Usefulness of rainfall estimated by PERSIANN in hydrologic modeling applied to river basin Jucar in Spain

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1. Introduction

In this study the usefulness of precipitation estimated by remote sensing was assessed through a rainfall-runoff hydrological model. Rainfall estimated by the PERSIANN algorithm was used from satellite measurements and it is available through a user-friendly interface of HyDIS (http://hydis8.eng.uci.edu/hydis-unesco/) and it enables to collect data in a selected region for a cumulative period interval, with information from March 1, 2000. (Sorooshian, Hsu et al. 2000; Hsu and Sorooshian 2008).

2. Case of Study

It is Jucar River Basin with an area of 21434 km^2. It basin is one of the most economic value in Spain due to its intense use (channels for irrigation, drinking water, dams, navigation, sports and river fisheries, tourism) that intensify the competition for water resources

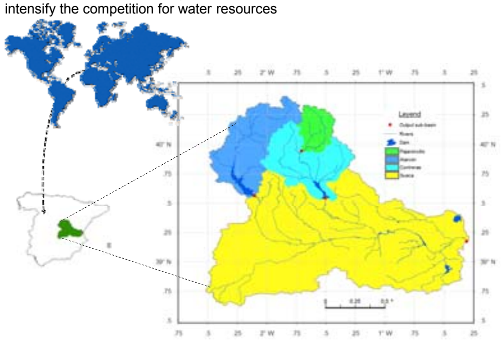

Fig 1. Study zone

3. Hydrological Model: TETIS

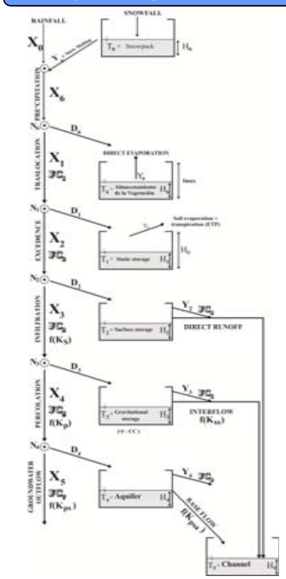

Fig 2. Conceptual diagram of TETIS model (cell i,j)

The hydrological model used is TETIS, developed by the IIAM-UPV (www.iiama.upv.es), which is a distributed hydrological simulation model with physically based parameters, representing the basin as a mesh of interconnected cells in topographic settings. For each cell, the model performs a water balance following a conceptualization of such tanks and it has a powerful optimization algorithm (SCE-UA) for automatic calibration of its parameters, initial values of state variables and initial values of moisture content. (Francés, Vélez et al. 2007).

Source information of River Jucar Basin required an arduous work of analysis, verification, preprocessing and codification to fit to a compatible format with TETIS model. The spatial scale used in the modeling corresponds to a cell size of 500m and the time scale is daily.

4. Spatial Information

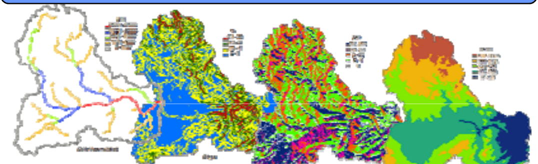

Fig 3. Cartography

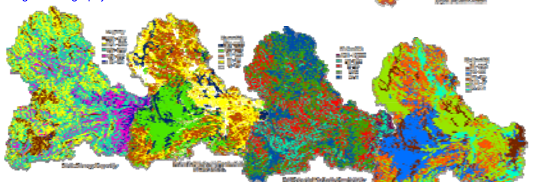

Fig 4. Hydrological Parameters

5. Ground Hydrometeorology Information

The information was collected from AEMET (Spanish Agency of Meteorology) and SAIH-CHJ (Automatic Hydrological Information System - Hydrographic Confederation of Jucar) stations and it included time series of rainfall, flow, temperature and reservoir information for the period from March 1, 2000 to October 31, 2009.

