Modelling the hydrological response of a small Mediterranean forested catchment: exploring the potential influence of the riparian-stream connection

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Mediterranean catchments

- ***Characteristics:***

  - ✓ Share hydrological processes from both ***wet*** and ***dry*** environments
  - ✓ Large range of weather conditions that lead to a ***complex*** stream ***hydrology***
  - ✓ ***High variability*** in the annual water balance
  - ✓ ***Seasonal pattern*** in hydrological behaviour:

CRITICAL POINT!

Transition period

- Long summer ***dry period*** → Switching behaviour of the permanent saturated zone. *(Gallart et al., 2002; Marc et al., 2001; Piñol et al., 1997)*
- ***Wetting-up*** period → Appearence of a perched water table quite fast draining. *(Burch et al.1987; Ocampo et al., 2006; Taha et al., 1997)*
- Autumn/winter ***wet period*** → Recharge of the deeper saturated areas. *(Butterworth et al., 1999; Pilgrim et al., 1997)*

Mediterranean catchments

Concepts and ideas developed by modellers for humid climate usually fail when applied to semi-arid regions and lead in many cases to unsatisfactory results

(Bernal et al., 2004; Bonell, 1993; Latron et al.; 2003,Pilgrim et al., 1988)

The challange of this study was to improve the representation and understanding of flow processes in Mediterranean catchments with special attention to the transition period

- ✓ Hydrological management of this critical areas
  (Chiew et al., 2002)
- ✓ Good prediction of geochemical and ecological responses
  (Schlesinger et al., 2006)

Study Site

The Fuirosos catchment (13 km²):

- ✓ is located in the ***North-East of Spain*** (latitude 41º42'N, longitude 2º34').

- ✓ is an ***almost pristine***, undisturbed forested catchment, which drains an intermittent stream. There is little agricultural activity and no urban areas.

Within the catchment there are ***four small reservoirs*** for human and cattle water supply.

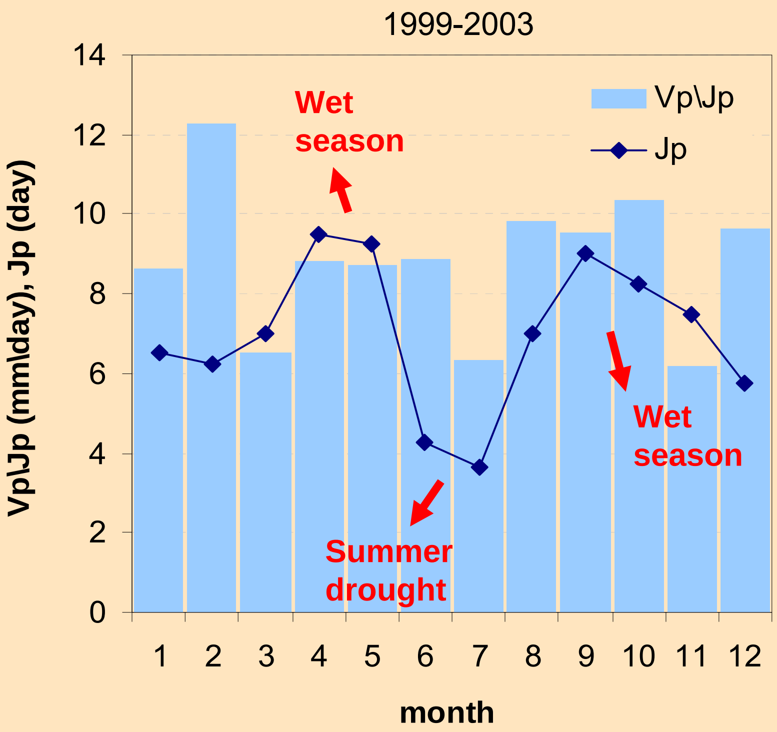
The main rock type is ***leucogranite*** (50.9%) followed by ***granodiorite*** (21.1%) and ***sericitic schists*** (23.5%). At the valley bottom there is an identifiable ***alluvial zone***, with a well developed ***riparian zone.***

The ***forest*** covers the 90% of the total cacthment area.

