The altimetry-derived gravity field for resolving hidden geological features around Taiwan

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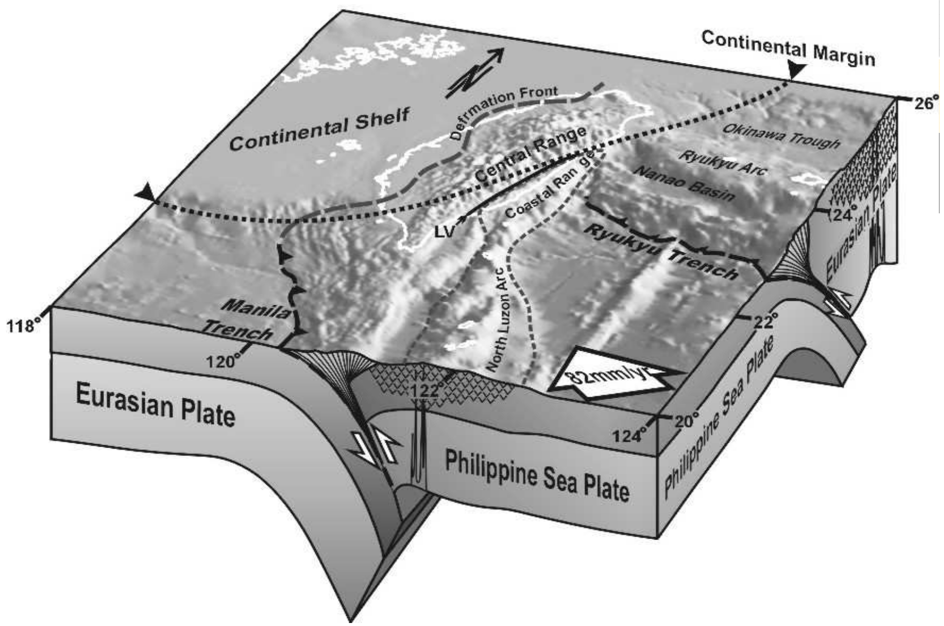
Outline

- Background
- Retracking Jason-1 GM waveforms
  - The sub-waveform retracker
  - Retracking performance
- Gravity field recovery and assessment
- Conclusions

Background

- Accurate marine gravity data can help to understand detailed seafloor tectonics.
- The accuracy of the global marine gravity has been greatly improved from CryoSat-2 and Jason-1 GM (Sandwell *et al*. 2014, Science)
  - ~1-2 mGal over deep oceans
  - ~10 mGal in coastal zones and high mesoscale variability areas
- The new global marine gravity is able to reveal buried tectonic structures, and will lead to more discoveries of tectonic features.
- The challenge remains in coastal areas
  - Distorted altimeter waveforms exist
  - SSH cannot be converted to gravity at a coastal point unless land gravity is also known.

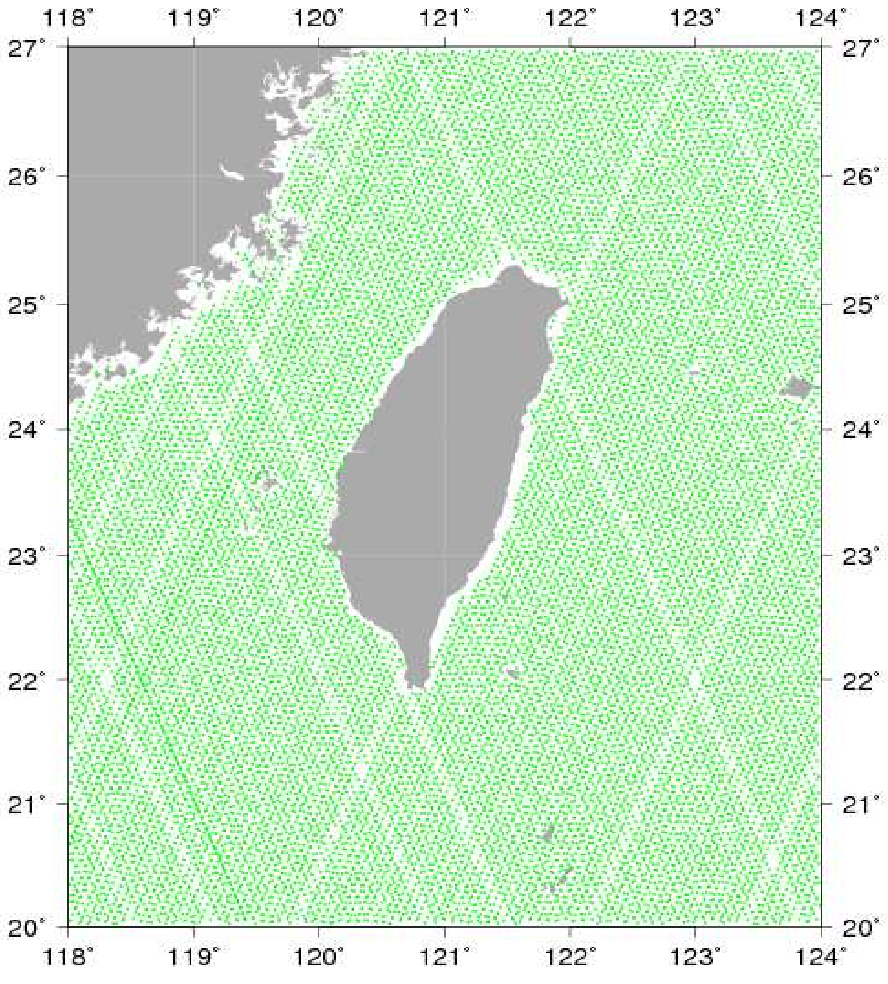
Background (Cont.)

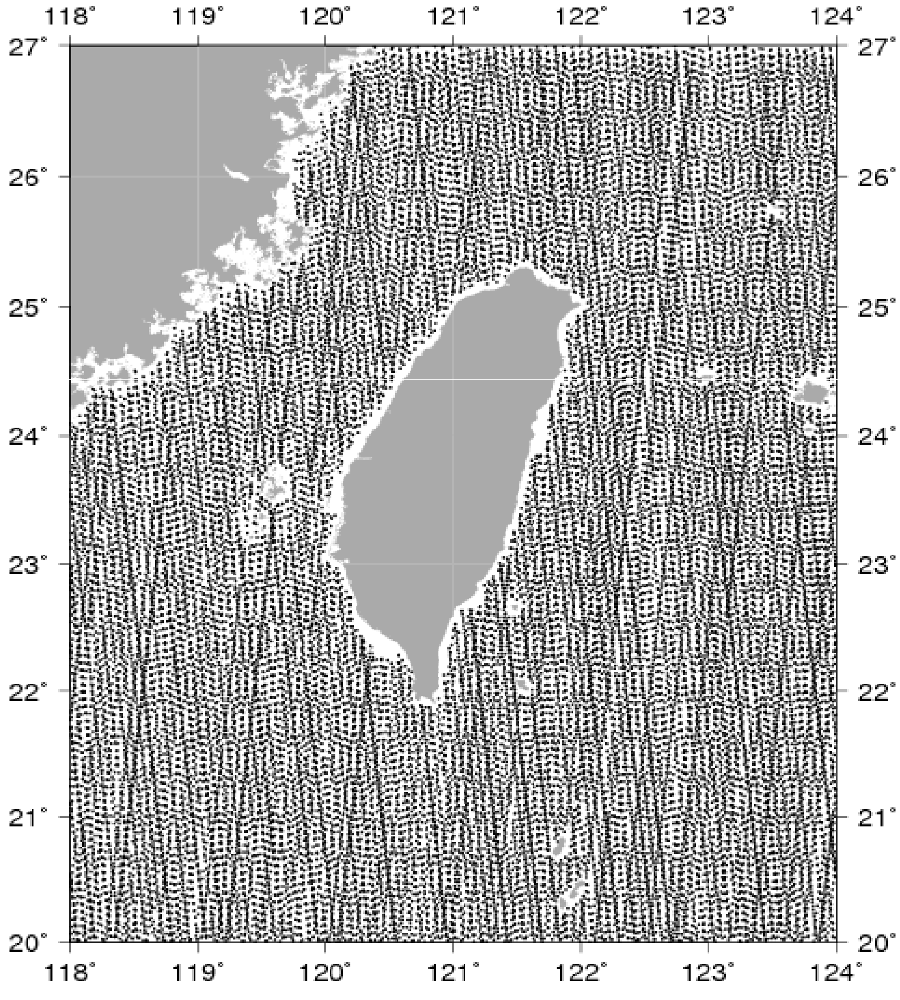


- The Taiwan gravity field
  - Important tectonic features.
  - Regional features: shallow water (< 200 m), small islands, and rugged coastlines.
  - Ship-track gravity data

