Progress in lake water storage algorithms

- Science Team SWOT June 2018 -

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Objectives

- Create a module with algorithms to :

  ➡ Measure the lake volume between two water heights from SWOT products. The steps to do this :
  - Creation of Digital Elevation Model (DEM)
  - Generation of water masks

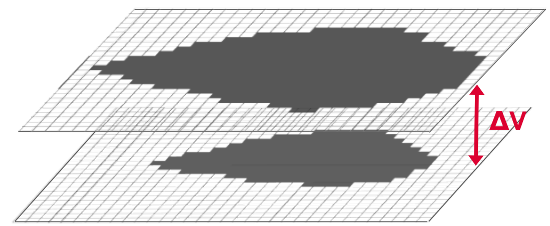
  ➡ Get the lakes' bathymetry

Creation of DEMs

- Why to create DEMs ?

1- To have case studies : lakes.

And to get water masks.



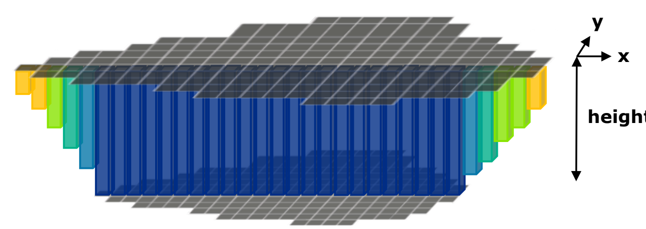
2- To measure the water volume variation

between different water levels (ΔV).

2.1- Volume measurement with algorithms.

3- Measurement comparison
=> ΔV error

2.2- Real volume mesurement from the DEM.




```
> Vpix = X_pixel_size * Y_pixel_size * height
> Vtot = sum(Vpix)
```

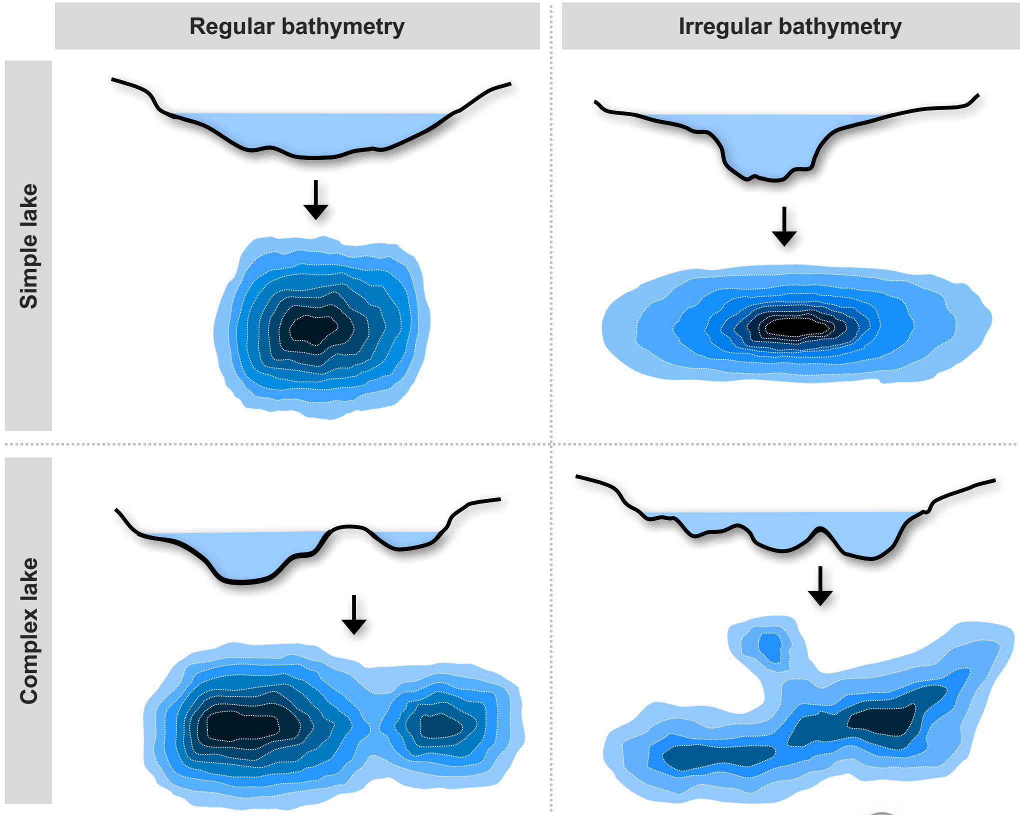
Creation of DEMs

- Some requirements to have in mind before creating DEM

➡ Settings must be configurable :

