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Hydrology of Plant: Modeling the interaction between Infiltration and Evapotranspiration

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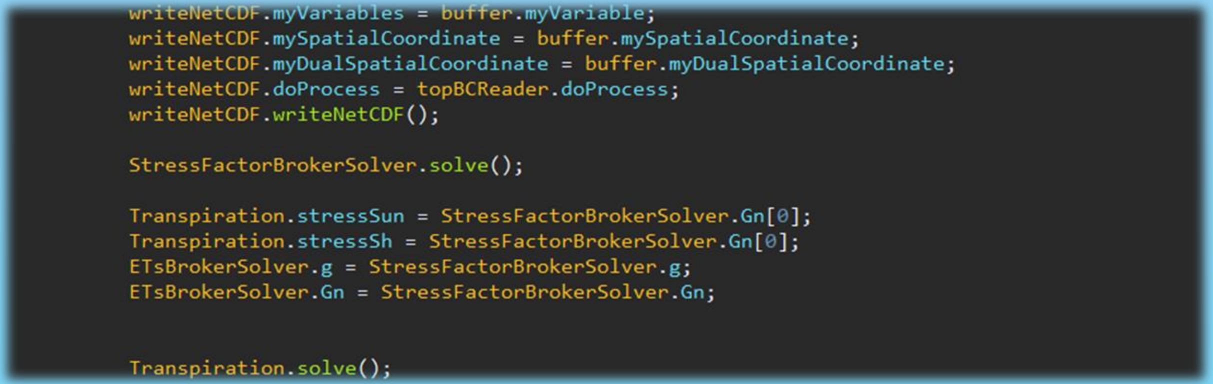
THE CHALLENGE

Analyzing the processes that regulate the system

soil - water - vegetation



```
writeNetCDF.myVariables = buffer.myVariable;
writeNetCDF.mySpatialCoordinate = buffer.mySpatialCoordinate;
writeNetCDF.myDualSpatialCoordinate = buffer.myDualSpatialCoordinate;
writeNetCDF.doProcess = topBCReader.doProcess;
writeNetCDF.writeNetCDF();

StressFactorBrokerSolver.solve();

Transpiration.stressSun = StressFactorBrokerSolver.Gn[0];
Transpiration.stressSh = StressFactorBrokerSolver.Gn[0];
ETsBrokerSolver.g = StressFactorBrokerSolver.g;
ETsBrokerSolver.Gn = StressFactorBrokerSolver.Gn;


Transpiration.solve();
```

Modeling a **virtual lysimeter** considering the **water and environmental stress** affecting the transpiration rate of plants.

