NON-STRUCTURAL MEASURES FOR FLOOD CONTROL PLANNING OF THE MILANO AREA

1 POLITECNICO MILANO

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Mediterranean Meeting
Monitoring, modelling, early warning of extreme events triggered by heavy rainfall
University of Calabria
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Objectives

To develop system for real time flood forecasting for Milan

Calibration of hydrological spatially distributed model

Integration with weather forecasting model

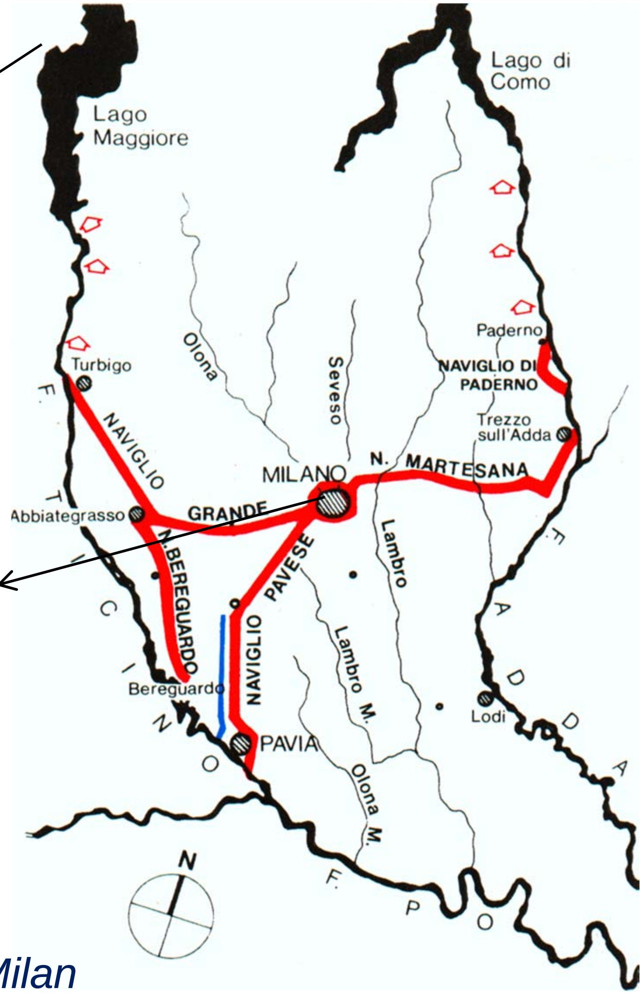
Reliability assessment by events reanalysis

Artificial channel network

Artificial channels: *Navigli*

The Milano urban area is one of the most populous in Italy and Europe (1.316.000 inhabitants live in 182 km^2), and it is also one of the most important economic area in the country.

