Mediterranean vegetation-water interactions: a model comparison at different complexity levels

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Introduction

- **The vegetation plays a key role** in the catchment's water balance, particularly in Mediterranean areas (Laio et al., 2001)
- In these water-controlled areas, the vegetation controls the water cycle through (Rodriguez-Iturbe et al., 2001):
  - Interception
  - Infiltration
  - **Evapotranspiration**
  - Surface runoff
  - Consequently, groundwater recharge

Introduction

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- In these water-controlled areas, the vegetation controls the water cycle through (Rodriguez-Iturbe et al., 2001)
- In some Mediterranean regions, the evapotranspiration may account for **more than 90%** of the precipitation → The proper knowledge of this process is vital (Andersen, 2008)
  - Question: static vegetation will reproduce properly Water Cycle in future Climate Change scenarios with different temperature and precipitation?

Introduction

- Traditionally, very few hydrological models had incorporated the **vegetation dynamics**
- But, in the last decades, the number of hydrological models taking into account the vegetation development has increased substantially

COMPLEX MODELS	SIMPLE MODELS
➢ Accurate description of the processes ➢ Sensation of total reliability ➢ High number of parameters ➢ High data requeriment	➢ Processes are schematized ➢ Low number of parameters ➢ Lower data requirement + Remote Sensing Data

Research questions

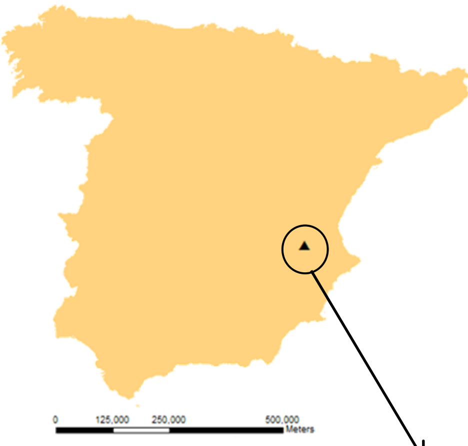
- Is a parsimonious and simple model **suitable** to reproduce water cycle and vegetation dynamics in semi-arid environments?
  - Present conditions
  - Future climate

- Can **satellite data be used** as an alternative source of information for model implementation (calibration and validation) when field data is not available?

Methodology/outline

- Description of the case study:
  - Study area: experimental plot in La Hunde forest (East Spain)
  - Parsimonious vegetation model (LUE-Model)
  - Complex vegetation model with successful results in the study area (Biome-BGC)
- Implementation of both models:
  - LUE Model: with only NDVI (satellite information)
  - Biome-BGC: with field data
- Analysis of results and conclusions

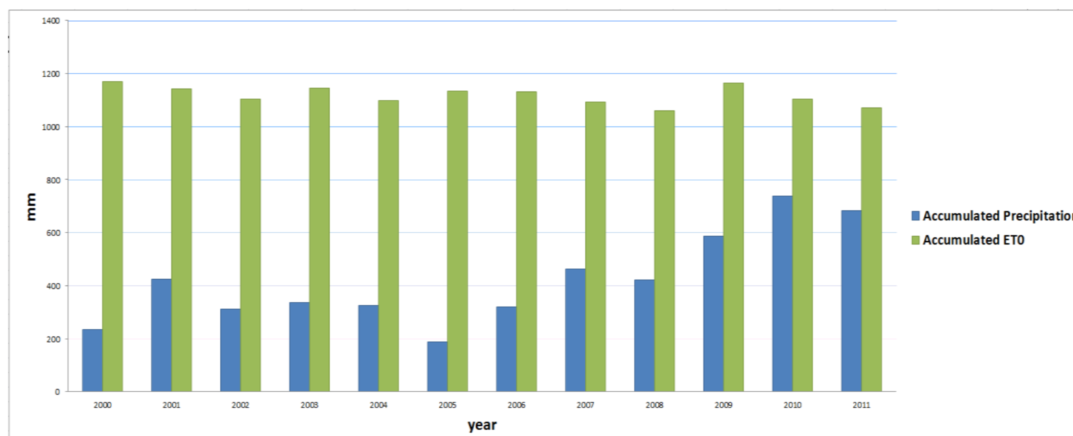
Study Area



Experimental plot location

- Mediterranean semiarid climate:
  - Water-controlled area
  - Strong annual seasonality
- Aleppo pine

