Multi-site modeling of land surface-atmosphere exchanges at the extent of an agricultural Mediterranean region

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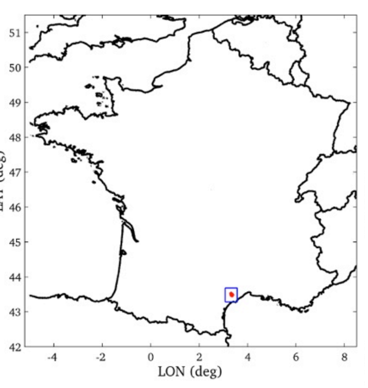
1 Context and objectives



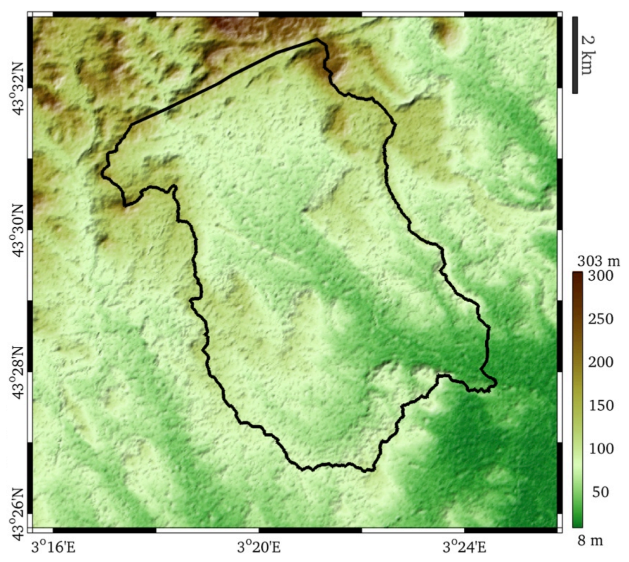
The accurate monitoring of the water cycle requires the knowledge about the spatial and temporal dynamics of water and energy exchanges between the land surface and the atmosphere. This is particularly important in Mediterranean regions, where evapotranspiration (ET) is the main component of the water balance and future projections in climate show a systematic decrease in annual rainfall.

The main goal of this work is to develop a modeling approach of soil-vegetation-atmosphere transfers at the extent of an agricultural watershed. A 1-D model with regional focus was proposed to simulate the energy and water balance of a row crop (vineyard).

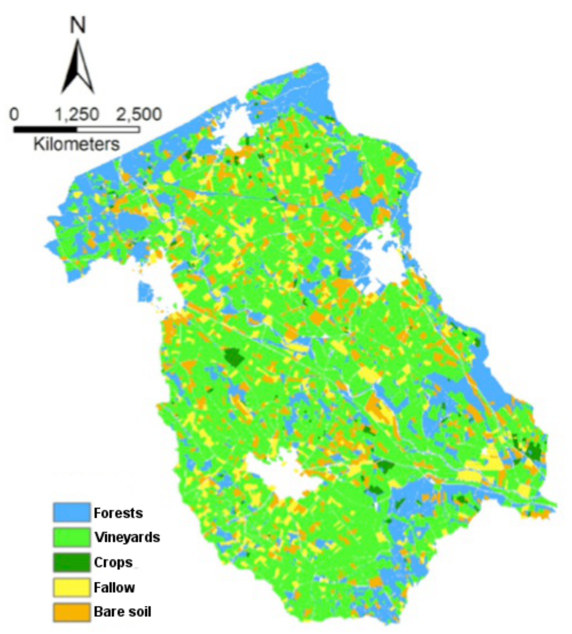
The approach is focused on three points:

1) Appropriate model formalism adapted to the study region
2) Obtaining realistic simulations by multi-objective calibration
3) Multi-site simulations by using remote sensing

2 Study site



La Peyne watershed (65 km²)
Département de l'Hérault
Southern France
Gentle slopes terrain (4.5%)
Subhumid Mediterranean climate
720 mm y^{-1} annual rainfall
1270 mm y^{-1} potential ET

