Glacier melt contributions to future natural streamflow in the Rhône bassin

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Large seasonal change of streamflow:

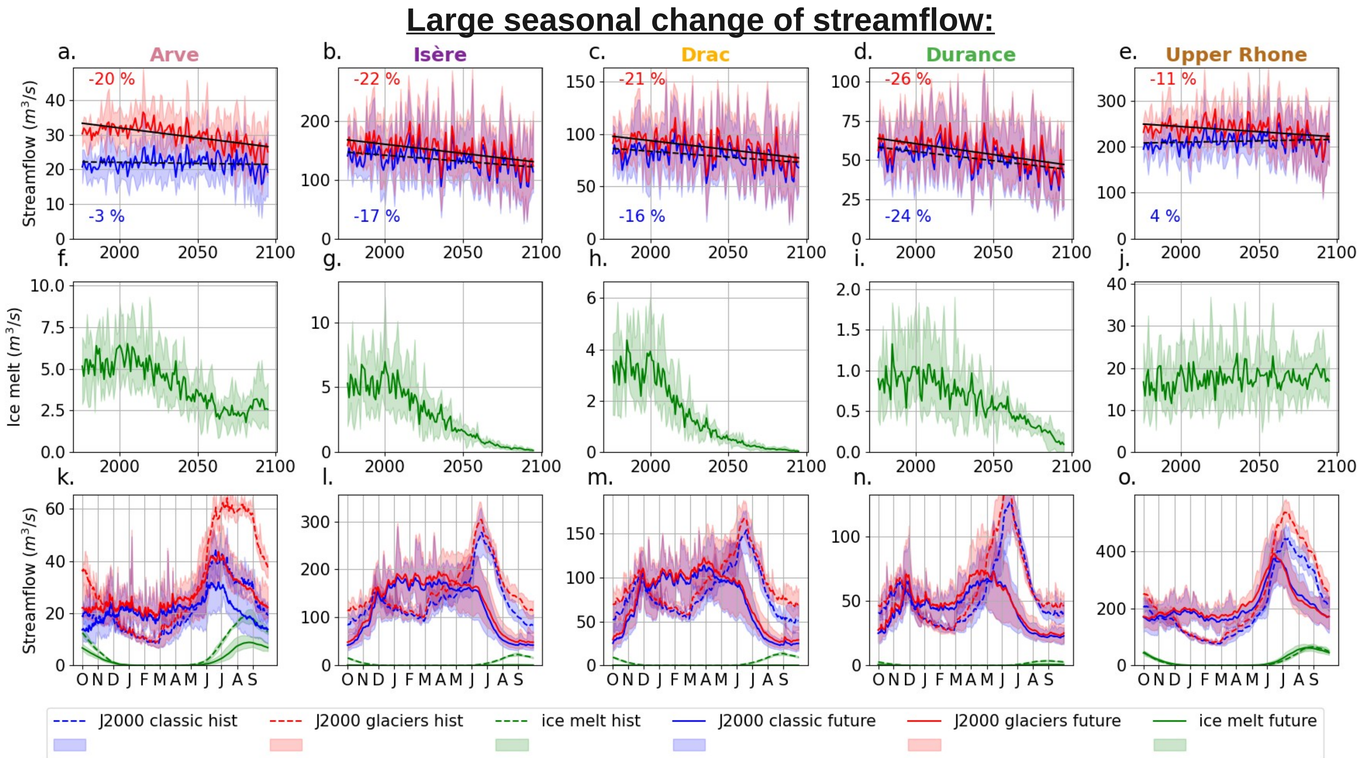

Fig.2: First row : Evolution of annual streamflow for 5 sub-basins forced by 6 climate simulations
Second row : Evolution of annual icemelt for 5 sub-basins forced by 6 climate simulations.
Third row : Seasonal evolution for historical (1976-2005, doted lines) and future (2066-2095, solid lines) periods.

Will glaciers still sustain summer streamflow in the Rhone basin by the end of the century ?