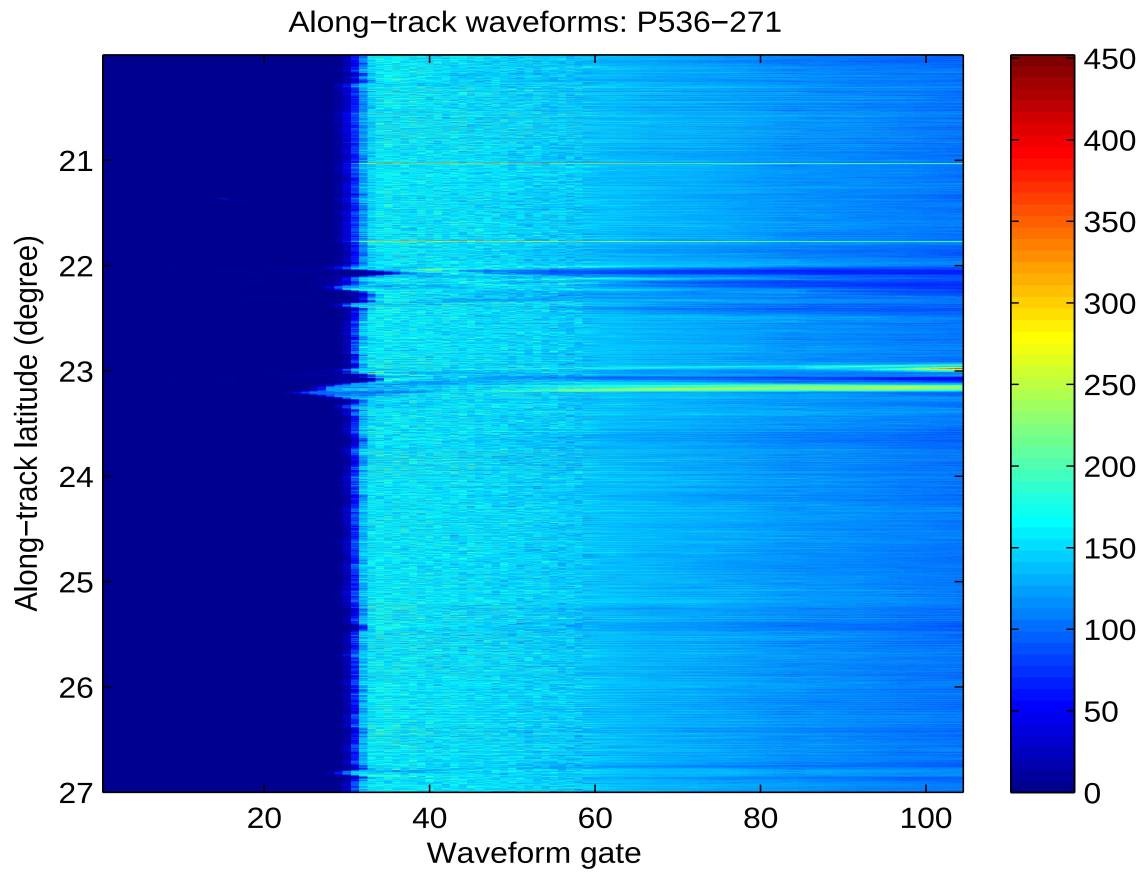
- The retracking results until now still show margins for SSH improvement near coastal areas
  - The quality and availability of retracked SSHs are still limited within ~10 km to the coastline
  - Two-pass retracking (Sandwell & Smith) largely reduces SSH error through smoothing SWH (~45 km half wavelength), but this may not be the case near coast

Jaons-1 GM (left) and Cryosat-2 (right) data around Taiwan





Jason-1 waveform features



- High noise level appears after leading edge and before gate ~60
- Waveforms corrupt frequently

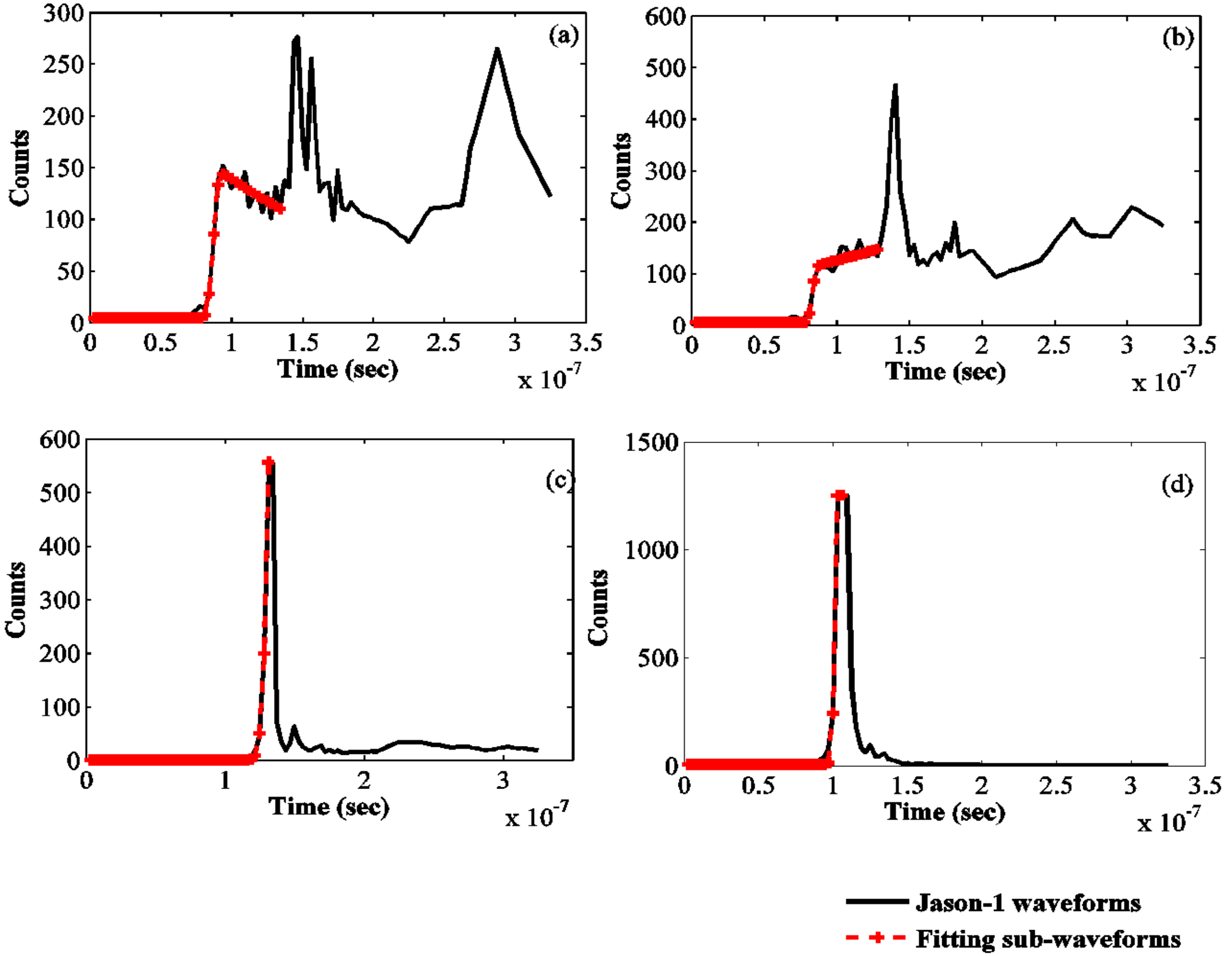
Retracking strategy

- Can SSH be retrieved at the same level, in terms of availability and precision, as those over open oceans for modelling of regional marine gravity field?
  - A dedicated waveform retracking procedure is necessary.
- The SSHs are derived by
  - A sub-waveform retracker by Idirs & Deng (2012)
  - A sub-waveform retracker ALES by Passaro et al. (2014)
  - A weighted waveform retracker IALES by Peng and Deng
    - IALES assigns a small weight to highly noisy waveform gates.
  - Two-pass retracking but with a suitable filter window (~14km) for SWHs in the study area,
  - Validation through comparisons with *in situ* tide-gauge and ship-track gravity data.

