

New airGR developments semi-distribution and data assimilation

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Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package
- 5 The new airGRiwrn package
- 6 Go further
- 7 References

Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package
- 5 The new airGRiwrn package
- 6 Go further
- 7 References

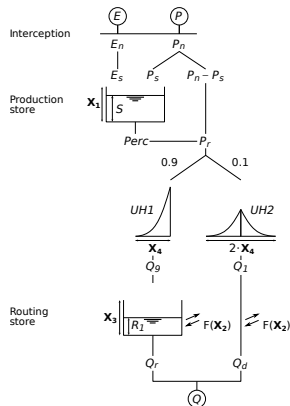
The GR rainfall-runoff models

Overview

GR models is a family of lumped hydrological models designed for streamflow simulation at various time steps applied in numerous countries and for diverse applications

The models are freely available in an **R-package** called **airGR** (Coron *et al.*, 2017, 2021)

The models can easily be implemented on a set of catchments with limited data requirements



GR4J model diagram

The airGR constellation

An ensemble of **R**-packages and **graphical user interfaces** for running GR rainfall-runoff models

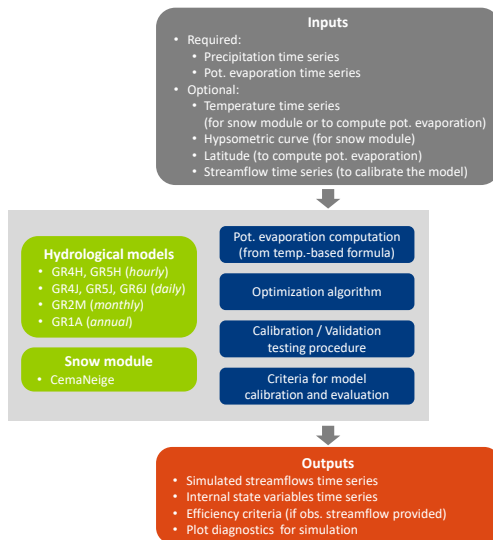


The GUIs are available on sunshine.irstea.fr

Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package
- 5 The new airGRiwrn package
- 6 Go further
- 7 References

Main components of the airGR package



New features since EGU-2020

airGR

- Semi-distributed GR hydrological modelling
 - ▶ the `RunModel()` function now allows to run semi-distribution
 - ▶ new `RunModel_Lag()` function to perform a single run for the Lag model
 - ▶ new vignette to explain how to manage with semi-distribution
- New version of the `SeriesAggreg()` time series aggregation function
 - ▶ can compute: regimes, quantiles, mean, sum, min, max
 - ▶ can be applied on: `data.frame`, `list` and outputs of `CreateInputsModel()` and `RunModel*()`
- Multi-objective calibration
 - ▶ explanation added in the *Plugging in new calibration algorithms* vignette

airGRteaching

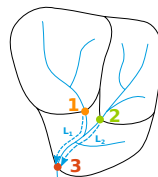
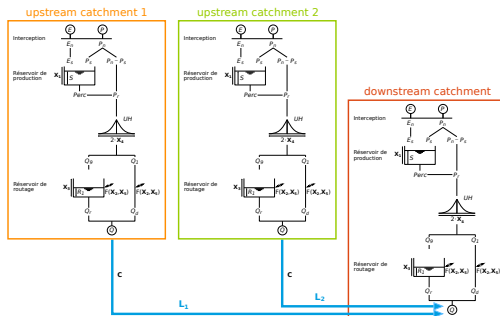
- The GUI launched by the `ShinyGR()` function can now run the monthly GR2M model (in addition to all daily models)

Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR**
- 4 The new airGRdatassim package
- 5 The new airGRiwrm package
- 6 Go further
- 7 References

Towards semi-distributed hydrological modelling

Sub-catchments are simulated from upstream to downstream



Running semi-distribution with airGR

Data preparation completed with upstream information

```
# Qupstream: upstream observed discharges
# LengthHydro: distance between upstream catchment outlets & the downstream one [km]
# BasinAreas: upstream and downstream areas [km²]
InputsModelDown <- CreateInputsModel(FUN_MOD = RunModel_GR4J, DatesR = BasinObs$DatesR,
                                      Precip = BasinObs$P, PotEvap = BasinObs$E,
                                      Qupstream = QObs[, c("Up1", "Up2")],
                                      LengthHydro = c(85, 52)
                                      BasinAreas = c(1450, 427, 870))
```

