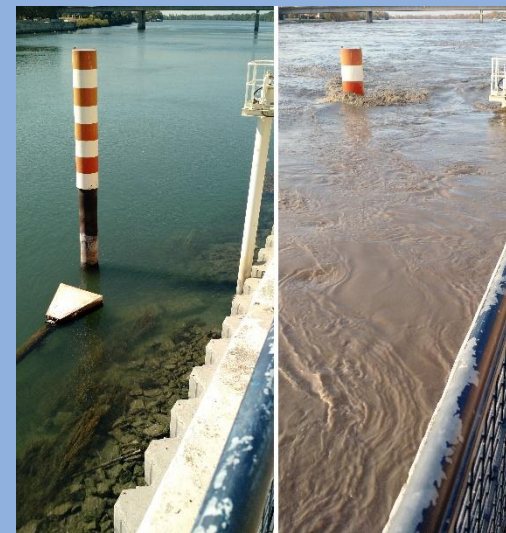


PREDICTION OF PARTICULATE AND DISSOLVED ^{137}Cs CONCENTRATIONS IN THE RHÔNE RIVER (FRANCE) USING MACHINE LEARNING

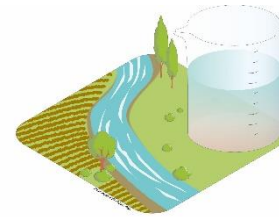
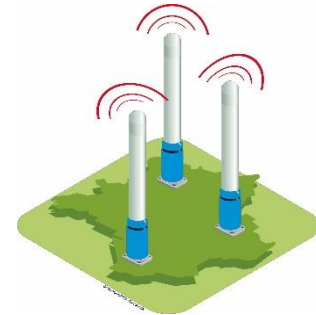
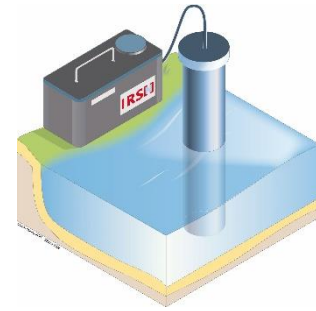
Lepage H., Nicoulaud-Gouin V., Boyer P.

Institut de Radioprotection et de Sûreté Nucléaire (IRSN), PSE-ENV/SRTE/LRTA,
BP 3, 13115, Saint-Paul-lez-Durance, France



Monitoring of the radioactivity

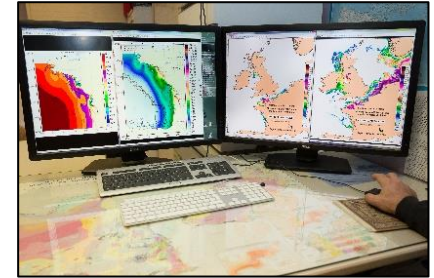
- **Radioactivity is everywhere** in the environment: natural (terrestrial or cosmogenic) and artificial (authorized or accidental releases).
- As for some non radiological contaminants (trace metal elements, organic micropollutants...), radioactive contents might **have to be monitored due to their potential radiotoxicity**.
- This is the case for rivers that might be affected both by routine and/or accidental liquid nuclear releases and by wash-of erosion of catchments contaminated by past fallouts.



Beyond monitoring, modeling

For several reasons it is required to model liquid and particulate concentrations of radionuclides in rivers:

- Logistical constraints for in situ monitoring (expensive, device problem...),
- Consistency of the monitoring (values in the expected range...),
- Estimation of the location/contribution of a source (release by a plant...),
- Short or long-term predictions (accidental release, climate change...),

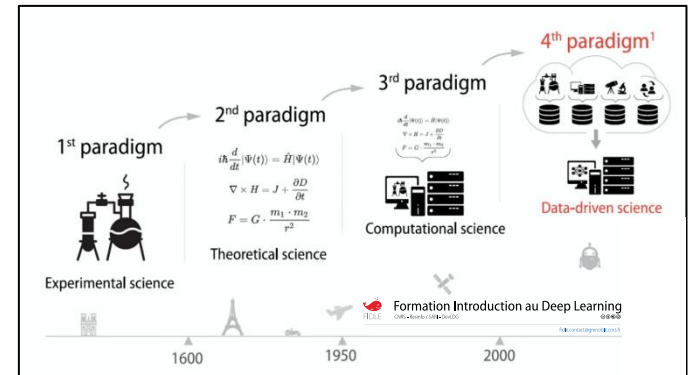


Semi-empirical models can be used:

- But they require data sometimes difficult to obtain (particle size, colloidal fraction, source term...) and they can be relied on several certain assumptions.

