→ MEASUREMENTS AND OBSERVATIONS IN THE 21st CENTURY CONFERENCE

A lysimeter laboratory experience for mass and energy fluxes measurements and hydrological models parameterization verification

POLITECNICO MILANO 1863

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Objectives

Laboratory experiments with a lysimeter which is fully equipped to measure all the process of the hydrological cycle

1. Monitoring of soil moisture profiles and the different hydrological processes in the laboratory lysimeter

2. Definition of the irrigation water requirements for different crops

3. Verification of the parameterization of the water and energy balance equations in the FEST-EWB hydrological model

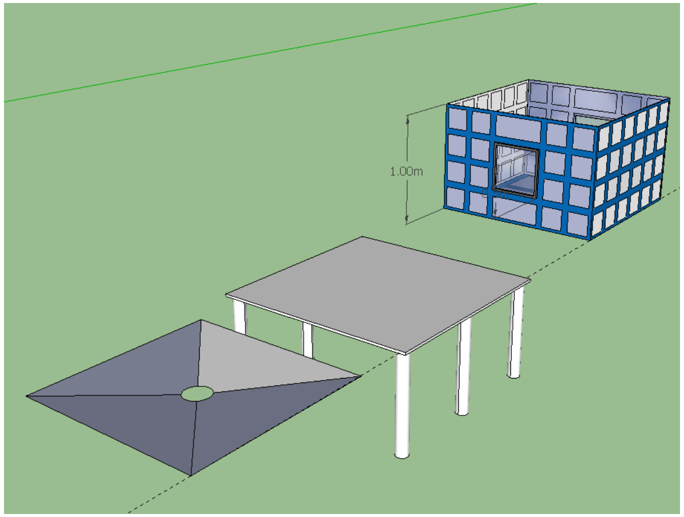
4. Evaluation of the accuracy of the measuring system

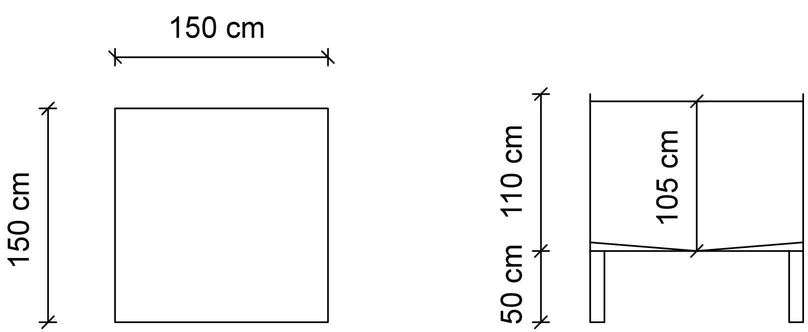
A weighing lysimeter is simply a large "flower pot"

ENVLAB

The lysimeter: its project

Structure weight = 956kg
Soil volume = 2.25m^3

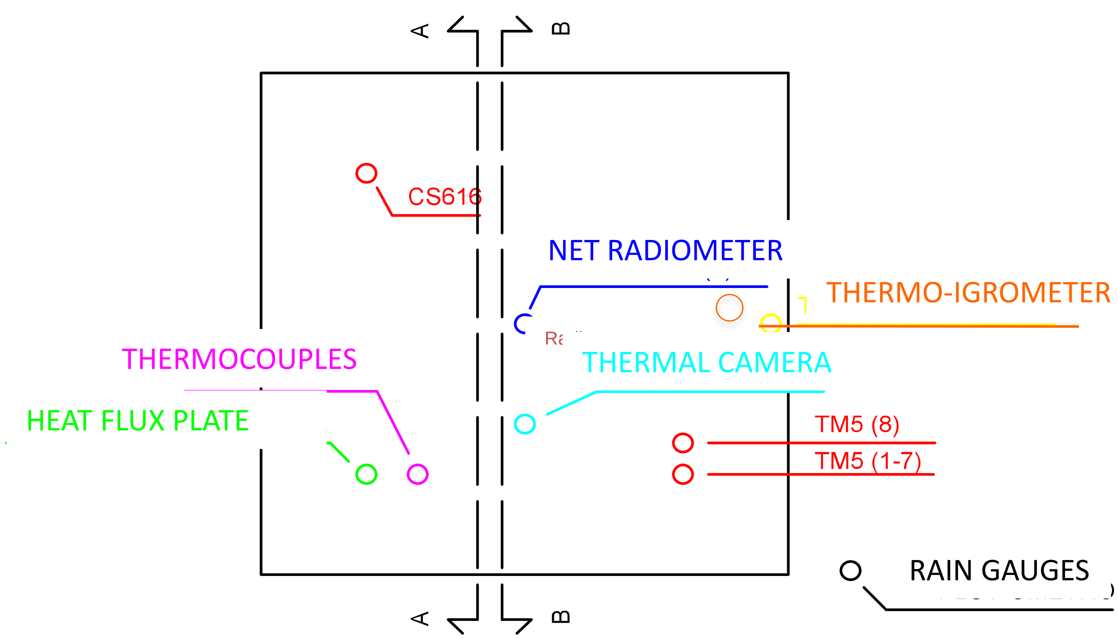




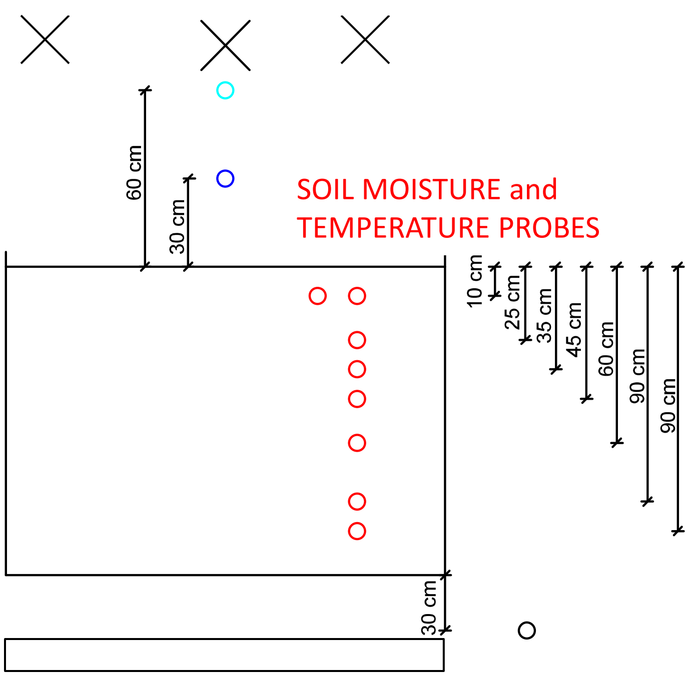
During the installation

The lysimeter: the instruments

From above



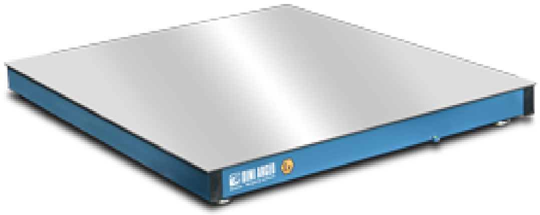
In front



The lysimeter instruments

SCALE

Maximum weight= 6000kg
accuracy = 0.5kg

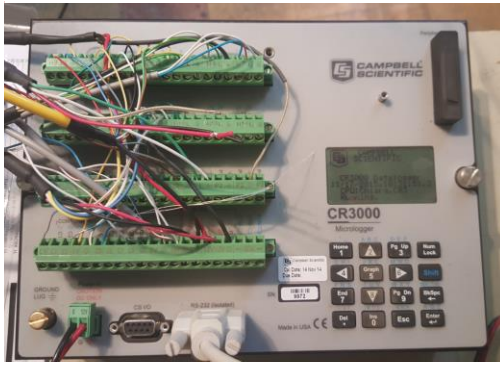


THERMO-IGROMETER

Range RH = 0.8%-100% (1.1 %)
Range Ta = -80/60° C (0.2 ° C)
Vaisala

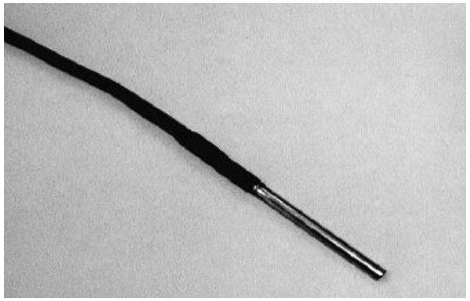
DATALOGGER

Campbell Scientific



THERMOCOUPLES

Range= -30/50° C
Accuracy = ± 0.5° C



HEAT FLUX PLATE

Huxeflux

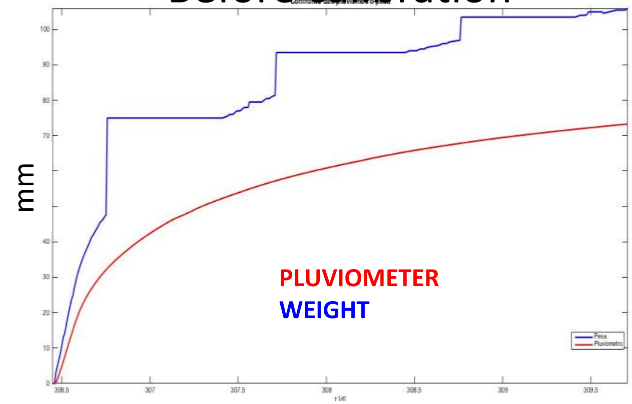
Artifical radiation
(6 spotlights of 400 W)

The lysimeter instruments: rain gauge calibration for drainage flux measurements

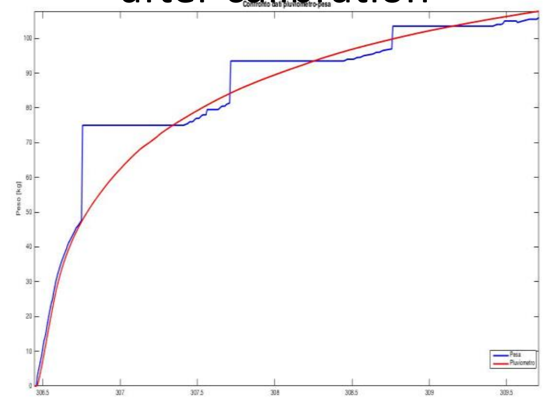
RAIN GAUGES

Calibration needed because tipping bucket rain gauges underestimates high intensity events (WMO, Lanza 2009)

