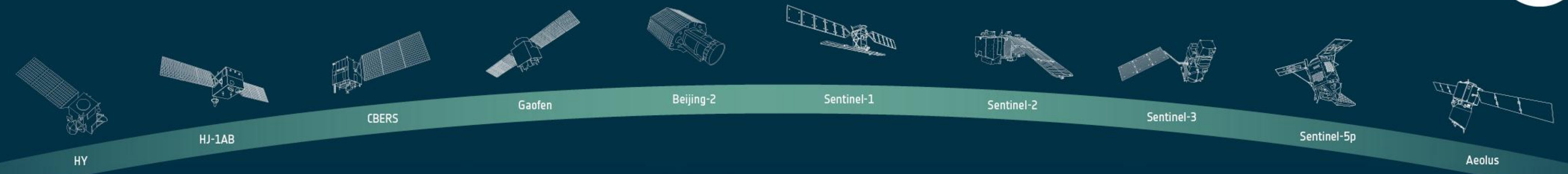


2022 DRAGON 5 SYMPOSIUM

MID-TERM RESULTS REPORTING

17-21 OCTOBER 2022

PROJECT ID. 59373

INVESTIGATION OF INTERNAL WAVES IN ASIAN SEAS USING EUROPEAN AND CHINESE SATELLITE DATA

DAY 2, 18 OCTOBER 2022
ID. 59373

PROJECT TITLE: INVESTIGATION OF INTERNAL WAVES IN ASIAN SEAS USING EUROPEAN AND CHINESE SATELLITE DATA

PRINCIPAL INVESTIGATORS: WERNER ALPERS, KAN ZENG

PRESENTED BY: KAN ZENG

The project ID 59573 have focused on:

1) Study of the effect of surface wave breaking on the radar imaging mechanism of internal waves

Magalhães et.al, 2021

2) Study on amplitude retrieval of internal waves from spaceborne SAR imagery based on an Euler Numerical Model and composite Bragg model.

ready to submit

3) Study on the temporal and spatial variation characteristics of internal waves in South China Sea with spaceborne SAR images.

EO Data Delivery

Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert "ftp"

ESA Third Party Missions	No. Scenes
1. TerraSAR-X	1
2. Radarsat-2	2
3.	
4.	
5.	
6.	
Total:	3
Issues:	

ESA Missions	No. Scenes
1. ERS-2/SAR	2
2. Envisat/ASAR	3
3. Sentinel-1/SAR	53
4.	
5.	
6.	
Total:	58
Issues:	

Chinese EO data	No. Scenes
1. GF3	10
2.	
3.	
4.	
5.	
6.	
Total:	10
Issues:	

Amplitude retrieval of internal waves from spaceborne SAR imagery based on an Euler numerical model and Composit Bragg model

Kan Zeng[1], Hengyu Li[1], Bingzhi He[1], Shuai Wang[1], Mingxia He[1], Werner Alpers [2]

[1] Ocean Remote Sensing Institute, Ocean University of China, Qingdao, China

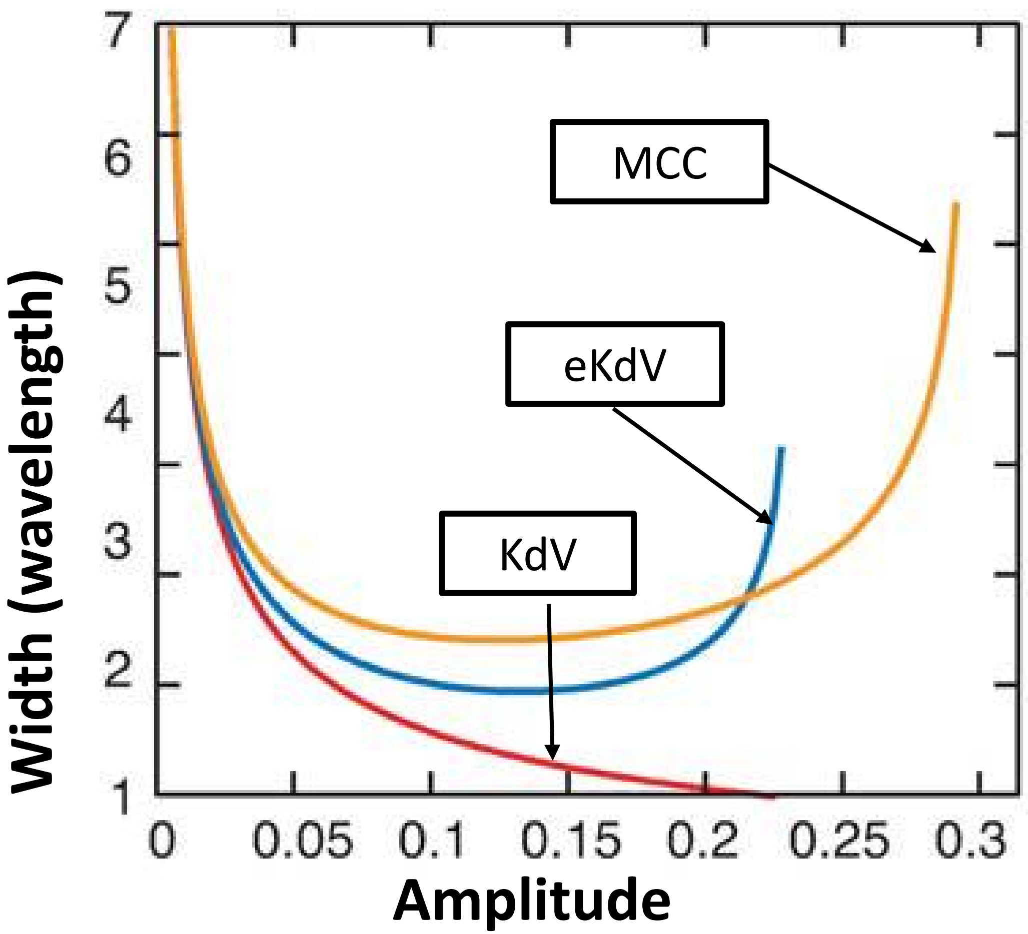
[2] Institute of Oceanography, University of Hamburg, Hamburg, Germany

Since long, attempts have been made to extract the amplitude of an internal solitary wave (ISW) from its width, which can be retrieved from SAR images.

According to the Korteweg-de Fries (KdV) equation, there is unique relationship between these two parameters.

However, the KdV equation does not apply for large-amplitude ISWs, better equations are the Extended KdV (eKdV) equation and the Miyata-Choi-Camassa (MCC) equations, which both give **not a unique relationship**, see next figure.

