COASTALT meeting

November 6-7th, 2008

Pisa, Italy

# Retracking Jason1 Altimeter Waveform over China Coastal Sea


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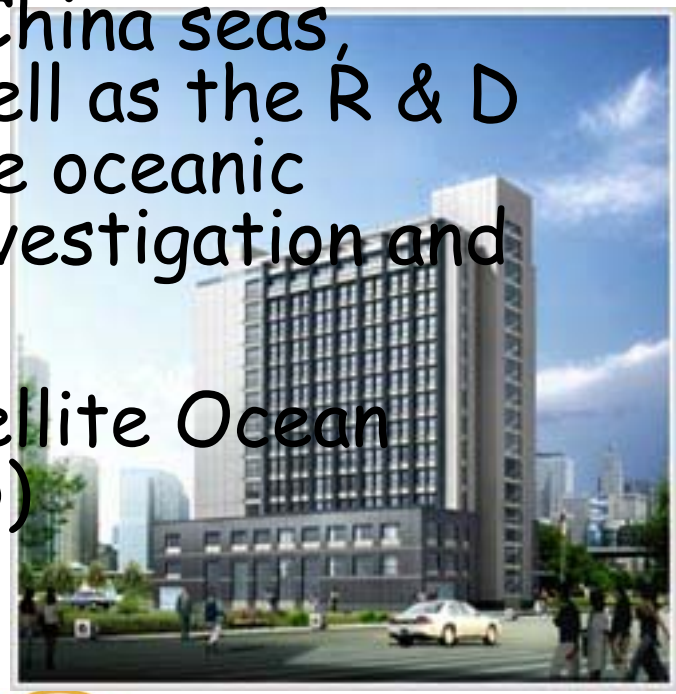
November 6, 2008

"Just as there is paradise in heaven, there are Suzhou and Hangzhou on earth."

国家海洋局
第二海洋研究所

- The Second Institute of Oceanography (SIO) which was established in 1966 is a non-benefit oceanographic research institute directly under the State Oceanic Administration (SOA) of China. It is mainly engaged in the ocean scientific research on China seas, oceans and polar regions as well as the R & D of the high technology for the oceanic environment and resources investigation and survey.
- State Key Laboratory of Satellite Ocean Environment Dynamics (SOED)



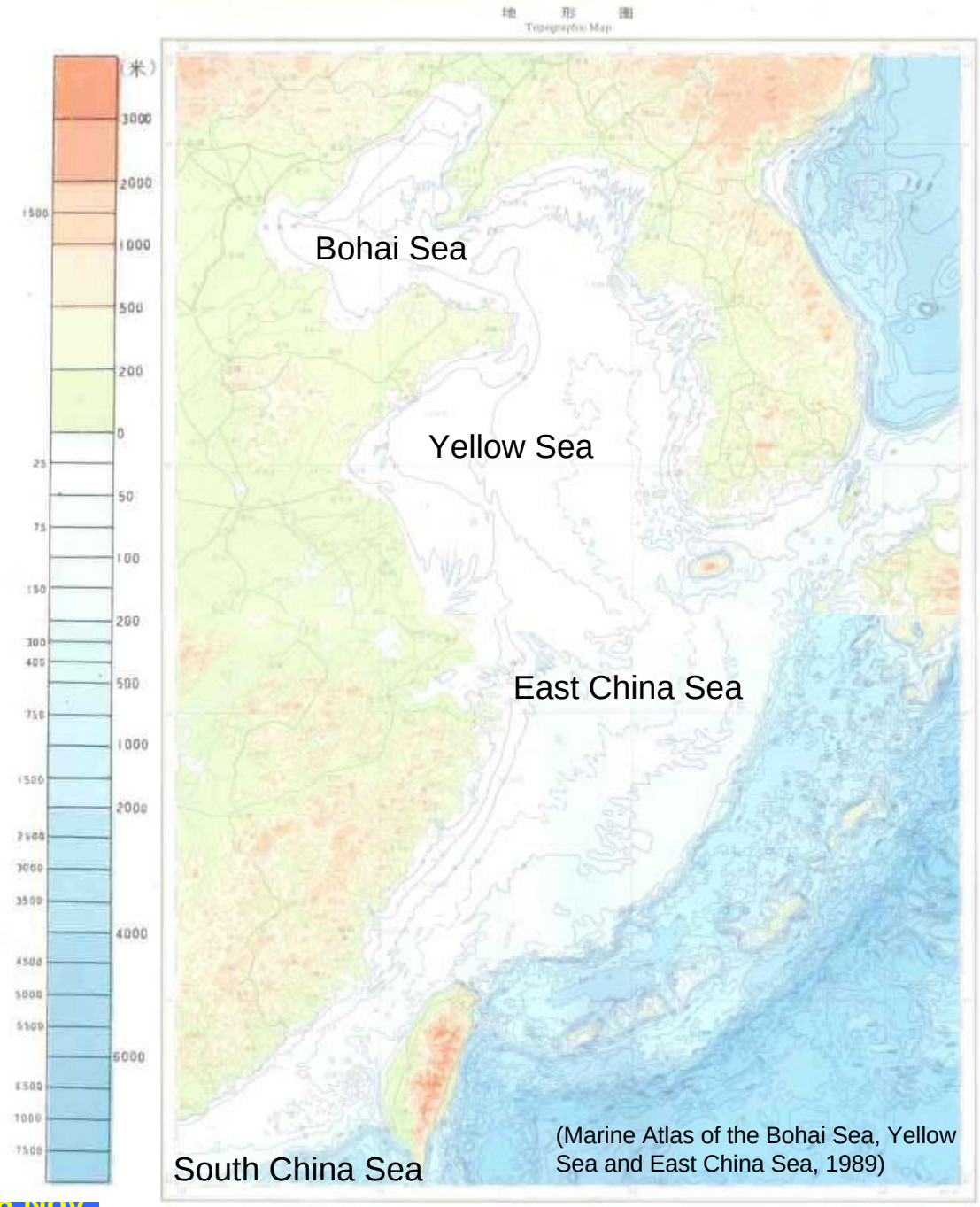
# Outline

1. Introduction
2. Altimetry Coastal Waveform analysis
3. Retracking algorithms
4. Results
5. Work under way

# 1. Introduction:

Studying region: China and neighbouring seas (105° E-130° E, 14° N-45° N)

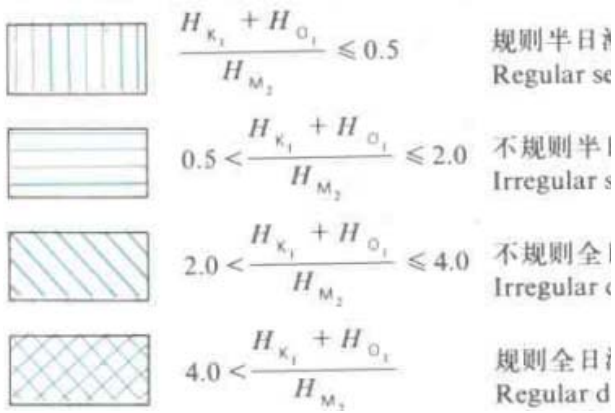
(1) bathymetry;
(2) tide;
(3) coastline.

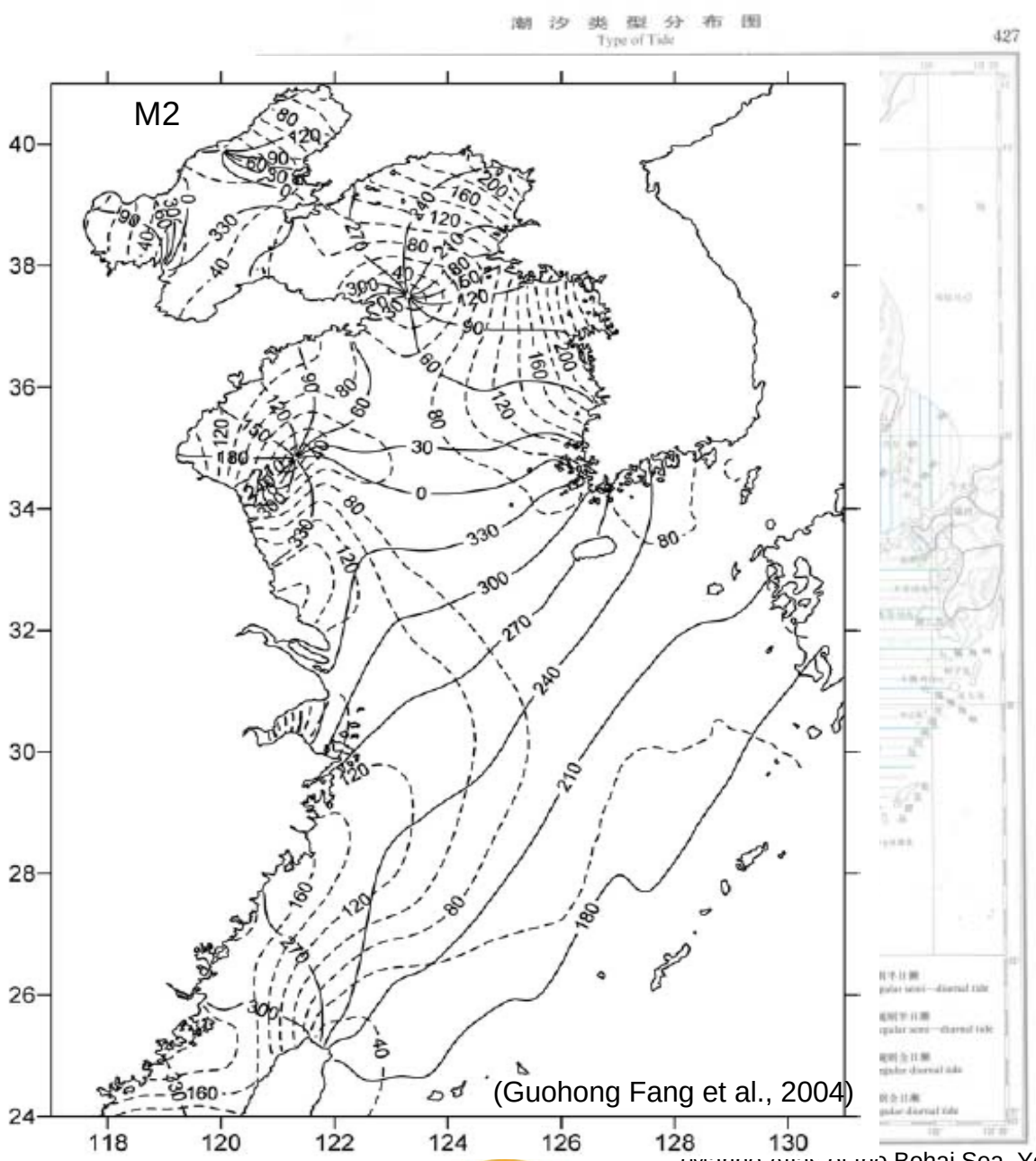



(Marine Atlas of the Bohai Sea, Yellow Sea and East China Sea, 1989)

# 1. Introduction
## China seas

(2) tide:
- Semi-diurnal tides & Diurnal tides
- Highly variable tides



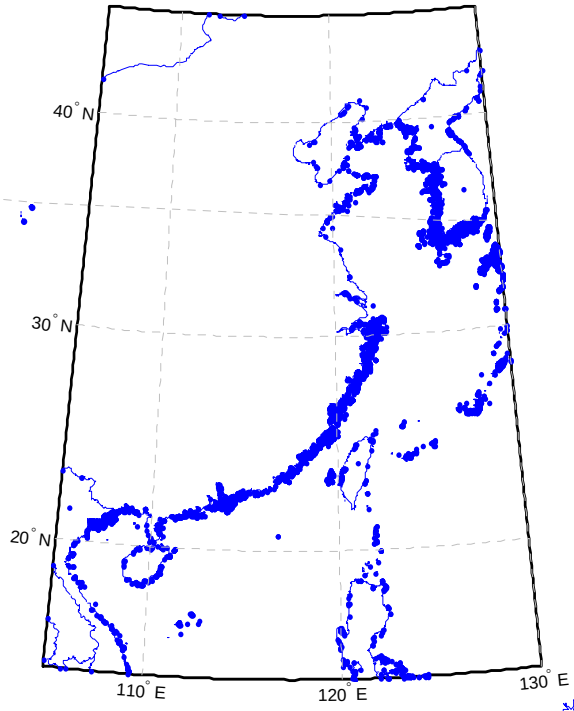




(Guohong Fang et al., 2004)

