COMPARISON OF CALIBRATION TECHNIQUES FOR A LIMITED-AREA ENSEMBLE PRECIPITATION FORECAST USING REFORECASTS

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CONSORTIUM FOR SMALL SCALE MODELING
COSMO

arpa
agenzia regionale prevenzione e ambiente dell'emilia-romagna

Aim

- To implement a calibration technique for the precipitation output provided by COSMO-LEPS, the Limited-area Ensemble Prediction System based on the non-hydrostatic limited-area model COSMO (10 km horizontal resolution)

- To investigate the potential of using reforecasts for the calibration of the COSMO-LEPS precipitation forecast

- To test different calibration techniques

Calibration strategy – methodologies

- Choice of methodologies which enable a calibration of 24-h quantitative precipitation forecasts (QPFs), not only of the probabilities of exceeding a threshold
  - aim:
    - improvement of COSMO-LEPS QPFs especially as an input for hydrological applications

- Selected methods:

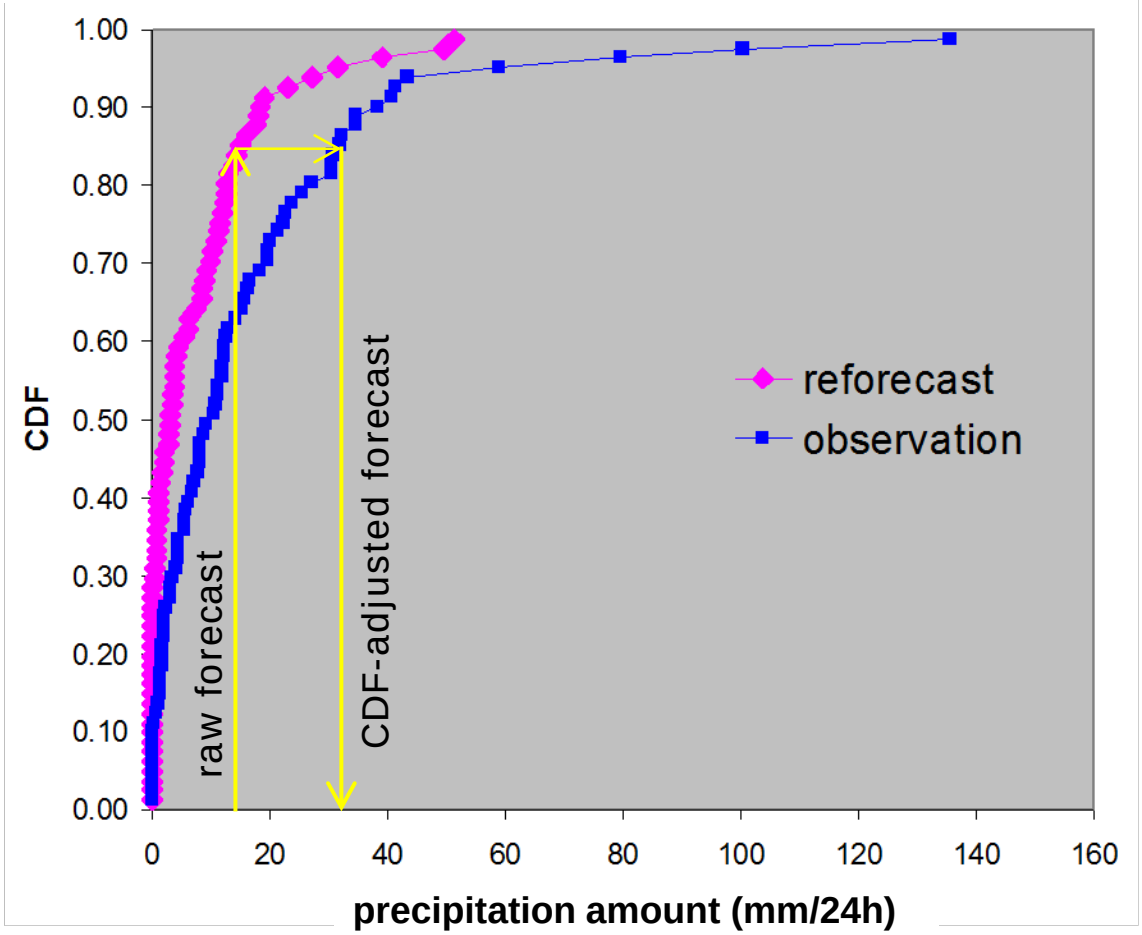
  - Cumulative Distribution Function (CDF)

  - Linear Regression (LR)

  - Analogs → similarity of precipitation at ground (ANL)
  - Analogs → similarity of geopotential at 700 hPa (anlZ)

Calibration strategy – methodologies

CDF-based corrections



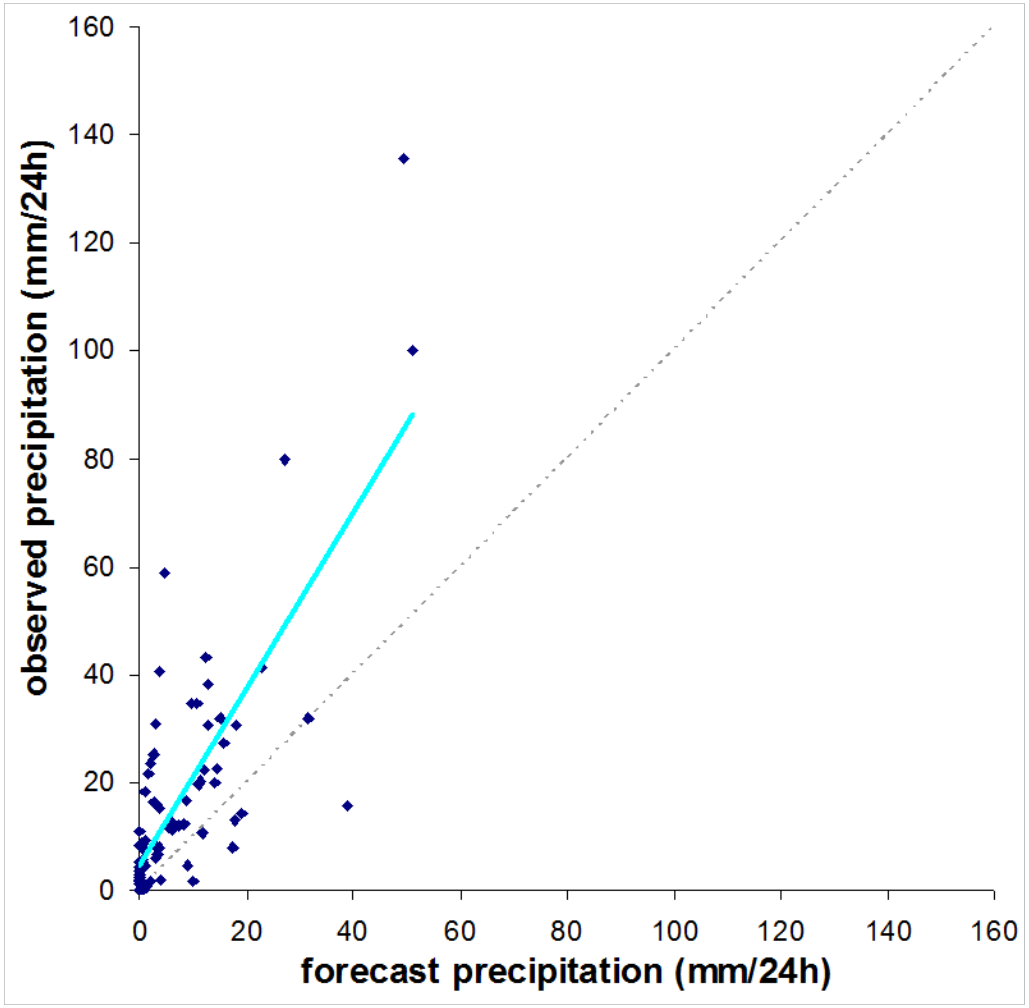
For each model grid point:

- fuchsia line ⇒ CDF of COSMO-LEPS reforecasts
- blue line ⇒ CDF of historical observations
- "raw forecast" ⇒ each member of the operational COSMO-LEPS

seasonal- and point-specific correction function

Calibration strategy – methodologies

Linear Regression



For each model grid point:

x-axis: COSMO-LEPS reforecasts

y-axis: historical observations

$$y_i = \beta_0 + \beta_1 x_i$$

seasonal- and point-specific correction function

Calibration strategy – methodologies

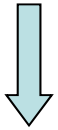
Analogs rainfall & upper air field

For each ensemble member at each 24-h forecast period:

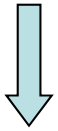
- the analog search is performed in terms of:
  - 24-h precipitation field over the study area

    or

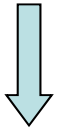
  - geopotential at 700 hPa (Z) over a suitable spatial domain



- the root-mean-square (rms) difference between the current forecast and each reforecast is computed *(comparison among fields from the same season)*



- the historical date with the smallest rms difference is chosen as the analog day, then the raingauge recordings of that past day are used as the calibrated QPFs



1 analog date for each 24-h forecast period

over the study area

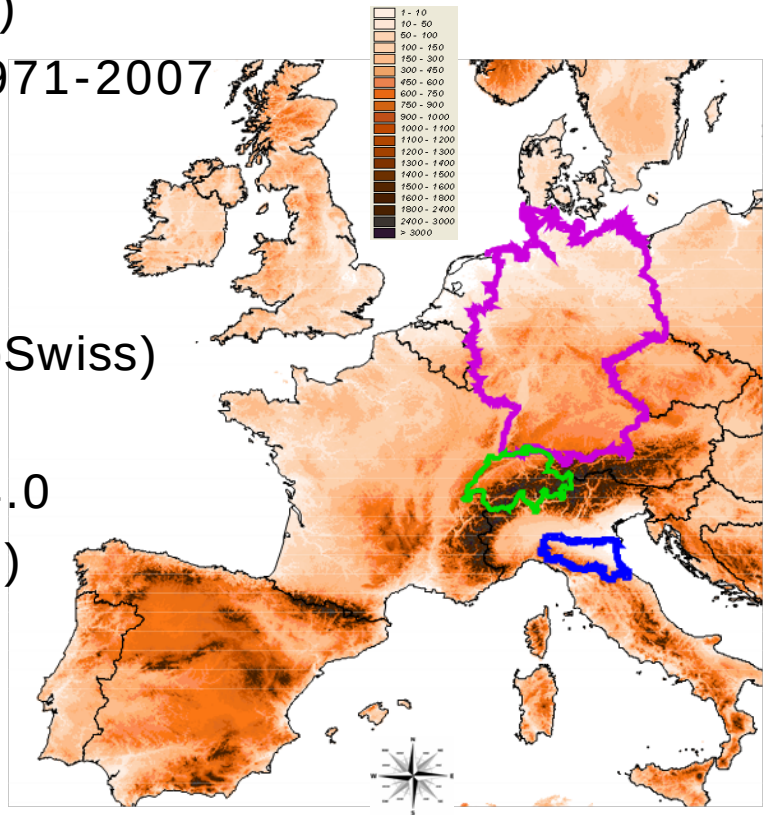
Calibration strategy - data collection & study areas

study areas

- Emilia-Romagna Region, Northern Italy (~ 22000 km²)
- Switzerland (~ 41000 km²)
- Germany (~ 357000 km²)

data collection

- observed precipitation (24-h raingauge data)
  - Emilia-Romagna Region (08-08 UTC), 1971-2007
  - Switzerland (06-06 UTC), 1971-2007
  - Germany (06-06 UTC), 1989-2007



- COSMO-LEPS reforecast QPFs (run by MeteoSwiss)
  - 30 years: 1971-2000
  - 1 member, nested on ERA40, COSMO v4.0
  - 1 run every three days at 12 UTC (+90h)

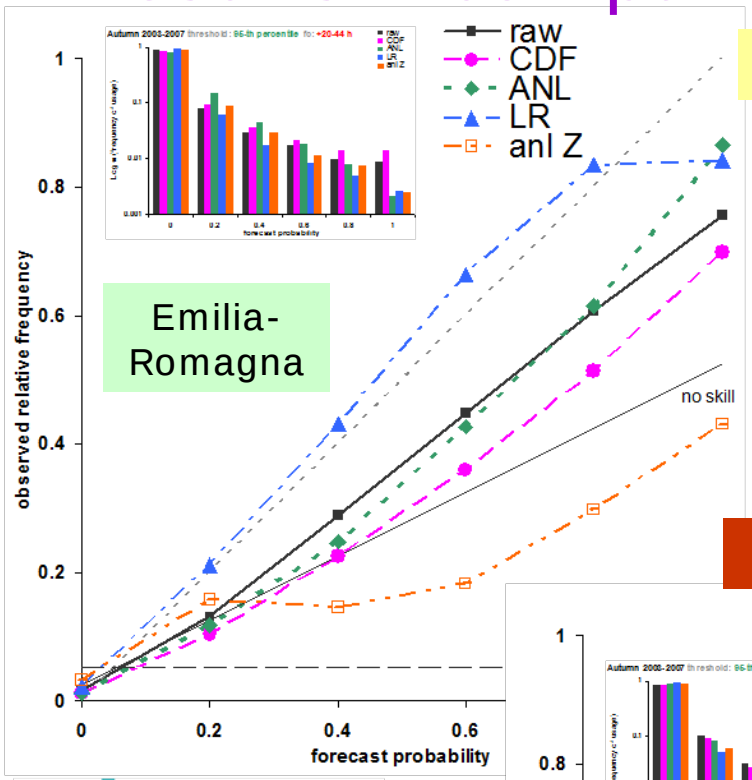
- COSMO-LEPS operational QPFs
  - 5 years: 2003-2007
  - 5-10-16 members (depending on the year), nested on selected members of the ECMWF Ensemble Prediction System
  - 1 run every day at 12 UTC (+120h)

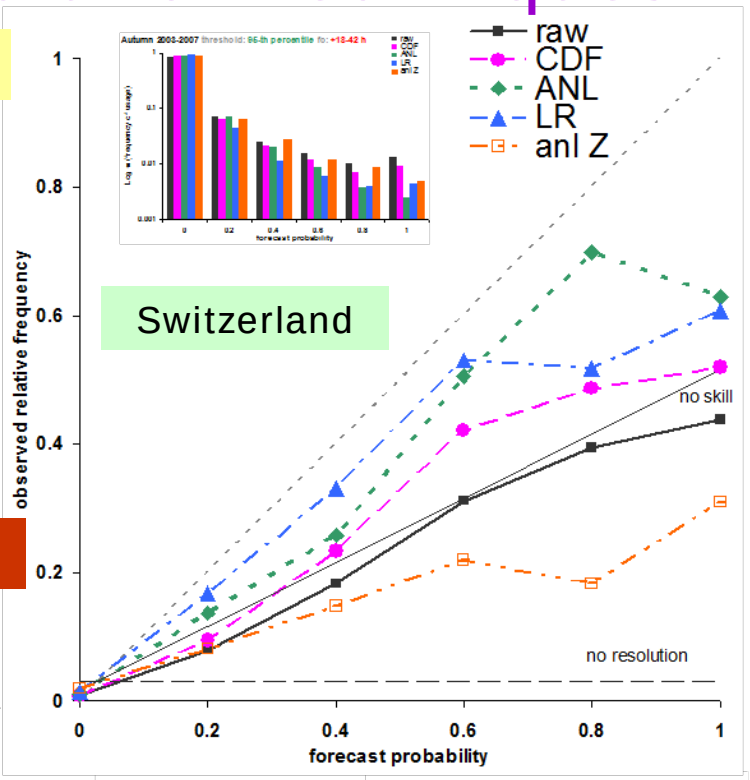
Results – comparison of calibration techniques

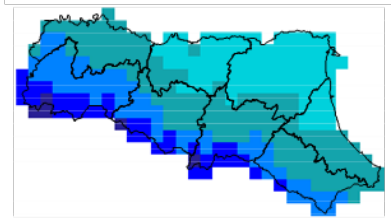
season: autumn

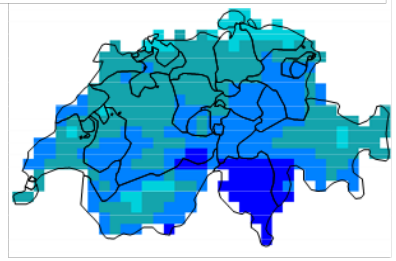
Attributes Diagram
verification period: 2003-2007
threshold: 95-th percentile

lead time: day 2



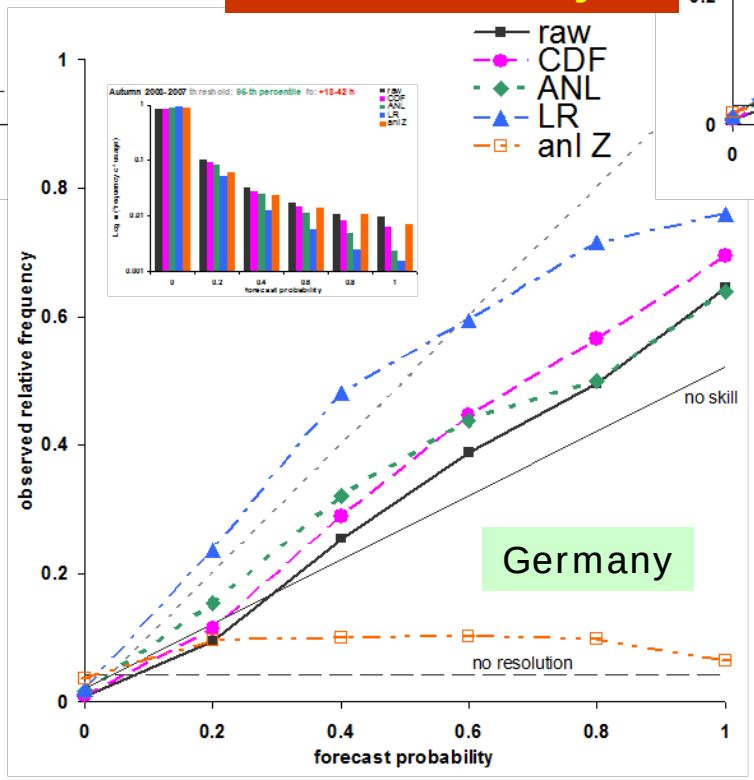


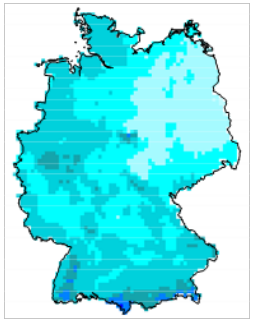




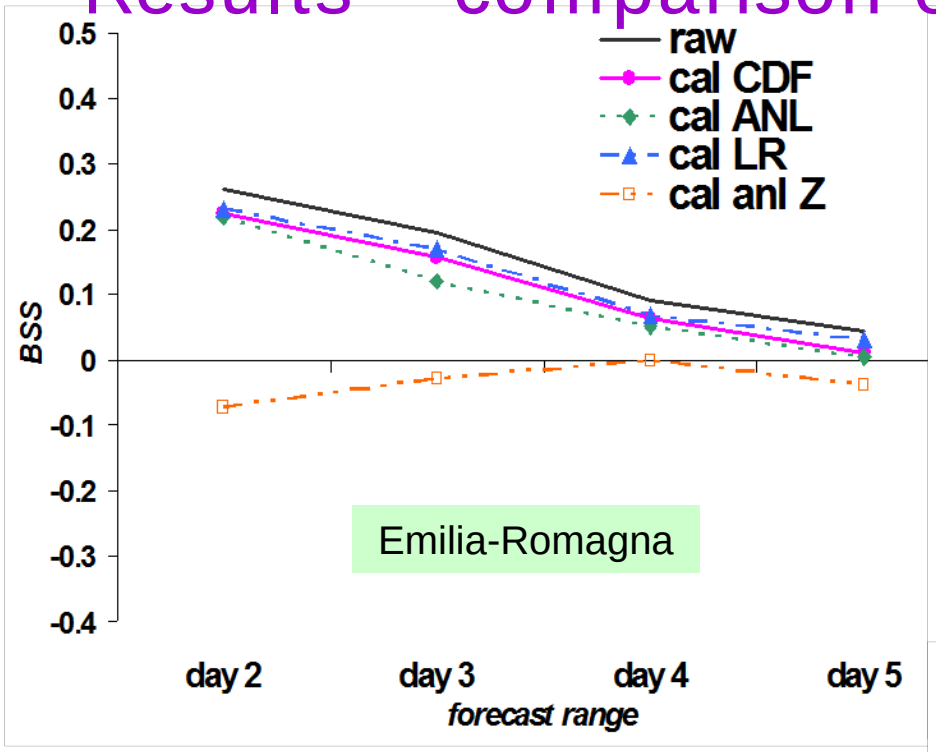
< 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10 - 15
15 - 20
20 - 30
30 - 45
> 45

