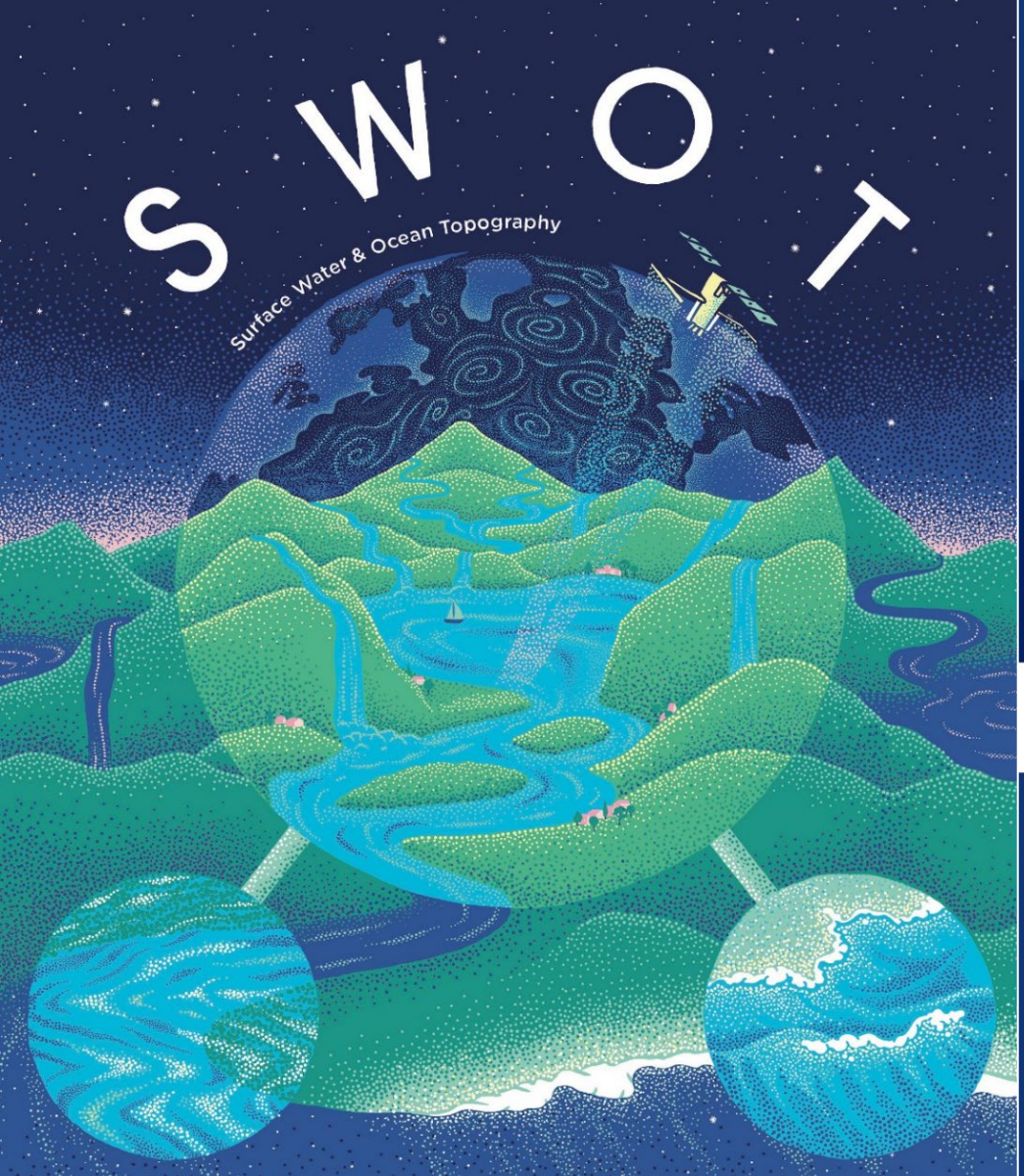


SWOT . CalVal

Example of SWOT data products over the Rhine

LEDAUPHIN Thomas, AZZONI Maxime, AMZIL Sabrine, MAXANT Jérôme, YESOU Hervé

21/06/2024

Context

- Presentation of results over the Rhine to major French players in the management and use of river water resources (EDF, VNF, DREAL, Region Grand Est & Larsim Group)

- Strong interest in the data for understanding hydraulic systems :
  - To help to manage channels
  - Managing flows at dams reach scale :
    - ➔ Flow/WSE relation (1D/2D modelisation)
    - ➔ Identification and analysis of internal flow waves

- Strong interest for Old Rhine renaturation initiative *(Poster 5 : Ledauphin T – Monday Tuesday):*
  - Identification of natural hydraulical structures
  - Relationship between the topography of the river surface observed by SWOT and the topography of the riverbed
  - Better understanting of river flow
  - SWOT profiles as virtual gauge station to complete in situ measurments

Assess the ability of SWOT PIXC L2 HR PGC0 and associated RiverSP products over the Rhine to meet these chalenges

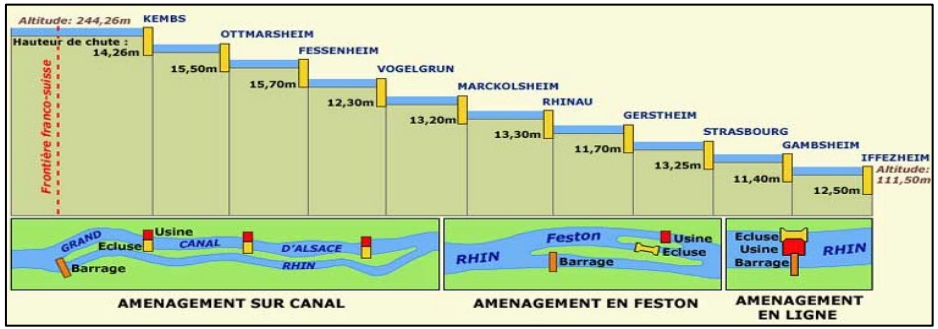
Study Area

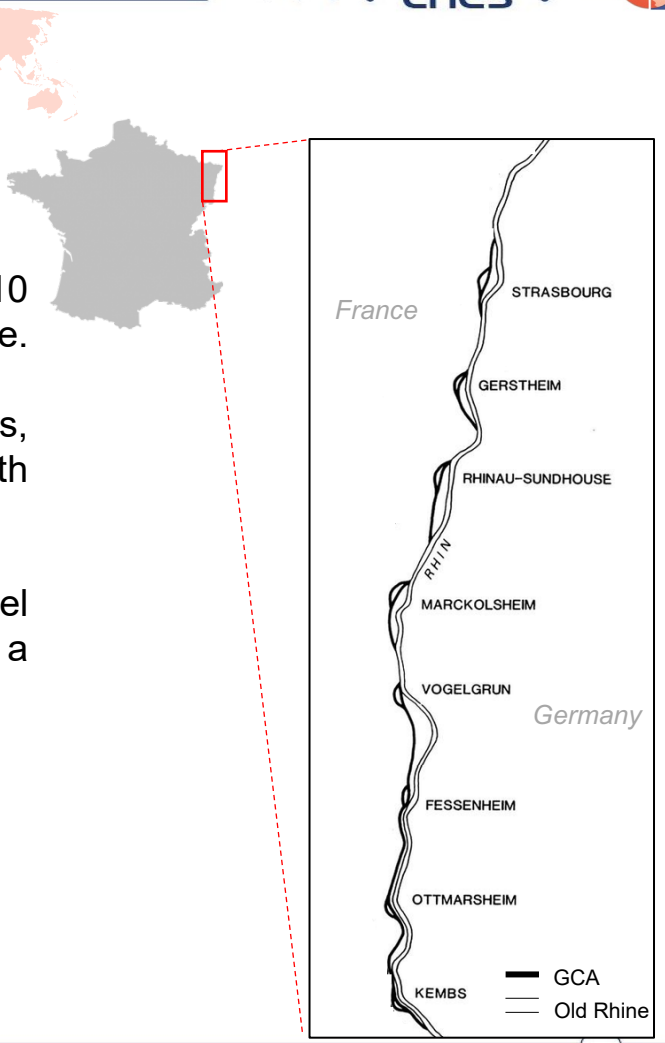
- Rhine River : Cal Val site Tier 1

- 180 km of the German-French border

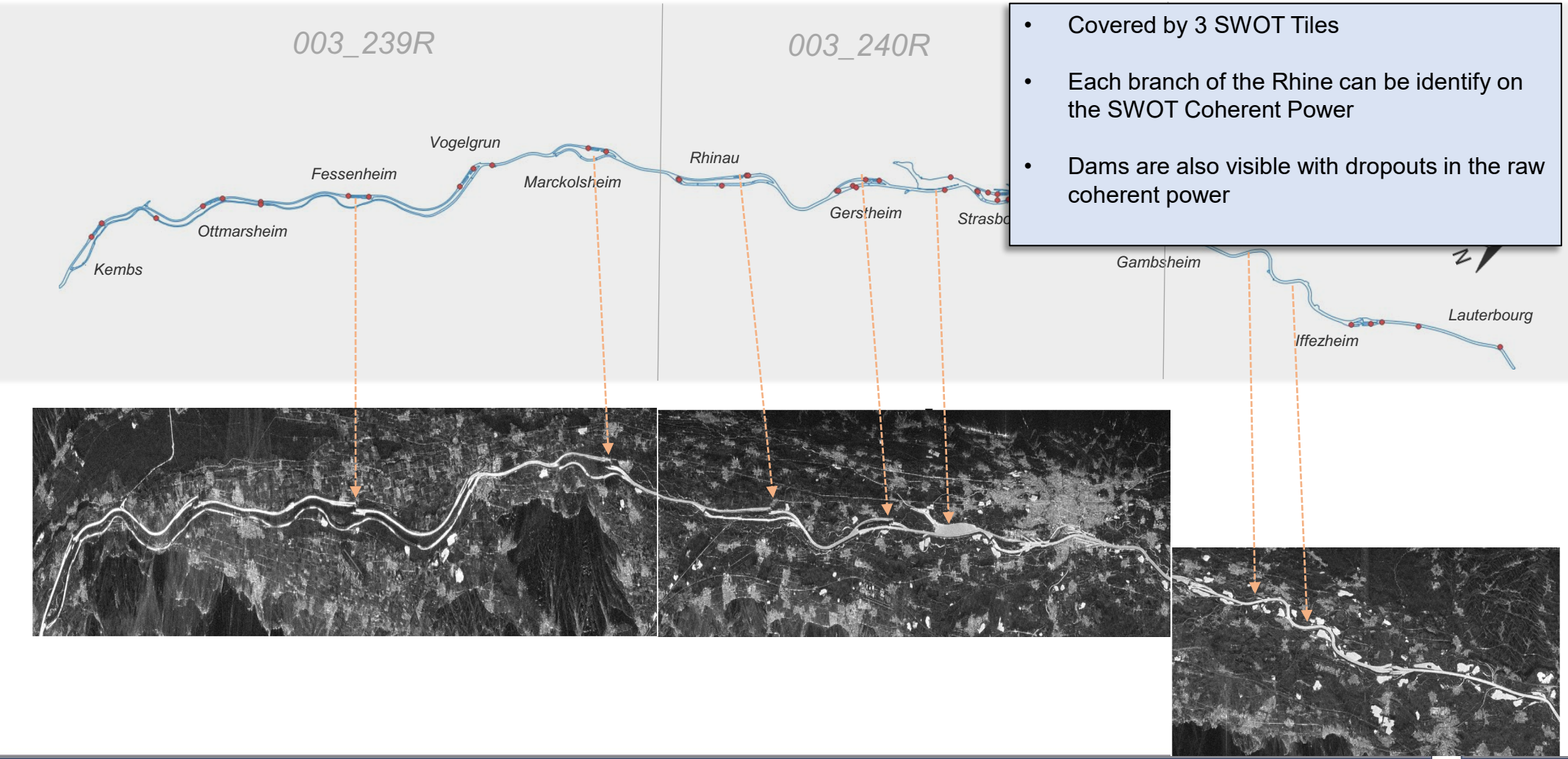
- Two hydraulic objects running in parallel :
  - The Western one, the **Grand Canal d'Alsace (GCA)** : succession of 10 hydropower dams with 12-14-m jumps, returning to a free river course. Width of 150 m
  - The Eastern side, the **Old Rhine** is flowing in more natural conditions, beginning with a first free segment of 40 km + 4 by-passed reaches (with 1-3 m jumps succession). Width of 80 m

