Cover

# The sensitivity of mesoscale heavy precipitation on atmospheric boundary layer over complex orography

**4th International EULAG Workshop**

Forward-in-time Differencing for Earth-System Models

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M. Bettiol[1,2], D. B. Giaiotti[1], F. Stel[1]
(1) ARPA FVG, Regional Center for Environmental Modeling, ITALY
(2) University of Trieste, Department of Physics, ITALY

# Outline

- The class of atmospheric events
- The awareness and the knowledge on those events
- The basic question
- Description of the numerical simulations
- Description of simulation and measurements comparison
- Results
- Further open questions

# The class of investigated events

**Heavy long lasting rain** over the **same area** in **complex orography**

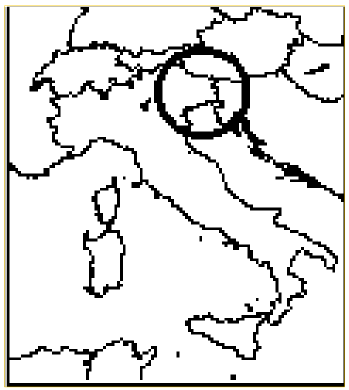
- **Heavy rain**: rain rates > 10 mm/5'
- **Long lasting**: continuous time series (> 1 hour) of heavy rain
- **Same area**: geographical surface about 5 km x 5 km or less
- **Complex orography**: steep mountains (h > 1000 m) and flat terrain

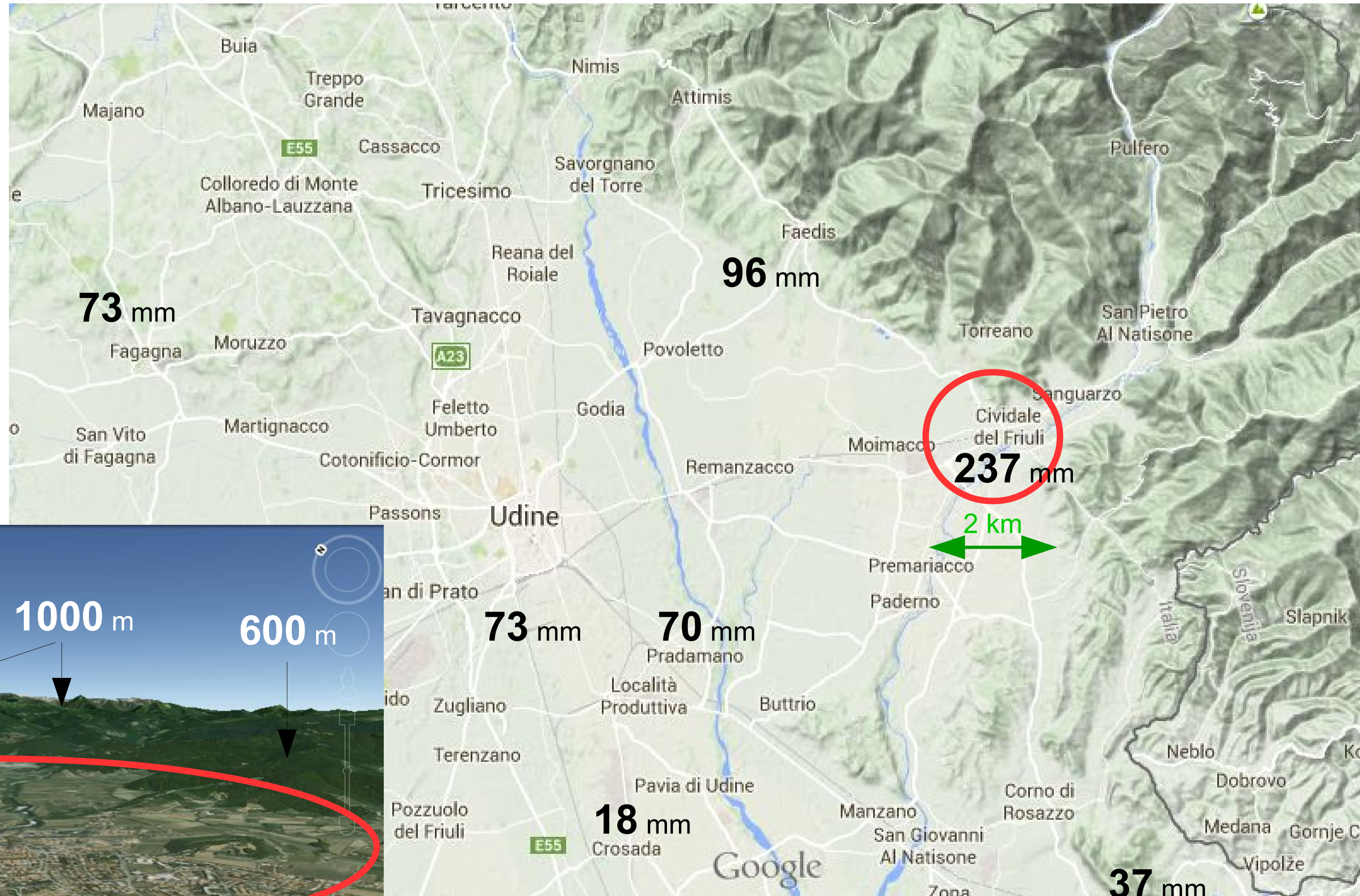
Why we are interested in this class of atmospheric events.

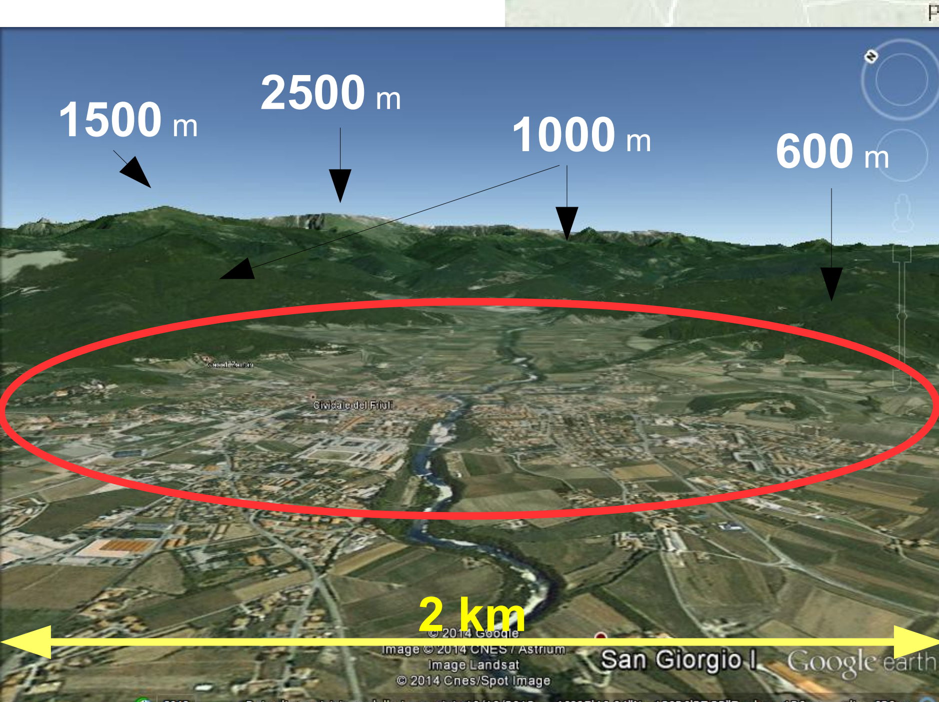
- Weather forecasts and risk management (support civil protection actions)
- Research on deep atmospheric convection and severe weather
- High Performance Computing efficiency