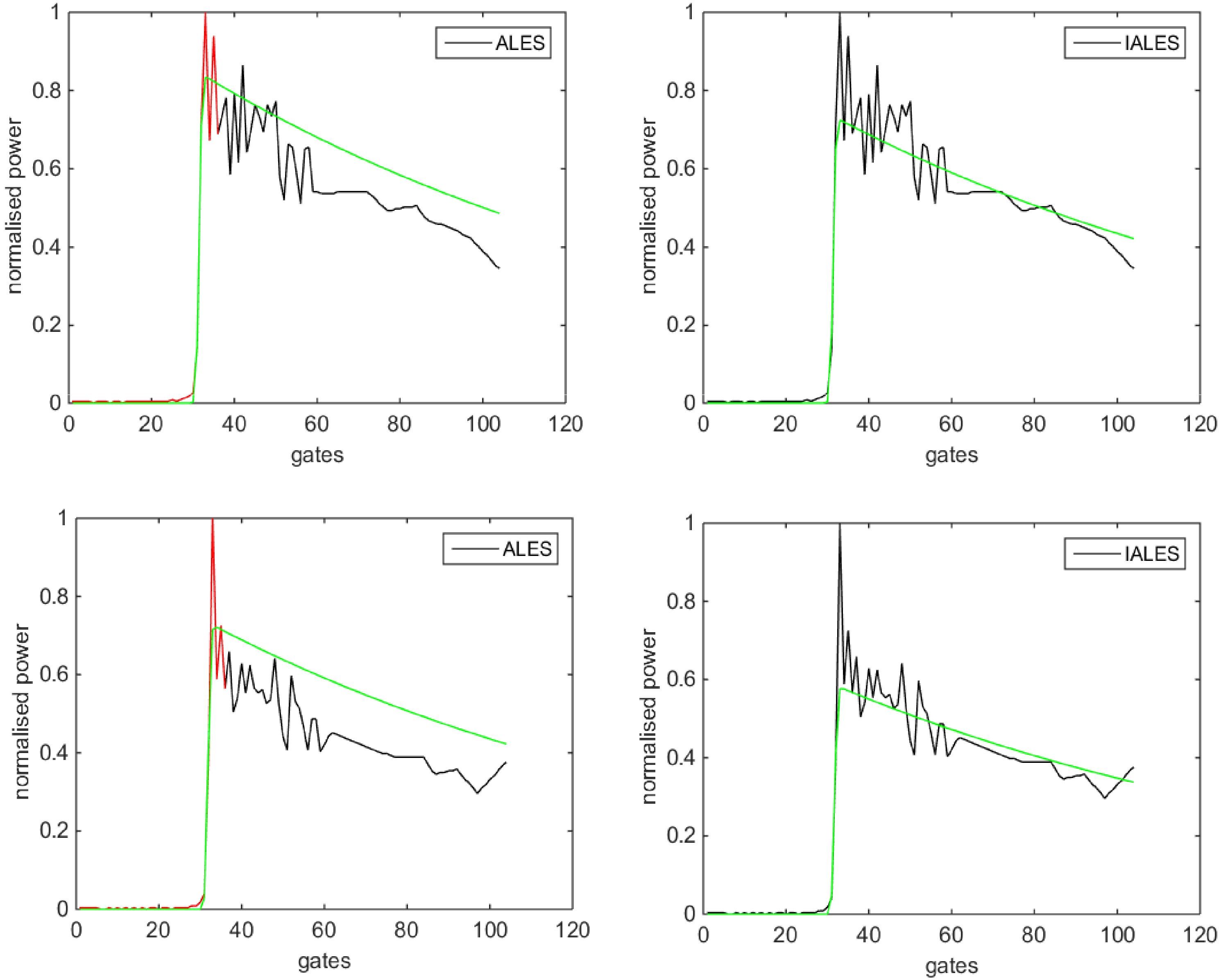
Jason-1 sub-waveform retracking

Sub-waveform fitting results from retracking Jason-1 multi-peak (top), and quasi specular (bottom) waveforms.

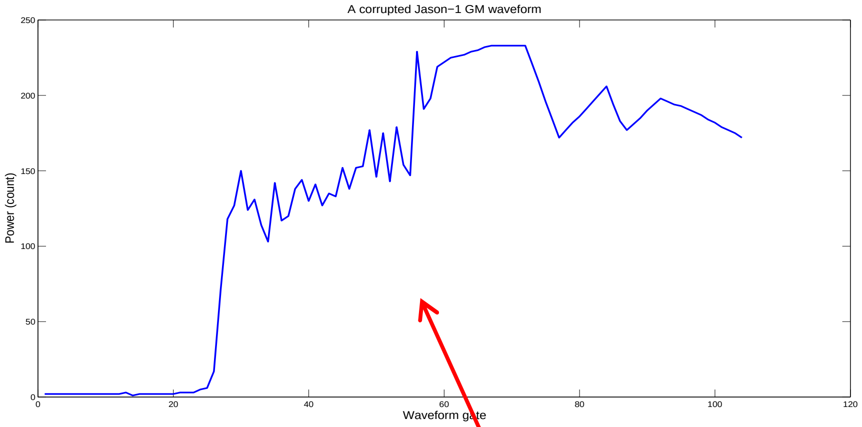
(Idris & Deng, 2014, Marine Geodesy)

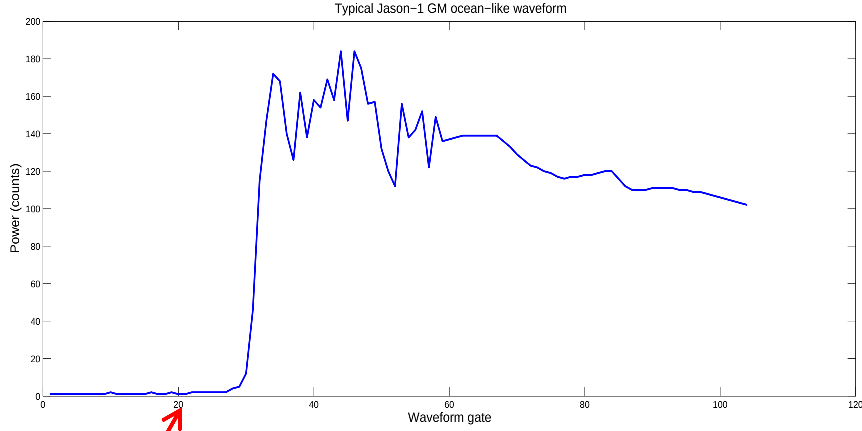


ALES (Passaro et al. 2014) and weighted retracker (ILAES, by authors)

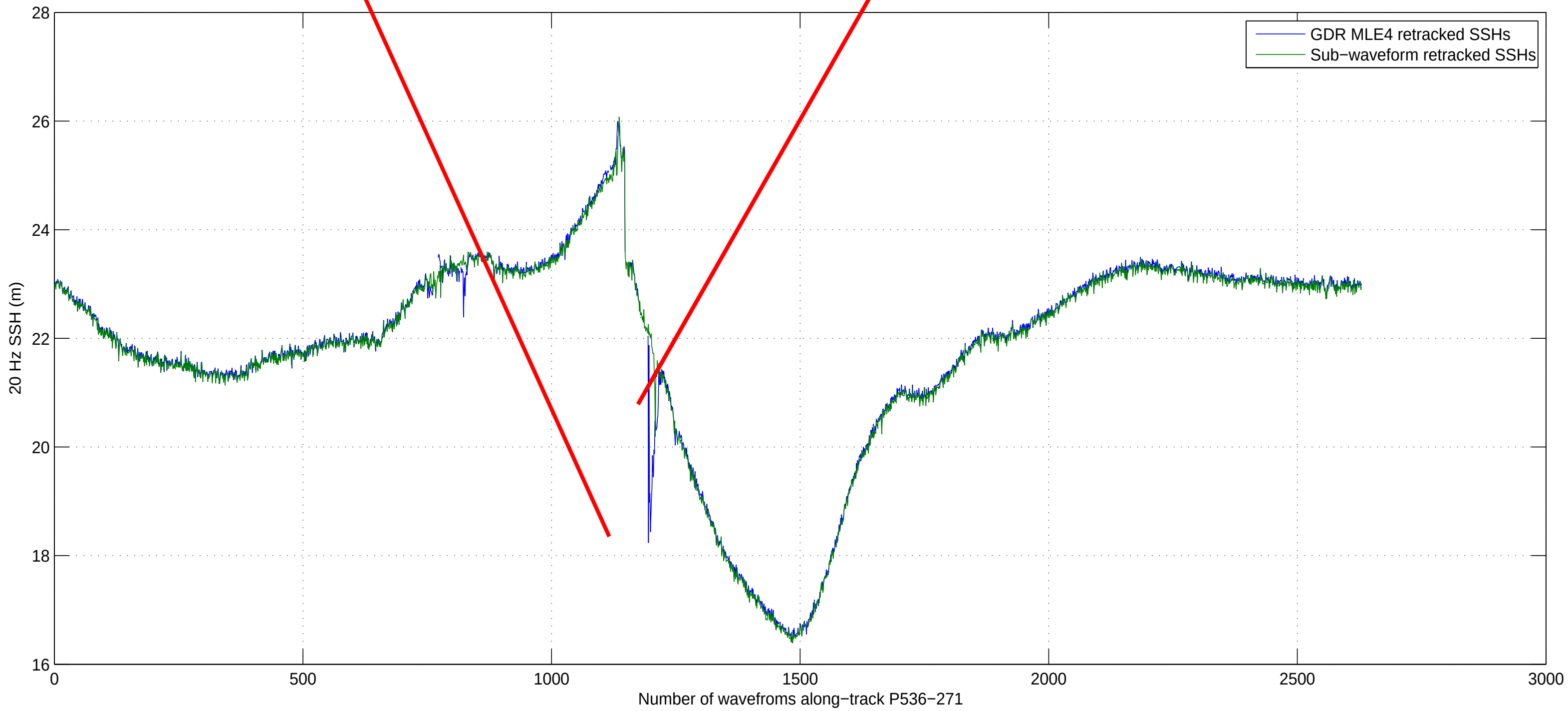


- IALES can achieve similar accuracy to ALES.
- But IALES works better than ALES for Brown-peaky waveforms.
- Results have been validated against TGs.