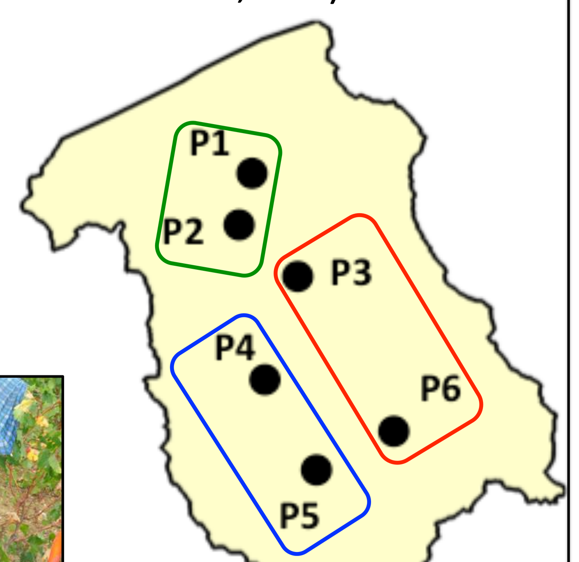


Land use:
70% cultivated with vineyards
90% of rainfed vineyards
Strong plot fragmentation (1 km)

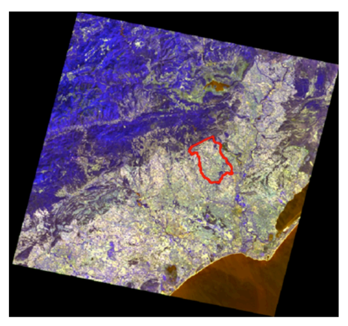
3 In-situ and satellite data

In-situ measurements were conducted on 6 experimental plots according to water stress conditions (high, intermediate, low)

- Meteorological data **P4**
- Eddy Covariance **P6**
- Soil moisture, vegetation (height, LAI) and watertable **P1-P6**



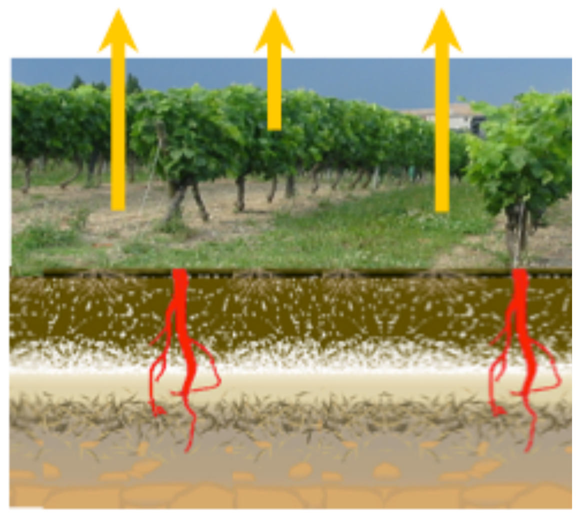
Satellite imagery
- **ASTER** 11 images 2007-2008 (90 m TIR)
- **Landsat 7 ETM+** 12 images 2007-2008 (60 m TIR)



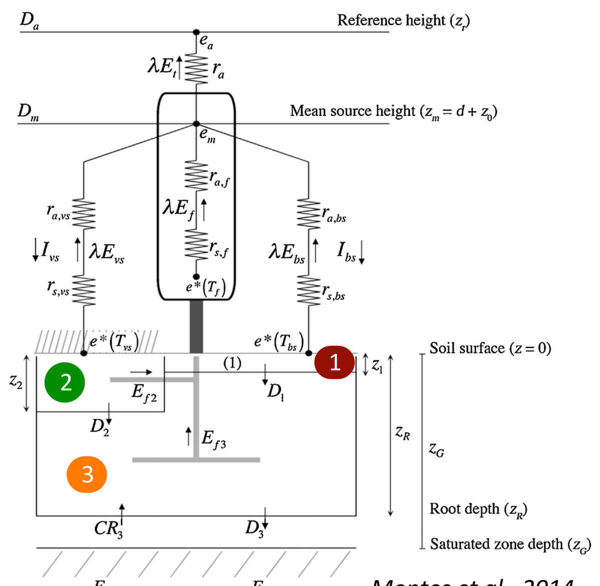
4 Modeling approach

Discontinuous plant structures
- Bare soil / grazing / main foliage
- Deep rooting
- Strong seasonality