# An event describing the class

## September 09, 2013 – Northeastern Italy



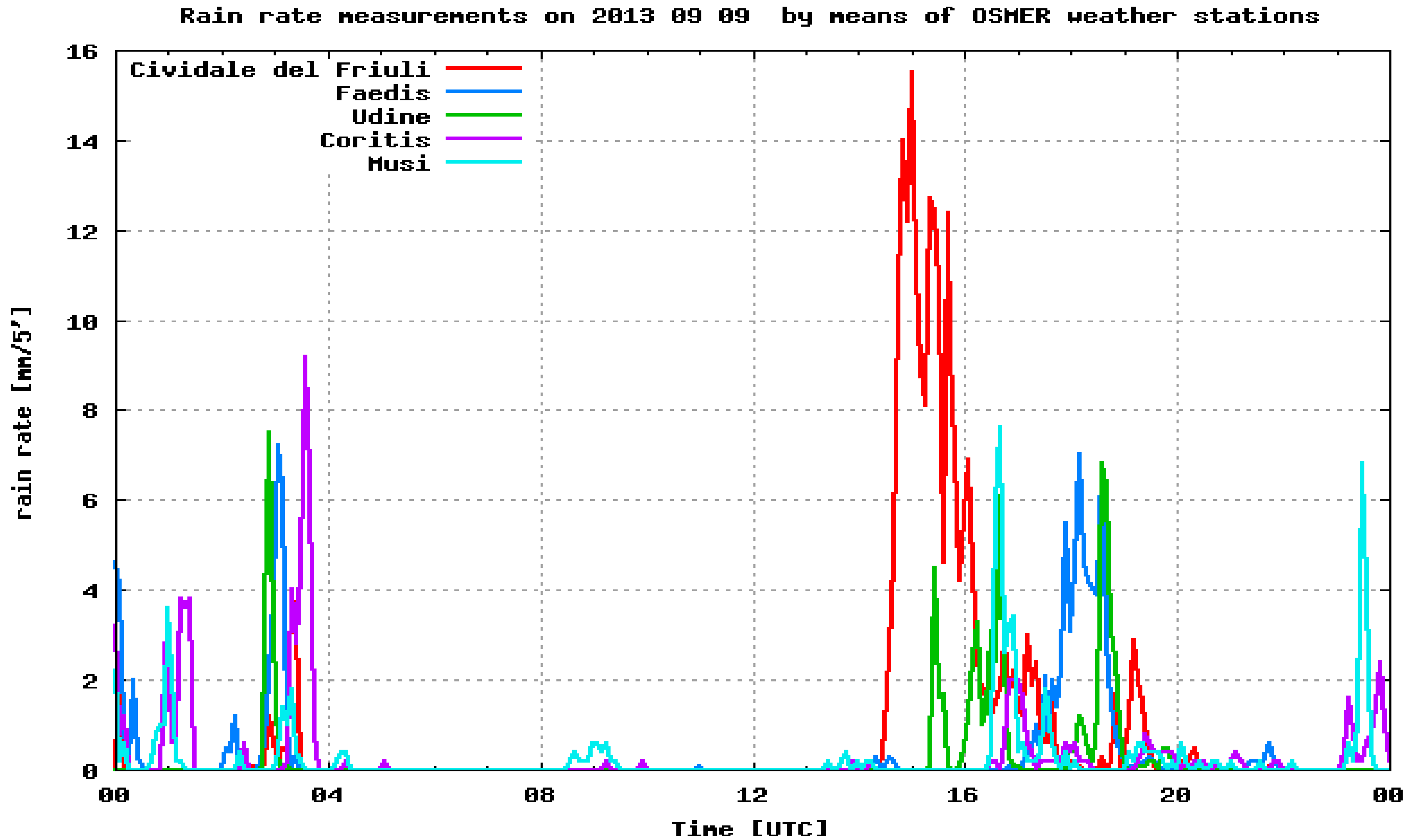



**100** civil protection volunteers involved to help flooded people
**1 MEuro** of costs and damages
At leas **one event/year** in the area (100 km x 100 km)

# Knowledge about such events: measurements

- High efficiency in water vapor condensation and precipitation (up to 20 mm/5')
- Persistence for more than one hour
- Large horizontal rain rate gradients (>100% change in about 2 km)

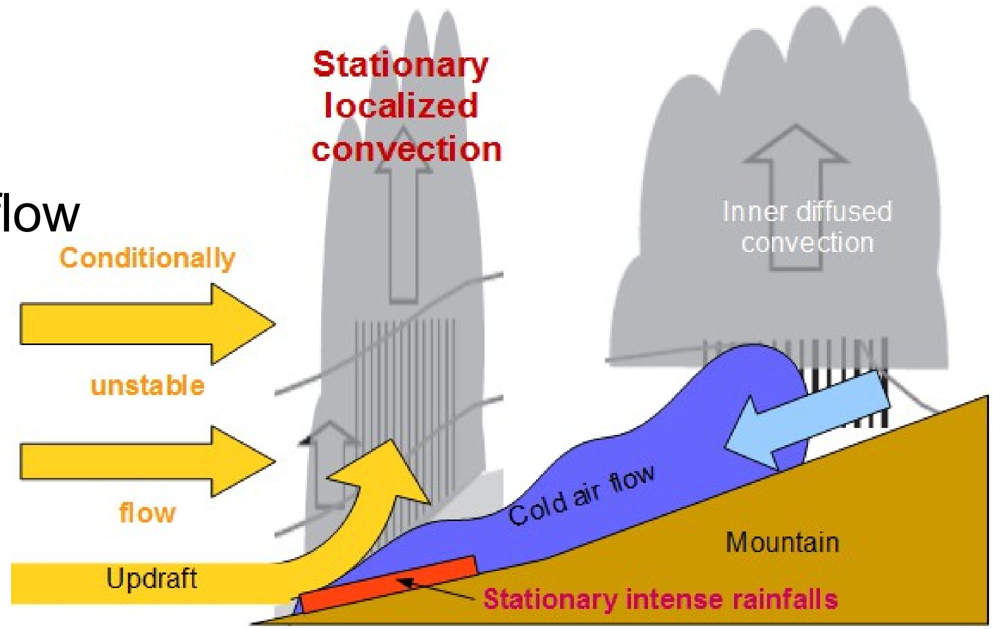


# Knowledge about such events: theoretical model

## Deep atmospheric convection stationary over the same area

### Mandatory elements

- Moist conditionally unstable synoptic flow
- Complex orography




### Conceptual model

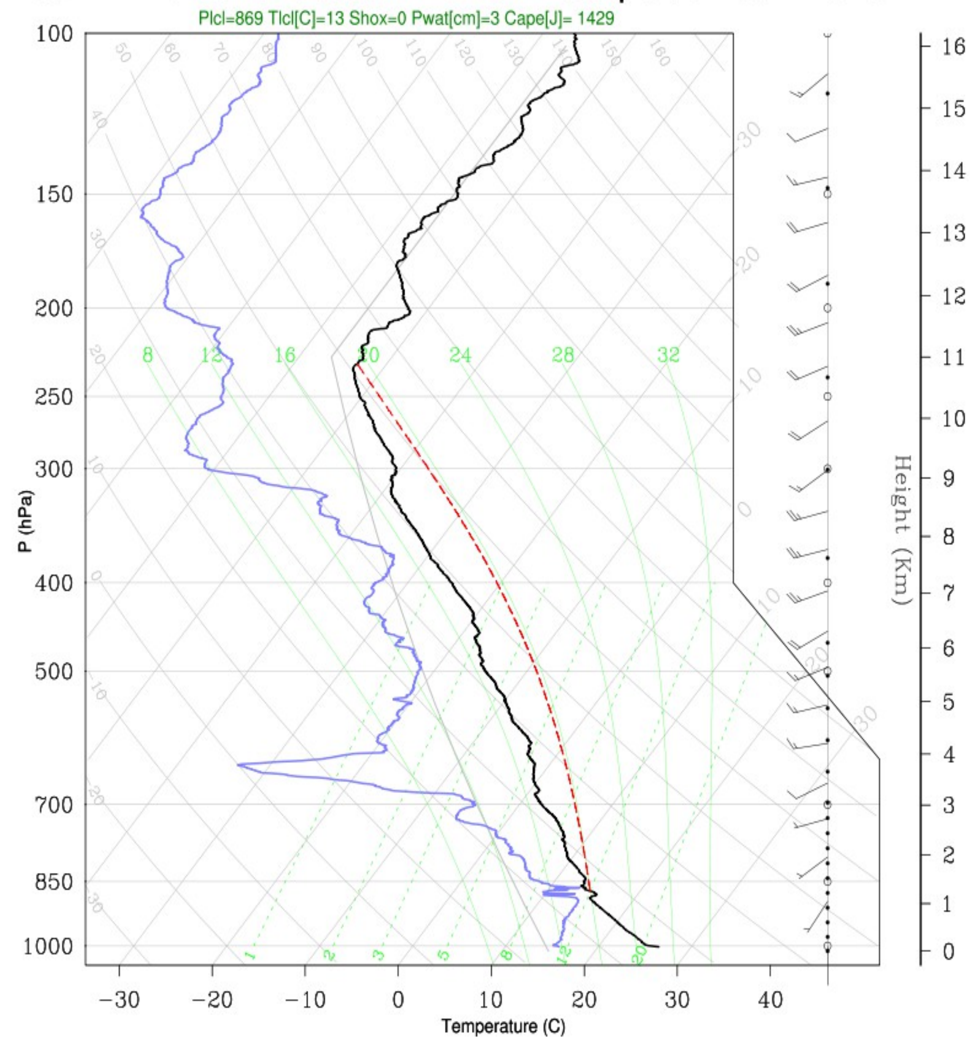
1. Conditionally unstable air impinging on mountains is lifted up to LFC
2. Deep convection take place and generates diffuse downdrafts
3. Downdraft flows are driven by orography in the boundary layer
4. In the boundary layer, synoptic flows and downdrafts interact lifting unstable air
5. The synoptic flow and the downdraft interact stationary in a restricted area

