POLITECNICO DI MILANO

The POLIMI forecasting chains for real time flood and drought predictions

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Session NH1.6/AS1.4/HS4.9 - Coupled atmosphere-hydrological modeling for improved hydro-meteorological predictions

POLITECNICO MILANO 1863

Background & Aims of the study

Over the last twenty years severe river floods and droughts have occurred in Europe, causing thousands of deaths and billion Euros in insured economic losses. Experience suggests that appropriate warnings with sufficient lead time can mitigate the consequences of heavy precipitation events and long dry periods. Therefore, meteorological forecasts coupled to hydrological models are nowadays widespread to decide on an early water-system control actions to prevent or reduce problems with floods, droughts or water quality and regulations.

The two faces of the same coin

Floods

Areas of study:

1. Three catchments located northern than Milan urban area (the Olona, Seveso and Lambro River basins)
2. Idro Lake between the Lombardy and Trentino Regions

Aim:

1. How early warning systems are an effective complement to structural measures for flood control in Milan city?
2. Can we forecast the water lake level for a better management of the upstream and downstream basin?

Droughts

Areas of study:

1. Muzza Bassa Lodigiana Consortium in the Po Valley, northern Italy
2. The Guzzetti agricultural company in the Capitanata area of the Puglia region, southern Italy
3. A golf course near Linate (Milan) airport

Aim: can we save irrigation water and use it in wiser way?

Meteorological models

Deterministic models by ISAC-CNR

GFS	spatial resolution: 50 km, Δt 3h, forecast horizon +144h
Bolam	spatial resolution: 11 km, Δt 1h, forecast horizon +72h
Moloch	spatial resolution: 1.5 km, Δt 1h, forecast horizon +45h

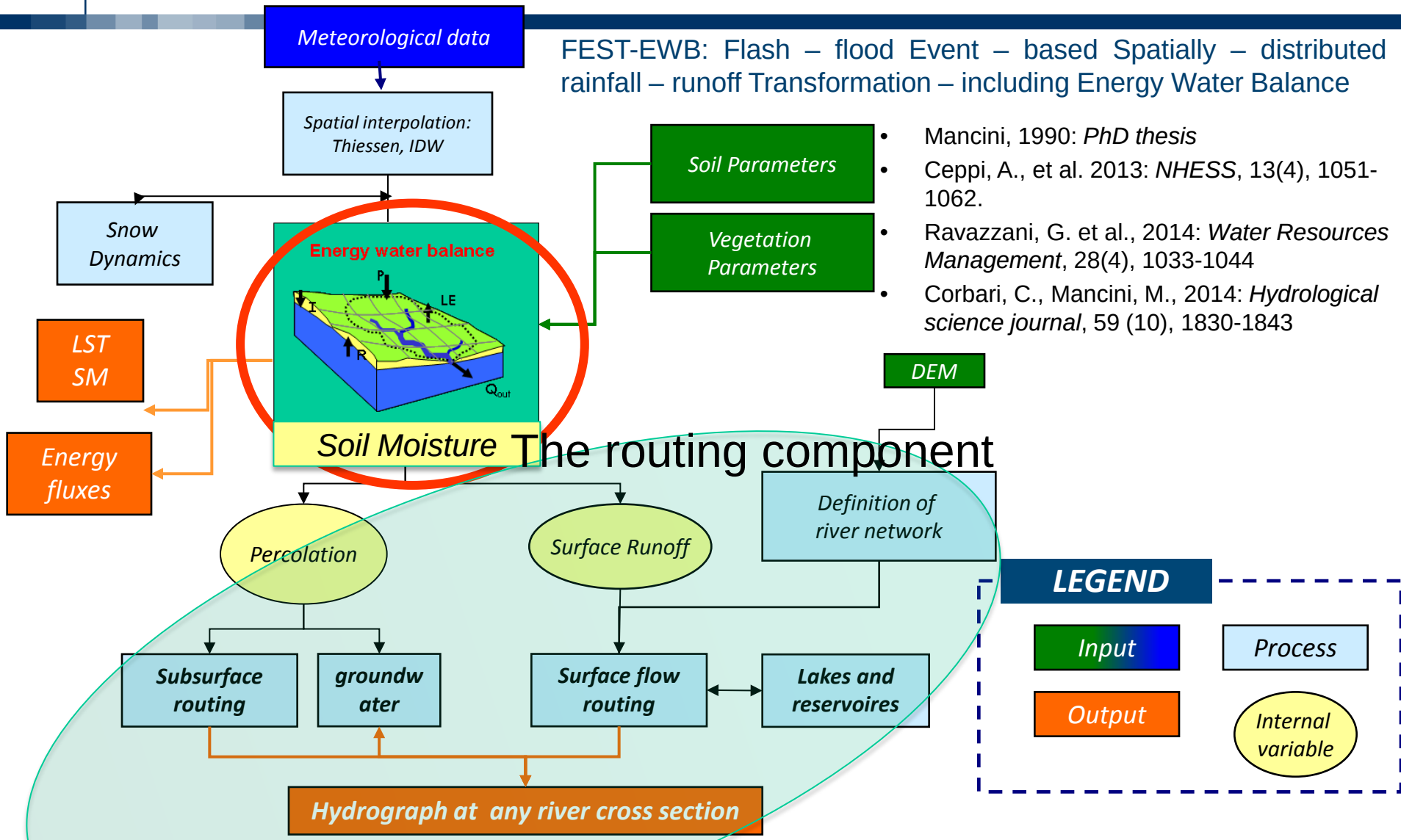
Probabilistic model by ARPA Emilia-Romagna

COSMO-LEPS	spatial resolution: 7 km, Δt 3h, forecast horizon +132h 16 ensemble

WRF	1. spatial resolution: 3 km, Δt 1h, forecast horizon +246h, by Terraria company 2. spatial resolution: 2.5 km, Δt 1h, forecast horizon +48h, by University of Baleari Islands 3. spatial resolution: 5.5 km, Δt 1h, forecast horizon +72h, 8 ensembles, by Epson Meteo Centre

The POLIMI hydrological model: FEST-EWB

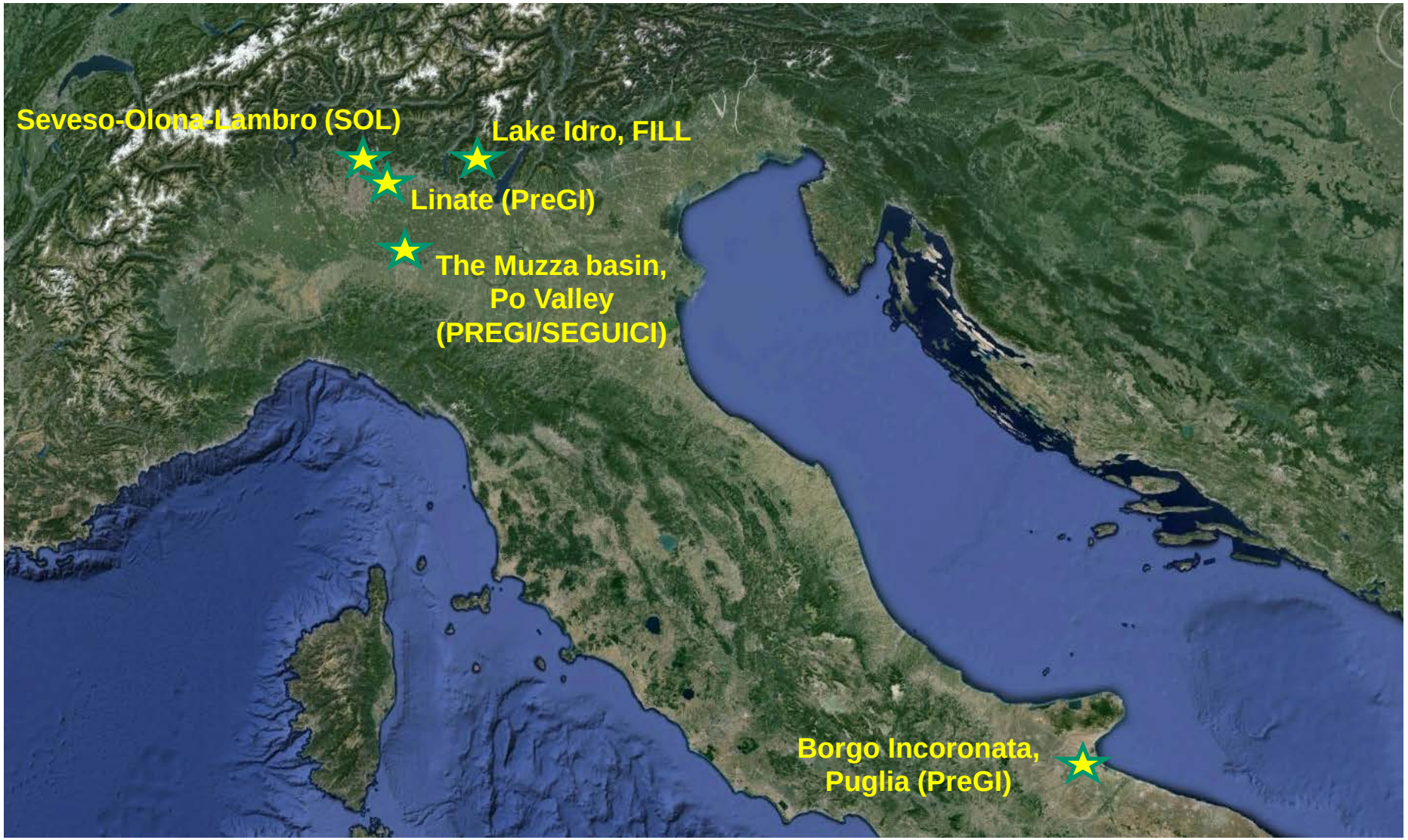
www.fest.polimi.it



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

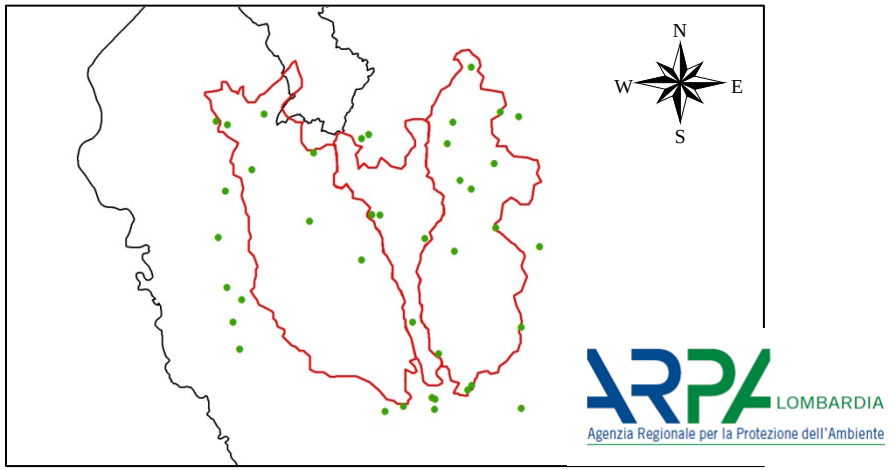
- Mancini, 1990: *PhD thesis*
- Ceppi, A., et al. 2013: *NHESS*, 13(4), 1051-1062.
- Ravazzani, G. et al., 2014: *Water Resources Management*, 28(4), 1033-1044
- Corbari, C., Mancini, M., 2014: *Hydrological science journal*, 59 (10), 1830-1843

Real time flood and drought forecasts: the POLIMI control dashboards

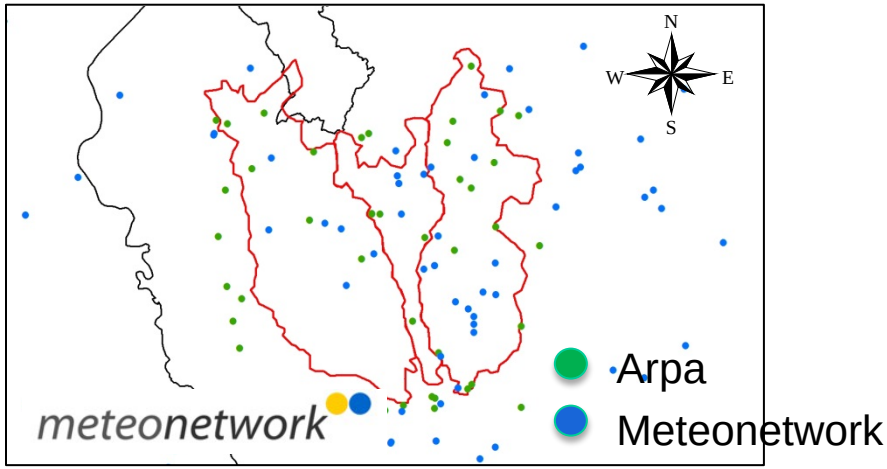


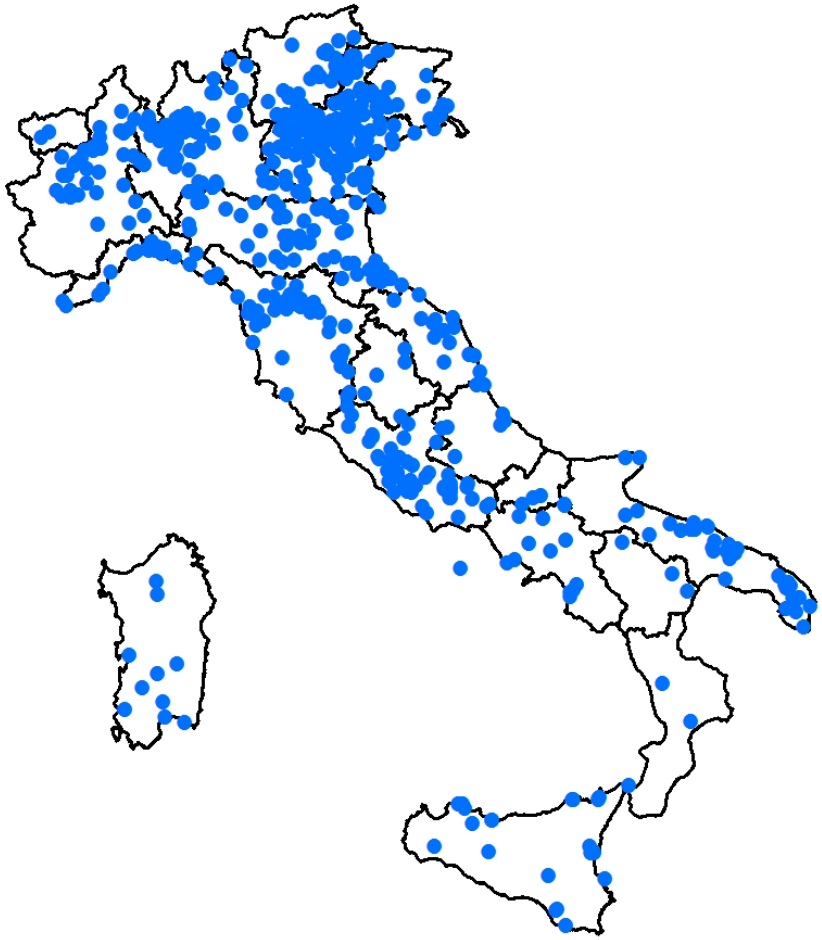
Observed weather data: official and *citizen scientist* stations