→ ET main component



Multi-source Formalism →



Montes et al., 2014

- Two modules: vegetation (energy balance) and soil water balance
- Contribution from 3 sources: bare soil *bs* (1), grass cover *vs* (2), main foliage *f* (3)
- Infiltration (*I*) *F*(rainfall), neglecting runoff
- Drainage (*D*): excess in relation to retention capacity
- Capillary rise (*CR*): Darcy's law

Total hourly latent heat (λE_t) obtained by (Lhomme et al., 2012)

$$\lambda E_t = \left(\frac{\Delta' + \gamma}{\gamma}\right)\left(P_f + P_{vs} + P_{bs}\right)\lambda E_p + \frac{\Delta}{\gamma}\left(P_f A_f r_{a,h}^f + P_{vs} A_{vs} r_a^{vs} + P_{bs} A_{bs} r_a^{bs}\right) / r_a$$

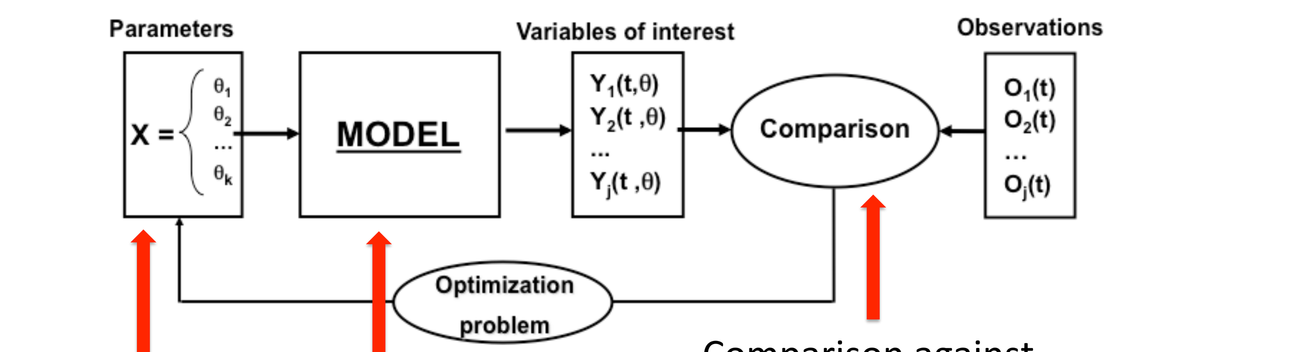
P_i: combinations of surface r_s and aerodynamic resistances r_a; A_i available energy for each component; Δ', Δ and γ thermodynamic parameters; λE_p potential ET.

Daily dynamic (*j*) balance of soil water content (SWC)

$$SWC_j = SWC_{j-1} + I_j \pm CR_j - \sum_{h=1}^{24} ET_j \pm D_j$$

5 Model calibration

Model calibration problem:

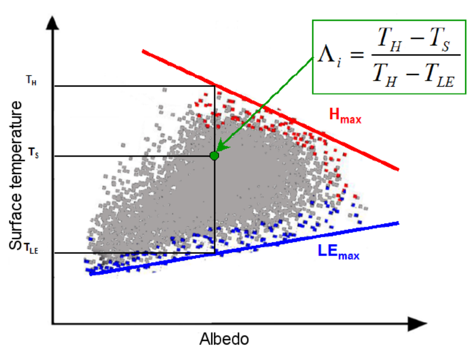


High number of parameters | High number of processes | Comparison against several variables

Method: **Multi-objective calibration Iterative Procedure** (Demarty et al, 2005)
- Iterative model sensitivity analysis
- Successive contractions of the feasible parameter space
- 10 iterations of 2.000 Monte Carlo simulations using random parameters
- Minimization of two objective functions: RMSE for ET and SWC

6 Satellite evapotranspiration

S-SEBI: Simplified Surface Energy Balance Index (Roerink et al., 2000)

