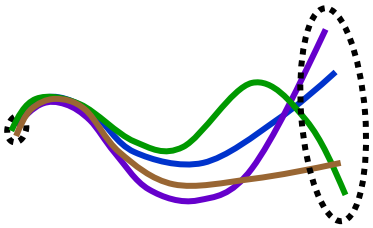
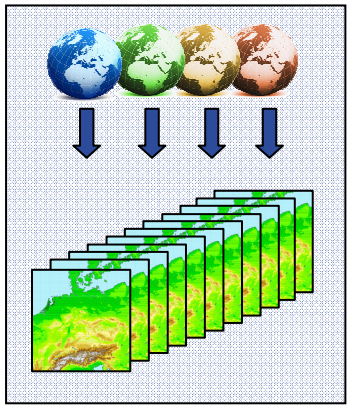
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

COSMO-DE-EPS

an operational convection permitting ensemble prediction system for the atmosphere





Christoph Gebhardt, Susanne Theis, Zied Ben Bouallègue, Andreas Röpnack, Nina Schuhen, Michael Buchhold

Deutscher Wetterdienst, DWD

Outline

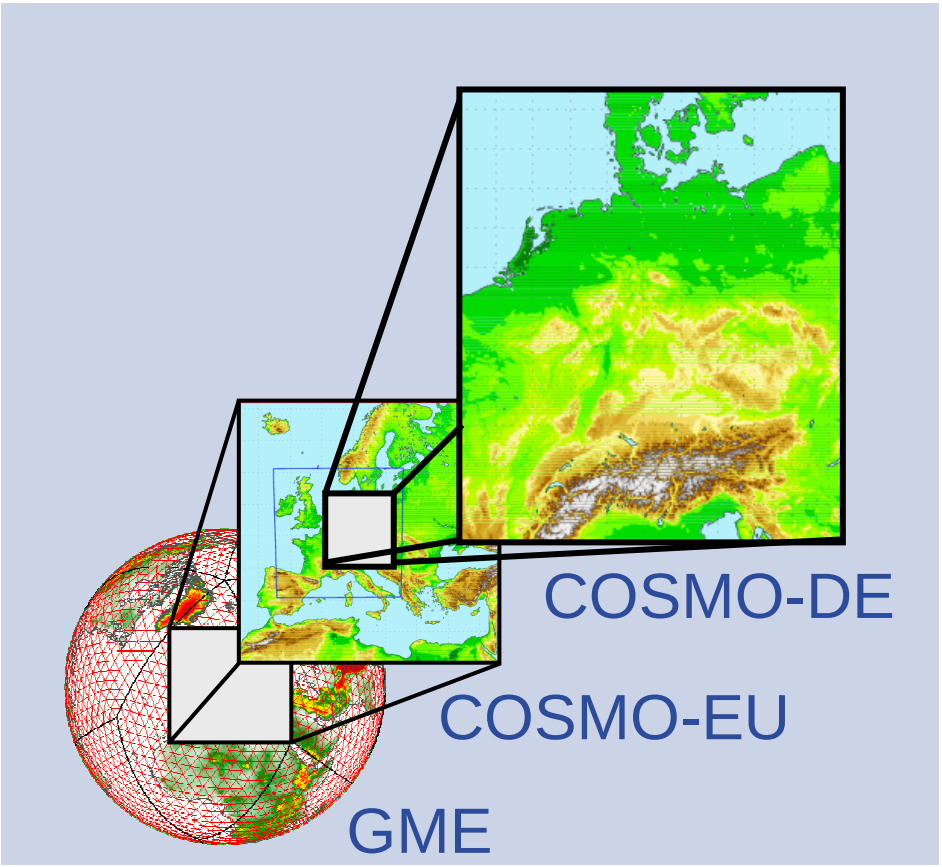
- ➔ COSMO-DE and COSMO-DE-EPS
  operational set-up and member generation of COSMO-DE-EPS
- ➔ Characteristics of COSMO-DE-EPS
  - case study
  - verification results
- ➔ broad overview of next steps
- ➔ example of an application

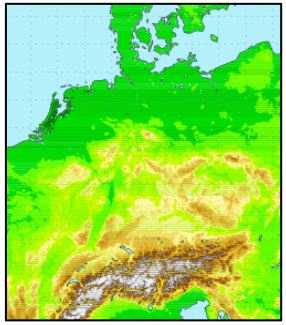
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

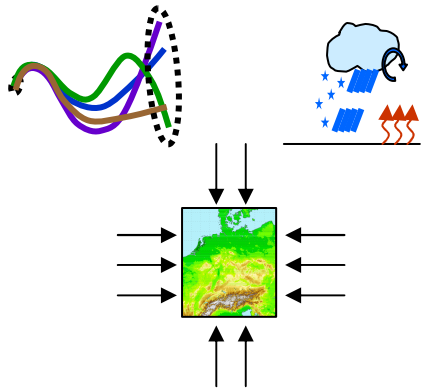
NWP Model COSMO-DE

(COSMO: Consortium for Small-scale Modeling)

- ➔ grid size 2.8 km
- ➔ no parameterization of deep convection *(convection permitting)*
- ➔ assimilation of radar data
- ➔ complex scheme for microphysics
- ➔ forecast range: 0-21 hours, 8 times a day (00, 03 UTC,...)







operational set-up of COSMO-DE-EPS:

- ➔ **20 members**
- ➔ **grid size: 2.8 km**

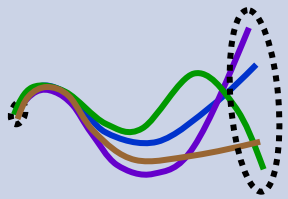
  convection-permitting
- ➔ **lead time: 0-21 hours,**

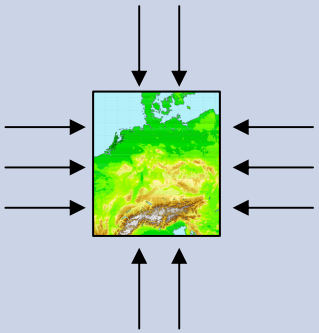
  8 starts per day (00, 03, 06,... UTC)
- ➔ **includes all features of deterministic COSMO-DE**

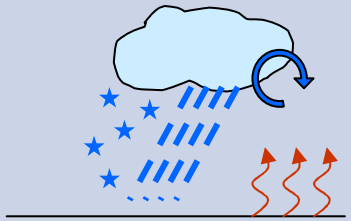
Generation of EPS members

representing uncertainty in

initial conditions	boundary conditions	model physics

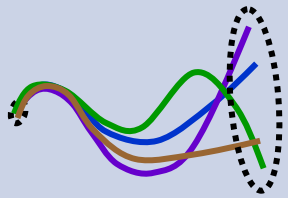
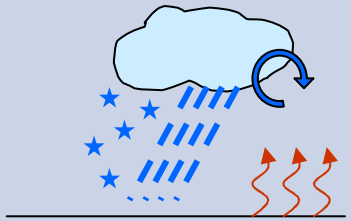






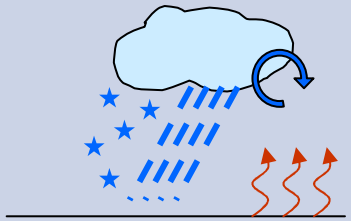
Generation of EPS members

representing uncertainty in

initial conditions	boundary conditions	model physics
	**“multi-model”** driven by different global models	

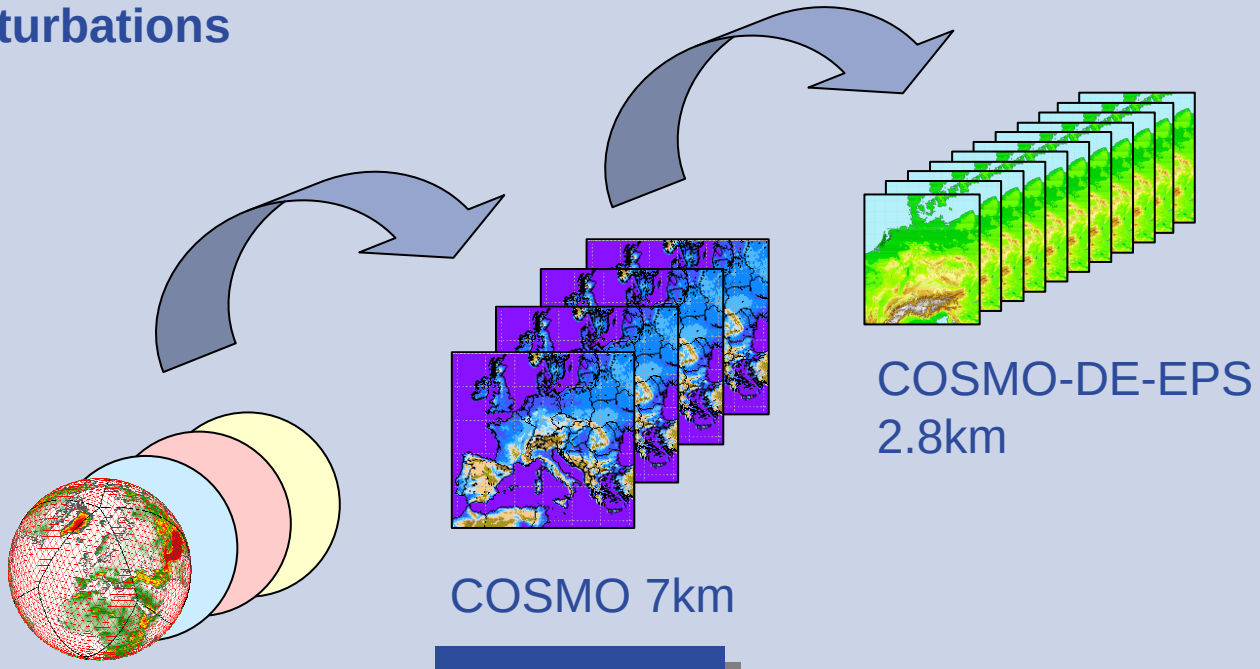
Generation of EPS members

representing uncertainty in

initial conditions	boundary conditions	model physics
“multi-model” the different global models are used to modify the initial conditions of COSMO-DE	**“multi-model”** driven by different global models	

