

# Hydrological modelling with R packages

Guillaume Thirel  
*INRAE, HYCAR Research Unit, France*

🏠 <https://webgr.inrae.fr>

🐦 @G\_Thirel



# Context

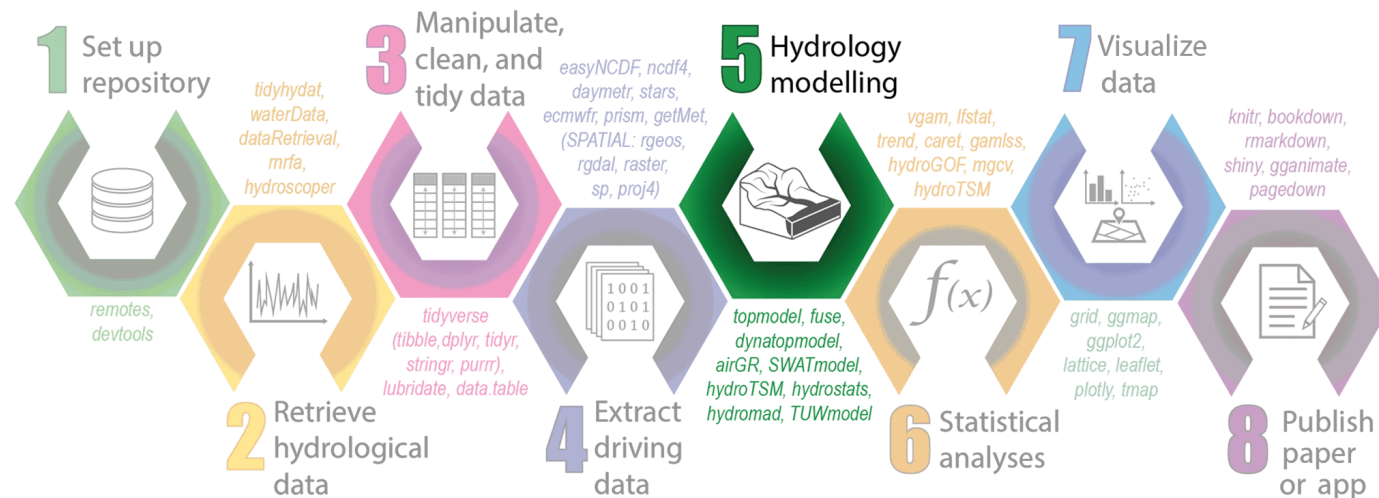
Thousands of R packages exist.

Slater et al. (2019):

- an overview of interesting packages in the hydrological workflow
- but there was no space for going into much details

We focus here on hydrological modelling

It is a primordial step in the hydrological workflow



# Rationale of this work

Hundreds of hydrological models exist, some are available in R

From the user point of view, there is a need for guidance in choosing a package:

- hydrological models fit different purposes
- packages present different functionalities
- uneven quality of documentation

In this work, we focused on:

- the differences between models
- the necessary model inputs
- the documentation
- the implementation

And we propose simple R codes to run these packages

# Aims of this presentation

To give an overview of:

- 8 available hydrological modelling R packages
- available hydrological models in these R packages

## What you will not get from this presentation but only from reading the paper

- how to run each package/model  
(see the supplementary material of the paper)
- an in-depth explanation of all hydrological models

# Collaborative international work led by Paul C. Astagneau

<https://doi.org/10.5194/hess-2020-498>

© Author(s) 2020. This work is distributed under the Creative Commons Attribution 4.0 License.



Abstract

Assets

Discussion

Metrics

17 Oct 2020

**Review status:** a revised version of this preprint is currently under review for the journal HESS.

## Hydrology modelling R packages: a unified analysis of models and practicalities from a user perspective

Paul C. Astagneau<sup>1,2</sup>, Guillaume Thirel<sup>1</sup>, Olivier Delaigue<sup>1</sup>, Joseph H. A. Guillaume<sup>3</sup>, Juraj Parajka<sup>4</sup>,  
Claudia C. Brauer<sup>5</sup>, Alberto Viglione<sup>6</sup>, Wouter Buytaert<sup>7</sup>, and Keith J. Beven<sup>8</sup>