(Marine Atlas of the Bohai Sea, Yellow Sea and East China Sea, 1989)

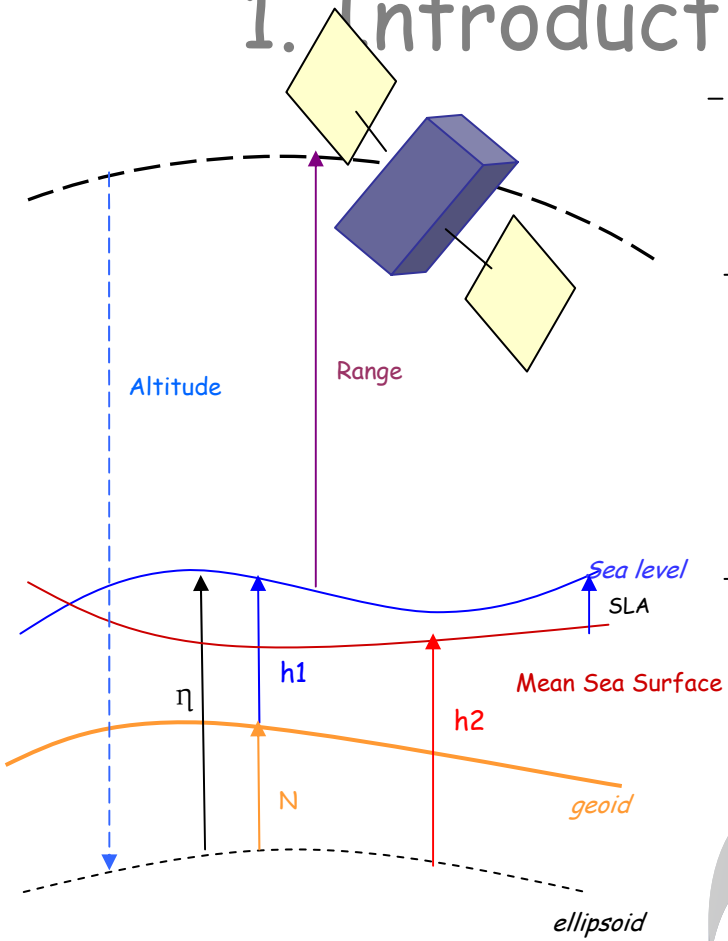
# 1. Introduction: China seas

## (3) Irregular Coastline




NOAA, (1:250,000)

# 1. Introduction :Radar altimetry




Four reference surfaces:

- Sea level
- Mean Sea Surface（GSFC00.1）
- Geiod (JGM3,OSU91A,EGM96)
- Ellipsoid

- Sea surface height—refered to Ellipsoid:

$$\eta = Altitude - Range$$

- Dynamic topography—refered to Geiod:

$$h1 = \eta - geoid - \Delta H_{tide} - \Delta H_{gp}$$

$h1: 2m$

$geoid: 100m$

$\Delta H_{tide}: 1-20m$

$\Delta H_{gp}: 1cm/mbar$

- Sea Level Anomaly—refered to MSS:

$$SLA = H_{alt} - H_{range} - MSS - \Delta H_{atm} - \Delta H_{SS} - \Delta H_{tide} - \Delta H_{gp}$$

$$\Delta H_{atm} = h_{wet\_tropo} + h_{dry\_tropo} + h_{iono}$$

$$\Delta H_{tide} = h_{ocean\_tide} + h_{solid\_earth\_tide} + h_{loading\_tide} + h_{pole\_tide}$$

$$\Delta H_{gp} = h_{inv\_bar} + h_{hf\_fluc}$$

ADT(h1)= SLA+MDT(h2)

MDT(h2)= MSS - Geoid

MDT:Mean Dynamic Topography

ADT:Absolute Dynamic Topography

# 1. Introduction :

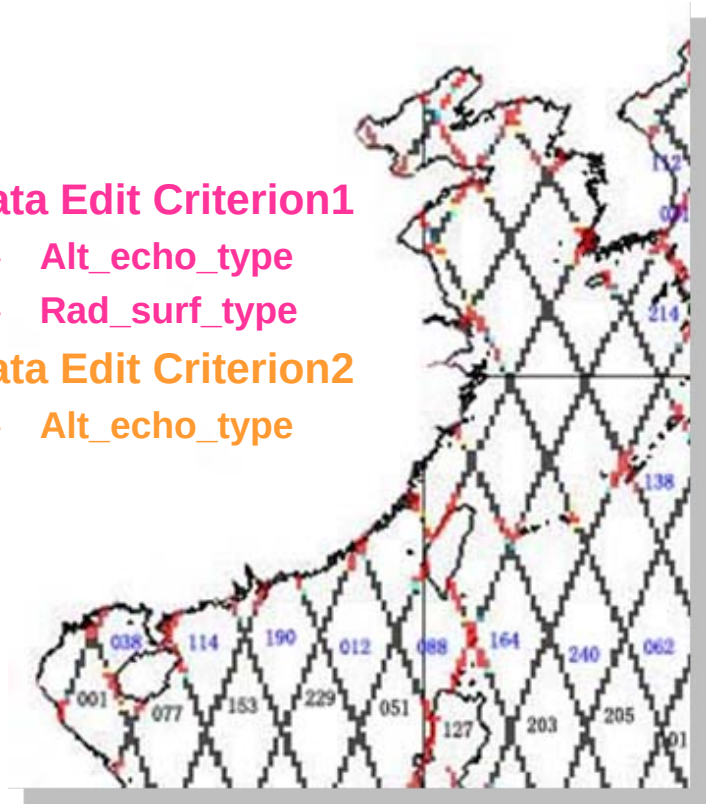
## Why coastal altimetry data are flagged?

- The reasons include not only the altimeter measurement itself, but also some geophysical corrections. The proximity of the land also makes it impossible to calculate the wet tropospheric correction, ocean tide correction and atmospheric high-frequency forcing correction accurately, as ones would for the open ocean.

# 1. Introduction

1. China and neighbouring areas (105° E-130° E, 14° N-45° N)
2. Jason1 cycle 164 (2006.6.16 to 2006.6.19)

- **Data Edit Criterion1**
  - **Alt_echo_type**
  - **Rad_surf_type**
- **Data Edit Criterion2**
  - **Alt_echo_type**




| Pass No. | A | B | A | B |
|---|---|---|---|---|
| 001 | 82.6 | 129.8 | 5.9 | 3.0 |
| 077 | 76.7 | 59.0 | 5.9 | 5.9 |
| | 76.7 | 64.9 | 35.4 | 5.9 |
| 153 | 59.0 | 94.4 | 23.6 | 11.8 |
| | 41.3 | 123.9 | 17.7 | 17.7 |
| | | 100.3 | | 17.7 |
| 229 | | 94.4 | | 11.8 |
| | 47.2 | 76.7 | 11.8 | 23.6 |
| 051 | | 76.7 | | 35.4 |
| | 88.5 | 94.4 | 17.7 | 53.1 |
| 038 | 47.2 | | 5.9 | |
| 114 | 112.1 | 112.1 | 29.9 | 29.9 |
| | 53.1 | | 11.8 | |
| 190 | 70.8 | | 17.7 | |
| 012 | 53.1 | | 5.9 | |
| 088 | 70.8 | | 17.7 | |
| 164 | 88.5 | 70.8 | 47.2 | 17.7 |
| | 118.0 | | 5.9 | |
| 240 | 53.1 | | 11.8 | |
| 062 | 100.3 | 100.3 | 11.8 | 11.8 |
| | 59.0 | | 11.8 | |
| 138 | 47.2 | 212.4 | 11.8 | 29.9 |
| | 70.8 | | 5.9 | |
| 214 | 88.5 | | 11.8 | |
| Mean | 62.7 | 58.8 | 13.5 | 11.5 |

A: Flagged Distance (Land to Ocean) /km

B: Flagged Distance (Ocean to land) /km

# 1.Introduction
# Summary

The problems of Coastal altimetry are widely recognized. Many projects have been launched to deal with these problems: ALBICOCCA (2001-2004);RAIES (2003,12-2004,12;ESA); CASH (2004.7-2006.1; RTE); ALTICORE (2006,12-2008, INTAS);COASTALT(2008,1-2009,7;ESA); PISTACH(2007,11-2009,3;CNES)…

The shortages of altimetry data near the coasts can be summarized as follows:

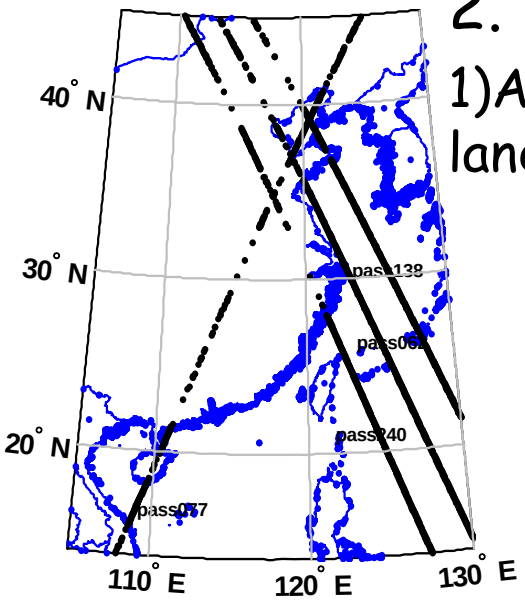
- Complexity of returned waveforms ( <20km);
- Spatial Sampling rate is too low (1 s, 7km; 1/20 s, 350m);
- Computation of some corrections:
  - Wet tropospheric corrections, computed from radiometer measurements are also less precise, or even missing, near the coasts. (~50km)
  - Tides are much more complex near the shores than in the open sea, and require a highly precise knowledge of the coastal geography to be accurately computed.
  - Rapid variations ("high frequency") must be taken into account in those areas (for the tides as well as for the atmospheric pressure).