➤ Use of data-driven models (machine learning)

- do not involve a large number of input parameters

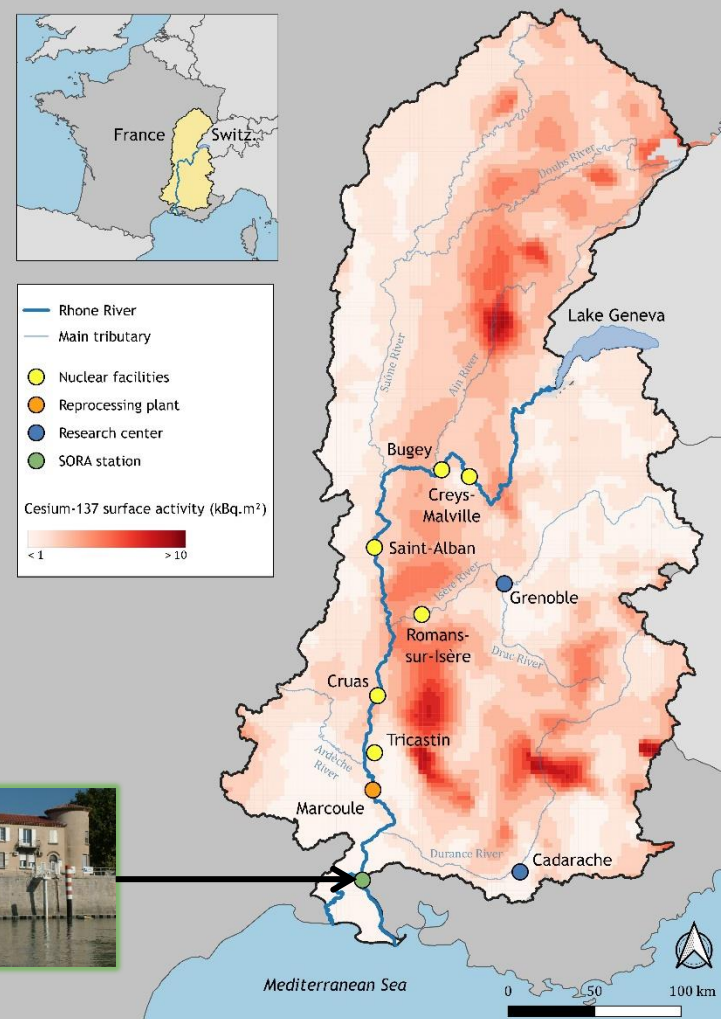


Objectives

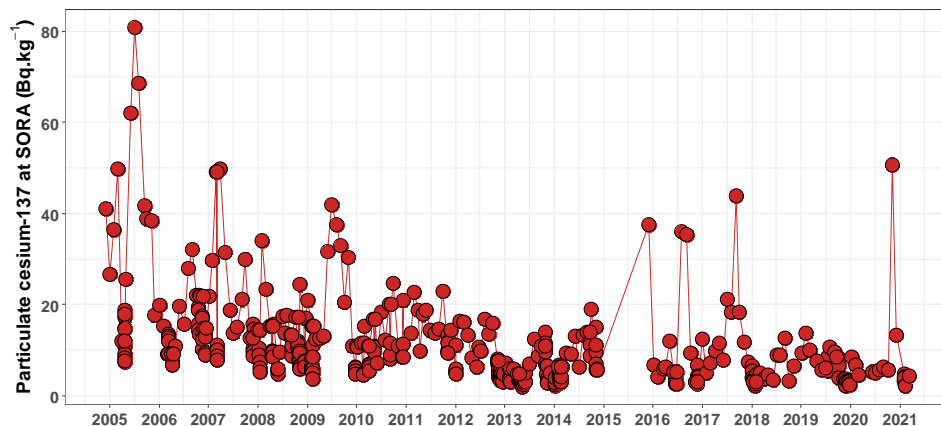
- Prediction of ^{137}Cs concentrations using machine learning
- Comparison with a semi-empirical modeling (based on Tomczak et al., 2021 - <https://doi.org/10.1016/j.envsoft.2021.105211>)
- Prediction of the monthly releases of a nuclear facility