Relationship between wave amplitude and width of a soliton according to different soliton models



KdV = Korteweg - de Vries

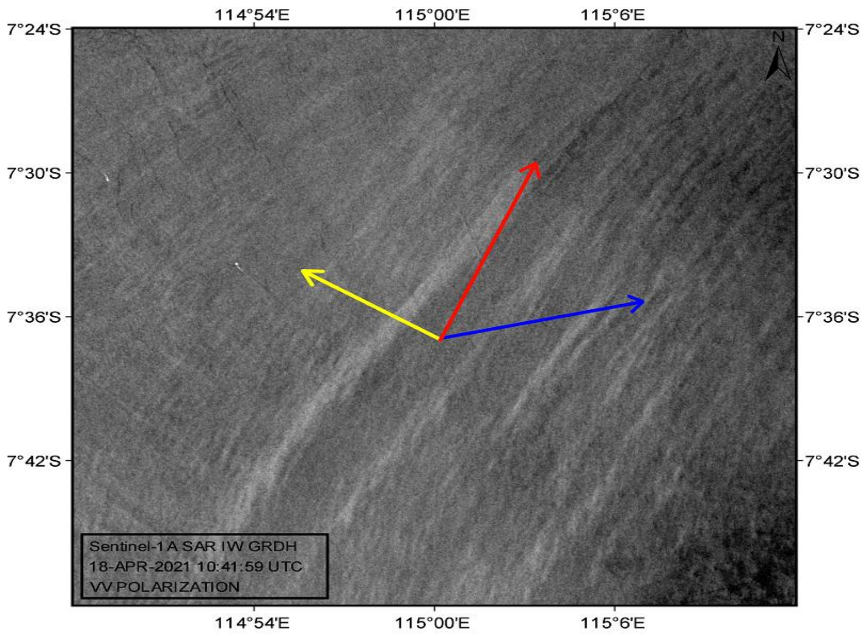
eKdV = extended KdV

MCC = Miyata-Choi-Camassa

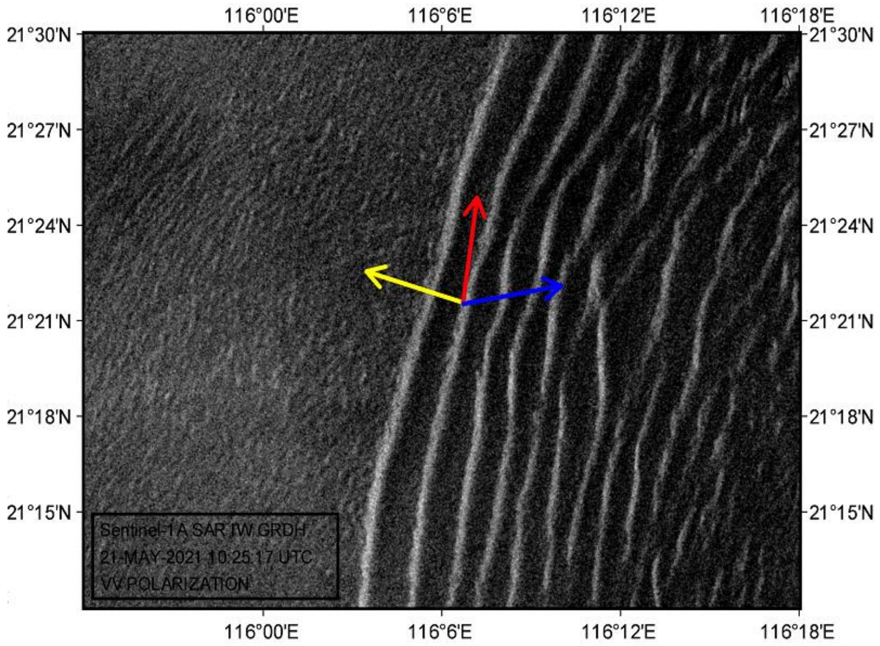
Helfrich and Melville, 2006

Simplified theory model such as Kdv, eKdv, mKdv, MCC assume the shape of each water layer is similar and has the same width. But the fact is that the width is different with layer depth.

So we choose numerical model instead of relatively simple theory model to simulate the internal wave for amplitude retrieval



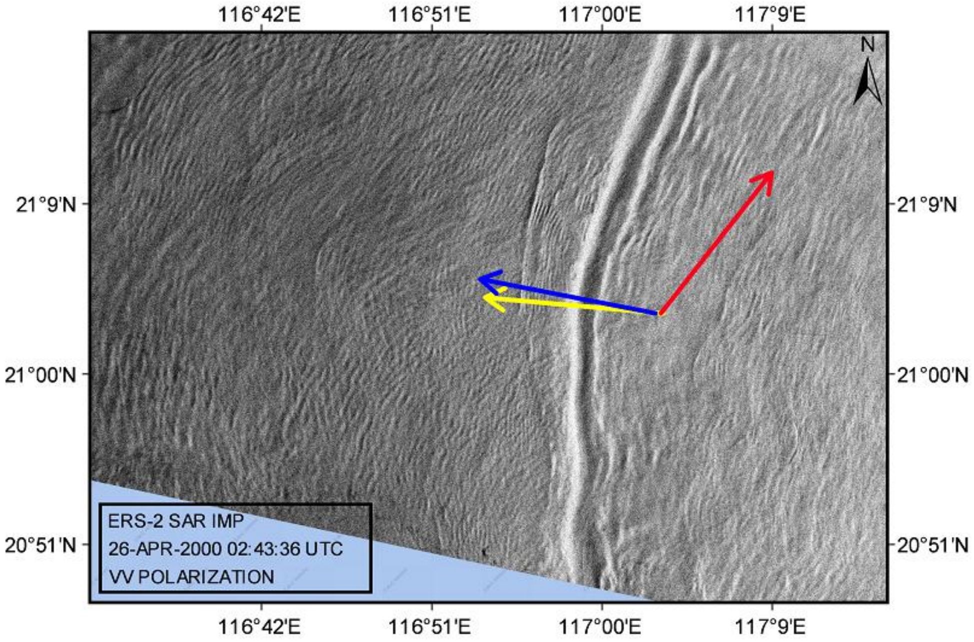
case 1

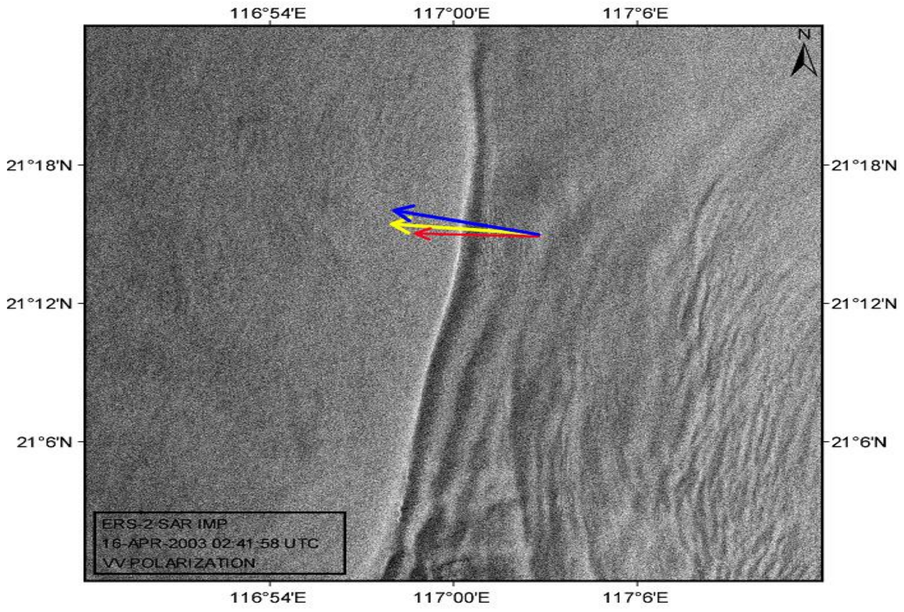


case 2

Yellow represents the internal wave propagation direction, red represents the wind direction, and blue represents look-direction of antenna.

left:the first event right :the second event （Sentinel-1A SAR)



