DTU Space

Heidi Ranndal,Ole B. Andersen, and Karina Nielsen

EOForChina, Final meeting

Studying possible improvements of altimetry over Chinese rivers

Science collaboration.

Very fruitful and dynamic interaction and collaboration and science progress.
DTU space providing satellite data to numerous partners and interaction.
Number of joint scientific publications and presentation.

Science achievements:

1. Updating the MWaPP retracker
2. Implementing Fully Focused SAR (FF-SAR) processing of Sentinel-3 data.
3. Studying ICESat-2 data
   - ATL03 and ATL13 data for river level determination
   - ATL03 data for inland water bathymetry

1. Updating the MWaPP retracker

- Originally proposed by DTU Space in Villadsen et al. (2016)
  - Finds the consistent peak in a series of waveforms retrieved over a waterbody to find the height that is common to the noisy waveforms, which should represent the water surface. Proved to be very useful over water bodies suffering from noisy waveforms.
- Improvements made by DTU Environment and DTU Space in Jiang et al. (2020)
  - Using a water mask (Global Surface Water Explorer occurrence value) to group waveforms over rivers
  - Using the the median waveform of the group to find the common peak instead of the mean waveform.

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Improved inland water levels from SAR altimetry using novel empirical and physical retrackers

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SUMMARY

Satellite altimetry has proven a valuable resource of information on river and lake levels where in situ data are sparse or non-existent. In this study several new methods for obtaining stable inland water levels from CryoSat-2 Synthetic Aperture Radar (SAR) altimetry are presented and evaluated. In addition, the possible benefits from combining physical and empirical retrackers are investigated.

The retracking methods evaluated in this paper include the physical SAR Altimetry MOde Studies and Applications (SAMOSA3) model, a traditional subwaveform threshold retracker, the proposed Multiple Waveform Persistent Peak (MWaPP) retracker, and a method combining the physical and empirical retrackers. Using a physical SAR waveform retracker over inland water has not been attempted before but shows great promise in this study.

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Evaluation of Sentinel-3 SRAL SAR altimetry over Chinese rivers

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ABSTRACT

Satellite radar altimetry observations of water surface elevation (WSE) have become an important data source to supplement river gauge records. Sentinel-3 is the first radar altimetry mission operating with a synthetic aperture radar (SAR) altimeter at global scale and with a new on-board tracking system (i.e. open-loop), which has great potential in terms of delivering reliable observations of inland water bodies for the next two decades (several future missions include an open-loop tracking mode). In this context, it is very important to investigate the data quality at an early stage. In this study, a comprehensive evaluation of Sentinel-3A (S3A) is conducted at 50 virtual stations (VS) located on a wide range of rivers in China.

The evaluation of Level 1 data shows that, over mountain rivers, a good prior surface elevation estimate on-board is vital to deliver useful datasets using the S3A open-loop tracking system. The Open-Loop

1. Updating the MWaPP retracker

The suggestions in Jiang et al. (2019) were tested at several locations.

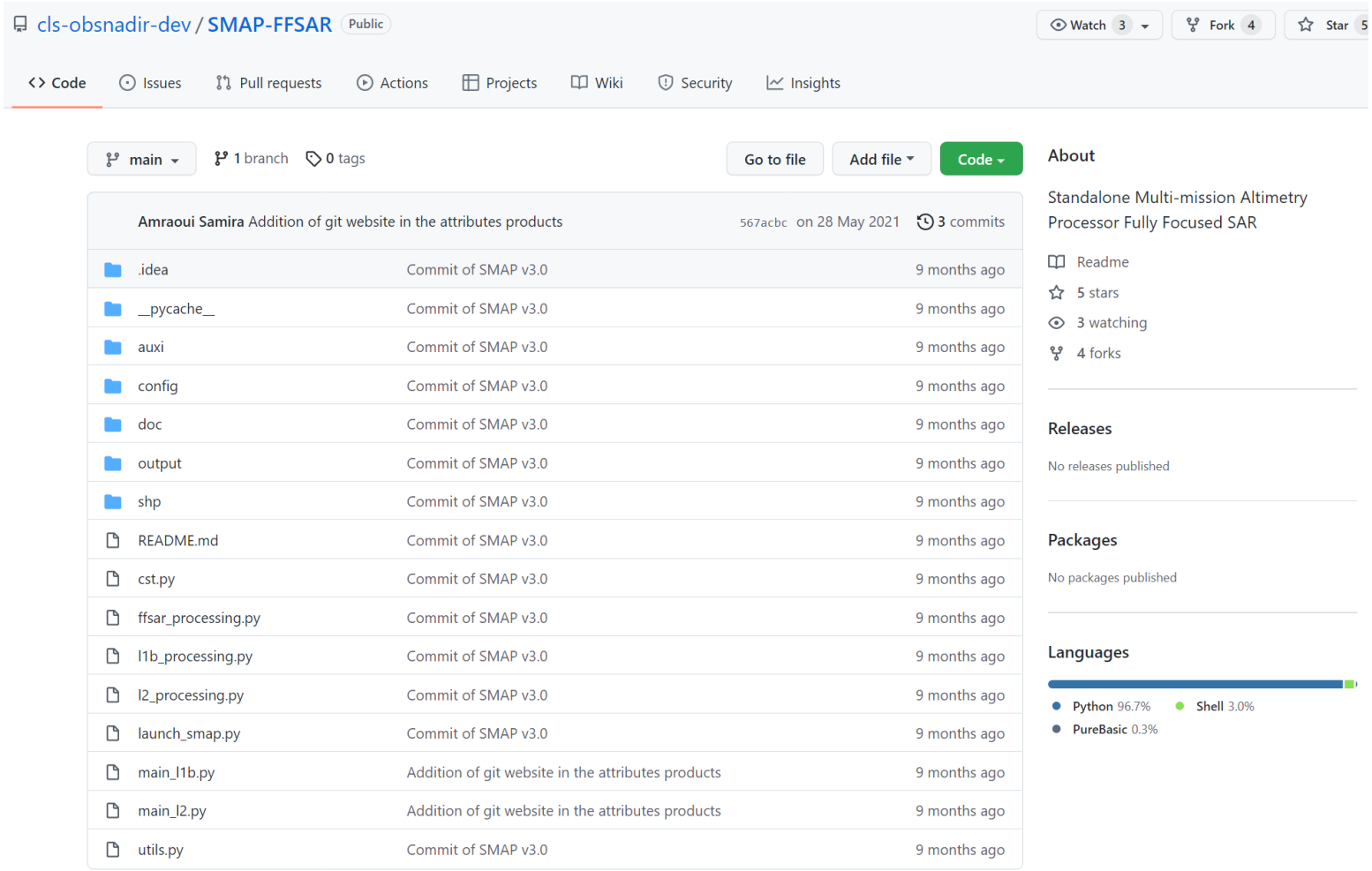
Median instead of mean: Not always the best, but in most cases.

Using a water mask to group all waveforms over a waterbody instead of using just five waveforms can be an issue over large lakes with residual geoid signals or wind effects, or for rivers running parallel to the track. I.e., in cases where we *can't* expect the true elevation at nadir to be the same along the track.

All in all, as long as one takes the area into account – the suggestions in Jiang et al. improved the retracker and the changes were implemented and the MWaPP+ retracker can be applied to all SAR waveforms.