Study location: the Rhône River in France

- One of the most nuclearized river in the world:
 - Four nuclear power plants,
 - Facilities of the nuclear fuel cycle (reprocessing plant...),
 - Research centers.
- Affected by past atmospheric fallouts (mostly Chernobyl)
- Monthly monitored for decades especially since 2004 with the installation of the SORA monitoring station:
 - Downstream of all the main radioactive sources,
 - Integrated dissolved and particulate sampling,
 - Separated and automated flood event sampling.



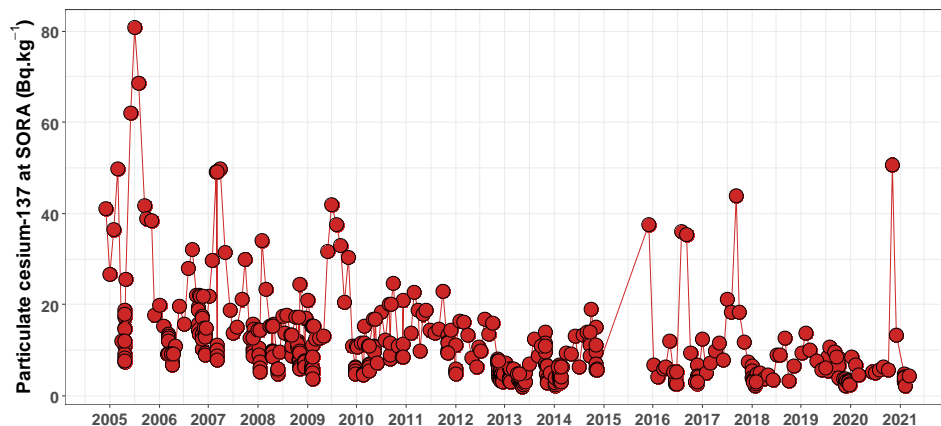
Behavior of the ^{137}Cs in the Rhône River



Sources:

- Soils affected by the atmospheric fallouts,
- Nuclear facilities especially the Reprocessing Center (RC) of Marcoule which represents 95% of the annual liquid release of ^{137}Cs in the river

Behavior of the ^{137}Cs in the Rhône River

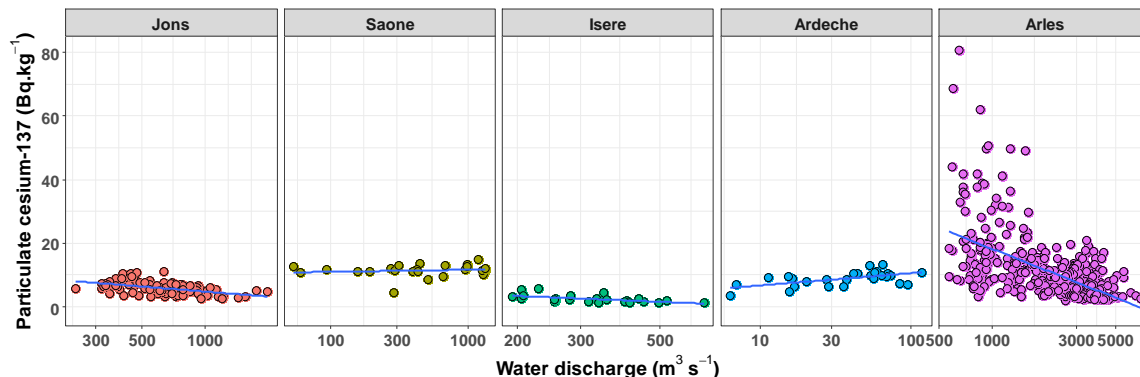


Sources:

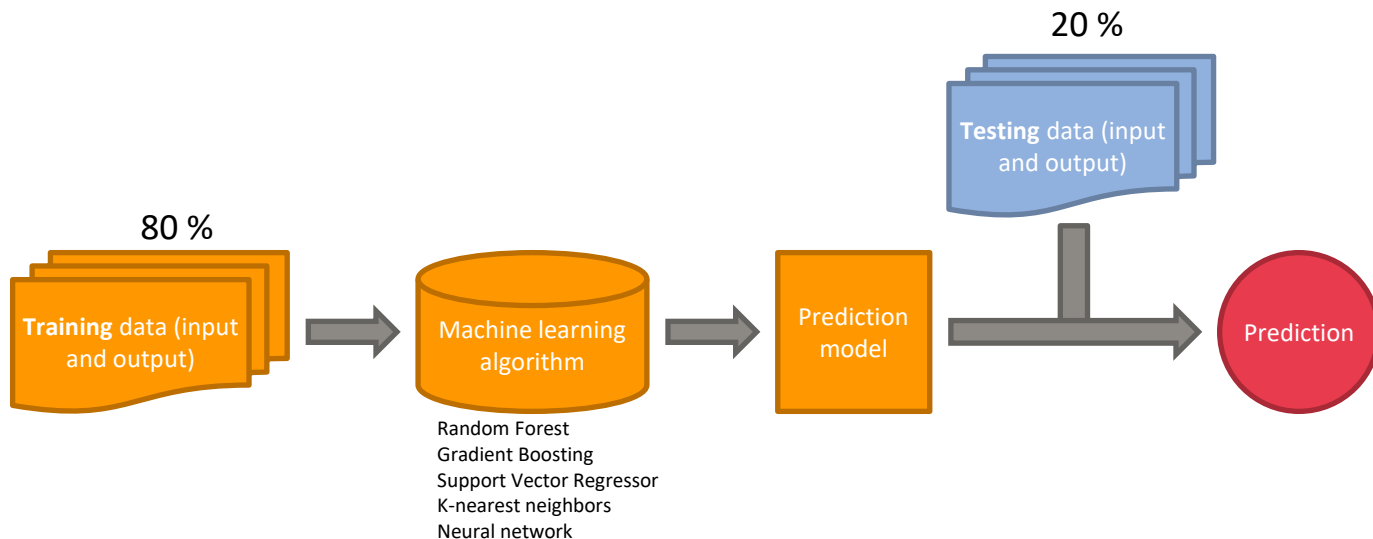
- Soils affected by the atmospheric fallouts,
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Cesium-137 concentrations differ as a function of hydrology and tributaries.

- Use of hydrological data for the application of machine learning.



Method



Input data:

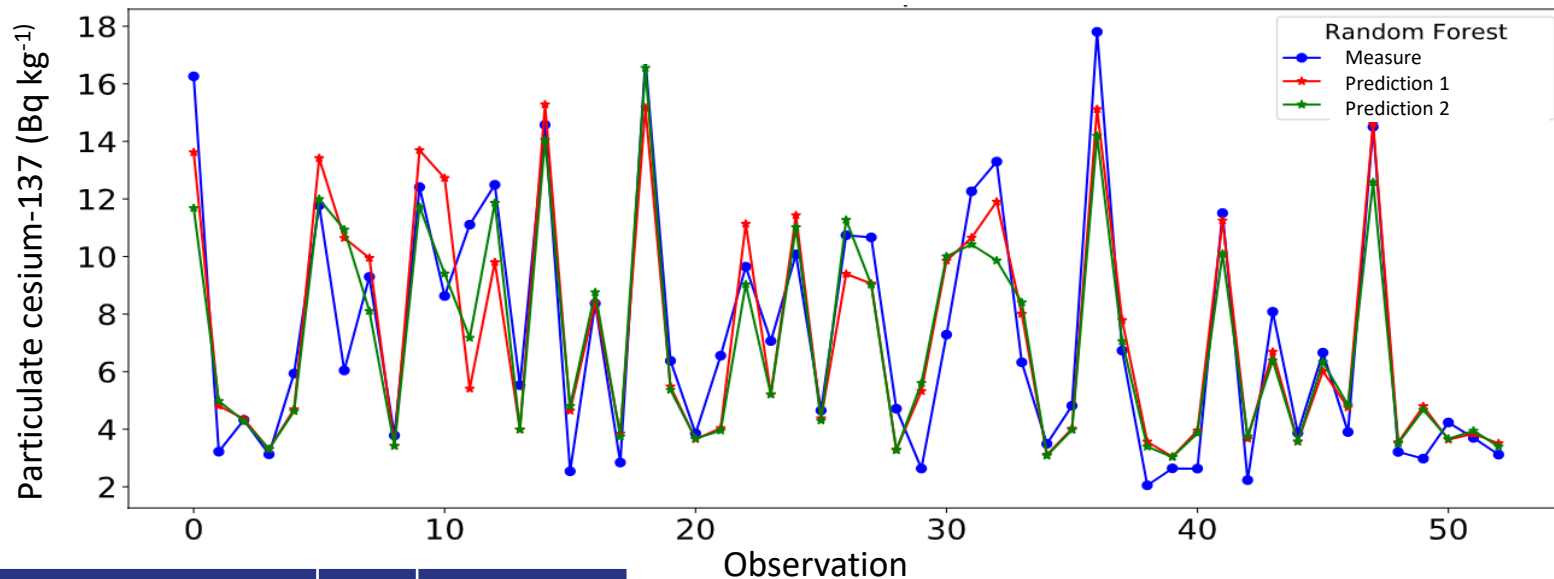
- Water discharge and SPM flux at the monitoring station (SORA) and from the main tributaries
- Releases of ^{137}Cs by the RC