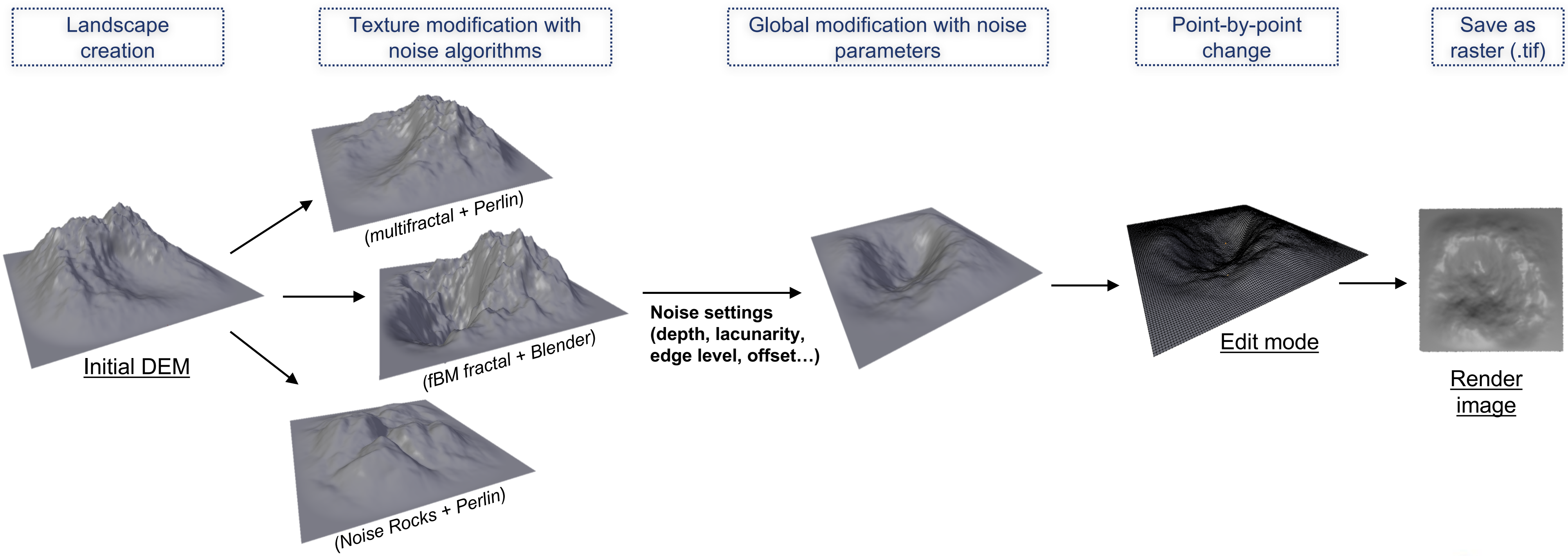
- pixel size ; matrix size
- known number of rows and columns
- height of each pixel

➡ Generate different DEMs to simulate the diversity of real lakes



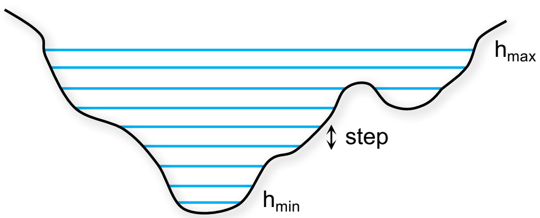
Creation of DEMs

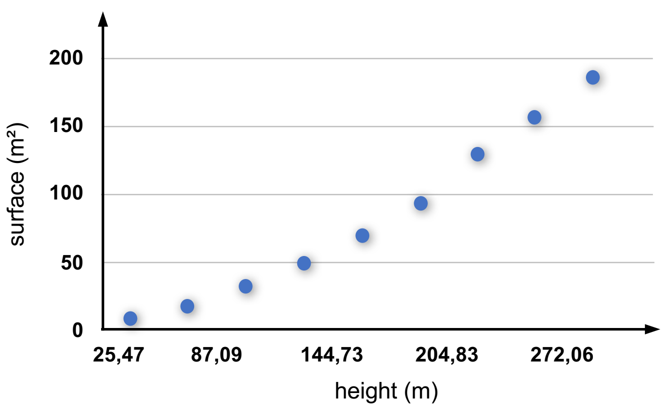
- How to create DEM ?
  - With free 3D modeling software : **Blender**