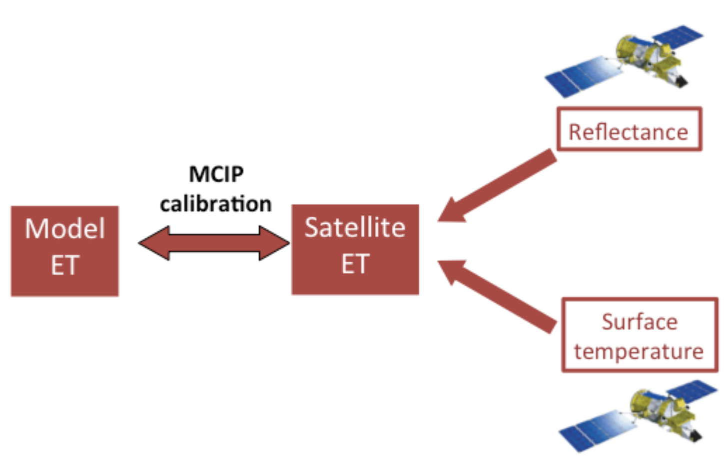


Evaporative fraction $\Lambda \approx \frac{T_H - T_S}{T_H - T_{\lambda E}}$

Daily ET as a function of net radiation $ET_d = \Lambda \frac{R_{n,d}}{\lambda}$

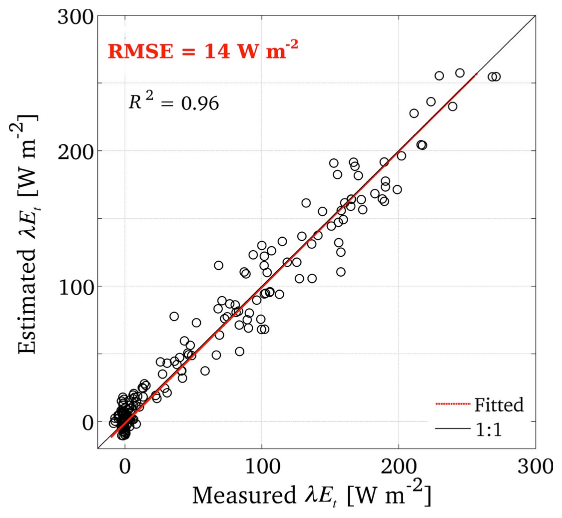
Approach

Model calibration by using ground validated satellite ET and measured soil water content on the 6 measurement points

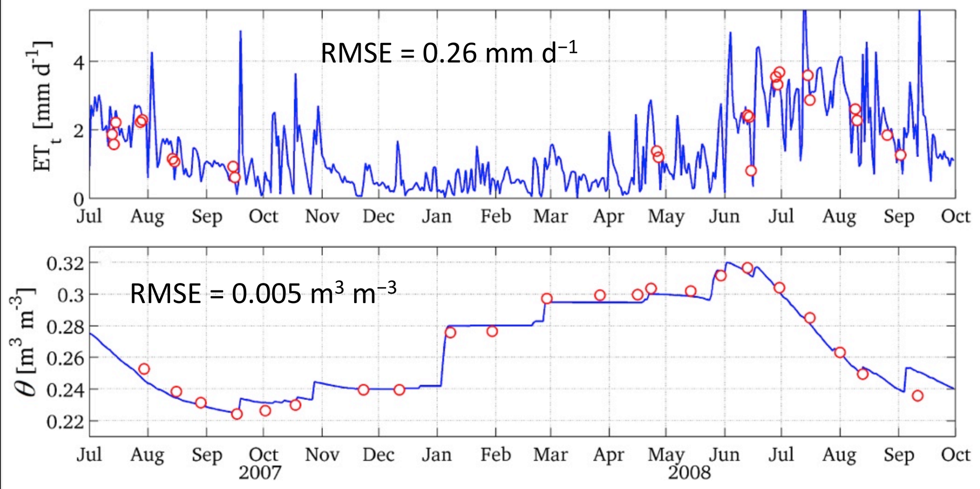


7 Results: site-scale model performance

1) Calibration of vegetation module
- Hourly simulations
- Validation with eddy covariance ET
- Forcing: meteorological and soil water content (θ)



2) Calibration of vegetation and soil modules
- Daily simulations
- Eddy covariance ET
- Neutron probes soil water content
- Forcing: meteorological data



