Hydrological modelling with R packages

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Context

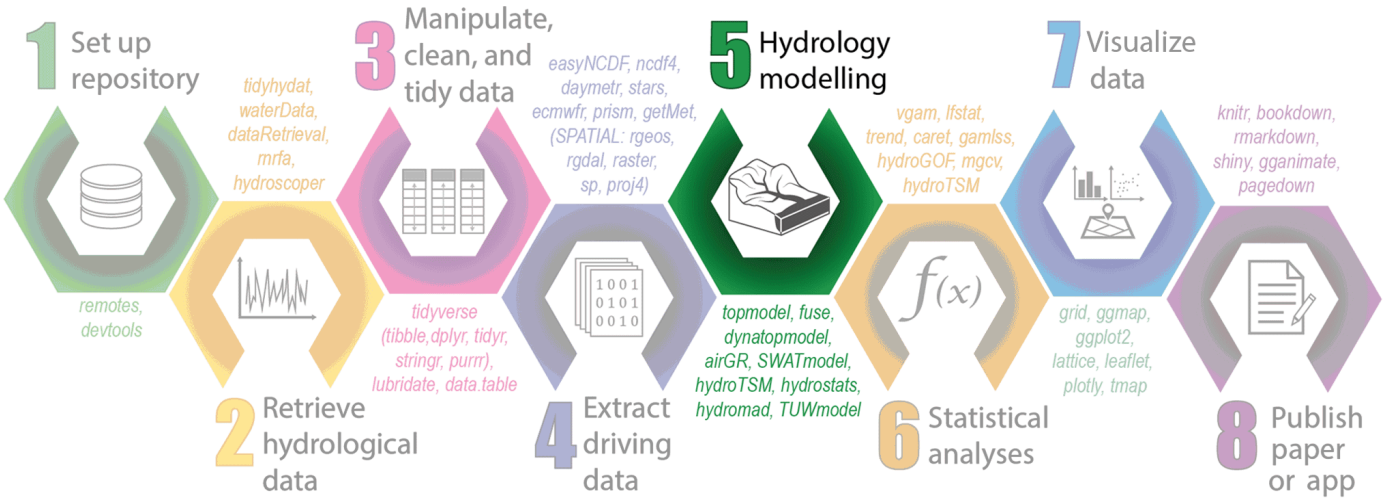
Thousands of R packages exist.

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

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

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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

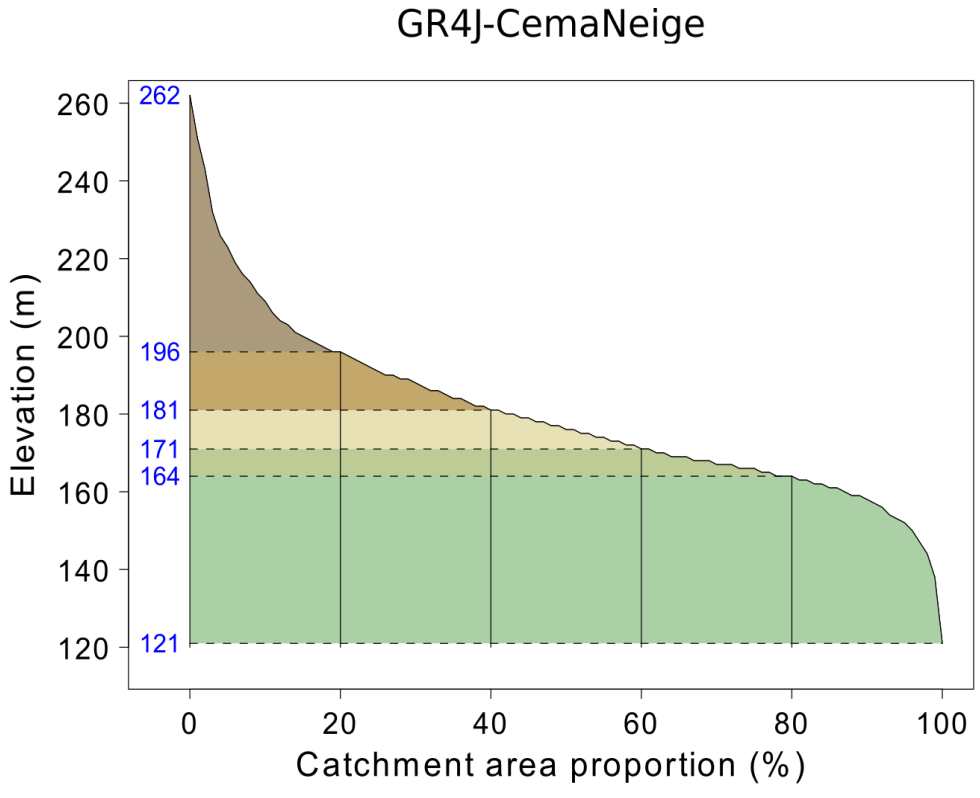
List of packages selected and the models they propose