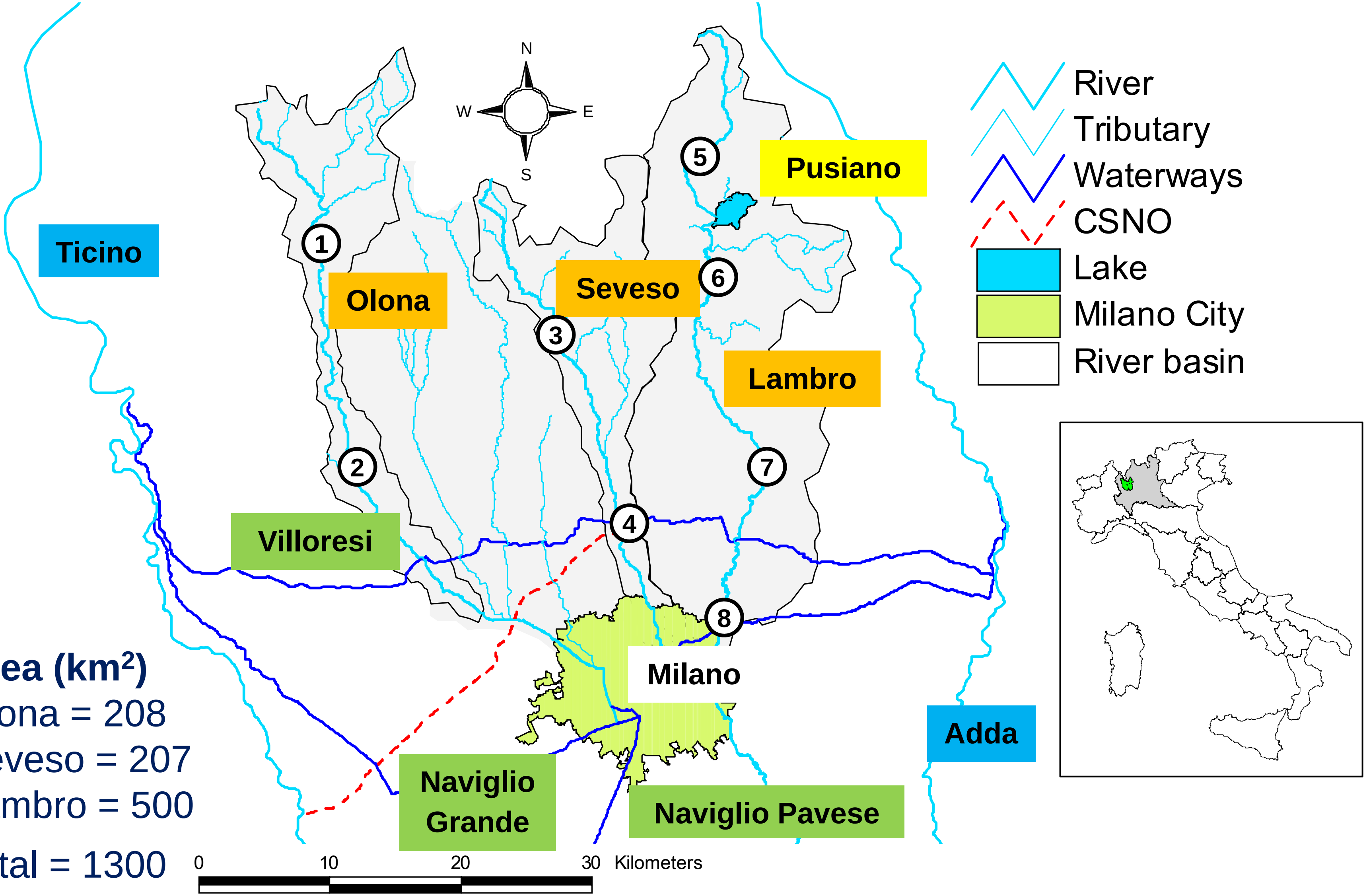
Milan is a **paradox**: far from important rivers but full of water. Artificial channels dug during the Middle Ages: drainage for land reclamation, irrigation, power (mills), navigation



Candoglia marble quarry

Milan Cathedral: *Domm de Milan*

Water network today



Area (km²)

