Lake storage variations algorithms update

- Science Team SWOT June 2019 -

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[Reminder] Objectives

- Create a module with algorithms to :
  - ➡ Measure the lake volume between two water heights from SWOT products.

The steps to do this :

1. Creation of Digital Elevation Model (DEM)
2. Extraction of the differents water masks from DEM

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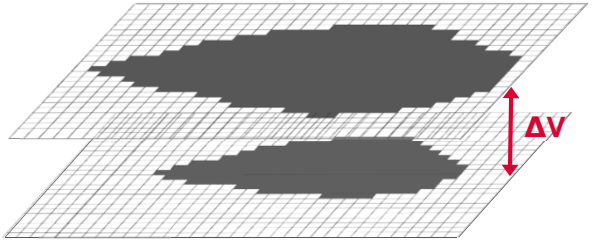
[Reminder] Creation of DEMs

- Why to create DEMs ?

1- To have case studies : lakes.

And to get water masks.

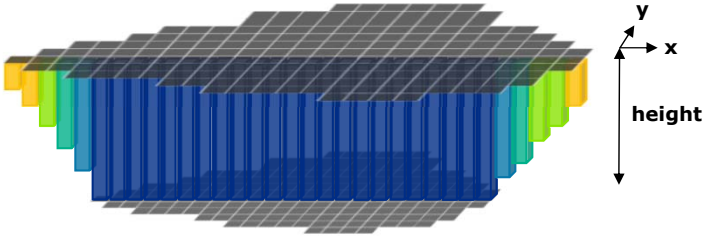
2- To measure the water volume variation between different water levels (ΔV).



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)
```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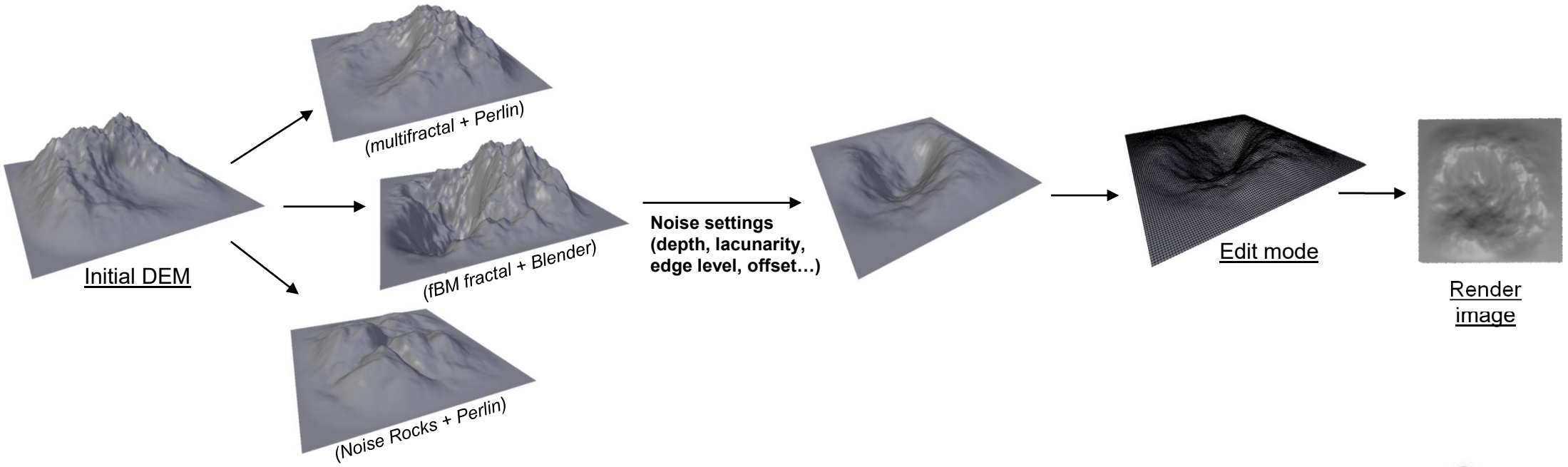
[Reminder] Creation of DEMs

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