Variable	Source	Source Format			
		File	Temporal Resolution	Coordinate System	Time
Precipitation	AEMET	CSV	Daily	WGS 1984	GMT 07-07 the next day
Precipitation, Flow	SAIH	ASCII	Five Minutal	UTM_Zone_30N	Local
Maximum and minimun temperature	AEMET	CSV	Daily	WGS 1984	GMT 07-07 the next day

The potential evapotranspiration (ETP) was obtained with the Hargreaves equation (FAO, 2006), this was previously calibrated with Penman-Monteith values available.

$$ETP = 0.0023(t_{med} + 17.78)\, R_0 * (t_{max} - t_{min})^{0.5}$$

Ground Gauge Rainfall

Ground gauge rainfall stations distributed in the Jucar River Basin are 189 and these were provided by SAIH and AEMET .

These stations equivalent to a density of 1/116 km^2.

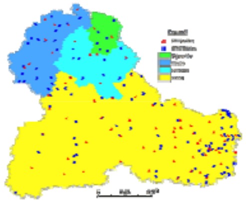

Fig 5. Ground Gauge Rainfall Stations

6. Satellite Rainfall Information

Rainfall estimated by PERSIANN was used with daily temporal resolution and spatial resolution of 0.25° for the period from March 1, 2000 to October 31, 2009. These are incorporated in ASCII format and interpreted in TETIS model as virtual stations located at the centroid of each rain grid cell .

Variable	Source Format
3532 files (one file per day) Start Date: 20000301 Ending Date: 20091031 (yearmmdd)	Files ASCII Time: GMT Unid: mm/d Header File: Xllcorner -2.625000 Yllcorner 36.87500 cellsize 0.25 nodata_value: -9999.0

Fig 6. Grid PERSIANN Rainfall

7. Methodology

Rainfall comparison

✓ The test used to analyze was the Pearson linear correlation and basic statistical parameters. These were obtained with the "Band collection statistics" tool of ArcGIS (raster images) and STADISTIC software.

✓Distributed rainfall (annual, monthly, daily) was obtained by three interpolation techniques with ArcGIS: IDW, kriging (spherical and exponential).

✓Areal rainfall (daily) was obtained as output of TETIS (interpolation with IDW method in each simulation time interval).

Hydrological modeling comparison

Implement TETIS model with daily ground gauge and satellite rainfall:

✓ Input: spatial Information, parameters (hydrological, geomorphologic), vegetation index and variables (rainfall, flow and evapotranspiration).

✓ Initial conditions of state variables

✓ Calibration and validation

✓ Output: Simulated flow, evolution of flows (vertical, horizontal) and storage in different tanks, final value of state variables, water balance in the Basin, model performance evaluation (Nash-Sutcliffe, error in volume, RMSE)

✓ Pearson linear correlation between observed and simulated flow.

8. Results

Rainfall comparison

Figure 7 shows the Pearson correlation daily with promising values of 0.70 and 0.60 in summer and winter respectively.

In summer having the highest values (23 mm/d) are concentrated in the lower and middle of the basin, this due to high evaporation due to higher temperatures in sea water and therefore more moisture in the surrounding areas of the coast. Whereas in winter, the highest values (41 mm/d) are concentrated in the upper and middle basin caused by the orography of the mountain of the Iberian System.

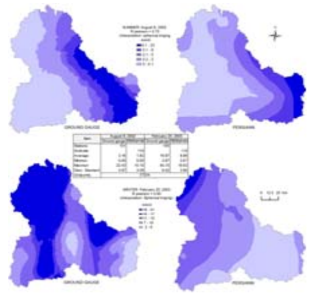

Fig 7. Daily ground gauge and PERSIANN Rainfall

The following figures 8, 9, show the Pearson correlation annual (-0.24) and monthly (0.64-summer, 0.44-winter).

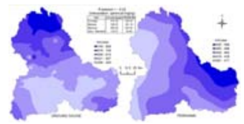

Fig 8. Annual ground gauge and PERSIANN Rainfall

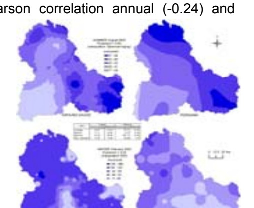

Fig 9. Month ground gauge and PERSIANN Rainfall

Figure 10 show daily areal rainfall and that there are significant differences in Pearson correlation: 0.4386 to 0.4766.