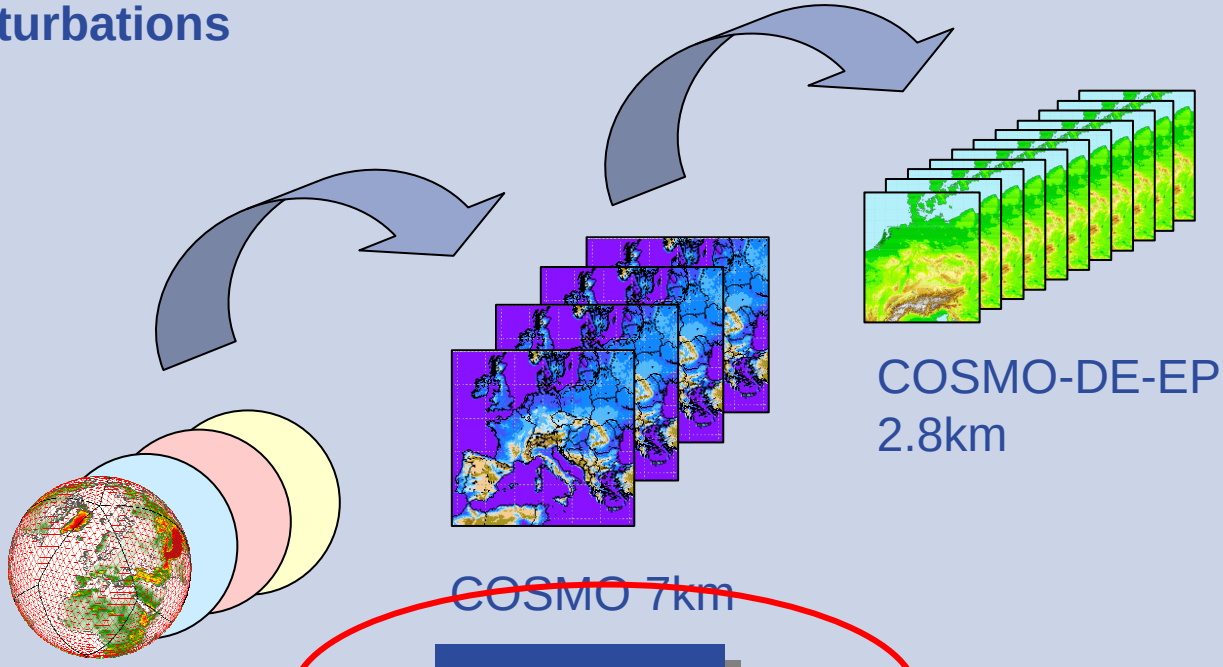
Generation of EPS members

BC-EPS for boundary and initial perturbations



Generation of EPS members

BC-EPS for boundary and initial perturbations



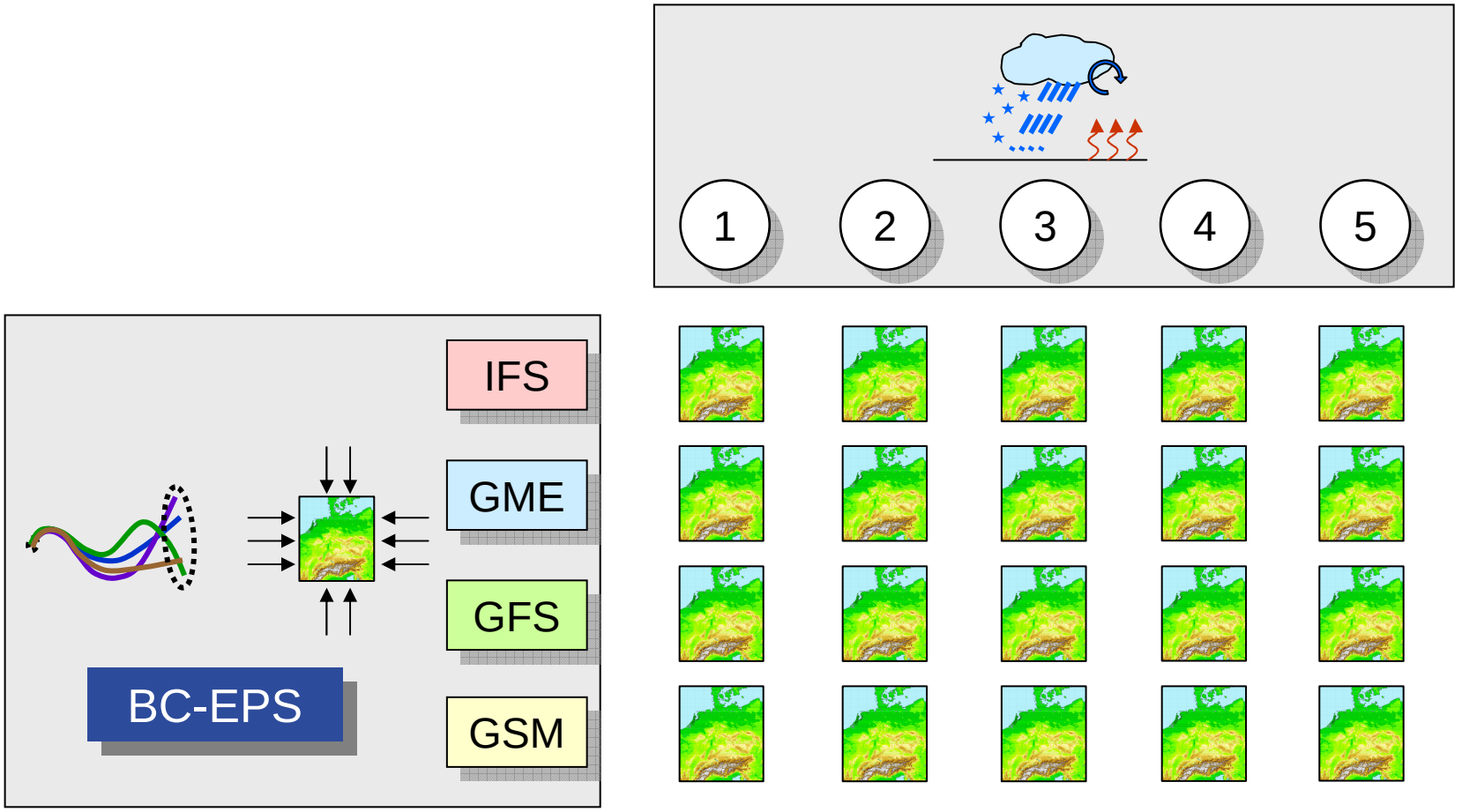
Generation of EPS members

focus on estimating the forecast uncertainty of convective precipitation (summer)

representing uncertainty in

initial conditions	boundary conditions	model physics
“multi-model”	**“multi-model”**	**“multi-configurations”**
the different global models are used to modify the initial conditions of COSMO-DE	driven by different global models	variation of parameters in model physics (non-stochastic, one fixed perturbation per member)

The 20 members of COSMO-DE-EPS

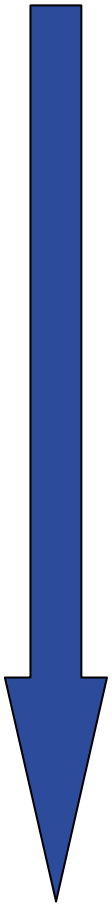


COSMO-DE-EPS status and plans

➔ **start of pre-operational mode (9th Dec 2010)**

➔ **evaluation by forecasters + verification**

switch to operational mode on 22nd May 2012



2010

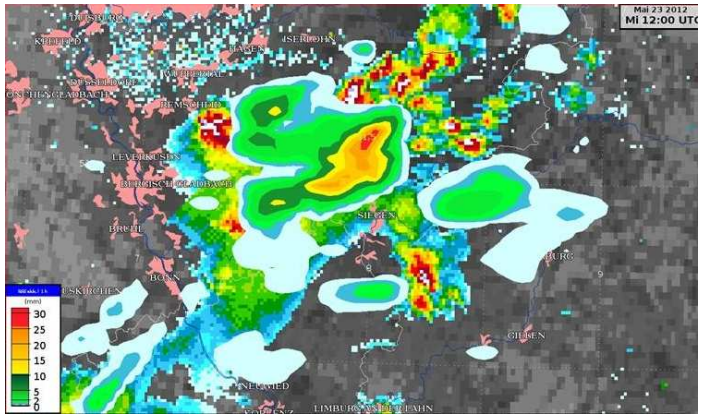
2011

2012

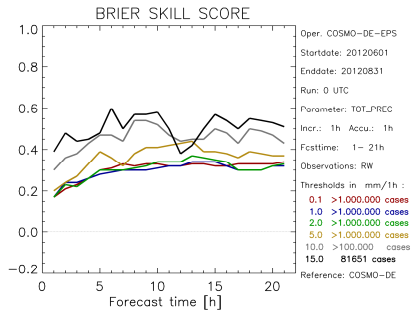
2013 / 14

Main results from (pre-)operational phase (20 members)

➔ **evaluation by forecasters (case studies):**



➔ **probabilistic verification (for periods of several months)**



Case study of 23rd May 2012, 12UTC (just to welcome the COSMO-DE-EPS ☺)

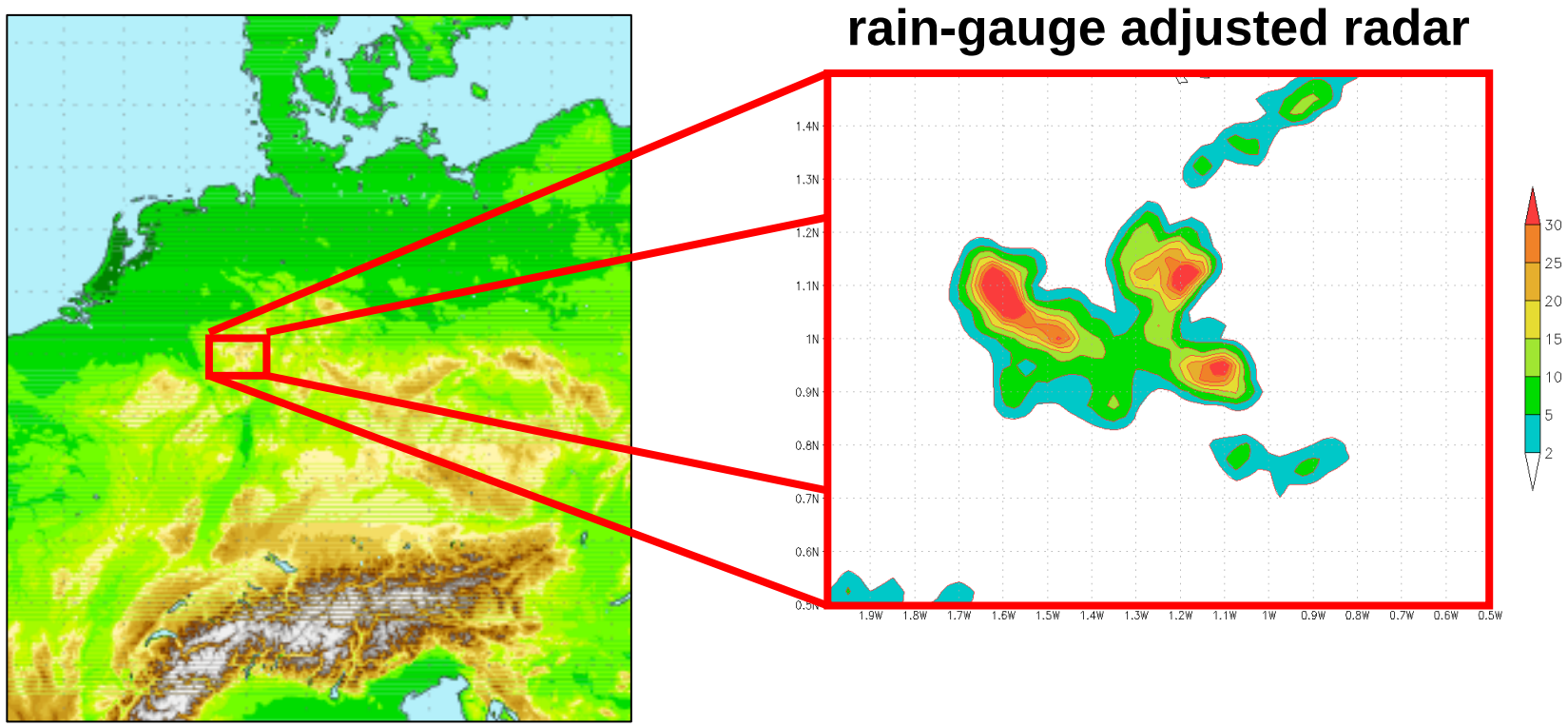
- ➔ severe precipitation event in Germany (North Rhine-Westphalia & Hesse)
- ➔ hourly precipitation up to 40 mm/h
- ➔ hail, thunderstorm, minor flooding and landslides

pictures:

