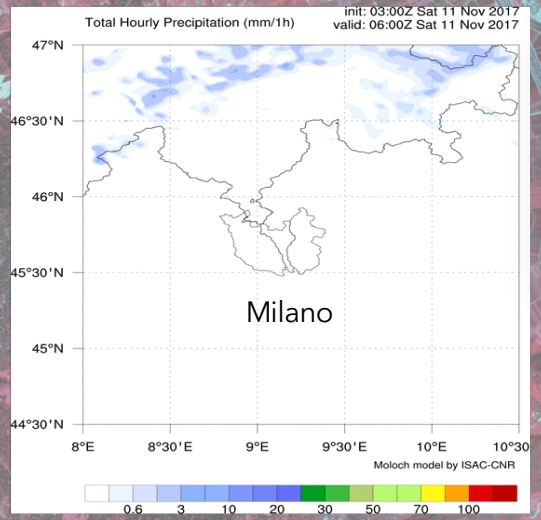
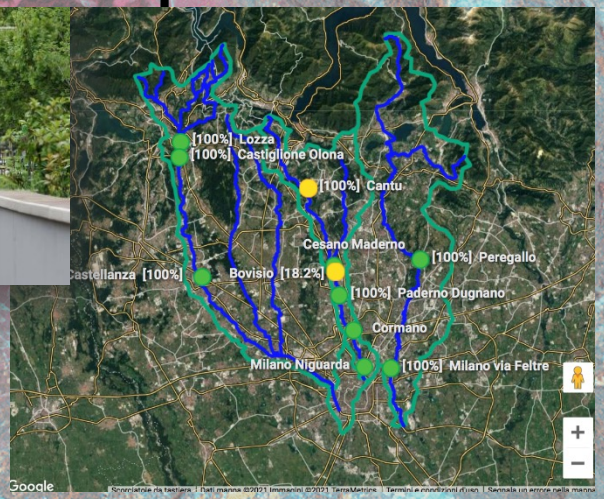
EUROGEO WORKSHOP 2023

Engineering solutions between structural and non-structural works for flood risk mitigation as adaptation measures to climate change





M.Mancini[1], G. Ravazzani[1], A. Ceppi[1] E. Gambini[1], G.Lombardi[2], S. Meucci[2] · Borgotti[3] , G. Galli [3]

1 Dica Politecnico di Milano Piazza L. da Vinci 32 20133 Milano (marco.mancini@polimi.it).
2 Monitoring and Modelling Hydrology (MMI. Srl) Via Ariberto 1 20123 Milano (s.meucci@mmidro,it)
3 Municipality of Bovisio Masciago .

BOLZANO 2-4 OCTOBER 2023

Warning System = Flood Forecast System + Preventive protection actions + Population Information

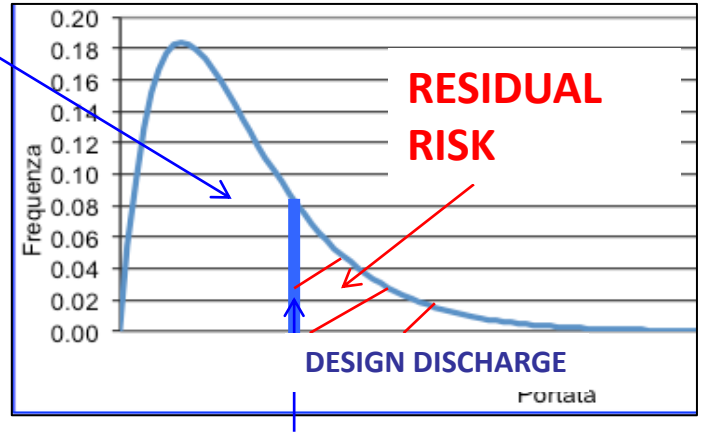
Flood risk management: a well known trade off between costs of hydraulic structures and damages reductions

Not to keep the water away from the people……but the people away from the water (Nemec, 1986)

Milano, July 2014

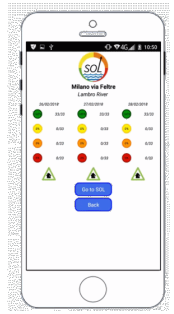
IXX, XX Century
Reducing flood Hazard (H)
STRUCTURAL MEASURES

MIN [Risk = E(damages) = H_i*E*V]



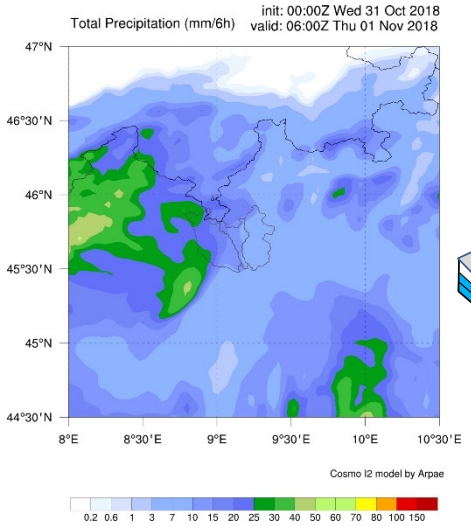
…increasing system resiliance (UN, SENDAY 2015 DEFINITIONs)

