Use of Icesat-2 data for upstream Yellow River hydraulic modelling

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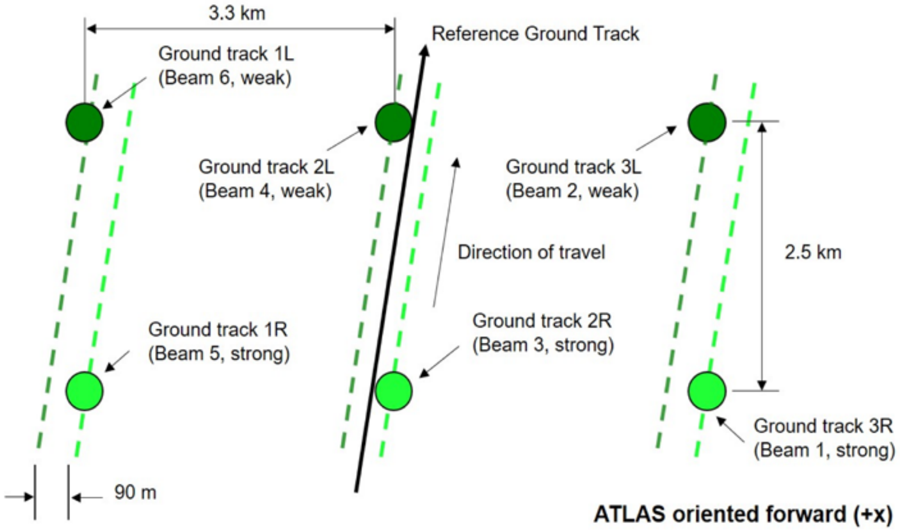
Objectives

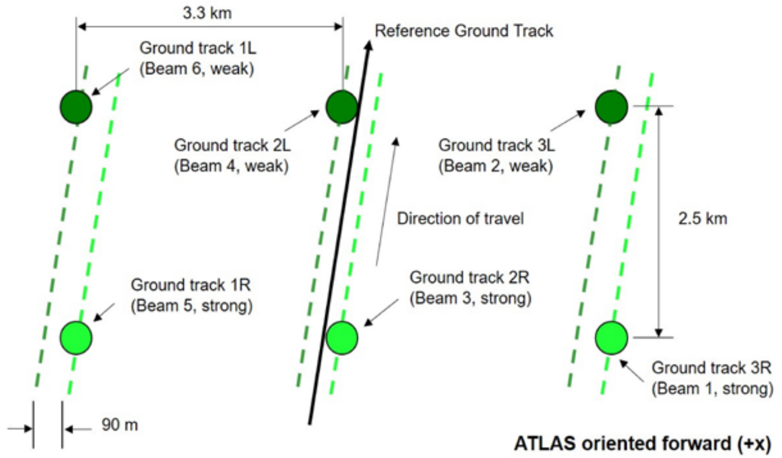
- **Create a 1D-hydraulic model of upstream Yellow River from Icesat-2 data**:
  - Icesat-2 provides high resolution data of inaccessible areas and ungauged river basins: 70 cm along track and down to 3.3 km inter-track.
  - The model will provide rating curves to estimate discharge from water surface elevation. Water surface elevation and discharge can be interpolated in space and time
  - Improve inland water monitoring on narrow river streams.

Icesat-2: Laser altimetry

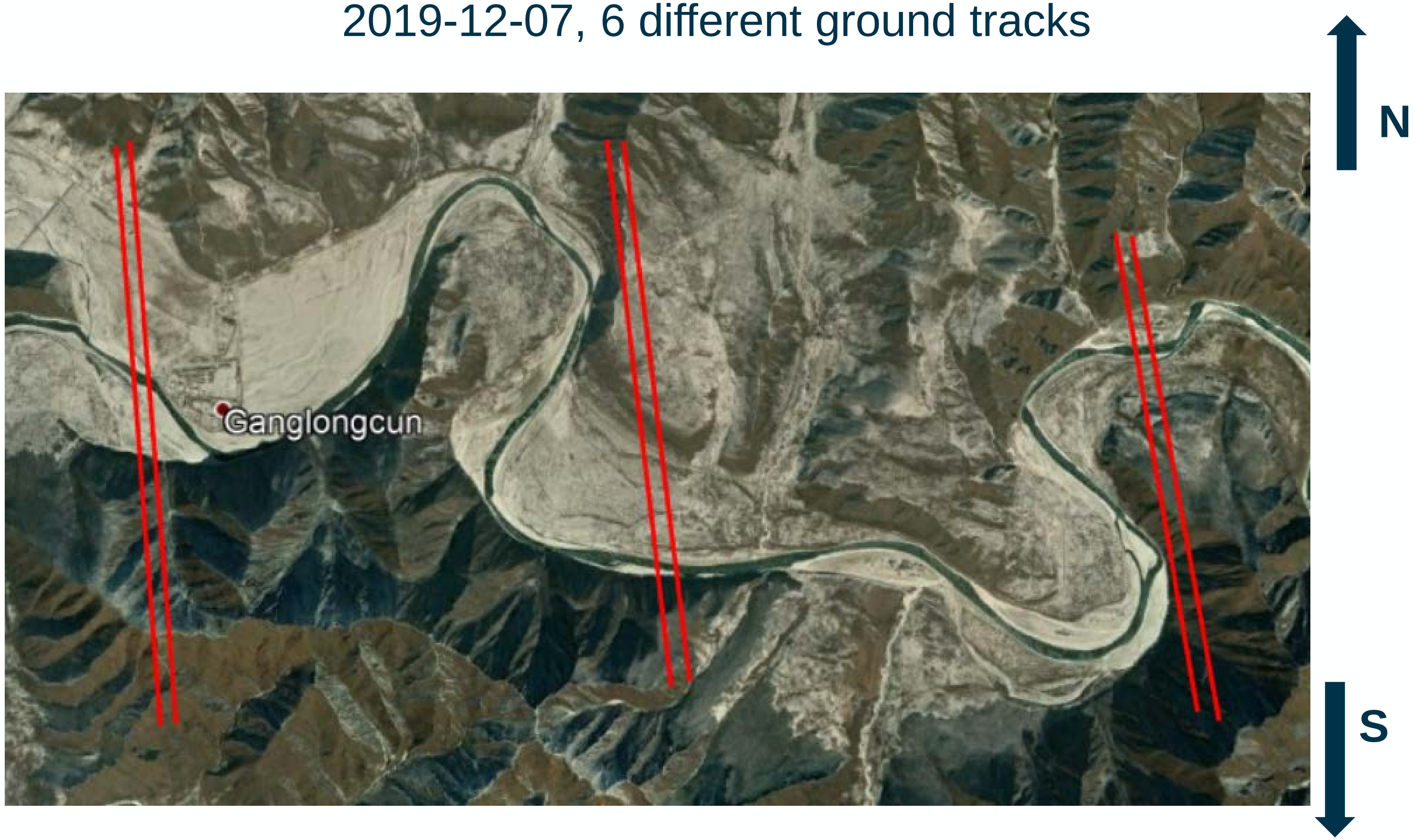
- Operating since September 2018
- Carries ATLAS (Advanced Topographic Laser Altimeter System)
- Repeat orbit every 91 days
- Along track resolution of 70 cm on the photon cloud product
- 28.8 km between Reference Ground Tracks (RGTs) at equator
- 6 different ground tracks: 2 beam configuration
- Limitation: Does not penetrate thick clouds