Output data (from 2010 to 2018):

- Particulate ^{137}Cs during baseflow and flood events
- Dissolved ^{137}Cs during baseflow

Data	Number of observations
Particulate ^{137}Cs	238
<i>Flood event</i>	154
<i>Baseflow</i>	84
Dissolved ^{137}Cs	71
Monthly release	64

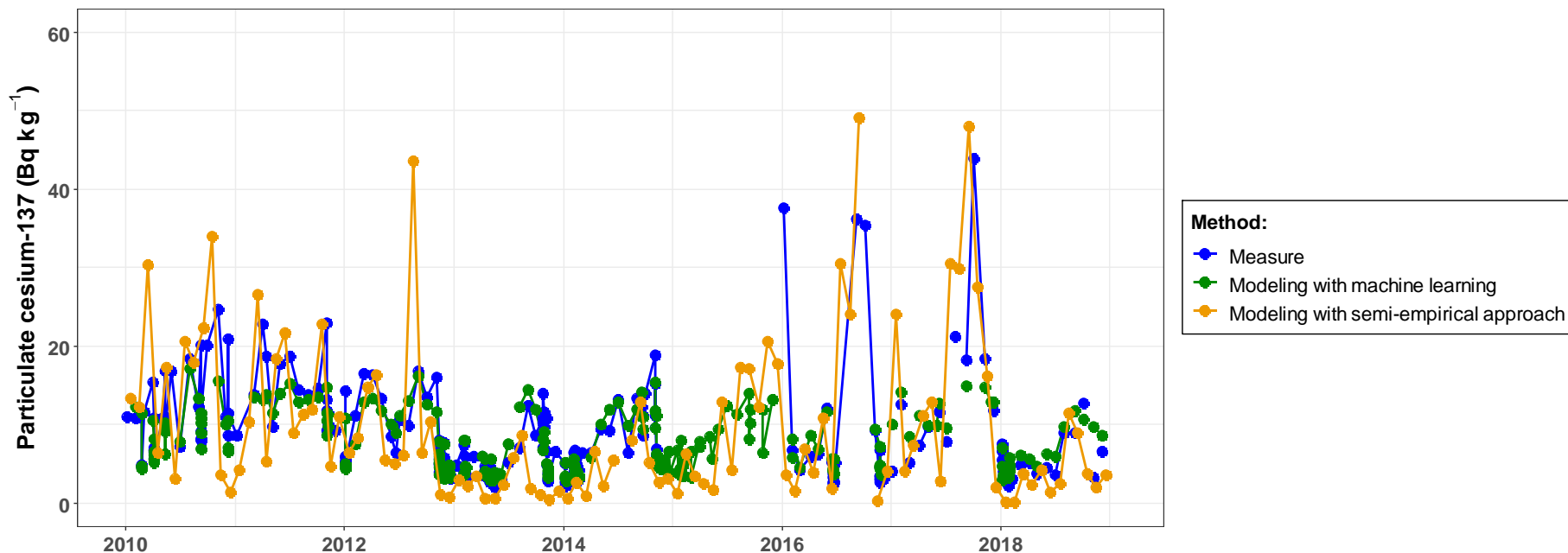
Prediction of particulate ^{137}Cs



Input variables	R2 (-)	RMSE (Bq kg^{-1})
Prediction 1: water discharges at Arles and from the Durance, Ardèche, Saône, Isère tributaries	0.82	1.81
