Reconstructing the spatial and temporal elevation signals from ICESat-2

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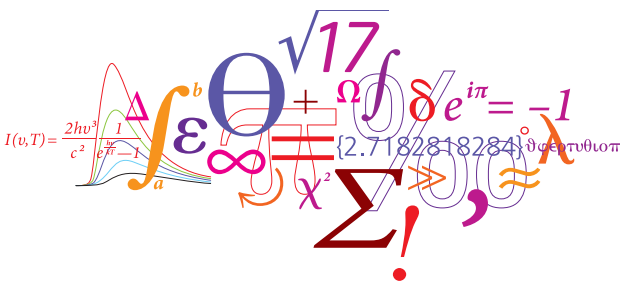

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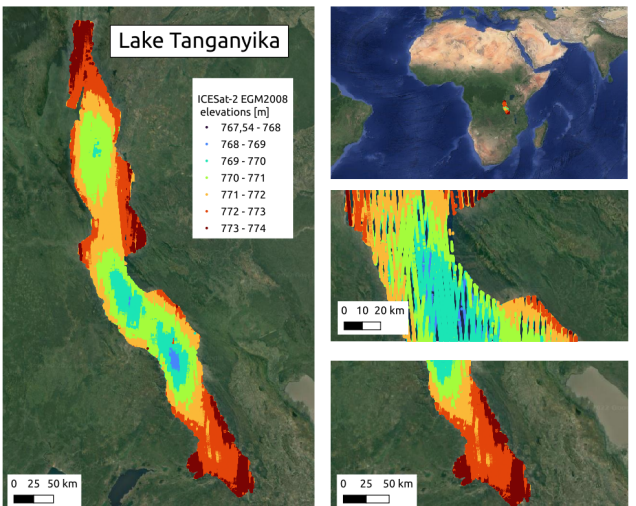
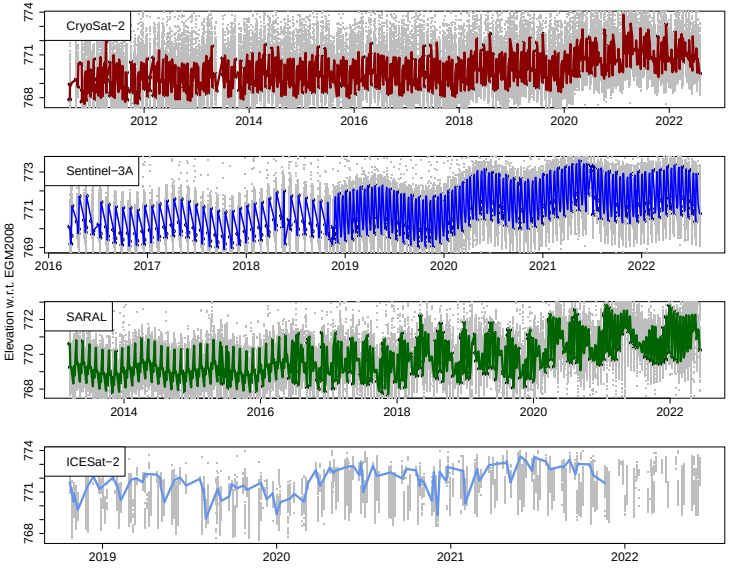
Motivation



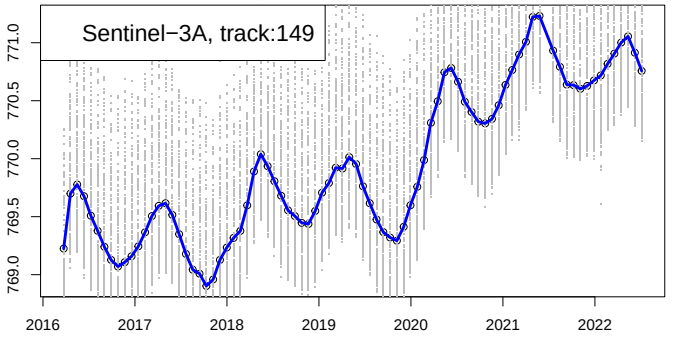
- It is known that residue geoid signals may be present on large lakes after correcting the water surface elevations for the geoid
- Previously modeled using CryoSat-2 and SARAL/AltiKa (Jiang at al., 2019)
- However, this is very clear with ICESat-2
- The residue signal affects the water level time series especially for geodetic altimetry missions