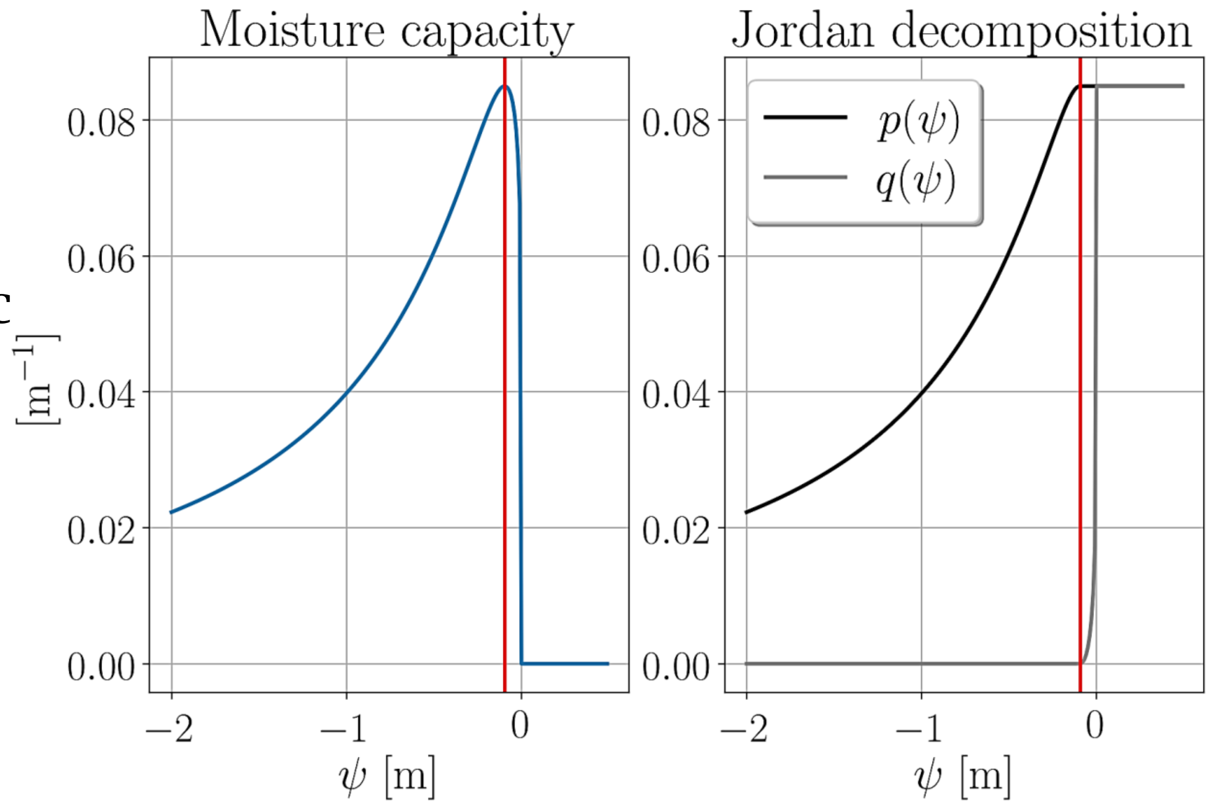
Richards' Model 1D

$$\frac{\partial \theta(\psi)}{\partial t} = \frac{\partial}{\partial z}\left[K(\psi)\frac{\partial}{\partial z}(\psi + z)\right] + S$$

The Richards' equation is solved using a semi-implicit finite volume method.

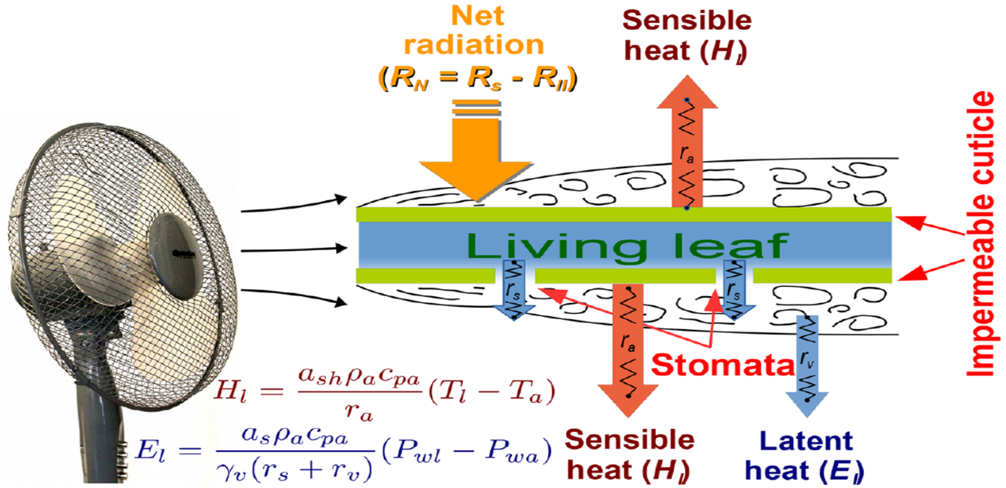
From a numerical point of view the main problem is related to the nonmonothonic behaviour of the soil moisture capacity.

To solve the resulting nonlinear system we use a nested Newton algorithm *(Casulli and Zanolli, 2010*) that guarantees the convergence of the solution for any time step.



By ***Niccolò Tubini*** (Working in Progress)

EvapoTranspiration Model: Prospero



Transpiration modelling of Scymanski e Or (2017)

The leaves have two evapotranspiring surfaces

Schymanski and Or (2017) evaluated the Penman-Monteith equation directly on the leaf scale, noting an important omission in the estimation of sensible heat exchanges.

$$ET = ETP(g_s)$$

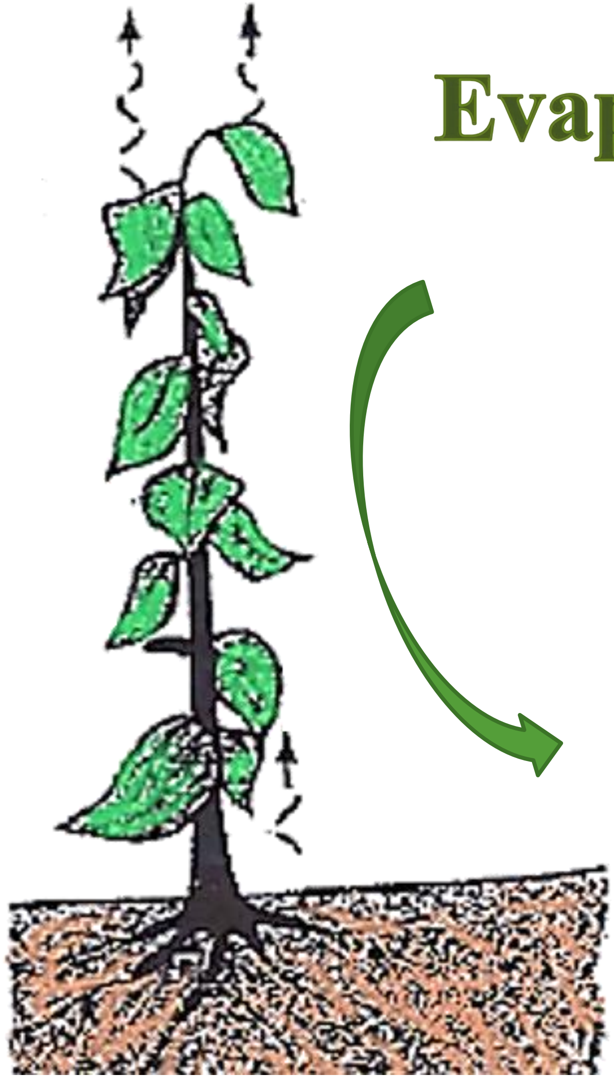
$$g_s = g_{s,max} \cdot f(R_{PAR}) \cdot f(T_a) \cdot f(VPD) \cdot f(\theta)$$