Summer low flows extreme partly sustained by ice melt:

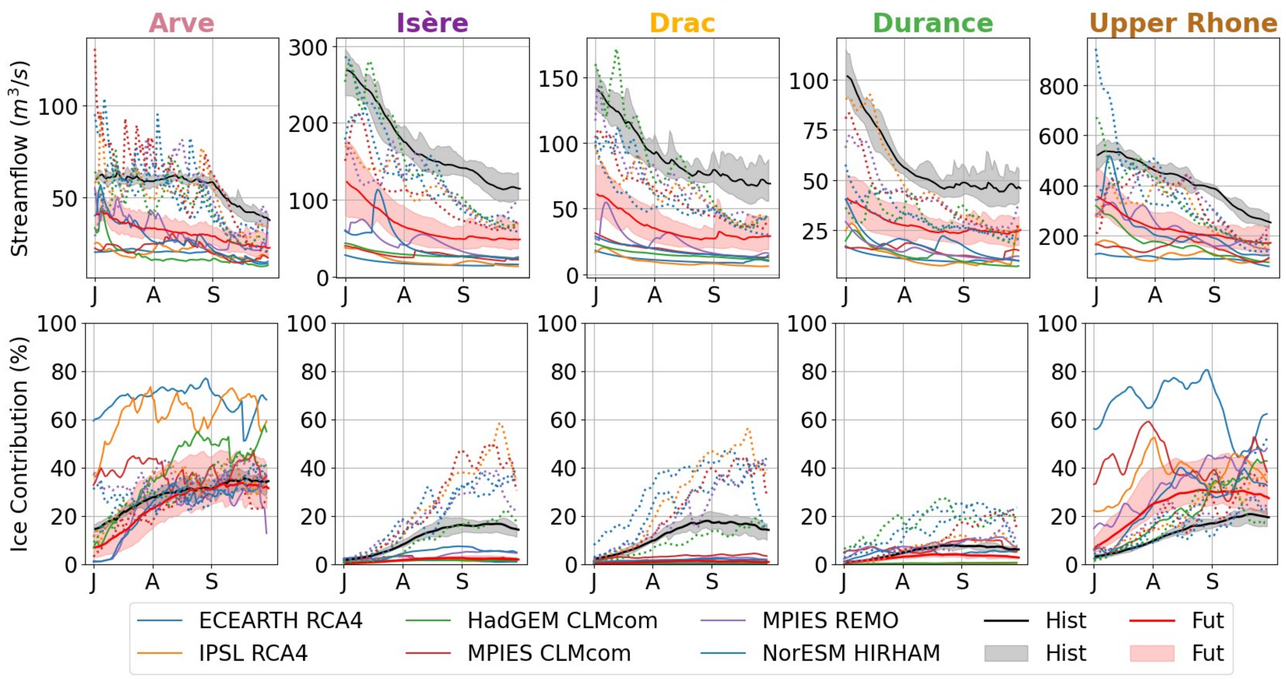

Fig.4: Evolution of streamflow (first row) and ice contribution (second row) in the end of summer for the year with the lowest September streamflow of each of the 6 models (colors) in the historical period (doted lines) and future period (solid lines). The model average is shown to compare to all years in the historical (black) and future periods (red).

A spatial variability of ice contribution to streamflow:

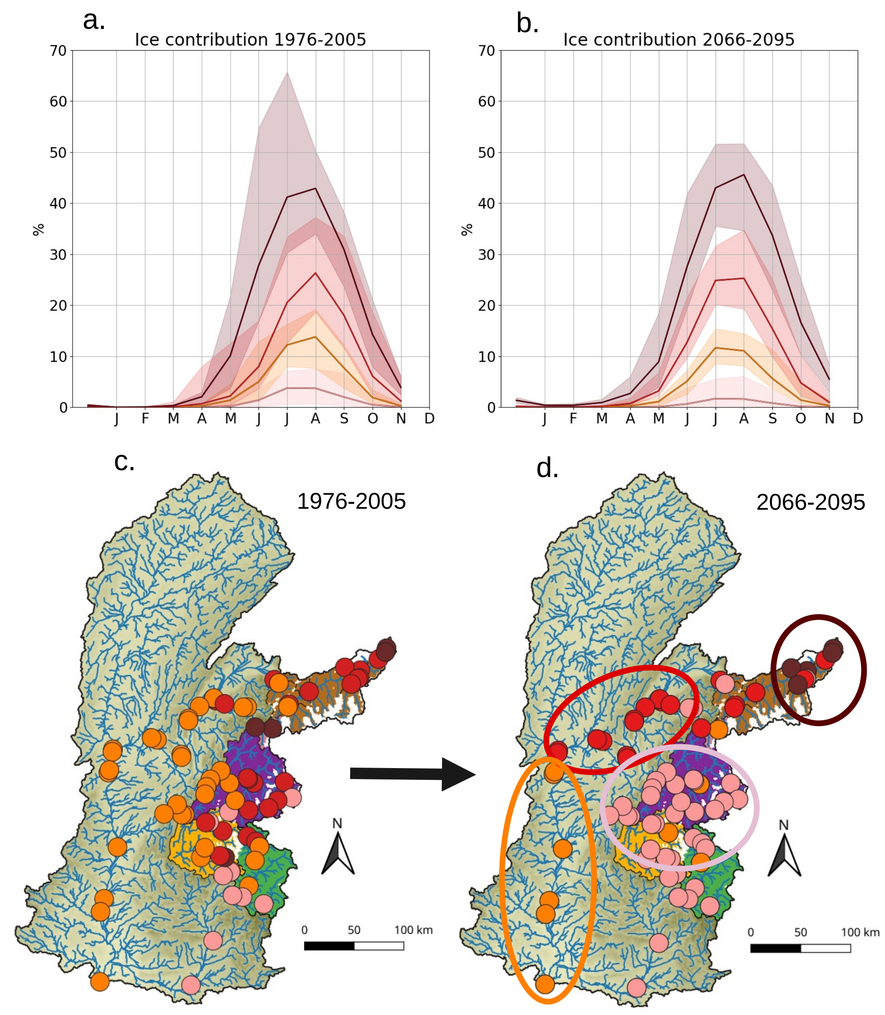

Fig.3: Classification of the main hydrometric stations (represented in c,d) in classes of similar seasonal ice contribution. a,b: Monthly ice contribution per class in the historical (1976-2005) and future (2066-2095) periods.

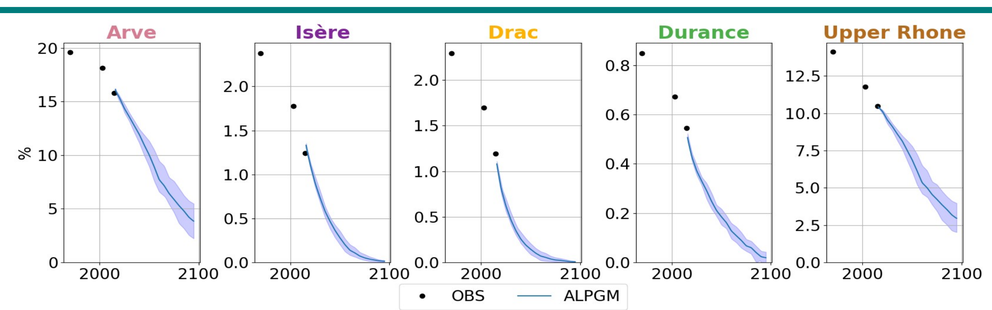

Fig.1: Evolution of glacier fraction (in %) per sub-basin with observations (dots) and the glacier model ALPGM forced by 6 climate simulations (2015-2095).

Take home messages:

- Dramatic decrease of summer streamflow in all watersheds, likely due to a change of snow regime

- Future summer low flows not sustained by glacier melt in most french sub-basins

- Arve and Upper Rhone will keep high melt rates (large glaciers remaining) sustaining low flows

Method and calibration results:

Model: J2000 hydrological model with dynamical glacier algorithm.

Input Data for calibration:

- temperature (T), precipitation (P) and evapotranspiration (ET_0) from SAFRAN reanalyses.

- observed glacier area in 1970, 2003 and 2015.

Calibration process: Streamflow (2003-2014), snow processes, and glacier mass balance (2003-2022), with a trial and error approach.

Input Data for projections:

- T, P, and ET_0 from 6 bias corrected (Adamont) climate modeling chains (Euro-cordex).

- future evolution of glacier area (ALPGM).