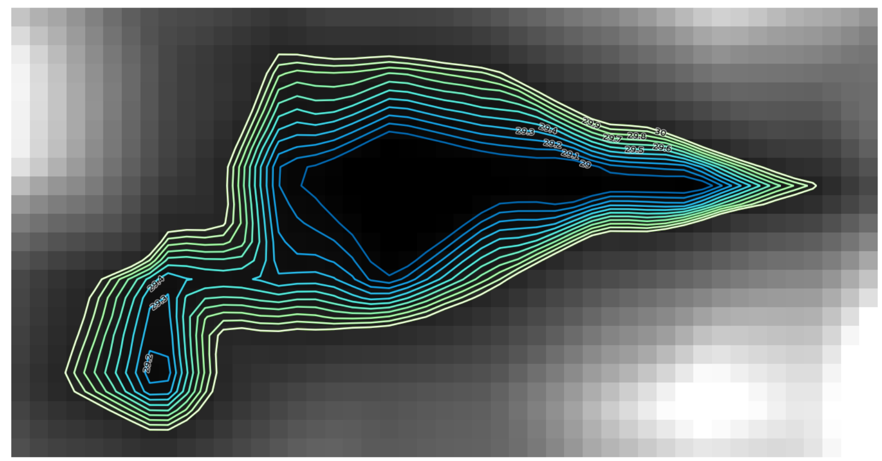


Creation of water masks

- Objectives : to create water masks from a DEM
- Each water mask corresponds to a surface and a water level such as will be the SWOT lakes products







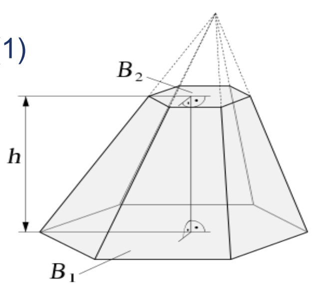
DEM of a lake and the corresponding water masks

Volume calculation with SWOT products (h, B)

- We consider that we have the final h & B SWOT products
- Quadratic hypothesis : we assume that the volume change can be approximated to the volume of a truncated pyramid
- Linear hypothesis: we assume that the volume change can be approximated to the volume of a trapezoid

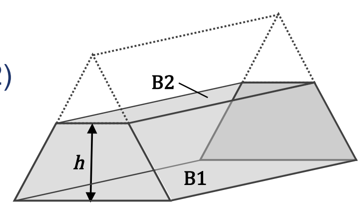
Basic formulas

(1)



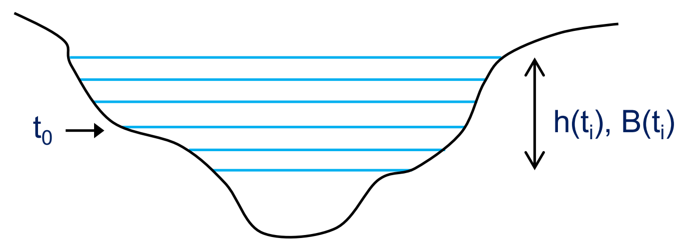
$$Volume = \frac{h}{3} . (B_1 + B_2 + \sqrt{B_1 * B_2})$$

(2)



$$Volume = \frac{h}{2} . (B_1 + B_2)$$

With SWOT



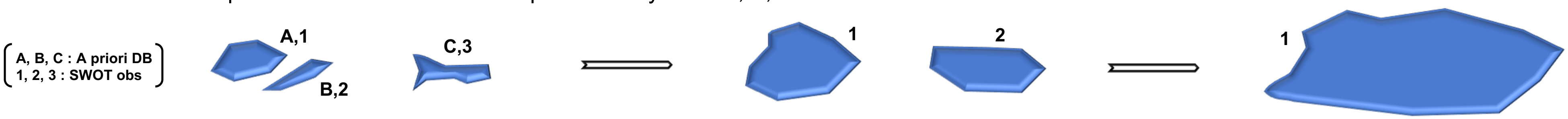
$$\Delta V\left(\frac{t_i}{t_0}\right) = \Delta V\left(\frac{t_{i-1}}{t_0}\right) + \frac{[B(t_i)+B(t_{i-1})+\sqrt{B(t_i)*B(t_{i-1})}]}{3} . [h(t_i) - h(t_{i-1})] \quad (1)$$

$$\Delta V\left(\frac{t_i}{t_0}\right) = \Delta V\left(\frac{t_{i-1}}{t_0}\right) + \frac{[B(t_i)+B(t_{i-1})]}{2} . [h(t_i) - h(t_{i-1})] \quad (2)$$

