



# **Blending a probabilistic nowcasting method with a high resolution ensemble for convective precipitation forecasts**

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WN3 Workshop – Oberpfaffenhofen 10.05.2010



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

1. Motivation
2. Data and Methods
3. Forecast Quality
4. Blending of the forecasts
5. Conclusions & Outlook

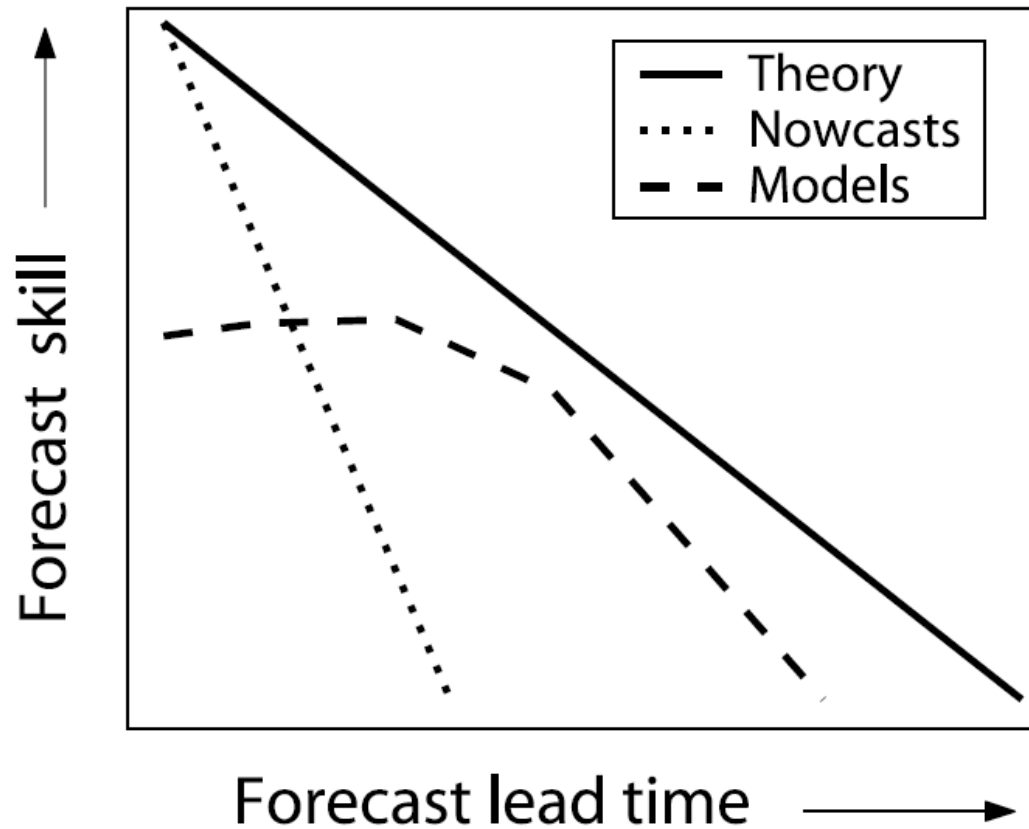