White et al. (1999)

Prospero model implements the *Schymanski and Or* solution at canopy scale with the introduction of stress factor about total solar radiation, air stress, vapour pressure deficit and water content

Michele Bottazzi's Ph.D. Thesis

LysimeterPro



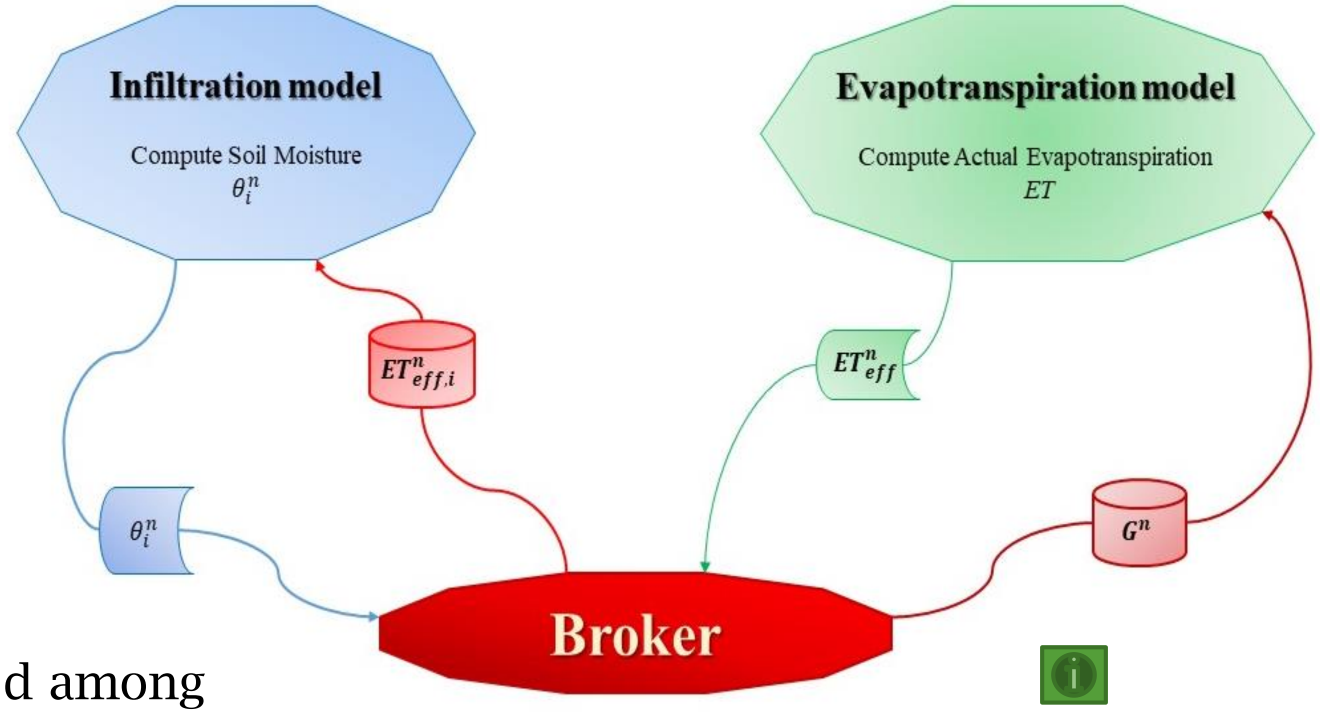
EvapoTranspiration Model

Infiltration Model

BROKER

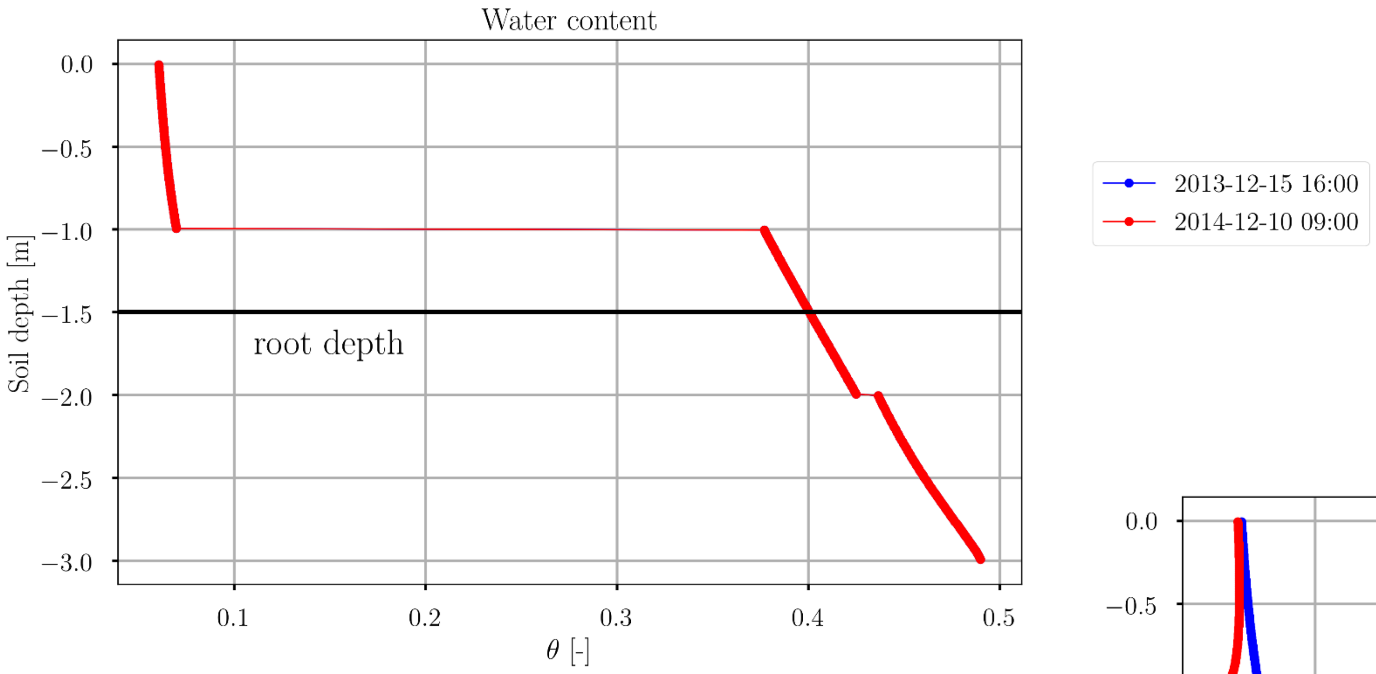
Concetta D'Amato's Master Thesis