- The difference in gradient is recovered by a series of metric weirs. At the level of a hydroelectric dam, the North-South offset will be 12-14 meters, with a lateral East-West offset of 8-10 m





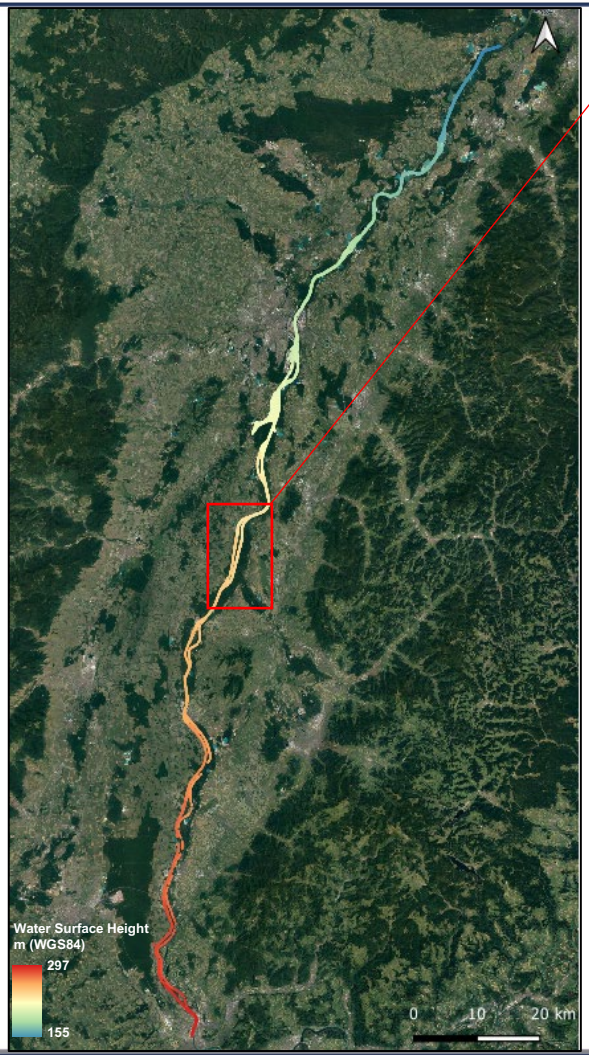
Rhine river observed by SWOT

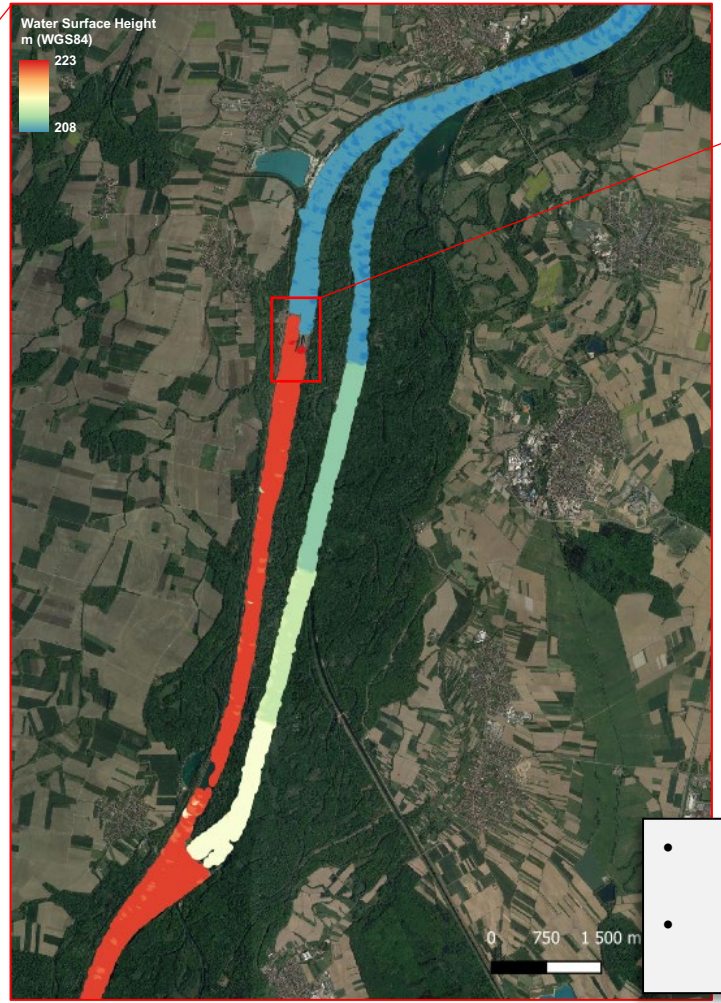


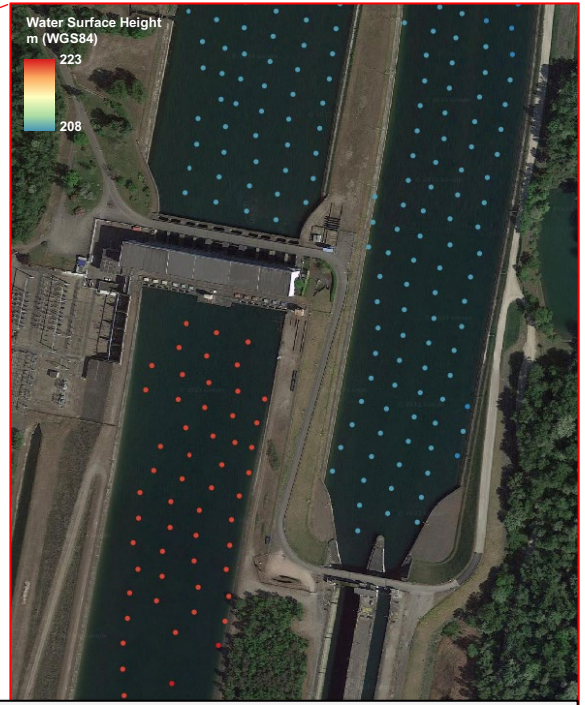
- Covered by 3 SWOT Tiles
- Each branch of the Rhine can be identify on the SWOT Coherent Power
- Dams are also visible with dropouts in the raw coherent power

PIXC L2 HR PGC0

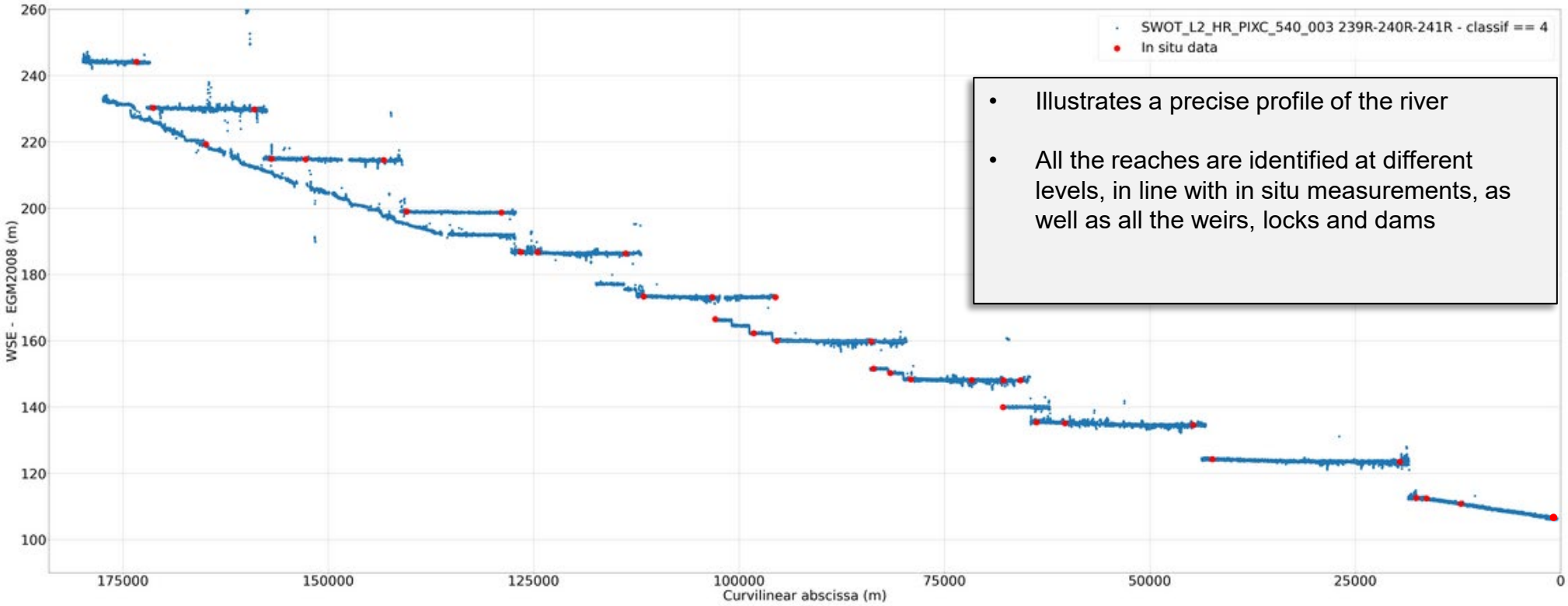
SWOT PIXC L2 HR PGC0 - Class 4 - Cycle 540