Bernd Brandt / wetteronline.de

wirsiegen.de

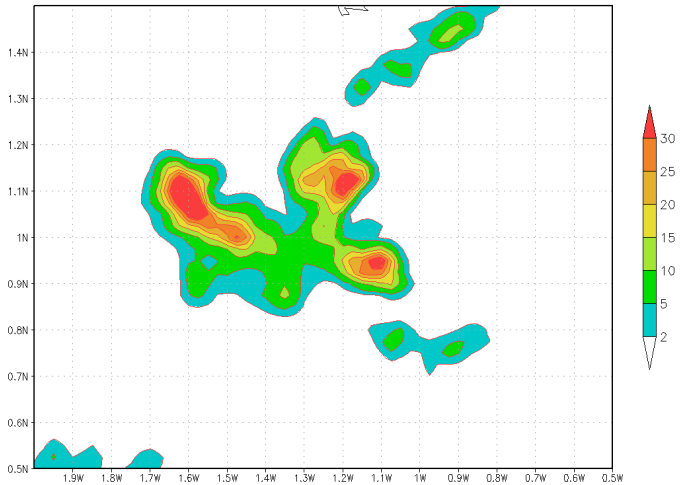
Case study of 23rd May 2012, 12 UTC



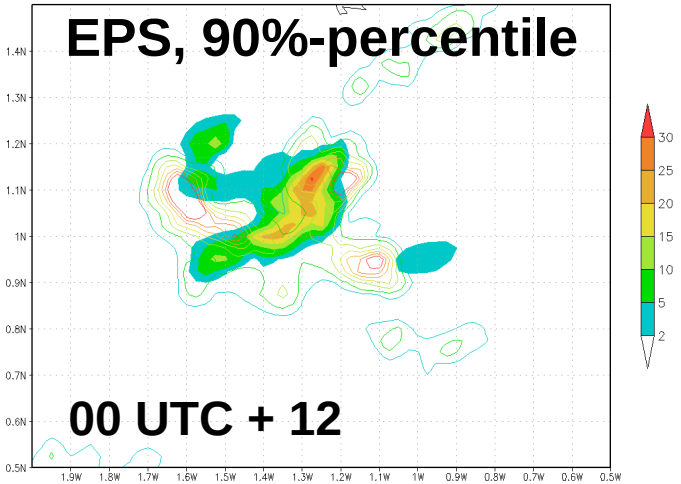
Case study of 23rd May 2012

hourly precipitation 11-12UTC

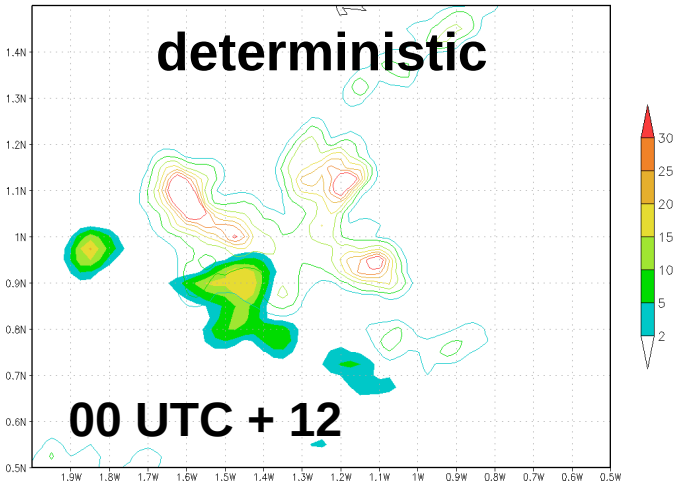
rain-gauge adjusted radar



EPS, 90%-percentile



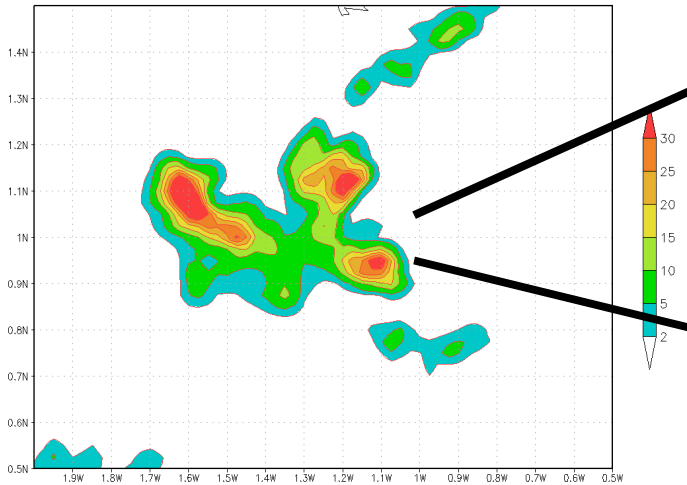
deterministic



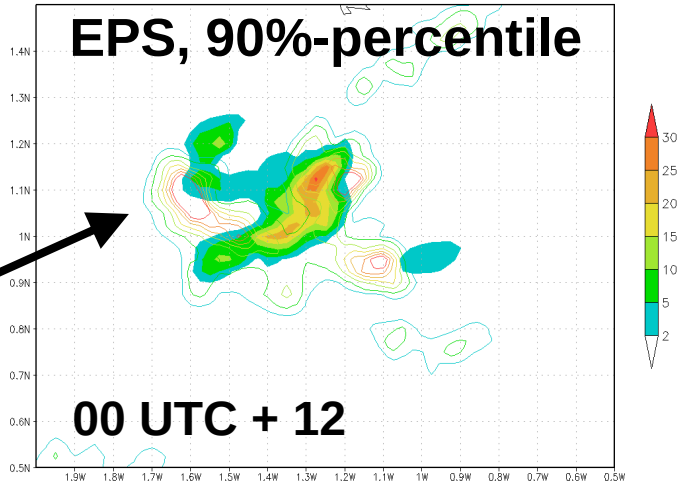
Case study of 23rd May 2012

hourly precipitation 11-12UTC

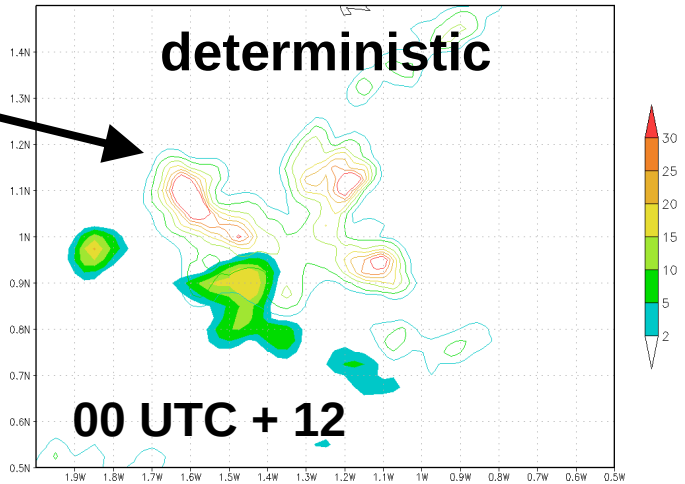
rain-gauge adjusted radar



EPS, 90%-percentile



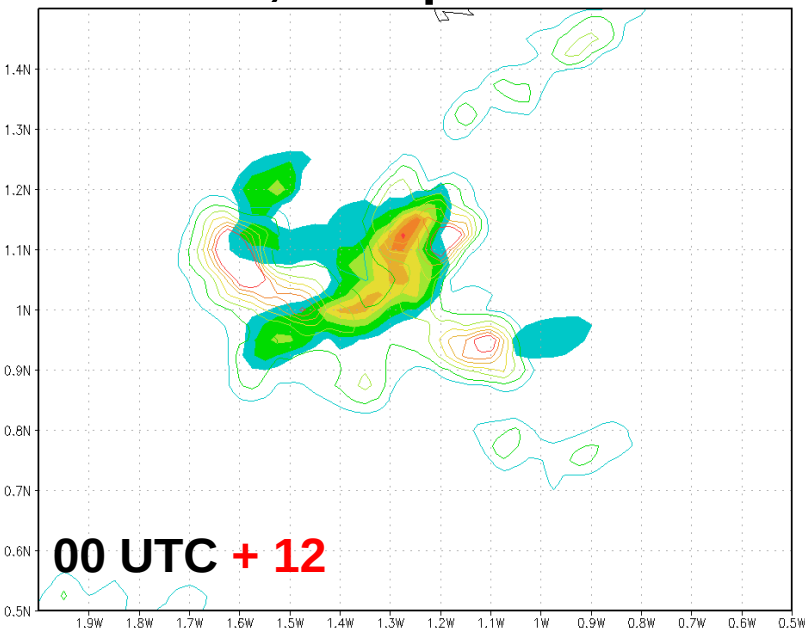
deterministic

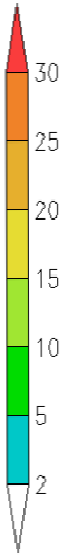


Case study of 23rd May 2012

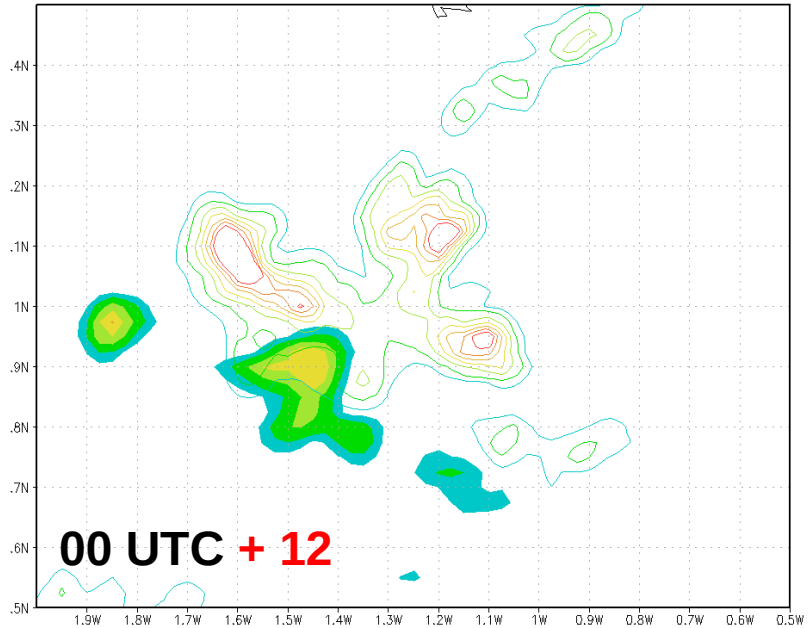
hourly precipitation 11-12UTC

EPS, 90%-percentile





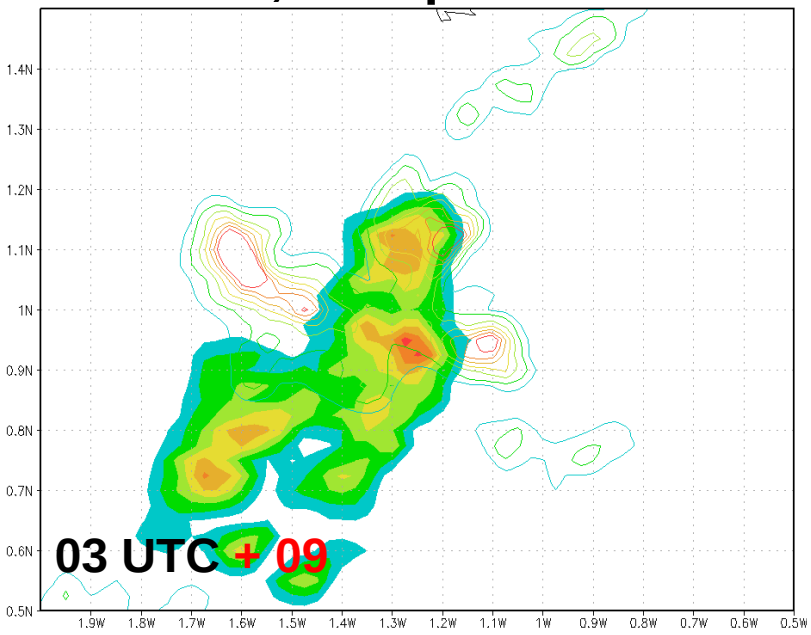
deterministic

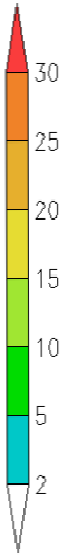


Case study of 23rd May 2012

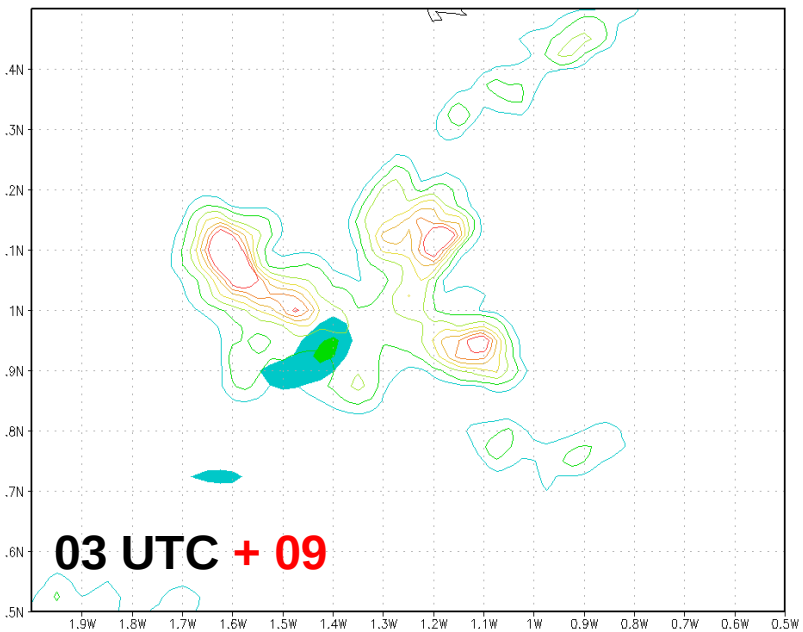