Icesat-2 ground tracks: Slope estimation



2019-12-07, 6 different ground tracks

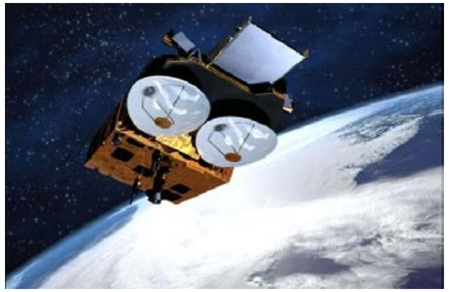


Use of water surface elevation slope:

- Help local estimations of discharge
- Assume uniform flow conditions
- Good approach to be used at virtual stations

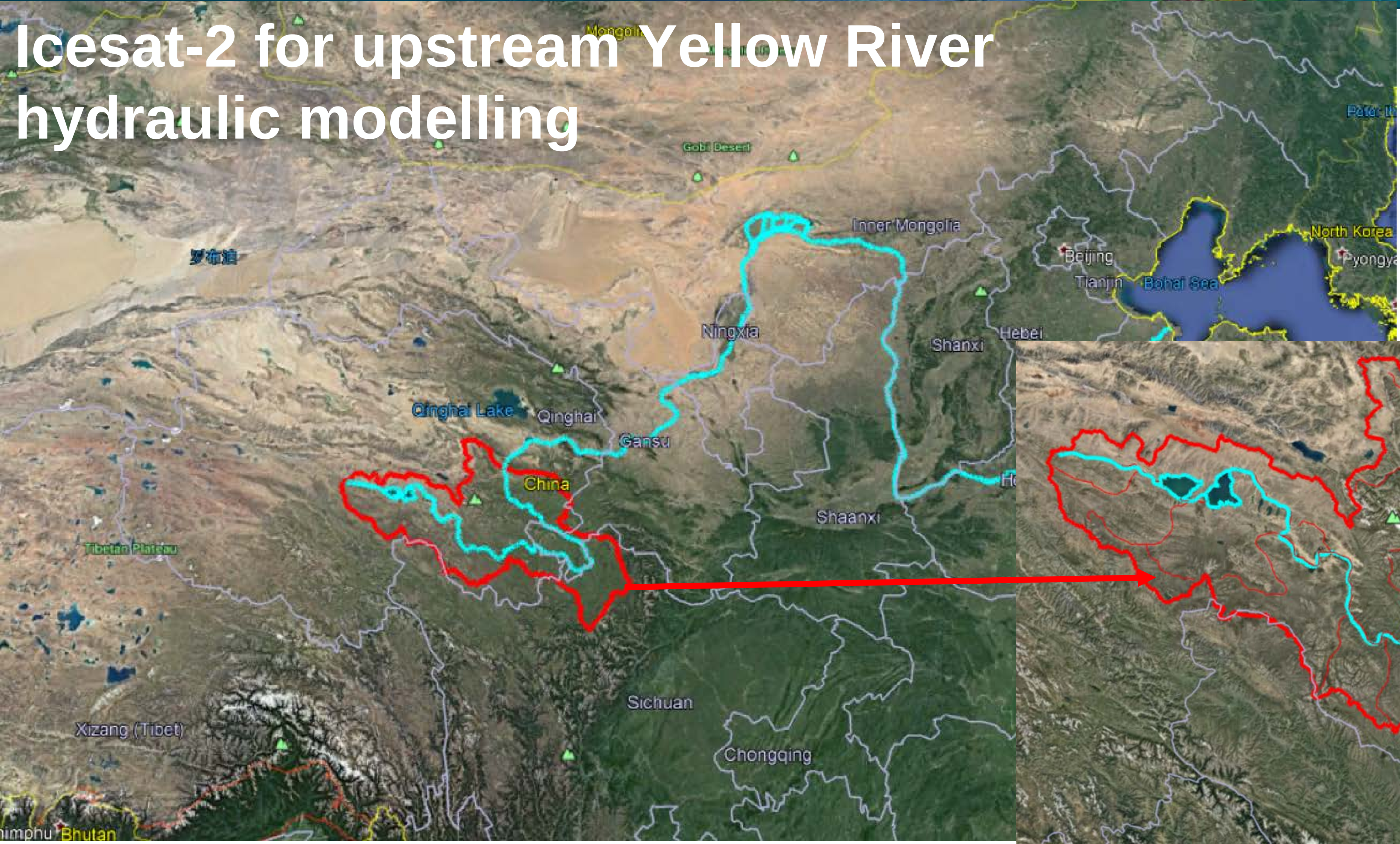
Altimetry missions

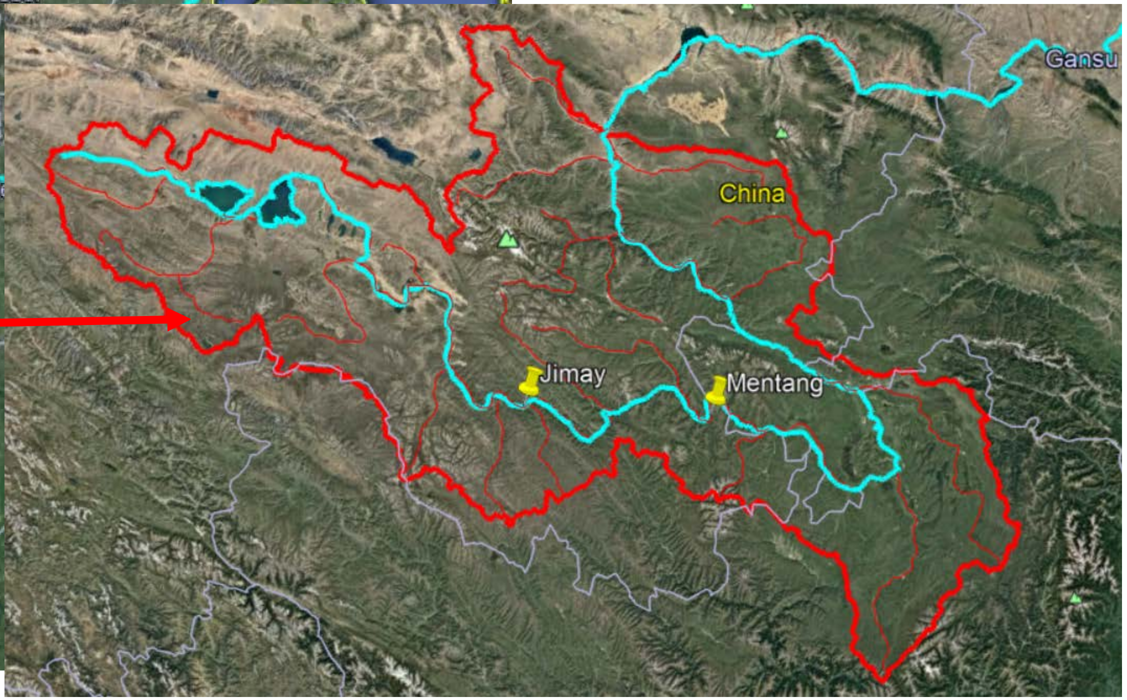
	IceSat-2	Sentinel-3	Cryosat-2
Repeat Cycle	91 days	27 days	369 days
Along track resolution	0.7 m (ATL03 product)	300 m	250 m
Footprint (cross track)	13 m	15 km	15 km
Ground track separation at Equator	28.8 km between RGTs, 3.3 km between beam GTs	52 km	7.5 km
Payload	Laser	Radar	Radar
Weather operation	Does not penetrate thick clouds	All weather conditions	All weather conditions



Icesat-2 for upstream Yellow River hydraulic modelling

- The hydraulic model is informed with IceSat-2 cross sections
- River Width 80-160 meters
- Complex surroundings



