# Global Prevalence of Non-Perennial Rivers and Streams

# Intermittent Rivers and Ephemeral Streams

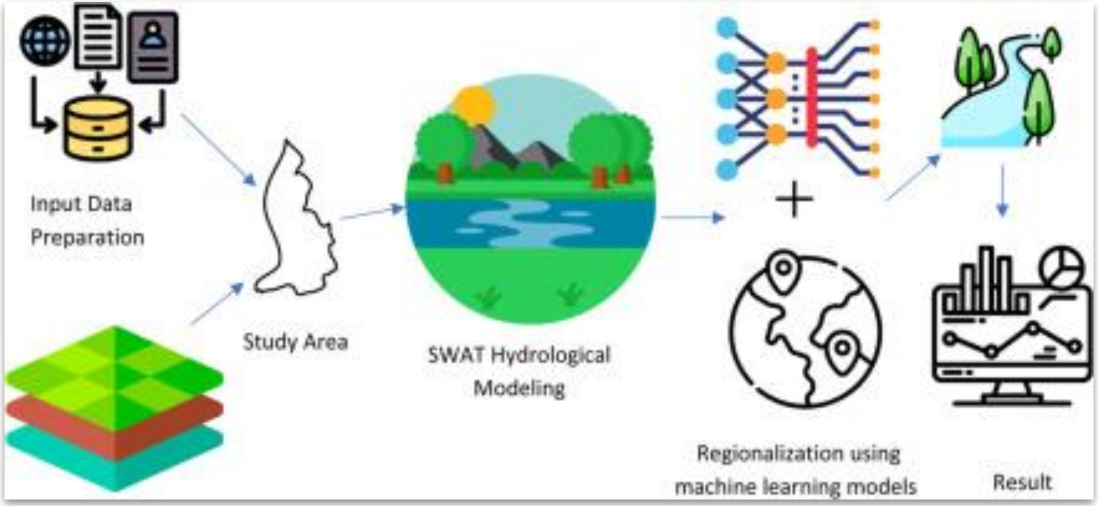
- IRES // non-perennial
- Stop flowing **at least 1 day per year**
- **Crucial role** for biodiversity and important landscape processes

# IRES - Growing Concern

- Many rivers have become intermittent
- Frequently **mismanaged or overlooked**
- No comprehensive global approach to managing IRES
- **First reach-scale model** to estimate distribution of IRES
- Quality-checked streamflow data combined with environmental predictors

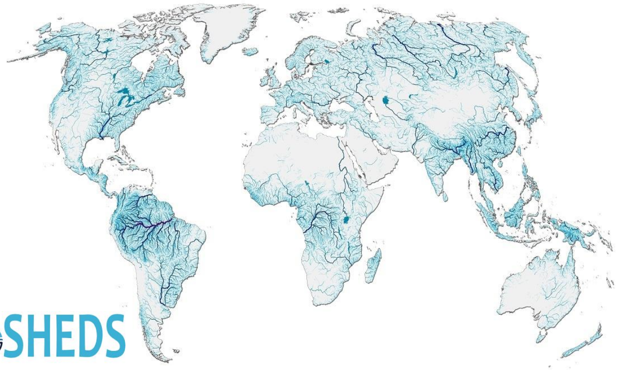
# Methods - Introduction

- **Understanding these rivers is crucial** : they make up a large part of the global river network, impact ecosystems, water availability, and affect human populations.

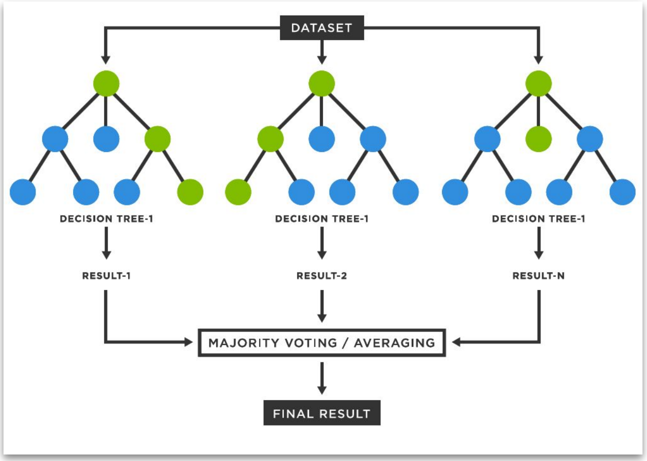


# Methods - Global hydrography & Model Training

- **MAF ≥ 0.1 m³/s** (over 23M km of river network !)
- **Random Forest** (RF) machine learning model (trained with 40 000 monitoring stations !)
- Stations providing **daily, monthly, seasonal, yearly data.**
- Why does this matter ? To **predict** which river will dry up without direct measurements.