LysimeterPro - BROKER

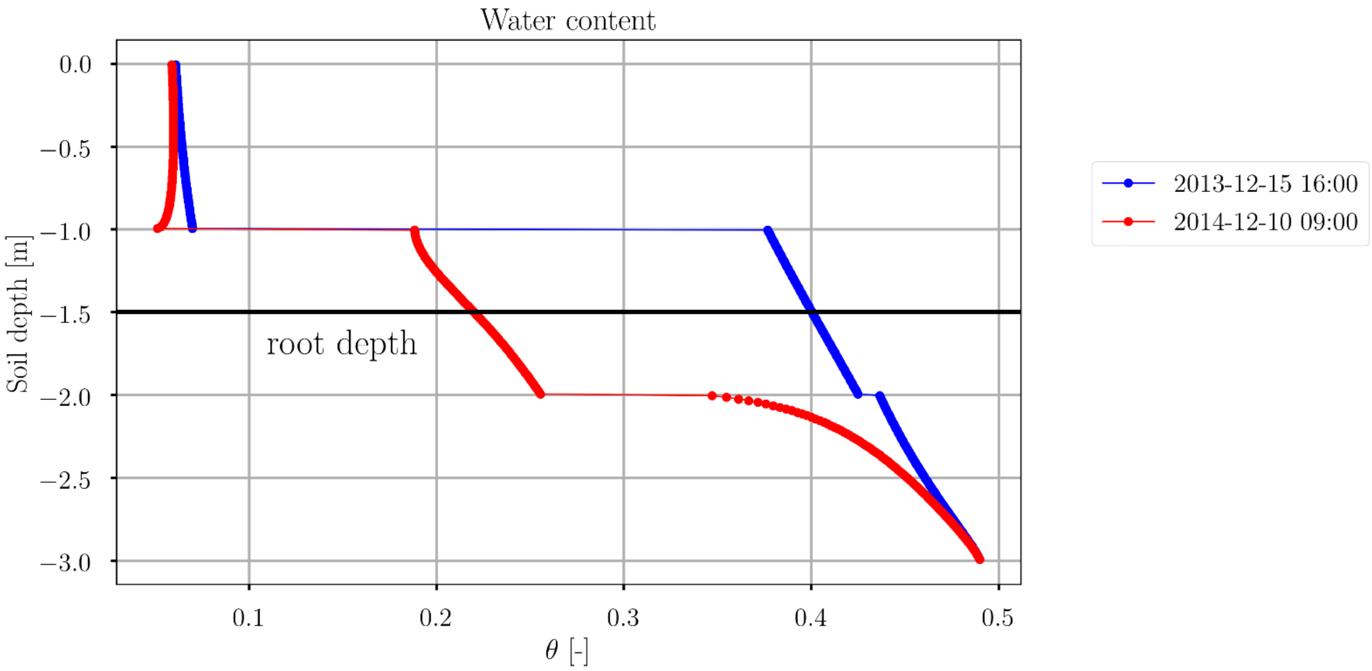


- Compute the **Stress factor** for the Evapotranspiration model considering the soil water content in the root zone.
- The Evapotranspiration flux is distributed among the control volumes in the root zone (*Source Term).*
- Broker is developed using **OOP** as well as the Richards' and ET model.
- Specifically the **Factory Design Pattern allows us to add** new stress factor models.