XXI Century: MANAGEMENT RESIDUAL RISK with warning system
NON STRUCTURAL MEASURES

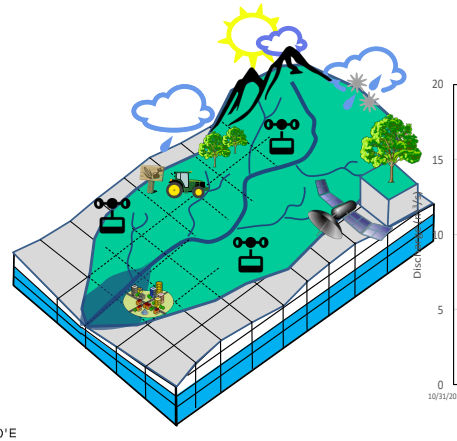


EUROGEO WORKSHOP 2023

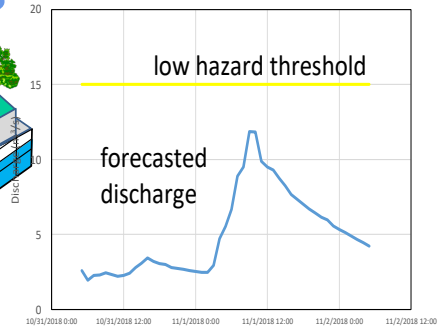
Observed precipitation
Precipitation forecast