Calibration using the combination of Lag model for upstream discharges transfer and GR4J model for the discharges of the downstream subcatchment

```
CalibOptionsDown <- CreateCalibOptions(FUN_MOD = RunModel_GR4J,
                                       FUN_CALIB = Calibration_Michel,
                                       IsSD = TRUE) # specify that it's a SD model

OutputsCalibDown <- Calibration_Michel(InputsModel = InputsModelDown,
                                       RunOptions = RunOptionsDown,
                                       InputsCrit = InputsCritDown,
                                       CalibOptions = CalibOptionsDown,
                                       FUN_MOD = RunModel_GR4J)
```

Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package**
- 5 The new airGRiwrn package
- 6 Go further
- 7 References

Performing data assimilation of streamflow with the GR models

Reference

- **Piazzì, G., Thirel, G., Perrin, C. & Delaigue, O. (2021).** Sequential data assimilation for streamflow forecasting: assessing the sensitivity to uncertainties and to updated variables of a conceptual hydrological model at basin scale. *Water Resources Research*, 57, doi: 10.1029/2020WR028390.



Water Resources Research

RESEARCH ARTICLE

10.1029/2020WR028390

Key Points:

- Estimation of forecast initial level of the routing store of a conceptual hydrological model ensures the most benefit from data assimilation
- Updating forecast initial conditions using the ensemble Kalman filter results in a greater improvement in predictive accuracy in the short term
- The particle filter guarantees a longer-lasting effect of the update of initial conditions over the forecast horizon

Supporting Information:

Supporting Information may be found in the online version of this article.

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Sequential Data Assimilation for Streamflow Forecasting: Assessing the Sensitivity to Uncertainties and Updated Variables of a Conceptual Hydrological Model at Basin Scale

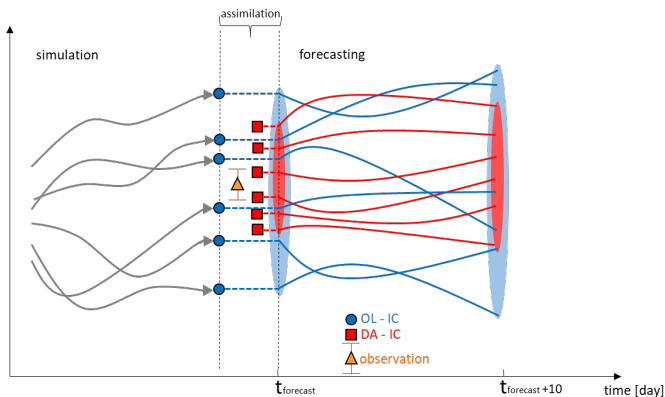
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Abstract Skillful streamflow forecasts provide key support to several water-related applications. Because of the critical impact of initial conditions (ICs) on forecast accuracy, ever-growing interest is focused on improving their estimates via data assimilation (DA). This study aims to assess the sensitivity of the DA-based estimation of forecast ICs to several sources of uncertainty and the update of different model states and parameters of a lumped conceptual rainfall-runoff model over 232 watersheds in France. The performance of two sequential ensemble-based techniques, namely, the ensemble Kalman filter (EnKF) and the particle filter (PF), is compared in terms of efficiency and temporal persistence (up to 10 days) of the updating effect through the assimilation of observed discharges. Several experiments specifically address the impact of the meteorological, state, and parameter uncertainties. Results show that an accurate estimate of the initial level of the routing store of the conceptual model ensures the most benefit to the DA-based estimation of forecast ICs. While EnKF-based forecasts outperform PF-

Principle of sequential data assimilation

Uncertain observed data are assimilated to constrain the GR model and the updated states are propagated through future lead times using the GR model



Running DA with airGRdatassim

airGRdatassim features

- Model available
 - ▶ only daily hydrological models (GR4J, GR5J & GR6J)
- Methods
 - ▶ Ensemble Kalman Filter (EnKF)
 - ▶ Particle Filter (PF)
- Assimilated variable
 - ▶ streamflow
- Specific perturbation procedures
 - ▶ meteorological forcing uncertainties (precipitation and/or potential evapotranspiration)
 - ▶ model states (production store level, routing store level and/or unit hydrographs)

Running DA with airGRdatassim

Data preparation:

```
## package loading
library(airGRdatassim)

## loading catchment data
data(L0123001, package = "airGR")
Param <- c(X1 = 194.243, X2 = -0.088, X3 = 117.740, X4 = 1.680, X5 = 0.000)

## run period selection
IndRun <- seq(which(format(BasinObs$DatesR, format = "%Y-%m-%d") == "2006-01-01"),
              which(format(BasinObs$DatesR, format = "%Y-%m-%d") == "2007-01-01"))

## preparation of the InputsModel object
InputsModel <- CreateInputsModel(FUN_MOD = RunModel_GR5J, DatesR = BasinObs$DatesR,
                                  Precip = BasinObs$P, PotEvap = BasinObs$E)
```