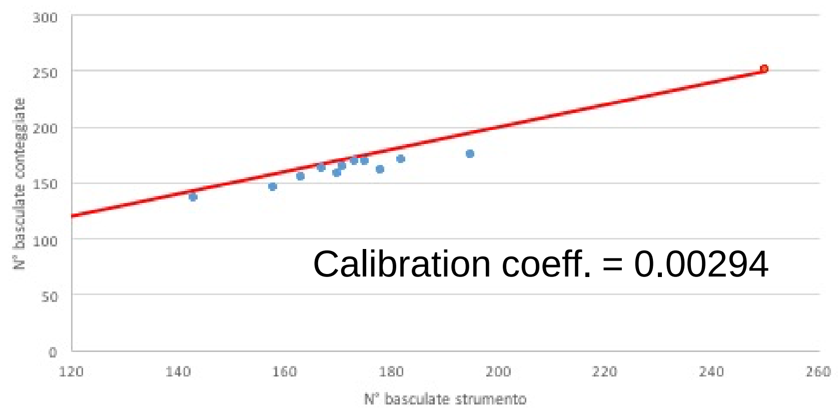
Before calibration



after calibration



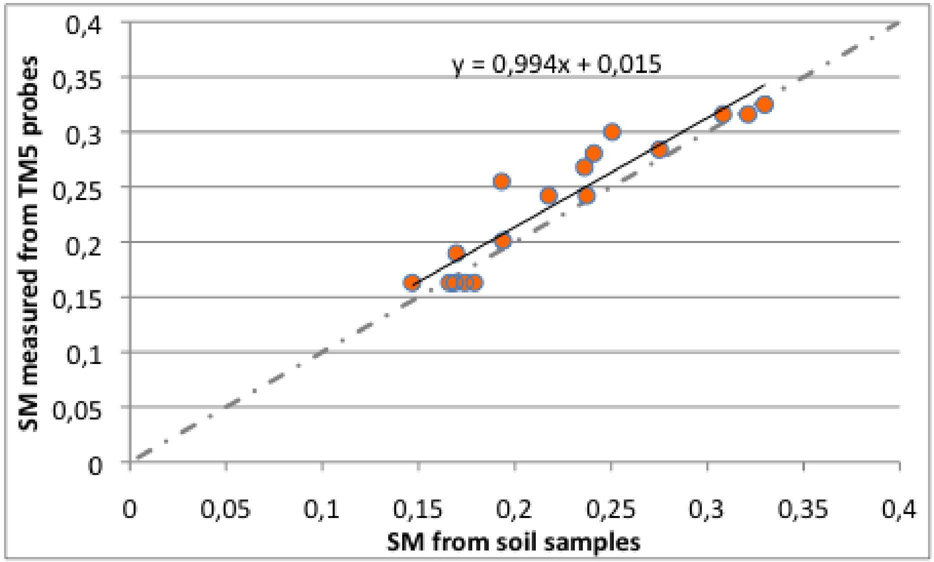
Known water volume



The lysimeter instruments: soil moisture probes calibration and soil type

SOIL MOISTURE and TEMPERATURE PROBES

Decagon devices



UMS HYPROP & KSAT (soil water retention curve)

KSAT- (cm/h) = 6.66

θ_s = 0.36

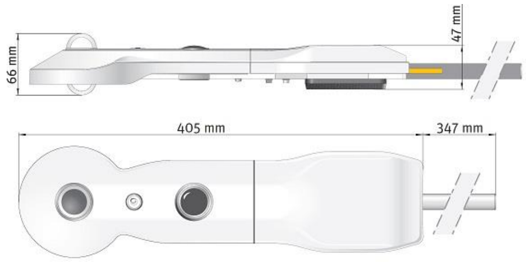
FC % = 26

WP % = 16.7

Thanks to Feki, Ravazzani

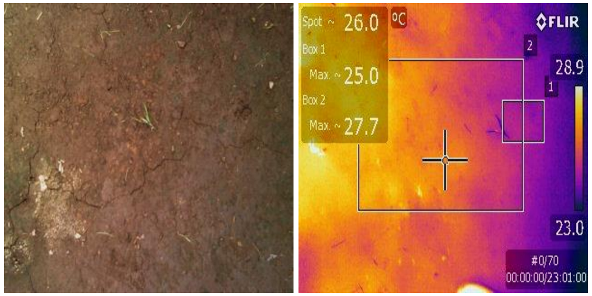
The lysimeter instruments: net radiometer and thermal camera

Measurements of incoming and outgoing shortwave and longwave radiation



NET RADIOMETER

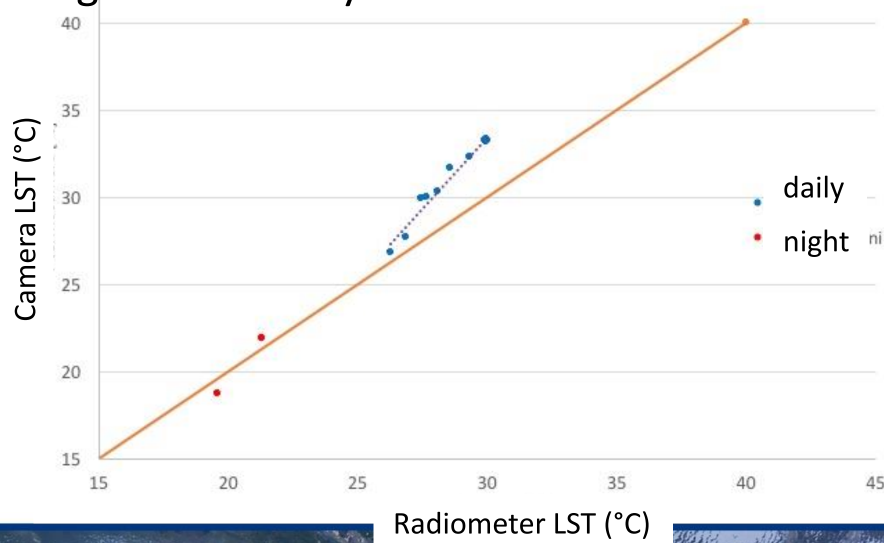
FOV outgoing = 150 °
FOV incoming= 180 °



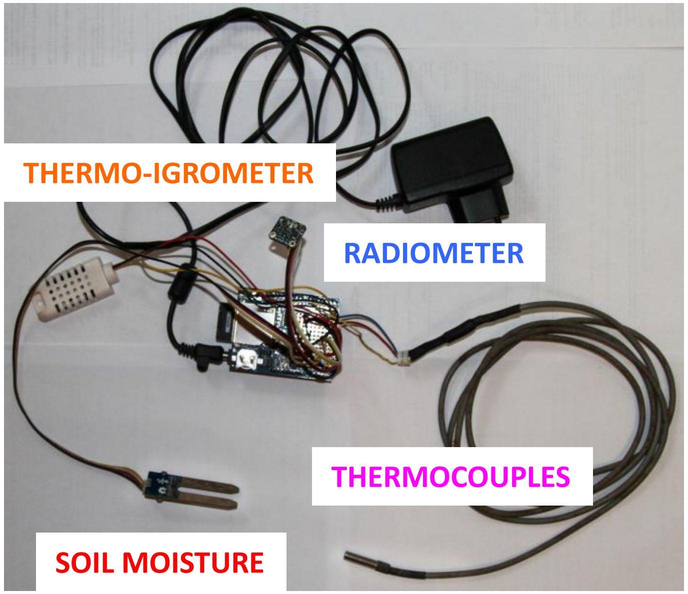
The net radiometer is installed at 60 cm over the soil, so the measuring area is larger then the lysimiter soil

THERMAL CAMERA

Range temperature = - 40/1500° C
Accuracy = ± 1° C
FOV 15 °

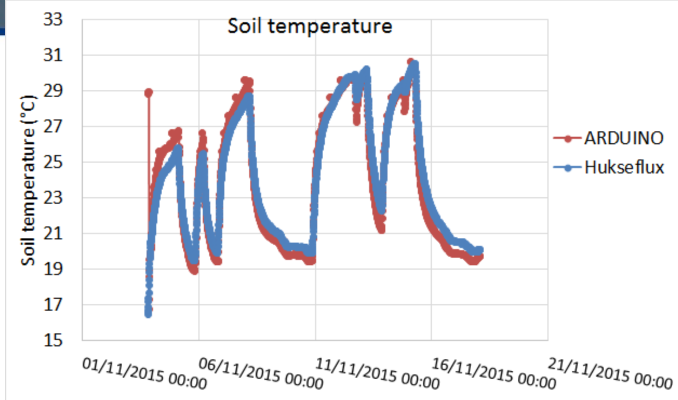


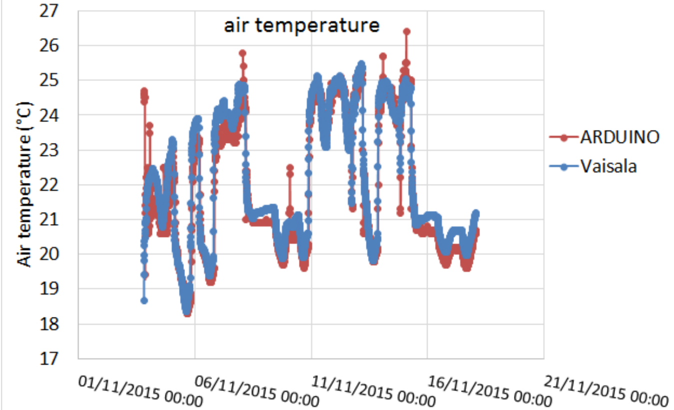
How accurate low cost instruments are? ARDUINO test