# 1. Motivation

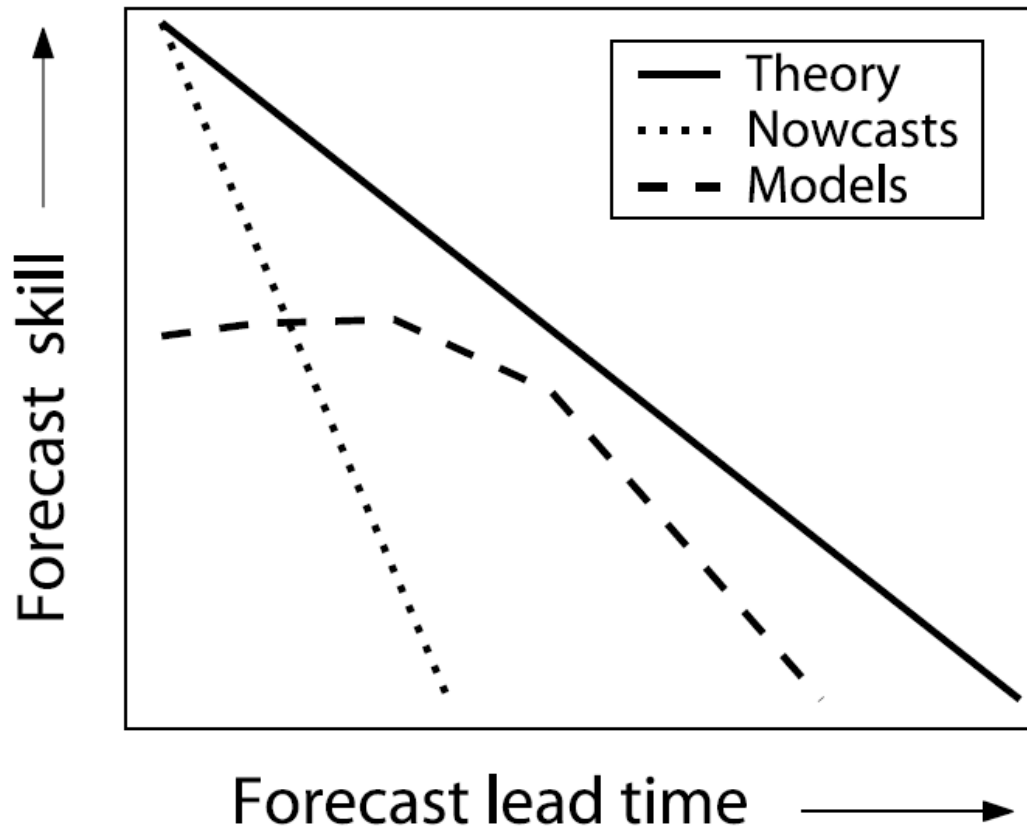


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# Forecast skill for convective precipitation

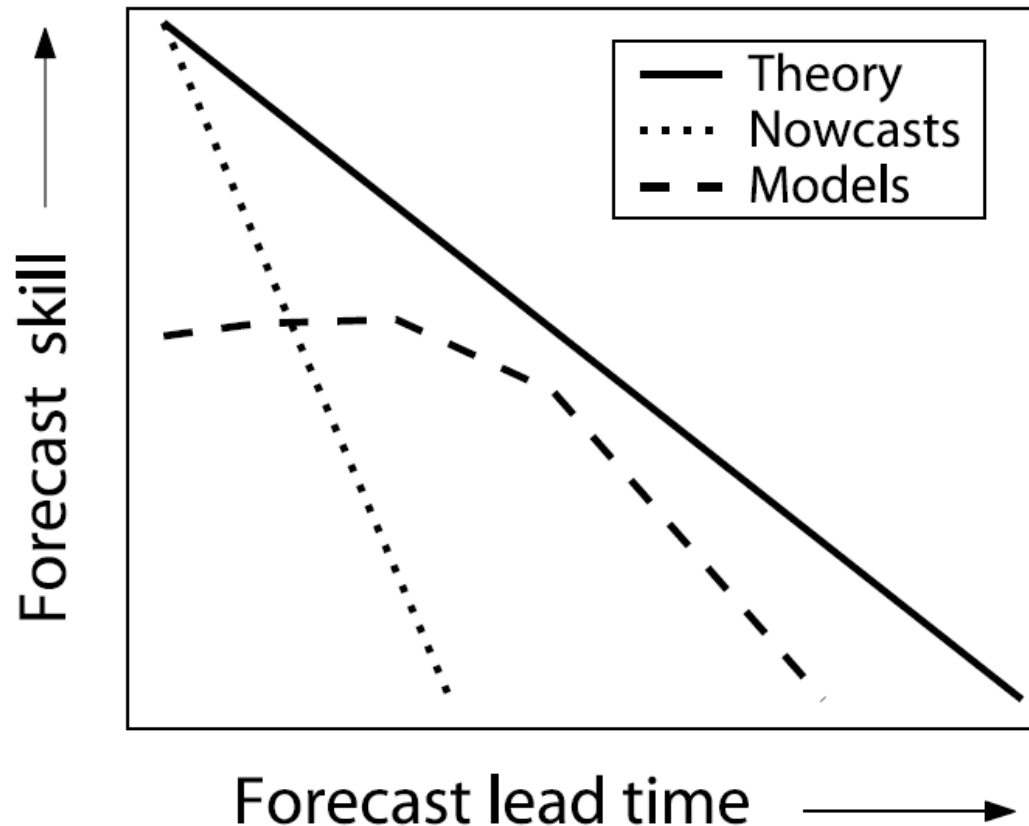


# Forecast skill for convective precipitation



- Theory:  
theoretical limit of predictability
- Nowcasts:  
rapid decrease of initially high skill
- NWP:  
superior after some time due to included dynamical effects