Prediction 2: Prediction 1 + RC releases	0.84	1.70

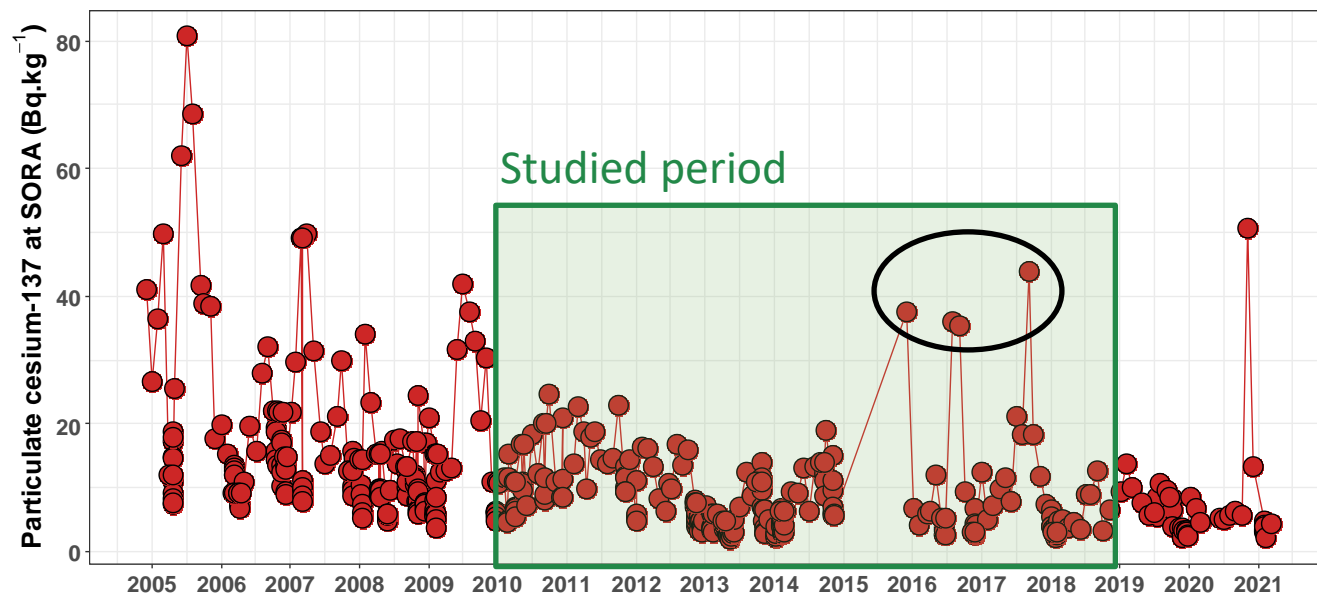
- Accurate prediction using only water discharge
- Low weight of the industrial releases which only occur 10% of the time each month

Comparison with semi-empirical modelling



- Semi-empirical modelling is accurate, but might overestimates the concentration during low-level water
- Machine learning approach fails to accurately estimate high, but rare, concentrations