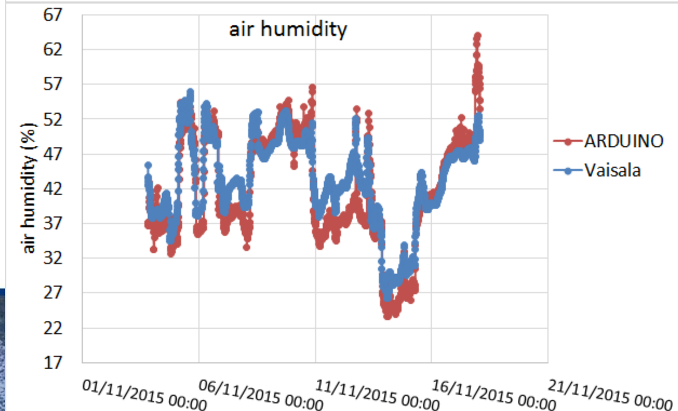


	RMSE
RH (%)	3,32
Ta (°C)	1,34
Tsoil (°C)	0,99

ARDUINO components	Cost euro	High quality standar components	Cost euro
Arduino board	25	Datalogger Campbell	3000
DataLogger Shield + memory card	28		
Soil moisture sensor	7	Decagon	120
Soil temperature sensor	8		
Air humidity and temperature sensor	16	Vaisala	800
Light sensor	10	Kipp Zonen	3000
total	**94**		**6920**





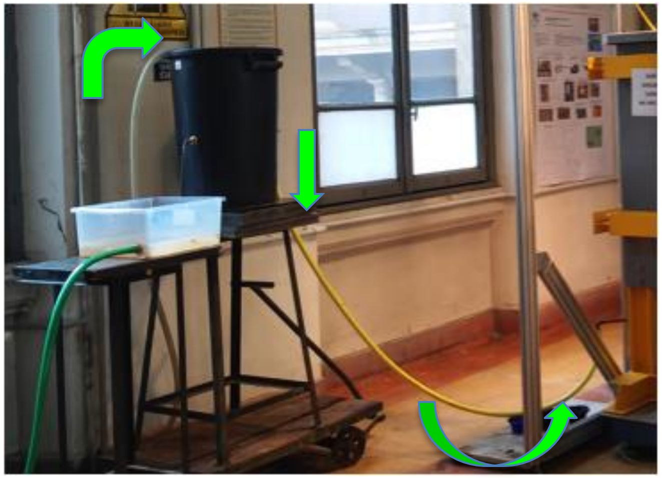


Testing irrigation efficiency and soil moisture profiles

Surface irrigation

Drip irrigation

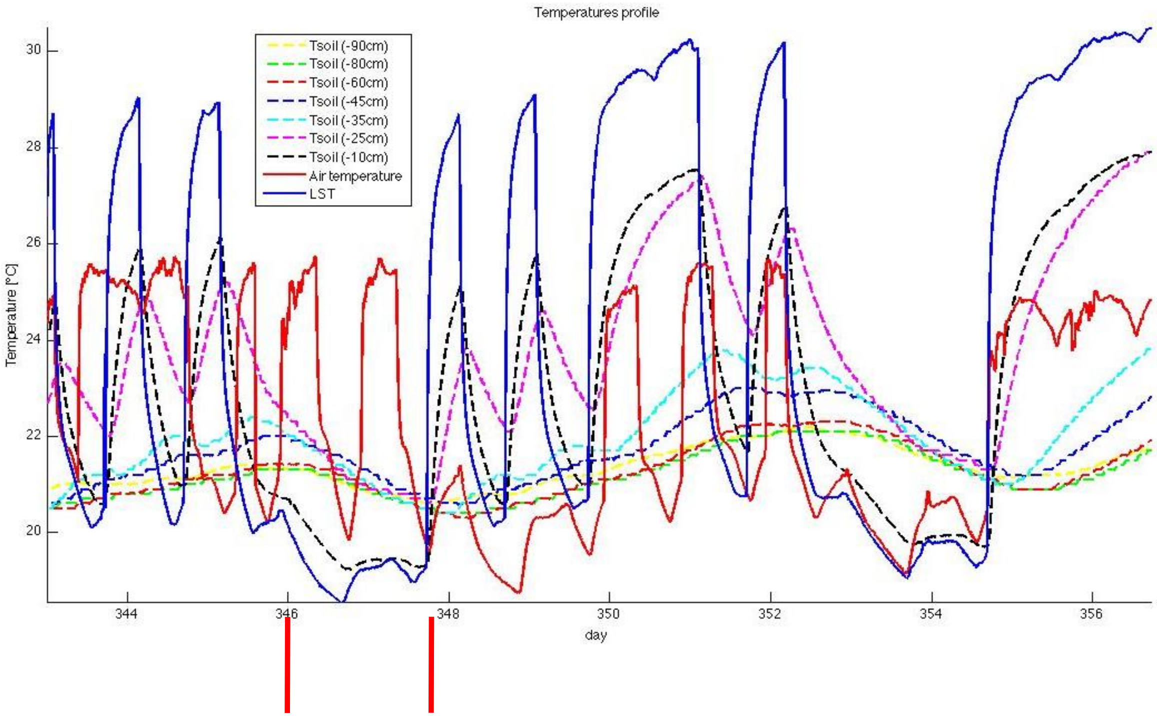
Irrigation from groundwater



	surface	drip	groundwater
Duration exp (day/ hours)	15 days	15 days	25 days
Duration irrigation	10 min	2 hours 10 min	13 days
Irrigation volume (L)	80.5	124,5	257,3

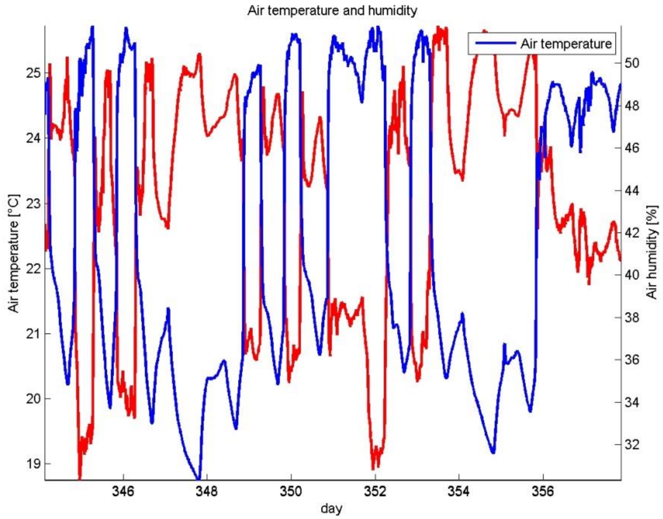
Surface irrigation: meteorological conditions of the lab and temperature profiles

- Daily cycle for air temperature, LST and soil superficial Temperature
- Weekly cycle for the soil deeper probes

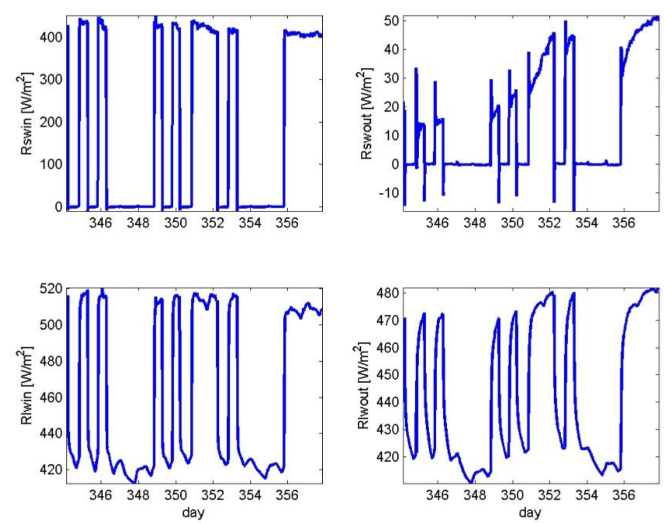


saturday sunday

Air temperature and humidity

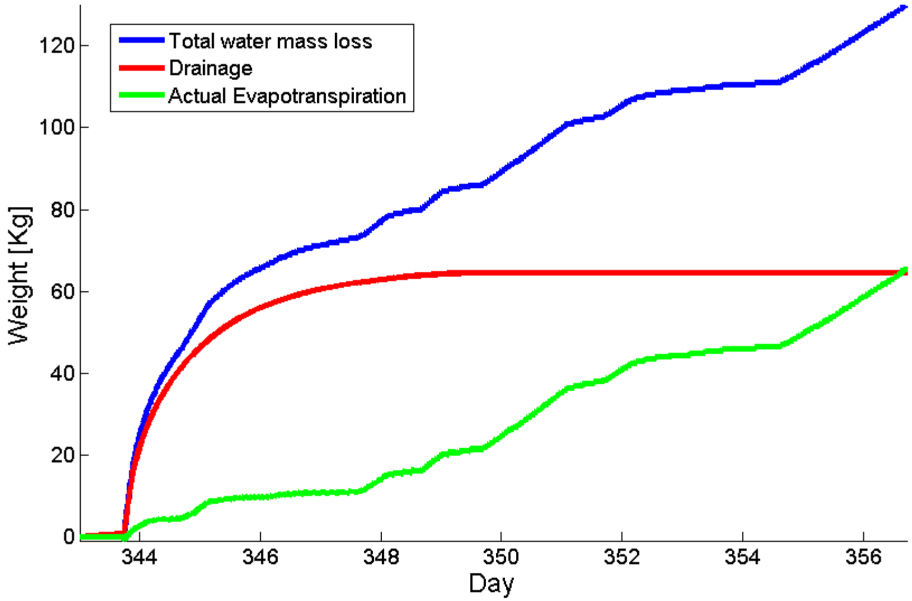


Net radiation



Surface irrigation: evapotranspiration estimates

Evapotranspiration estimated from the difference between the scale weight change and the drainage flux