hourly precipitation 11-12UTC

EPS, 90%-percentile





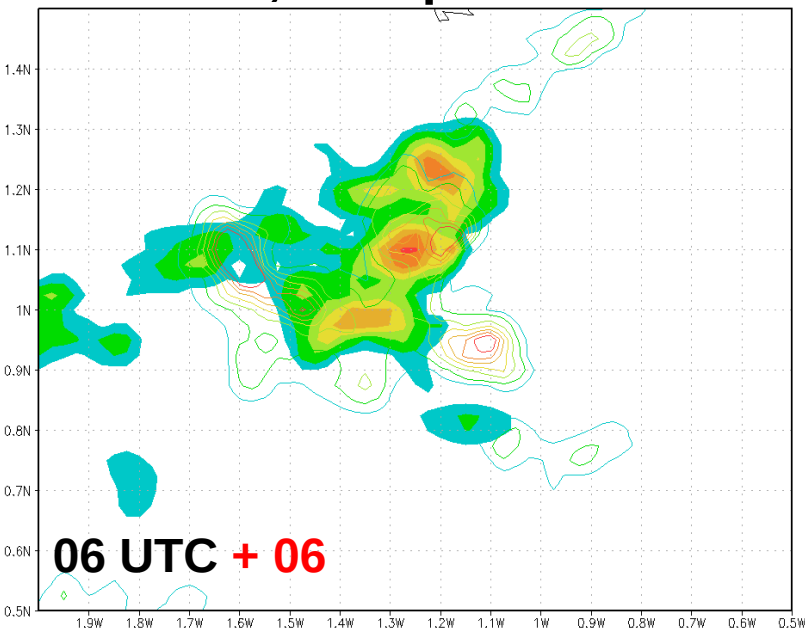
deterministic

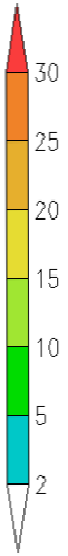


Case study of 23rd May 2012

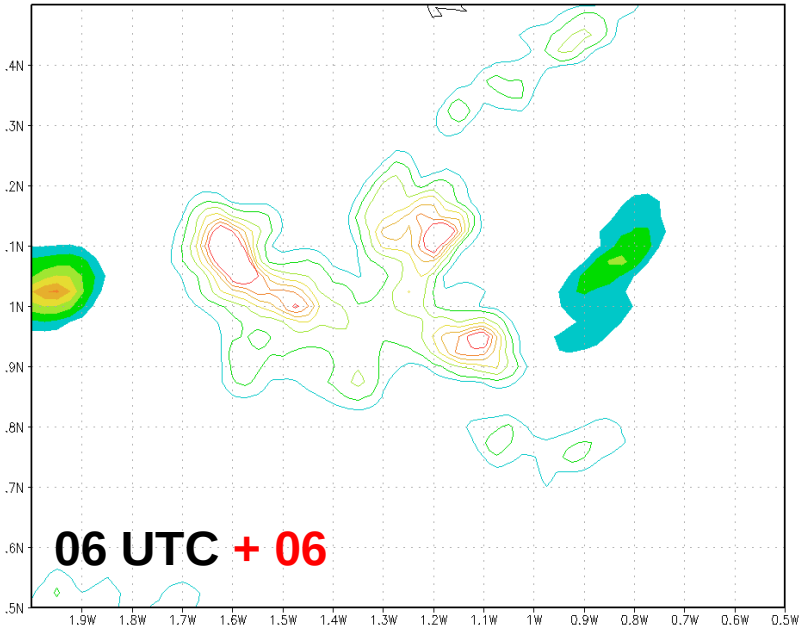
hourly precipitation 11-12UTC

EPS, 90%-percentile





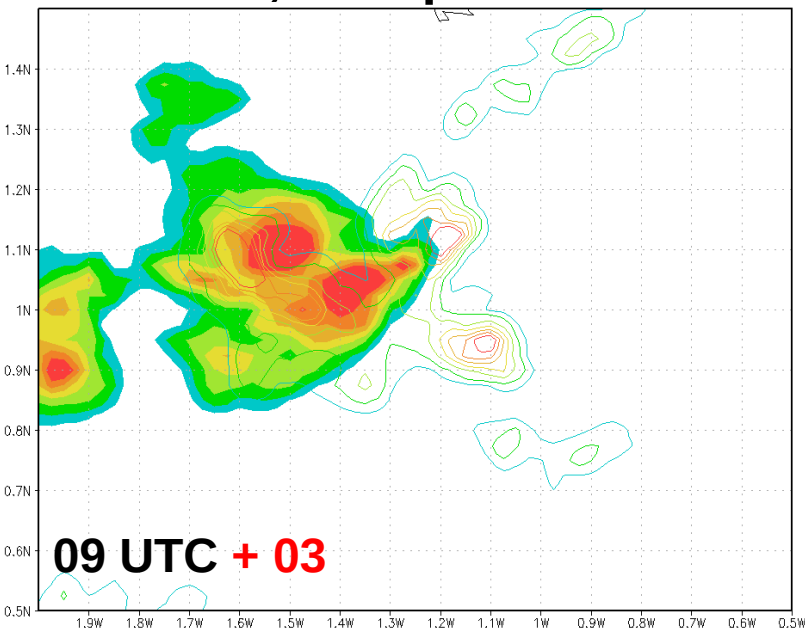
deterministic

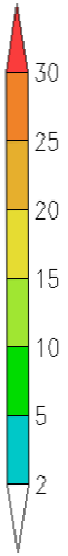


Case study of 23rd May 2012

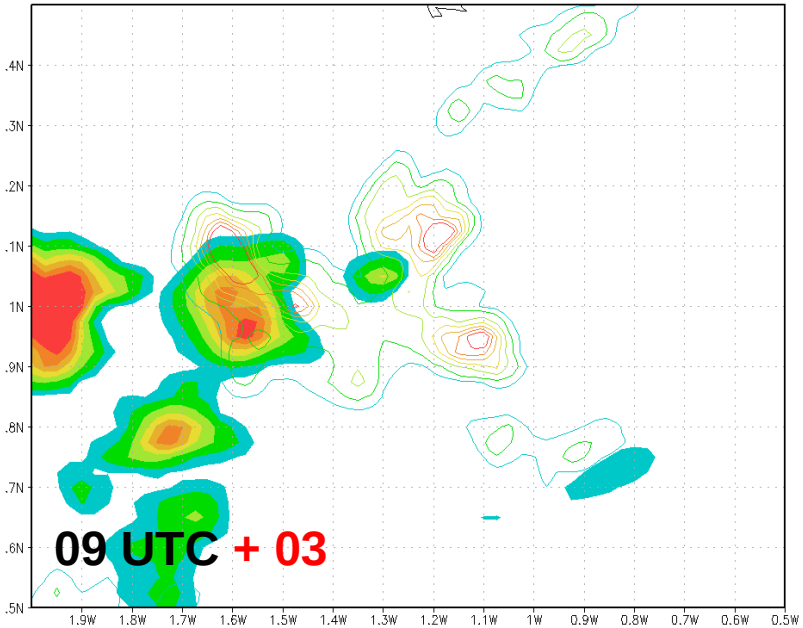
hourly precipitation 11-12UTC

EPS, 90%-percentile





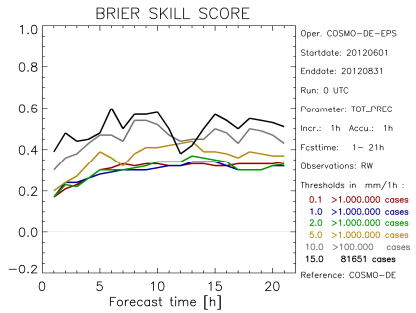
deterministic



Main results from (pre-)operational phase (20 members)

- ➔ **evaluation** by forecasters (case studies):
  - ➔ additional benefit for **precipitation** forecasts
  - ➔ provides **early signals for severe weather**
  - ➔ most beneficial for **convective precipitation** in summer
  - ➔ reduced jumpiness between consecutive runs

- ➔ **probabilistic** verification (for periods of several months)



