Assessing regional crop water demand using a satellite-based combination equation with a land surface temperature component

María C. Moyano[a], Mónica García[b], Lucía Tornos[a], Laura Recuero[a], Alicia Palacios-Orueta[a], Luis Juana[a]

[a] Polytechnic University of Madrid, Spain (m.moyano.perez@upm.es)

[b] Denmark Technical University (mgarc@env.dtu.dk)

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1 Introduction

In arid and semiarid regions, **around 90% of annual rainfall is returned to the atmosphere through evapotranspiration (*ET*).** Accuracy in estimations of spatial and temporal variations of evapotranspiration is crucial to improve hydrological and agricultural management, mostly in Mediterranean regions, where climate change may aggravate water scarcity.

➢ A process-based model was applied to estimate surface energy fluxes including **daily *ET*** based on a modified version of the Priestley-Taylor Jet Propulsion Laboratory (PT-JPL) model, from 2003 to 2013.

2 Objectives

PT-JPL ⟵ **Comparison** ⟶ WATEN

- ➢ Satellite based evapotranspiration model.
- ➢ Incorporating thermal RS information for soil moisture.
- ➢ Field data needed: air temperature and solar radiation.

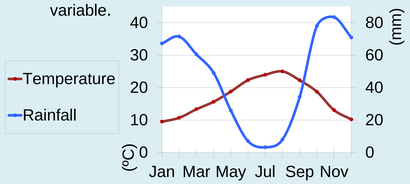
- ➢ Hydrological model.
- ➢ Field data needed: precipitation, irrigation, energy consumption for drainage discharge.

➢ Can a satellite based *ET* model that does not need field calibration predict *ET* similarly to a hydrological model at regional level?

3 Study area

➢ The 15000 ha B-XII Irrigation District is one of the largest irrigated areas in Spain. It is part of the Guadalquivir basin, near the Atlantic coast of South-West Spain.

➢ It presents Mediterranean climate with Atlantic influence. Warm and dry summers; temperate and semi-humid winters. Rainfall is highly variable.



4 Data and methodology

Satellite data: MODIS Terra and Aqua *v5* 1km resolution (http://reverb.echo.nasa.gov/)

- ❖Daily Land Surface Temperature and emissivity (MOD11A2, MYD11A2).
- ❖16 day-composite *NDVI* (MOD13A2) and *LAI/fAPAR* (MOD15A2).
- ❖8 day-composite broadband surface albedo (MCD43B3).

Climatic data: agro-climatic station IFAPA: Lebrija I

- ❖Air Temperature.
- ❖Incoming solar radiation.

4 Data and methodology

4.1 PT-JPL model (Fisher et al., 2008) with land surface temperature component (García et al., 2013)

λE potential — λE constraints

Evapotranspiration $\lambda E = \lambda E_c + \lambda E_s$

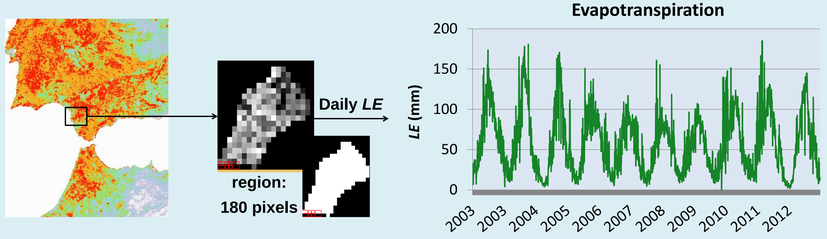
canopy $\boldsymbol{\lambda E_c} = \alpha_{PT} \cdot \frac{\Delta}{\Delta+\gamma} \cdot (Rn - Rn_s) \cdot f_g \cdot f_m \cdot f_t$

soil $\boldsymbol{\lambda E_s} = \alpha_{PT} \cdot \frac{\Delta}{\Delta+\gamma} \cdot (Rn_s - G) \cdot f_{SM\text{-}ATI}$

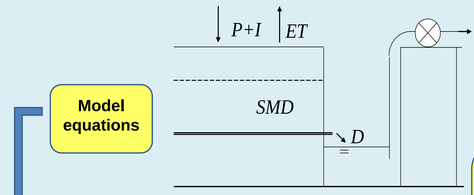
New soil moisture constraint: Apparent Thermal Inertia *ATI*

$$ATI = C \cdot \frac{1-\alpha}{(LST_{Day} - LST_{Night})} \; ; \; f_{SM\text{-}ATI} = \frac{ATI - ATI_{min}}{ATI_{max} - ATI_{min}}$$