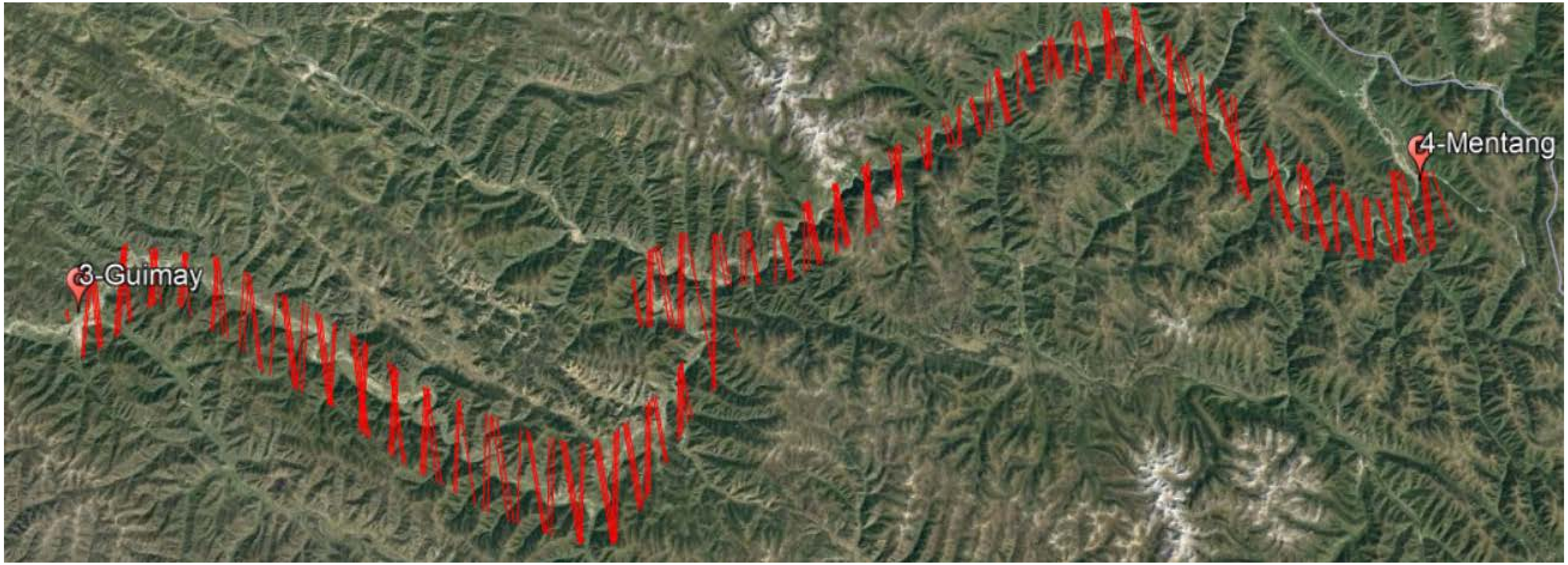


Icesat-2 for hydraulic modelling

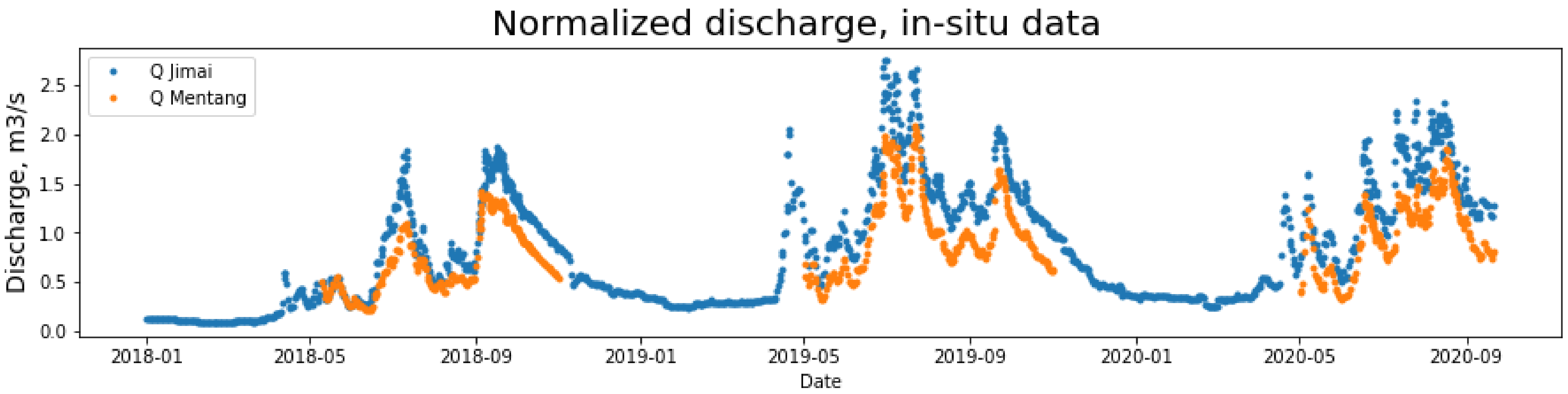
- Provides valuable information for hydraulic modelling:
  - River width, water surface elevation and cross-section geometry
  - High spatial resolution of inland water bodies
  - Repeat orbit: Acquisition at different times in the same area

Jimay-Mentang river range

- Around 100 Icesat-2 Cross sections covering the whole are for low season
