Climate and hydrological uncertainties in projections of floods and low flows in France

Eric Sauquet[1], **Jean-Philippe Vidal**[1],
Charles Perrin[2], Pierre-Yves Bourgin[2,*],
Mathilde Chauveau[2,3], Sébastien Chazot[3],
Nathalie Rouchy[4]

[1]**Irstea**, UR HHLY, Hydrology-Hydraulics Research Unit
[2]**Irstea**, UR HBAN, Hydrosystems and Bioprocesses Research Unit
[3]**BRL ingénierie**
[4]**Météo-France**, DP/SERV/BEC
*now at Coyne-et-Bellier

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Eau et changement climatique

Toujours un temps d'avance

Outline

Types of uncertainties considered

1. Uncertainty in General Model Circulation (GCM)

- 7 GCMs from CMIP3 experiments under the A1B emissions scenario
- Downscaled with a weather type method (Boé et al., 2006)
- Representative range of changes for the 2050s
  - Increase in temperature (1.4°C to 3.5°C)
  - Small decrease in precipitation, more marked in summer (-20%) but with high regional discrepancies

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2. Uncertainty in hydrological model structure (HM)
   - GR4J: lumped conceptual model calibrated on each target catchment (Perrin et al., 2003)
   - ISBA-MODCOU: a suite of a land surface scheme and a distributed hydrogeological model not fully calibrated at the catchment scale (Habets et al., 2008)

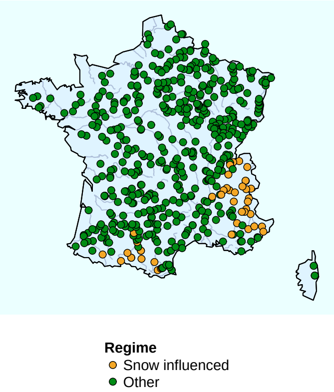
Hydrological modelling framework

Catchments

- 1522 catchments, 543 common to GR4J and Isba-Modcou

Hydrological runs

- Under Observed climate
  - Run (and calibrated for GR4J) under Safran reanalysis (Vidal et al., 2010) over 1961-1990
- Under GCM-derived climate
  - Control period (1961-1990)
  - Future period (2046-2065)



High and low flow indices

Low flow indices

- QMNA5: annual minimum monthly flow with a 5-year return period (policy threshold in France)
- Q95: daily flow value exceeded 95% of the time
- Low flow month: average month of annual minimum flow

High and low flow indices

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High flow indices

- Q10: daily flow value exceeded 10% of the time
- QJXA10: annual maximum daily flow with a 10-year return period
- Flood day: average Julian day of annual maximum flow

Analysis framework

Changes and errors

period \ datatype	Observed	Safran-derived	GCM-derived
Observation			
Control			
Future			

Analysis framework

Changes and errors

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- Index-specific changes examined between GCM-derived control and future periods

Analysis framework

Changes and errors

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- Index-specific errors computed:
  - $E1_h$: hydrological modelling bias

Analysis framework

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Analysis framework

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- Index-specific errors computed:
  - $E1_h$: hydrological modelling bias
  - $E2_h$: natural (modelled) variability
  - $E3_{h,g}$: hydrological impact of GCM bias over control period

Analysis framework

Index-specific 14-member multimodel changes

What are the projected multimodel average changes?

- Multi-GCMs (7) x multi-HMs (2) average change $\boldsymbol{\mu}$

How consistent are those multimodel changes?

- Multi-GCMs (7) x multi-HMs (2) signal-to-noise ratio $\left|\frac{\mu}{\sigma}\right|$

What is the most prominent type of uncertainty?

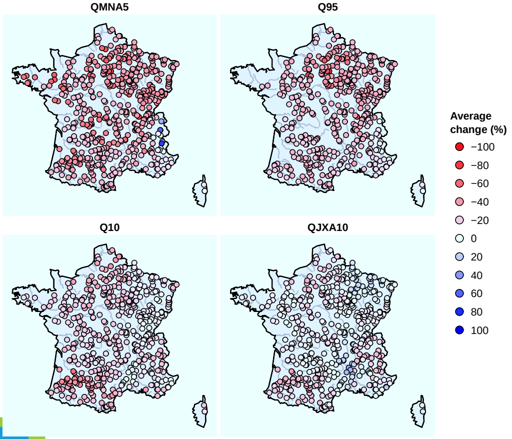
- Decomposition of variance between hydrological models and GCMs (von Storch and Zwiers, 1999, chap. 9)

Is it possible to reduce the uncertainty in changes?