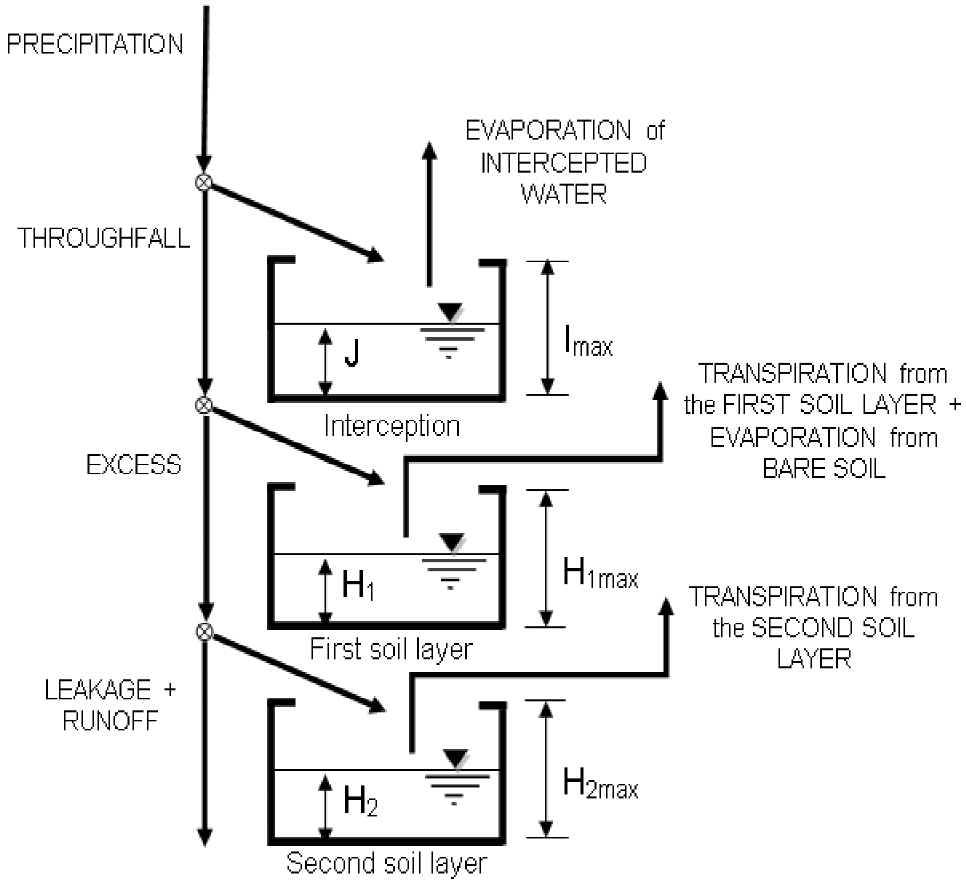
Mean annual **precipitation:** 419mm
Mean annual **ET_0**: 1,118mm



LUE model

Hydrological sub-model

Quevedo and Francés (2012)