- In-situ discharge and WSE measurements from gauge stations Jimay and Mentang



Jimay-Mentang river range: In-situ data 2018-2020



Icesat-2 derived parameters: WSE and river width

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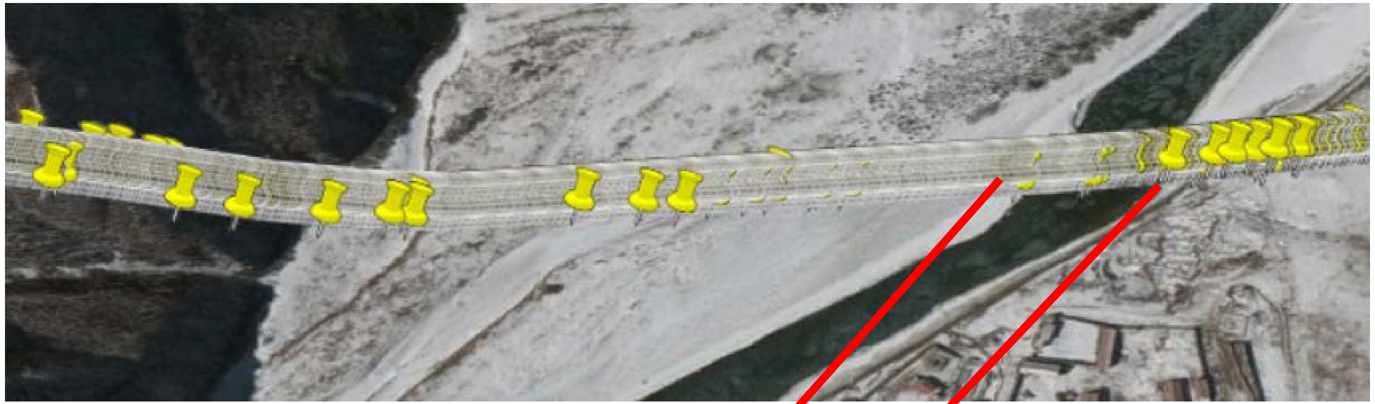

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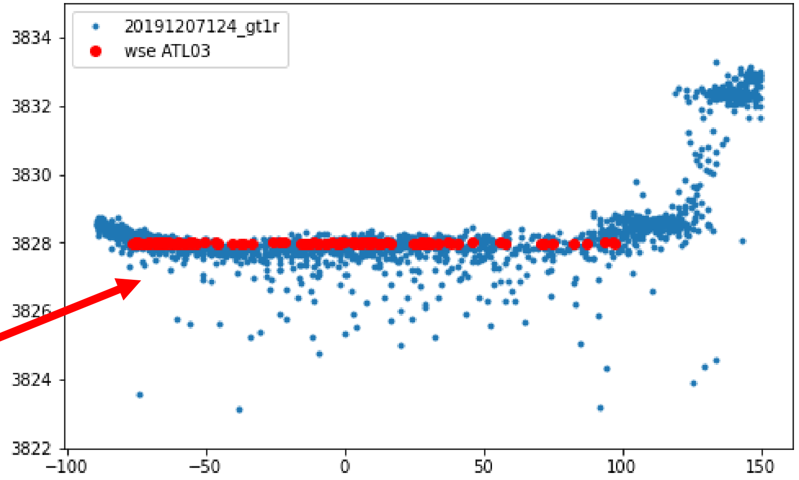
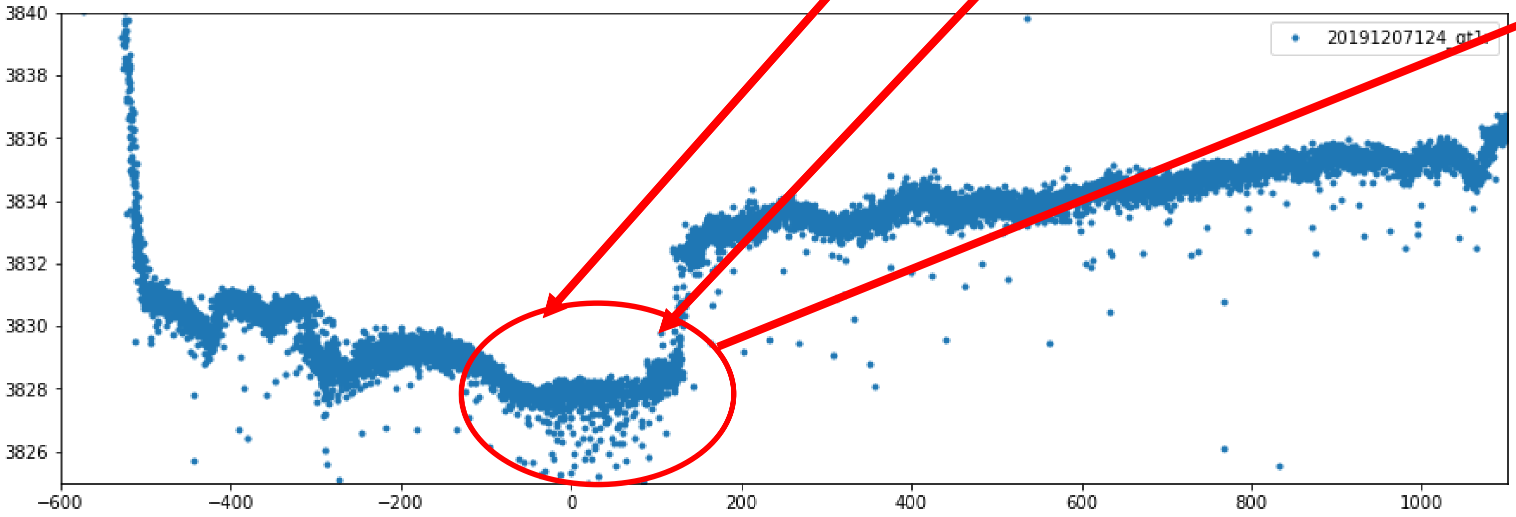