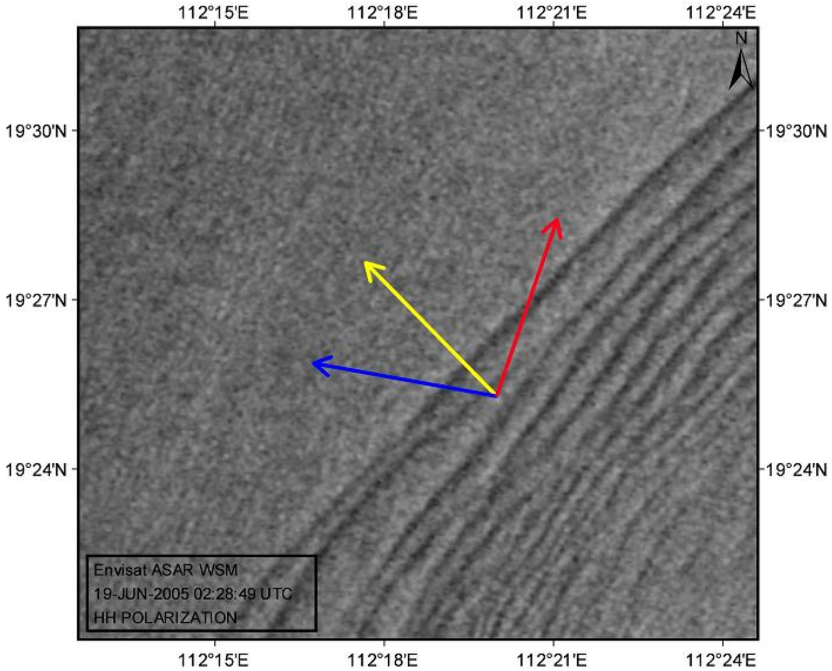


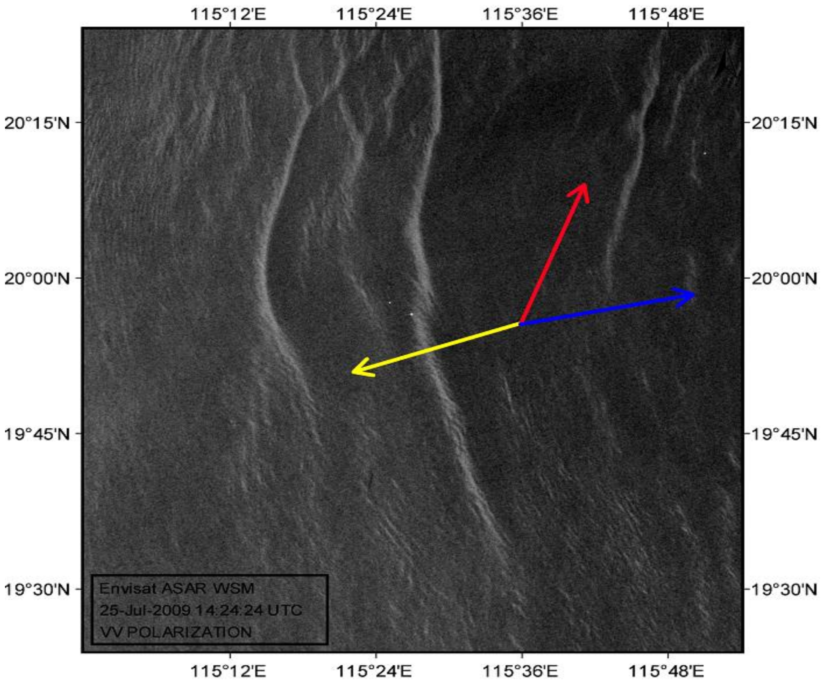
case 3

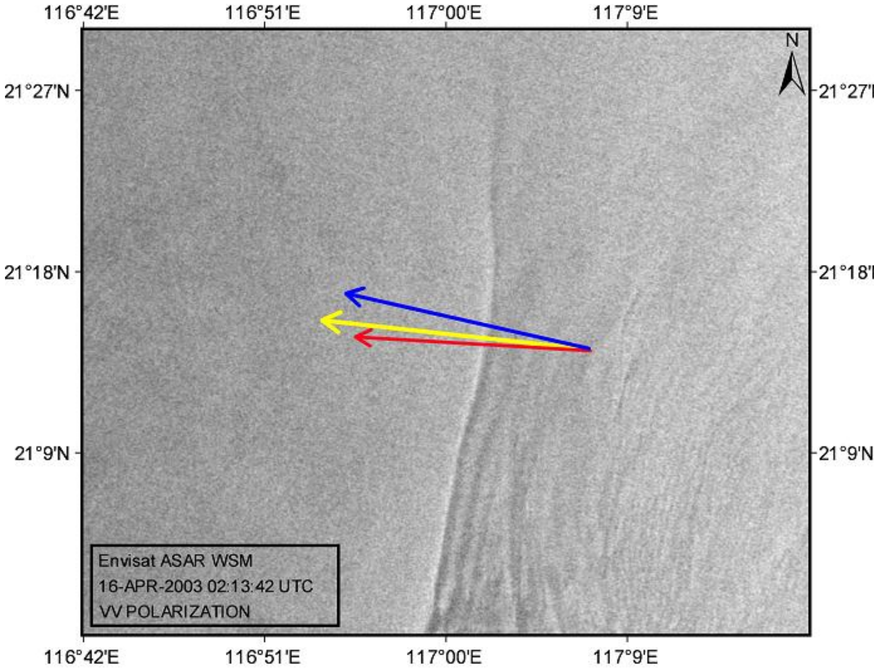
case 4

Yellow represents the internal wave propagation direction, red represents the wind direction, and blue represents look-direction of antenna.

left:the third event right :the fourth event (ERS-2 SAR)



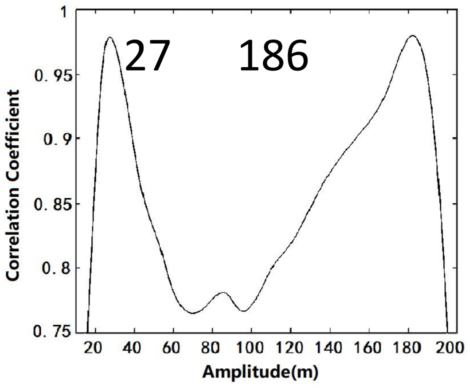


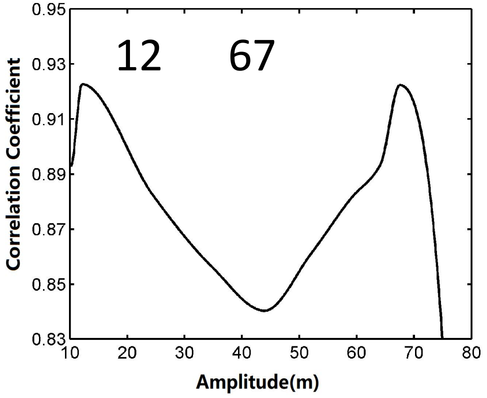


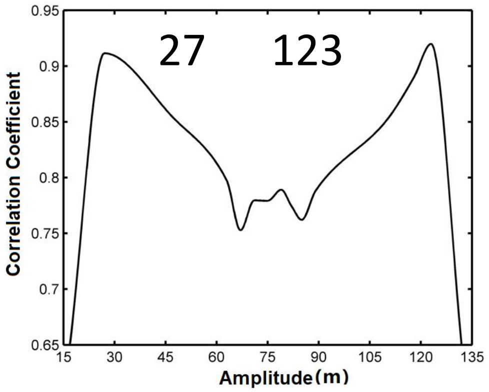
case 5 case 6 case 7

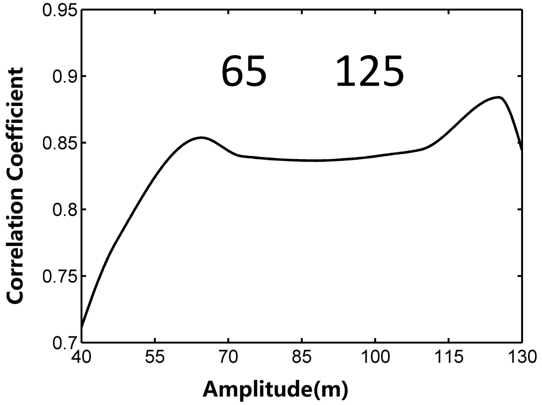
Yellow represents the internal wave propagation direction, red represents the wind direction, and blue represents look-direction of antenna.