Landscape creation | Texture modification with noise algorithms | Global modification with noise parameters | Point-by-point change | Save as raster (.tif)



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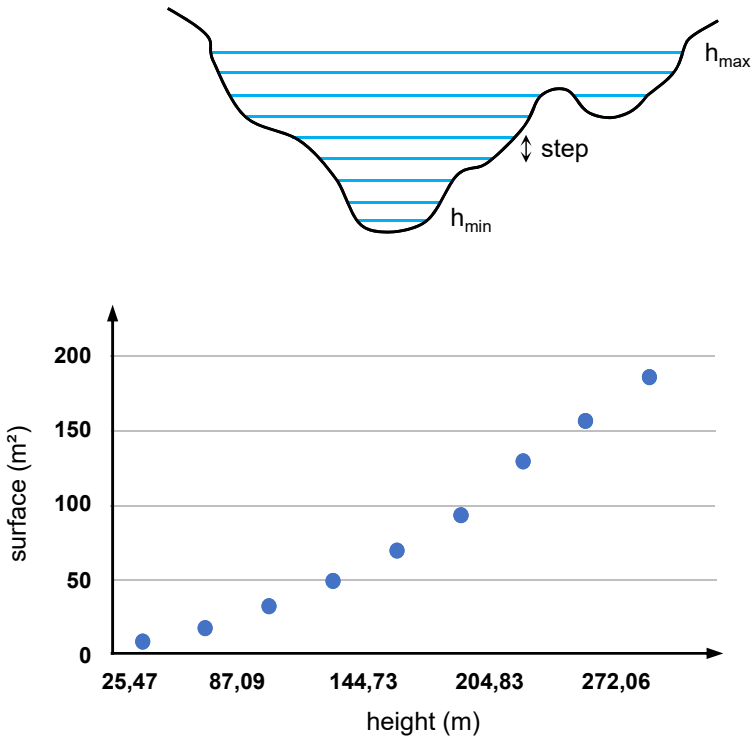
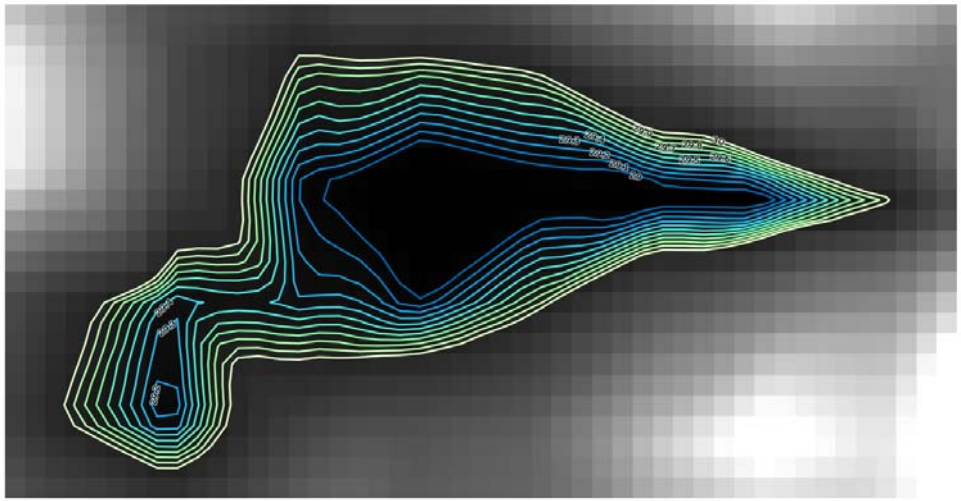
[Reminder] Creation of water masks

- 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

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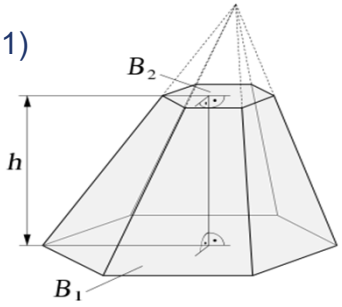
[Reminder] Volume calculation with SWOT products (h, B)

- 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

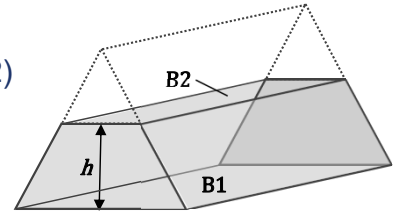
Basic formulas

(1)



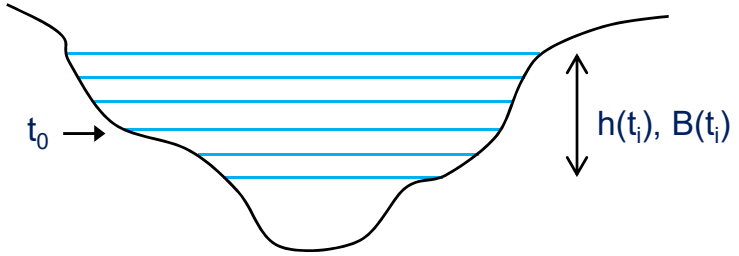
$$Volume = \frac{h}{3} . (B_1 + B_2 + \sqrt{B_1 * B_2})$$

(2)



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

With SWOT



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

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

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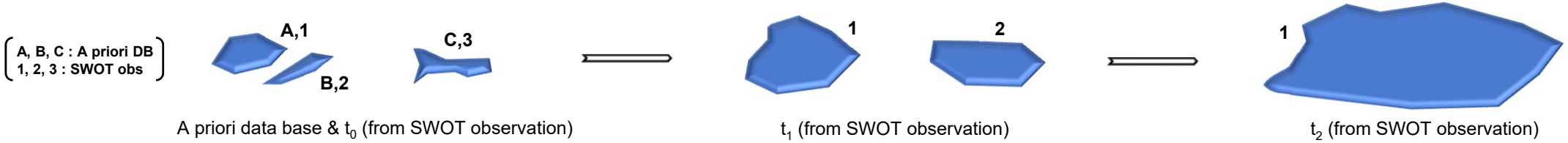
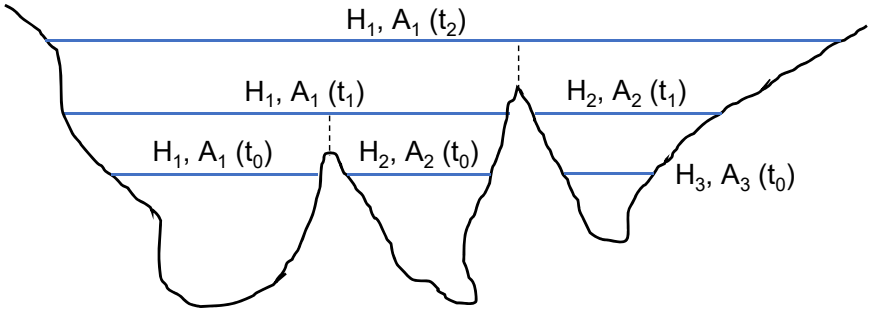