Study Site

General water balance analysis:

- ✓ Monthly mean temperature ranges from 3ºC in January to 24ºC in August *(Bernal et al., 2004)*
- ✓ Average annual **precipitation** is **750 mm** *(Ninyerola et al., 2000)*, and the annual average **number of rainy days** is **81** (P≥4 mm)



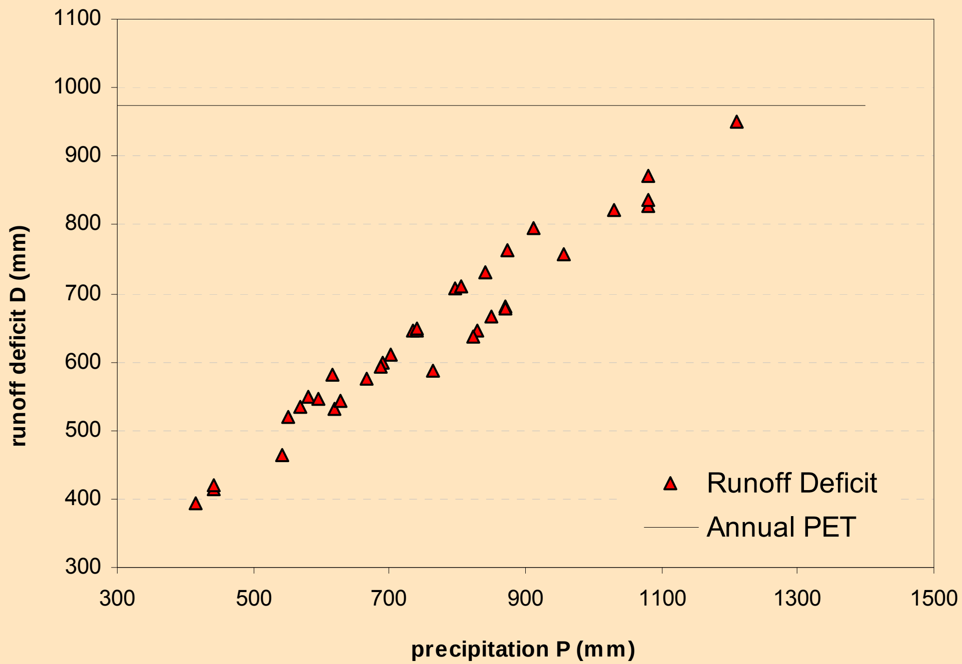
Jp : monthly number of rainy days

Vp\Jp : total precipitation per rainy days

There are two identifiable ***wet periods***: one during ***spring*** and the other during ***autumn;*** and a ***summer drought***.

General water balance analysis:

- ✓ Average annual potential evapotranspiration (**PET**) is approximately **975 mm**, according to the Penman Method
- ✓ The average annual runoff deficit (D) is approximately **640 mm**, with a **Q/P** coefficient of **15%**



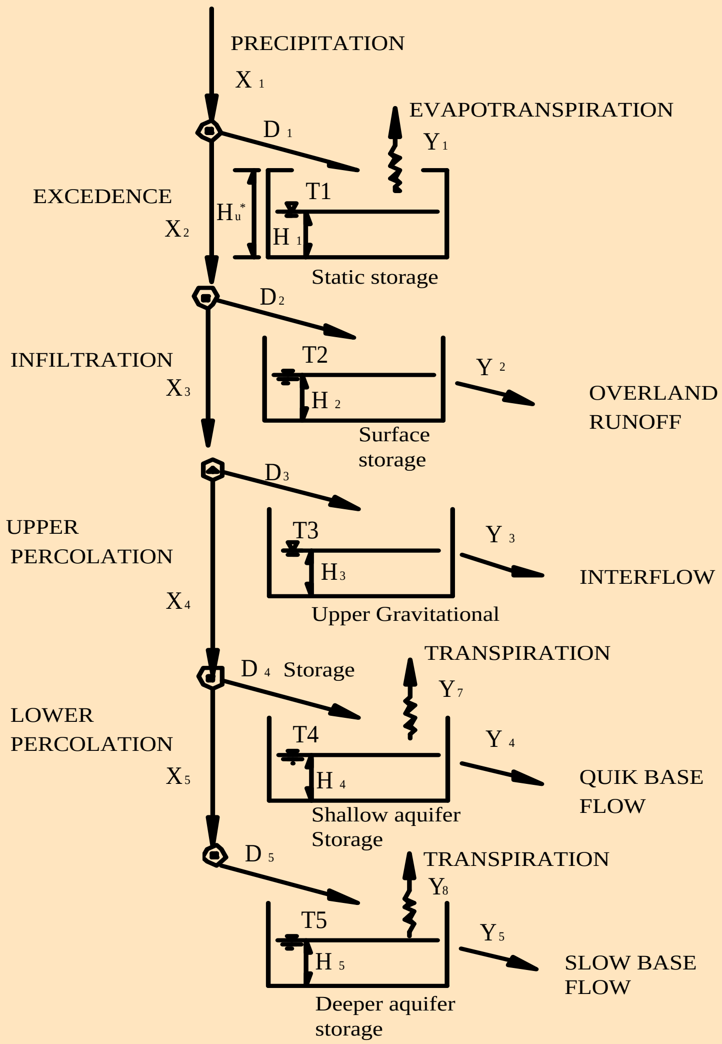
The graph points out that the ***runoff deficit*** can be basically related with ***evapotranspiration***, since the annual precipitation is lower than the evaporative demand.