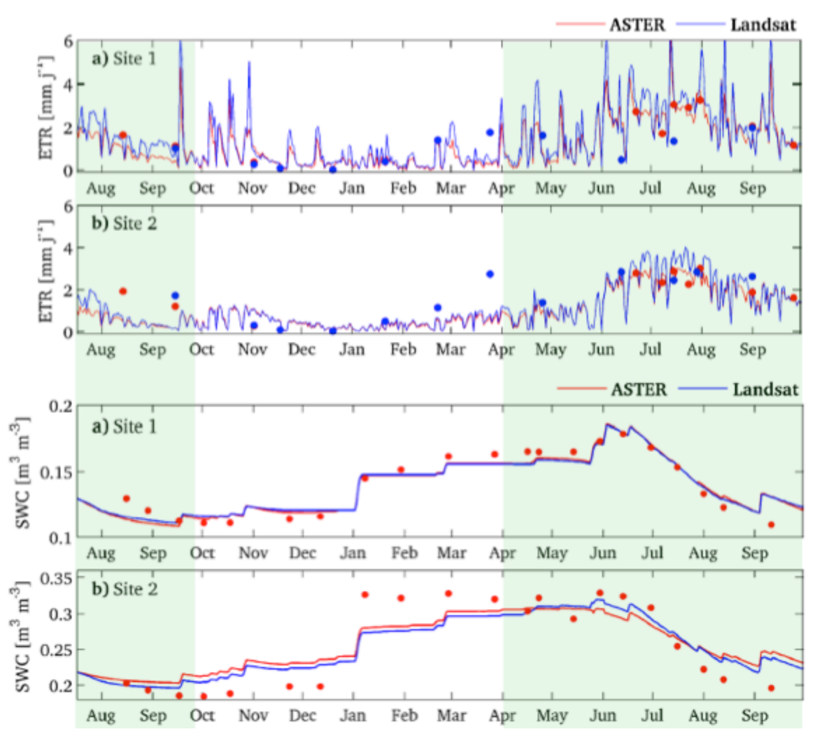
- Restitution of seasonal dynamics
- Low residual error of calibration

8 Results: Multi-site model performance

Comparison of the performance of ASTER and Landsat ET to calibrate the model ET and SWC for 2 contrasting sites in terms of soil water content:

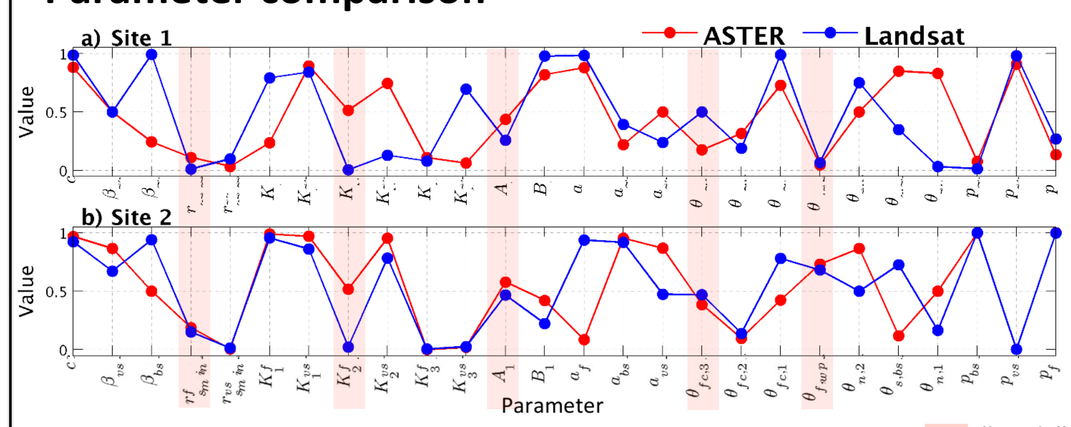
ASTER
ET RRMSE 25%
SWC RRMSE 5%

Landsat
ET RRMSE 65%
SWC RRMSE 6%



Uncertainties:
- Spring: semi-cloudy days
- Time distribution of data
- Shallow watertable

Parameter comparison



Normalized values of 26 parameters

"High" sensitivity parameters

Similar values
r^f_{min} : min. stomatal resistance
A_1 : bare soil resistance

Different values
K^f_2 : stomatal conductance (VPD) → simulation periods
$\theta_{f,wp}$: deep soil wilting point → 2 different sites

"Optimal" parameters are case dependent (equifinality)
Some degree of correspondence between sites and parameters

9 Concluding remarks of preliminary results

- Model performance → restitution of daily and seasonal dynamics
- Model performance → restitution of key processes after calibration
- Multi-site approach possible with limitations → in situ input data
- Further research → calibration for phenological stages and top soil water content (Ground Penetrating Radar)

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