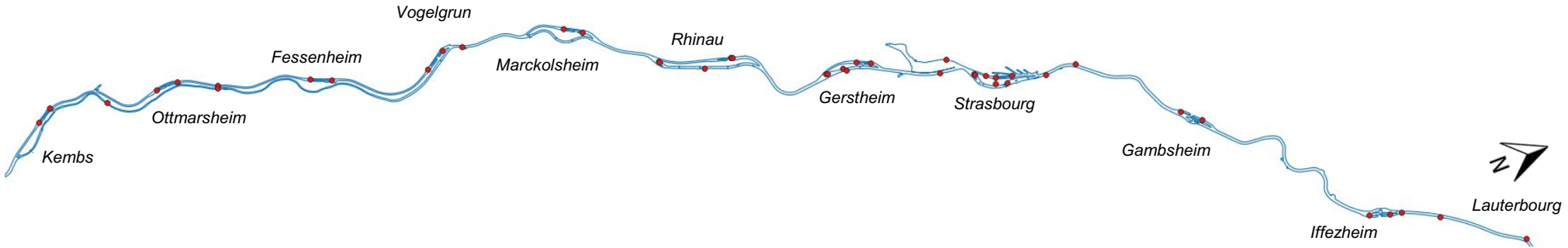


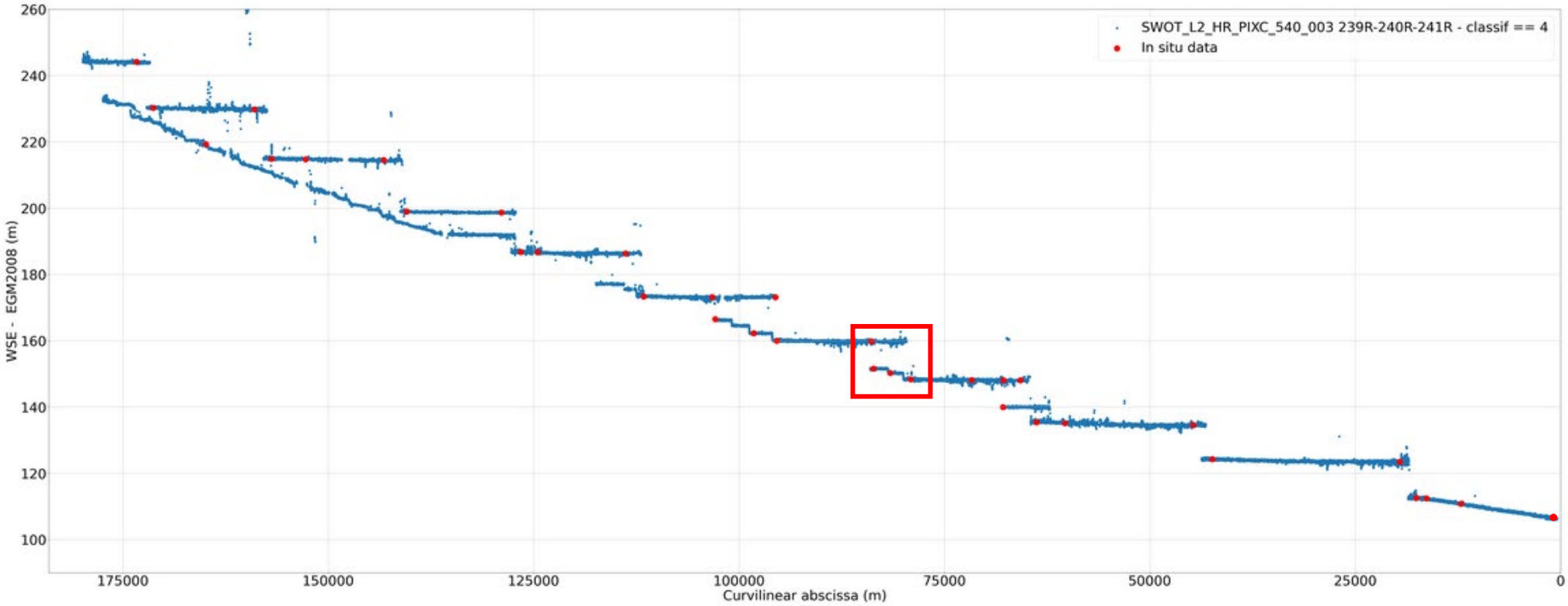


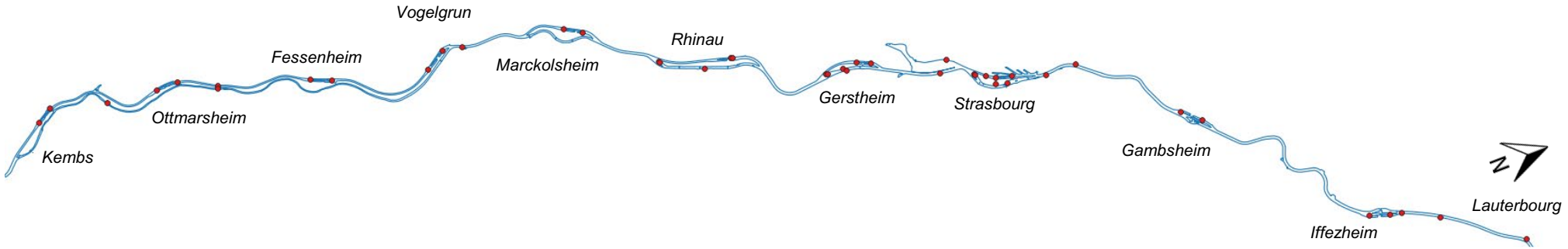
- Globale slope of the Rhine well illustrated
- Identification of the weirs, locks and dams



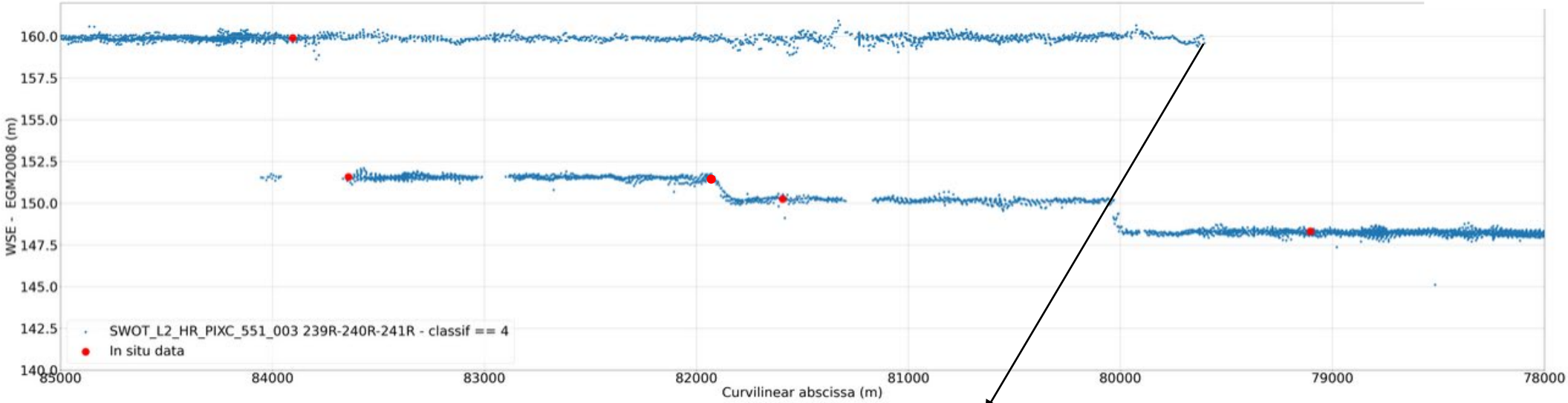
- Illustrates a precise profile of the river
- All the reaches are identified at different levels, in line with in situ measurements, as well as all the weirs, locks and dams




SWOT_L2_HR_PIXC_540_003 239R-240R-241R - classif == 4
In situ data
WSE - EGM2008 (m)
Curvilinear abscissa (m)
260
240
220
200
180
160
140
120
100
175000
150000
125000
100000
75000
50000
25000
0

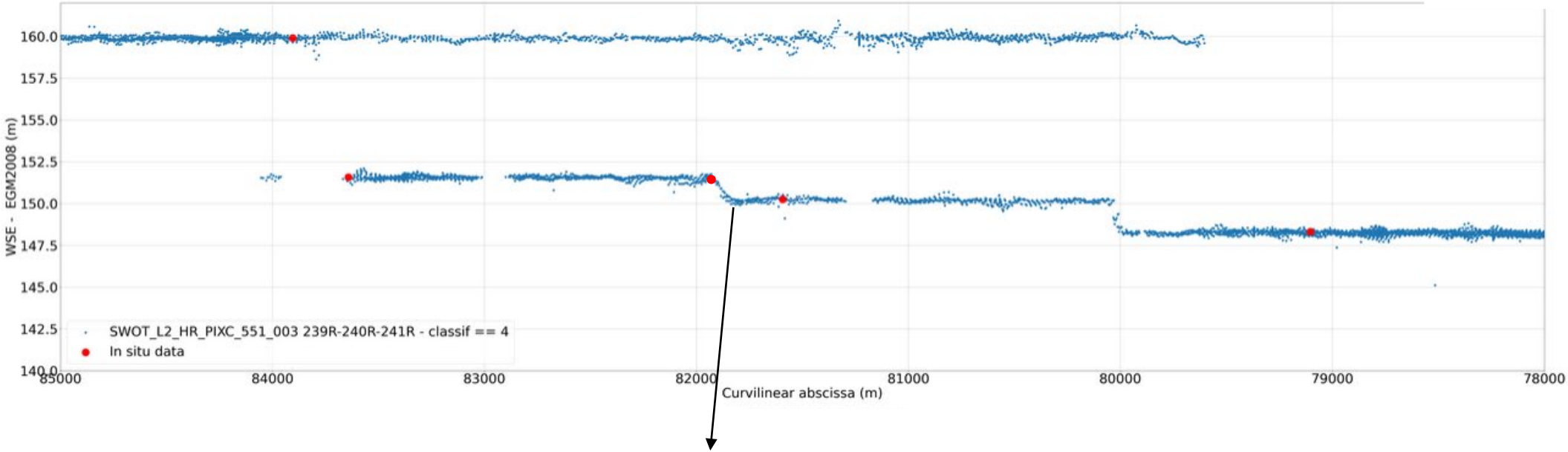

Vogelgrun
Fessenheim
Rhinau
Marckolsheim
Ottmarsheim
Kembs
Gerstheim
Strasbourg
Gambsheim
Lauterbourg
Iffezheim
N

Gerstheim Dam (GCA)



- ~12 meters dam
- In line with the EDF dam's description

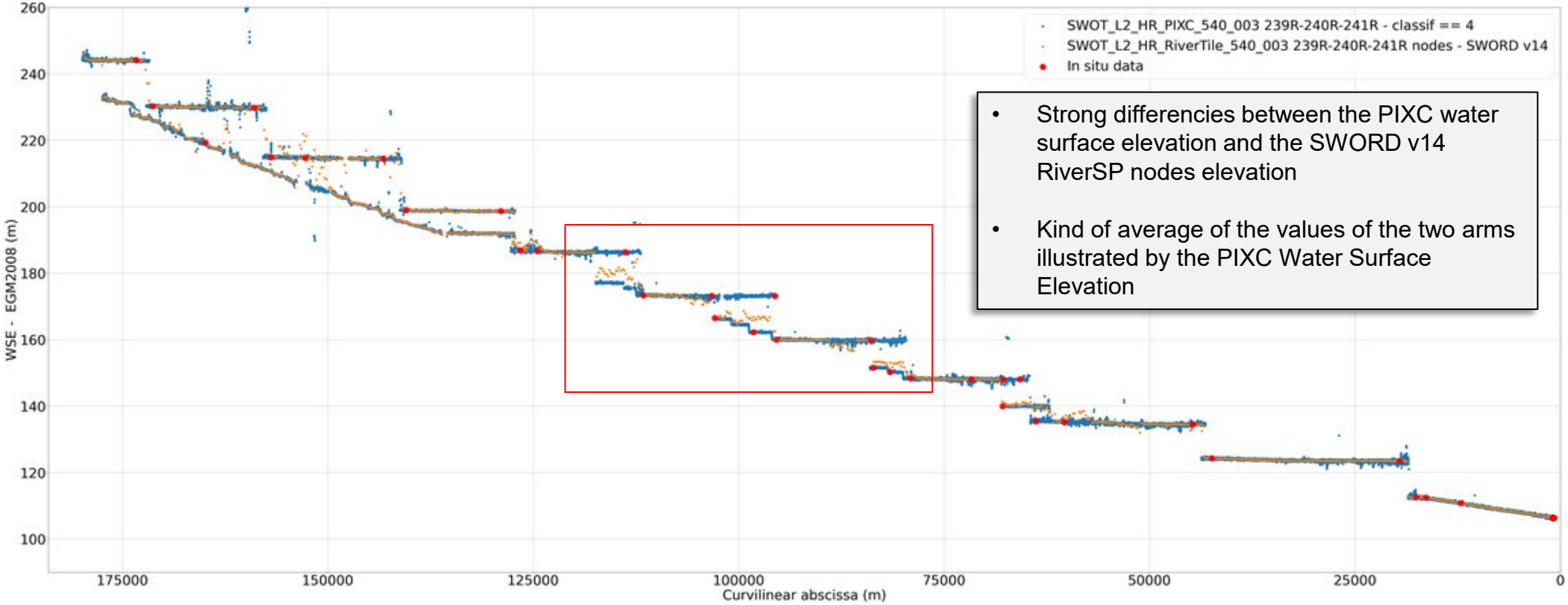
Weir on Gertheim (Old Rhine)



