Latest developments of the airGR rainfall-runoff modelling R-package: composite calibration/evaluation criterion and improved snow model to take into account satellite products

Olivier Delaigue[1], Guillaume Thirel[1], Philippe Riboust[1,2]

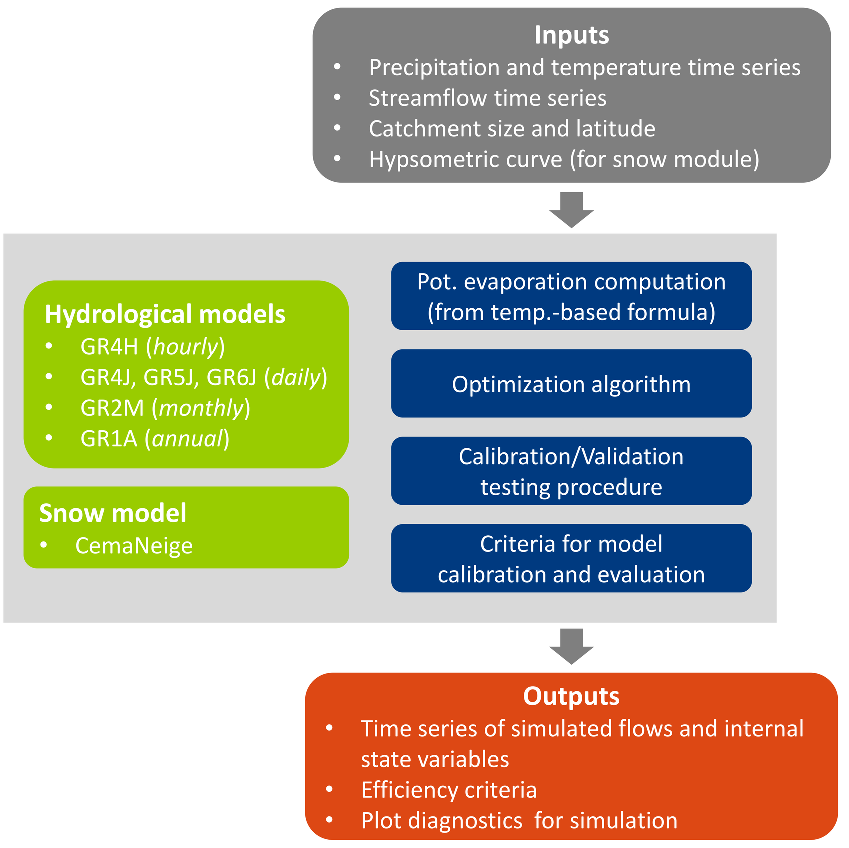
[1] IRSTEA – Hydrology Research Group (HYCAR) – Antony, France
[2] Conseil Général des Hauts-de-Seine – Nanterre, France

GR is a family of lumped hydrological models designed for flow simulation at various time steps. The models are freely available in an R package called airGR (Coron *et al.*, 2017, 2019). The models can easily be implemented on a set of catchments with limited data requirements.

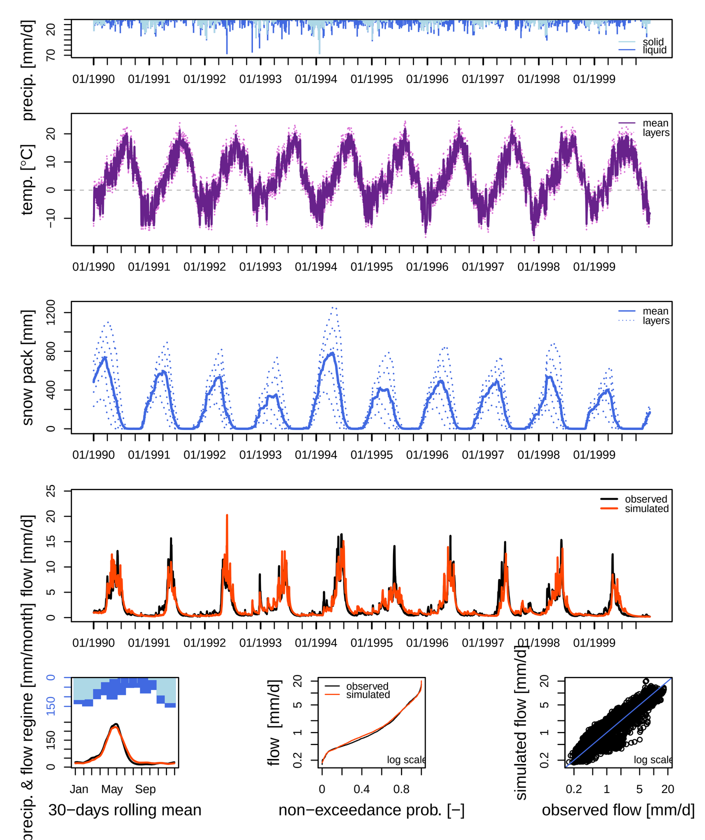
GR hydrological models

- Designed with the objective to be as efficient as possible for flow simulation at various time steps (from hourly to interannual)
- Warranted complexity structures and limited data requirements
- Can be applied on a wide range of conditions, including snowy catchments (CemaNeige snow routine included)