- The area interested by the interaction is a function or synoptic flow intensity, and stability, the cold air outflow and the orography shape.

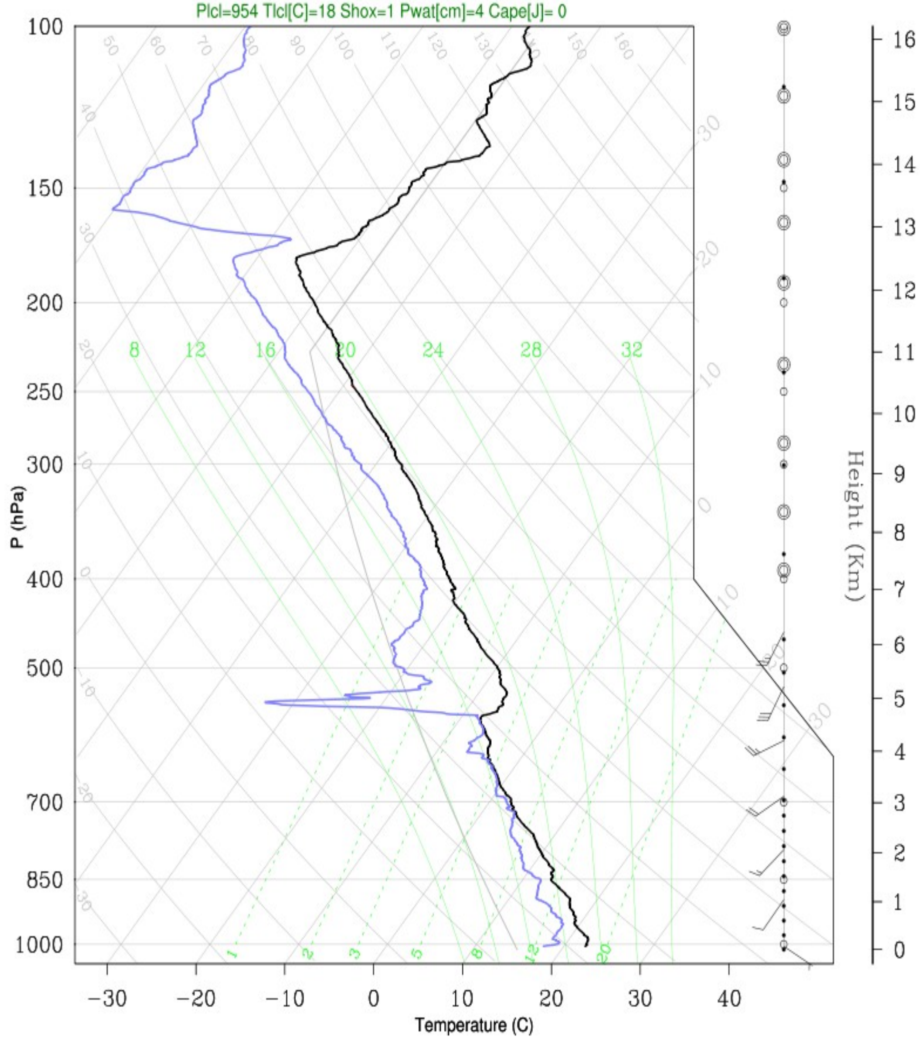
# Measured vertical profiles at WMO 16044

The flash flood took place from 14:00 UTC to 16:00 UTC.
Here are thermodynamic profiles measured 20 km upstream the event area