Water balance

Interception storage

$$\frac{dJ}{dt} = I - \min\left(ET_o \cdot f_t, J\right)$$

First soil layer

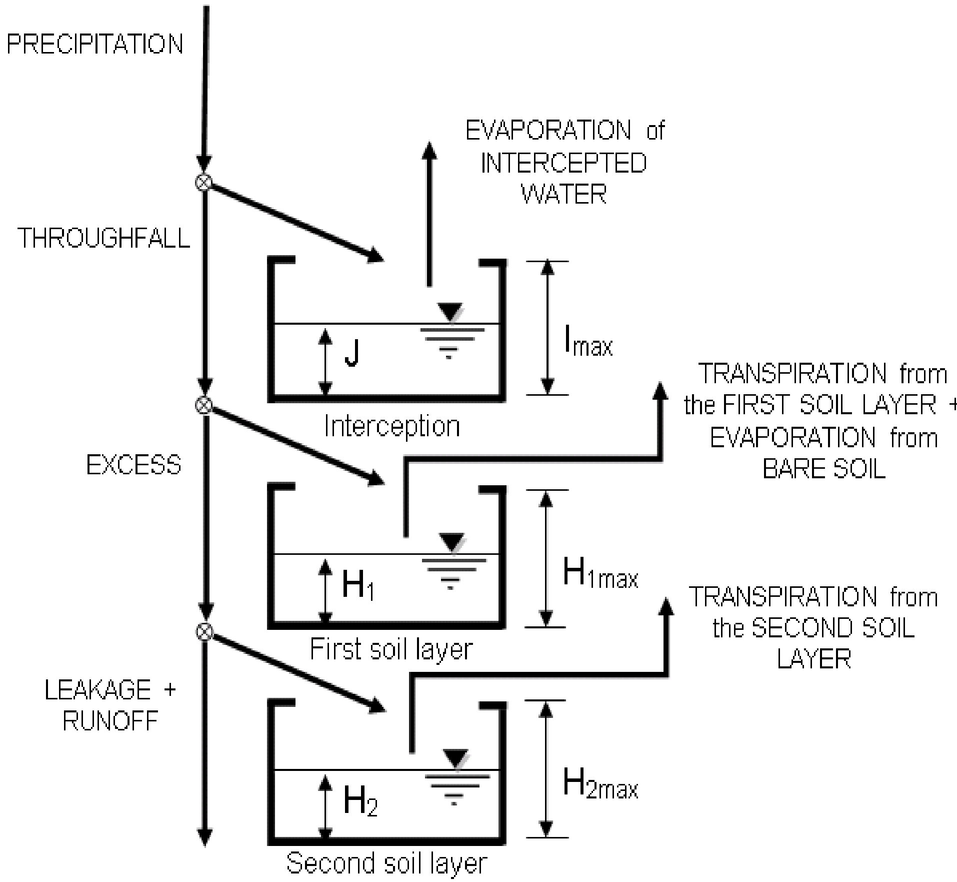
$$\frac{dH_1}{dt} = \left(P - I\right) - D - E - T_1$$

Second soil layer

$$\frac{dH_2}{dt} = D - L - T_2$$

LUE model

Hydrological sub-model



Transpiration

FAO: $$\left[T = ET_o \cdot \lambda_v \cdot \lambda_s \right]$$

$$T_1 = ET_o \cdot f_t \cdot \min\left(LAI,1\right) \cdot \beta_t\left(H_1\right) \cdot r_1$$

$$T_2 = ET_o \cdot f_t \cdot \min\left(LAI,1\right) \cdot \beta_t\left(H_2\right) \cdot \left(1 - r_1\right)$$

Bare Soil Evaporation

$$E = ET_o \cdot f_b \cdot \beta_b\left(H_1\right)$$

LUE model

Dynamic Vegetation sub-model

Pasquato et al. (2014)

$$\frac{dB_l}{dt} = \left(LUE \cdot \varepsilon \cdot APAR - \mathrm{Re}\right) \cdot \varphi_l - \kappa_l \cdot B_l$$

$$\varphi = 1 - \frac{LAI}{LAI_{\max}}$$

LEAF BIOMASS

B_l [kg DM m^{-2} veg cover]

