Flash flood early warning using ensemble weather forecasts

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Cagliari, 27/05/2010

Is there a way to provide early warning for flash floods?

"Early": 12hrs-several days before?

Note: presented work here, is work in progress..

European Commission
Joint Research Centre
Institute for Environment and Sustainability

EFAS
European Flood Alert System

Wednesday 26th of May 2010

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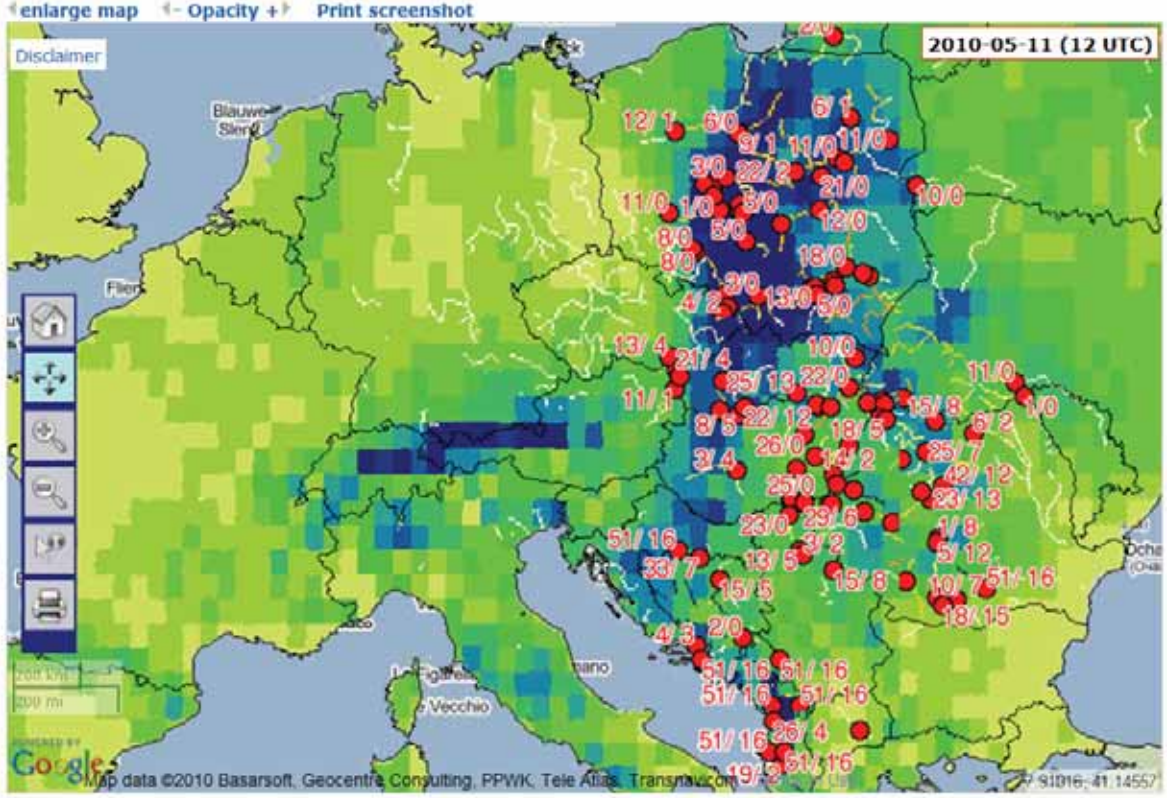
EFAS forecasting

EFAS forecasts available from **2009-01-01** to **2010-05-26 (00 UTC)**

enlarge map | - Opacity + | Print screenshot



Select layers

Select the date

2010-05-11 12

Background layers

- [x] Country Borders
- [ ] Urban Areas
- [ ] Major Rivers
- [x] Google background

General layers

- [x] Reporting Points High
- [ ] Reporting Points Medium
- [x] Flood Probability > 48h
- [x] Flood Probability < 48h
- [ ] Real-time hydrographs

Expert layers

- [ ] Combined Det. High Alert
- [ ] Combined Det. Severe Alert
- [ ] No. EPS Above Severe
- [ ] No. EPS Above High
- [ ] No. COSMO Above Severe
- [ ] No. COSMO Above High
- [ ] Det. ECMWF

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European Flood Alert System

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2010 from the 18th May onwards

Read More

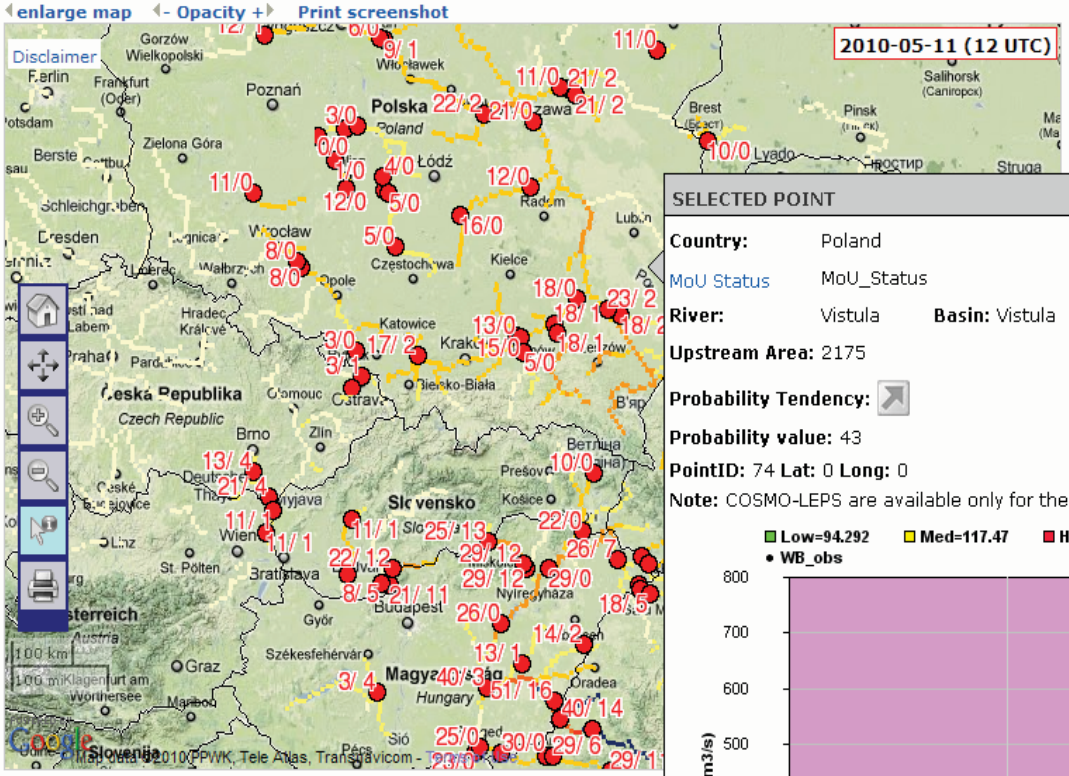
EFAS forecasts persistently a considerable probability of flooding for

RO – Jiu river basin

EFAS forecasting

EFAS forecasts available from **2009-01-01** to **2010-05-17 (12 UTC)**

enlarge map - Opacity + Print screenshot



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Warnings sent out to MS authorities and MIC on 12 May