VERIFICATION OF COSMO-DE-EPS

all results for hourly precipitation

summer 2012

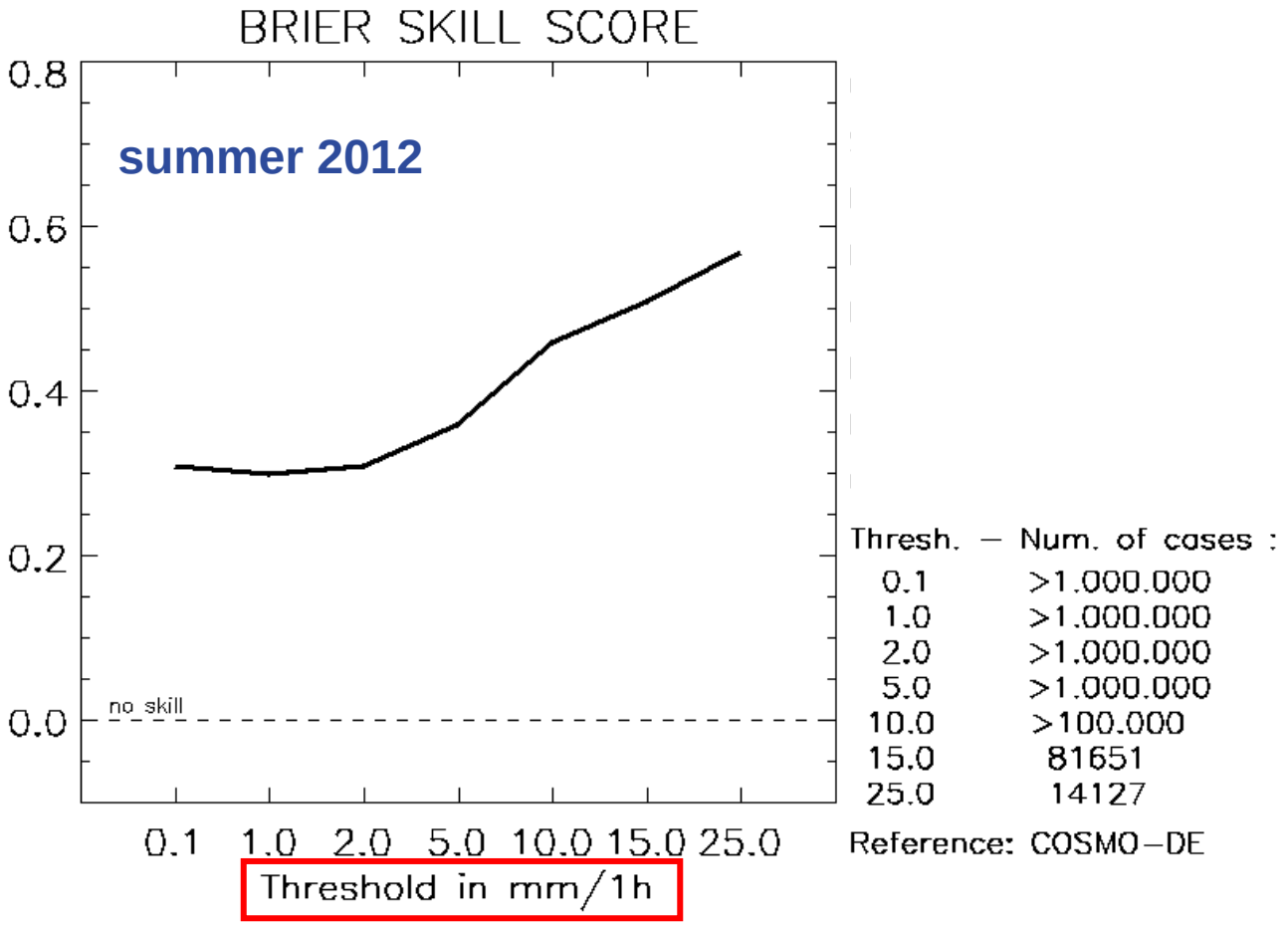
winter 2011/12

00 UTC run

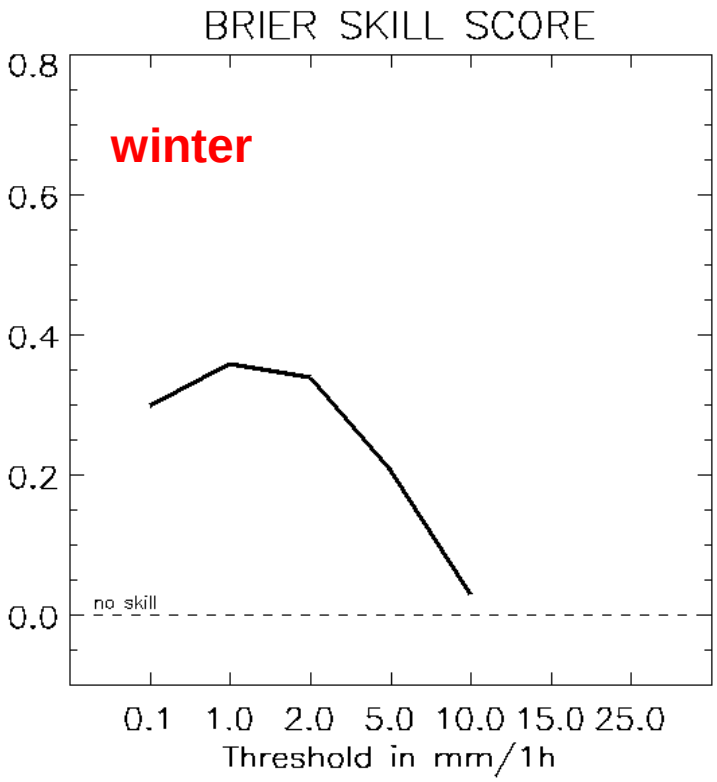
EPS not calibrated or post-processed

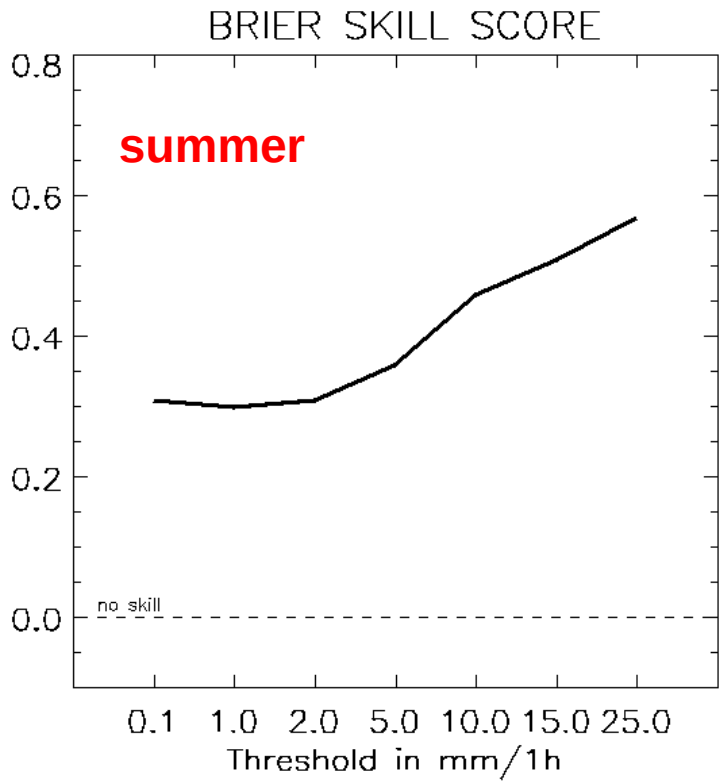
observations: rain-gauge adjusted radar (upscaled to COSMO-DE grid)

Brier Skill Score (reference: deterministic run of COSMO-DE)



Brier Skill Score (reference: deterministic run of COSMO-DE)





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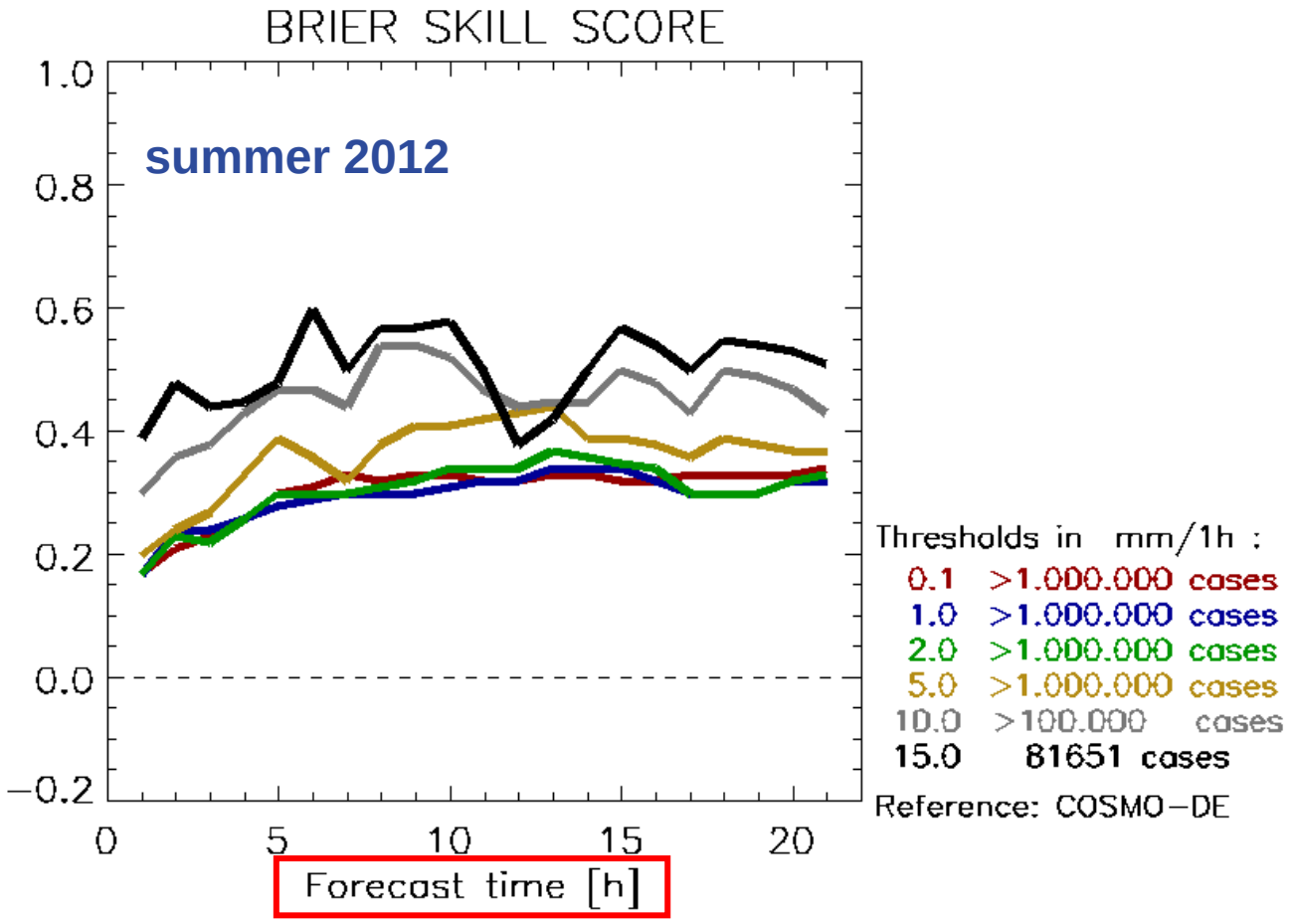
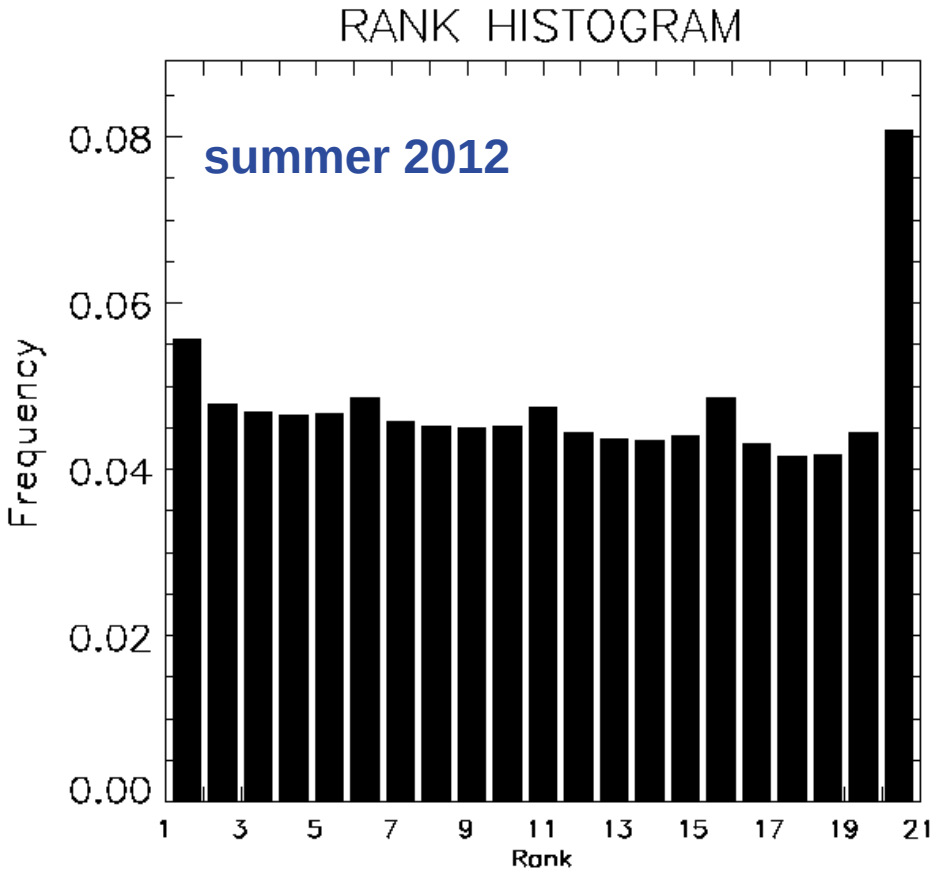
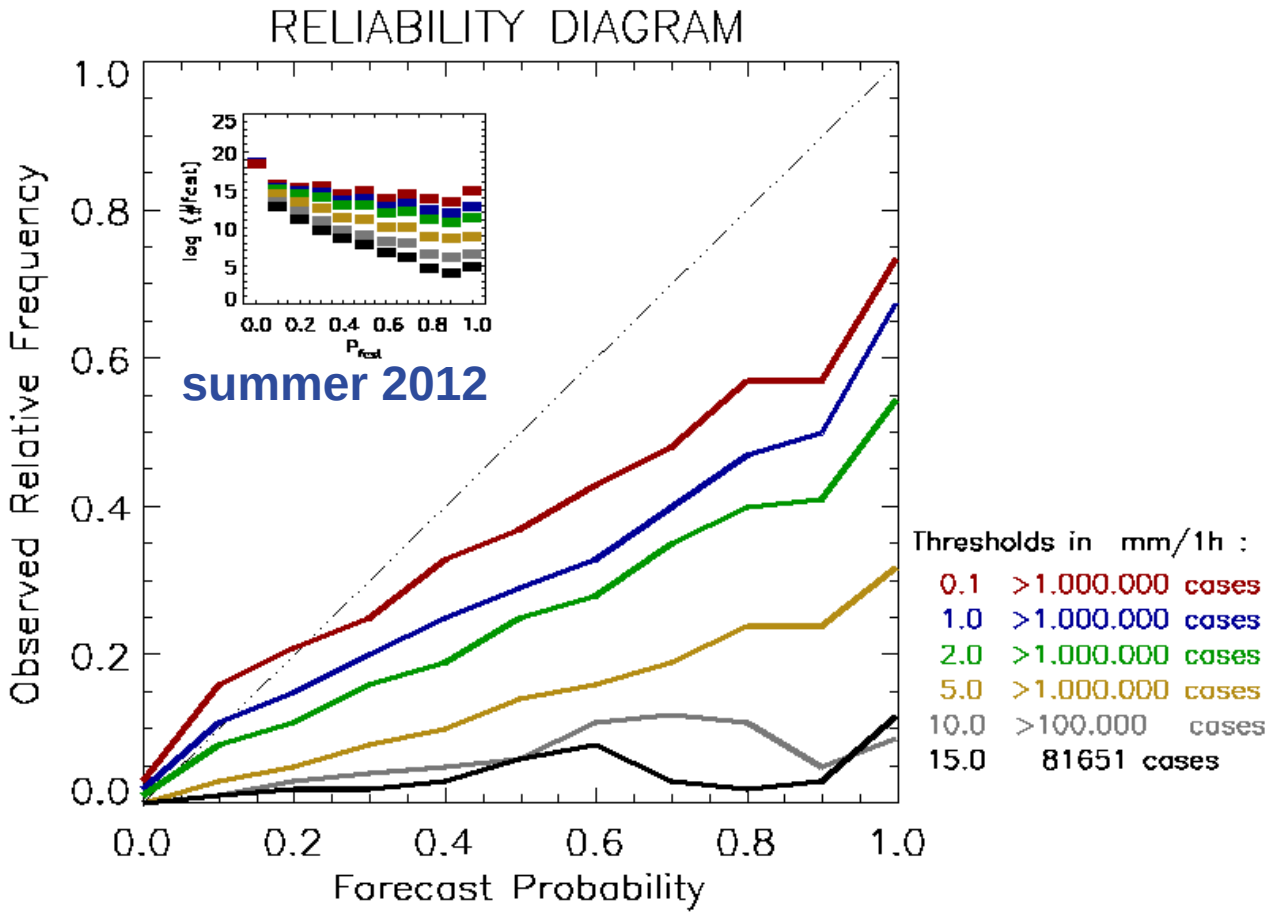


