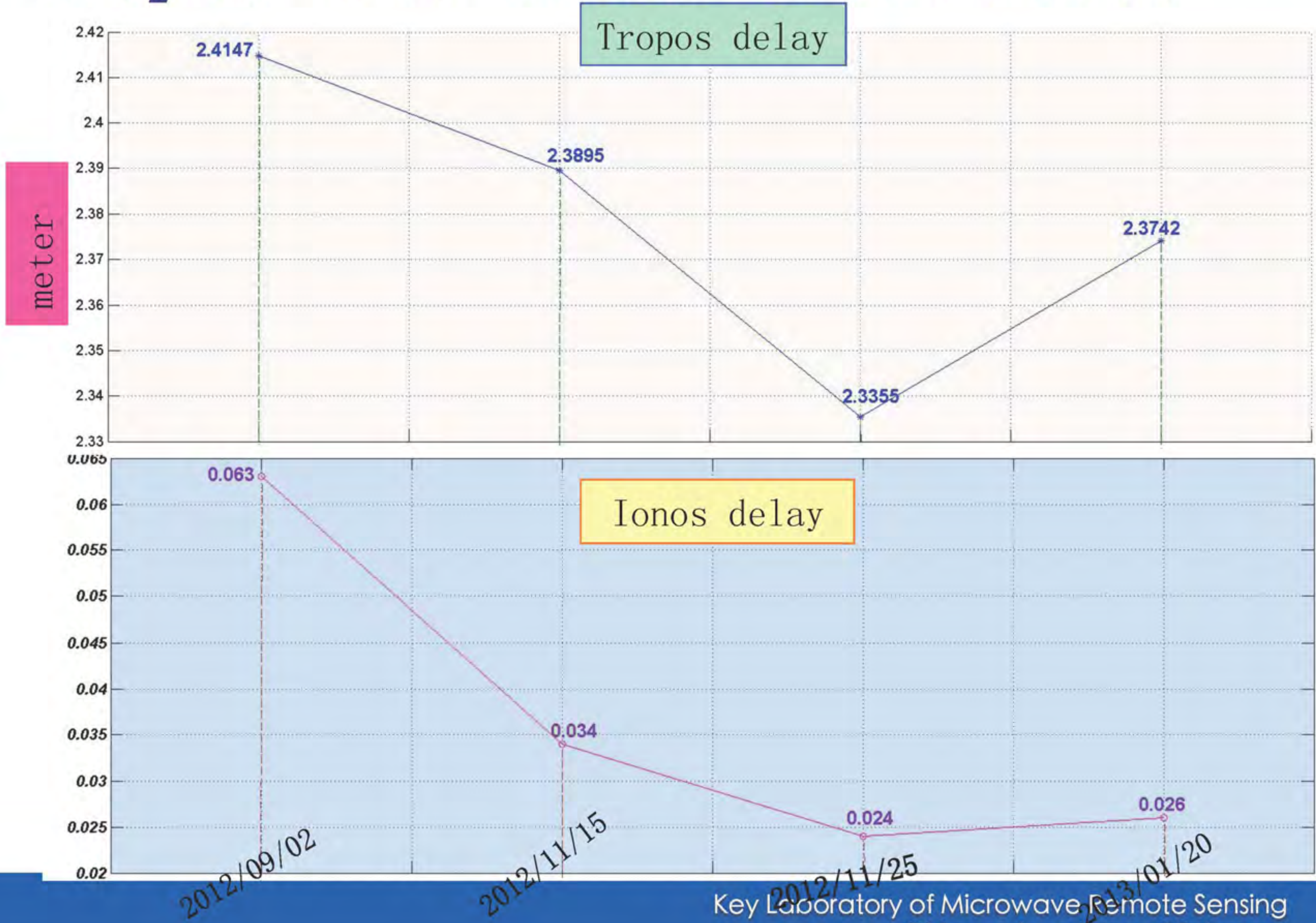




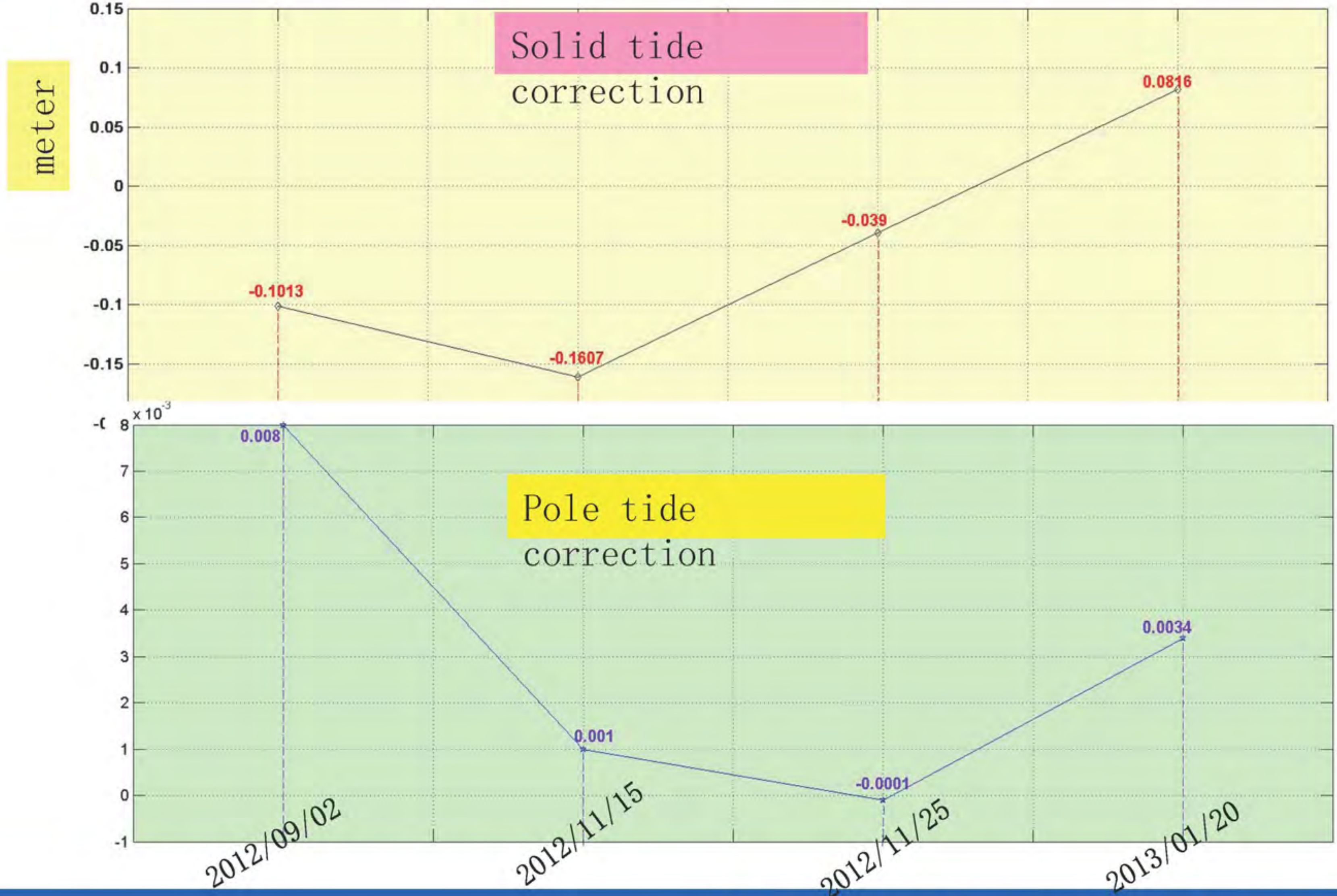
closest epoch



Tropos and ionos correction



Geophysical correction



Doppler correction

$$f = -\frac{v}{\lambda}$$

$$f_d = -\frac{\Delta d}{T\lambda_c}$$

$$d_f = f_d \frac{W_t}{W_f} C$$

$\Delta d : R_n - R_{n-1}$

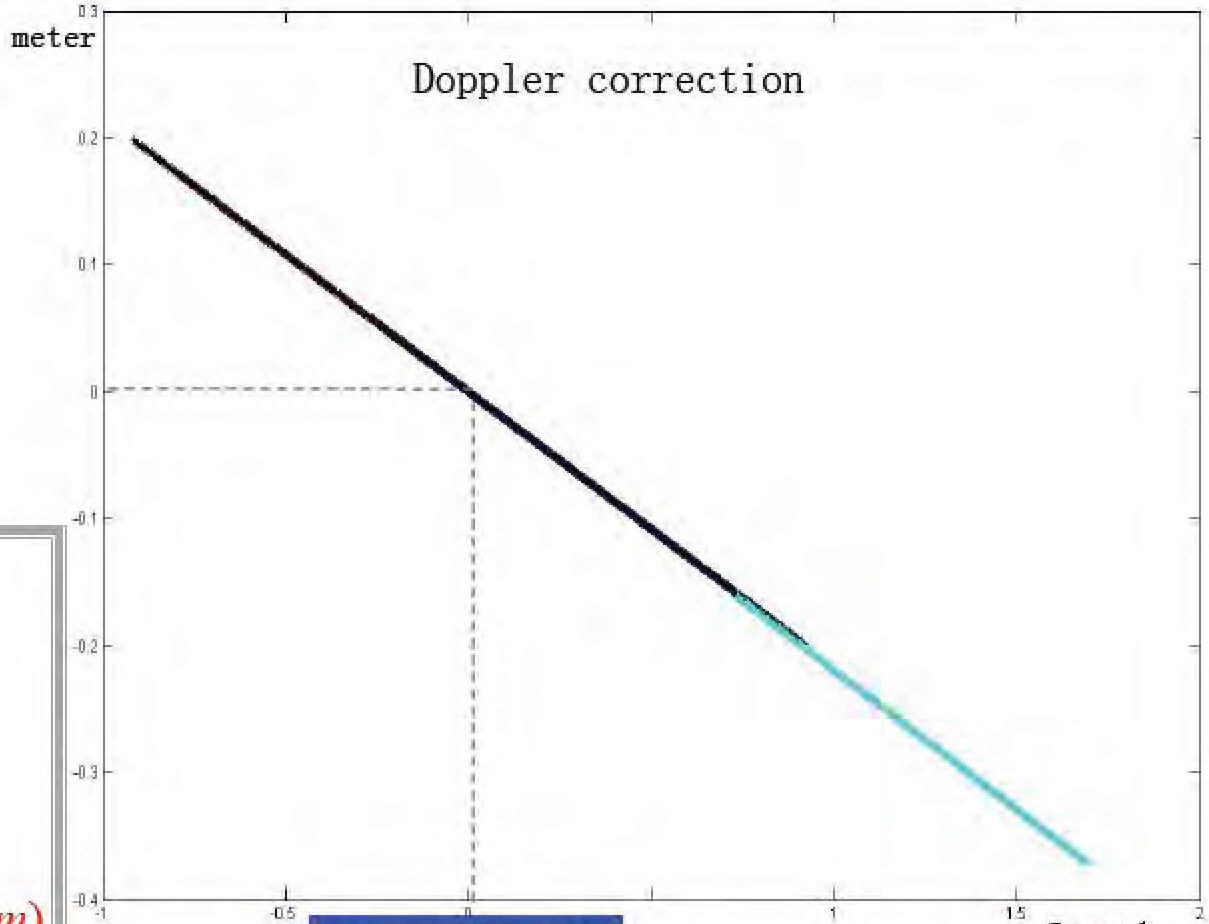
$T : Period$

$\lambda_c : Wavelength$

$W_t : PulseWidth$

$W_f : Bandwidth$

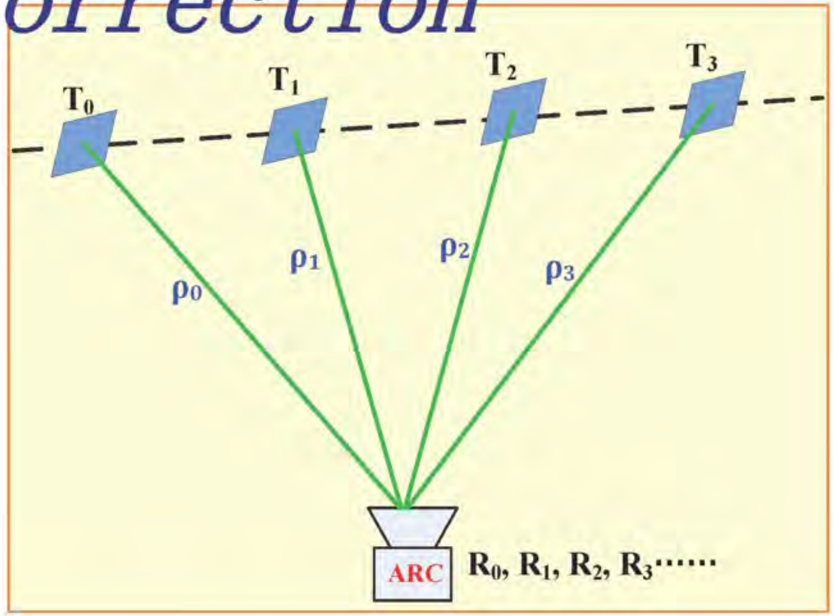
$d_f : DopplerCorrection(m)$



Closest epoch

Clock drift correction

$$\begin{cases} R_0 = T_0 + \rho_0/c + \Delta t & (1) \\ R_1 = T_1 + \rho_1/c + \Delta t & (2) \\ R_2 = T_2 + \rho_2/c + \Delta t & (3) \\ R_3 = T_3 + \rho_3/c + \Delta t & (4) \end{cases}$$



(2)-(1), (3)-(2), (4)-(3)……

$$\begin{cases} \Delta R_0 = (T_1 - T_0) + \frac{\rho_1 - \rho_0}{c} \\ \Delta R_1 = (T_2 - T_1) + \frac{\rho_2 - \rho_1}{c} \\ \Delta R_2 = (T_3 - T_2) + \frac{\rho_3 - \rho_2}{c} \end{cases}$$

