The POLIMI forecasting chain for flood and drought predictions

Politecnico di Milano

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EPSON METEO CLIMA E AMBIENTE

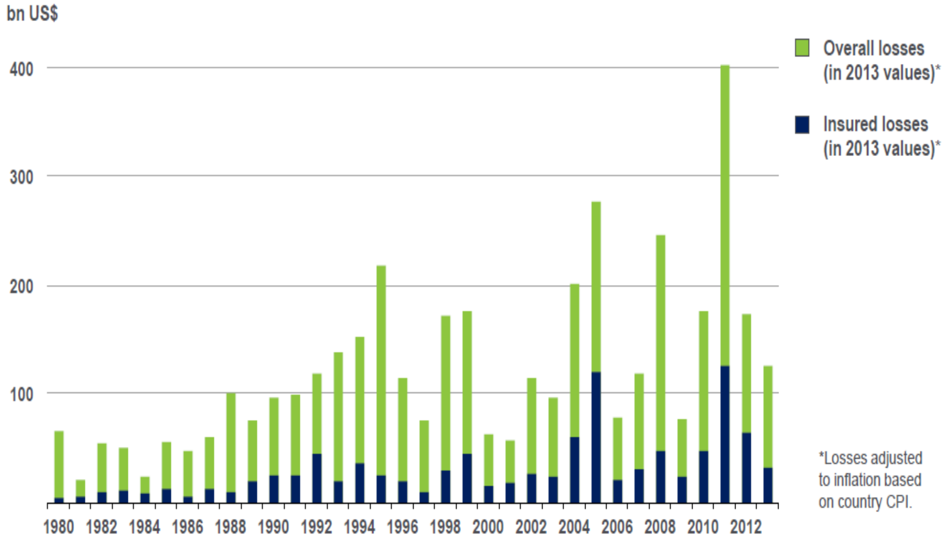
MMI Modellistica e Monitoraggio Idrologico







Social and financial impact: extreme events and financial losses



Main floods in the last 15 years in Italy and Europe

Italy

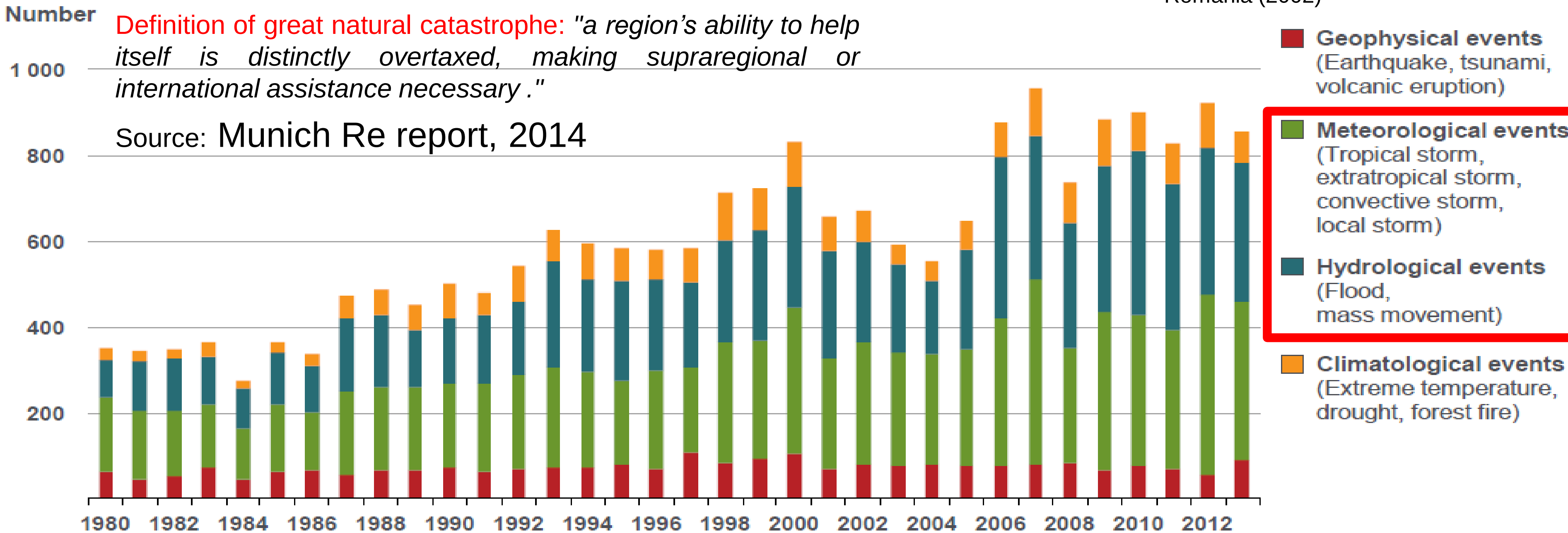
- Liguria (2010, 2011, 2012) and Sardinia (2013)
- Tuscany, Veneto, Campania (2010)
- Messina, Tuscany (2009)
- Piedmont (2008)
- Marche (2006)
- Lombardy (2002)
- Calabria (2000, 2006, 2011)
- Piedmont/Aosta Valley (2000)

Europe

- Serbia (2014)
- Spain (2012)
- Polond, Czech Republic and Germany (2010)
- United Kingdom (2007, 2009, 2014)
- Austria, Switzerland (2007)
- Germany (2006, 2010, 2013)
- Romania, Moldava, Switzerland, Austria (2005)
- Polond, Czech Republic, Germany, Romania (2002)

Definition of great natural catastrophe: *"a region's ability to help itself is distinctly overtaxed, making supraregional or international assistance necessary ."*

Source: Munich Re report, 2014



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 can be used to decide on an early water-system control action to prevent or reduce problems with floods, droughts or water quality.

The two faces of the same coin

Floods

Background: The complex flood protection system of Milan and surroundings developed in the last 60 years has not been able to protect its urban area, which frequently flooded in the last 25 years; hence the improvement of the Milan flood control system needs a synergism between structural and non-structural engineering approaches.

The POLIMI forecasting chain: WRF (deterministic, 1 km) + FEST-WB model (200 m)

Area of study: three catchments located northern than Milan area (the Olona, Seveso and Lambro River basins)

Target: how early warning systems are an effective complement to structural measures for flood control in Milan city?

Droughts

Background: In recent years frequent periods of water scarcity have enhanced the need to use water more carefully, even in European areas traditionally rich of water such as the Po Valley in northern Italy.

The POLIMI forecasting chain: WRF (probabilistic with 20 ensemble members, 18 km) + FEST-EWB (200 m)

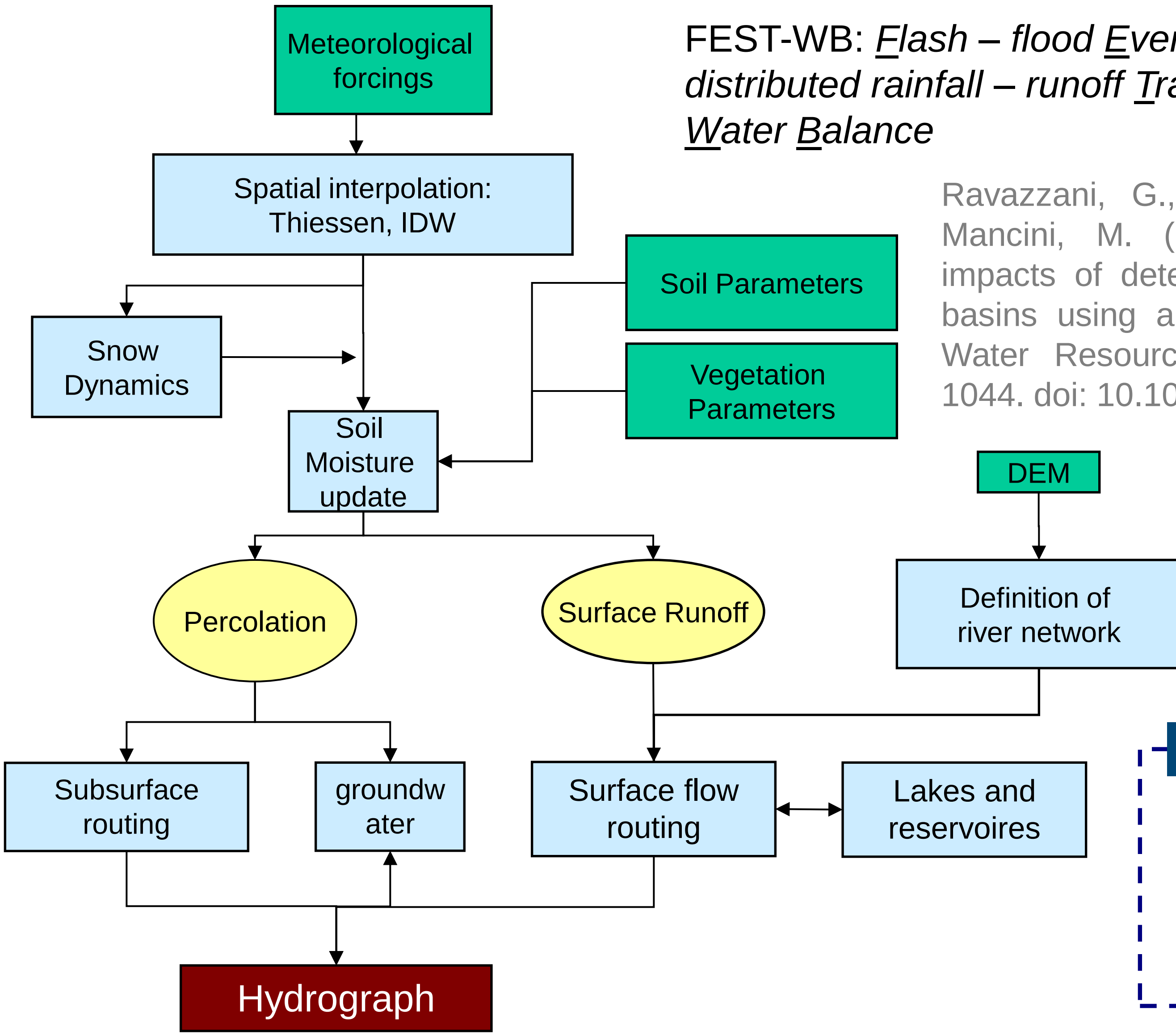
Area of study: Muzza Bassa Lodigiana Consortium in the Po Valley, northern Italy.

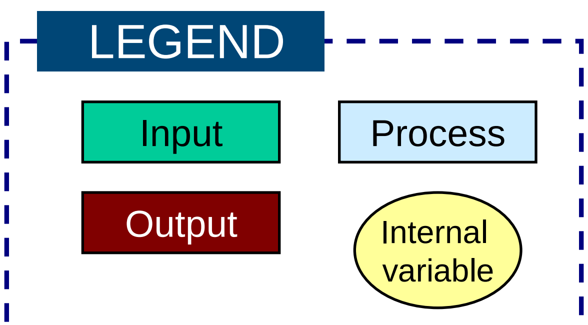
Target: development and implementation of the real-time drought forecasting system in the experimental test-site of a maize field in Livraga (Lodi): can we save irrigation water and use it in wiser way?

FEST-WB hydrological model

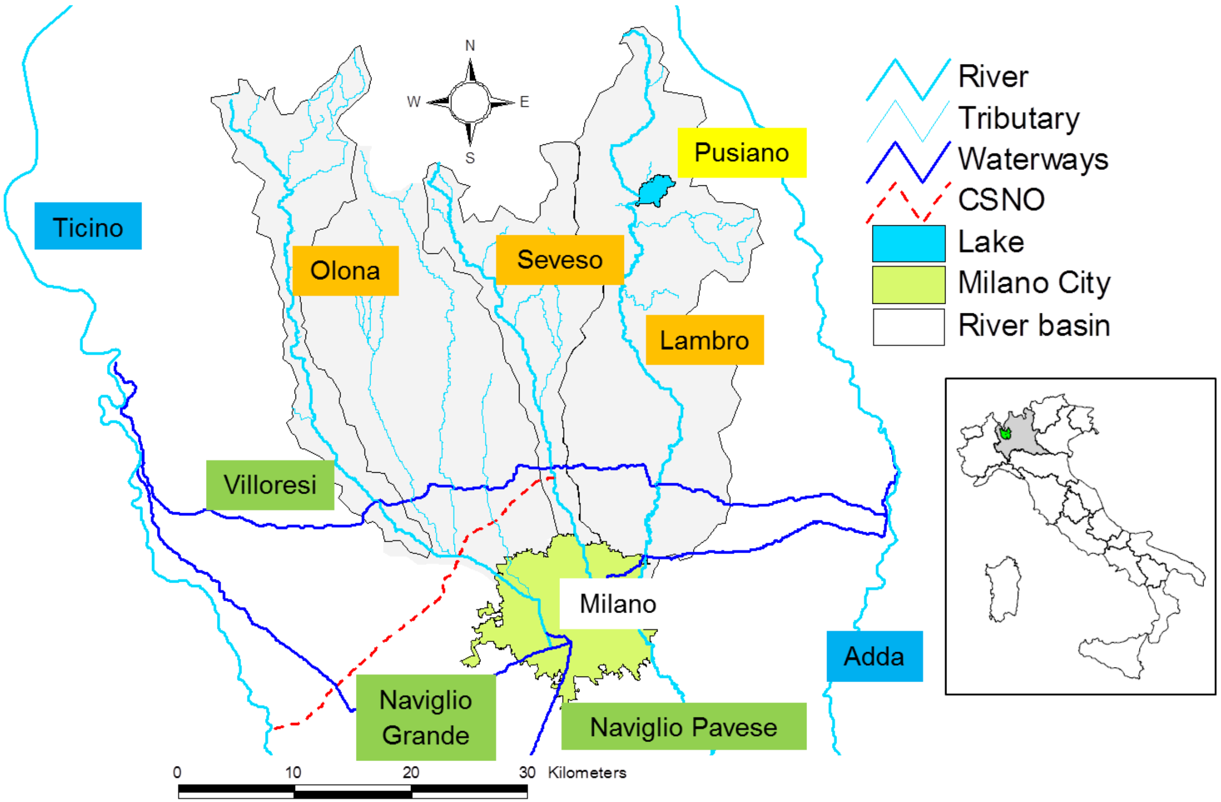
FEST-WB: *Flash – flood Event – based Spatially – distributed rainfall – runoff Transformation – including Water Balance*

Ravazzani, G., Gianoli, P., Meucci, S., and Mancini, M. (2014). Assessing downstream impacts of detention basins in urbanized river basins using a distributed hydrological model, Water Resources Management, 28(4), 1033-1044. doi: 10.1007/s11269-014-0532-3.