SELECTED POINT

Country: Poland

MoU Status MoU_Status

River: Vistula **Basin:** Vistula

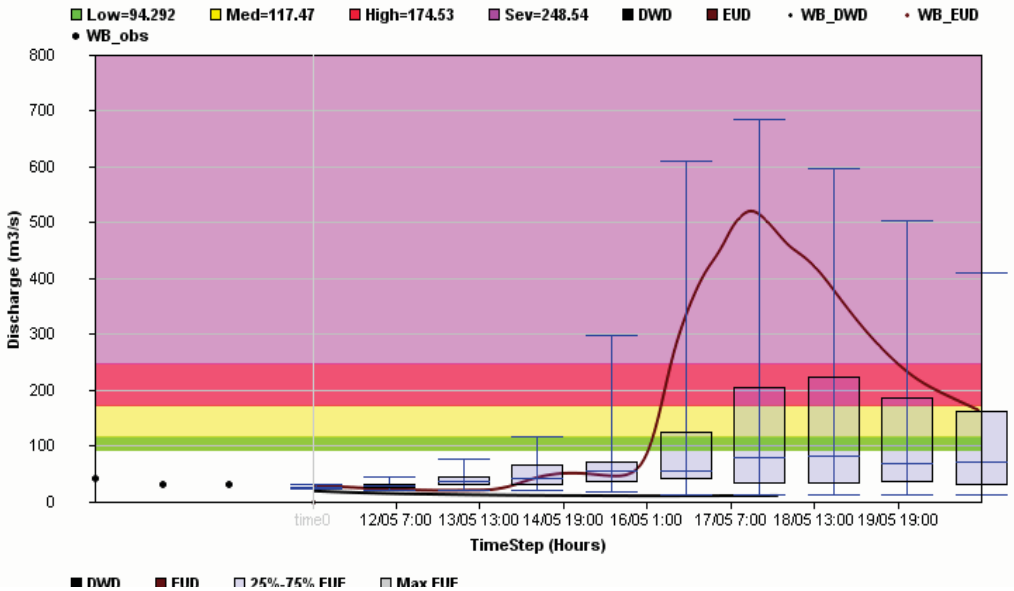
Upstream Area: 2175

Probability Tendency:

Probability value: 43

PointID: 74 **Lat:** 0 **Long:** 0

Note: COSMO-LEPS are available only for the 12:00 forecast



EFAS Forecasting

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SELECTED POINT

EUE > HAL

Forecast Day	8	9	10	11	12	13	14	15	16	17	18	19	20
2010050800													
2010050812									1	1			
2010050900											1		
2010050912											1		
2010051000											1	5	
2010051012											6	8	
2010051100											1	10	16
2010051112											3	16	21

EUE > SAL

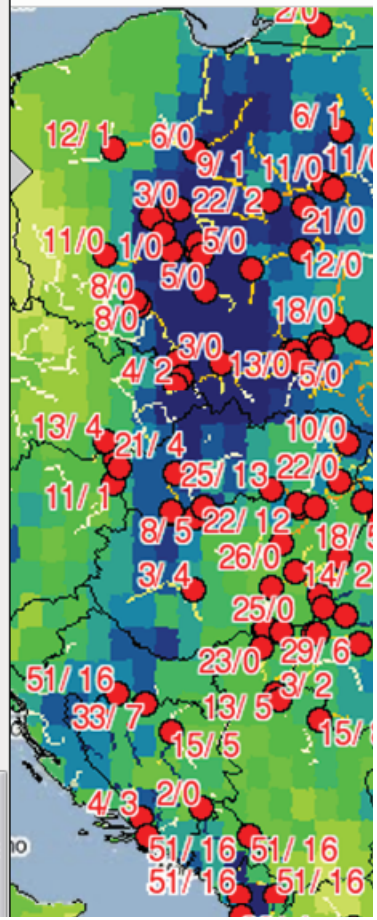
Forecast Day	8	9	10	11	12	13	14	15	16	17	18	19	20
2010050800													
2010050812									1				
2010050900													
2010050912													
2010051000												2	
2010051012											2	4	
2010051100												2	9
2010051112											1	8	15

COS > HAL

Example:

Vistula at Warsaw (PL)

Peristent forecasts from 10 May 00:00 onwards



Aim of flash-flood research

- Develop, test & evaluate a nested approach:
  - From EFAS pan-European 5km
  - Trigger 1km regional ‘EFAS’ forecasts
  - Further work by local institutes with detailed models, radar and gauge data

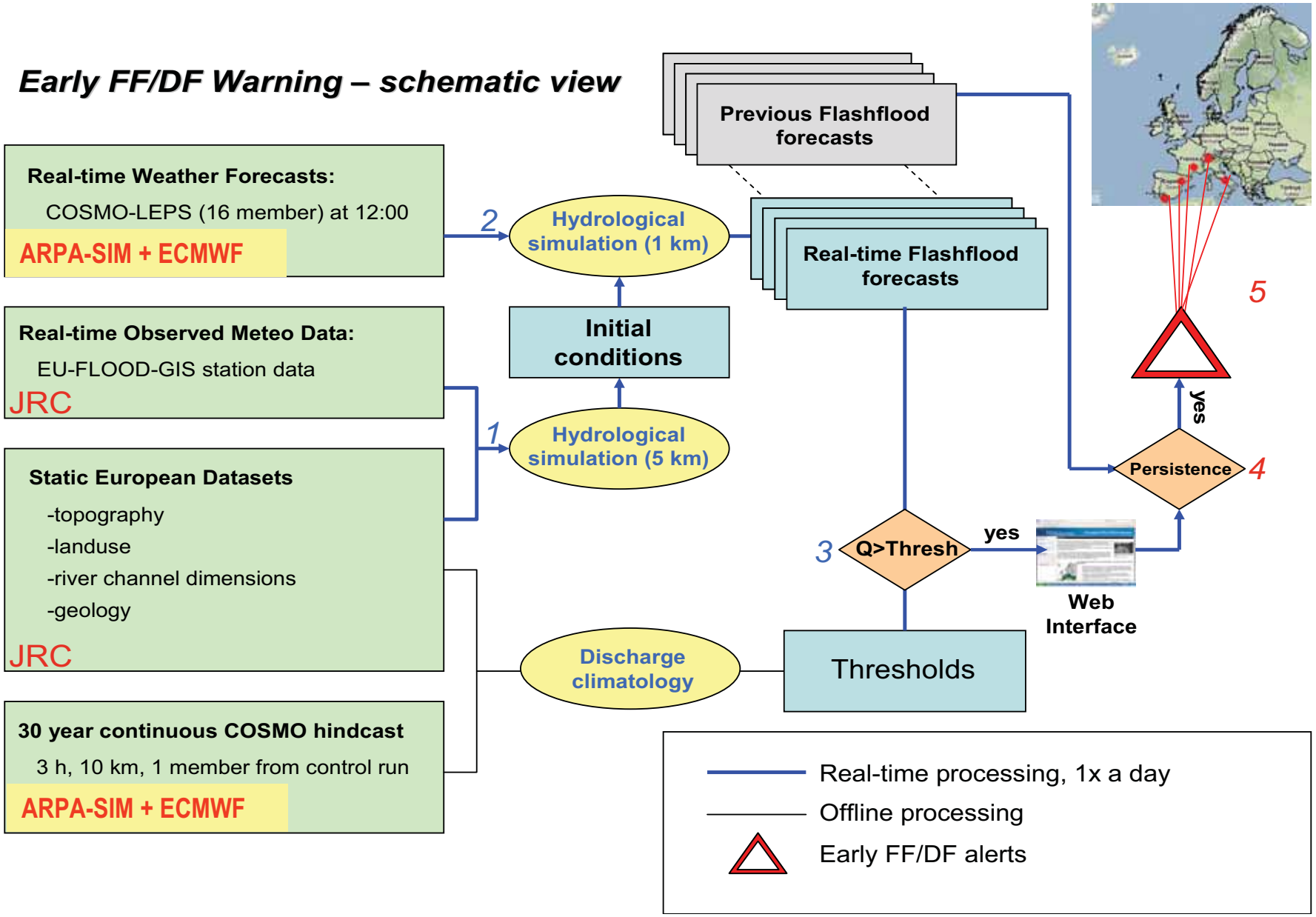
IMPRINTS Competitive Project

IMPRINTS: IMproving Preparedness and RIsk maNagemenT for flash floods and debriS flow events