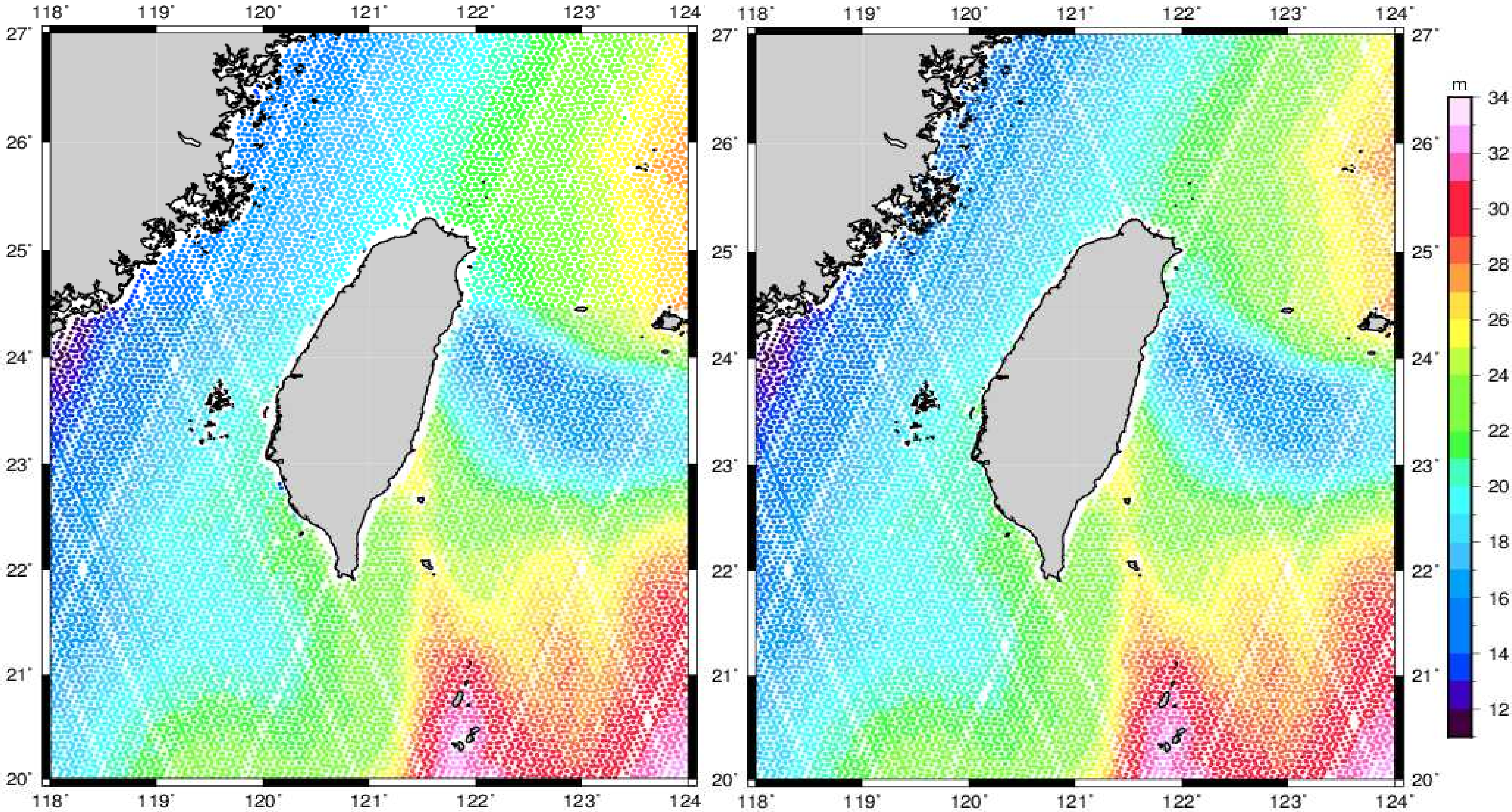




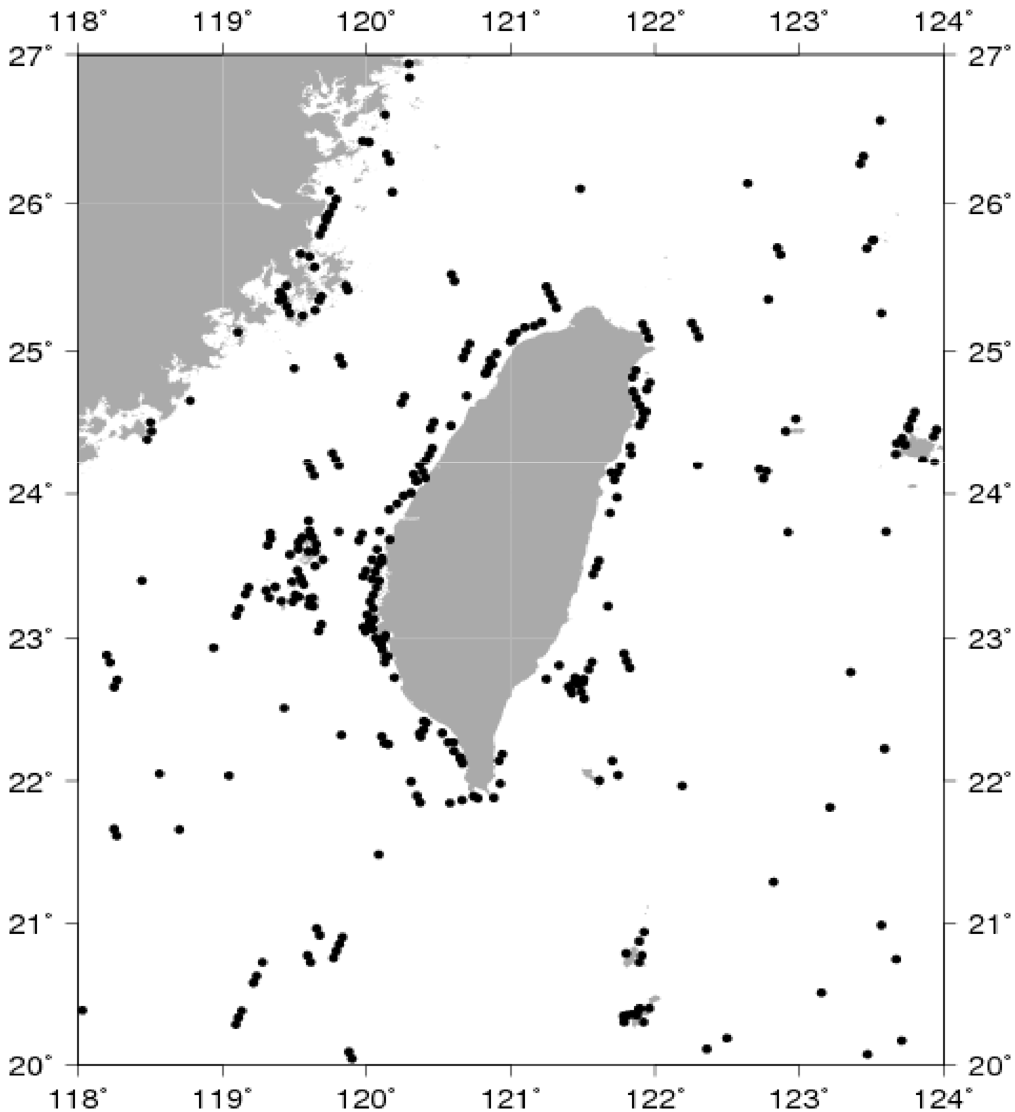
Retracked along-track 20hz SSHs



GDR MLE4 (left) and sub-waveform (right) retracked SSHs



Recovered Jason-1 GM 1Hz SSHs



- Recovered SSHs are mainly near shoreline and around small islands.
- GDR SSHs are also missing over deep oceans.