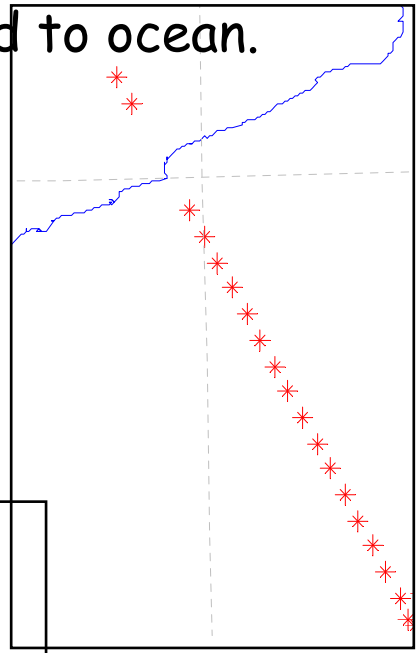
# Outline

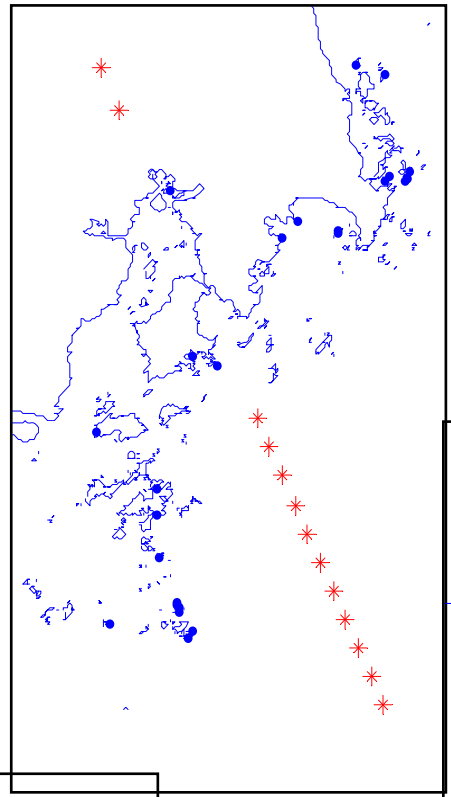
1. Introduction
2. Altimetry Coastal Waveform analysis
3. Retracking algorithms
4. Results validation
5. Work under way

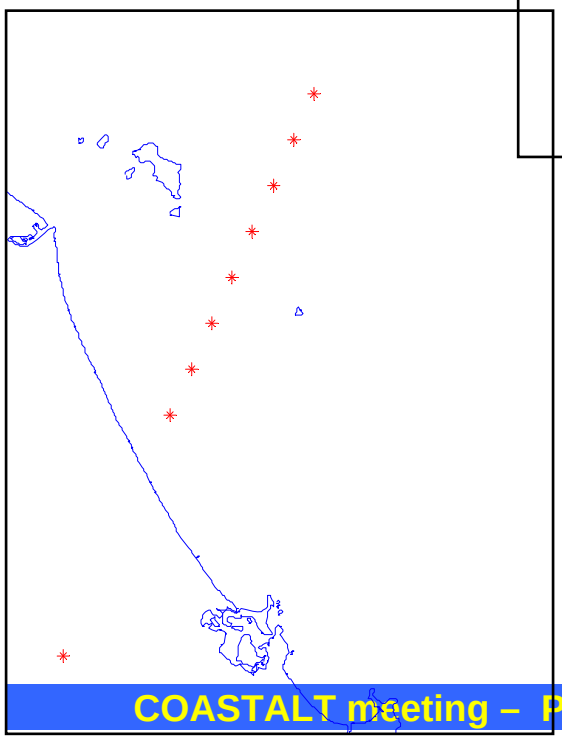
# 2. Altimetry Coastal Waveform analysis

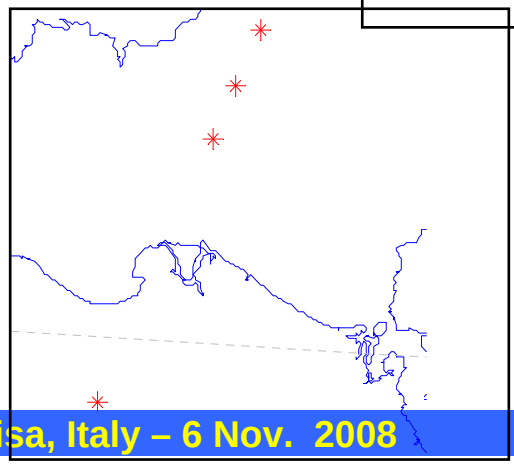
1)Altimeter Jason1 Loss track sometimes, especially from land to ocean.

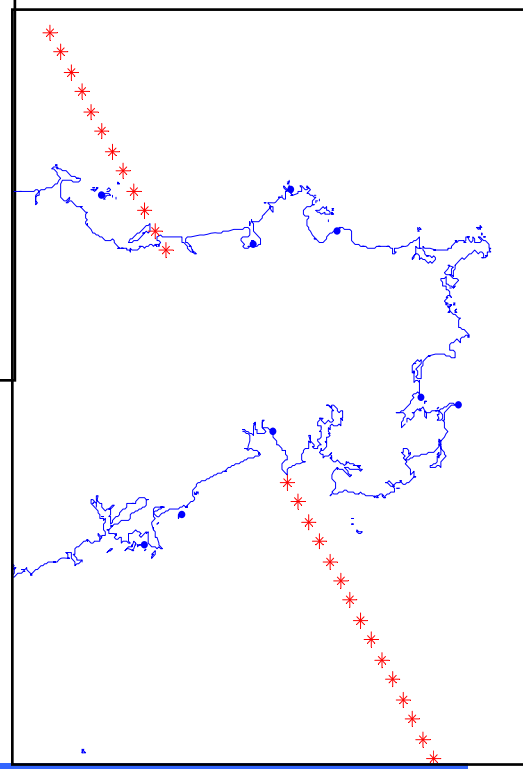




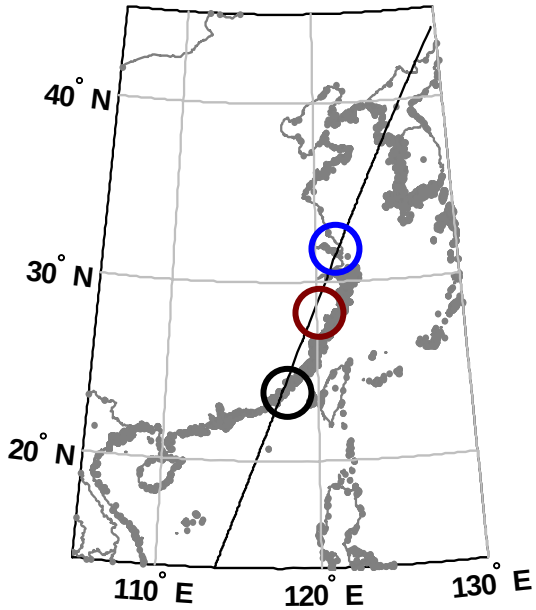






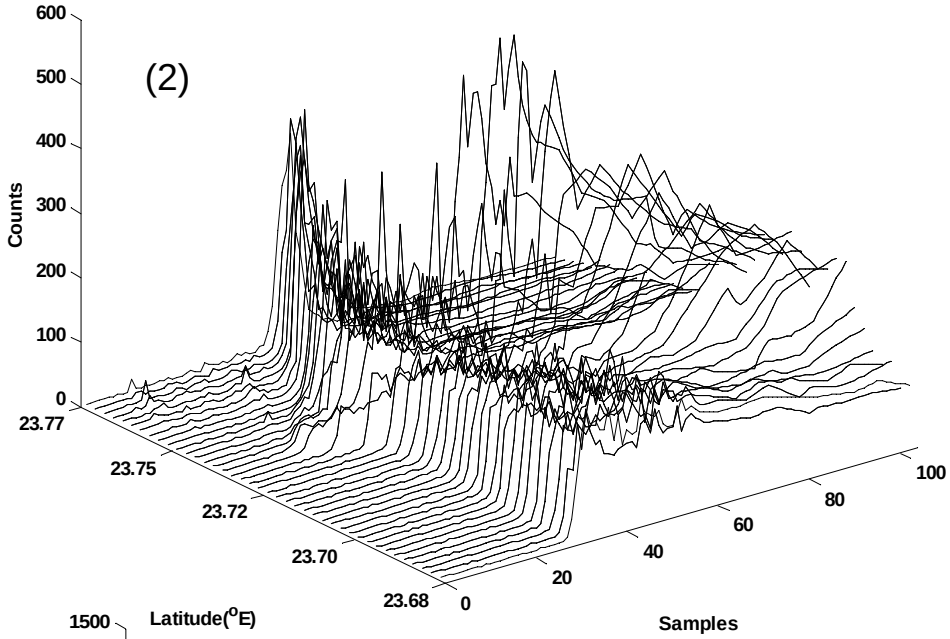
# 2. Altimetry Coastal Waveform analysis

(1)

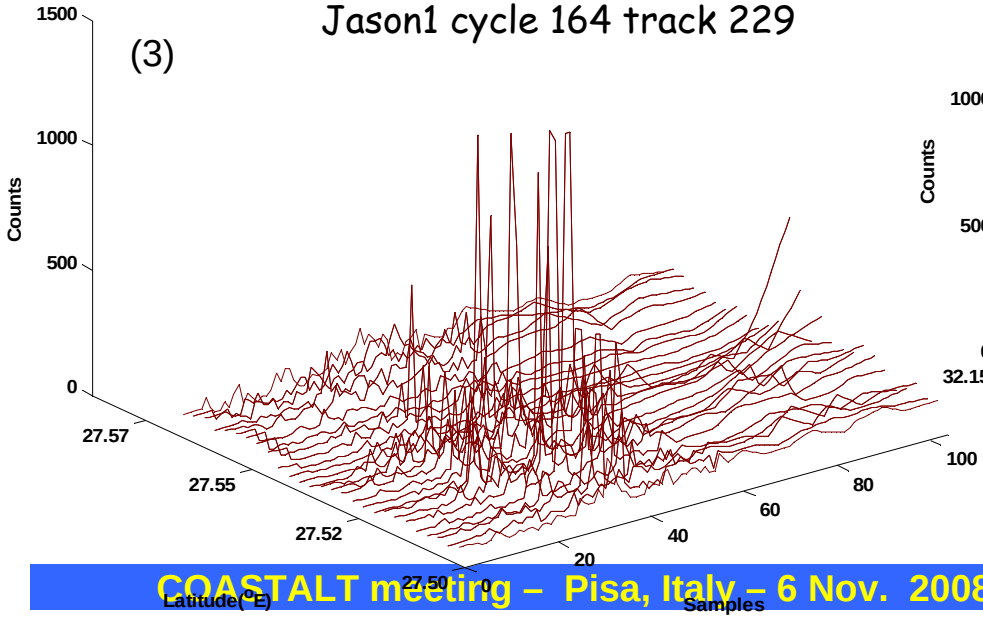



Jason1 cycle 164 track 229

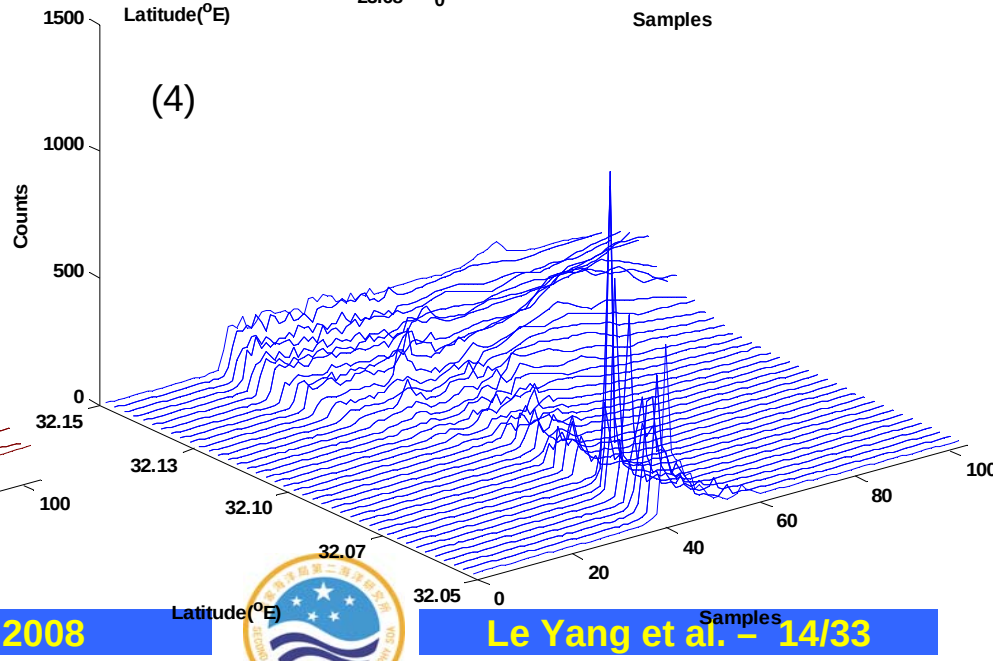
(2)