LIGHT USE EFFICIENCY

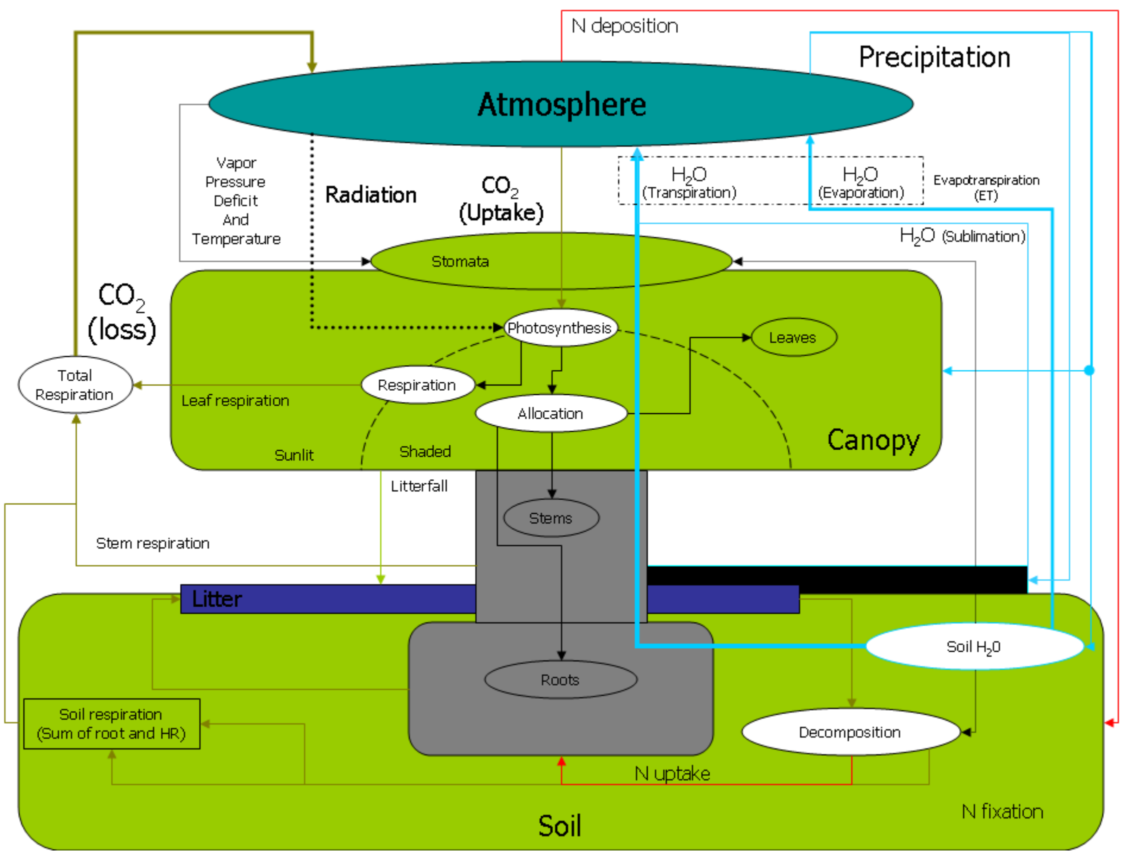
LUE [kg DM m^{-2} MJ^{-1}]

Stress factor ε depends on:

- Water Stress => connection with hydrological sub-model
- Temperature

$$LAI = B \cdot SLA \cdot f_t$$

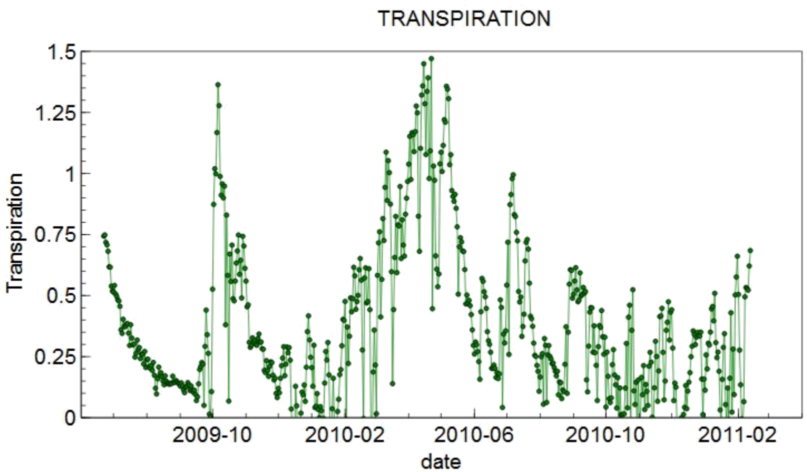
Biome-BGC model

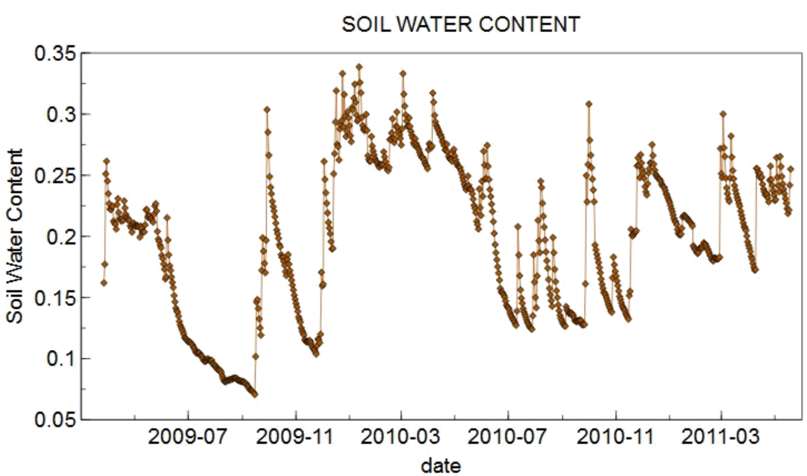


BIOME-BGC

- Complex physically-based model
- Oriented to individuals
- Source: Numerical Terradynamic Simulation Group. Montana University

Field data





TRANSPIRATION

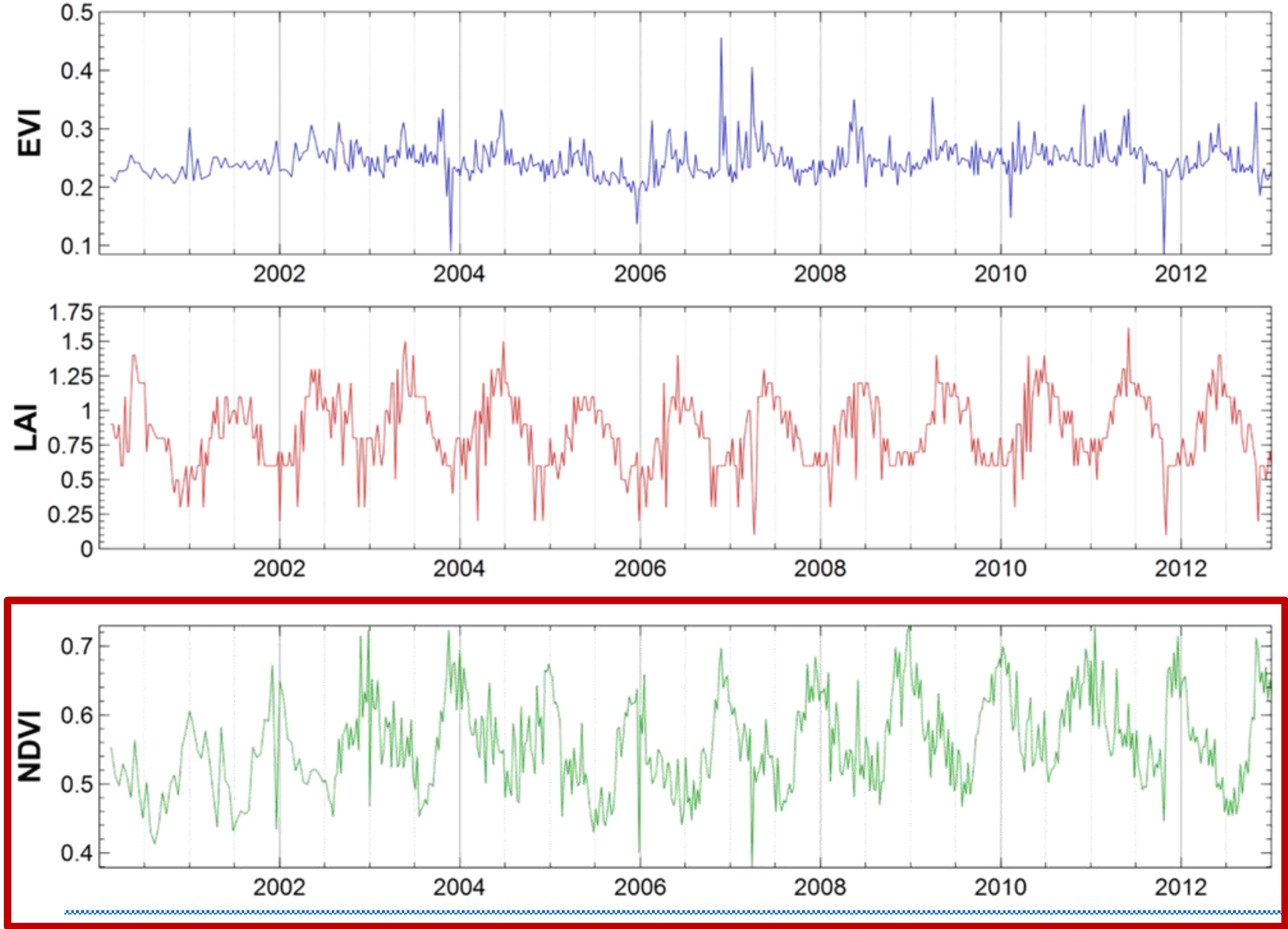
- Sap flow sensors → Heat-Ratio Method
- Three theoretical diameter classes

