Combining interpolation of daily gauge and satellite rainfall data to evaluate an hydrological model (SWAT)

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Scientifical Context and objectives :

How useful are satellite-based rainfall estimates (SRFE) as forcing data for hydrological applications in Peruvian Andes? Which SRFE should be useful for hydrological modelling? What could researchers do to increase the performance of SRFE-driven hydrological simulations? To address these three research questions, two SRFE (TRMM 3B42RT and PERSIANN CCS) are evaluated within a hydrological application for the time period 2004–2012. The focus is on the assessment of the hydrological performance of: (a) the individual calibration of model for observed data of precipitation (b) SRFE-specific calibration and (c) of the calibration of the observed combined with SRFE precipitation, where the last one will be obtained by interpolation techniques (merging).

Study site and data

The Vilcanota basin river is located in the southern Peruvian Andes at the department of Cusco, the Vilcanota river is one of the tributaries of the Amazon River system.

Drainaje basin	9638 km^2	Mean anual precipitation:	850 mm (2000 – 2012)
Elevation:	1778 to 6309 m.	Mean anual discharge:	136 m^3/s (2000 – 2012)

In order to obtain model parameters in SWAT, a wide range of input datasets is required, including: information on topography, vegetation, soil properties and hydro-meteorological data which were obtained from different sources:

- Digital Elevation Model (DEM) with a 90 m resolution was obtained from the NASA Shuttle Radar Topography Mission (SRTM).
- Precipitation, temperature and streamflow data covering the 2000-2012 period were obtained from the Peruvian Hydro meteorological Service.

The main characterisitics of soil and vegetation in the Vilcanota basin are:

- Soil: Predominant soil types in the study area are Lithosols and Kastanozems (FAO-UNESCO 1988).
- Vegetation: The land cover is dominated by natural grassland (82.7%), shrublands (10.4%), scattered areas of traditional cultivation (1.7%), and small glaciers and lakes represent a smaller percentage.