<sup>1</sup> Université Paris-Saclay, INRAE, HYCAR Research Unit, Antony, France

<sup>2</sup> Sorbonne Université, Paris, France

<sup>3</sup> Institute for Water Futures and Fenner School of Environment & Society, Australian National University, Canberra, Australia

<sup>4</sup> Institute of Hydraulic and Water Resources Engineering, TU Vienna, Vienna, Austria

<sup>5</sup> Hydrology and Quantitative Water Management Group, Wageningen University and Research, Wageningen, The Netherlands

<sup>6</sup> Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Turin, Italy









<sup>7</sup> Department of Civil and Environmental Engineering, Imperial College London, London, UK

<sup>8</sup> Lancaster Environment Centre, Lancaster University, Lancaster, UK

Received: 25 Sep 2020 – Accepted for review: 15 Oct 2020 – Discussion started: 17 Oct 2020

**Abstract.** Following the rise of R as a scientific programming language, the increasing requirement for more transferable research, and the growth of data availability in hydrology, R packages containing hydrological models are becoming more and more available to hydrologists. Corresponding to the core of the hydrological studies workflow, their value is increasingly meaningful regarding the reliability of methods and results. Despite package and model distinctiveness, no study has ever provided a comparison of R packages for conceptual rainfall-runoff modelling from a user perspective, contrasting their philosophy, model

# List of packages selected and the models they propose

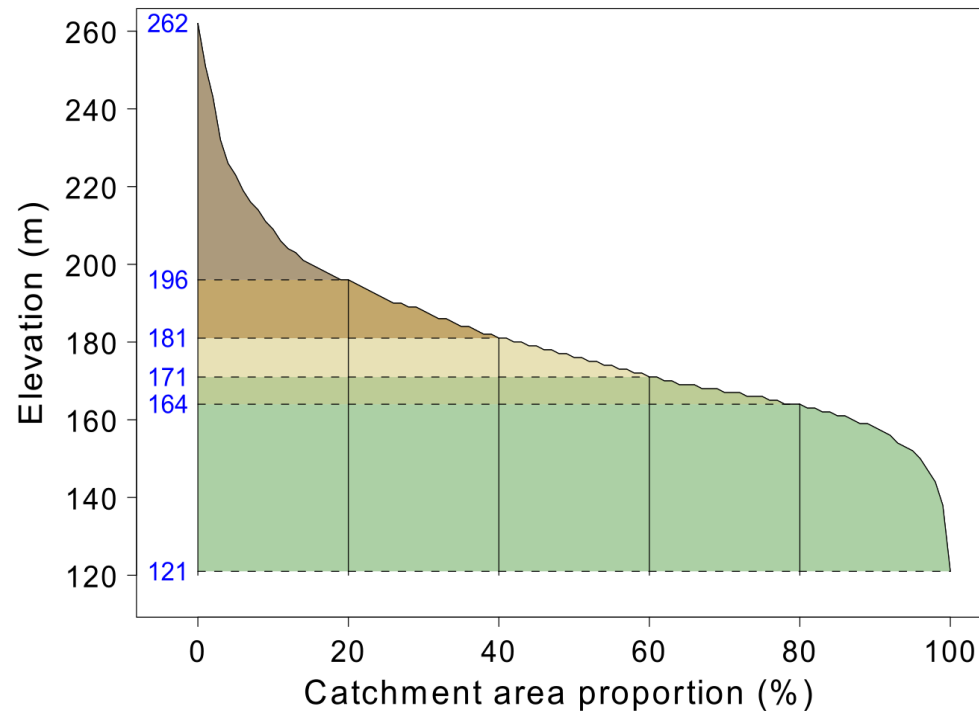
Package	Repository	Hydrological models	Snow model
airGR		GR models	✓
dynatopmodel		Dynamic TOPMODEL	
HBV.IANIGLA		HBV	✓
hydromad		IHACRES AWBM GR4J Sacramento	✓
sacsmaR		Sacramento	✓
topmodel		TOPMODEL 1995	
TUWmodel		Modified HBV	✓
WALRUS		WALRUS	✓