16044 RDS at 20130909 12 UTC   lifted parcel 150 m amsl




16044 RDS at 20130909 00 UTC   lifted parcel 150 m amsl

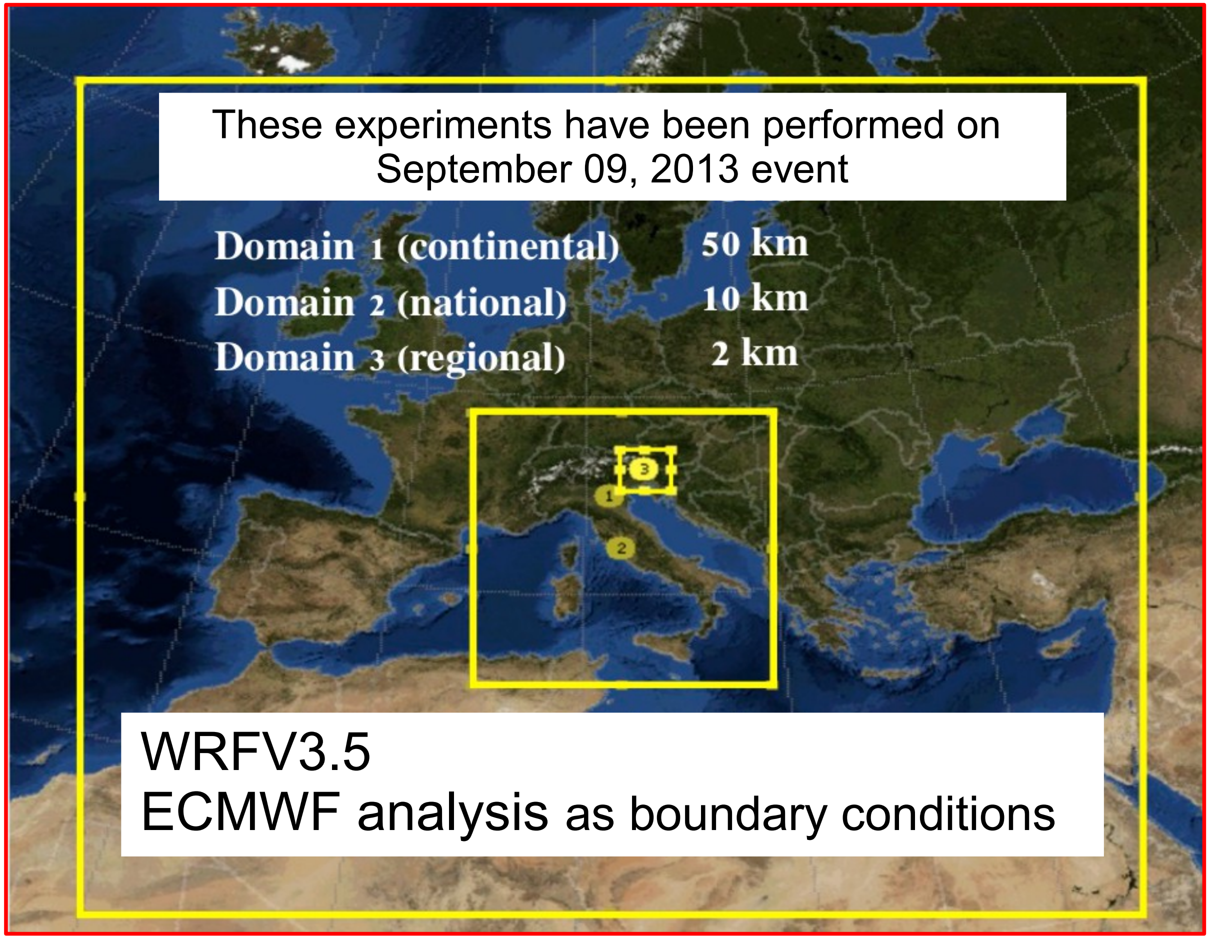



The synoptic flow was towards the orographyc barrier and it was weak

# The basic question

## Are nowadays LAMs able to simulate such class of atmospheric events?

- Simulations with uniform flows and simple orography are known form literature.
- What about WRF model in real cases?




WRF is run operationally at ARPA FVG

Forecasts span 5 days

Boundary and initial conditions are GFS

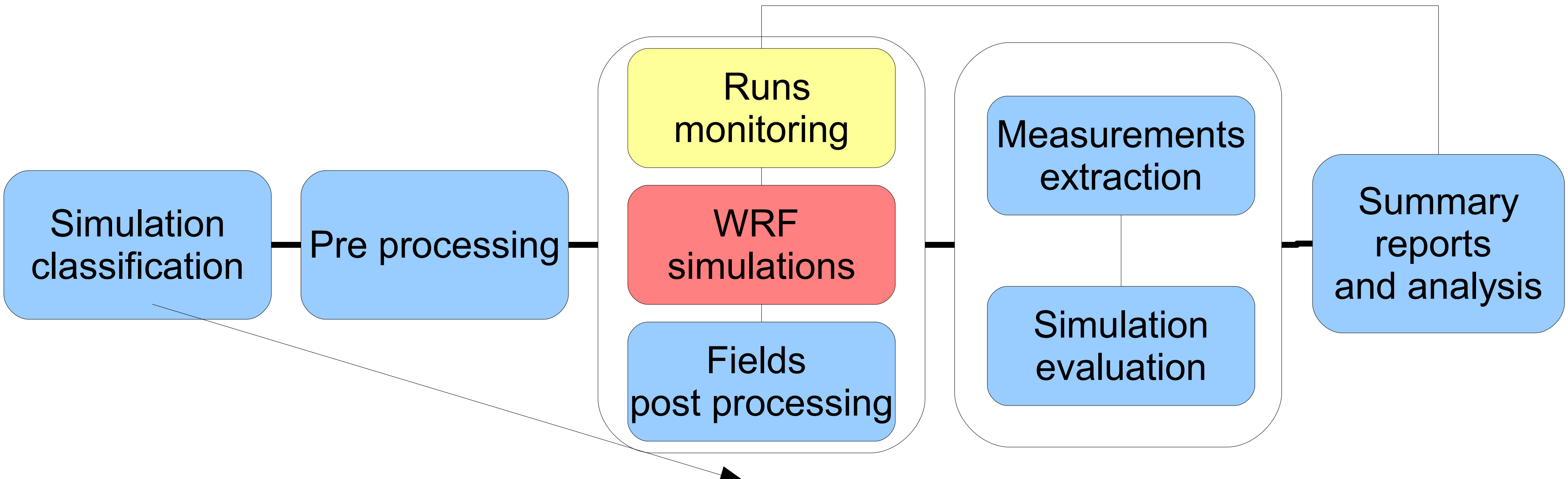
3 nested domains to reach 2 km resolution over NE Italy

Orography resolution 30”

HPC shared+distributed memory 32 cores

# Experiments organization and execution

- All numerical experiments are implemented as **workflows** composed by actions
- A new experiment  workflow is defined by means of initialization files
- Simulation chains are run automatically according HPC resources availability




**WRF rain sensitivity on:**

- Horizontal resolution
- Nested domains feedback effects
- Initial and boundary condition
- Boundary layer schemes

| Code | Inizio/fine | Doms | Risoluzione | dt | Procs | Feedback | Note |
|---|---|---|---|---|---|---|---|
| AA | 06-09-13/10-09-2013 | 3 | 50, 10, **2** | 240, 40, 40/6 | 32 | ON | Manca |
| AB | 06-09-13/10-09-2013 | 4 | 50, 10, 2,   1 | 240, 40, 40/6, 40/12 | 32 | ON | |
| AC | 06-09-13/10-09-2013 | 3 | 50, 10, 2 | 240, 40, 40/6 | 32 | OFF | Come . |
| AD | 08-09-13/10-09-2013 | 4 | 50, 10, 2,   1 | 40, 40, 40/6, 40/12 | 16 | ON | Come . |
| AE | 08-09-13/10-09-2013 | 4 | 45, 9,  1.8, 0.6 | 180, 36, 6, 1 | 16 | ON | Interro Il resta |
| AF | 08-09-13/10-09-2013 | 5 | 45, 9,  1.8, 0.6, 0.3 | 180, 36, 6, 1, 0.5 | 16 | ON | |
| AG | 08-09-13/10-09-2013 | 4 | 45, 9,  1.8, 0.6 | 180, 36, 6,   1 | 16 | OFF | |
| AH | 08-09-13/10-09-2013 | 5 | 45, 9,  1.8, 0.6, 0.3 | 180, 36, 6,   1, 0.5 | 16 | OFF | |

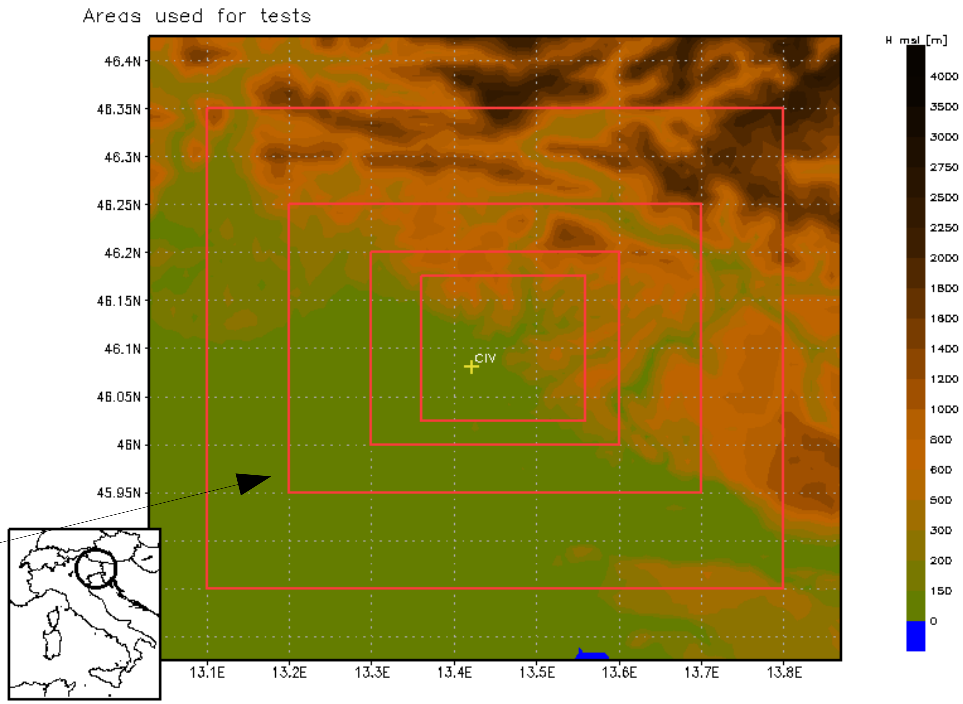
# Simulation and measurements comparison