Official ARPA Lombardy stations



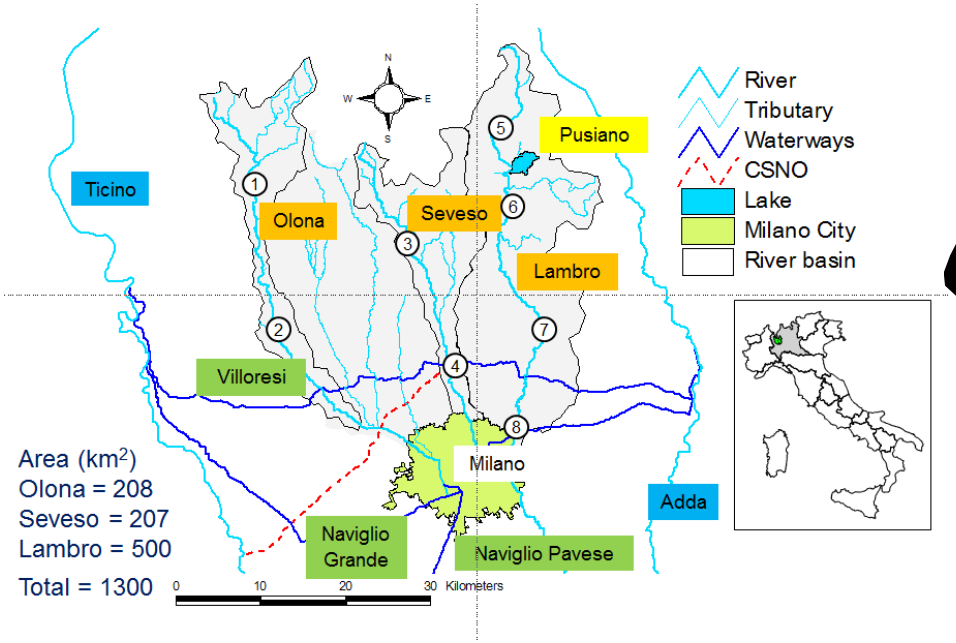
ARPA + Meteonetwork stations

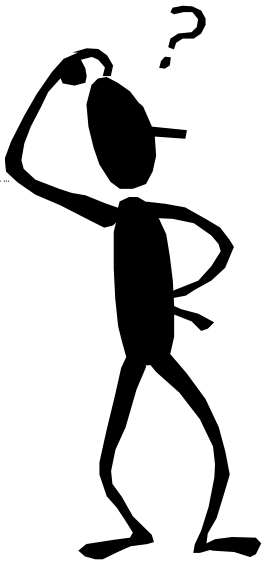




- ~ 850 weather stations
- real time data every 20 minutes

The Milan urban basins: Seveso-Olona-Lambro (SOL)