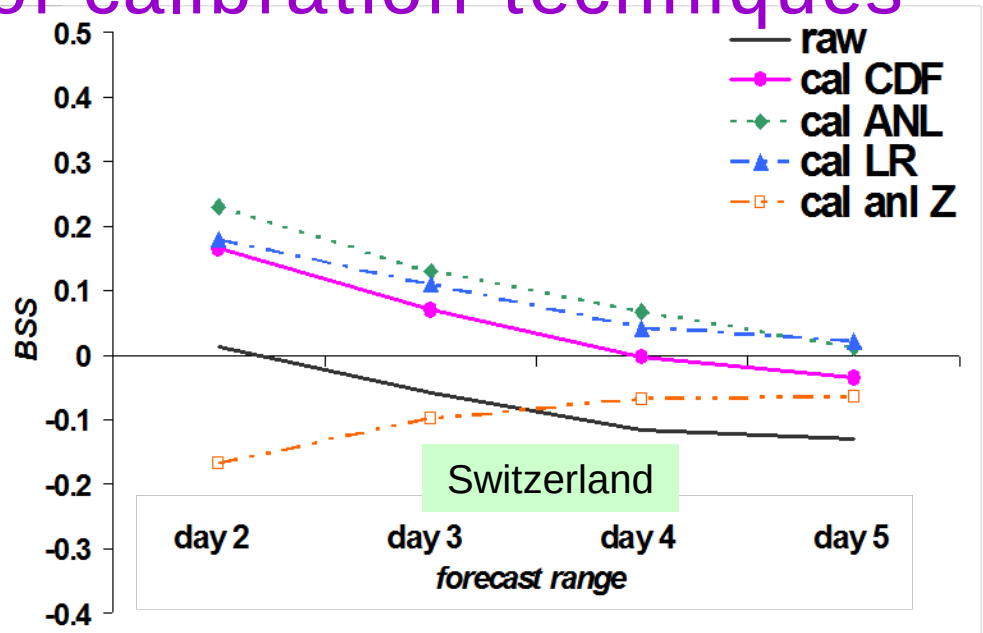
mm / 24h

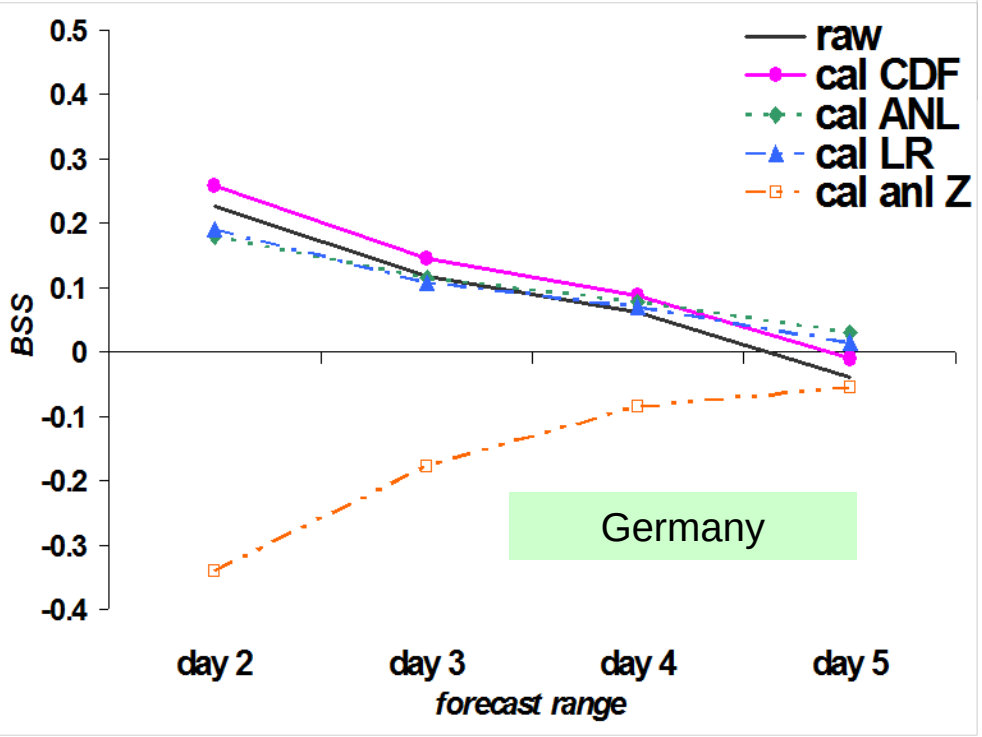




Results – comparison of calibration techniques



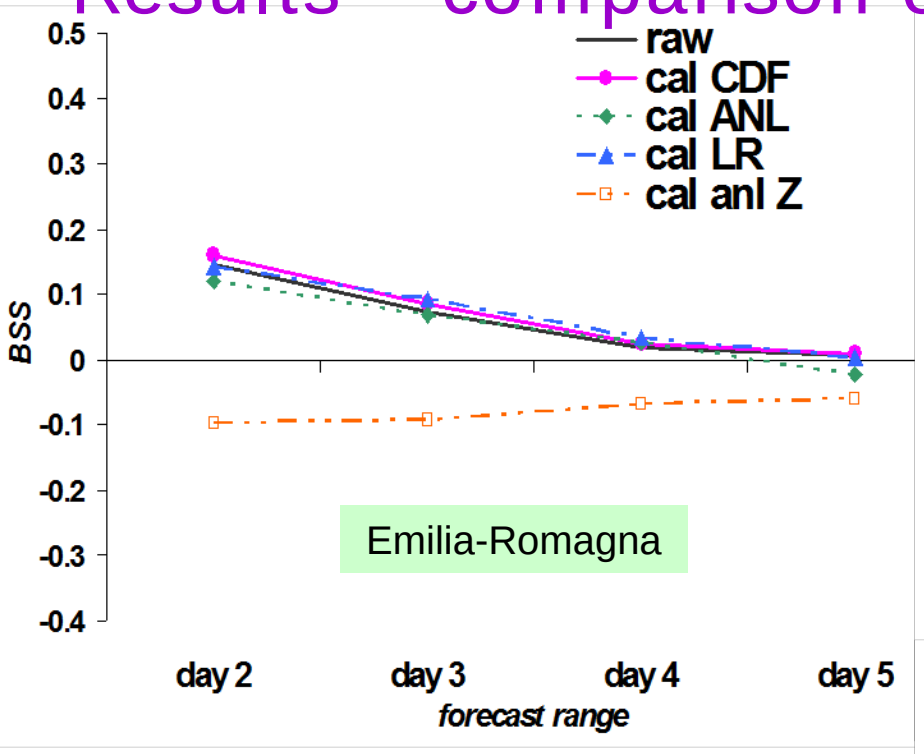


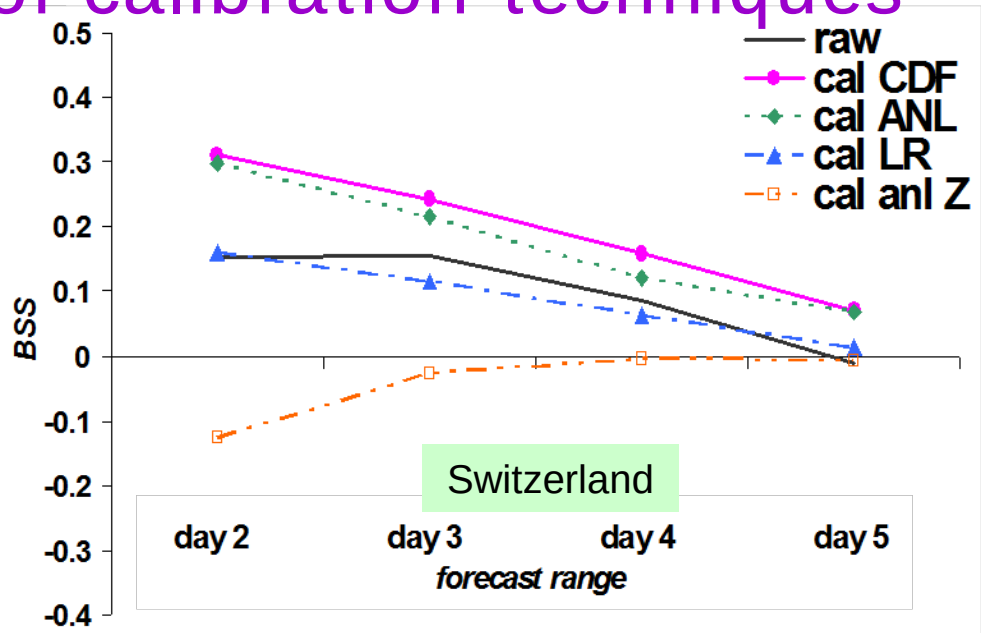


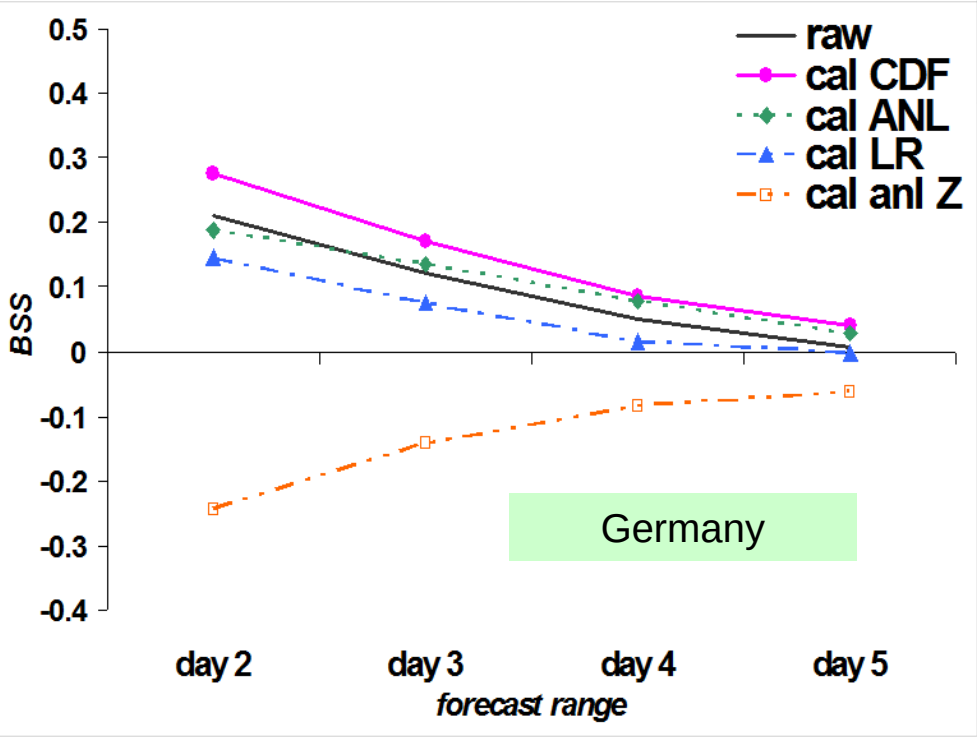
Brier Skill Score
verification period: 2003-2007
season: autumn
threshold: 95-th percentile

- increase of skill over Switzerland and Germany for the ensembles calibrated by CDF, LR and rainfall analogs
- no beneficial impact by calibration over Emilia-Romagna

Results – comparison of calibration techniques







Brier Skill Score
verification period: 2003-2007
season: spring
threshold: 95-th percentile

- increase of skill over Switzerland and Germany for the ensembles calibrated by CDF and rainfall analogs
- slight increase of skill over Emilia-Romagna for the ensembles calibrated by CDF and LR

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model

the coupling strategy

ensemble of TOPKAPI runs driven by COSMO-LEPS

+120 h

autumn & spring 2003 - 2008

every day

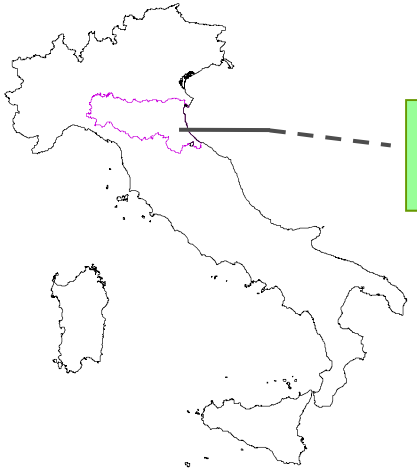
12 UTC

t

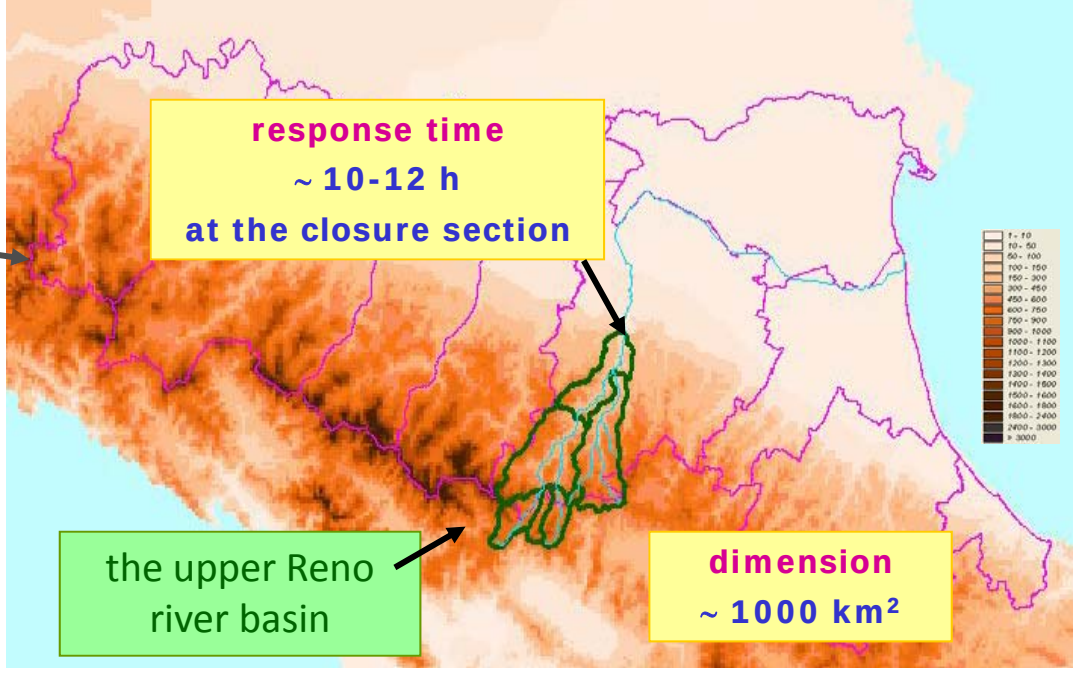
the hydrological model

TOPKAPI
(TOPographic Kinematic APproximation and Integration)
physically-based distributed rainfall-runoff model

the study catchment

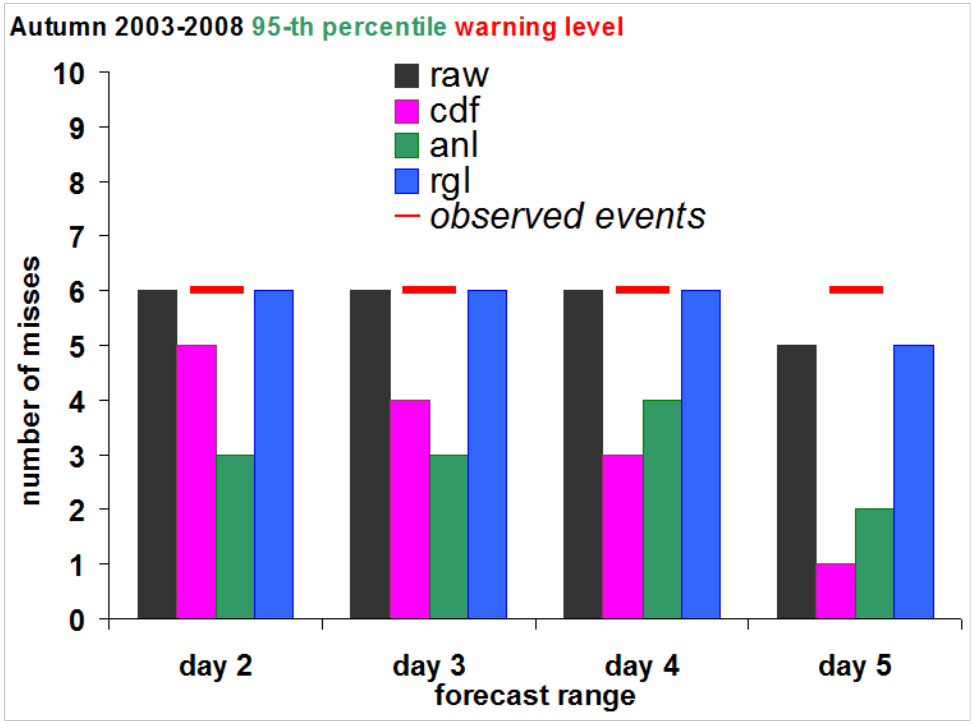


Emilia-Romagna



Verification of the calibration - coupling of COSMO-LEPS with an hydrological model

missed events
verification period: 2003-2008
season: autumn

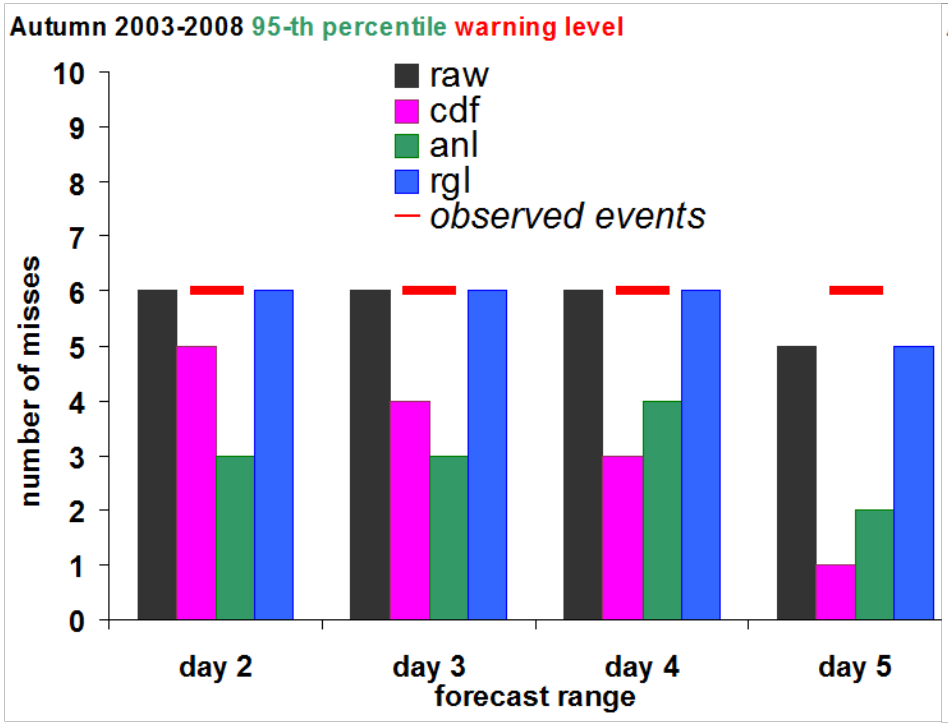


95-th percentile

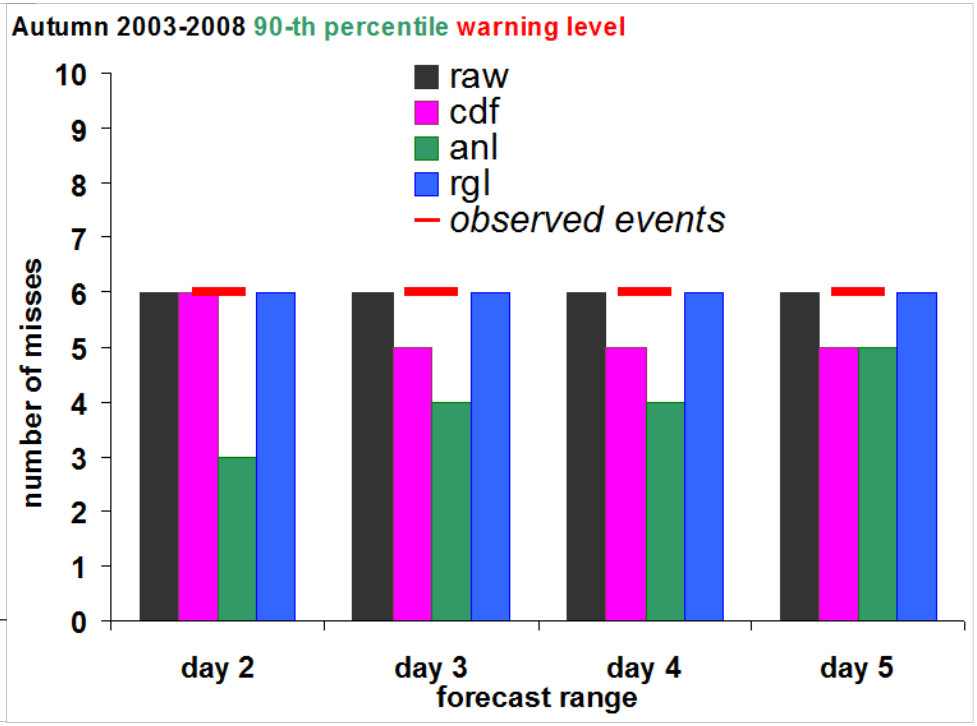
- all the events missed by the raw and LR-calibrated ensembles up to day 4
- reduction of misses for the ensembles calibrated by CDF and rainfall analogs