[Reminder] Create more complex theorical bathymetry in the simulator

- 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

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

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

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

Iteration after 1 year :

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

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

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

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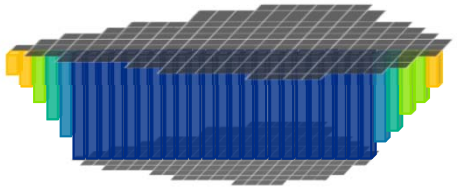
Algorithm tests

1. Errors induced only by algorithms

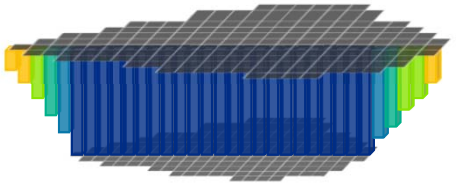


Real volume

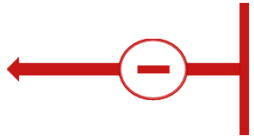
ΔV Error

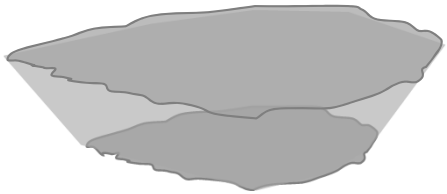
Volume measurement from the Water Masks (using both algorithms)

2. Errors induced by algorithms and the use of SWOT products



Real volume





Volume measurement from SWOT simulator products (using both algorithms)