HydroSHEDS

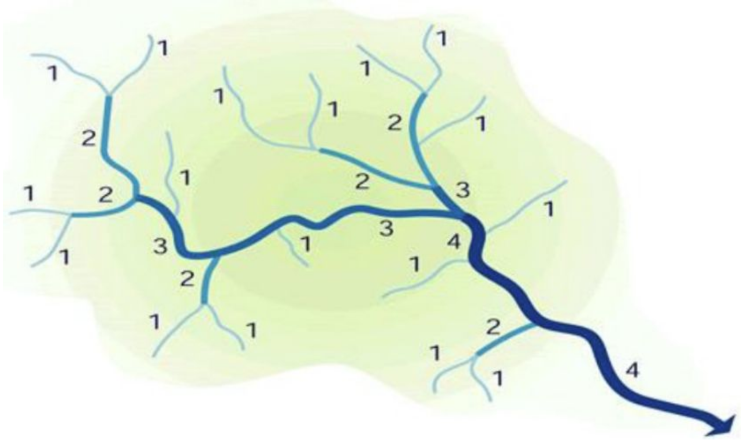


# Methods - Predicting Intermittence with Machine Learning

- **113 hydro-environmental predictor variables** (soil types, temperature, …)

- **Split RF model** applied (more reliable depending on sizing)
  - For **small-to-medium rivers** (MAF < 10 m³/s)
  - For **large rivers** (MAF ≥ 1 m³/s)

- **More accurate predictions** overall.



# Methods - Impacts on Humans & Global Extrapolation

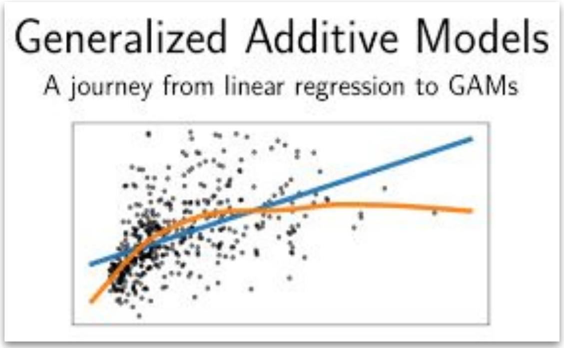
- Using **WorldPop 2020** data

- Data more limited for small rivers.

- Use of a **Generalized Additive Model** (GAM)

  (to extrapolate IRES prevalence down to 0.01 m³/s)

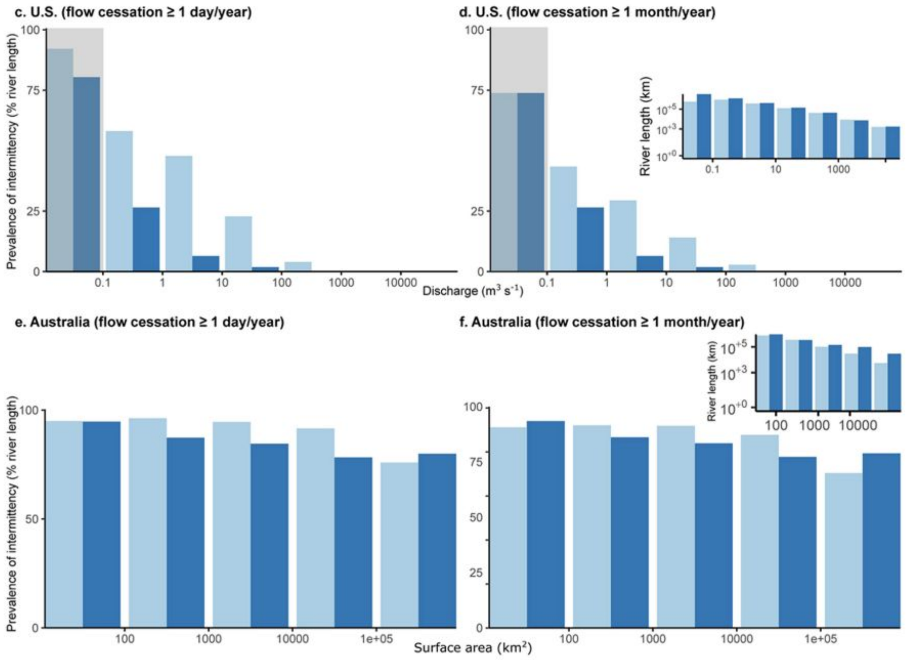
- **51%-60%** of global rivers and streams
  with MAF ≥ 0.01 m³/s are intermittent !