Olona = 208

Seveso = 207

Lambro = 500

Total = 1300

Historical floods

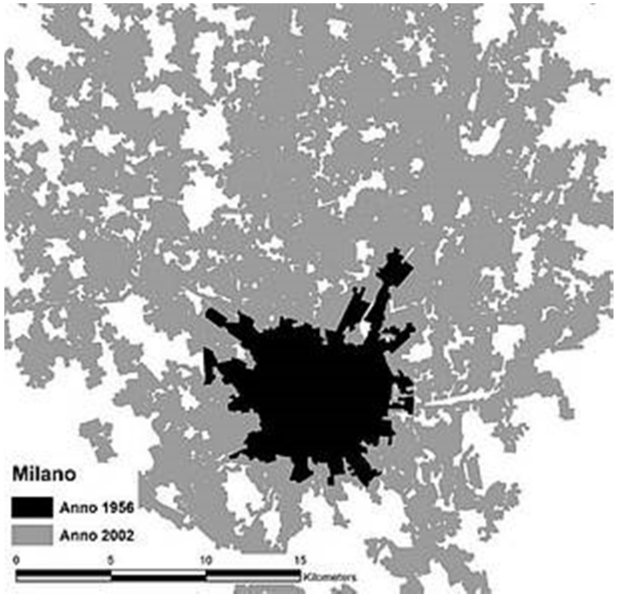
Olona flood, 1917

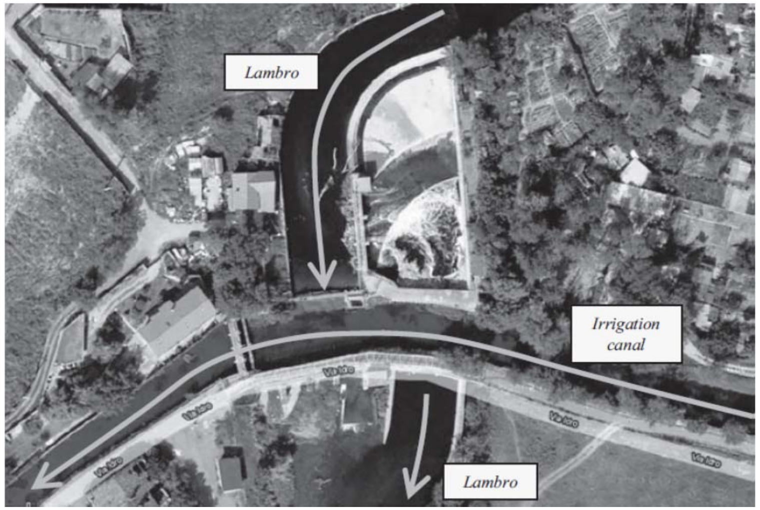
Seveso flood, 1980

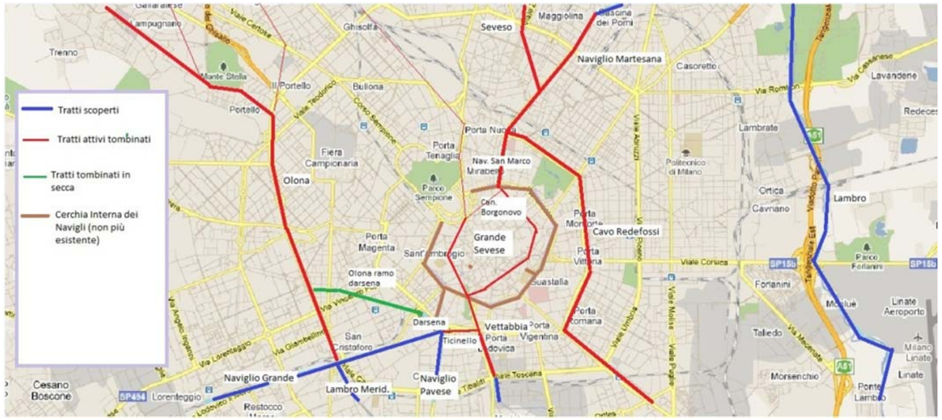
Structural measure

Bypass channel (CSNO, acronym from Italian “Canale Scolmatore di Nord Ovest”). Built from 1954 to 1980. Discharge capacity 30 m^3/s

Urban development: where are water courses?