- 1/1,5 m dam
- Depending to the river flow

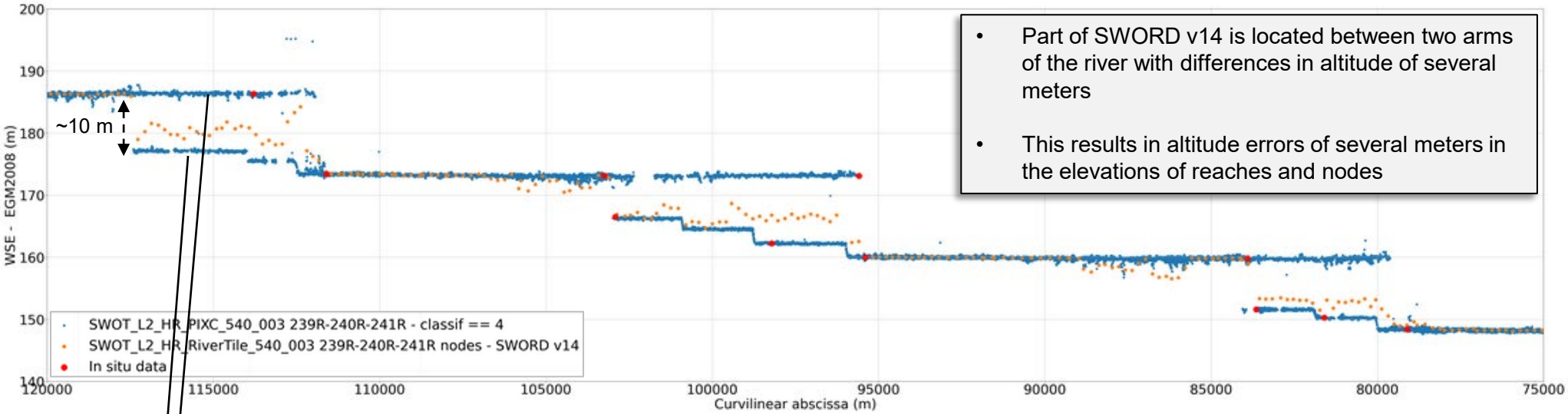
Nominal RiverSP products

SWORD v14



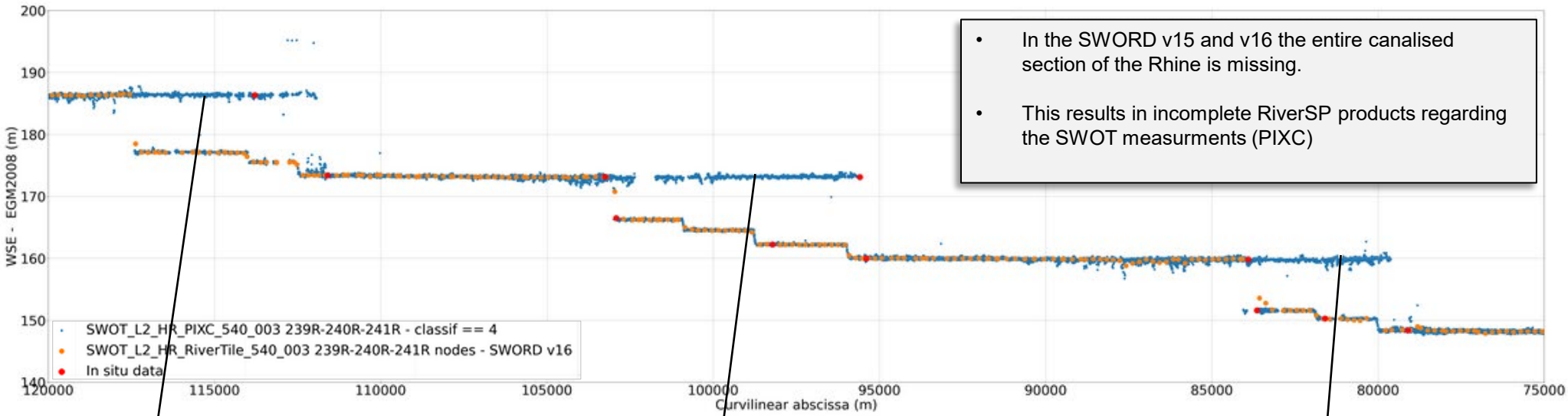
- Strong differencies between the PIXC water surface elevation and the SWORD v14 RiverSP nodes elevation
- Kind of average of the values of the two arms illustrated by the PIXC Water Surface Elevation

SWORD v14

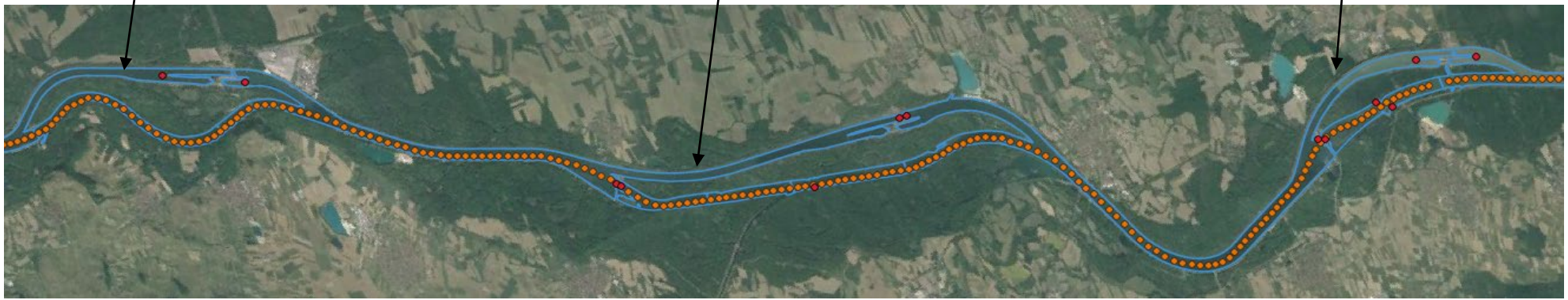


- Part of SWORD v14 is located between two arms of the river with differences in altitude of several meters
- This results in altitude errors of several meters in the elevations of reaches and nodes

SWORD v15 & v16



- In the SWORD v15 and v16 the entire canalised section of the Rhine is missing.
- This results in incomplete RiverSP products regarding the SWOT measurments (PIXC)



Limitations of SWORD version over this part of Rhine

- SWORD v14, v15 & v16 :
  - Can’t be used as they don’t match with the Rhine morphology

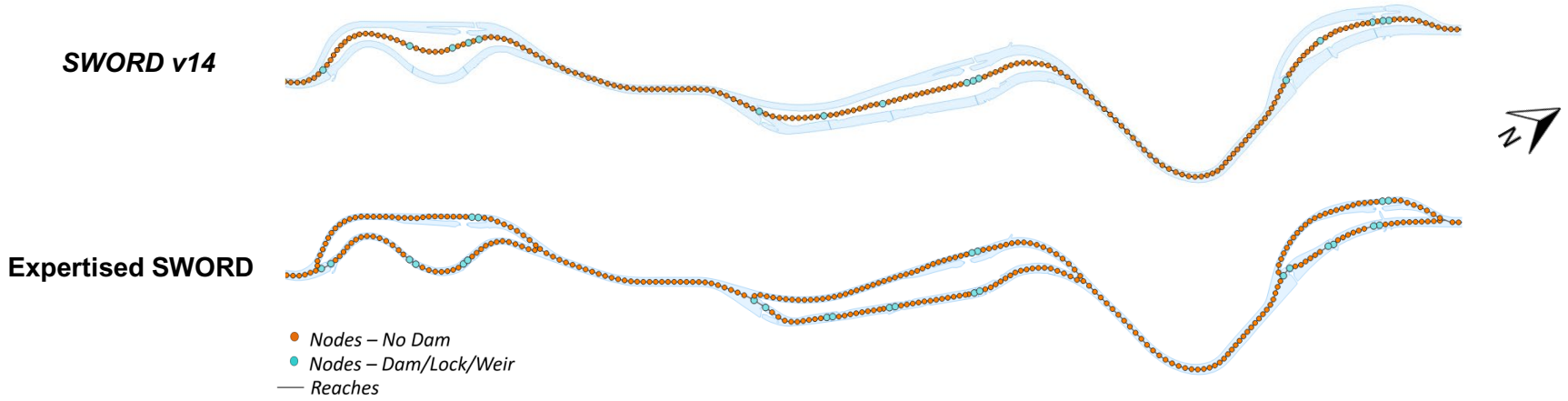
- At reach scale we also observe inconsistencies with reaches poorly located on the dam and some dams not represented

- Create an **Improved SWORD** (SWORD Expert) that corresponds to the morphology of the Rhine to obtain RiverSP products that are representative of the PIXC products and the quality of SWOT measurments

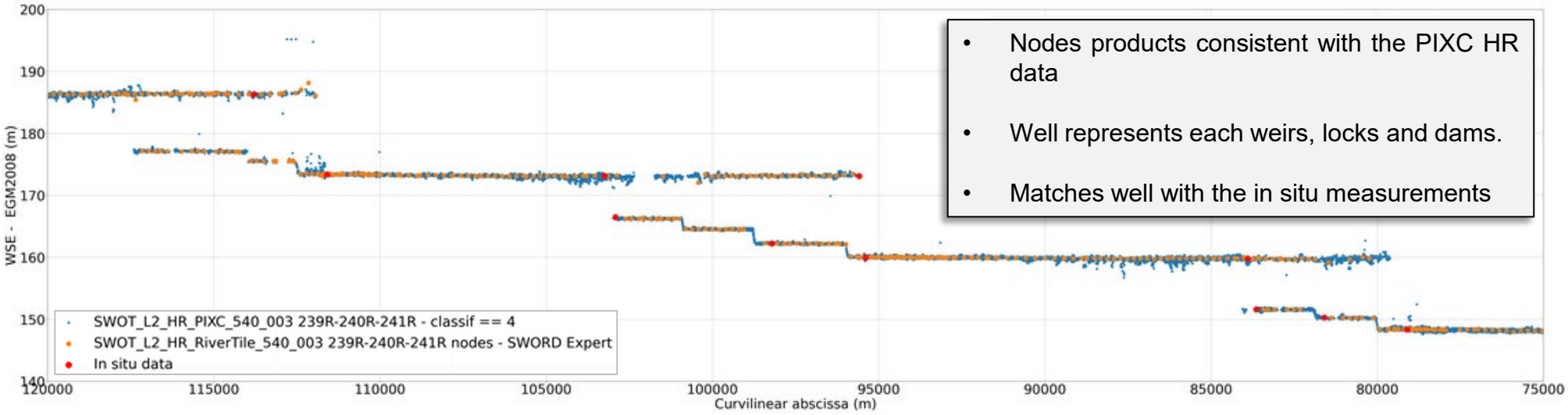
➔ Reprocess all RiverSP products over the CalVal period (On the CNES HPC)