# Analysis from a modeller perspective

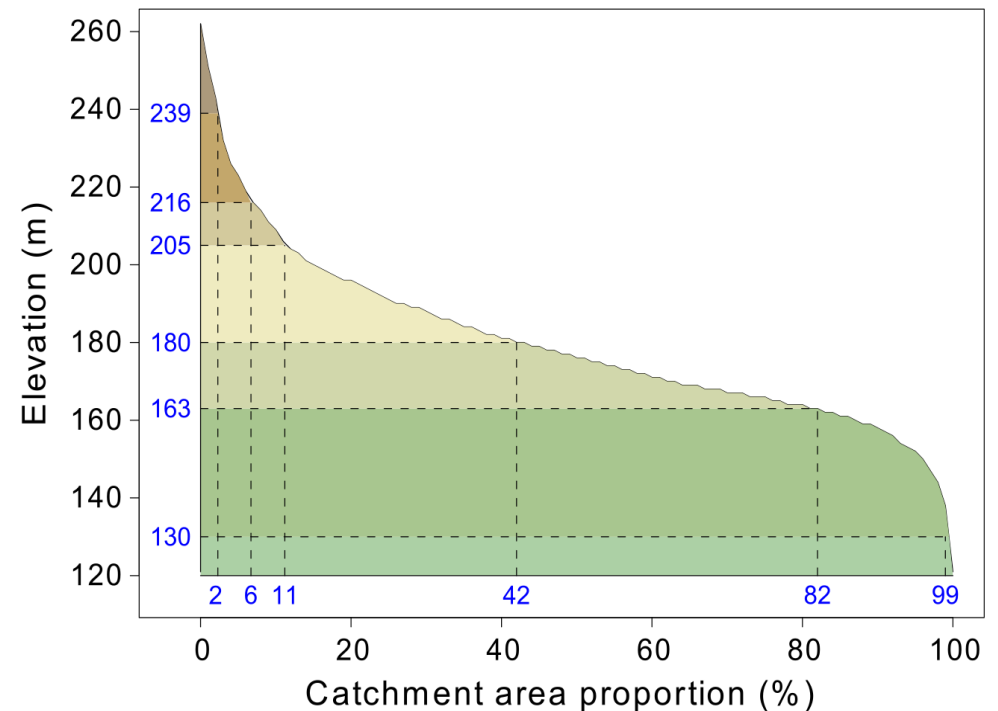
# Differences in spatial resolution

The snow models

GR4J-CemaNeige



TUWmodel and SNOW-17



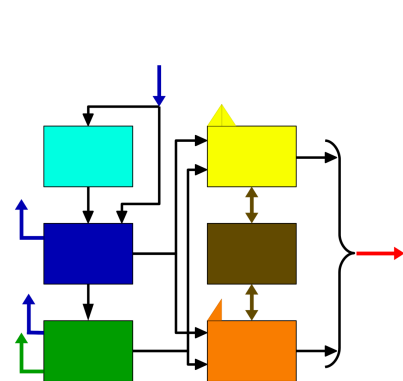


# Differences in spatial resolution

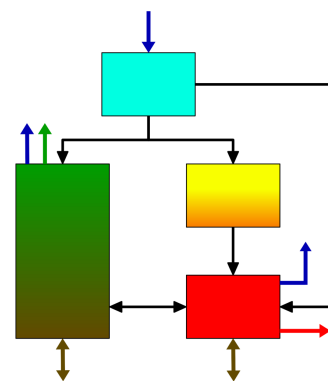
The hydrological models

Package	Model	Lumped	HRUs	Sub-catchments	Routing between HRUs and/or subcatchments
airGR	GR4J	✓		✓	
dynatopmodel	TOPMODEL (dynamic)		✓		✓
HBV.IANIGLA	HBV	✓			
hydromad	GR4J	✓			
hydromad	IHACRES-CMD	✓			
hydromad	Sacramento	✓			
sacsmar	Sacramento	✓	✓	✓	✓
topmodel	TOPMODEL (1995)	~	~		✓
TUWmodel	Modified HBV	✓	~	~	✓
WALRUS	WALRUS	✓			

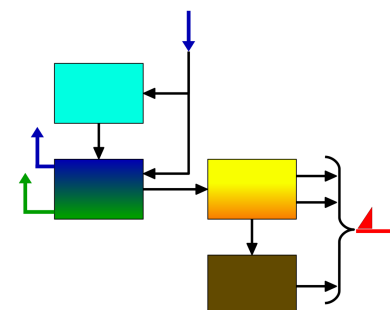
# Unified diagrams of models



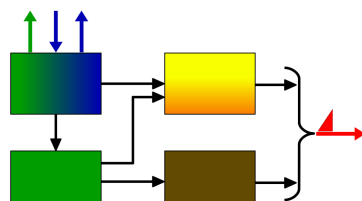
GR4J of `airGR` and `hydromad`. The snow box is only for CemaNeige of `airGR`. Modified from de Boer-Euser et al. (2017).