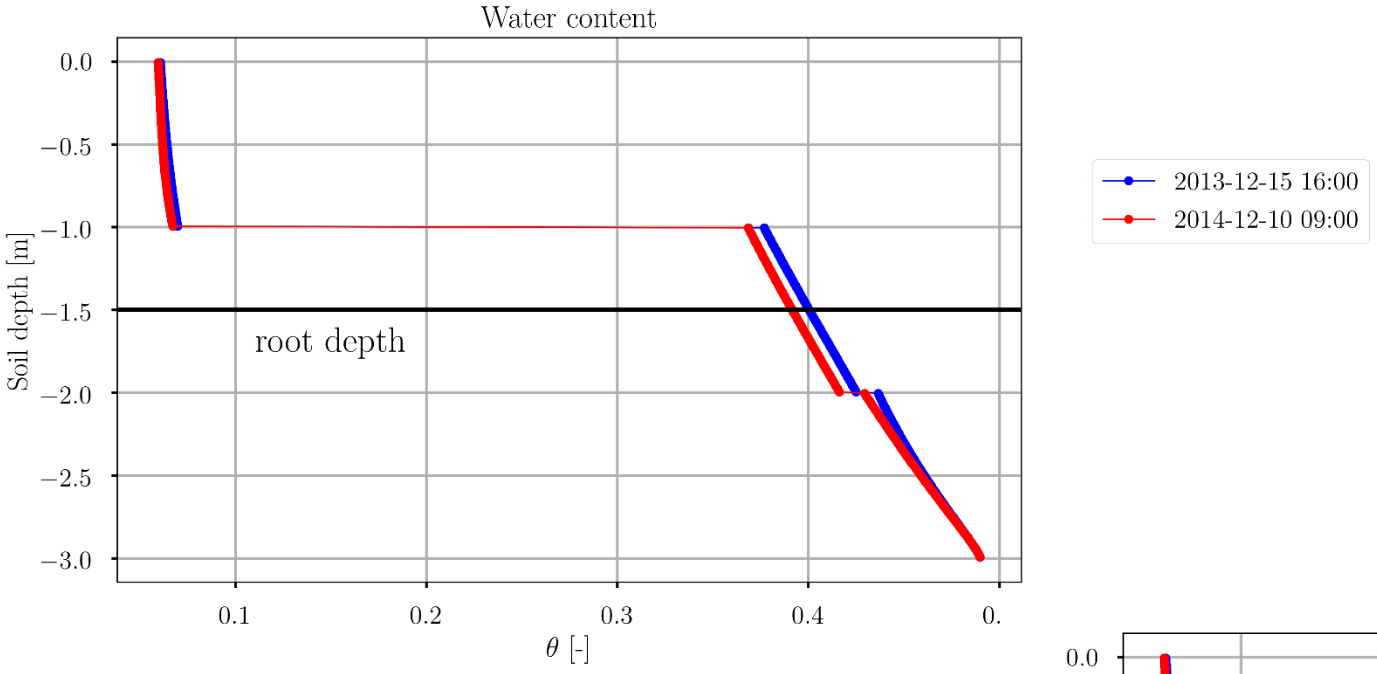
Preliminary results



Water sol profile with no flux at the top and bottom of the domain with an hydrostatic initial condition