➔ Qualification of RiverSP products over the CalVal period in comparison with in situ data

➔ Integration of the improved SWORD in the next version of the SWORD



Expert RiverSP products

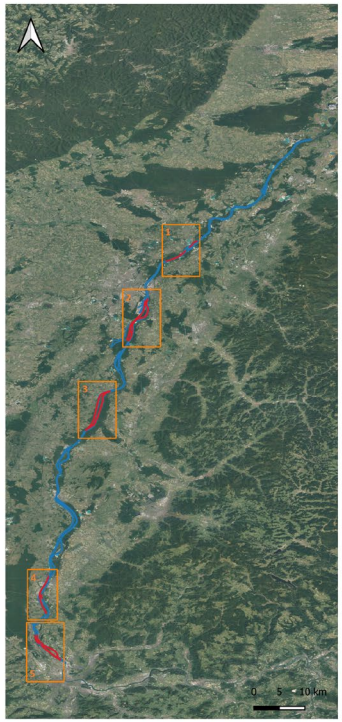


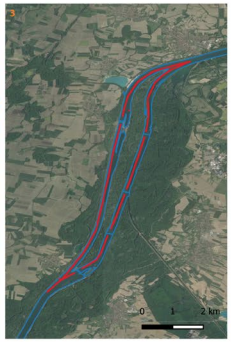
- Nodes products consistent with the PIXC HR data
- Well represents each weirs, locks and dams.
- Matches well with the in situ measurements

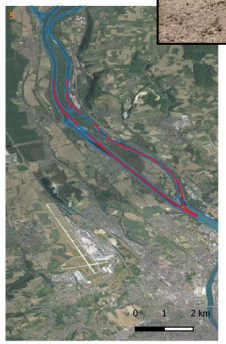
Comparison insitu / Expert RiverSP product

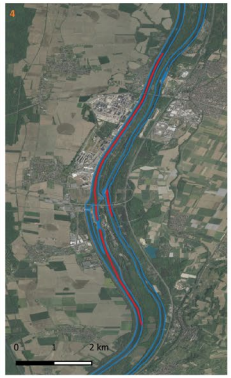
Insitu data

- 44 stations along the Rhine river (WSE, river flow)
- 7 different owners
- Convert to EGM2008
- Daily acquisition with less than 15 min time steps
- Over the entire CalVal period, before and after
- Drone flights









VIGICRUES
Service d'information sur le risque de crues des principaux cours d'eau en France

WSV.de

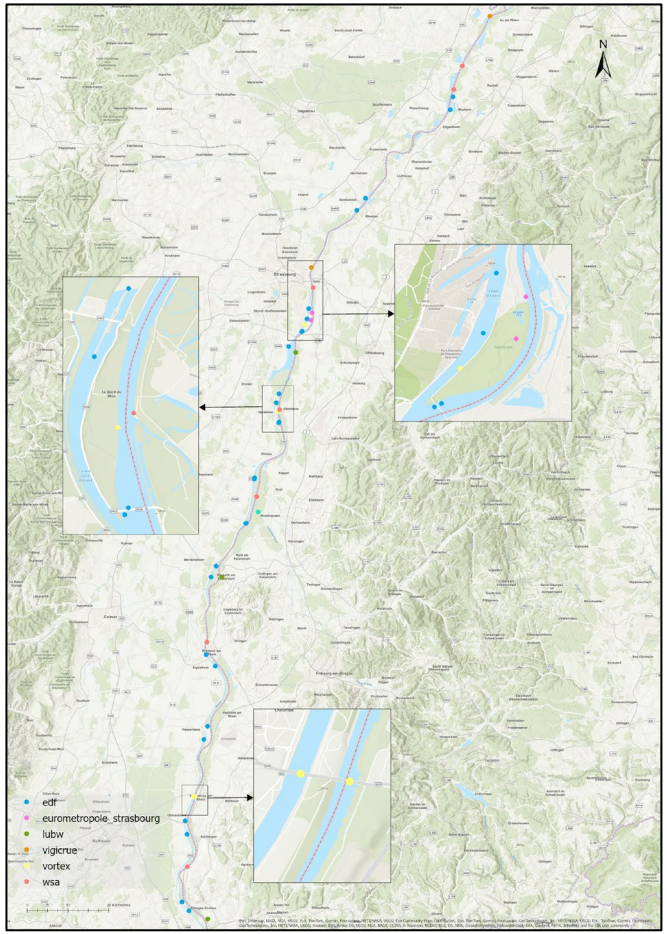
EDF

LUBW
Landesanstalt für Umwelt Baden-Württemberg

OECS

Strasbourg.eu
eurometropole

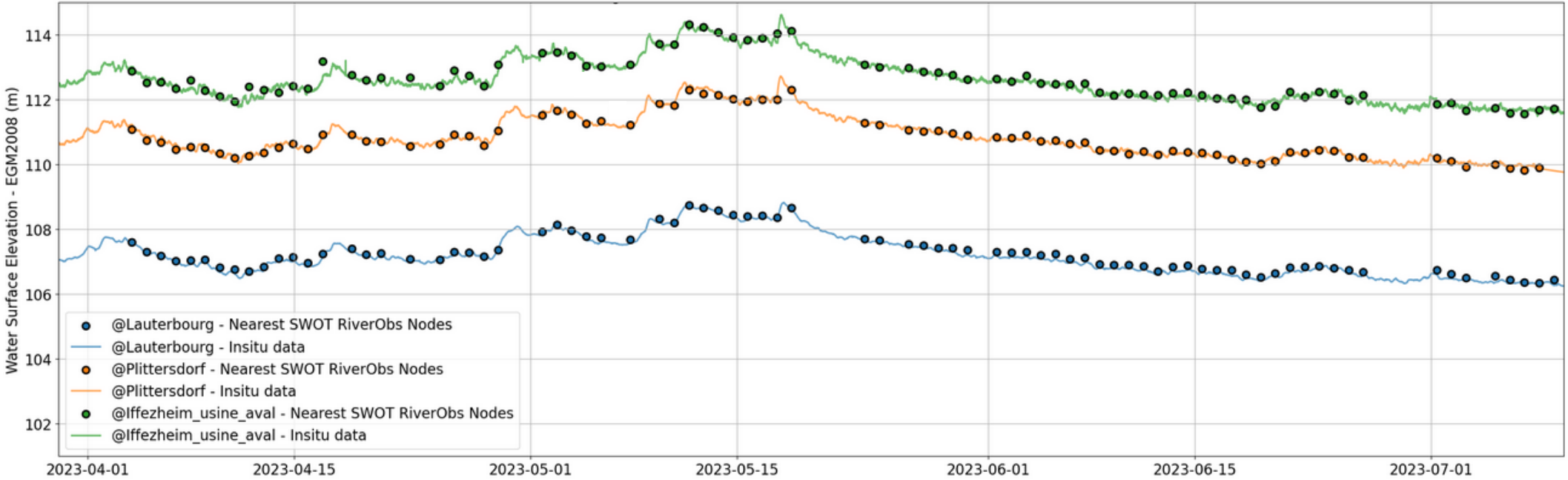
VORTEX.IO



At station scale : comparison insitu data vs nearest node

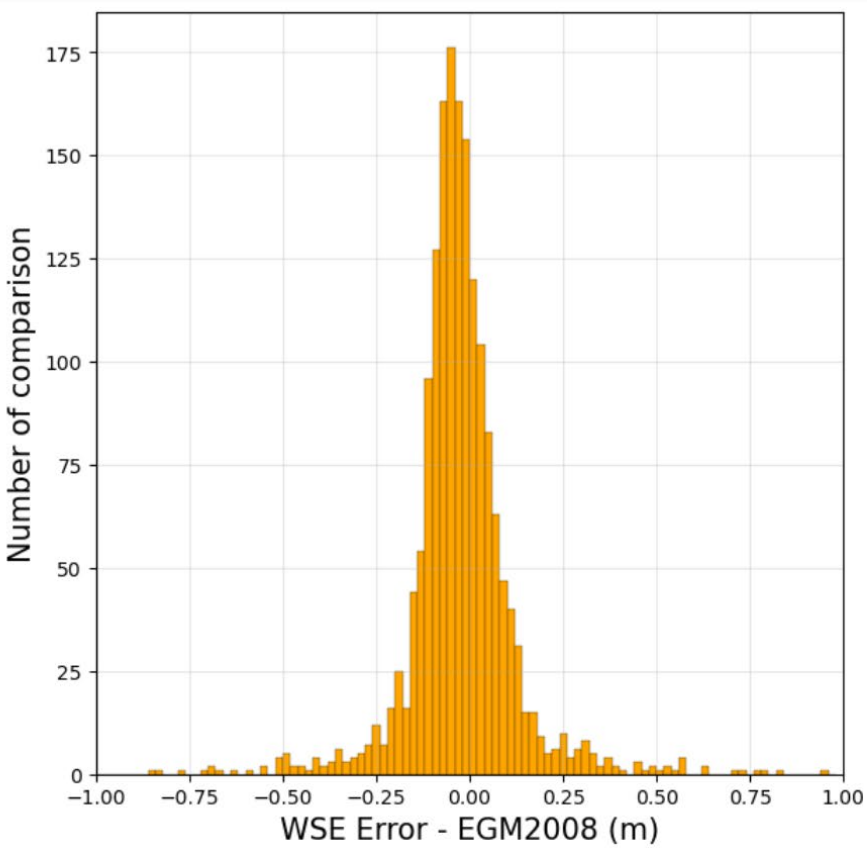
Example for the stations located on the reach between Iffezheim and Lauterbourg (last reach)