Main components of the airGR package



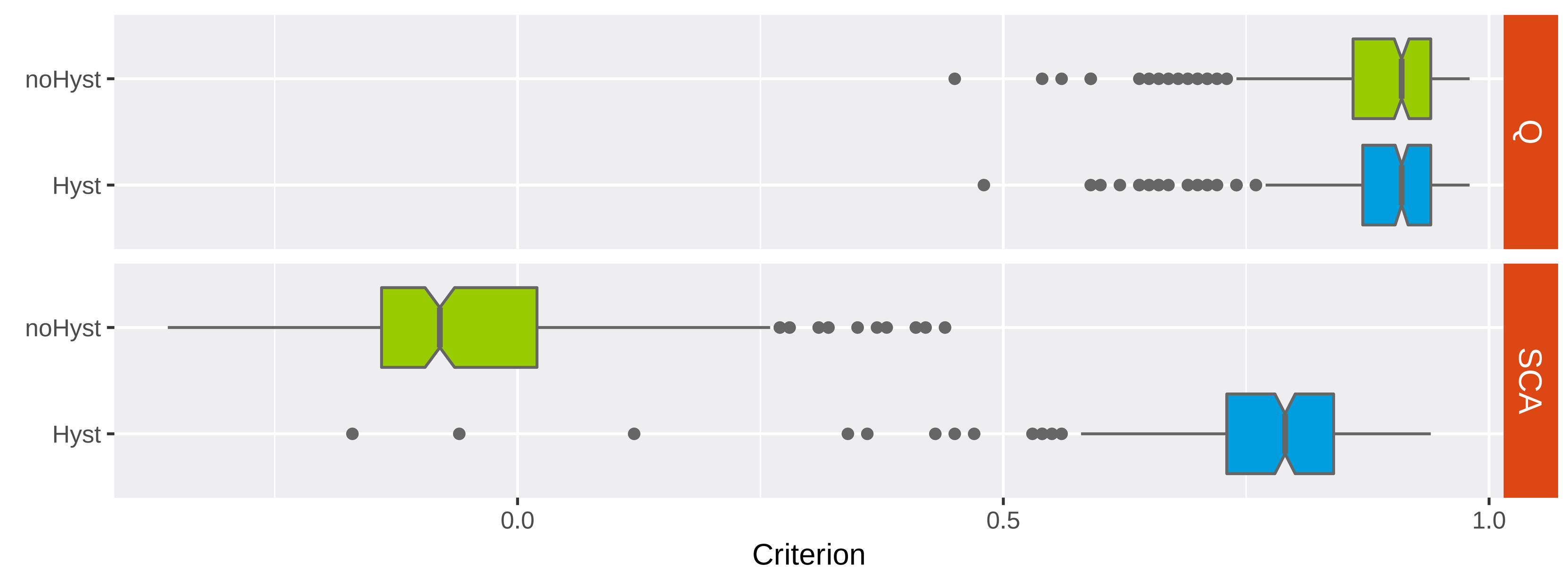
Plot diagnostics example (GR4J with CemaNeige)



New features since EGU 2018 – airGR 1.0.5.12 vs airGR 1.2.13.16

- It is now possible to use a composite criterion to calibrate a GR model
  It can combine different:
  - error criteria (NSE, KGE, KGE')
  - variables (flow, snow cover area [SCA], snow water equivalent [SWE])
  - variable transformations (raw, square root, logarithm, inverse, sorted)
  - weights for the different variables
- A version of CemaNeige including a SWE-SCA Linear Hysteresis allows to use satellite SCA for calibration (Riboust *et al.*, 2019)
  - A new vignette explains how to use it

Validation performance criteria distributions on SCA and flow using CemaNeige with or without the Linear Hysteresis



Using a composite criterion for calibration of the Linear Hysteresis CemaNeige

- Variables needed (note the need for the SCA data)

```
##       DatesR P    T   E   Qls   Qmm  SCA1  SCA2  SCA3  SCA4  SCA5
## 1 2000-02-25 0  0.7 0.5 19046 0.721 0.228 0.678 0.865 0.935    NA
## 2 2000-02-27 0  0.1 0.4 18218 0.690 0.127 0.562 0.806 0.913 0.959
## 3 2000-02-28 0 -1.0 0.3 18855 0.714 0.158 0.604 0.844 0.932 0.946
```