2. Fully-Focused SAR processing

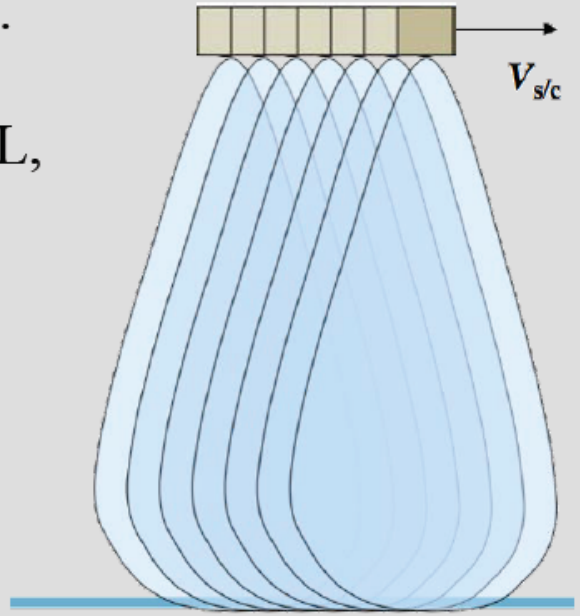
- Using the open source SMAP FF-SAR processor developed by CLS/ESA/CNES.
- The user can determine the number of looks used to derive the surface height
- Possible to increase the along-track resolution down to 50 cm.



Fully Focused SAR-

Conventional Altimeter

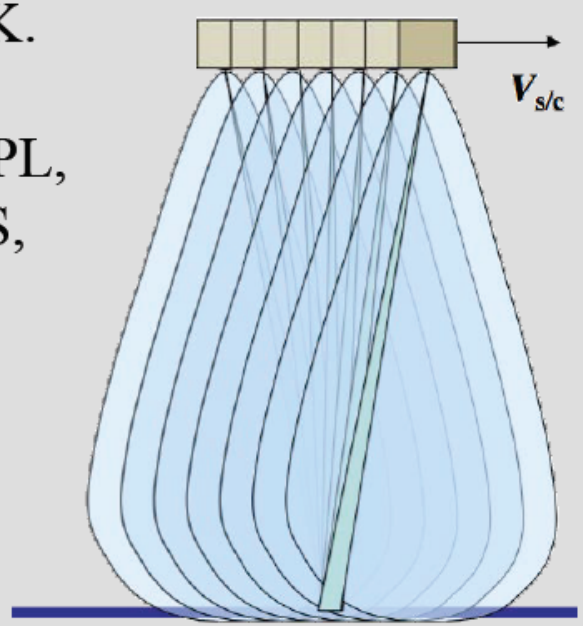
Image K. Raney, JHU/APL, TGARS, 1998



- Low Resolution Mode
- Pulse limited footprint (circular)
- 1.5 / 5 km res. depending on SWH
- Open burst operation
- PRF ~ 2 kHz

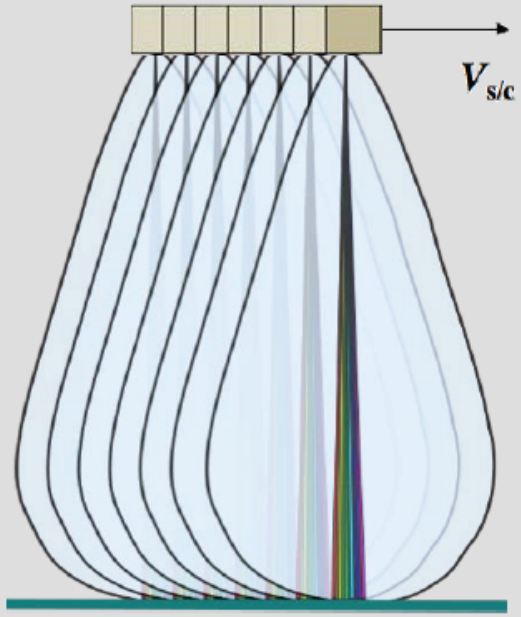
Delay-Doppler Altimeter

Image K. Raney, JHU/APL, TGARS, 1998



- Unfocused SAR processing
- ~300 m resolution Along-Track
- Pulse limited across-track
- Closed Burst
- PRF ~ 18 KHz

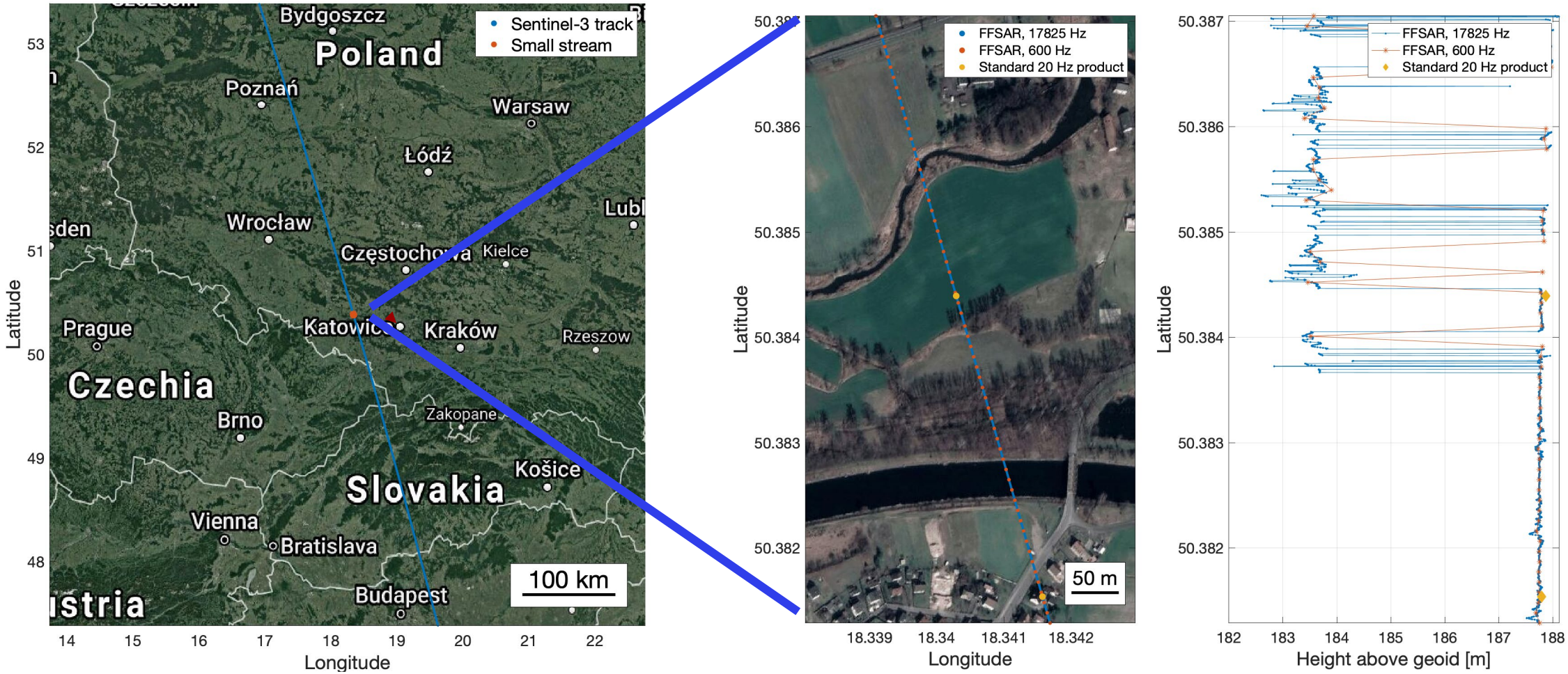
Focused SAR Altimeter



- Fully Focused SAR processing
  Coherent processing for ~2 seconds
- Resolution Along-Track ~ 0.5 m
- Pulse limited across-track
- Closed Burst
- PRF ~ 18 KHz