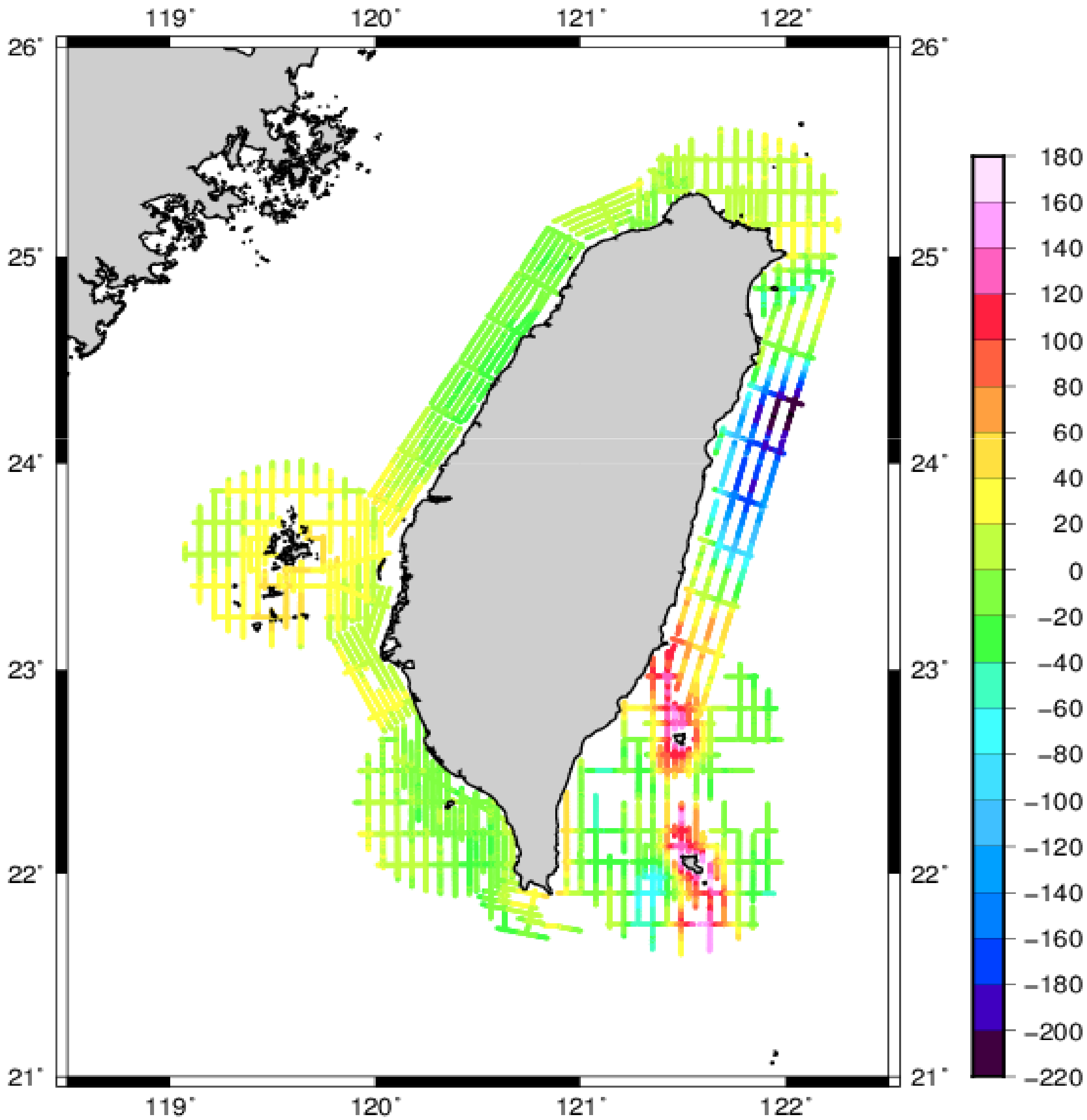
Determination of the marine gravity field

- Data include Jason-1 GM and Cryosat-2
- The marine gravity field is determined using DTU's both techniques of the DTU and NCTU
  - e.g., the remove-compute-recover technique with the inverse Vening Meineszs method (Hwang, 1998)
- Different cases are investigated:
  - Case 1: Jason-1 GDR data
  - Case 2: Jaosn-1 GDR data + Cryosat-2 data
  - Case 3: Jaosn-1 sub-waveform retracked data
  - Case 4: Jaosn-1 sub-waveform retracked data + Cryosat-2 data
- Assess the accuracy of altimeter-derived marine gravity models based on all available ship-track gravity data.

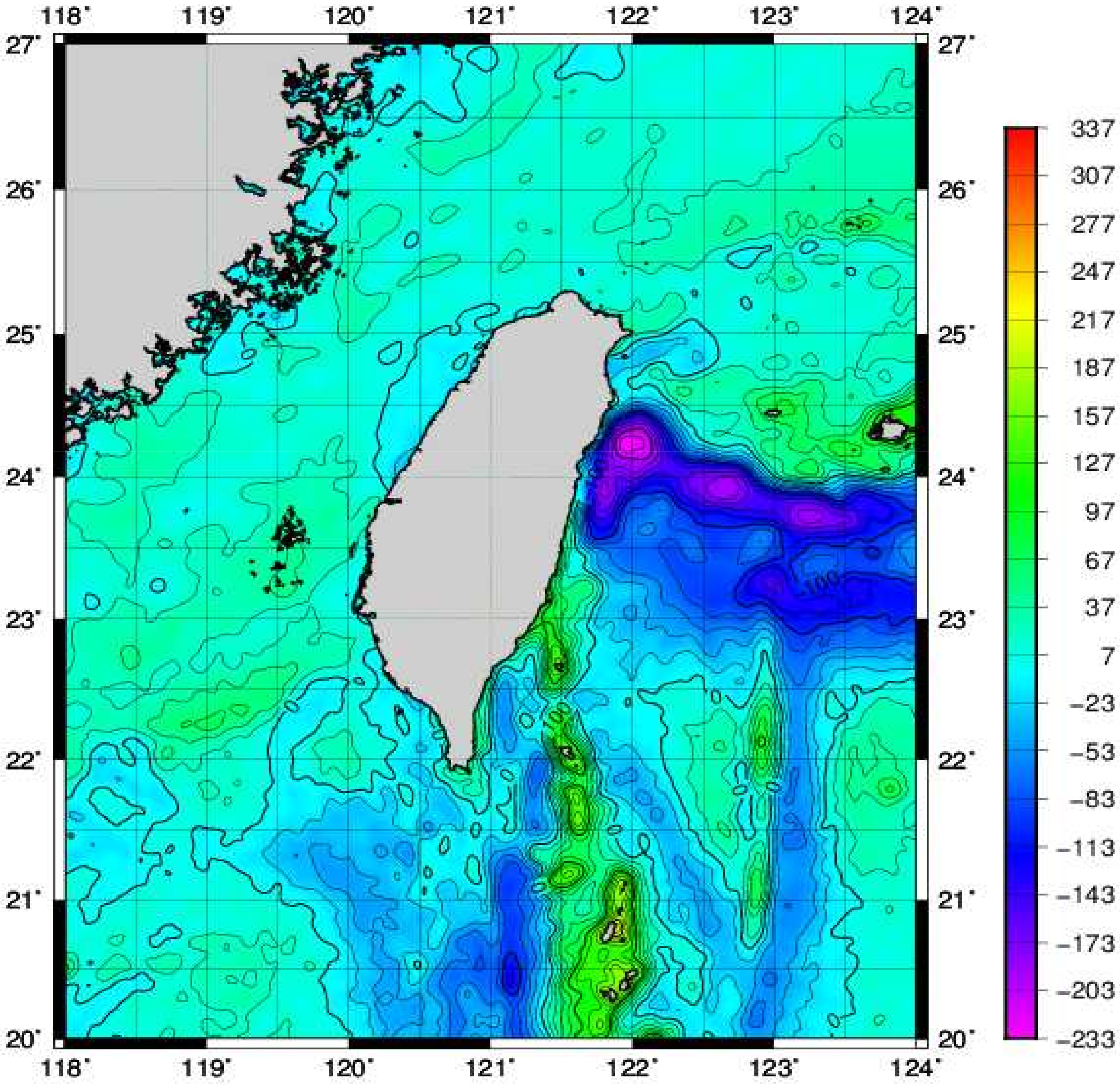
Distribution of Ship-track free-air gravity anomalies (mGal) around Taiwan

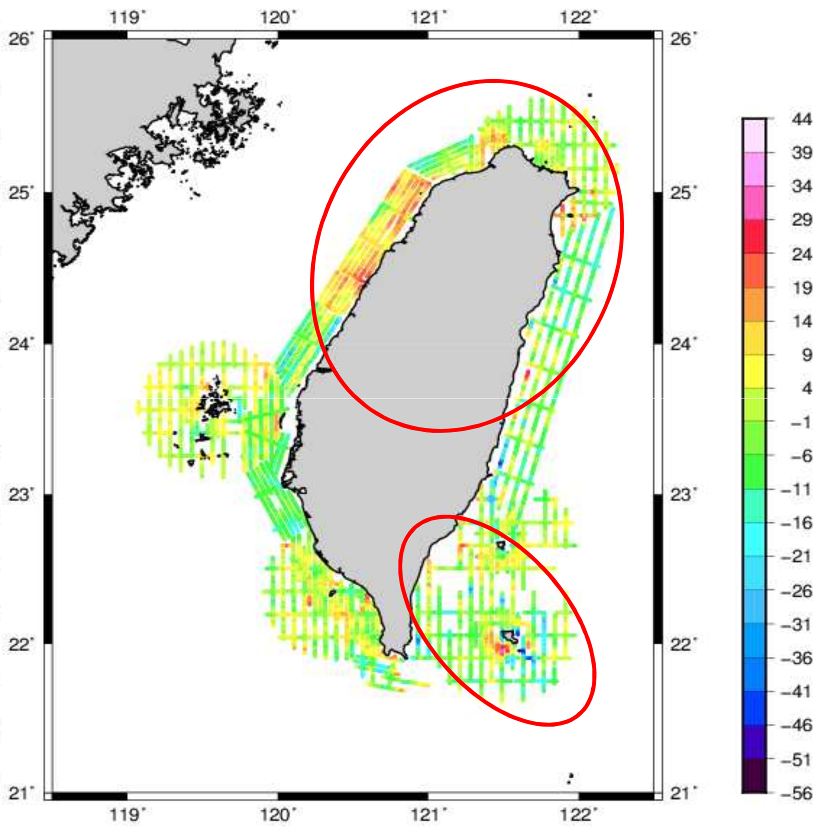
Data accuracy:
0.08-2.35 mGal

(Hwang et al. 2014, Tectonophysics)