Area of study for flood forecasts



Complex and anthropized channel network due to:

- many artificial channels for water supply
- sewerage system
- structural works for flood protection (Diotti sluice, CSNO, detention basin of Ponte Gurone)

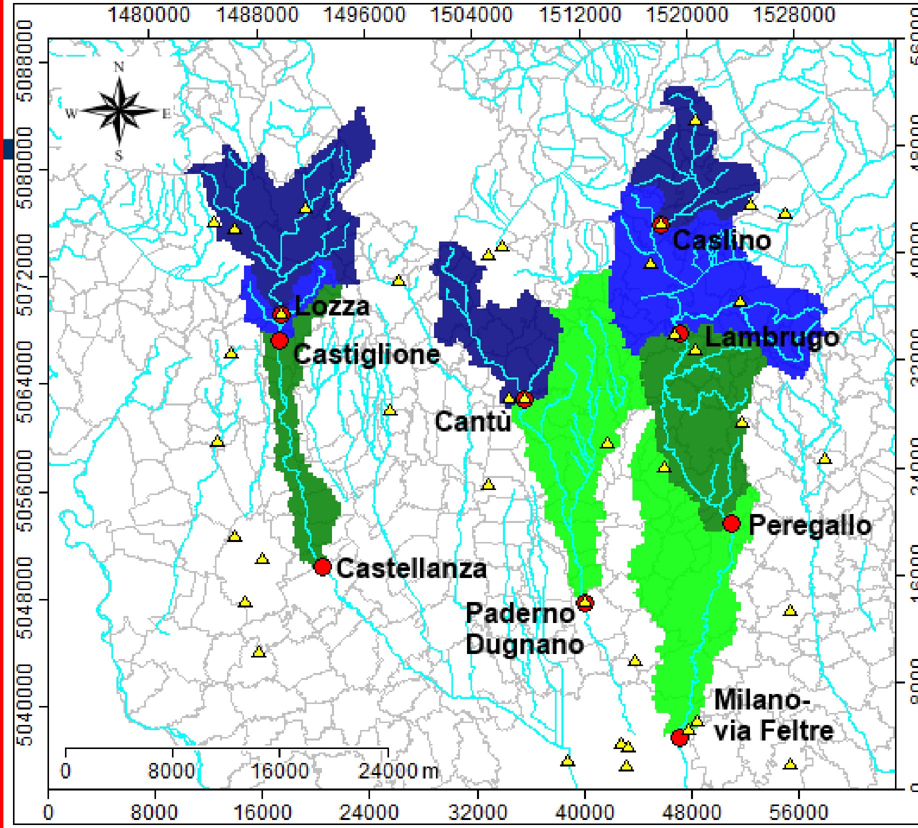
Change of natural discharge

Basin	Gauging Section	Area [km^2]	Lag Time [h]
Olona	Castellanza (VA)	162.6	6.9
Seveso	Paderno Dugnano (MI)	175.36	7.5
Lambro	Milano, via Feltre	382.84	13.7

FEST-WB: input data

Hourly Meteorological Data:

- Temperature [°C]
- Precipitation [mm]
- Air Humidity [%]
- Short Wave Solar Radiation [W/m^2]



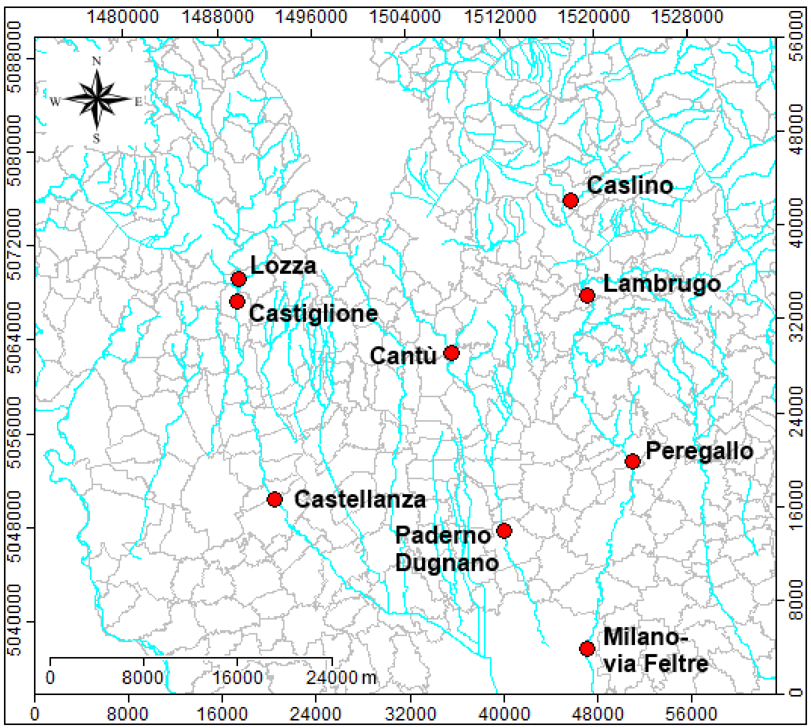
Basin	N° Stations			
	Air Temperature	Precipitation	Air Humidity	Solar Radiation
Olona	2	3	0	0
Seveso	4	4	2	2
Lambro	10	9	6	2
TOTAL	**36**	**41**	**22**	**10**

Hourly Hydrological Data

- Water level [cm]
- Rating curve

→ Discharge [m^3/s]

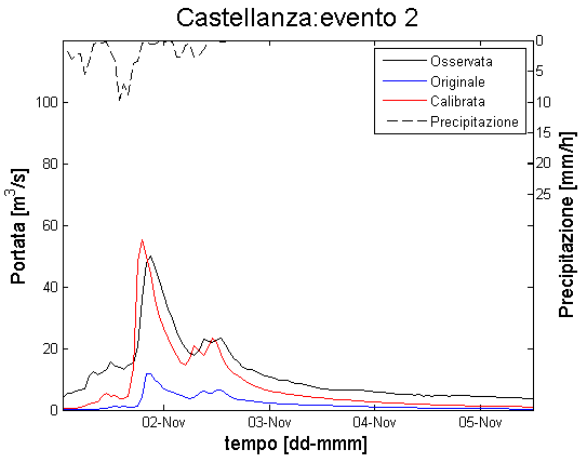
ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

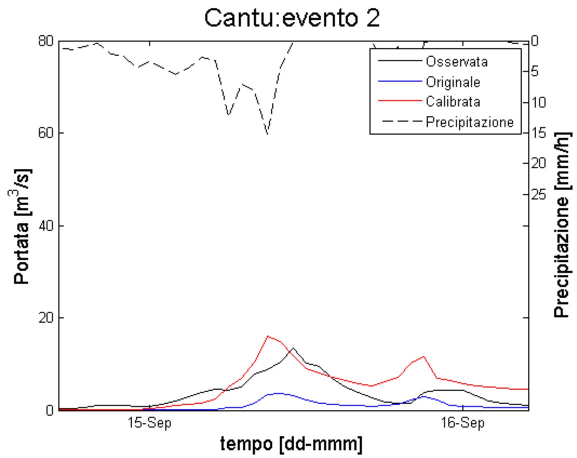


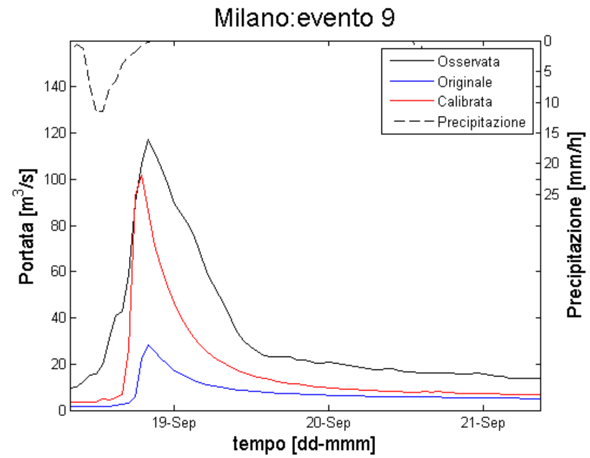
Basin	Gauging Station	Rating curve	State
Olona	Lozza	Yes	Active
	Castiglione	No	-
	Castellanza	Yes	Active
Seveso	Cantù	Yes	Historical
	Paderno Dugnano	No	-
Lambro	Caslino d'Erba	Yes	Active
	Lambrugo	Yes	Active
	Peregallo	Yes	Active
	Milano - via Feltre	Yes	Active

Calibration of the FEST-WB model (2003-2010 events)

Basin	Gauging Station	err Q_{max} [%]	
		Befor e	After
Olona	Lozza	**-50.7**	**0.27**
	Castellanza	**-51.8**	**0.12**
Seveso	Cantù	**-65.5**	**-10.9**
Lambro	Caslino	**78.4**	**0.57**
	Peregallo	**-72.1**	**1.5**
	Milano	**-74.8**	**-3.54**



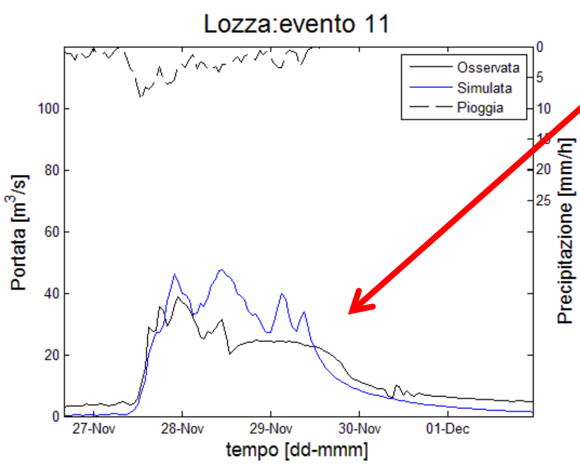


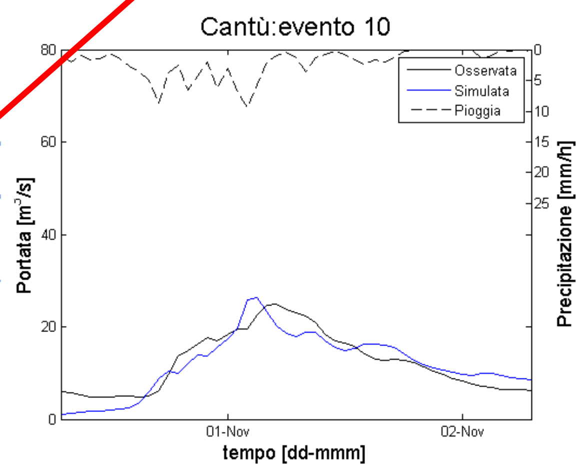


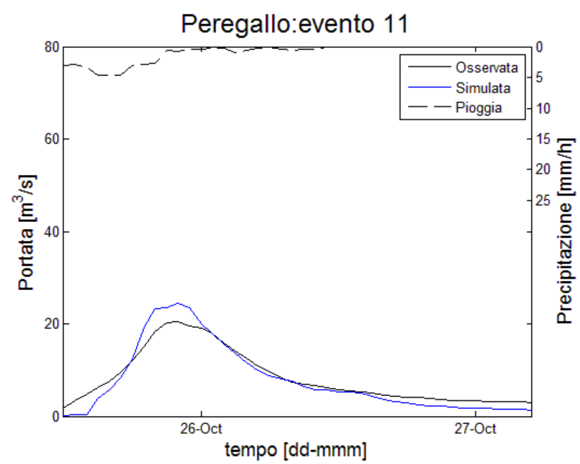
Validation of the FEST-WB model (2011-2012 events)

Basin	Station	err Q_{max}[%]
Olona	Lozza	26.0
	Castellanza	16.7
Seveso	Cantù	-8.9
Lambro	Caslino	14.5
	Peregallo	1.2
	Milano	-25.5

Problems due to detention basin effects at Ponte Gurone dam, operative since 2010