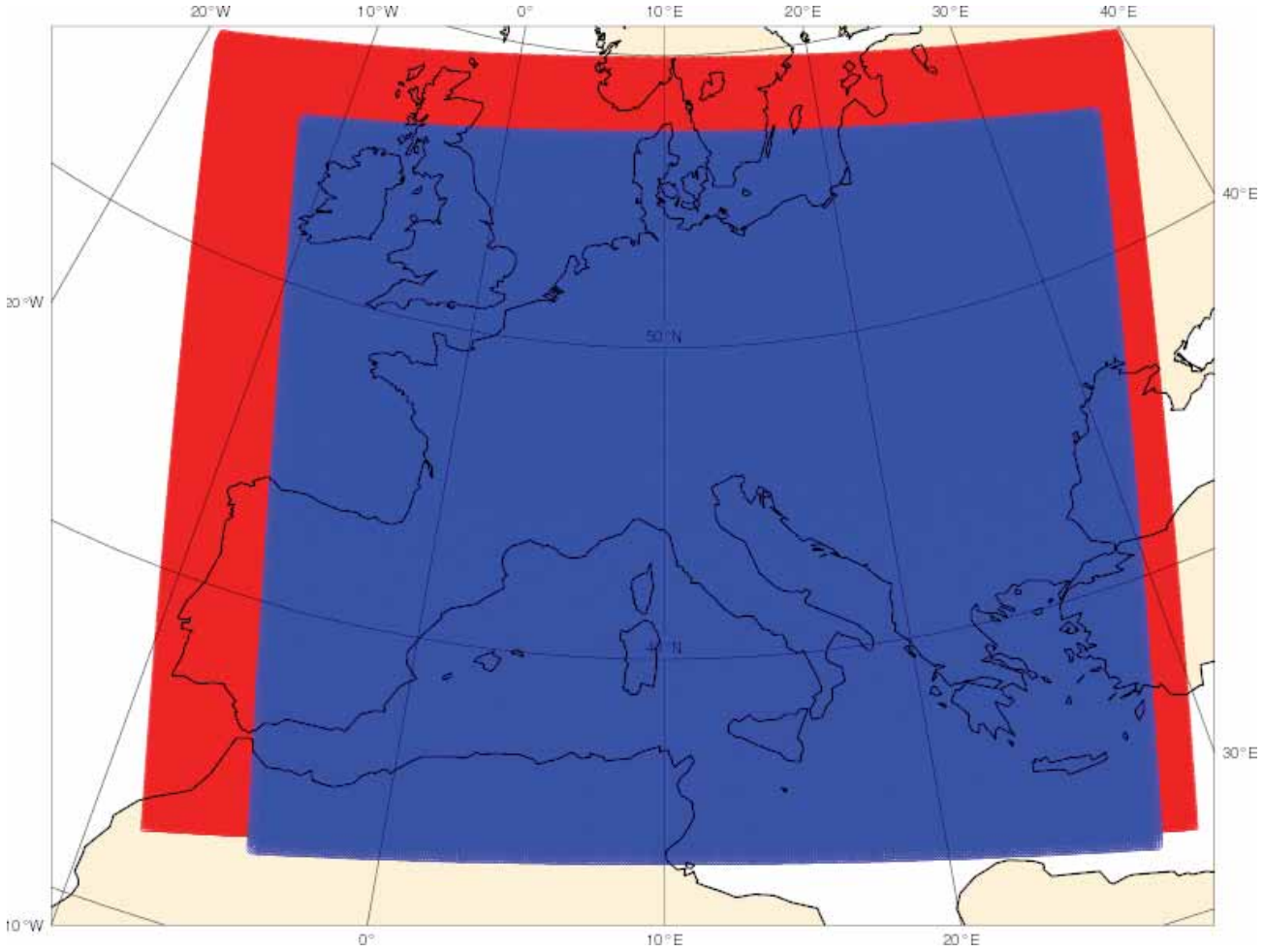
- EC FP7 Project
- 18 Partner Institutes
- Duration: 42 months (JRC – 24 months)

The aim or ultimate objective of IMPRINTS is to contribute to the reduction of loss of life and economic damage through the improvement of the preparedness and the operational risk management of flash flood and debris flow generating events, as well as contributing to sustainable development through reducing damages to the environment.

Flash Flood Warning – schematic view



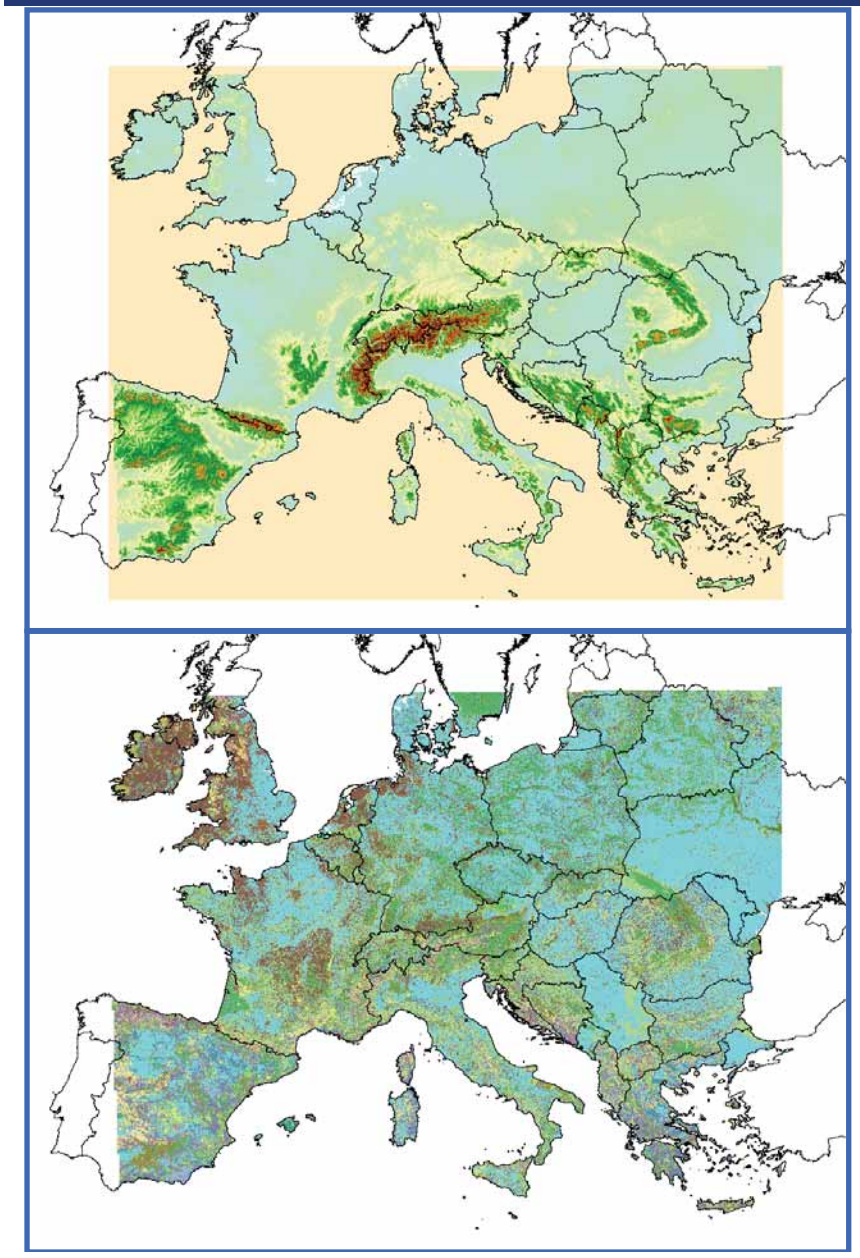
COSMO-LEPS: Limited Area Ensemble Prediction System (ARPA-SIM Bologna)