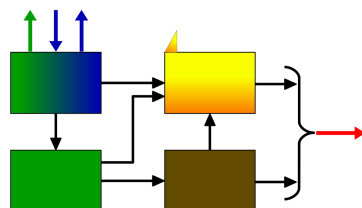
Model of WALRUS, modified from de Boer-Euser et al. (2017).



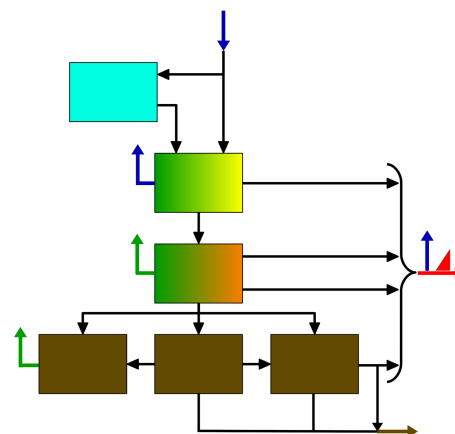
HBV of `TUWmodel` and `HBV.IANIGLA`.



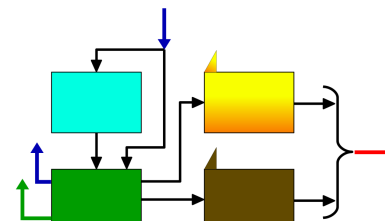
TOPMODEL 1995 of `topmodel`.



Dynamic TOPMODEL of `dynatopmodel`.



Sacramento of `sacsmar` and `hydromad`. The snow box is only for `sacsmar`.



IHACRES-CMD of `hvdromad`.

- Snow
- Interception
- Root zone storage
- Very quick runoff
- Fast runoff
- Groundwater
- Surface water
- ▲ Lag function
- ↔ Losses or gains
- ↓ In: precipitation
- ↑ Out: evaporation
- ↑ Transpiration
- Generated discharge
- Internal fluxes

# Analysis from a package user perspective

# Models inputs

Package	Model(s)	Time step(s)	Inputs (TS)	Inputs (static)	Nb. of param.
airGR	GR models	H D M A	P PET		[1 ; 6]
dynatopmodel	Dynamic TOPMODEL	Flex.	P PET	DEM	8
HBV.IANIGLA	HBV	Flex.	P PET		[7 ; 9]
hydromad	GR4J	D	P PET		4
	IHACRES-CMD	Flex.	P PET		6
	Sacramento	$\geq$ H	P PET		13
sacsmar	Sacramento	D	P PET	SA	13
topmodel	TOPMODEL 1995	Flex.	P PET	DEM	10
TUWmodel	Modified HBV	$\leq$ D	P PET	SA	10
WALRUS	WALRUS	Flex.	P PET	soil type	3