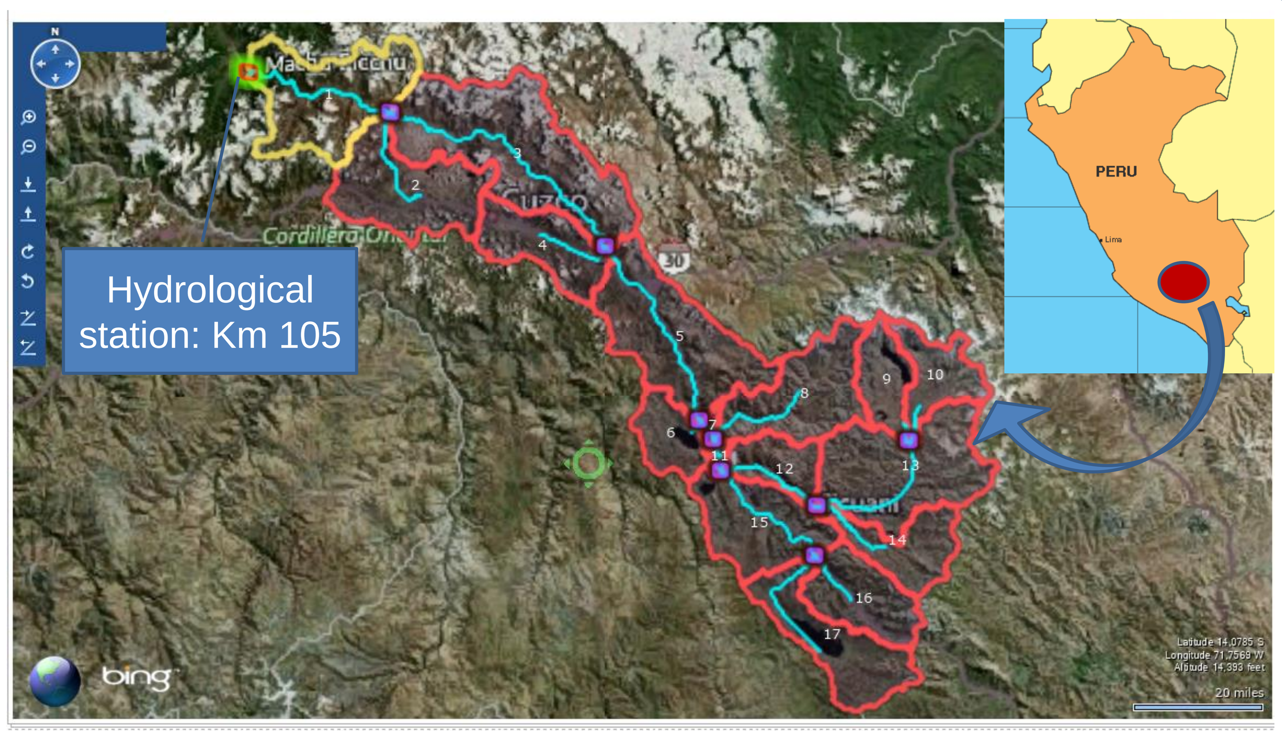

Fig.1: Study area.

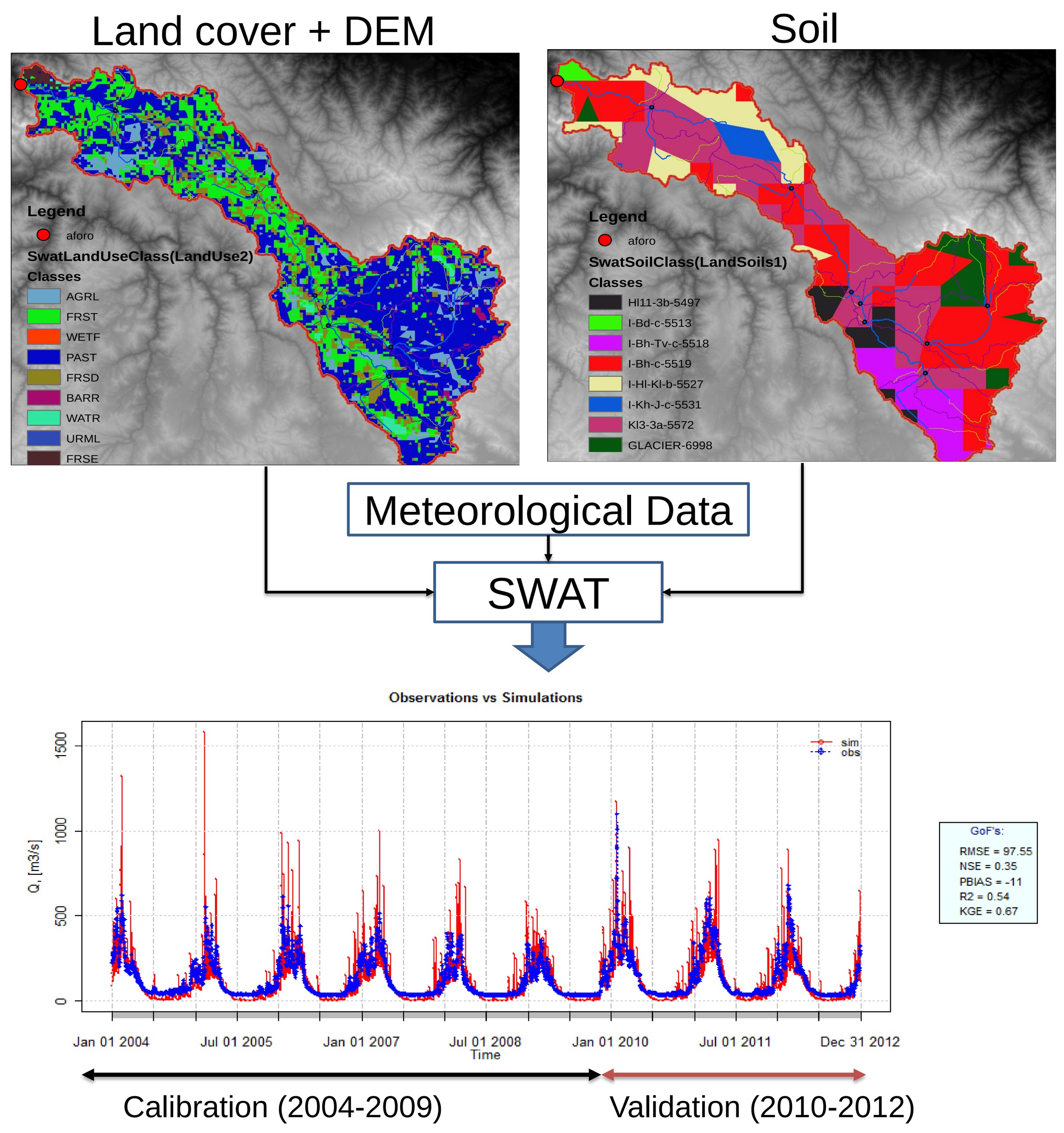

Fig.2: Scheme of the model and results in daily step without any calibration

Methodology :

In this work we present only the methodology and results of the hydrological modelling using the observed data of precipitation.