Rank histogram



reliability diagram



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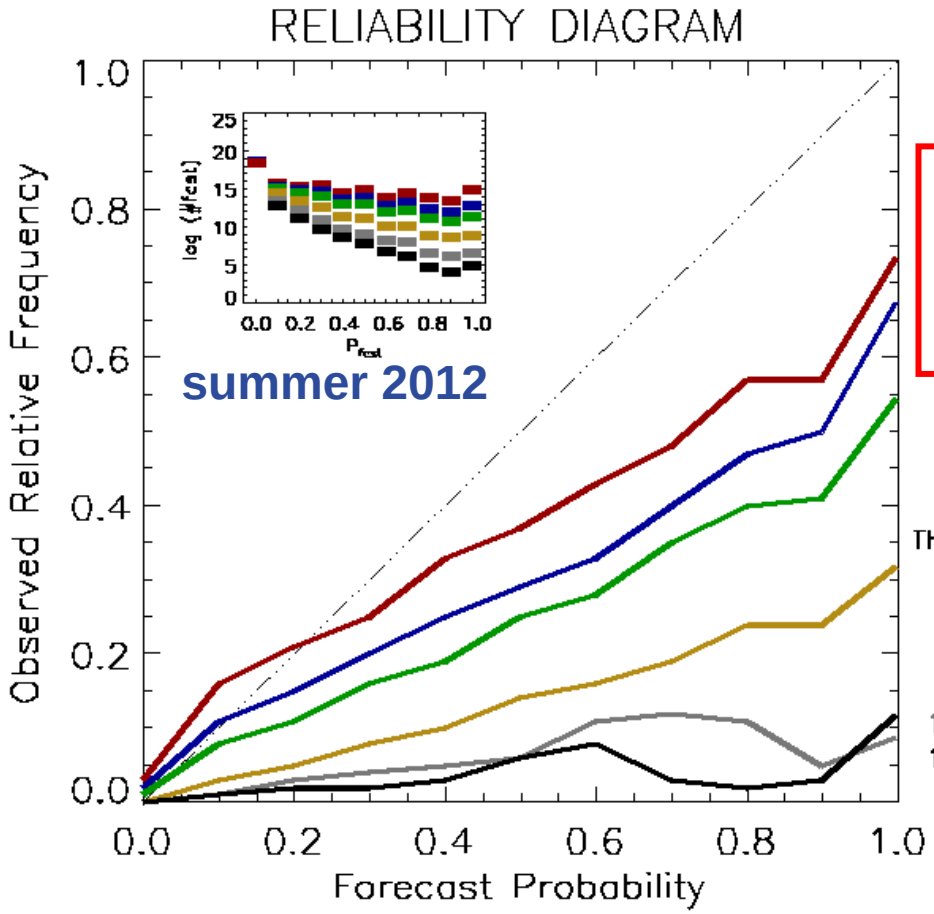


calibration developed but not yet operational

➔ see slides later on

Thresholds in mm/1h :

0.1	>1.000.000 cases
1.0	>1.000.000 cases
2.0	>1.000.000 cases
5.0	>1.000.000 cases
10.0	>100.000 cases
15.0	81651 cases