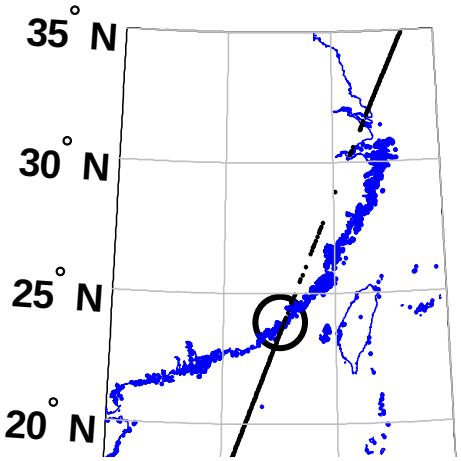



(3)




(4)






Jason-1 Cycle164Pass229

Record2121No.5-Record2122No.4

Waveform Interval:

0.05s,350m

==========

Radiometer Flag on: 94.4km

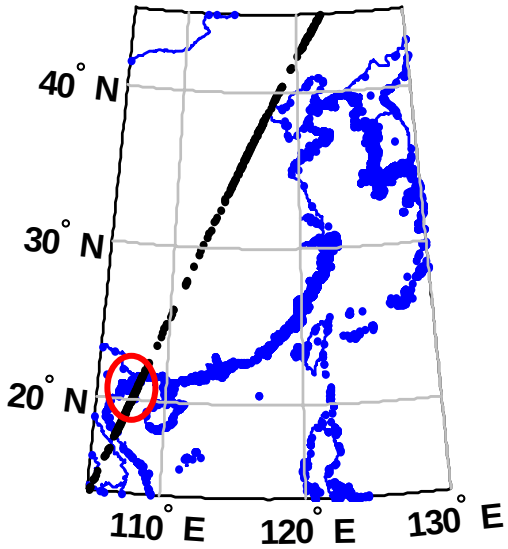
Altimeter Flag on: 11.8km

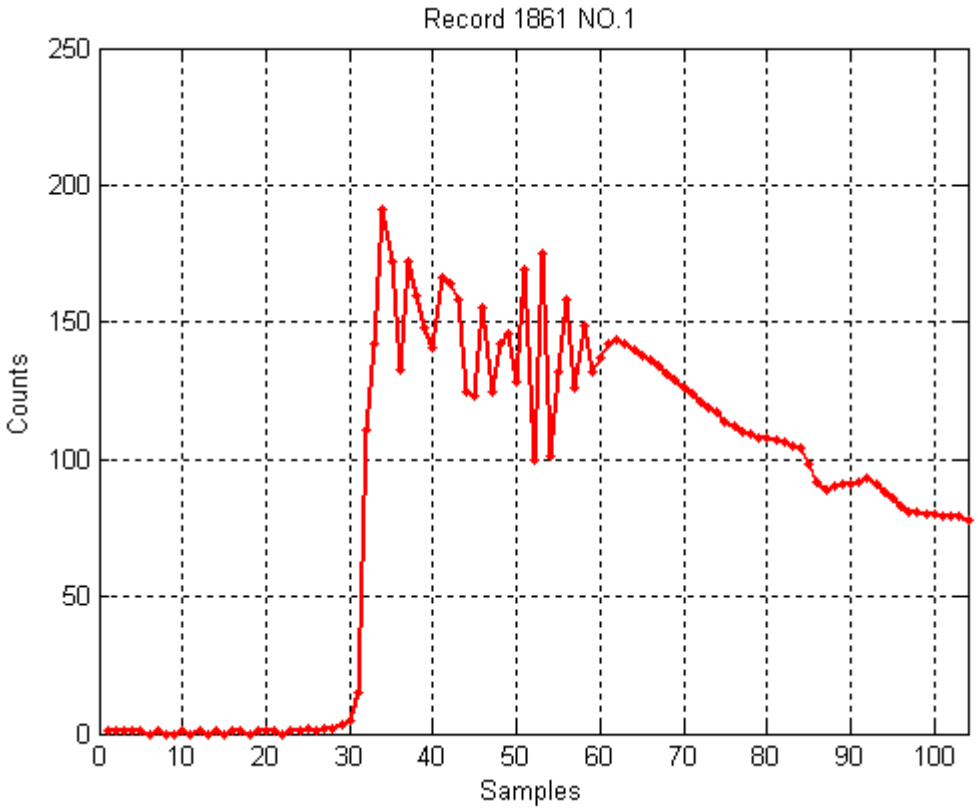
1：10.63km，

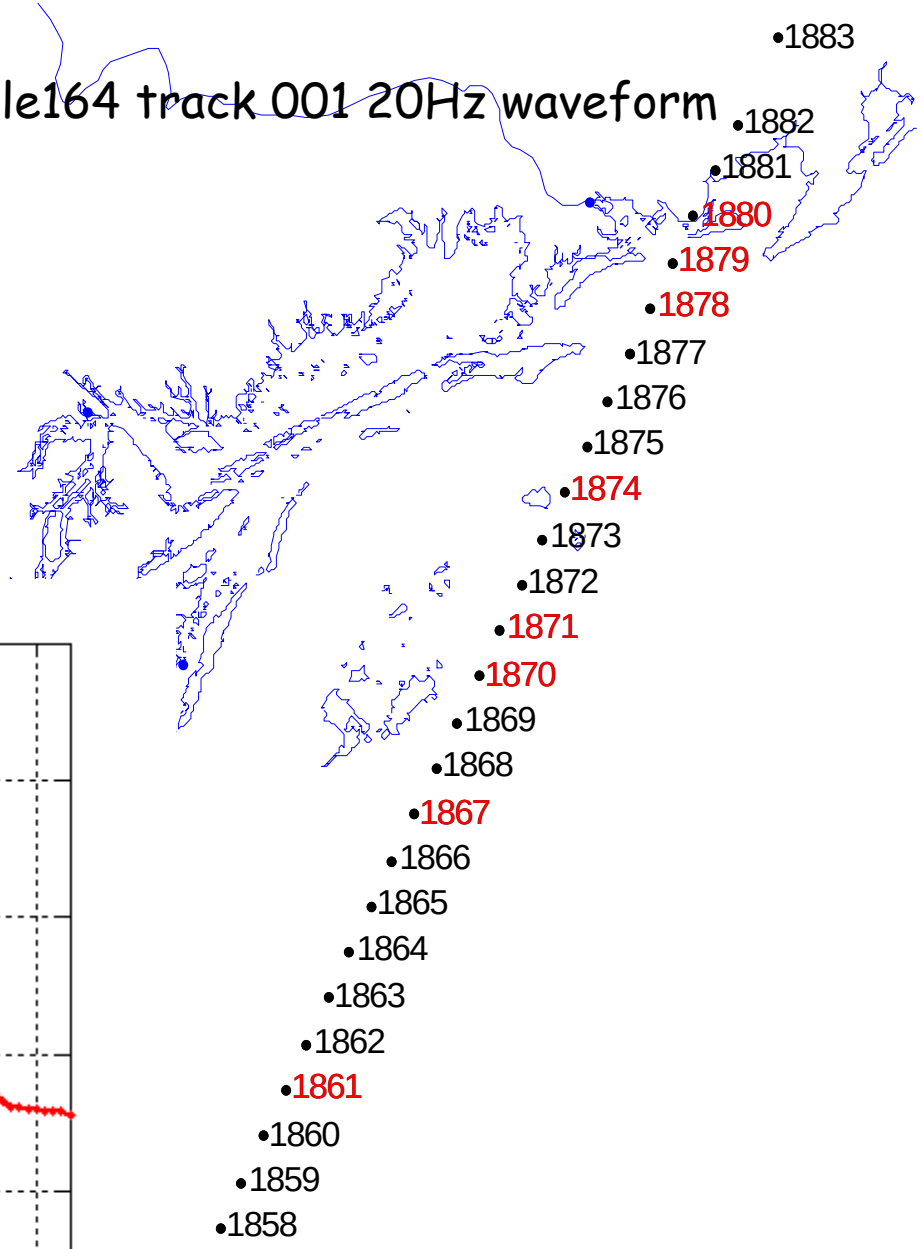
17：5.90km，

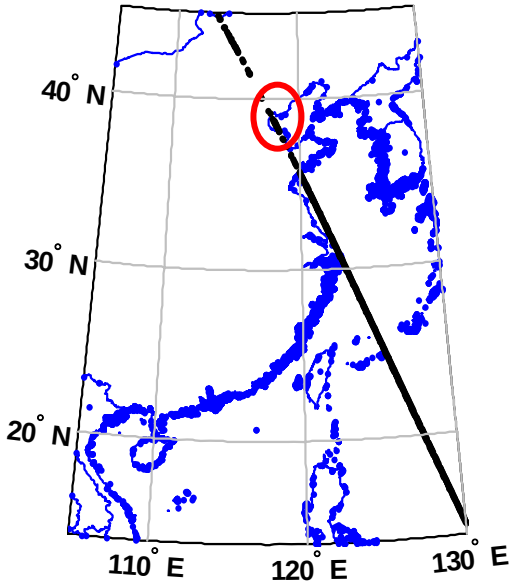
20：5.03km，

# Jason1 cycle164 track 001 20Hz waveform

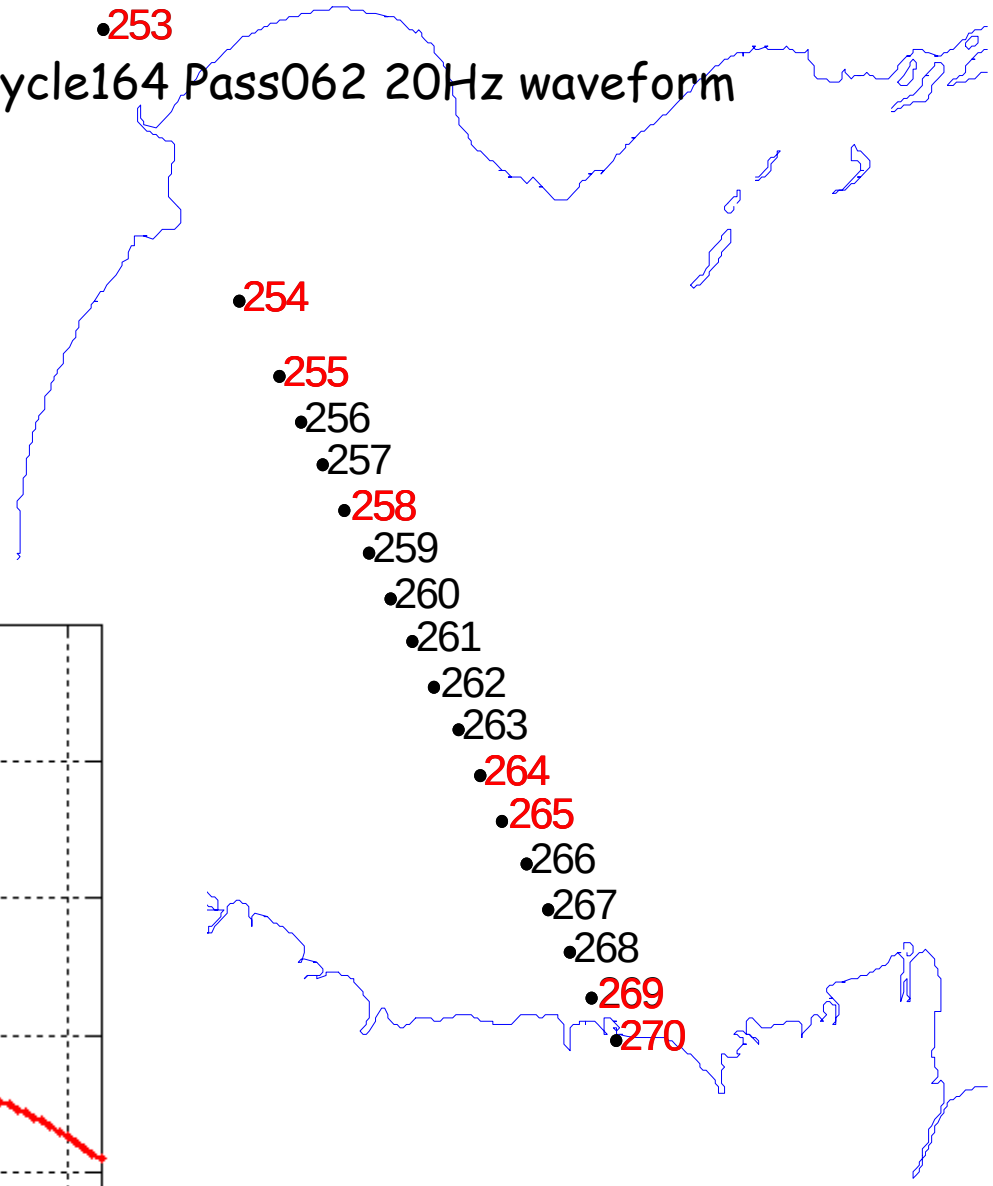


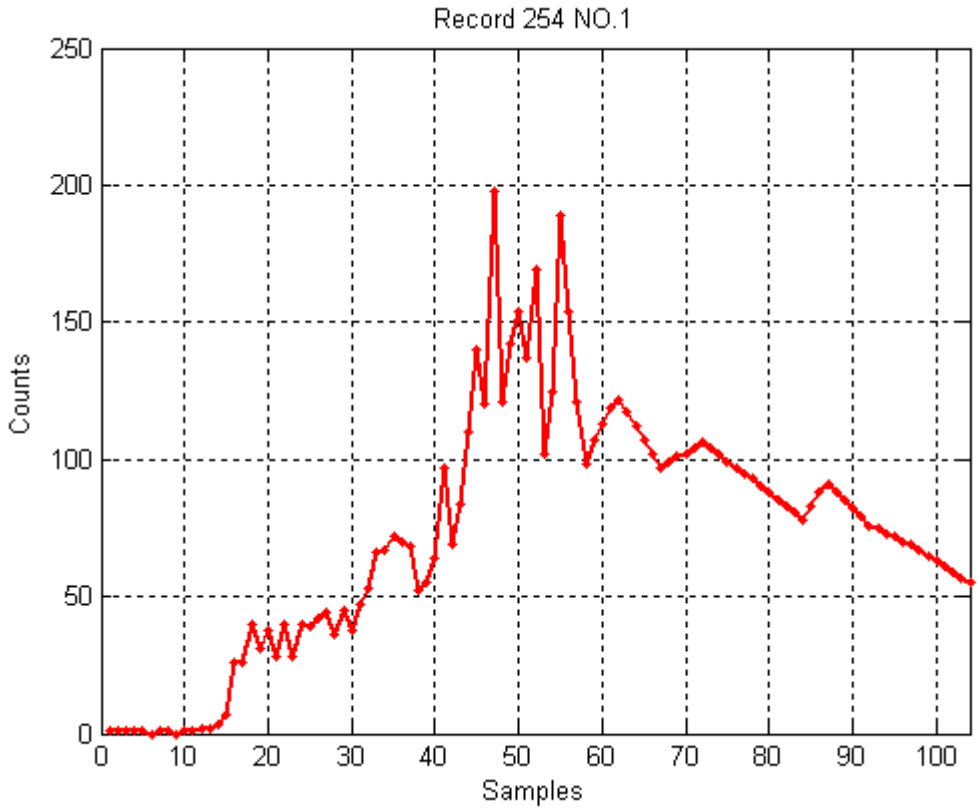



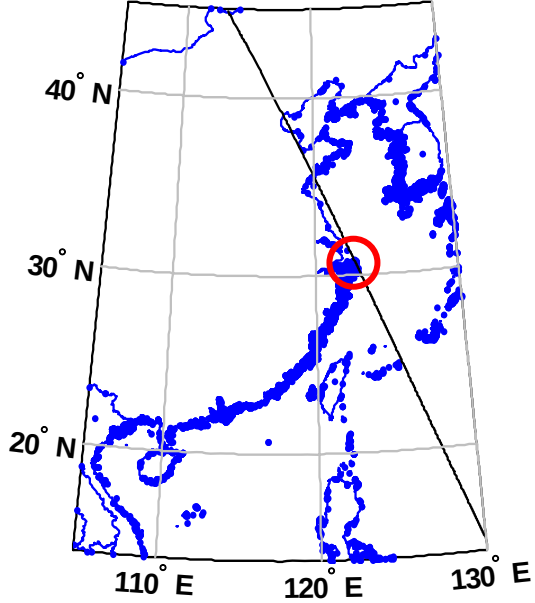