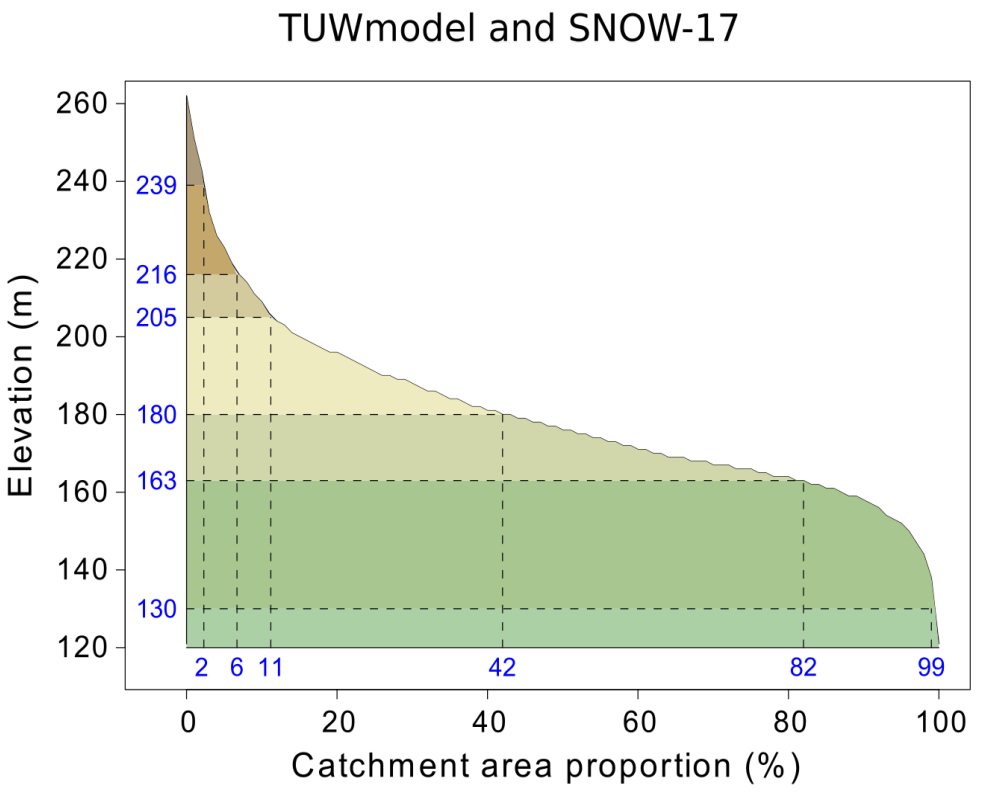
Package	Repository	Hydrological models	Snow model
airGR		GR models	✓
dynatopmodel		Dynamic TOPMODEL	
HBV.IANIGLA		HBV	✓
hydromad		IHACRES AWBM GR4J Sacramento	✓
sacsmaR		Sacramento	✓
topmodel		TOPMODEL 1995	
TUWmodel		Modified HBV	✓
WALRUS		WALRUS	✓