- Variance weighted by index-specific normalized and combined errors $\frac{1}{|E1_h| \cdot |E2_h| \cdot \left|E3_{h,g}\right|}$

Results

Multi-GCMs multi-HMs average changes



Low flow indices

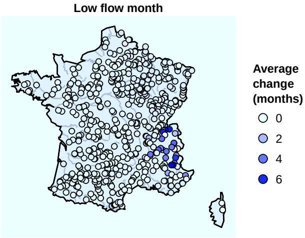
- Dramatic decrease of low flows over France
- Small increase in QMNA5 for snowmelt-fed catchments

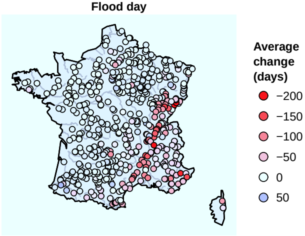
High flow indices

- Small decrease in Q10 and QJXA10
- Small increase in the Cévennes area (severe convective events)

Results

Multi-GCMs multi-HMs average changes





Low flow indices

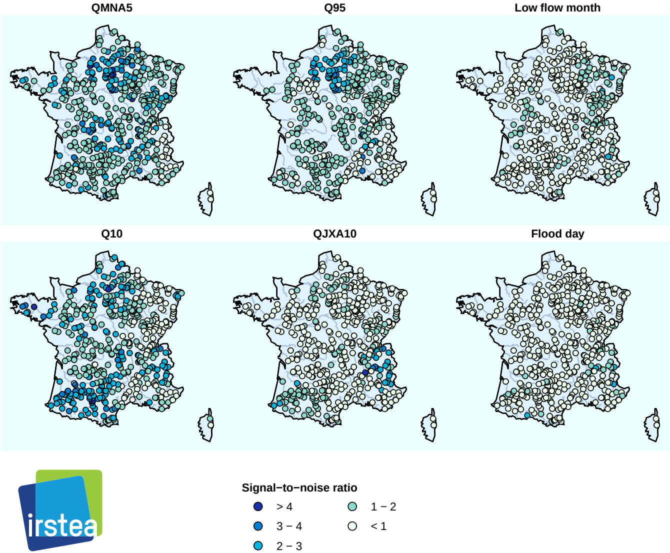
- Positive 15-day lag of low flow month over most of France
- Alpine snowmelt-fed regime evolving towards rainfall-fed regime

High flow indices

- Earlier flood day in the south-eastern part
- Shifts from various seasons

Results

Signal-to-noise ratio $\left|\frac{\mu}{\sigma}\right|$



Low flow indices

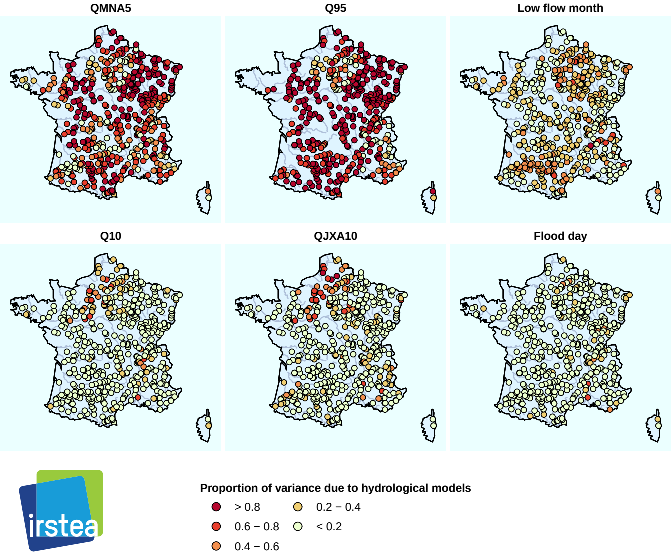
- Consistent changes for QMNA5 (and Q95)
- Highly consistent changes for the aquifer-dominated Seine basin
- Poorly consistent changes in low flow month

High flow indices

- Consistent changes for Q10
- Highly consistent changes for Alpine catchments
- Poorly consistent changes in flood day