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model

missed events
verification period: 2003-2008
season: autumn



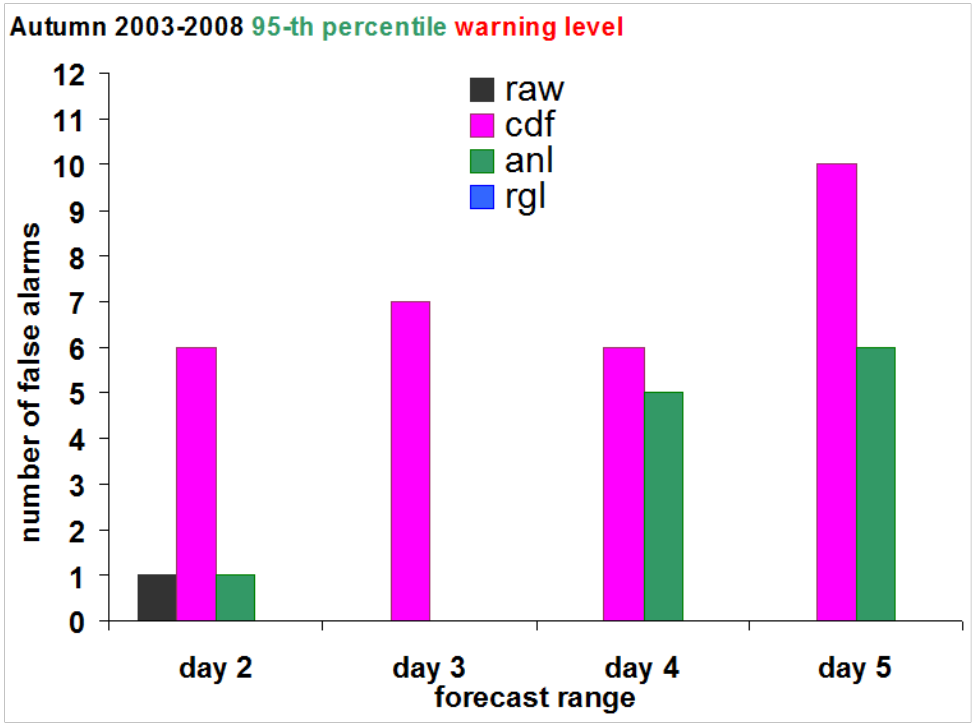
95-th percentile



90-th percentile

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model

false alarms
verification period: 2003-2008
season: autumn

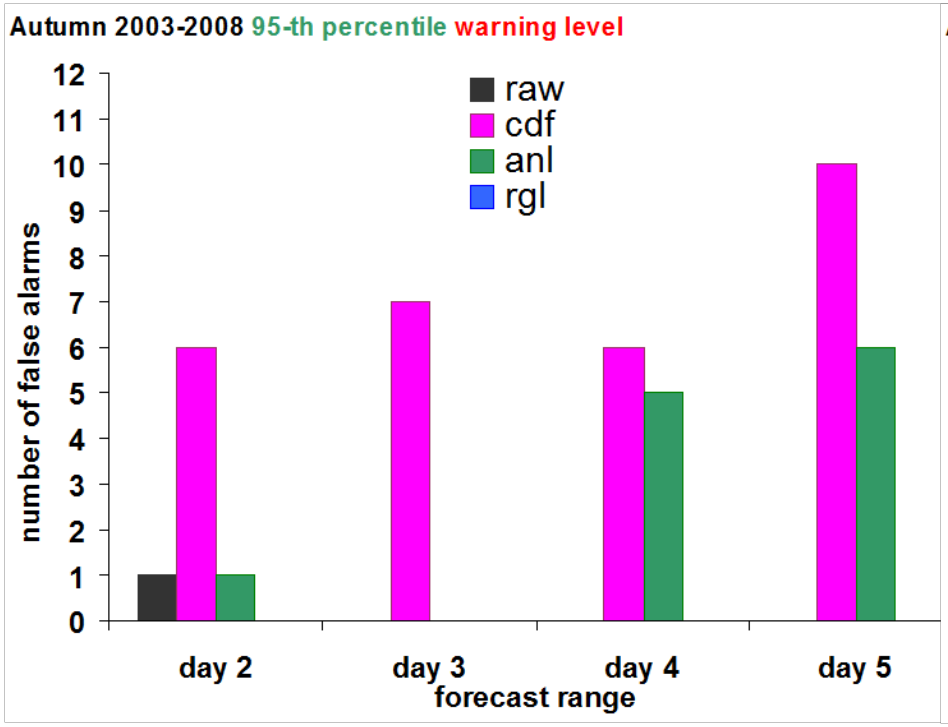


95-th percentile

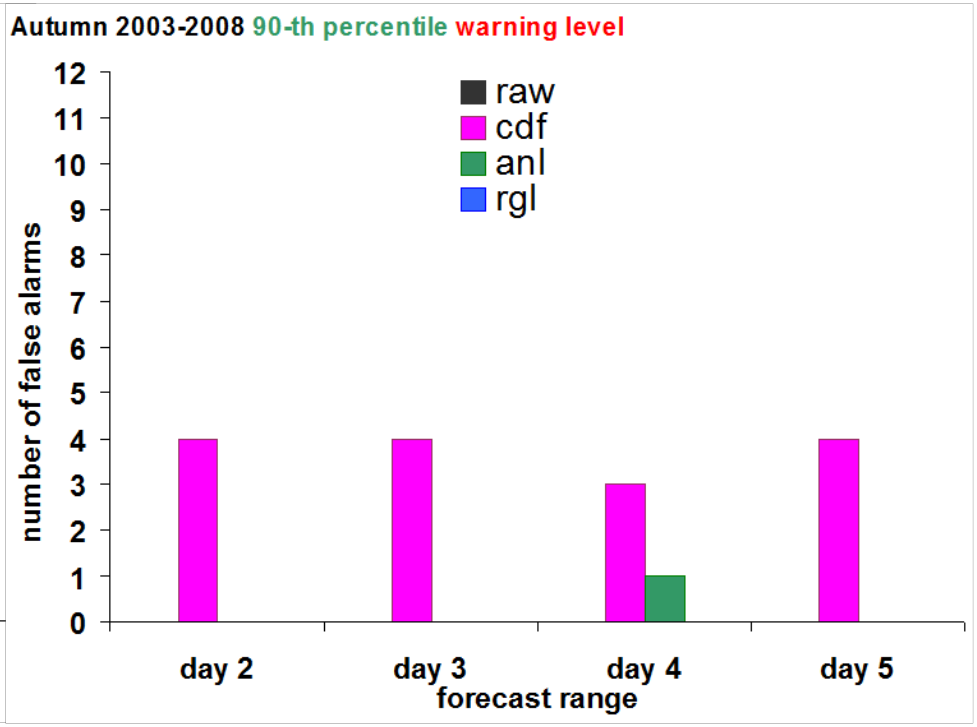
- no false alarms for the raw and LR-calibrated ensembles
- only for longer lead times, increase of false alarms for the ensemble calibrated by rainfall analogs
- many false alarms for the ensemble calibrated by CDF

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model

false alarms
verification period: 2003-2008
season: autumn



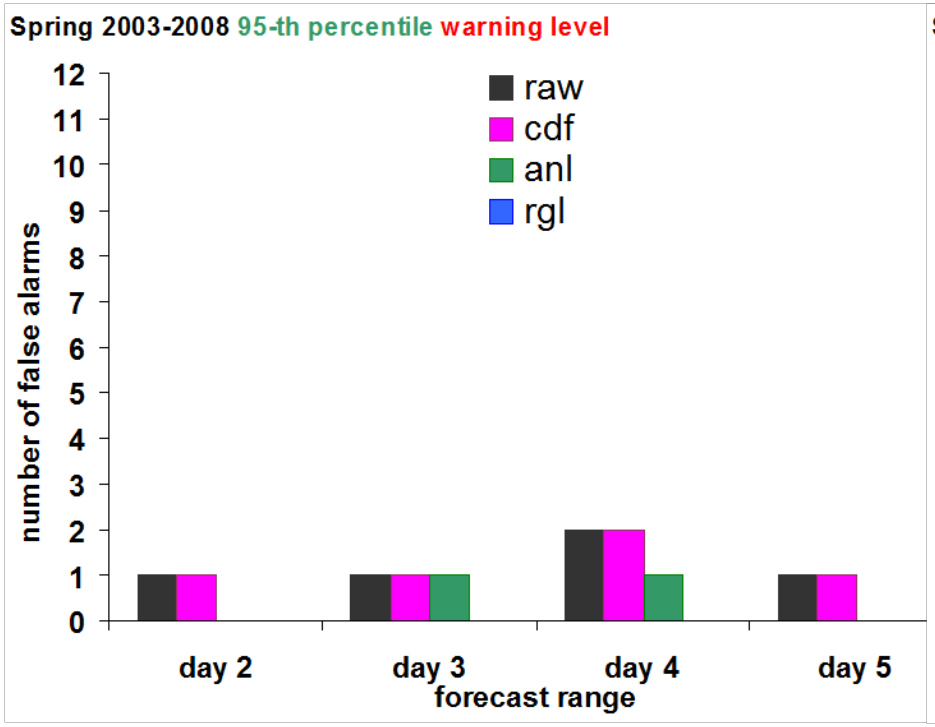
95-th percentile

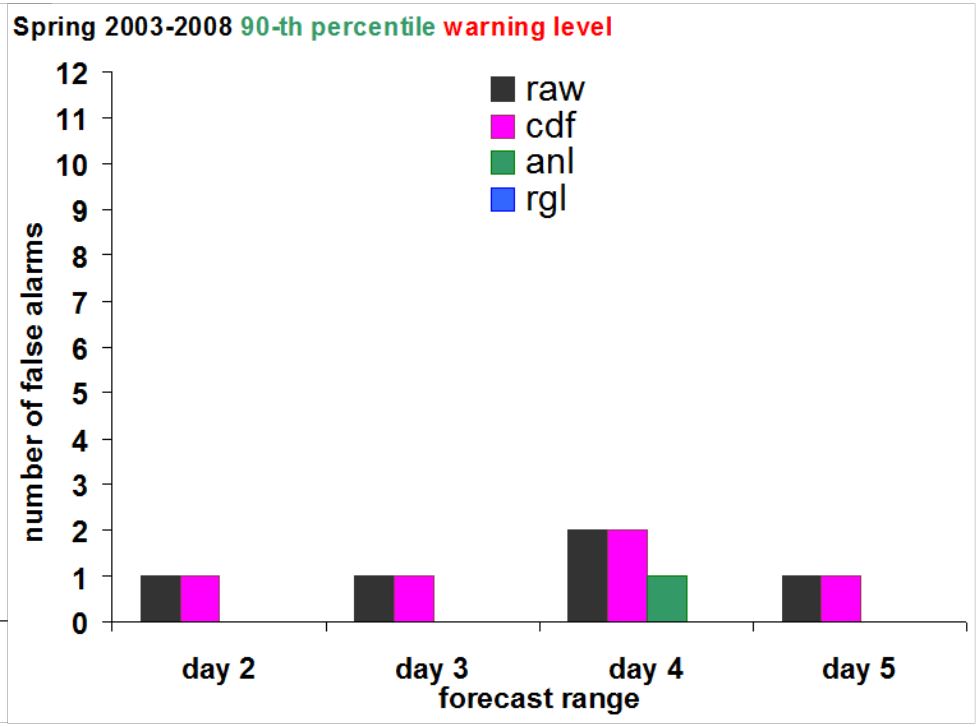


90-th percentile

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model

false alarms
verification period: 2003-2008
season: spring



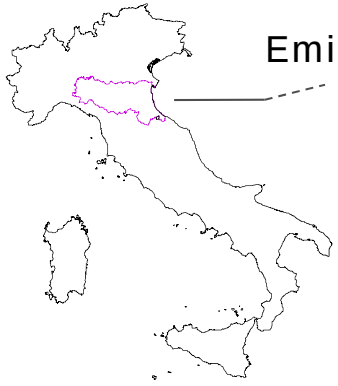


95-th percentile

90-th percentile

- reduction of false alarms for the ensemble calibrated by rainfall analogs
- no increase of false alarms for the ensemble calibrated by CDF

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model



Emilia-Romagna Region

Calcara (Samoggia)

Casalecchio Chiusa (Reno)

Castenaso (Idice)

Sesto Imolese (Sillaro)

Mordano (Santerno)

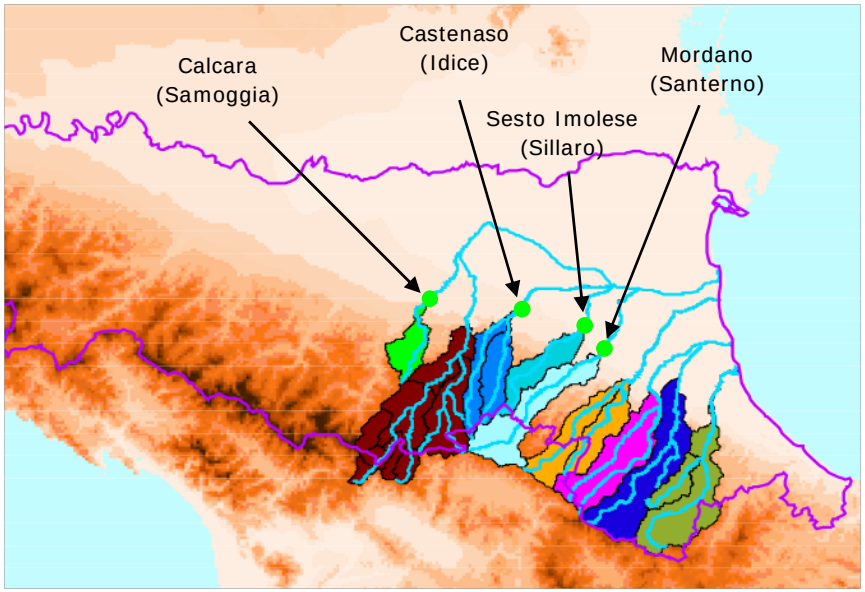
1 - 10
10 - 50
50 - 100
100 - 150
150 - 300
300 - 450
450 - 600
600 - 750
750 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1800
1800 - 2400
2400 - 3000
> 3000

[m]