The WRF meteorological model for flood forecasts

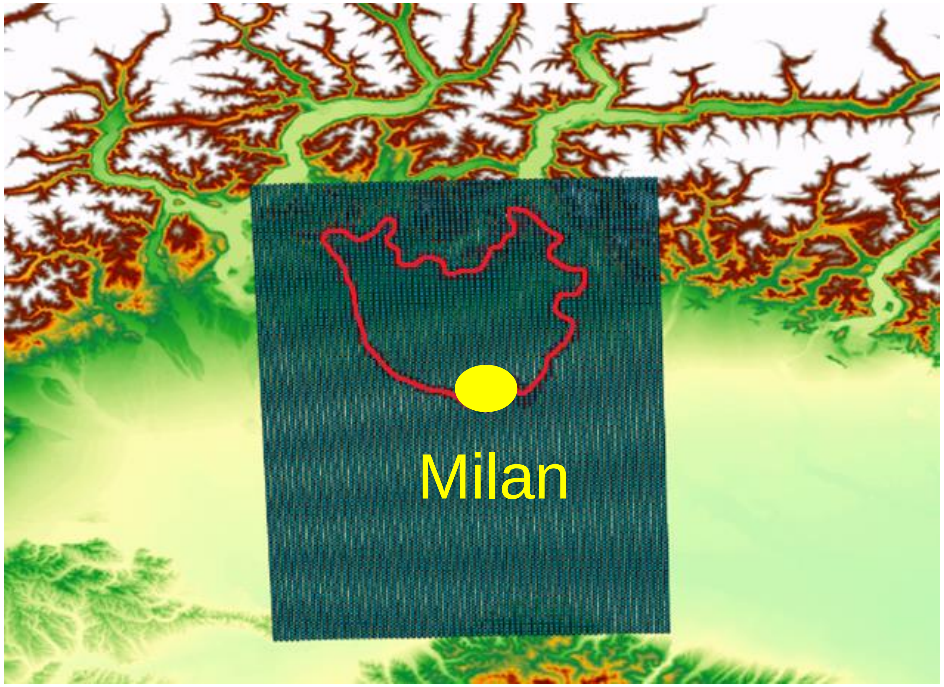
The meteorological model used in this study is the WRF-ARW v.3.5 developed by the National Center for Atmospheric Research (NCAR)

- Spatial resolution: 3 nested domains 12 km -> 4 km -> 1 km
- Temporal output: 1 hour
- Vertical level: 37 (non-hydrostiatic)
- Forecast horizon: 36 hours
- Starting run @ 12:00 UTC
- IC and BC provided by the GFS model (@12 km)
- Cloud microphysics scheme: Eta
- Longwave radiation scheme: RRTM (Rapid Radiative Transfer Model)
- Shortwave radiation scheme: Dudhia
- Land surface model: Noah with 4 soil layers and 24 types of soil
- PBL scheme: Bougeault-Lacarrère
- Owner: MOPI – Epson Meteo Centre

OUTPUT:

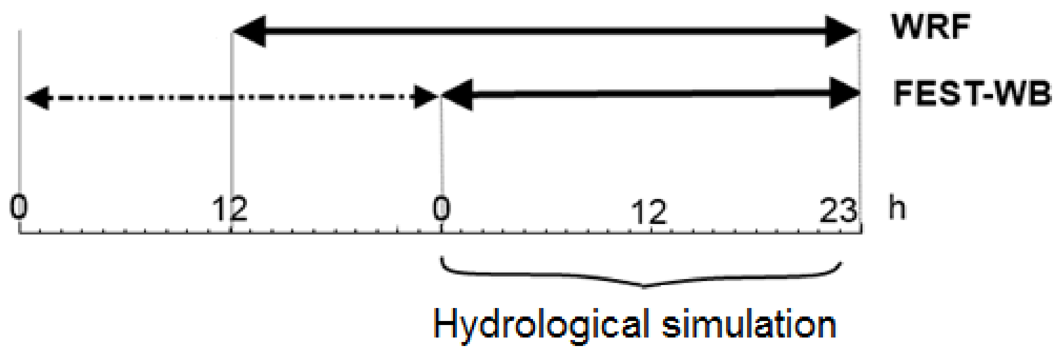
Deterministic forecasts of hourly temperature at 2m above ground and precipitation provided by MOPI – Epson Meteo Centre

The WRF model domain



Re-analysis of flood events

The cascade forecasting system applied in this study is currently based on hydrological model initialization from meteorological model output



The re-analysis is based on the exceeding of the alert threshold (code 1):

- event: the observed discharge exceeds the warning threshold
- no-event: the observed discharge did not exceed the warning threshold

Basin	Gauging Station	Level [m]	Discharge [m³/s]
Olona	Lozza	-	36*
	Castellanza	1.80	43
Seveso	Cantù	1.20	13
	Paderno Dugnano	2.30	75**
Lambro	Caslino d'Erba	-	6*
	Peregallo	1.00	30
	Milano, via Feltre	2.10	83

$* \ Q2 = Q1\frac{A2}{A1}$ $** \ Q = Qmax \ @ \ Ornati \ section + Qmax \ of \ the \ CSNO$

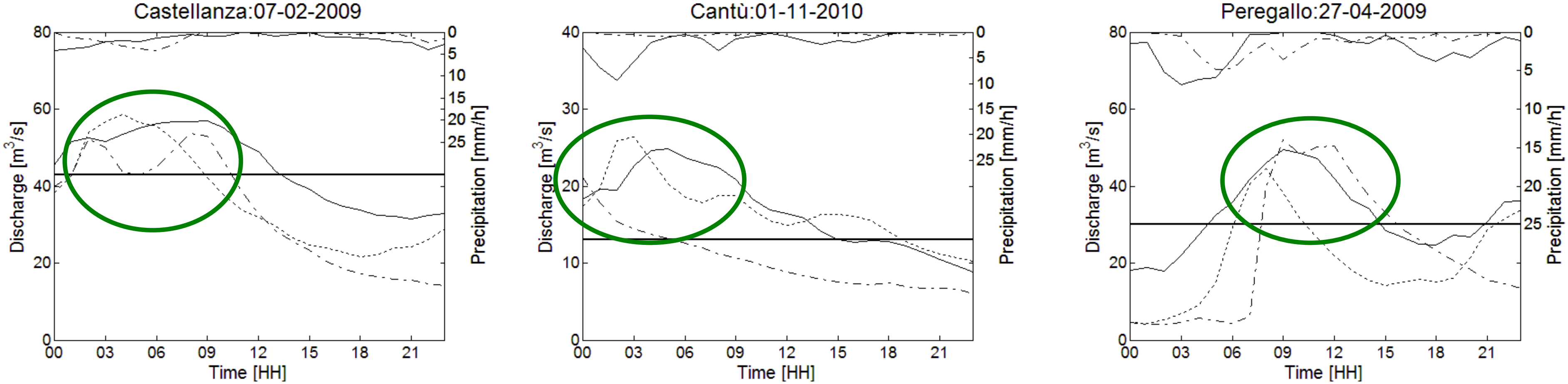
Courtesy of Civil Protection of the Lombardy Region

Re-analysis of flood events

A total of 15 events (45 analyzed days considering the peak, the rising and recession limb) between 2008 and 2010 were selected to value the hydro-meteorological chain performance, coupling the WRF meteorological model with the FEST-WB hydrological model.

Case Study	Day	Type of Event
1	17,18 May 2008	Convective
2	12,13,14 July 2008	Convective
3	12,13,14 September 2008	Convective
4	4,5,6 November 2008	Stratiform
5	30 November,1,2 December 2008	Stratiform
6	6,7,8 February 2009	Stratiform
7	27,28,29 April 2009	Stratiform
8	7 July 2009	Convective
9	17,18 July 2009	Convective
10	23,24,25,26 December 2009	Stratiform
11	2,3,4,5,6,7 May 2010	Stratiform
12	11,12,13 August 2010	Convective
13	18,19 September 2010	Convective
14	31 October, 1,2,3, November 2010	Stratiform
15	15,16,17 November 2010	Stratiform

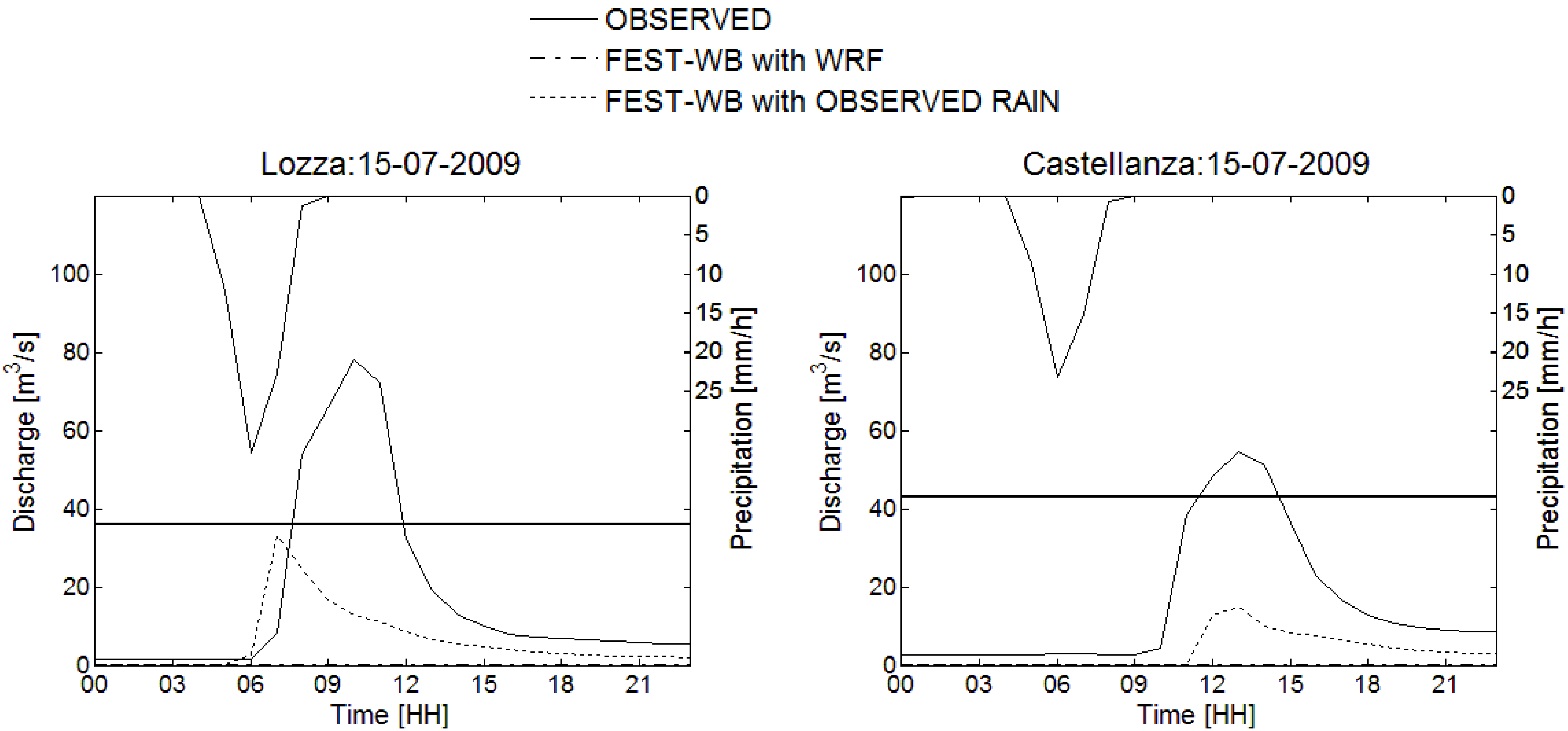
Stratiform events



key

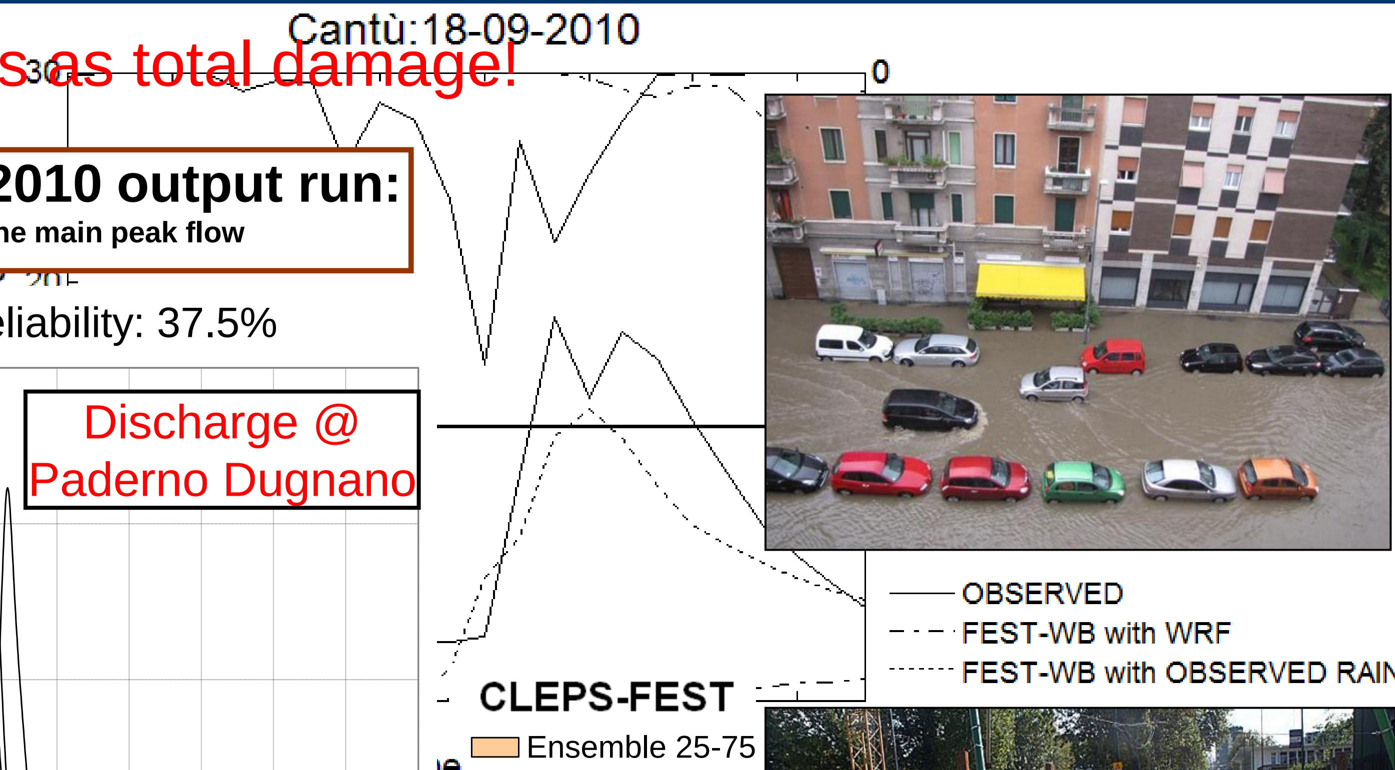
- OBSERVED
- FEST-WB with WRF
- FEST-WB with OBSERVED RAIN