Motivation



- The residue signal deteriorates the time series

Motivation



- We can do a descent job when just considering one track
- A common reference is needed if more tracks are used to reconstruct the water level time series
- To improve the water level time series based on geodetic mission like CryoSat-2 we must be able to minimize the effect of the residue signal
  - Assuming that the spatial signal is constant in time, we can try to separate

Spatial-temporal Model

- We assume that the ICESat-2 observations can described as

$$H_{i,t} = \omega_i + \mu_t + \epsilon_{i,t} \quad \text{where } \epsilon_{i,t} \sim N(0, \sigma^2_{obs})$$

- Here $t = 1, \ldots, N$ where N is the number of times and $i = 1, \ldots, M$, where M is the number of cells in the spacial grid
- Here μ is a random walk and ω is a Gaussian Markov random field described as

$$\mu_t = \mu_{t-1} + \eta_i \quad \text{where } \eta_t \sim N(0, \sigma^2_{RW})$$

$$\omega \sim N(0, \sigma^2_{\omega} Q^{-1})$$

- The precision matrix Q (inverse covariance matrix) is defined as $Q = Q_0 + I$
- Here Q_0 specifies the neighbor structure and is given by

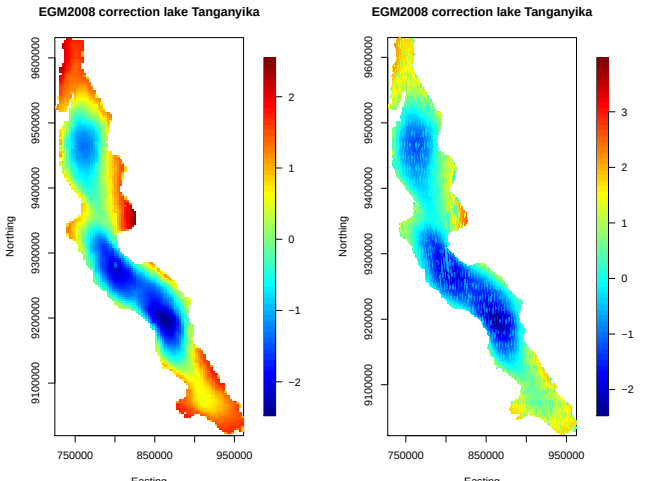
$$Q_0(i,j) = \begin{cases} \phi\#\text{neighbors}, & \text{if } i = j, \\ -\phi, & \text{if } i \sim j, \\ 0, & \text{otherwise.} \end{cases} \tag{1}$$

- Here ϕ is a parameters that controls the correlation

Pratical Workflow

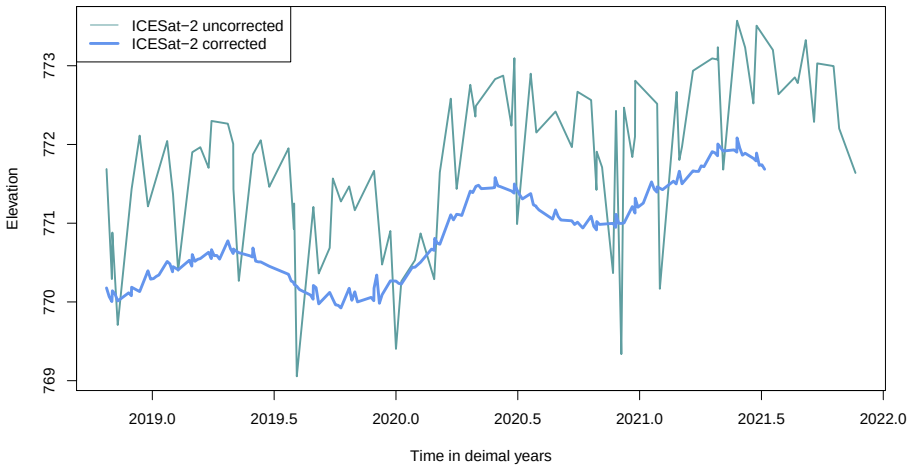
- Project ICESat-2 data to UTM coordinates
- Define a grid for the spatial solution, must define spatial resolution
- Use e.g. lake shapefile to define lake boundary in the grid
- Set up the neighbor structure, the Q_0 matrix
- Assign measurements to grid cells
- Use model (previous slide) to estimate residual grid and time series
  - Model is implemented in R via the R-package "TMB" `http://tmb-project.org`