study area: Reno river sub-basins

catchment dimension
200 - 1000 km²

response time
7-13 h

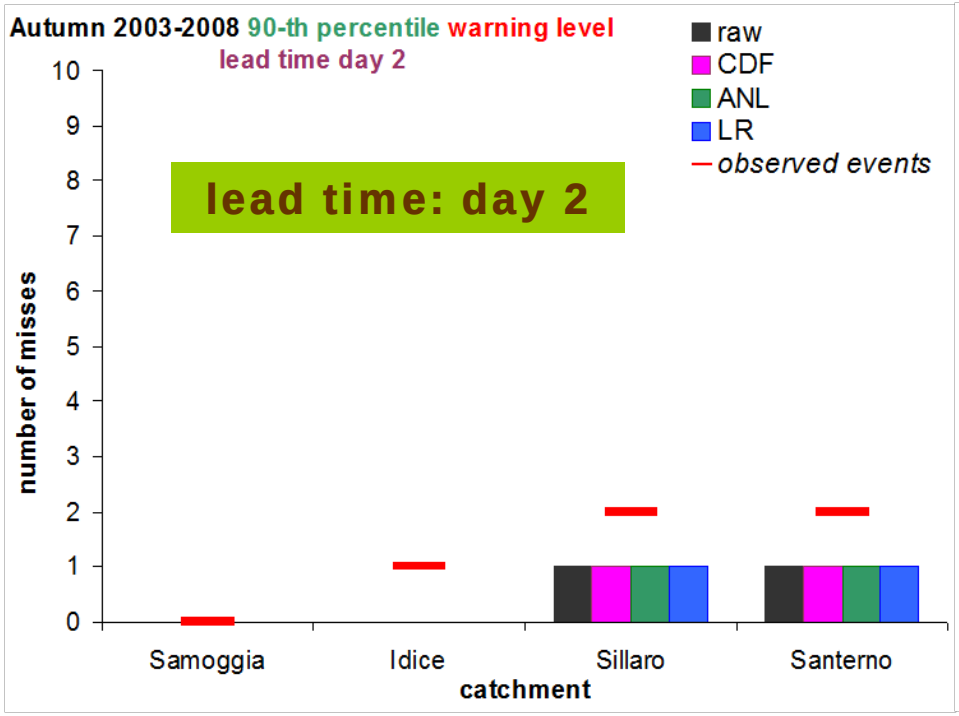


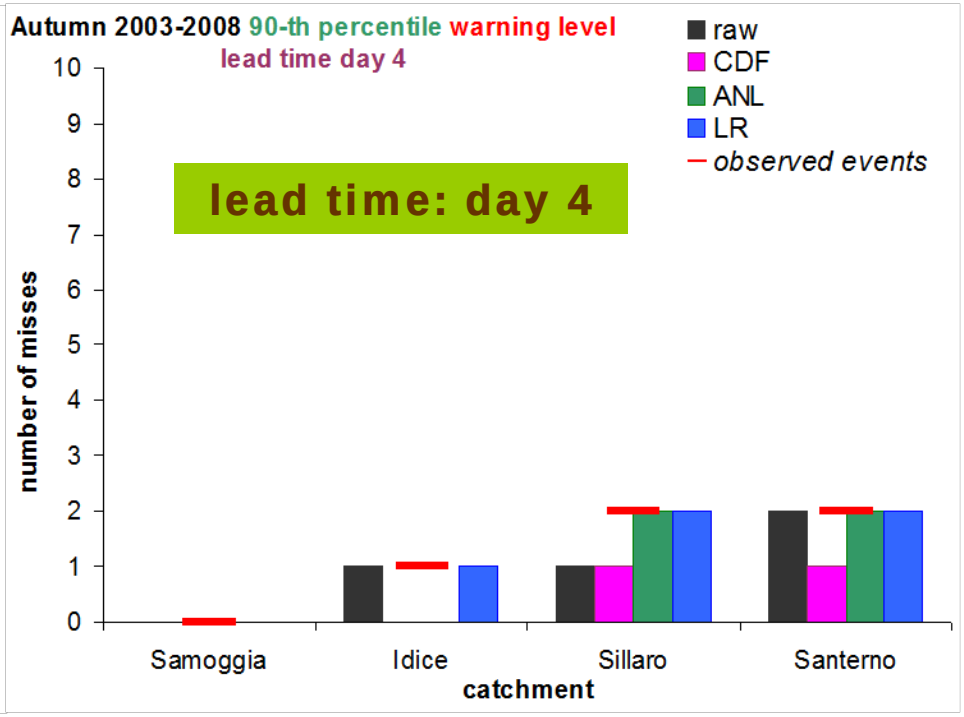
study area:
Reno river sub-basins

missed events

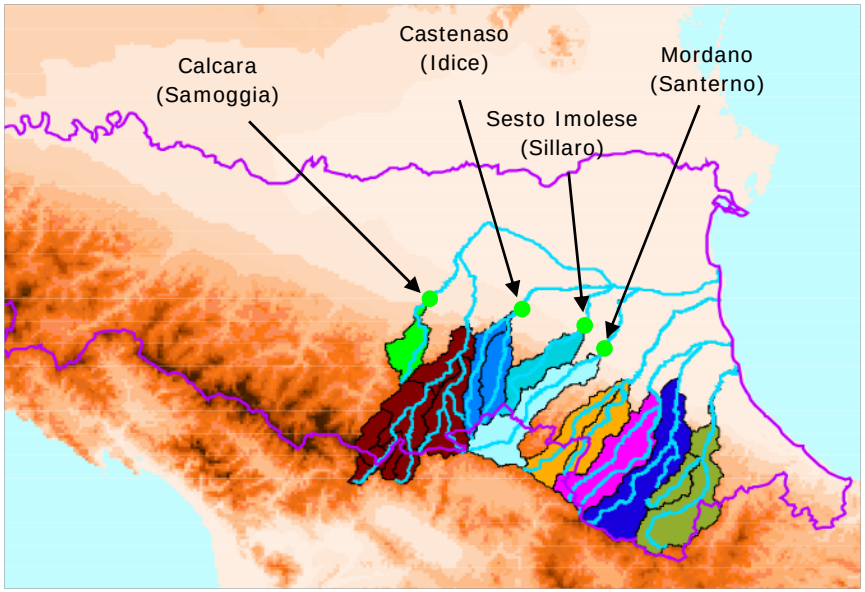
verification period: 2003-2008

season: autumn



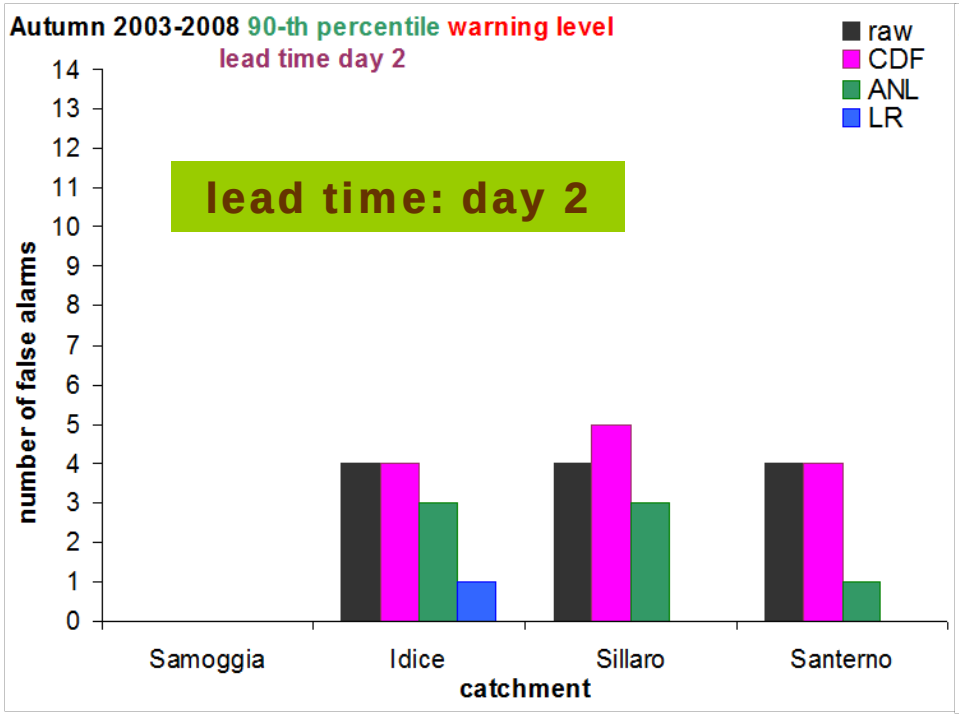


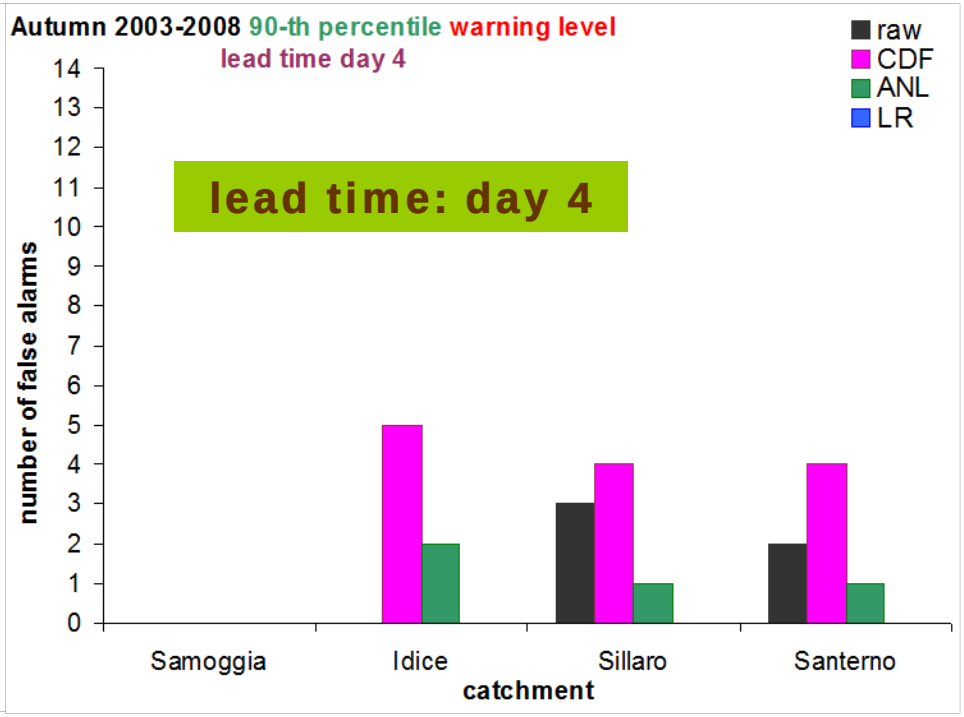
90-th percentile of the discharge ensemble



study area:
Reno river sub-basins

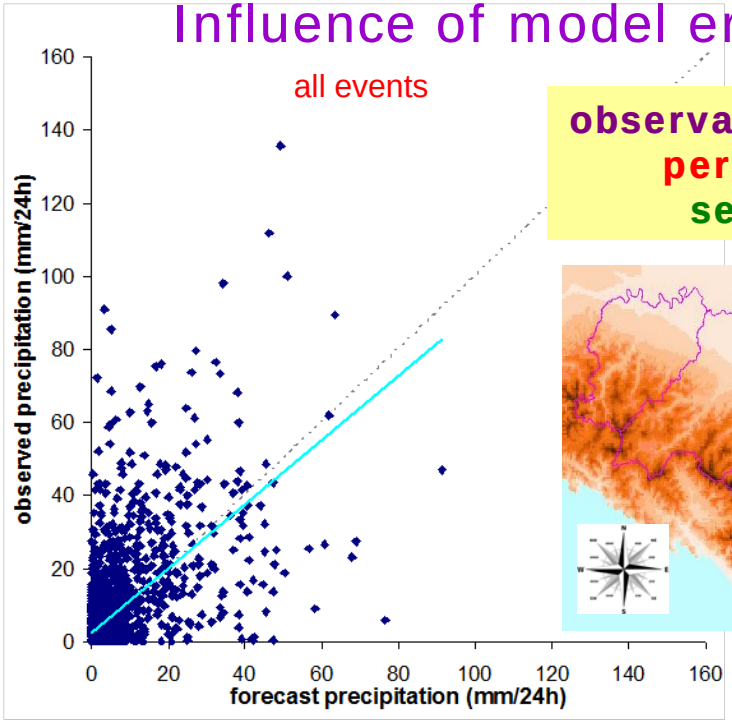
false alarms
verification period: 2003-2008
season: autumn



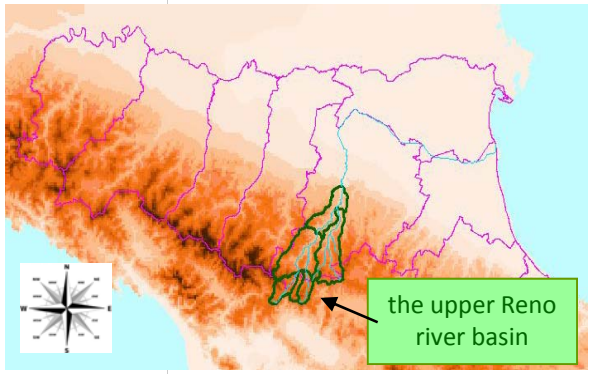


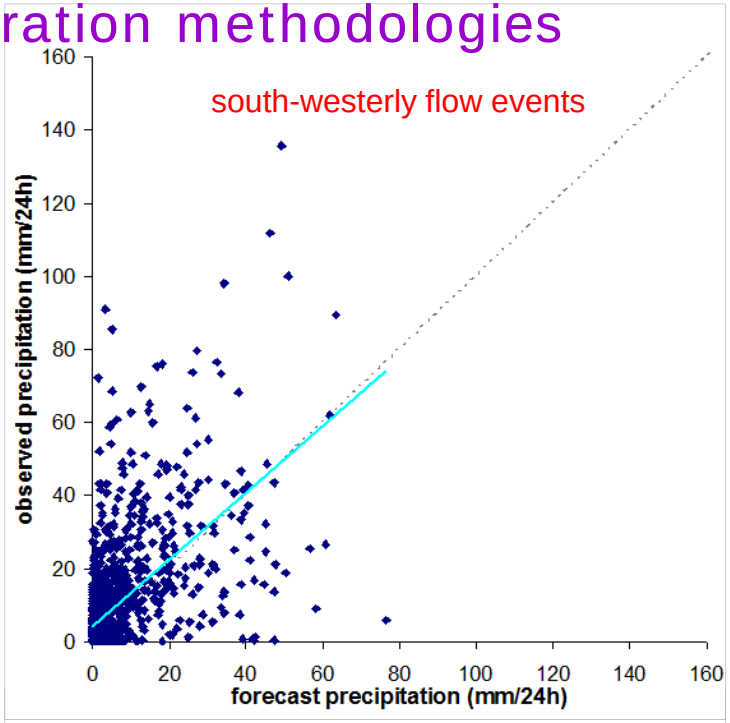
90-th percentile of the discharge ensemble

Influence of model errors on the calibration methodologies



observations vs reforecasts
period: 1971-2000
season: autumn





poor performance for calibration over Emilia-Romagna

⇩

lack of a strong relationship between forecast and observed data

⇩

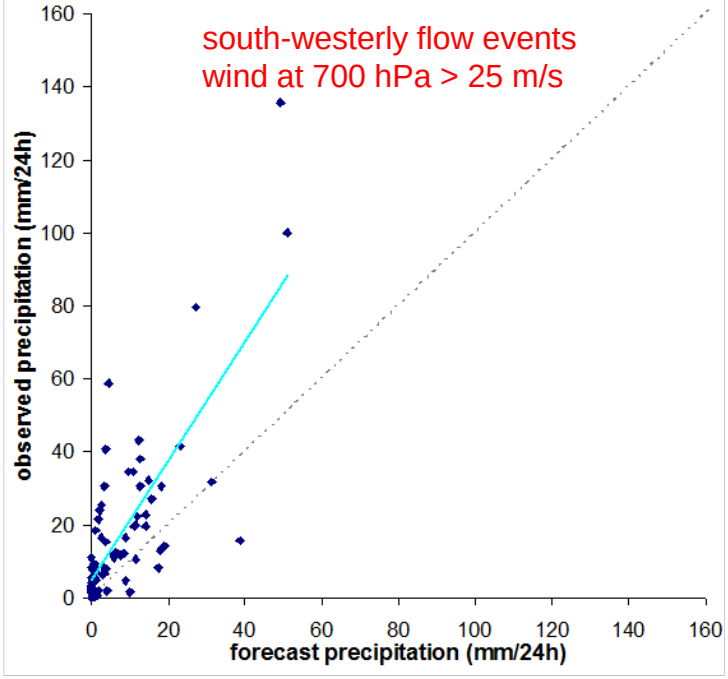
the model error is influenced by
geography, orography and flow direction

⇩

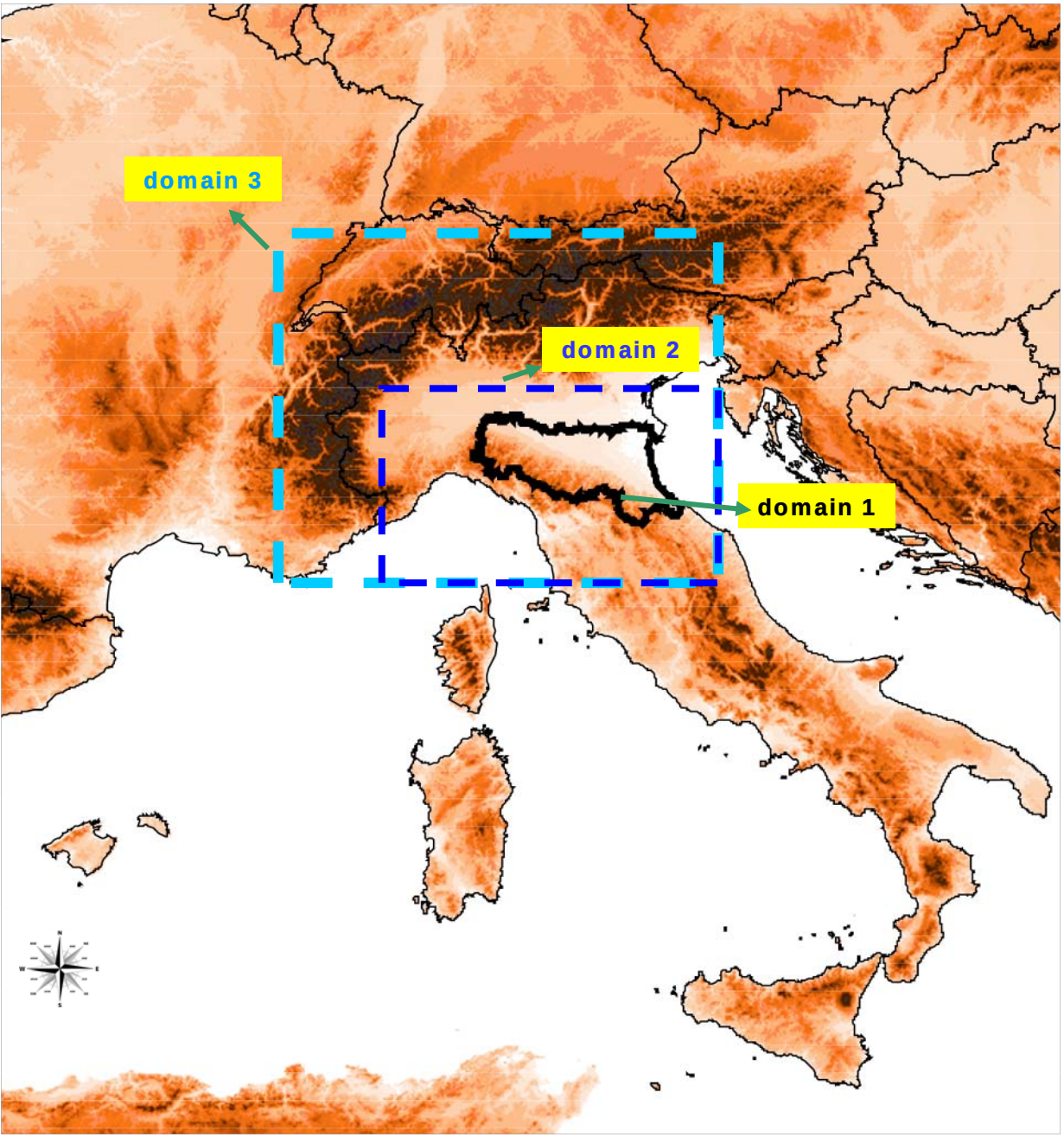
division of the training sample in order to pool data which have similar model errors with respect to a given meteorological situation

⇩

need of generating weather-regime dependent correction functions



Influence of model errors on the calibration methodologies



in case of heavy rainfall events,
overestimation of the precipitation
in upwind areas
in presence of a mountain range,
with a related underestimation
in the downwind regions

⇩

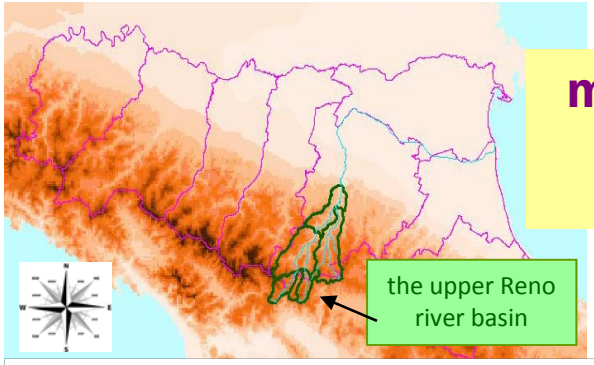
optimization of the spatial domain
used for the analog search
with respect to
the model error structures
of the precipitation field

⇩

test on 3 different spatial domains
for the Emilia-Romagna case study

Influence of model errors on the calibration methodologies

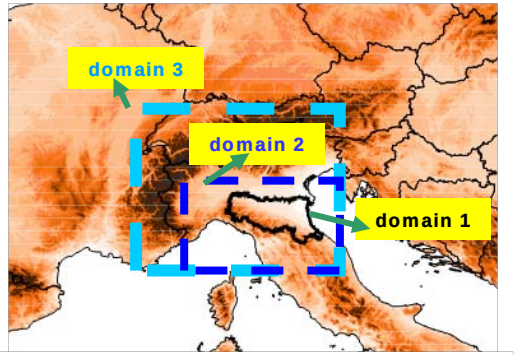
Testing different domain size for the analog search of the rainfall field over ER

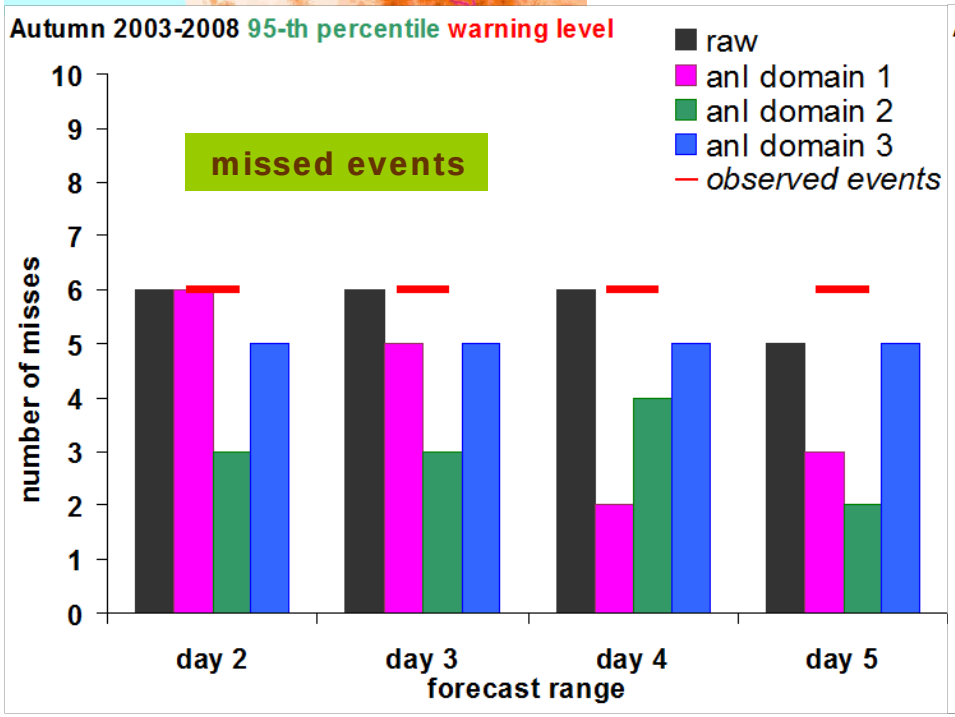


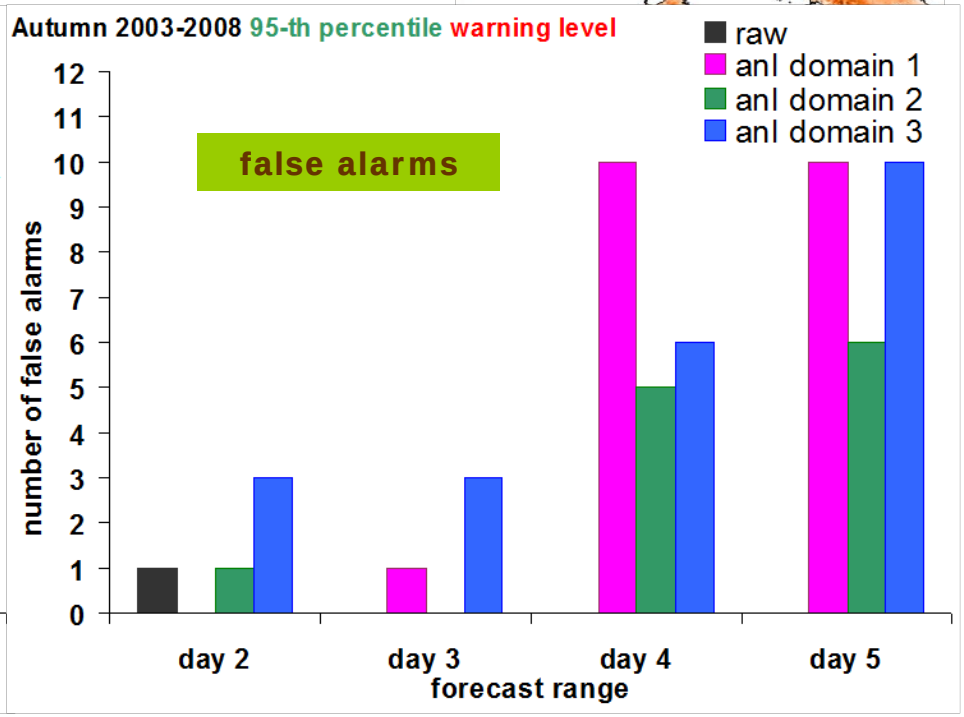
missed events & false alarms

verification period: 2003-2008

season: autumn







95-th percentile of the discharge ensemble

remarkable impact of the size of the spatial domain used for the analog search

Concluding remarks

- The calibration of COSMO-LEPS QPFs provides a beneficial impact over Switzerland and Germany.

- No significant improvements result over Emilia-Romagna from the statistical analysis on the calibrated QPFs, but the coupling with an hydrological model reveals a beneficial impact of calibration on the reduction of missed events for the Reno river basin.

- Need of generating correction functions which are weather-regime dependent in order to improve the performance of the calibration based on Linear Regression and Cumulative Distribution Function.

- The optimal size of the spatial domain used for the search of analogs should be defined taking into account typical model error structures, which depend on the meteorological situation.

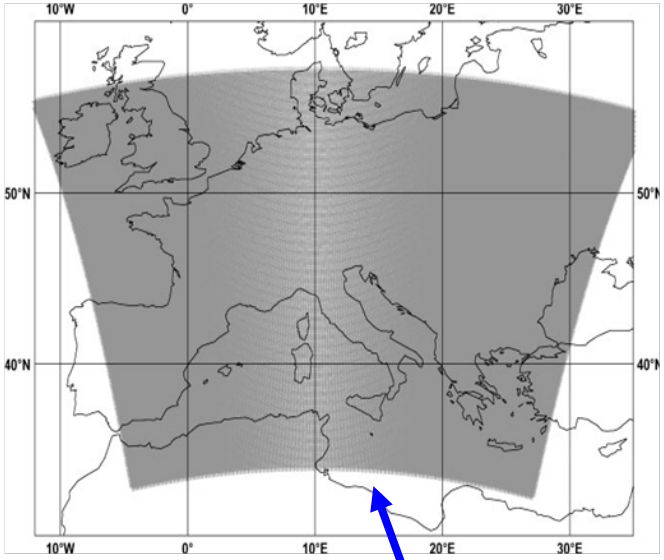
The limited-area ensemble prediction system COSMO-LEPS

configuration of COSMO-LEPS

COSMO-LEPS is based on the non-hydrostatic limited-area model COSMO, daily running (12 UTC) at ECMWF since November 2002.