Olona basin: July 2009 convective event



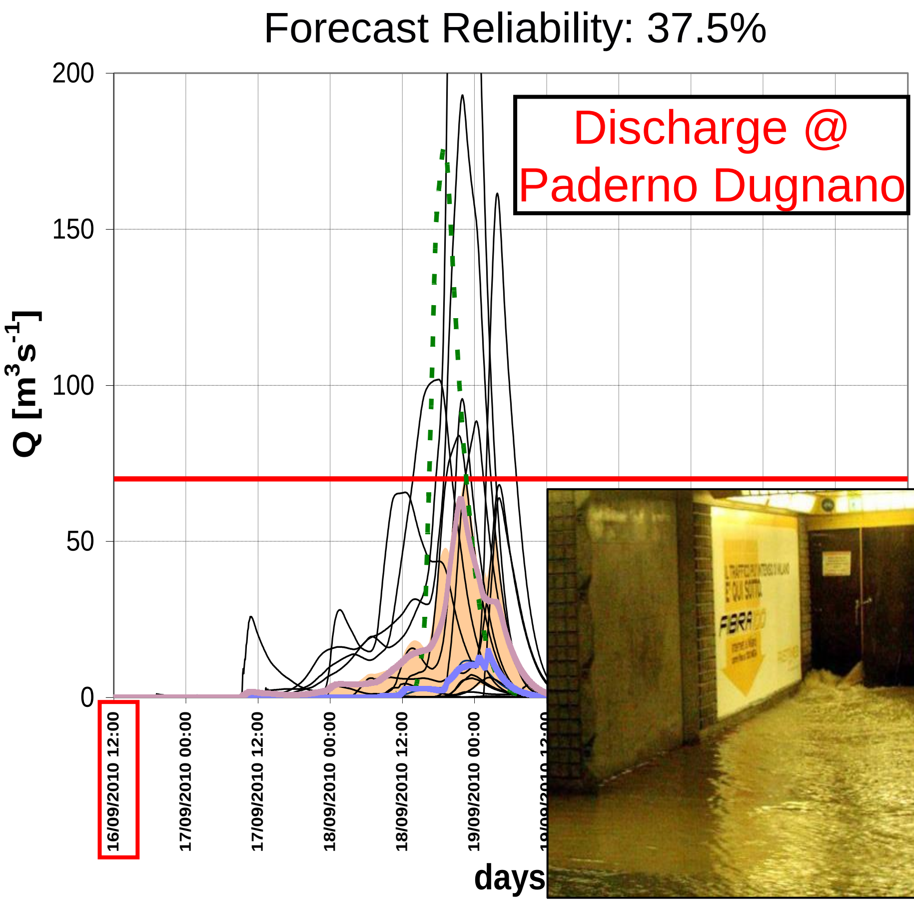
Seveso basin: September 2010 convective event

80 milion of Euros as total damage!

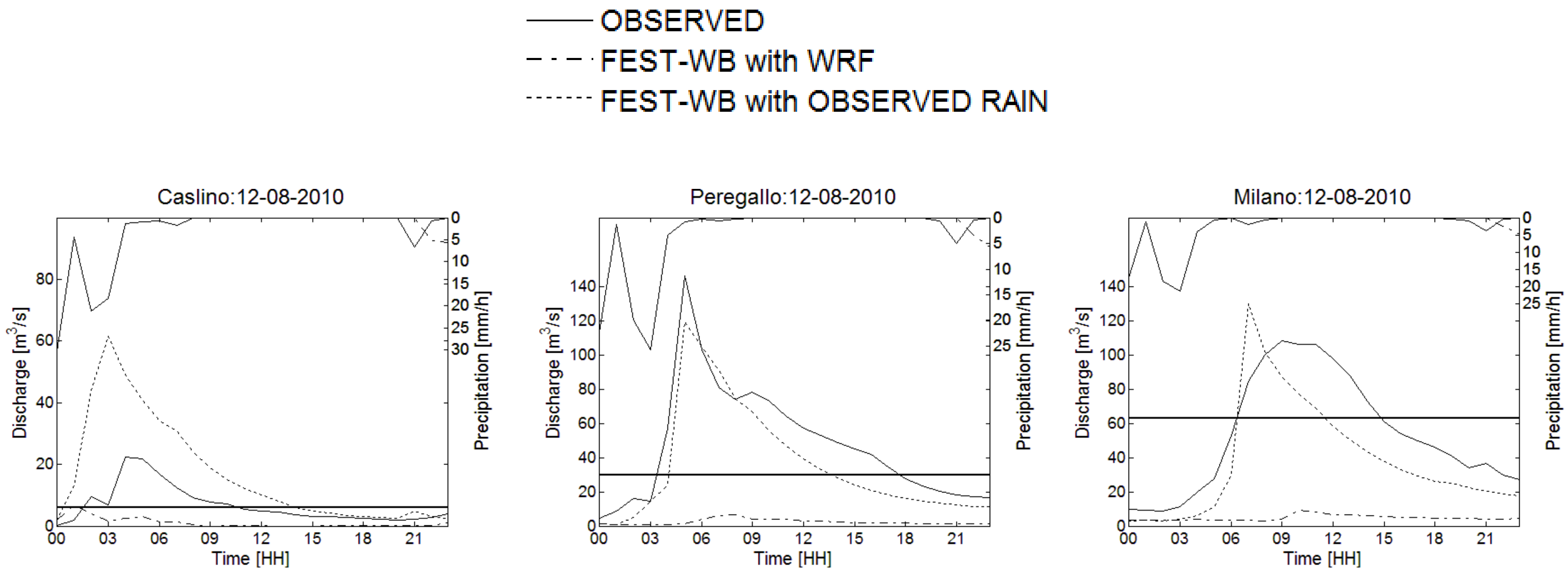


16 September 2010 output run:

36-48 h before the main peak flow



Lambro basin: August 2010 convective event



Skill scores of performance

		OBSERVED EVENT	
		YES	NO
FORECASTED EVENT	YES	HIT (a)	FALSE ALARM (b)
	NO	MISS (c)	CORRECT REJECTION (d)

The contingency table gives an overview of the predictive capabilities of the hydro-meteorological chain

Index	Equation	Perfect Score
POD (Probability Of Detection)	$\frac{a}{a+c}$	1
F (False alarm rate)	$\frac{b}{b+d}$	0
CSI (Critical Success Index)	$\frac{a}{a+b+c}$	1
CPI (Correct Performance Index)	$\frac{a+d}{n}$	1

Wilks, 2006

Performance for each basin

Olona

		OBSERVED EVENT YES	OBSERVED EVENT NO
FORECASTED EVENT	YES	13	2
	NO	10	75

Seveso

		OBSERVED EVENT YES	OBSERVED EVENT NO
FORECASTED EVENT	YES	7	2
	NO	12	79

Lambro

		OBSERVED EVENT YES	OBSERVED EVENT NO
FORECASTED EVENT	YES	41	4
	NO	54	36

Index	Olona	Seveso	Lambro
POD	0.57	0.37	0.43
F	0.03	0.03	0.10
CSI	0.52	0.33	0.41
CPI	0.88	0.84	0.57

Global performance

The performance of the hydro-meteorological chain is not so high, but it is encouraging with a POD equal to 45%.

The presence of false and missed alarms is due to:

- low performance of the WRF model during convective events
- uncertainty in the estimated threshold @ Paderno Dugnano gauging station
- not accurate calibration of the hydrological model @ Milano gauging station in the Lambro River basin

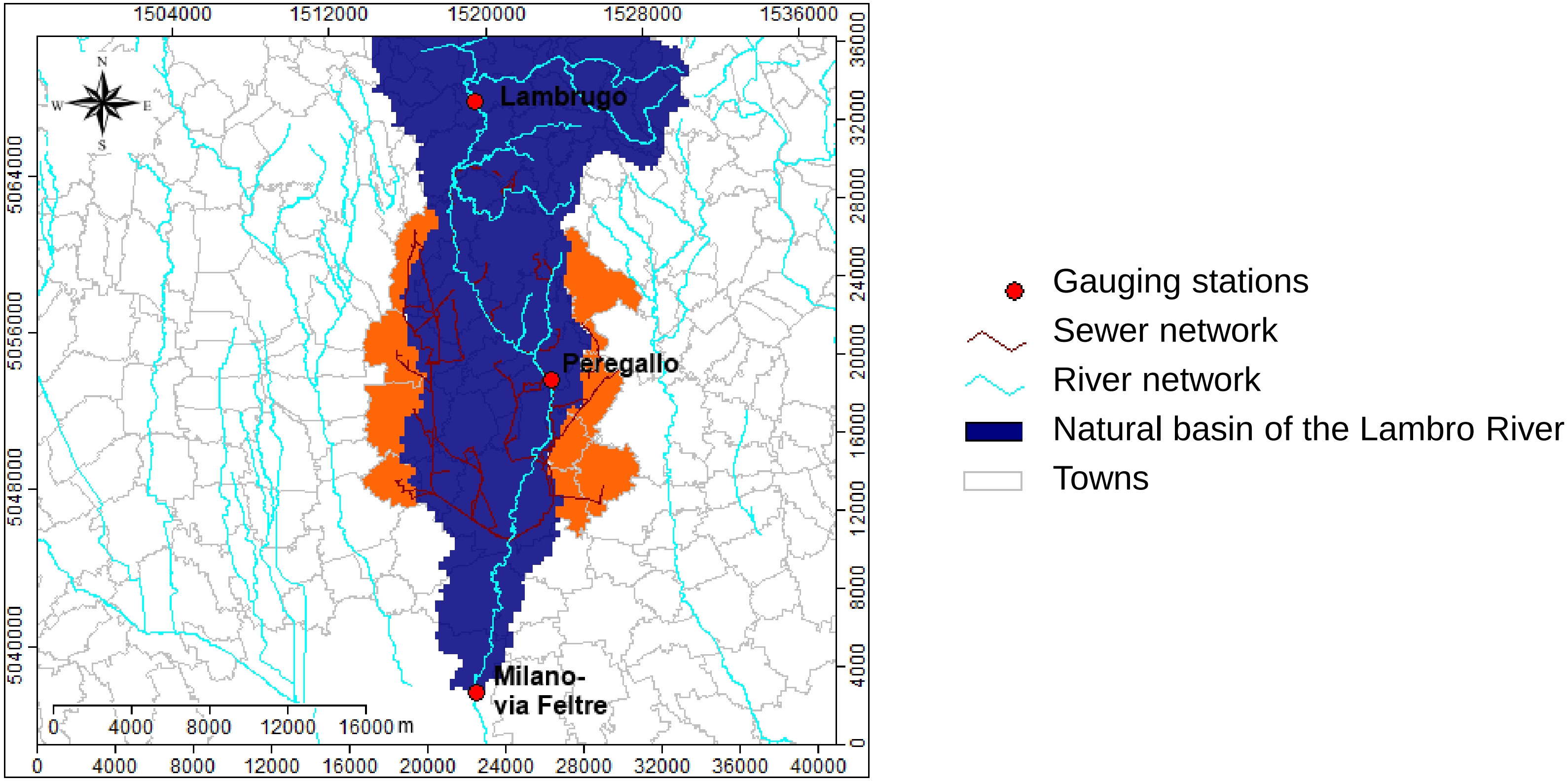
		OBSERVED EVENT	
		YES	NO
FORECASTED EVENT	YES	61	8
	NO	76	180

Index	Value
POD	0.45
F	0.04
CSI	0.42
CPI	0.74

Critical problems in the Lambro River basin (1)

1. The sewerage system in the province of Monza does not let to quantify how much water flows into the Lambro River during flood events

Urbanized territories, which are not included in natural basin of the Lambro River, contribute to increase the runoff at the gauging section.