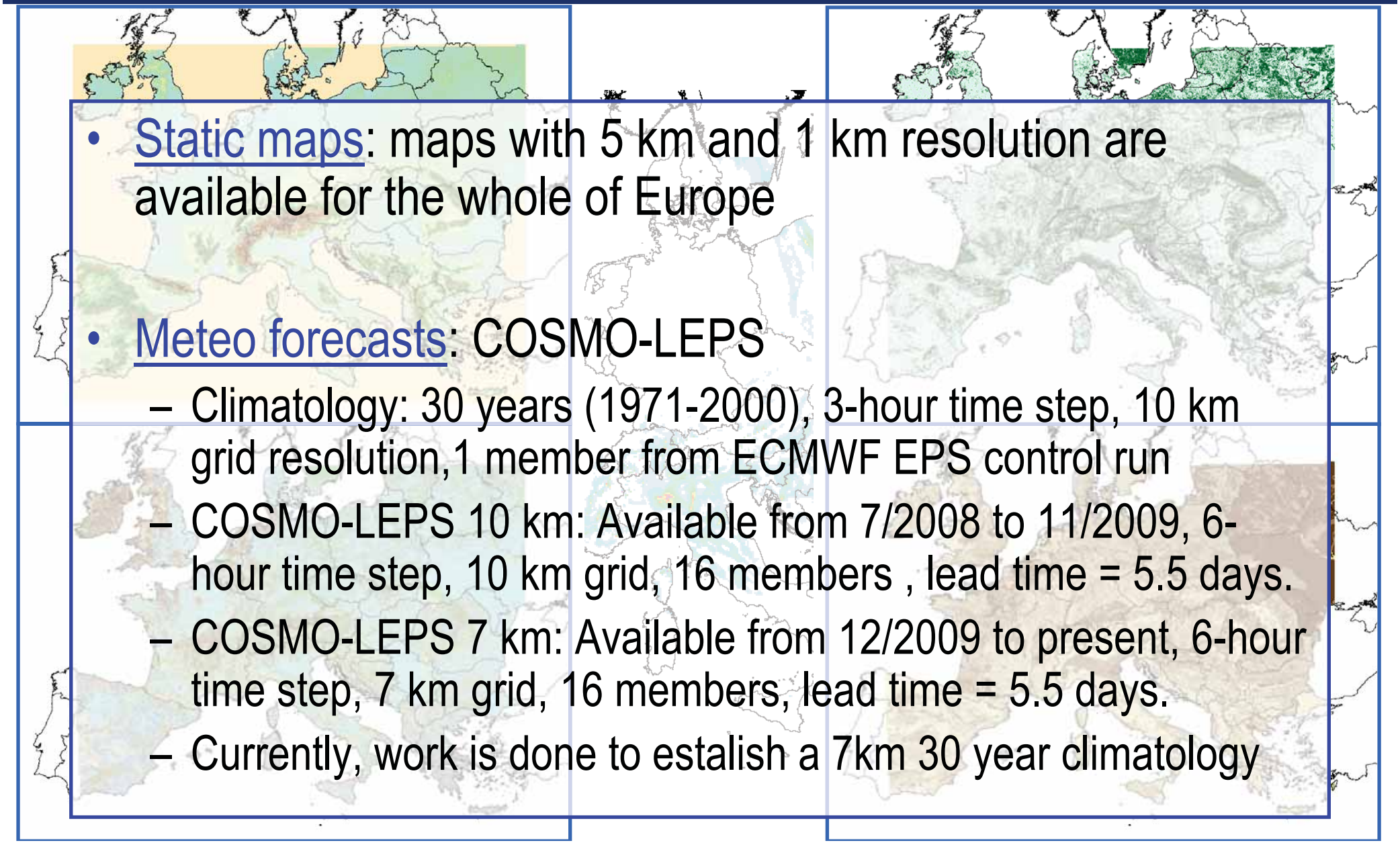
MAIN FEATURES:

- initial time: 12 UTC (i.e. once a day);
- COSMO-LEPS configuration
  - 16 members (selected from ECMWF-EPS, at 32km res.);
  - hor. res. = 7 km (red) (10 km before 2009, blue)
  - 32 vertical levels;
  - forecast length: 132h (5.5 days);
  - archived variables: up to +132h, every 3h;
  - output fields archived at ECMWF;
- **Developed by ARPA-SIM (Bologna)**
- **Run at ECMWF**

Data for hydrological simulation



Data for hydrological simulation



- Static maps: maps with 5 km and 1 km resolution are available for the whole of Europe

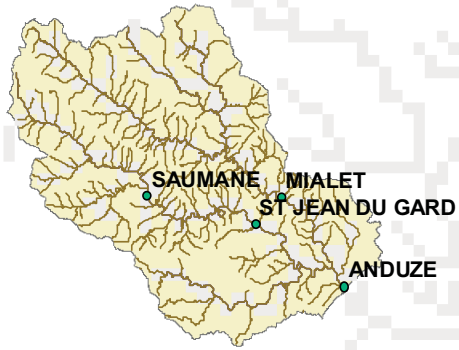
- Meteo forecasts: COSMO-LEPS
  - Climatology: 30 years (1971-2000), 3-hour time step, 10 km grid resolution,1 member from ECMWF EPS control run
  - COSMO-LEPS 10 km: Available from 7/2008 to 11/2009, 6-hour time step, 10 km grid, 16 members , lead time = 5.5 days.
  - COSMO-LEPS 7 km: Available from 12/2009 to present, 6-hour time step, 7 km grid, 16 members, lead time = 5.5 days.
  - Currently, work is done to estalish a 7km 30 year climatology

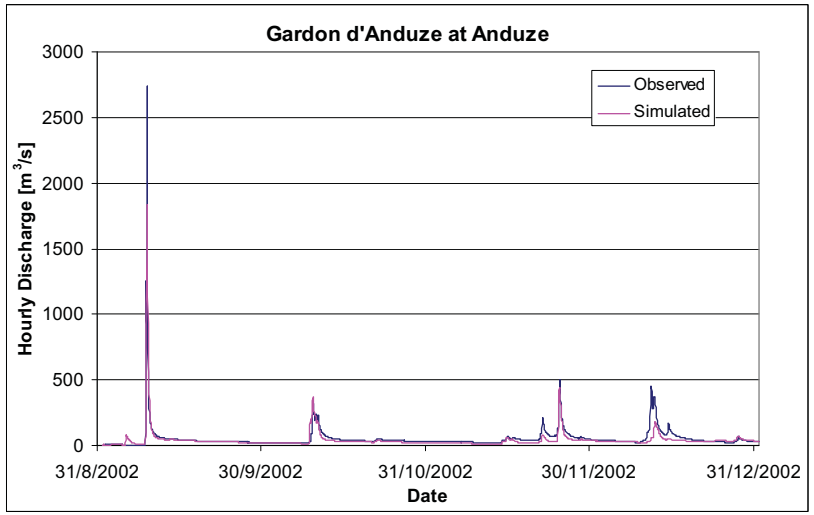
Case study – Gardon d'Anduze

Location: Gard region (France)

Area: 550 km^2 at Anduze

Considered catchment area:
1850 km^2





Calibration: Sep to Dec 2002 – 4 months of hourly precipitation (interpolated from raingauges) and discharge measurements at Anduze

Sub-catchment analysis

- Activate a regional flash flood forecast, based on a computationally light indicator

Research issues:

1. Which automatic rule/indicator is useful to activate the 1 km regional hydrological simulation/forecast
2. Is there an influence of initial conditions (soil moisture, snow, groundwater, initial discharge)

Rule to activate the 1 km simulation (1)

Two options are tested:

1. Indication from the 5 km hydrological simulation
2. Measure the severity of accumulated upstream precipitation

A sub-catchment hydrological analysis is activated for a certain 1x1 km^2 pixel when:

1. Positive indication from the rule above;
2. Catchment area < 5000 km^2

The Index method

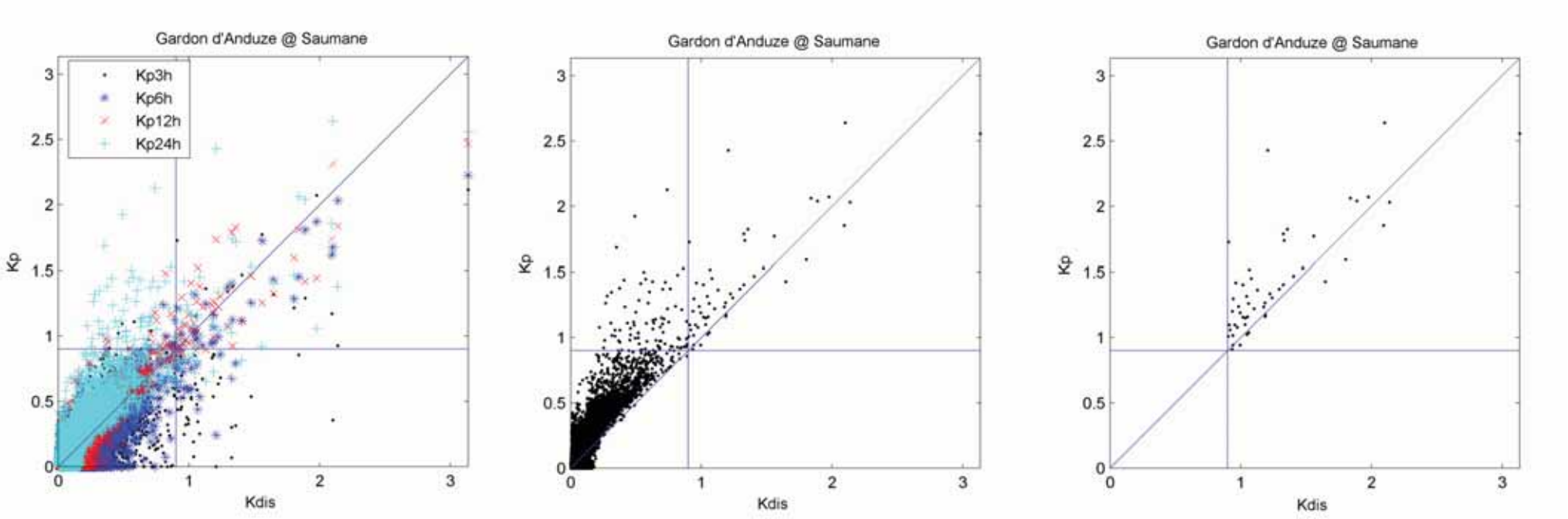
For a generic variable x_i (prcp, discharge, etc) at a certain time step *i*, let's calculate a normalized value, by dividing it by the corresponding mean of the annual maxima $E(x_{max,year})$:

$$Kx_i = \frac{x_i}{E(x_{\max,year})}$$

The normalized coefficient *Kx* has some advantages:

- It's a continuous measure of the severity of discharges (and other variables)
- Can be used to compare different variables together (e.g, discharge vs. prcp)
- It's not affected by bias in QPF (useful for comparing forecasts vs. observations)
- Can be easily linked to return periods

Precipitation anomaly (Kp) is a good indicator of discharge anomaly (Kdis)



- Kp_{max} = maximum index of cumulated upstream precipitation for durations 3, 6, 12, 24 hours
- $Kp_{max,1km}$ is a better predictor of $Kdis_{1km}$ for severe events

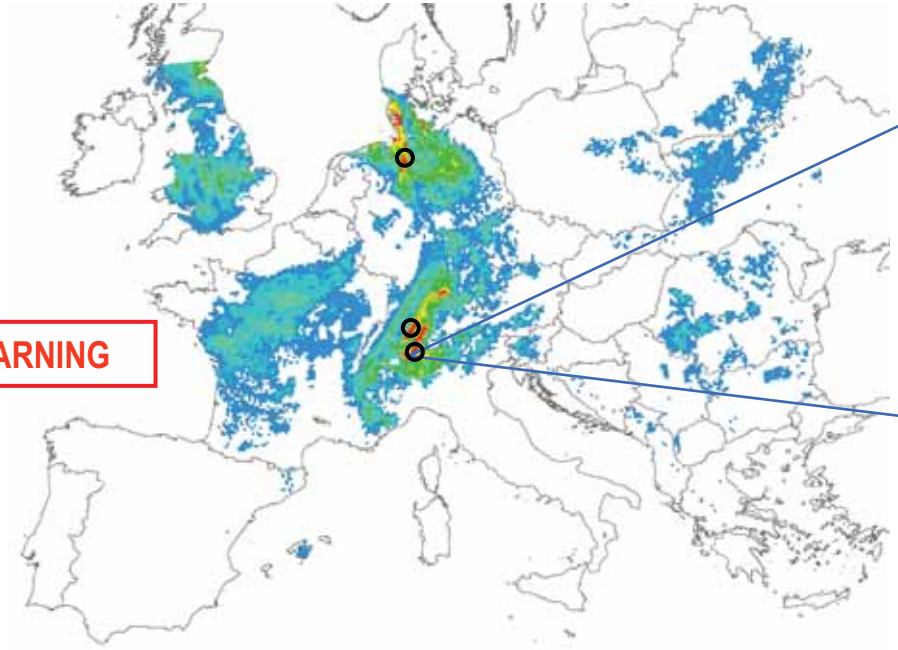
Rule to activate the 1 km simulation (2)

Advantages of the precipitation index K_{pr}:

- No need to run 5km hydrological simulations
- Few space required on disk
- It uses a more accurate (1 km) river network

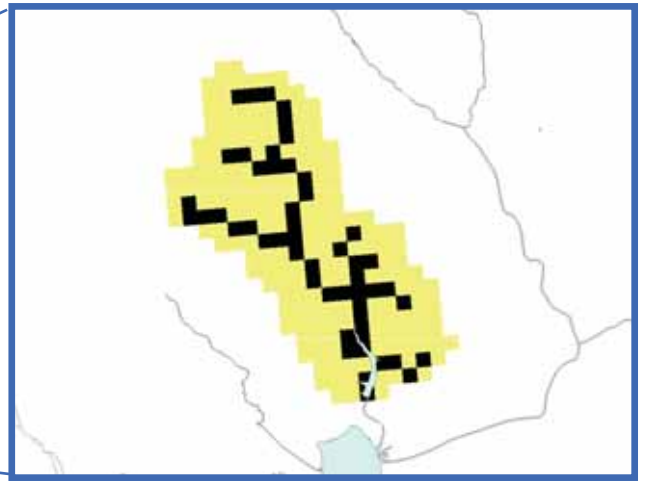
Flash Flood Warning – schematic view

PRECIPITATION-BASED INDICATOR (COSMO-LEPS)

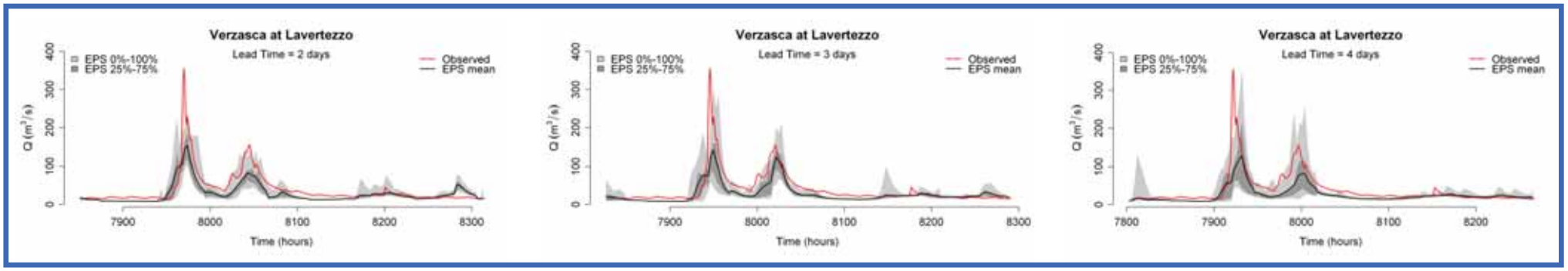


= WARNING

HYDROLOGICAL SIMULATION (CATCHMENT SCALE)



