The POLIMI forecasting chains for real time flood and drought predictions

A. Ceppi, G. Ravazzani, C. Corbari, M. Mancini

Vienna, 18 - 22 April 2016

Session NH1.6/AS1.4/HS4.9 - Coupled atmosphere-hydrological modeling for improved hydro-meteorological predictions
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?
<table>
<thead>
<tr>
<th>Model</th>
<th>Resolution</th>
<th>Forecast Horizon</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GFS</strong></td>
<td>50 km, Δt 3h</td>
<td>+144h</td>
<td>Deterministic models by ISAC-CNR</td>
</tr>
<tr>
<td><strong>Bolam</strong></td>
<td>11 km, Δt 1h</td>
<td>+72h</td>
<td></td>
</tr>
<tr>
<td><strong>Moloch</strong></td>
<td>1.5 km, Δt 1h</td>
<td>+45h</td>
<td></td>
</tr>
<tr>
<td><strong>COSMO-LEPS</strong></td>
<td>7 km, Δt 3h</td>
<td>+132h, 16 ensemble</td>
<td>Probabilistic model by ARPA Emilia-Romagna</td>
</tr>
<tr>
<td><strong>WRF</strong></td>
<td>1. 3 km, Δt 1h</td>
<td>+246h, Terraria company</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. 2.5 km, Δt 1h</td>
<td>+48h, University of Baleari Islands</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. 5.5 km, Δt 1h</td>
<td>+72h, 8 ensembles, by Epson Meteo Centre</td>
<td></td>
</tr>
</tbody>
</table>
The POLIMI forecasting chain for flood and drought predictions


- Mancini, 1990: PhD thesis
- 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

- Seveso-Olona-Lambro (SOL)
- Lake Idro, FILL
- Linate (PreGI)
- The Muzza basin, Po Valley (PREGI/SEGUICI)
- Borgo Incoronata, Puglia (PreGI)
The POLIMI forecasting chain for flood and drought predictions

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)**

Area (km²)
- Olona = 208
- Seveso = 207
- Lambro = 500
Total = 1300
The Milan urban basins: Seveso-Olona-Olmabro (SOL), recent floods

15/07/2009
• The Olona flood (Varese): 30 million €

18/09/2010
• The Seveso flood (Milan): 80 million €

08/07/2014
• The Seveso flood (Milan): 55 million €

15/11/2014
• The Lambro flood (Monza): 6 million €
Real time operative non-structural measures

Dashboard SOL: Seveso-Olona-Lambro
Dashboard SOL: Seveso-Olona-Lambro

Hydro-Meteo Forecasts based by GFS + FEST
Initialized on 2016-04-11

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

Discharge
Cumulated Precipitation
Temperature
Hydro-Meteo Forecasts based by BOLAM + FEST

Initialized on 2016-04-11

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

Dashboard SOL: Seveso-Olona-Lambro

The POLIMI forecasting chain for flood and drought predictions
Hydro-Meteo Forecasts based by Moloch + FEST

Initialized on 2016-04-11

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

Discharge
Cumulated Precipitation
Temperature
Hydro-Meteo Forecasts based by CLEPS + FEST

Initialized on 2016-04-11

Dashboard SOL: Seveso-Olona-Lambro

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

Discharge
Cumulated Precipitation
Temperature
Hydro-Meteo Forecasts based by **WRF + FEST**

Initialized on **2016-04-11**

- **Forecast horizon**: 48 hours
- **Spatial grid**: 5.5 km
- **8 ensembles**
- **Epson Meteo Centre**

**Discharge**

**Cumulated Precipitation**

**Temperature**
The Multi-Model approach

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

Tunnel (galleria degli agricoltori)

Gated spillway

Basin area: 1473 km²
Dashboard FILL: Lake regulations

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

COSMO-LEPS precipitation forecasts

FEST-WB simulations for lake level
Dashboard FILL: Lake regulations

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

Regolare 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.

<table>
<thead>
<tr>
<th>Valori apertura paratie:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>0.1</td>
</tr>
<tr>
<td>G2</td>
<td>0.1</td>
</tr>
<tr>
<td>G3</td>
<td>0.1</td>
</tr>
<tr>
<td>G4</td>
<td>0.1</td>
</tr>
<tr>
<td>G5</td>
<td>1.2</td>
</tr>
<tr>
<td>G6</td>
<td>0.3</td>
</tr>
<tr>
<td>G7</td>
<td>0.1</td>
</tr>
</tbody>
</table>

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

FEST-WB simulations for lake level

The POLIMI forecasting chain for flood and drought predictions
PREvision and Guide for Irrigation (PREGI): coupling meteorological forecasts and hydrological model for irrigation water needs

The POLIMI forecasting chain for flood and drought predictions

Satellite data (LST, albedo, NDVI)

Ground data meteorological

INIZIALIZATION RUN

other forcings
temperature
precipitation
station 1
station 1
station 2
station N

FEST-WB

SM
now

Soil moisture observations

FORECASTING RUN

other forcings
temperature
precipitation

FEST-WB

SM
future

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

North Italy

Surface irrigation

South Italy

Drip irrigation

Forecasted rainfall
Irrigation

Forecasted rainfall
Irrigation

Surface irrigation

Drip irrigation

percolation

The POLIMI forecasting chain for flood and drought predictions
To follow or not to follow the forecast system
Can we save irrigation water coupling meteorological forecasts and hydrological model?

The SEGUCICI Project

Smart technologies for water resources management for civil consumption and irrigation

Secugnago
San Rocco al Porto
Livraga

Soil Moisture [-]
Precipitation [mm]
Air Temperature [°C]
Forecasts based by **WRF & FEST-EWB**

The SEGUICI Project

![Graph showing cumulated precipitation and soil moisture over days from 20/06/2015 to 17/07/2015. The graph includes lines for soil moisture day +8, stress threshold, and precipitation day +8. The y-axis represents soil moisture [-] ranging from 0.20 to 0.36, and the x-axis represents days from 20/06/2015 to 17/07/2015. Cumulated precipitation [mm] is shown on the right y-axis, ranging from 0.0 to 50.0.]
Forecasts based by WRF & FEST-EWB

The POLIMI forecasting chain for flood and drought predictions
Forecasts based by **WRF & FEST-EWB**
The SEGUICI Project: SM performance evaluation

Smart technologies for water resources management for civil consumption and irrigation

Secugnago

Quality control during the 2015 growing season:
From 1 June to 30 September

Livraga

From (cyber-)space to ground: new technologies for smart farming, Submitted to Hydrology Research
The POLIMI forecasting chain for flood and drought predictions

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/m²]
Hydrological model output: Soil Moisture observations

Milano: golf course near Linate (Milan) airport

Current situation and forecasts of soil moisture
Hydrological model output:
Evapotranspiration, Land Surface Temperature observations

ET (mm/day)

1 June 2015

1 July 2015

1 August 2015

T (°C)
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 increased. 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 km² (flood events) and events with evapotranspiration rates of about 7-8 mm per day over areas of a few thousand of km² (drought events).
Thank you for your attention

alessandro.ceppi@polimi.it