$T_n - T_{n-1}$ = constant

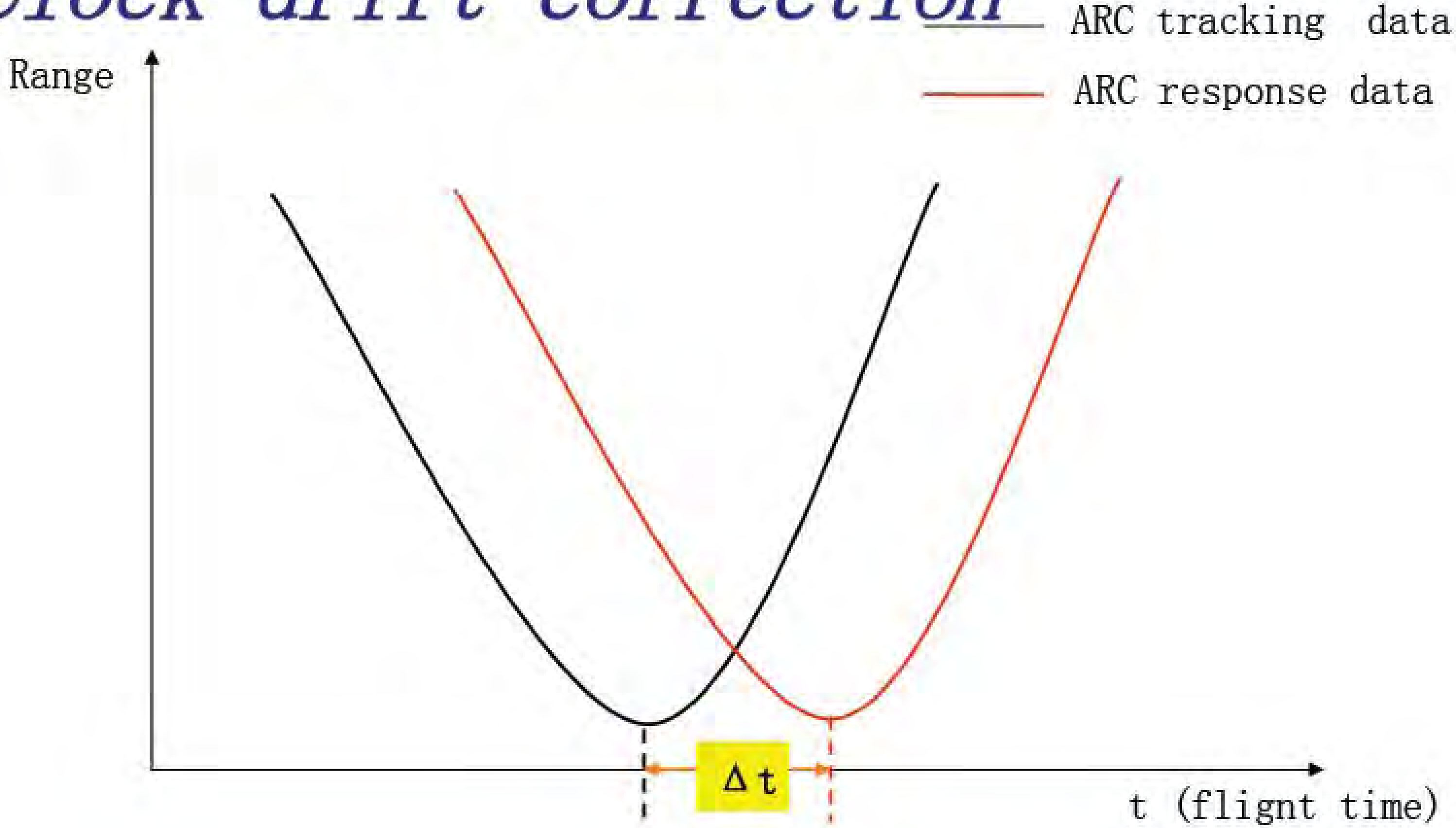
$$\begin{cases} \Delta R_0' = \frac{\rho_1 - \rho_0}{c} \\ \Delta R_1' = \frac{\rho_2 - \rho_1}{c} \\ \Delta R_2' = \frac{\rho_3 - \rho_2}{c} \end{cases}$$

$\sum \Delta R_n'$

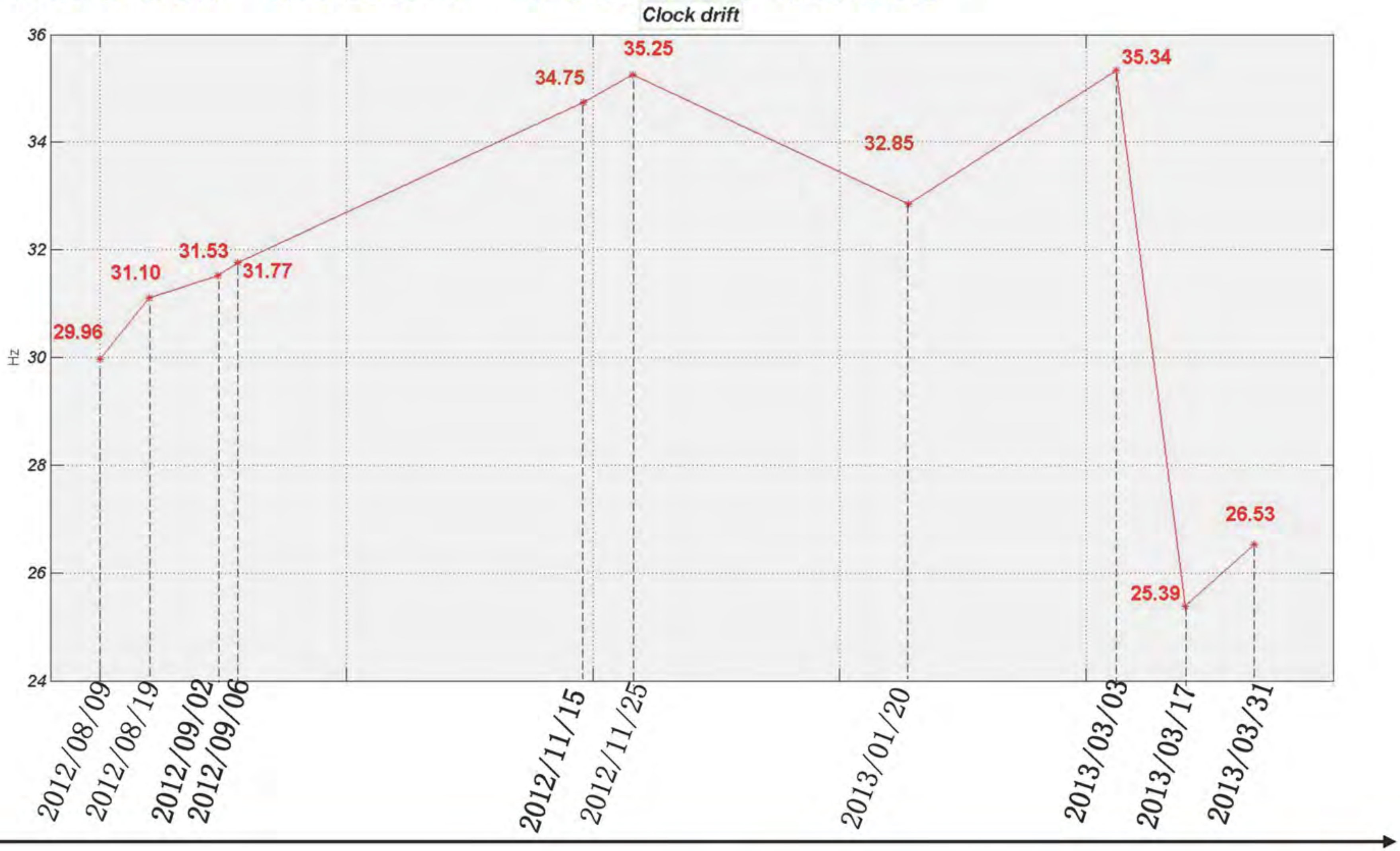
$$\begin{cases} s_0 = \Delta R_0' + \Delta R_1' \\ s_1 = \Delta R_1' + \Delta R_2' \\ s_2 = \Delta R_2' + \Delta R_3' \end{cases}$$