2. Fully-Focused SAR processing

Sentinel-3A, June 28th, 2018



Work done by DTU Space for the EOForChina project

2. Fully-Focused SAR processing

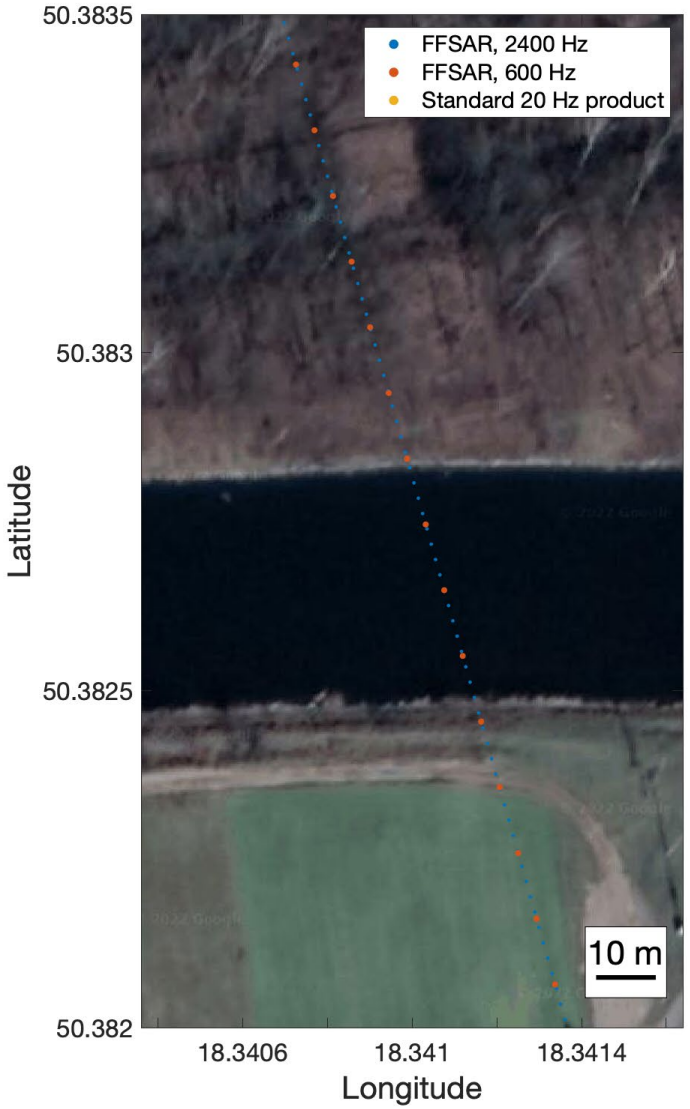
600 Hz ~ 15 m resolution

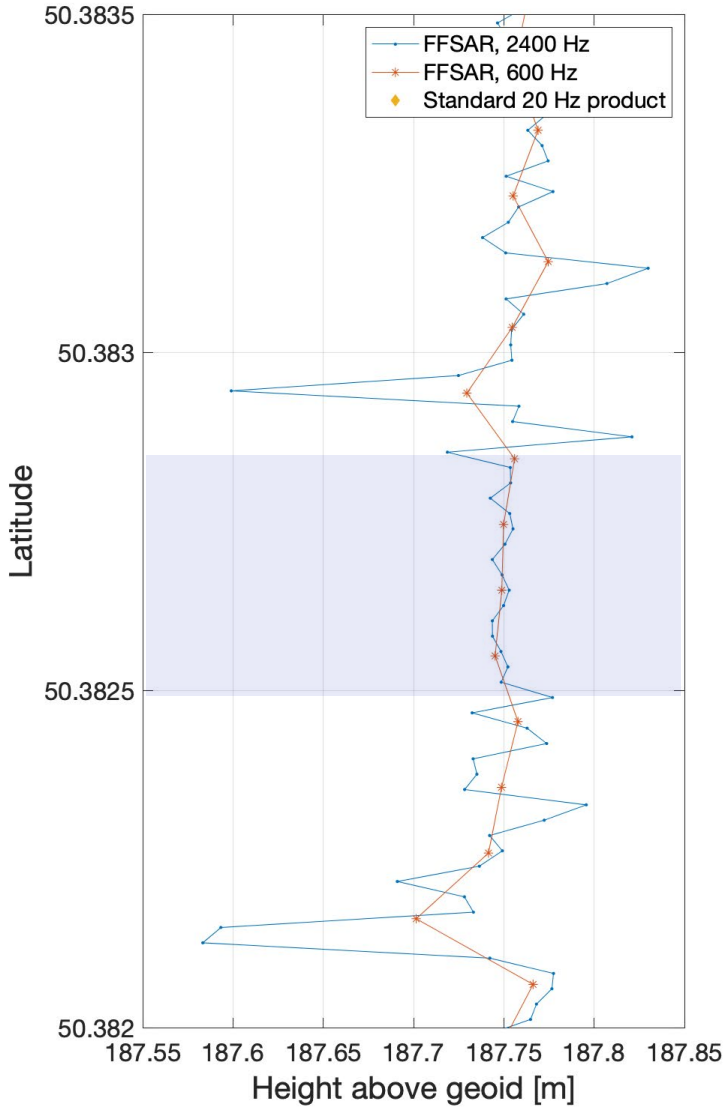
2400 Hz ~ 2.5 m resolution along track

Standard deviation of shaded area:

0.45 mm for 600 Hz product (4 data points)

2 cm for 2400 Hz product (16 data points)