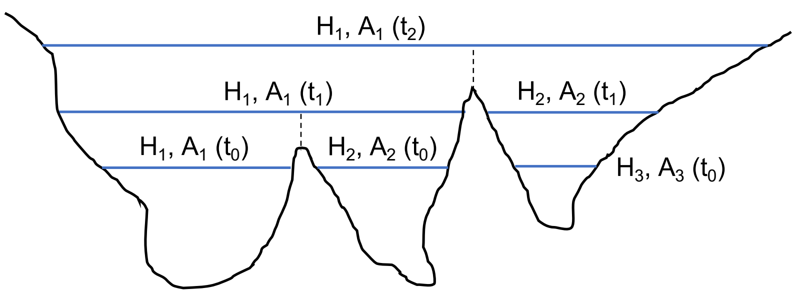
Create more complex theorical bathymetry in the simulator

- Complex multi lakes case

The A priori lake database must be update each year : A, B, C ⇨ 1



A priori data base & t_0 (from SWOT observation) t_1 (from SWOT observation) t_2 (from SWOT observation)



At t_1

$$\Delta V_1\left(\frac{t_1}{t_0}\right) = \Delta V_A\left(\frac{t_1}{t_0}\right) + \Delta V_B\left(\frac{t_1}{t_0}\right)$$

- $$\Delta V_A\left(\frac{t_1}{t_0}\right) = \frac{[H_1(t_1) - H_1(t_0)].[\alpha_1.A_1(t_1) + A_1(t_0) + \sqrt{\alpha_1.A_1(t_1) * A_1(t_0)}]}{3}$$
- $$\Delta V_B\left(\frac{t_1}{t_0}\right) = \frac{[H_1(t_1) - H_2(t_0)].[\alpha_2.A_1(t_1) + A_2(t_0) + \sqrt{\alpha_2.A_1(t_1) * A_2(t_0)}]}{3}$$
- $$\alpha_1 = \frac{A_1(t_0)}{A_1(t_0) + A_2(t_0)}$$
- $$\alpha_2 = \frac{A_2(t_0)}{A_1(t_0) + A_2(t_0)}$$

$$\Delta V_2\left(\frac{t_1}{t_0}\right) = \Delta V_C\left(\frac{t_1}{t_0}\right) = \frac{[(H_2(t_1) - H_3(t_0)] * [A_2(t_1) + A_3(t_0) + \sqrt{A_2(t_1) * A_1(t_0)}]}{3}$$

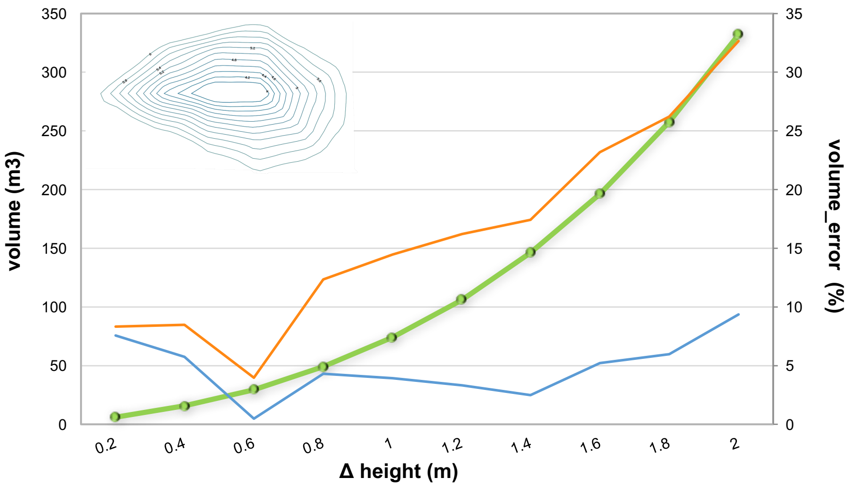
At t_2 ⟶ $$\Delta V_1\left(\frac{t_2}{t_0}\right) = \Delta V_1\left(\frac{t_1}{t_0}\right) + \Delta V_A\left(\frac{t_2}{t_1}\right) + \Delta V_C\left(\frac{t_2}{t_1}\right)$$

