



MARSEILLE
27 MAY-3 JUNE 2022

SHORT COURSES
FRIDAY MAY 27 2022

ICOLD
27TH CONGRESS
90TH ANNUAL
MEETING
27^{ÈME} CONGRÈS
90^{ÈME} RÉUNION
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Course 3: Analysis methods of dam monitoring data

Cours n°3: Les méthodes d'analyse des mesures d'auscultation des barrages

Fiber optic temperature data analysis methods

Méthodes d'analyse des mesures de température par fibre optique

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dam monitoring data - 27/05/2022

Outline

Plan

- **Distributed fiber optic measurements technologies**

Technologies de mesure répartie par fibre optique

- **The use of temperature data for dam and dykes' safety**

Utilisation des mesures de température dans le cadre de la sûreté des digues et barrages

- **Analysis methods**

Méthodes d'analyse

- Raw data analysis

Analyse des données brutes

- Statistical analysis

Analyse statistique

- Physics-based analysis method

Méthode d'analyse à base physique

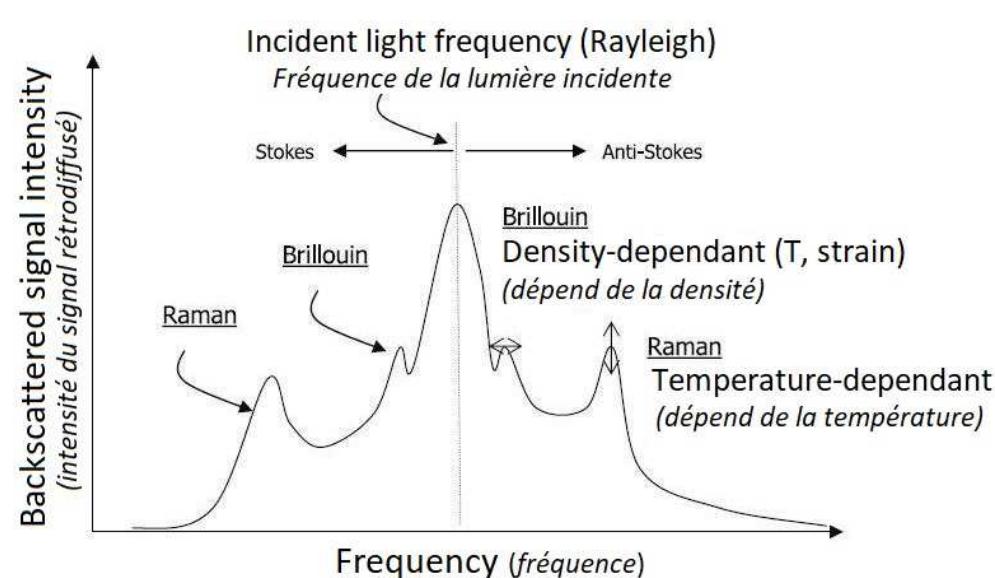


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Distributed fiber optic measurements technologies