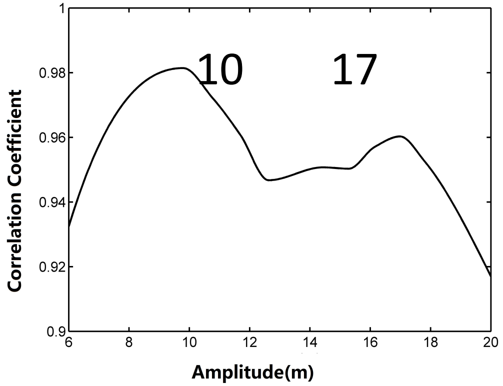
left:the fifth event(HH) middle :the sixth event right :the seventh event (Envisat ASAR)

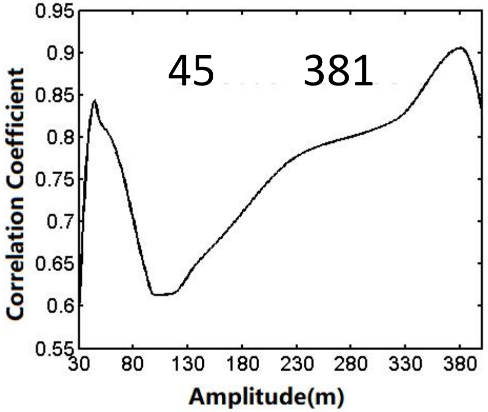

27
186
Correlation Coefficient
Amplitude(m)

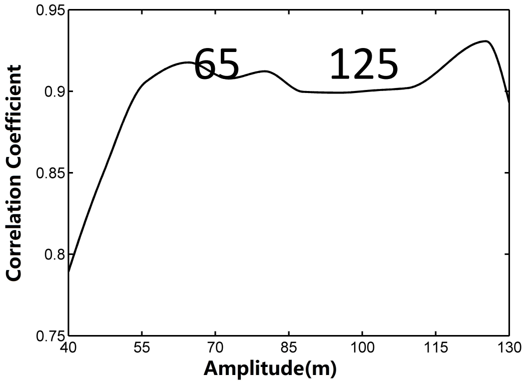

12
67
Correlation Coefficient
Amplitude(m)

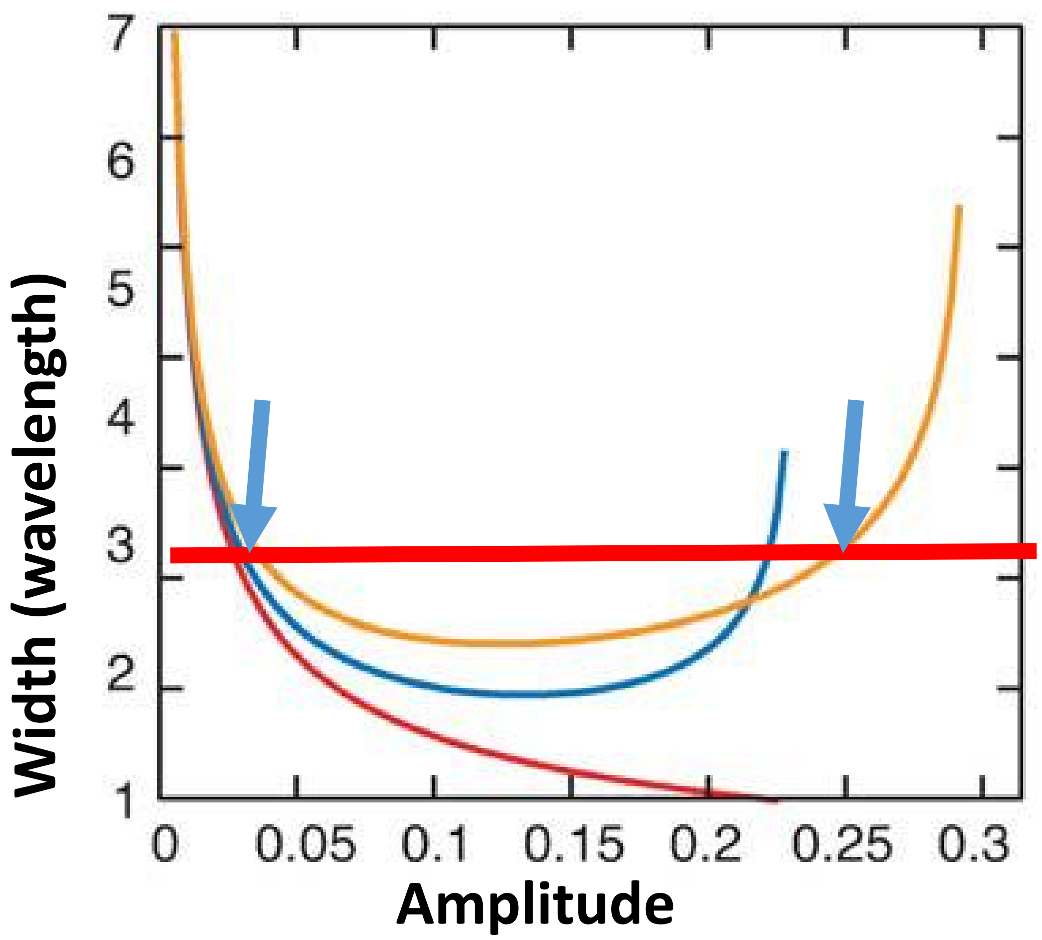

27
123
Correlation Coefficient
Amplitude(m)


65
125
Correlation Coefficient
Amplitude(m)


10
17
Correlation Coefficient
Amplitude(m)


45
381
Correlation Coefficient
Amplitude(m)


65
125
Correlation Coefficient
Amplitude(m)



For a given width, there is an ambiguity in the amplitude of the ISW.

