Modeling sediment dynamics in the Amazon-Andean basin of the Ucayali River, using the SWAT model

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G-MOD

Scientifical context and objectives :

Since 2003, the work of the **HYBAM Observatory** (Fig.1) (Geodynamical, hydrological and biogeochemical control of erosion, alteration and material transport in the Amazon basin;) has allowed quantification of discharges, sediment loads and geochemical fluxes from major Amazonian tributaries with accuracy, precision and over a long period. (Guyot et al., 2007; Laraque et al., 2009; Martinez et al., 2009; Armijos et al., 2013; Vauchel et al., submitted).

In the foreland basin, the sedimentary contributions from Andean tributaries and the remobilization processes in the floodplain could mask an important sedimentation in subsidence zones. Also, the spatial distribution of erosion into the Amazon-Andean basin is poorly documented due to the lack of monitoring point.

The last decades have seen consequent advances in large-scale hydrological models development. These models can be an effective tool to supplement the conventional monitoring network. In the Amazon basin, one of the key remaining problems in modeling concerns the floodplain hydrological processes, which are important factor in the Amazon hydrology.

We have chosen as a test basin for running the SWAT model in the Amazon-foreland system the Ucayali river Basin, where we assessed water and sediment budget with conventional and remote sensing data in a previous work (Santini et al., 2014).

Using the SWAT model, we first expect to reproduce sediment dynamics and water fluxes at the Andean piedmont, without floodplain. By this way and for the first time ever, we will propose a physically based spatial distribution of erosion yields in the Andean range, allowing further complementary studies. Secondly ,we try to include the floodplain in the project and we will test the model 's ability to reproduce the water flows and sediment dynamics (sediment production, deposition, remobilization and routing).

Study site

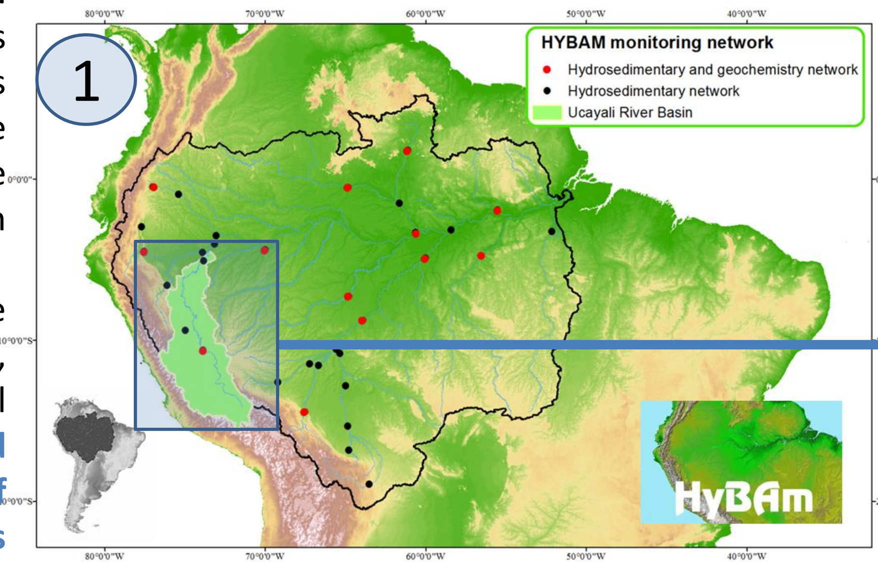
The Ucayali River basin stretches for ~350 500 km² between 15.5°S to 4.7°S. At the outlet its flow is **13 500 m³ s⁻¹**. It may be divided roughly into four parts (Fig.2): An Andean domain lined by the Eastern Cordillera with steep slopes and its adjacent sub-Andean fold and thrust belt, a wide monocline hydraulically controlled by the tectonic load of the thrust system. Further, the Ucayali River meanders towards the NNW over a vast piggyback basin. North of the Contamana arch, the river dives into the Marañón foredeep.

Total suspended sediment load of the Ucayali river represents 35% of the total 850 Mt yr^{-1} delivered by the Amazon River to the Oceans (Martinez et al, 2009; Santini et al., 2014). In this major tributary of the most important fluvial system in the world, **water flows and sediment dynamics are both controlled by a still active tectonic, a marked seasonality and the presence of two of the major cells of extreme precipitation on the Andean eastern flanks** (Espinoza et al., 2015). **It results a complex sediment dynamics**, with an Andean production assessed to be 520 Mt yr^{-1} and a important sedimentation (around 220 Mt yr^{-1}) in the foreland system (Fig. 3). In the floodplain, important processes of erosion and remobilization have been identified.