Technologies de mesure répartie par fibre optique

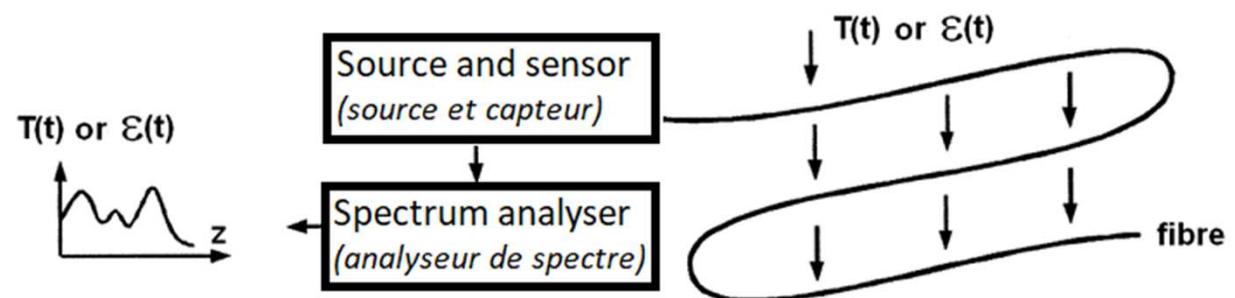
- FO measurements = various technologies
 - Ponctual or integrated measurements (SOFO, Osmose, etc.)
 - Semi-distributed (Fiber Bragg Gratings)
 - Distributed (Brillouin, Raman, Rayleigh)
- Various measurands
 - Acoustic
 - leakage/internal erosion detection (vibro-acoustic measurements)
 - ground movement (acoustic emission)
 - Strain
 - macrostability monitoring, sinkholes detection (soil)
 - crack monitoring in concrete
 - Temperature
 - leakage detection on dams, dykes and pipelines



Distributed fiber optic measurements technologies

Technologies de mesure répartie par fibre optique

- resistance to electromagnetic interference and immunity to corrosion
- high measuring point density (up to 30,000)
- real time compatible
- high sensitivity (1 to 20 $\mu\text{m}/\text{m}$, 0.1°C)
- long-term reliability (MTBF 5 to 10 years);
- localization of events



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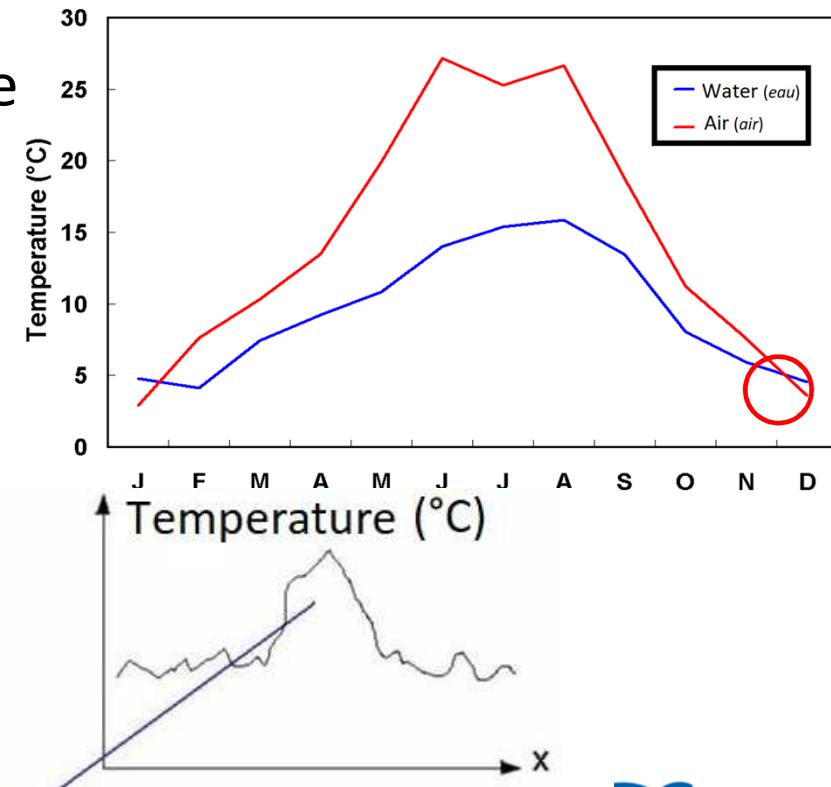
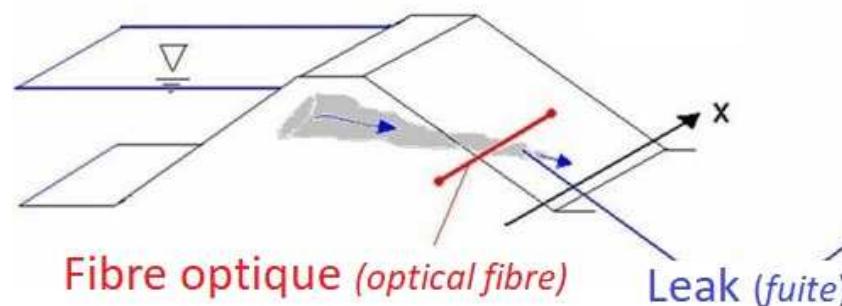