$T_n - T_{n-1}$ = thoeretical transmit interval ?

Clock drift correction



Clock drift correction



Summary

Unit: meter

Item\data	2012/09/02	2012/11/15	2012/11/25	2013/01/20	2013/03/03	2013/03/17
ARC hardware	21.78	21.78	21.78	21.78	21.78	21.78
Clock diff	0.7401	0.8163	0.8277	0.7986	0.8301	0.8295
Tropos	2.4147	2.3895	2.3355	2.3994	2.3399	2.3496
Ionos	0.063	0.034	0.024	0.026	0.034	0.065
Solid tide	-0.1013	-0.1607	-0.039	0.0816	0.1163	0.0722
Pole/ocean tide	0.008	0.001	-0.0001	0.0034	0.014	0.013
HY-2 Alitmeter instru corr	5.4515	5.4690	5.4543	5.4620	5.4732	5.4711

Maximum difference: 2.17cm
Standard: 0.91cm

Calibration of Scatterometers with global ocean (R S Yun, X L Dong, and KNMI scatterometry team)

- **Scatterometer absolute calibration**
  - **Transponders**
    - **Earth-based radar pulse stability limitation**
    - **Strong geographical and time limitations; few measurements**
    - **Weather influence**
  - **sea ice/snow**
    - **Geographical and time limitations; sparse measurements**
    - **Melt area backscatter instability**
  - **rain forest**
    - **Geographical and time limitations; sparse measurements**
    - **Small diurnal cycle**
    - **Other geographical features(e.g., rivers, forest reduction)**

Scatterometer absolute calibration

NWP Ocean Calibration(NOC)

- The NOC may be applied over a large portion of the globe and consequently may provide accurate results over a relatively short period.
- Drift of scatterometer backscatter can be inspected by NOC in time.
- NOC has been applied successfully for the European Remote-Sensing Satellite (ERS) and Advanced SCATterometer (ASCAT) C-band fan-beam scatterometer wind products at KNMI.

Ku-band scatterometer NOC

- QuikSCAT/OSCAT/HY-2A is Ku band pen-beam conical scanning scatterometer; CFOSAT/SCAT is Ku band fan-beam rotating scanning scatterometer
- WVCs experience the same set of incidence angle, but different azimuth; ASCAT WVCs have same azimuth and different inc.
- The atmosphere is not transparent at Ku band wavelengths and rain leads in particular to attenuation and volume scattering
- Rain roughens the sea surface at low winds
- KNMI QC flag, which is commonly used in the KNMI scatterometer wind products and shows excellent performance in screening rainy WVCs was used for QuikSCAT/OSCAT scatterometer NOC.

Ku-band NOC method per WVC

-The wind Geophysical Model Function (NSCAT2):

$$\sigma^0(\theta,v,\phi)=B_0(\theta,v)(1+B_1(\theta,v)\cos\phi+B_2(\theta,v)\cos(2\phi))$$

Where, θ is incidence angle, v is wind speed.

ϕ is azimuth wind direction angle w.r.t. radar beam,

- In **Fourier analysis** and for fixed θ (scanning beam):

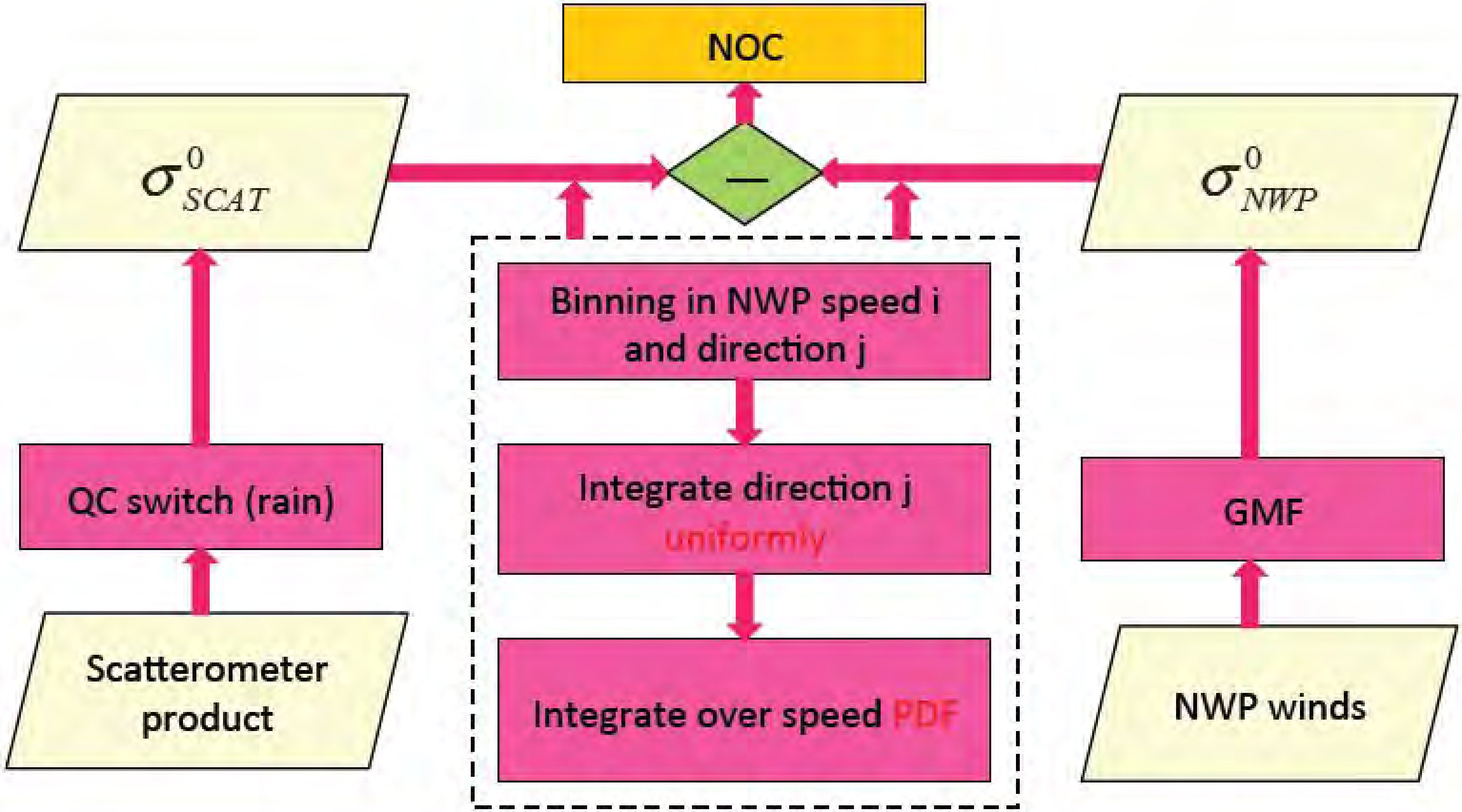
$$\sigma^0(v,\phi)=\frac{1}{2}a_0(v)+a_1(v)\cos\phi+a_2(v)\cos(2\phi)$$

