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Investigating the impact of temporal resolution on a snow model used for hydrological modelling

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Introduction

Context

- A good understanding and accounting of snow accumulation and melt is required in mountainous areas for hydrological applications (flood forecasting)
- In France, the flood forecasting tool GRP (running at 5-min. to daily time step) is used with the CemaNeige snow model (Valéry et al., 2014)
  - Based on a degree-day approach
  - Improved performance through the use of MODIS SCA (Riboust et al., 2019)
  - Consistency of parameter values between time steps is unknown
  - Currently median parameter values of the daily time step are used at all time steps

Questions to answer

- To which extent are the parameters of the model consistent across time steps?
- Is the model complexity sufficient to simulate the snow influence at the catchment scale at sub-daily time steps?

Catchments and data

- 235 snow-influenced catchments in continental France (Fig.1 – Riboust et al., 2019)
- Period: from 1st January 2000 to 31st December 2015
- Data:
  - precipitation (Comephore; Vidal et al., 2010)
  - air temperature (Safran; Tabary et al., 2012)
  - flow (Banque Hydro; Leleu et al., 2014)
  - snow cover area (SCA) (MODIS data)

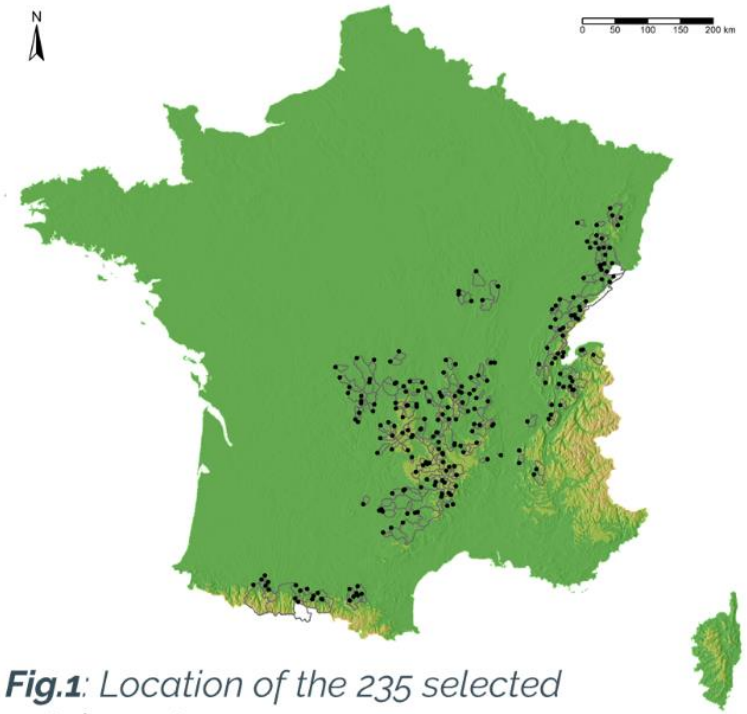

***Fig.1**: Location of the 235 selected catchments*

Methods

- Models:
  - **GR4J** (daily) and **GR4H-I** (hourly) lumped conceptual rainfall-runoff models
  - Modified CemaNeige (Riboust et al., 2019), accounting for the hysteresis between snow water equivalent (SWE) and SCA, with four parameters:
    - **cT**: weighting coefficient for snow pack thermal state (-)
    - **Gseuil**: percentage of annual snowfall defining the melt threshold (-)
    - **Gacc**: accumulation threshold (mm)
    - **Kf**: degree-day melt coefficient (mm/°C/time step)
    - Spatialized into **five altitude bands**
- Calibration with the KGE' index: 75% runoff and 25% MODIS SCA