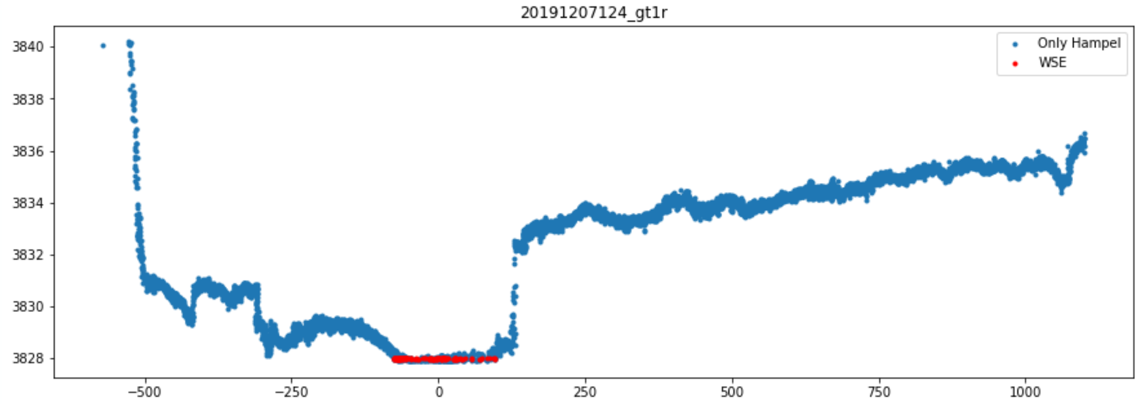


Identify water surface:

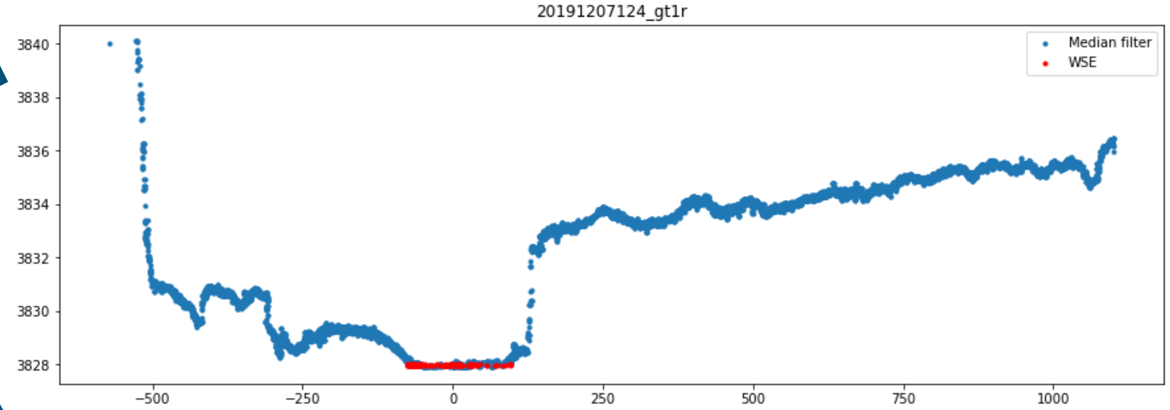
- Flat and dense cloud of photons
- Gaussian Kernel distribution
- Information on river width