The Milan urban basins: Seveso-Olona-Olmabro (SOL), recent floods

15/07/2009

- The Olona flood (Varese): 30 milion €

18/09/2010

- The Seveso flood (Milan): 80 milion €

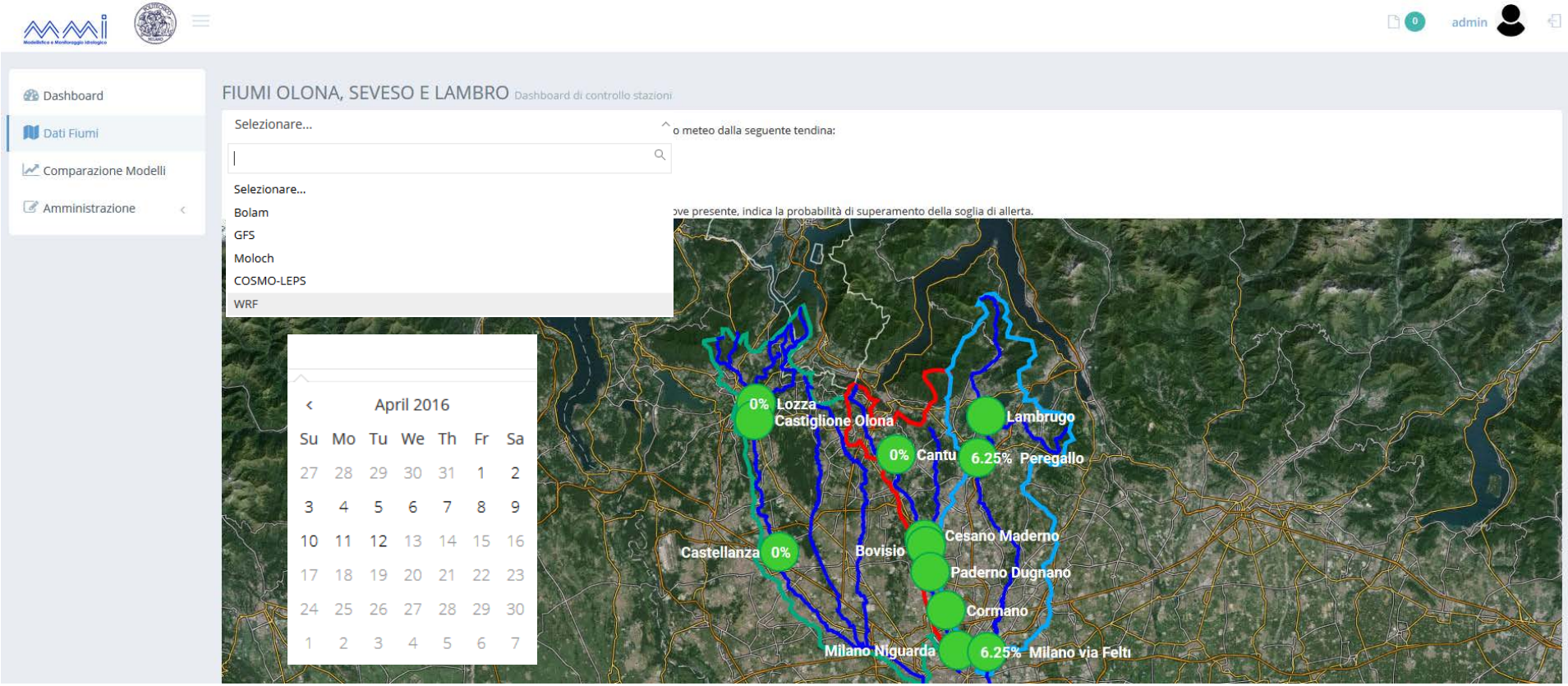
08/07/2014

- The Seveso flood (Milan): 55 milion €

15/11/2014

- The Lambro flood (Monza): 6 milion €

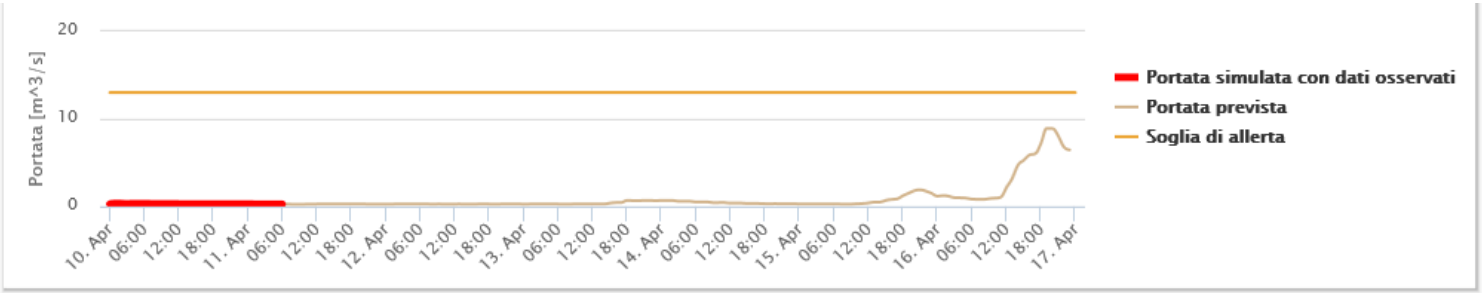
Dashboard SOL: Seveso-Olona-Lambro

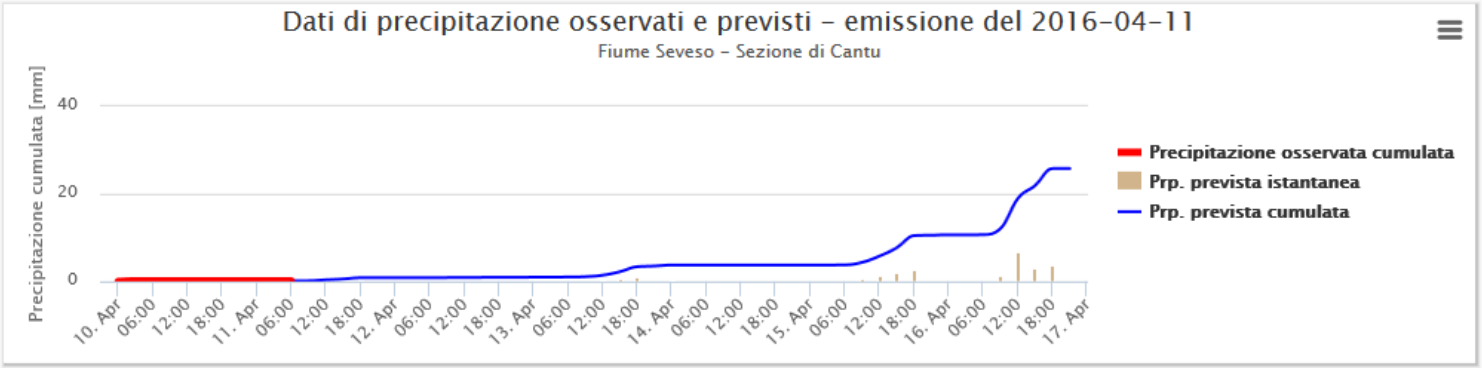


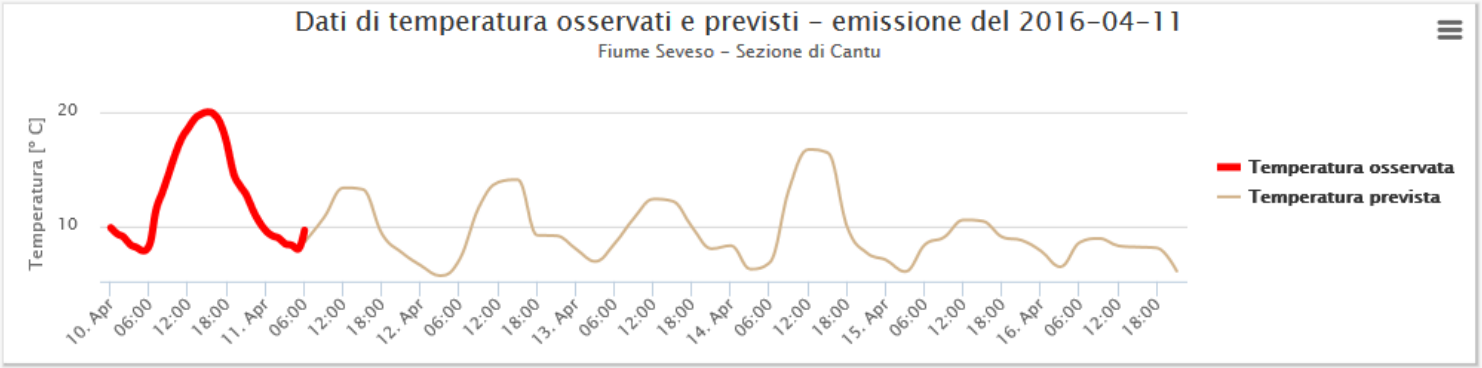
Dashboard SOL: Seveso-Olona-Lambro

Hydro-Meteo Forecasts based by GFS + FEST

Initialized on 2016-04-11







Forecast horizion:
144 hours
Spatial grid: 50 km
Deterministic model
ISAC-CNR

Discharge

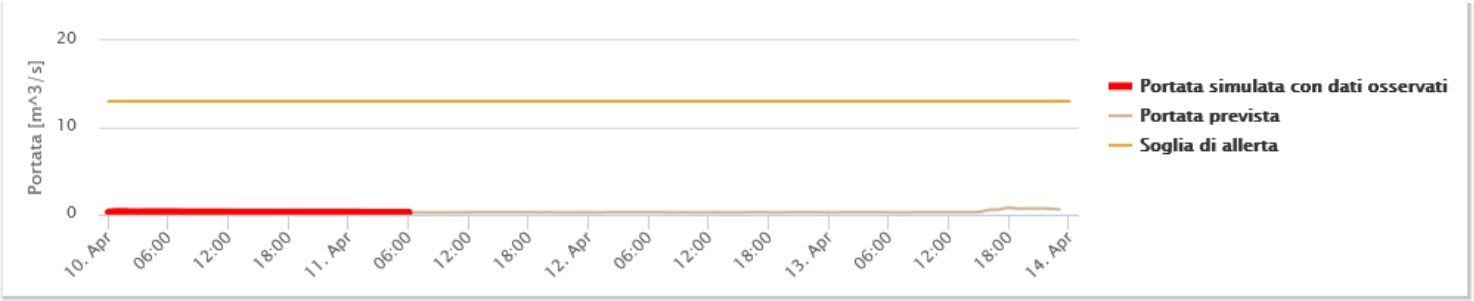
Cumulated Precipitation

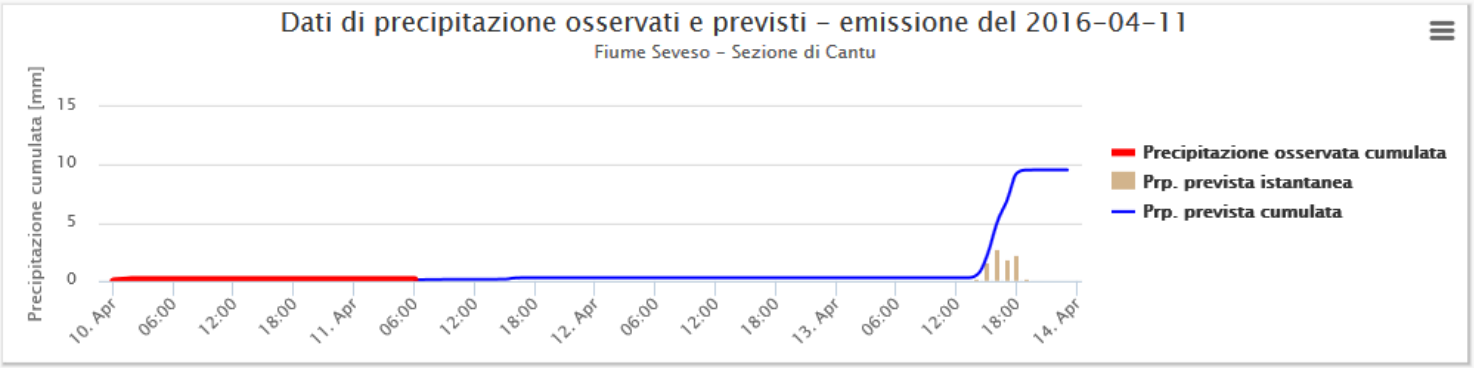
Temperature

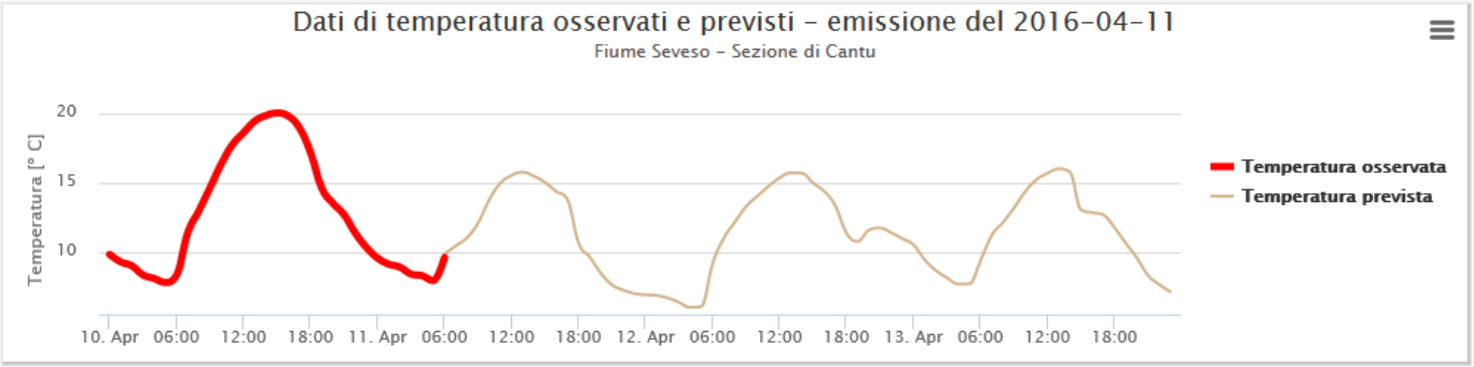
Dashboard SOL: Seveso-Olona-Lambro

Hydro-Meteo Forecasts based by BOLAM + FEST

Initialized on 2016-04-11







Forecast horizion
72 hours
Spatial grid: 11 km
Deterministic model
ISAC-CNR

Discharge

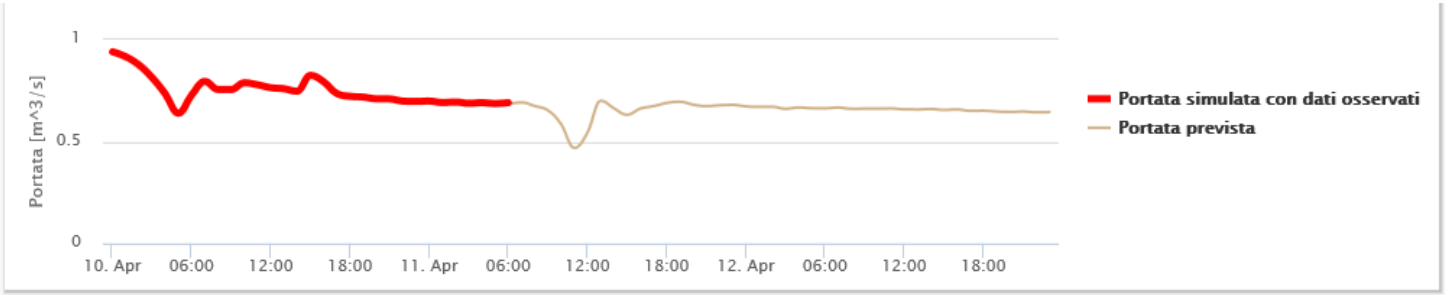
Cumulated Precipitation

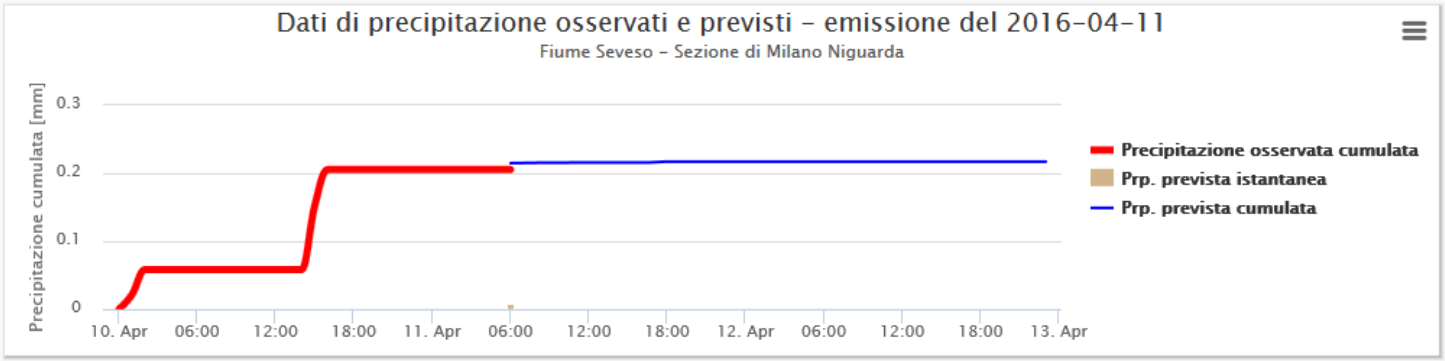
Temperature

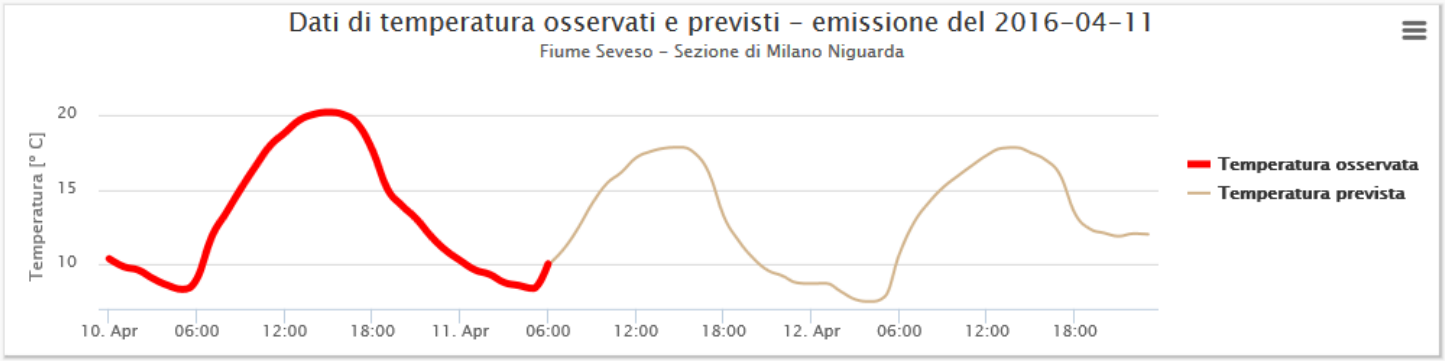
Dashboard SOL: Seveso-Olona-Lambro

Hydro-Meteo Forecasts based by Moloch + FEST

Initialized on 2016-04-11







Forecast horizion
45 hours
Spatial grid: 1.5 km
Deterministic model
ISAC-CNR

Discharge

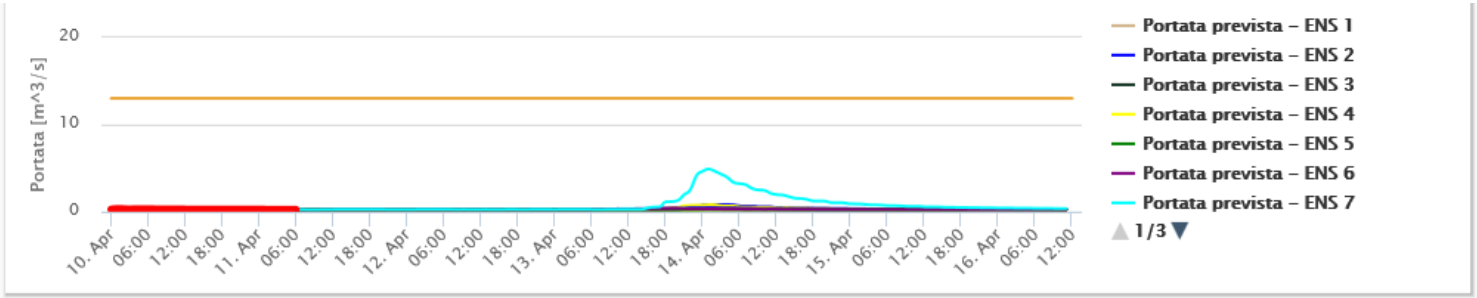
Cumulated Precipitation

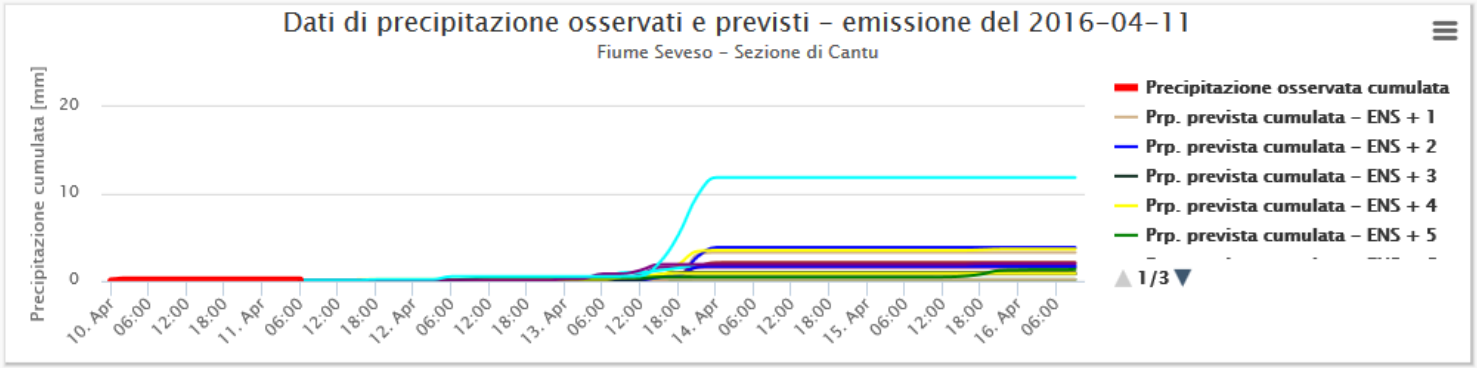
Temperature

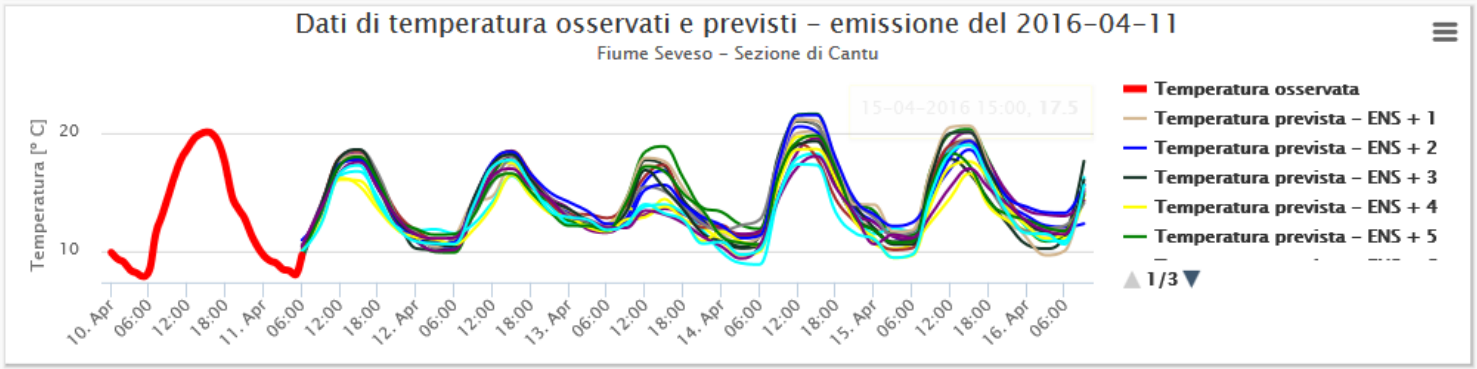
Dashboard SOL: Seveso-Olona-Lambro

Hydro-Meteo Forecasts based by CLEPS + FEST

Initialized on 2016-04-11







Forecast horizion
132 hours
Spatial grid: 7 km
16 ensembles
ARPA-EM

Discharge

Cumulated Precipitation

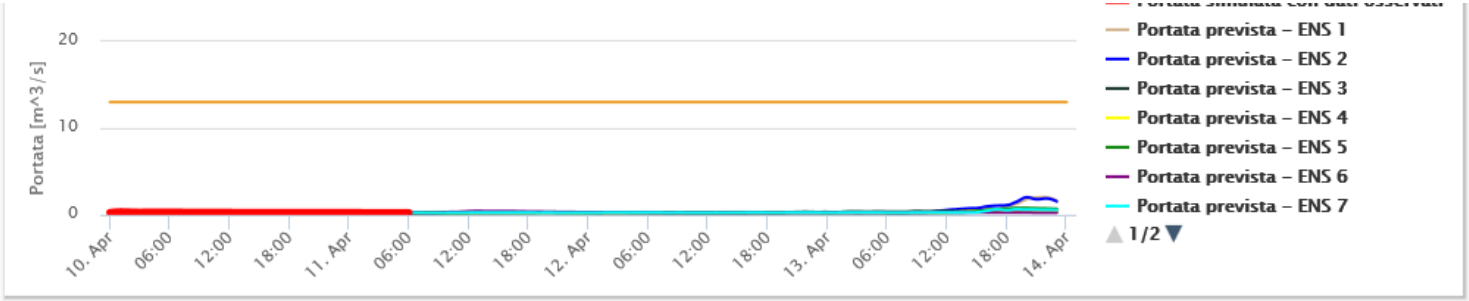
Temperature

Dashboard SOL: Seveso-Olona-Lambro

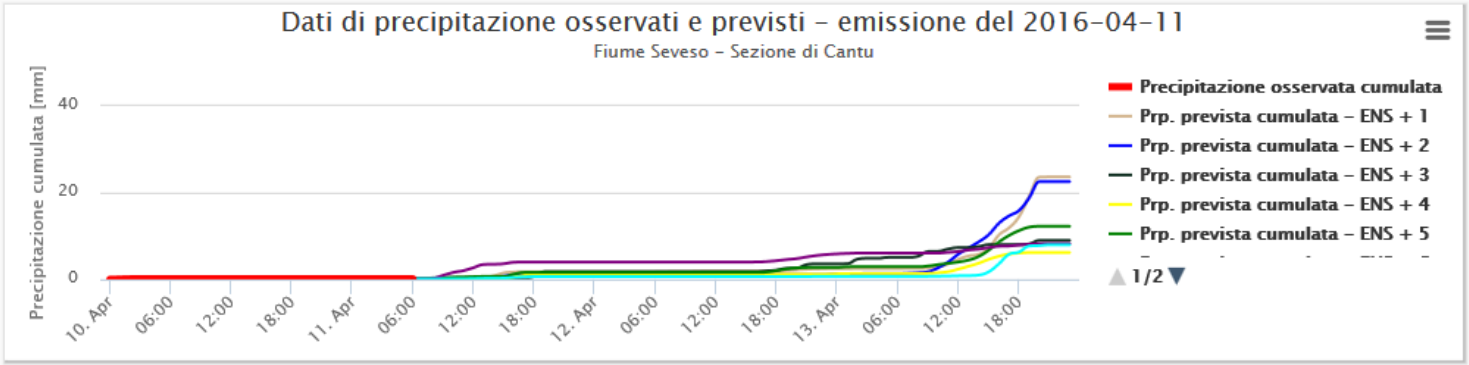
Hydro-Meteo Forecasts based by WRF + FEST