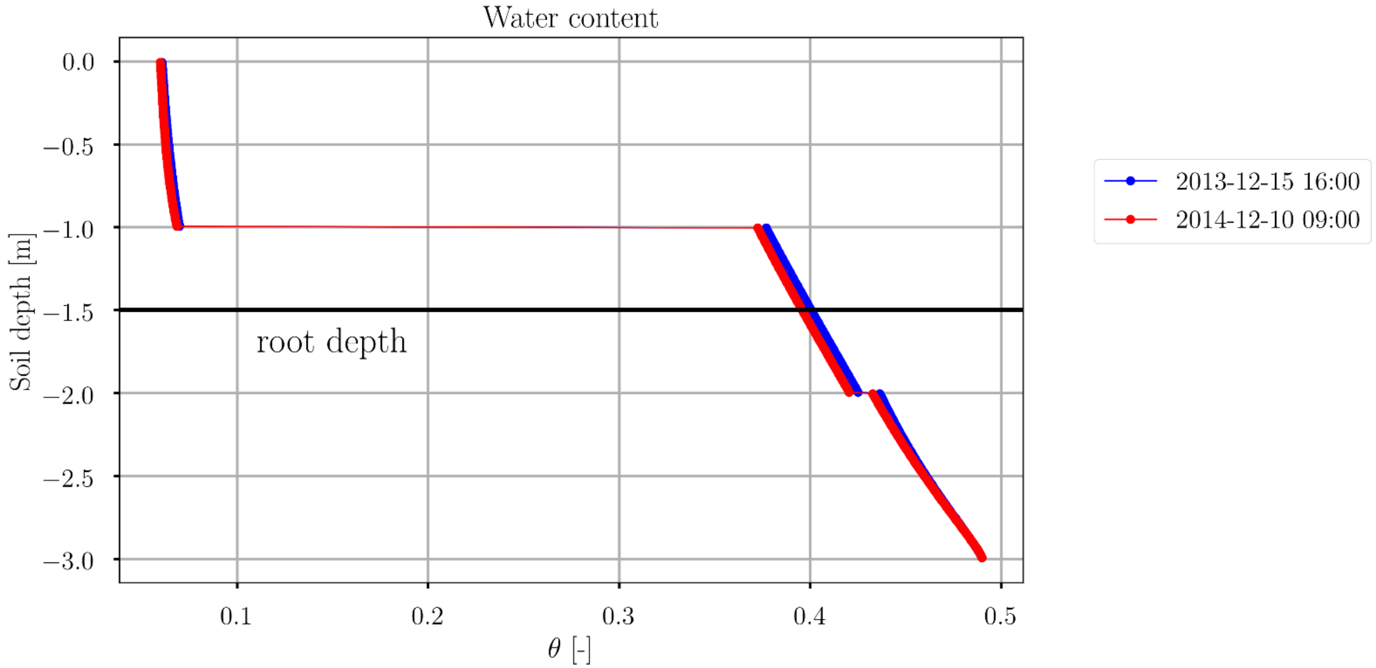


Water soil profile in a synthetic simulation with Potential Evapotranspiration flux