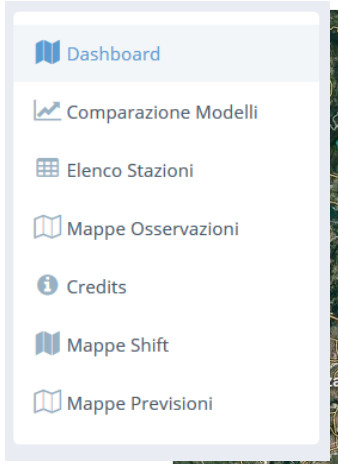
Hydrological model

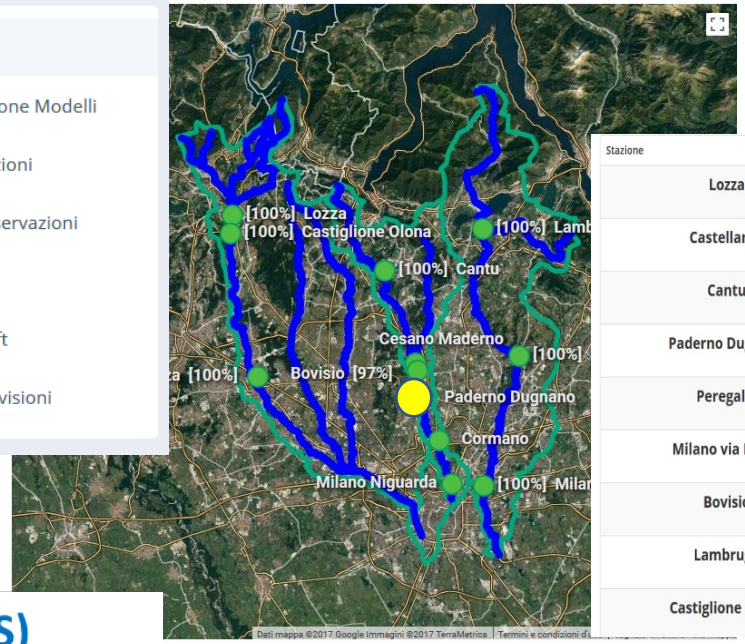


Real time Flood forecast



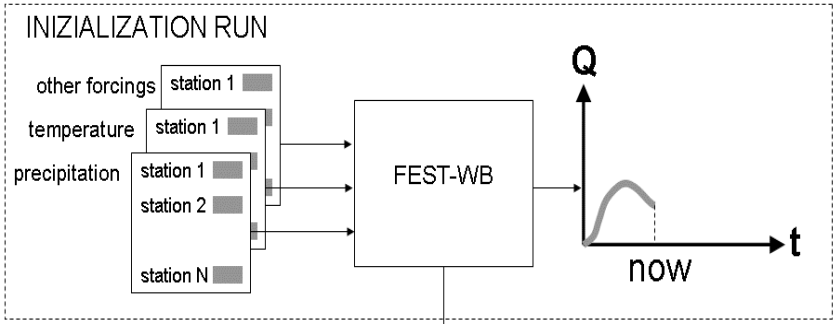
SOL FloWS Dashboard

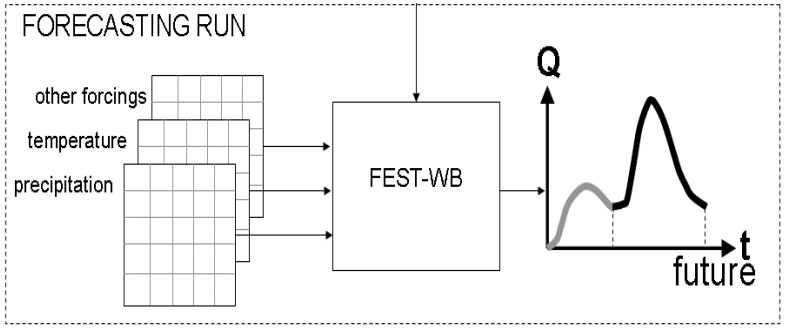




Stazione	Oggi	Domani	Dopodomani
Lozza			
Castellanza			
Cantu			
Paderno Dugnano			
Peregallo			
Milano via Feltre			
Bovisio			
Lambrugo			
Castiglione Olona			

Warning System for Flood Risk Mitigation of the Milano Area (SOL-FloWS)





Hydrometric warning thresholds

BOLZANO 2-4 OCTOBER 2023

EUROGEO WORKSHOP 2023

Major Floods and Minor flood events in Milan urban Area

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 €

15/05/2018

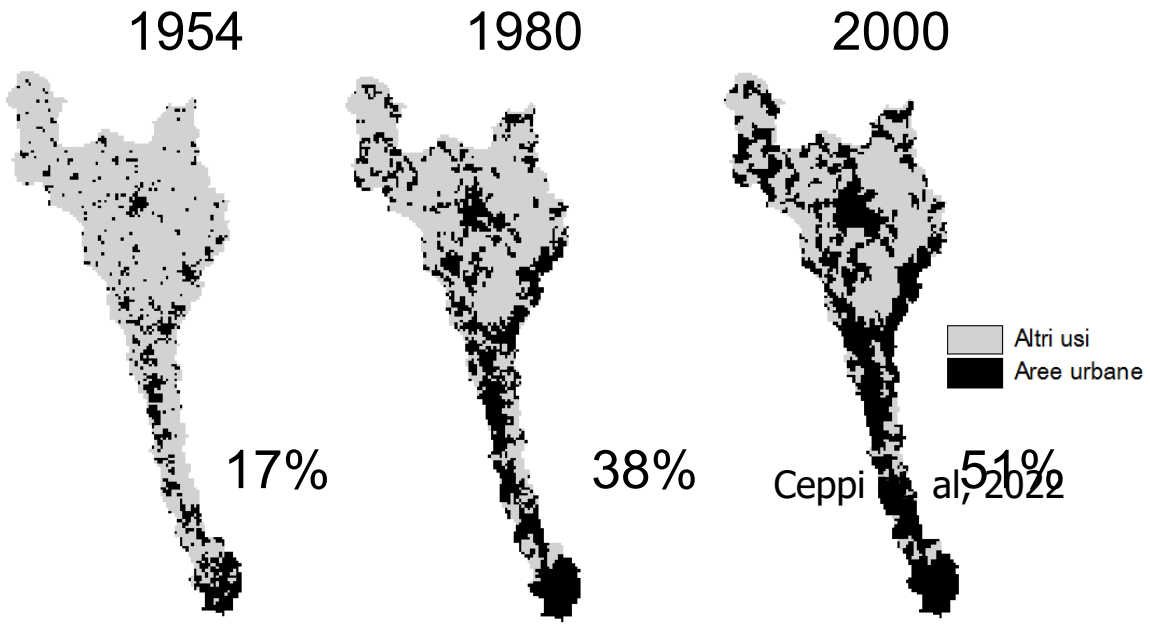
24/07/2020

21/09/2021

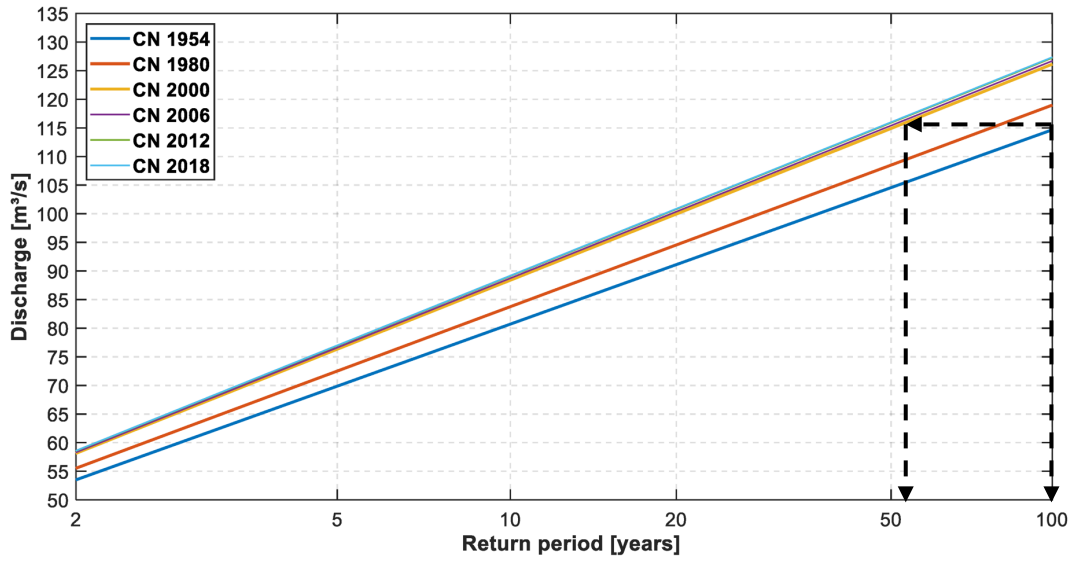
- Olona flood (Canegrate)