Initialized on 2016-04-11

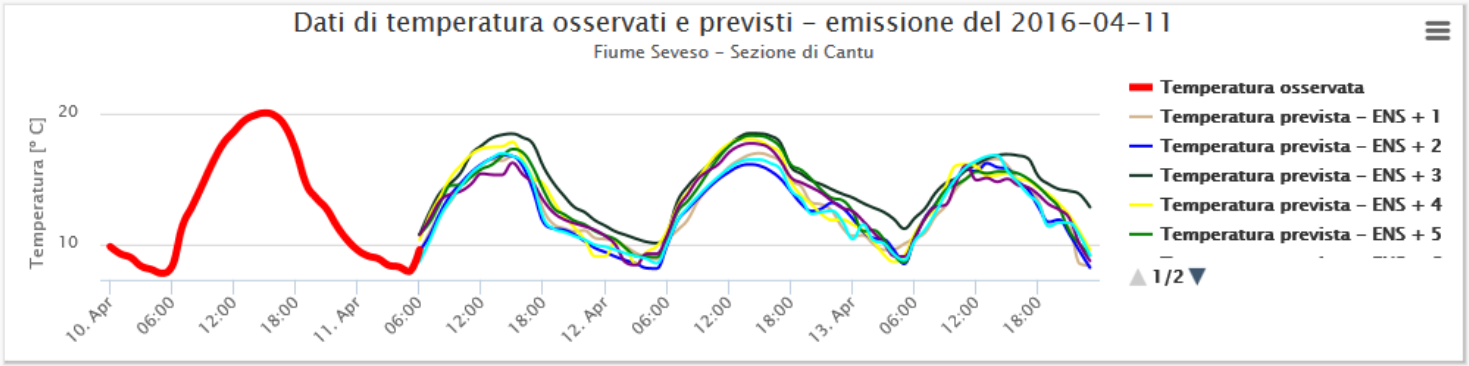
Forecast horizion
48 hours
Spatial grid: 5.5 km
8 ensembles
Epson Meteo Centre



Discharge



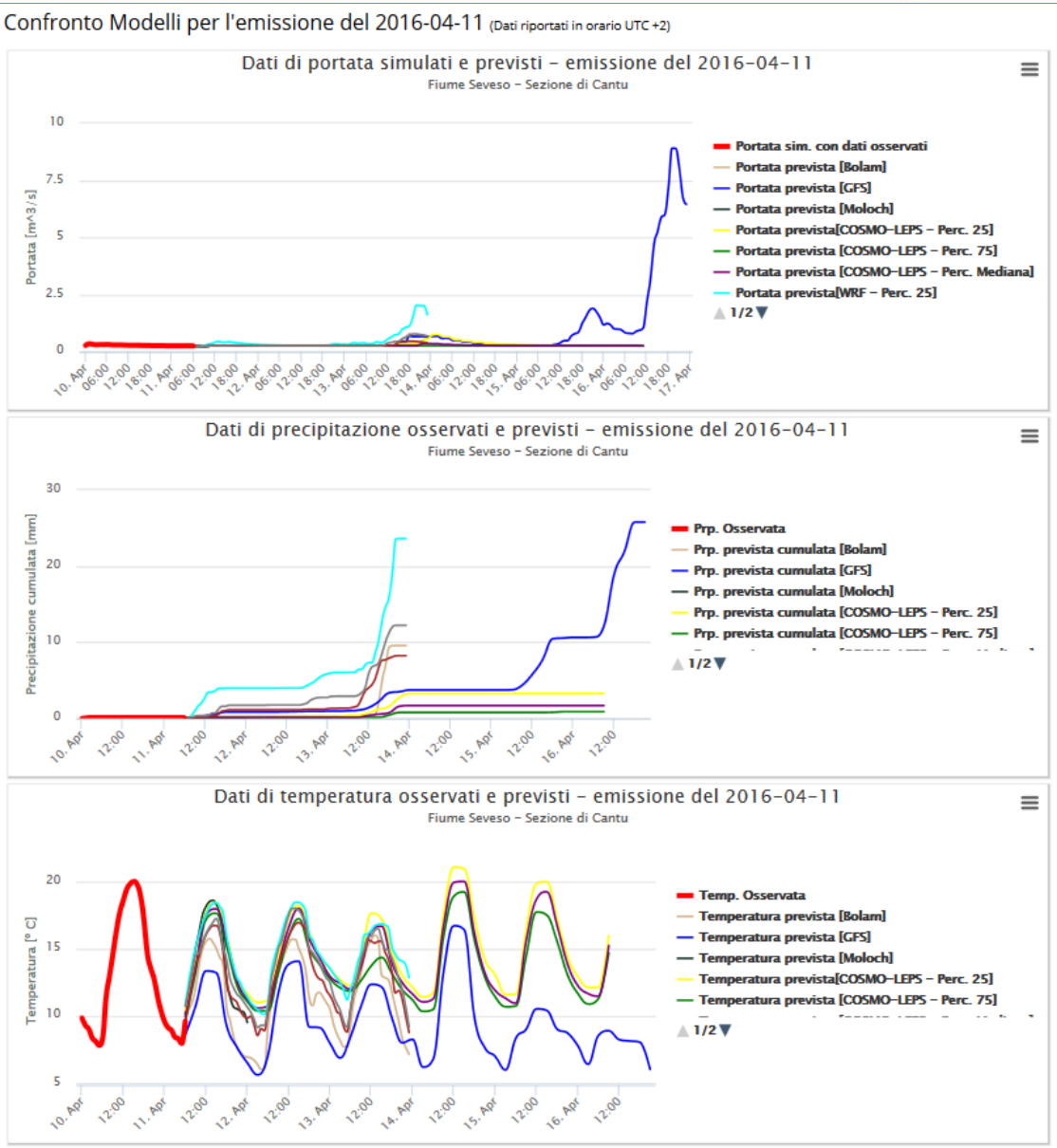
Cumulated Precipitation



Temperature

Dashboard SOL: Seveso-Olona-Lambro

The Multi-Model approach

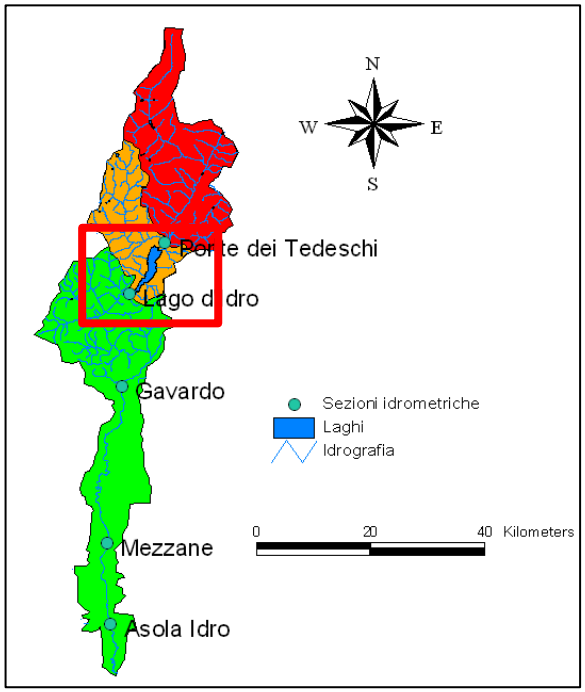


Ravazzani., G., Amengual, A., Ceppi, A., Romero, R., Homar, V., Mancini, M. A hydro-meteorological ensemble prediction system for real-time flood forecasting purposes in the Milano area. ***Submitted to Journal of hydrology.*** *Special issue "Flash floods, hydro-geomorphic response and risk management"*

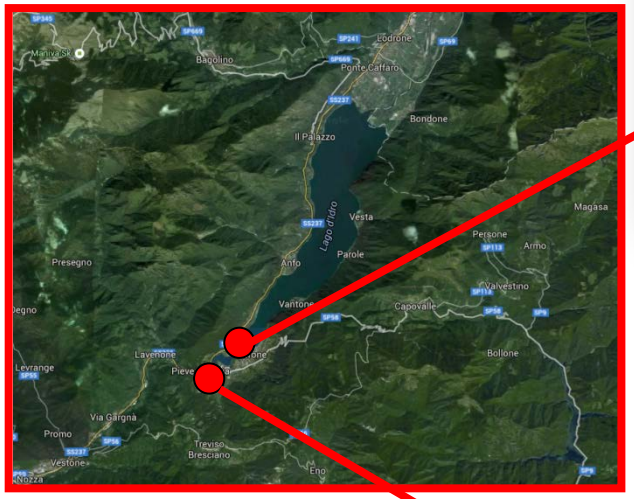
Dashboard FILL: Forecast of Idro Lake Level project

Idro lake, the first regulated lake in Italy since 1923 for irrigation purpose

Lake level control and downstream flood attenuation



Basin area: 1473 km^2



Tunnel (galleria degli agricoltori)

Gated spillway

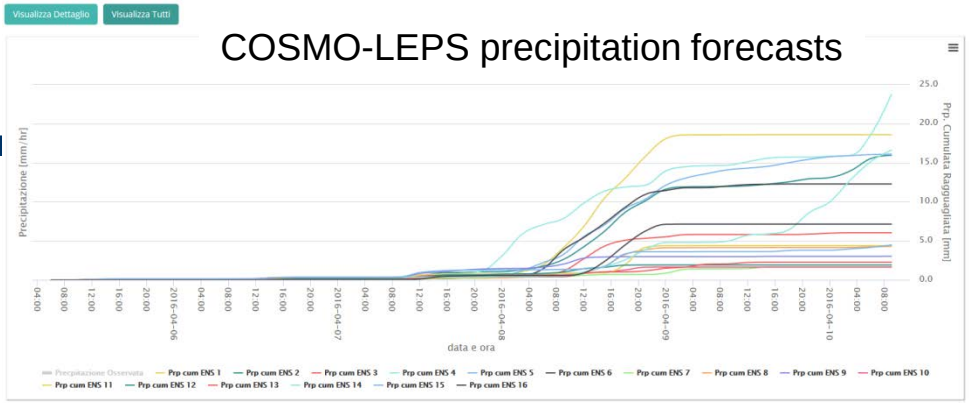
AIPo Agenzia Interregionale per il fiume Po

MMI Modellistica e Monitoraggio Idrologico s.r.l.

Dashboard FILL: Lake regulations

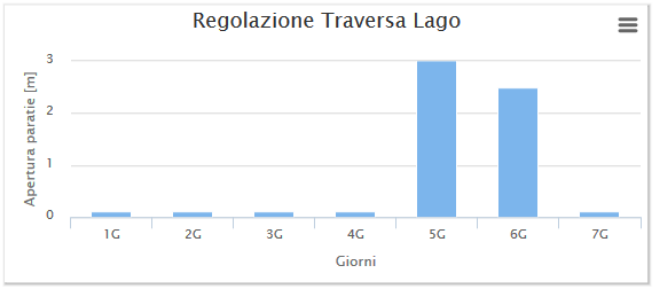
Forecasts min/max lake levels [m asl] according to COSMO-LEPS & FEST-WB coupled simulations

Gate openings [m]



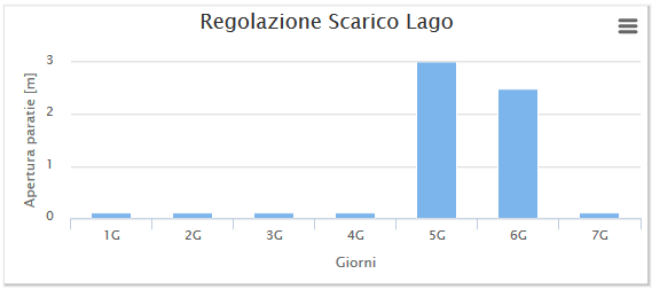
REGOLAZIONI Modello utilizzato: Cosmo-Leps>> Data emissione: 2016-04-05

Regloare i valori di apertura delle paratie direttamente nei grafici. Una volta completata la regolazione premere il pulsante "Elabora dati" per avviare la simulazione.
***ATTENZIONE:** i tempi di simulazione possono essere lunghi.*



Valori apertura paratie:

G1	0.1
G2	0.1
G3	0.1
G4	0.1
G5	3.0
G6	2.5
G7	0.1



Valori apertura paratie:

G1	0.1
G2	0.1
G3	0.1
G4	0.1
G5	3.0
G6	2.5
G7	0.1

☐ Abilita Galleria Enel ☐ Elabora comunque simulazione

☐ Aggiungi al Report

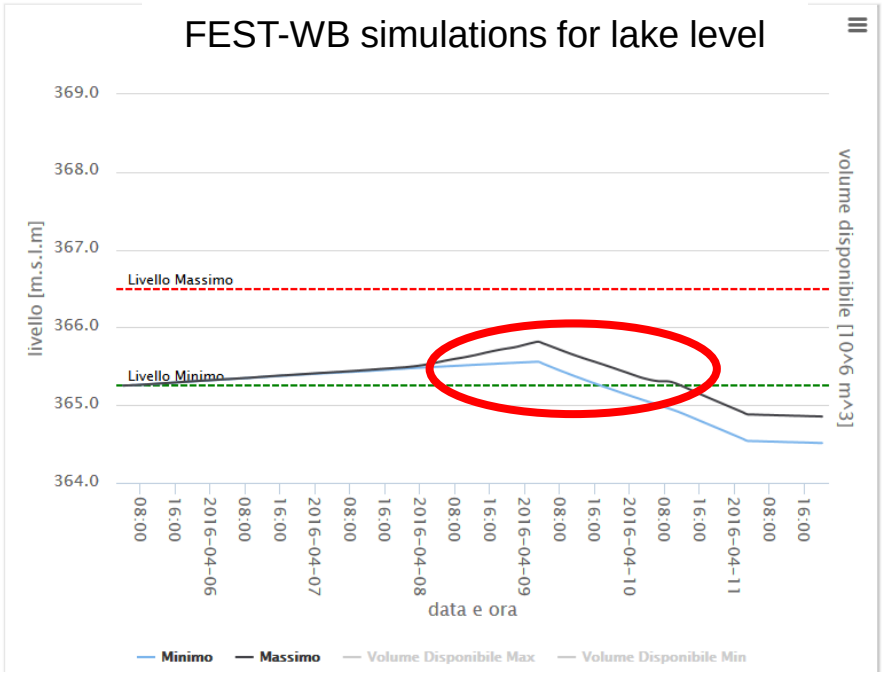
Nome:

admin-Cosmo-Leps-13-04-2016_12-59

***ATTENZIONE:** salvare su base dati allunga notevolmente i tempi di simulazione*

Elabora dati

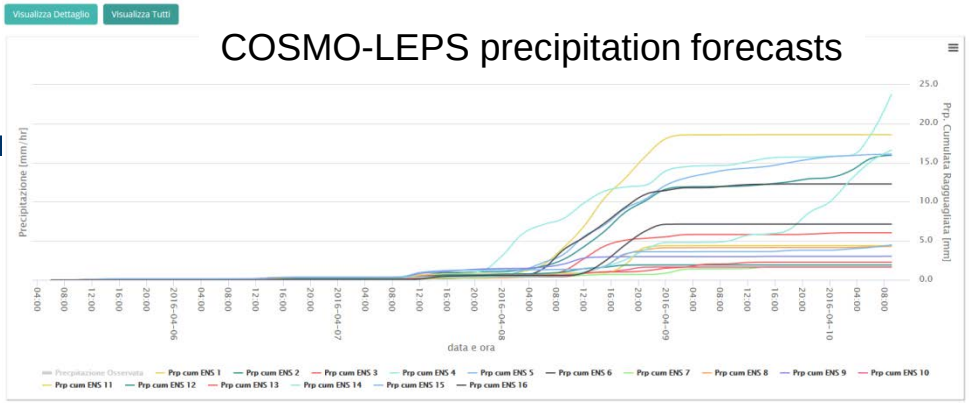
Dati riportati in orario UTC +2



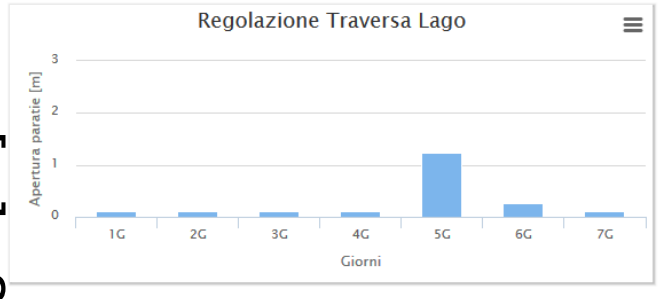
Dashboard FILL: Lake regulations

Forecasts min/max lake levels [m asl] according to COSMO-LEPS & FEST-WB coupled simulations