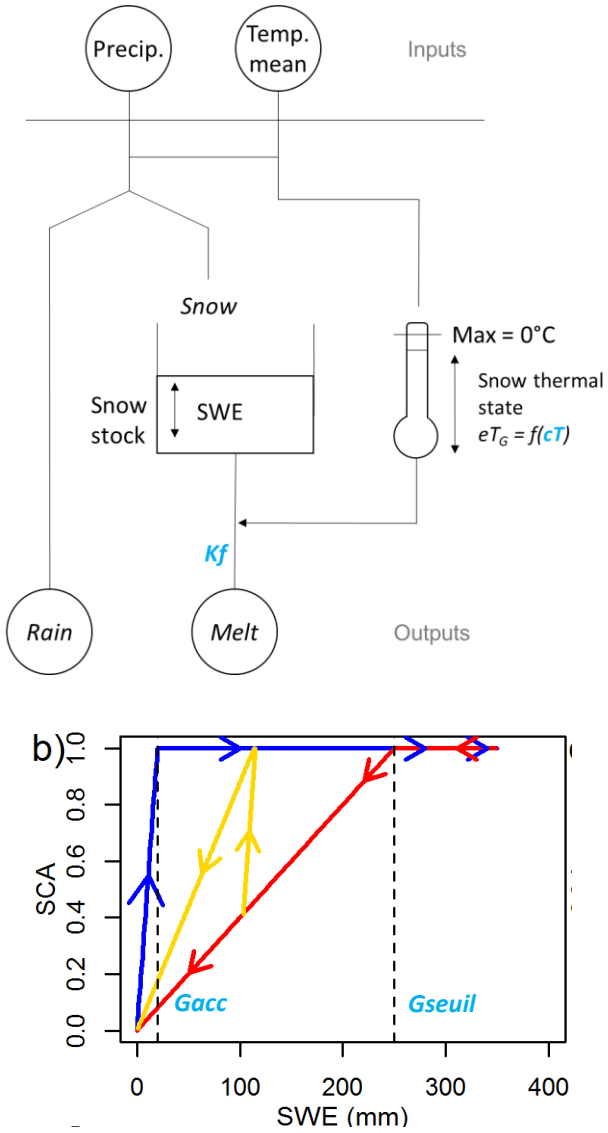

***Fig.2**: Schematic representation of the CemaNeige model and its associated SWE-SCA hysteresis curve*

Results

Performance of daily and hourly models on flow (Q) and SCA

Aggregation of hourly simulations to a daily time step for comparison

- **Good performances** at both time steps
- **Better for Q than SCA** (median values > 0.8)
- For both variables: **performances are slightly better at hourly** (aggregated) than daily time step

Fig.3 shows results in validation, with parameters calibrated on an independent period