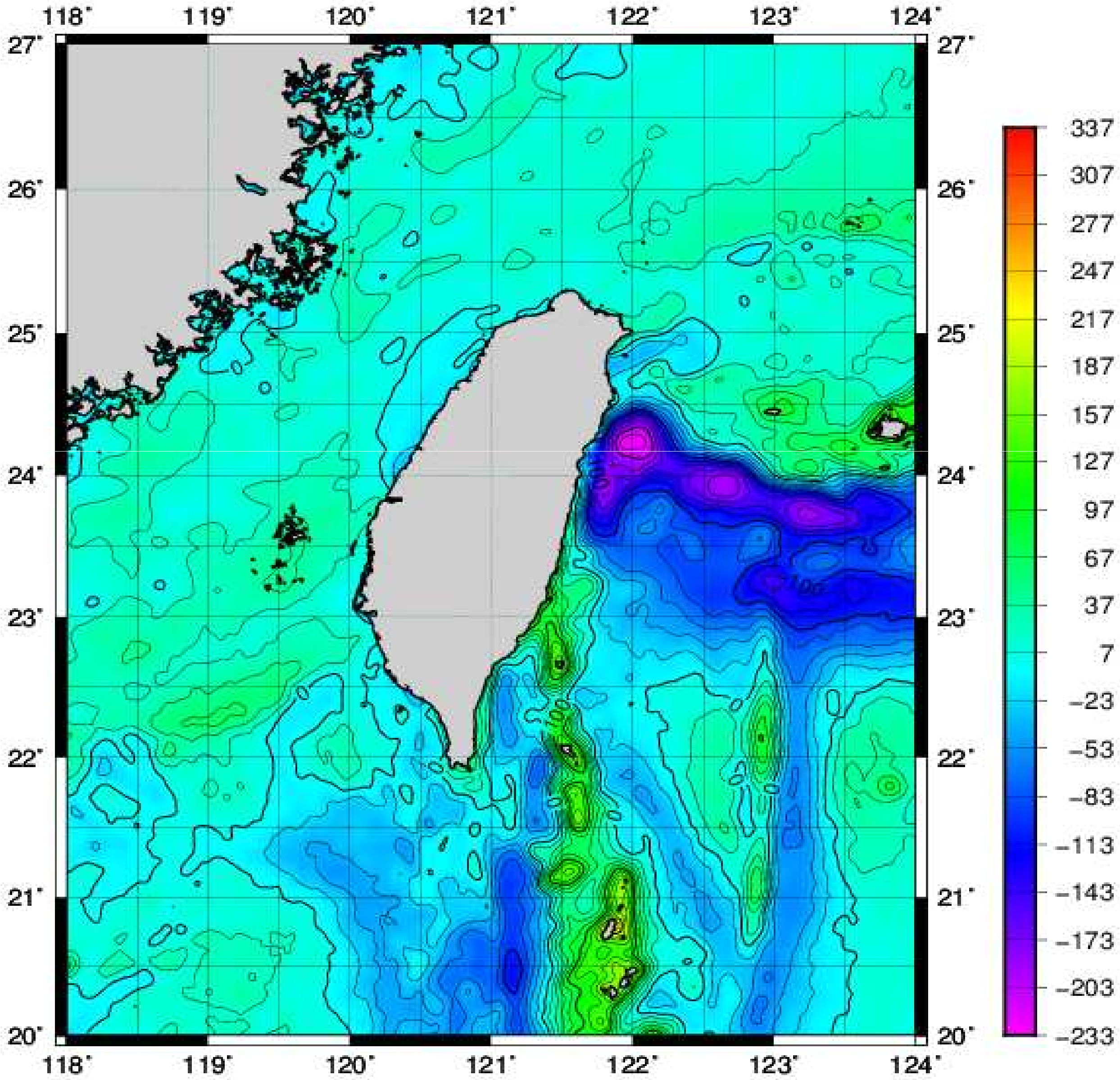
Case 1: Free-air gravity anomalies (FAGA) from Jason-1 GDR SSHs (in mGal)

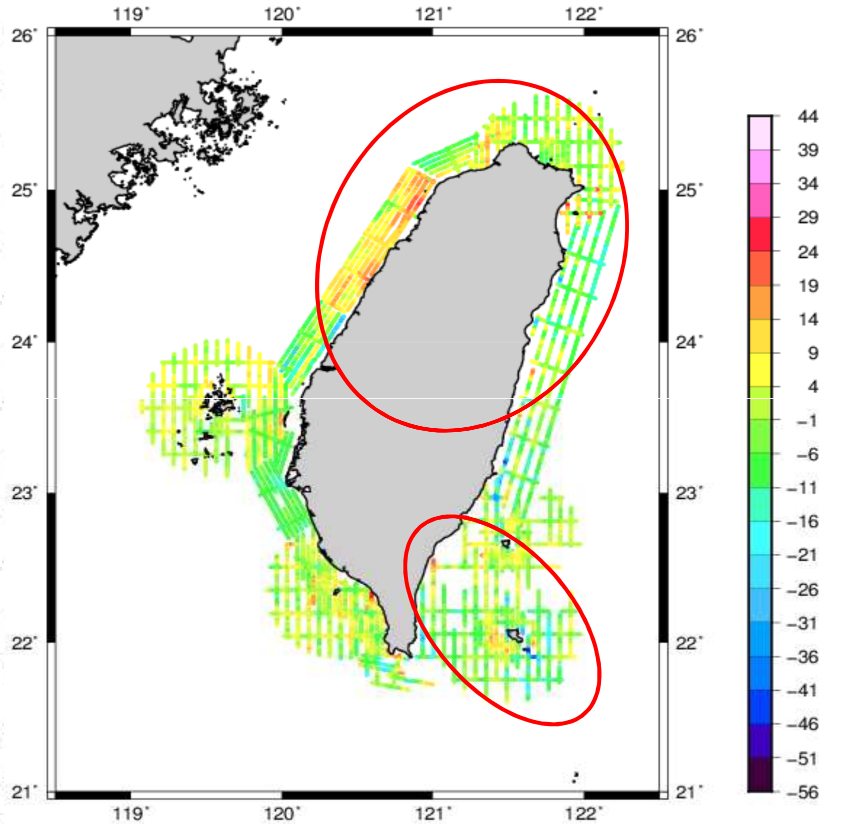




Validated against ship-track gravity

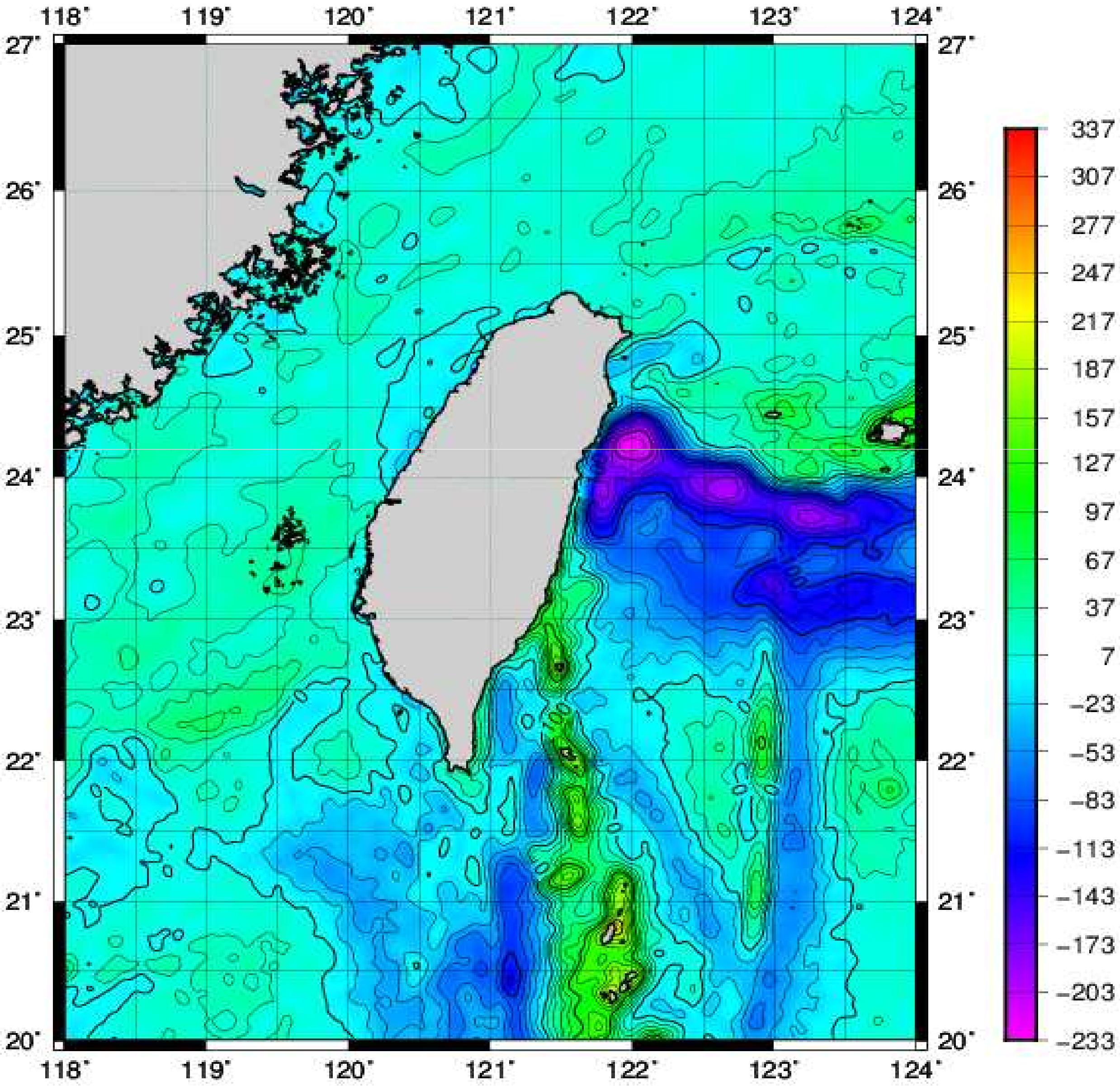
Case 2: FAGA from Jason-1 GDR + Cryosat-2 SSHs (in mGal)