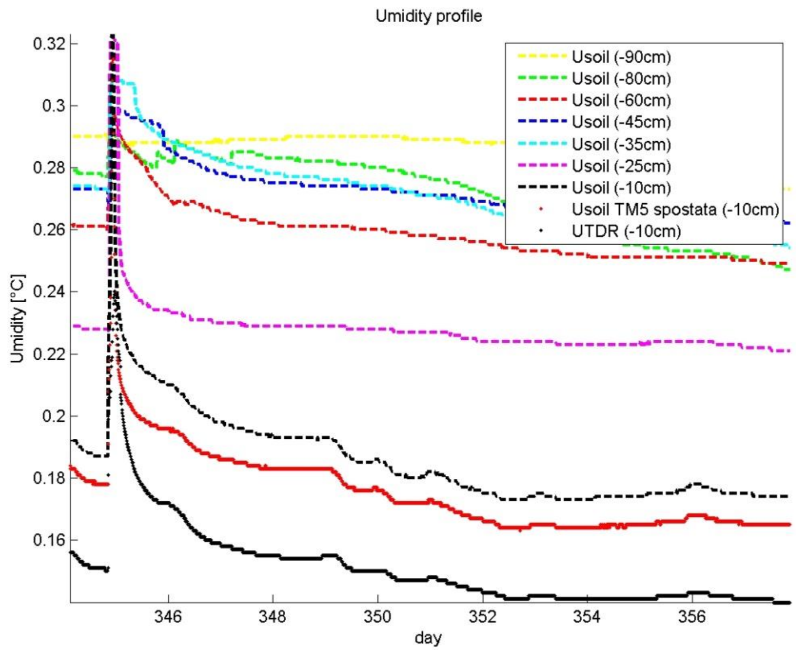


ET eff = $\Delta P - Q_{perc} = 68.38$kg

$\Delta P \longrightarrow$ weight change (133kg)

$Q_{perc} \longrightarrow$ drainage from rain gauges (64.62kg)

Surface irrigation: soil moisture profiles



Saturation soil moisture value reached by the superficial probes (10 cm, 25 cm)

18 hours before irrigation
Just after irrigation
2 h after irrigation
27 h after irrigation
13 days after irrigation

How much water was added to the system:

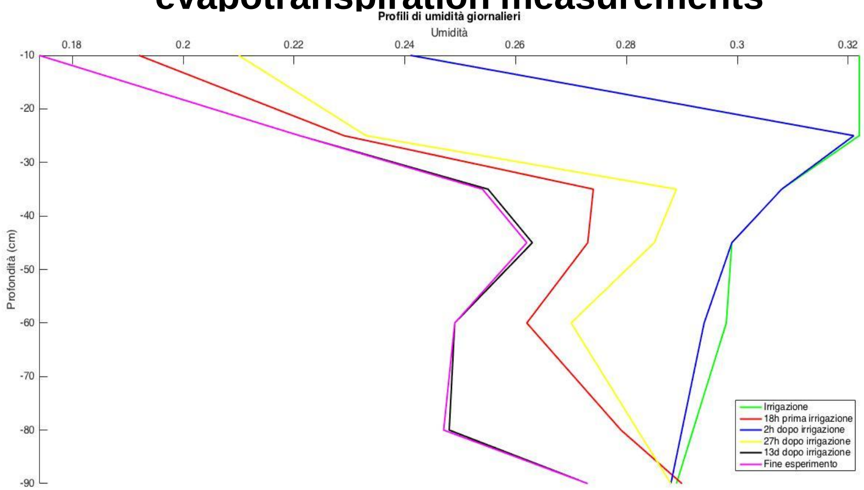
- Measured from the weighter → 80,5 L
- Integration of the area between the green and red lines → 83 L

Error of 10%, due to:

•Probes accuracy

•Spatial heterogeneity of the SM profiles

SM profiles to check percolation and evapotranspiration measurements



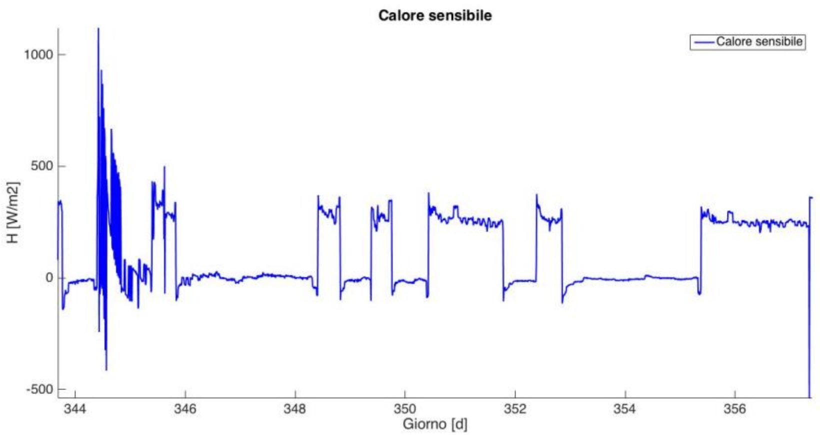
Surface irrigation: water and energy balance closure

esa

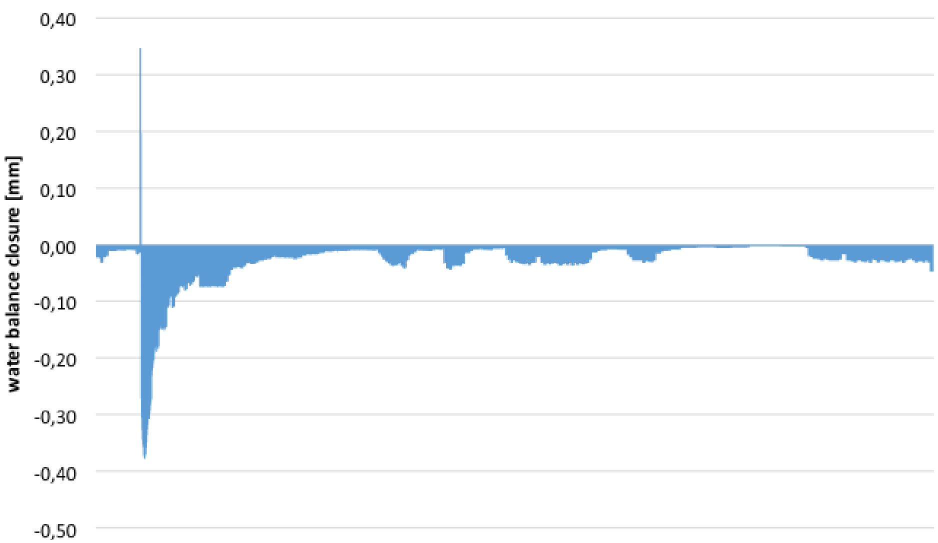
Water balance $\boxed{P} - \boxed{E} - \boxed{\cancel{Q}} - \boxed{\frac{dS}{dt}} + \boxed{\varepsilon} = 0$

Energy balance $\boxed{R_n} - \boxed{LE} - \boxed{G} - \boxed{H} = 0$

Sensible heat flux

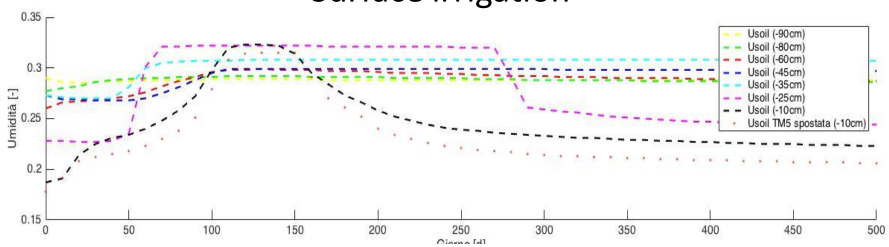


Residual error: less than 0.4 mm

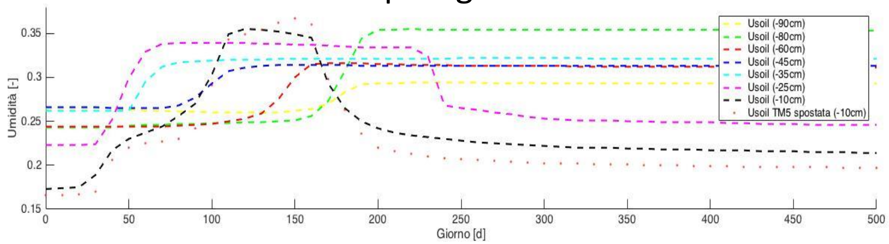


Comparison between soil moisture profiles under surface, drip and groundwater irrigation