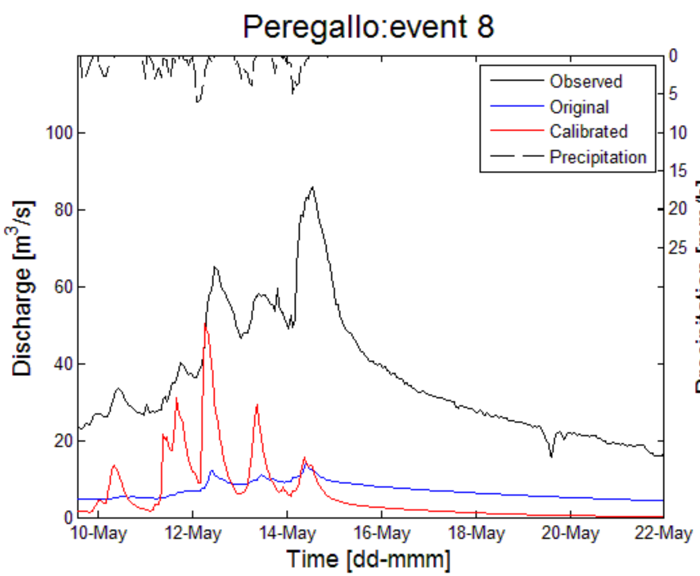


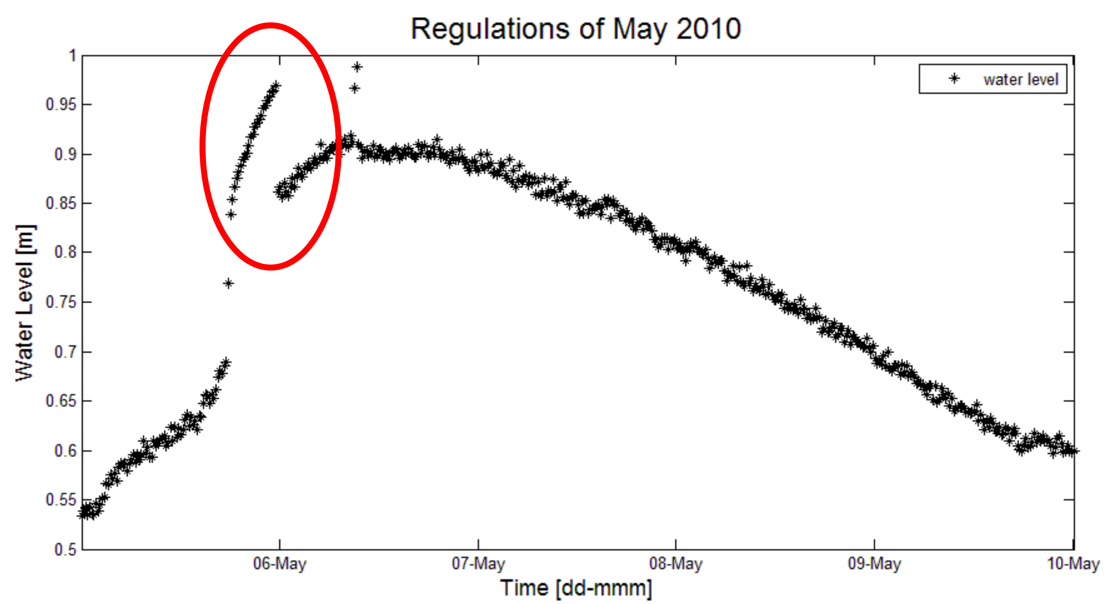
Critical problems in the Lambro River basin (2)

Problems for reproducing the peak flood and runoff due to lake regulations

2. Diotti sluice: impossible to quantify how much water is released into the Lambro River due to regulations of the water level of the Pusiano Lake water level.

Diotti sluice





Conclusions for flood predictions

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

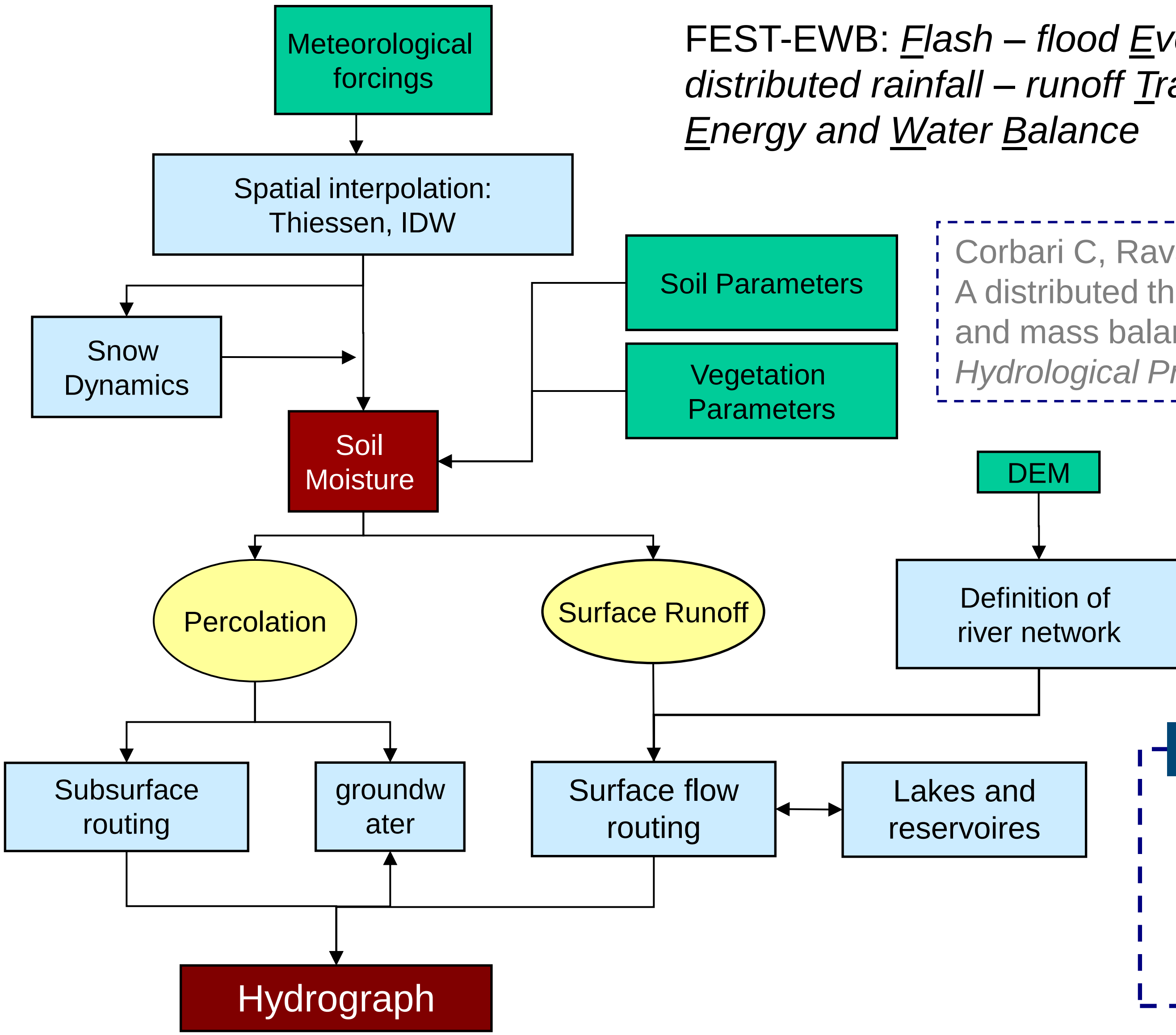
1) Meteorological data (above all precipitation) are not sufficient to cover the entire basin area, and even hydrological information needs to be incresead.

2) The spatial resolution (1 km) of the WRF model is not approriate, in particular for forecasting convective events. A multi-model approcah, coupling high resolution deterministic models with coarser, but probabilistic models, is suggested.

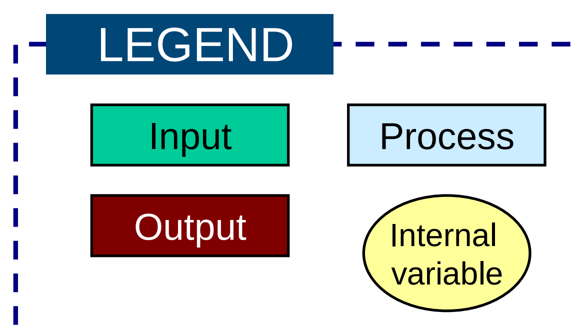
3) A higher forecast horizon (48-72 hours) is necessary for civil protection actions in such hydrological cathcments.

FEST-EWB hydrological model

FEST-EWB: *<u>F</u>lash – flood <u>E</u>vent – based <u>S</u>patially – distributed rainfall – runoff <u>T</u>ransformation – including <u>E</u>nergy and <u>W</u>ater <u>B</u>alance*

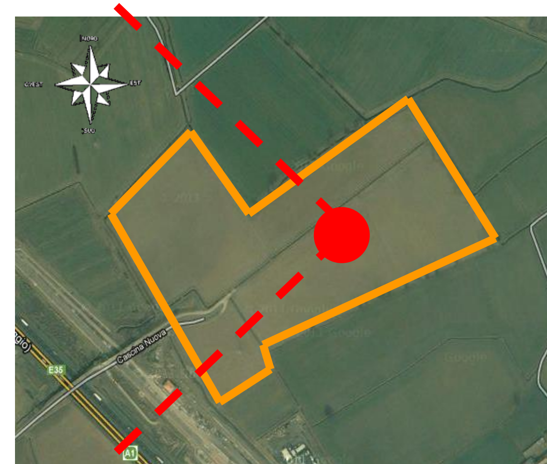


Corbari C, Ravazzani G, and Mancini M, 2011: A distributed thermodynamic model for energy and mass balance computation: FEST–EWB. *Hydrological Processes* 25(9), 1443-1452



Eddy covariance station and TDR probes

Uvrada
Weather stations
DEM Lombardy Region
Value

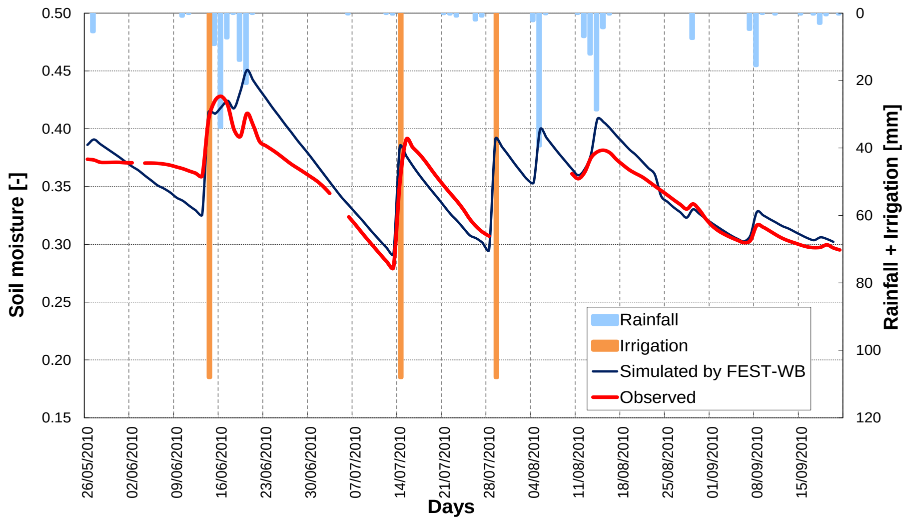


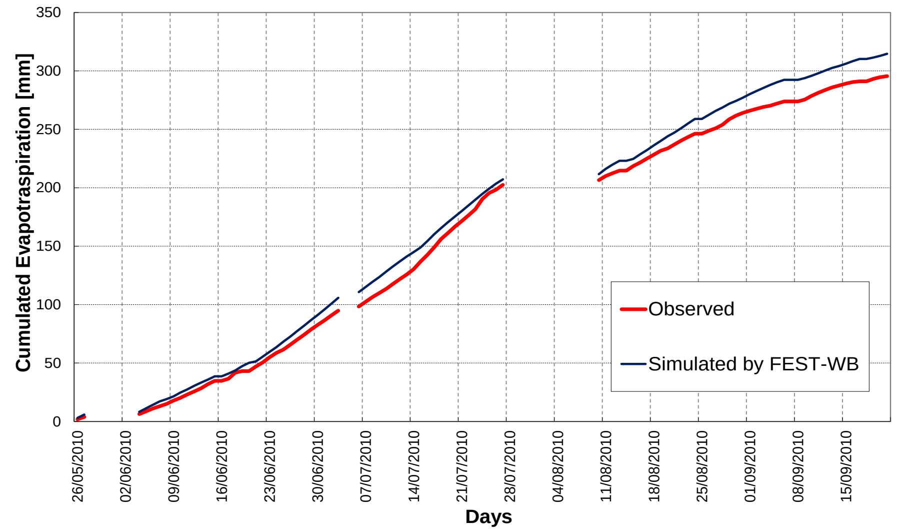
Kilometers

The territory of the MBL consortium covers an area of 740 km^2 in which there are more than 150 irrigation basins and thousands of irrigation sub-basins which include the private lots of landowners

Actual evapotranspiration fluxes and soil moisture measures

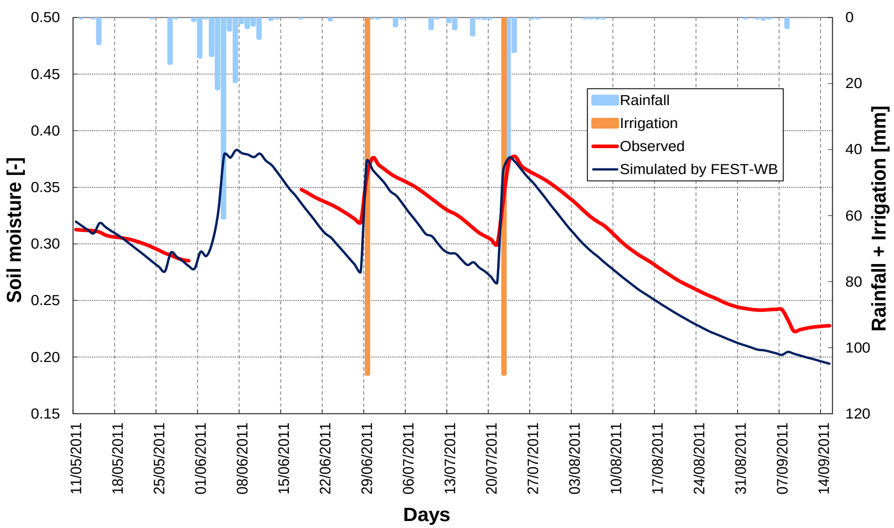
Calibration of the FEST-EWB model (2010-2011)