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

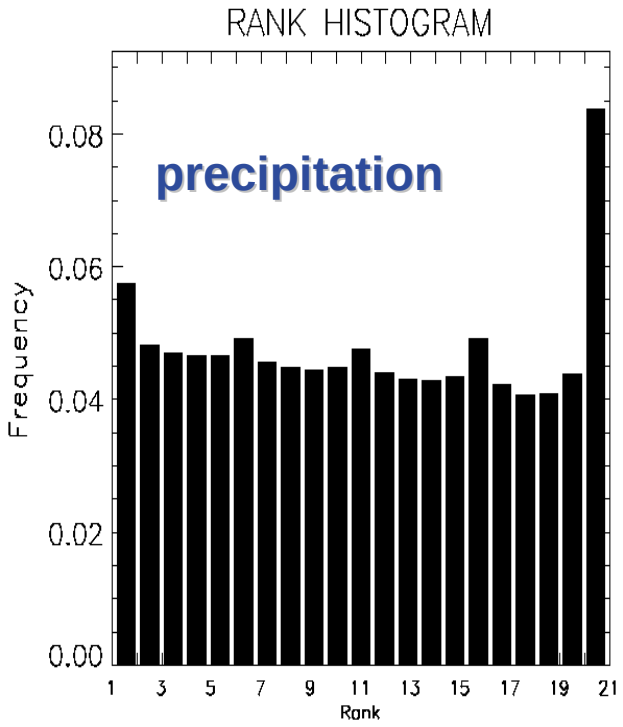
VERIFICATION OF COSMO-DE-EPS

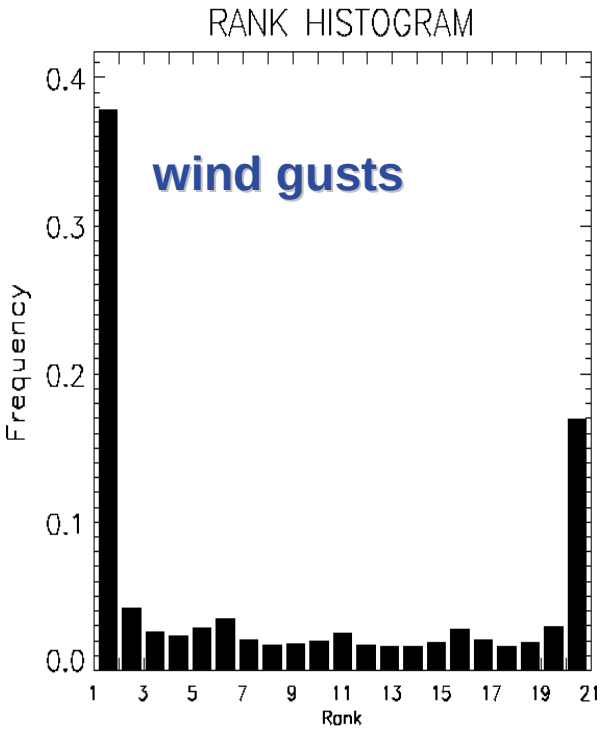
other variables

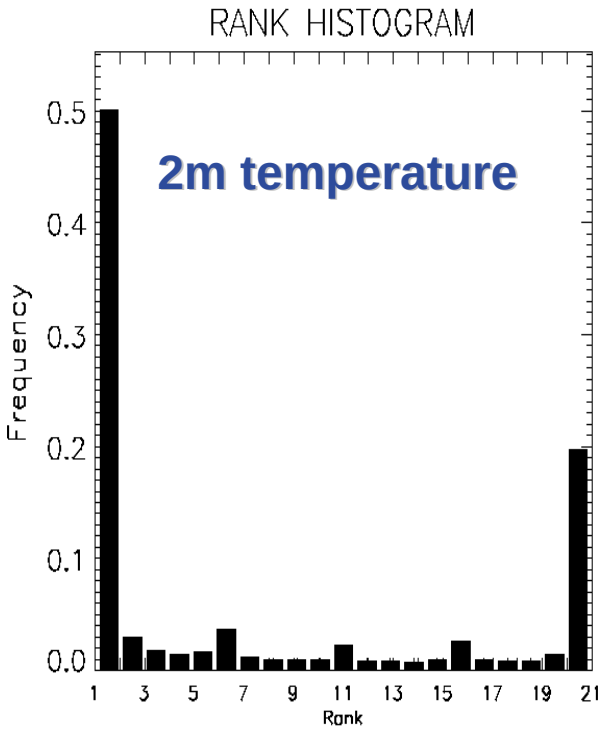
summer 2012

observations: SYNOP

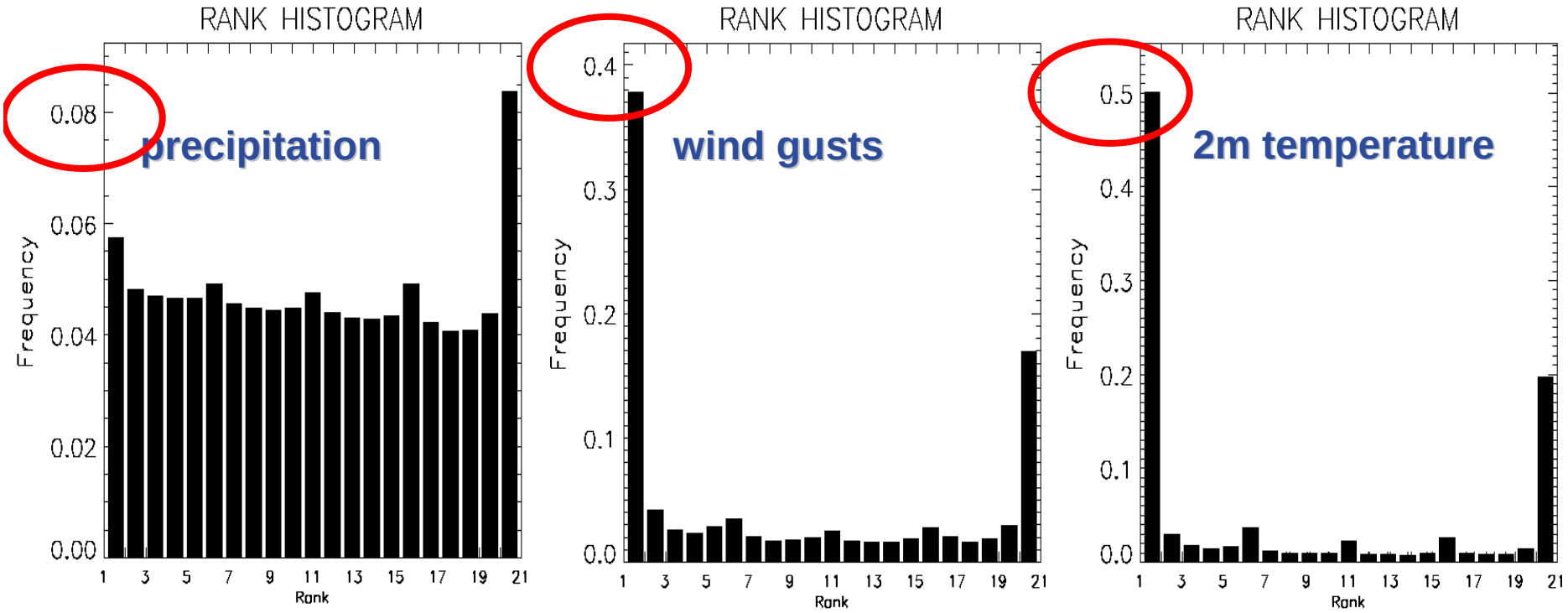
Rank histogram







Rank histogram



Main results from (pre-)operational phase (20 members)

- evaluation by forecasters (case studies):
  - additional benefit for precipitation forecasts
  - provides early signals for severe weather
  - most beneficial for convective precipitation in summer
  - reduced jumpiness between consecutive runs

- probabilistic verification (for periods of several months)
  - probabilities perform better than deterministic “yes/no”
  - particularly for high precipitation thresholds
  - particularly for longer lead times
  - drawback: underdispersion (esp. for wind gusts and T_2M)

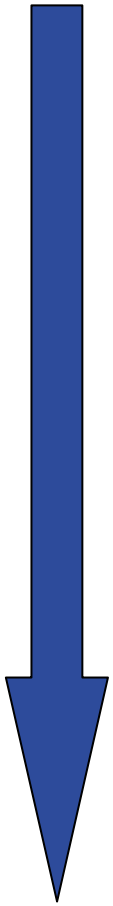
COSMO-DE-EPS status and plans

➔ **start of pre-operational mode (9th Dec 2010)**

➔ **evaluation by forecasters + verification**

switch to operational mode on 22nd May 2012

➔ **upgrade to 40 members, redesign**



2010

2011

2012

2013 / 14

upgrade to 40 members

- ➔ quantify more sources of forecast uncertainty
- ➔ use of COSMO-LEPS members as boundary conditions (COSMO-LEPS is driven by IFS EPS of ECMWF)
- ➔ additional physics perturbations (diffusion, roughness length)
- ➔ perturbation of soil moisture
- ➔ use of COSMO-DE-EPS in research projects dealing with renewable energy

⇨ poster by Andreas Röpnack

COSMO-DE-EPS status and plans

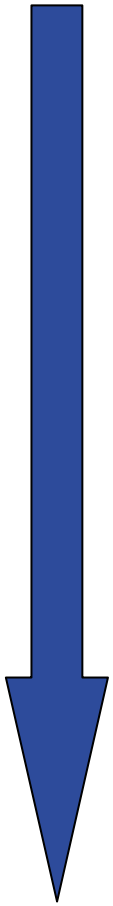
➔ start of pre-operational mode (9th Dec 2010)

➔ evaluation by forecasters + verification

switch to operational mode on 22nd May 2012

➔ upgrade to 40 members, redesign

➔ statistical postprocessing



2010

2011

2012

2013 / 14

LOGISTIC REGRESSION

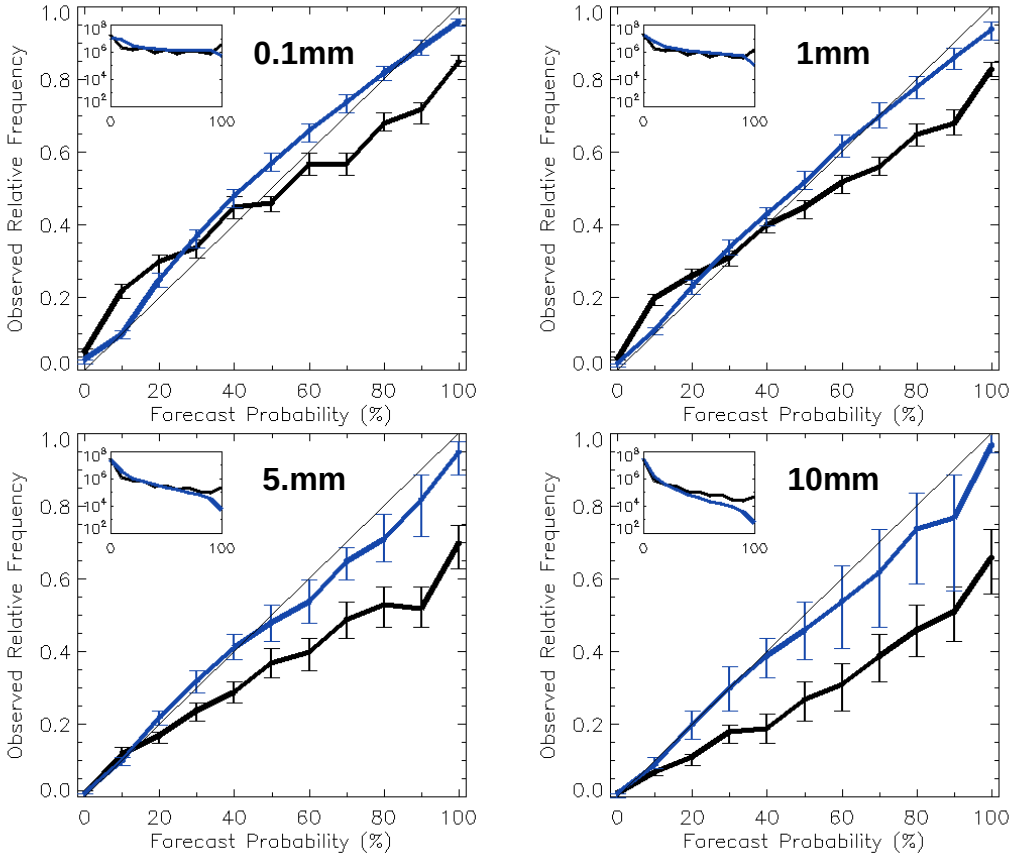
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Extended Logistic regression with **interaction terms**

Predictor: **ensemble mean**
+ power transformation
+ weighting

Training period: 45 days
Daily update
6-hourly precipitation

Original ensemble forecasts
Calibrated ensemble forecasts



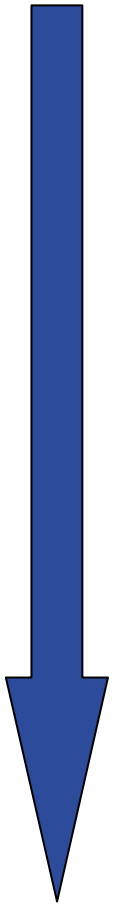
⇨ **poster by Zied Ben Bouallègue**

COSMO-DE-EPS status and plans

- start of pre-operational mode (9th Dec 2010)
- evaluation by forecasters + verification

switch to operational mode on 22nd May 2012

- upgrade to 40 members, redesign
- statistical postprocessing
- lagged average forecast
- initial conditions by LETKF ("KENDA")
- lateral boundary conditions by ICON EPS



2010

2011

2012

2013 / 14

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

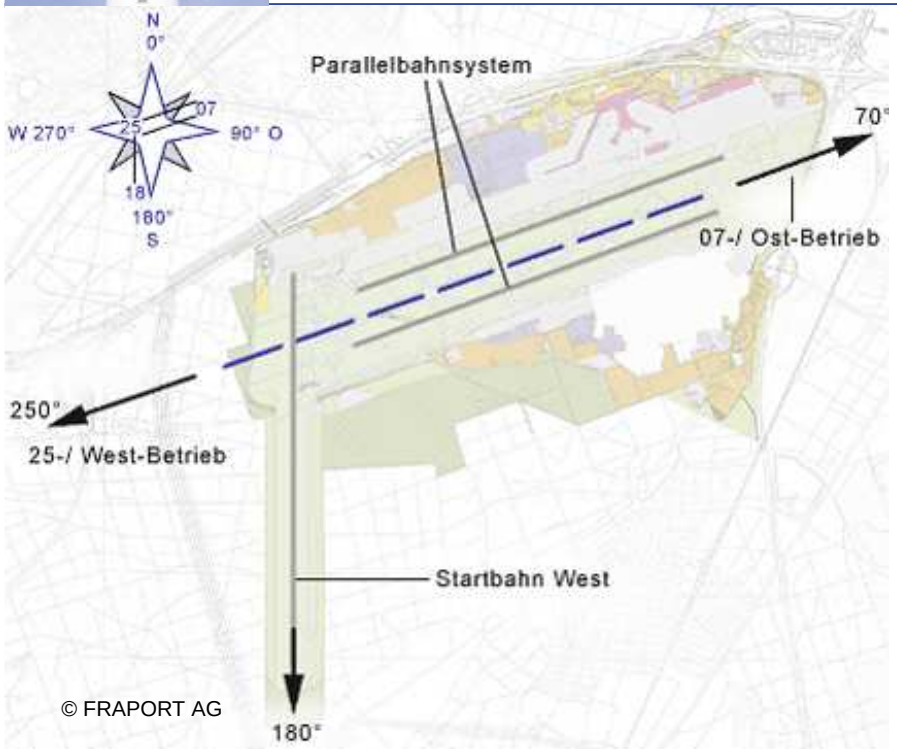
EPS-based wind forecasts for Frankfurt Airport