Icesat-2 : Cross-section geometry processing

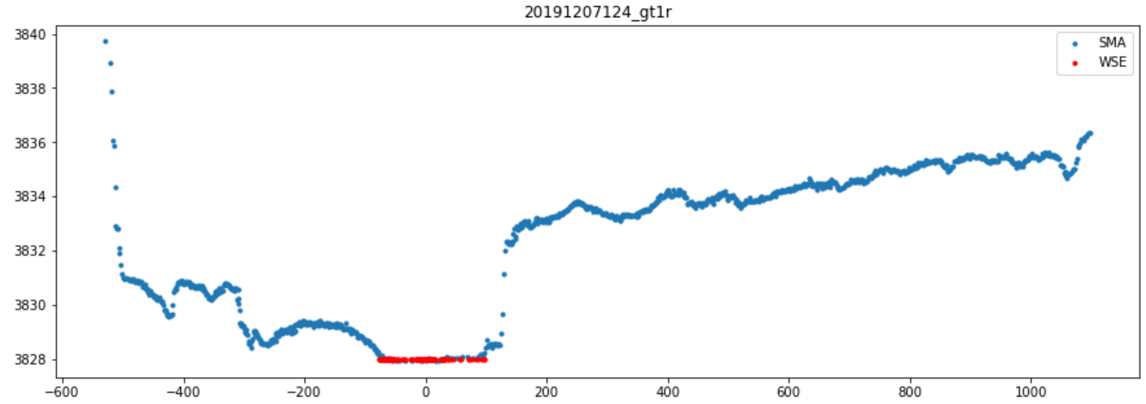
Outlier removal: Hampel filtering



Median filter



Smoothing: Simple moving average



r-channel geometry: Submerged portion

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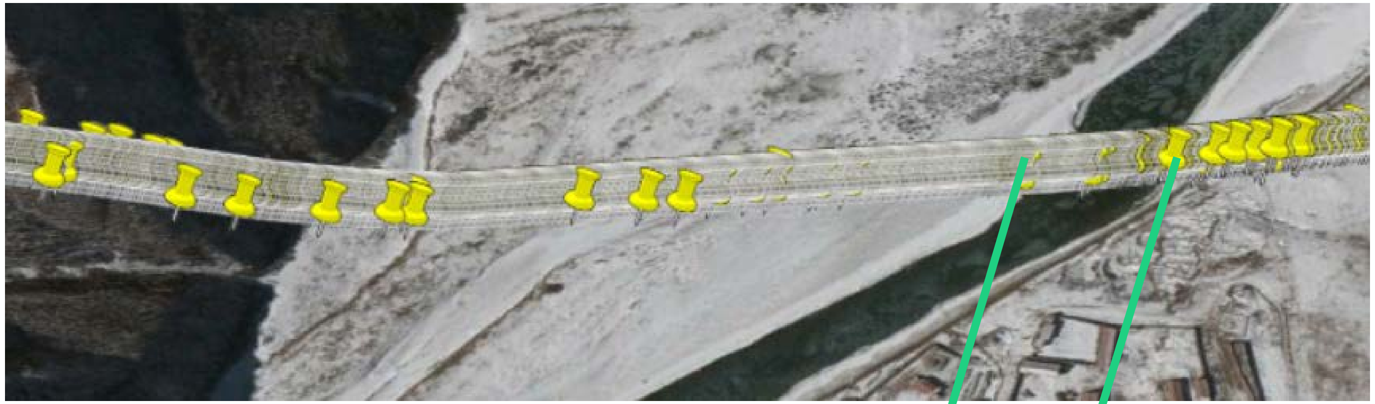
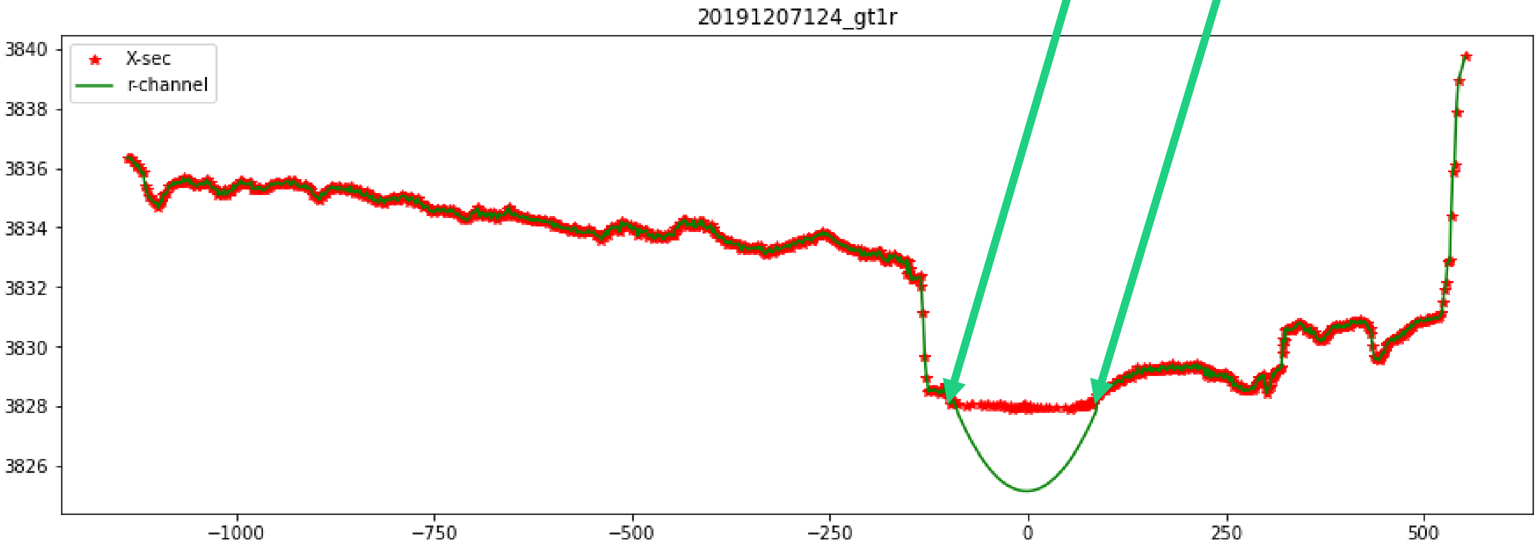




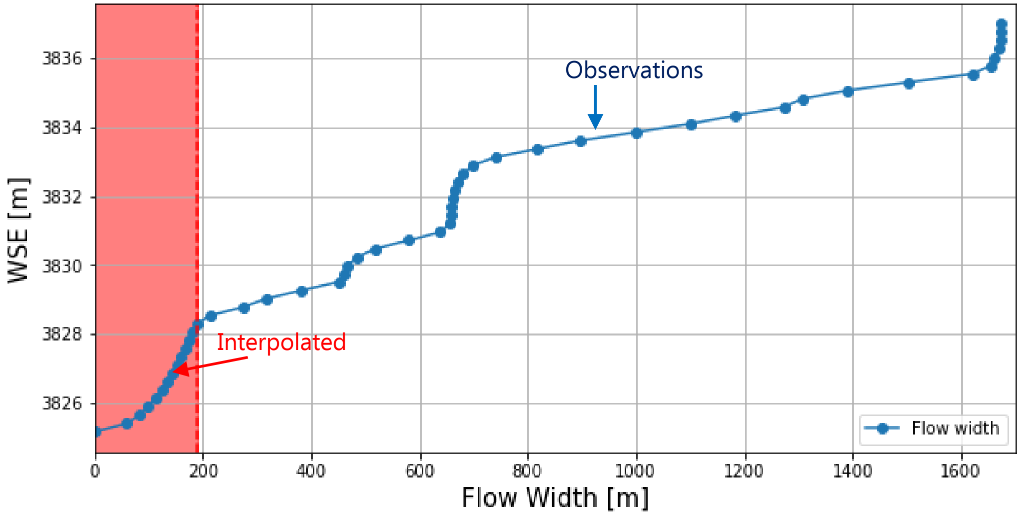
r-Channel Geometry (Dingman, 2006):