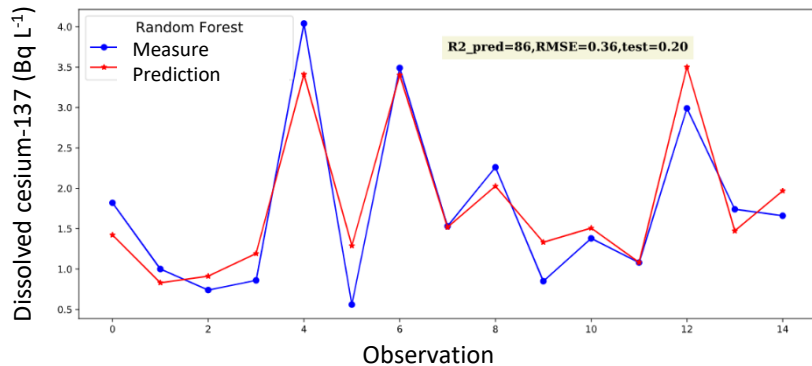
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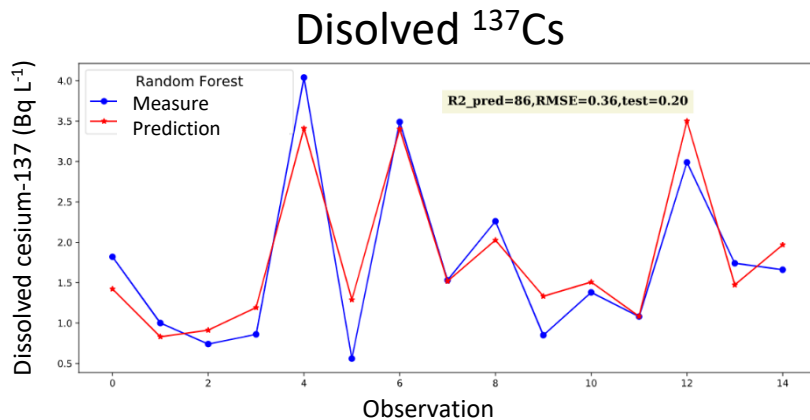
Other modelling

Disolved ^{137}Cs

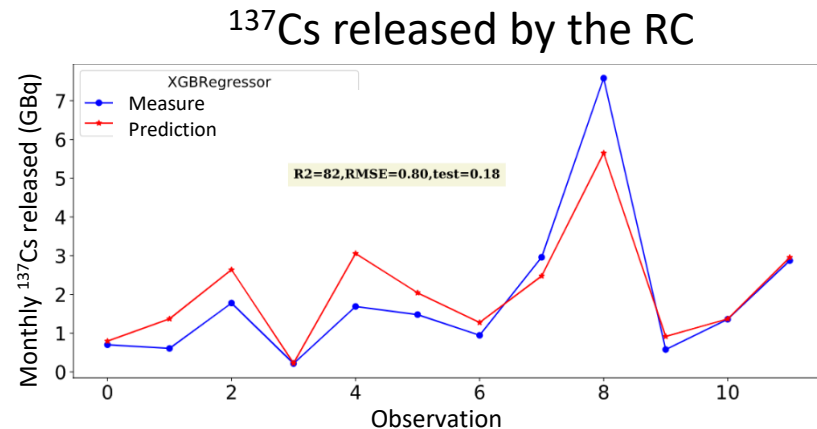


Input variables	R2 (-)	RMSE (Bq L ⁻¹)
Water discharge at Arles and of the Durance tributary, SPM flux of the Isère tributary	0.86	0.5

Other modelling



Input variables	R2 (-)	RMSE (Bq L ⁻¹)
Water discharge at Arles and of the Durance tributary, SPM flux of the Isère tributary	0.86	0.5



Input variables	R2 (-)	RMSE (GBq)
^{137}Cs and ^{60}Co concentrations at Arles and water discharge at Arles	0.82	0.44

■ Accurate simulation for both output (dissolved ^{137}Cs and monthly releases by RC)

⚠ Low number of data → more work must be done to confirm the results

Conclusion

■ Complementarity between:

- Monitoring
- Data-driven modeling (faster, constrained by learning but more accurate)
- Semi-empirical modeling (applicable everywhere but requires specific parameters)

■ Validation of the approach and use of this data-driven modeling

- Applicable to reconstruct gaps and make predictions in "normal" operating situations
- Allows to highlight monitoring anomalies (what we observe vs. what we should see)
- Can be for example an easily deployable operational tool to help monitoring identify anomalies

■ Will be used to reconstruct past contamination with sediment cores to complete missing or sparse monitoring

Thank you for your attention