The ArcSWAT 2012 interface is used to setup and parameterize the model. On the basis of DEM and the stream network, we discretized the basin into 17subbasins, which were further subdivided into 644 HRUs based on soil, landuse, and slope characteristics. Each HRU is thought to be a uniform unit where water balance calculations are made.

The entire simulation period is from 2000 to 2012. The first 4 years are used as equilibration period to mitigate the initial conditions and so were excluded from the analysis.

We established 2004 to 2009 period for calibration and 2010 to 2012 as validation period, where 12 parameters were selected for calibration based on preceded studies, and results from Latin Hypercube-one factor at a Time (LH-OAT) parameter sensitivity analysis using the HydroPSO package in R (Zambrano-Bigiarini and Rojas, 2012). Then the SUFI-2 algorithm (Abbaspour et al., 2004) included in SWAT-CUP software package (Abbaspour, 2011), was used for model calibration and validation.

The model performance during calibration was assessed using the modified Kling-Gupta Efficiency (KGE) (Kling et al., 2012). According to Kling (cited by Thiemig et, al. 2012) the hydrological performance can be classified using KGE as showed in Table 2.

Tab.1: Parameters used in the calibration

Parameter_Name	Definition	Process	Min_value	Max_value	Fitted_Value
1:R__CN2.mgt	Initial SCS CN II value	Runoff	-0.15	0.15	0.143
2:V__CH_K2.rte	Effective hydraulic conductivity in main channel alluvium [mm/h]	Routing	5	200	175.625
3:V__ALPHA_BF.gw	Base flow alpha factor [days]	Groundwater	0.01	0.99	0.427
4:V__CH_N2.rte	Manning's "n" value for the main channel	Routing	0.016	0.05	0.036
5:R__SOL_AWC(..).sol	Available water capacity [mm H2O/mm soil]	Runoff	-0.25	0.25	-0.163
6:R__SOL_K(..).sol	Saturated hydraulic conductivity [mm/h]	Runoff	-0.25	0.25	-0.138
7:V__RCHRG_DP.gw	Deep aquifer percolation factor	Groundwater	0	1	0.825
8:R__OV_N.hru	Manning's "n" value for overland flow	Runoff	-0.25	0.25	-0.013
9:V__GW_DELAY.gw	Groundwater delay time [days]	Groundwater	0	500	162.500
10:V__GWQMN.gw	Threshold water depth in the shallow aquifer for flow [mm]	Groundwater	0	1000	975.000
11:V__GW_REVAP.gw	Groundwater "revap" coefficient	Groundwater	0	0.2	0.005
12:V__REVAPMN.gw	Threshold water depth in the shallow aquifer for "revap" [mm]	Groundwater	1	500	312.875

Tab.2:

Assessment according KGE
good (KGE P ≥ 0.75),
intermediate (0.75 > KGE ≥ 0.5),
poor (0.5 > KGE > 0.0) and
very poor (KGE ≤ 0.0).