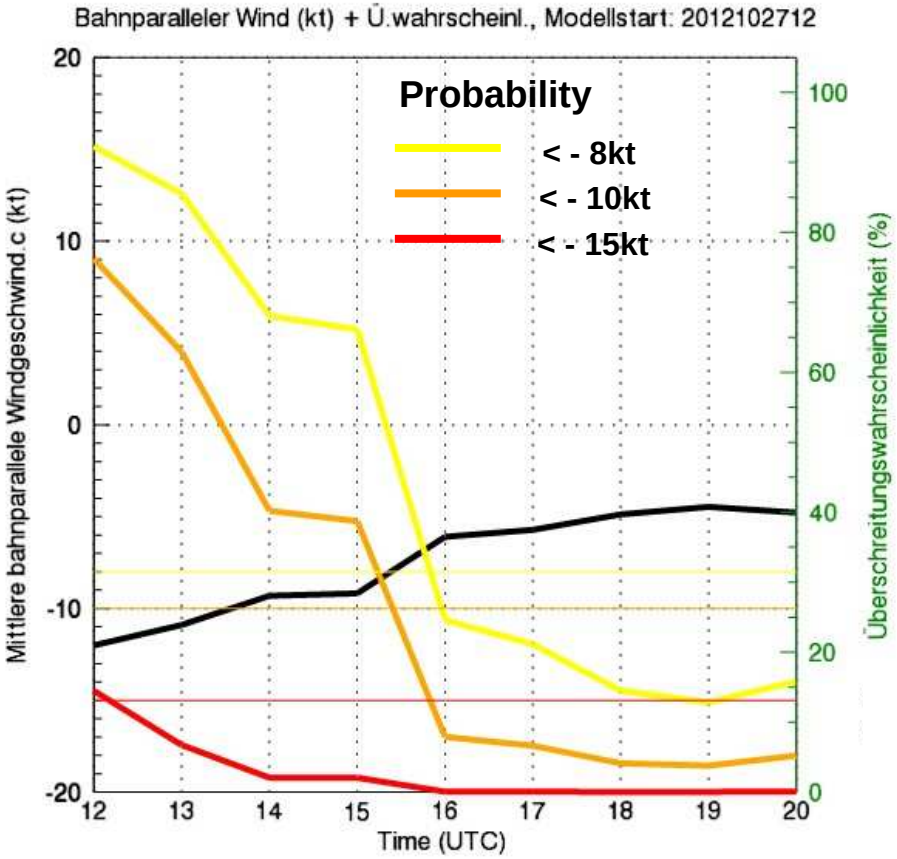
Isabel Alberts // Michael Buchhold

Luftfahrt**Fo**rschungsprogramm:
innovativer Air**Port** (LuFo iPort)

Frankfurt Airport

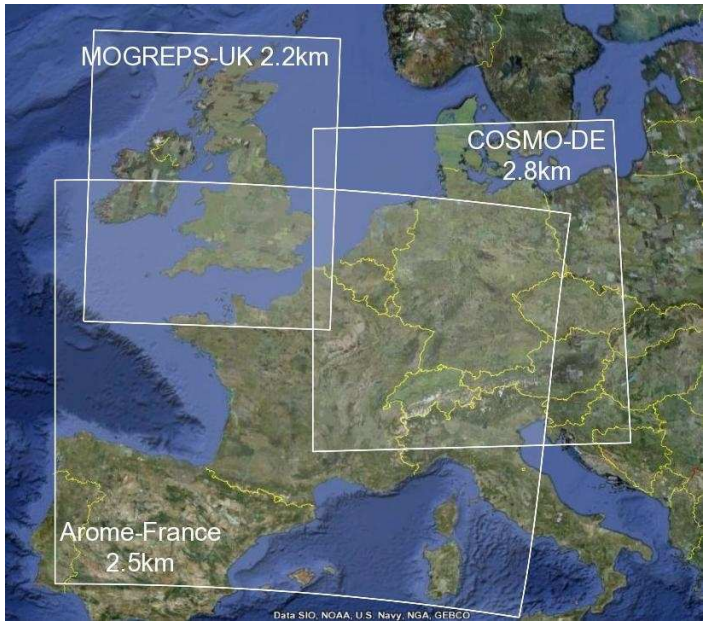
Deutscher Wetterdienst
Wetter und Klima aus einer Hand





SESAR Task “Convective Super-EPS“

- Single European Sky Air Traffic Management Research
- Cooperation of Météo France (lead), UK MetOffice and DWD
- provide intercalibrated, probabilistic products for ATM on a combined domain / common grid



REFERENCES

Gebhardt, C., Theis, S. E., Paulat, M., Ben Bouallegue, Z., 2011: *Uncertainties in COSMO-DE precipitation forecasts introduced by model perturbations and variation of lateral boundaries*, Atmos. Res.

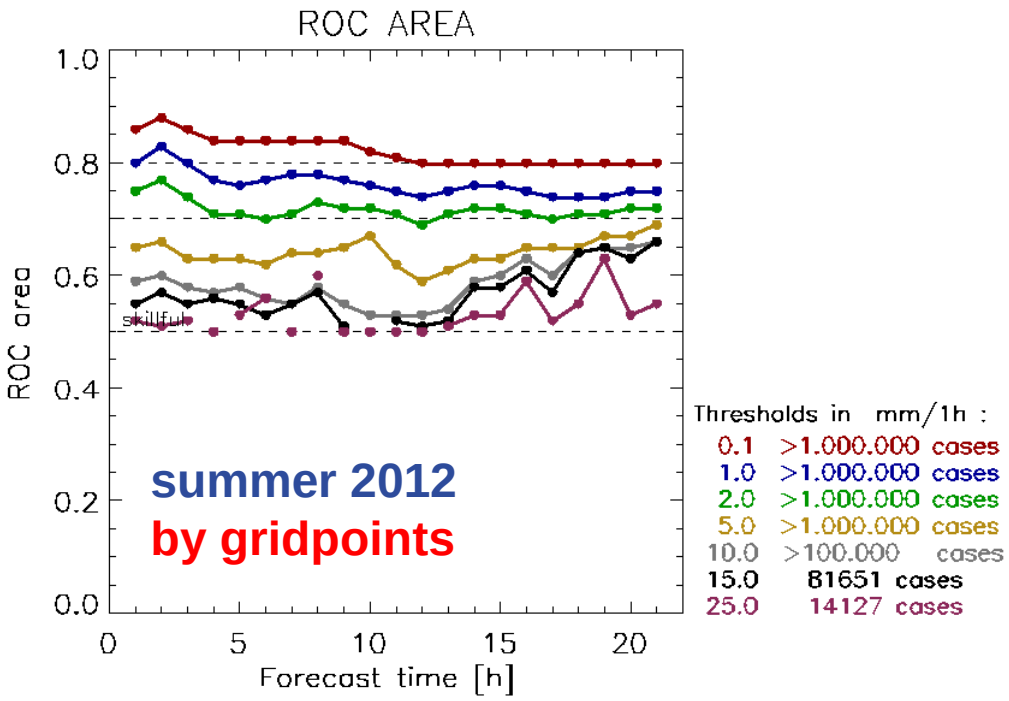
Peralta, C. , Ben Bouallegue, Z., Theis, S. E., Gebhardt, C. 2012: *Accounting for initial condition uncertainties in COSMO-DE-EPS*, Journal of Geophysical Res.

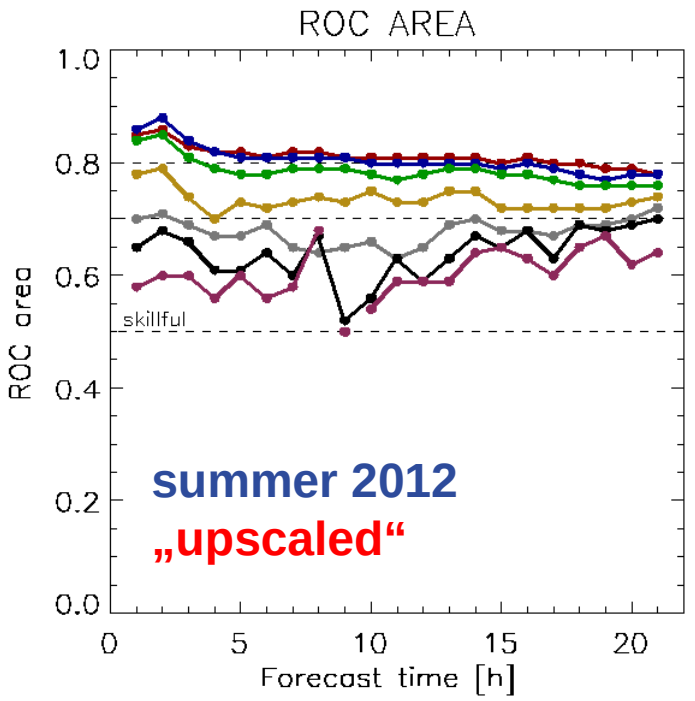
Ben Bouallègue, Z., 2012: *Calibrated short-range ensemble precipitation forecasts using extended logistic regression with interaction terms*, submitted to Wea. Forecasting

☺ Thank you ☺

extra slides

ROC area





spatially “upscaled“ means:

event somewhere within a 10x10 grid points environment

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Benefits from **past error statistics**

Logistic regression approach :

$$z = \beta_0(T) + \beta_1(T)x \qquad p = \frac{e^z}{1 + e^z}$$

Choice of predictors ***x***. Estimation of the ***β*** over a training period.
Calibrated probabilities ***p*** for a threshold ***T*** directly addressed

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Extended Logistic regression including the predictand threshold as predictor provides the **full probability distribution**

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(Wilks 2009)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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Extended Logistic regression including the predictand threshold as predictor provides the **full probability distribution**

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(Wilks 2009)

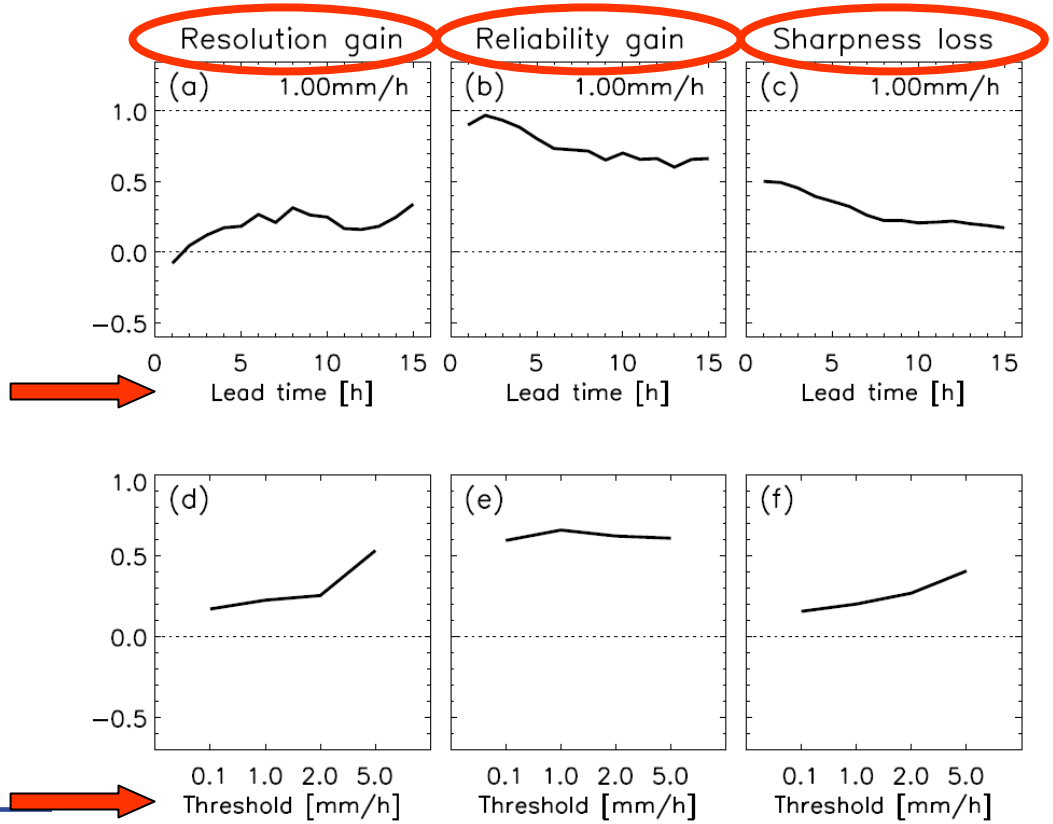
Extended Logistic regression with **interaction terms** fully describes the influence of *T* on all the original ***β***

$$z = \beta_0 + \beta_1 x + \beta_2 T + \beta_3 T x$$

(Ben Bouallègue, 2012)

Lagged average forecast LAF

➔ **combination of members from consecutive COSMO-DE-EPS runs to improve the representation of forecast uncertainty**



LAF (20+20+20 members) compared to COSMO-DE-EPS

hourly precipitation

June 2011