2. Fully-Focused SAR processing - Yangtze River

Area with a lot of specular targets

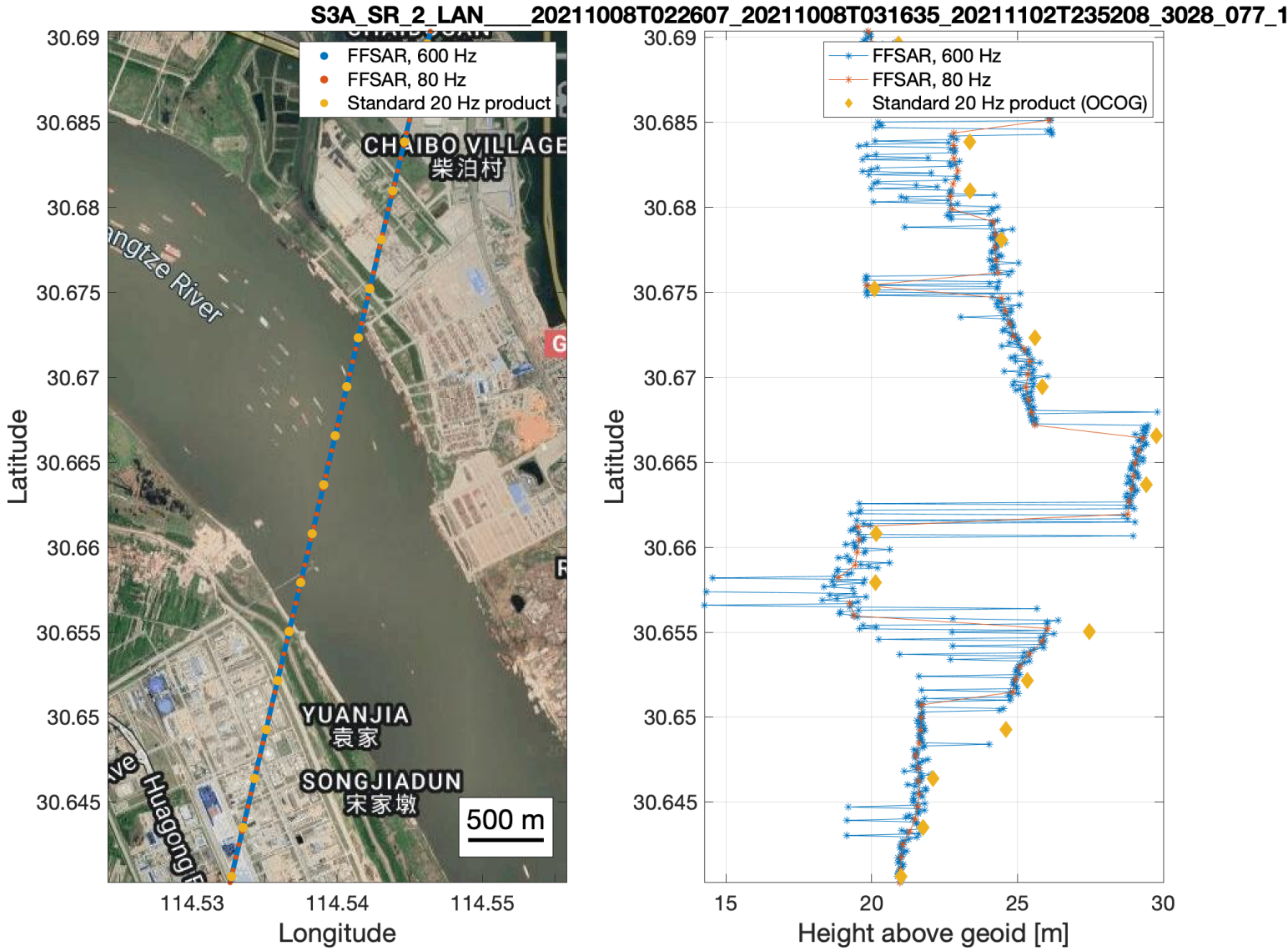
Causes noisy waveforms

The MWaPP retracker also fails in this area

FFSAR does not provide better results in this area – simply because of all the scatterers

80 Hz ~ 115 m resolution

600 Hz ~ 15 m resolution

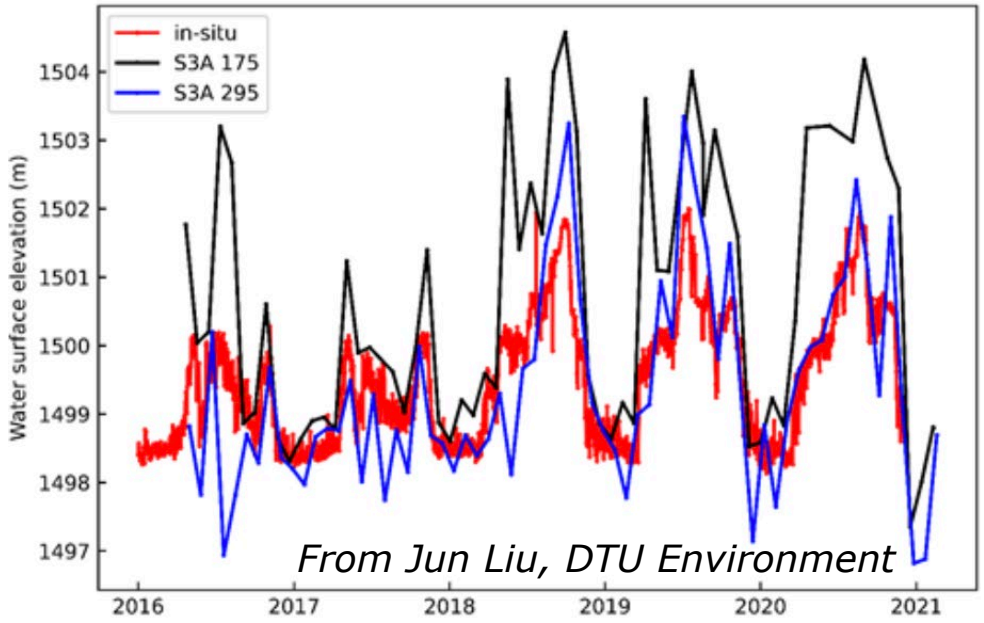


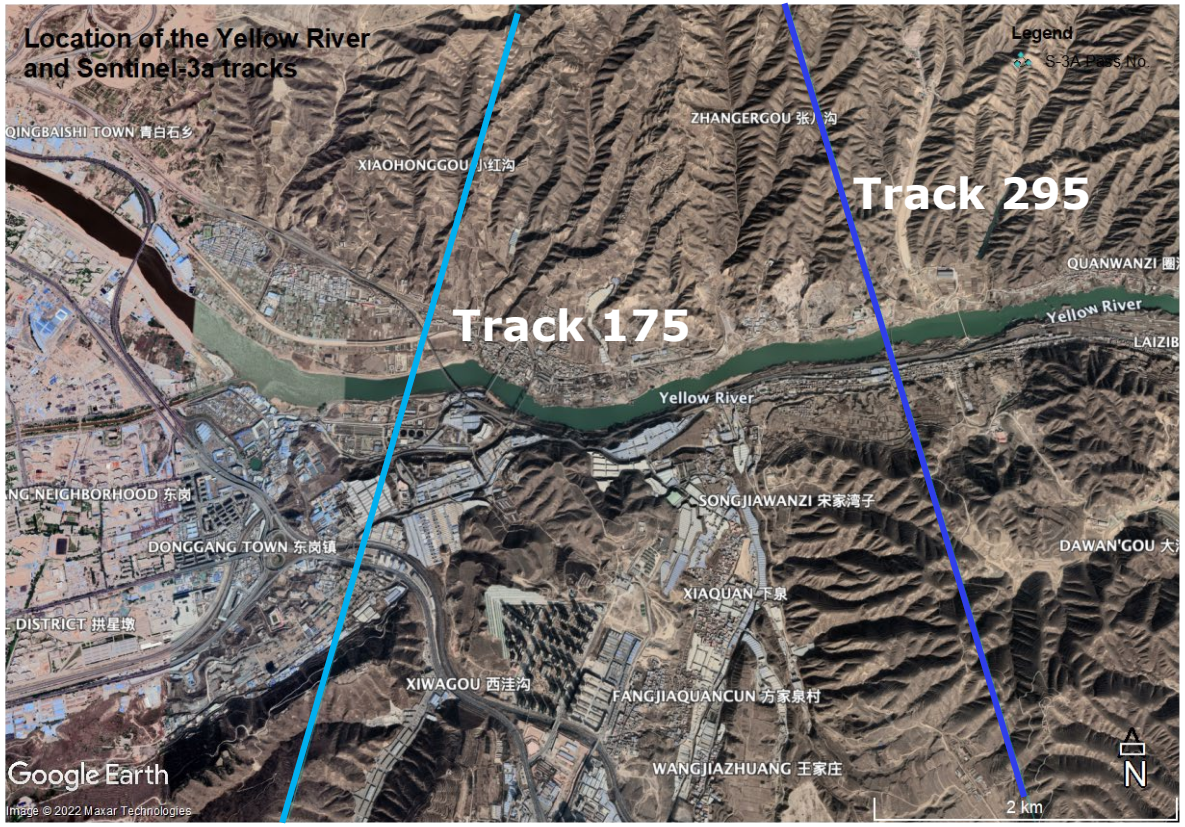
2. Fully-Focused SAR processing - Yellow River

Area with a lot of specular targets and topography within the footprint.