SOIL WATER CONTENT

- Soil Moisture sensors
- 30cm depth
- 9 sensors: 6 with tree's direct influence and 3 without

Satellite Data

MODIS PROCESSED DATA BY NASA:



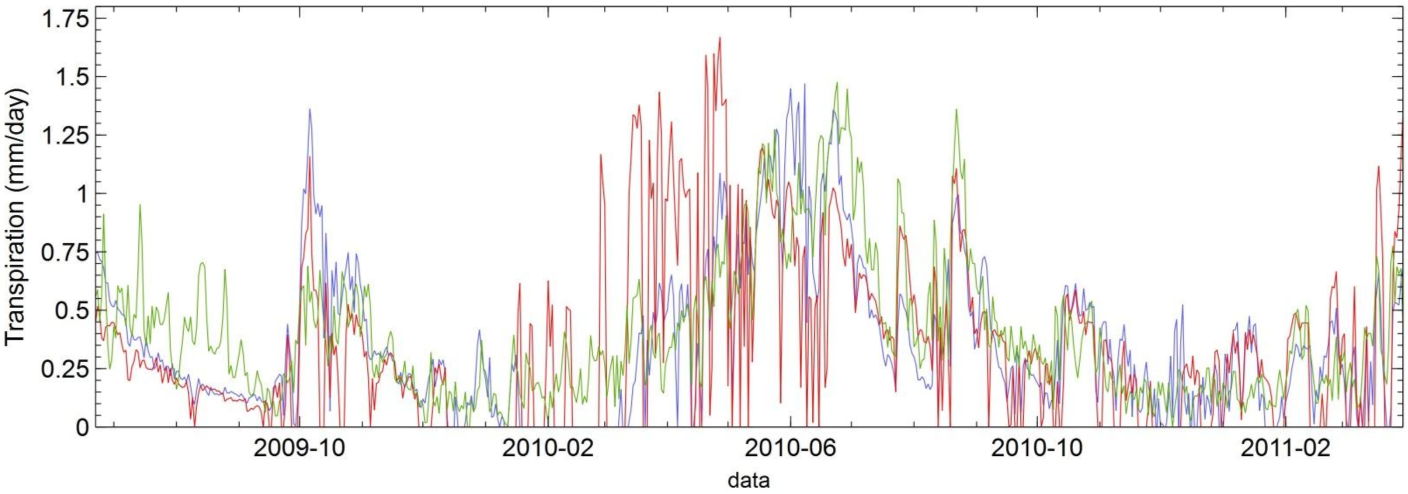
EVI
250m; 16days
No sense!

LAI
1km; 16days
max: March/May
min: Nov/January
Inconsistent with field data!

