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Application of a conceptual distributed dynamic vegetation model to a semi-arid basin, SE of Spain

By:

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Research framework

- **Dynamic vegetation modelling in semi-arid climate**

  - Dynamic modelling because there is a dynamic interaction between soil, vegetation and atmosphere. At least 1 vegetation related variable is a state variable.

  - Semiarid regions receive precipitation (≈ 200 – 400 mm p.a.) below potential evapotranspiration (Köppen climate classification) → water is the limiting factor

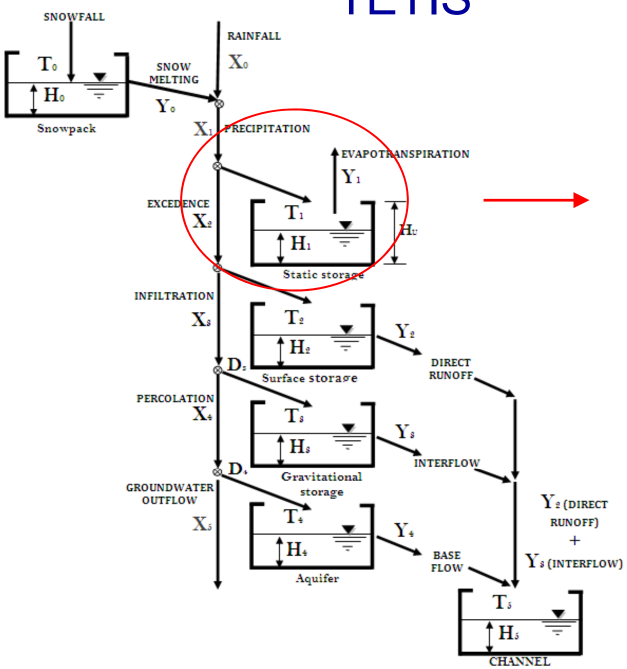
Introduction

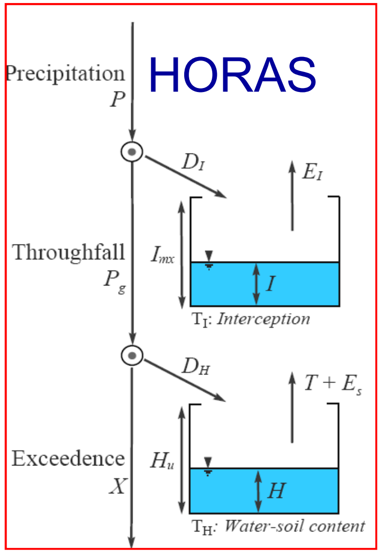
- **Insolation**
  - ➢ Controls ET and consequently soil moisture
  - ➢ Depends on:
    - - Solar radiation: Latitude, time (hour/month)
    - - DEM: slope, orientation and topographic shadows (north/south slopes)
- **NDVI**
  - ➢ Numerical indicator of surface “greenness” calculated using remote sensing measurements

Model: TETIS-VEG

- **TETIS** (Francés et al., J. of Hydrol., 2007) : conceptual distributed hydrol. model
- **HORAS** (Quevedo and Francés, HESS, 2009): conceptual dynamic natural vegetation model for arid and semiarid zones

TETIS





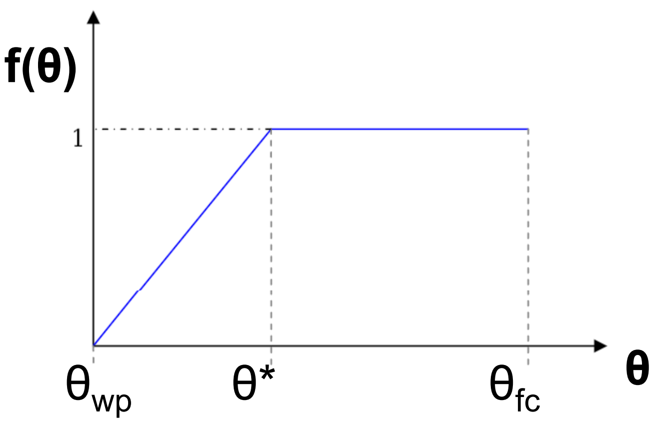
- State variables:
  - **6** for rainfall-runoff model
  - **R**: relative leaf biomass for vegetation model
- Parameters:
  - **8** for rainfall-runoff model
  - **6** for vegetation model