Recent floods

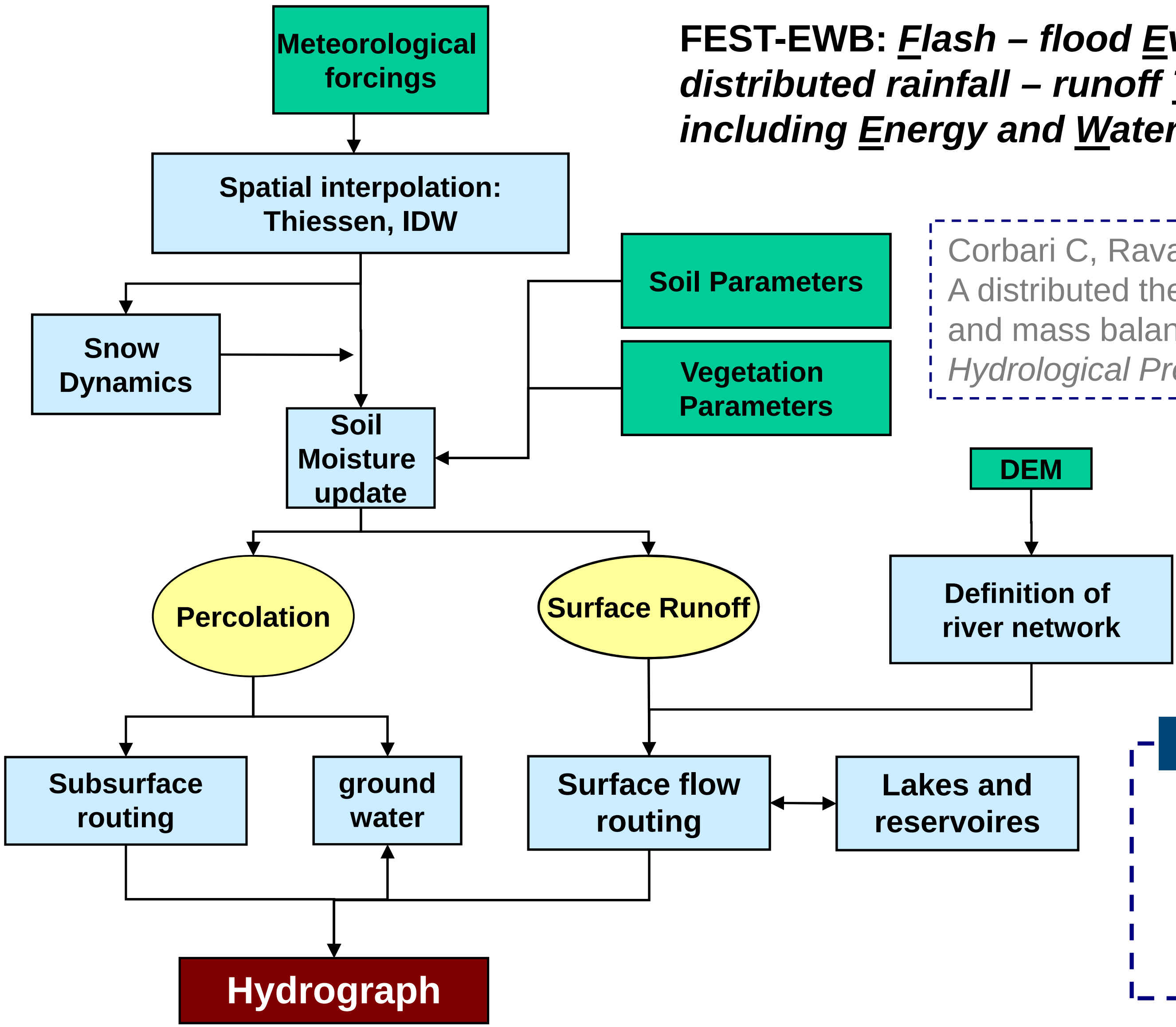
Seveso flood, 18 September 2010

80 milion Euro as total damage!