The different model runs are nested on some selected members of the ECMWF Ensemble Prediction System (EPS), chosen by means of an ensemble-size reduction technique based on a Cluster Analysis algorithm.

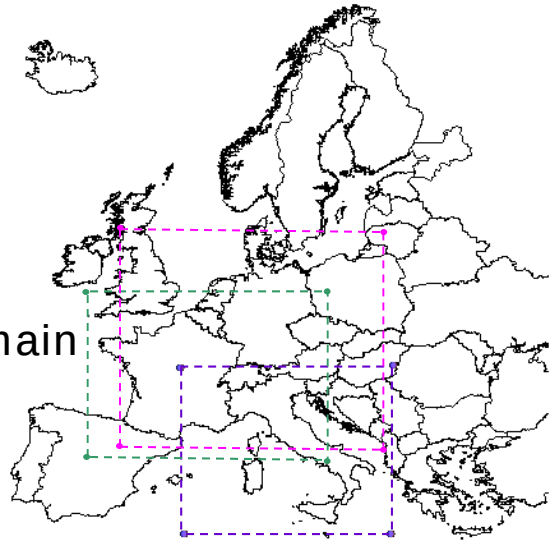
	Nov 2002	summer 2004	summer 2005	spring 2006
boundary conditions	EPS forecasts			
initial conditions	EPS analyses			
deep convection parameterisation	Tiedtke	Tiedtke or Kain-Fritsch (randomly selected)		
horizontal resolution (km)	10			
forecast range (h)	120			132
prognostic treatment of precipitation	no			yes
vertical resolution (layers)	32			40
number of members	5	10		16



spatial domain of COSMO-LEPS

Calibration strategy – methodologies

Analogs upper air field



For each ensemble member and 24-h forecast period:

the analog search is performed in terms of

geoptential at 700 hPA, 12 UTC, over a selected spatial domain

↓

- the root-mean-square (rms) difference between the current forecast and each reforecast is computed, averaged over a sub-sample of the grid points of the selected spatial domain

↓

- the historical date with the smallest rms difference is chosen as the date of the analog, then the past raingauge recordings are used as the calibrated forecast

↓

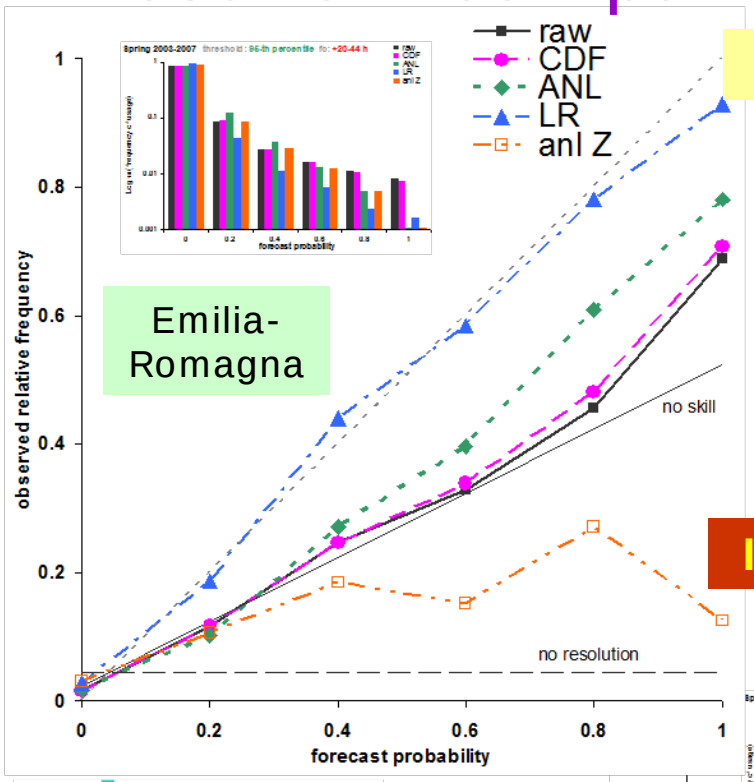
1 analog date for the whole spatial domain

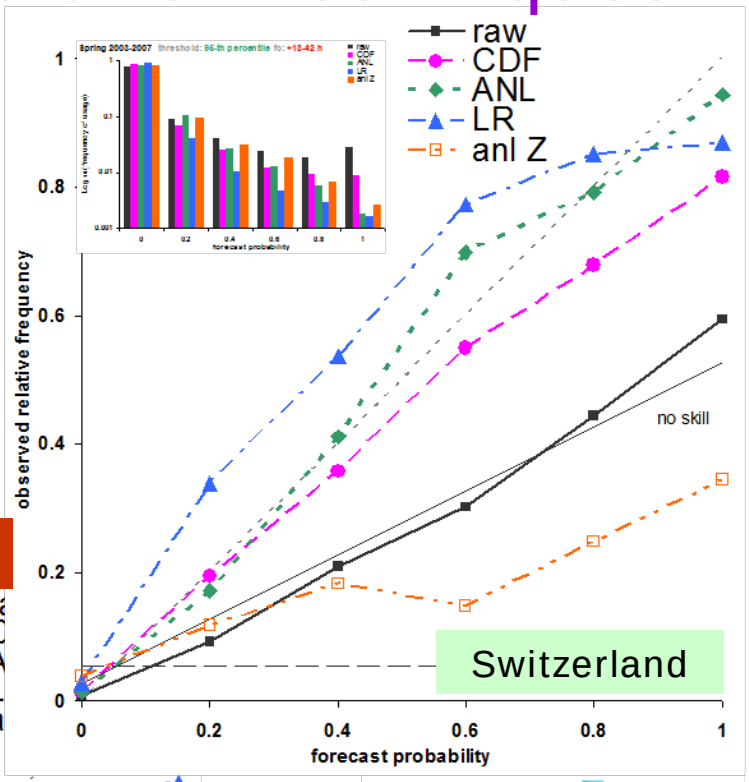
and for each 24-h forecast period

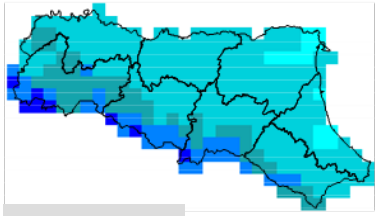
Results – comparison of calibration techniques