Gate openings [m]

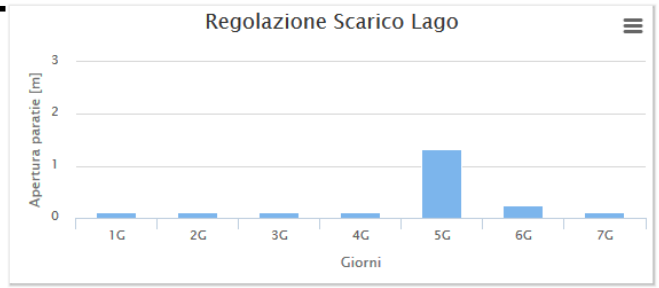


Regloare i valori di apertura delle paratie direttamente nei grafici. Una volta completata la regolazione premere il pulsante "Elabora dati" per avviare la simulazione.
ATTENZIONE: *i tempi di simulazione possono essere lunghi.*



Valori apertura paratie:

G1	0.1
G2	0.1
G3	0.1
G4	0.1
G5	1.2
G6	0.3
G7	0.1



Valori apertura paratie:

G1	0.1
G2	0.1
G3	0.1
G4	0.1
G5	1.3
G6	0.2
G7	0.1

☐ Abilita Galleria Enel

☑ Elabora comunque simulazione

☐ Aggiungi al Report

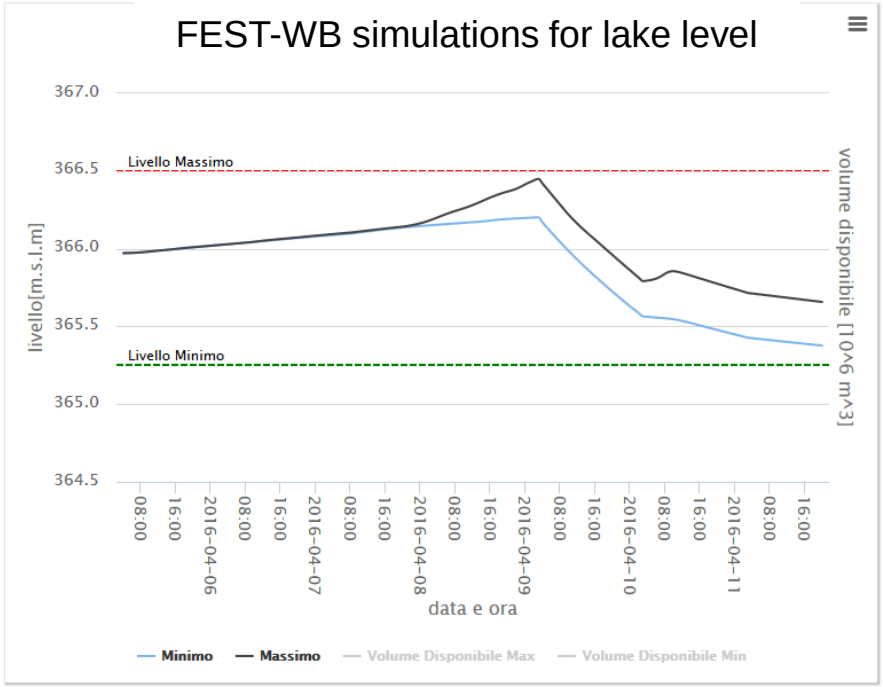
Nome:

admin-Cosmo-Leps-13-04-2016_12-59

ATTENZIONE: *salvare su base dati allunga notevolmente i tempi di simulazione*

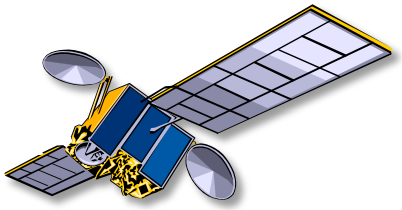
Elabora dati

Dati riportati in orario UTC +2



PREvision and Guide for Irrigation (PREGI): coupling metereological forecasts and hydrological model for irrigation water needs

Satellite data (LST, albedo, NDVI)



Ground data meteorological

Soil moisture observations

INIZIALIZATION RUN

other forcings — station 1

temperature — station 1

precipitation — station 1, station 2, station N

FEST-WB

SM

now

t

Soil moisture forecasts

FORECASTING RUN

other forcings

temperature

precipitation

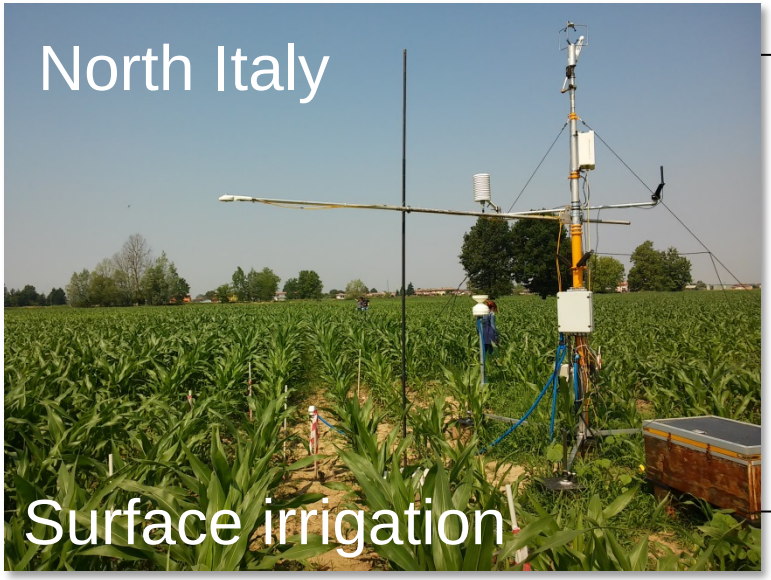
FEST-WB

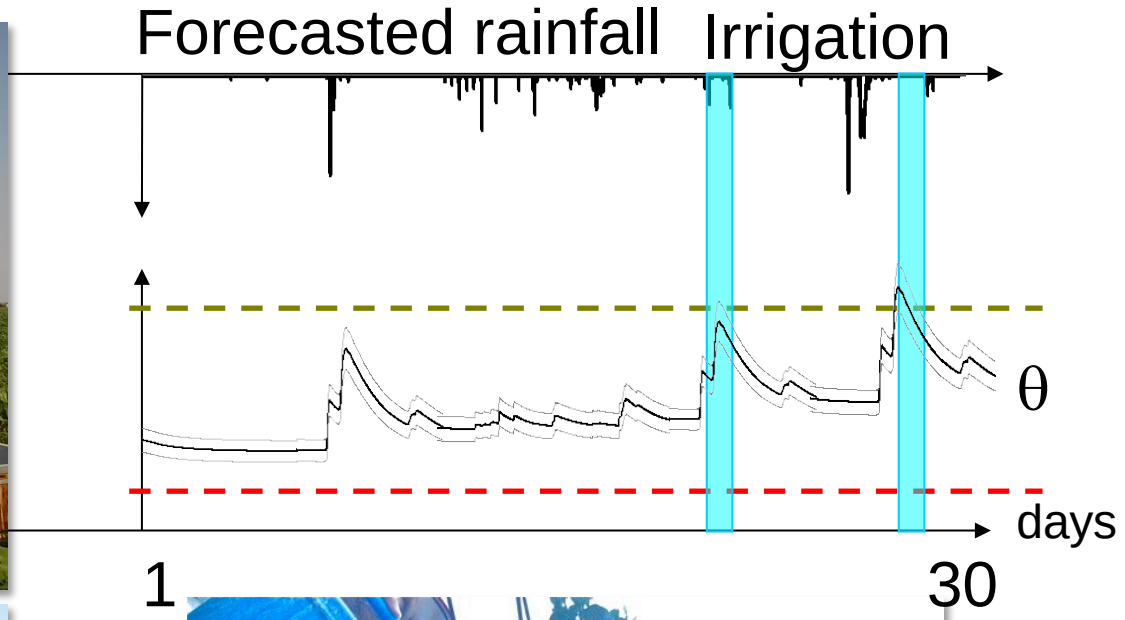
SM

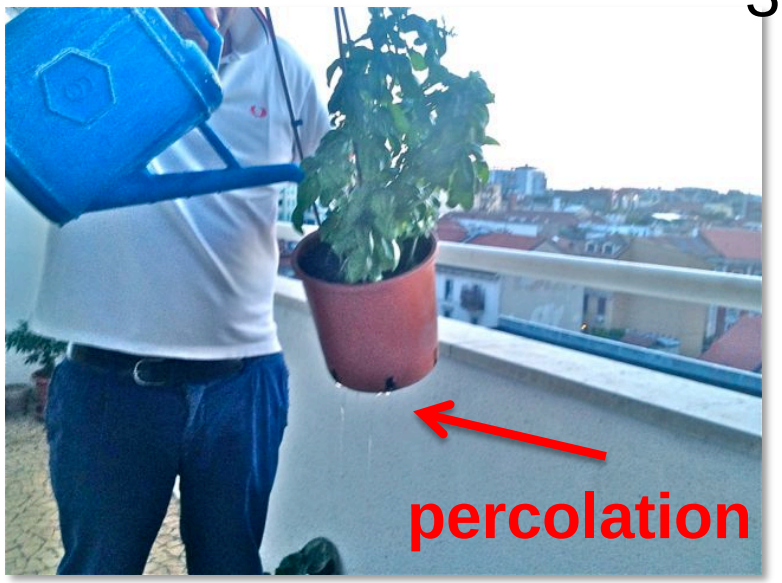
future

t

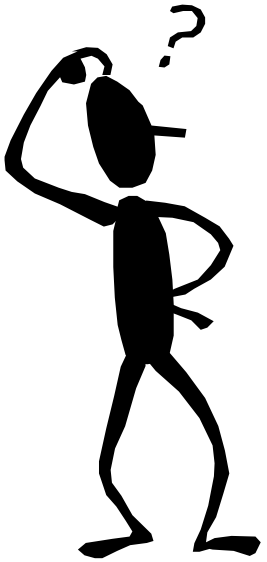
Crop irrigation water: synergism between soil water balance model and weather forecasts