Simulations evaluation is focused on
a) **rain rate efficiency** b) **rain amount over the event**

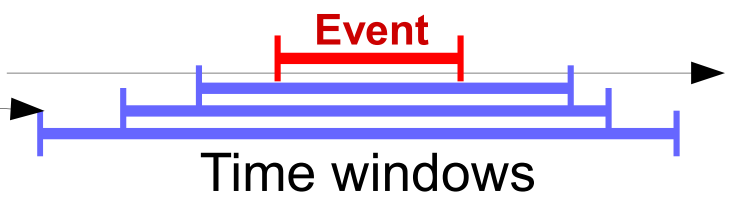
Common problems in meteorological simulations quality evaluation
- Time consistency between fields and measurement points time series
- Space consistency between fields and measurement points

Approach adopted for time consistency.
- Define a time window centered on the event
- Compare all simulated grid point time series with measurements inside the time window

Approach adopted for space consistency.
- Define an area centered on the event area
- Compare all simulated grid point time series with measurements inside the area



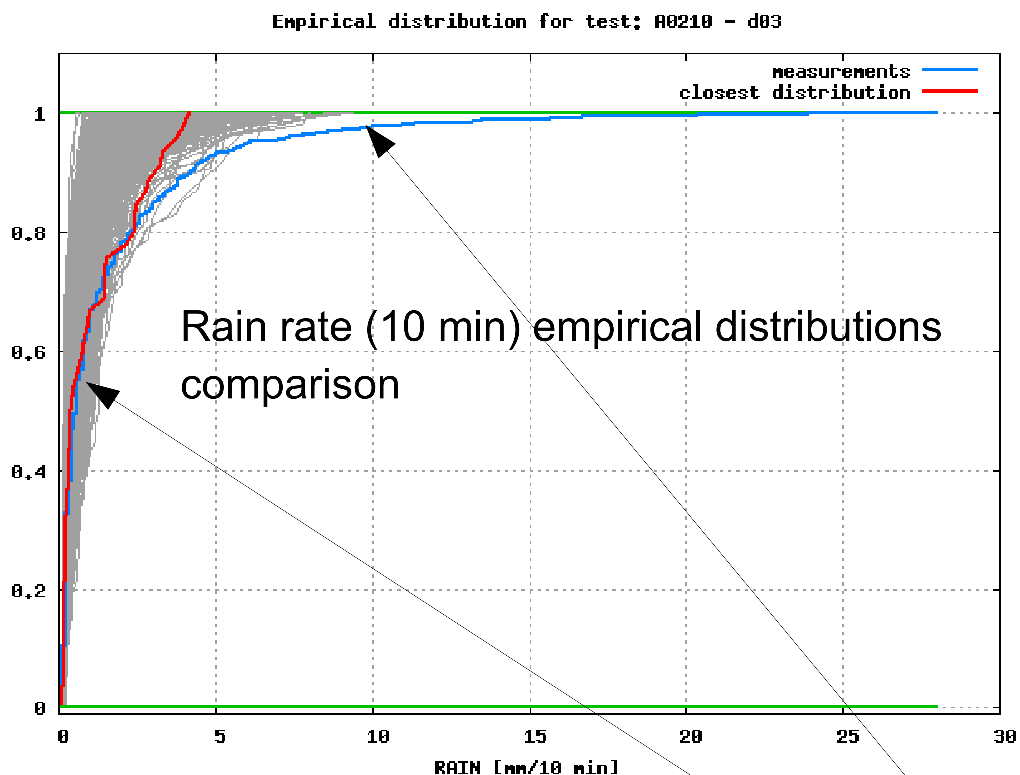

Decrease **area** and **time windows** sizes

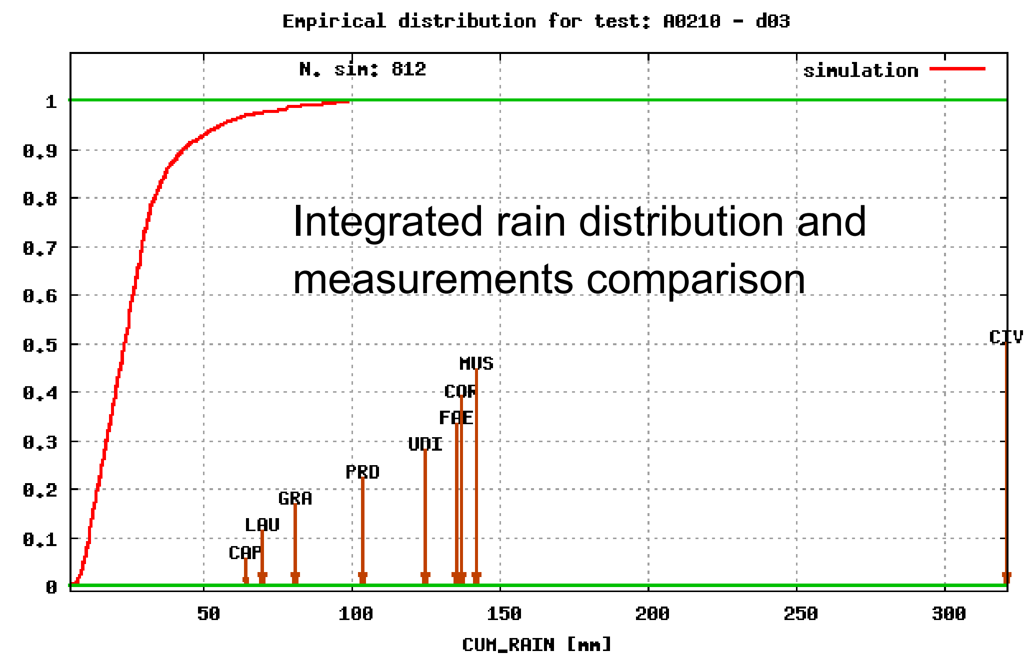


# Empirical distribution approach

**The basic concept is:** the model gets close to the reality within the area/time window

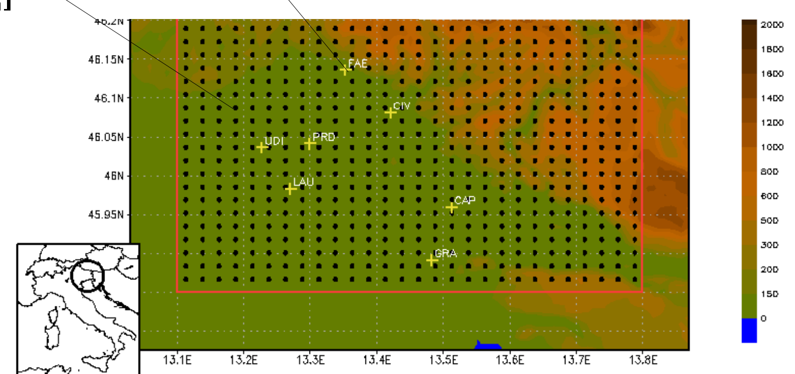
Compare all grid points data with the corresponding measurements in the area/time window