Angle of track wrt. river is important!

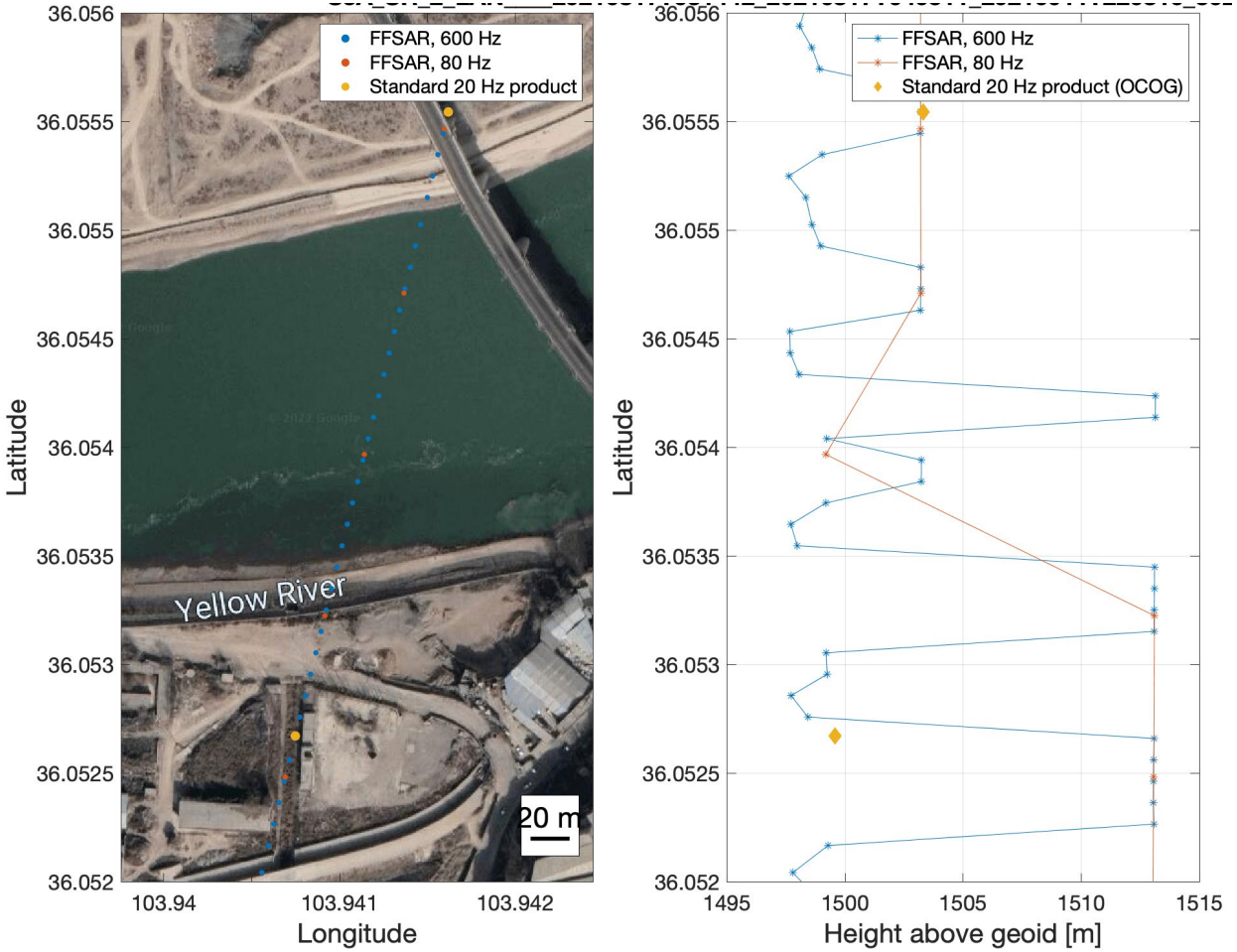
WSE from track 175 are too high compared to the in situ.