Water supply in the wettest year is still not enough to satisfay the PET.

NO REASONS TO CONSIDER GROUNDWATER OUTFLOW!! → Bedrock characteristics also support this hypothesis

Model descripion

SD4 : Semidistributed 4-response Model



1. *Static tank*: Initial abstractions and water retained by capillary force

$$D_1(t)=\min\left\{X_1(t)\cdot\left(1-\frac{H_1(t)}{H_u^*}\right)^2;H_u^*-H_1(t)\right\}$$

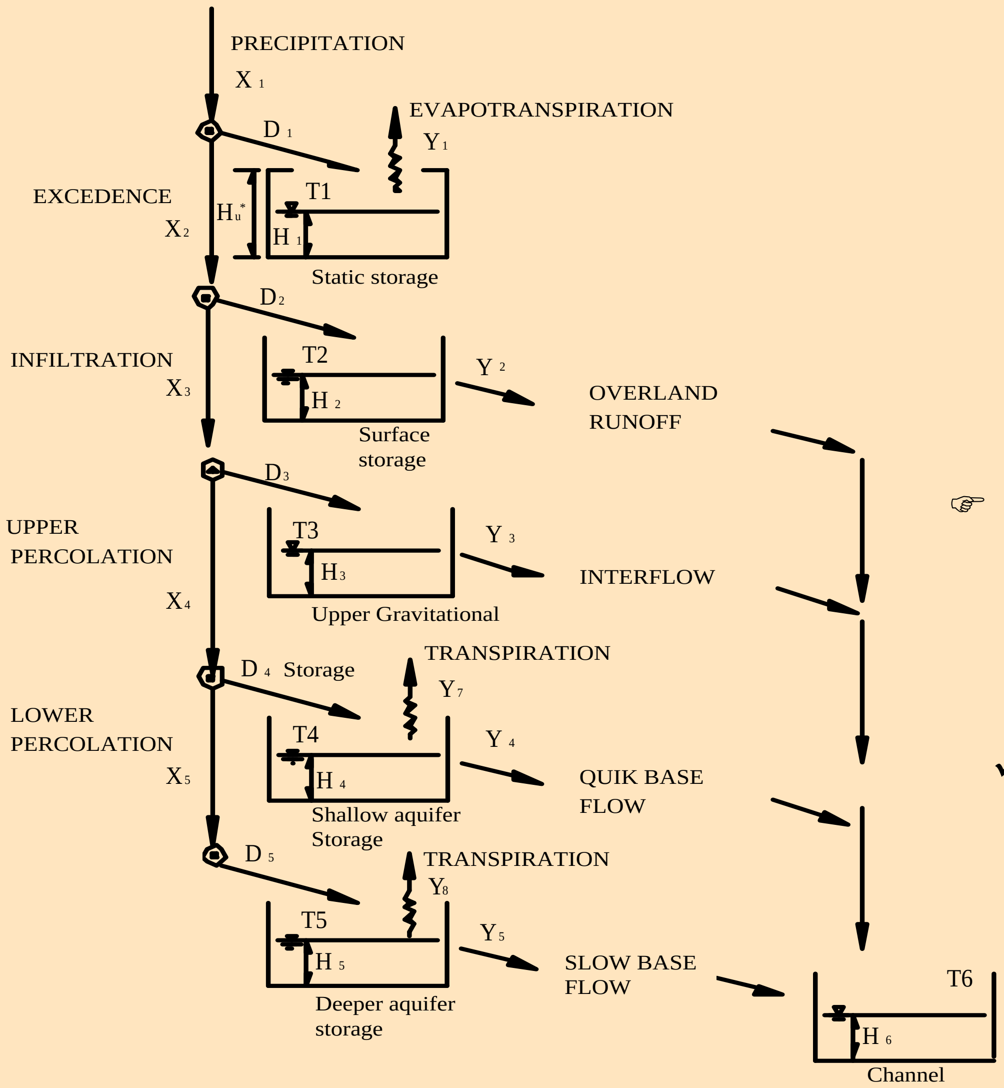
$$Y_1(t)=\min\left\{ET_p(t)\cdot FC\cdot\lambda(m)_{m=1,\dots,12}\cdot\delta(m)_{m=1,\dots,12};H_1(t)\right\}$$

$$Y_{i=2,\dots,5}(t)=\frac{H_{i=2,\dots,5}(t)}{t_{i=1,\dots,4}}$$

2. *Surface tank:* Water flowing over the surface or into the organic *horizon O*, as *overland flow.*
3. *Gravitational tank:* Water flowing into a soil-gravel layer, *horizon A*, as *interflow*.
4. *Shallow aquifer:* This tank represents a perched aquifer that may appear in the upper weathered bedrock layer, *horizon B*. The flow that is released from it, is thought to be a key process during the wetting-up period.