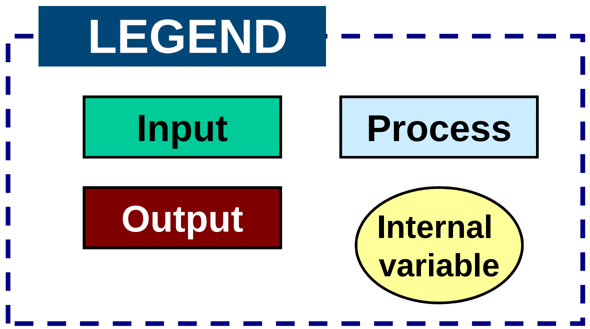
Seveso flood, 25 June 2014

FEST-EWB hydrological model

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

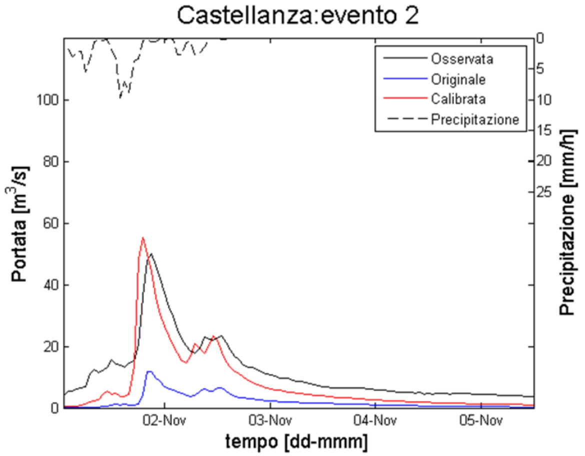


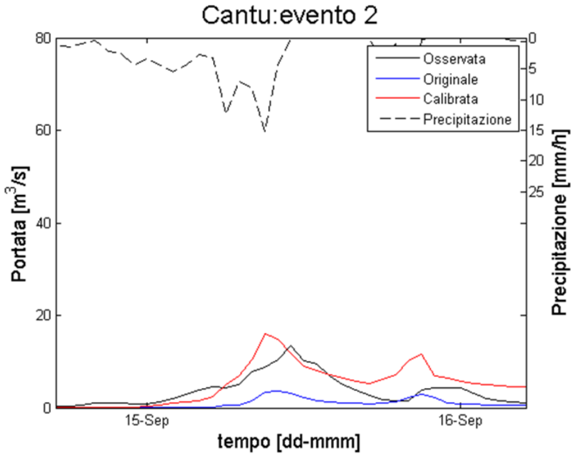
Corbari C, Ravazzani G, and Mancini M, 2011: A distributed thermodynamic model for energy and mass balance computation: FEST–EWB. *Hydrological Processes* 25(9), 1443-1452

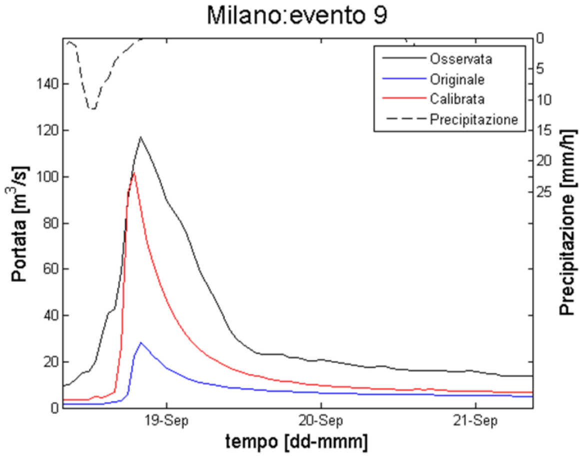


Calibration of the FEST-WB model (2003-2010 events)