The development of remote sensing techniques such as the continental altimetry and water color monitoring with MODIS images today allow us to complement conventional hydrologic network data (Calmant et al., 2008; Martinez et al., 2009, Espinoza-Villar et al., 2012). In this study, remote sensing-derived hydrological data sets will be used additionally to in situ data for validation.

Validation data: observed in-situ data from the HYBAM observatory and remote-sensing derived hydrological dataset

1



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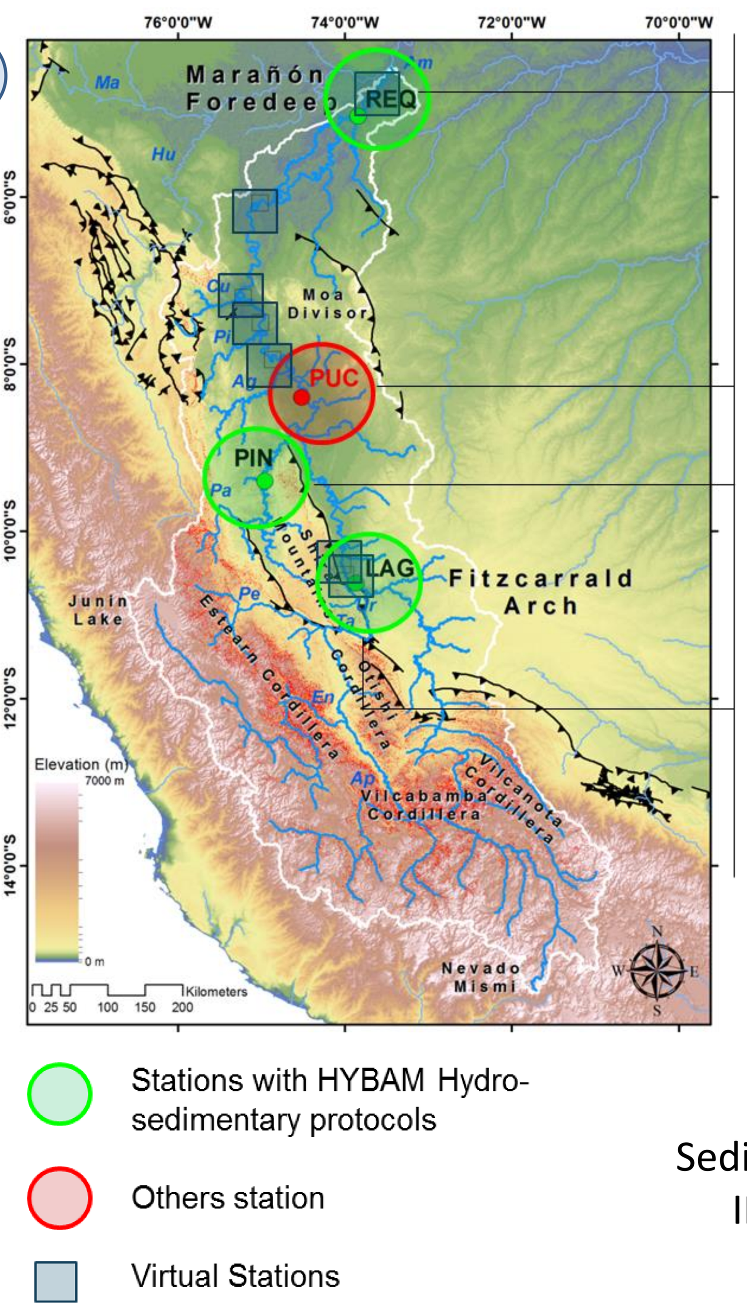
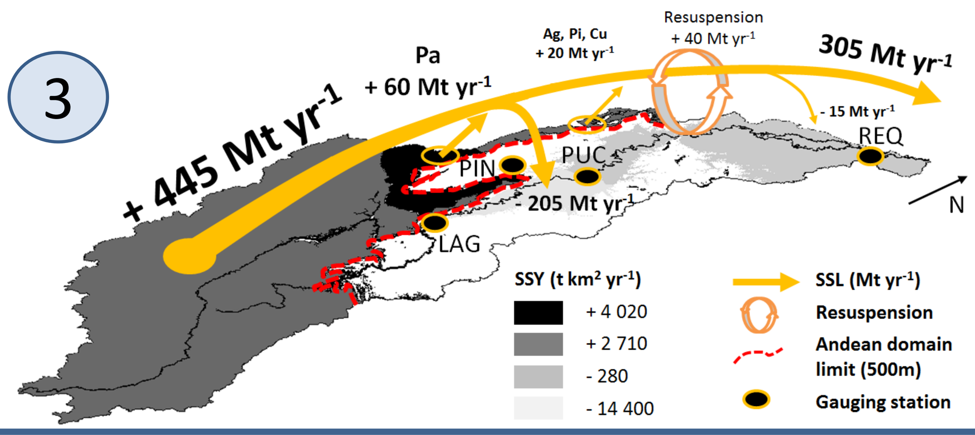