# Methods - Validating the Model

- **Predictions compared** to the US, Australia and Brazil with knowledge of potential discrepancies

- Validation with **on-the-ground observations** from the US Pacific Northwest and France




**Extended Data Fig. 5 | Quantitative comparison between the predicted prevalence of flow intermittence and national estimates. a–f**, Comparisons were conducted for France (**a**, **b**), the USA (**c**, **d**), and Australia (**e**, **f**), on the basis of two thresholds of flow intermittence, either ≥1 zero-flow day per year (**a**, **c**, **e**) or ≥1 zero-flow month (30 days) per year (**b**, **d**, **f**), on average. Bars for mapped rivers and streams with MAF < 0.1 $m^3 s^{-1}$ (for France and the USA) are greyed out as they were not included in the calculation of summary statistics. Inset graphs in **b**, **d**, **f** show comparisons of total river network length (log-transformed *y* axis), which in case of discrepancies can explain some of the differences in the predicted prevalence of intermittence.

# Results

IRES represent:

- 41% of mapped global river network with $MAF>0.1m^3/s$
- 51%-60% when extrapolating to streams with $0.01m^3/s<MAF<0.1m^3/s$

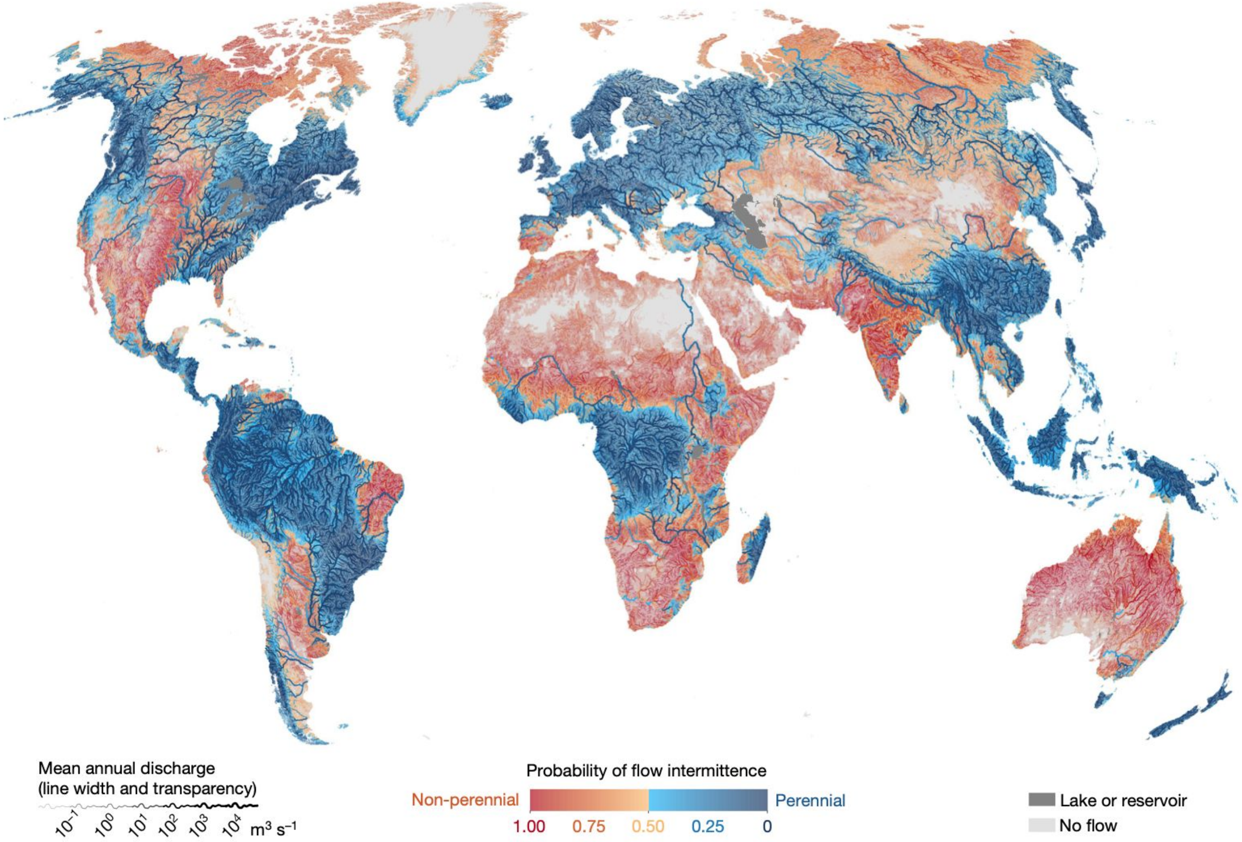



**Fig. 1 | Global distribution of non-perennial rivers and streams.** Intermittence is defined as flow cessation for at least one day per year on average. The median probability threshold of 0.5 was used to determine the binary flow intermittence class for each reach in RiverATLAS[27]. Mapping software: ArcMap (ESRI).

# Results

- River flow tends to become more permanent with **increasing drainage area** and **distance from the headwater** in a basin
- Small headwater streams constitute high proportion of total stream length

For flow to occur : water **inputs > losses**

- Climate conditions influence greatly streams and river flow cessation

## Table 1 | Global prevalence of IRES across climate zones and streamflow size classes

| Climate zone[a] | Prevalence of intermittence (% of network length) by streamflow size class ($m^3 s^{-1}$) | | | | | | | Total intermittence (% length) | Total stream length[b] ($\times 10^3$ km) |