-Integrating uniformly over the azimuth angle:

$$a_n(v)=\frac{1}{\pi}\int_0^{2\pi}\sigma^0(v,\phi)\cos(n\phi)d\phi \qquad n=0,1,2.$$

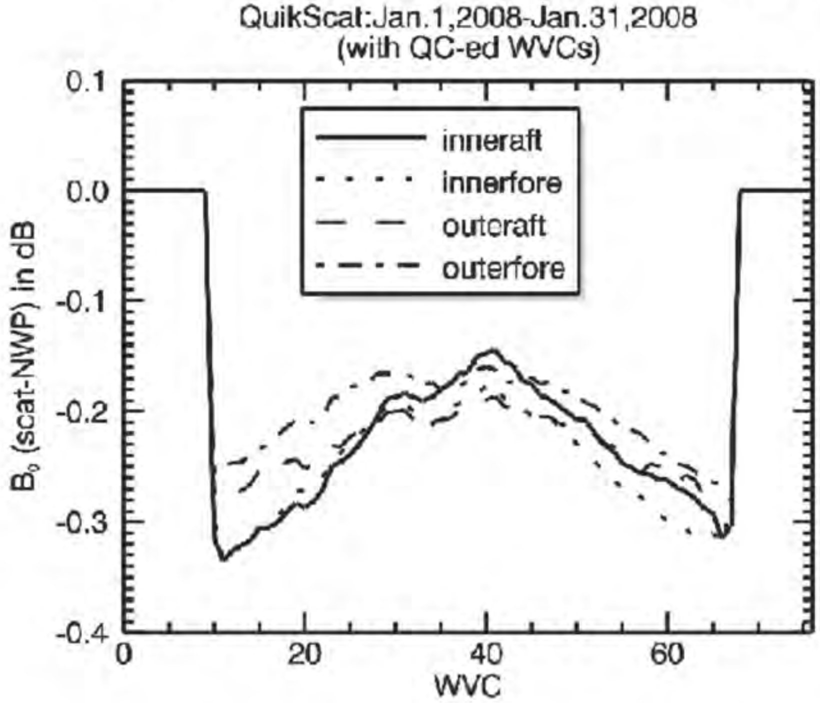
$$\left\langle\sigma^0\right\rangle=\int_0^{\infty}2a_0(v)PDF(v)dv$$