Requena		REQ
H		1996-2015
Q		1996-2015
SSC		2003-2015
IRR		2000-2015
Pucallpa		PUC
H		1987-2015
Q		1999-2015
SSC		-
IRR		2000-2015
Puerto Inca		PIN
H		2009-2015
Q		2009-2015
SSC		2012-2015
IRR		-
Lagarto		LAG
H		2009-2015
Q		2009-2015
SSC		2009-2015
IRR		2000-2015

Data:
H: Water levels
Q: Water discharges
SSC: Suspended Sediment Concentration
IRR: Reflectance data from MODIS 8-days composite image

Sediment budget in the Ucayali River basin

3



Input data

Input data	Data source	References
Weather	SENAMHI Peru / Global Weather Data for SWAT	
DEM	SRTM 90	Lehner et al. 2008; Farr et al., 2007
Soils	FAO (Harmonized World Soil Database)	
Land Use	Derived from Global Land Cover 2000 product South America, Joint Research Centre	Eva et al., 2002

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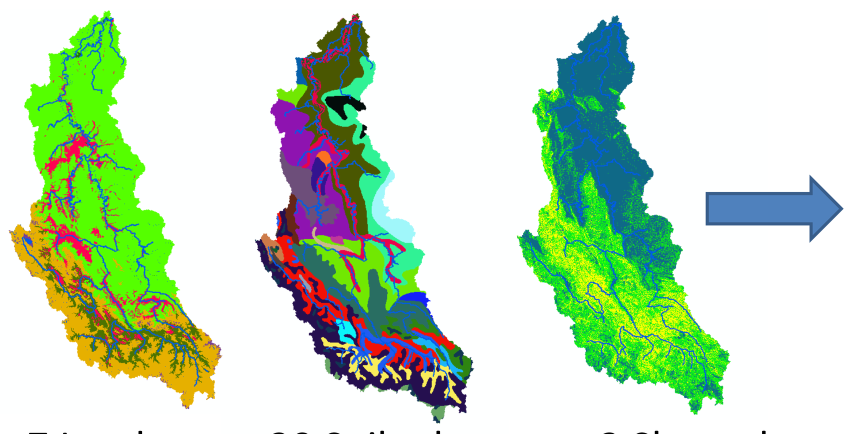

7 Land use | 30 Soils classes | 3 Slope classes (0-10%, 10-45%, 45-100%)

83 sub-basins
2912 HRUs

Modeling issue, first model runs and next steps

Observed data show an important lag between the Andean flood peak, well correlated with the sediment peak, and the flood peak at the basin outlet (Fig. 5 and 6).

Thus, floodplain processes are keys issue, inundation playing an important role in large-scale flood propagation, sediment dynamics (coarse and fine sediment loads are decoupled as shown in Fig. 7) and in the interaction between surface an atmosphere. Delay in aquifer recharge and release also play an important role in the hydrograph transfer.

In the SWAT model, water is routed through the channel network using the Muskingum method, a variation of the kinematic wave model, SWAT assuming the channels have trapezoidal shape. As shown by Trigg et al. (2009), Amazon rivers flood waves are subcritical and diffusive and the classical Muskingum method is sometime not appropriate to reproduce flood inundation and backwater effects. First runs of the SWAT model show that the implantation of the routing method could not be able to reproduce correctly the water routing in the large-scale Ucayali river floodplain (Fig 8). On the contrary, the routing method seems well adapted to the piedmont stations.

Mean discharge and Suspended Sediment Load (observed data)

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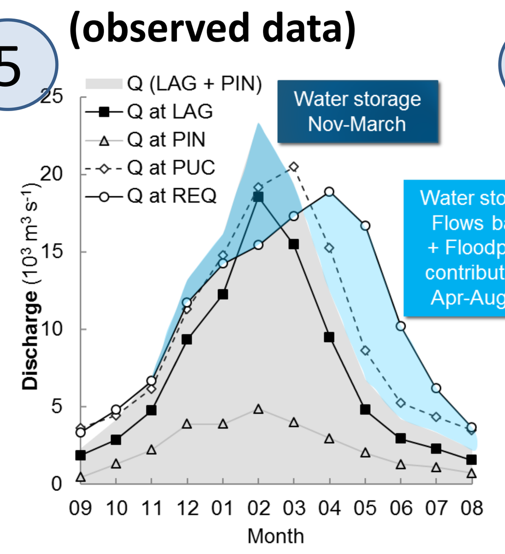