THRESHOLD EXCEEDANCE ANALYSIS + PERSISTENCE



Chain of flash-flood forecasting

- EFAS pan-European 5km water balance
  - Provides initial conditions (soil moisture, snow pack, discharge)
    - Uses 100m subgrid information on elevation & landuse
- Rainfall analysis of COSMO-LEPS at 7-10 km
  - Normalise to locate areas of extreme rainfall forecasted
- In those windows, run ‘EFAS’ at 1km, driven by COSMO-LEPS 7-10 km to provide first estimate/forecast of flash flood
  - Main advantage: more accurate representation of river network
- Further work by local institutes with detailed models, radar and gauge data

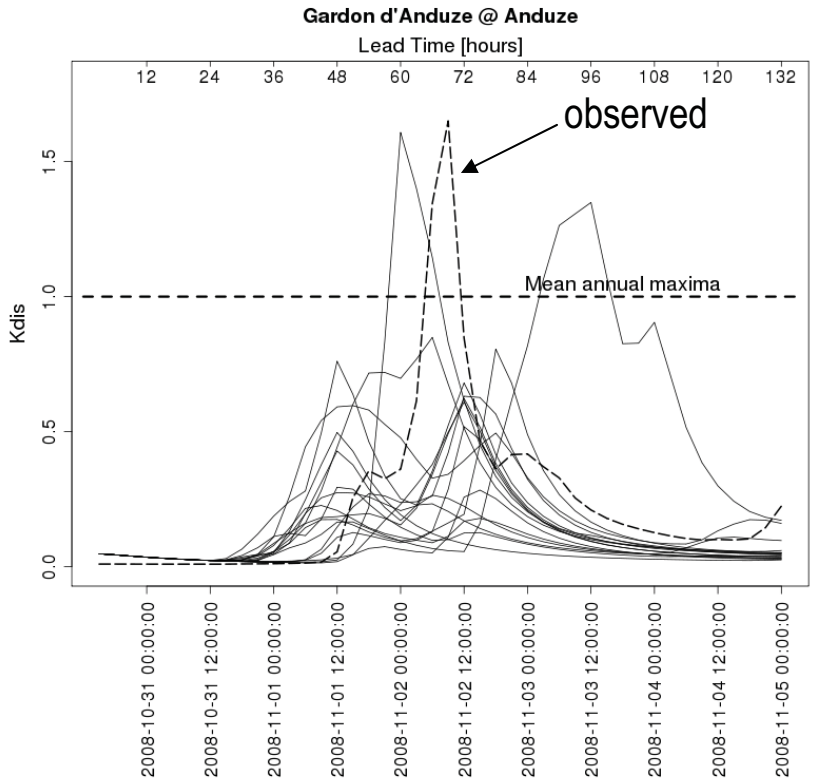
Flash flood forecast: first results

Gardon d'Anduze

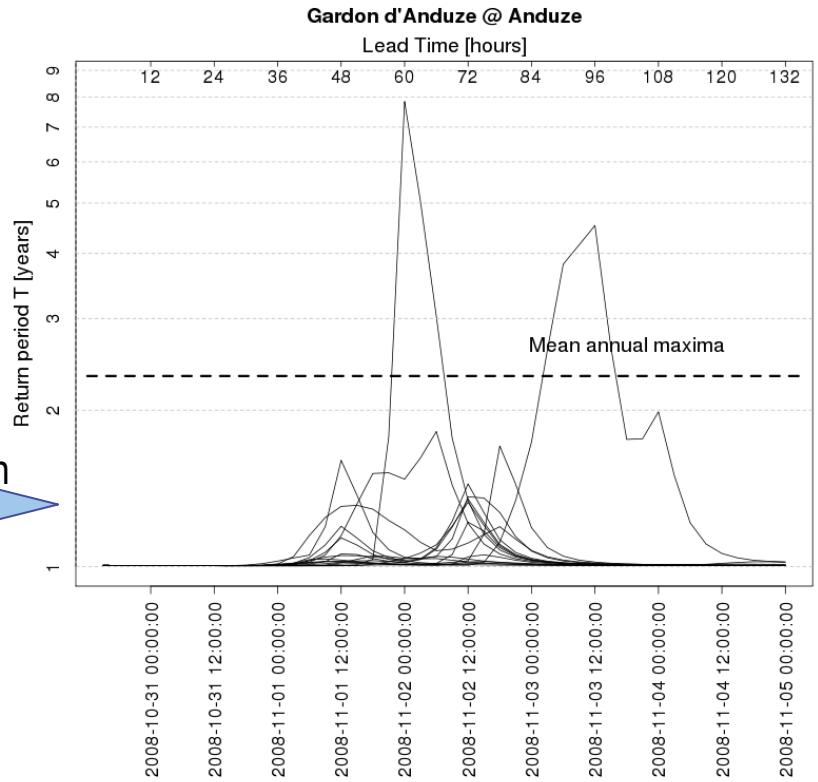
Nov 2nd, 2008

COSMO-LEPS 16 members

LISFLOOD - 1 km, 3 hours



Gumbel distribution



Persistence of forecast

		29/10/2008		30/10/2008		31/10/2008		1/11/2008		2/11/2008		3/11/2008	
		0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24	0-12	12-24
FORECAST DAY	28/10/2008	0%	0%	0%	0%	0%	0%	6%	6%	6%	6%		
	29/10/2008			0%	0%	0%	0%	13%	19%	19%	0%	0%	0%
	30/10/2008					0%	0%	0%	6%	6%	0%	6%	6%
	31/10/2008							0%	0%	13%	13%	0%	0%
	1/11/2008									0%	13%	0%	0%

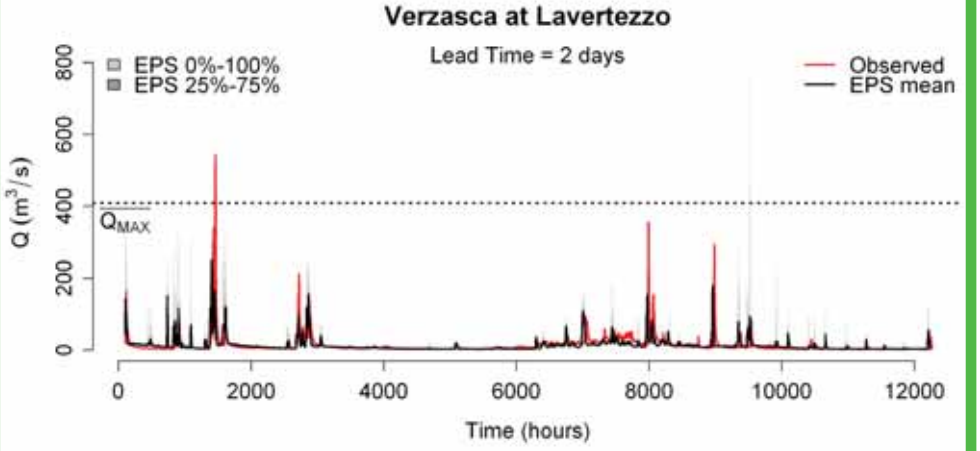
Observed threshold exceedance

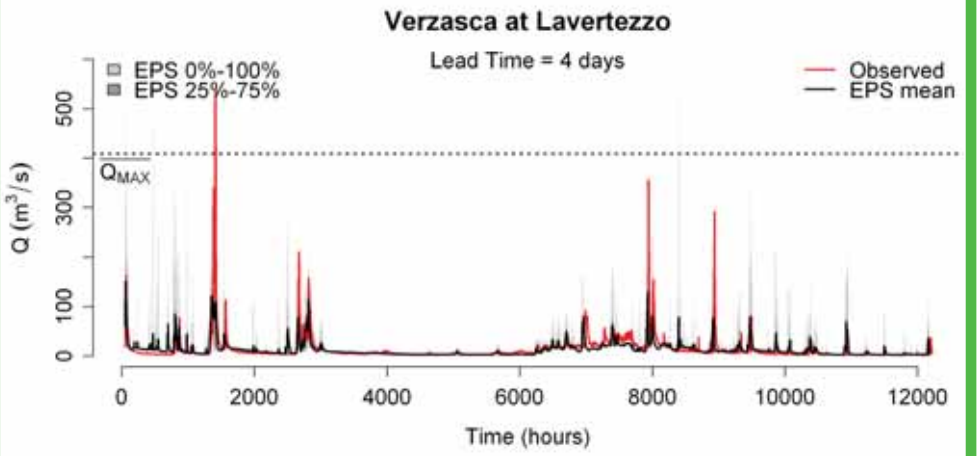
Few hydrograph members above threshold but persistent forecast