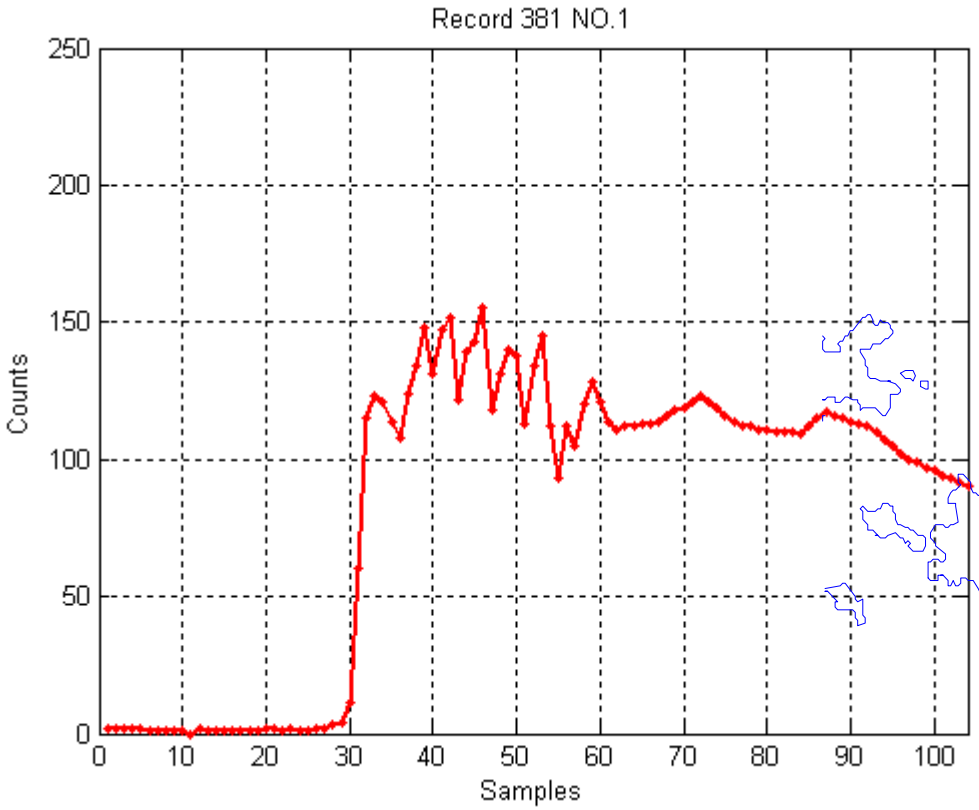

# Jason1 Cycle164 Pass062 20Hz waveform

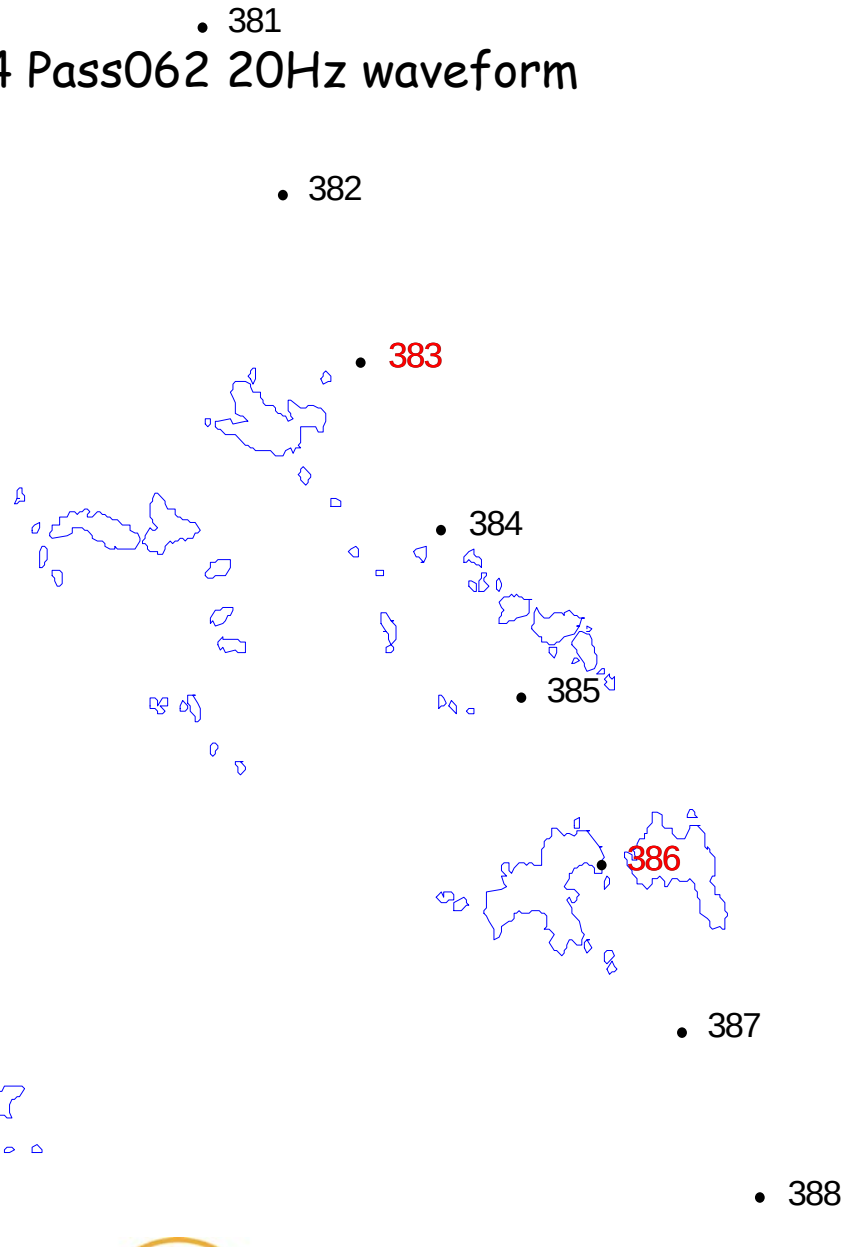


# Jason1 Cycle164 Pass062 20Hz waveform



# 2. Altimetry Coastal Waveform analysis

## Summary

- Loss data sometimes, especially from land to ocean (5~10km).
- Strong land returns contaminate the altimetry waveforms (~10km): Ocean to land & land to Ocean.
- Irregular coastlines result in discontinued flagged altimeter records.
- Many flagged 20Hz waveform data can be used by employing waveform retracking algorithms.