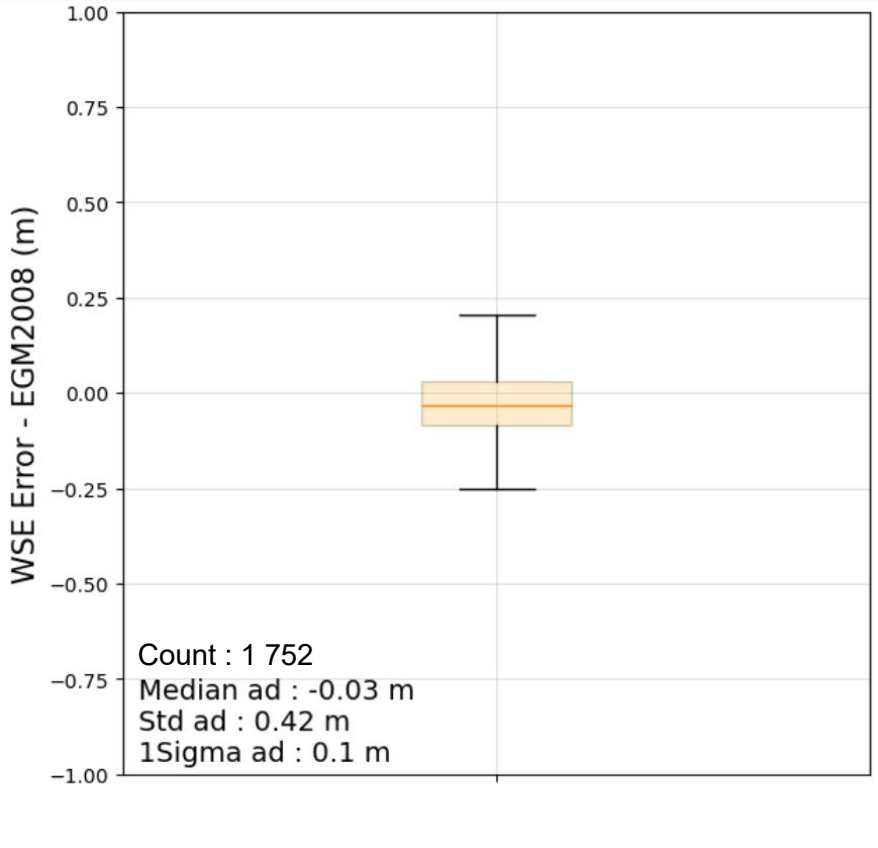
Station	WSE Error Sigma0 (m)
Iffezheim usine aval	0.09
Plittersdorf	0.09
Lauterbourg	0.11



At station scale : comparison insitu data vs nearest node

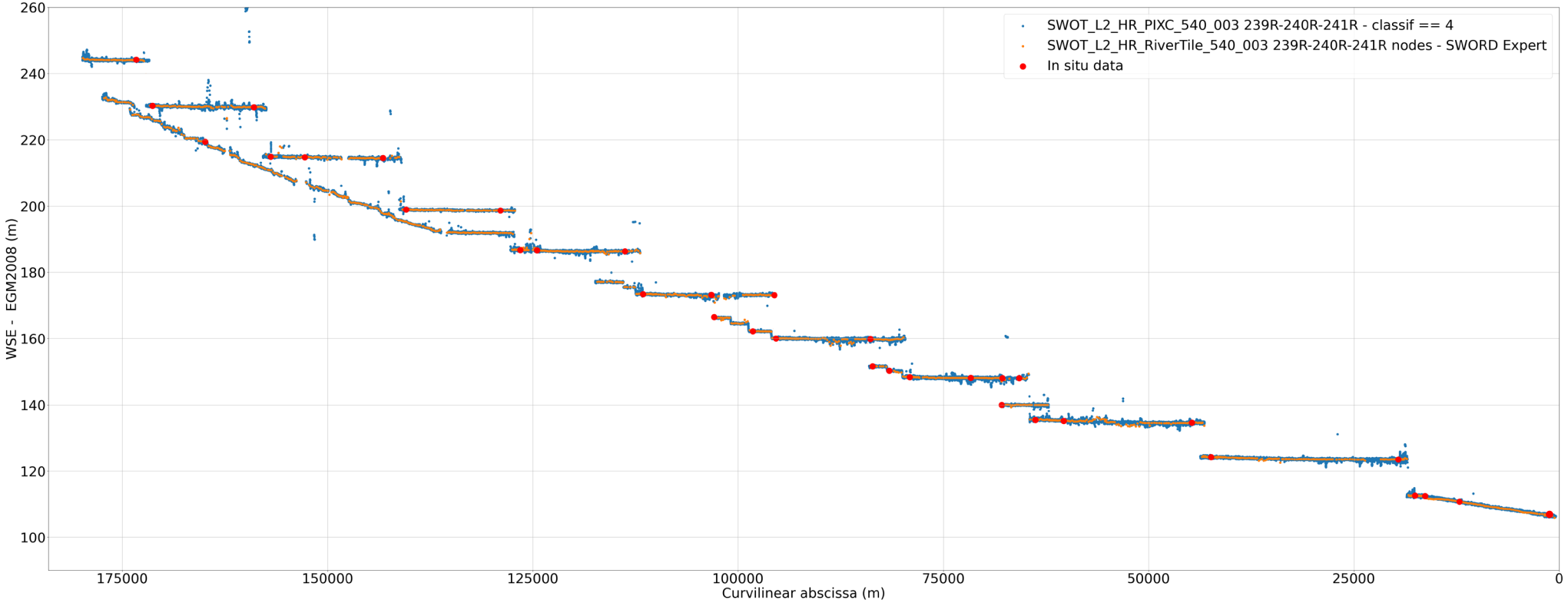
Global metrics over CalVal period : Cycle 475 to 578 – Without measurements flags as « bad » quality





At reach scale :

- More than 10 reaches with at least two stations. In most cases, at least one upstream and one downstream, enabling in situ data interpolation at each node/PIXC and validate reach WSE and slope.



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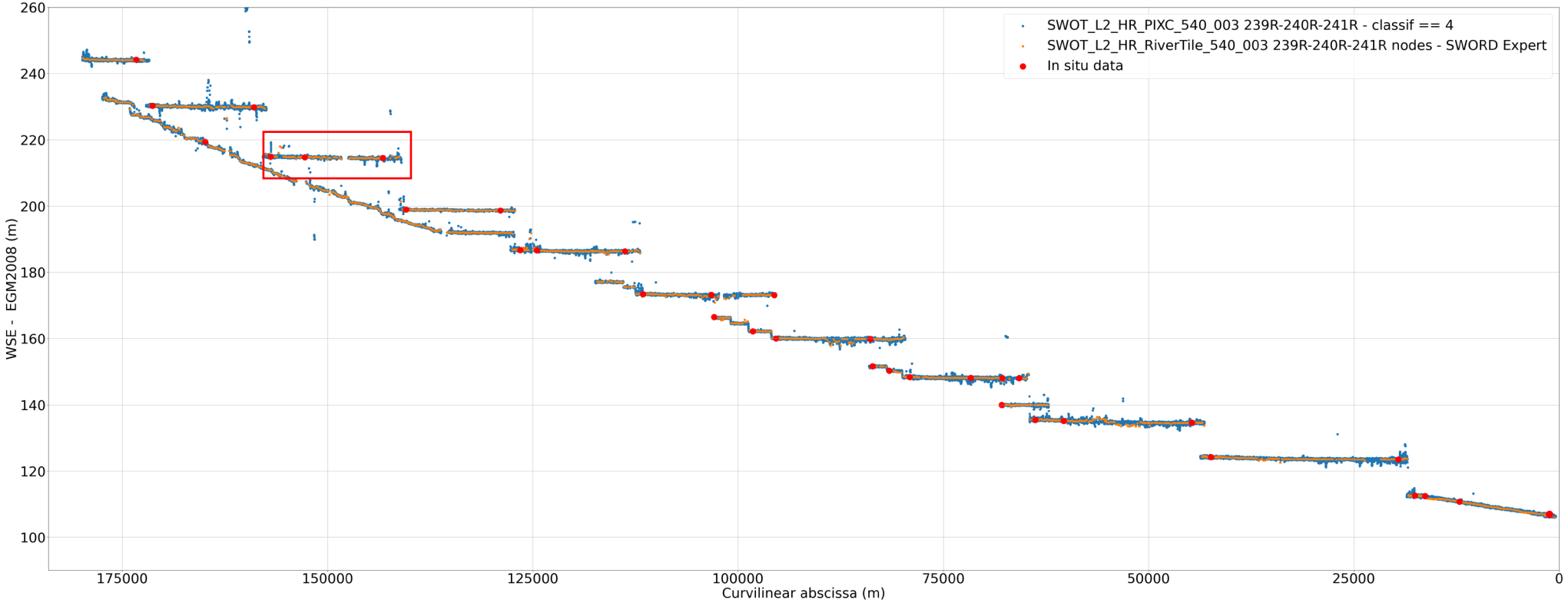
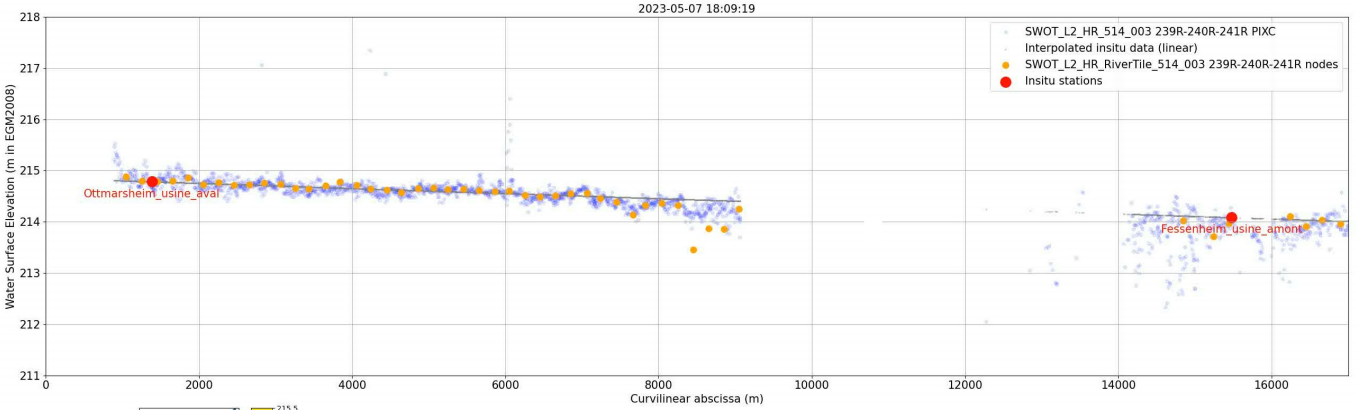
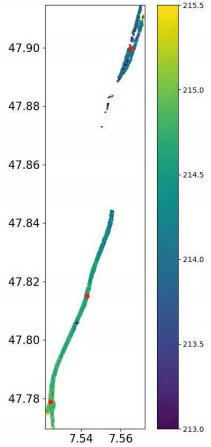
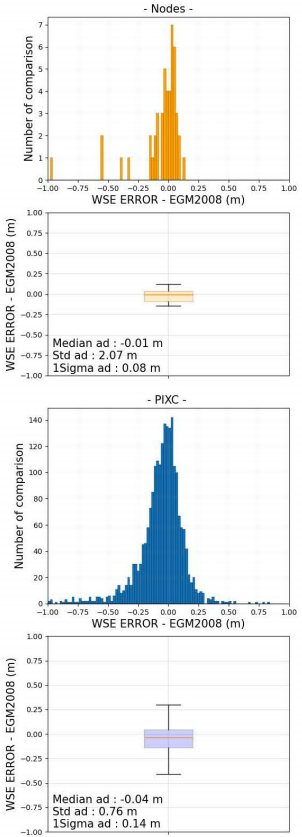