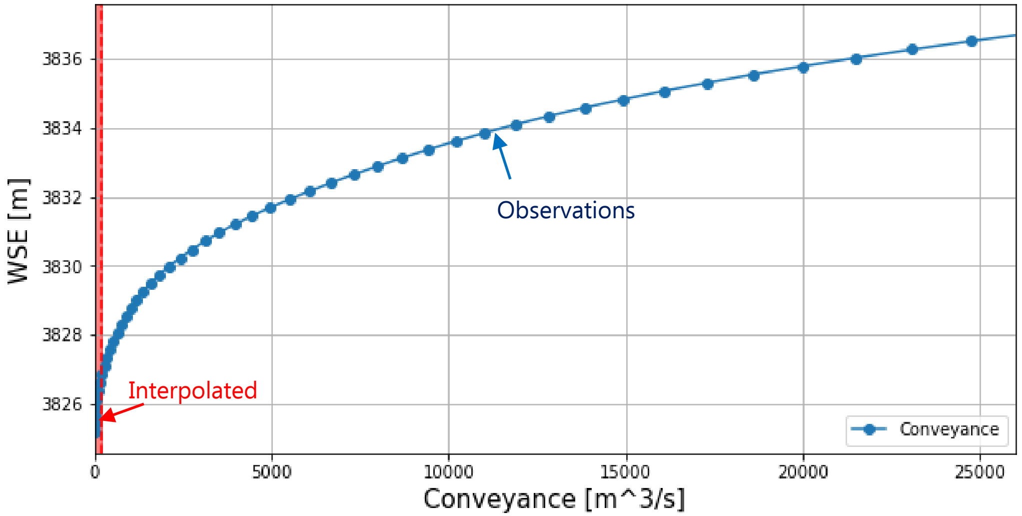
- r → X-sec form exponent
- Height above the lowest channel elevation

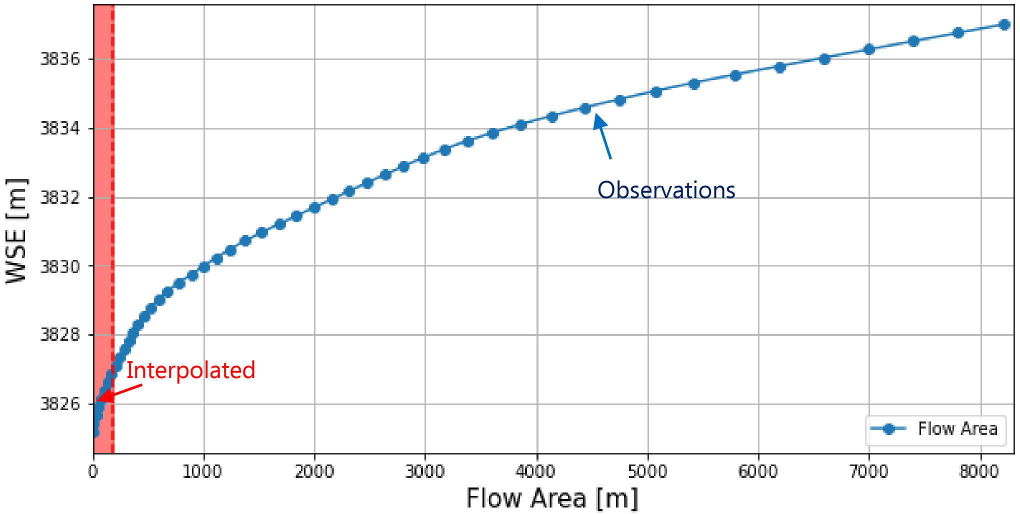
Icesat-2: Geometric characteristics

- Lookup tables of geometric characteristics given water level (most of it from observed data):
  - o Conveyance
  - o Flow Area
  - o Flow Width

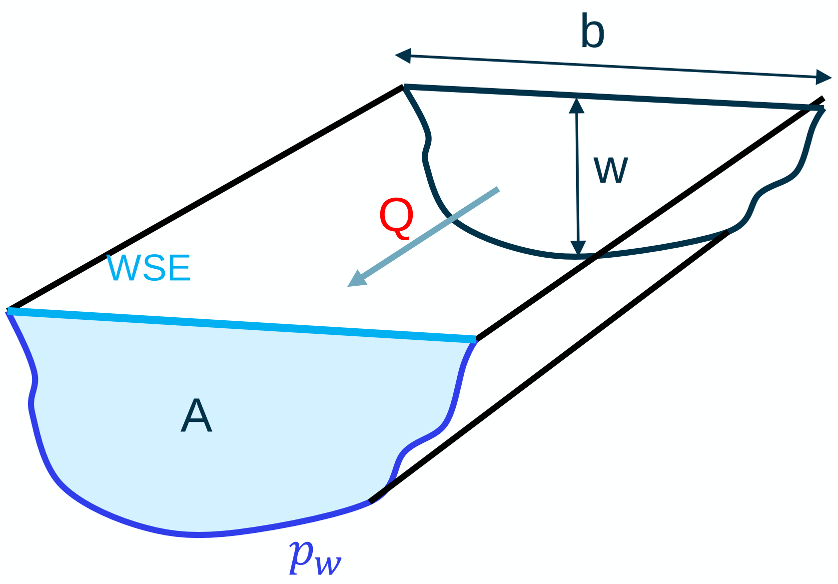
- Results from IceSat-2 data initial conditions Initial conditions: $depth_0 = 2.5$ m, $r_0 = 2.3$, $n_0 = 0.04$