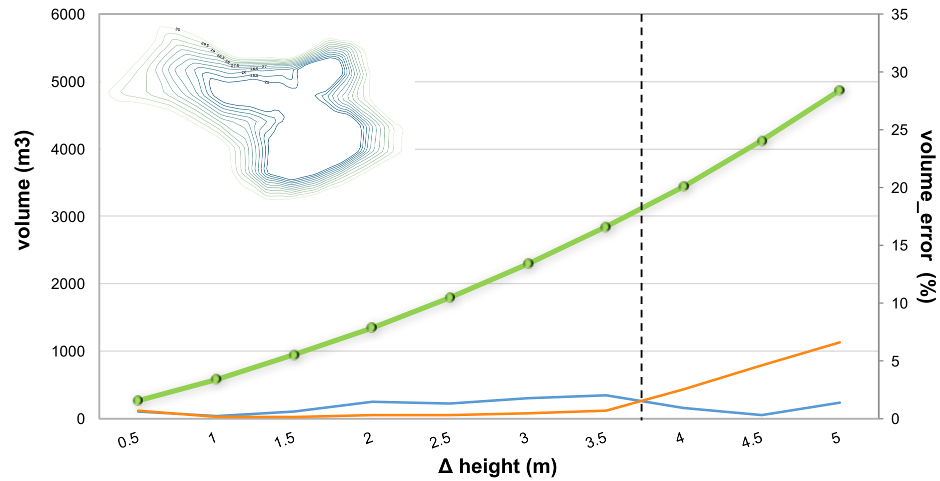
Iteration after 1 year :

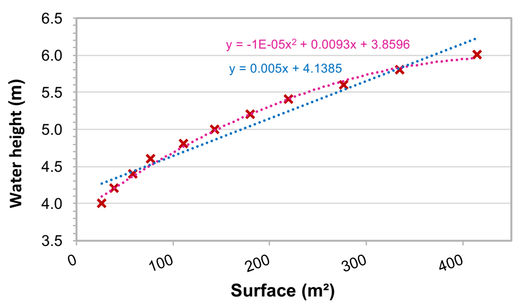
$$\boldsymbol{\Delta V_1\left(\frac{t_i}{t_0}\right) = \Delta V_1\left(\frac{t_{i-1}}{t_0}\right) + \Delta V_A\left(\frac{t_{i-1}}{t_i}\right) + \Delta V_B\left(\frac{t_{i-1}}{t_i}\right) + \Delta V_C\left(\frac{t_{i-1}}{t_i}\right)}$$

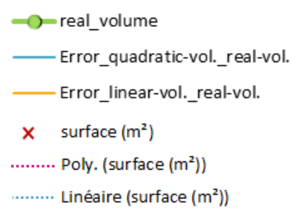
Problem if one of the A, B or C lake disapears totally at t_i ➞ the corresponding storage change is set to zero.

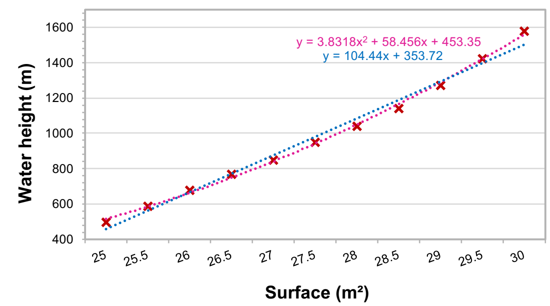
Measuring the volume variation between two water levels of a simple lake