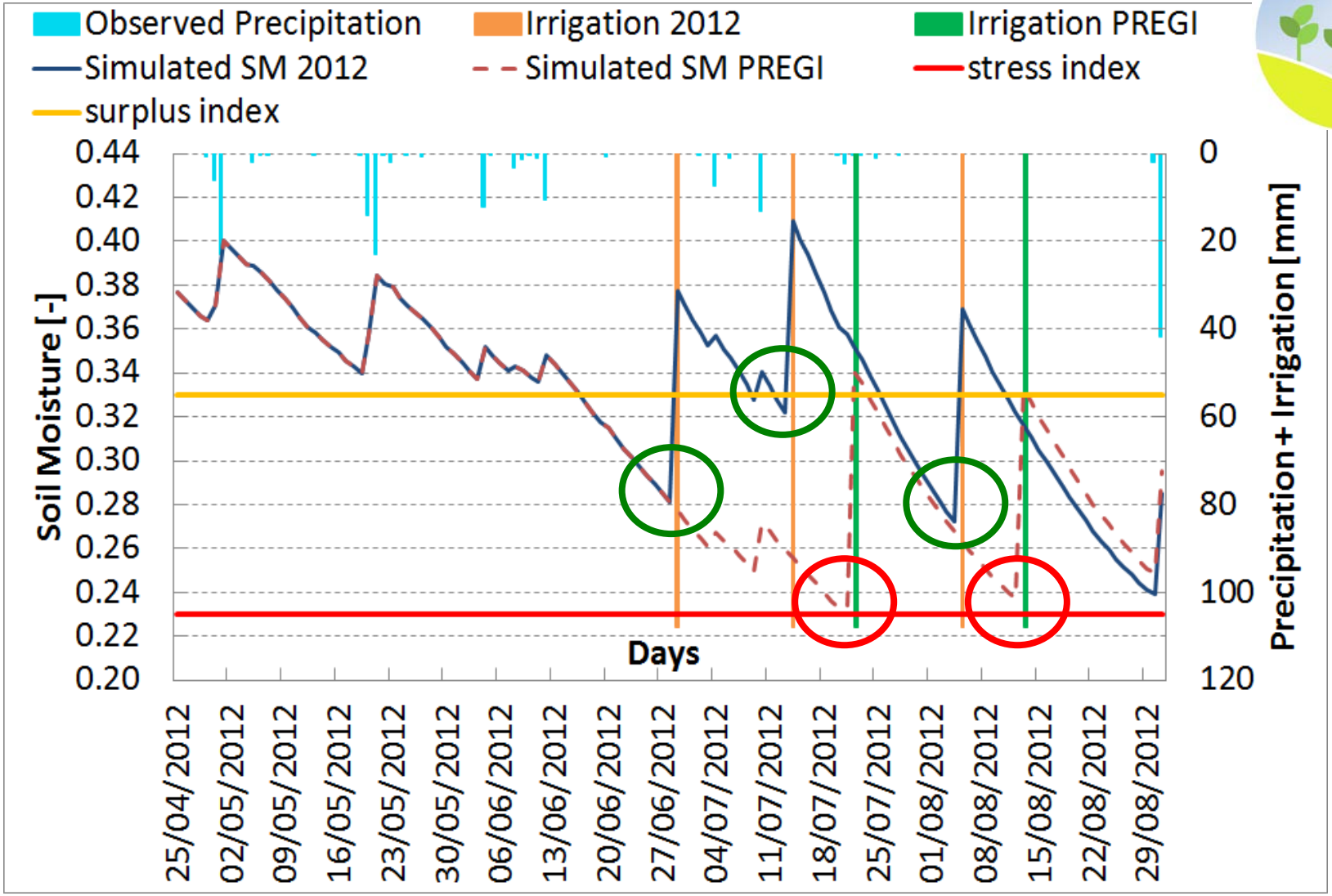




To follow or not to follow the forecast system



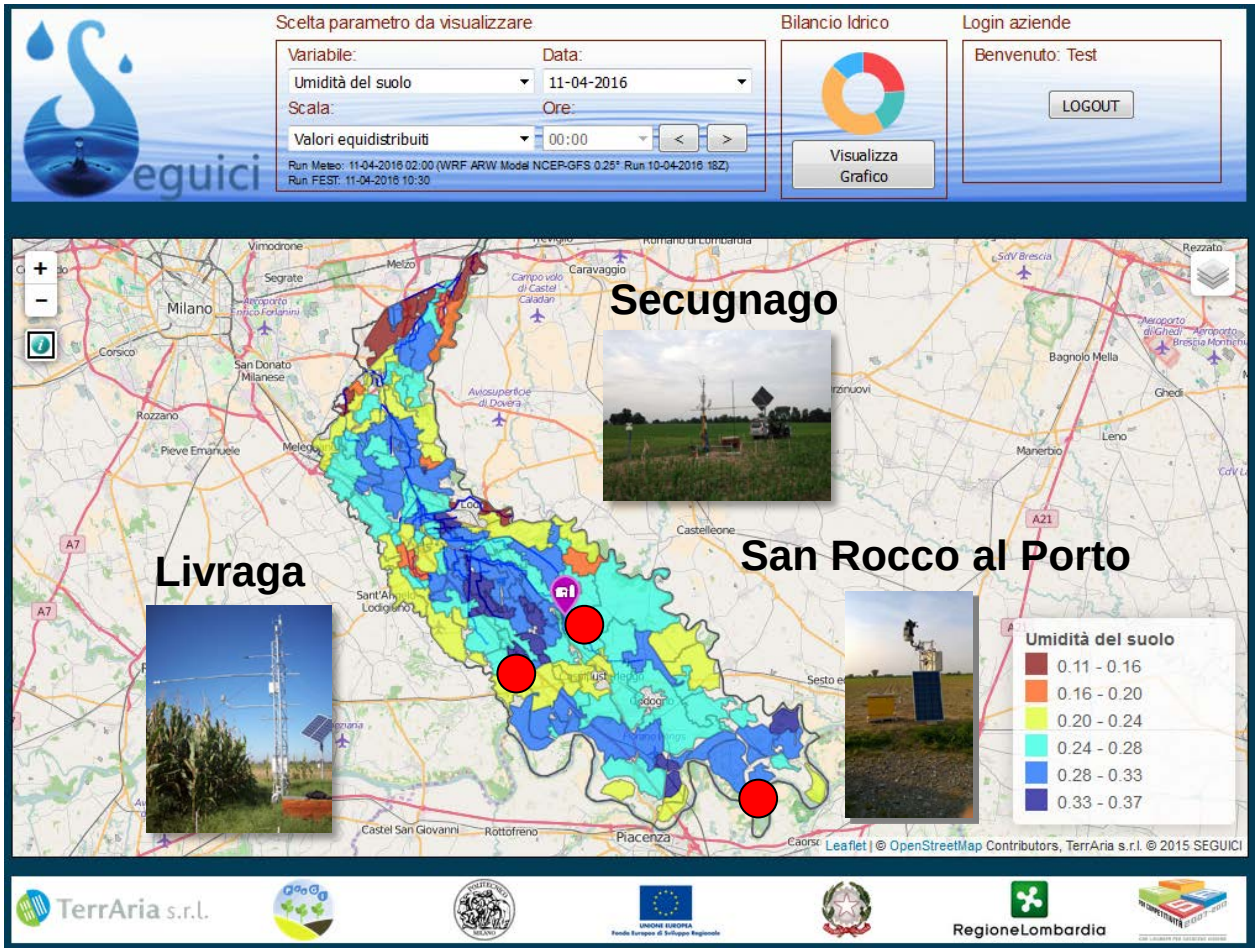
Can we save irrigation water coupling metereological forecasts and hydrological model?



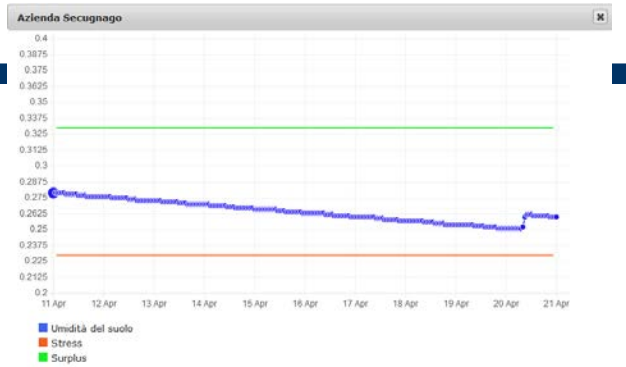
Ceppi, A., Ravazzani, G., Corbari, C., Salerno, R., Meucci, S., and Mancini, M., (2014) Real time drought forecasting system for irrigation management, Hydrol. Earth Syst. Sci., 18, 3353–3366.

The SEGUICI Project

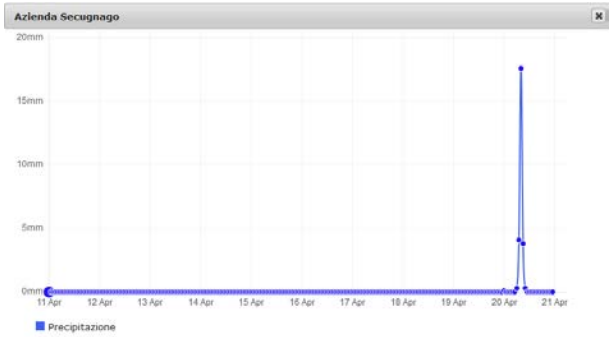
Smart technologies for water resources management for civil consumption and irrigation



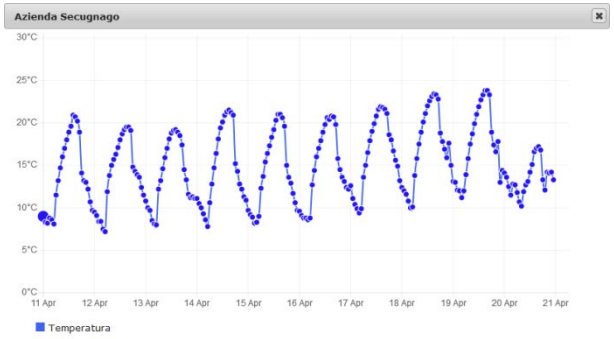
Soil Moisture [-]

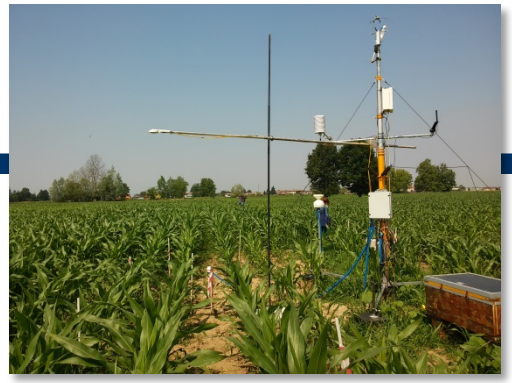


Precipitation [mm]

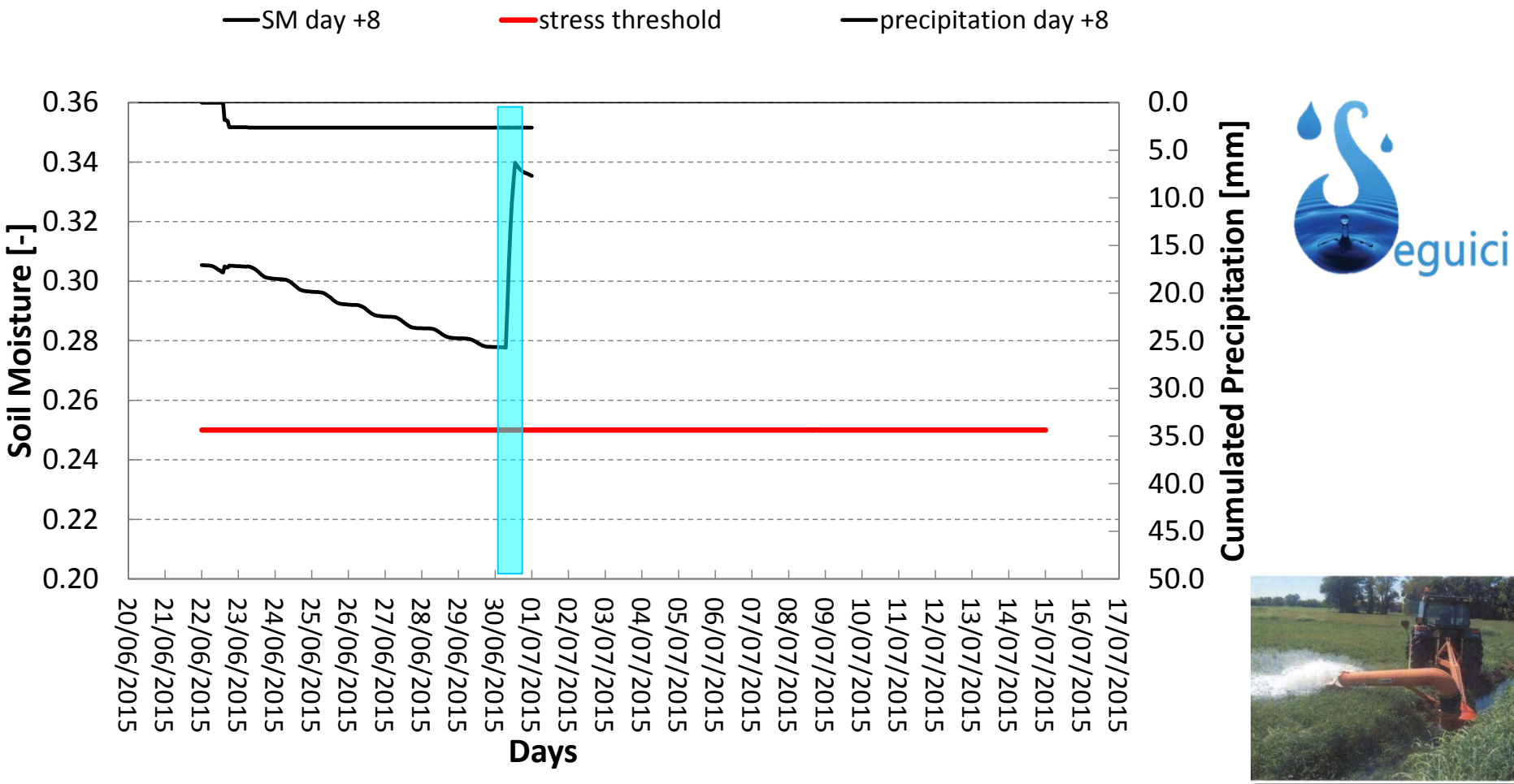


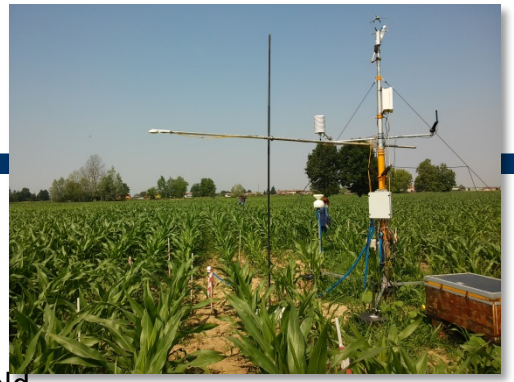
Air Temperature [°C]