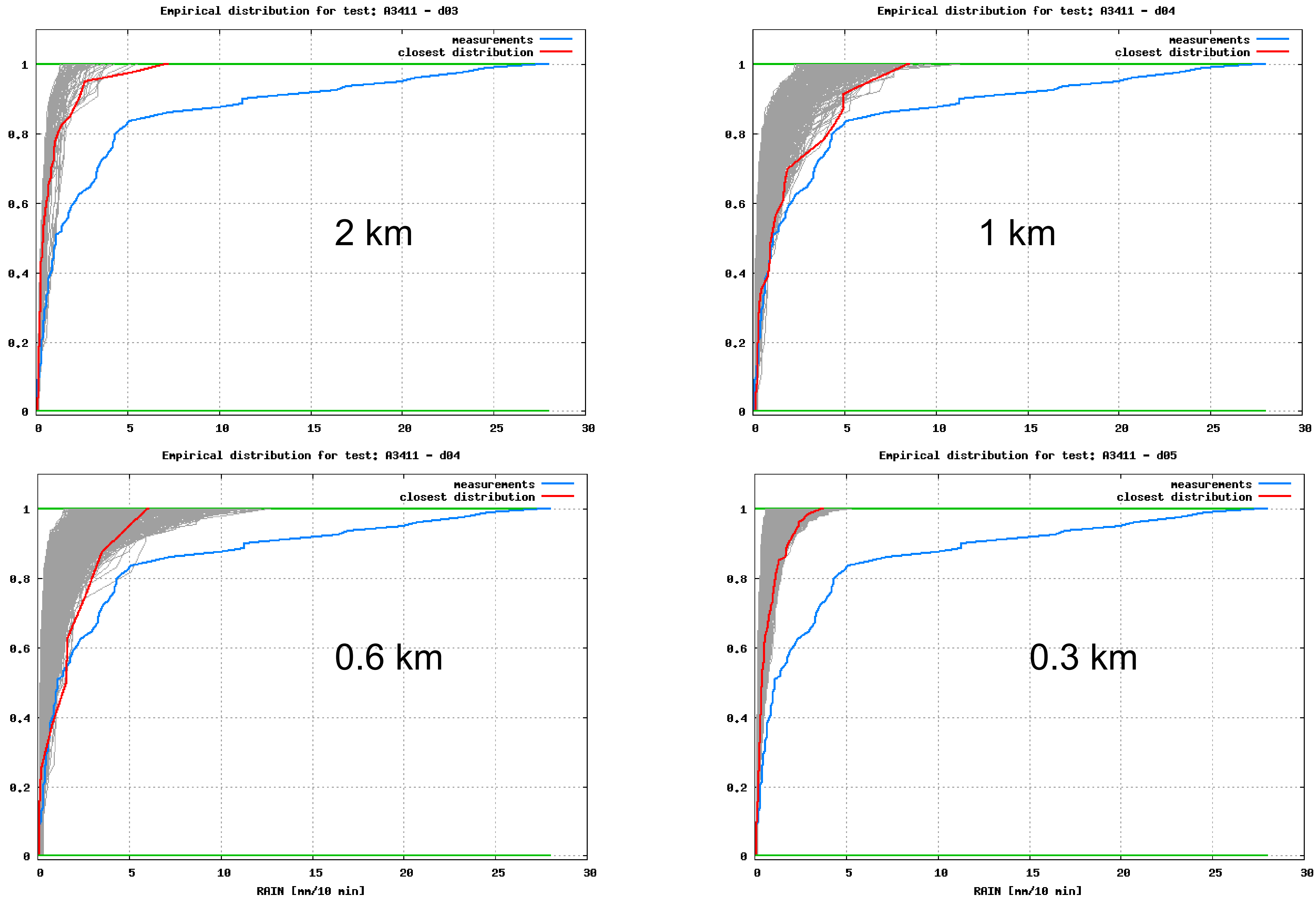

# Simulations statistics
# Data ;min;0.01;0.05;0.1;0.5;0.9;0.95;0.99;max;ave
d03_all_int.simu;4.77;7.59;9.602;11.33;23.34;43.17;56.21;82.902;100.2;26.07

Quantitative statistical tests and statistical estimators are used as closeness measurement

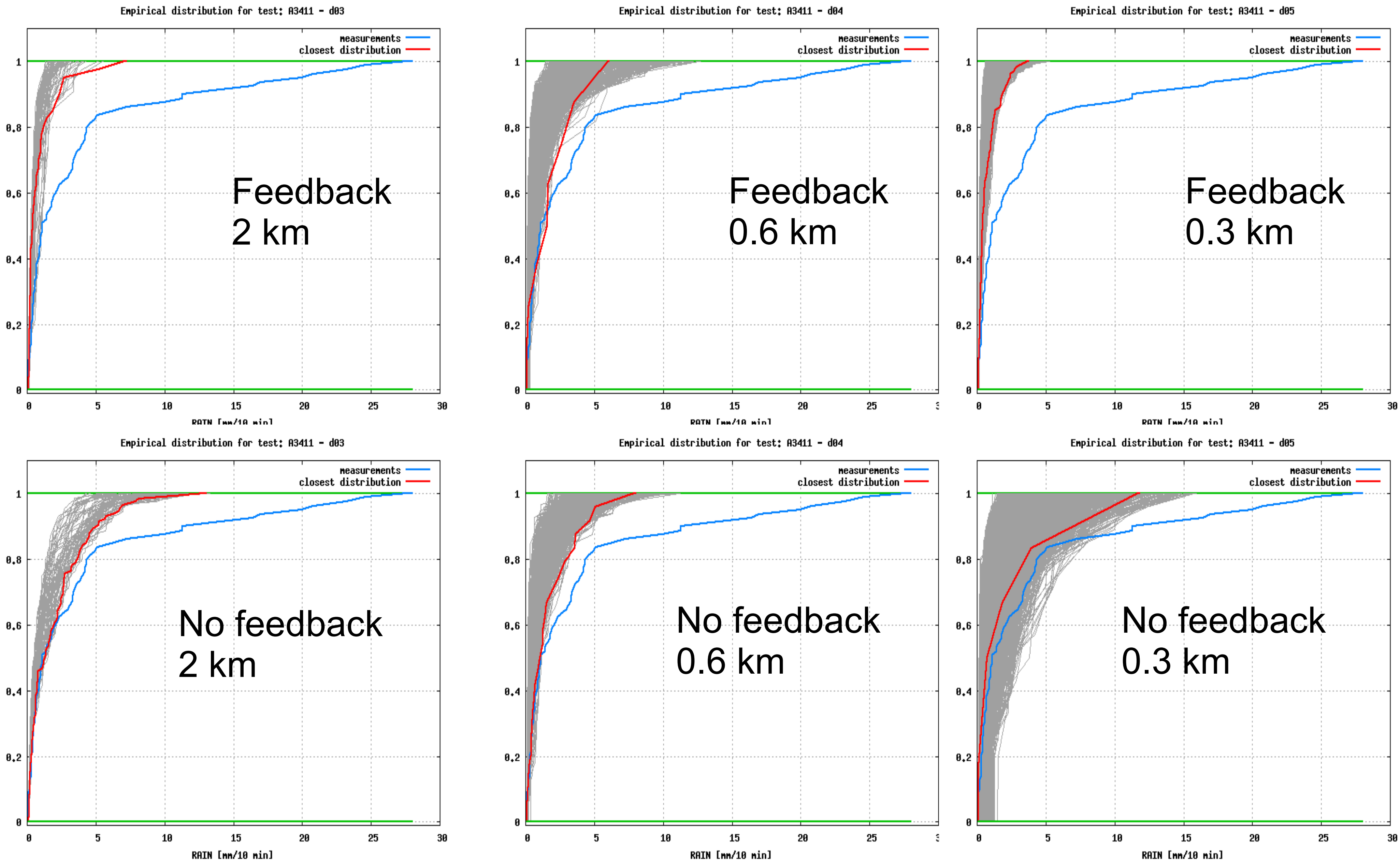


# Maximum rain rate and model resolution

## Nested domains feedback ON



# Maximum rain rate and domains nesting feedback



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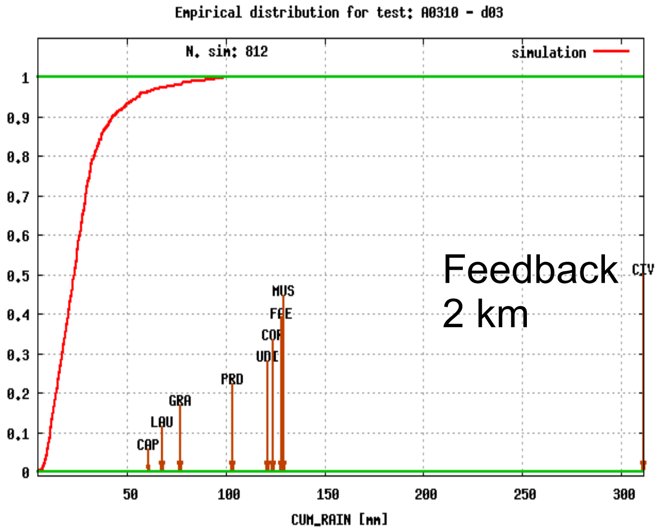
# Integrated rain and domains nesting feedback