Vegetation state variable

- The state variable **R** is equivalent to FAO crop coefficient (Allen et al., 1998) but not fixed in time

$$\boxed{T = ETP \cdot R \cdot f(\theta)}$$

If water and energy are available



θ_{wp} : soil moisture at wilting point
θ^*: critical soil moisture
θ_{fc}: soil moisture at field capacity

- Model is based on the hypothesis:

↑ insolation → ↑ transpiration → ↓ soil moisture → ↓ biomass

Negative feedback

Dynamic vegetation equations

- R ranges between 0 and 1
- R=1 when vegetation transpiration is at its potential

- Original eq.

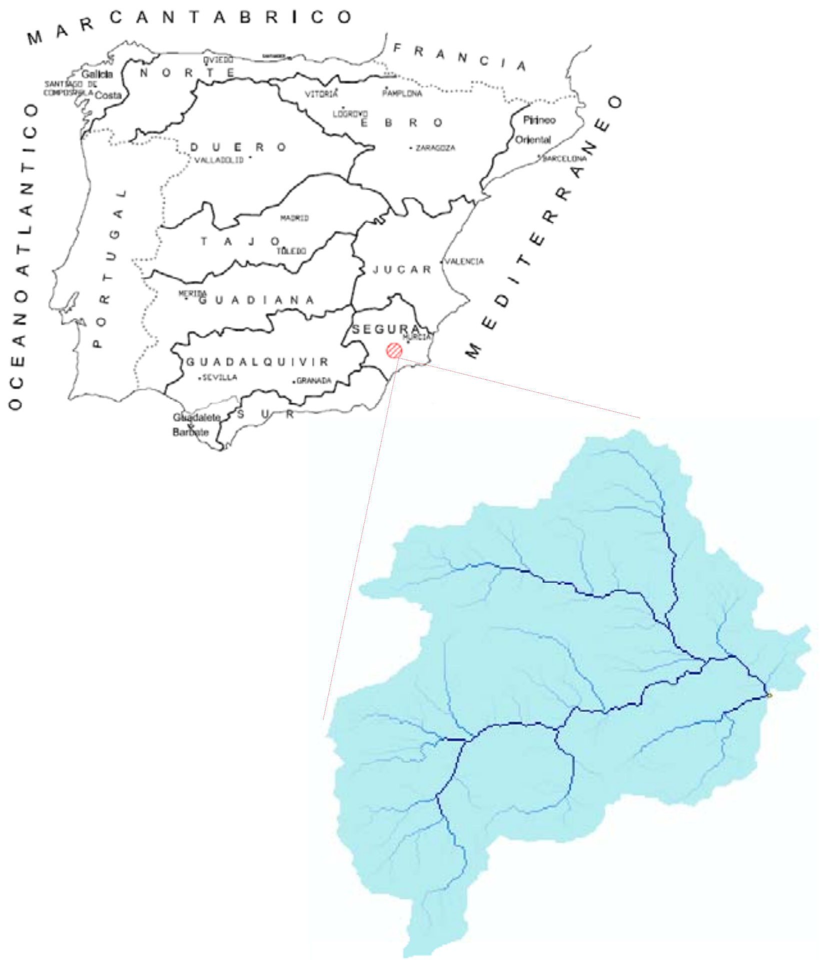
$$\frac{dR}{dt} = \boxed{\alpha\left(\frac{T}{T_{mx}}\right)^{c}}\boxed{-k_{nat}R - k_{ws}\zeta^{q}R}$$

- Logistic-type eq.

$$\frac{dR}{dt} = \boxed{\alpha\left(\frac{T}{T_{mx}}\right)^{c}(1-R)^{a}}\boxed{-k_{nat}R - k_{ws}\zeta^{q}R}$$