Results

Proportion of variance due to hydrological models



Low flow indices

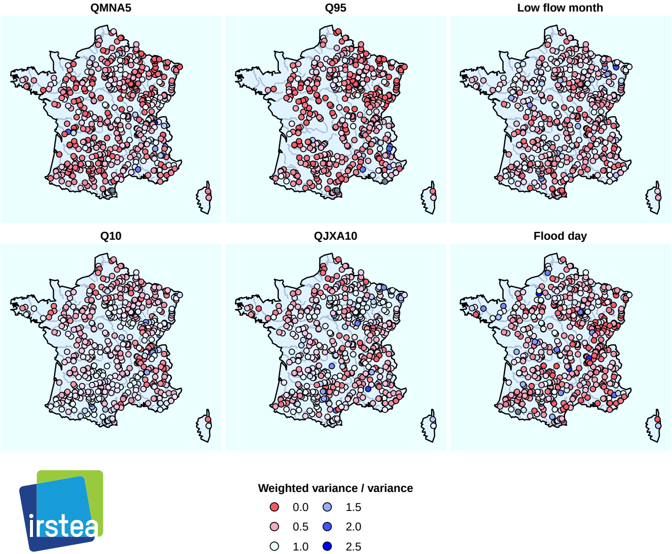
- HM structure = main source for QMNA5 and Q95
- Smaller proportion for Seine basin (and Alpine catchments)
- 50-50 for low flow month

High flow indices

- GCM configuration = main source for Q10 and QJXA10
- Smaller proportion for Seine basin
- GCM configuration = main source for flood day

Results

Ratio of weighted variance to variance



Low flow indices

- Large reduction of variance for QMNA5 and Q95
- Moderate reduction for low flow month
- A few cases of increase

High flow indices

- Small reduction in variance for Q10 and QJXA10
- Moderate reduction for flood day
- A few increases

Conclusions

What are the projected multimodel average changes?

- Dramatic decrease of low flows over France
- Rather small decrease in high flows
- Alpine snowmelt-fed regimes evolving towards rainfall-fed regimes

How consistent are those multimodel changes?

- Consistent changes for low flows, especially for the aquifer-dominated Seine basin
- Generally poorer agreement on high flows, except for Alpine catchments
- Poor agreement on seasonality changes

Conclusions

What is the most prominent type of uncertainty?

- Hydrological models for low flow indices
- Both types equivalent for low flow seasonality
- GCMs for high flow indices (and mean flows, see Christierson et al. (2012))

Is it possible to reduce the uncertainty in changes?

- Yes, in most cases, by conditioning on present-day errors
- Detailed analysis yet to be done to assess most relevant error types
  - Quality of measurements / anthropogenic influences: high and low flow reference networks (Giuntoli et al., 2012a,b)
  - Hydrological modelling errors: different performances between HMs
  - Natural variability between observation and control period
  - Hydrological errors due to biases in downscaled GCM climatology

References

Boé, J., Terray, L., Habets, F., and Martin, E. (2006). A simple statistical-dynamical downscaling scheme based on weather types and conditional resampling. *J. Geophys. Res.*, 111(23):D23106.

Christierson, B. v., Vidal, J.-P., and Wade, S. D. (2012). Using UKCP09 probabilistic climate information for UK water resource planning. *J. Hydrol.*, 424-425:48–67.

Giuntoli, I., Renard, B., and Lang, M. (2012a). Floods in france. In Kundzewicz, Z. W., editor, *Changes in flood risk in Europe*. IAHS Press.

Giuntoli, I., Renard, B., Vidal, J.-P., and Bard, A. (2012b). Low flows in France and their relationship to large scale climate indices. *J. Hydrol., submitted*.

Habets, F., Boone, A., Champeaux, J.-L., Etchevers, P., Franchistéguy, L., Leblois, E., Ledoux, E., Le Moigne, P., Martin, E., Morel, S., Noilhan, J., Quintana Seguí, P., Rousset-Regimbeau, F., and Viennot, P. (2008). The SAFRAN-ISBA-MODCOU hydrometeorological model applied over France. *J. Geophys. Res.*, 113:D06113.

Perrin, C., Michel, C., and Andréassian, V. (2003). Improvement of a parsimonious model for streamflow simulation. *J. Hydrol.*, 279(1-4):275–289.

Vidal, J.-P., Martin, E., Franchistéguy, L., Baillon, M., and Soubeyroux, J.-M. (2010). A 50-year high-resolution atmospheric reanalysis over France with the Safran system. *Int. J. Climatol.*, 30(11):16271644.

von Storch, H. and Zwiers, F. (1999). *Statistical analysis in climate research*. Cambridge University Press, Cambridge.

Thank you for your attention

Contact

Jean-Philippe Vidal

jean-philippe.vidal@irstea.fr

www.irstea.fr/en/vidal