# Simulations statistics
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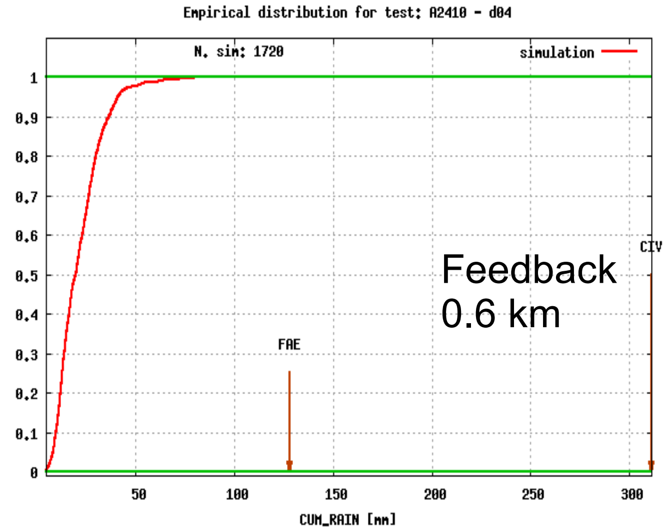


# Simulations statistics
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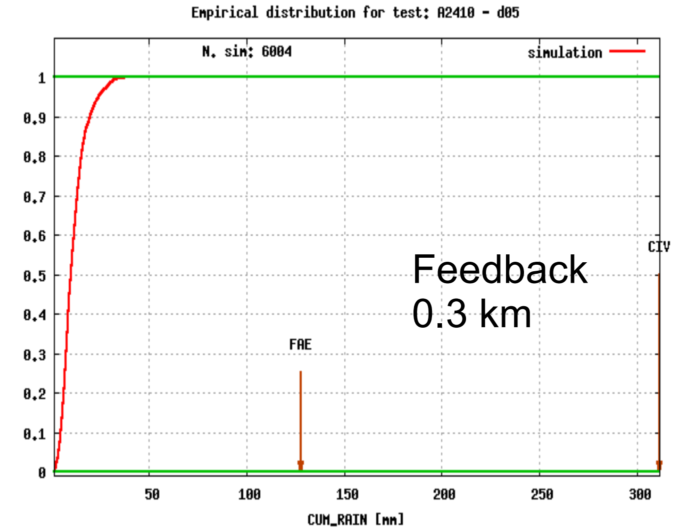


# Simulations statistics
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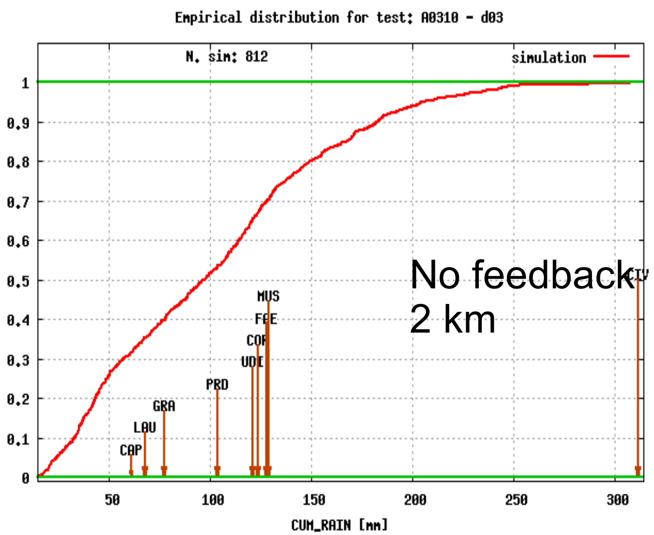


# Simulations statistics
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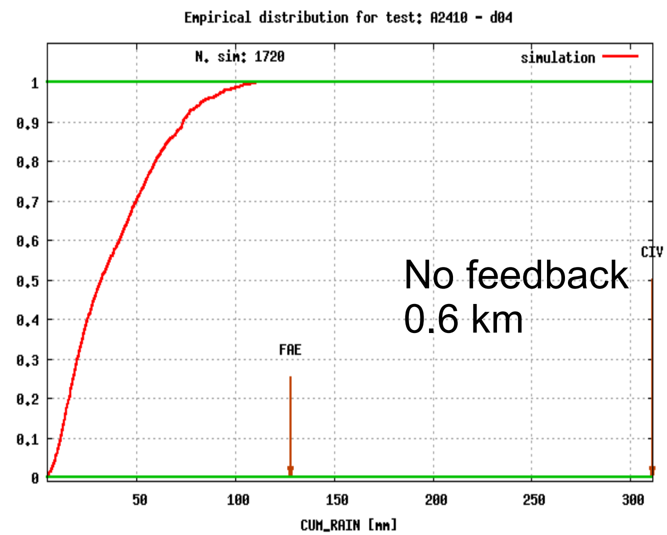


# Simulations statistics
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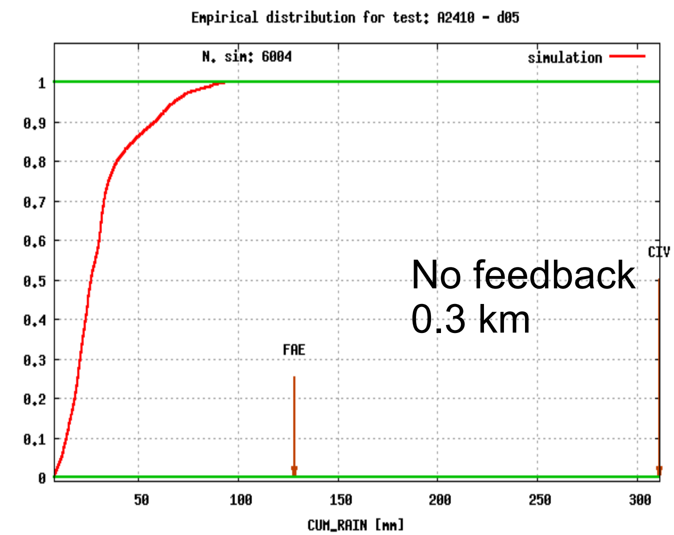
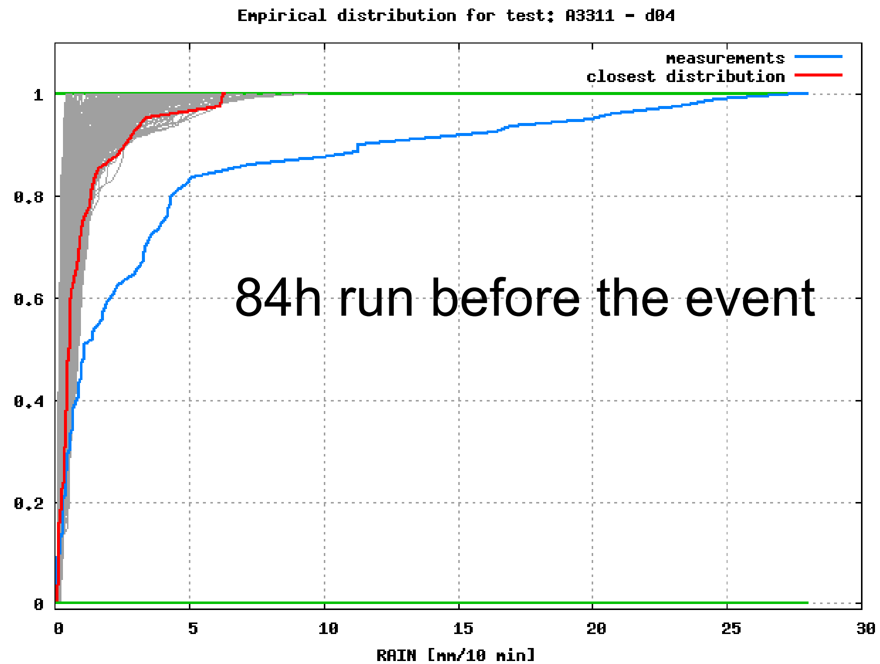
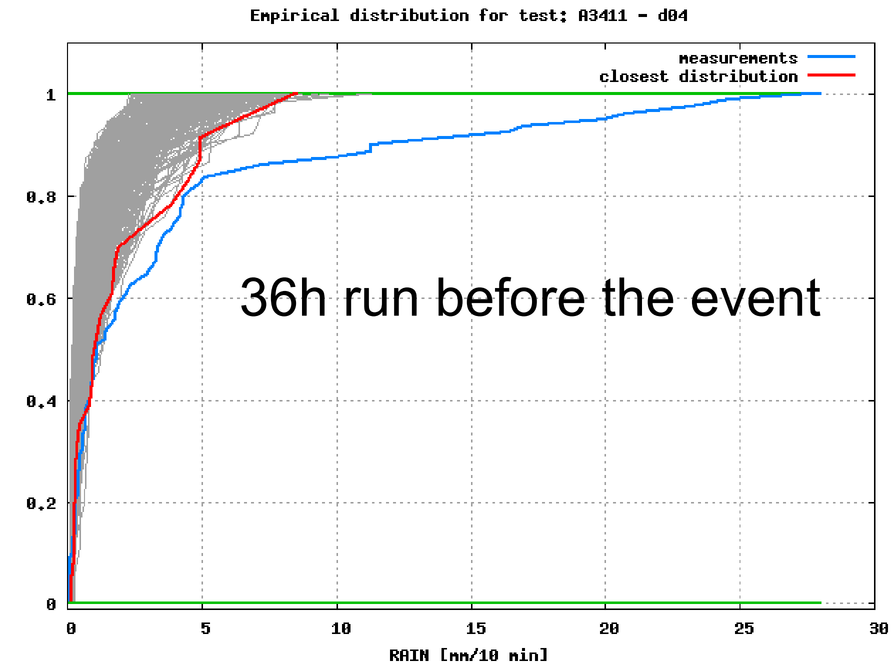