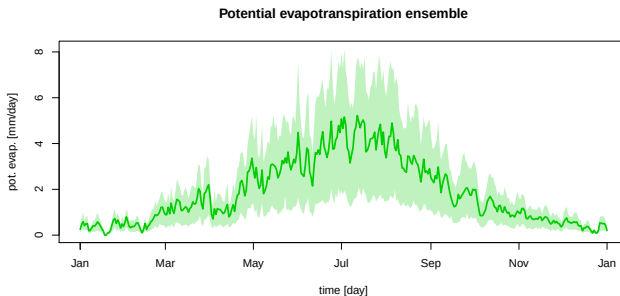
Running DA with airGRdatassim

Perturbed meteorological ensemble:

```
## number of ensemble members
NbMbr <- 30L

## preparation of perturbed meteorological ensemble
InputsPert <- CreateInputsPert(FUN_MOD = RunModel_GR5J,
                                DatesR = BasinObs$DatesR,
                                Precip = BasinObs$P, PotEvap = BasinObs$E,
                                NbMbr = NbMbr)

## results preview on a subset on one perturbed variable
plot(InputsPert[IndRun], which = "PotEvap")
```



Running DA with airGRdatassim

Data assimilation simulation using Particle Filter:

```
OutputsModelDA <- RunModel_DA(InputsModel = InputsModel,
                               InputsPert = InputsPert,
                               Qobs = BasinObs$Qmm,
                               IndRun = IndRun,
                               FUN_MOD = RunModel_GR5J, Param = Param,
                               DaMethod = "PF", NbMbr = NbMbr,
                               StatePert = c("Prod", "Rout"))
```

Graphical assessment of the results:

```
plot(OutputsModelDA, Qobs = BasinObs$Qmm[IndRun])
```

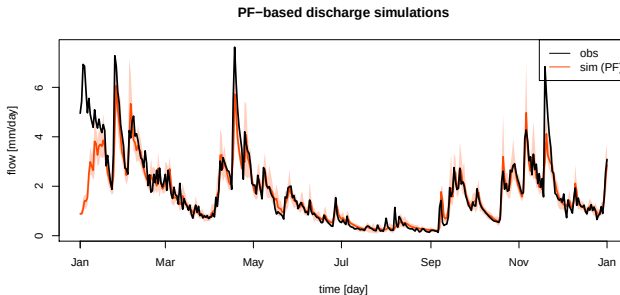


Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package
- 5 The new airGRiwrn package**
- 6 Go further
- 7 References

Integrated Water Resources Management modeling

airGRiwrn features

- Extension of the airGR R-package for handling Integrated Water Resources Management modelling
 - ▶ See EGU21-2190 in the same session

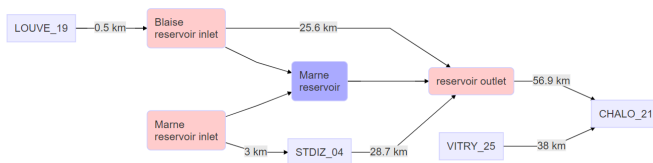


Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package
- 5 The new airGRiwrn package
- 6 Go further**
- 7 References

- <https://hydrogr.github.io/airGR/>

airGR

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DOI: 10.26454/CH21106

1 What is the airGR package?

2 Installation

3 Misc

References

airGR: the INRAE GR Hydrological Models in a R Package

Update: 2021-03-30

1 What is the airGR package?

1.1 Presentation

airGR is a package which brings into the R software the hydrological modelling tools used and developed at the Catchment Hydrology Research Group of IRSTEA (France), including the GR rainfall-runoff models and a snowmelt and accumulation model, CemaNeige. Each model core is coded in Fortran to ensure low computational time. The other package functions (i.e. mainly the calibration algorithms and the efficiency criteria calculation) are coded in R.

The airGR package has been designed to fulfil two major requirements: to facilitate the use by non-expert users and to allow flexibility regarding the addition of external criteria, models or calibration algorithms. The names of the functions and their arguments were chosen to this end. airGR also contains basics plotting facilities.

1.2 The airGR hydrological models

Six hydrological models and one snowmelt and accumulation model are implemented in airGR. The snow model can be used alone or together with the daily hydrological models.