Model descripion

SD4 : Semidistributed 4-response Model



5. *Deep aquifer:* Represents the permanent saturated zone into a deeper weathered bedrock layer. It is thought to be constitued by several bedrock depressions which may exert a significant control on water mobility.

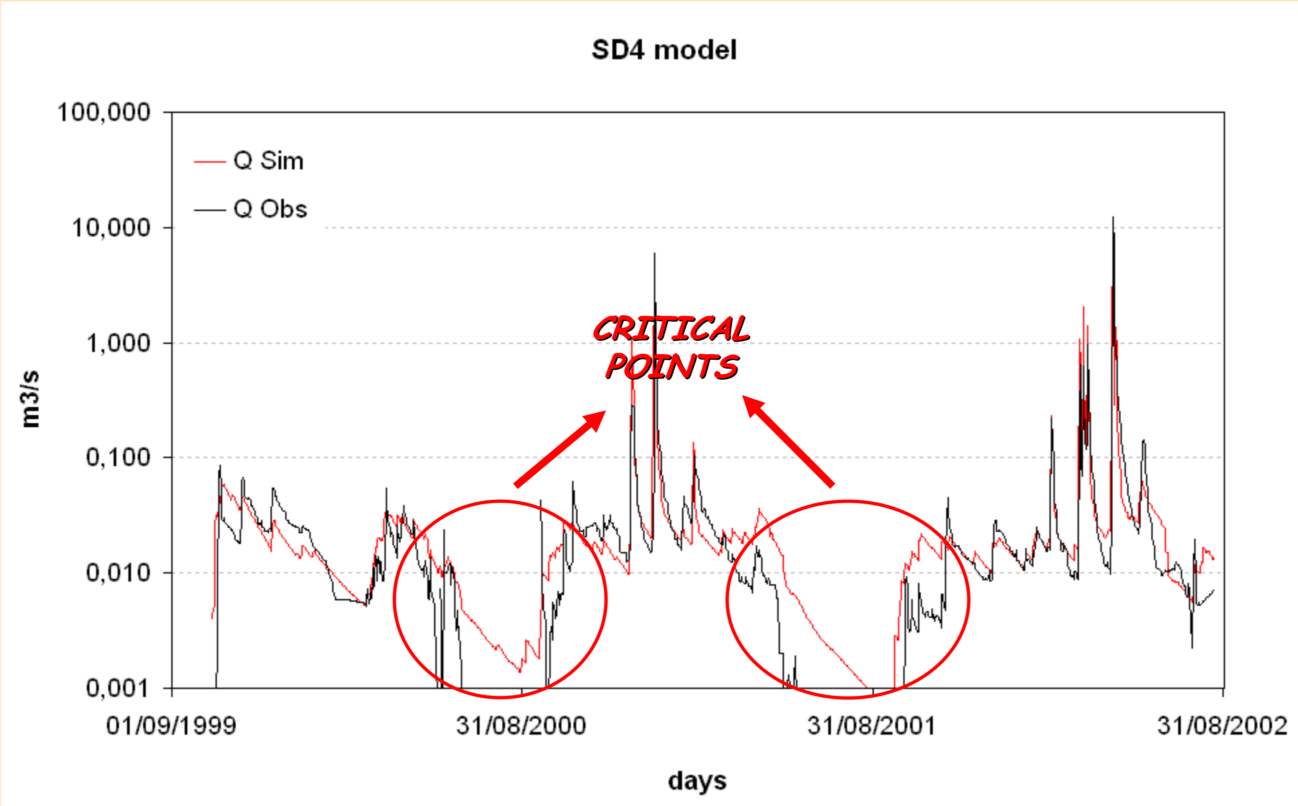
$$Y_{i=2,..,5}(t) = \frac{H_{i=2,..,5}(t)}{t_{i=1,..,4}}$$

☞ Both aquifers are thought to be accesible by the root system.