|---|---|---|---|---|---|---|---|---|---|
| | *Extrapolated*[c] | Mapped | | | | | | Including \| (excluding) extrapolated stream class[c] | |
| | *[$10^{-2}$, $10^{-1}$)* | [$10^{-1}$, 1) | [1, 10) | [10, $10^2$) | [$10^2$, $10^3$) | [$10^3$, $10^4$) | ≥$10^4$ | | |
| Extremely hot and arid | *100* | 100 | 100 | 98 | 49 | 0 | – | 99 \| (98) | 1,032 \| (249) |
| Hot and arid | *100* | 100 | 100 | 97 | 46 | 0 | – | 99 \| (98) | 990 \| (238) |
| Arctic 1 | *100* | 92 | 71 | 100 | – | – | – | 96 \| (92) | 11 \| (6) |
| Warm temperate and xeric | *99* | 96 | 89 | 59 | 11 | 0 | 0 | 96 \| (89) | 1,351 \| (444) |
| Extremely cold and wet 2 | *100* | 93 | 69 | 34 | 0 | – | – | 96 \| (87) | 766 \| (243) |
| Extremely hot and xeric | *99* | 90 | 95 | 90 | 45 | 0 | 0 | 95 \| (89) | 4,551 \| (1,605) |
| Arctic 2 | *100* | 89 | 18 | 8 | – | – | – | 92 \| (82) | 98 \| (41) |
| Cool temperate and xeric | *94* | 81 | 70 | 37 | 2 | 0 | – | 87 \| (72) | 1,709 \| (552) |
| Extremely cold and mesic | *96* | 70 | 45 | 34 | 26 | 22 | 0 | 83 \| (61) | 8,083 \| (3,051) |
| Extremely cold and wet 1 | *92* | 59 | 10 | 1 | 0 | – | – | 72 \| (50) | 227 \| (109) |
| Cold and mesic | *90* | 47 | 26 | 6 | 3 | 0 | 0 | 70 \| (37) | 8,189 \| (3,084) |
| Warm temperate and mesic | *84* | 45 | 35 | 16 | 1 | 0 | 0 | 63 \| (39) | 3,582 \| (1,646) |
| Hot and dry | *77* | 47 | 36 | 23 | 7 | 0 | 0 | 62 \| (41) | 4,054 \| (1,683) |
| Cool temperate and dry | *65* | 46 | 34 | 11 | 0 | 0 | 0 | 57 \| (39) | 4,087 \| (1,325) |
| Hot and mesic | *77* | 30 | 24 | 23 | 5 | 0 | 0 | 54 \| (27) | 4,452 \| (2,023) |
| Extremely hot and moist | *35* | 18 | 20 | 21 | 4 | 0 | 0 | 30 \| (18) | 19,117 \| (6,002) |
| Cool temperate and moist | *52* | 18 | 10 | 0 | 0 | 0 | – | 29 \| (13) | 1,164 \| (691) |
| Cold and wet | *34* | 1 | 0 | 0 | 0 | 0 | – | 14 \| (1) | 493 \| (299) |
| **World** | ***70*** | **47** | **35** | **26** | **9** | **1** | **0** | **60 \| (41)** | **63,956 \| (23,291)** |