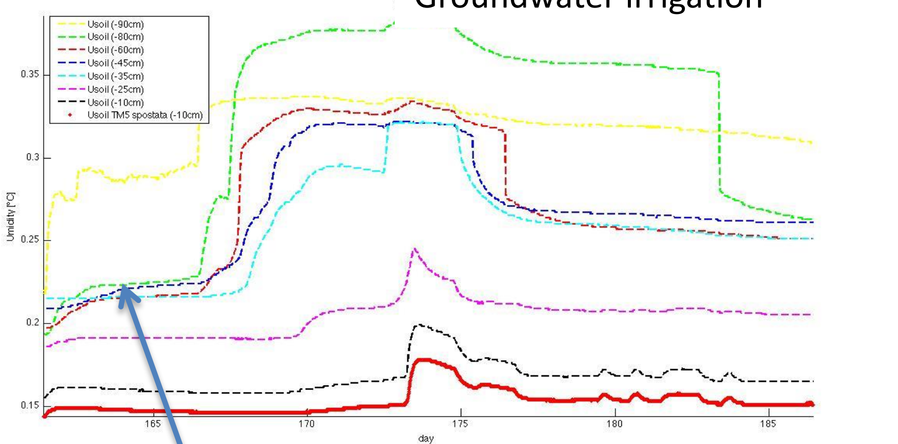
Surface irrigation



drip irrigation



Groundwater irrigation



Water head not sufficient

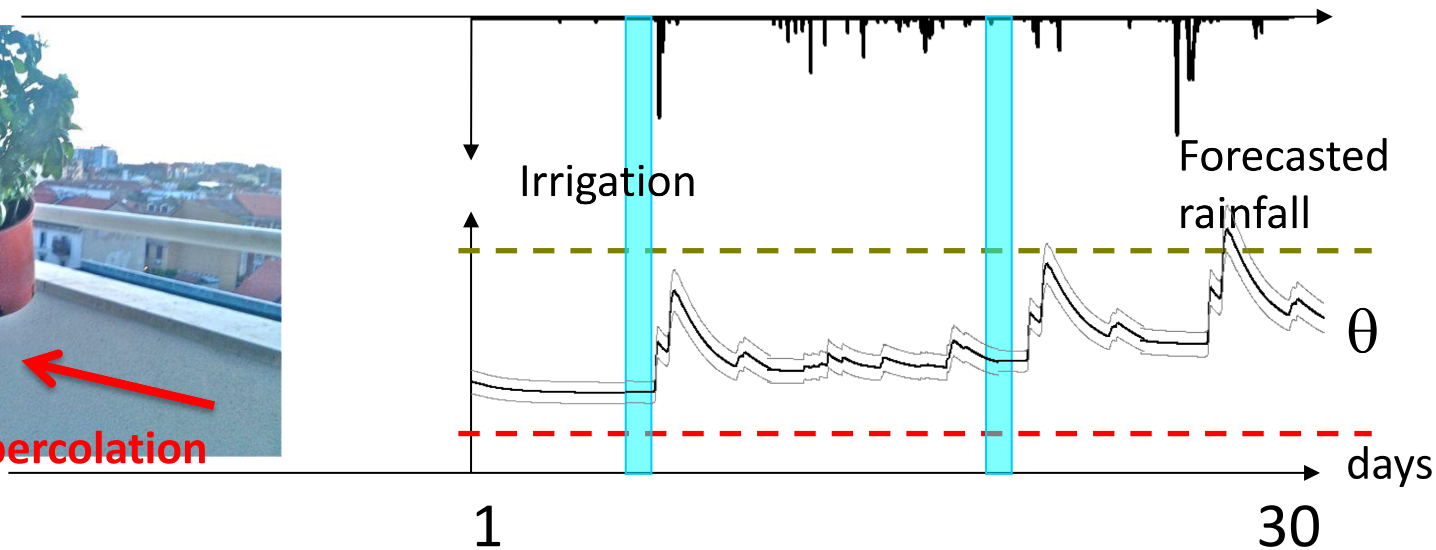
Time of the infiltration front at different depths changes with irrigation type

- SM responds later during drip irrigation than surface irrigation
- groundwater system is a low process and of course SM responds in the opposite way

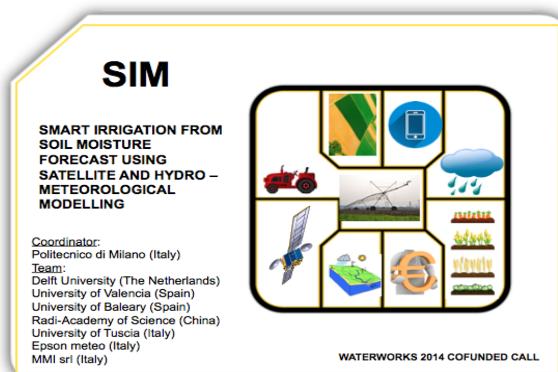
SM probes depth [cm]	t surface [min]	t drip [min]	t ground water [days]
10	10	20	12 days
25	30	30	8 days
35	40	50	6 days
45	50	80	5 days
60	50	100	50 min
80	60	150	40 min
90	60	170	30 min

What happens with vegetation? When to irrigate?

Crop irrigation water: synergism between soil water balance model and meteo forecast



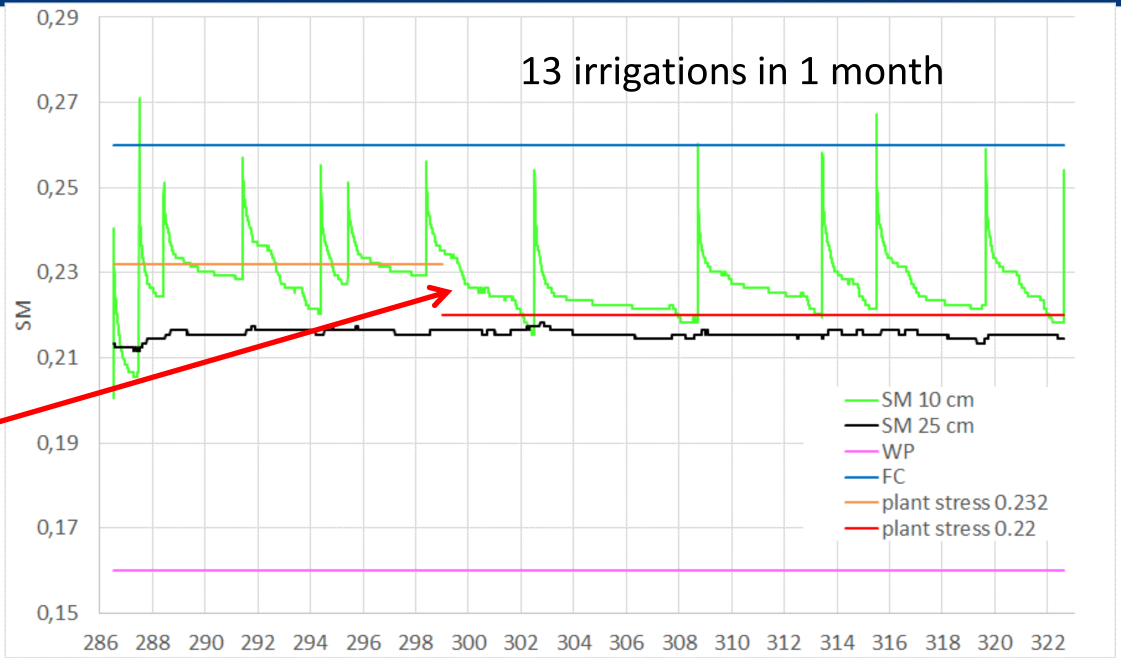
An operative system for **real-time forecast of irrigation water requirements** providing **actual and forecasted soil moisture dynamics** at using **high spatial resolution satellite**, quantitative **meteorological forecast** and detailed distributed **hydrological modelling**



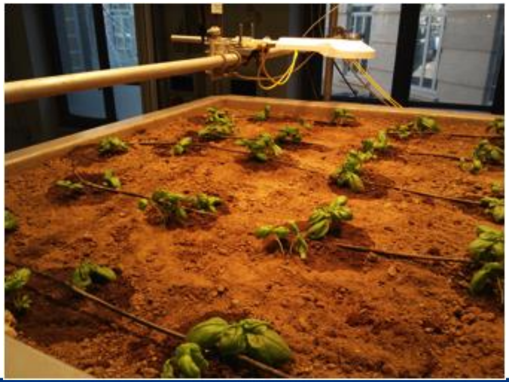
What happens with vegetation? When to irrigate?

Triggering irrigation according to measured (or <u>forecasted</u>) **soil moisture** value and **plant stress threshold**

After 14 days the plant threshold (from FAO) is lowered



Basil planted on 12 october (day 286)

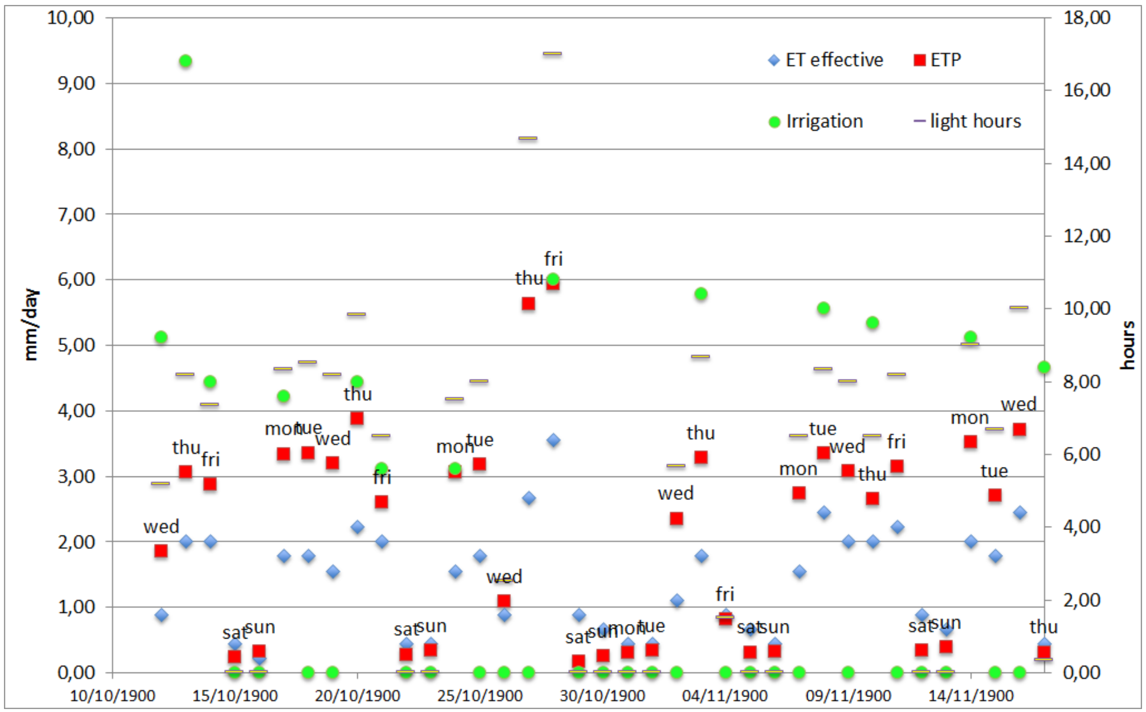


17 november (day322)

Stress threshold is a fucntion of:
-soil type
-vegetation type
-vegetation growth strage
-climatology