✓ Conceptual scheme for each HRU

✓ All the tanks are described as linear storages and drain directly to the stream tank

Results with the SD4 Model



Nash Index: 0.77

Total balance Vol. Err. : 4.6%

N. of days with Sim. Q < 0,001 m^3/s : 28

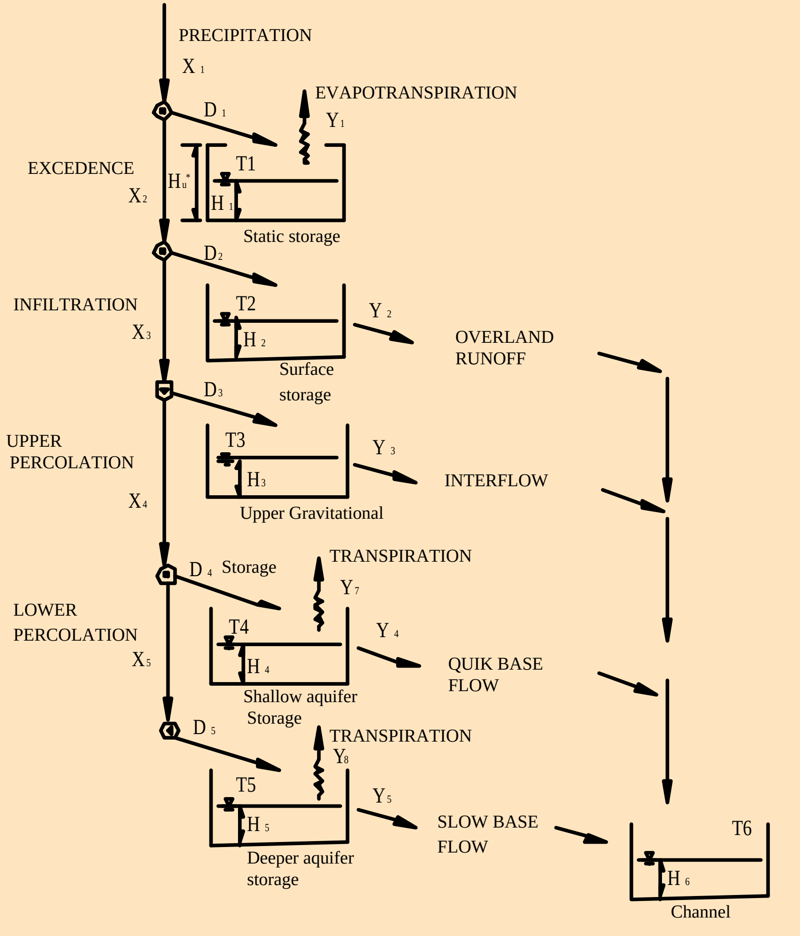
Sim. Peak: 8.7 m^3/s

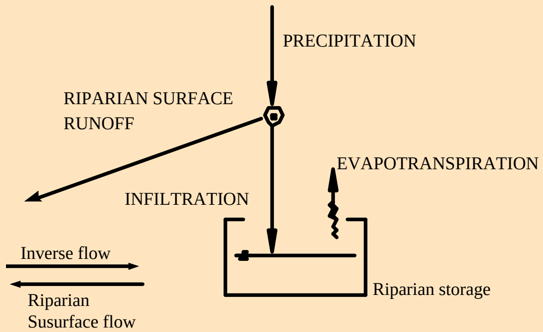
Obs. Peak: 10.9 m^3/s

N. of days with Obs. Q < 0,001 m3/s : 220

Model description

SD4-R : Semidistributed 4-response Model plus a riparian tank

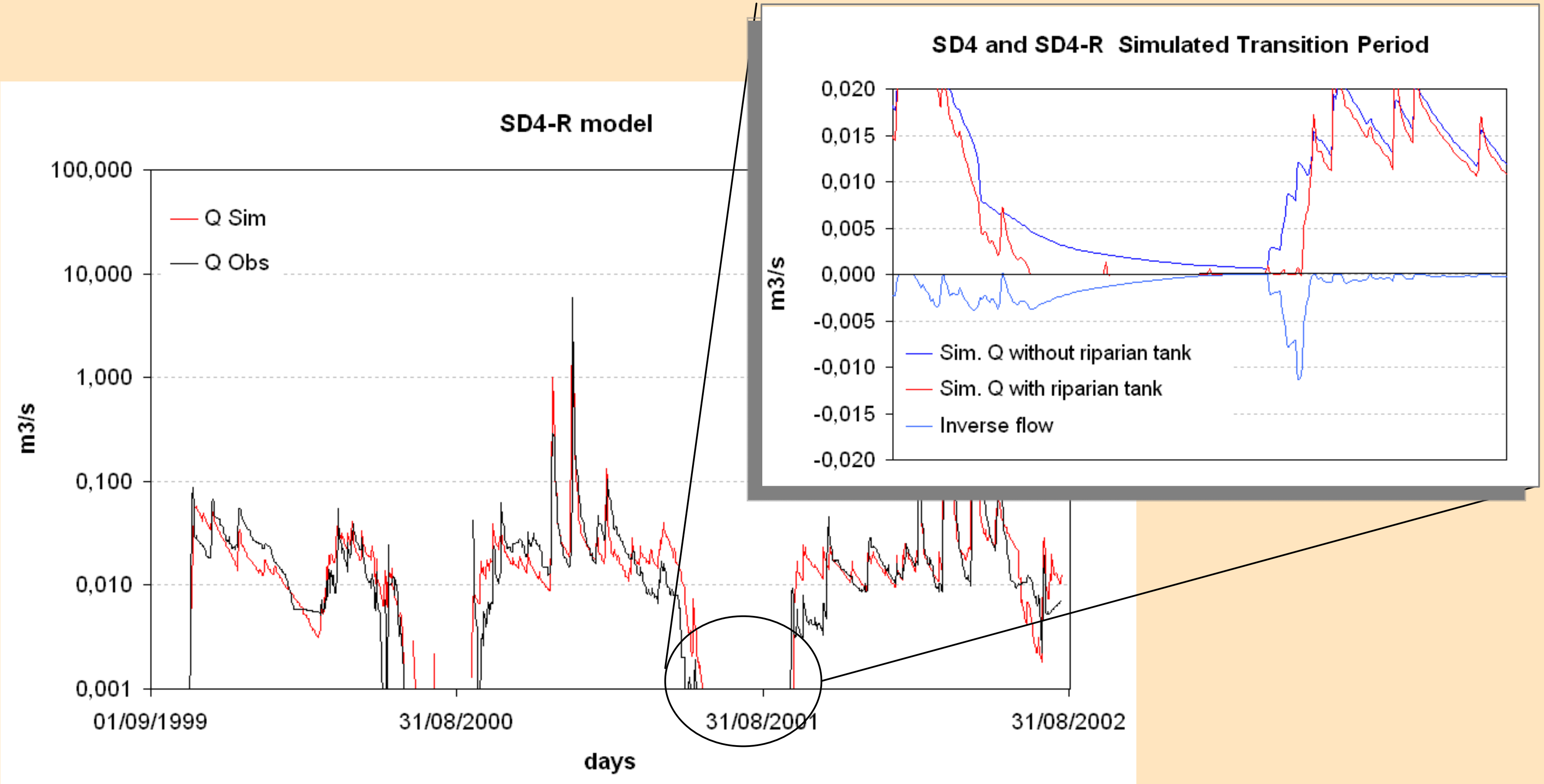




✓ Exchanges of water are generated accordign to the difference between the river stage (d) and the riparian gruondwater head (e), the hydraulic conductivity and the effective porosity of the soil.

$$F_{d,i} = \pm K_r \cdot \left(\frac{e-d}{m} \right) \cdot (2 \cdot f \cdot c)$$