Parameter	Description
α [d^{-1}]	Ratio between maximum net assimilation carbon and potential leaf biomass
T_{mx} [mm d^{-1}]	Maximum transpiration rate
c [-]	Shape exponent
k_{nat} [d^{-1}]	Seasonal leaf shedding
k_{ws} [d^{-1}]	Leaf shedding due to water stress
q [-]	Nonlinearity effect exponent
a [-]	Logistic equation exponent

Study site: Valdeinfierno catchment (Spain)

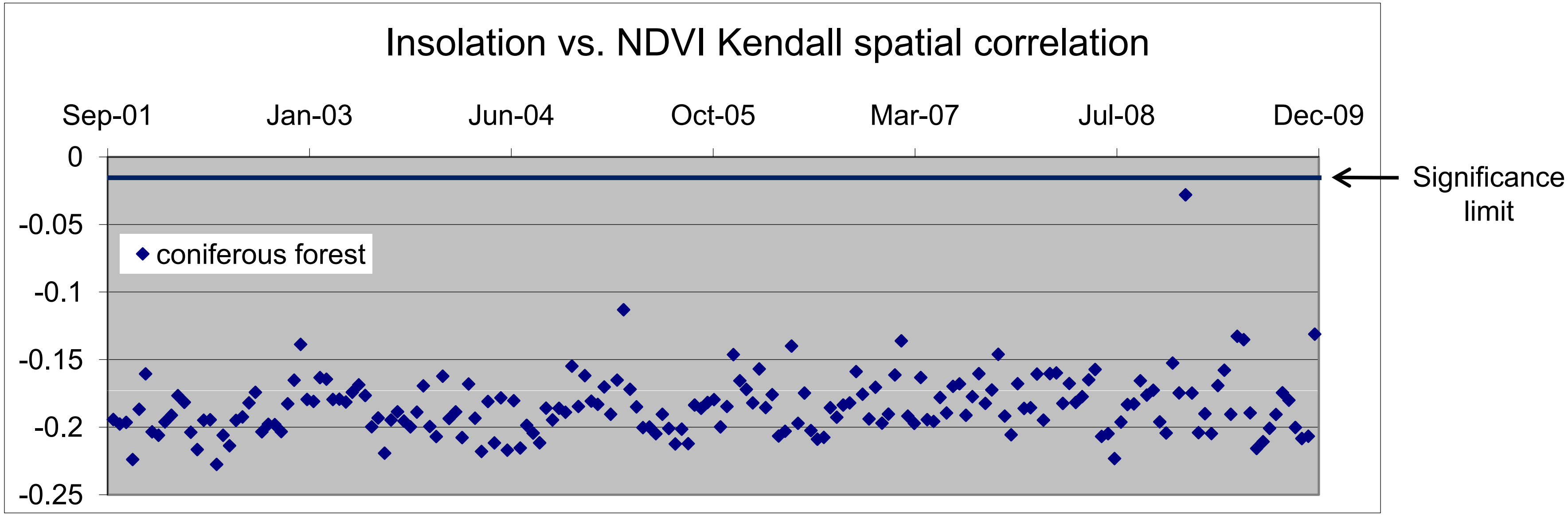


- Catchment area: 440 km^2
- Semi-arid climate $\begin{bmatrix} ETP = 1180 \text{ mm} \\ P = 330 \text{ mm} \end{bmatrix}$
- Intermittent stream
- Natural cover 60%:
  - Coniferous forest (Pines) 32.7%
  - Shrubland 9.1%
  - Mixed forest/shrubland 18.2%

NDVI vs. insolation correlation

- 8 years of MODIS NDVI images (250m, 16days) were analyzed
- A negative and statistically significant ($p<0.025$) spatial correlation was found between NDVI and insolation for coniferous forest zones
- Shrublands and mixed forest/shrubland zones did not show the same behaviour (González-Hidalgo et al., 1996)

NDVI vs. insolation correlation



We are going to concentrate on pine forest zones

Objectives

- Explain the behaviour shown by pine cover (negative correlation between insolation and NDVI)