Comparison Nodes & PIXC class 4 vs interpolated in situ data



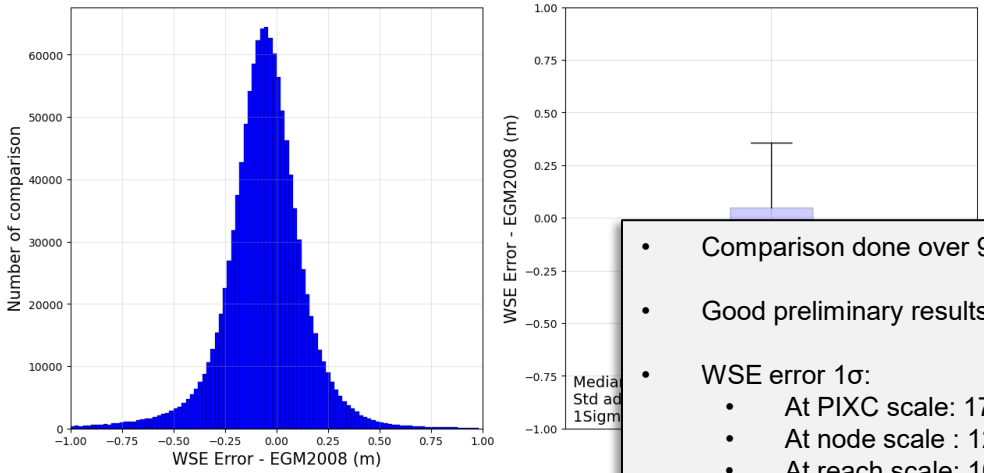




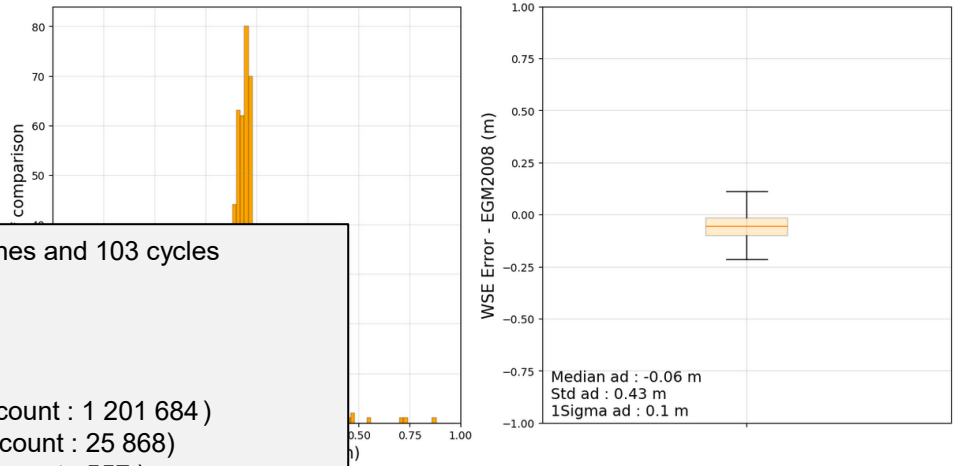
- WSE and slope variations
- Dark water effect
- Phase unwrapping problems

Global metrics over CalVal period : Cycle 475 to 578 – Without measurements flags as « bad » quality

WSE Error at PIXC scale

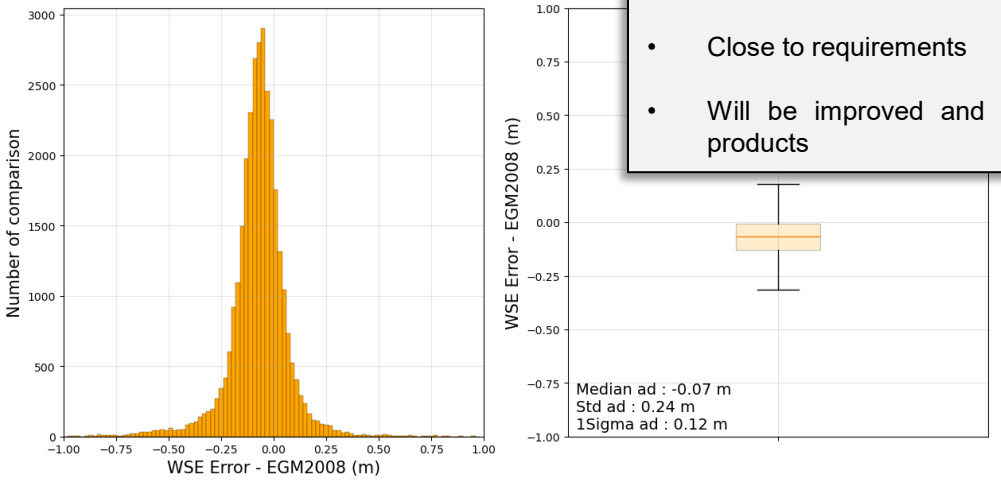


Mean WSE Error at reach scale

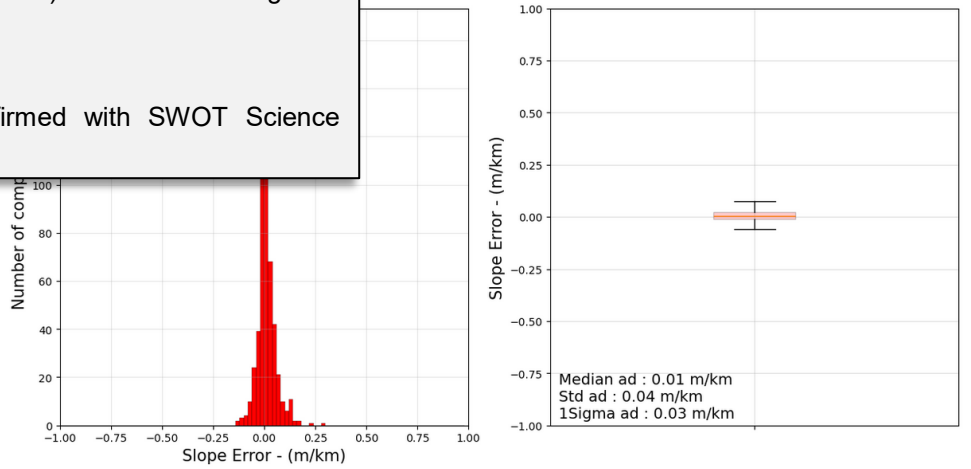


- Comparison done over 9 reaches and 103 cycles
- Good preliminary results
- WSE error 1σ:
  - At PIXC scale: 17 cm (count : 1 201 684)
  - At node scale : 12 cm (count : 25 868)
  - At reach scale: 10 cm (count : 557)
- Slope error: 3 cm/km (count : 557) ➔ To be check again
- Close to requirements
- Will be improved and confirmed with SWOT Science products