Results with the SD4-R Model

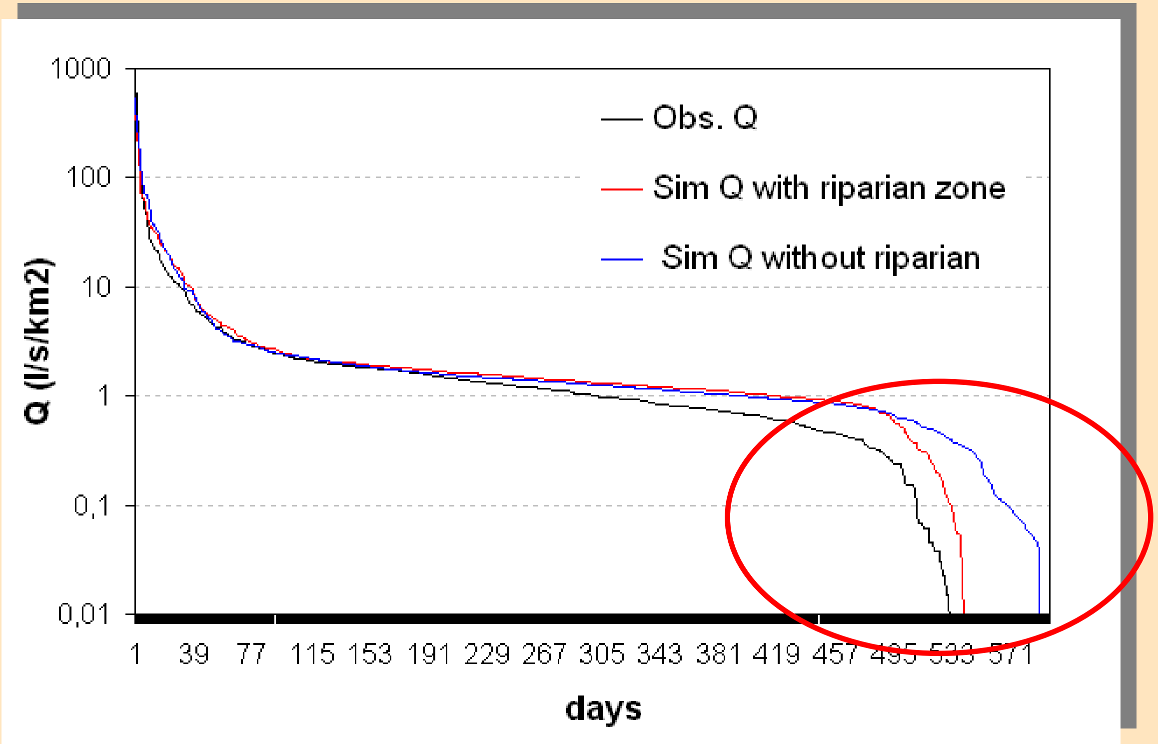


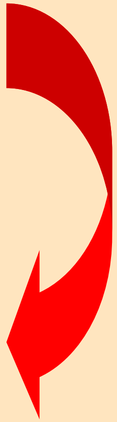
Nash Index:	0.76
Sim. Peak:	8.5 m^3/s
Obs. Peak:	10.9 m^3/s
Total balance Vol. Err. :	-0.3%