Additional informatiom is needed

Simulate the modulation of Internal wave

Composite Bragg model is used to calculate the modulation of IW

$$\sigma_{0pq} = \int_{all\,facets} \sigma_0(\theta_i)$$

for each piece of sea surface facet

$$\sigma_{0\mathrm{pq}}(\theta_i) = \begin{cases} \sigma_{0\mathrm{GO}} & \theta_i < \theta_t \\ \sigma_{0\mathrm{pq}BG} & \theta_i \geq \theta_t \end{cases}$$

Geometric Optical

Bragg scattering

$$\sigma_{0BG} = 16\pi k^4 cos^4\theta_i G_{pq}(\theta_i, \boldsymbol{n}) W(2ksin\theta_i, \varphi - \varphi_w)$$

directional ocean wave spectrum

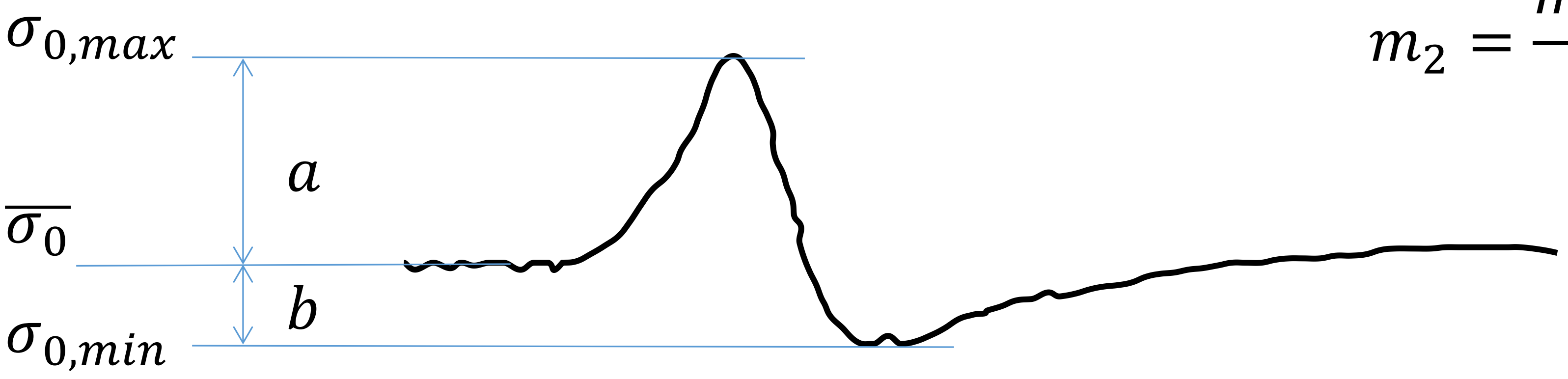
$$W(k_B, \varphi - \varphi_w) = \frac{1}{2\pi} k_B^{-4} B_h (1 + \Delta(k_B) cos(2(\varphi - \varphi_w))) + \frac{a}{2} k_B^{-4} cos^2(\varphi_{IW} - \varphi) \frac{\partial U_{IW}}{\partial x_\alpha}$$

background (Elfouhaily et al.1997)

modulation

sea surface current gradient

Measure the modulation of Internal wave from SAR imagery

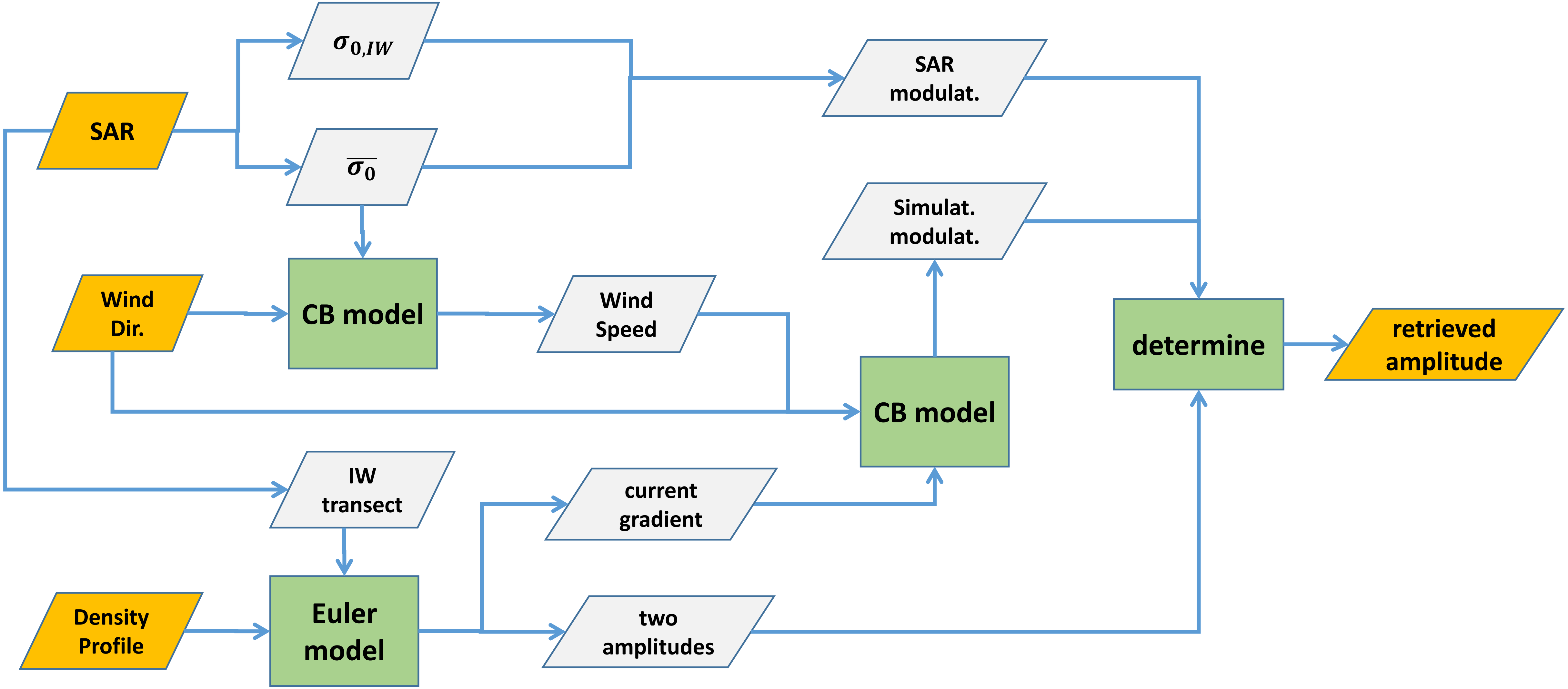


$$m_1 = \frac{a+b}{\overline{\sigma_0}}$$

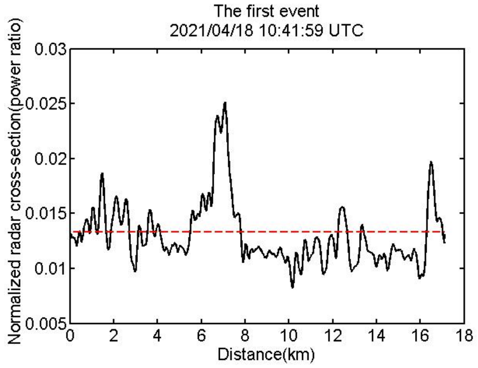
$$m_2 = \frac{max(a,b) \times 1.5}{\overline{\sigma_0}}$$

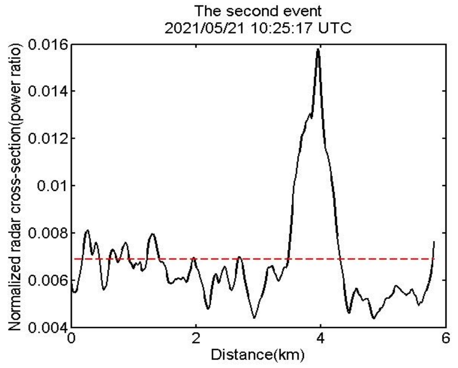
$$m_{SAR} = max(m_1, m_2)$$

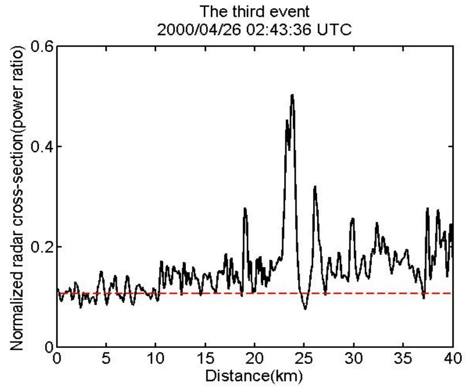
Algorithm flow chart of internal wave amplitude retrieval from SAR imagery