(http://www.fao.org/)

What happens with vegetation? Irrigation water needs



Weekend: ETP and ET are about 0.5 mm/day due to no solar radiation

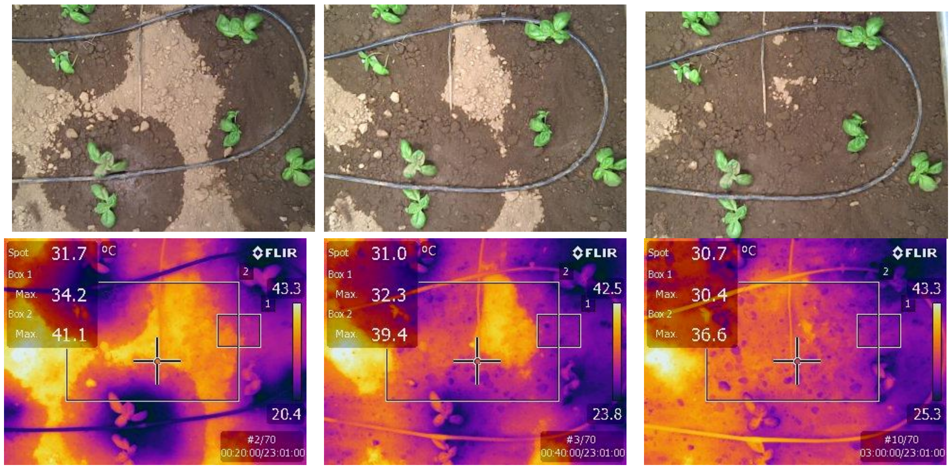
Week day:
ETP is around 3 mm/day
ET is in mean 2 mm/day

ET is slighty changing with vegetation growing, but irrigations are more frequent (even with a lower stress threshold)

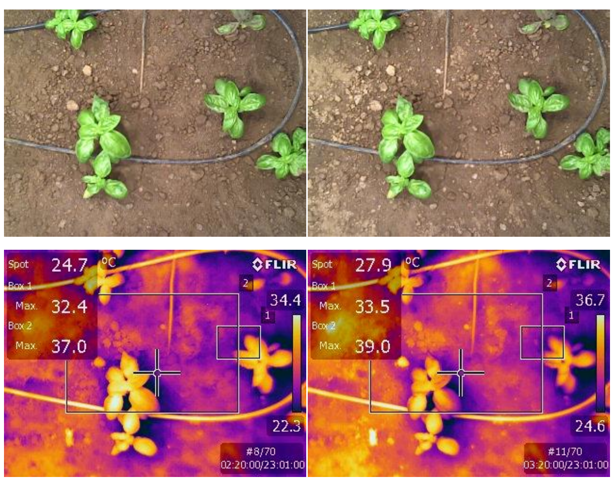
Deficit irrigation?
Irrigation water quantity equal to ET? 50 % of ET?

LST changes and Leaf area index estimation

13 october during irrigation

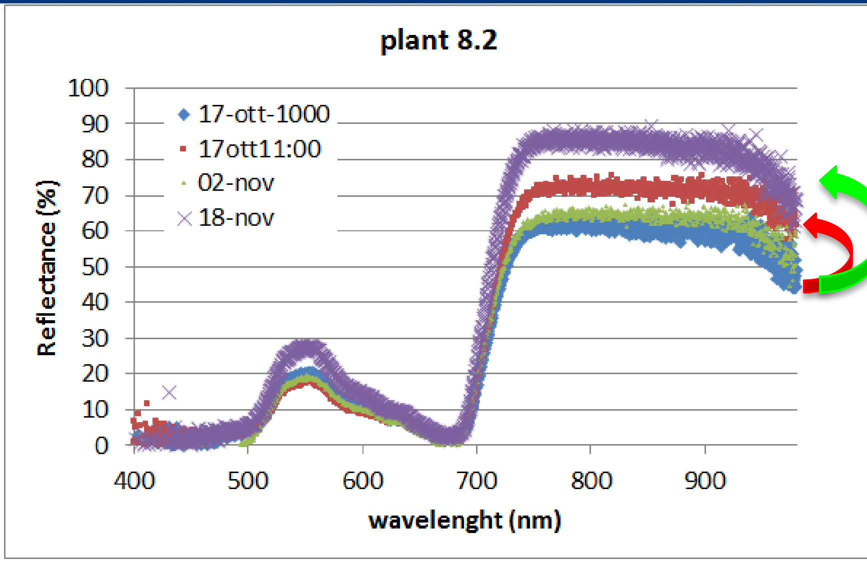


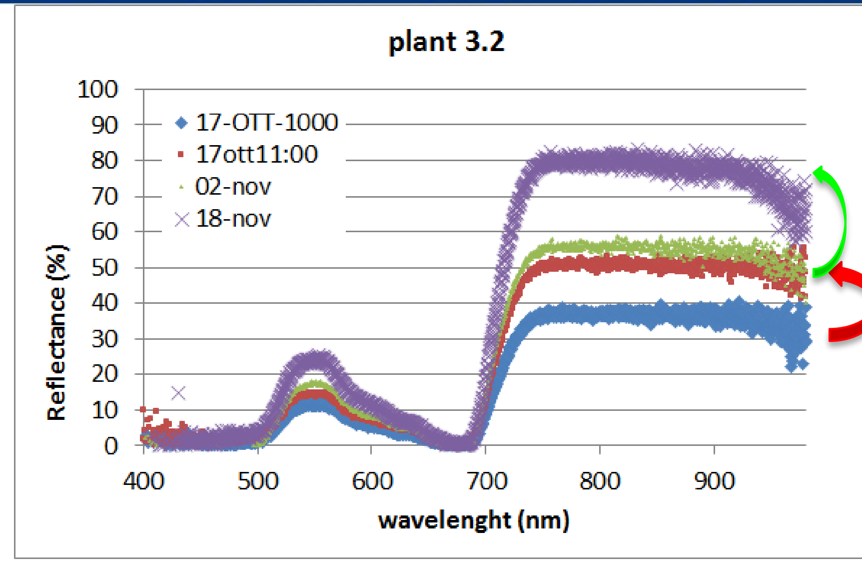
7 november



- Irrigation patterns
- Vegetation patterns: pixel variability of LST
- Estimation of leaf area index LAI

Vegetation spectra and water content





1) Considerable difference in the spectra according to water stress: + VIS, -NIR

	SM		Days from last irrigation
17 october 2016 10:00	0.22	**Strees thr**	4
17 october 2016 11:00	0.251		1 hour after irrigation
2 november	0.221	**Strees thr**	5
18 november	0.23		1 day after irrigation

2) Plants are growing: Large difference in the green and NIR bands from 17 october to 18 november

Verification of the parameterization of the water and energy balance equations in the FEST-EWB hydrological model

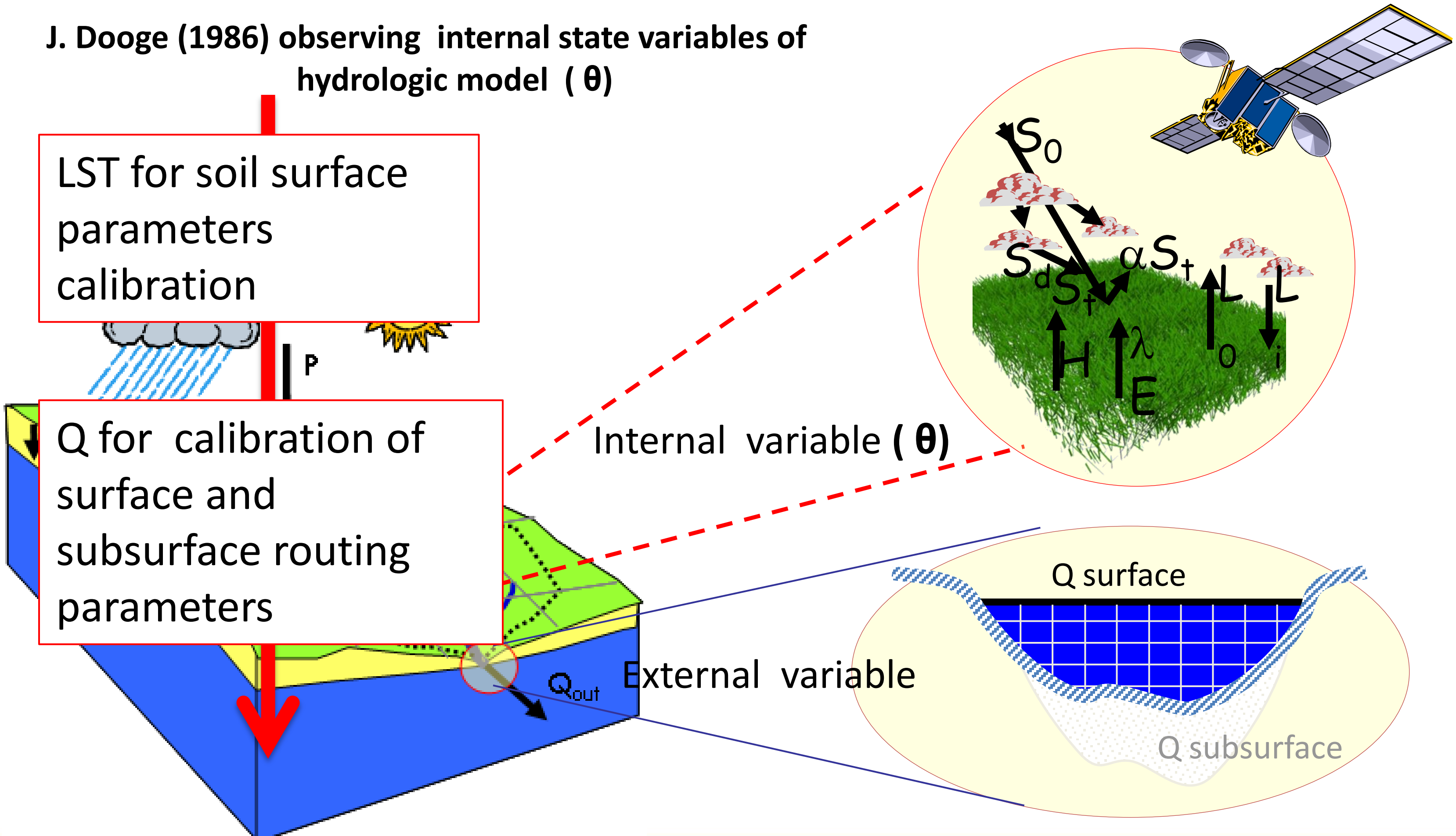
Hydrological model calibration: IN SERIES technique using distributed satellite LST & local discharges