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The use of temperature data for dam and dykes' safety

Utilisation des mesures de température pour la sûreté des digues et barrages

- Temperature is a well-known indicator of the presence of leakage: a preferential flow modifies locally the temperature of the structure
- Estimation of the flow rate by analysing the amplitude and/or phase shift of the annual temperature



Typical installations

Modalités d'installations représentatives

- Rhine river
 - In a trench

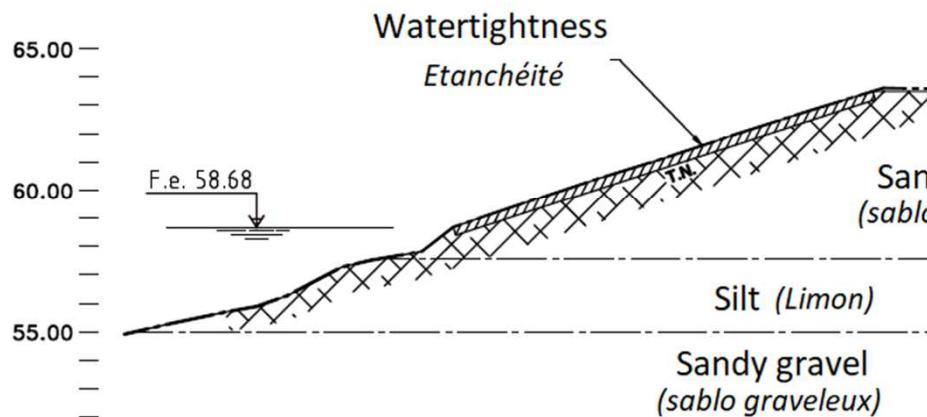


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Typical installations

Modalités d'installations représentatives

- Rhone river
 - Under downstream toe
 - During reinforcement works



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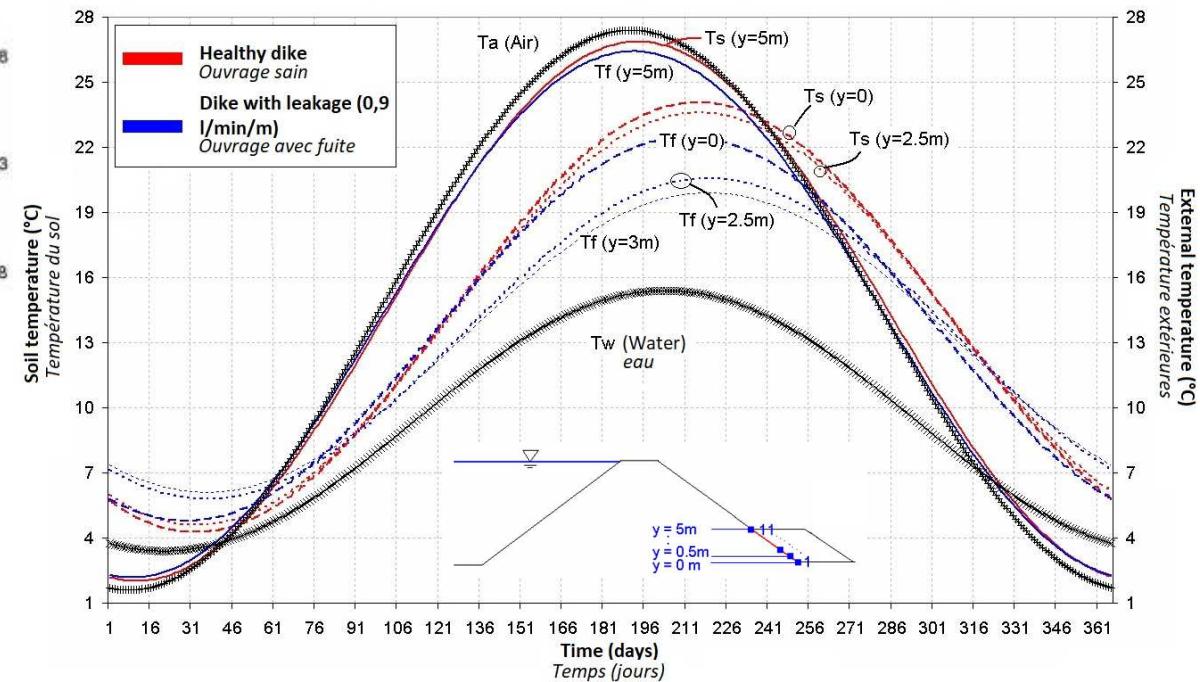
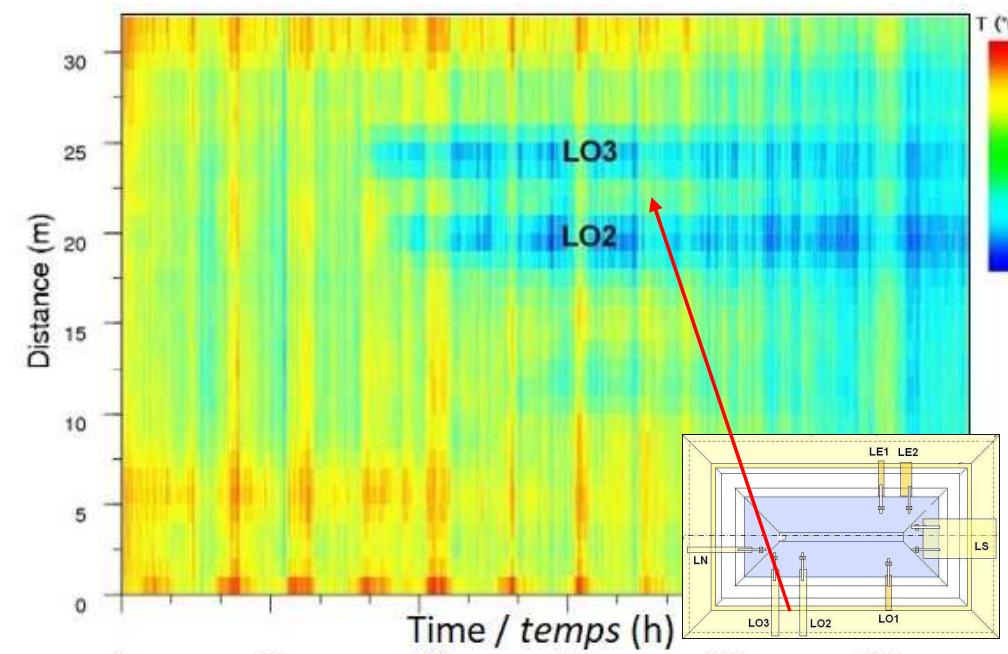