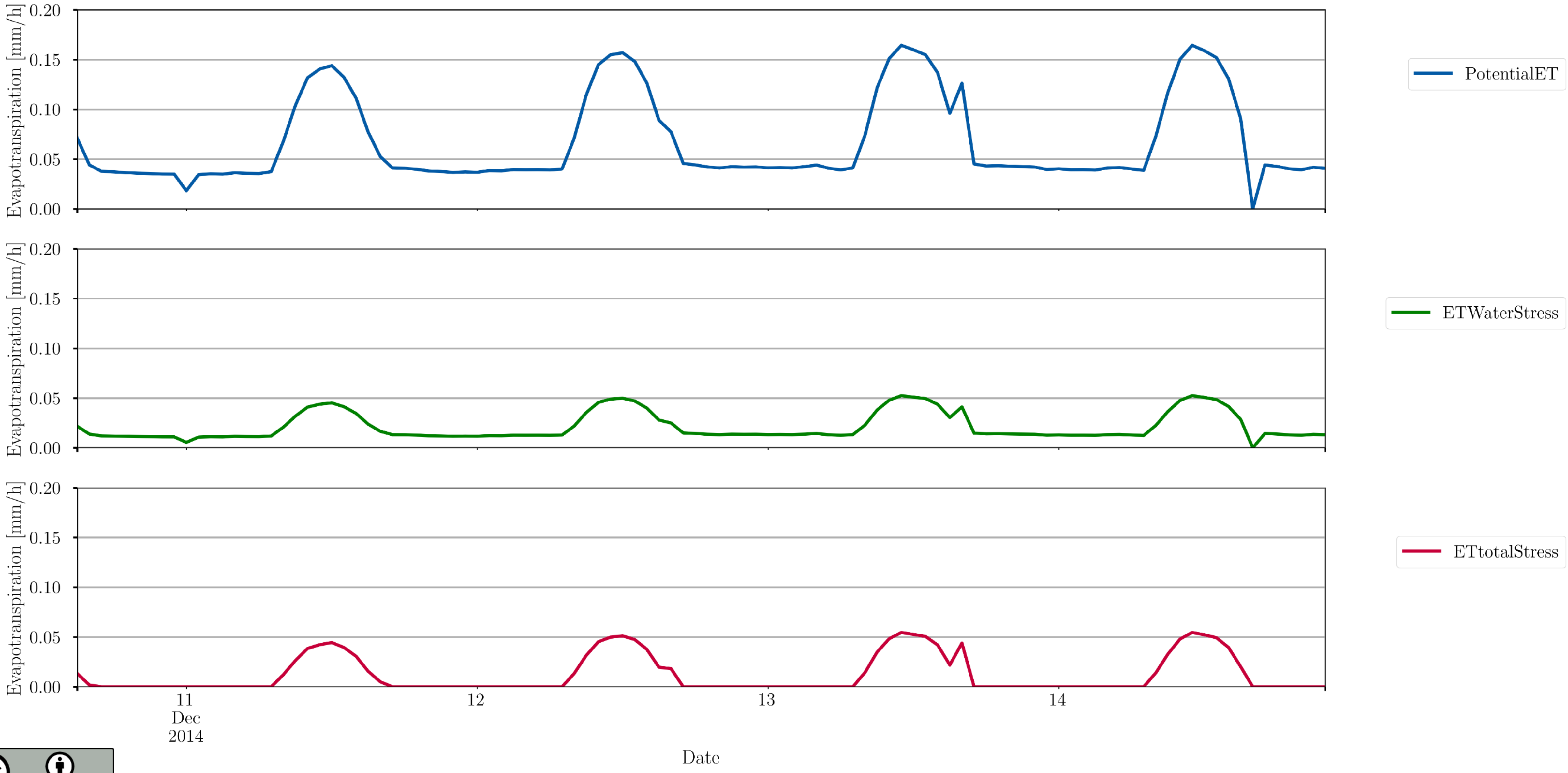


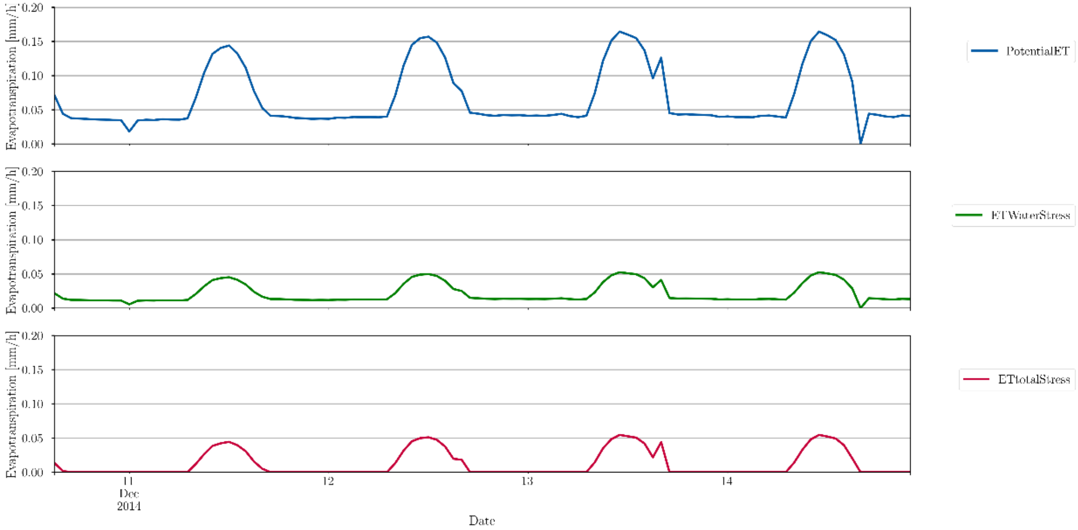
Water soil profile in a sisntetic simulation with Evapotranspiration flux stressed by only the water stress

Water soil profile in a sisntetic simulation with Evapotranspiration flux stressed by environmental and water stress

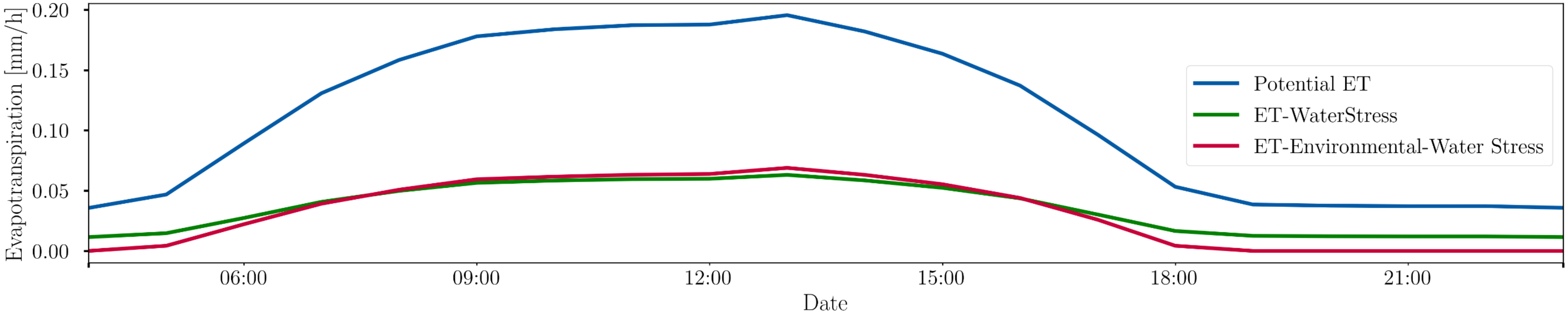


Different Evapotranspiration rate by using stress factors





Detail of the different Evapotranspiration rate using stress factors in a random day



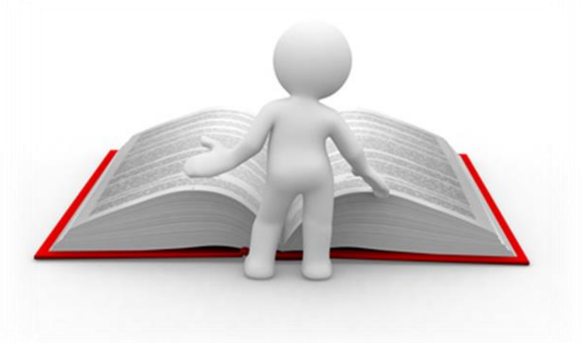
Summary

- ❖ ***LysimeterPro*** *is a valid flexible model for the computation of Infiltration and Evapotranpiration;*