season: spring

lead time: day 2

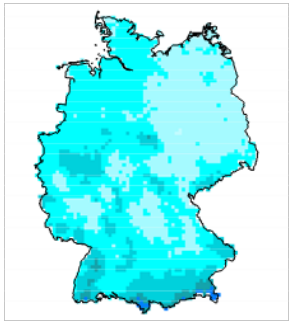


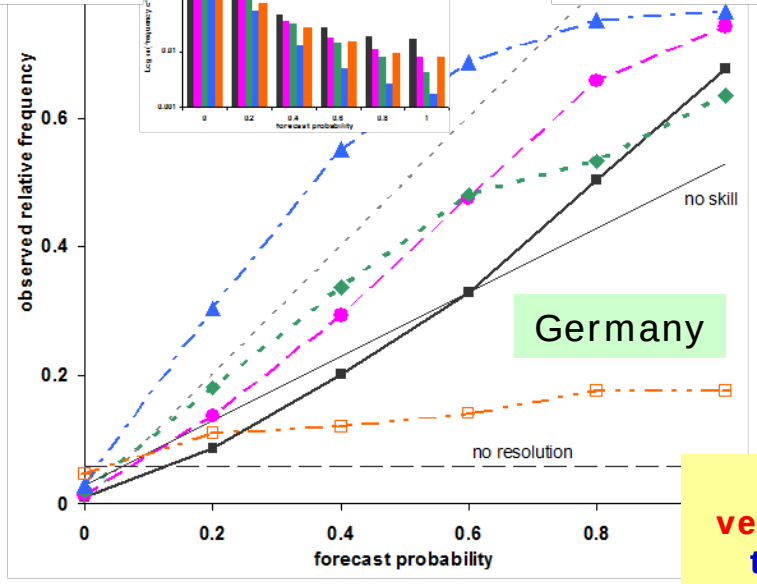


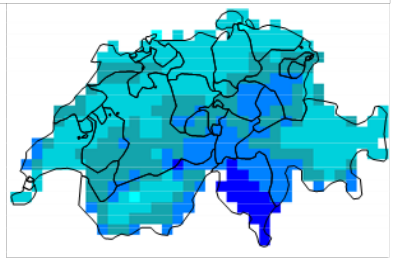


mm / 24h

< 2.5
2.5 - 5
5 - 7.5
7.5 - 10
10 - 15
15 - 20
20 - 30
30 - 45
> 45
No Data

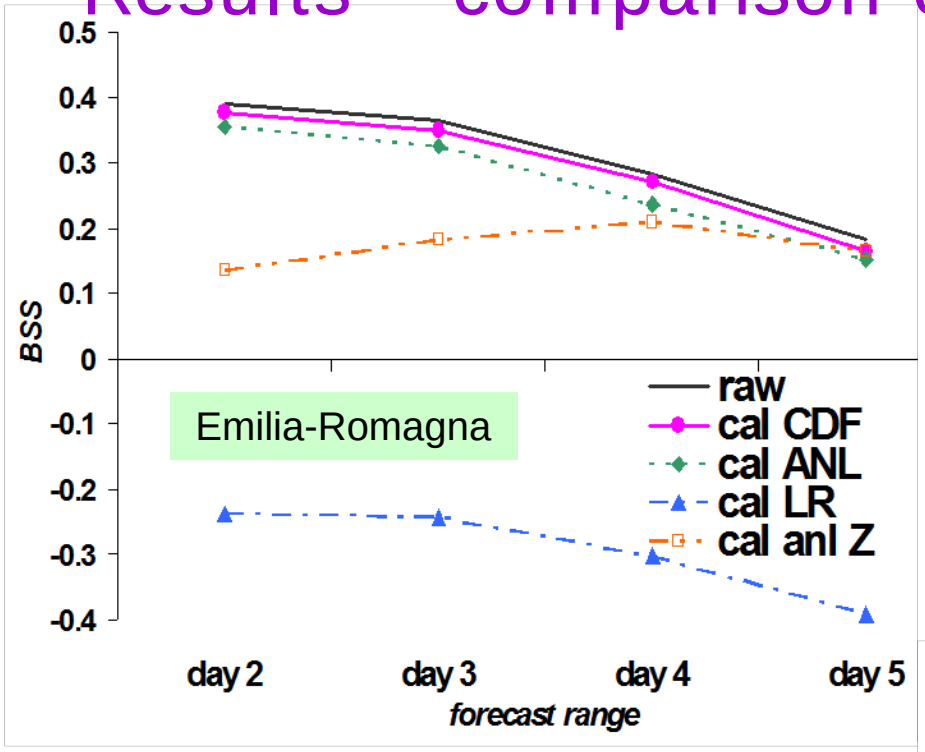


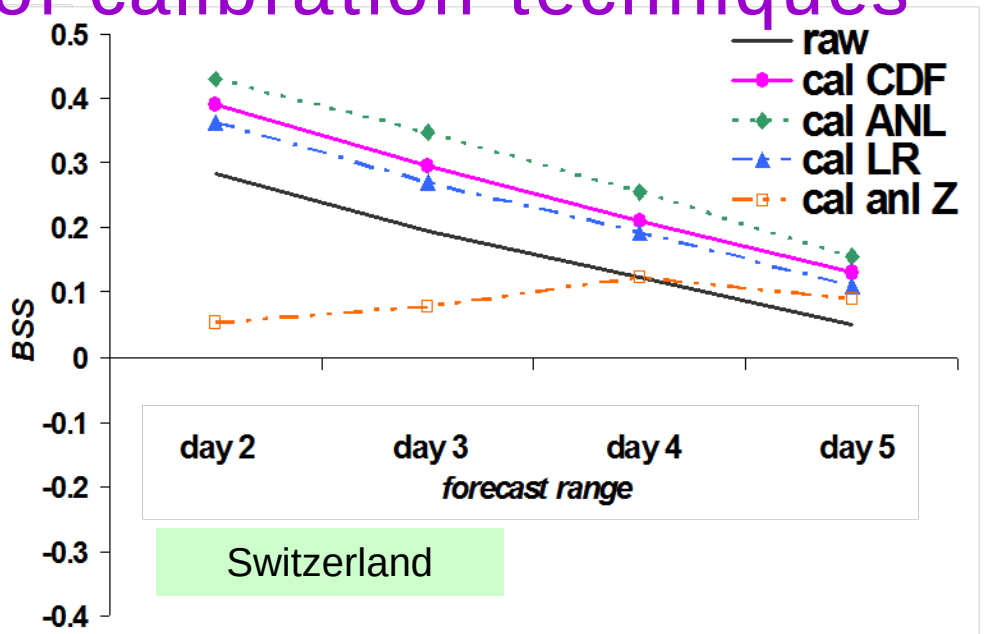


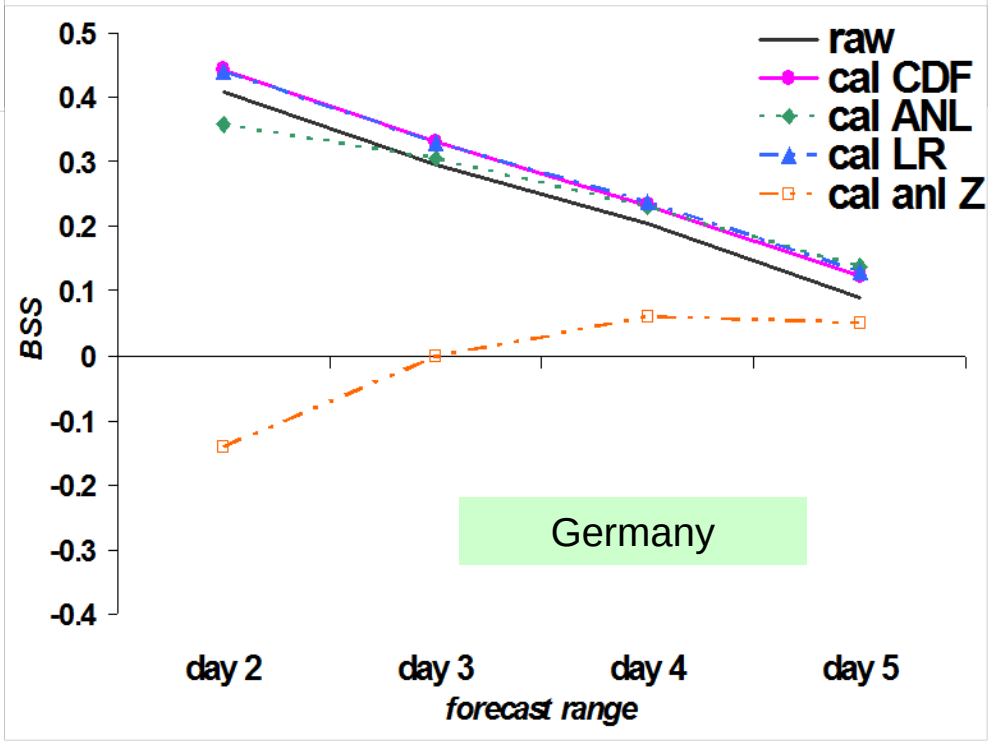


Attributes Diagram
verification period: 2003-2007
threshold: 95-th percentile

Results – comparison of calibration techniques







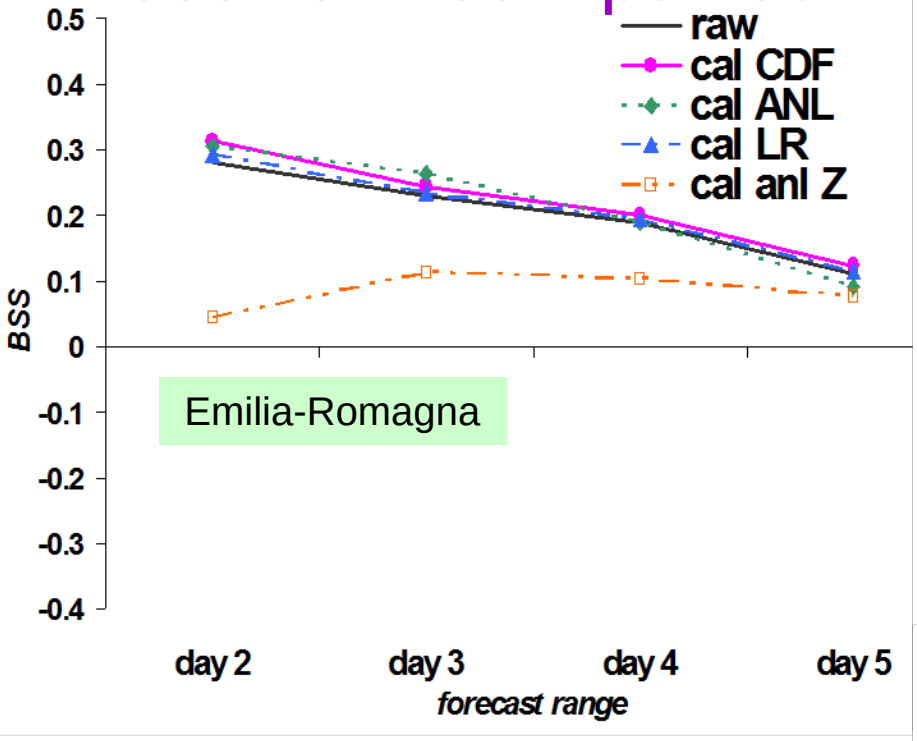
Brier Skill Score

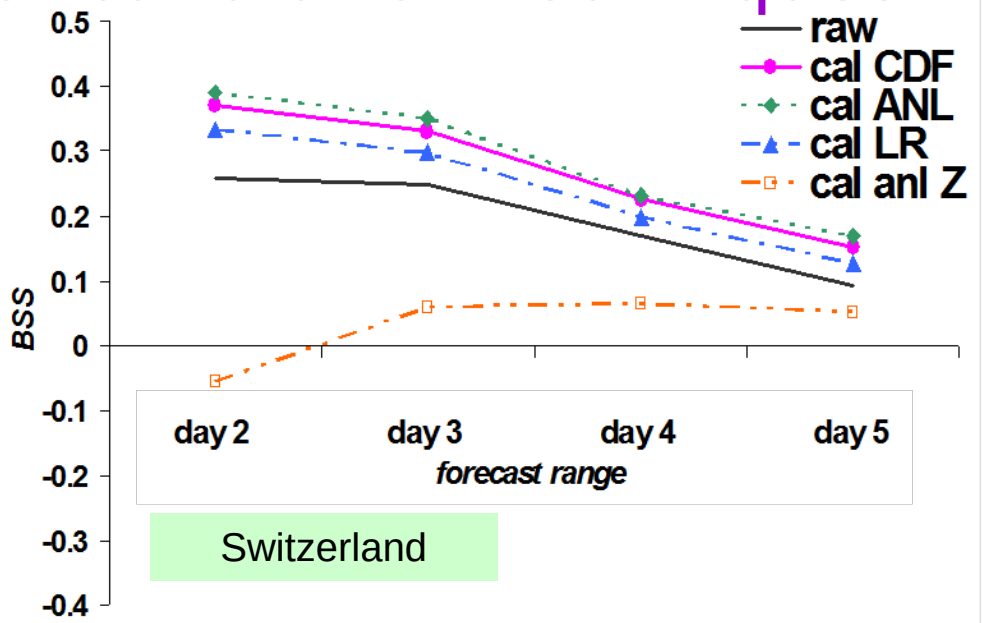
verification period: 2003-2007

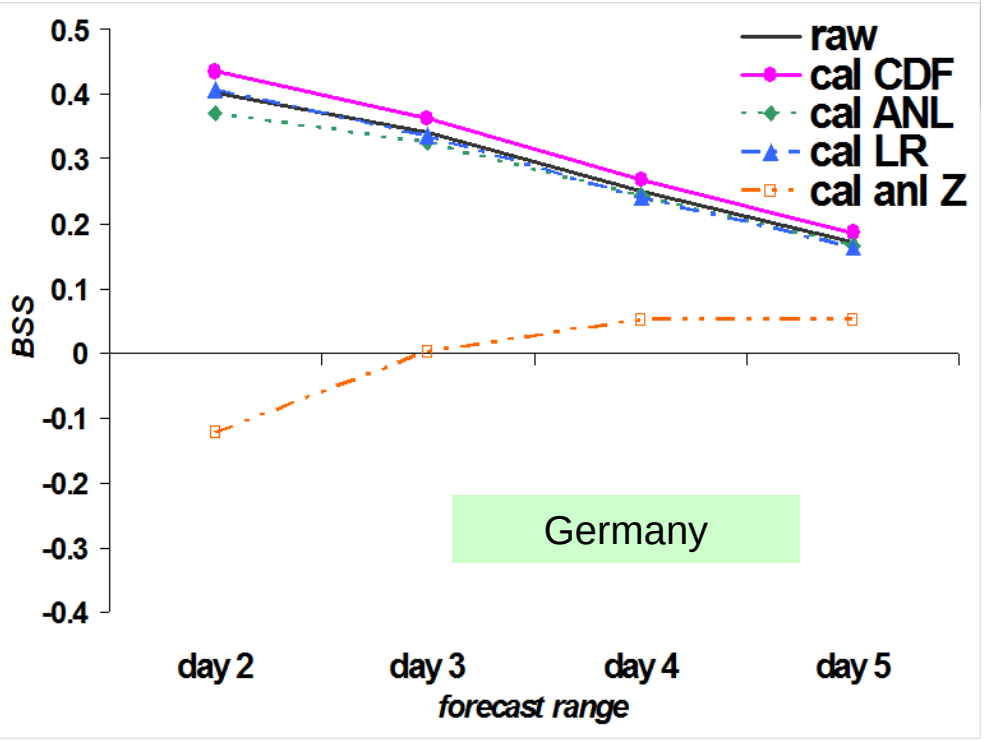
season: autumn

threshold: 80-th percentile

Results – comparison of calibration techniques







Brier Skill Score

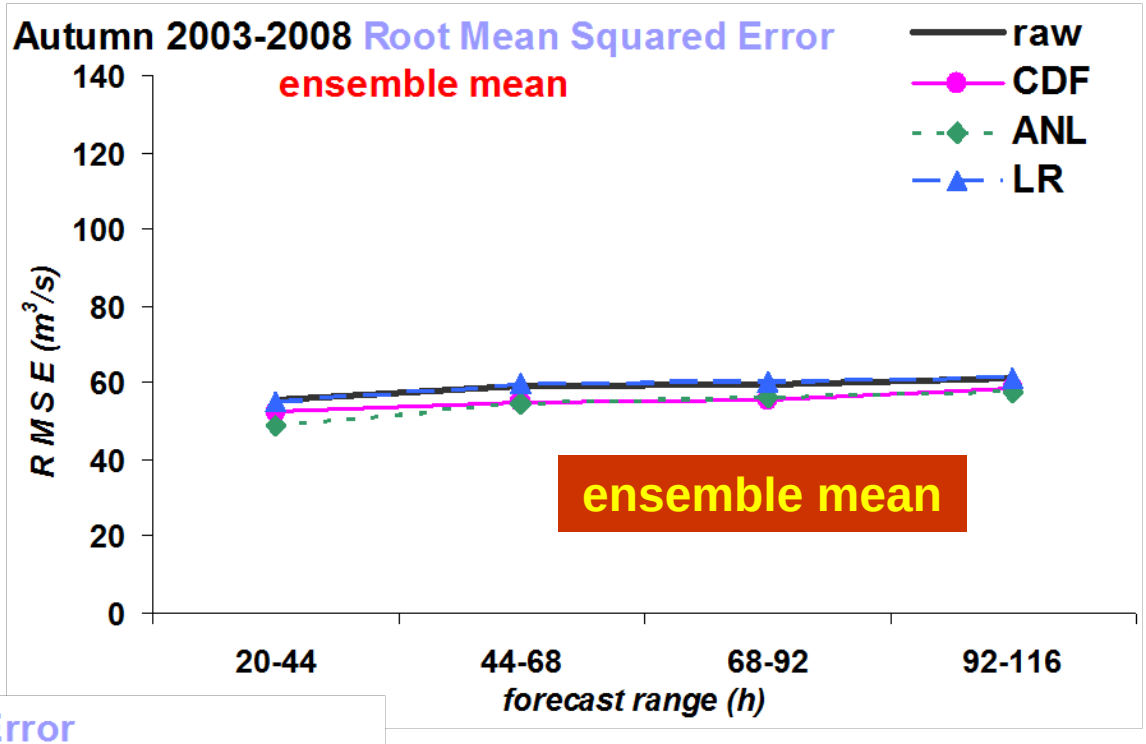
verification period: 2003-2007

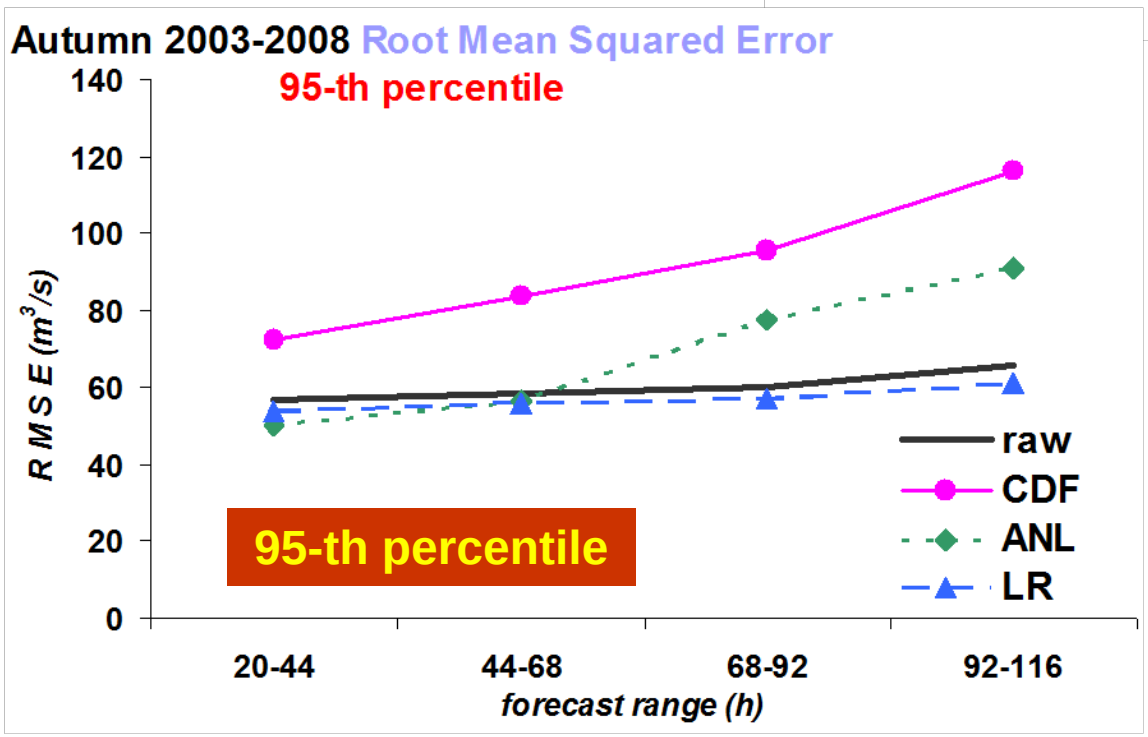
season: spring

threshold: 80-th percentile

season: autumn

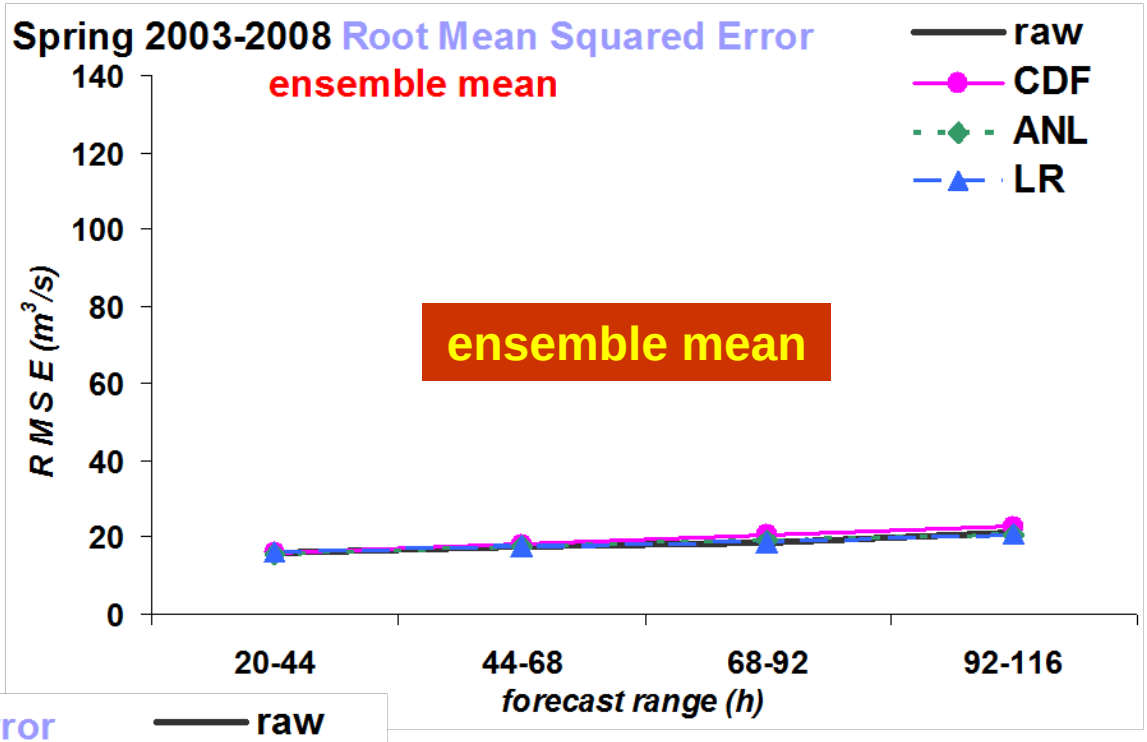
RMSE

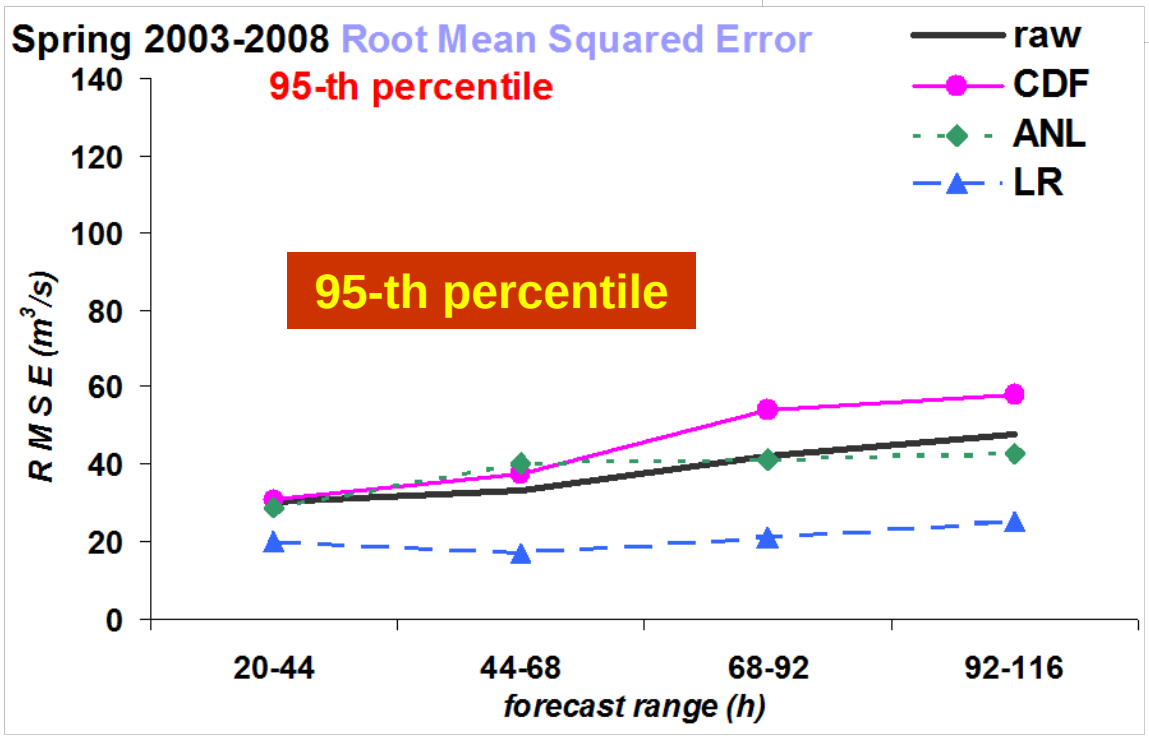




season: spring

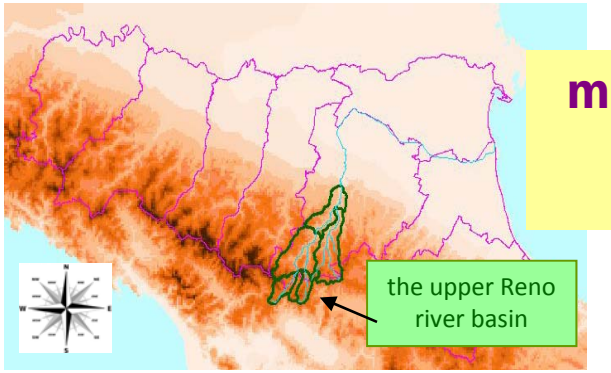
RMSE





Influence of model errors on the calibration methodologies

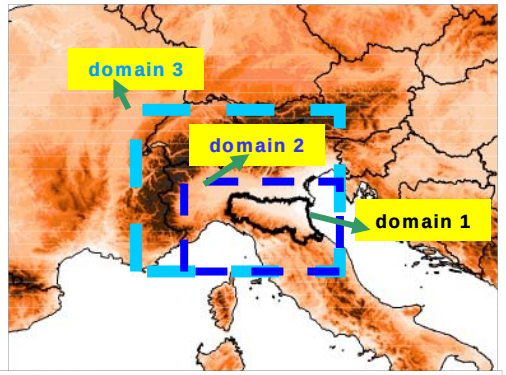
Testing different domain size for the analog search of the rainfall field over ER

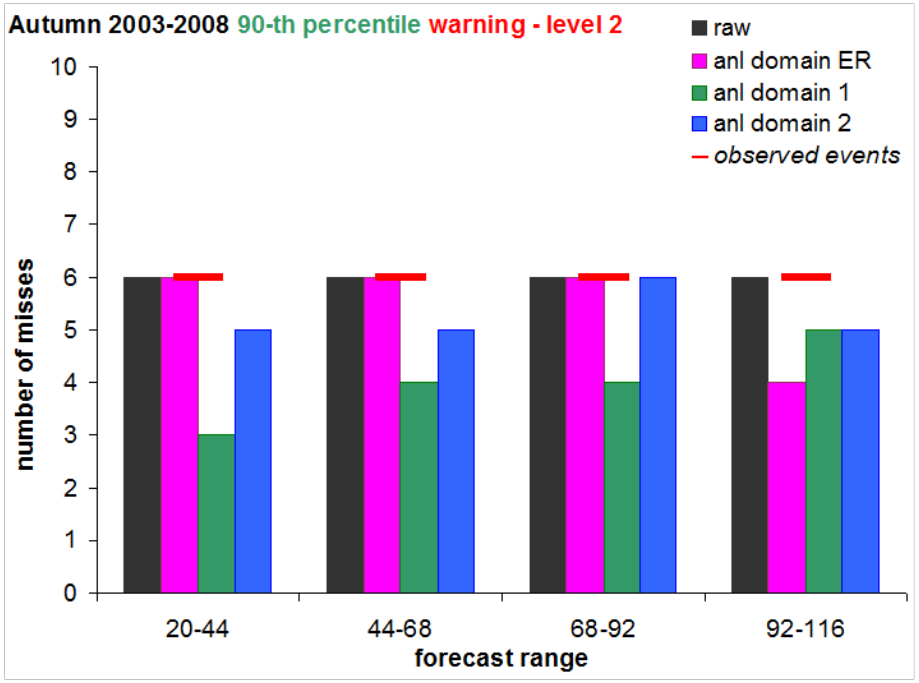


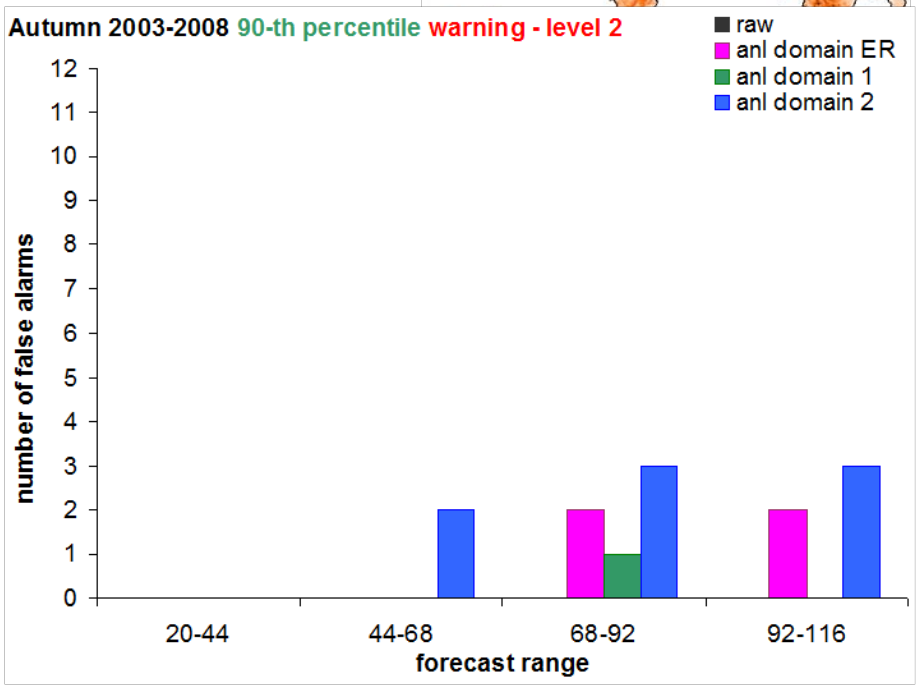
missed events & false alarms

verification period: 2003-2008

season: autumn



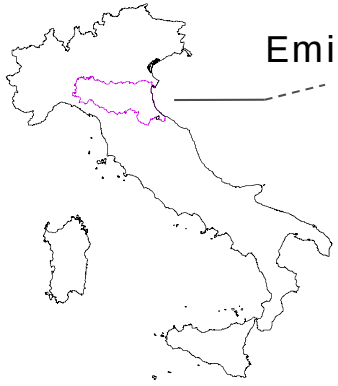




90-th percentile of the discharge ensemble

remarkable impact of the size of the spatial domain used for the analog search

Verification of the calibration - coupling of COSMO-LEPS with an hydrological model



Emilia-Romagna Region

Calcara (Samoggia)

Casalecchio Chiusa (Reno)

Castenaso (Idice)

Sesto Imolese (Sillaro)

Mordano (Santerno)

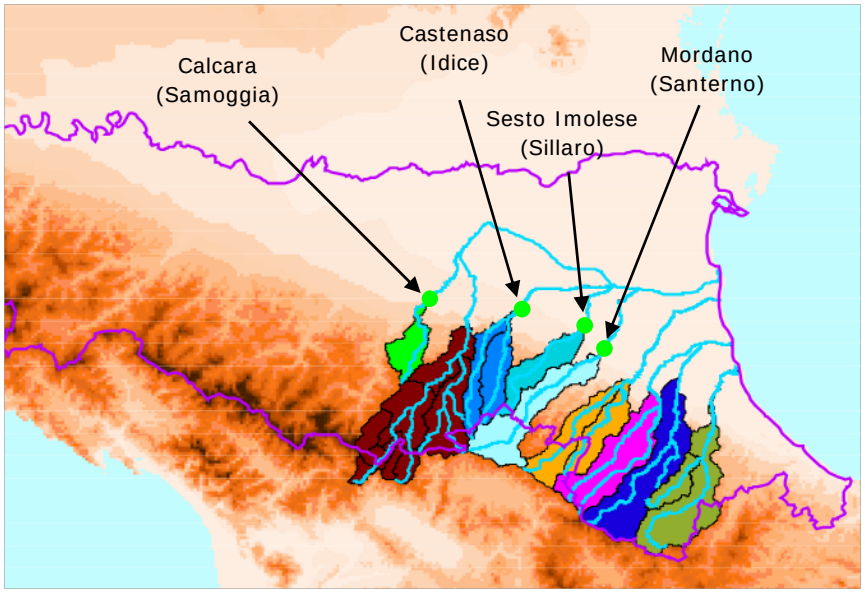
1 - 10
10 - 50
50 - 100
100 - 150
150 - 300
300 - 450
450 - 600
600 - 750
750 - 900
900 - 1000
1000 - 1100
1100 - 1200
1200 - 1300
1300 - 1400
1400 - 1500
1500 - 1600
1600 - 1800
1800 - 2400
2400 - 3000
> 3000