# Forecast skill for convective precipitation



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⇒ **Intrinsic uncertainty in methods & phenomena requires:**

- 1. Probabilistic view**
- 2. Combination of forecasts**



## 2. Methods





## **2. Methods**

# **Derivation of probabilities**





⇒ forecast: Probability of exceedance (19dBZ)

$$P(t_0 + \tau, x, L) = \text{Pr ob}\{\Psi(t_0 + \tau, x) \geq L\}$$

$\tau$ : lead time

$\text{Pr ob}$ : Probability operator

$x$ : position

$\Psi$ : precipitation field

$L$ : threshold (here: always 19dBZ!)



# **2. Methods**

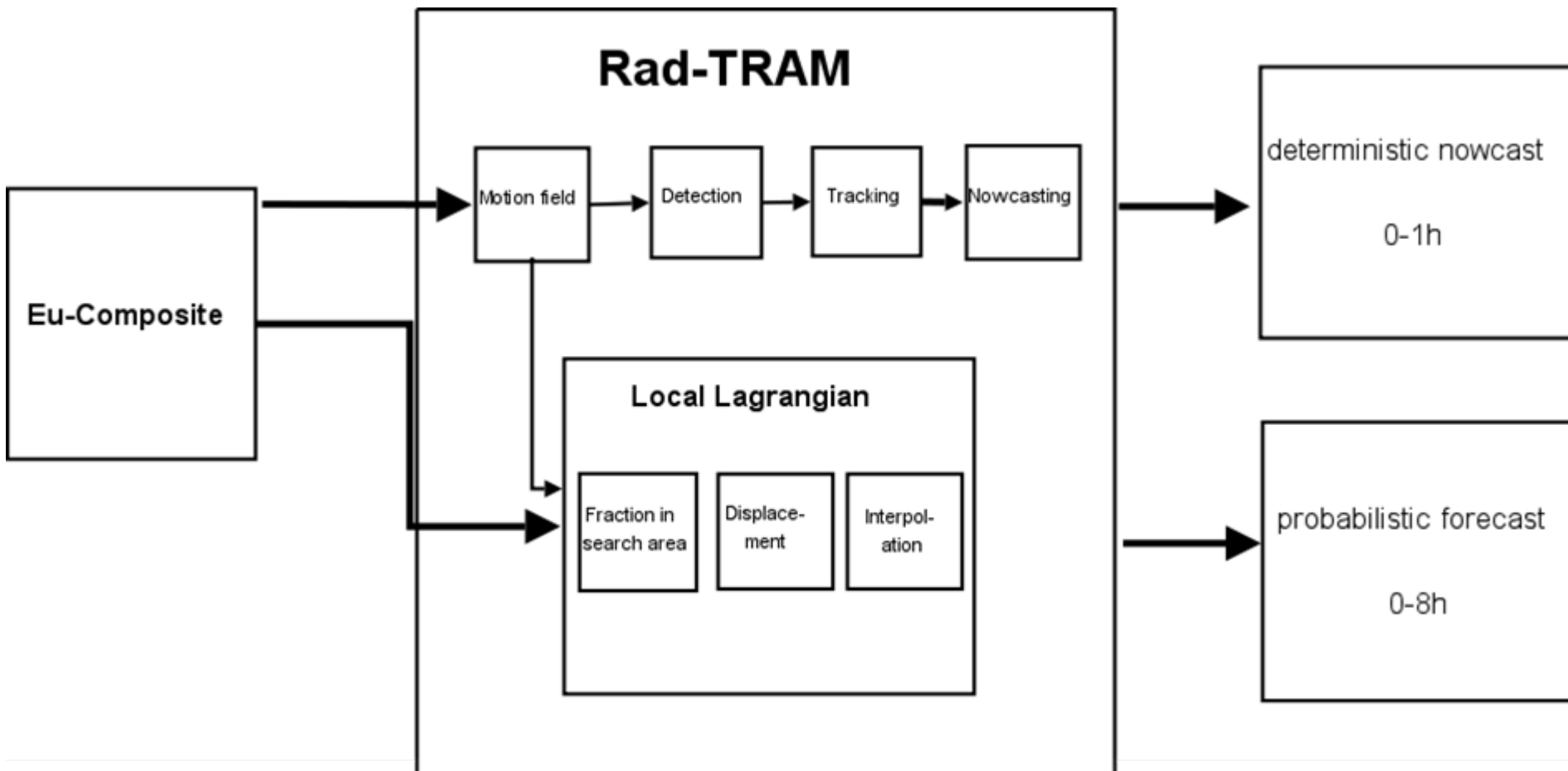
## **Derivation of probabilities**

### **NOWCASTING**



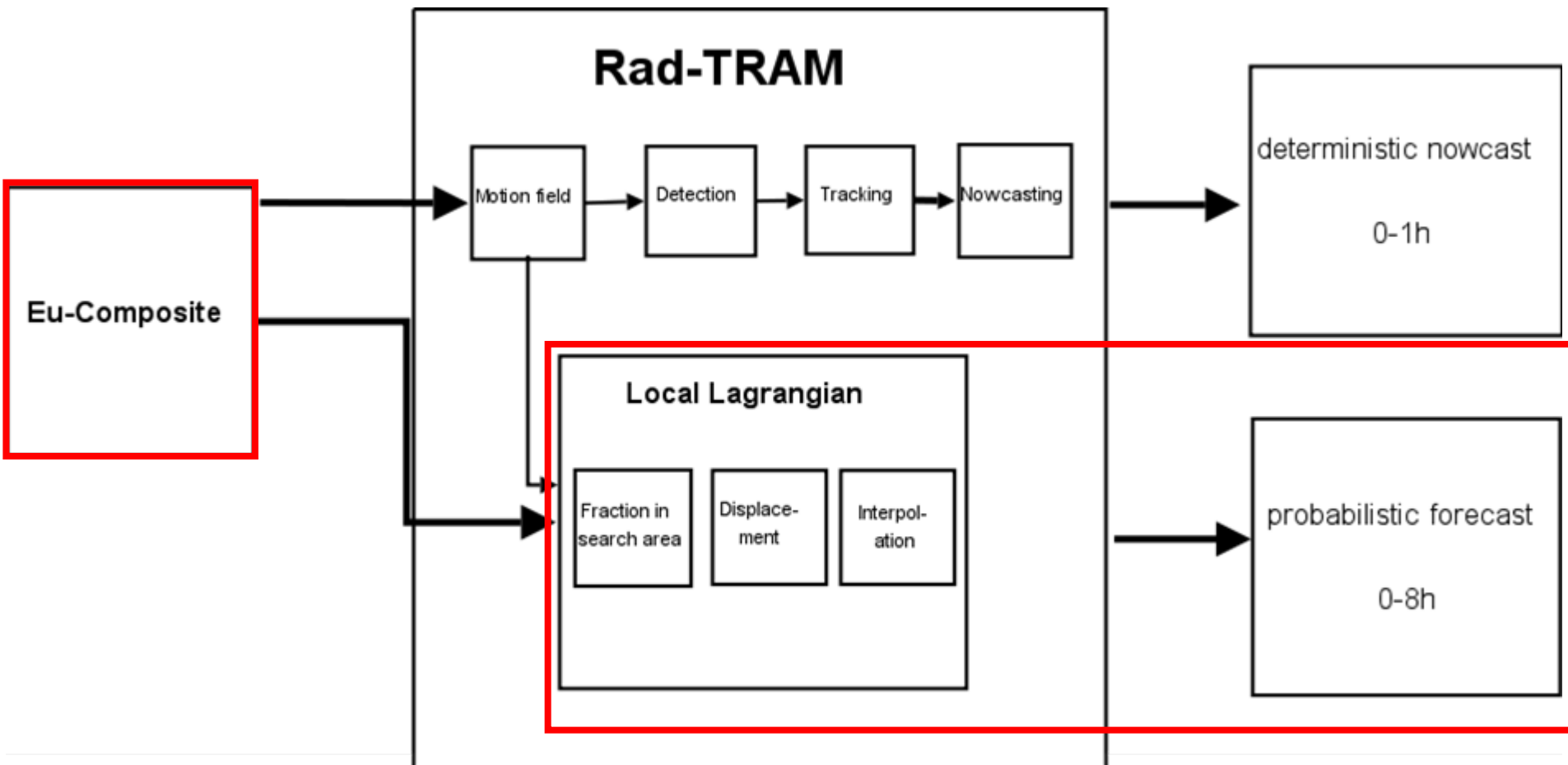
# Schematic overview Rad-TRAM

## Radar Tracking and Monitoring