Corbari & Mancini, 2014 (JHM)
Corbari et al., 2014, (HSJ)

J. Dooge (1986) observing internal state variables of hydrologic model (θ)

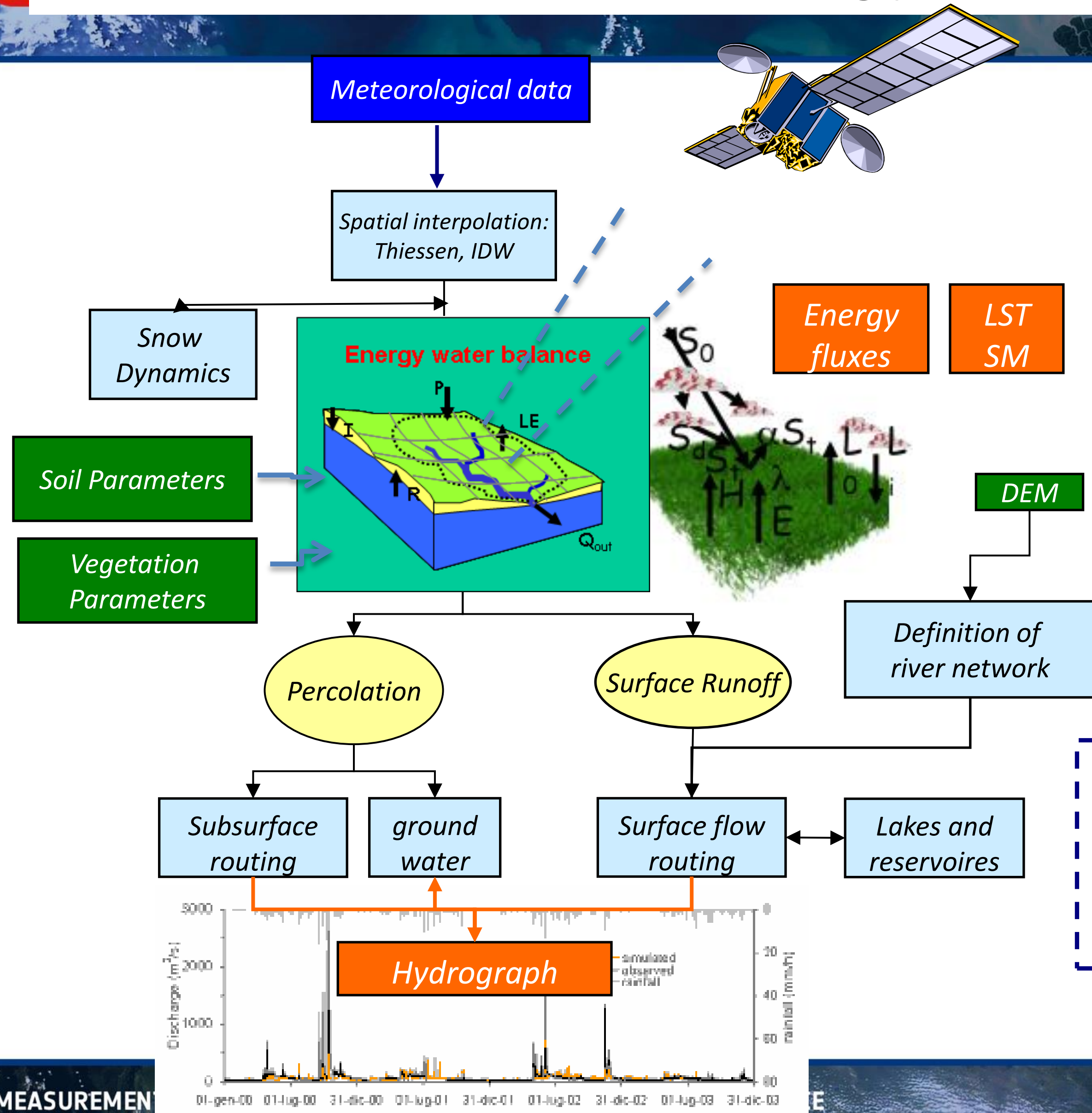
LST for soil surface parameters calibration

Q for calibration of surface and subsurface routing parameters



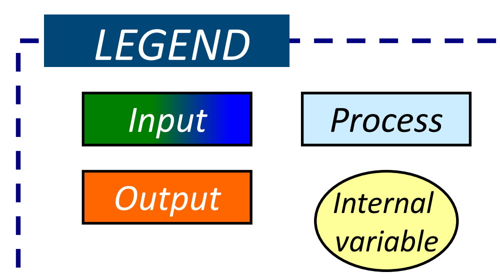
Dooge J.C.I. (1986). Looking for hydrologic laws, Water Resour. Res., 22 (9) 46S-58S.

Distributed Hydrological & Hydraulic MODEL with continuous in time soil moisture accounting (FEST-EWB - by POLIMI)

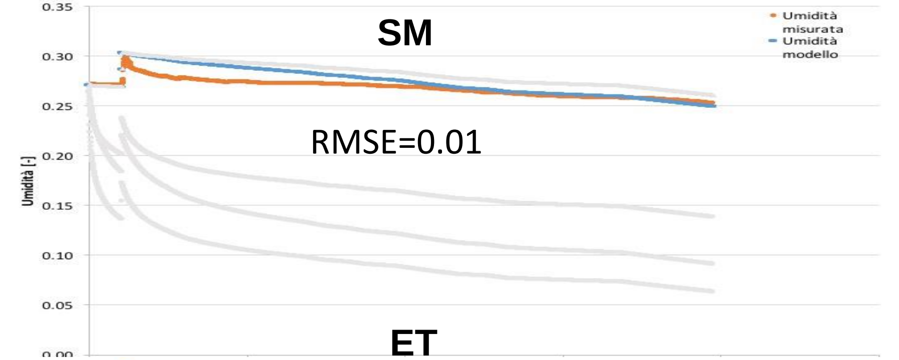


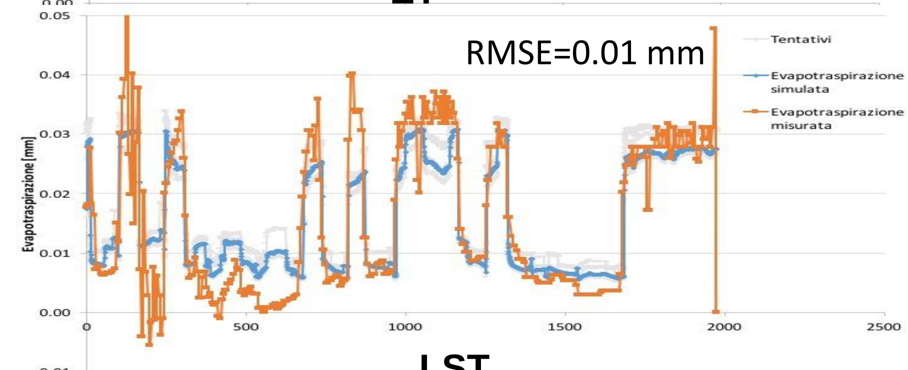
FEST-EWB: Flash – flood Event – based Spatially – distributed rainfall – runoff Transformation – including Energy - Water Balance

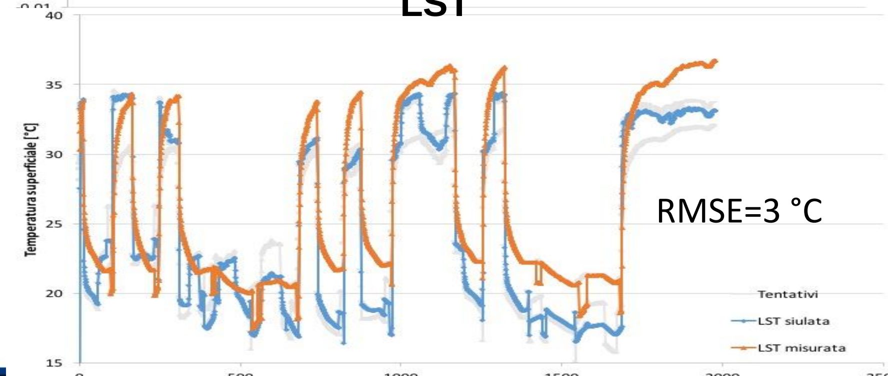
[Mancini phd 90; Montaldo et al., 2007; Rabuffetti et al.,2008; Corbari et al., 2009; Ravazzani et al., 2011; Corbari et al., 2011]