[m]

study area: Reno river sub-basins

catchment dimension
200 - 1000 km²

response time
7-13 h

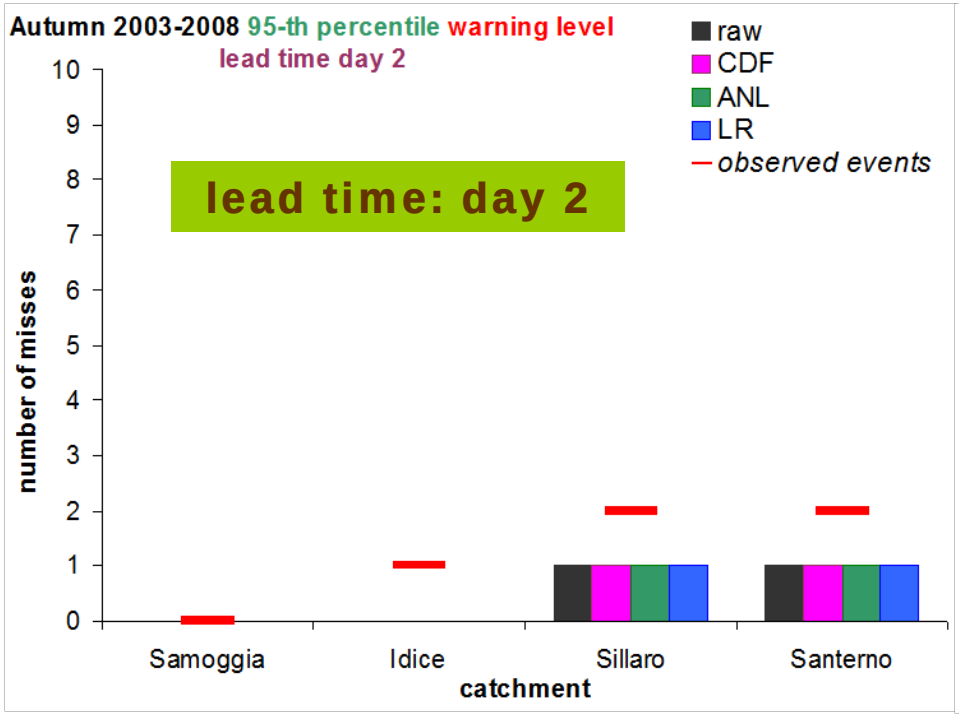


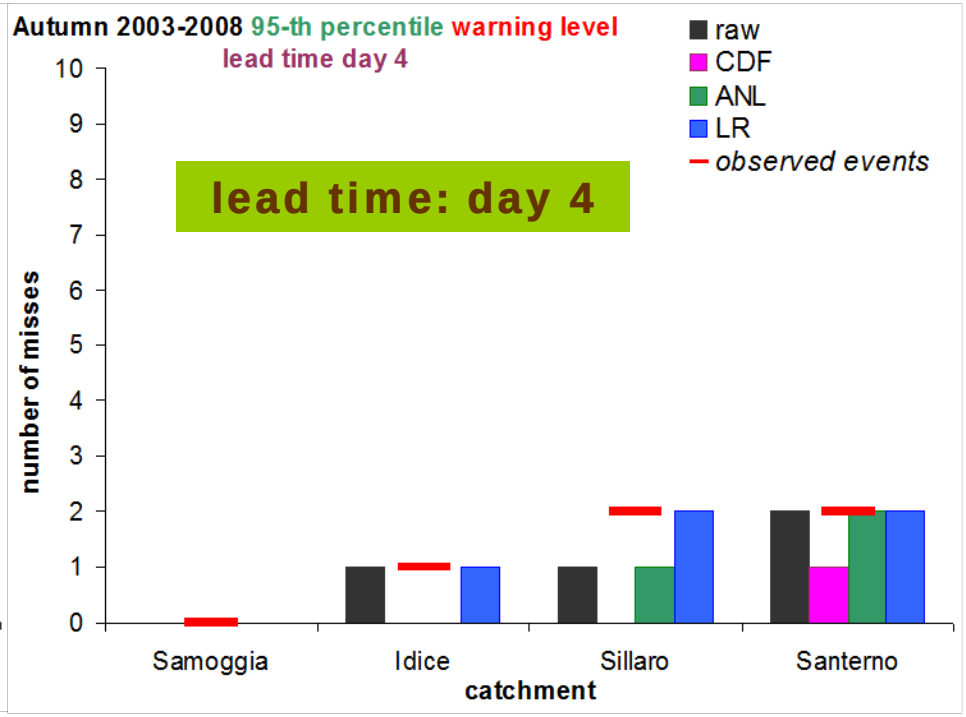
study area:
Reno river sub-basins

missed events

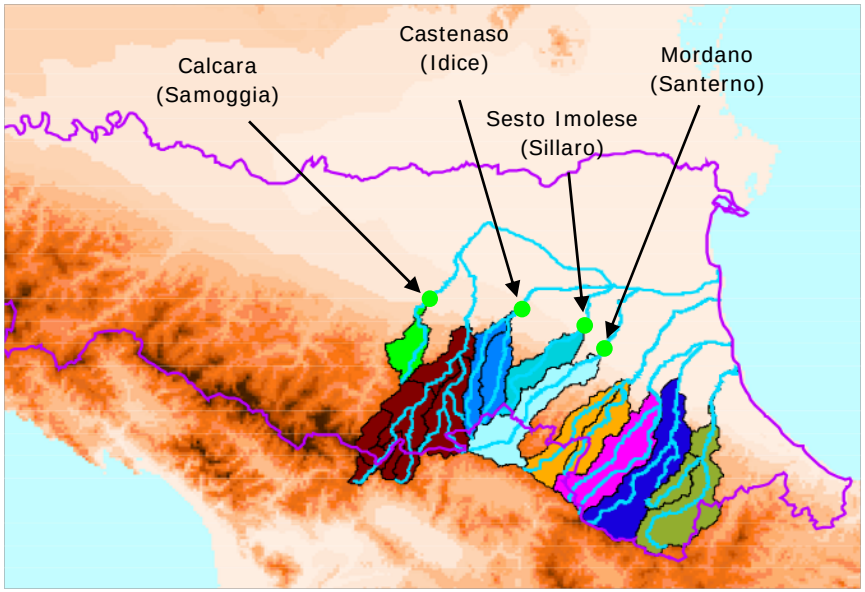
verification period: 2003-2008

season: autumn





95-th percentile of the discharge ensemble

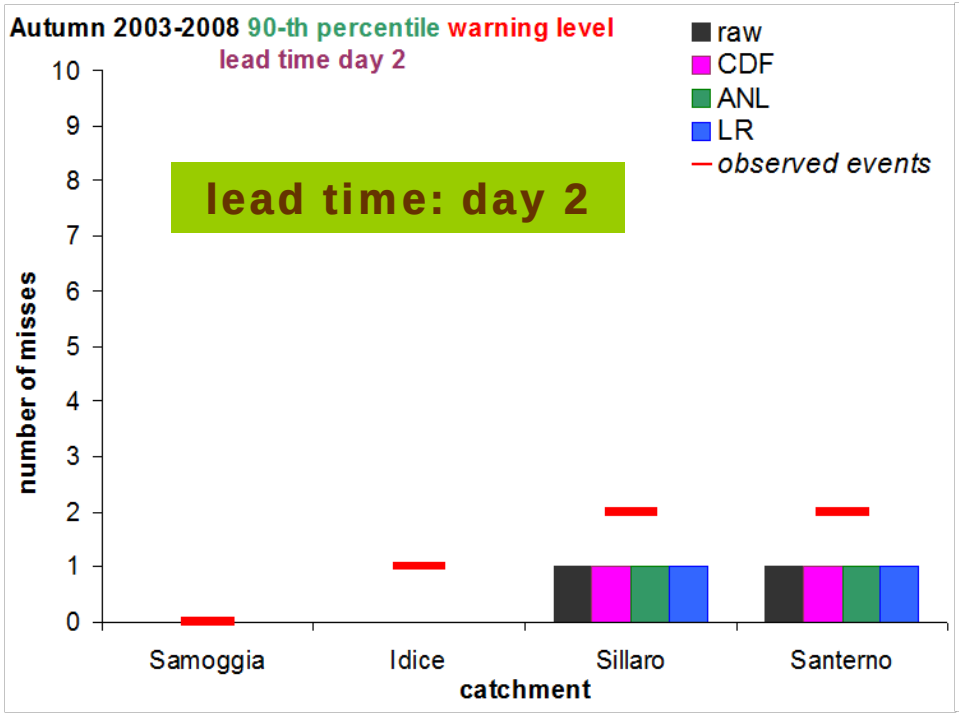


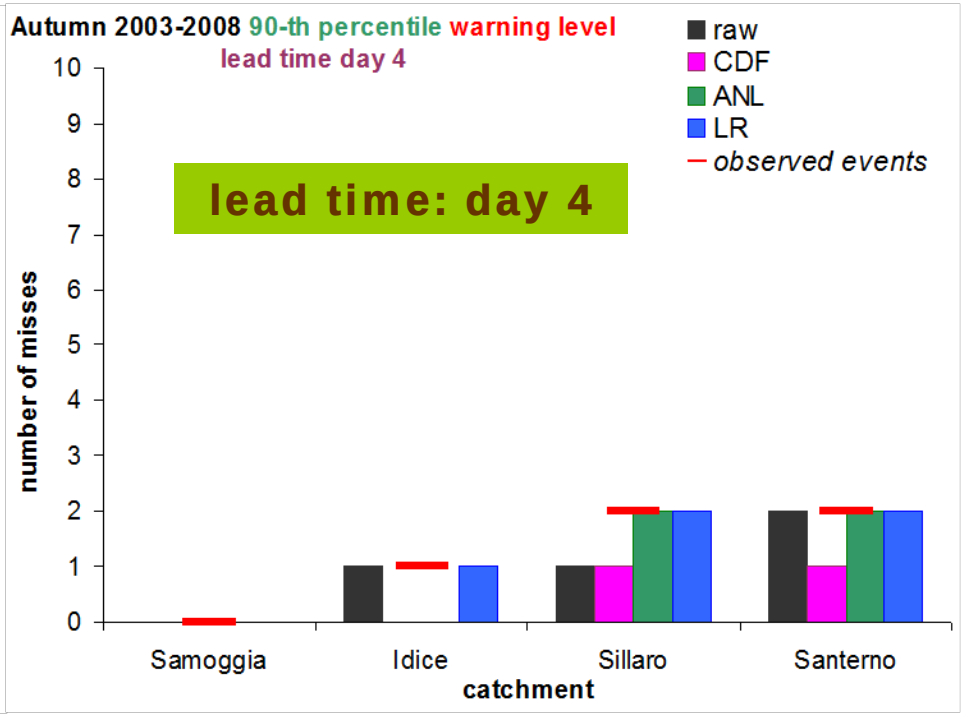
study area:
Reno river sub-basins

missed events

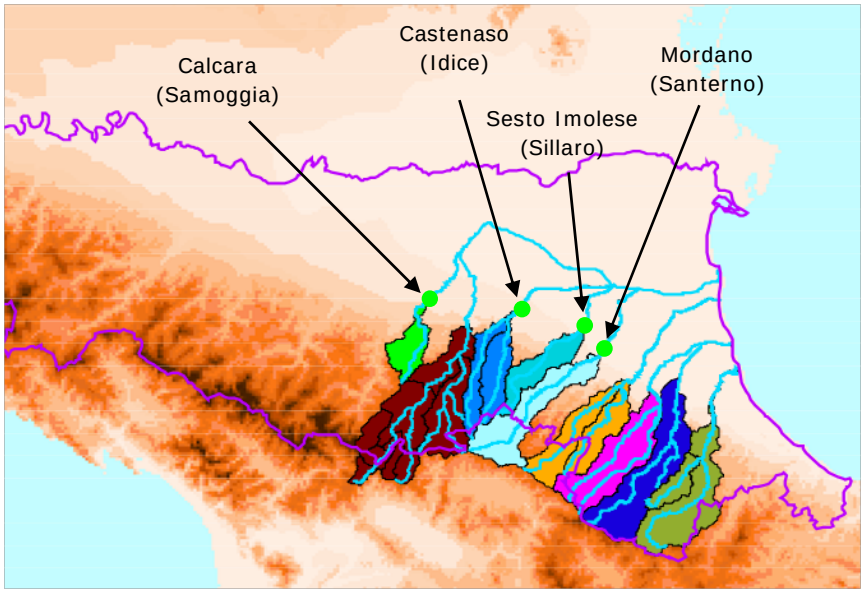
verification period: 2003-2008

season: autumn





90-th percentile of the discharge ensemble

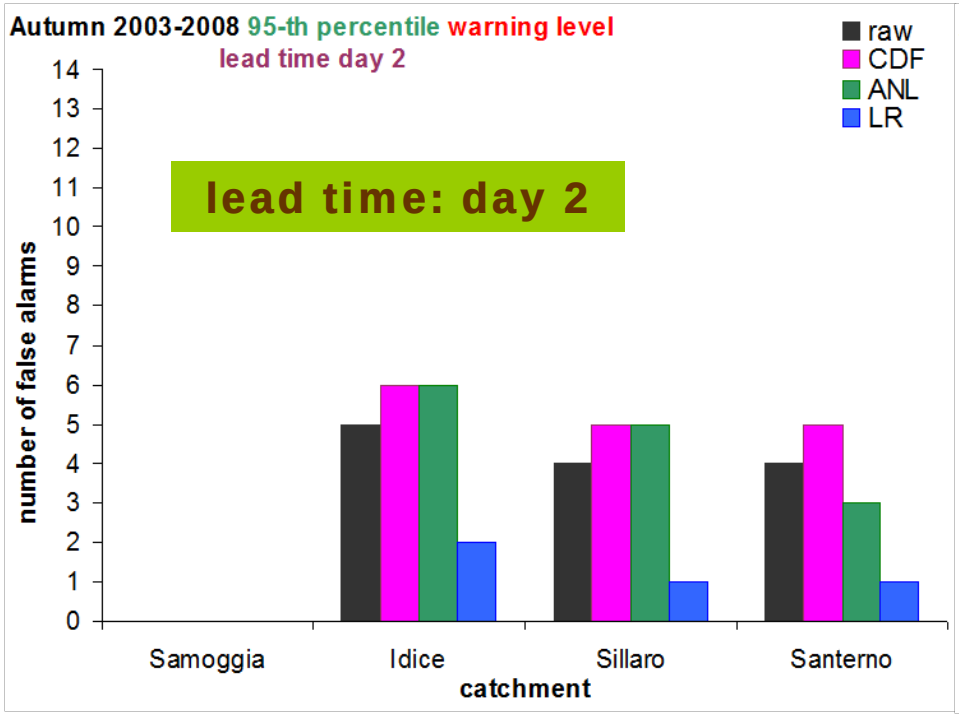


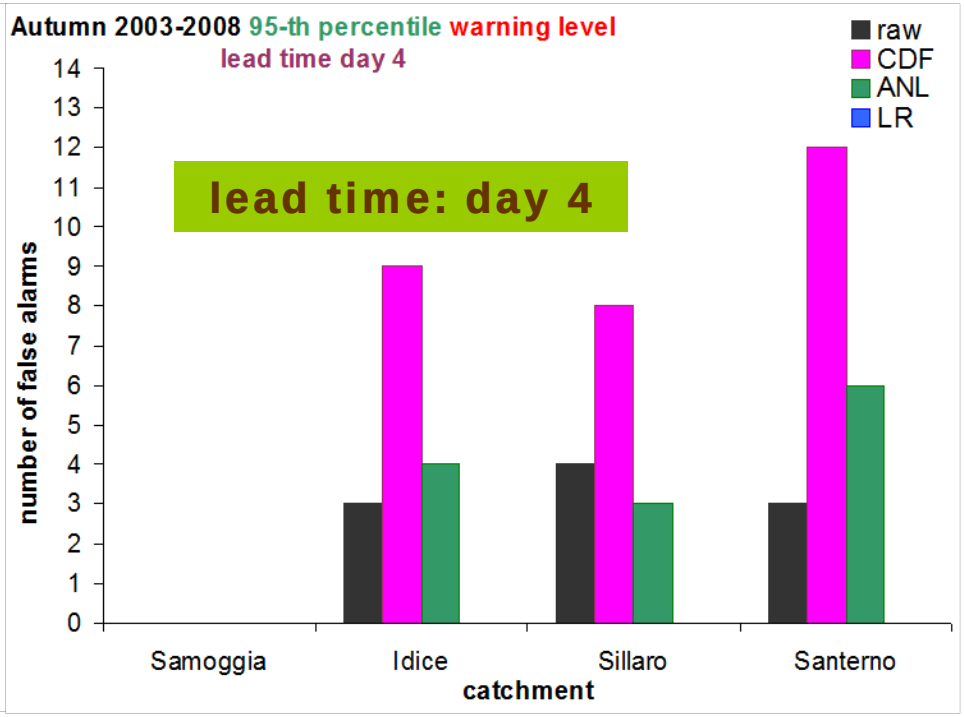
study area:
Reno river sub-basins

false alarms

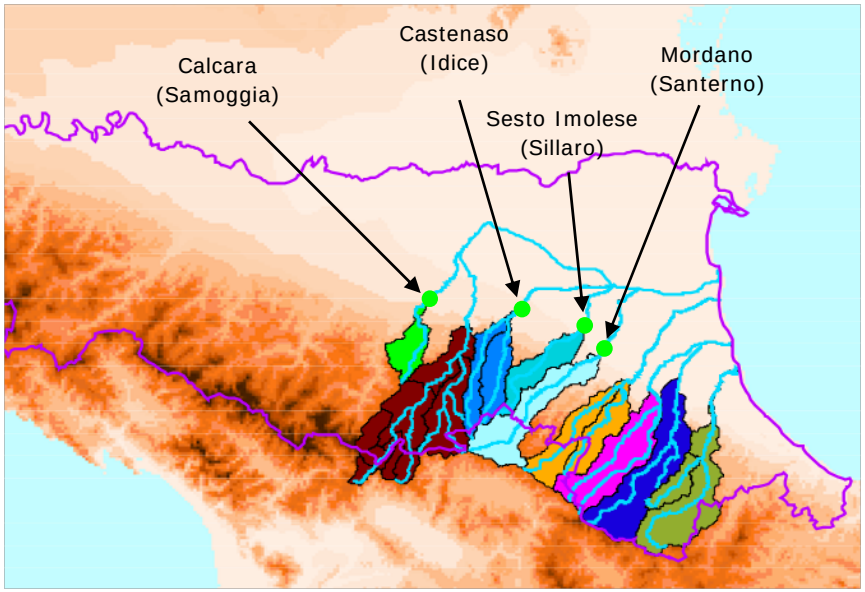
verification period: 2003-2008

season: autumn



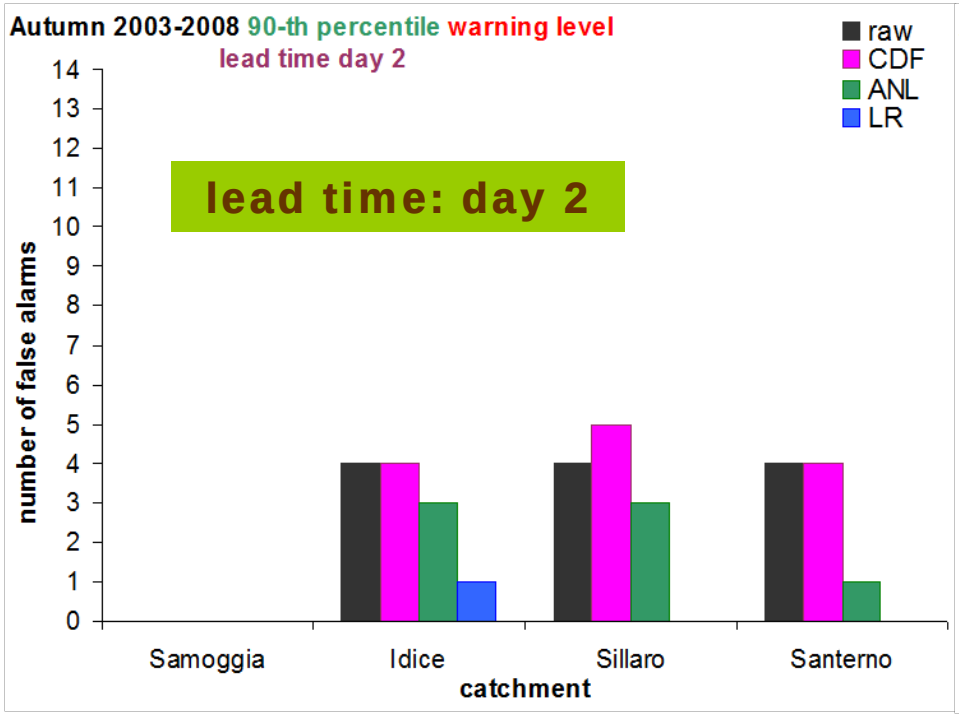


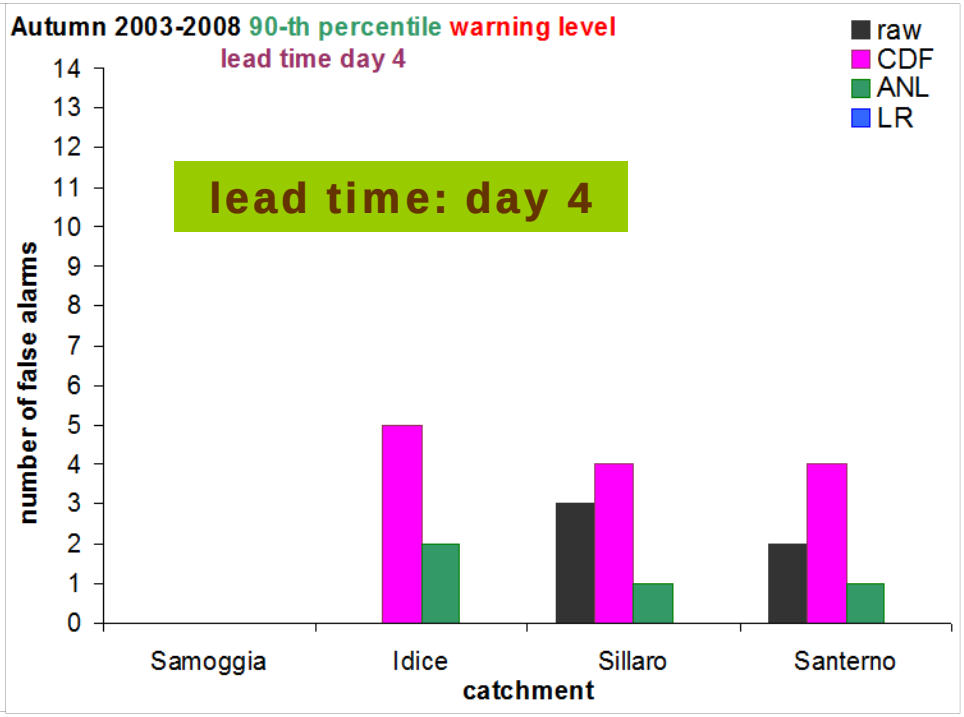
95-th percentile of the discharge ensemble



study area:
Reno river sub-basins

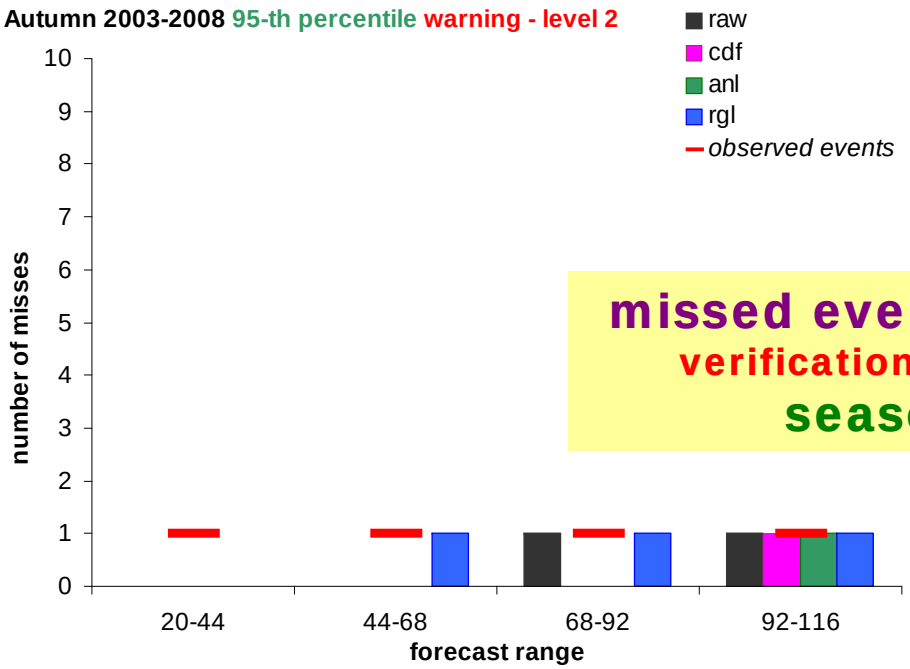
false alarms
verification period: 2003-2008
season: autumn