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Analysis methods : raw data

Analyse des données brutes

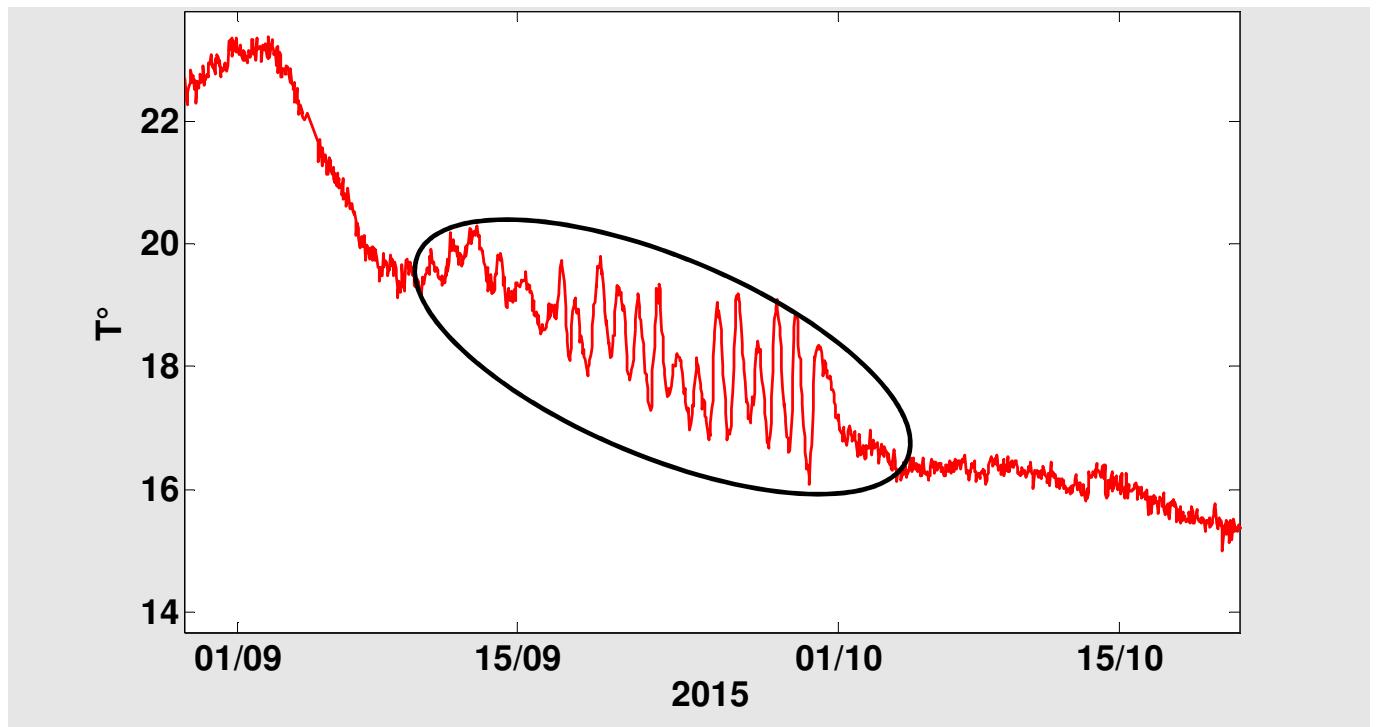
- Correlation FO measurements / water temperature