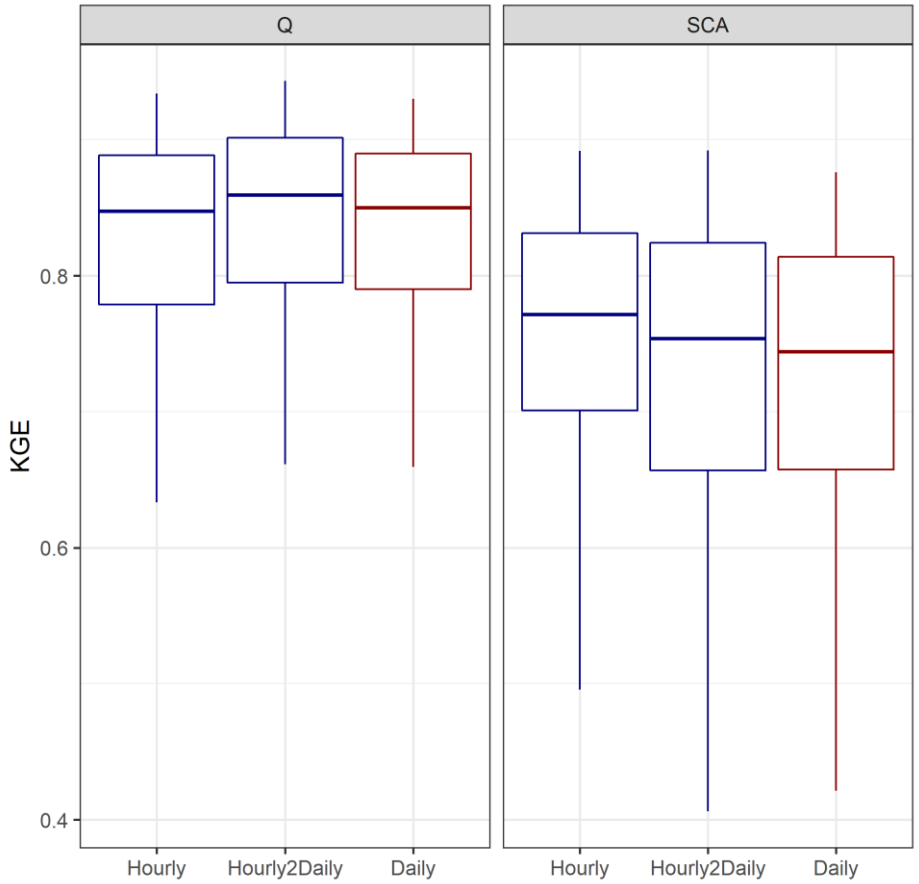

***Fig.3**: KGE score on Q and SCA, at hourly (blue), hourly-aggregated-to-daily (blue) and daily (red) time steps*

Results

Snow module parameters: daily vs. hourly time step

- **Kf** and **Gacc are overall consistent across time steps**, but with higher values at the daily time scale
- **Gseuil** and **cT show more variability**

- The instability of cT and Gseuil cannot be explained by any interactions between these two parameters

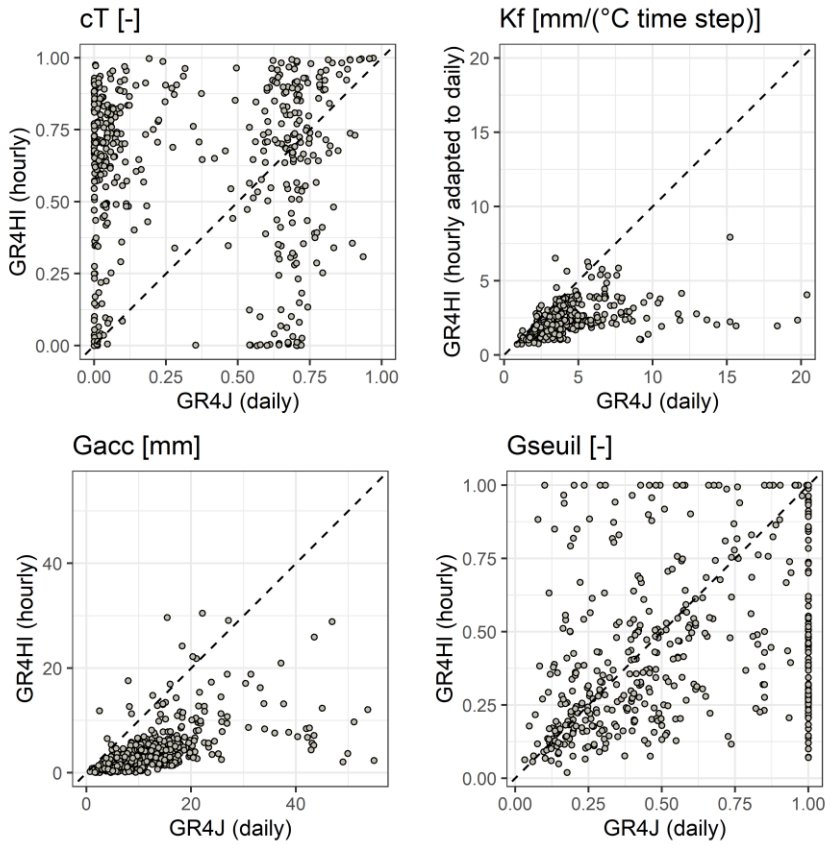

***Fig.4**:Comparison of the four snow module parameters calibrated at the hourly (y-axis) and daily (x-axis) time steps*

Results

Melt event

- Similar total annual melt volume by the daily and hourly models
- Dynamics of the melting process differ between time steps
- Example of two melt events:
  - Both models perform well (top)
  - Hourly model GR4H-I performs better (bottom)