(large scale simulator)

Water Masks (polygons)

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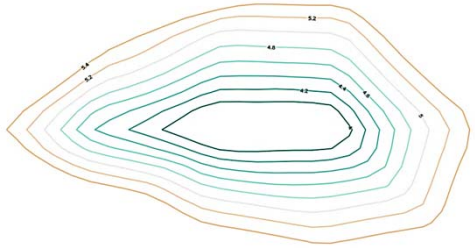
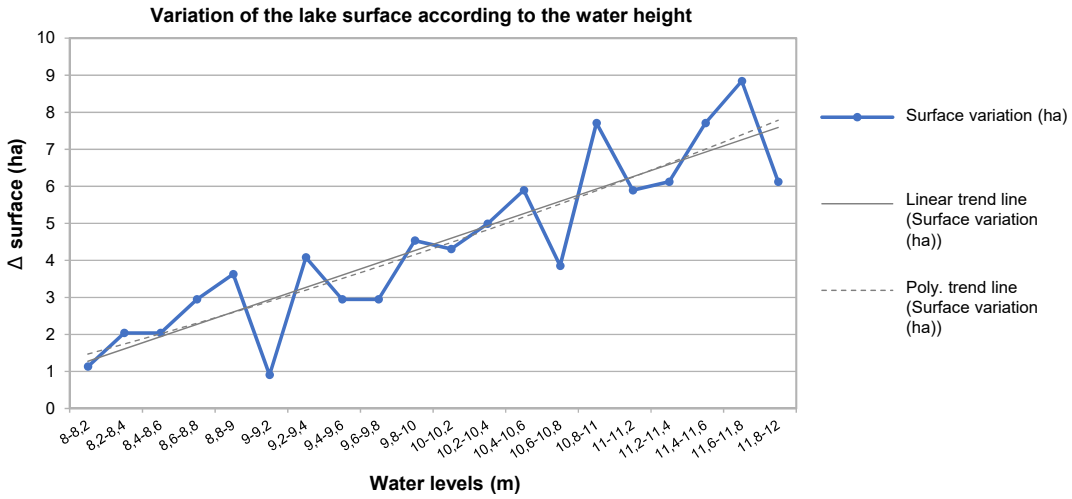
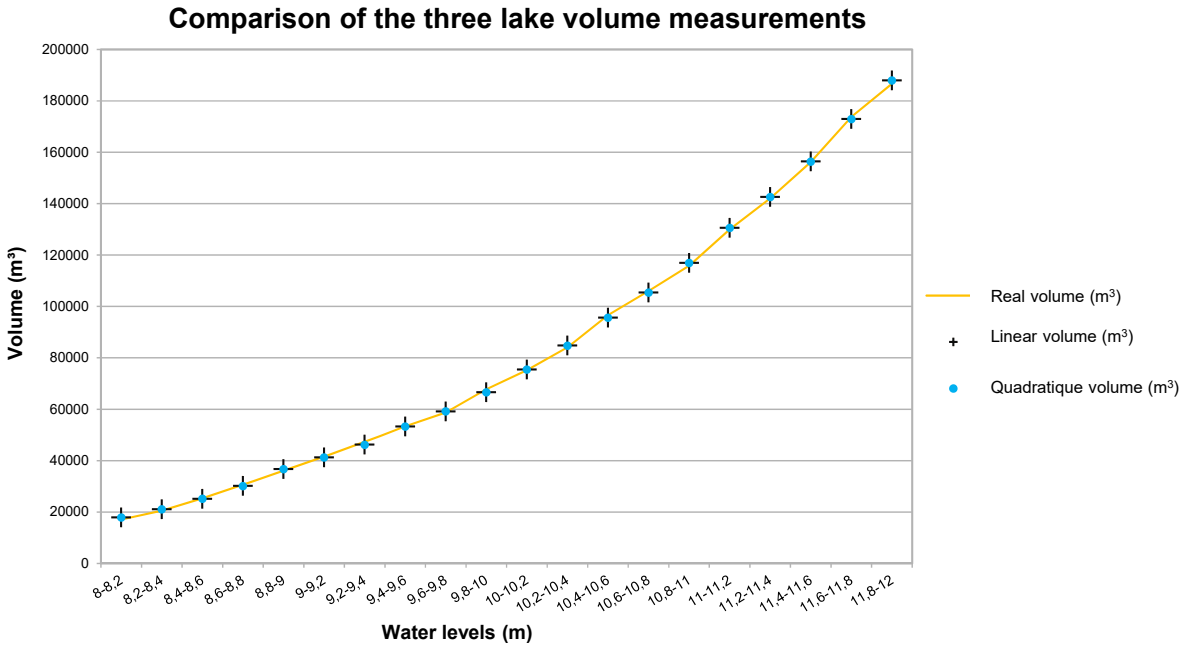
1. Test of the errors induced by the algorithms

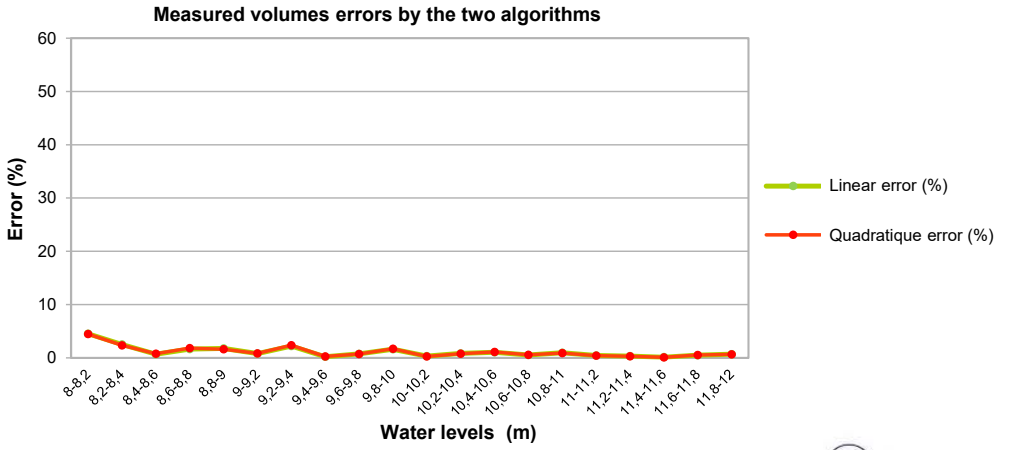
a) Storage change measured from the WM of a simple lake case



- simple lake
- h min = 4m ; h max = 6m
- height between two water levels : 0,2m
- min area = 26,20m² ; max area = 414,22m²







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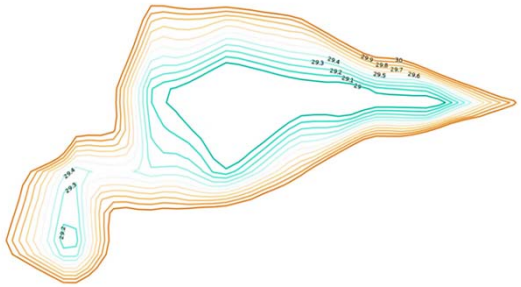
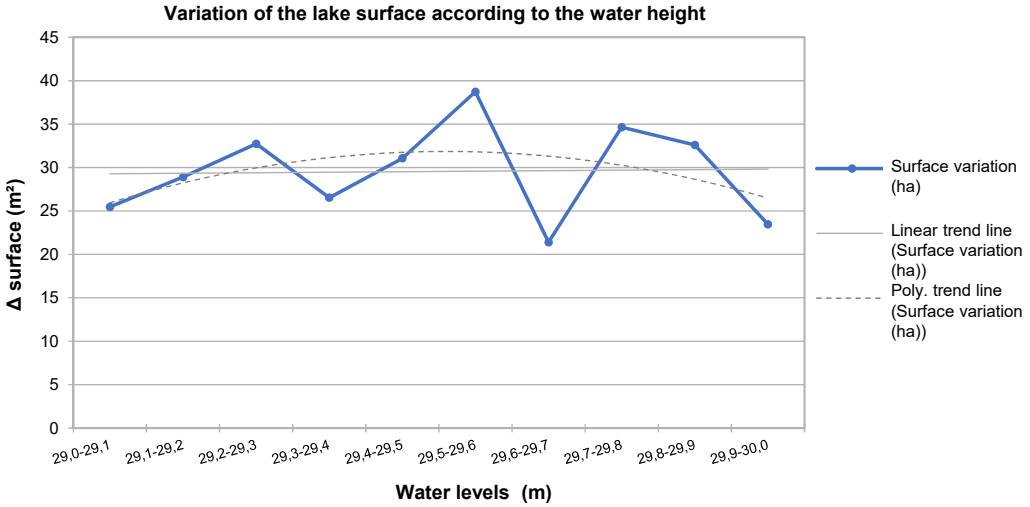
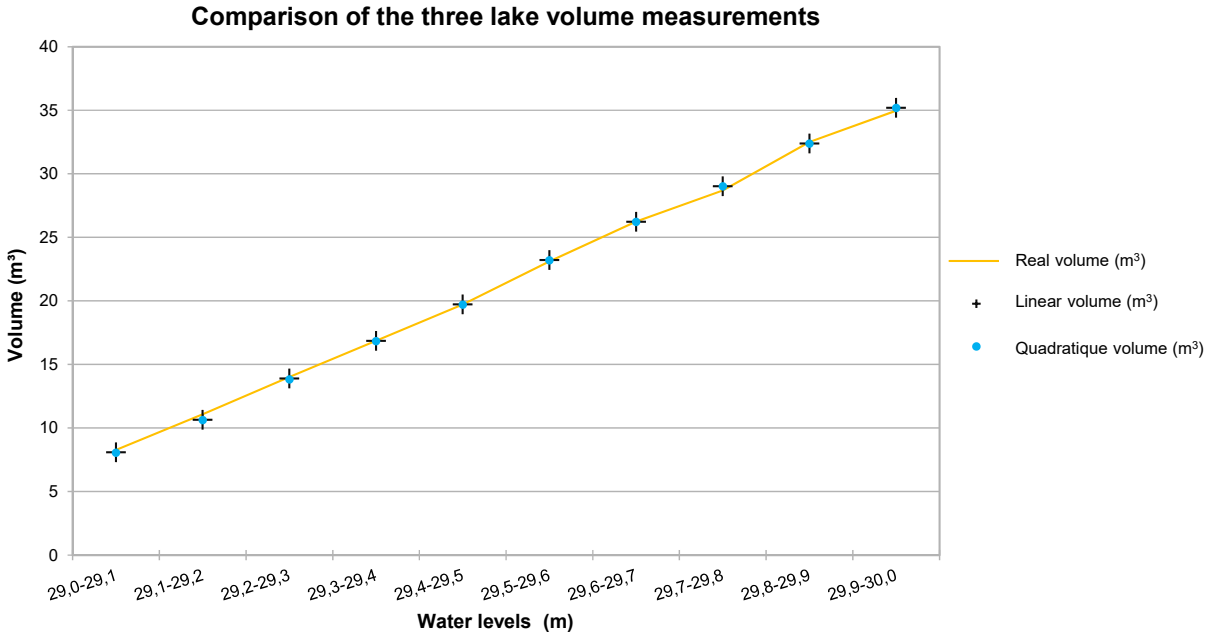
1. Test of the errors induced by the algorithms

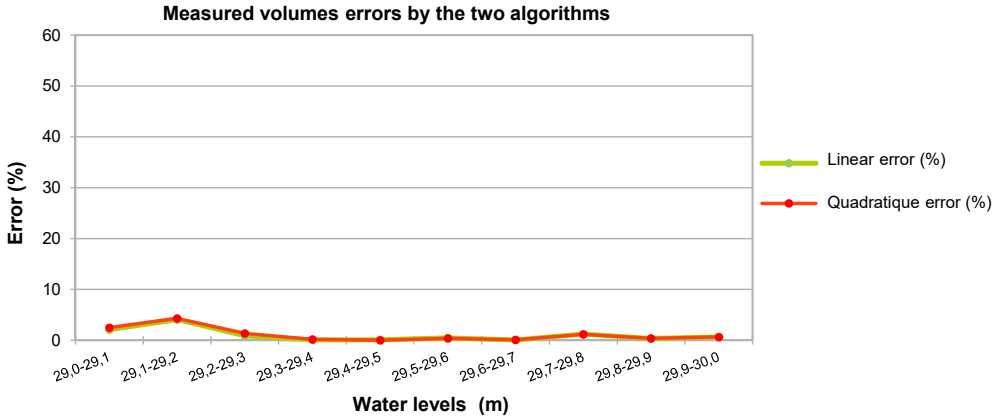
b) Storage change measured from the WM of a complex lake case



- complex lake (only for 3 water levels)
- h min = 29m ; h max = 30m
- height between two water levels : 0,1m
- min area = 68,26m² ; max area = 363,79m²