15/09/2023

- Seveso flood (Milan)

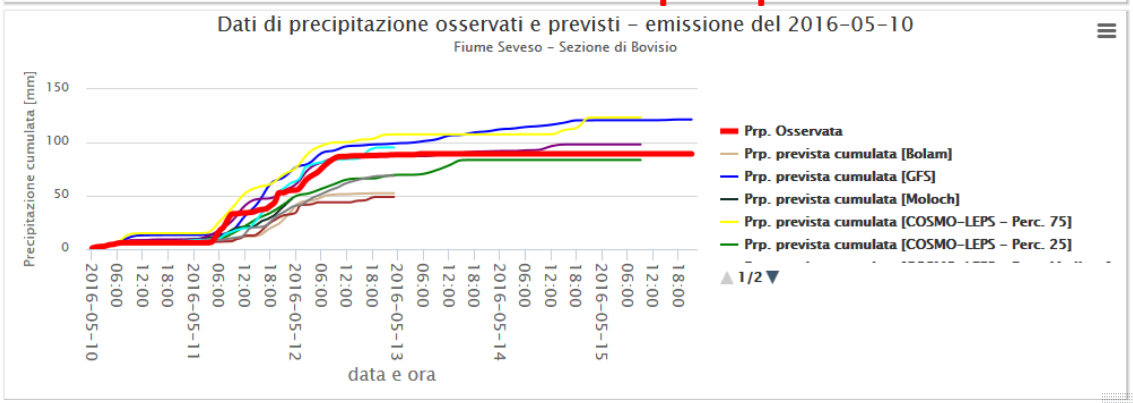


Ceppi et al., 2022

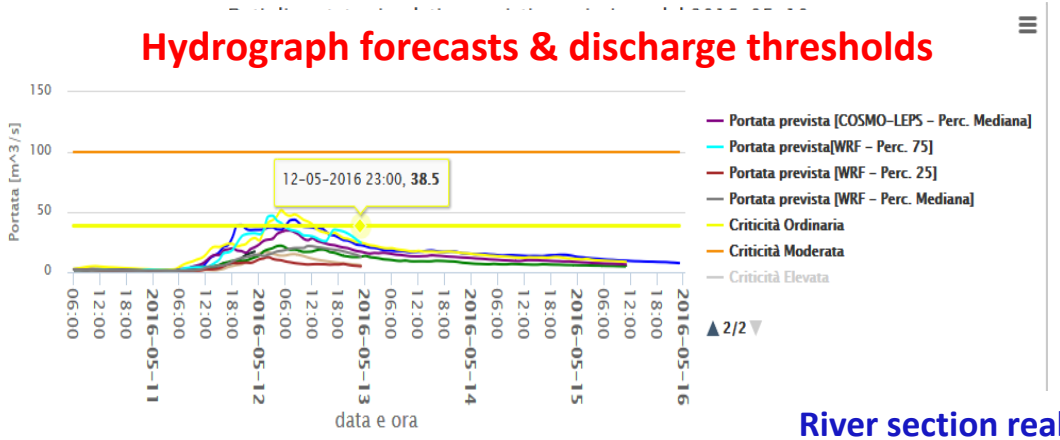


EUROGEO WORKSHOP 2023

Multi-model meteo forecast: precipitation

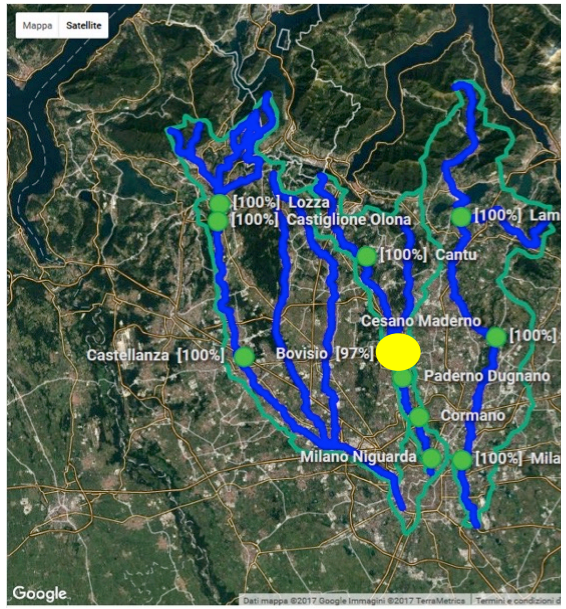


Hydrograph forecasts & discharge thresholds



SOL FloWS : Seveso Olona Lambro Food Warning System
Real time Flood Hydrograph Forecast and Observation