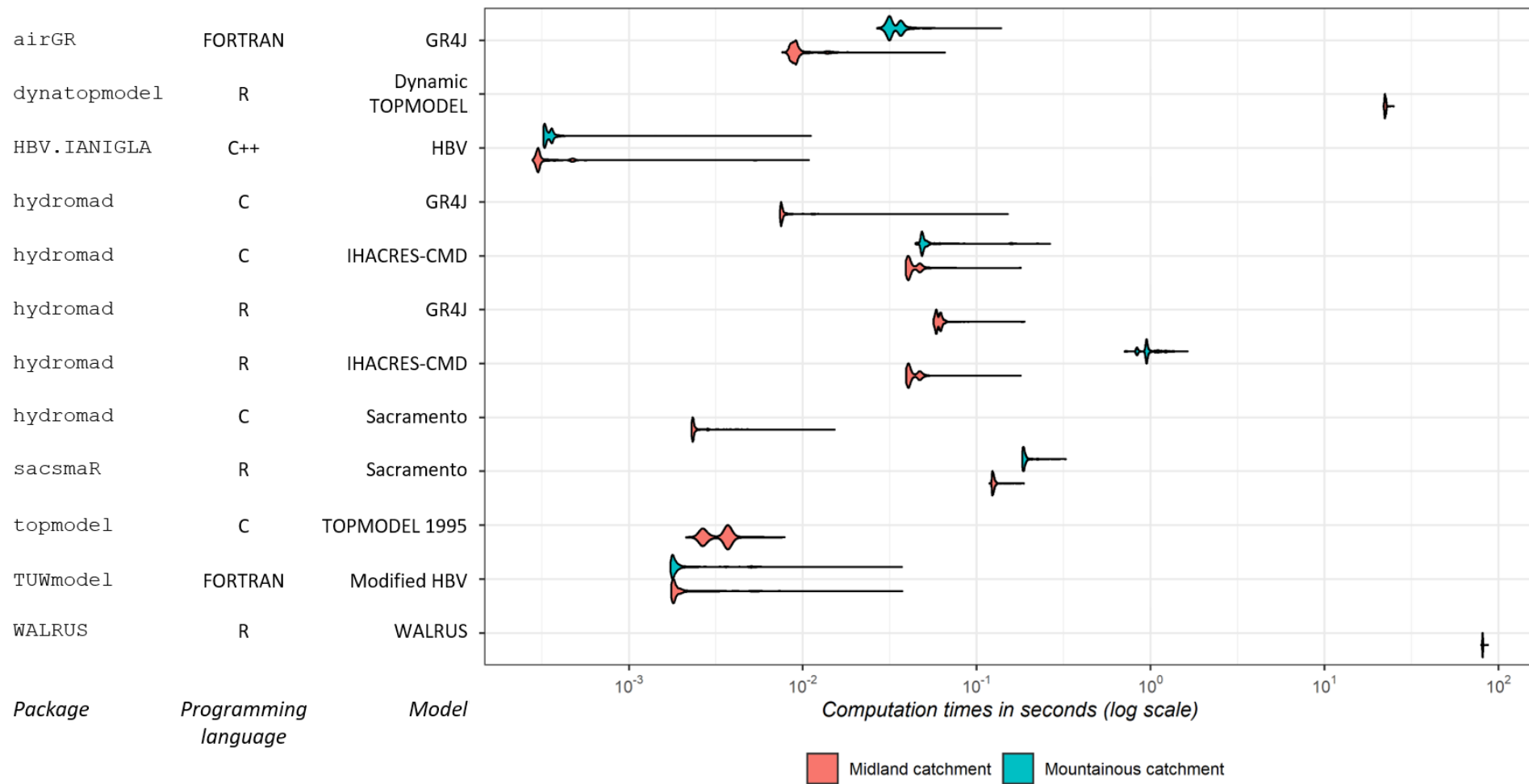
# Models outputs

Package	Model(s)	TS of AET and TS of RC	TS of internal fluxes	TS of store levels	Spatially distributed
airGR	GR models	✓	✓	✓	
dynatopmodel	Dynamic TOPMODEL	✓	~	✓	✓
HBV.IANIGLA	HBV	✓	~	✓	
hydromad	GR4J	✓	~	✓	
	IHACRES-CMD	✓	~	✓	
	Sacramento	✓		✓	
sacsmar	Sacramento				
topmodel	TOPMODEL 1995	✓	~		✓
TUWmodel	Modified HBV	✓	~	✓	✓
WALRUS	WALRUS	✓	✓	✓	