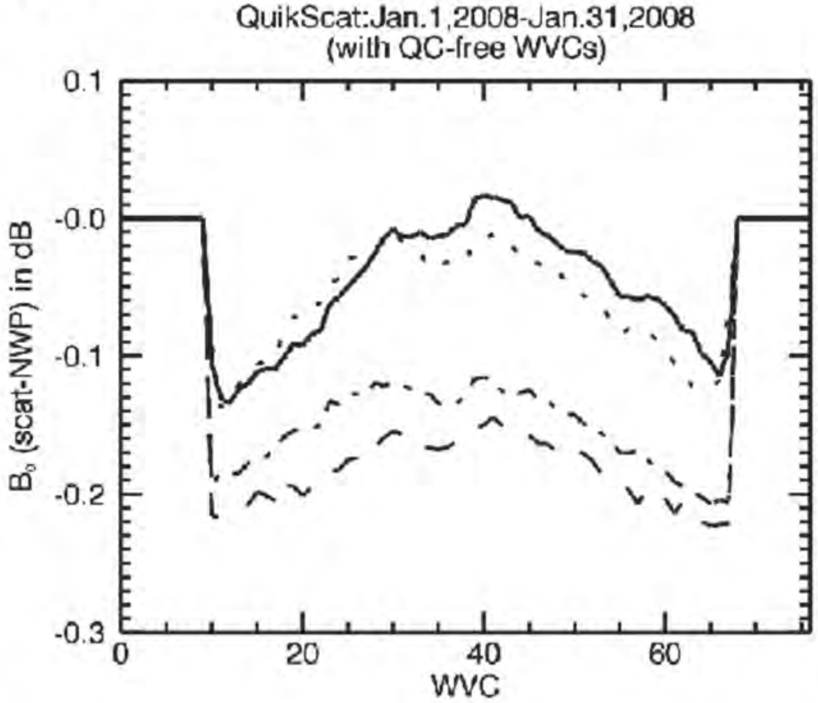
Ku-band NOC method per WVC



QuikSCAT NOC and Validation

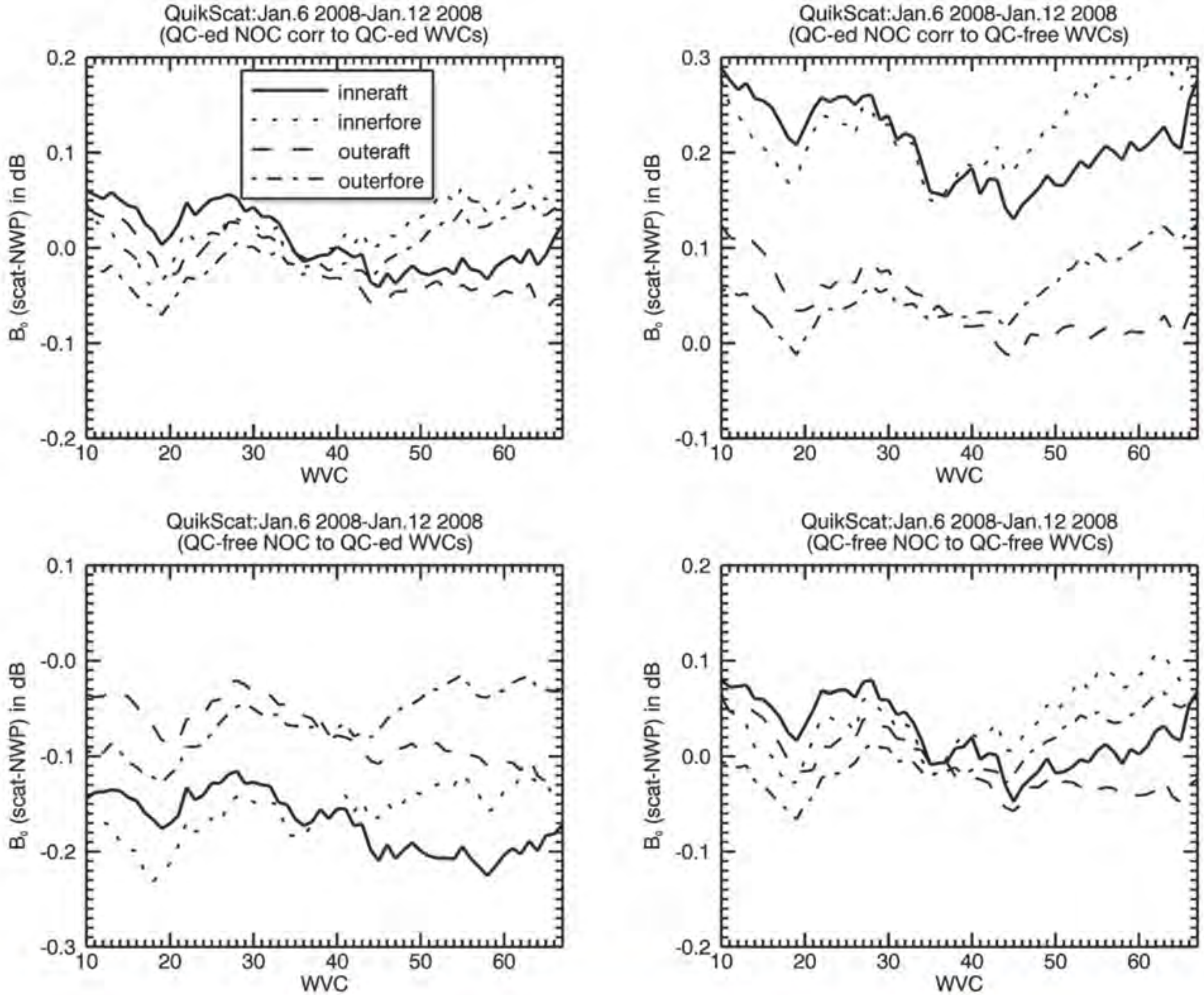
The average of the QuikSCAT ocean calibration residuals over January 2008.
(a) with QC-ed WVCs and (b) with QC-free WVCs.





- Rain QC provides VV & HH consistency
- Rain most affects inner
- Fore & aft looks are very close

QuikSCAT NOC and Validation



The average of the QuikSCAT NOC residuals over January 6th, to 12th, 2008 after correction.

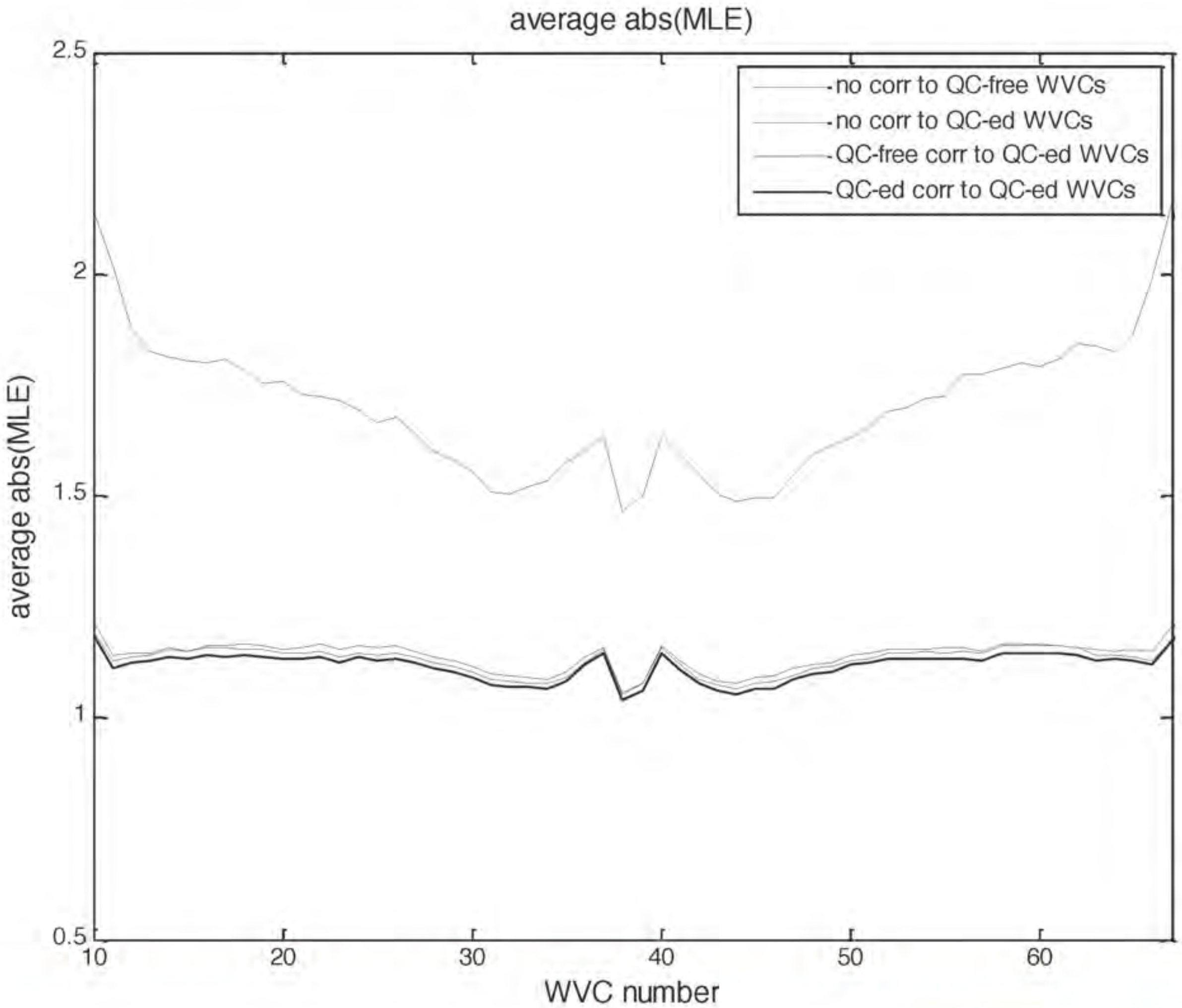
(a) QC-ed NOC correction on QC-ed WVCs;

(b) QC-ed NOC correction on QC-free WVCs;

(c) QC-free NOC correction on QC-ed WVCs;