- ❖ *Results show very important effect of* ***water stress*** *in the Evapotranspiration rate;*

- ❖ *Significant changes of the* ***water profile*** *in soil with Evapotranspiration;*

- ❖ *This approach introduce a time lag between the solution of the Richards' equation and Prospero.*



Next Steps

I. *Coupling Infiltration and Evapotranspiration by using* ***water suction;***

II. *Plant' model to take in account the* ***water storage*** *and the* ***travel time*** *within the plant;*

III. New parametrization *for the computation of the environmental and water stress.*

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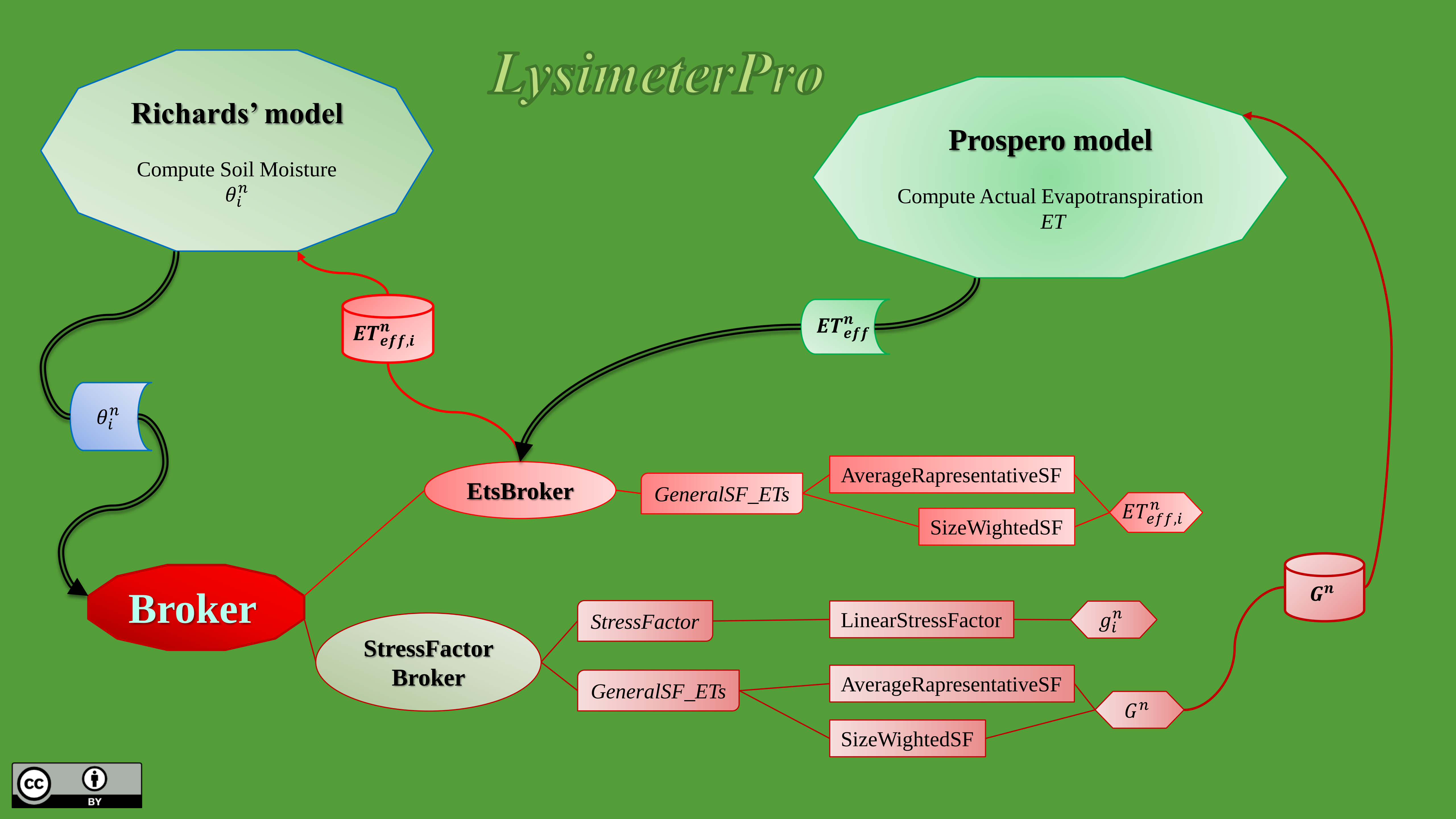
Questions and Suggestions ?


LysimeterPro
Richards' model
Compute Soil Moisture
θ_i^n
Prospero model
Compute Actual Evapotranspiration
ET
$ET^n_{eff,i}$
ET^n_{eff}
θ_i^n
EtsBroker
GeneralSF_ETs
AverageRapresentativeSF
SizeWightedSF
$ET^n_{eff,i}$
Broker
StressFactor Broker
StressFactor
LinearStressFactor
g_i^n
GeneralSF_ETs
AverageRapresentativeSF
SizeWightedSF
G^n
G^n