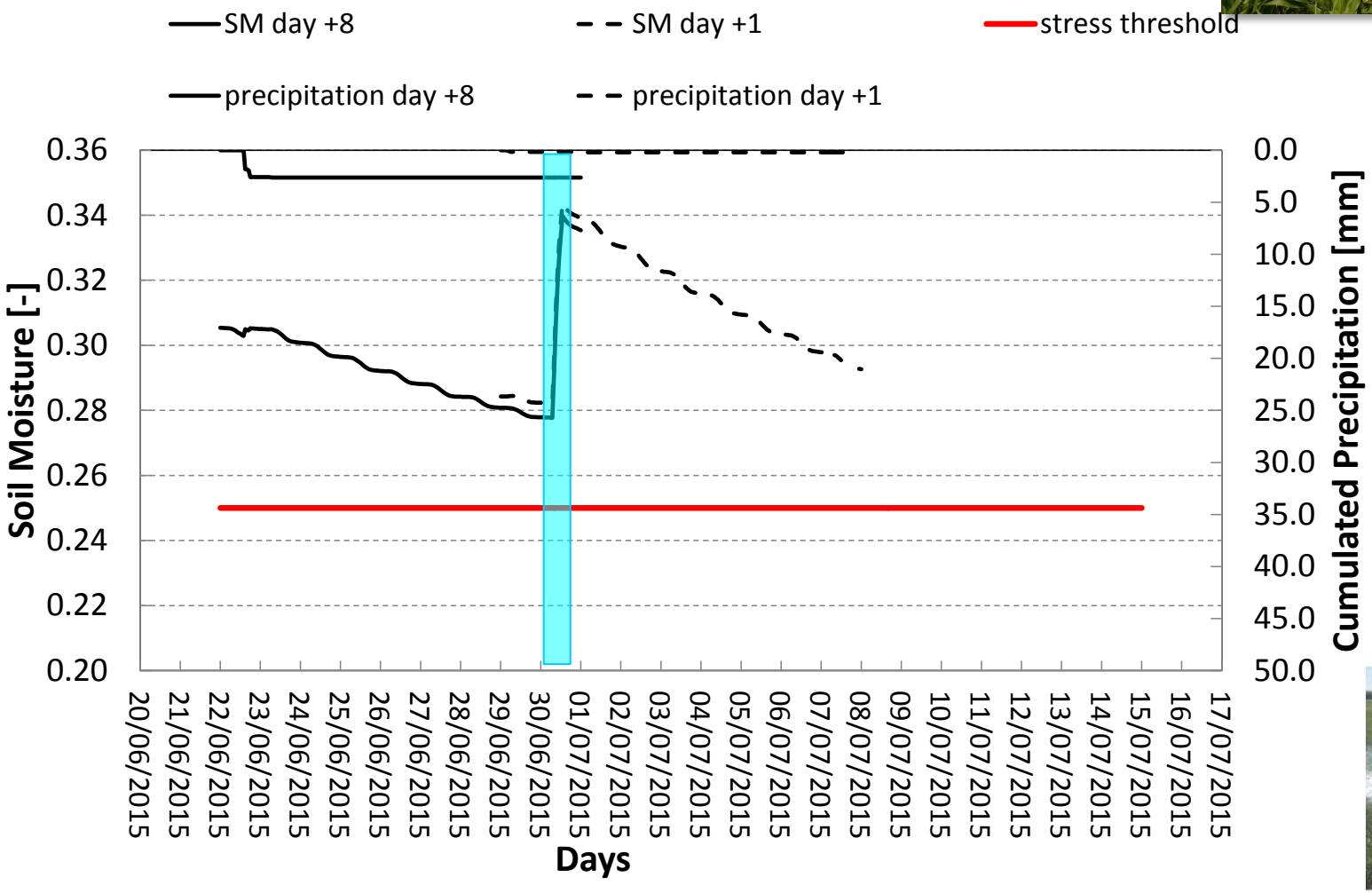


Forecasts based by WRF & FEST-EWB

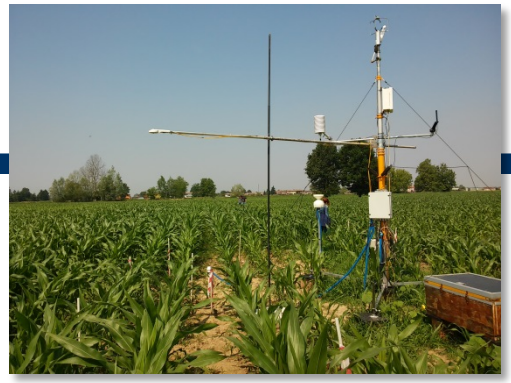




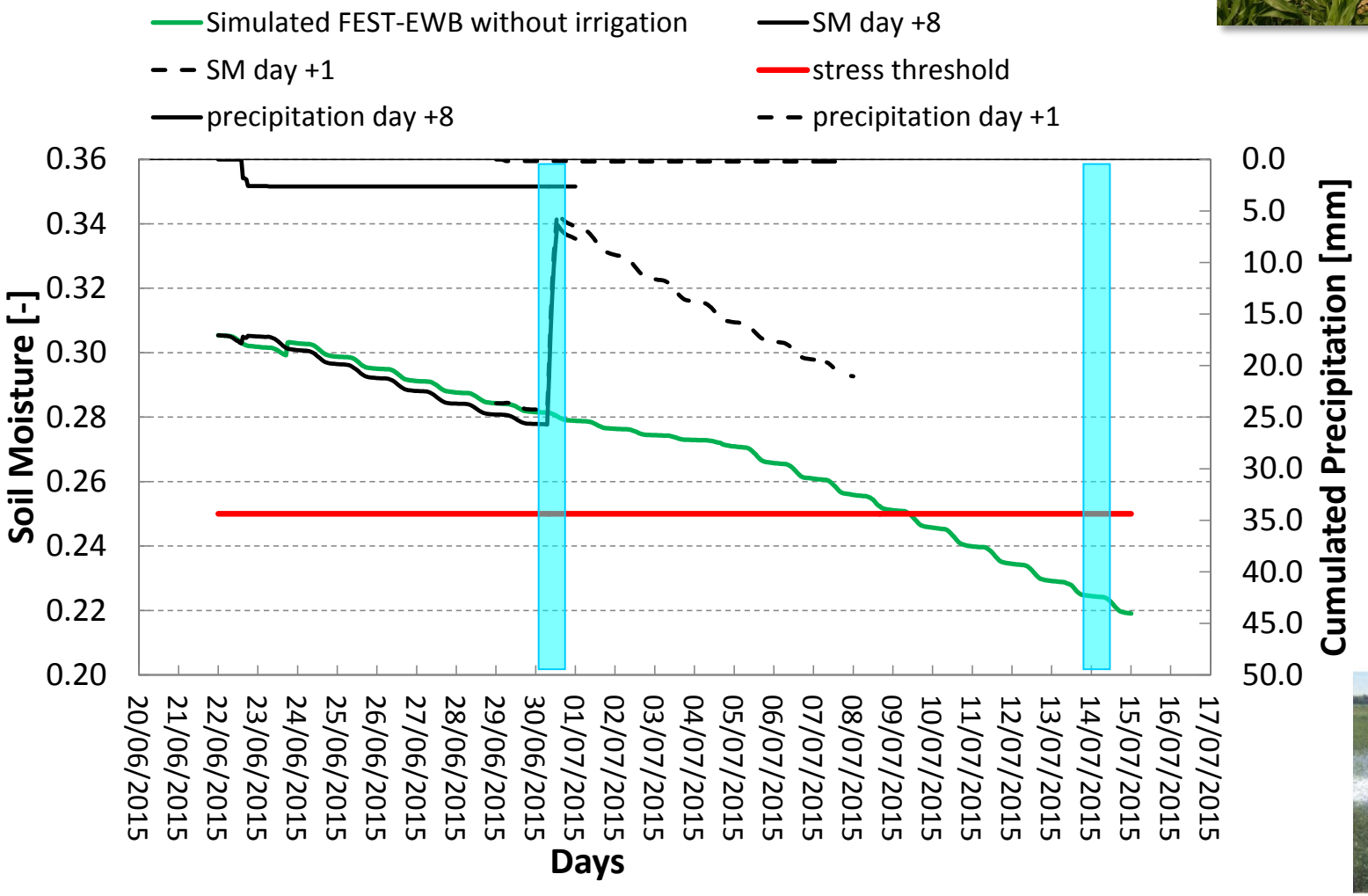
Forecasts based by WRF & FEST-EWB



The SEGUICI Project



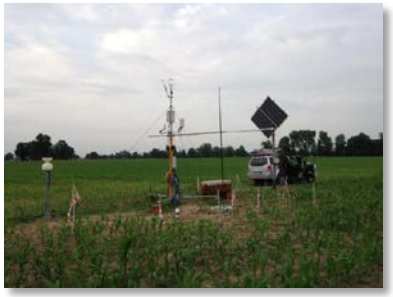
Forecasts based by WRF & FEST-EWB



The SEGUICI Project: SM performance evaluation

Smart technologies for water resources management for civil consumption and irrigation

Secugnago



Soil Moisture

Lead Time

SM - EWB									
Secugnago	**d+0**	**d+1**	**d+2**	**d+3**	**d+4**	**d+5**	**d+6**	**d+7**	**d+8**
R^2 [-]	0.92	0.85	0.86	0.84	0.78	0.74	0.69	0.62	0.50
MAE [-]	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.03
MRE [%]	0.69%	0.18%	-0.88%	-1.65%	-2.28%	-3.17%	-3.62%	-3.79%	-3.58%

Livraga

Quality control during the 2015 growing season:

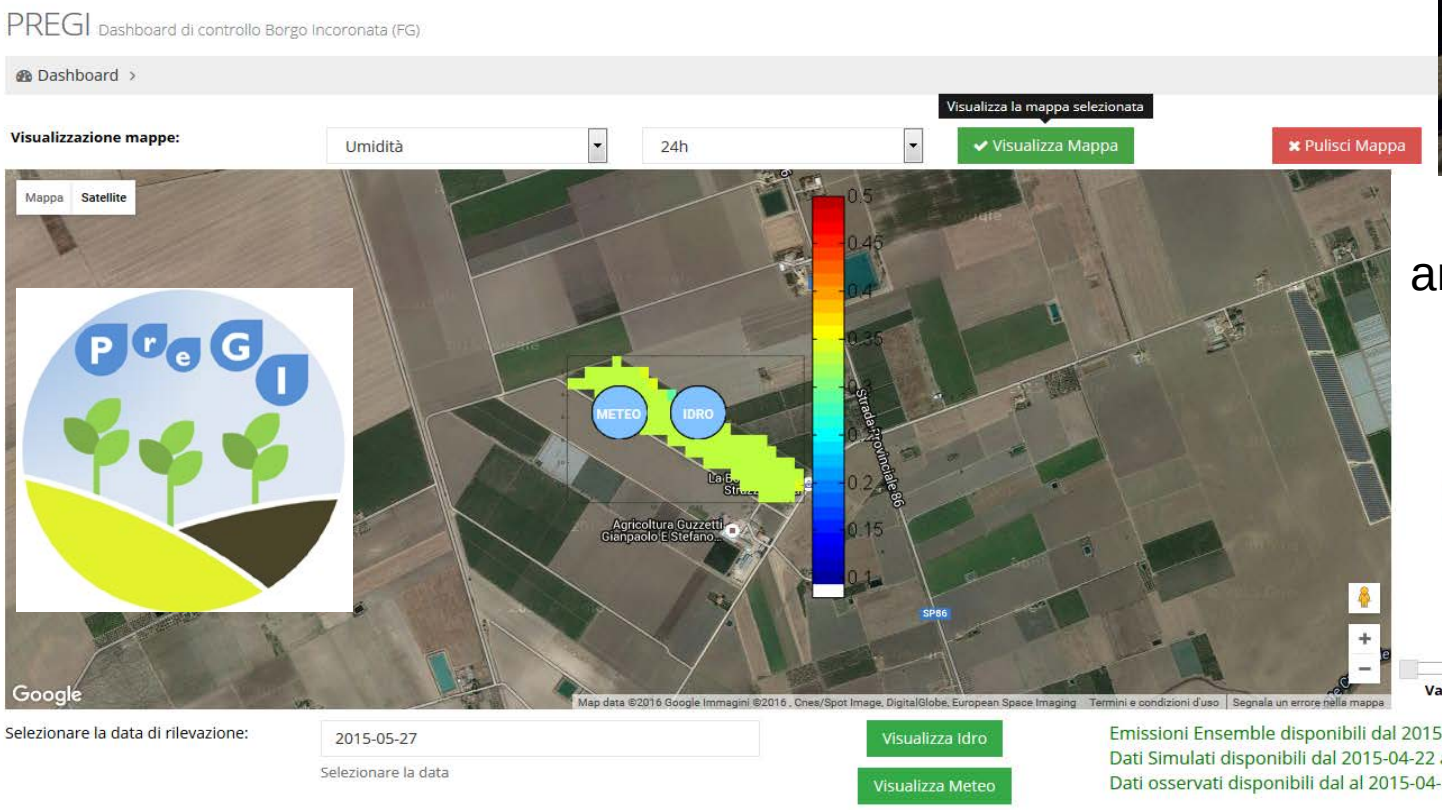
From 1 June to 30 September

SM - EWB									
Livraga	**d+0**	**d+1**	**d+2**	**d+3**	**d+4**	**d+5**	**d+6**	**d+7**	**d+8**
R^2 [-]	0.94	0.88	0.88	0.86	0.82	0.78	0.75	0.71	0.63
MAE [-]	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
MRE [%]	0.32%	0.38%	0.19%	0.08%	0.04%	-0.10%	-0.22%	-0.21%	-0.11%

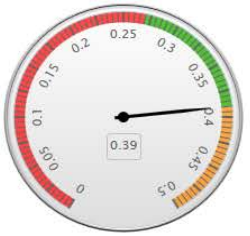
From (cyber-)space to ground: new technologies for smart farming, Submitted to Hydrology Research

Hydrological model output: Soil Moisture forecasts

Puglia, southern Italy, the Capitanata area: the Guzzetti agricultural company

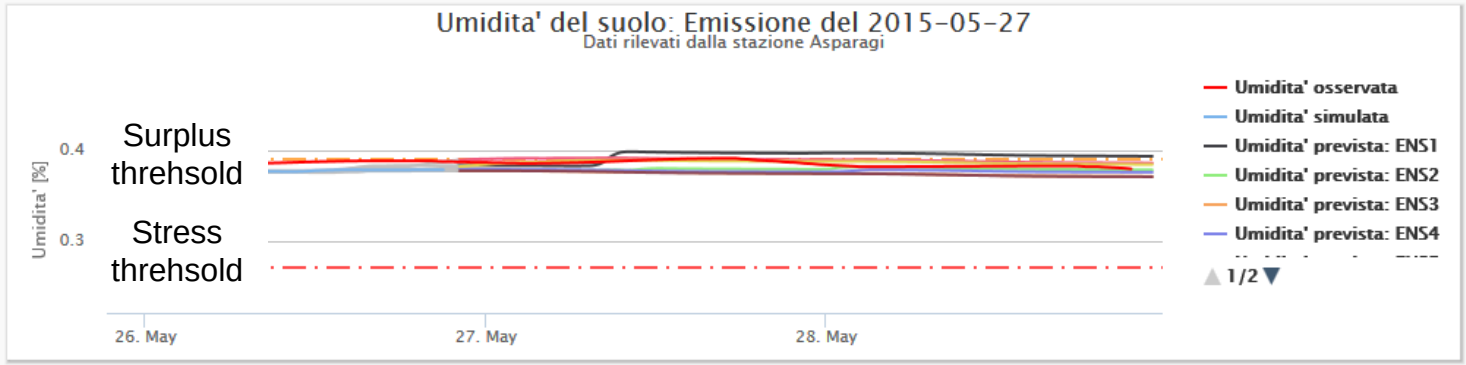


Current situation and forecasts of soil moisture

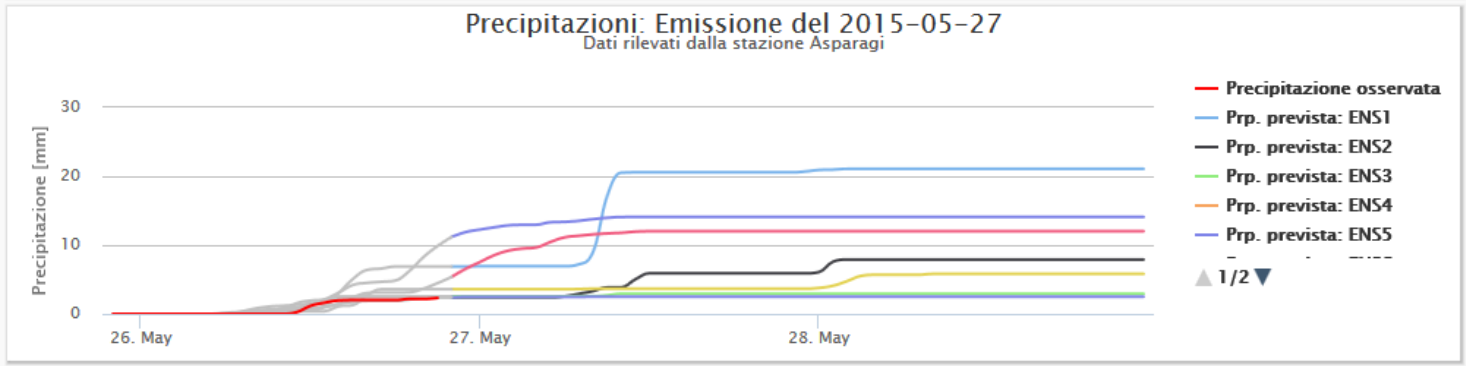


Local hourly forecasts of hydrological variables from the FEST-EWB and WRF models

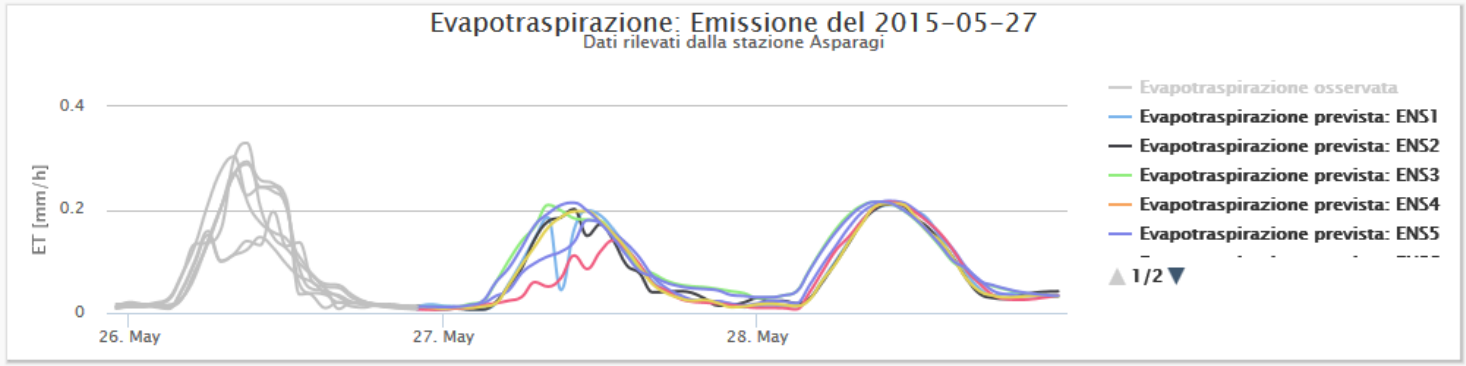
Forecast issued on 2016-05-27 for 48 hours ahead



Soil moisture [-]



Accumulated Precipitation [mm]

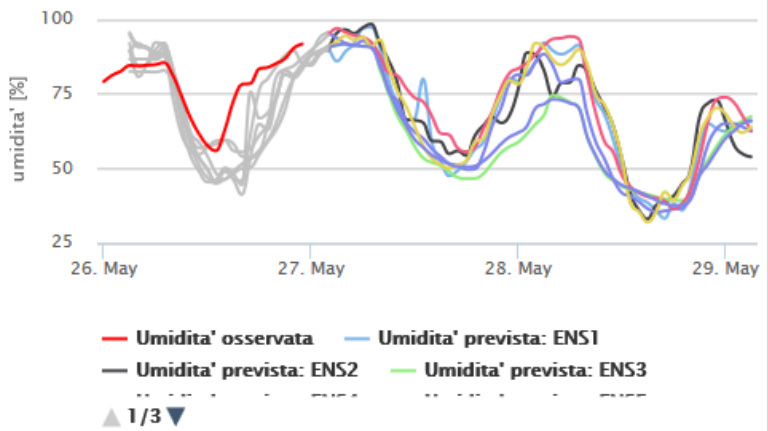


Hourly Evapotranspiration [mm/h]