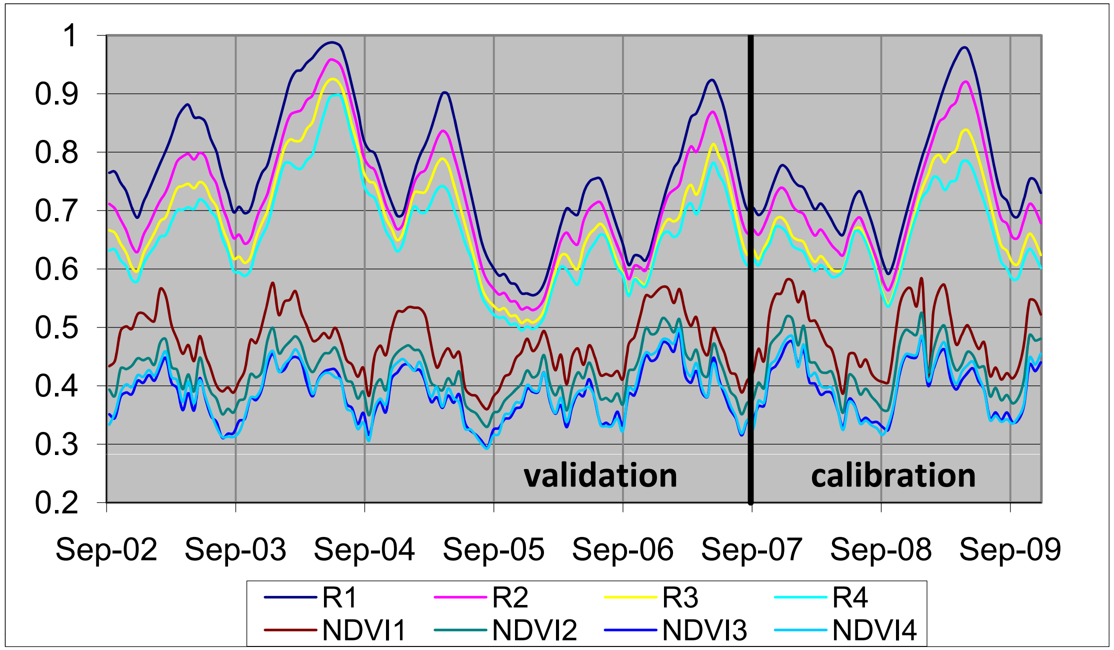
- Compare the logistic type equation with the non-logistic type one

Methodology

- MODIS NDVI images were used to **calibrate** and **test** the vegetation models
  - NDVI measures the “greennes”, R measures the transpiration capability respect to potential one
  - Calibration to maximize NDVI vs. R correlation
- Surface was divided into **4 classes**, based on received insolation
  - 1^{st} class ≈ north slope; ... ; 4^{th} class ≈ south slope
  - Conceptual model: cannot reproduce with precision phenomena at cell scale