The North Milan basin 1400 km^2 https://www.sol.polimi.it/



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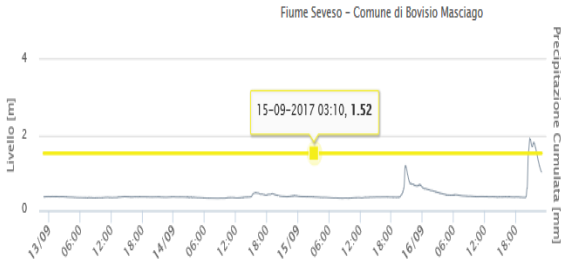
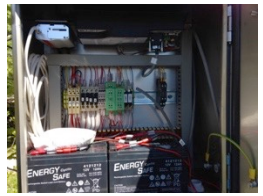
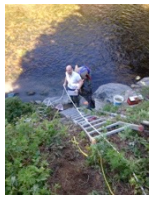
Peregallo			
Milano via Feltre			
Bovisio			
Lambrugo			
Castiglione Olona			

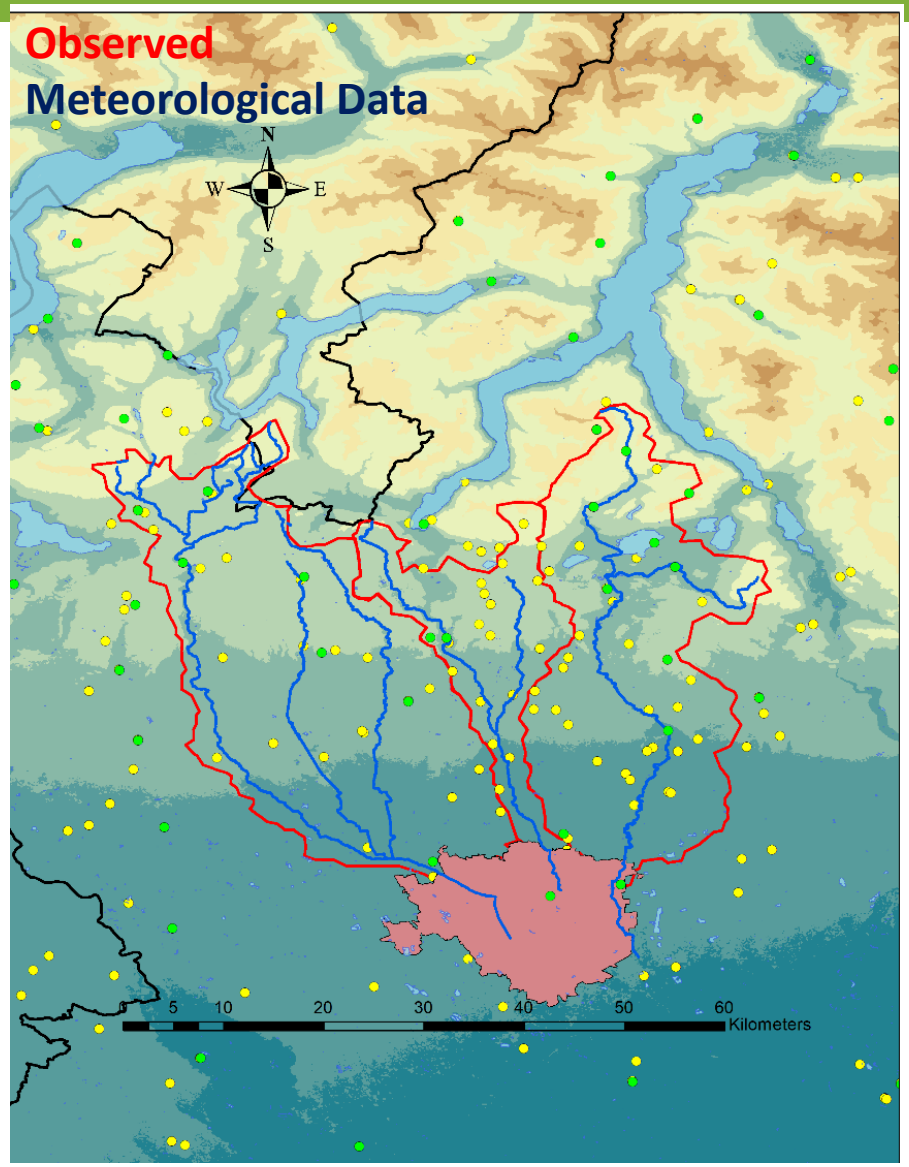
River section real time level /discharge monitoring







EUROGEO WORKSHOP 2023



Legend

- ARPA Lombardia Weather Stations
- Meteonetwork Weather Stations
- Main Rivers
- Lakes
- Milano City
- SOL River Basins
- Borders

DEM

<VALUE>

- 0-100
- 100-200
- 200-300
- 300-500
- 500-1000
- 1000-1500
- 1500-2000
- 2000-2500
- 2500-3000
- 3000-4000