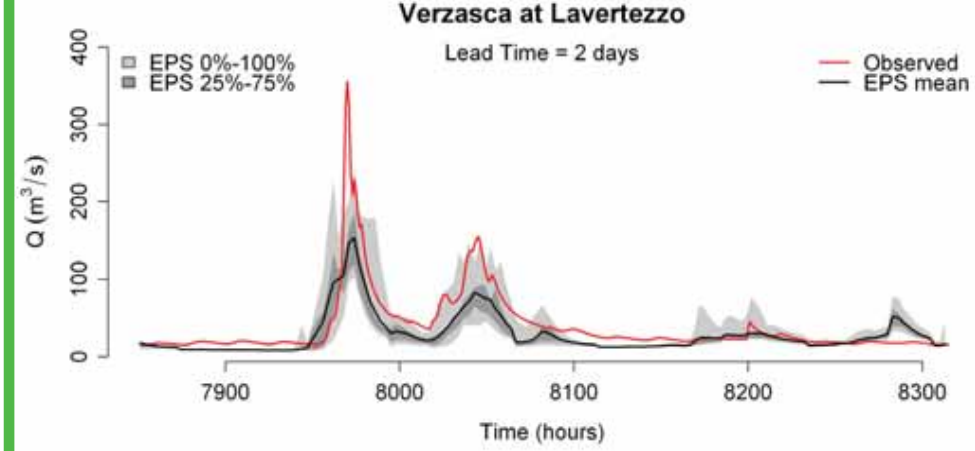
How to maximize the information of probabilistic forecasts & persistence to optimize the detection of severe events?

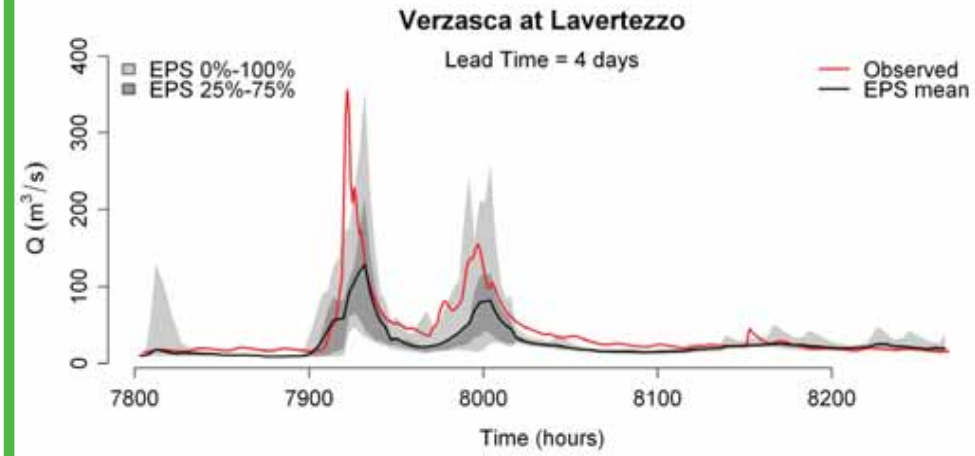
Extensive analysis needed

Operational results - continuous run 2008-2009









Verzasca catchment (CH) - 07/2008 to 11/2009 continuous run

COSMO-LEPS 16 members - fixed Lead Time 2-4 days

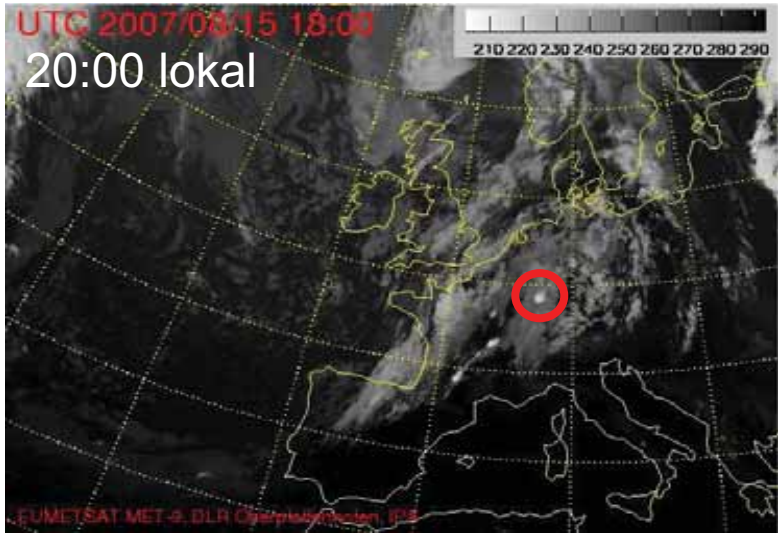
Can we predict flash floods? How to continue?

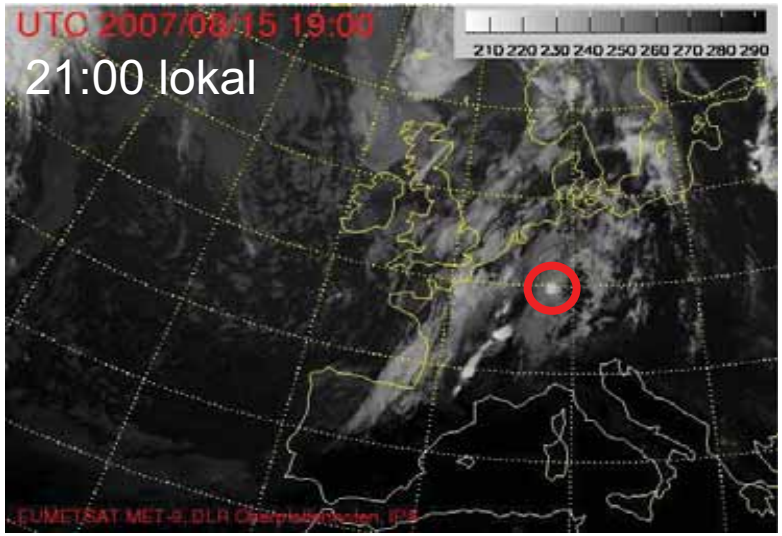
- Well… : work in progress..
- We tested a framework aimed towards probabilistic flash flood early warning. The adopted methodology is derived from that of the European Flood Alert System (EFAS)
- The long term continuous weather hindcast (COSMO 30-year) is of crucial importance as reference climatology, and it is coherent with operational weather forecasts.
- Current weather predictions give useful support in flash flood forecasting, though some limitations are detected in quantitative discharge estimation.
- Persistence of forecasts improves the accuracy in detecting severe events. An objective use of persistence will be included in following studies.
- Extensive assessment of forecast accuracy is envisaged by means of different skill scores

But..