Analysis from a modeller perspective

Differences in spatial resolution

The snow models



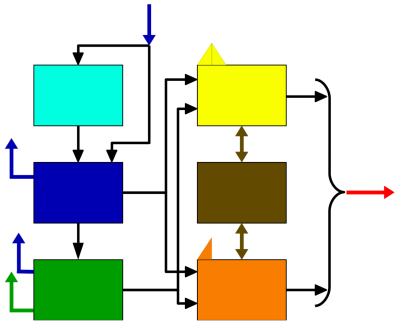


Differences in spatial resolution

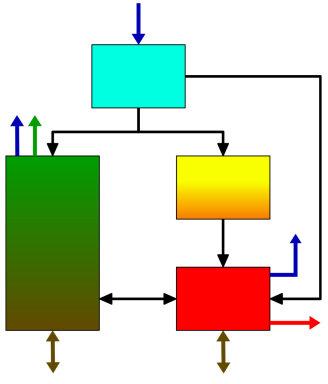
The hydrological models

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	✓			

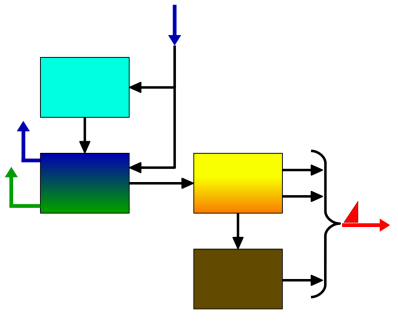
Unified diagrams of models



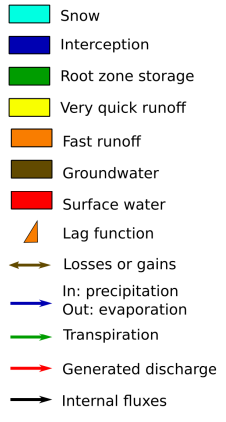
GR4J of `airGR` and `hydromad`. The snow box is only for CemaNeige of `airGR`. Modified from de Boer-Euser et al. (2017).

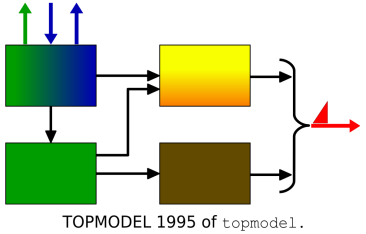


Model of `WALRUS`, modified from de Boer-Euser et al. (2017).

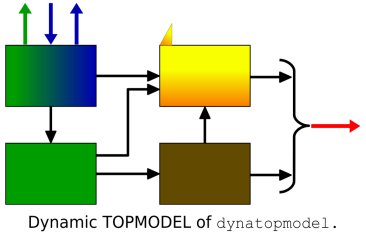


HBV of `TUWmodel` and `HBV.IANIGLA`.

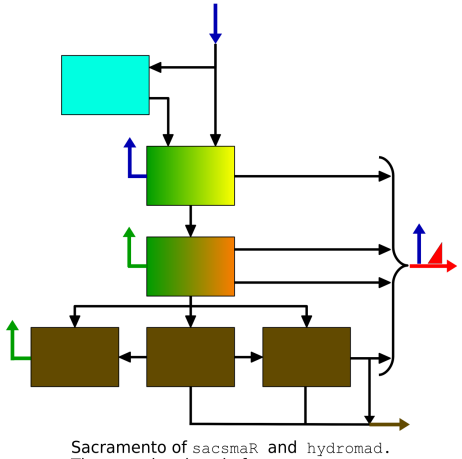




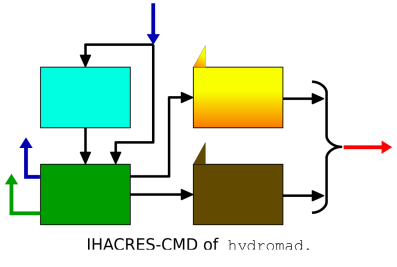
TOPMODEL 1995 of `topmodel`.



Dynamic TOPMODEL of `dynatopmodel`.



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



IHACRES-CMD of `hydromad`.