Analysis methods : raw data

Analyse des données brutes

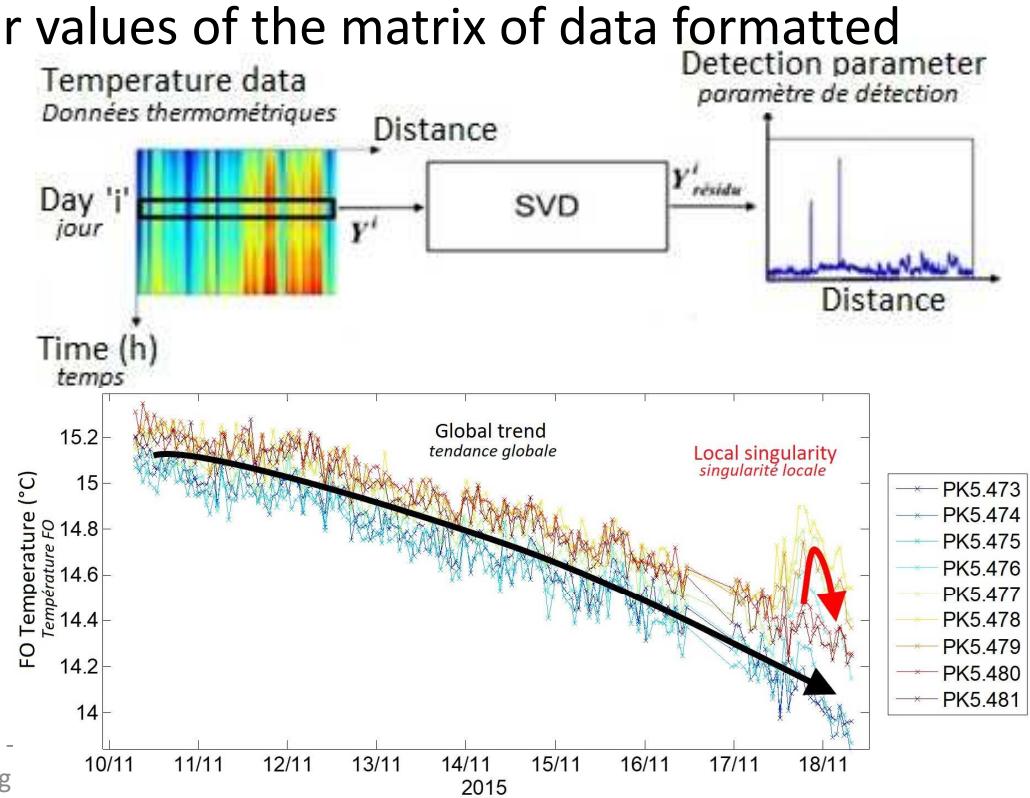
- Geological variability / soil imbibition
 - Daily temperature variations FO very small unless :
 - The FO is closer to the surface (permanent effect)
 - Soil is more conductive (imbibition, transient phenomenon)



Analysis methods : statistical analysis

Analyse statistique

- AJOUT Method: locating atypical thermal behaviours along a given dyke line, which is considered to be mostly non-leaking.
 - Means: Decomposition into singular values of the matrix of data formatted for each day D of measurement
 - Hypothesis
 - the signature of a leak in the temperature field is characterised by an atypical $t \rightarrow T(X=x_{\text{leak}}, t)$ profile
 - The proportion of leaky profiles in a dike is low (<30%).

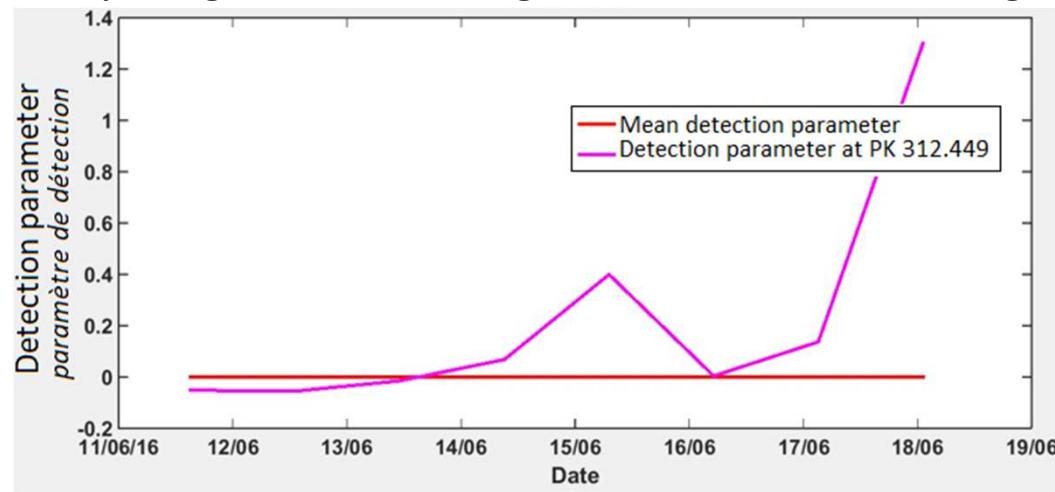


Analysis methods : statistical analysis

Analyse statistique

- AJOUT Method

- The local increase of the detection parameter with time effectively signals the onset/increase of an imbibition phenomenon:
 - whose origin is not necessarily internal erosion (can also be rain for example),
 - whose effect is not necessarily dangerous / alarming for the structure (loading of a flood protection dam)