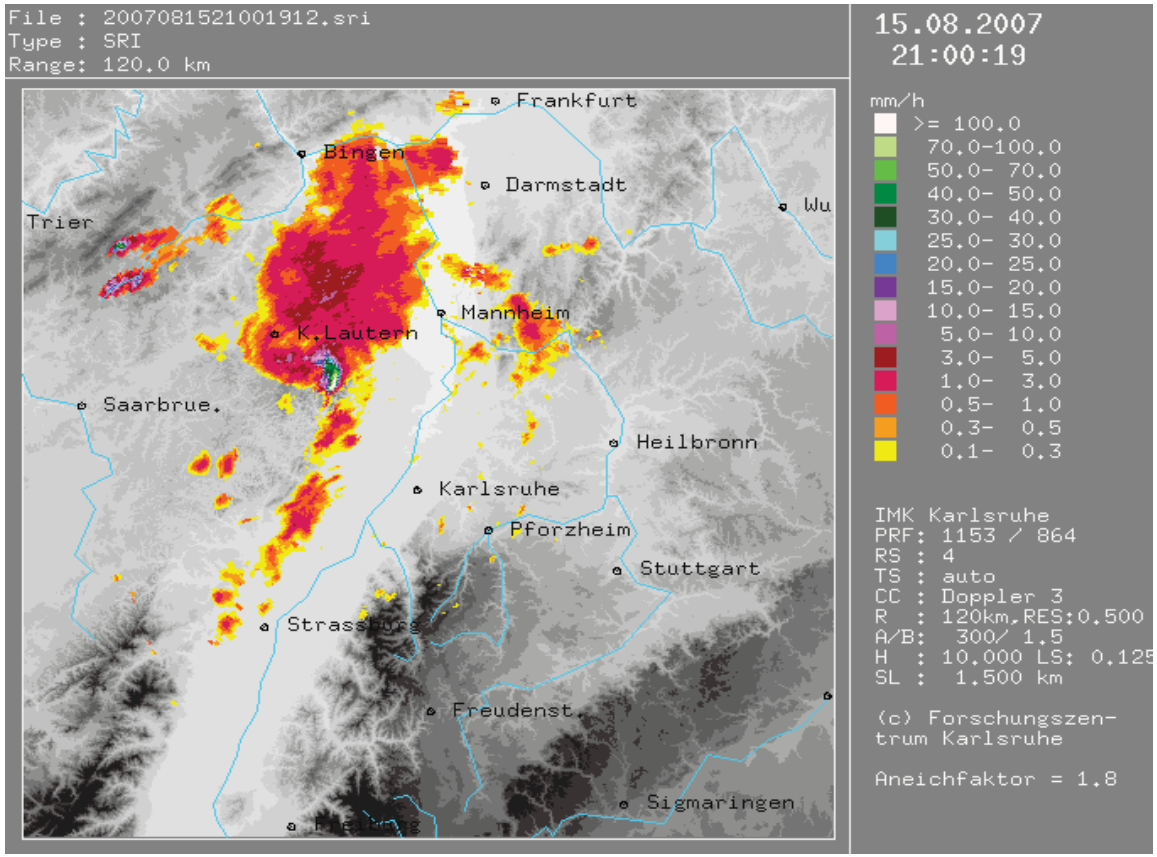
- Some flash floods are captured (e.g. Verzasca)
- But others are missed or mis-located in COSMO-LEPS forecasts (e.g. Czech Rep 2009)
- Further work needed:
  - false alarm rate/ long term analysis
- Also:
  - Higher spatial resolution Numerical Weather Ensemble Prediction models are needed

Convective event 2007



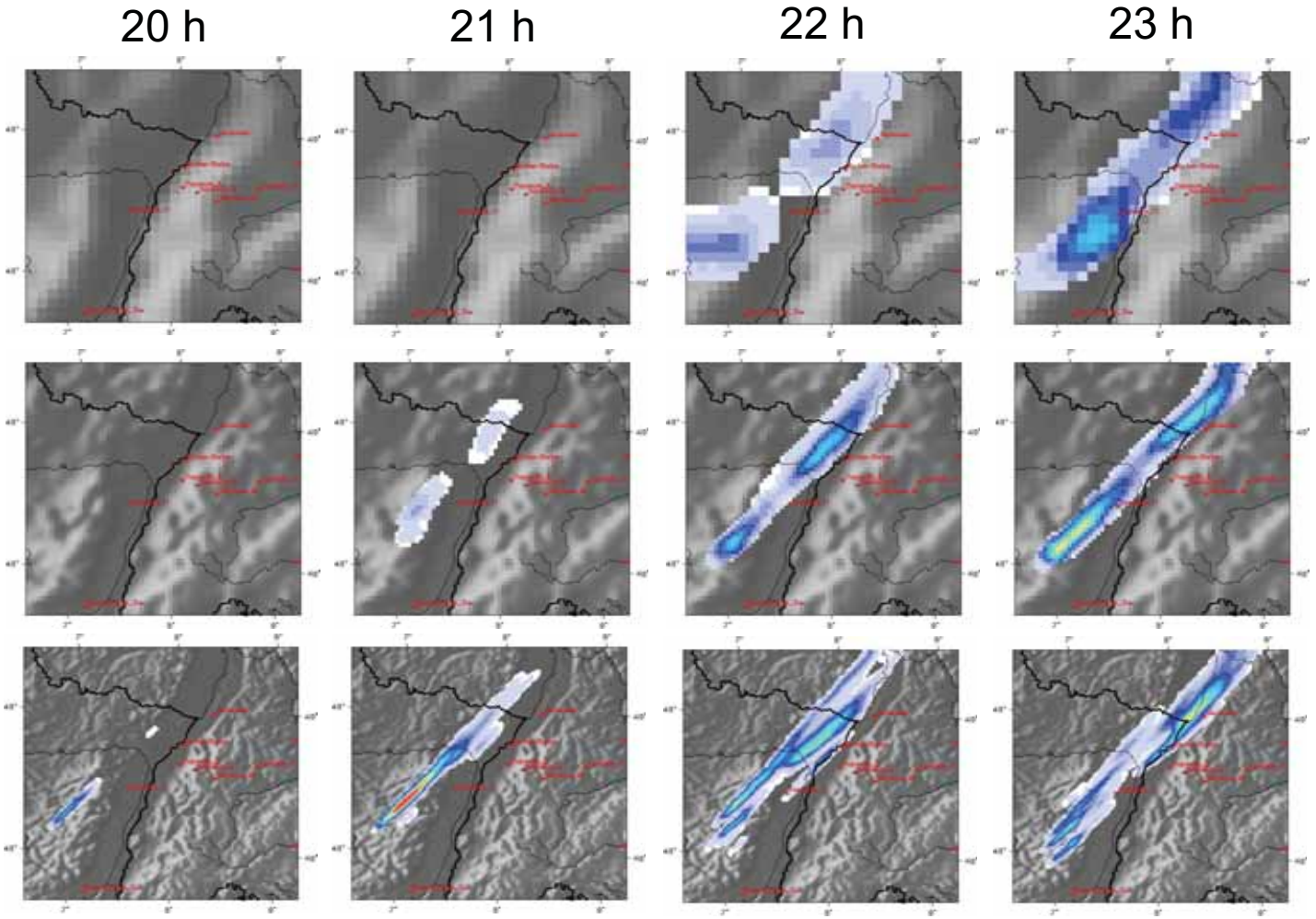


15 August 2007



Convective event 2007, near Karlsruhe (DE)

COSMO-Modell



Future outlook

- ECMWF develops towards establishing NWP/EPS at 2-4km resolution globally within 10 years, and is fully assimilating satellite input (snow cover, soil moisture, other products)
  - This would potentially enable to better capture flash floods

- We need NWP/EPS at 500m/1km grid scales, in order to better capture the convective events, and better represent orography in the NWP models
  - During development and testing, more attention should be given to the skill to predict extreme rainfall!
  - Data assimilation of radar and satellite rainfall patterns