[a]Global Environmental Stratification (GEnS)[32], see Extended Data Fig. 1a.

[b]Excluding sections of river reaches contained within a lake.

[c]Extrapolated statistics based on the main estimate (as opposed to the lower-bound estimate, see Methods for details).

# Results - two climate extremes

High prevalence of flow intermittence caused by different climate conditions

Extremely hot and dry

- Low precipitation
- High evapotranspiration

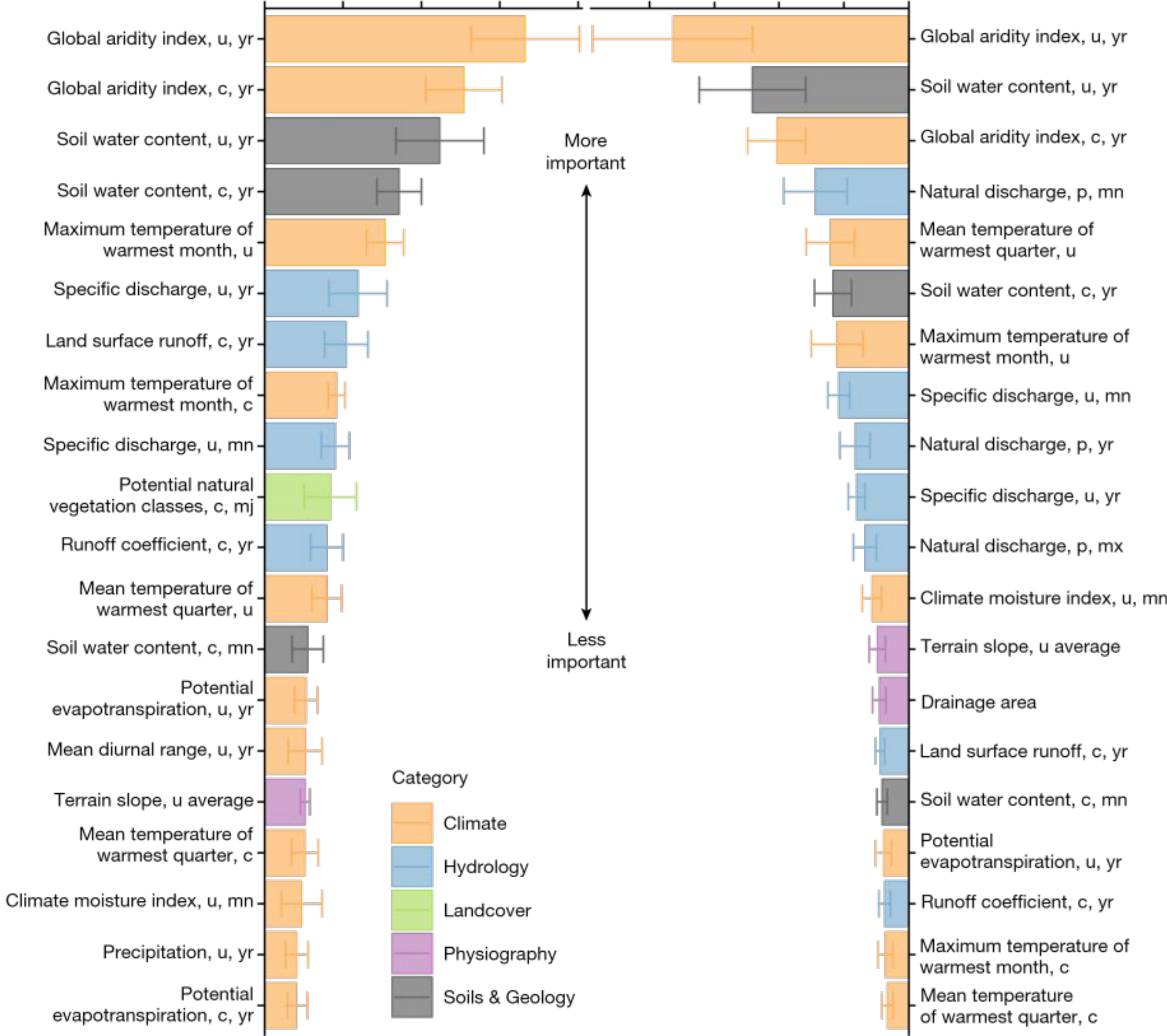
Extremely cold

- Precipitation in snow form
- Streams freezing

# Model performance and uncertainties

- Predictor variables classed
- Importance of aridity and soil water content

p : point
c : local catchment
u : upstream



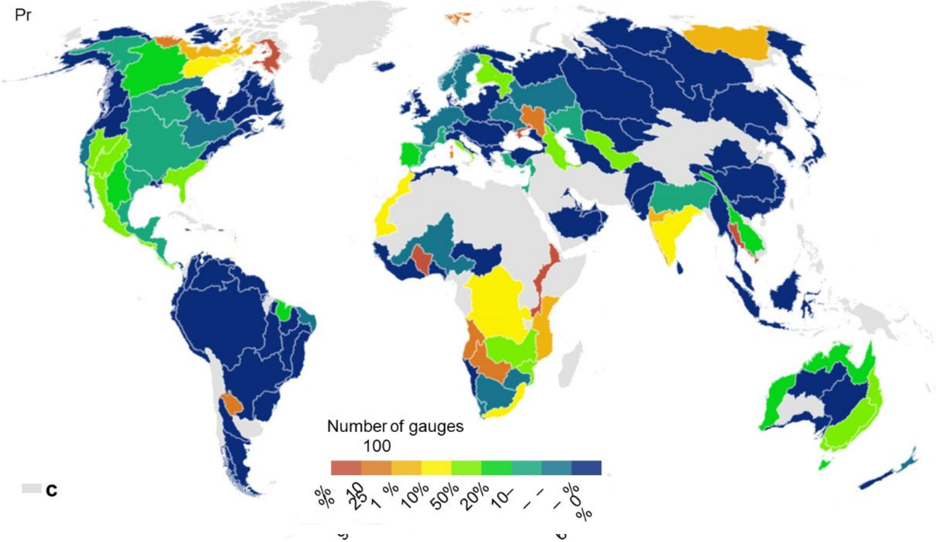
# Model performance and uncertainties

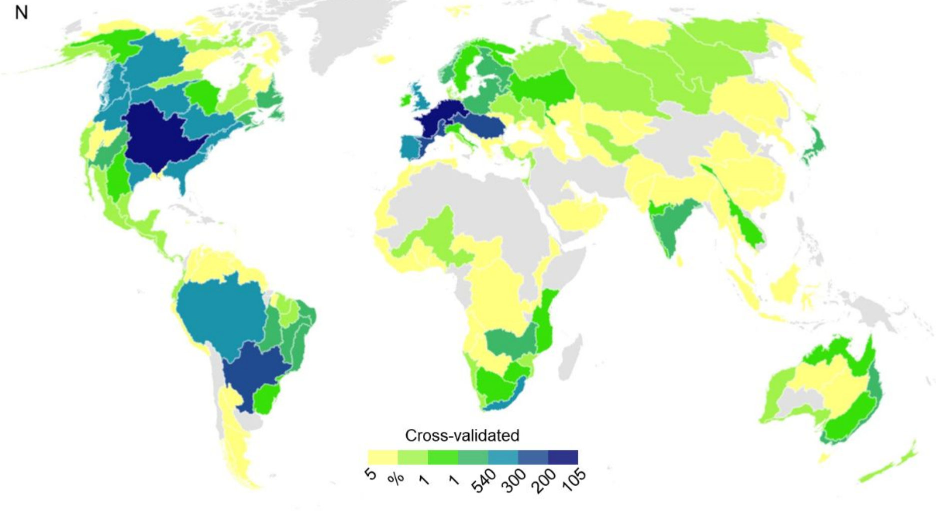