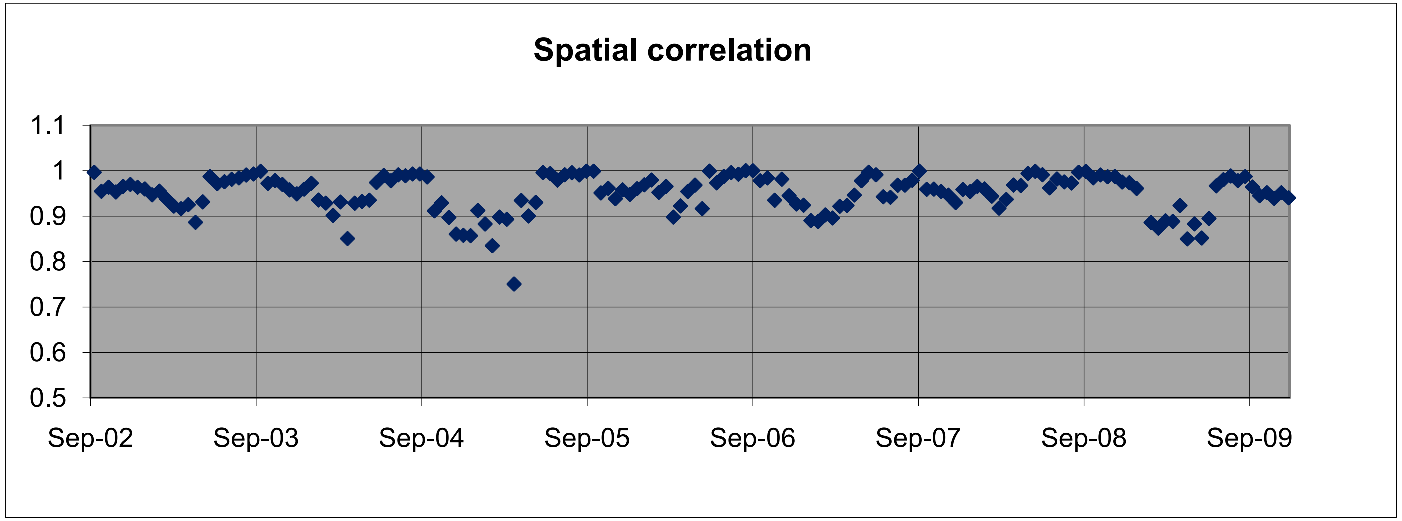
Non-logistic eq.: time correlation

- R vs. NDVI Pearson time correlation of the 4 classes
  - Calibration: 0.31; 0.41; 0.46; 0.48
  - Validation: 0.20; 0.29; 0.30; 0.26
- Delay in R evolution with respect to NDVI



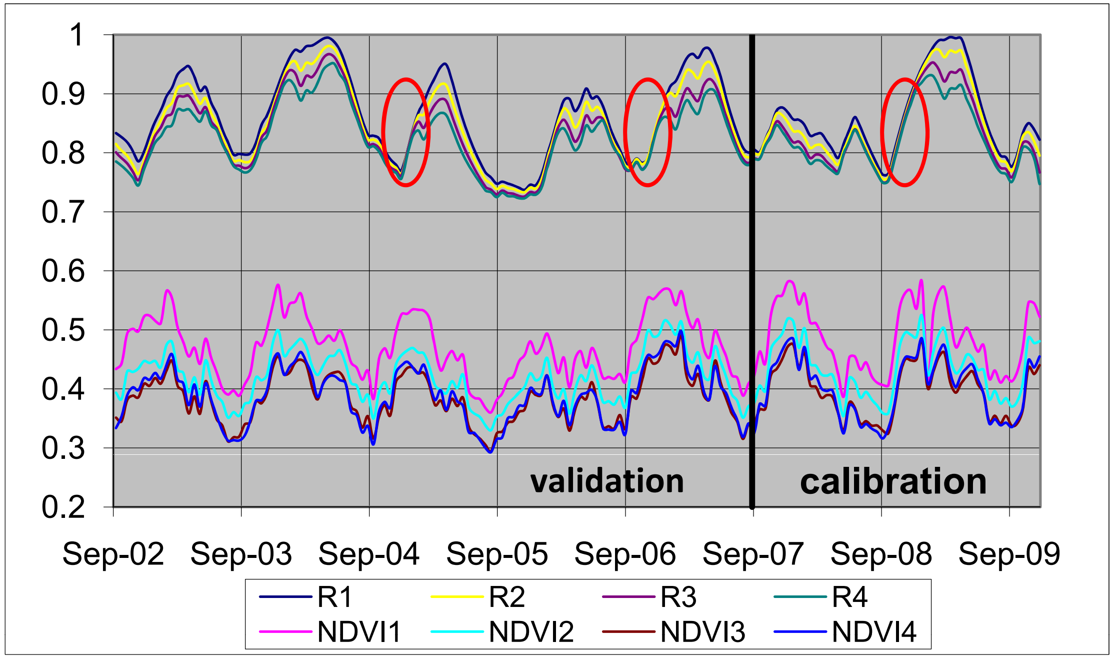
Non-logistic eq.: spatial correlation

- Considering the 4 classes as 4 cells and analyzing the R vs. NDVI spatial correlation:
  - Average correlation 0.95
  - Separation between the 4 curves is very similar for R and NDVI