- Data preparation

```
## preparation of the InputsModel object
inMod <- CreateInputsModel(FUN_MOD = "RunModel_CemaNeigeGR4J",
                           DatesR = basinObs$DatesR, Precip = basinObs$P,
                           PotEvap = basinObs$E, TempMean = basinObs$T,
                           ZInputs = median(basinInfo$HypsoData),
                           HypsoData = basinInfo$HypsoData, NLayers = 5)
```

- Calibration options preparation (note the need for the new `IsHyst` argument)

```
## calibration period selection
IndCal <- seq(which(format(basinObs$DatesR, format = "%Y-%m-%d") == "2000-09-01"),
              which(format(basinObs$DatesR, format = "%Y-%m-%d") == "2005-08-31"))

## preparation of the CalibOptions object
optCal <- CreateCalibOptions(FUN_MOD = "RunModel_CemaNeigeGR4J",
                             FUN_CALIB = Calibration_Michel, IsHyst = TRUE)

## preparation of the RunOptions object for the calibration period
optRun <- CreateRunOptions(FUN_MOD = "RunModel_CemaNeigeGR4J", InputsModel = inMod,
                           IndPeriod_Run = IndCal, IsHyst = TRUE)
```

- Composite criterion preparation

```
## efficiency criteria: 75 % KGE'(Q) + 5 % KGE'(SCA) on each of the 5 layers
inCrit <- CreateInputsCrit(FUN_CRIT = rep("ErrorCrit_KGE2", 6),
                           InputsModel = inMod, RunOptions = optRun,
                           Obs = basinObs[IndCal, c("Qmm", "SCA1", "SCA2",
                                                    "SCA3", "SCA4", "SCA5")],
                           VarObs = list("Q", "SCA", "SCA", "SCA", "SCA", "SCA"),
                           Weights = list(0.75, 0.05, 0.05, 0.05, 0.05, 0.05))
```

- Model calibration

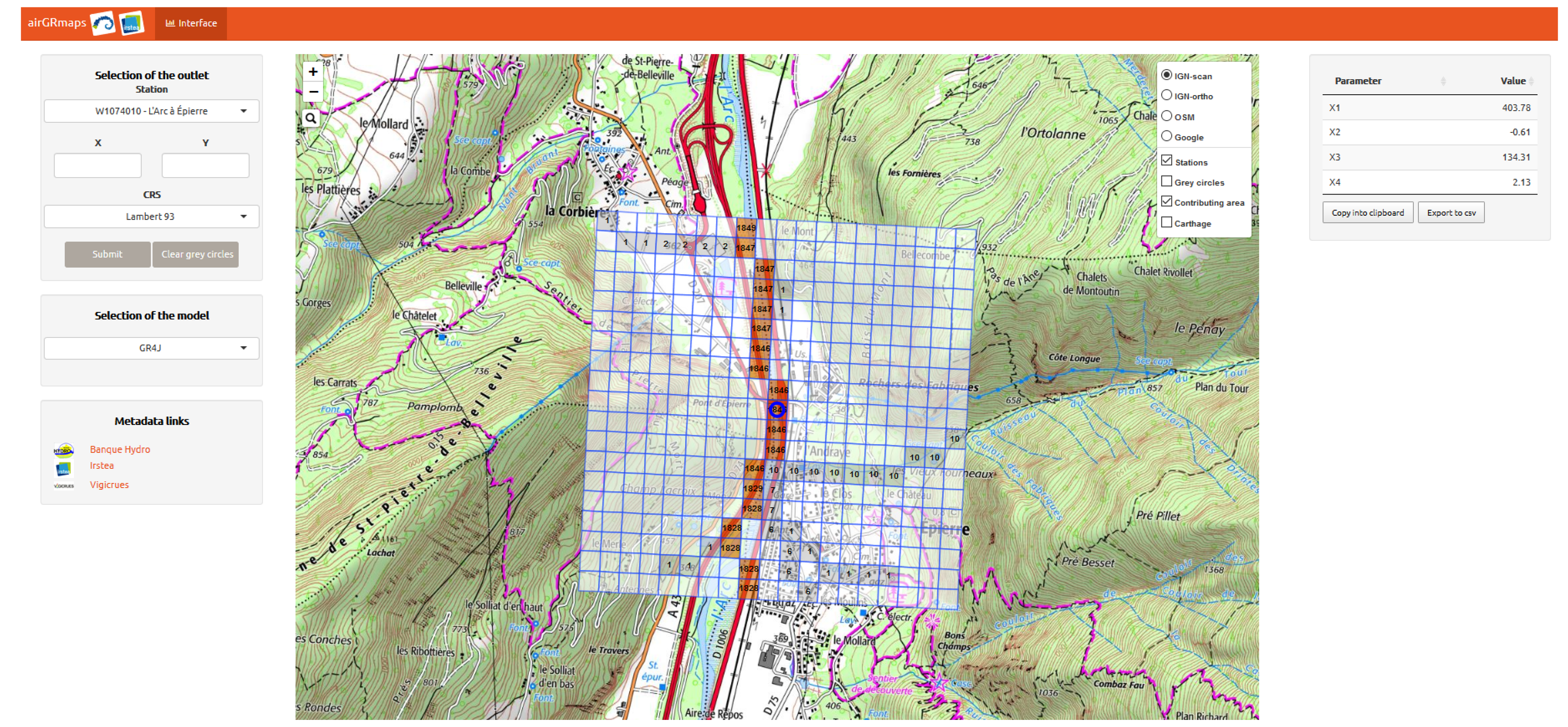
```
## calibration (GR4J with CemaNeige)
outCal <- Calibration(InputsModel = inMod, RunOptions = optRun,
                      InputsCrit = inCrit, CalibOptions = optCal,
                      FUN_MOD = "RunModel_CemaNeigeGR4J",
                      FUN_CALIB = Calibration_Michel)

Grid-Screening in progress (0% 20% 40% 60% 80% 100%)
Screening completed (6561 runs)
Param =  432.681,  -0.020,  83.096,    2.384,    0.002,    3.787,  15.000,    0.850
Crit.  Composite    = 0.8139
Steepest-descent local search in progress
Calibration completed (107 iterations, 8248 runs)
Param =  419.893,    0.517,  275.687,    1.345,    0.632,    3.864,  16.911,    0.472
Crit.  Composite    = 0.8995
Formula:  sum(0.75 * KGE'[Q], 0.05 * KGE'[SCA], 0.05 * KGE'[SCA],
0.05 * KGE'[SCA], 0.05 * KGE'[SCA], 0.05 * KGE'[SCA])
```