Cross validation

- Overall 90-92% accuracy
  → predictions unbiased globally

Issues raised by cross-validation

- Less represented catchments
- Boundaries

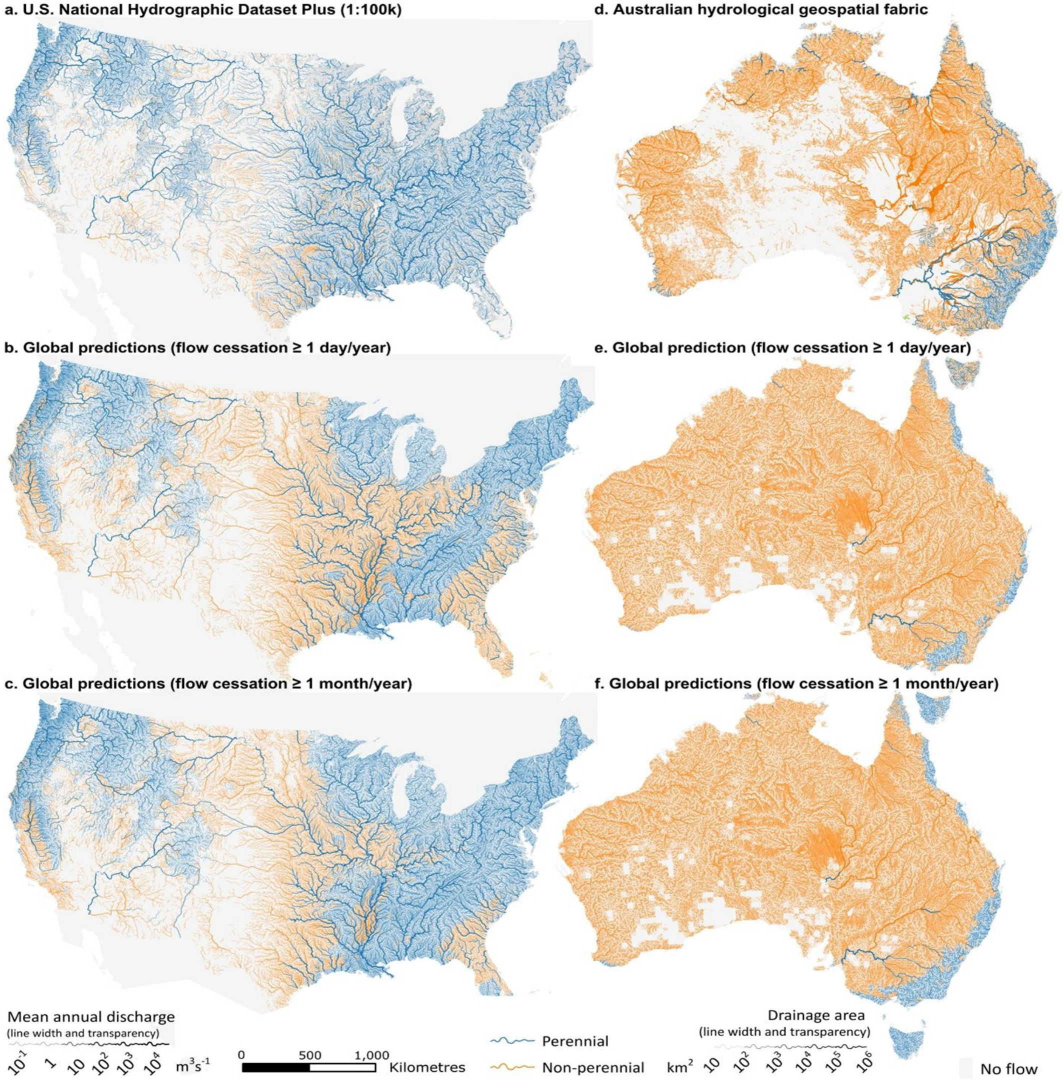


# Model performance and uncertainties

Comparison vs. national maps

- Not considered as accuracy
- Good results on most national maps
- Problem of US (36%) and Australia
  → Difference of definition