# 3. Retracking algorithms

3.1 standard waveform processing algorithm:

Ocean fitting algorithm

3.2 waveform retracking algorithms:

- 3.2.1 Ice-1/OCOG
- 3.2.2 Ice-2
- 3.2.3 Sea Ice/Threshold
- 3.2.4 Beta5/9

# 3.1 Ocean fitting algorithm

(Brown,1977) convolution expression of the surface return power:

$$W(t) = P_{FS}(t) * q_s(t) * p_r(t)$$

(Hayne,1980) Analytical expression of the return waveform: (Ignoring the non-gaussian distribution of sea surface, ie $\lambda_s = 0$ )

$$W(t) = A\exp(-v)[1+erf(u)]$$

其中 $v = a((t-t_0) - \frac{a}{2}\sigma_c^2), u = \frac{(t-t_0) - a\sigma_c^2}{\sqrt{2}\sigma_c}, a = \alpha - \frac{\beta^2}{4}$

$$\alpha = \frac{\ln 4}{\sin^2(\theta/2)} \frac{c}{h} \frac{1}{(1+h/R)} \cos(2\xi)$$

$$\beta = \frac{\ln 4}{\sin^2(\theta/2)} [\frac{c}{h} \frac{1}{(1+h/R)}]^{1/2} \sin(2\xi) \quad A = Au * \exp(\frac{-4\sin^2(\xi)}{\gamma})$$

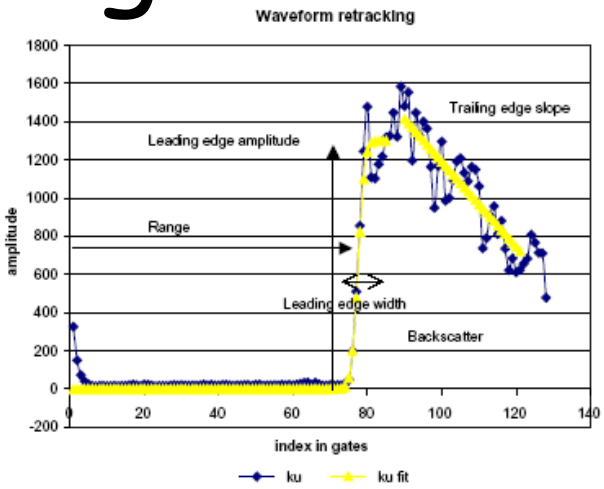
$h$-Satellite altitude (m)

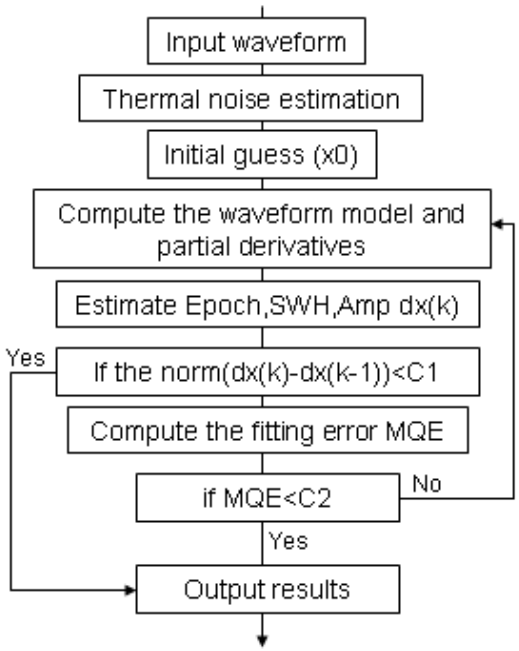
$R$-Radius of the Earth (m)

$\theta$-Antenna beamwidth at 3 dB

$\xi$-off nadir angle

$\sigma_c$-$\frac{SWH}{2*c}(s)$, $SWH$-Significant waveheight (m)



# 3.2 waveform retracking algorithm

- Altimeter waveform retracking consists in ground-processing altimeter waveforms to obtain better range estimates than those obtained with on-board tracking algorithms.
- The algorithm retrieves the point of the radar echo corresponding to the effective satellite to ground range.
- Many specific retrackers exist, most were initially developed for ice surface: OCOG (Wingham, 1986; Bamber,1994), Ice-2 (Legresy and Remy, 1997 ), Beta5/9 (Martin, 1983) , S/V (Davis, 1993), Threshold (Laxon, 1994).
- Those retracker are widely employed to retrieve ranges for other surfaces, such as Land, Inland lake and river, and Coastal water.
- OCOG, Ice-2, Beta5,Threshold algorithms are compared for china and neighbouring coastal seas.

# Outline

1. Introduction
2. Altimetry Coastal Waveform analysis
3. Retracking algorithms
4. **Results**
5. Work under way

# 4. Results

Altimeter Data: Jason1 SGDR cycle155 to cycle188 (March 2006 to February 2007) over China and neighboring seas (105° E-130° E, 14° N-45° N).
Tide gauge data: Chinese National Marine Data and Information Service of the State Oceanic Administration.

- 4.1 Inter-comparison of Jason1 SLA at Crossovers

$$SLA = H_{\text{alt}} - H_{\text{range}} - MSS - \Delta H_{\text{atm}} - \Delta H_{\text{SS}} - \Delta H_{\text{tide}} - \Delta H_{\text{gp}}$$

$$\Delta H_{atm} = h_{wet\_tropo} + h_{dry\_tropo} + h_{iono}$$

$$\Delta H_{tide} = h_{ocean\_tide} + h_{solid\_earth\_tide} + h_{loading\_tide} + h_{pole\_tide}$$

$$\Delta H_{gp} = h_{inv\_bar} + h_{hf\_fluc}$$

- 4.2 Jason1-Ground Comparison of SSH

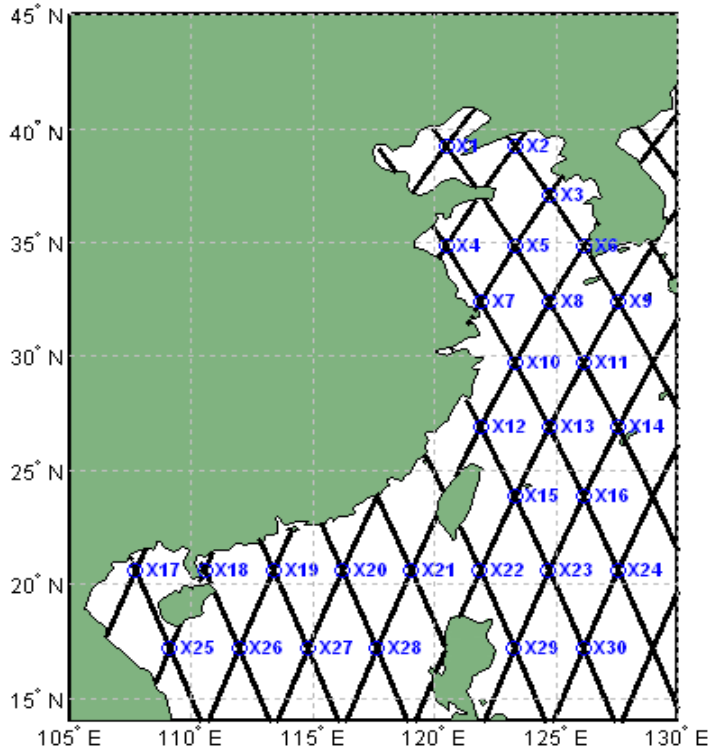
$$SSH = H_{alt} - H_{range} - \Delta H_{atm} - \Delta H_{ss} - \Delta H'_{tide}$$

$$\Delta H_{atm} = h_{wet\_tropo} + h_{dry\_tropo} + h_{iono}$$

$$\Delta H'_{tide} = h_{solid\_earth\_tide} + h_{loading\_tide} + h_{pole\_tide}$$

# 4 Results

## 4.1 Inter-comparison of Jason1 SLA at Crossover Points




distances to land<10km: 3
10km<distance to land<50km: 6
50km<distance to land<100km: 8
distance to land>100km: 13

| X no. | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 |
|---|---|---|---|---|---|---|---|---|---|---|
| PassA no. | 077 | 153 | 229 | 153 | 229 | 051 | 229 | 051 | 127 | 051 |
| PassD no. | 138 | 214 | 214 | 062 | 138 | 214 | 062 | 138 | 214 | 062 |
| Latitude (N) | 39.22 | 39.22 | 37.1 | 34.83 | 34.83 | 34.83 | 32.37 | 32.37 | 32.37 | 29.73 |
| Longitude (E) | 120.48 | 123.31 | 124.73 | 120.48 | 123.31 | 126.14 | 121.9 | 124.73 | 127.56 | 123.31 |
| Distance (km) | 52.02 | 17.81 | 71.92 | 60.17 | 171.23 | 41.05 | 165.79 | 84.11 | 59.97 | 290.05 |
| X no. | X11 | X12 | X13 | X14 | X15 | X16 | X17 | X18 | X19 | X20 |
| PassA no. | 127 | 051 | 127 | 203 | 127 | 203 | 001 | 077 | 153 | 229 |
| PassD no. | 138 | 240 | 062 | 138 | 240 | 062 | 038 | 114 | 190 | 012 |
| Latitude (N) | 29.73 | 26.89 | 26.89 | 26.89 | 23.86 | 23.86 | 20.61 | 20.61 | 20.61 | 20.61 |
| Longitude (E) | 126.15 | 121.9 | 124.73 | 127.56 | 123.3 | 126.13 | 107.71 | 110.54 | 113.37 | 116.2 |
| Distance (km) | 99.25 | 111.49 | 25.73 | 1.55 | 44.54 | 116.10 | 27.89 | 6.13 | 120.82 | 53.52 |
| X no. | X21 | X22 | X23 | X24 | X25 | X26 | X27 | X28 | X29 | X30 |
| PassA no. | 051 | 127 | 203 | 025 | 077 | 153 | 229 | 051 | 203 | 025 |
| PassD no. | 088 | 164 | 240 | 062 | 038 | 114 | 190 | 012 | 164 | 240 |
| Latitude (N) | 20.61 | 20.61 | 20.61 | 20.61 | 17.19 | 17.19 | 17.19 | 17.19 | 17.19 | 17.19 |
| Longitude (E) | 119.03 | 121.86 | 124.69 | 127.52 | 109.12 | 111.95 | 114.78 | 117.61 | 123.27 | 126.1 |
| Distance (km) | 228.11 | 4.47 | 273.76 | 502.87 | 116.88 | 35.30 | 224.98 | 250.76 | 79.73 | 380.27 |

# 4 Results

## 4.1 Inter-comparison of Jason1 SLA at Crossovers

| Distance | | Ocean | Ice2 | OCOG | Sea Ice |
|---|---|---|---|---|---|
| d(3)<10km | N | 1.6% | 0.0% | 19.4% | 19.4% |
| | bias (m) | 0.050 | NaN | 0.823 | 0.814 |
| | rms (m) | 0.050 | NaN | 1.179 | 1.286 |
| | std (m) | 0.000 | NaN | 0.845 | 0.995 |
| 10km<d(6)<50km | N | 90.3% | 6.9% | 74.2% | 90.3% |
| | bias (m) | 0.184 | 0.875 | 0.194 | 0.178 |
| | rms (m) | 0.417 | 1.328 | 0.951 | 0.395 |
| | std (m) | 0.375 | 0.998 | 0.931 | 0.353 |
| 50km<d(8)<100km | N | 92.3% | 9.3% | 81.5% | 93.1% |
| | bias (m) | 0.037 | 0.892 | 0.158 | 0.037 |
| | rms (m) | 0.232 | 1.086 | 0.895 | 0.326 |
| | std (m) | 0.229 | 0.620 | 0.880 | 0.324 |
| d(13)>100km | N | 92.6% | 8.2% | 79.9% | 92.3% |
| | bias (m) | 0.084 | 0.764 | 0.148 | 0.110 |
| | rms (m) | 0.238 | 1.106 | 0.730 | 0.286 |
| | std (m) | 0.223 | 0.794 | 0.714 | 0.263 |

$$bias = \frac{1}{N}\sum_{i=1}^{N}\left(SLA^{i}_{a} - SLA^{i}_{d}\right)$$

$$rms = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(SLA^{i}_{a} - SLA^{i}_{d}\right)^{2}}$$