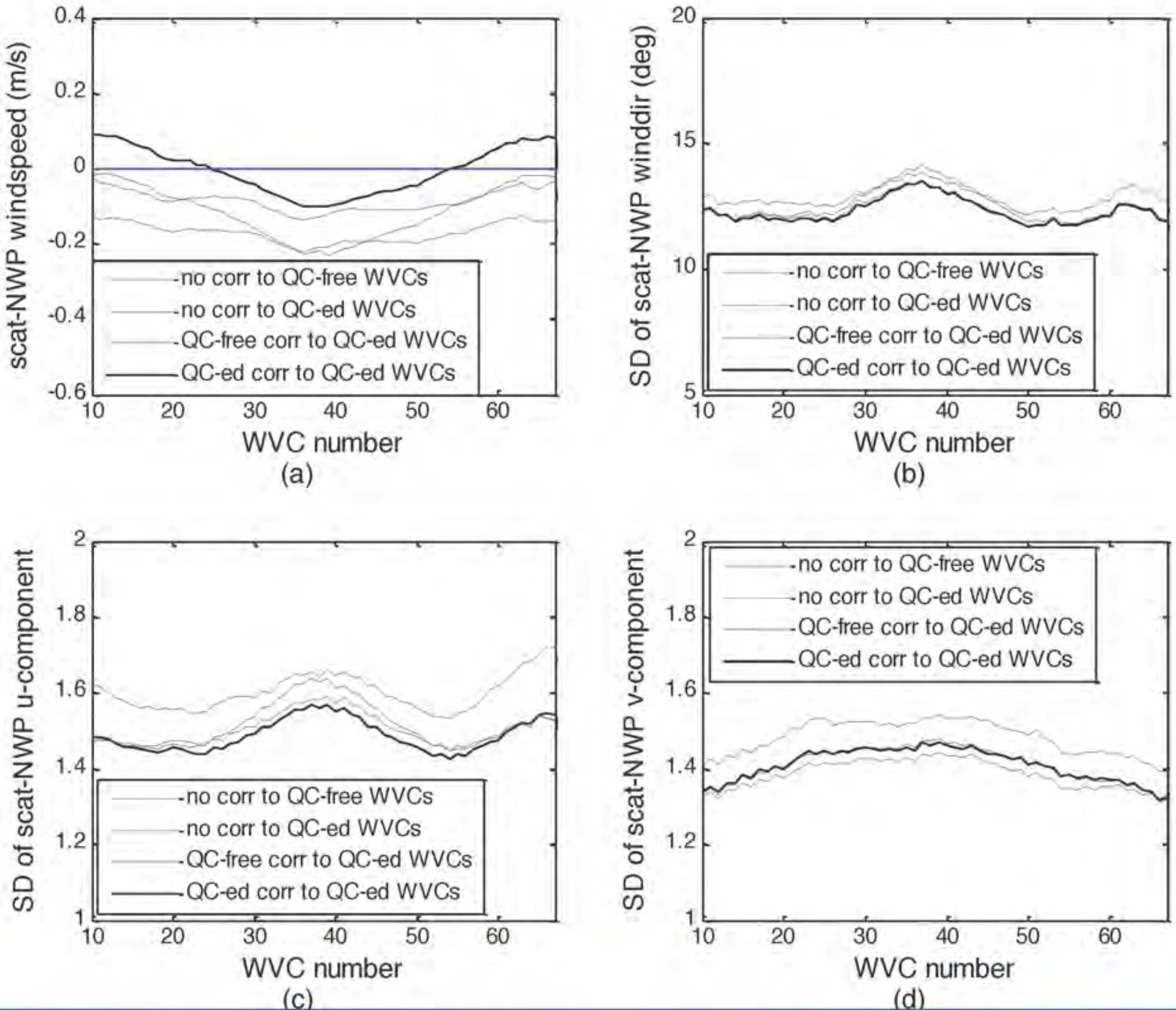
(d) QC-free NOC correction on QC-free WVCs;

QuikSCAT NOC and Validation



- Rain causes a large inversion residual, MLE (dashed line)
- QC removes rain, gives more consistent σ^0 sets with GMF
- QC-ed NOC provided the lowest MLEs for all WVCs

QuikSCAT NOC NWP Validation

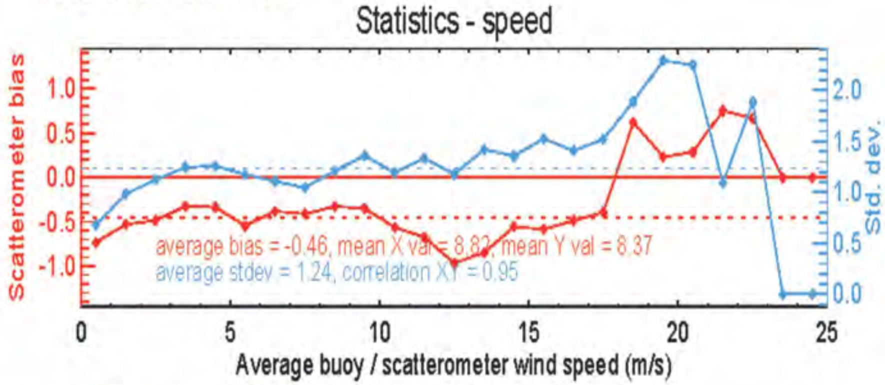


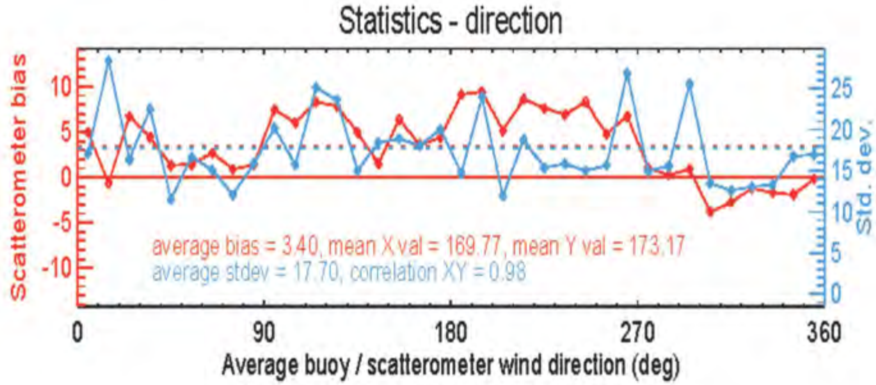
QuikSCAT versus ECMWF winds for the period January 6, to 12, 2008.