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Analysis methods : physics-based analysis

Méthode d'analyse à base physique

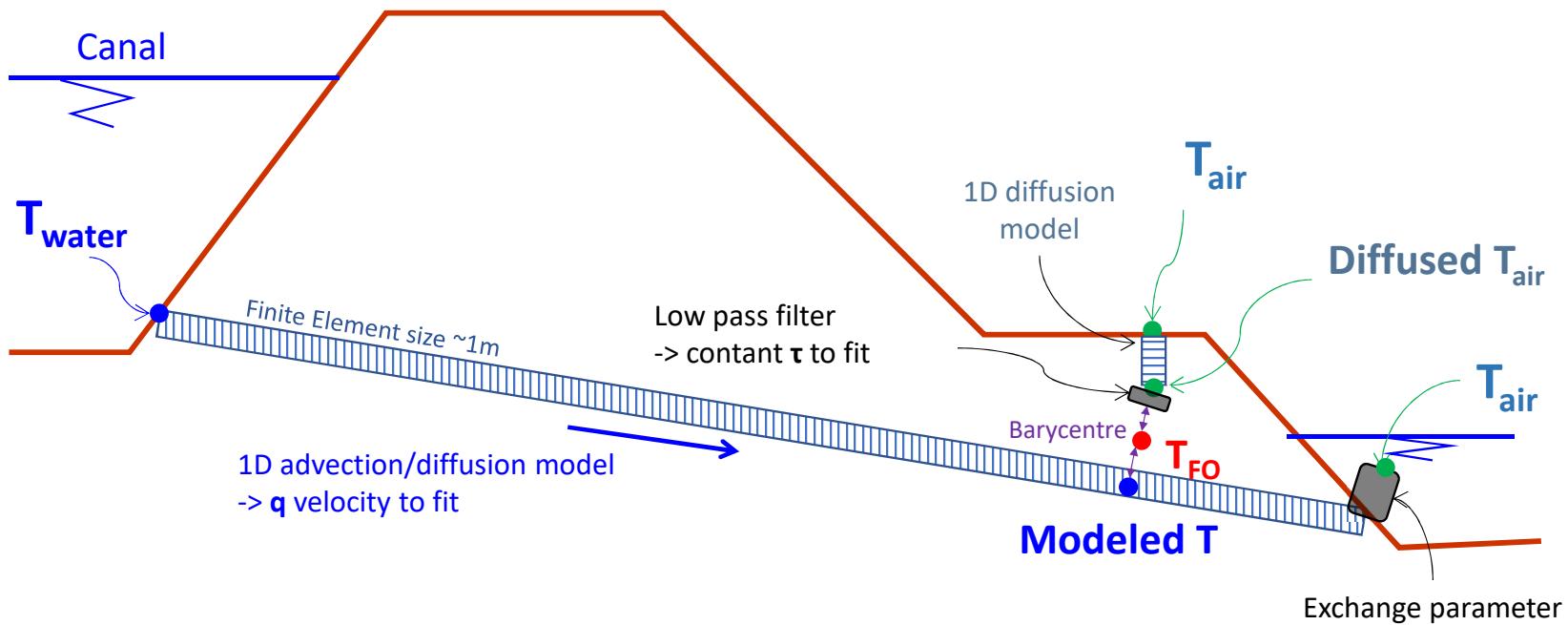
- Diguomatic method

- Purpose of the method: to estimate the flow velocities in the structure by searching for a physical model to calculate the measured temperatures in the body of the structure from the air and water temperatures.
- Mean: adjustment of the parameters of a 1D advection-diffusion model of water and air temperature through the dam, by successive iterations.