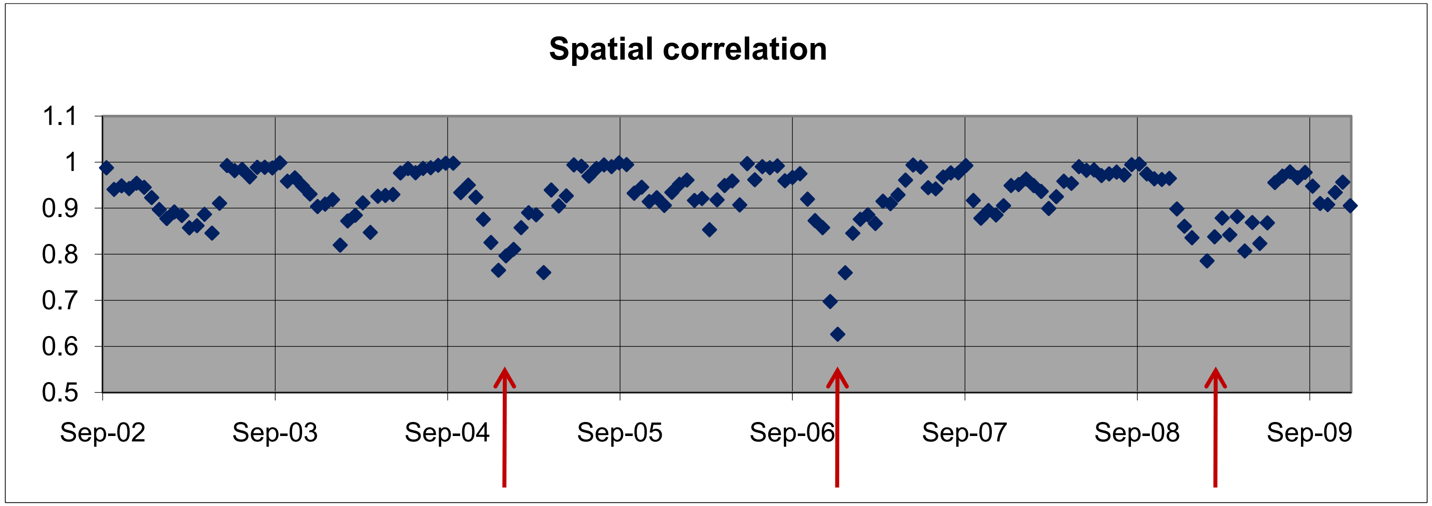
Logistic-type eq.: time correlation

- R vs. NDVI Pearson time correlation of the 4 classes
  - Calibration: 0.51; 0.56; 0.59; 0.56
  - Validation: 0.40; 0.49; 0.52; 0.48
- Lower delay and only in 2004 and 2005



Logistic-type eq.: spatial correlation

- Considering the 4 classes as 4 cells and analyzing the R vs. NDVI spatial correlation:
  - Average correlation 0.93
  - Separation between the 4 R curves tends to disappear particularly in rising limbs



Conclusions

- Both equations show a satisfactory reproduction of NDVI dynamic

- Non-logistic equation:
  - good representation of spatial vegetation variability
  - shows a delay of R evolution with respect to NDVI; that may be explainable if transpiration were shown to present the same delay

- Logistic-type equation:
  - lower delay shown => better time variability reproduction
  - worse representation of spatial vegetation variability

Future research lines

- Considering that:
  - NDVI and R are not the same variable
  - R measures actual transpiration with respect to potential one
  - Eq.1 shows a delay of R with respect to NDVI

Analysis of real ET (satellite) is needed to understand if this delay is physically explainable or not.

- Further sites will be analyzed to determine which equation represents better vegetation dynamics.

Thank you for your attention