NDVI
250m; 16days
max_1: Nov/December
max_2: April/May
min: July/August

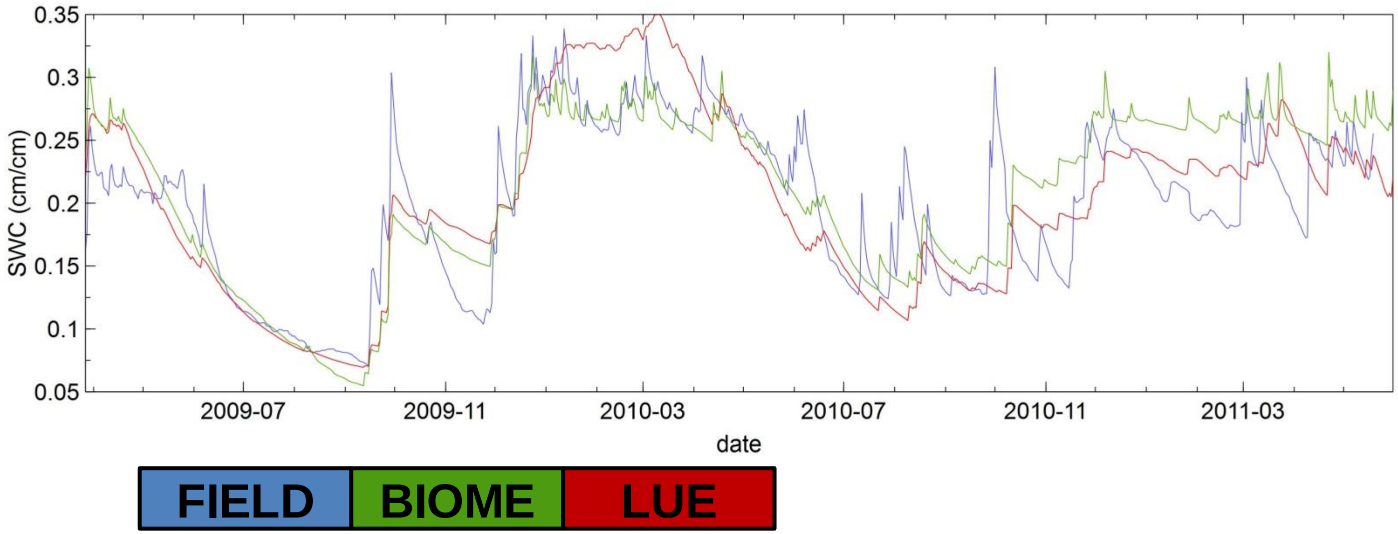
IAHR 2015

Implementation of the models



LUE-MODEL
RMSE= 0.360 E=0.34

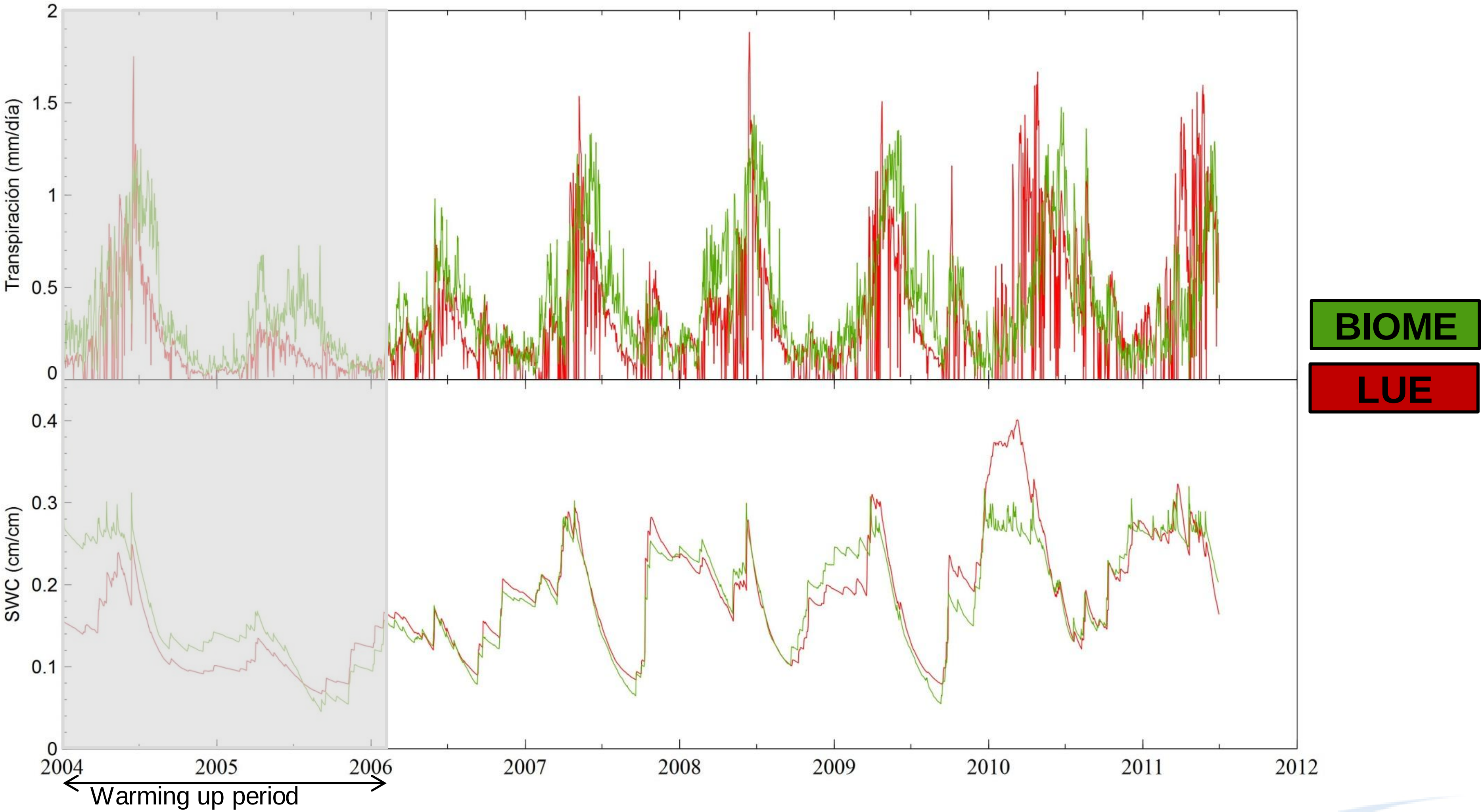
BIOME-BGC
RMSE= 0.282 E=0.64



LUE-MODEL
RMSE= 0.06 E=0.42

BIOME-BGC
RMSE= 0.05 E=0.517

Comparison between models



Comparison between models

LUE-MODEL
Applied at plot scale

Flows	Dry year (2005)		Wet year (2010)	
	mm	%	mm	%
Ppt	188		739	
ET (EI+T+Es)	165.18	87.86	431.87	58.44
Excedence	16.34	8.69	326.93	44.24
Blue/Green	**0.098**		**0.757**	

BIOME-BGC
Applied in one tree

Flows	Dry year (2005)		Wet year (2010)	
	mm	%	mm	%
Ppt	188		739	
ET (EI+T+Es)	208.46	110.883	543.87	73.59
Excedence	0	0	202.67	27.42
Blue/Green	**0**		**0.373**	

Comparison between models

LUE-MODEL
Applied at plot scale

Flows	Dry year (2005)		Wet year (2010)	
	mm	%	mm	%
Ppt	188		739	
ET (EI+T+Es)	165.18	87.86	431.87	58.44
Excedence	16.34	8.69	326.93	44.24
Blue/Green	**0.098**		**0.757**	

BIOME-BGC
Average of various trees

Flows	Dry year (2005)		Wet year (2010)	
	mm	%	mm	%
Ppt	188		739	
ET (EI+T+Es)	156.30	83.14	408.80	55.32
Excedence	16.34	8.69	330.10	44.67
Blue/Green	**0.104**		**0.807**	

Comparison between models

- Is a dynamic vegetation model really necessary?

DYNAMIC

Flows	Dry year (2005)		Wet year (2010)	
	mm	%	mm	%
Ppt	188		739	
ET (EI+T+Es)	165.18	**91.0**	431.87	**56.9**
Excedence	16.34	9.0	326.93	43.1
Blue/Green	**0.098**		**0.757**	

STATIC

Flows	Dry year (2005)		Wet year (2010)	
	mm	%	mm	%
Ppt	188		739	
ET (EI+T+Es)	147.00	**81.4**	385.37	**50.9**
Excedence	33.47	18.6	370.99	49.1
Blue/Green	**0.227**		**0.963**	

Conclusions

- Reliable estimates of spatial and temporal variations of actual evapotranspiration as well as precipitation are vital to obtain reliable estimates of the available water resources=> in some situations it can be necessary to deal with the **vegetation dynamics**

- A **parsimonious model** is able to adequately reproduce the dynamics of vegetation and also reproduces properly the soil moisture variations

- **Satellite information can be used for implementation of simple models,** when there are not enough available field information to implement a complex one

Many thanks for your attention

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