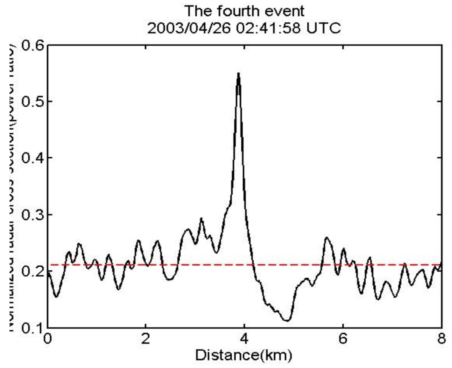


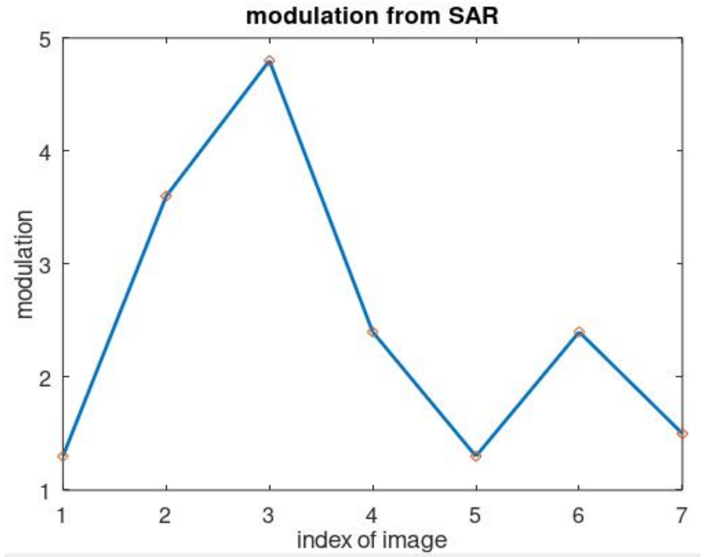
Internal wave transects extracted from SAR image