Analysis methods : physics-based analysis

Méthode d'analyse à base physique

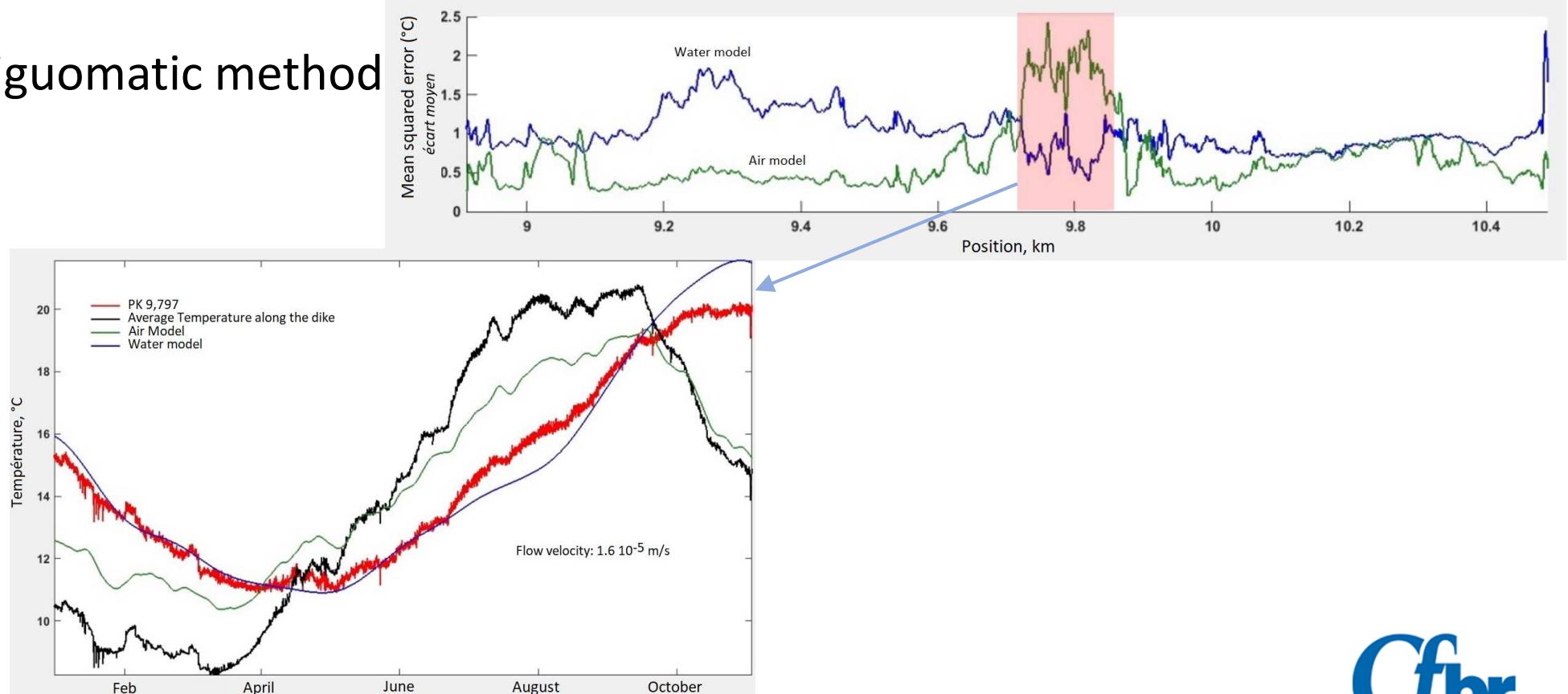
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Analysis methods : physics-based analysis

Méthode d'analyse à base physique

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