The models can be called within airGR using the following functions:

- `RunGR4J_GRAH()` : four-parameter hourly lumped hydrological model (Mathvet 2005)
- `RunGR4J_GRAH()` : five-parameter hourly lumped hydrological model (Ficchi 2017; Ficchi, Perrin, and Andréassian 2019)
- `RunGR4J_GRAJ()` : four-parameter daily lumped hydrological model (Perrin, Michel, and Andréassian 2003)
- `RunGR4J_GRAJ2()` : five-parameter daily lumped hydrological model (Le Moine 2006)
- `RunGR4J_GRAJ2()` : six-parameter daily lumped hydrological model (Prud'homme et al. 2011)
- `RunGR4J_GRAJ2M()` : two-parameter monthly lumped hydrological model (Mouelhi 2003; Mouelhi et al. 2006a)
- `RunGR4J_GRAJ4()` : two-parameter yearly lumped hydrological model (Mouelhi 2003; Mouelhi et al. 2006b)
- `RunGR4J_CemaNeige1()` : two-parameter degree-day snowmelt and accumulation model (Videly, Andréassian, and Perrin 2014; Rebouss et al. 2019)
- `RunGR4J_CemaNeigeGR4H()` : combined use of GR4H and CemaNeige
- `RunGR4J_CemaNeigeGR4J()` : combined use of GR4J and CemaNeige
- `RunGR4J_CemaNeigeGR4J2()` : combined use of GR4J2 and CemaNeige
- `RunGR4J_CemaNeigeGR4J2M()` : combined use of GR4J2M and CemaNeige
- `RunGR4J_CemaNeigeGR4J4()` : combined use of GR4J4 and CemaNeige

Version control

Software development activities (needs & bug reports)

■ <https://gitlab.irstea.fr/HYCAR-Hydro/airGR>

The screenshot displays the GitLab web interface for the **airGR** project. The left sidebar contains navigation links for Project overview, Details, Activity, Releases, Repository, Issues (35), Refinements, Merge Requests (5), CI/CD, Operations, Packages & Registries, Analytics, Wiki, Snippets, and Members. The main content area shows the project overview for **airGR**, including statistics (1,288 Comments, 9 Branches, 23 Tags, 1.2 MB Files, 178.9 MB Storage, 23 Releases) and a description: "R package. Suite of GR Hydrological Models for Precipitation-Runoff Modelling". Below this, there are tabs for README, CHANGELOG, CI/CD configuration, and No license. All rights reserved. A table of recent commits is displayed, showing the file name, the last commit message, and the last update time.

Name	Last commit	Last update
R	fix: Qoutput conversion error with several updat...	2 days ago
data	v1.3.2.31 CLEAN: Ignorant flows set to NA in LPT2...	1 year ago
inst	docs(git): save CdfNet results in a Rds file a...	2 months ago
man	Revert "docs(man): remove comment lines in Run...	14 hours ago
src	v1.6.9.35 refactor(fortran): change numeric type in ...	2 months ago
tests	style(test): use a lower case to write the exponent v...	3 days ago
vignettes	docs(git): remove warning message when air...	2 weeks ago
Buildsystem	v1.6.8.21 refactor(SeriesAgg): Change Tablere...	4 months ago
gitignore	chore(gitignore): add exception for manual pdf (not...	3 months ago

Table of contents

- 1 Introduction
- 2 Package features
- 3 Semi-distribution option in airGR
- 4 The new airGRdatassim package
- 5 The new airGRiwrm package
- 6 Go further
- 7 References**

Packages references

airGR

- Coron, L., Thirel, G., Delaigue, O., Perrin, C. and Andréassian, V. (2017). The Suite of Lumped GR Hydrological Models in an R package. Environmental Modelling and Software, 94, 166-171. doi: 10.1016/j.envsoft.2017.05.002.
- Coron, L., Delaigue, O., Thirel, G., Dorchies, D. Perrin, C. and Michel, C. (2021). airGR: Suite of GR Hydrological Models for Precipitation-Runoff Modelling. R package version 1.6.10.4. URL: <https://CRAN.R-project.org/package=airGR>, doi: 10.15454/EX11NA.

airGRdatassim

- Piazzzi, G., Thirel, G., Perrin, C. and Delaigue, O. (2021). Sequential data assimilation for streamflow forecasting: assessing the sensitivity to uncertainties and to updated variables of a conceptual hydrological model. Water Resources Research, doi: 10.1029/2020WR028390.
- Piazzzi, G. and Delaigue, O. (2021). airGRdatassim: Suite of Tools to Perform Ensemble-Based Data Assimilation in GR Hydrological Models. R package version 0.1.3. URL: <https://gitlab.irstea.fr/HYCAR-Hydro/airgrdatassim>, doi: 10.15454/WEYYVZ.