N. of days with Obs Q < 0,001 m^3/s : 220

N. of days with Sim Q < 0,001 m^3/s : 193

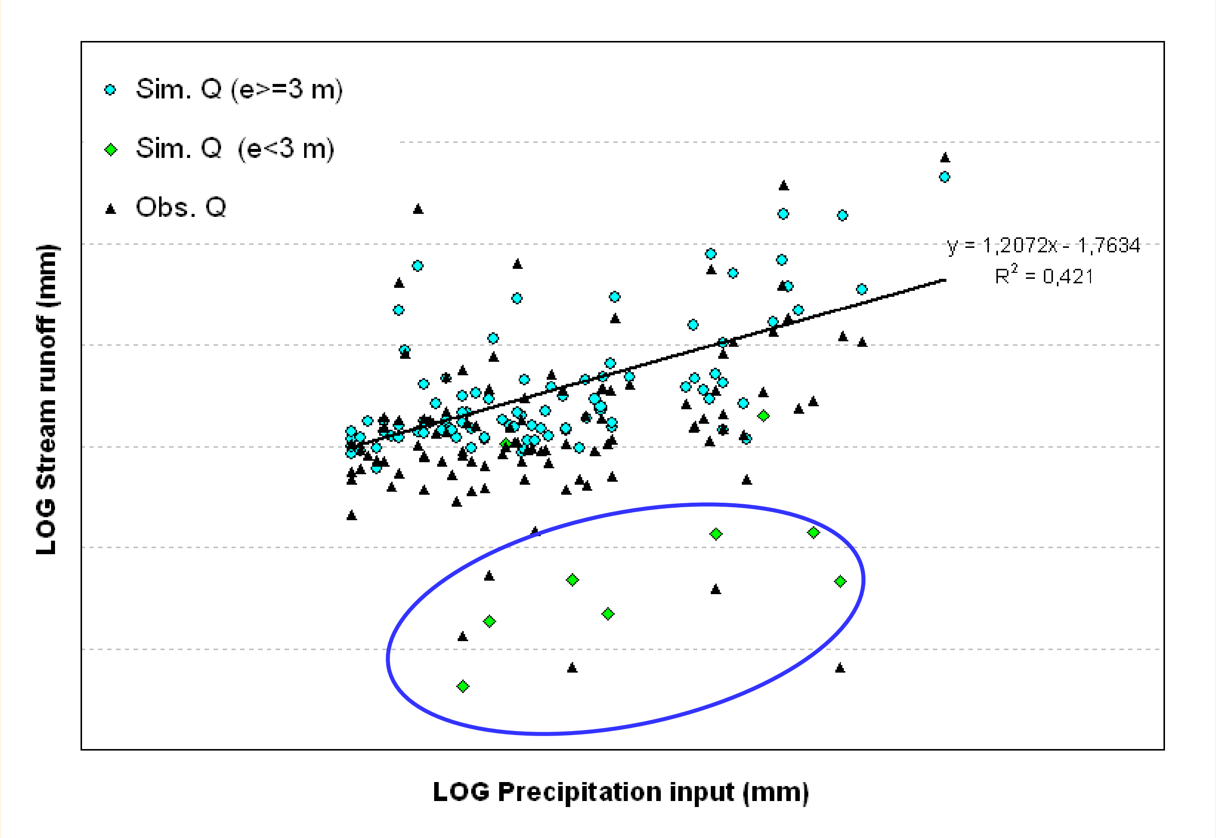
Results Analysis





Riparian Zone effect on low flow

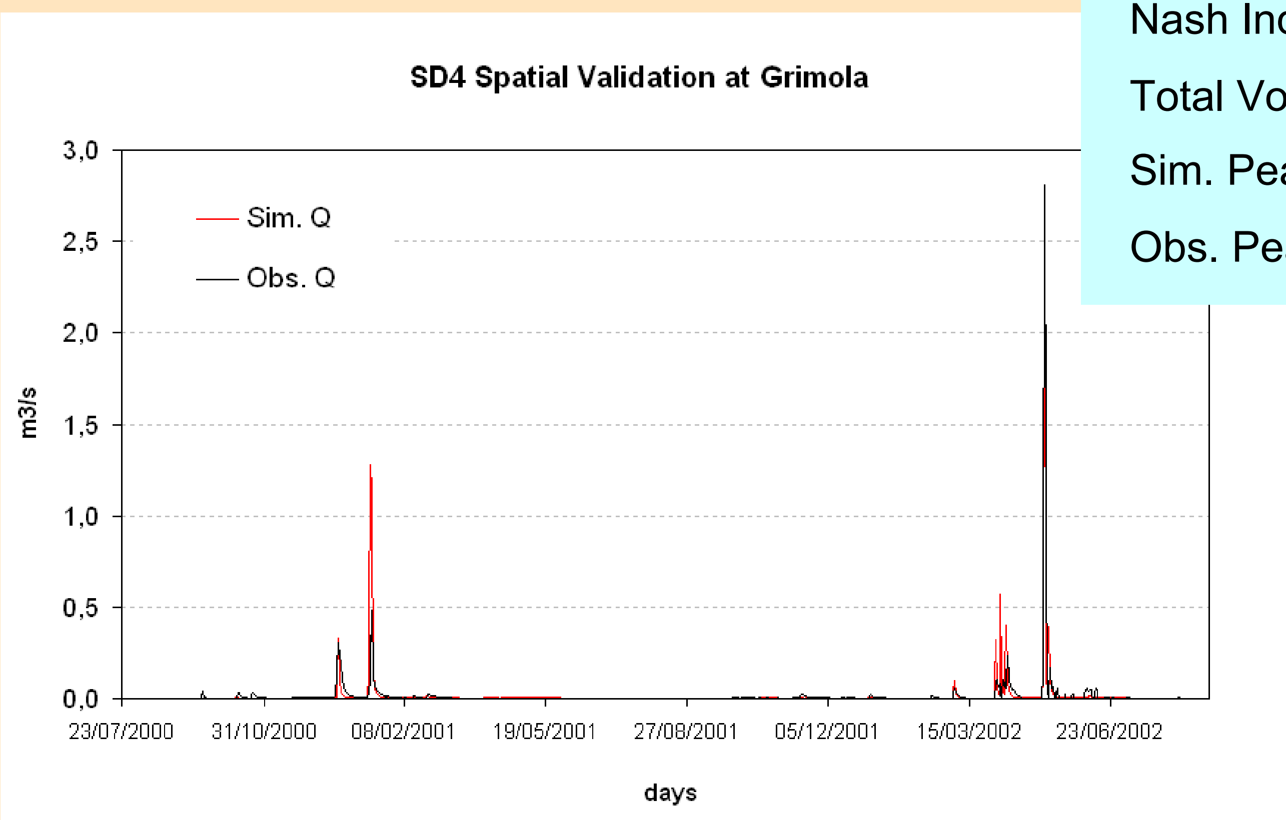
Results Analysis



Water availability in the riparian area affects the relationship between rainfall inputs and stream runoff.

Stream runoff and the rainfall input get better correlated only after riparian groundwater store raises its water table level above the streambed

Spatial Validation



Nash Index: 0.77

Total Vol. Err. : 4.6%

Sim. Peak: 2.5 m3/s

Obs. Peak: 2.8 m3/s

N. of days with Obs Q < 0,001 m^3/s : 82

N. of days with Sim Q < 0,001 m^3/s : 75

There is *no need* of an additional *transpiration mechanism* to simulate the transition period!

✓ Temporal validation had similar performance

Conclusions

- Models developed for humid climate can not capture the characteristic ***inter-annual*** and ***intra-annual variability*** of Mediterranean catchments.

- The ***transition period*** from dry to wet condition has been noted as a ***critical point*** to be reproduce by available rainfall-runoff models.

- In the analysis of an ***intermittent stream*** the riparian zone may represent an ***important mechanism*** to explain the transition period.

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