Citizen-science association data

meteonetwork

Institutional data

ARPA LOMBARDIA
Agenzia Regionale per la Protezione dell'Ambiente

METEOROLOGICAL FORECAST DATA

GFS	50 km, Δt 3h, +144h
Bolam	8.3 km, Δt 1h, +72h
Moloch	1.25 km, Δt 1h, +45h

ISAC

Cosmo-2I	2.2 km, Δt 3h, +48h
Cosmo-5M	5 km, Δt 3h, +72h

arpae
agenzia prevenzione ambiente energia emilia-romagna

COSMO-LEPS	7 km, Δt 3h, +132h 20 ensemble

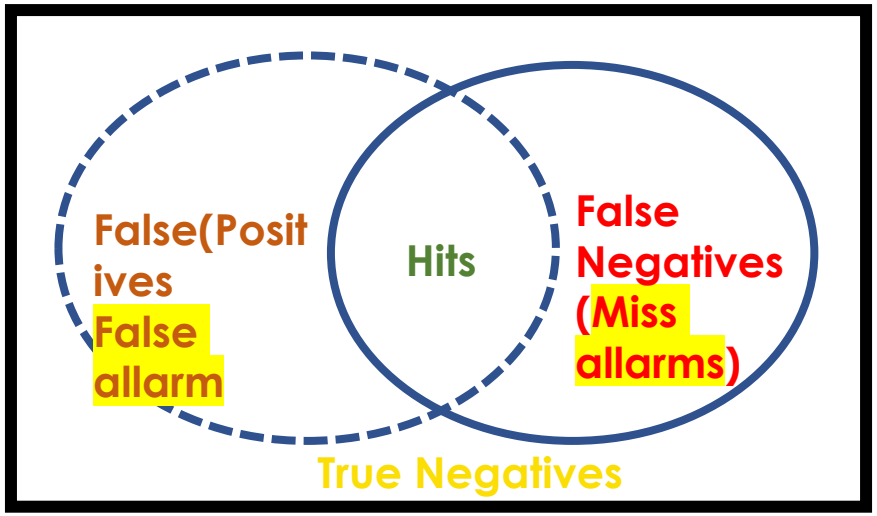
arpae
agenzia prevenzione ambiente energia emilia-romagna

WRF	5.5 km, Δt 1h, +72h 8 ensemble

EXPERT METEO
WEATHER & CLIMATE

EUROGEO WORKSHOP 2023

The FloWS -SOL performance (2019-2022) for events exceeding yellow discharge threshold



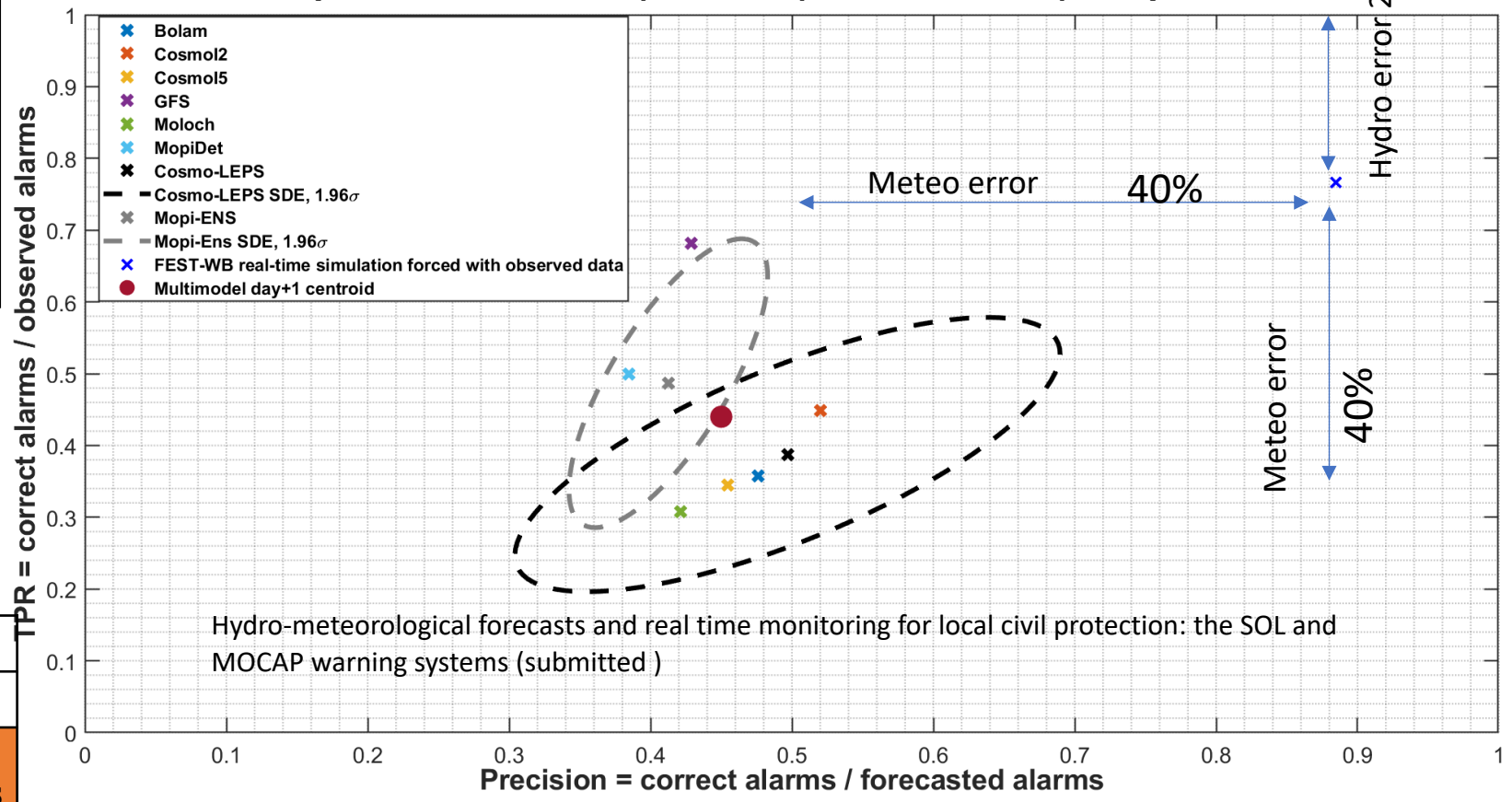
% Forecast correct alarm / observed alarm (True Positive Ratio)