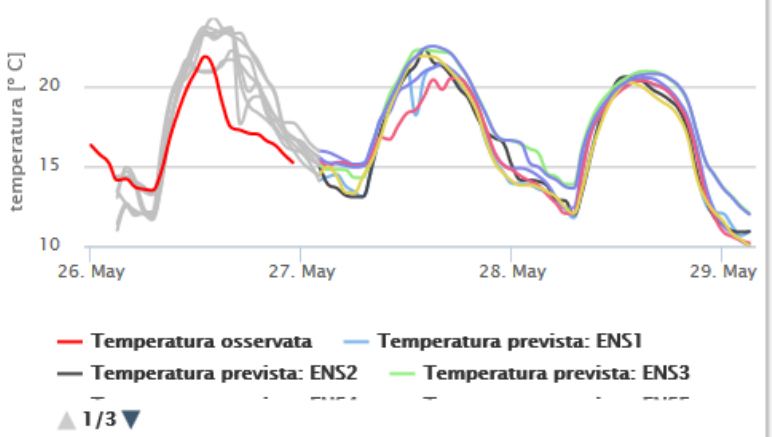
Local hourly forecasts of meteorological variables from the FEST-EWB and WRF models

Forecast issued on 2016-05-27 for 48 hours ahead

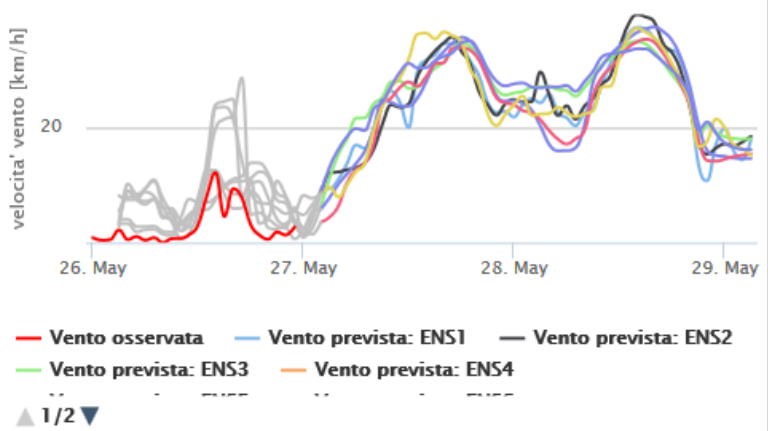
Relative Humidity [%]



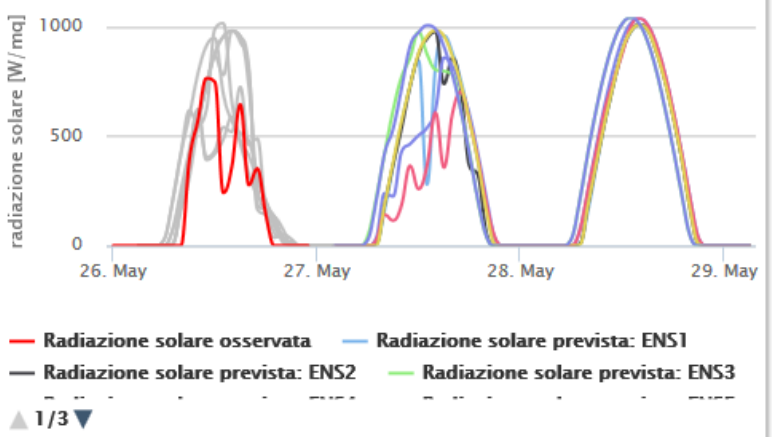
2m air temperature [°C]



Wind speed [km/h]



Solar radiation [W/m^2]



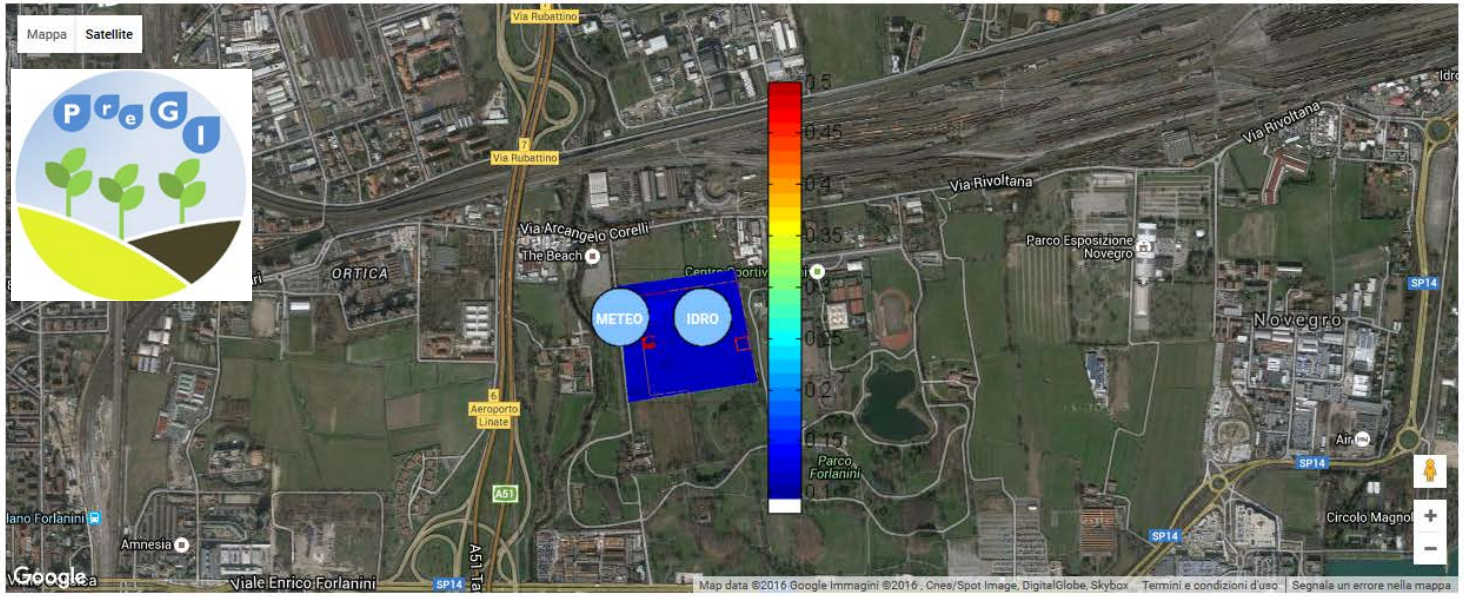
Hydrological model output: Soil Moisture observations

Milano: golf course near Linate (Milan) airport

PREGI Dashboard di controllo Centro Sportivo Saini, Milano

Dashboard ›

Visualizzazione mappe: Umidità 24h Visualizza la mappa selezionata ✔ Visualizza Mappa ✖ Pulisci Mappa



Current situation and forecasts of soil moisture

Valore del: 2016-03-17 02:00:00

Selezionare la data di rilevazione: 2015-06-01

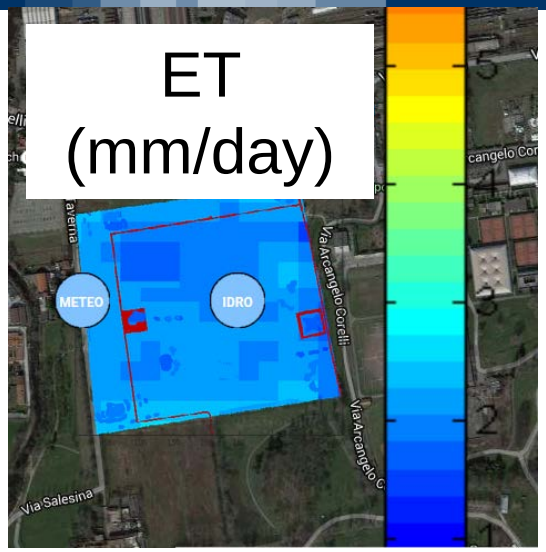
Selezionare la data

Visualizza Idro

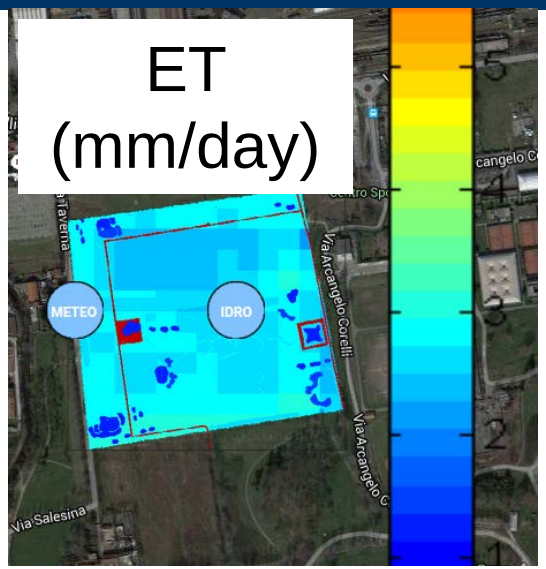
Visualizza Meteo

Emissioni Ensemble disponibili dal 2015-04-23 al 2016-03-18
Dati Simulati disponibili dal 2015-04-22 al 2016-03-18
Dati osservati disponibili dal al 2015-04-20 al 2016-12-30

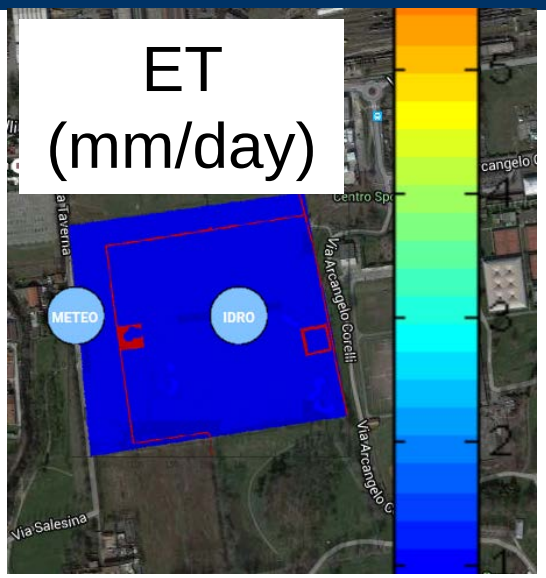
Hydrological model output:
Evapotranspiration, Land Surface Temperature observations



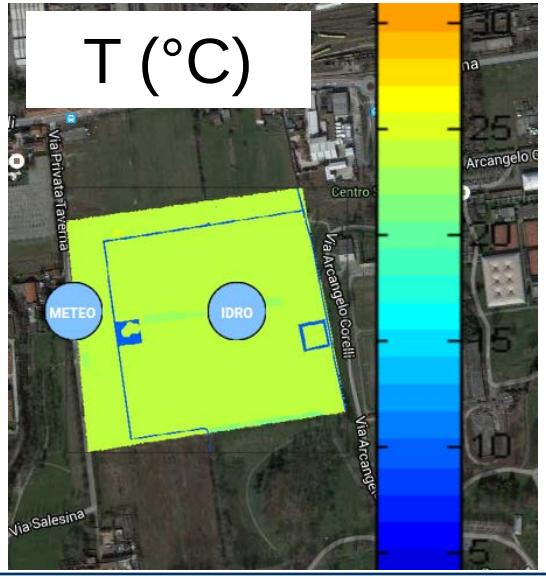
1 June 2015

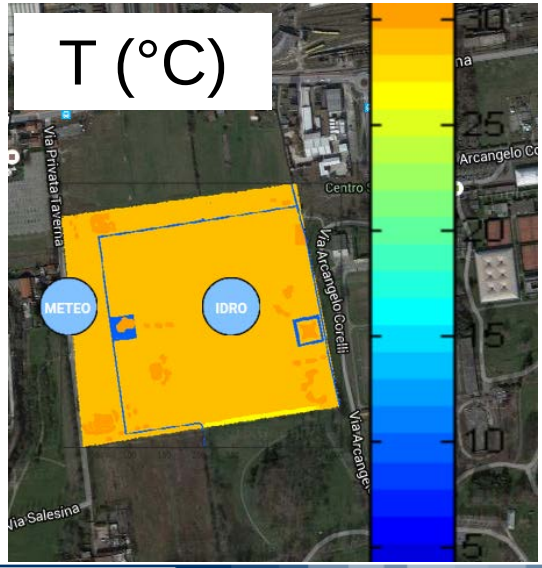


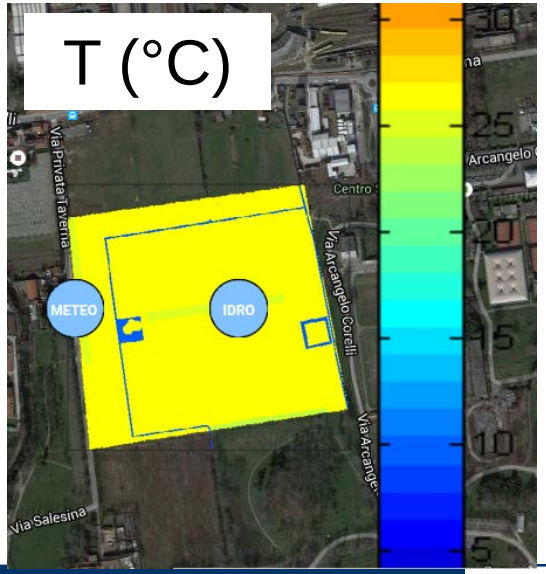
1 July 2015



1 August 2015







Scientific research & risk mitigation

Public authority

Scientists

Flood and drought mitigation risk requires knowledge and accurate analyses that must be acquired by scientists and recognized by public authorities.

The role of scientific research and technological development must be appreciated and tested by institutions.

Conclusions for flood predictions

As non-structural method, the POLIMI hydro-meteorological chain can be used to predict floods in Milan urban area or to regulate the Idro Lake water level, however some suggestions are strictly required to improve the hydro-meteorological chain:

1) Meteorological data (above all precipitation) are not always sufficient to cover the entire basin area, and even hydrological information needs to be incresead. Additional data coming from radar networks are suggested.
2) A forecast horizon of two days is required for an operational chain over the three urban basins, and accurate quantitative forecasts are necessary at least one day in advance.
3) The use of hydrological ensemble prediction systems is also an effective and promising tool to help civil protection actions in regulating the Idro Lake.

Conclusions for drought predictions

The implementation of an operative system for **real-time forecast of irrigation water needs** over an irrigation area is a parsimonious support for water management that provide **actual and forecasted soil moisture dynamics** at **high spatial resolution, and it can mitigate conflicts in water use among farmers, hydroelectric producers, environmental agencies, tourist activities.**

The system combines **satellite monitoring of LST and vegetation at high spatial resolution**, quantitative **meteorological forecasts** and detailed distributed **hydrological modelling** of soil water balance and crop water needs.

This developed tool for irrigation management has a higher reliability in comparison with flood forecasting systems, because it is characterized by slower and persistent weather dynamics over larger areas. One can consider, for instance, the large difference in hydrological processes between rainfall events with intensities which can reach up to 100 mm h^{-1} over areas of a few tens of km^2 (flood events) and events with evapotranspiration rates of about 7-8 mm per day over areas of a few thousand of km^2 (drought events).

Thank you for your attention

alessandro.ceppi@polimi.it