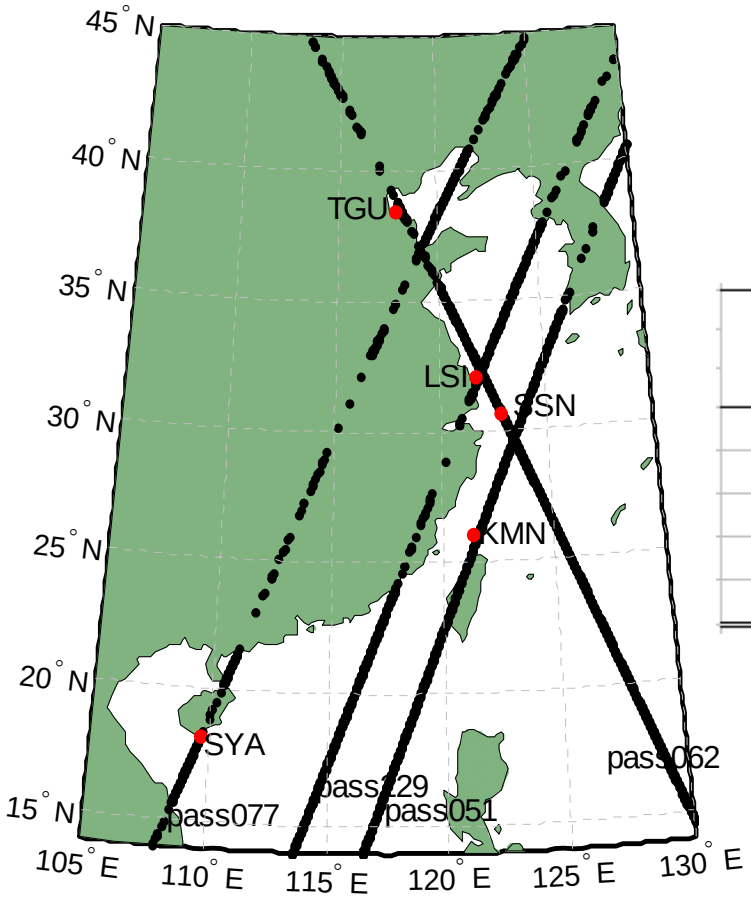
$$std = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(SLA^{i}_{a} - SLA^{i}_{d} - bias\right)^{2}}$$

$$N : -2.5m < SLA < 2.5m$$

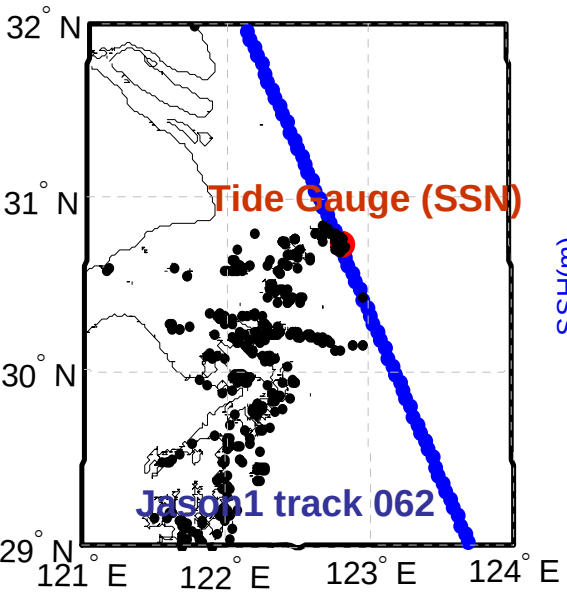
- The distance to the nearest land is larger than 50km: Ocean retracker is most accurate. However, the rms and std of the Ocean retracker is around 0.23m. The reason could be the 20Hz data is used instead of the 1Hz data.
- The distance is less than 50km: the successful retracking results of Ocean algorithm decrease significantly compared to OCOG and Threshold algorithms. The rms and std of OCOG algorihtm is lower than Threshold algorithm.

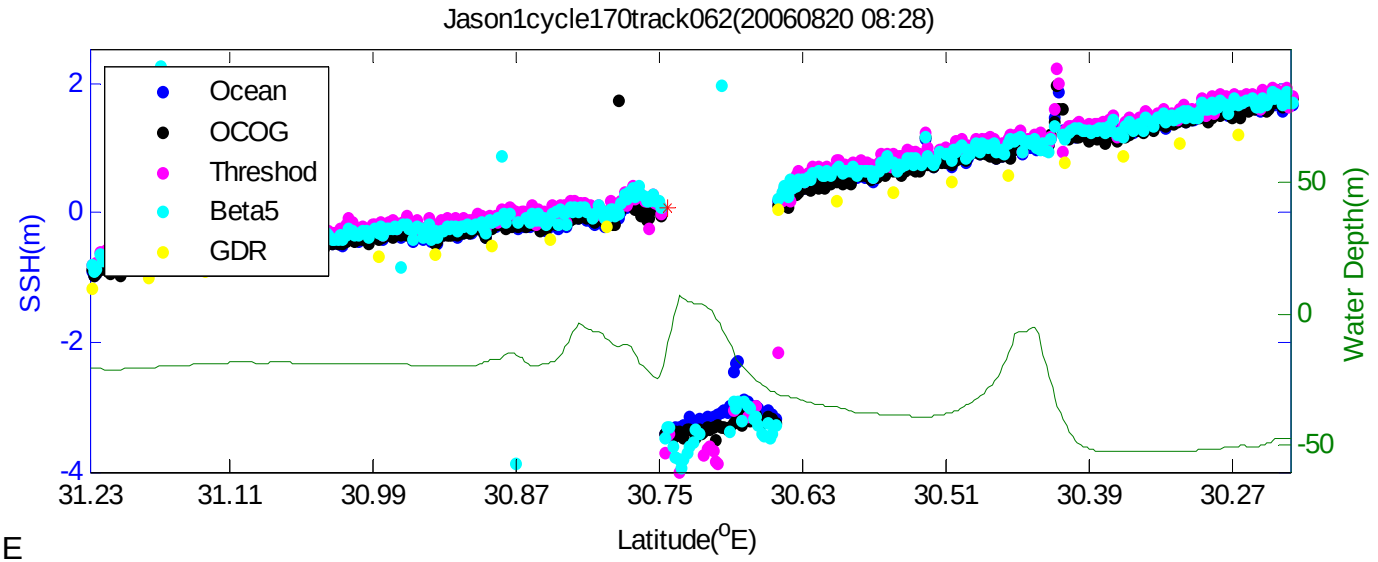
# 4 Results

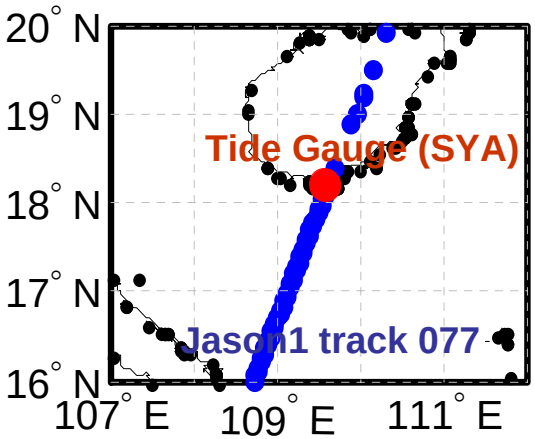
## 4.2 Jason1-Ground Comparison of SSH

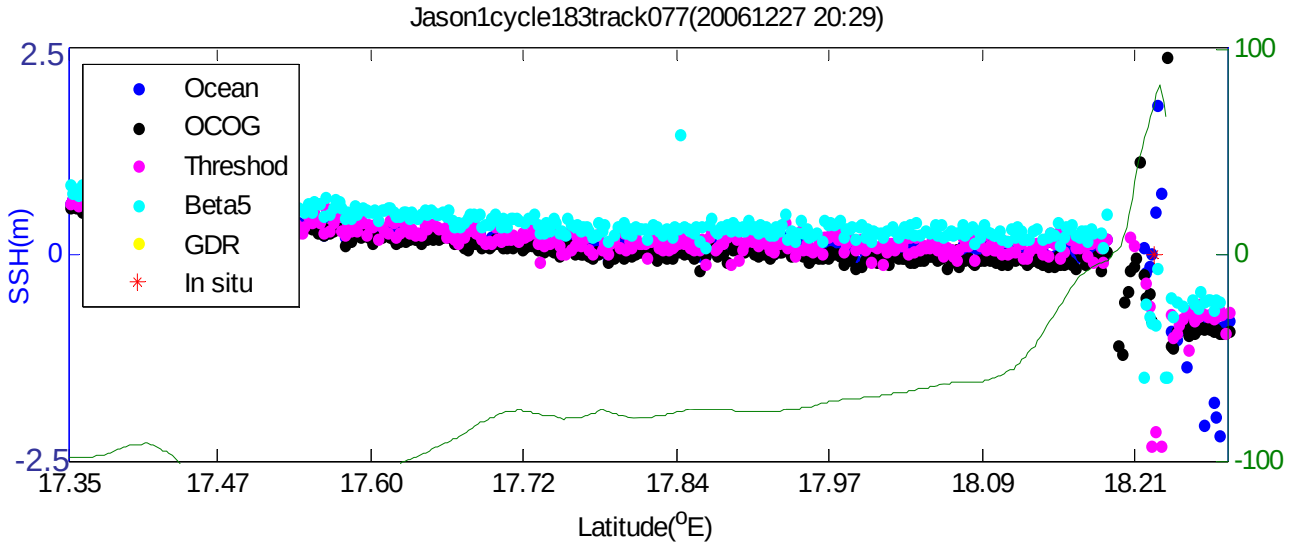


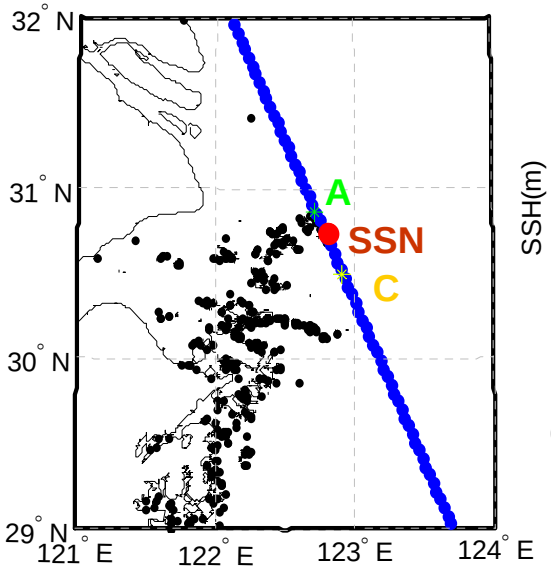

| Name | Latitude (°N) | Longitude (°E) | Distance to Land (km) | Jason1 track No. | Distance to Jason1 track (km) |
|---|---|---|---|---|---|
| SSN | 30.75 | 122.8 | 1.897 | 062 | 4.08 |
| KMN | 26.08 | 121.28 | 83.792 | 051 | 19.63 |
| TGU | 38.55 | 117.82 | 17.858 | 062 | 21.39 |
| LSI | 32.13 | 121.62 | 5.754 | 077 | 34.28 |
| SYA | 18.23 | 109.53 | 0.053 | 138 | 3.73 |