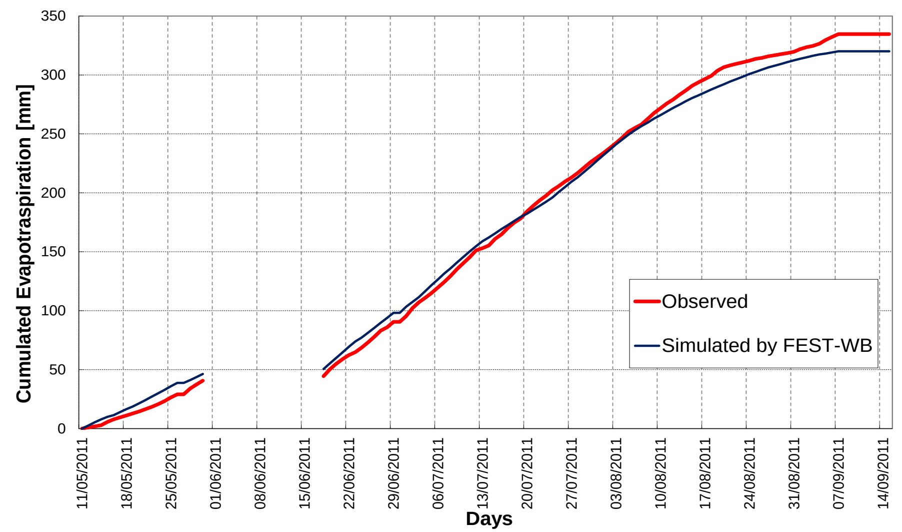




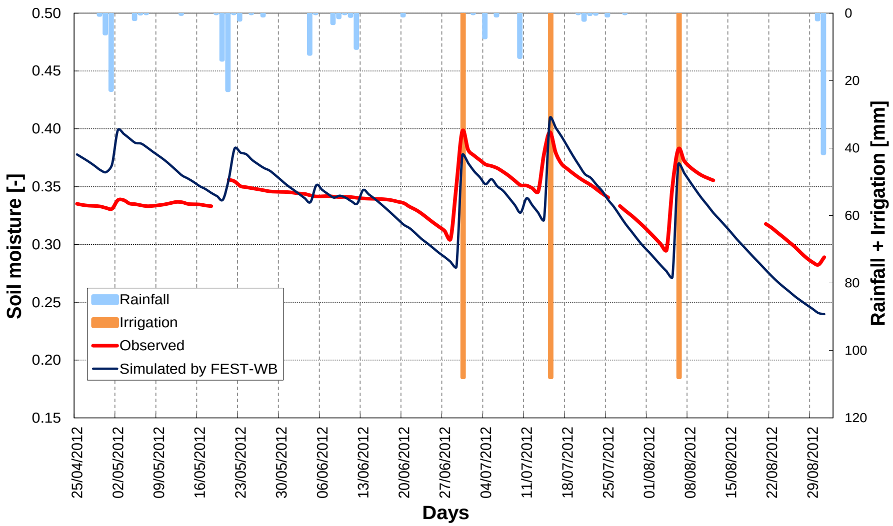
Soil moisture

Evapotranspiration

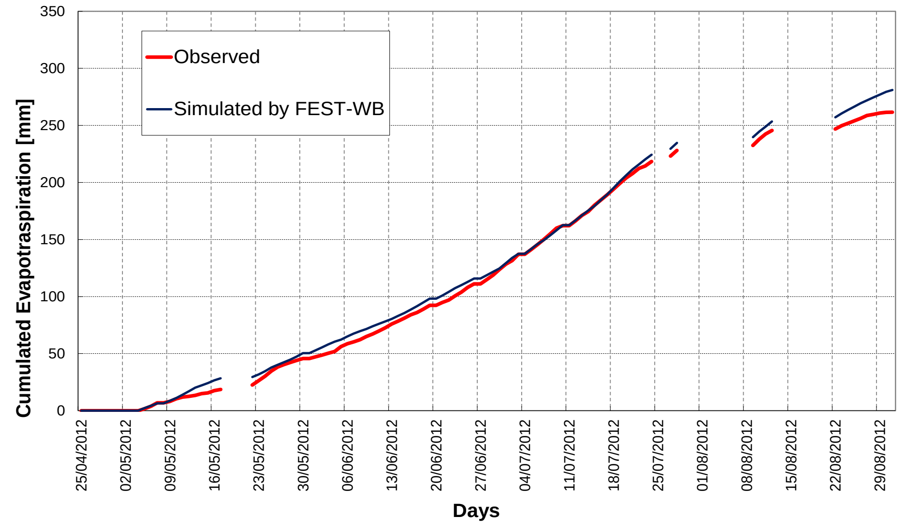




Validation of the FEST-EWB model (2012)



Soil moisture



Evapotranspiration

Consorzio Bonifica Muzza Bassa Lodigiana

ROGGIA PORRA NUOVA — L'orario ha inizio il 3 di aprile alle ore 04,00 — Ruota di giorni 14 per un totale di ore 360 — ANNO 2009

PROPRIETA'	PODERE	ORARIO DURATA	ORARIO INIZIO	MESE E GIORNI IN CUI COMPETE L'IRRIGAZIONE											
FERRARI PIETRO E TERESA		02.30	4.00	3-apr	18-apr	3-mag	18-mag	2-giu	17-giu	2-lug	17-lug	1-ago	16-ago	31-ago	15-set
BOSONI PIERO EREDI	RAMPINA	15.00	6.30	3-apr	18-apr	3-mag	18-mag	2-giu	17-giu	2-lug	17-lug	1-ago	16-ago	31-ago	15-set
SCOTTI UMBERTO	ROSA DEL PROPRIO	06.00	21.30	3-apr	18-apr	3-mag	18-mag	2-giu	17-giu	2-lug	17-lug	1-ago	16-ago	31-ago	15-set
SCOTTI BRUNO	ROSA DEL PROPRIO	02.00	3.30	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
FASOLI GIACOMO	CAMPO LOCATO	00.30	5.30	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
VIRTUANI LUIGI E ANGELO		01.06	6.00	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
GIAVERI MARIO		00.24	7.06	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
GIAVERI PIETRO	CAMPO PERSIA II°	00.45	7.30	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
CATTIVELLI C.	CAMPAZZO	00.45	8.15	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
BOSONI PIERO EREDI	RAMPINA	03.30	9.00	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
GIAVERI MARIO	CAMPI PERSIA/LOCATO	01.00	12.30	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
FASOLI GIACOMO	CAMPO LOCATO	00.30	13.30	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
CHIODA EREDI	CASCINA VECCHIA	20.00	14.00	4-apr	19-apr	4-mag	19-mag	3-giu	18-giu	3-lug	18-lug	2-ago	17-ago	1-set	16-set
DEDE' ALBERTO E CARLA	ROSA DEL PROPRIO	22.00	10.00	5-apr	20-apr	5-mag	20-mag	4-giu	19-giu	4-lug	19-lug	3-ago	18-ago	2-set	17-set
CATTIVELLI C.	CAMPAZZO / PERSIA	07.00	8.00	6-apr	21-apr	6-mag	21-mag	5-giu	20-giu	5-lug	20-lug	4-ago	19-ago	3-set	18-set
VALENTI G. CESARE	CAMPAZZO	04.00	15.00	6-apr	21-apr	6-mag	21-mag	5-giu	20-giu	5-lug	20-lug	4-ago	19-ago	3-set	18-set
IST. MILAN. MARTINIT E STEL.	CAMPAZZO	16.00	19.00	6-apr	21-apr	6-mag	21-mag	5-giu	20-giu	5-lug	20-lug	4-ago	19-ago	3-set	18-set
IST. MILAN. MARTINIT E STEL.	RAMPINA	07.00	11.00	7-apr	22-apr	7-mag	22-mag	6-giu	21-giu	6-lug	21-lug	5-ago	20-ago	4-set	19-set
IST. MILAN. MARTINIT E STEL.	SAN GIOVANNI	09.00	18.00	7-apr	22-apr	7-mag	22-mag	6-giu	21-giu	6-lug	21-lug	5-ago	20-ago	4-set	19-set
VALENTI G. CESARE	CAMPAZZO	03.00	3.00	8-apr	23-apr	8-mag	23-mag	7-giu	22-giu	7-lug	22-lug	6-ago	21-ago	5-set	20-set
IST. MILAN. MARTINIT E STEL.	SAN GIOVANNI	03.00	6.00	8-apr	23-apr	8-mag	23-mag	7-giu	22-giu	7-lug	22-lug	6-ago	21-ago	5-set	20-set
SCANDELLI FRATELLI	LIVRAGA	05.00	9.00	8-apr	23-apr	8-mag	23-mag	7-giu	22-giu	7-lug	22-lug	6-ago	21-ago	5-set	20-set
FONDAZIONE VITTADINI	LIVRAGA	06.00	14.00	8-apr	23-apr	8-mag	23-mag	7-giu	22-giu	7-lug	22-lug	6-ago	21-ago	5-set	20-set
FONDAZIONE VITTADINI	CANTONE	06.00	20.00	8-apr	23-apr	8-mag	23-mag	7-giu	22-giu	7-lug	22-lug	6-ago	21-ago	5-set	20-set
FONDAZIONE VITTADINI	DOSSINO	08.00	2.00	9-apr	24-apr	9-mag	24-mag	8-giu	23-giu	8-lug	23-lug	7-ago	22-ago	6-set	21-set
IST. MILAN. MARTINIT E STEL.	LUOGO NUOVO	09.00	10.00	9-apr	24-apr	9-mag	24-mag	8-giu	23-giu	8-lug	23-lug	7-ago	22-ago	6-set	21-set
PASSARINI GIULIO	CAMPO DI CASA	01.00	19.00	9-apr	24-apr	9-mag	24-mag	8-giu	23-giu	8-lug	23-lug	7-ago	22-ago	6-set	21-set
CHIODA EREDI	CASCINA VECCHIA	52.00	20.00	9-apr	24-apr	9-mag	24-mag	8-giu	23-giu	8-lug	23-lug	7-ago	22-ago	6-set	21-set
DEDE' ALBERTO E CARLA	ROSA DEL PROPRIO	20.00	0.00	12-apr	27-apr	12-mag	27-mag	11-giu	26-giu	11-lug	26-lug	10-ago	25-ago	9-set	24-set
CHIODA EREDI (SCOTTI)		02.30	20.00	12-apr	27-apr	12-mag	27-mag	11-giu	26-giu	11-lug	26-lug	10-ago	25-ago	9-set	24-set
CHIODA EREDI (FERRARI)		00.30	22.30	12-apr	27-apr	12-mag	27-mag	11-giu	26-giu	11-lug	26-lug	10-ago	25-ago	9-set	24-set
CHIODA EREDI (SPAGLIARDI)		07.00	23.00	12-apr	27-apr	12-mag	27-mag	11-giu	26-giu	11-lug	26-lug	10-ago	25-ago	9-set	24-set
CHIODA EREDI (ROSSI)		06.00	4.00	13-apr	28-apr	13-mag	28-mag	12-giu	27-giu	12-lug	27-lug	11-ago	26-ago	10-set	25-set
CHIODA EREDI	CASCINA VECCHIA	32.00	11.00	13-apr	28-apr	13-mag	28-mag	12-giu	27-giu	12-lug	27-lug	11-ago	26-ago	10-set	25-set
ROSSI FRATELLI		08.00	10.00	14-apr	29-apr	14-mag	29-mag	13-giu	28-giu	13-lug	28-lug	12-ago	27-ago	11-set	26-set
UTENZA ROG. PORRA NUOVA		02.00	3.00	15-apr	30-apr	15-mag	30-mag	14-giu	29-giu	14-lug	29-lug	13-ago	28-ago	12-set	27-set
GRECCHI ETTORE	CASCINA NUOVA	30.00	5.00	15-apr	30-apr	15-mag	30-mag	14-giu	29-giu	14-lug	29-lug	13-ago	28-ago	12-set	27-set
A.AG. PACCHIARINI DANIELA	RONCHI	04.00	11.00	16-apr	1-mag	16-mag	31-mag	15-giu	30-giu	15-lug	30-lug	14-ago	29-ago	13-set	28-set
SPAGLIARDI GIANBATTISTA		09.00	15.00	16-apr	1-mag	16-mag	31-mag	15-giu	30-giu	15-lug	30-lug	14-ago	29-ago	13-set	28-set
Az. Ag. SARCHIO s.s.	CA' DEL PARTO	08.00	0.00	17-apr	2-mag	17-mag	1-giu	16-giu	1-lug	16-lug	31-lug	15-ago	30-ago	14-set	29-set
DEDE' ALBERTO E CARLA	ROSA DEL PROPRIO	20.00	8.00	17-apr	2-mag	17-mag	1-giu	16-giu	1-lug	16-lug	31-lug	15-ago	30-ago	14-set	29-set
SOMMANO HH.MM.		360.00													