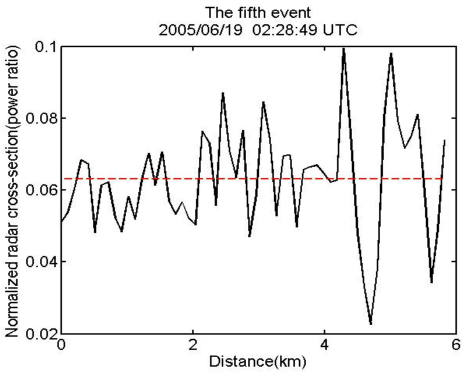


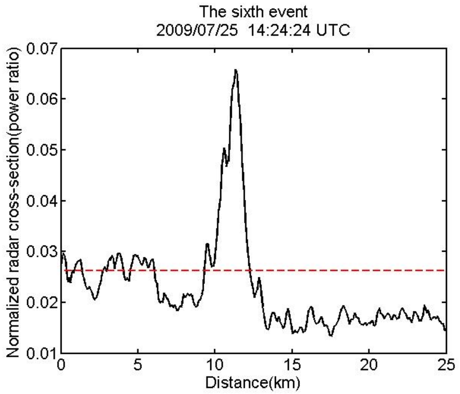


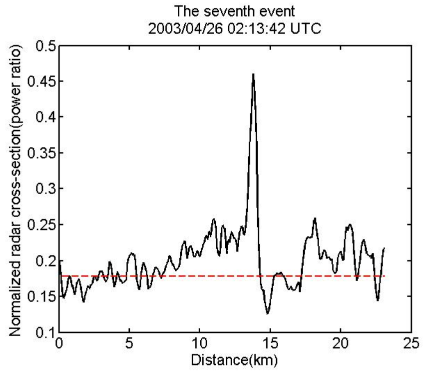




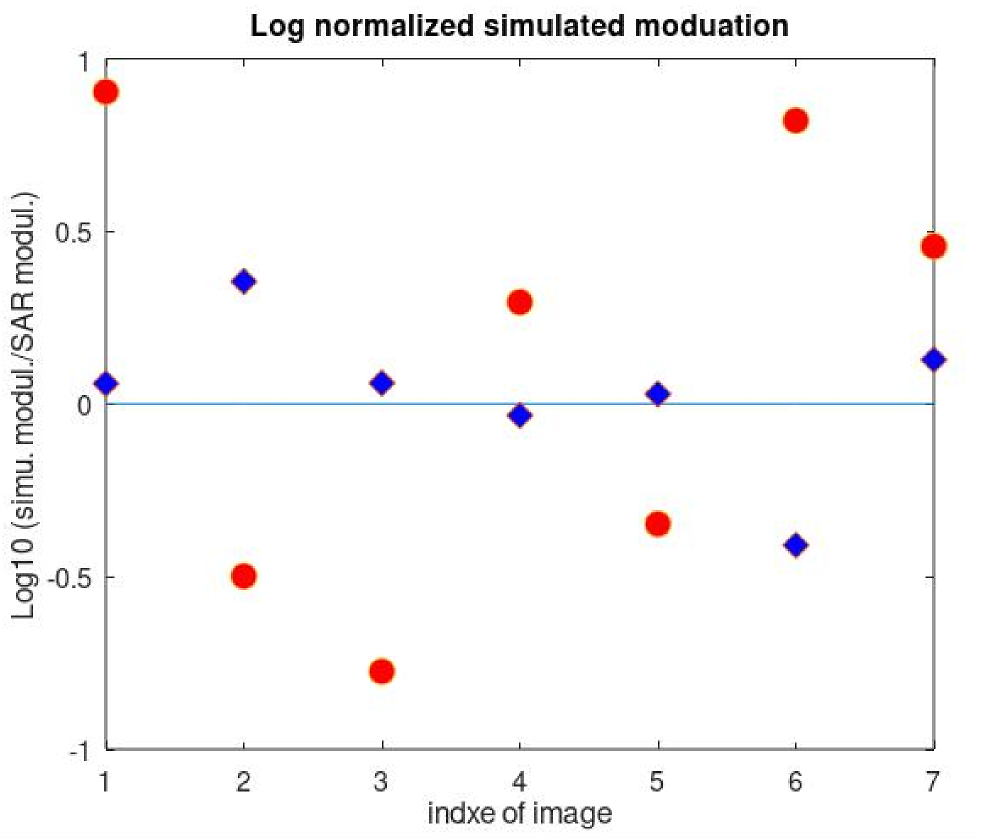






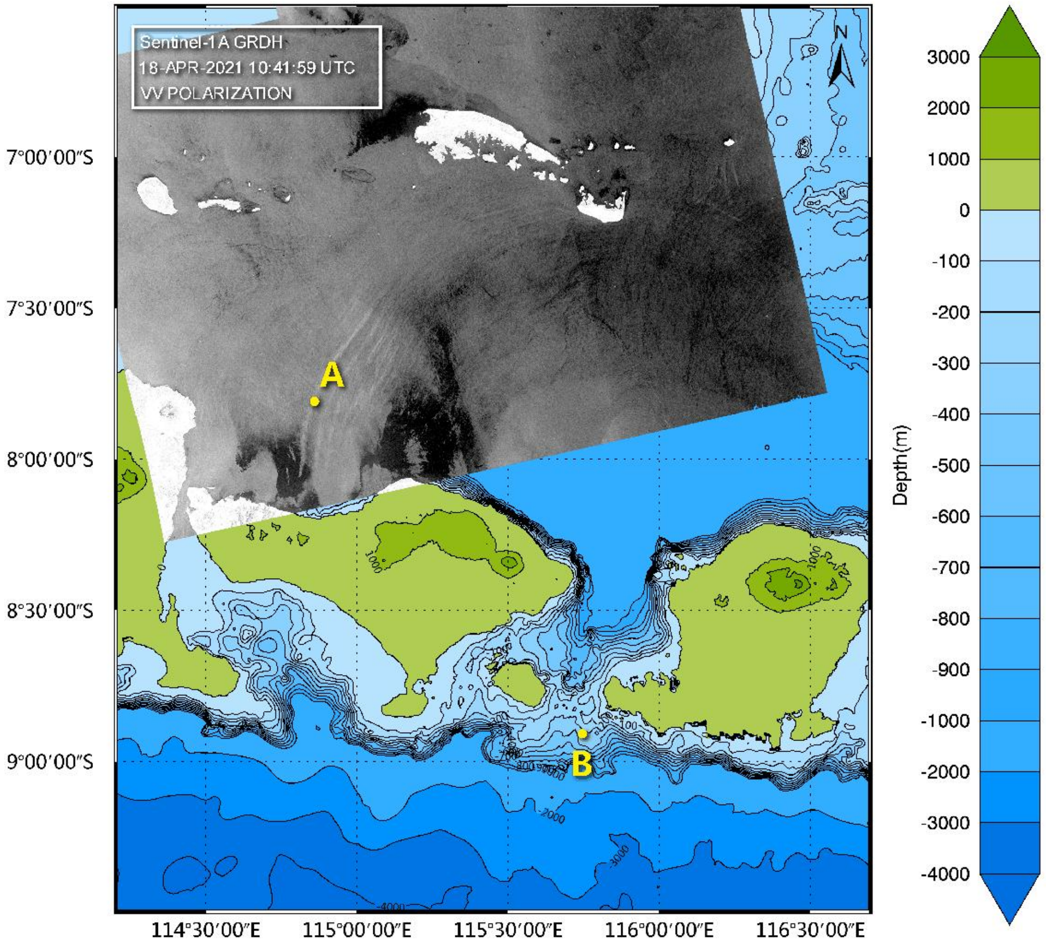


$$m_{norm} = log_{10}\left(\frac{m_{sim}}{m_{SAR}}\right)$$



amplitude obtained by runing Euler model

index	small	large	in-situ	
1	27	186		
2	12	67		
3	27	123	>100	Liu et al.,2004
4	65	125	70	Hsu et al.,2004
5	10	17	18	Zhang et al.,2016
6	45	381	50	Wang et al.,2015
7	65	125	70	Hsu et al.,2004