$$TPR = \frac{Hits}{Hits + False\ Negatives}$$

$$Precision = \frac{Hits}{Hits + False\ Positives}$$

Exceeding of discharge treshold		Observed alarm	
		Yes	No
Predicted alarm	Yes	Hits	False Positives
	No	False Negatives	True Negatives

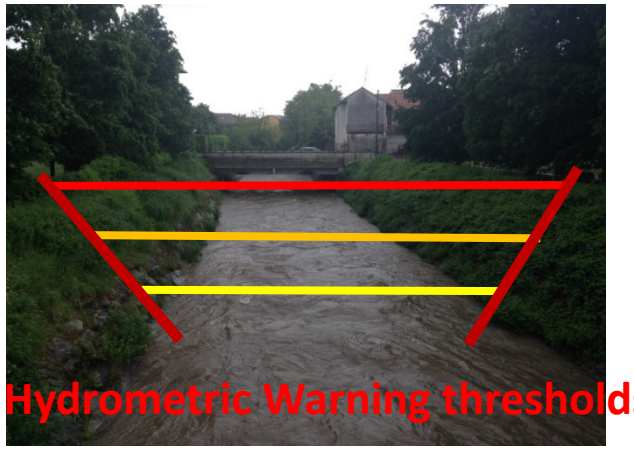
Multi-model scores for the day+1 forecast
(Precision-Recall plot or "performance plot")



Hydro-meteorological forecasts and real time monitoring for local civil protection: the SOL and MOCAP warning systems (submitted)

Do we prefer systems that minimize false (precision) or missed alarms (TPR) ?

The FloWS -SOL performance (2019-2022) for events exceeding yellow discharge threshold in one cross section (Seveso @ Bovisio Masciago)