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

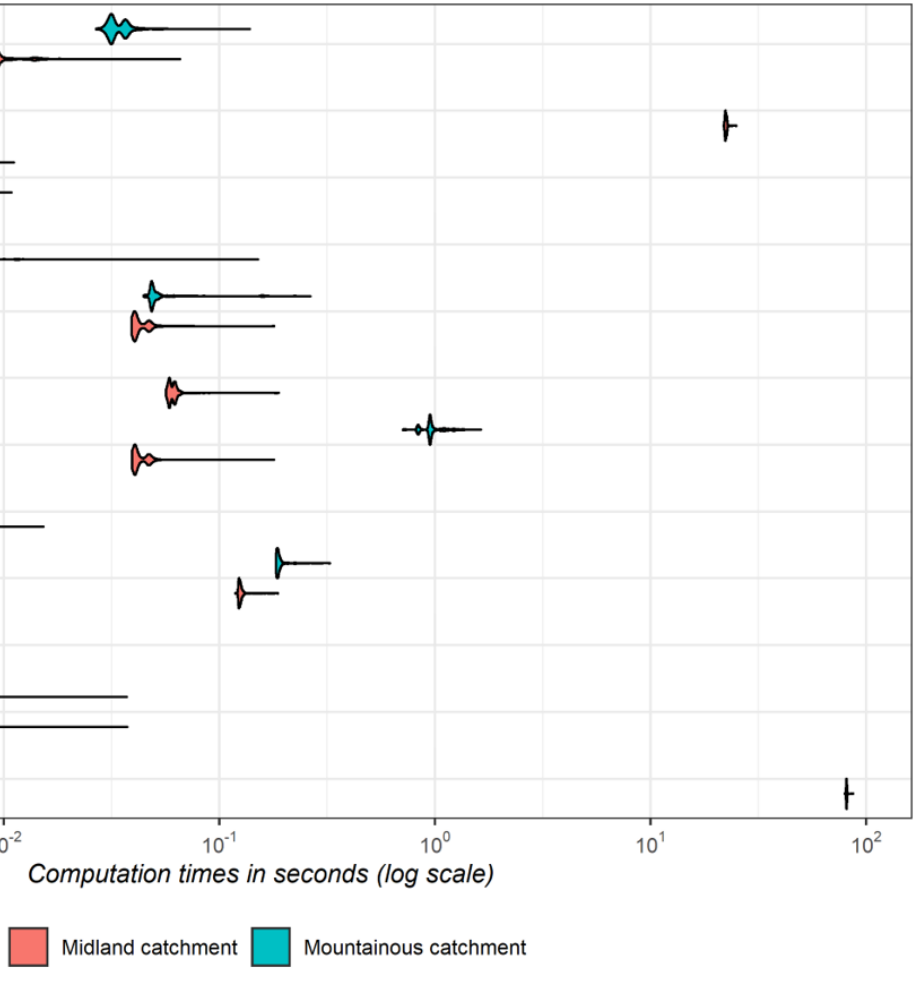
Package	Model(s)	TS of AET and TS of RC	TS of internal fluxes	TS of store levels	Spatially distributed
airGR	GR models	✓	✓	✓	
dynatopmodel	Dynamic TOPMODEL	✓	~	✓	✓
HBV.IANIGLA	HBV	✓	~	✓	
hydromad	GR4J	✓	~	✓	
	IHACRES-CMD	✓	~	✓	
	Sacramento	✓		✓	
sacsmaR	Sacramento				
topmodel	TOPMODEL 1995	✓	~		✓
TUWmodel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

Package	*Programming language*	*Model*
airGR	FORTRAN	GR4J
dynatopmodel	R	Dynamic TOPMODEL
HBV.IANIGLA	C++	HBV
hydromad	C	GR4J
hydromad	C	IHACRES-CMD
hydromad	R	GR4J
hydromad	R	IHACRES-CMD
hydromad	C	Sacramento
sacsmaR	R	Sacramento
topmodel	C	TOPMODEL 1995
TUWmodel	FORTRAN	Modified HBV
WALRUS	R	WALRUS



Running the hydrological models

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