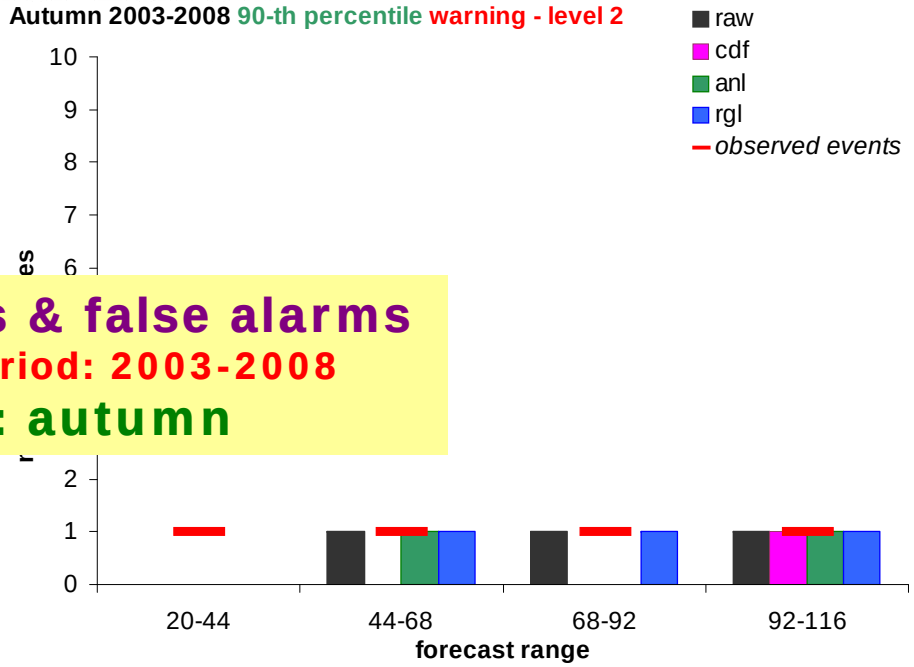




90-th percentile of the discharge ensemble

Catchment: Idice

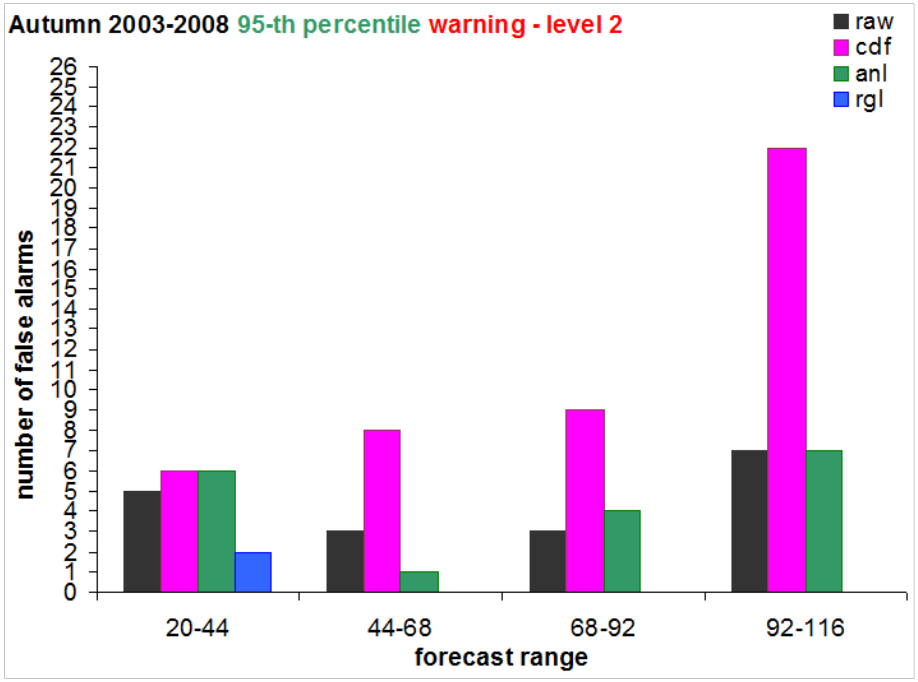


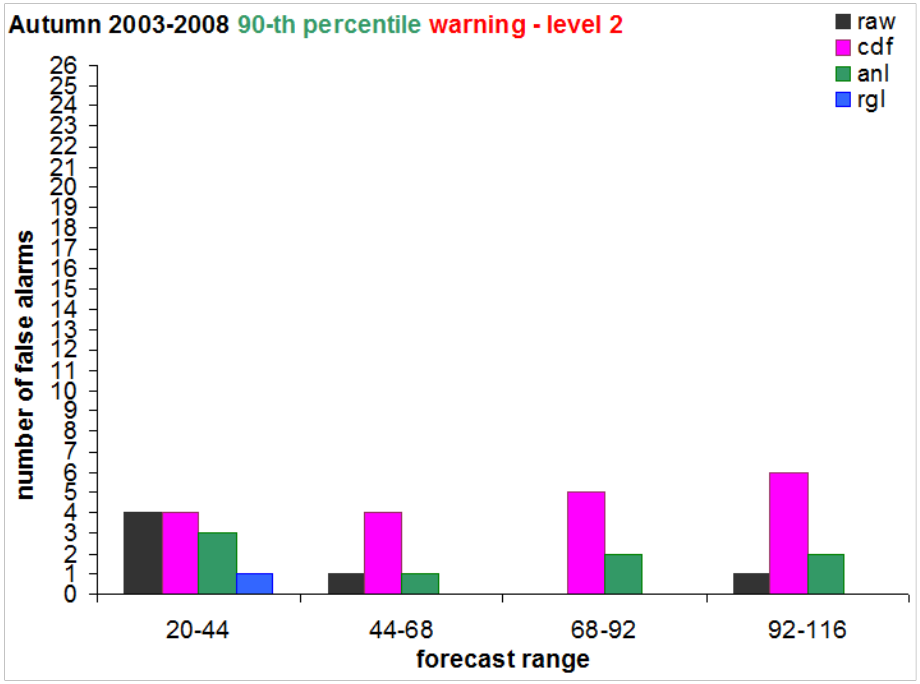


missed events & false alarms

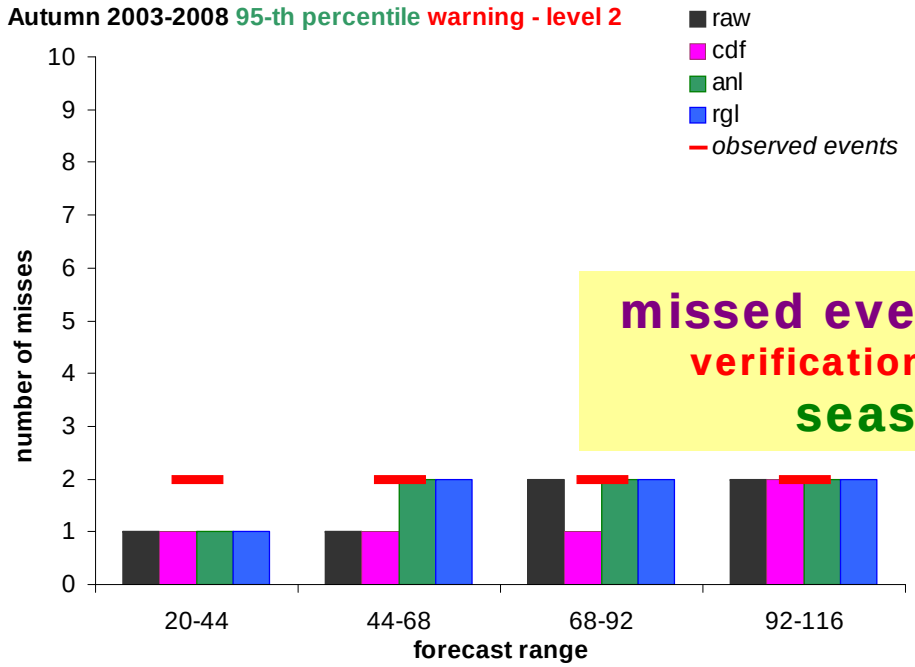
verification period: 2003-2008

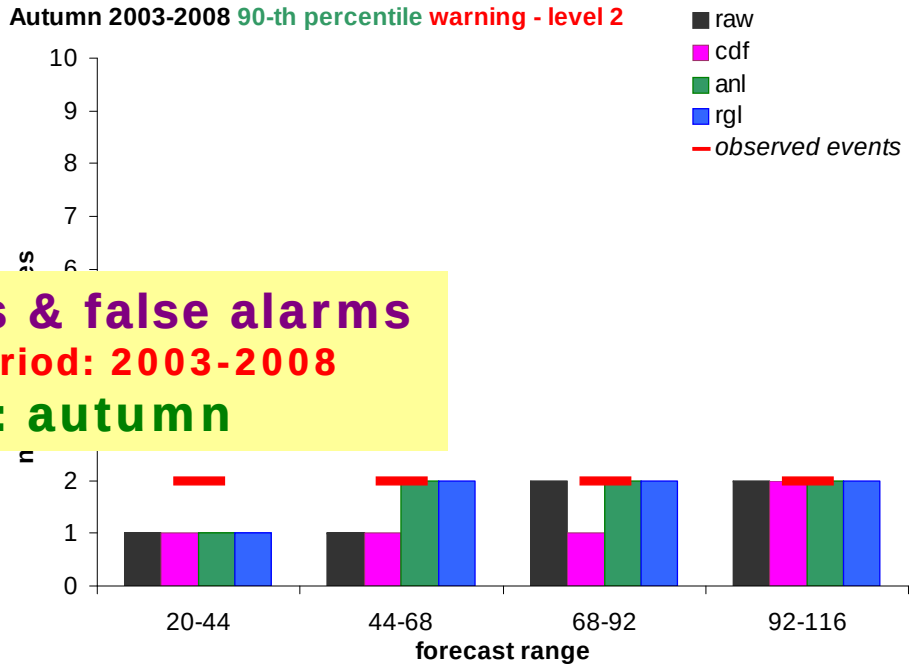
season: autumn





Catchment: Santerno

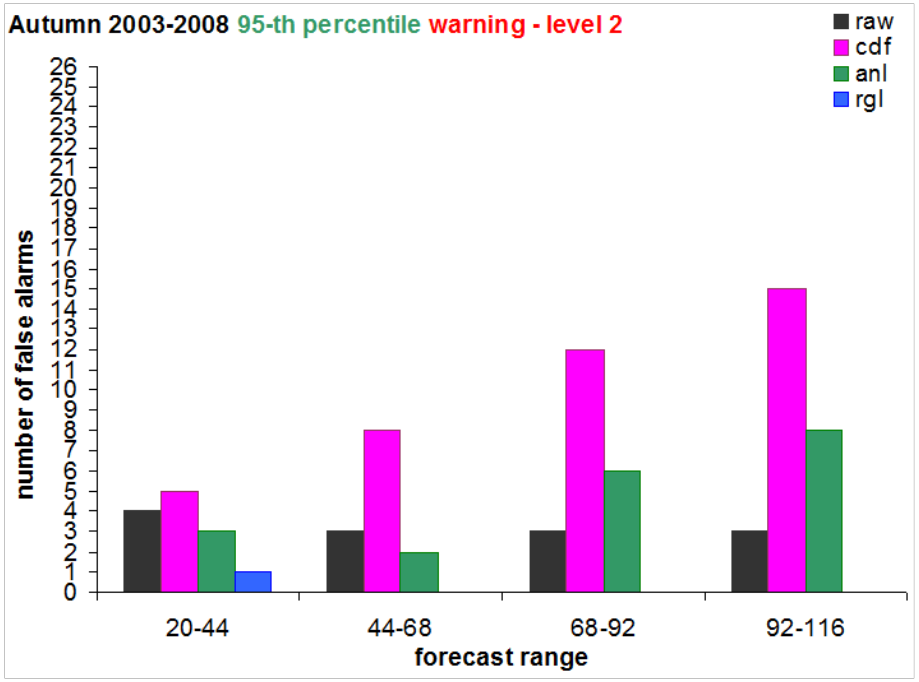


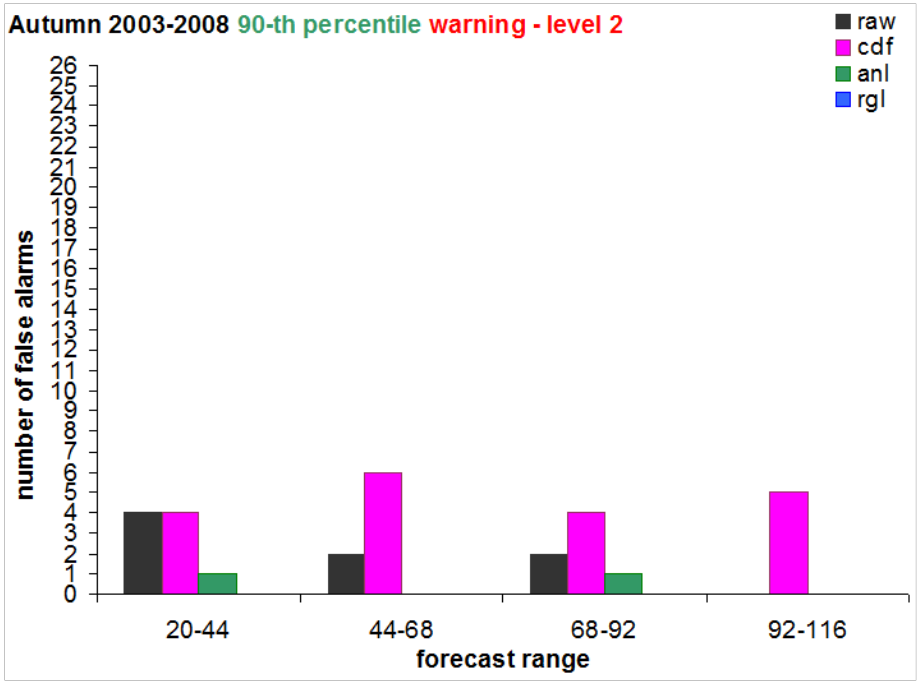


missed events & false alarms

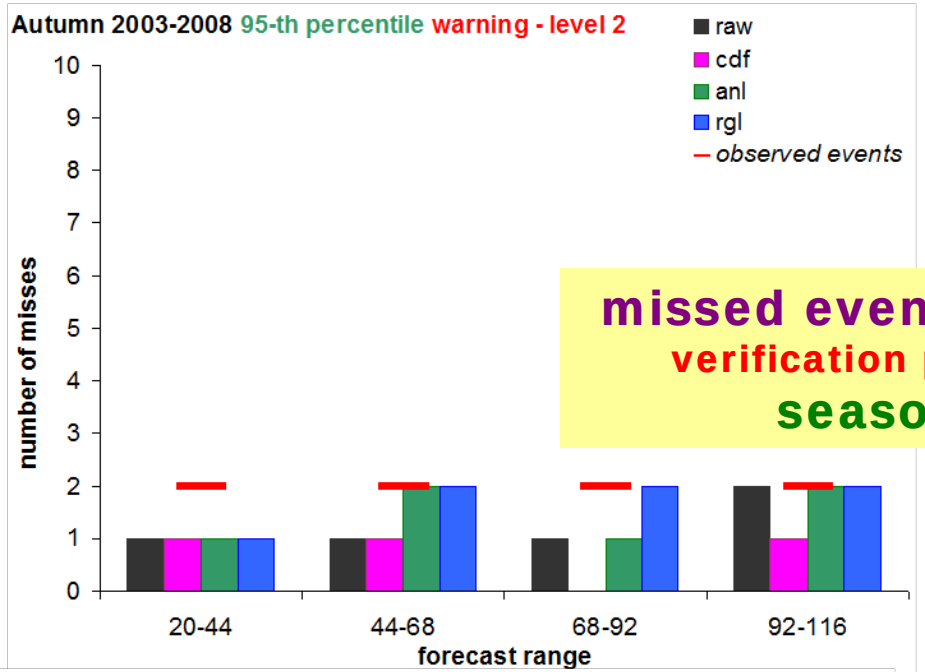
verification period: 2003-2008

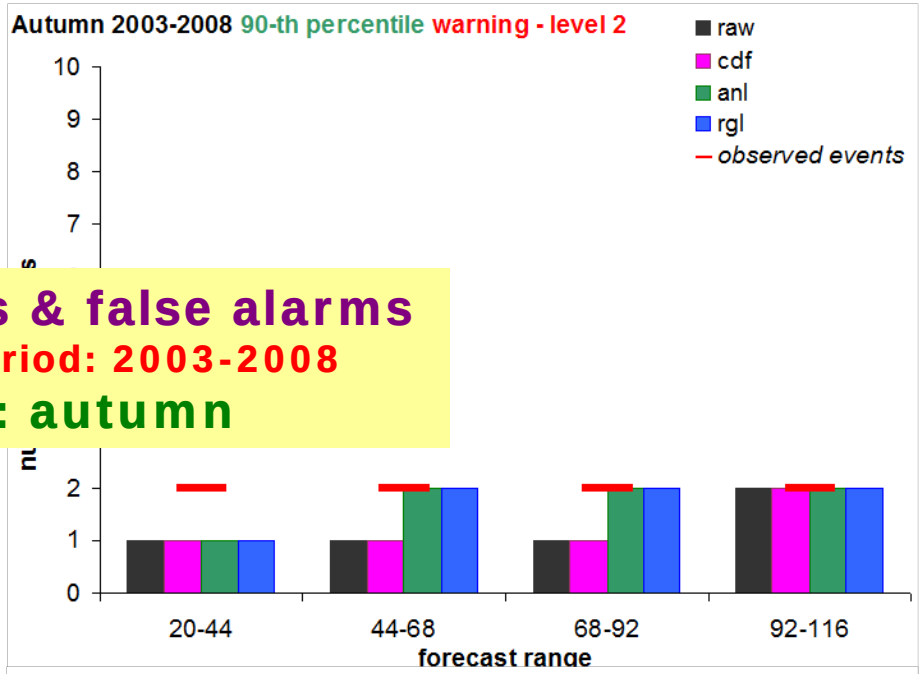
season: autumn





Catchment: Sillaro





missed events & false alarms

verification period: 2003-2008

season: autumn