- NOC after QC provides lowest speed bias, as expected
- Also, lowest wind direction SD and lowest zonal wind component SD
- NOC has small detrimental effect on meridional wind component SD

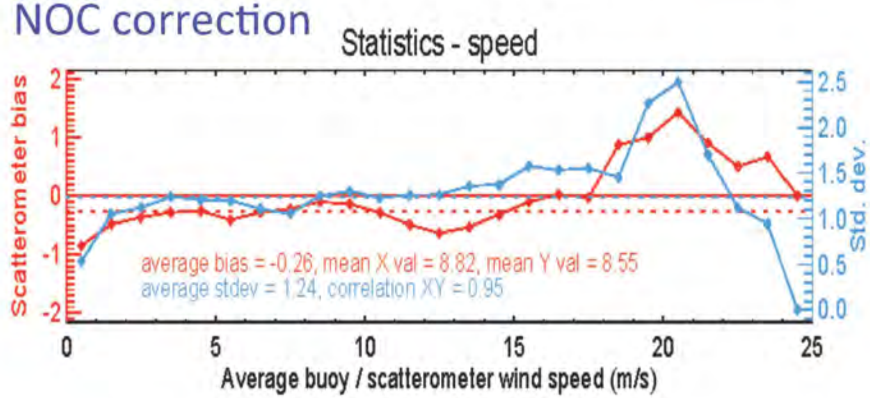
QuikSCAT NOC buoy Validation

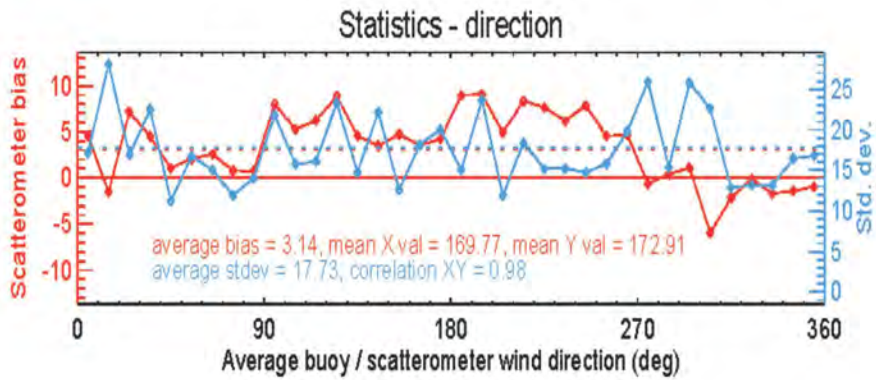
No correction





NOC correction





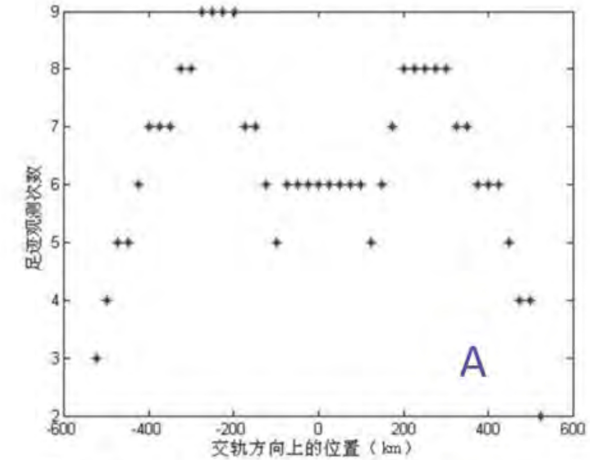
- NOC correct the speed bias
- No other significant effects on direction and wind components

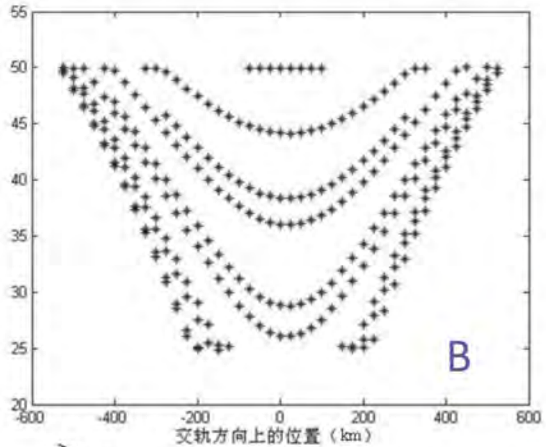
QuikSCAT NOC and Validation

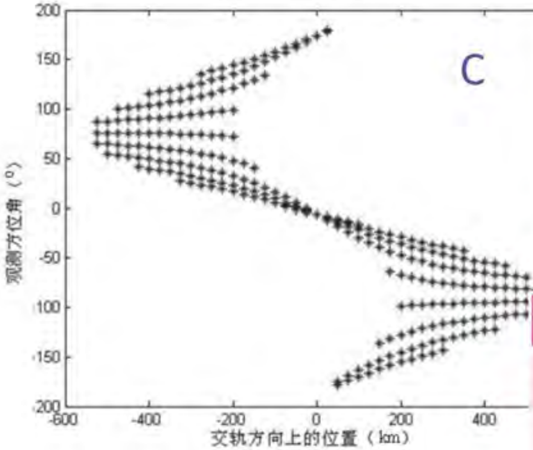
Table 1: QuikSCAT collocated buoy validation (Jan.2008)

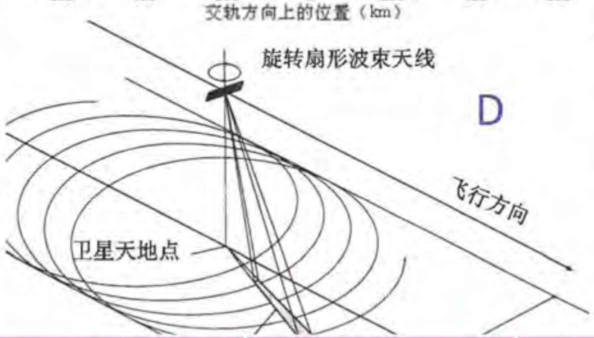
	Wind Speed (m/s): Average bias/ Average stdev	Wind Direction (deg): Average bias/ Average stdev	u component (m/s): Average bias/ Average stdev	v component (m/s): Average bias/ Average stdev
No NOC correction (wind vector)	(3127) -0.46/1.24	(2860) 3.4/17.70	(3129) 0.35/1.85	(3130) 0.04/1.95
QC-ed NOC correction (wind vector)	(3125) -0.26/1.24	(2860) 3.14/17.73	(3129) 0.34/1.86	(3129) -0.03/1.98

RFSCAT NOC Brief Introduction









Unlike ASCAT or QSCAT/ OSCAT/HY-2A,
for 1 WVC with different across-track position:

- view number is different (fig. A)

Accordingly,

- incidence angle different for different view (fig. B)
- azimuth angle different for different view (fig. C)

Scatterometer	View numver	Incidence angle	Azimuth angle
ASCAT	3	Fixed	Fixed for 3 beams
QuikSCAT/OSCAT	4(inner WVCs)	Fixed for 2 beams	Fixed for 4 views
RFSCAT	3,4,5,6,7,8,9	Not fixed	Not fixed

Conclusions

- RFSCAT(CFOSAT/SCAT) is a rotating fan-beam scatterometer, there is a **mix** of incidence angles and azimuth angles for every WVC
- NWP Ocean Calibration method can be applied on RFSCAT(CFOSAT /SCAT), **definitely necessary.**
- RFSCAT NOC should be more complicated, and it is should be a correction table of incidence angle, not of WVC number or across-swath position (need much more work on it…)

Future works

- **Calibration with ocean and Amazon forest for azimuth variation**
- **Antenna pattern and satellite attitude calibration techniques**

Thank You!