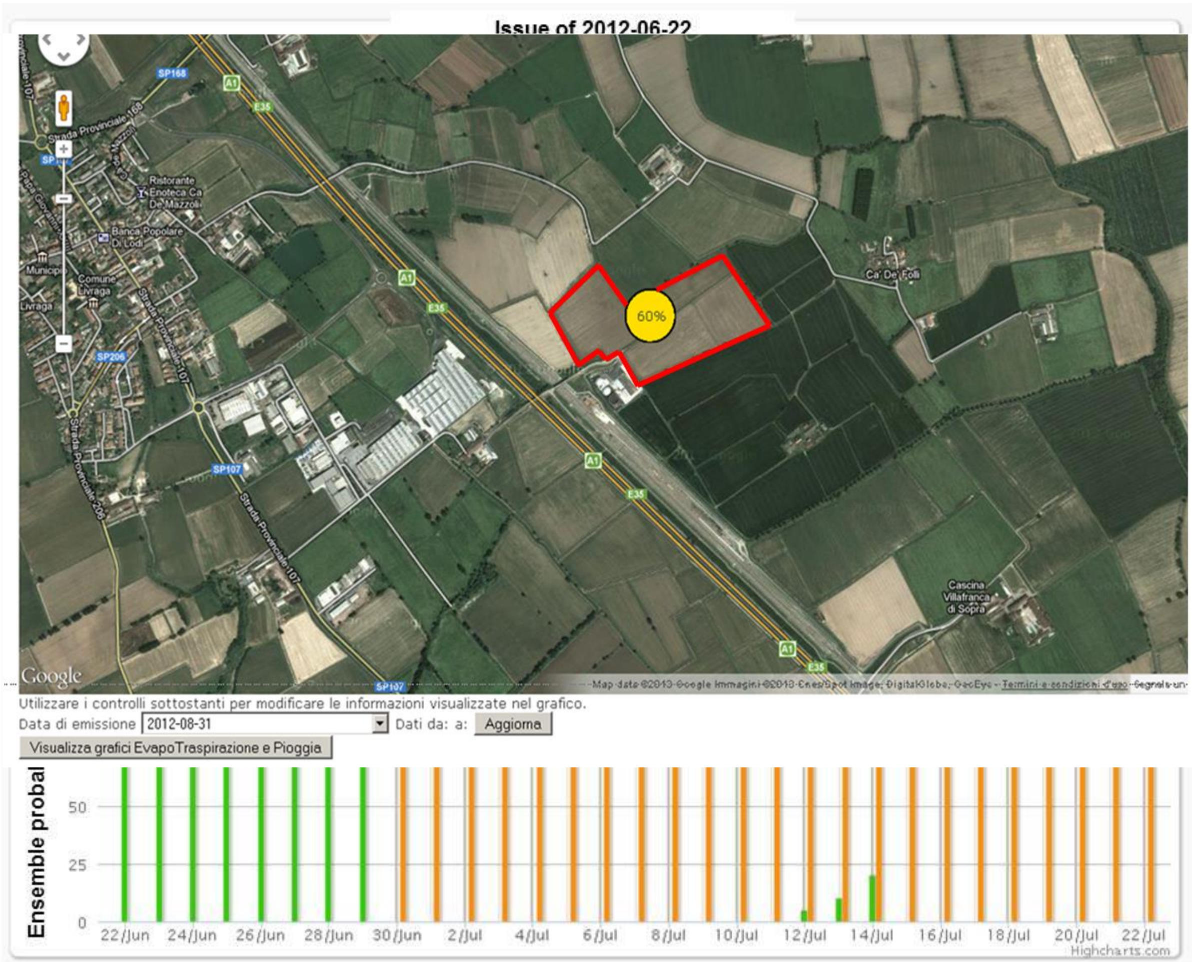
Time table for irrigation water allotments

The PRE.G.I. system: Hydro-meteorological forecast for irrigation management

Our idea was to create a web application where farmers are able to monitor real-time soil moisture conditions and forecasts. The knowledge of Quantitative Precipitation Forecasts (QPFs) for the following weeks combined with the updating of hydrological conditions makes it possible to obtain a tool for water distribution management in cultivated areas in order to improve irrigation scheduling, minimize irrigation costs and save water

Soil moisture forecasts

Probability to exceed the water surplus and stress threshold

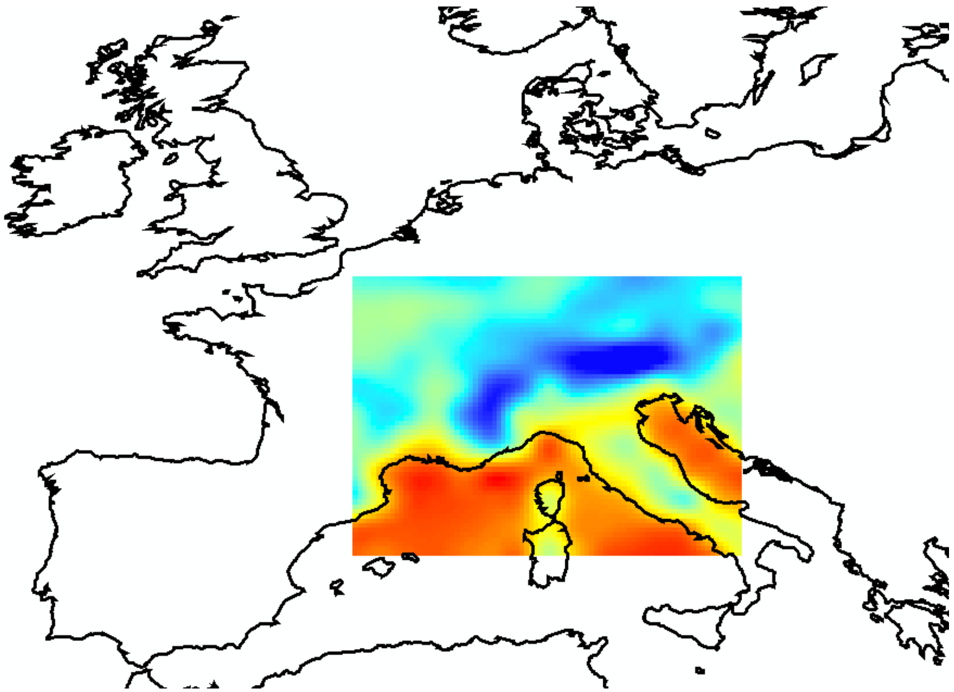


The WRF meteorological model for drought predictions

The probabilistic forecast was provided by the REPS (Regional Ensemble Prediction System), based on the WRF-ARW model, implemented and developed by the Epson Meteo Centre.

- **Spatial Resolution:** 18 km
- **Temporal output:** 12 h
- **Vertical levels:** 36 (non-hydrostatic)
- **Ensemble members: 20,** each perturbation of the ensemble is produced by an algorithm developed by the EMC based on a special application of Ensemble Transform Kalman Filter (EnTKF)
- **Forecast horizon:** + 30 days
- **Run starting at:** 00:00 UTC
- **IC and BC** are provided by a Global Ensemble Prediction System (GEPS) based on a modified version of the WRF-ARW applied at the global scale, which has a grid mesh size of 200 km
- **Owner:** MOPI – Epson Meteo Centre

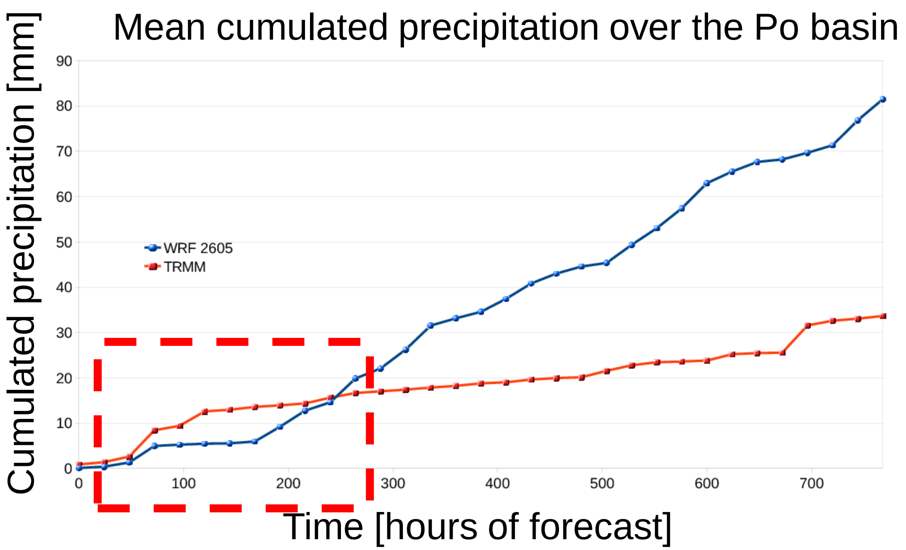
The WRF model domain



WRF model: performance reanalysis

67 dry events where selected during 2003 and 2008

Initialization: 26 May 2006

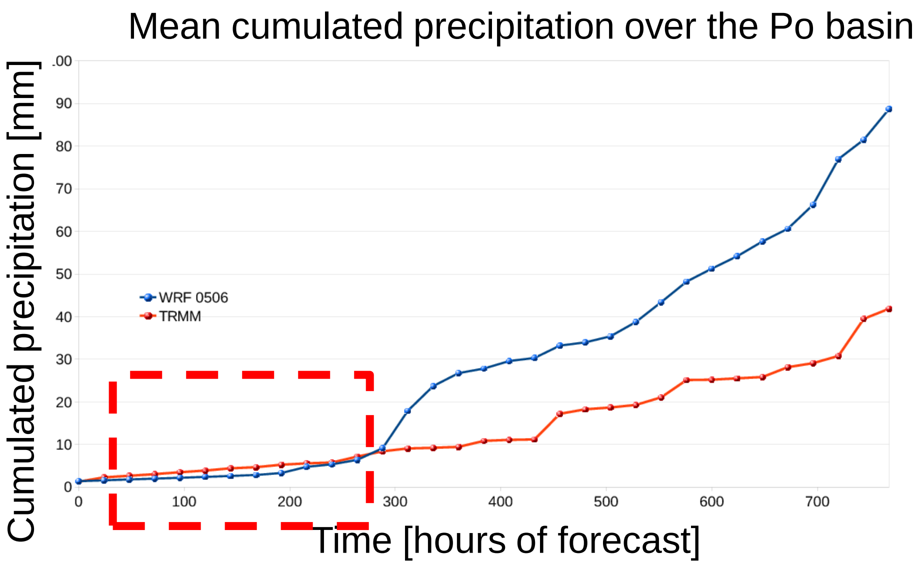


(a)

Cumulated precipitation:

Comparison between WRF vs TRMM

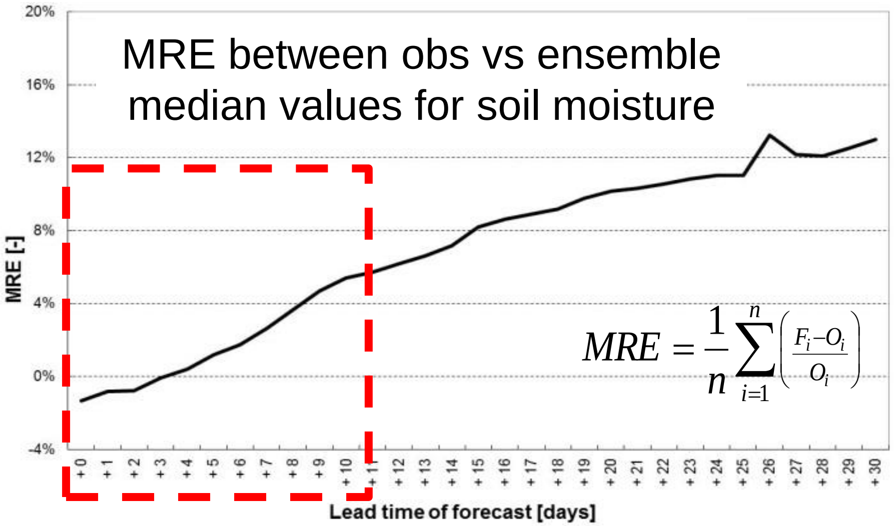
Initialization: 5 July 2006

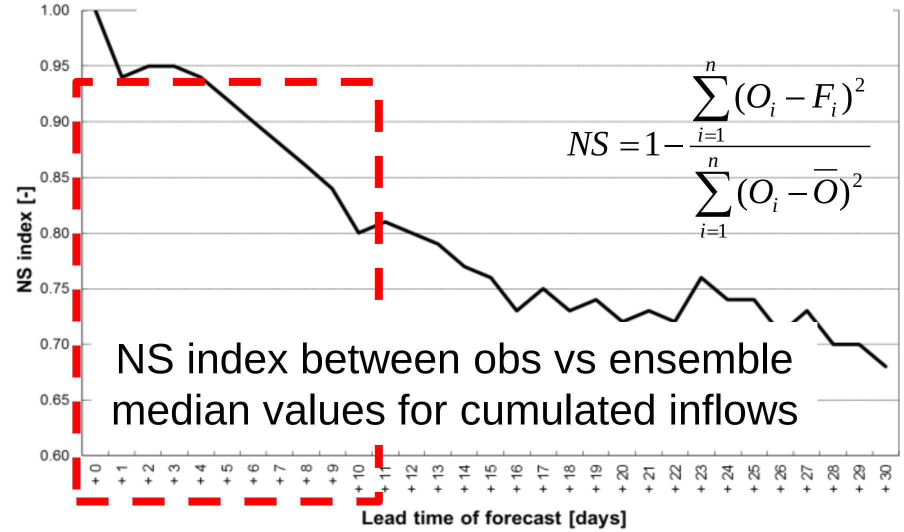


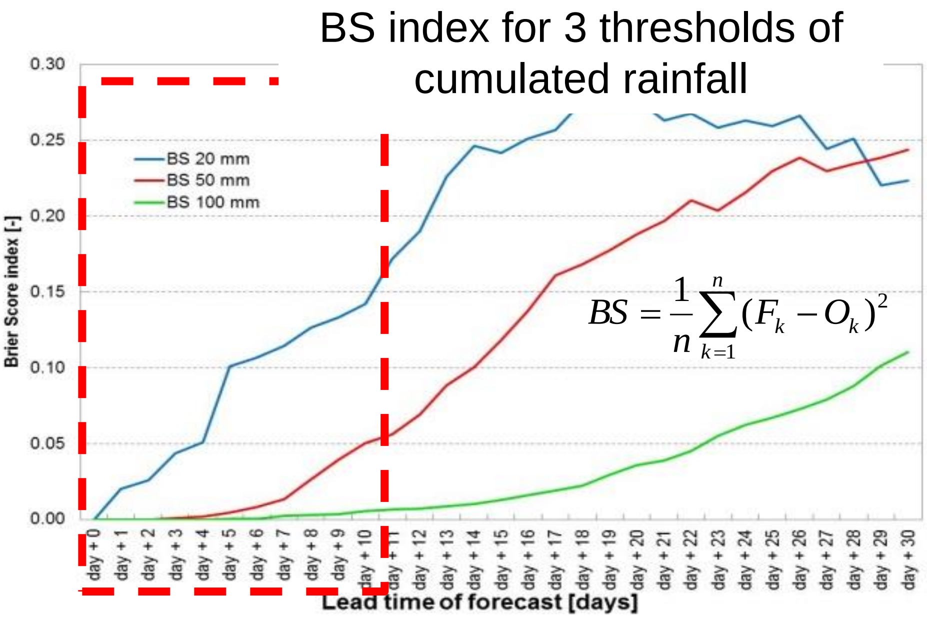
(b)