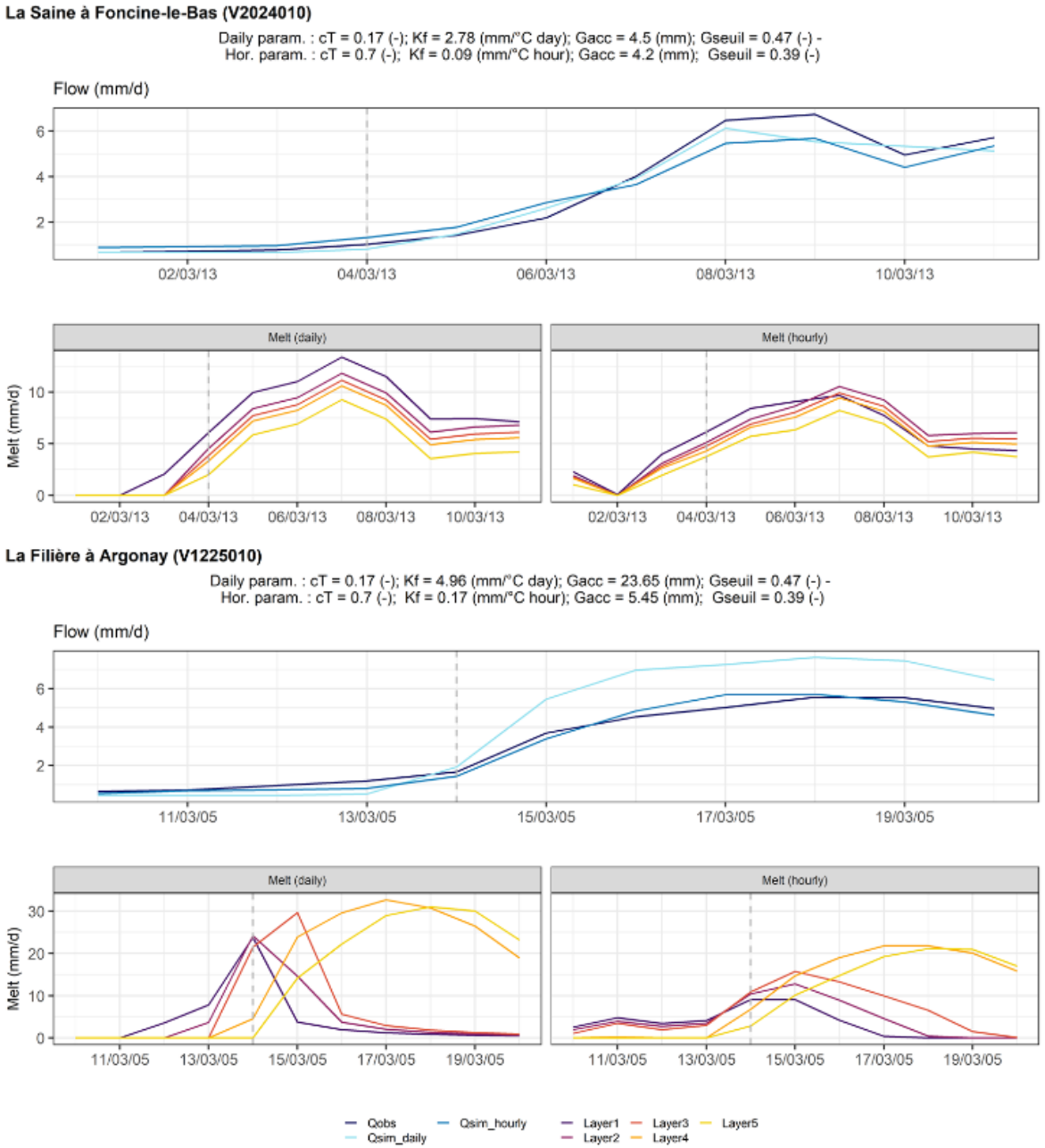

***Fig.5**: Example of two melt events*
Observed and simulated flows (graph at the top)
Melt at the daily time step (graph at the bottom left) and at the hourly time step aggregated to daily (graph at the bottom right)

Conclusion & perspectives

- Summary
  - Good and similar performances for models at both time steps (hourly and daily)
  - Outputs of the snow model consistent across time steps
  - Impact of time step visible on the representation of processes during melt events but overall good representation of flow either at daily or hourly time step

- Further steps
  - Forecasting perspectives
  - Complementary analysis of internal fluxes of the model
  - Investigating potential issues linked to calibration: lack of sensitivity, lack of robustness, etc.

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