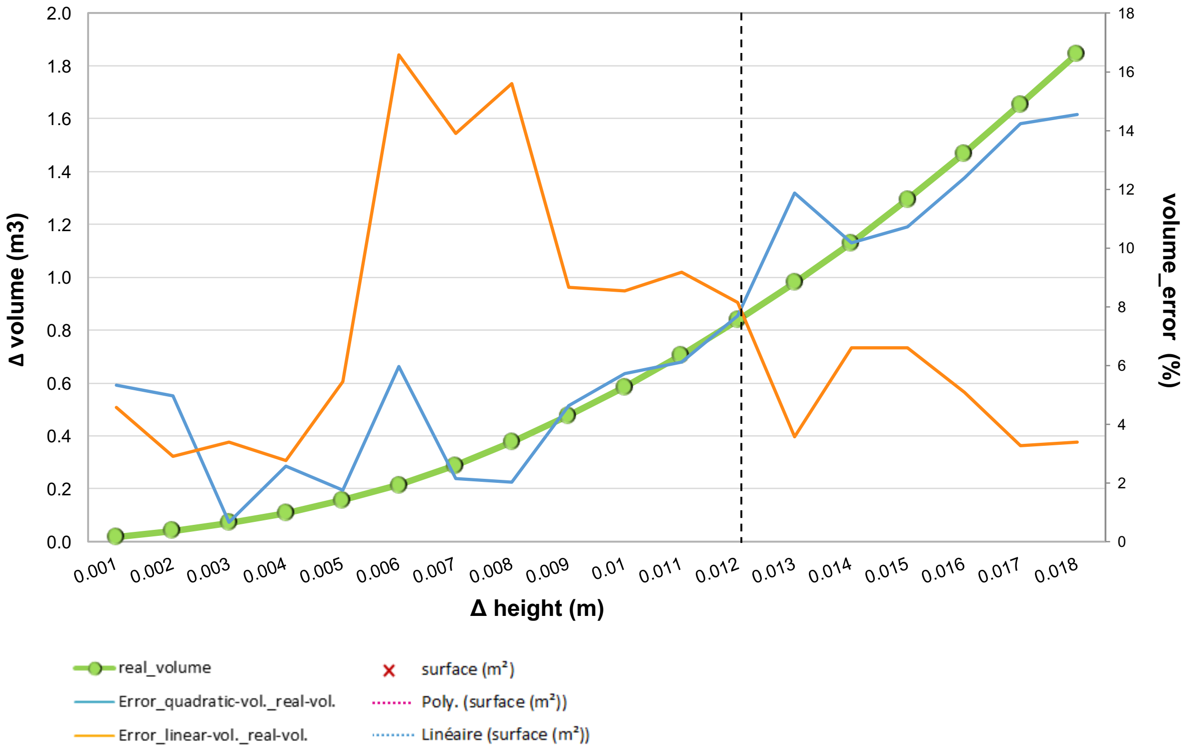


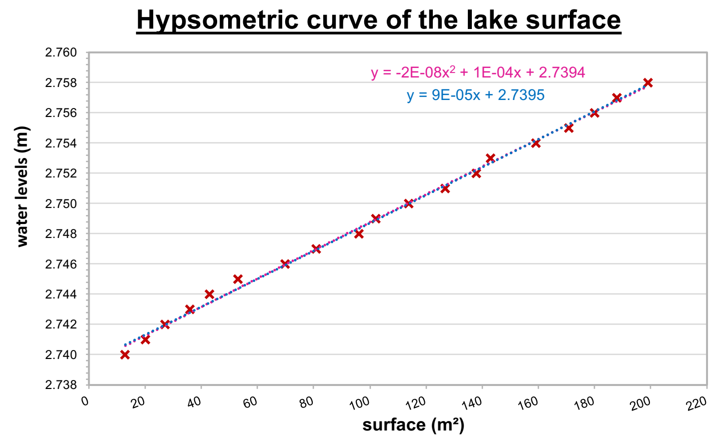


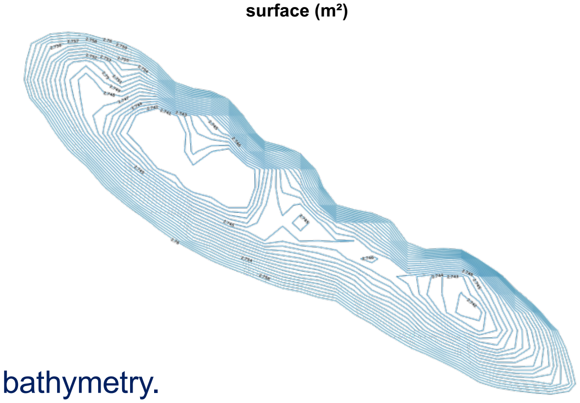


- With homogeneous water surface variation, the quadratic hypothesis is better to use.
- With irregular water surface variation we can use jointly both algorithms.

Measuring the volume variation between two water levels of a complex lake







- Both algorithms can be used to measure the volume variation in a single lake according to its bathymetry.

Conclusion

The work done so far :

- Handling a DEM software
- Algorithms to measure lake volume variations with the DEMs created were tested
- First results with variable errors were obtained

Perspectives :

- To use more complex formulas that are adapted to different lake topologies
- To work on more case studies
- To create the tool that will extract bathymetry from SWOT products

DEM creation	**Water masks creation**	**Test of the algorithms**	**The consideration of SWOT error**	**Extraction of the lakes' bathymetry**

Thank you for your attention

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