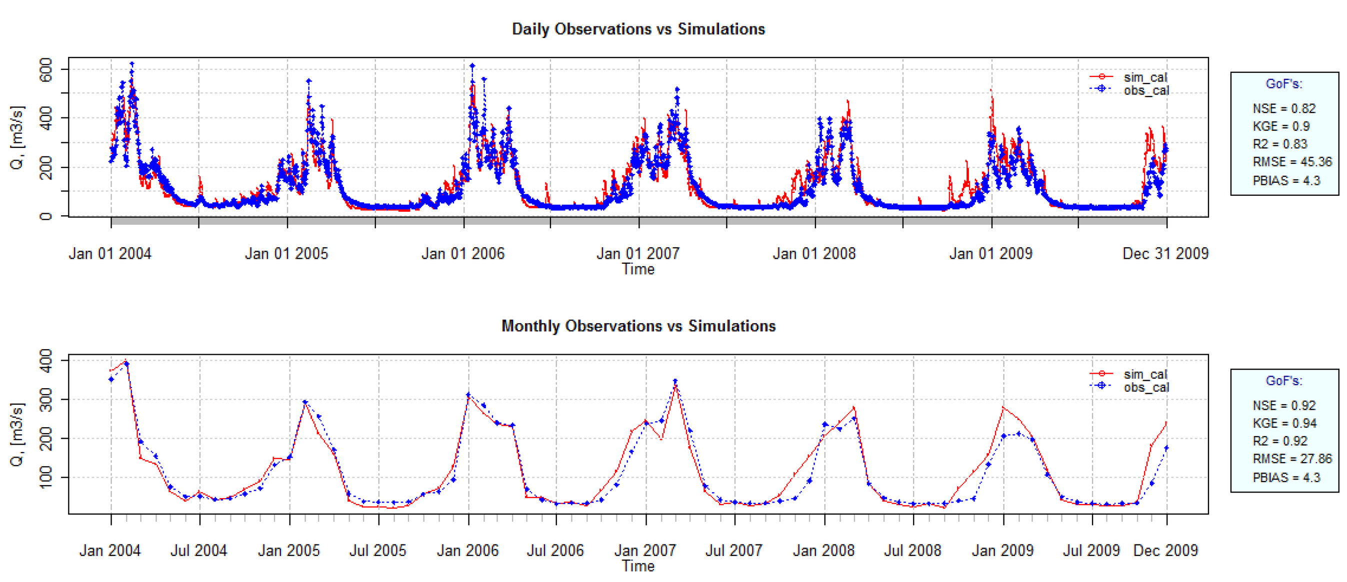

Fig.3: Results of the calibration for daily and monthly periods

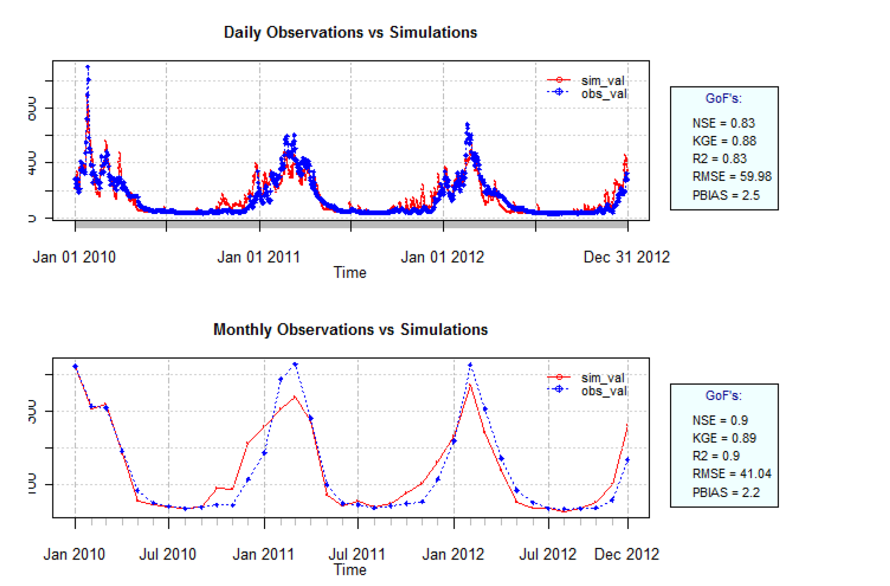

Fig.4: Results of the validation for daily and monthly periods

Results :

As shown in Fig. 2 the SWAT model by default can characterize the overall patterns of observed flow (as intermediate) according to KGE. Where clearly we can see that the low flows were underestimated and the high flows were overestimated, so we calibrated the parameters that influence the base flow (groundwater) and superficial flow (runoff) shown in table 1 for the calibration.

After calibration

As shown in Fig. 3, the simulated flow matched the observed flow well in terms of overall patterns during the calibration period with good measures of efficiency (KGE > 0.9, NASH > 0.8, R2 > 0.8) in time steps of daily and monthly.

The RMSE of 45 m^3/s for daily time step, is the mean error of estimation and according to R^2, more than 80% of the variability of daily discharges observed in the basin are explained by the model, remained uncertainties are probably due to: (i) conceptual simplifications (e.g., SCS curve number method for flow partitioning), (ii) processes occurring in the watershed but not included in the program (e.g., wind erosion, wetland processes), (iii) processes that are included in the program, but their occurrences in the watershed are unknown to the modeler or unaccountable because of data limitation (e.g., dams and reservoirs, water transfers), and (iv) input data quality.

