A hydro-meteorological ensemble prediction system for real-time flood forecasting purposes in the Milano area

G. Ravazzani, A. Ceppi, M. Mancini

A. Amengual, R. Romero, V. Homar

European Geosciences Union
General Assembly 2015
Vienna | Austria | 12 – 17 April 2015

Flash floods, hydro-geomorphic response, forecasting and risk management
Objectives

Milan is a flood prone area that was frequently flooded in the last years.

Previous study showed that deterministic simulation may not properly forecast flood severity of convective events mainly due to difficulties in correct localizing rainfall peaks.

Explore different setups of ENSEMBLE simulation to detect what is the most reliable for real time flood forecasting of convective events in Milan.
Ensemble Prediction System for flood forecasting in Milan

Water courses network in Milan

River basin
- Ticino
- Olona
- Seveso
- Lambro
- Pusiano
- Villoresi
- Milano
- Naviglio Grande
- Naviglio Pavese
- Adda

Area (km²)
- Olona = 208
- Seveso = 207
- Lambro = 500
- Total = 1300

CSNO
Waterways
Lake
Milano City
River basin

0 10 20 30 Kilometers
Bypass channel (CSNO, acronym from Italian “Canale Scolmatore di Nord Ovest”).
Built from 1954 to 1980.
Discharge capacity 30 m$^3$/s
Land use change

<table>
<thead>
<tr>
<th>Year</th>
<th>Urban Area</th>
<th>Curve Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>1954</td>
<td>17%</td>
<td>74</td>
</tr>
<tr>
<td>1980</td>
<td>38%</td>
<td>77</td>
</tr>
<tr>
<td>2000</td>
<td>51%</td>
<td>80</td>
</tr>
</tbody>
</table>
Recent floods

Seveso flood, 18 September 2010

80 million Euro as total damage!

Seveso flood, 8 July 2014
Ensemble Prediction System for flood forecasting in Milan

Planned structural measure

Detention basin

Total volume: 3520000 m³

September 2010

- No detention basins
- With detention basins

Warning threshold

Discharge (m³/s)

October 2010

- No detention basins
- With detention basins

Warning threshold

Discharge (m³/s)
FEST-WB hydrological model

Meteorological forcings

Spatial interpolation: Thiessen, IDW

Snow Dynamics

Soil Parameters

Vegetation Parameters

Soil Moisture update

Percolation

Surface Runoff

Subsurface routing

ground water

Surface flow routing

Lakes and reservoires

Definition of river network

DEM


Ensemble Prediction System for flood forecasting in Milan
### Calibration of the FEST-WB model (2003-2010 events)

<table>
<thead>
<tr>
<th>Basin</th>
<th>Gauging Station</th>
<th>err $Q_{max} [%]$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
</tr>
<tr>
<td>Olona</td>
<td>Lozza</td>
<td>-50.7</td>
</tr>
<tr>
<td></td>
<td>Castellanza</td>
<td>-51.8</td>
</tr>
<tr>
<td>Seveso</td>
<td>Cantù</td>
<td>-65.5</td>
</tr>
<tr>
<td></td>
<td>Caslino</td>
<td>78.4</td>
</tr>
<tr>
<td>Lambro</td>
<td>Peregallo</td>
<td>-72.1</td>
</tr>
<tr>
<td></td>
<td>Milano</td>
<td>-74.8</td>
</tr>
</tbody>
</table>

#### Basin Stations and Events:

- **Castellanza: evento 2**
- **Cantu: evento 2**
- **Milano: evento 9**
Dynamical downscaling performed with WRF 3.4 with: 2.5 km grid spacing and 28 vertical levels.

IC: Data coming from the global ECMWF EPS, aiming at sampling the distribution of plausible atmospheric states. ECMWF-EPS generated by perturbing an analysis with the singular vector technique.

We generate a high-resolution EPS by selecting members exhibiting the most large spread to encompass better any possible issues of underdispersion.
**ENSEMBLE setup**

- **MUF (Multi Physics forecast 20 members)**: uncertainties in model physical parameterizations. Combinations of different planetary boundary layer (PBL) and moist microphysical (MP) parameterizations:
  - MP schemes: Lin, Eta (Ferrier), WRF single-moment 6-class (WSM6); Goddard; and New Thompson
  - PBL schemes: Yonsei University (YSU); 1.5-order Mellor-Yamada-Janjic (MYJ); Mellor-Yamada Nakanishi Niino (MYNN) level 2.5; and asymmetric convection model 2 (ACM2)

- **IC (20 members)**: uncertainties in the initial and lateral boundary conditions

- **LAF (lagged average forecast 12 members)**: Mimics ensemble systems, but at low computational cost. LAF ensembles reflect flow-dependent forecast errors
  LAF: Reference (unperturbed) global ECMWF forecasts at each lead-time
  Reference physical parameterizations for all the IC and LAF members: the WSM6 microphysical scheme and the MYJ PBL scheme.
Re-analysis of two major convective flood events

SEPTEMBER 2010

Precipitation 2010 (mm)
- 1 - 14
- 14 - 27
- 27 - 40
- 40 - 54
- 54 - 67
- 67 - 80
- 80 - 94
- 94 - 107
- 107 - 120
- 120 - 133

Ensemble Prediction System for flood forecasting in Milan
Re-analysis of two major convective flood events

JULY 2014

Seveso

Lambro

Olona

Precipitation 2014 (mm)
- 26 - 39
- 39 - 51
- 51 - 64
- 64 - 76
- 76 - 89
- 89 - 102
- 102 - 114
- 114 - 127
- 127 - 139
- 139 - 152
### SEPTEMBER 2010

Percentage of ensemble members exceeding threshold

<table>
<thead>
<tr>
<th>Exceeding Threshold</th>
<th>Seveso</th>
<th>Lambro</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cantu</td>
<td>Peregallo</td>
</tr>
<tr>
<td>9/17/2010 IC</td>
<td>20.0%</td>
<td>35.0%</td>
</tr>
<tr>
<td>Multiphysic_3h</td>
<td>50.0%</td>
<td>85.0%</td>
</tr>
<tr>
<td>Lagged</td>
<td>18.2%</td>
<td>54.5%</td>
</tr>
</tbody>
</table>

Multiphysic have the best performance, Initial Condition the worst.
In general IC and Multiphysic_1h have the best performance.

Multiphysic_1h is better than the Multiphysic_3h for the Seveso basin.

Multiphysic_3h is better than the Multiphysic_1h for the Lambro basin.
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) The multiphysics forecast gave better or equal performance to classical IC ensemble.

4) The LUF is a method that requires far less resources than a real ensemble system but it proved to give not so bad results.

5) Future developments involve the analysis of more events in order to confirm the good performance achieved by the MUF and to detect if there are some physical schemes more capable than the others in simulating convective events in Milan area.

THANK YOU FOR YOUR ATTENTION