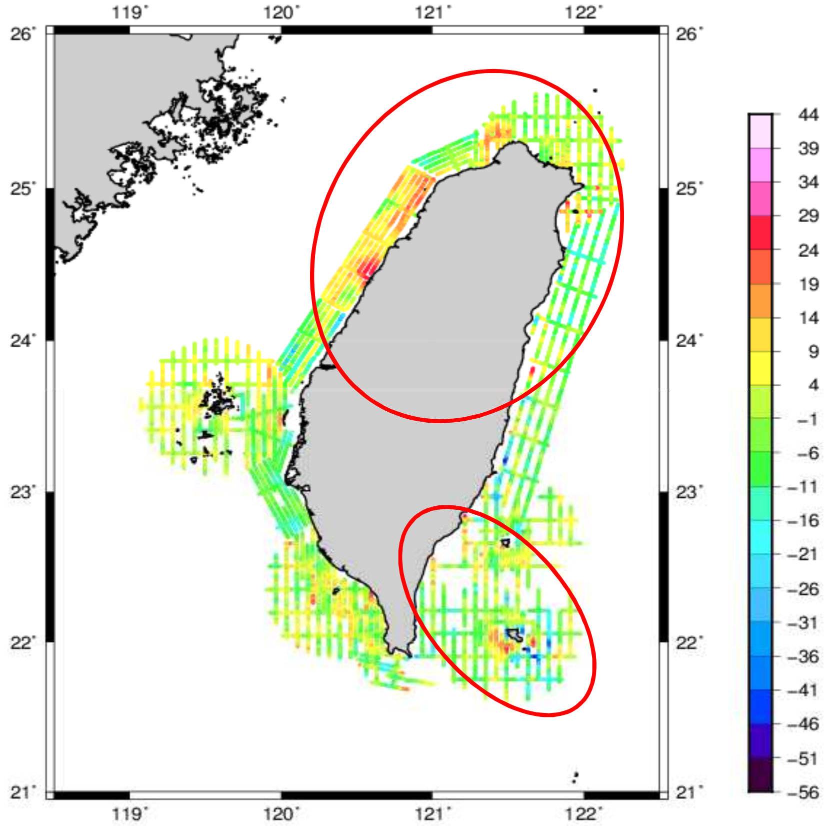




Validated against ship-track gravity

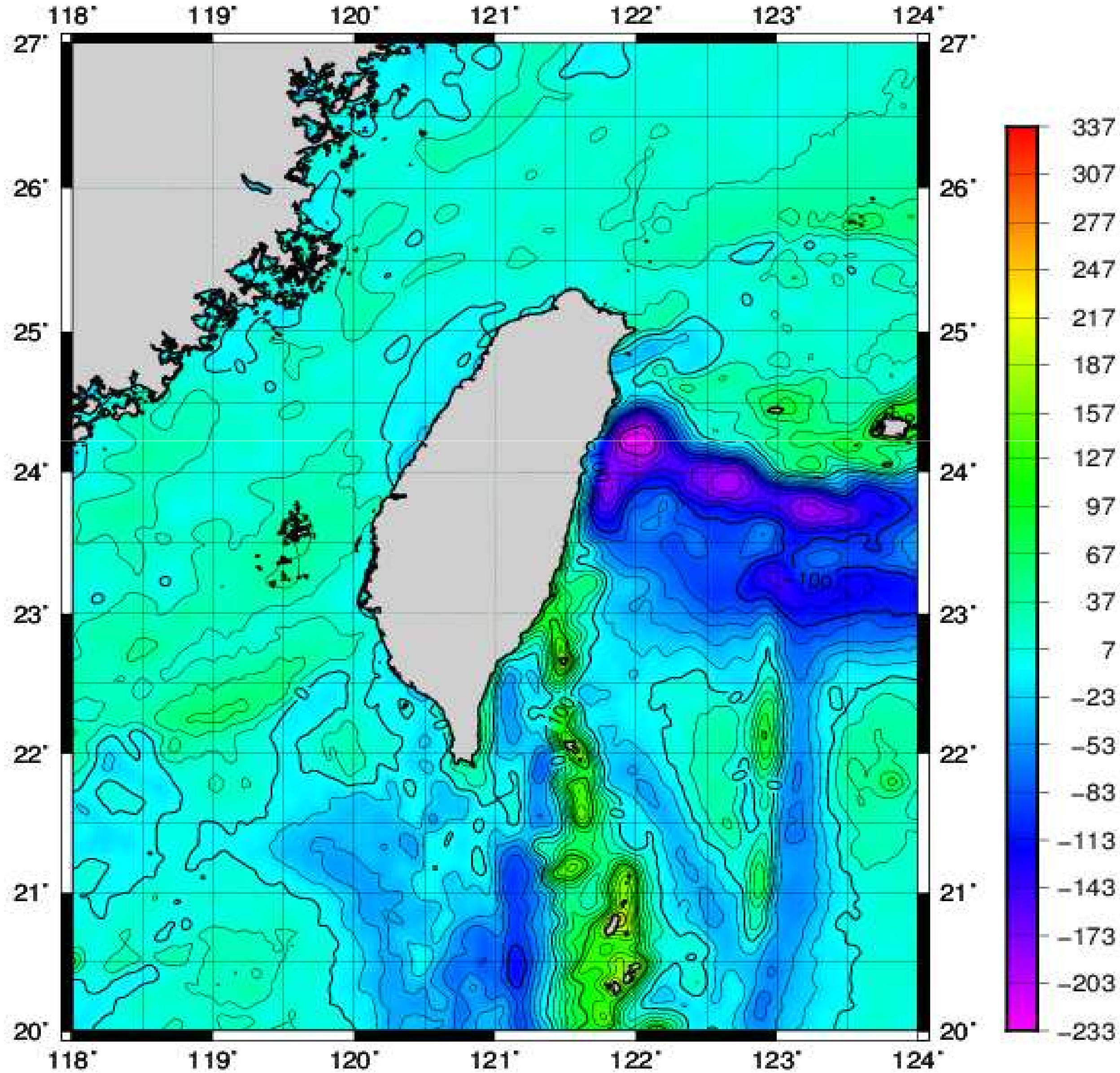
Case 3: FAGA from sub-waveform retracked Jason-1 SSHs (in mGal)