In the validation stage it was found good performance as well as in calibrations stage, moreover we can see that the model was able to reproduce the extreme flood event occurred in 2010 (Lavado Casimiro et al. 2010).

Finally in the Fig. 4 is shown the Hydrological balance of the Vilcanota river basin after calibration. Where 50% of the precipitation is evapotranspired, 40% of the precipitation becomes in streamflow and 10% is for aquifer recharge.

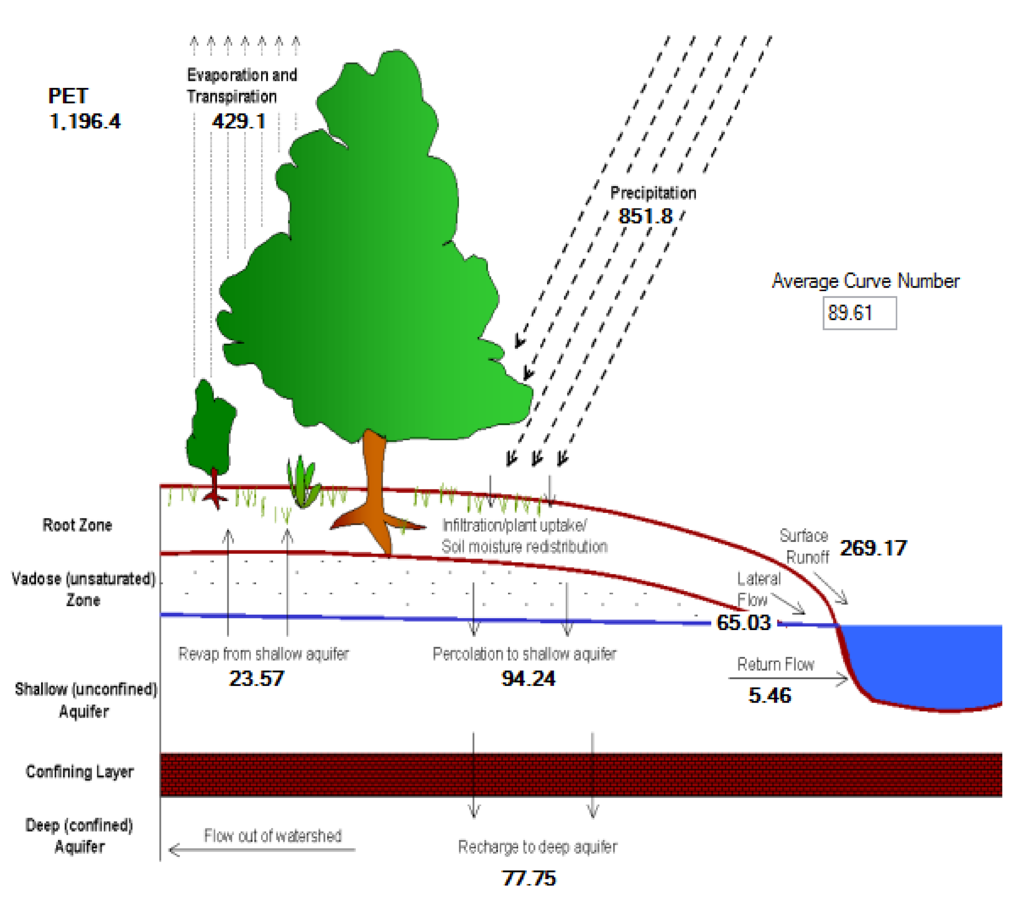

Fig.4: Hydrological balance of the Vilcanota river basin, main components and results in mm. (after calibration)

Conclusions

In this study the hydrological model of the Vilcanota river basin was built using the well-established SWAT program. The model was calibrated for river discharge station (km. 105), using the algorithm SUFI-2 in SWAT-CUP tool. The SWAT model effectively simulated streamflow in the study area considering the five main performance evaluation metrics used.

To asnwer the three questions of the Scientific Context this research is still continuing to evaluate the impacts of the satellite-based rainfall estimates (SRFE) as forcing data for hydrological applications in Peruvian Andes.

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