1D hydraulic model workflow



WSE = water surface elevation

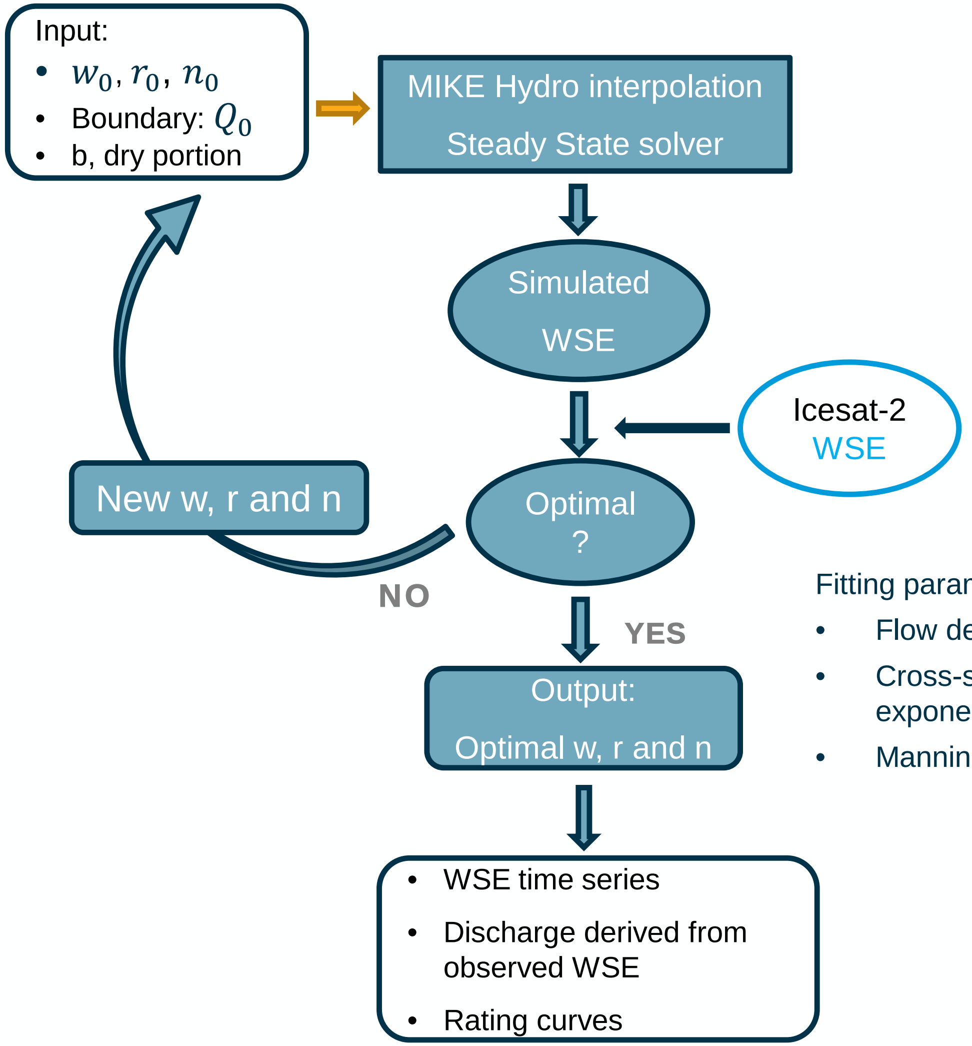
w = flow depth

Q = discharge

b = water surface width

p_w= wetted perimeter (r-geometry)

A = cross sectional flow area



Fitting parameters:

- Flow depth, w
- Cross-section form exponent, r
- Manning's number n

1D hydraulic model: Flow accumulation map

Assumptions

- 2 in-situ data sets for discharge, upstream and downstream
- Discharge is distributed as flow accumulation map
- No need for rainfall-runoff model

Two scenarios:

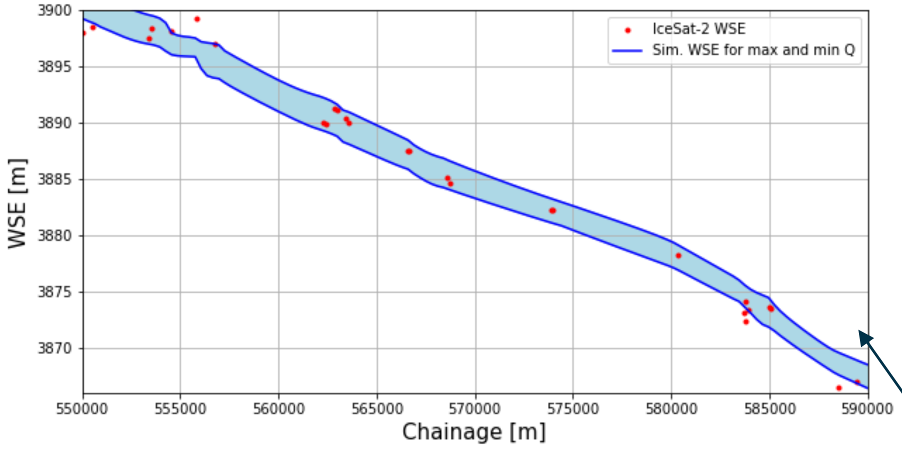
- In-situ data at 2 stations: specific runoff same as contributing area:

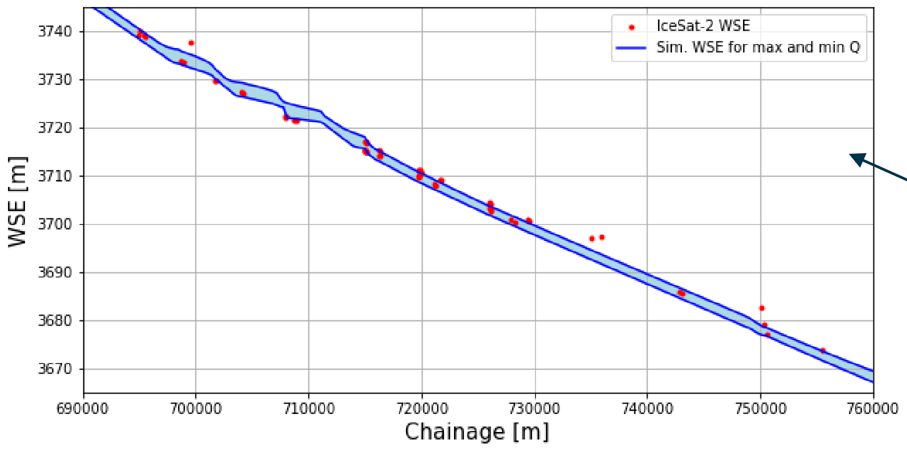
$$Q_x = \frac{UPA_x - UPA_0}{UPA_{end} - UPA_0}(Q_{end} - Q_0)$$

- In-situ data at upstream station only: specific runoff same as upstream:

$$Q_x = \frac{UPA_x - UPA_0}{UPA_0} Q_0$$

1D hydraulic model: Steady-State solver





- Steady state solution of Saint-Venant equations
- Creates WSE profile along the river for selected discharge
- Efficient calibration for spatially dense water surface elevation observations at low computational cost (Kittel,2021)

- Steady State solution for maximum and minimum discharge from Mentang in-situ data (downstream). No calibration
- Initial conditions: $depth_0 = 2.5$ m, $r_0 = 2.3$, $n_0 = 0.04$
- IceSat-2 water surface elevation measurements represented by red dots
- After calibration we expect precision to cm level thanks to IceSat-2 precise measurements

Next steps

- 1st parameter calibration with available data: Using steady state solver for hydraulic model
- Add regularization term for depth at each cross-section, depending on monthly water level
- Derive rating curves from calibrated model. Estimations of discharge from water surface elevation along the river at any time
- Study the performance of the model and the possibility of integrating rainfall-runoff model

Thanks for your attention