Skill scores of performance for the 2012 growing season

O_i = observed values
F_i = median of forecasted values
$\overline{O_i}$ = the average of observed values
n = numbers of analyzed events







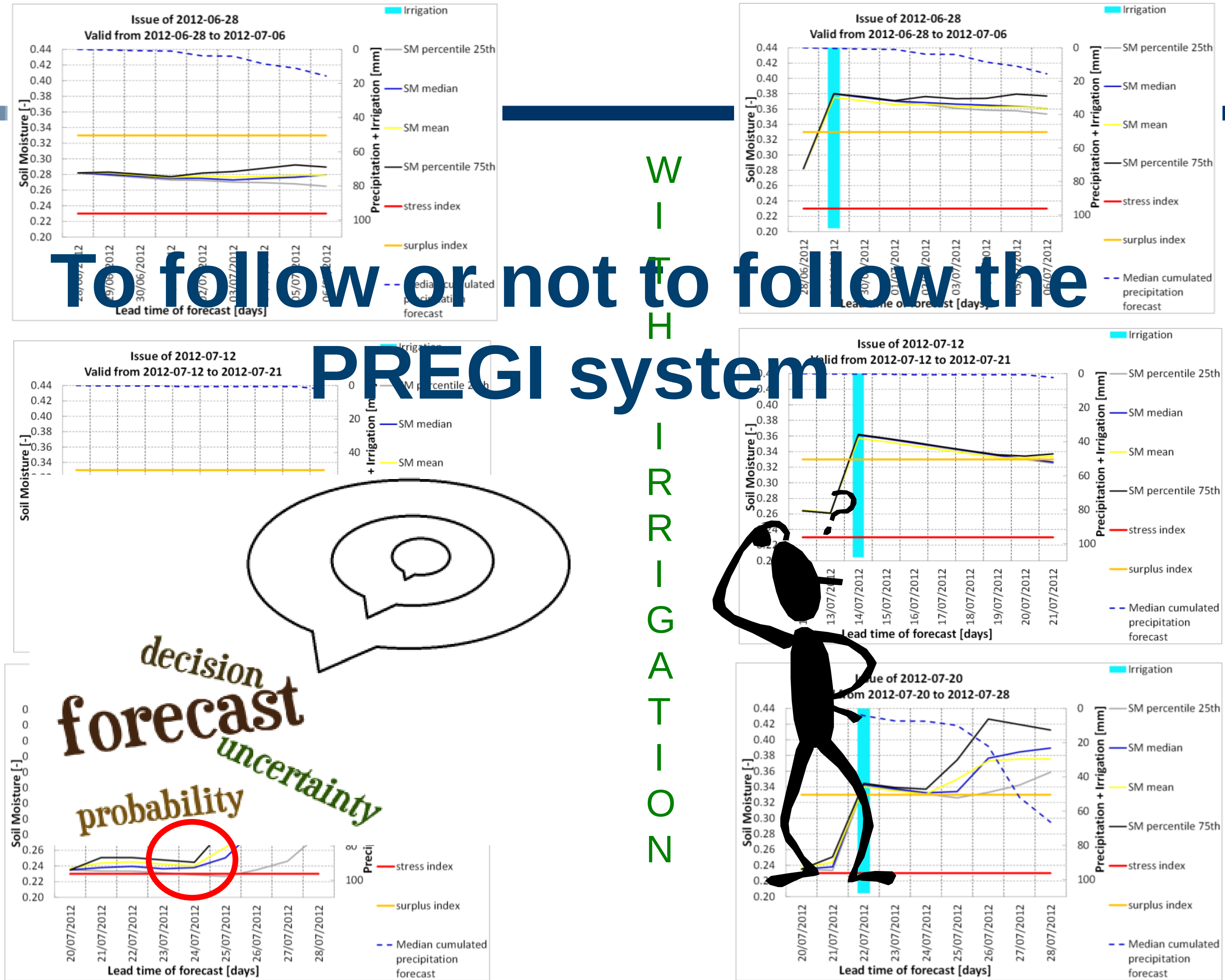
The results show how it was possible by combing meteorological and hydrological models to have reliable soil moisture forecasts for up to 7 and 10 days respectively, with a mean relative error of less than 10%, and cumulated precipitation forecasts with a NS index above 0.80 and a BS score lower than 0.15.

N = number of forecasting instances
F_k = the probability that an event was forecasted
O_k = the actual outcome of the event at instance k (0 if it doesn't happen and 1 if it happens)

To follow or not to follow the PREGI system

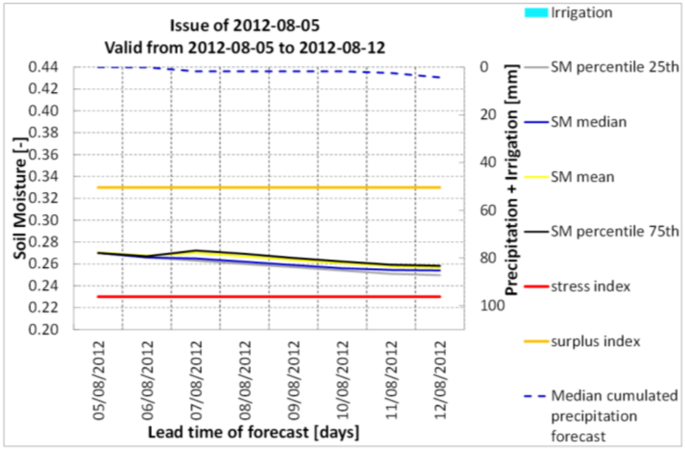
NO IRRIGATION

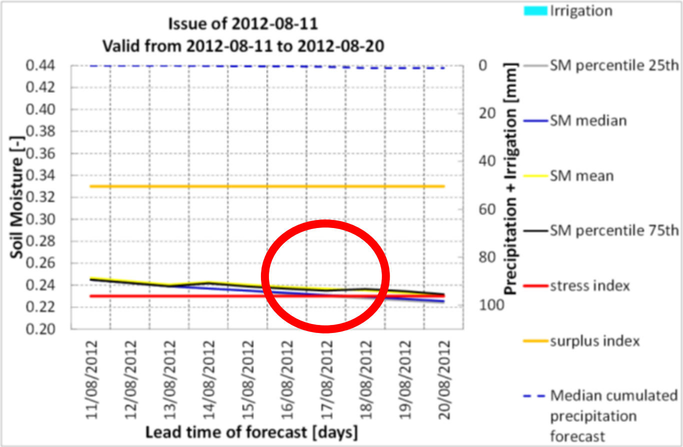
WITH IRRIGATION



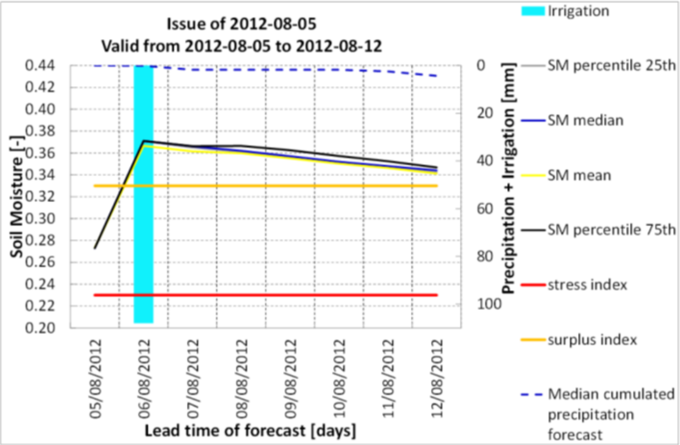
To follow or not to follow the PREGI system

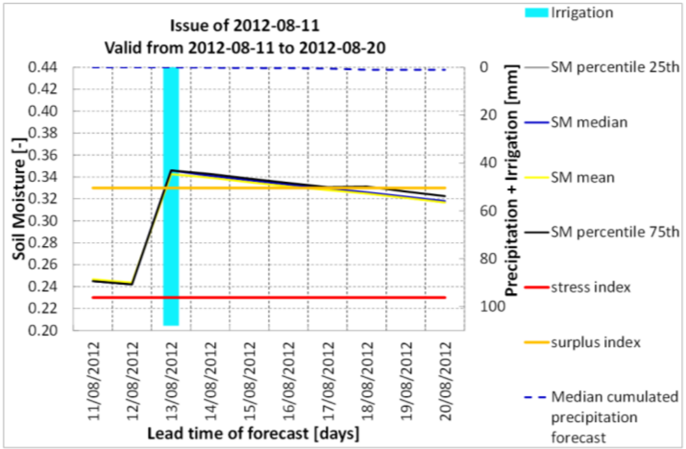
NO IRRIGATION



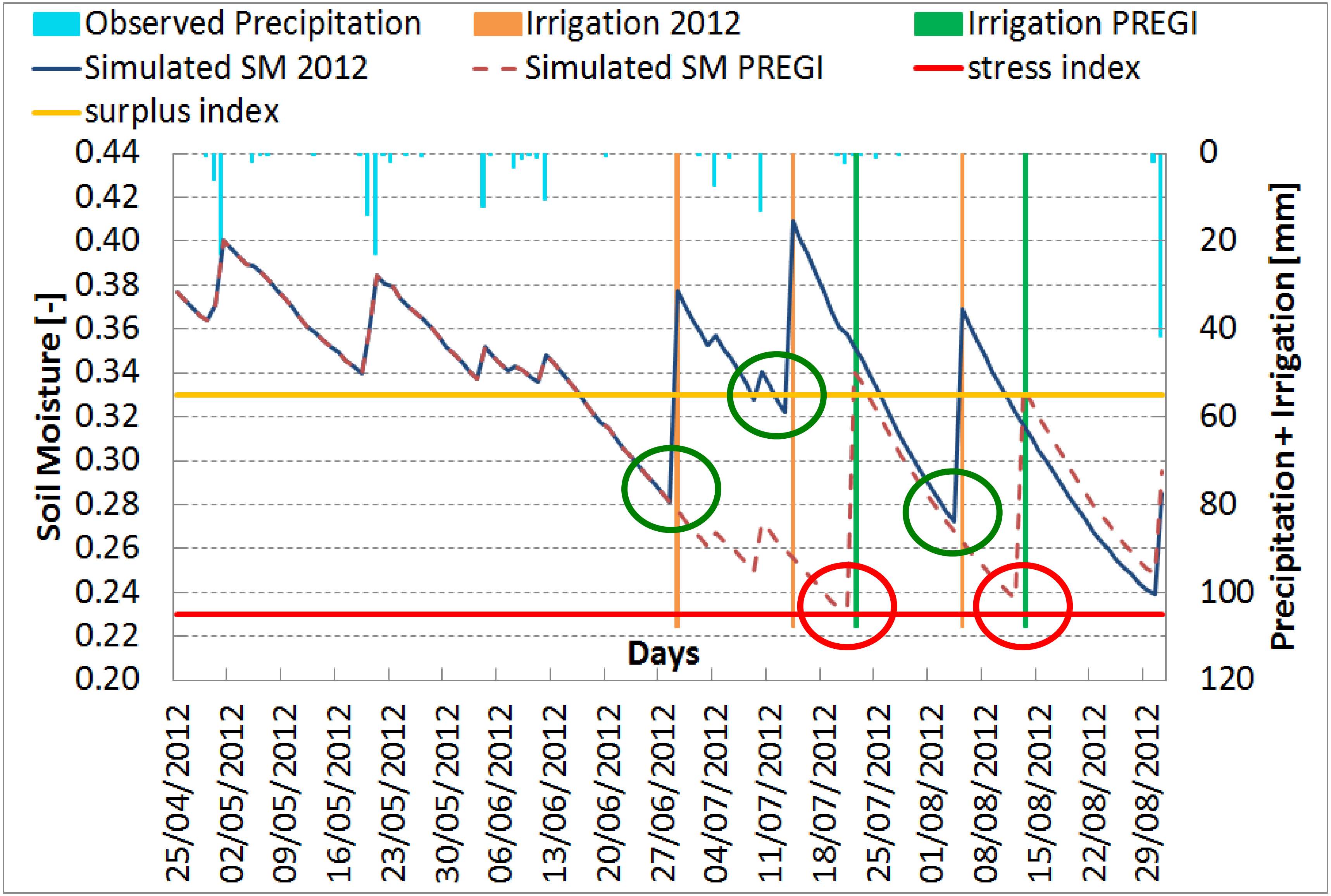


WITH IRRIGATION





Summary: can we save irrigation water?



Conclusions for drought predictions

1. 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).

2. The benefits of this project are both direct and indirect: the direct benefits regard the monitoring and forecasting of soil water content according to the current state of soil moisture values and water crop requirements, while the indirect benefits regard the optimization of water irrigations pursuing the best quantitative distribution, in particular periods of water scarcity, in order to minimize production losses caused by water stress due insufficient watering

3. One of the future developments is to extend these analyses over different sites with other case studies during future growing seasons. However, a limit for replicating this system in other areas will be that of obtaining real-time data (weather and soil moisture information), amounts and scheduled irrigation dates, which are usually not easy to acquire in real time.


Thank you for
your attention