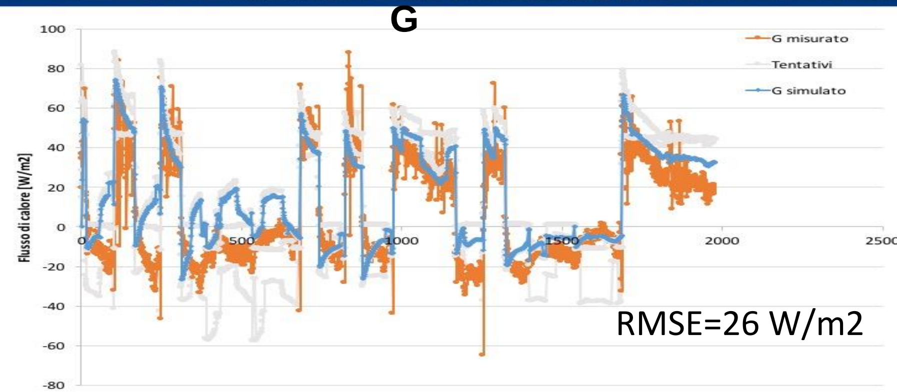


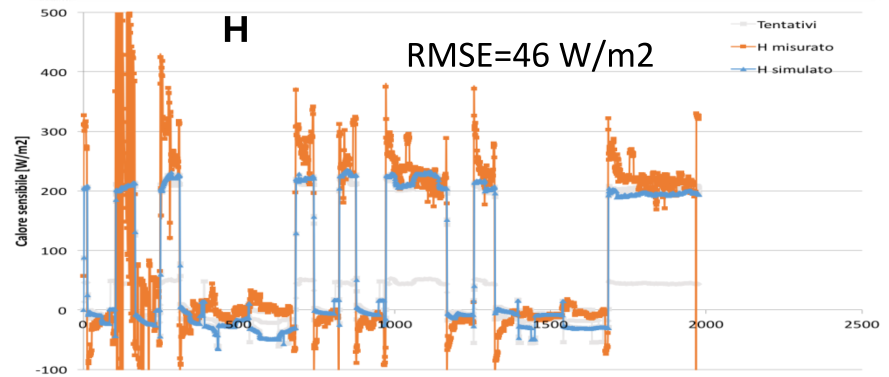
FEST-EWB model PARAMETERS calibration using the surface irrigation experiment

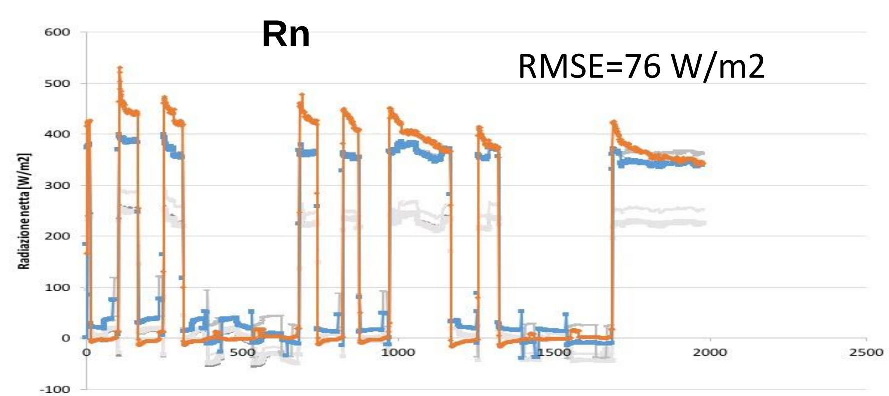




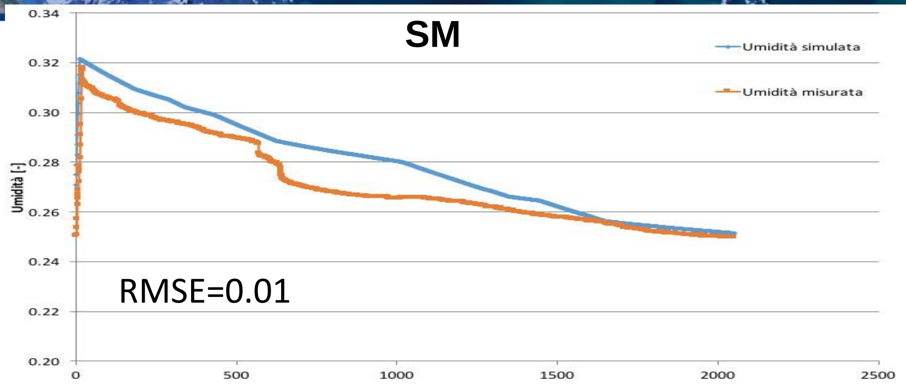


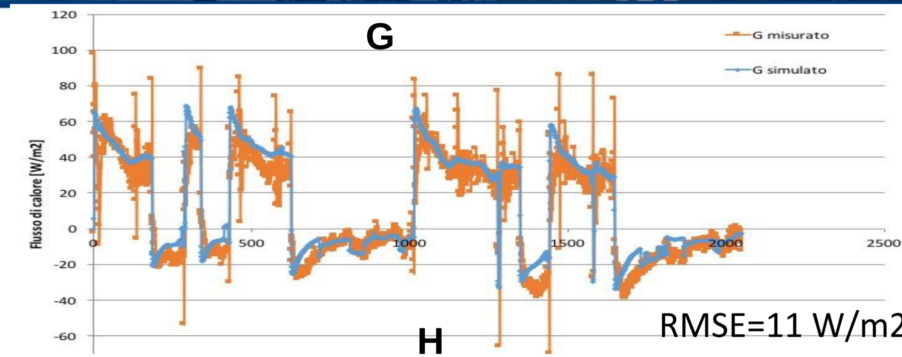


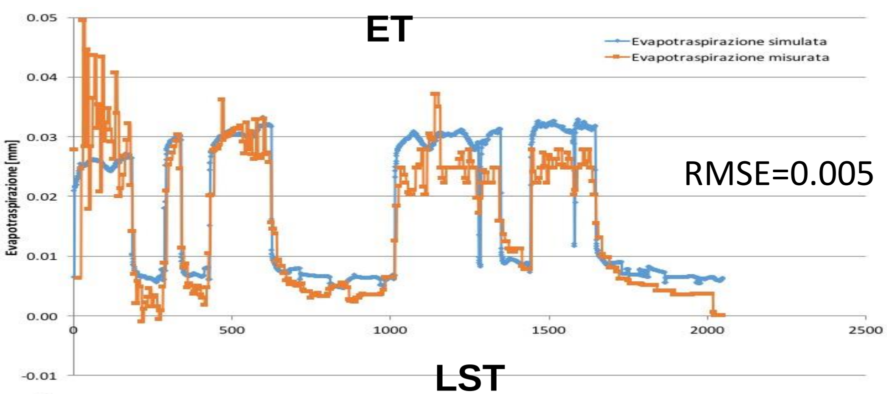


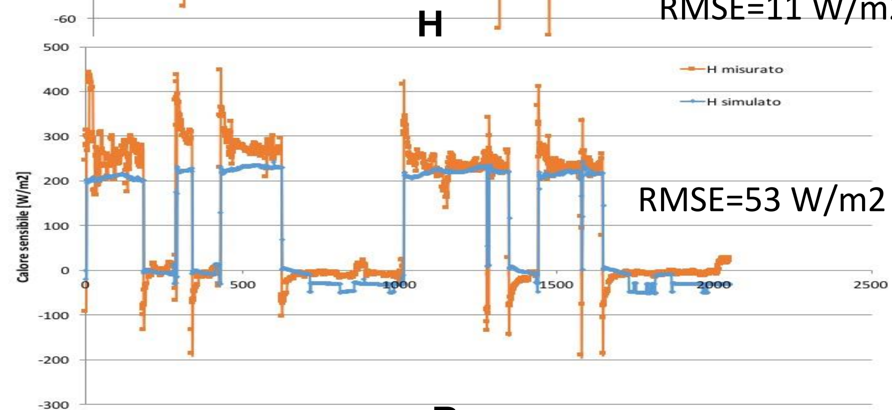


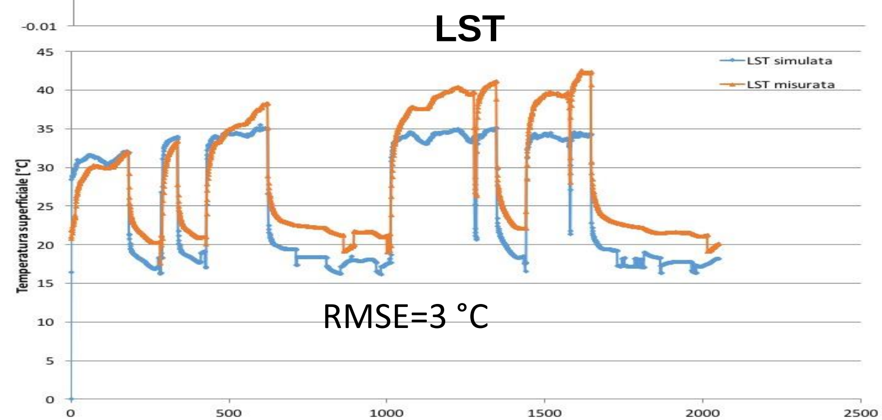
FEST-EWB model PARAMETERS validation using the drip irrigation experiment

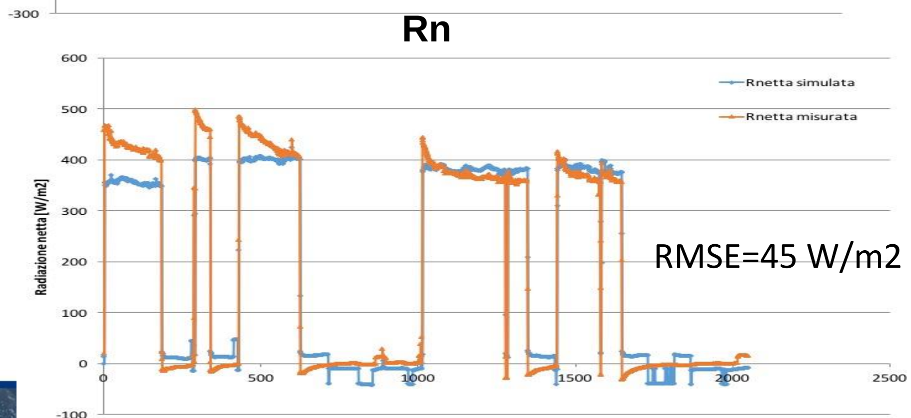












Conclusions … work in progress

- The instrumented lysimeter allowed to measured the different hydrological fluxes and soil mositure dynamics under different irrigation techniques
- Vegetation analysis is promising to better define irrigation water needs
- An experiment in a controlled environment helps to check the parameterization of the equations of FEST-EWB model

… I hope to find tomorrow the basil still green!!!