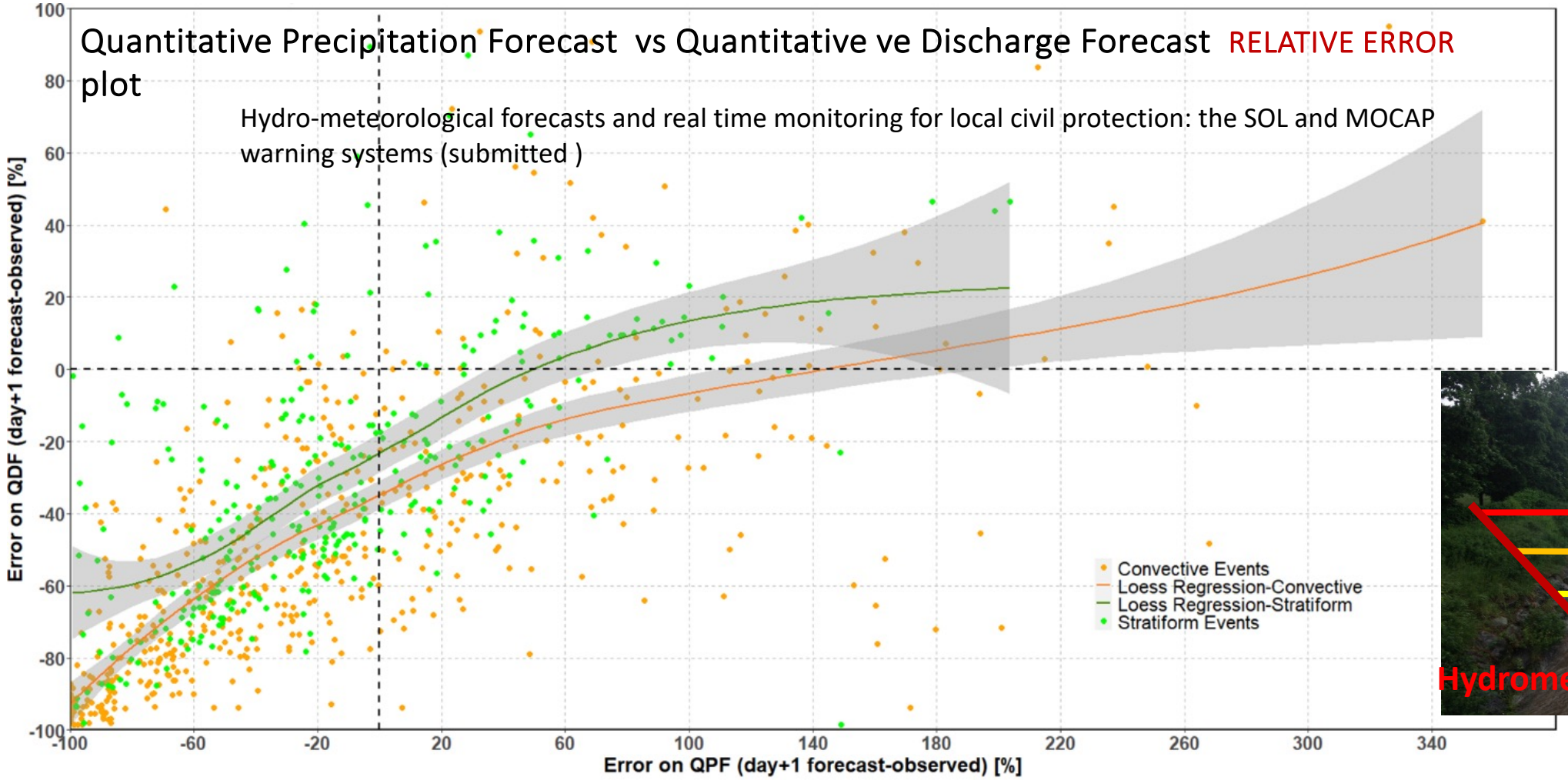
Observed rainfall &FEST-WB (2019-2022)

	FEST-WB
Hits	23
False alarms	3
Missed alarms	7
TPR	0.77
PPV	0.88

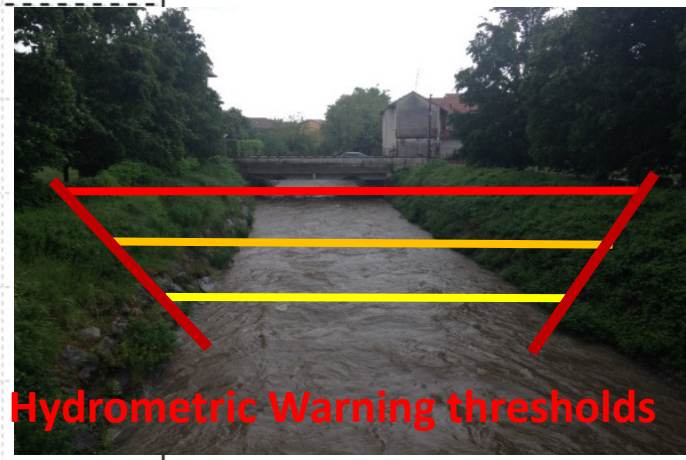
	Bolam	Cosmo-2I	Cosmo-5M	GFS	Moloch	MopiDet	Cosmo-LEPS median	Mopi-ENS median
Hits	10	13	10	15	8	15	11	15
False alarms	11	12	12	20	11	24	11	19
Missed alarms	18	16	19	7	18	15	16	14
TPR	0.36	0.45	0.34	0.68	0.31	0.50	0.39	0.52
PPV	0.48	0.52	0.45	0.43	0.42	0.38	0.48	0.40

Quantitative Precipitation Forecast vs Quantitative ve Discharge Forecast RELATIVE ERROR plot

Hydro-meteorological forecasts and real time monitoring for local civil protection: the SOL and MOCAP warning systems (submitted)



Seveso River
@Bovisio Masciago



QPF (Quantitative Precipitation Forecast) vs **QDF** (Quantitative discharge forecast) relative error evaluation for all the observed events exceeding the first warning threshold at the **day+1**, separating between **stratiform** and **convective** events.

Conclusion

Flood warning systems using Multi Model Meteo Forecast may be realized as non structural measure for flood damage reduction .
Meteo Model configurations that maximize the % of correct forecasted alarms respect to all observed allarm (TPR) have to be preffered

Structural hydraulic work design discharge may be reduced considering the cost benefit analysis supported also by early warning systems for residual risk management.

Smaller design discharge implies smaller structural works with higher social acceptance and smaller maintenance costs.

Came safely to Milan!

Thank you for your attention

POLITECNICO
MILANO 1863

The Real Time Hydrology group website, research team lead by Prof. Marco Mancini

The SOL System dashboard