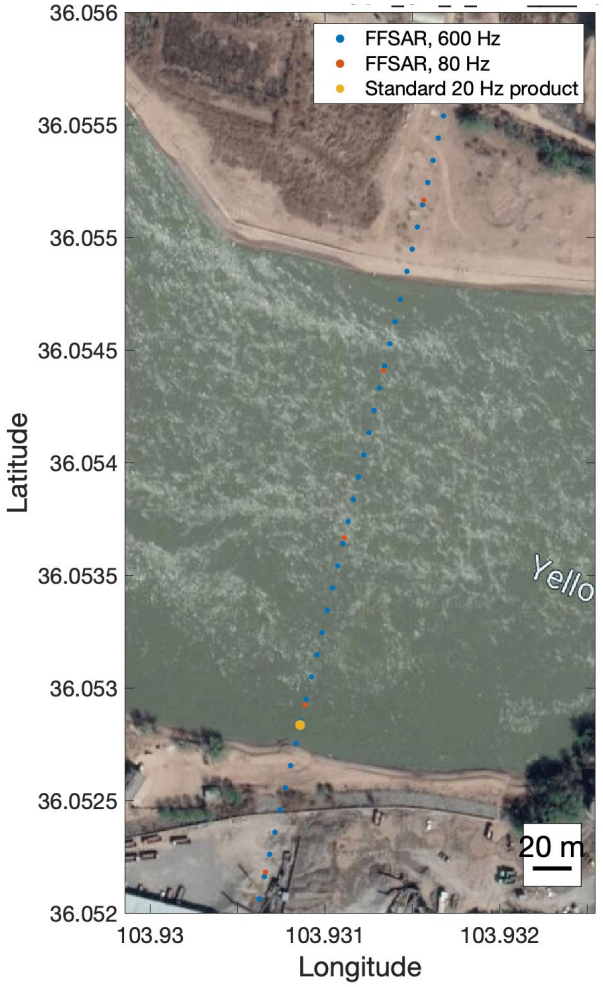


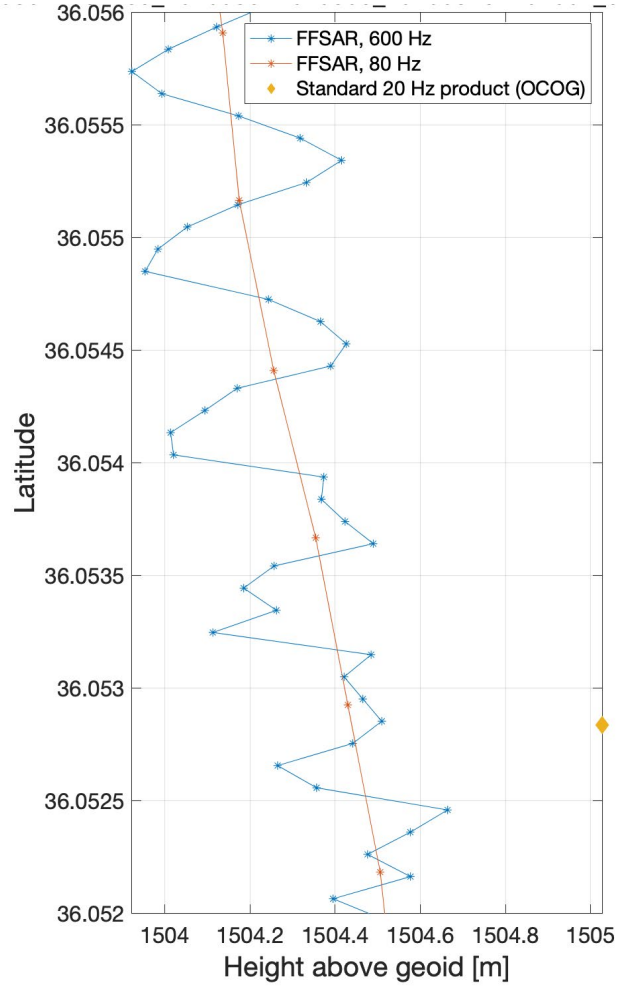
2. Fully-Focused SAR processing - Yellow River

Track 175: August 17, 2021



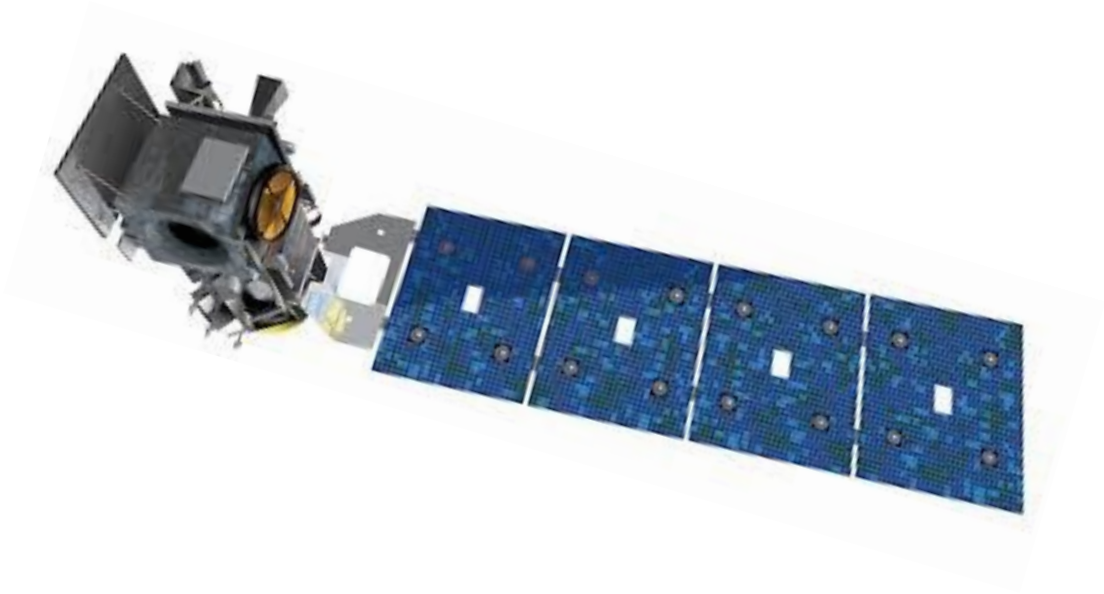
Track 175: August 31, 2020





3. Studying new possibilities with ICESat-2

- ICESat-2 data have been investigated for several purposes
  - Obtaining precise and accurate water levels
  - Retrieving information about the river banks
  - The possibility of capturing bathymetry signals



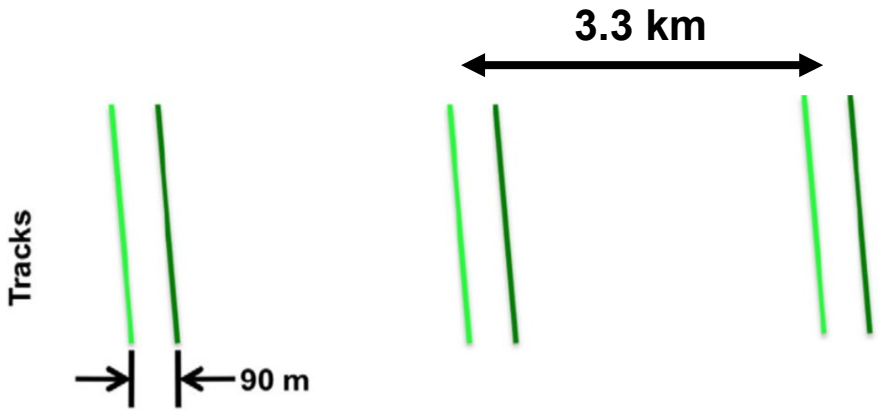
About ICESat-2:

Laser altimeter

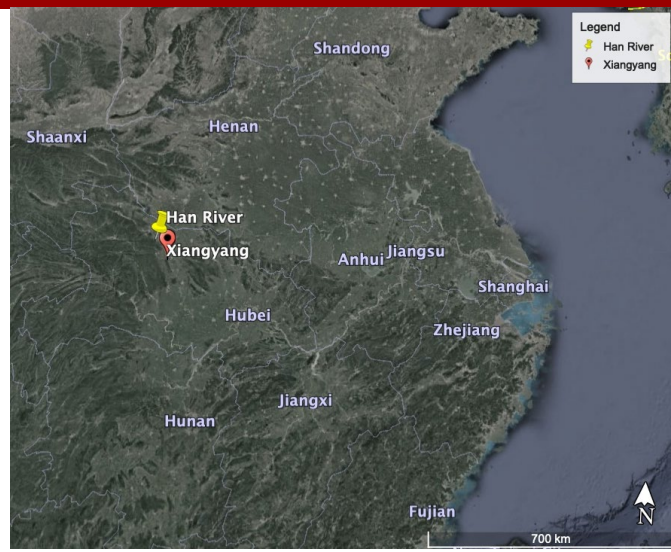
6 beams

Repeat period of 90 days

Is able to determine the point of reflection for every single photon with a very high precision!