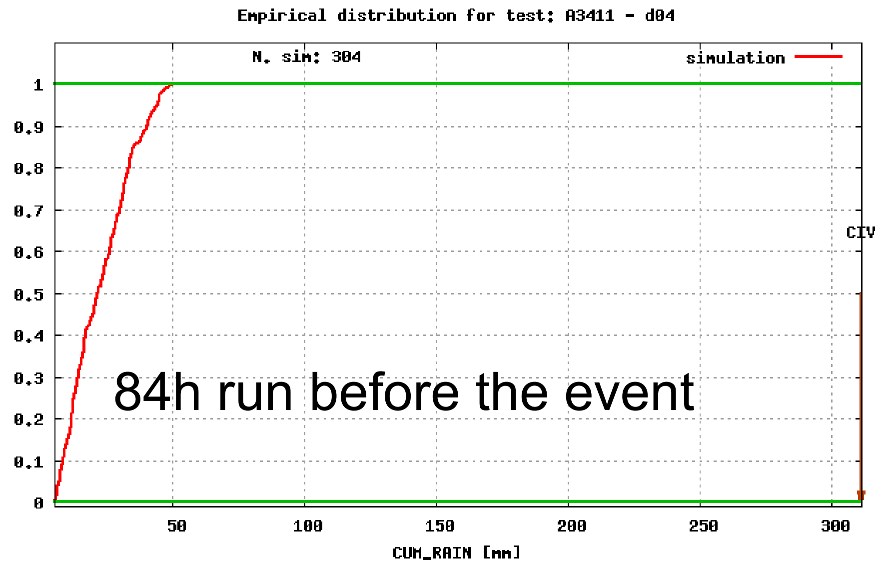

# Simulations statistics
# Data ;min;0.01;0.05;0.1;0.5;0.9;0.95;0.99;max;ave
d05_all_int.simu;7.697;8.42698;11.55443;13.92444;26.23141;58.36859;67.96918;86.02168;93

# Effects of initial conditions

Example 0.6 km resolution




# Simulations statistics
# Data ;min;0.01;0.05;0.1;0.5;0.9;0.95;0.99;max;ave
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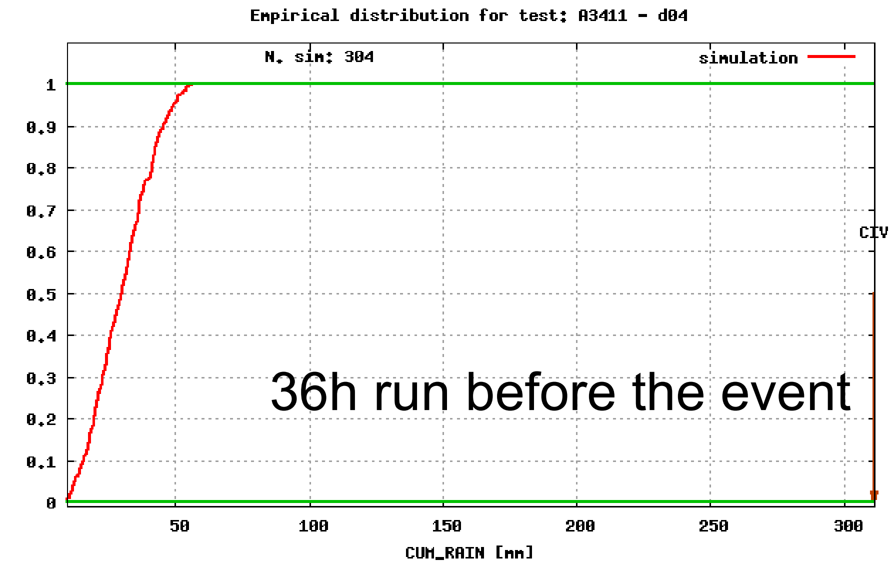


# Simulations statistics
# Data ;min;0.01;0.05;0.1;0.5;0.9;0.95;0.99;max;ave
d04_all_int.simu;9.62;10.57;12.45;15.8;29.95;45.75;49.49;54.16;57.73;30.32

# Summary of main results

**Increasing horizontal resolution.**

Domains feedback ON

- the maximum rain rate increases up to 0.6 km (orography resolution), then at 0.3 km maximum rain rate decreases
- the integrated rain increases as resolution increases up to 0.6 km (orography resolution), then at 0.3 km it decreases

Domains feedback OFF

- the maximum rain rate increases
- the integrated rain decreases

**Effects of domains feedback.**

- The feedback reduces the extreme rain rate
- The feedback reduced the range of empirical distribution rain rates

**Effects of initial conditions.** Longer run (more than 48h) before the event

- Reduction of the extreme rain rate and distribution dispersion
- No significant effects on integrated rainfalls

# Open questions and remarks

The typical space and time scales of the ingredients required to produce such events suggest the models should simulate accurately from the synoptic scale down to the microscale, allover the domain and the time window covered.

## Besides the pure research purposes

- Is it worth to invest resources in improving the reliability of extreme rain rates empirical distribution simulated by numerical models? (personally **YES**).
  - Weather forecast face extreme rain rates frequently.
  - Climate change scenarios aim to recognize shifts in rain rates distribution.
- Is it necessary LAMs (and GCMs) reproduce the extreme rain rate events with their typical space and time scale? (personally **NO**).
  - Extreme weather events forecasts is only one part of risk management. Information is degraded along the management chain.
  - For climate change purposes microscale features are averaged.

## A proposal to EULAG community

- In the EULAG community, is the interest to investigate the class of events here described, coupling EULAG with a mesoscale model (WRF)?
  - Mesoscale boundary conditions, measurements and expertise may be given by ARPA FVG.

# Last slide

Thanks for your attention