airGR websites: get started with the packages or discover advanced uses

- High degree of customization with airGR:
  - `https://hydrogr.github.io/airGR/`
- Simple features to learn hydrology with airGRteaching (Delaigue *et al.*, 2018, 2019):
  - `https://hydrogr.github.io/airGRteaching/`

airGRmaps interface (Génot & Delaigue, 2019) to get parameter values of GR4J, GR5J or GR6J all over France



Future developments

- airGRmaps: parameter maps on France for GR4J, GR5J & GR6J models for ungauged bassins (Poncelet *et al.*, submitted) available soon through a Shiny interface
- airGRtools: different useful tools like event detection, statistics computations (Base Flow Index, Standardized Streamflow Index), etc.

Download the airGR packages on the Comprehensive R Archive Network

- airGR: `https://CRAN.R-project.org/package=airGR/`
- airGRteaching: `https://CRAN.R-project.org/package=airGRteaching/`

References

- Coron L., Delaigue, O., Thirel, G., Perrin C. & Michel C. (2019). airGR: Suite of GR Hydrological Models for Precipitation-Runoff Modelling. R package version 1.2.13.16. URL: `https://CRAN.R-project.org/package=airGR`.
- Coron, L., Thirel, G., Delaigue, O., Perrin, C. & Andréassian, V. (2017). The suite of lumped GR hydrological models in an R package. *Environmental Modelling & Software*, 94, 166–171. DOI: `10.1016/j.envsoft.2017.05.002`.
- Delaigue, O., Coron, L. & Brigode, P. (2019). airGRteaching: Teaching Hydrological Modelling with the GR Rainfall-Runoff Models ('Shiny' Interface Included). R package version 0.2.6.14. URL: `https://CRAN.R-project.org/package=airGRteaching`.
- Delaigue O., Thirel G., Coron L. & Brigode P. (2018). airGR and airGRteaching: Two Open-Source Tools for Rainfall-Runoff Modeling and Teaching Hydrology. In: HIC 2018. 13th International Conference on Hydroinformatics. *EPiC Series in Engineering*, 541–548. EasyChair. DOI: `10.29007/qsqj`.
- Poncelet, C., Andréassian, V., & Oudin, L. (submitted). Regionalization of Hydrological Models by Group Calibration. *Water Resources Research*.
- Riboust, P., Thirel, G., Le Moine, N. & Ribstein, P. (2019). Revisiting a simple degree-day model for integrating satellite data: implementation of SWE-SCA hystereses. *Journal of Hydrology and Hydrodynamics*, 1, 67, 70–81. DOI: `10.2478/johh-2018-0004`.

National Research Institute of Science and Technology for Environment and Agriculture

HYDRO

Photography encouraged