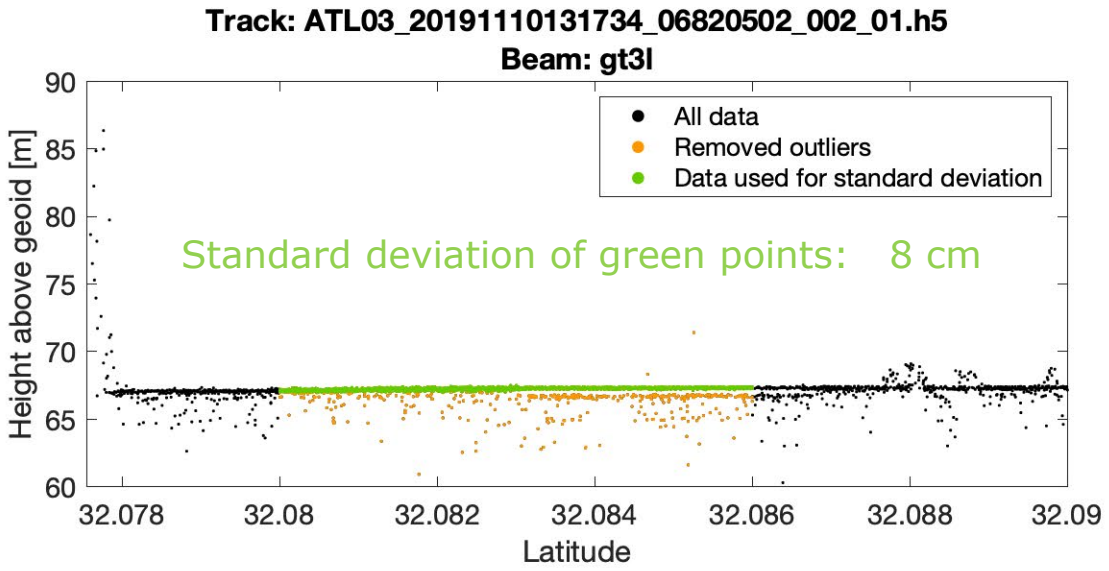
3. New possibilities with ICESat-2

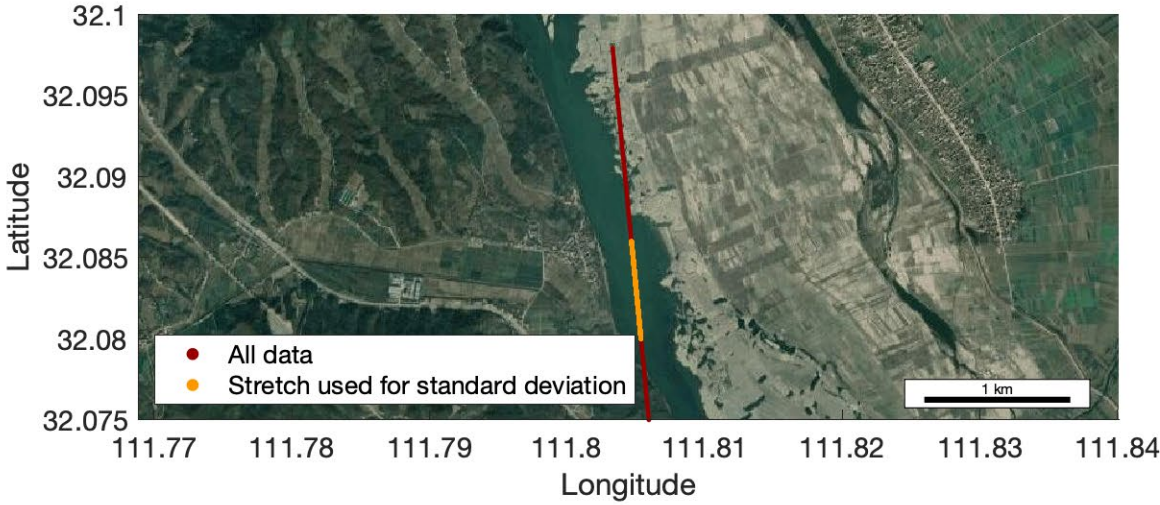


In general, ICESat-2 data are very precise.

However, elevation estimates are only availble under cloud free conditions, which make single VS time series even more sparse.

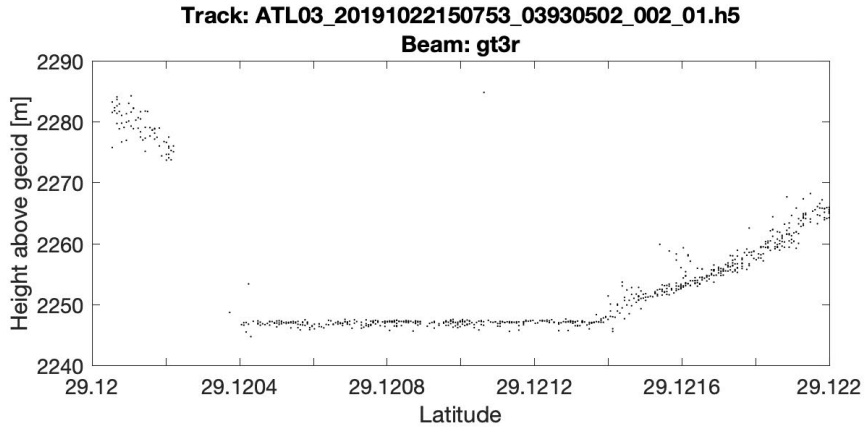
These data are from the photon data product (ATL03), but the inland water product ATL13 is sufficient almost all cases, and is computationally easier to handle.