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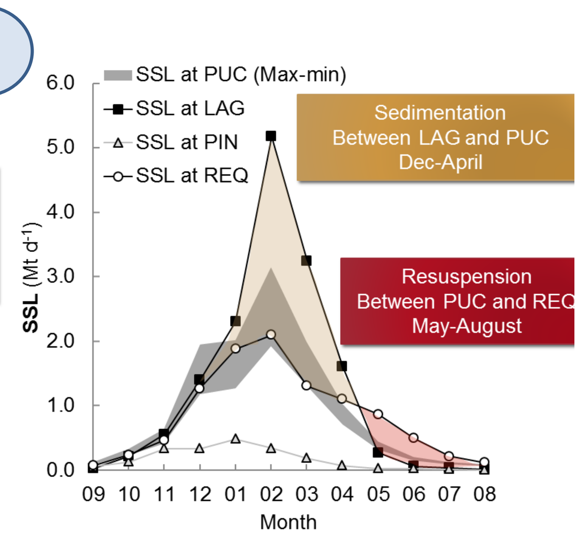

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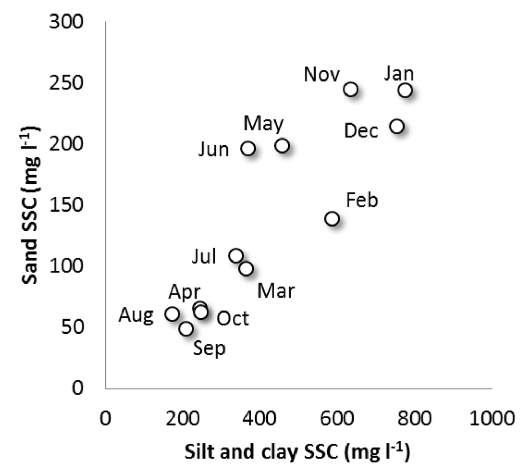
Relationship between Sand concentration and fine sediment concentration (silt + clay)



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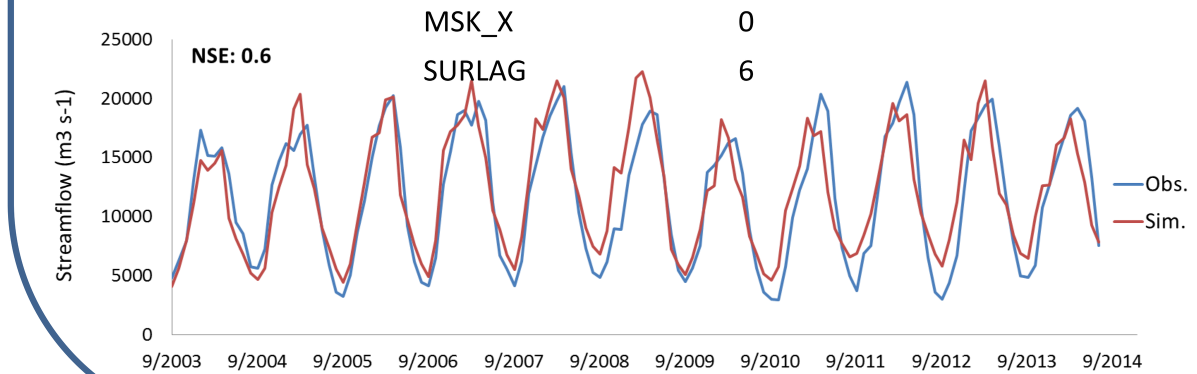
First run



Parameter values (Basin)	
MSK_CO1	10
MSK_CO2	0.1
MSK_X	0
SURLAG	6

Parameters values (floodplain's HRUs)	
GW_DELAY	60 days
ALPHA_BF	0.1
GWQMN	0.01
REVAPMN	1000 mm
OV_N	0.01
CN	60
CH_N2	0.016

Next steps

In this first simulation, we used the Global Weather Data for SWAT, because SENAMHI weather data set needs to be checked before to use. It could be a first source of error. Evapotranspiration values could be wrong too and need to be assessed with more accuracy. Having established a robust weather base, we propose to check the ability of the model in calculate the channel and floodplain characteristics for water routing. After this, the study will aim to improve the routing of flow rates in the floodplain by adapting the Muskingum method implanted in the model to the Amazon rivers or creating a "full hydrodynamic model" module (Paiva et al., 2011, 2012).

Finally, we will check the ability of the model to predict basin erosion and sediment transport in a daily time step.

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