Also, show lower value (<1 mm/d) that the satellite reported as values of 20 to 25 mm/d (even values of 35 mm/d for Alarcon) this is due to the effects of cirrus clouds (ice crystals) that does not develop rainfall but the satellite register presence of rainfall.

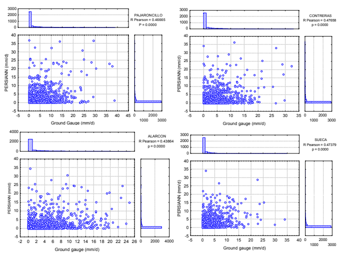

Fig 10. Daily ground gauge and PERSIANN areal rainfall

Hydrological modeling comparison

With ground gauge rainfall obtained excellent results with Nash-Sutcliffe index of 0.874 (calibration), 0.81 (temporal validation) and from 0.62 to 0.75 (space-time validation).

However the calibration and validation with PERSIANN rainfall generated unsatisfactory values, being the best performance with calibration in Pajaroncillo and Sueca. . It also shows that there is higher probability (0.83, 0.80) of accuracy of "no rain" detection. (Fig. 11, 12)

Main characteristics of calibration with PERSIANN Rainfall	Pajaroncillo	Sueca
	Jul 02 - Jul 03 Δt = day	Jul 02 - Jul 03 Δt = day
Observed peak flow (m^3/s)	54.075	361.095
Simulated peak flow (m^3/s)	28.394	275.226
N° data	396	396
Observed average flow (m^3/s)	5.964	90.568
Observed volume (Hm^3)	204.038	3098.745
Simulated volume (Hm^3)	186.357	2664.485
Error in volumen (%)	-8.666	-14.014
Nash-Sutcliffe index (NSE)	0.384	0.499
Mean Square Error (RMSE) (m^3/s)	4.647	40.599
Cumulative area (km^2)	860.75	21523

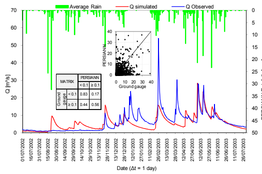

Fig 11. . Observed and simulated hydrograph with PERSIANN Rainfall in Pajaroncillo

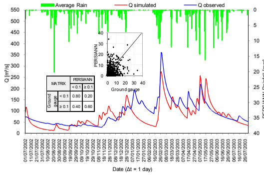

Fig 12. . Observed and simulated hydrograph with PERSIANN Rainfall in Sueca

Figure 13 shows the Pearson correlation between observed and simulated flow with PERSIANN rainfall in the hydrological modeling

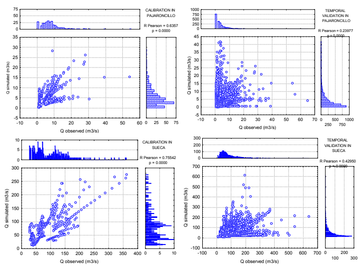

Fig 13. . Observed and simulated flow with PERSIANN Rainfall

9. Conclusions

In summary, there are lower values with PERSIANN rainfall, which is influenced by warm rain on the coast and these are not quantified by the satellites as cold clouds and, therefore, it does not register the presence of rainfall. Whereas in winter, the rainfall is more concentrated over the mountains of the Iberian System and this effect orographic is not represented by the satellites. Also PERSIANN rainfall tends to overestimate the areas with small amounts of rain, this is due to the effects of cirrus clouds. Furthermore, the uncertainty and bias of PERSIANN rainfall have been transferred to hydrological modeling.

Following the study, ground gauge and satellite rainfall will be combined using a Bayesian technique to reduce uncertainty and bias. With the advancement of science, new satellite sensors and technologies will improve the detection and its utility in hydrologic modeling.

10. Acknowledgments

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11. References

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➢Sorooshian, S., K.-L. Hsu, et al. (2000). "Evaluation of PERSIANN System Satellite–Based Estimates of Tropical Rainfall." Bulletin of the American Meteorological Society 81(9): 2035-2046.