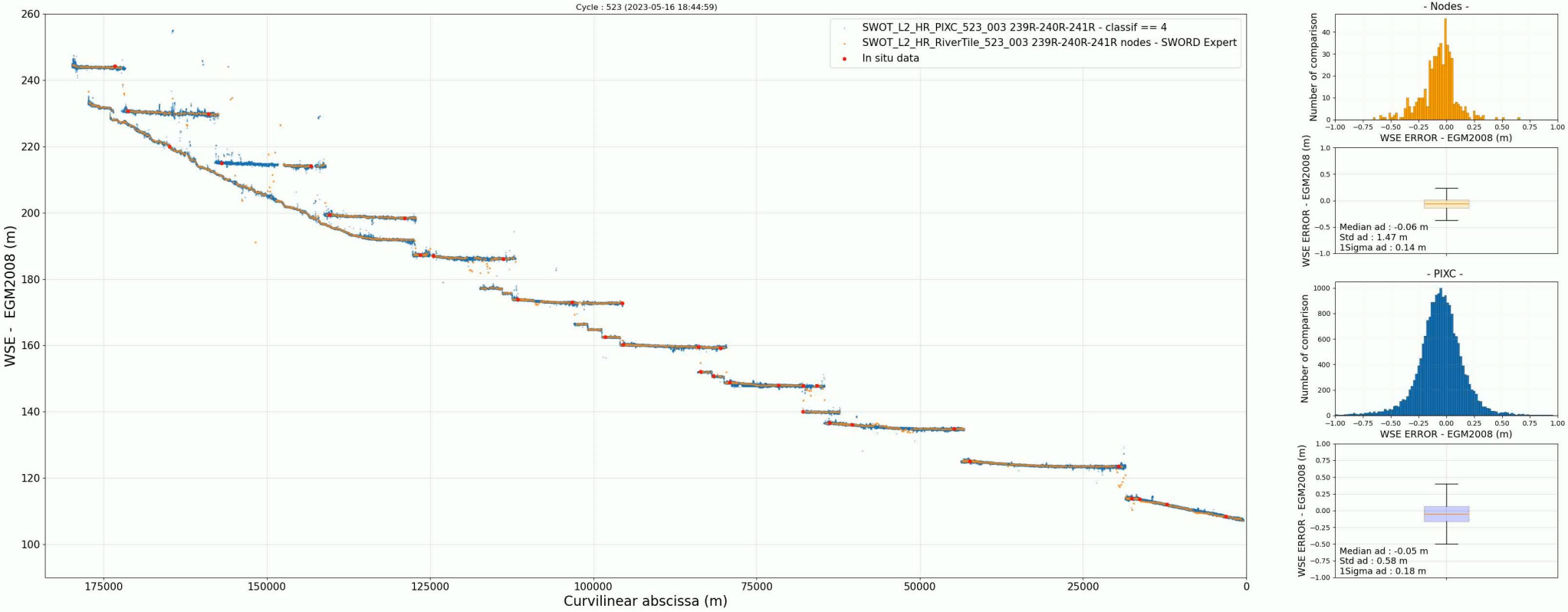
WSE Error at no



Error at reach scale

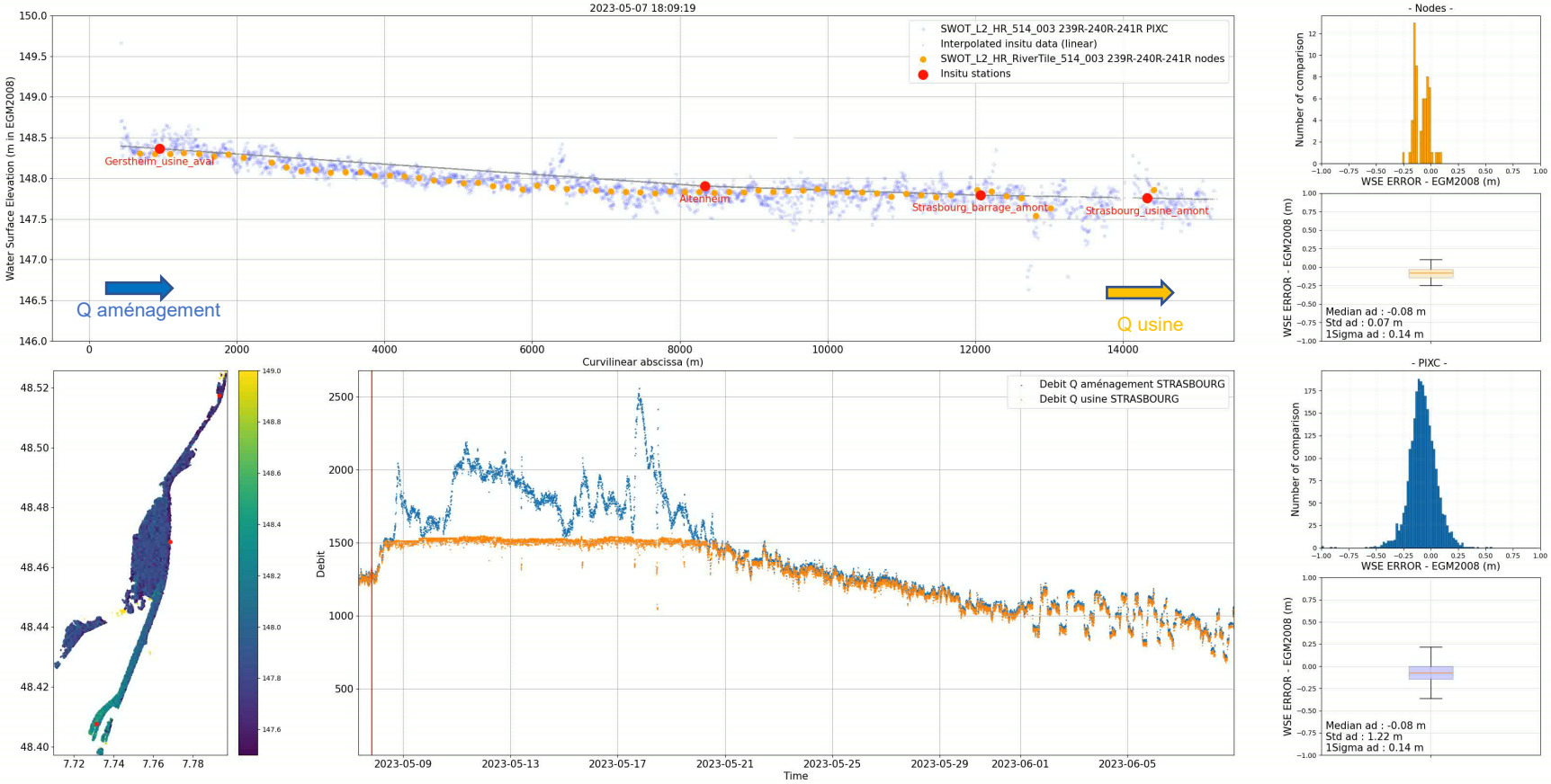


Daily profiles over 180 km of the Rhine river

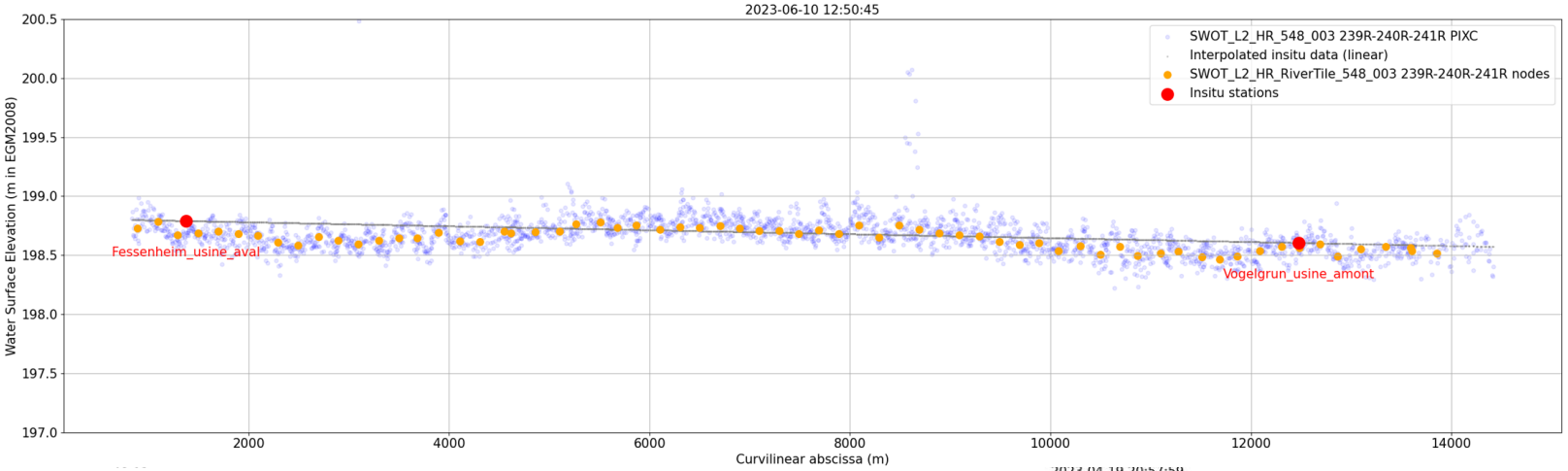


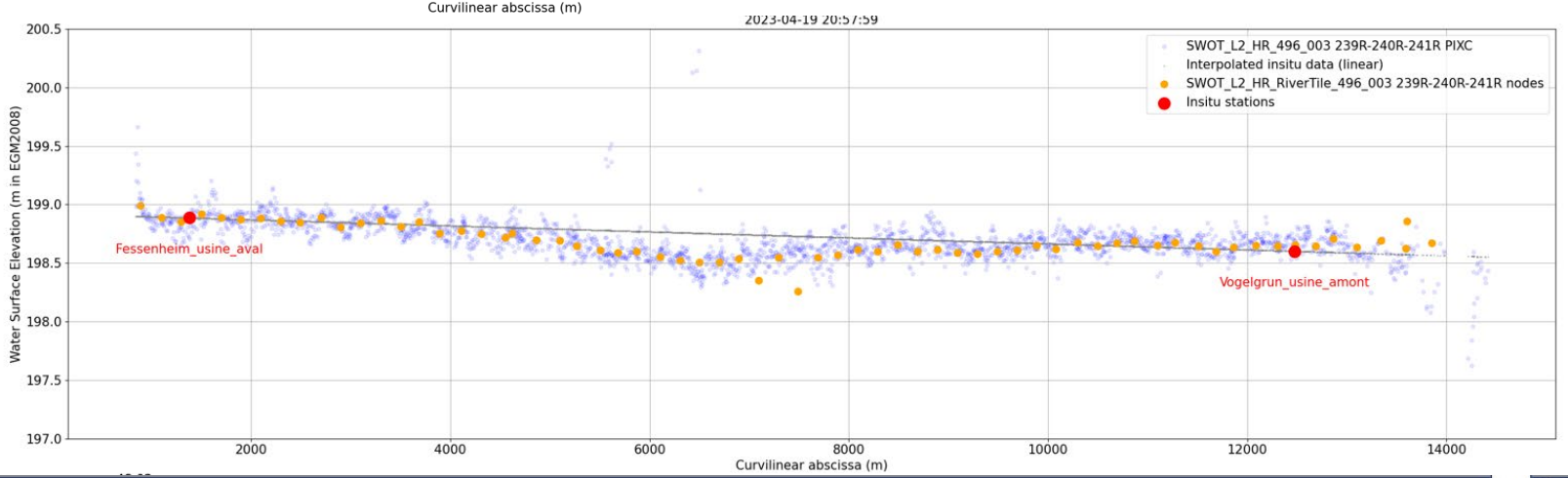
Evolution of river profiles as function of the flow

Evolution of SWOT profiles and river flow - Strasbourg reach in flood and low-water flow.



Identification of internal flow waves due to the dams management





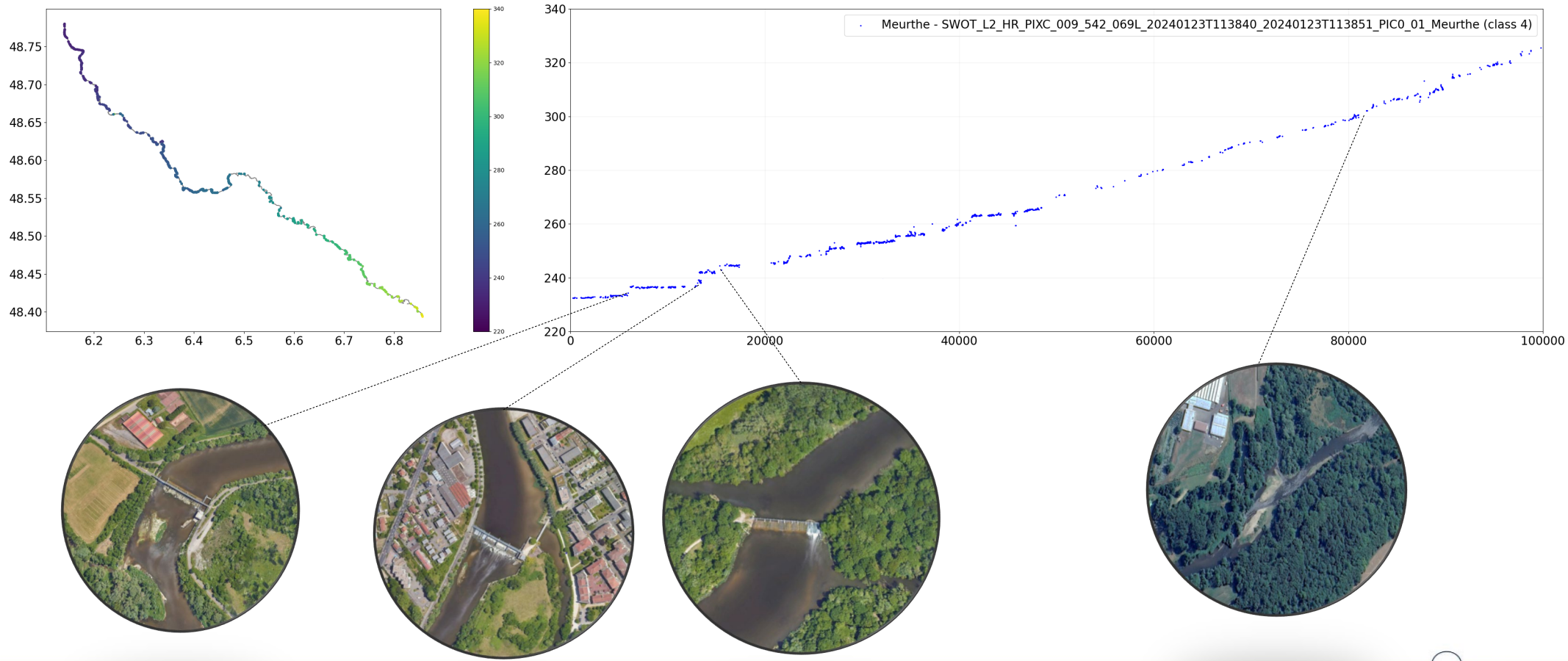
Conclusion & Outlook

- Limitation of the SWORD v14, 15 and 16 over this area
- Implementation of an improved SWORD corresponding to the morphology of the Rhine (dams, weirs, locks, etc.)
- Integration of the improved SWORD into the next SWORD version
- Generation of SWOT L2 RiverSP products with RiverObs algorithm over the whole CalVal period (using CNES HPC)
- Validation done over 9 reaches and 103 cycles
- Accuracy of SWOT measurement demonstrated
  - At node scale : 12 cm
  - At reach scale: 10 cm
- Many intersiting phenomenas can be identified with this data

Application and collaboration will continue in order to further explore the capabilities of SWOT data

Next step

Analysis of SWOT capacity over narrow rivers (between 30 and 60 meters : Meurthe, Moselle, Ill rivers).



Acknowledgments

- Thank you to the CNES team for their constant support and the confidence they have shown in us. Especially to Nicolas, Roger, Damien, Claire and Mathilde
- Thanks to Charlotte from CS and Kevin from Hydromatters for their help in launching RiverObs with the improved SWORD
- Thank you Pierre-André from INRAE and again Kevin, for the rich discussions and advices
- Thank to the Vortex-io team for the availability of the data and discussing about the validation process. Especially to Valentin
- Such results would not have been possible without access to in situ data. Many thanks to the teams at EDF, VNF, DREAL and Eurometrople in Strasbourg