# Package functionalities

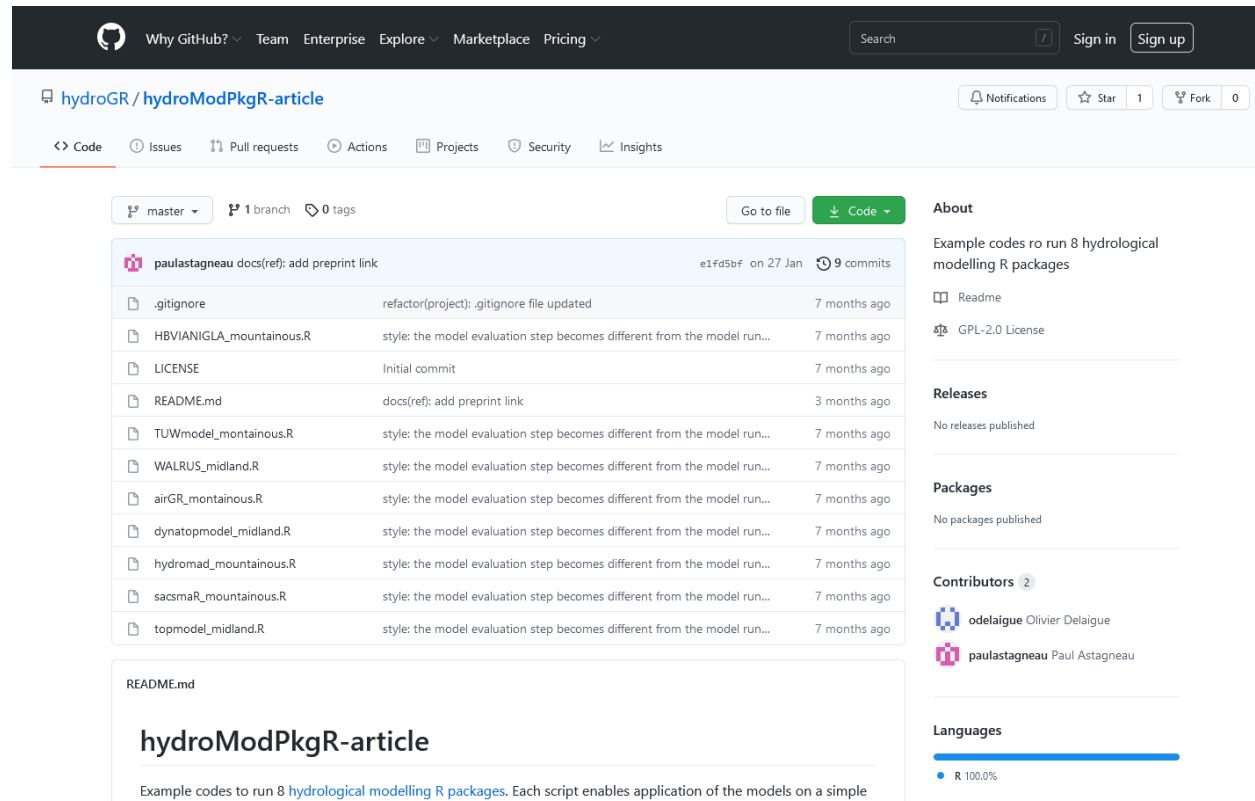
Package	Data preprocessing function	Criteria	Data transfo.	Automatic calibration	Plot function	Graphical user interface	Independent snow function
airGR	✓	✓	✓	✓	✓	✓	✓
dynatopmodel	✓	✓			✓		
HBV.IANIGLA	✓						✓
hydromad	✓	✓	✓	✓	✓		
sacsmaR							✓
topmodel	✓	✓					
TUWmodel		~		~		✓	
WALRUS	✓	✓	✓	~	✓	≈	✓

# CPU times



# Running the hydrological models

Example codes are provided at <https://doi.org/10.15454/3PPKCL>



The screenshot displays the GitHub interface for the repository `hydroGR/hydroModPkgR-article`. The repository is owned by `hydroGR` and has 1 star and 0 forks. The main branch is `master` with 1 branch and 0 tags. The repository contains 9 commits and 10 files. The files listed are:

File	Description	Time
<code>.gitignore</code>	refactor(project): .gitignore file updated	7 months ago
<code>HBVIANIGLA_mountainous.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>LICENSE</code>	Initial commit	7 months ago
<code>README.md</code>	docs(ref): add preprint link	3 months ago
<code>TUWmodel_mountainous.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>WALRUS_midland.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>airGR_mountainous.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>dynatopmodel_midland.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>hydromad_mountainous.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>sacsmar_mountainous.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago
<code>topmodel_midland.R</code>	style: the model evaluation step becomes different from the model run...	7 months ago

The README.md file is titled `hydroModPkgR-article` and contains the text: "Example codes to run 8 hydrological modelling R packages. Each script enables application of the models on a simple".

The repository also includes a sidebar with the following sections:

- About**: Example codes to run 8 hydrological modelling R packages.
- Readme**: Link to the README file.
- Releases**: No releases published.
- Packages**: No packages published.
- Contributors**: 2 contributors: `odelaigue` (Olivier Delaigue) and `paulastagneau` (Paul Astagneau).
- Languages**: R 100.0%.