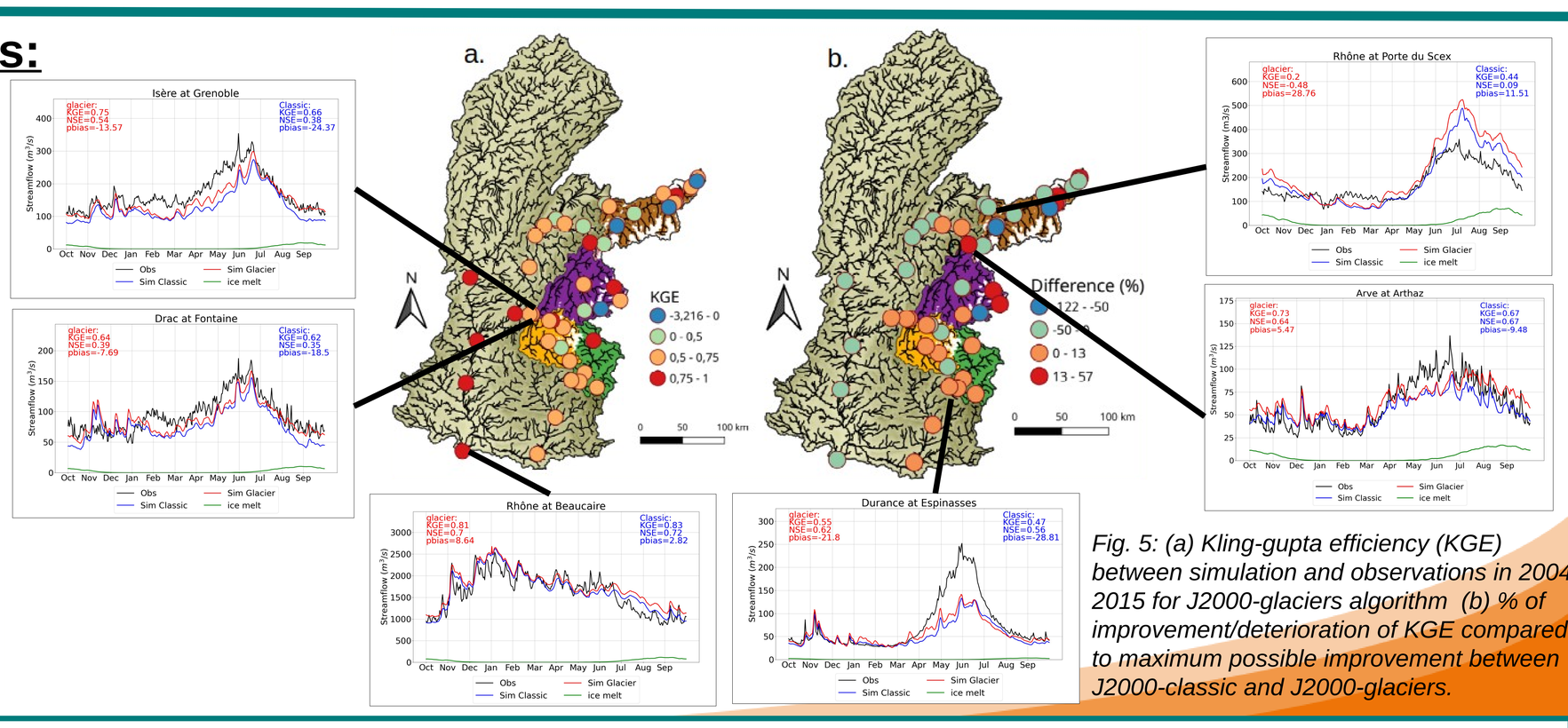

Fig. 5: (a) Kling-gupta efficiency (KGE) between simulation and observations in 2004-2015 for J2000-glaciers algorithm (b) % of improvement/deterioration of KGE compared to maximum possible improvement between J2000-classic and J2000-glaciers.

Reference : Olivier Champagne, Anthony Lemoine, Thomas Condom, Isabelle Gouttevin, Jordi Bolibar, et al.. Modélisation hydrologique distribuée du Rhône: Intégration d'un module de dynamique glaciaire dans J2000-Rhône. INRAE - RiverLy. 2024. ⟨hal-04863102⟩