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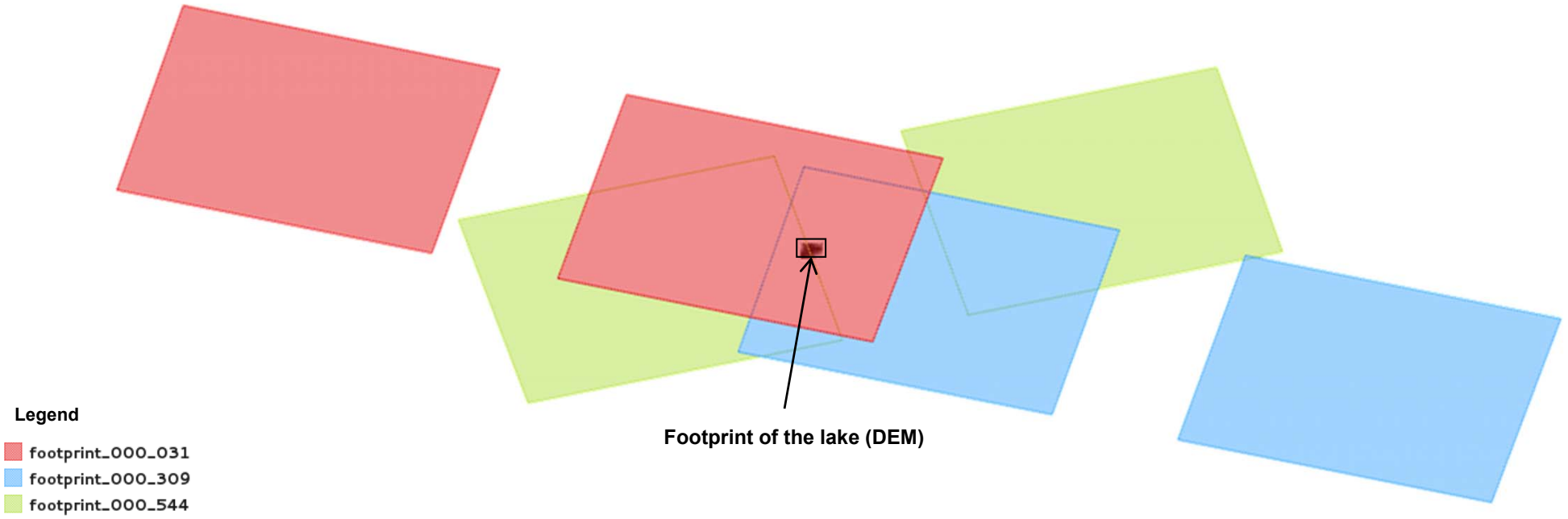
2. Errors induced by algorithms and the use of SWOT products

a) Use of the large scale simulator

1. Selection of the orbits whose swath overlaps our lake
2. Pixels Cloud (PixC) creation according to the selected swath
3. Creation of the lake polygon from the simulated data (*LakeTile processing*)



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1. Selection of the orbits whose swath overlaps our lake
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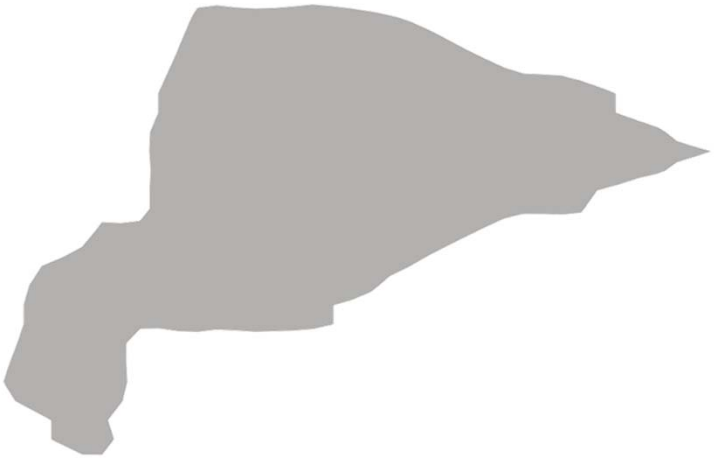
3. Creation of the lake polygon from the simulated data (*LakeTile processing*)

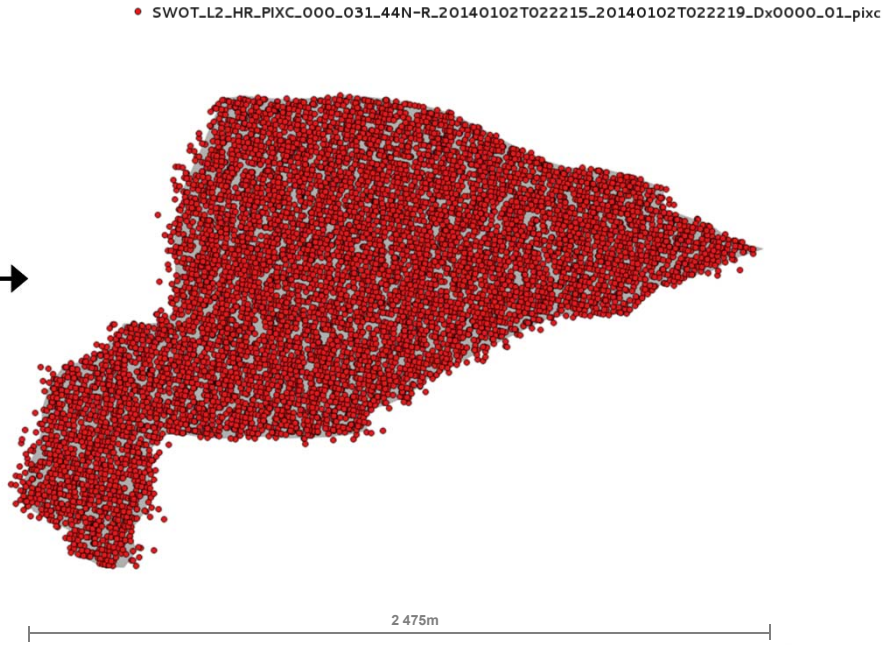
Lake polygone for a given water level

(input)



(large scale simulator)

Pixel Cloud created for one swath (output)



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2. Errors induced by algorithms and the use of SWOT products

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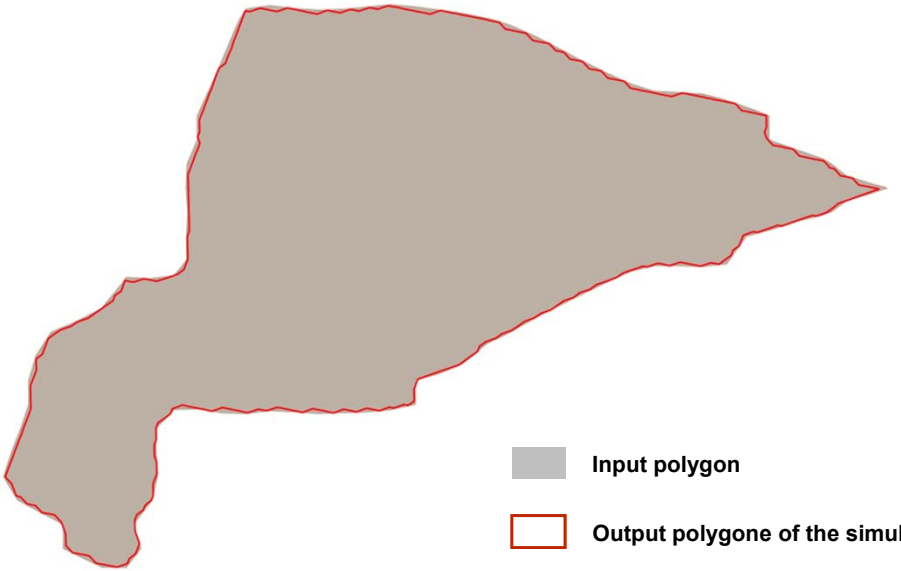