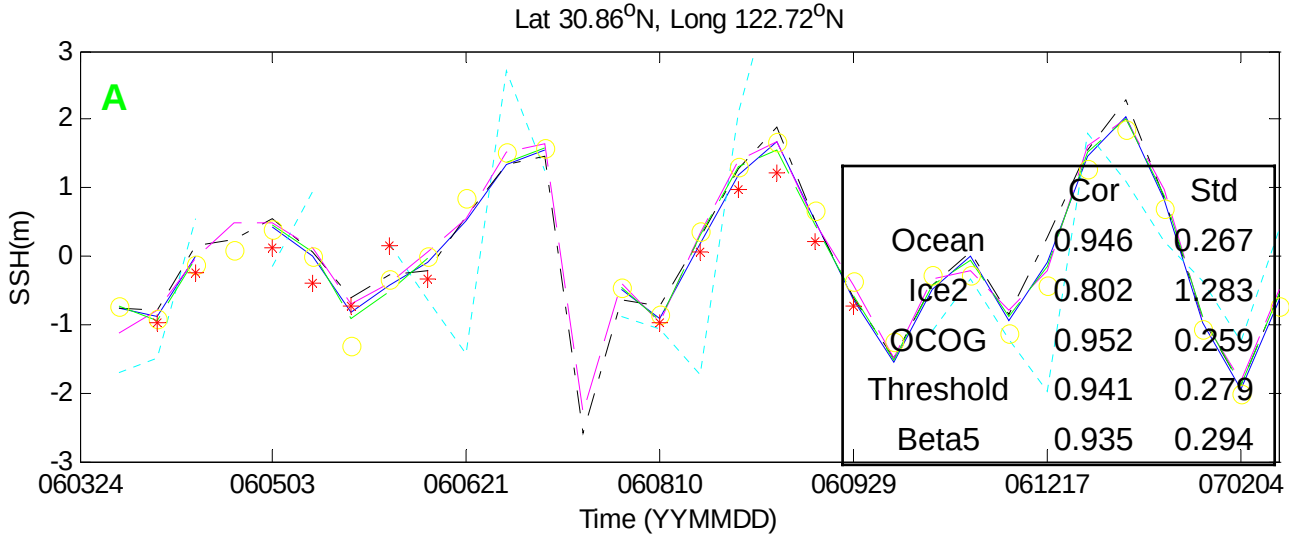

32° N
31° N
30° N
29° N
121° E
122° E
123° E
124° E
Tide Gauge (SSN)
Jason1 track 062

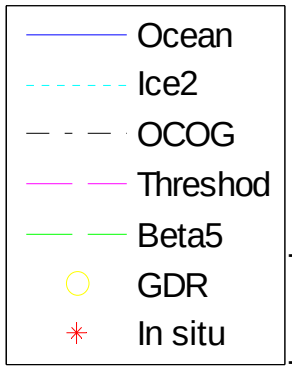

Jason1cycle170track062(20060820 08:28)
Ocean
OCOG
Threshod
Beta5
GDR
SSH(m)
Water Depth(m)
Latitude(°E)
31.23
31.11
30.99
30.87
30.75
30.63
30.51
30.39
30.27

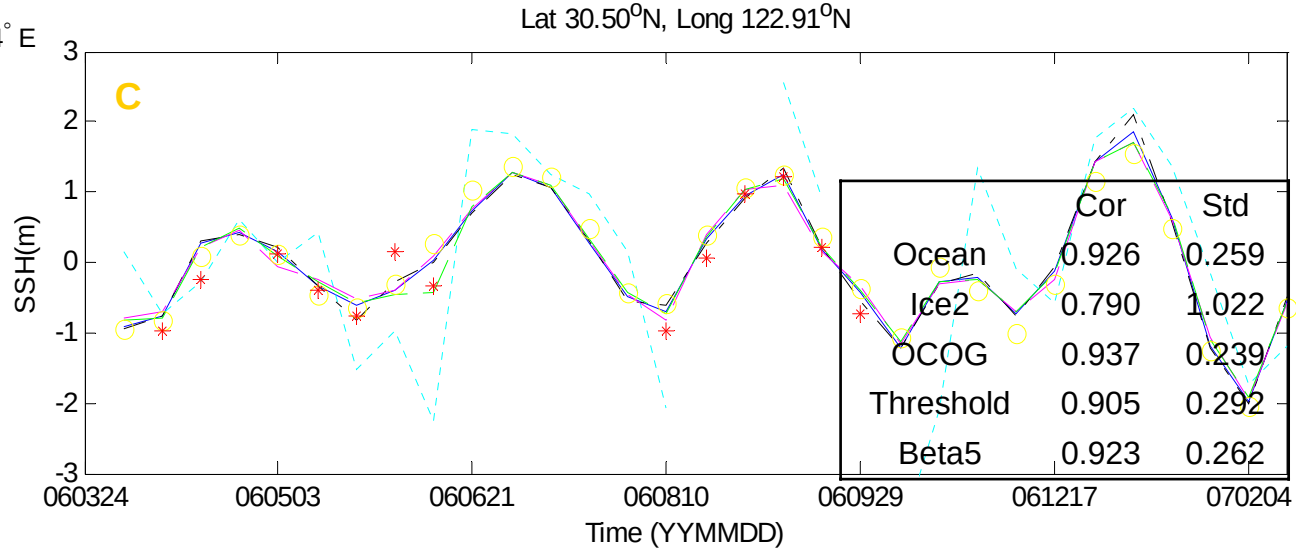

20° N
19° N
18° N
17° N
16° N
107° E
109° E
111° E
Tide Gauge (SYA)
Jason1 track 077

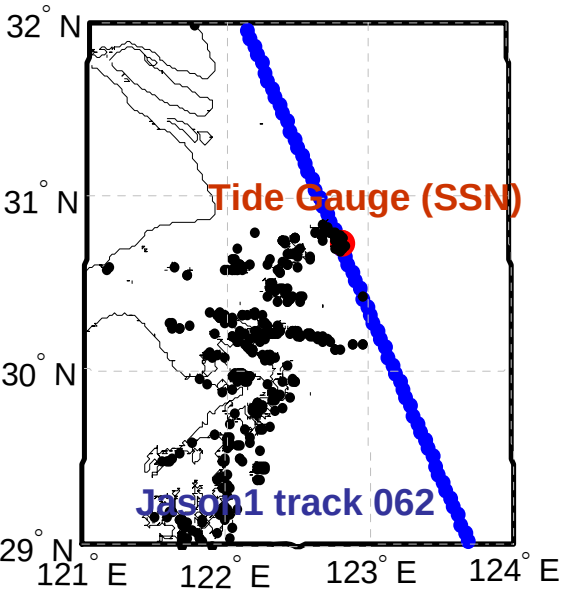

Jason1cycle183track077(20061227 20:29)
Ocean
OCOG
Threshod
Beta5
GDR
In situ
SSH(m)
Water Depth(m)
Latitude(°E)
17.35
17.47
17.60
17.72
17.84
17.97
18.09
18.21


32° N
31° N
30° N
29° N
121° E
122° E
123° E
124° E
A
SSN
C

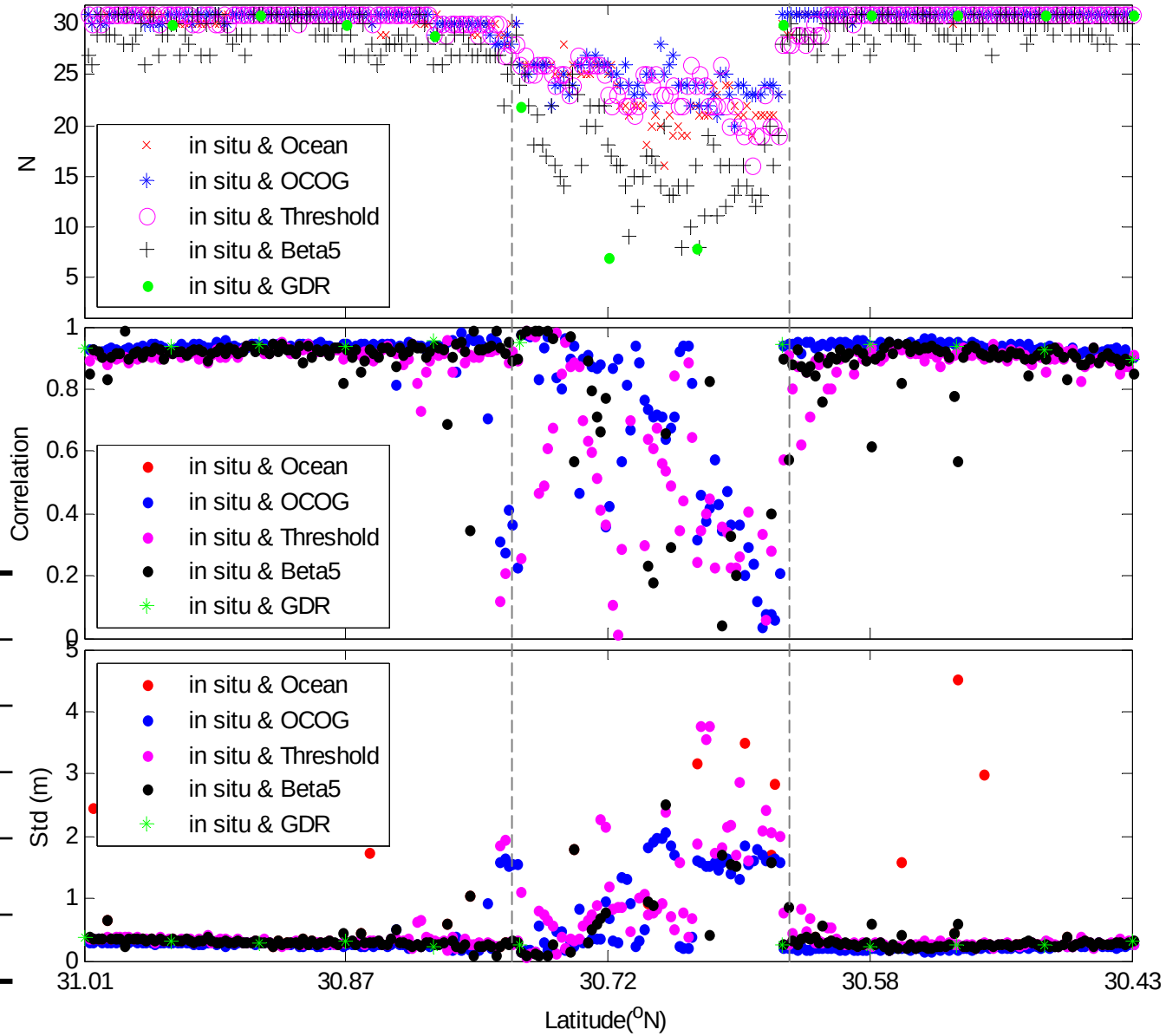

Lat 30.86°N, Long 122.72°N
A
SSH(m)
Time (YYMMDD)
060324
060503
060621
060810
060929
061217
070204
Cor
Std
Ocean 0.946 0.267
Ice2 0.802 1.283
OCOG 0.952 0.259
Threshold 0.941 0.279
Beta5 0.935 0.294


Ocean
Ice2
OCOG
Threshod
Beta5
GDR
In situ


Lat 30.50°N, Long 122.91°N
C
SSH(m)
Time (YYMMDD)
060324
060503
060621
060810
060929
061217
070204
Cor
Std
Ocean 0.926 0.259
Ice2 0.790 1.022
OCOG 0.937 0.239
Threshold 0.905 0.292
Beta5 0.923 0.262




| | N(31) | Cor | Std |
|---|---|---|---|
| Ocean | 30.7 | 0.899 | 0.336 |
| Ice2 | 27 | 0.431 | 1.257 |
| OCOG | 30.7 | 0.889 | 0.355 |
| Thres-hold | 30.7 | 0.868 | 0.387 |
| Beta5 | 29.1 | 0.877 | 0.372 |



# Conclusions

- The altimetry sea surface heights are unusable where the distance to land is 50 to 100 km. However, the distance where the altimeter measurement itself is affected is only around 10 km to land.
- Coastal ocean return waveforms do not conform to the Brown model as the coast is approached (~10km).
- By employing retracking algorithm with 20 Hz waveform, higher sampling ratio data can be derived (but noisy).
- The Ocean algorithm is the most accurate when the distance of altimeter nadir measured point is more than 10 km from the nearest land. But the standard Ocean fitting algorithm cannot be used in the coastal altimeter waveform processing.
- Among the four retracking algorithms, OCOG retracking algorithm is appropriate considering both the accuracy and valid result percentage of the Jason1 SLA crossover inter-comparisons and Jason1-in situ SSH comparisons.

# 5. Work under way

- Further validate the retracking algorithms with longer term in situ data.
- Waveform recognition and extraction.
- Jason1-Ground Comparison of SWH.

$$\underline{\text{Corrected SWH}} = \underline{\text{SWH}} + \text{Instrument Correction}$$

- Analyse Multi-satellite data. (Jason1/ Jason2/Envisat RA2).

# Thank you!