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**





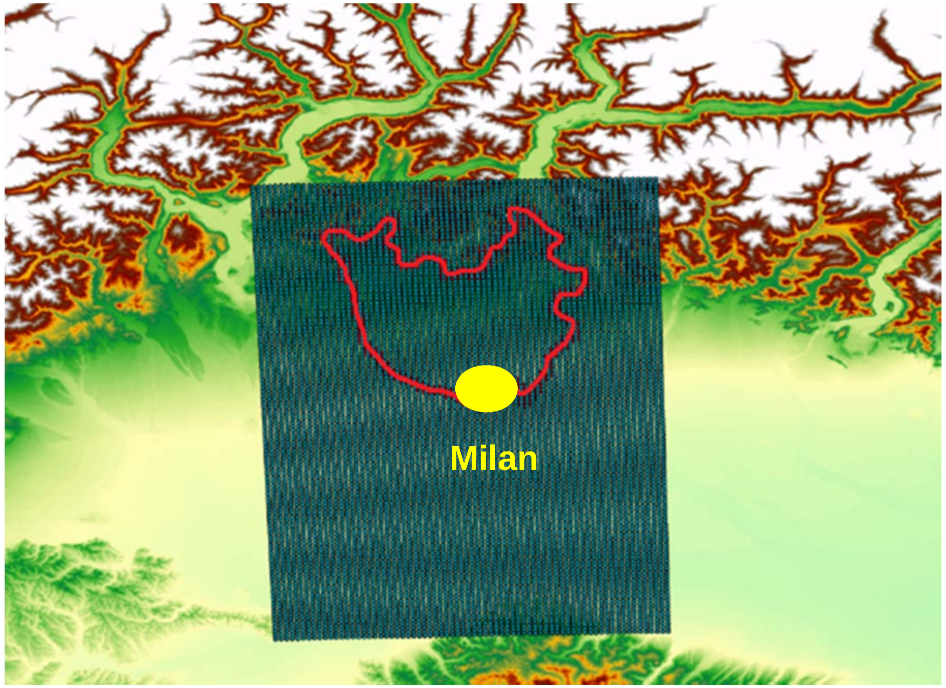


The WRF meteorological model for flood forecasts

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

The WRF model domain

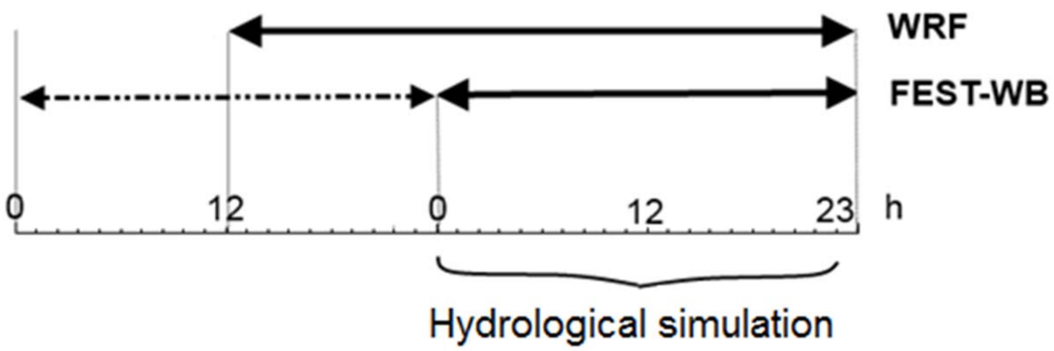


OUTPUT:

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

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

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

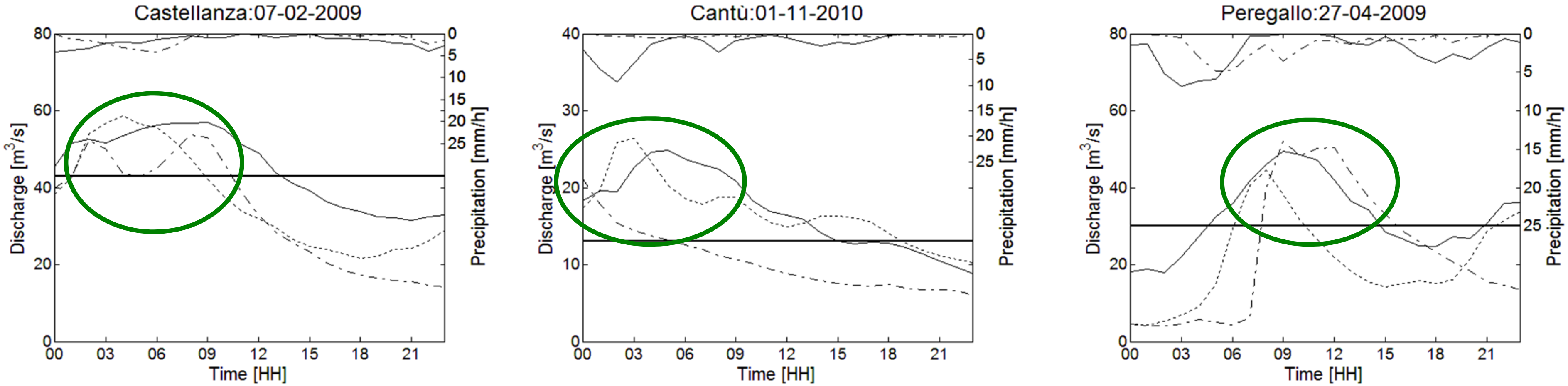
Courtesy of Civil Protection of the Lombardy Region