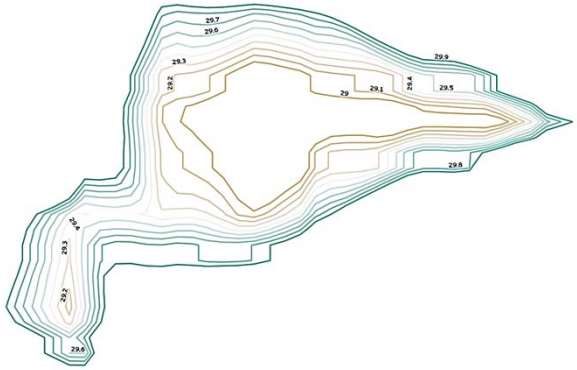
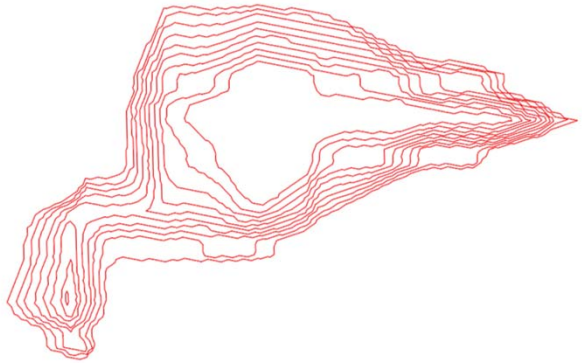




Shapes of the different water levels extrated from the DEM



Shapes of the different water levels generated par le simulateur

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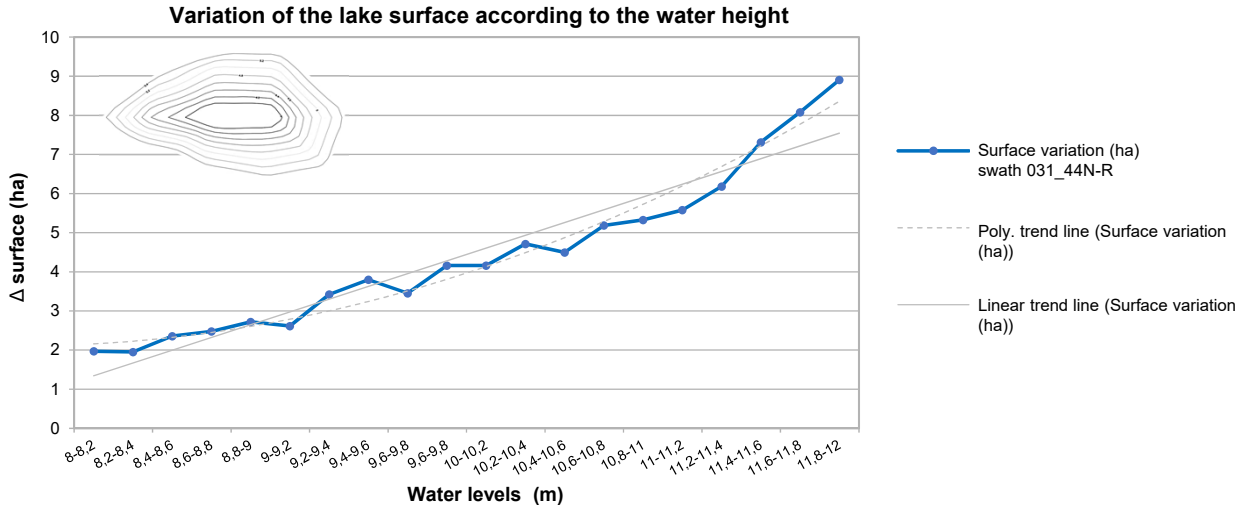
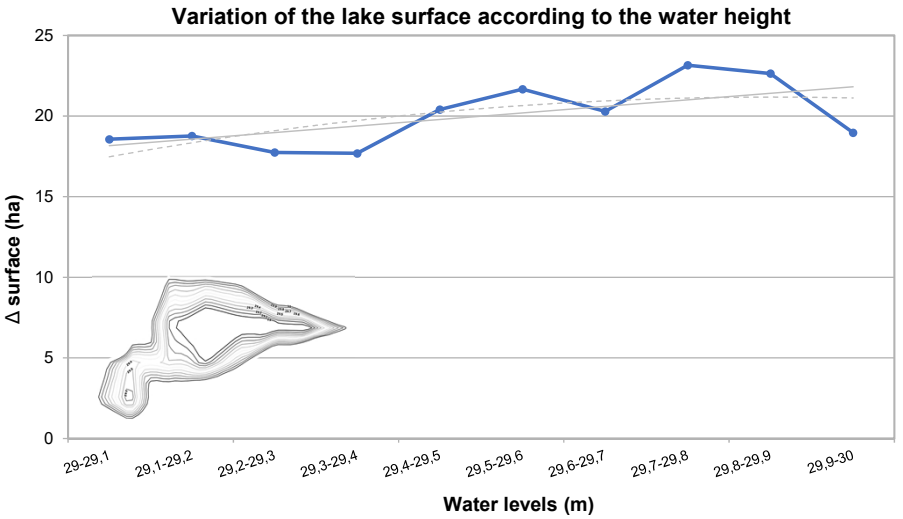
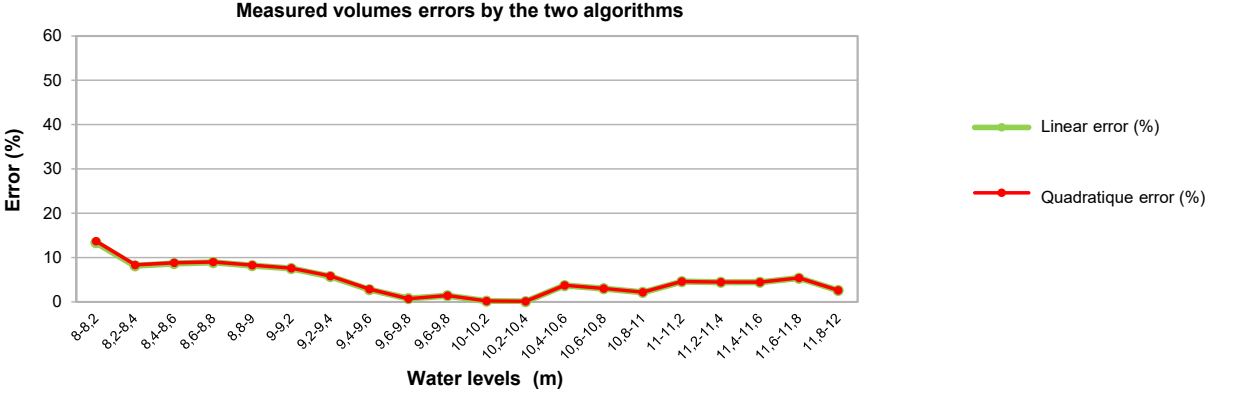
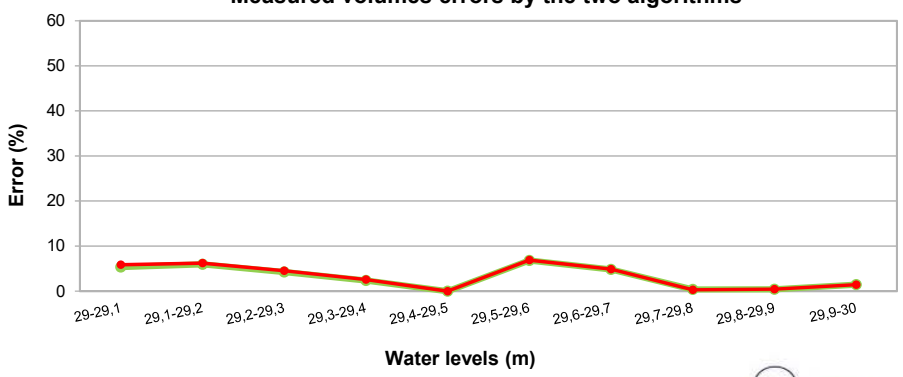
2. Errors induced by algorithms and the use of SWOT products

b) Storage change measured on a single lake case and a complex lake case (**constant** height variation between water mask)









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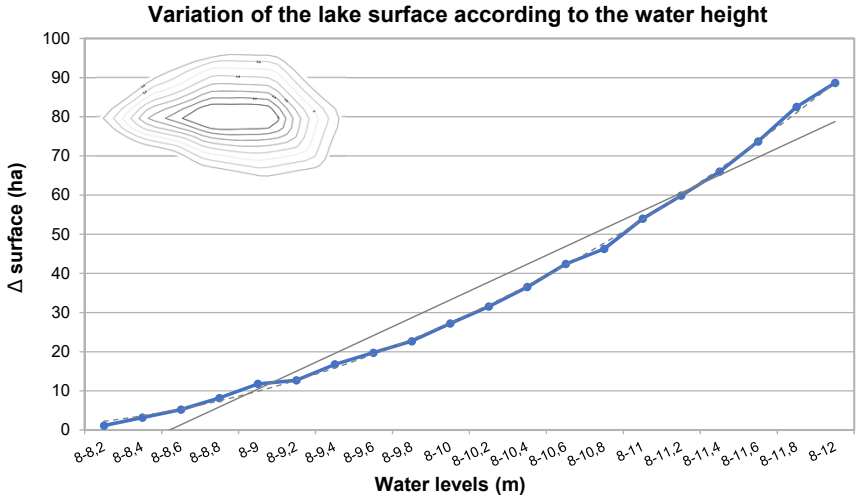
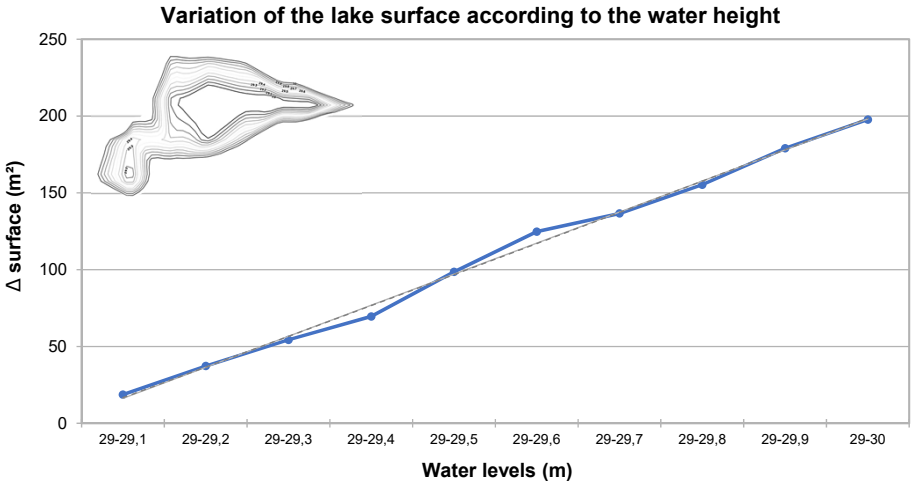
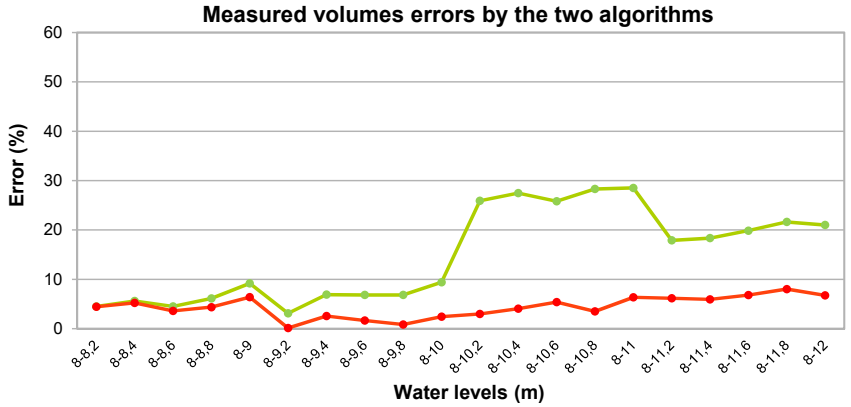
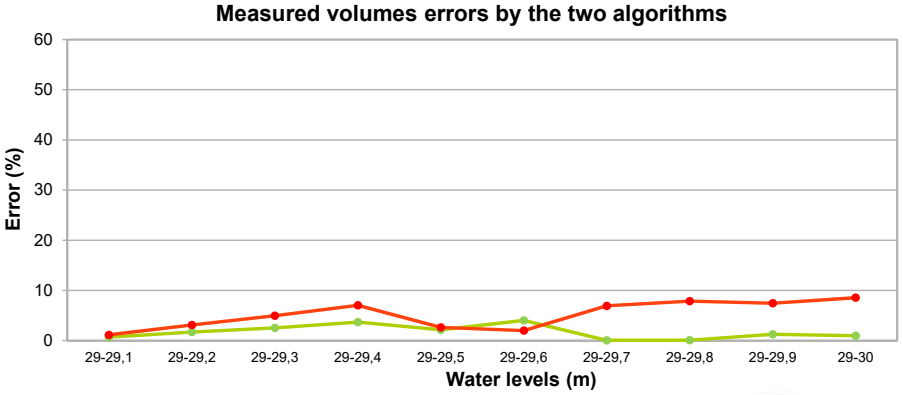
2. Errors induced by algorithms and the use of SWOT products

b) Storage change measured on a single lake case and a complex lake case (height variation between water levels **increases**)