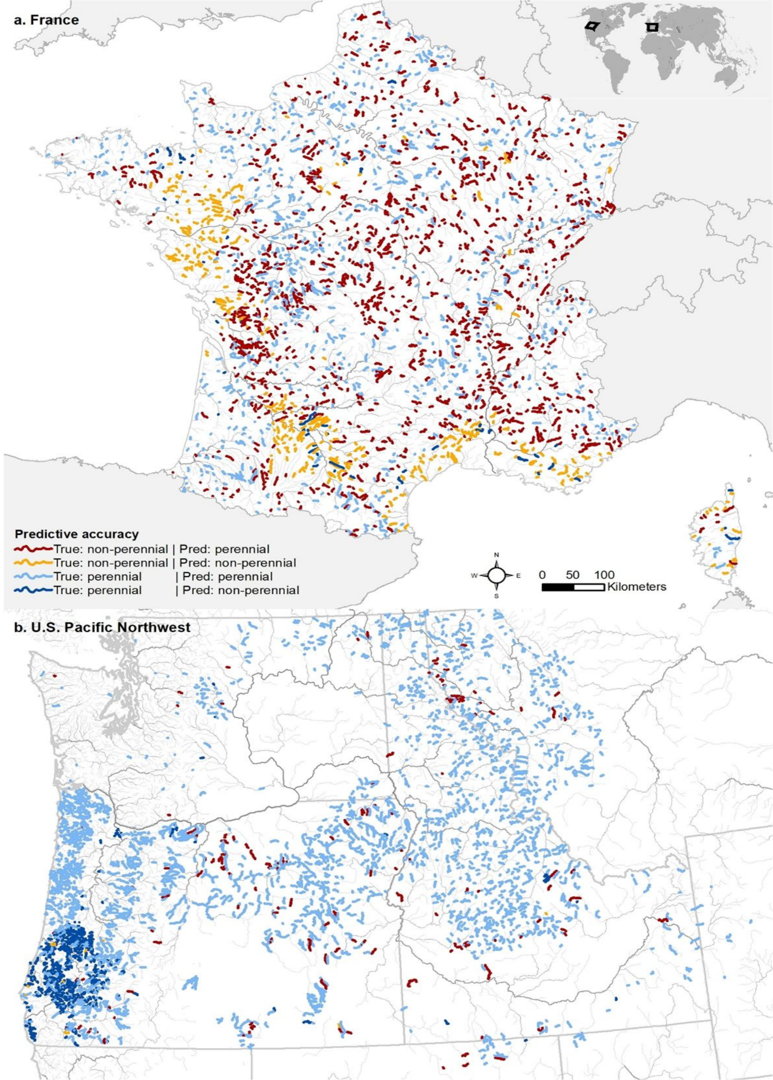


# Model performance and uncertainties

Comparison vs. national observation datasets

- Difficulty for small streams (0.5 m³/s)
- France underestimated
- US overestimated

- Hard to disentangle human effects
- Lack of precise data
  → Caution advised for small streams



# Conclusion

While current models define hydrological connectivity as either free-flowing or fragmented by barriers, this paper demonstrates that temporary fragmentation due to climate conditions is far more common than previously recognized.

Areas for future research :

- Spiritual and societal values[3]
- Ecosystem services[1]
- Anthropic impact[2]
- Evolution of these results in 50 years
- Groundwater recharge[1]

# References


[1] Shanafield, M., Bourke, S. A., Zimmer, M. A., & Costigan, K. H. (2021). An overview of the hydrology of non-perennial rivers and streams. *Wiley Interdisciplinary Reviews: Water*, *8*(2), e1504.

[2] Falasco, E., Bona, F., Risso, A. M., & Piano, E. (2021). Hydrological intermittency drives diversity decline and functional homogenization in benthic diatom communities. *Science of the Total Environment*, *762*, 143090.

[3] Kurniawan, W., & Hidayati, T. (2021). River, Modernity, and Everyday Religion: An investigation on the New Spiritual Engagement between Society and River. *International Journal of Educational Research & Social Sciences*, *2*(6), 1632-1639.