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 assess 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



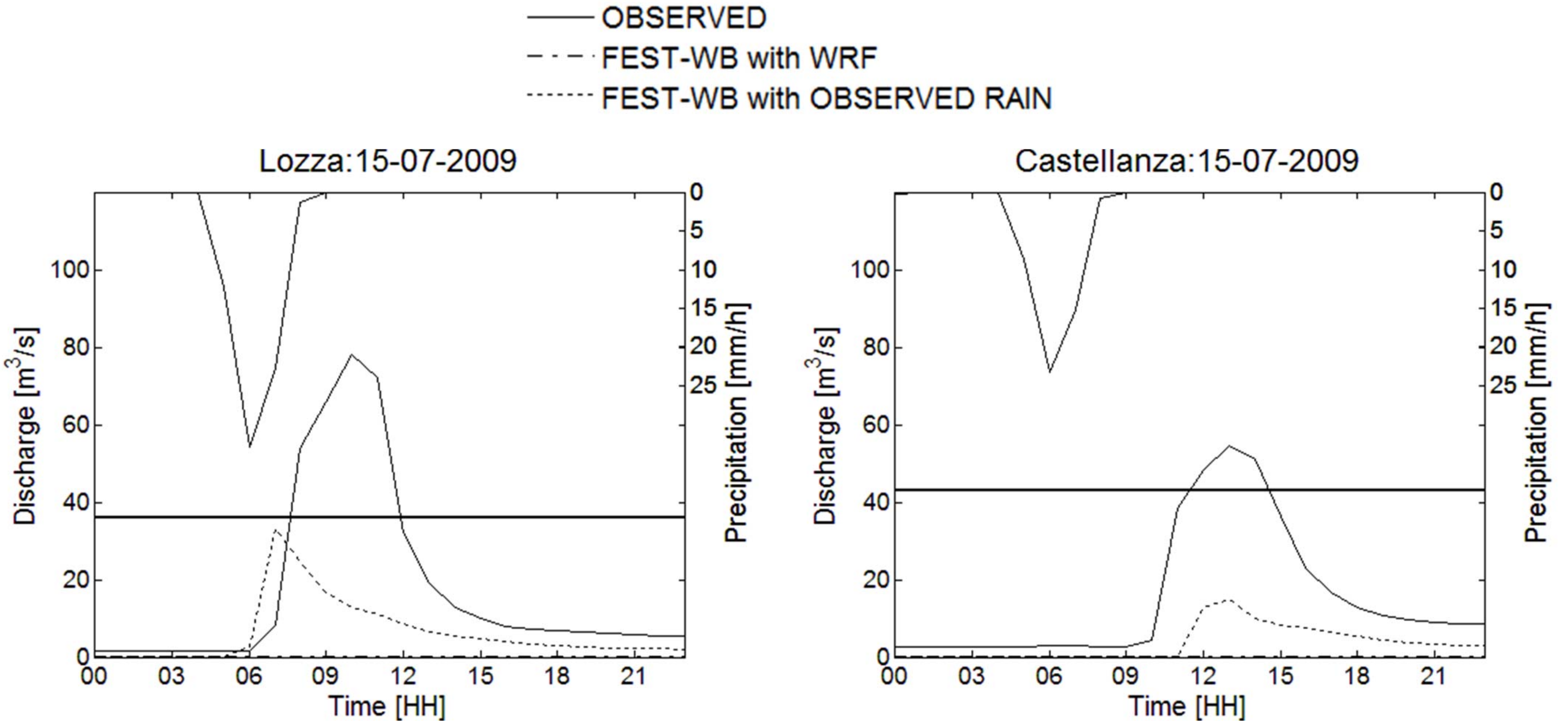
key

—— OBSERVED

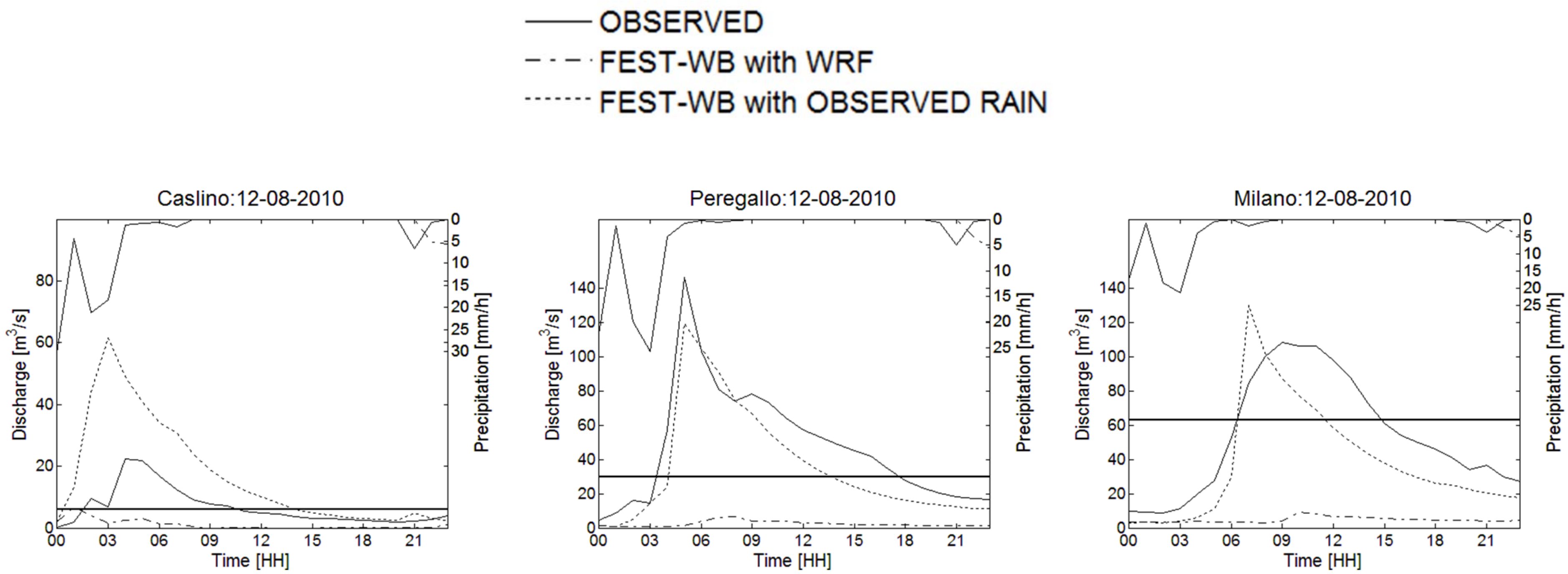
– · – FEST-WB with WRF

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

Olona basin: July 2009 convective event



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

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**

<table>
<tr><th colspan="2"></th><th colspan="2">OBSERVED EVENT</th></tr>
<tr><th colspan="2"></th><th>YES</th><th>NO</th></tr>
<tr><th rowspan="2">FORECASTED EVENT</th><th>YES</th><td>61</td><td>8</td></tr>
<tr><th>NO</th><td>76</td><td>180</td></tr>
</table>

Index	Value
POD	0.45
F	0.04
CSI	0.42
CPI	0.74

Conclusions and future developments

1) Despite structural measures, flood residual risk in Milan is still very high due to land use change in the past years that lead to an increase of flood frequency

2) A spatially distributed hydrological model can be effectively used to simulate flood events

3) When the hydrological model is coupled to weather forecast model, system performance decreases mainly due to systematic understimation of convective events

4) Future developments include the involvement of Ensemble Probabilistic weather forecast model to assess the degree of reliability of discharge predictions.

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

THANK YOU FOR YOUR ATTENTION