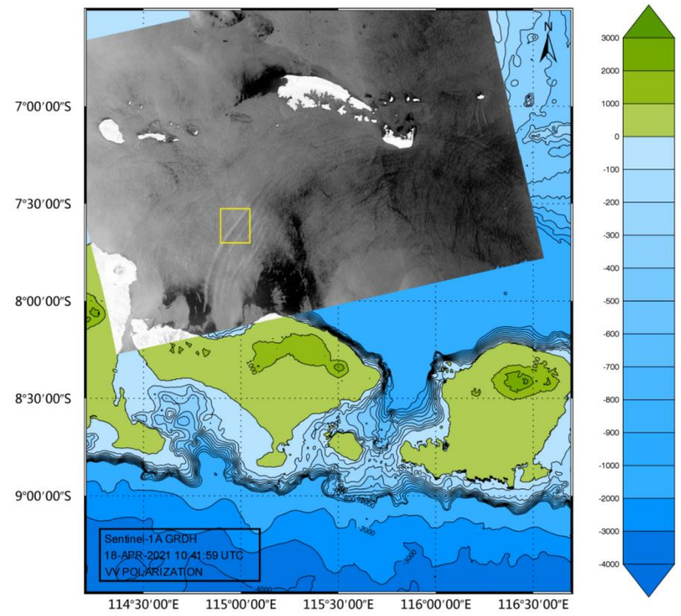


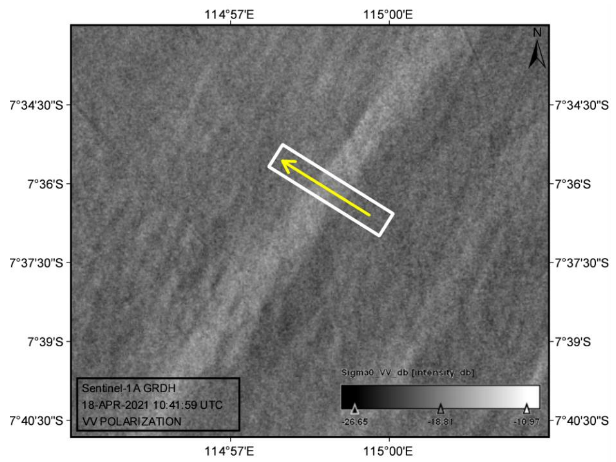
18, April, 202110:41:59 UTC

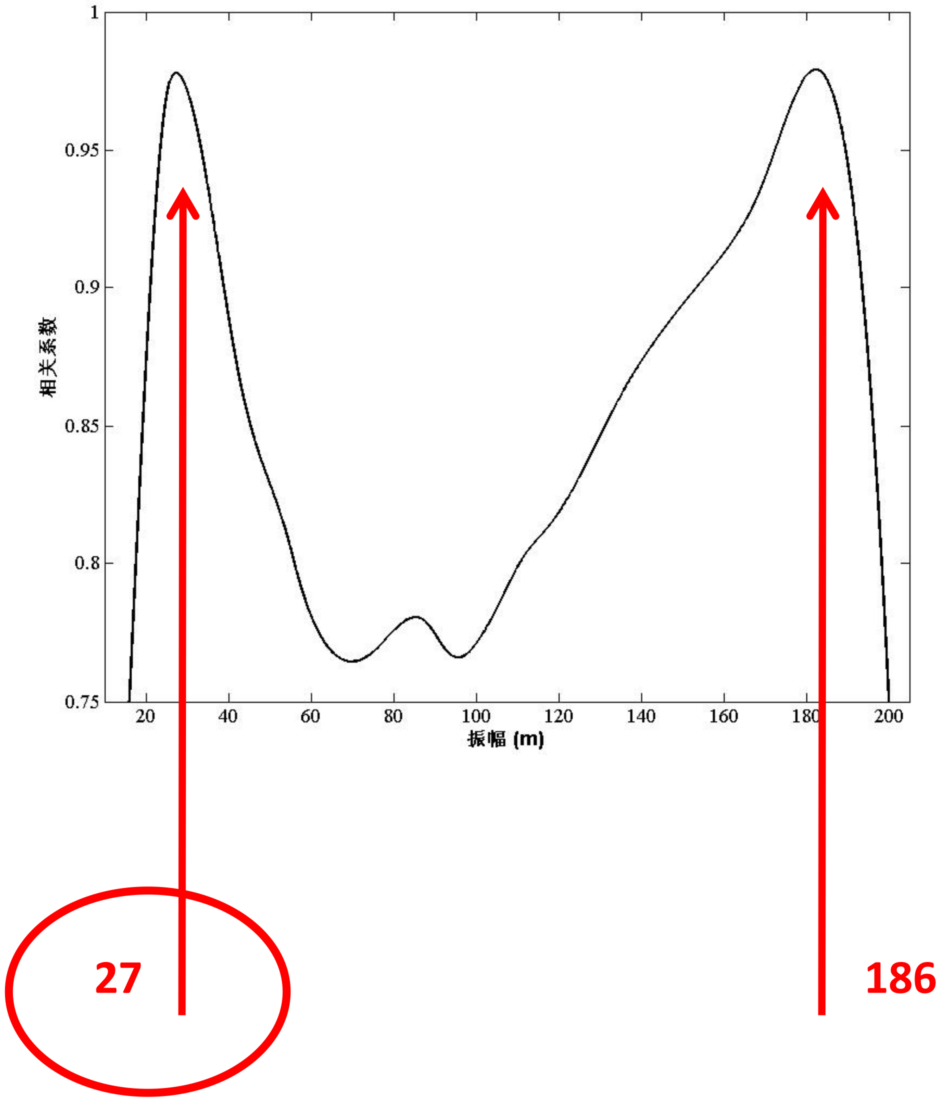
SAR in Bali Sea

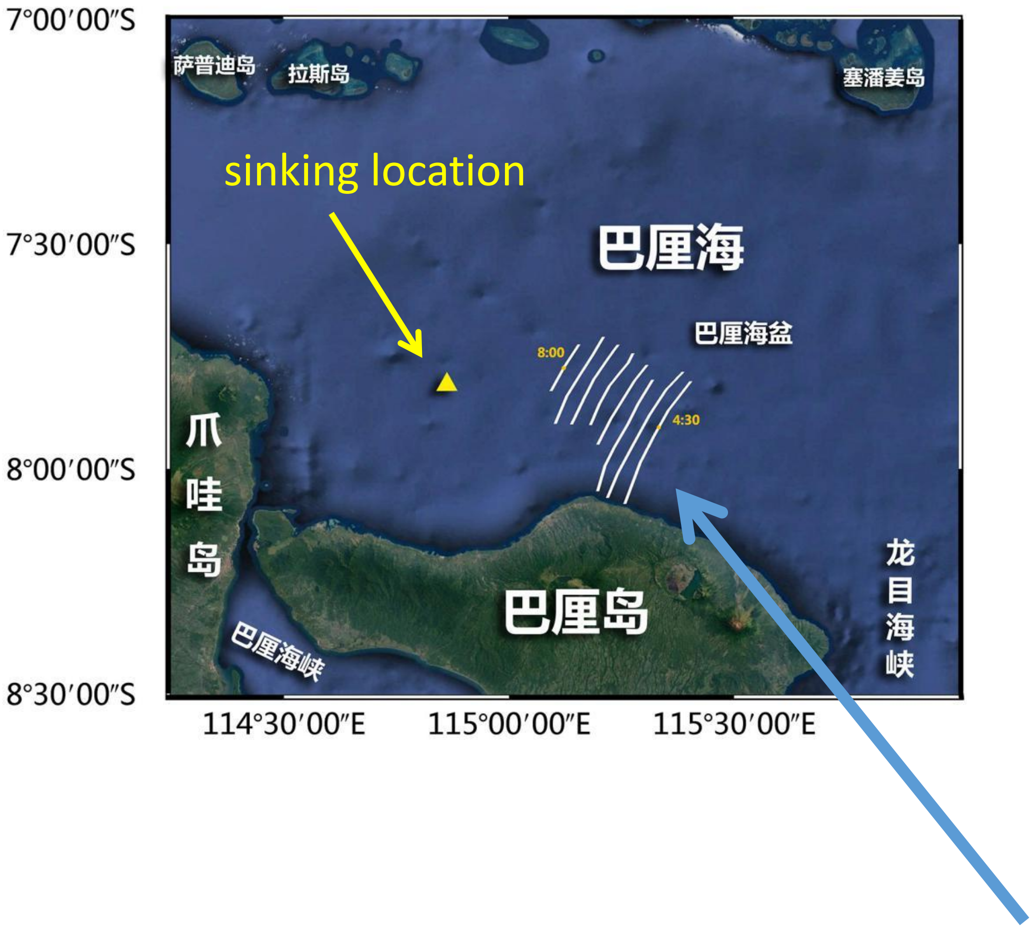
A： location of sinking event
B： Lombok strait

Sinking event of Indonesia Submarine Nangala
20, April, 2021 20:00-21:00 UTC


7°00'00"S
7°30'00"S
8°00'00"S
8°30'00"S
9°00'00"S
114°30'00"E
115°00'00"E
115°30'00"E
116°00'00"E
116°30'00"E
Sentinel-1A GRDH
18-APR-2021 10:41:59 UTC
VV POLARIZATION


114°57'E
115°00'E
7°34'30"S
7°36'S
7°37'30"S
7°39'S
7°40'30"S
Sentinel-1A GRDH
18-APR-2021 10:41:59 UTC
VV POLARIZATION


相关系数
振幅 (m)
27
186



IW speed
meaured by Himawari-8
2.35 m/s

phase velocity correspoinding
to **small** amplitude
2.38 m/s

phase velocity correspoinding
to **large** amplitude
3.26 m/s

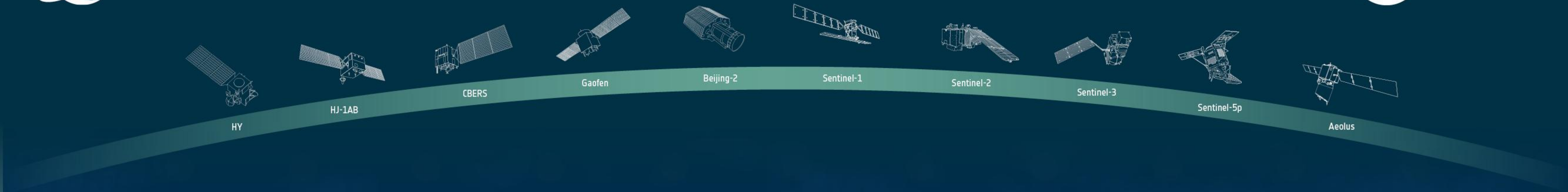
Internal wave tracked by the Japanese stationary weather satellite Himawari-8 every 30-minutes.

index	small	large	in-situ	
1	27	186		1.3%
2	12	67		N/A
3	27	123	>100	N/A
4	65	125	70	7.1%
5	10	17	18	5.6%
6	45	381	50	10%
7	65	125	70	7.1%

6.6%

Summary

- A SAR intenral wave amplitude retrieval algorithm is proposed. It uses an Eurler model to obtain two amplitude candidates and uses the composite Bragg model for SAR imaging sea surface to choose the final result out of the two amplitudes.
- 5 case studies show the proposed algorithm may obtain amplitudes from SAR imagey with relative error less than 10%.
- More experiments are needed to verify the general applicability of the algorithm.


HY
HJ-1AB
CBERS
Gaofen
Beijing-2
Sentinel-1
Sentinel-2
Sentinel-3
Sentinel-5p
Aeolus

Thank you!