4.2 Regionalization of PT-JPL model: application to the B-XII ID



4.3 Hydrological model WATEN (Moyano et al., 2015)



Model equations

EVAPOTRANSPIRATION

$$ET = \begin{cases} ET_P & \cdot \; (SMD \le RAM) \\ ET_P \cdot \frac{TAM - SMD}{TAM - RAM} & \cdot \; (SMD > RAM) \end{cases} +$$

DRAINAGE

$$D = \begin{cases} P \cdot (1 - R_P) + I \cdot (1 - R_I) & + \\ (P \cdot R_P + I \cdot R_I - SMD_{i-1} - ET) & \cdot \; (P \cdot R_P + I \cdot R_I - SMD_{i-1} - ET > 0) \end{cases}$$

SOIL MOISTURE DEFICIT

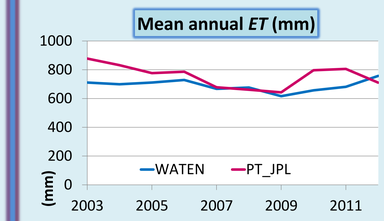
$$SMD = \begin{cases} (SMD_{i-1} + ET - P \cdot R_P - I \cdot R_I) & \cdot \; (0 < SMD_{i-1} + ET - P \cdot R_P - I \cdot R_I < TAM) \; + \\ TAM & \cdot \; (SMD_{i-1} + ET - P \cdot R_P - I \cdot R_I > TAM) \end{cases}$$

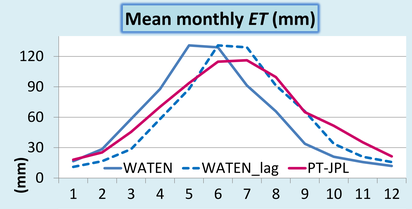
Model parameters

- ***TAM***: Total Available Moisture in the soil.
- ***p***: mean fraction of *TAM* before water stress occurs.
- ***R_P***: fixed percentage for effective precipitation.
- ***R_I***: irrigation efficiency.

5 Results

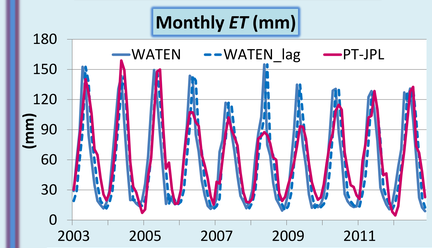
Comparison PT-JPL model versus lumped hydrological model WATEN



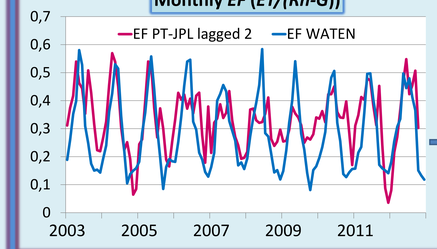


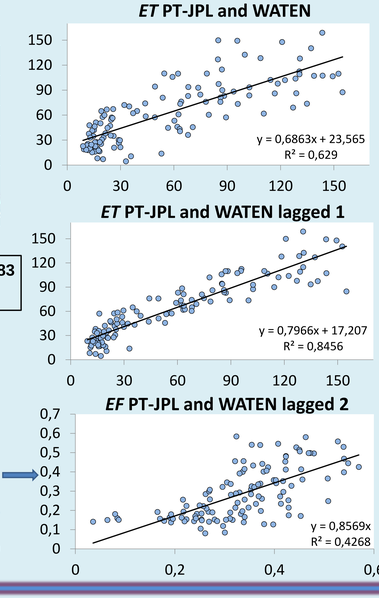
PT-JPL = 757mm; **WATEN** = 691mm
Mean annual difference = 9.6%

Nash-Sutcliffe *e2* = 0.702; *e2* $_{1month\text{-}lag}$ = 0.92
Pearson *ρ* = 0.85; $\rho_{1month\text{-}lag}$ = 0.98



***ρ* = 0.79 $\rho_{1month\text{-}lag}$ = 0.92; *e2* = 0.61 *e2* $_{1month\text{-}lag}$ = 0.83**
***RMSE* = 2.34mm**





6 Conclusions

➢ The results showed that the thermal PT-JPL model is a suitable and simple tool for predicting *ET* at regional level, requiring only air temperature and incoming solar radiation apart from standard satellites-products freely available. In comparison with the hydrological model, that requires meteorological and in-situ discharge data to quantify irrigation, the satellite-based model presents a great advantage for regionalization of *ET*, providing also finer time-step estimates (8-days) apart from monthly estimates.

➢ When accounting for the uncertainty in time in the estimates of the discharge used to calibrate the hydrological model (using lag correlations) the correlations and errors between the two models improved both *ET* and the evaporative fraction (*EF*).

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