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Storage change module

- LakeTile processing steps

F0 • Select pixels not processed by River Processor (except reservoirs)

F1 • Identify all separate entities in the water mask

F2 • Retrieve pixels corresponding to entities entirely inside the tile

F3 • Refine pixel geolocation

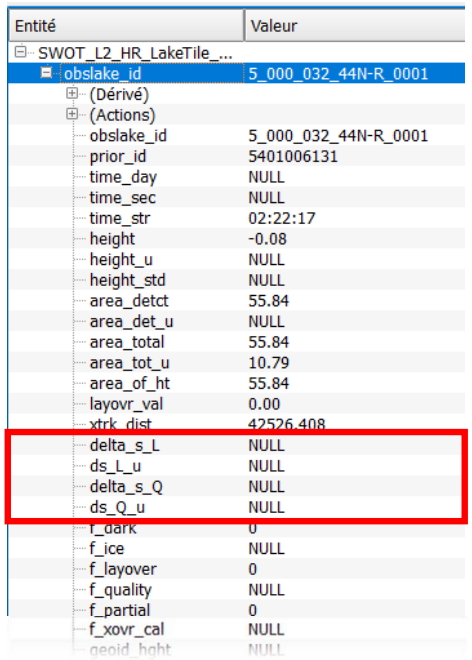
F4 • Compute lake product

F5 • Link to prior lake database

F6 • Update lake product with storage change

For lakes entirely inside the tile

(Credits : C. Pottier)



Entité	Valeur
SWOT_L2_HR_LakeTile_...	
obslake_id	5_000_032_44N-R_0001
(Dérivé)	
(Actions)	
obslake_id	5_000_032_44N-R_0001
prior_id	5401006131
time_day	NULL
time_sec	NULL
time_str	02:22:17
height	-0.08
height_u	NULL
height_std	NULL
area_detct	55.84
area_det_u	NULL
area_total	55.84
area_tot_u	10.79
area_of_ht	55.84
layovr_val	0.00
xtrk_dist	42526.408
delta_s_L	NULL
ds_L_u	NULL
delta_s_Q	NULL
ds_Q_u	NULL
f_dark	0
f_ice	NULL
f_layover	0
f_quality	NULL
f_partial	0
f_xovr_cal	NULL
geoid_hght	NULL

- **delta_s_L** : storage change measured with the linear hypothesis
- **ds_L_u** : associated uncertainty
- **delta_s_Q** : storage change measured with the quadratic hypothesis
- **ds_Q_u :** associated uncertainty

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Conclusions and perspectives

Successful validation of algorithms

⇒ the volume variation errors are less than 15% for the different case studies

⇒ Integration of a module simplified version in the processing chain of the large-scale simulator

Perspectives :

- Continue to test the algorithms on other case studies whose polygons were obtained with the large-scale simulator
- Set up a test that defines the threshold (variation of water or surface height) from which one hypothesis should be used rather than the other
- Integrate the part of the module that measures storage change for complex lake cases

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