Spatial reconstruction of ICESat-2 water levels

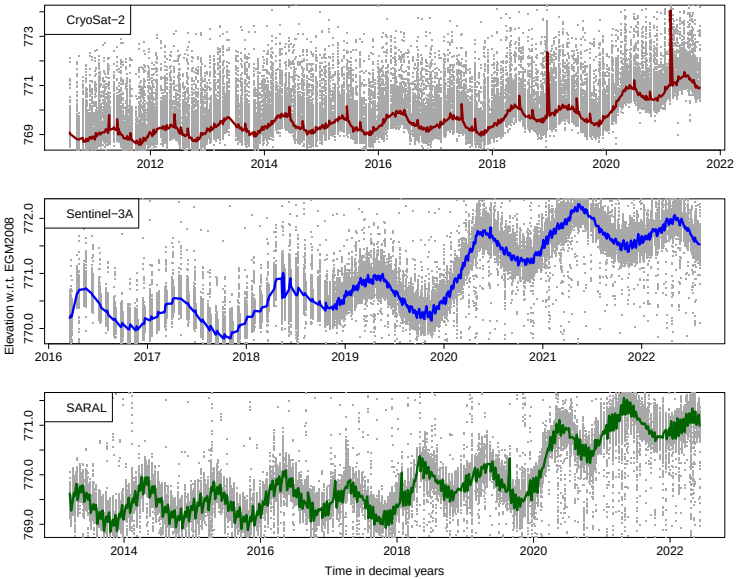


- Left: 3 x 3 km grid cells, Right: 1 X 1 km grid cells
- In the 1 X 1 km solution we see the tracks, Correlation in the data is not accounted for

Temporal reconstruction of ICESat-2 water levels

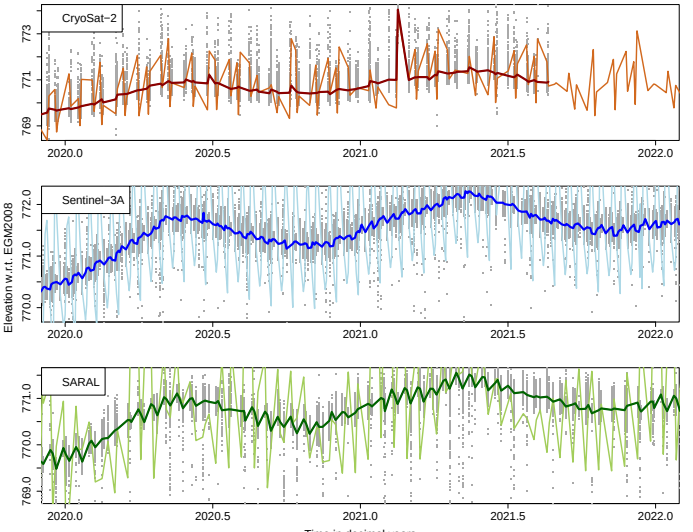


Corrected water level time series



- Still some residue signal, but much better than before

Corrected water level time series



- The improvement is more evident when zooming in
- The lighter colors show the water level time series before the correction

Summary

- Set up a spatial-temporal model to describe the ICESat-2 water levels
- Apply spatial grid to correct the water level from other altimetry missions
- We obtain improved water level time series from CryoSat-2, AltiKa, and Sentinel-3
- More investigations are needed to improve the model
- To space agencies: **Missions in a geodetic orbit (like CryoSat-2, ICESat-2) are essential for hydrology**

Thank you, questions?

Please, consider submitting to EGU 23-28 April 2023

G3.2 **EDI**

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