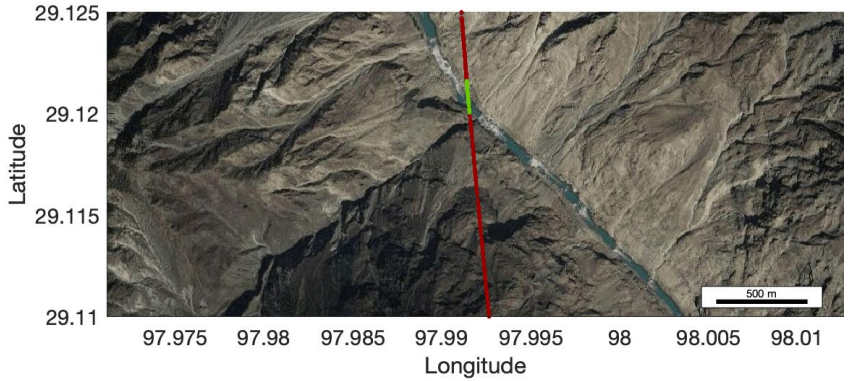




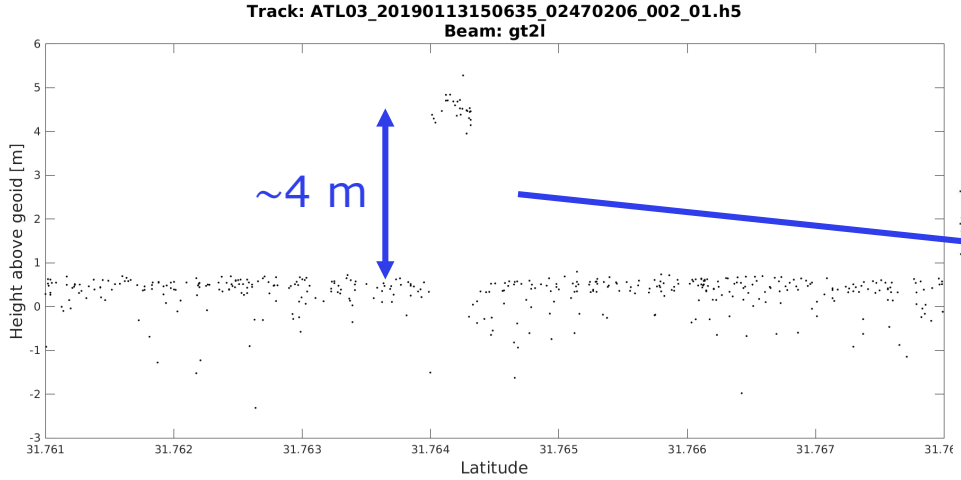
3. New possibilities with ICESat-2

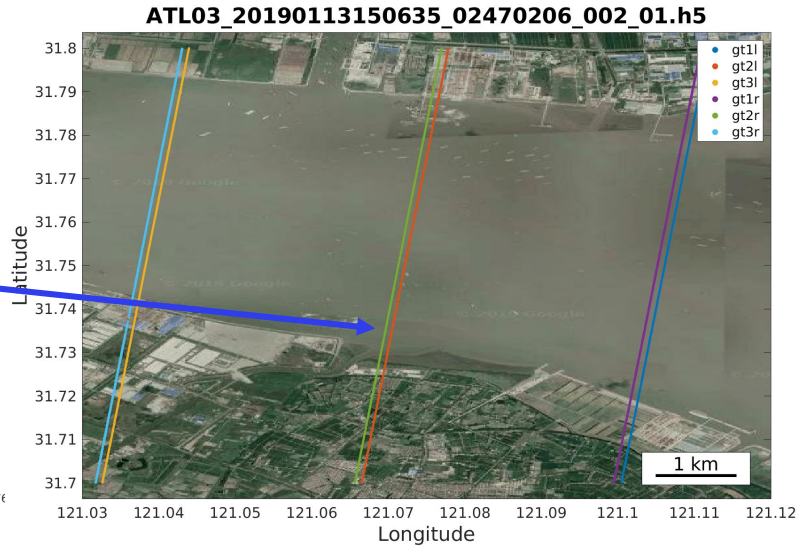
ICESat-2 is able to provide river elevations in areas where radar altimeters fail – like in narrow rivers in mountainous regions.





Because of the high along-track resolution of the photon data, ships on the rivers can also be detected.



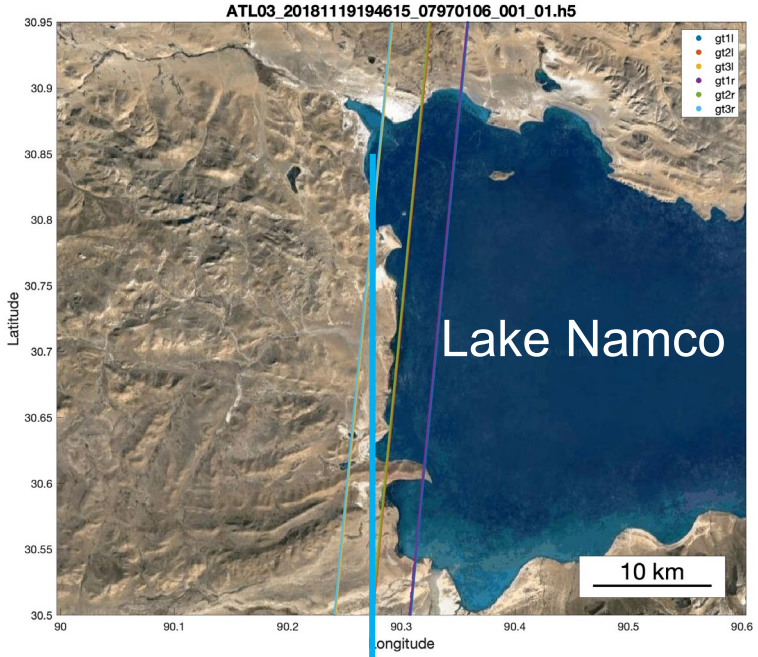


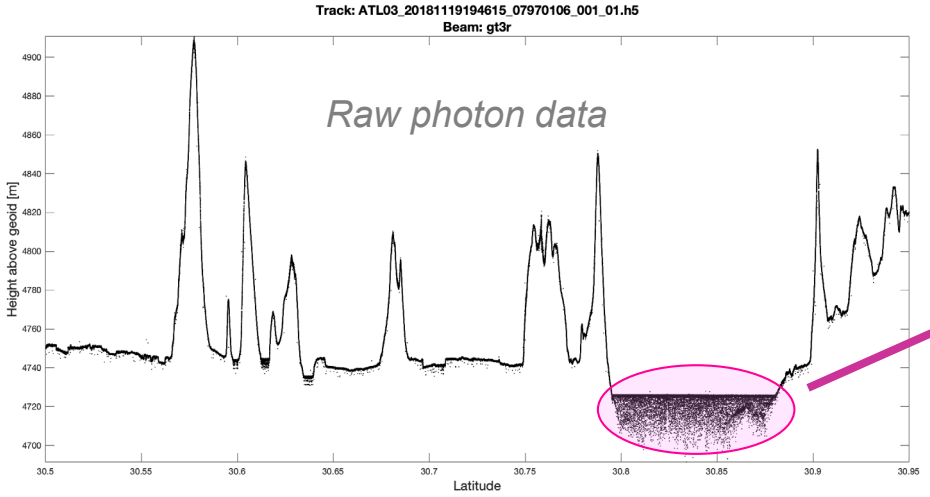
3. New possibilities with ICESat-2

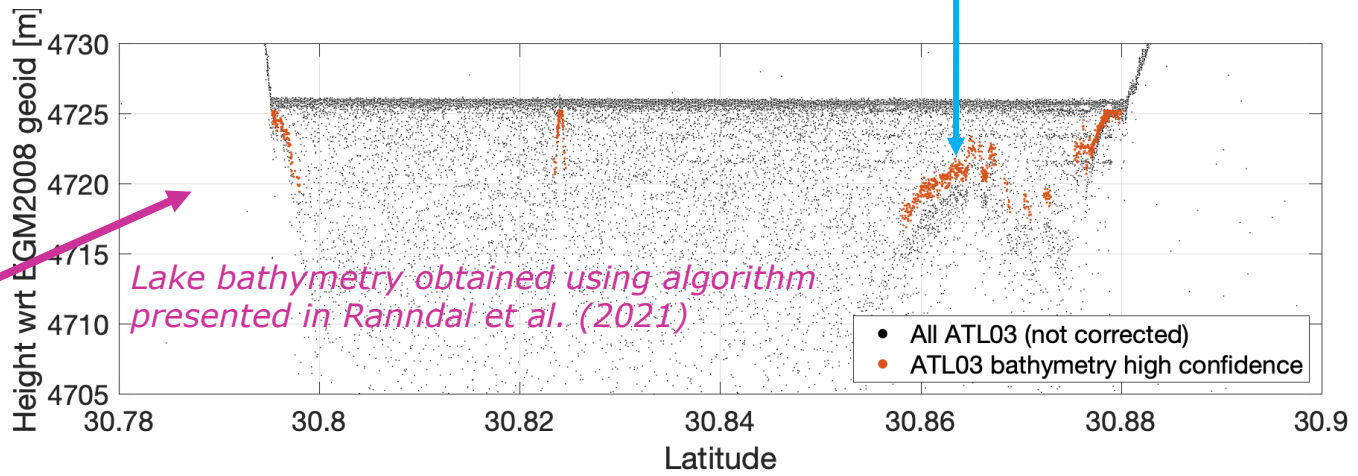
ICESat-2 can also detect photons reflected beneath the water surface.

The laser can reach a depth of down to 40 m under *ideal* conditions.

River bathymetry was not found for any of the studied rivers, but lake bathymetry was found for Lake Namco.







Conclusions / outlook

- Obtaining accurate river levels from satellite radar altimetry in Chinese rivers is challenging due to the size of the altimeter footprint and the high number of scatterers.
- Remains difficult when using MWaPP in SAR mode, and even when using FFSAR
- Combining FF-SAR processing with MWaPP retracker should be attempted?
- Laser data from ICESat-2 is able to provide reliable river levels in the most challenging areas but limitation due to cloud cover.
- S3 A/B and S6 NRT data is now available (S6 higher temporal and along track res).
- Surface Water and Ocean Topography (SWOT mission) will be launched in late 2022.