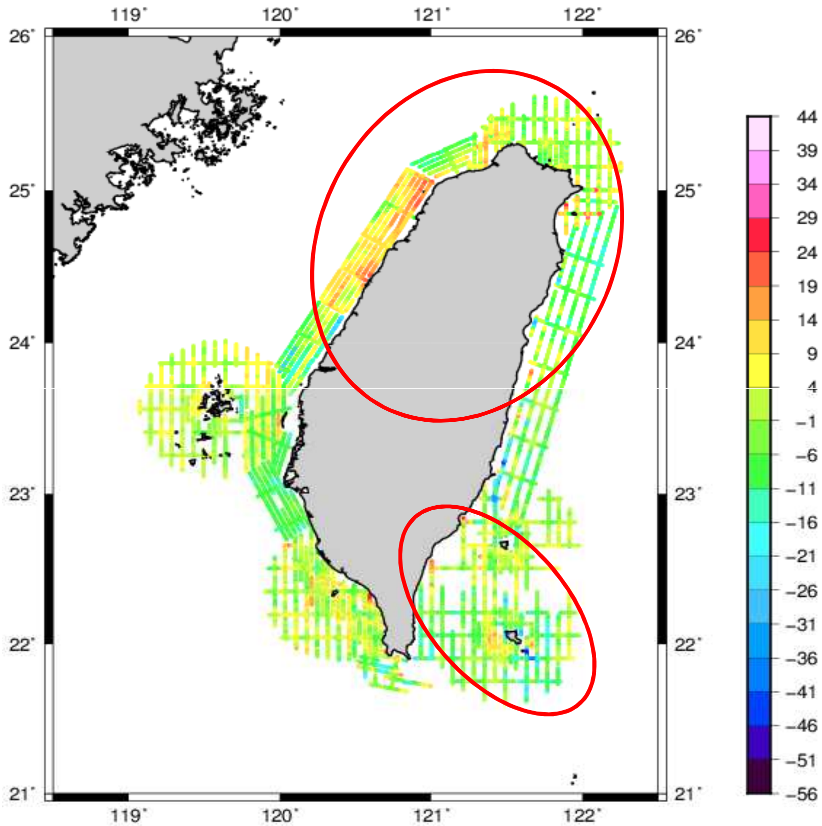




Validated against ship-track gravity

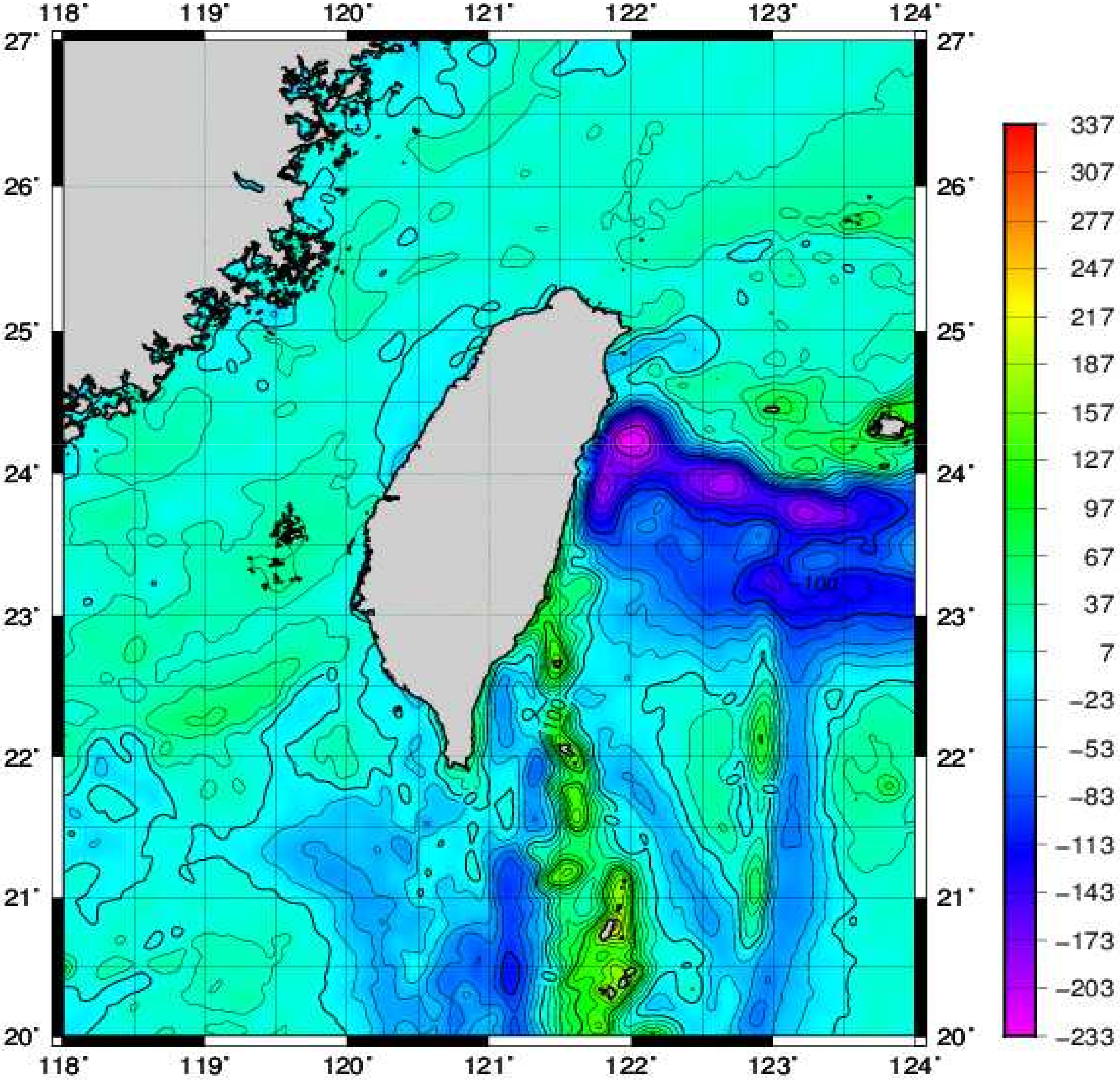
Case 4: FAGA from sub-waveform retracked Jason-1 + Cryosat-2 SSHs (in mGal)

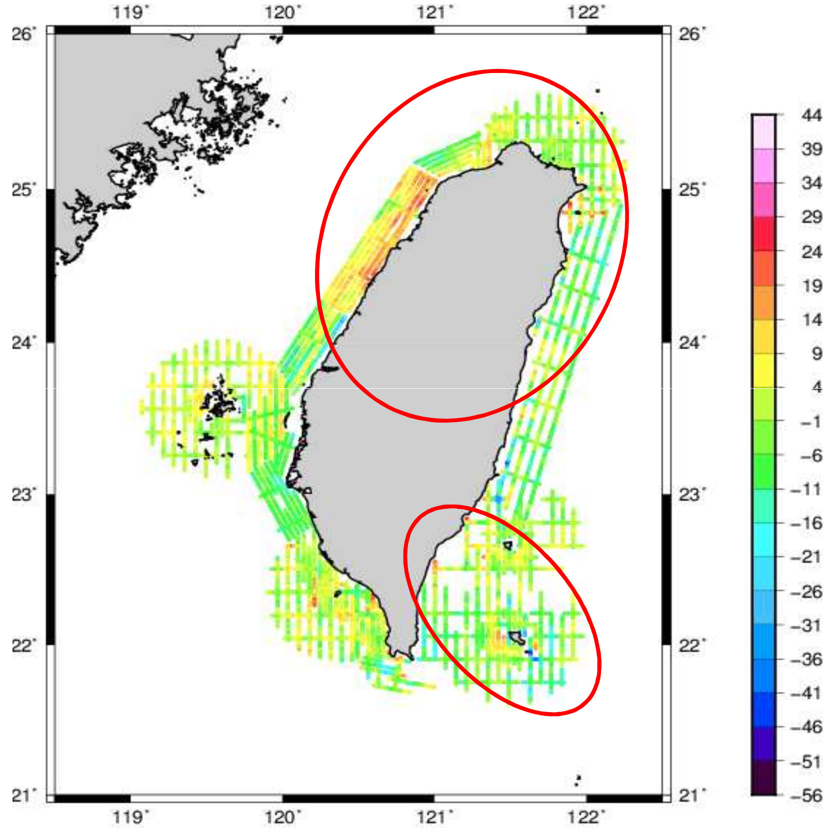




Validated against ship-track gravity

DTU15 FAGA (in mGal)





Validated against ship-track gravity

Comparison between modelled and ship-track FAGA

unit: mGal

Gravity model	Mean	Max	Min	STD	RMS
GRD Jason-1	-0.37	39.89	-53.04	9.12	9.13
GRD Jason-1 + Cryosat-2	-0.62	39.89	-53.05	8.26	8.29
Retracked Jason-1	-0.42	41.00	-54.06	8.96	8.96
Retracked Jason-1+Cryosat-2	-0.67	40.79	-56.50	8.21	8.24
DTU15	-0.62	41.91	-56.70	8.09	8.11

Considering the mean rms error 1.22 mGal for ship-track gravity data, the accuracy of altimeter-derived gravity is ~8 mGal.

Conclusions

- A dedicated retracking procedure retrieves more SSHs than GDR MLE4 retracker over the area, in particular, near the coastline.
- When compared to ship-track gravity data, our retracked SSHs result in a more accurate gravity field.
- The altimeter-derived marine gravity has so far an accuracy ~8 mGal around Taiwan.
- The study is continuing for resolving high-resolution tectonic features.
- To achieve a 1-2 mGal accuracy for efficient extraction of tectonic features around Taiwan, it requires
  - increasing altimeter data volume
  - developing novel data-processing strategies and gravity recovery methods

THANK YOU

DTU Space
National Space Institute

國立交通大學
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Thanks and Questions

2016 OSTST meeting, La Rochelle, France, 1 – 4 Nov 2016