# Schematic overview Rad-TRAM

## Radar Tracking and Monitoring



# Rad-TRAM: Radar Tracking and Monitoring

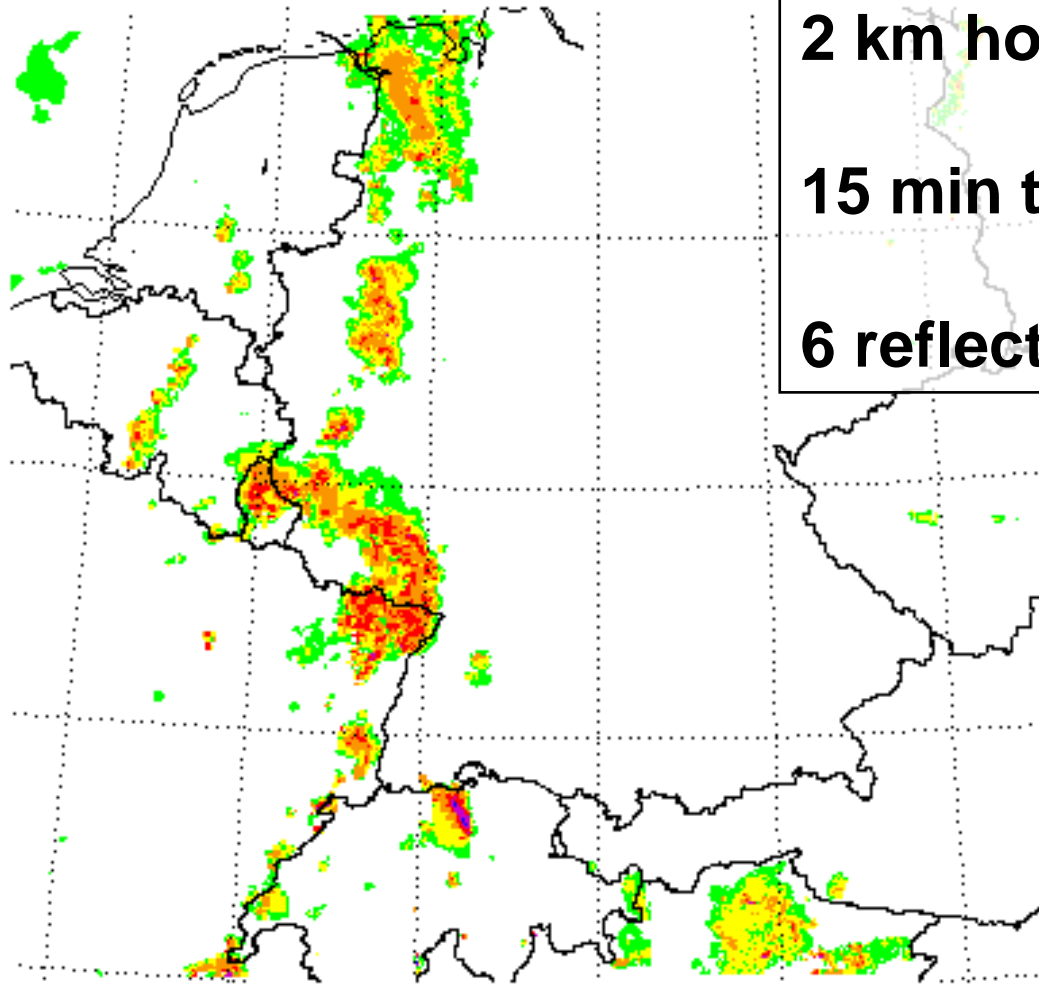
12.08.2007 23:15 UTC

European Radar Composite (DWD)

2 km horizontal resolution

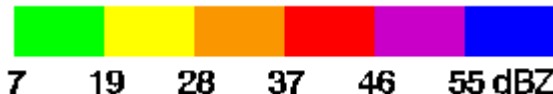
15 min temporal resolution

6 reflectivity classes



DLR

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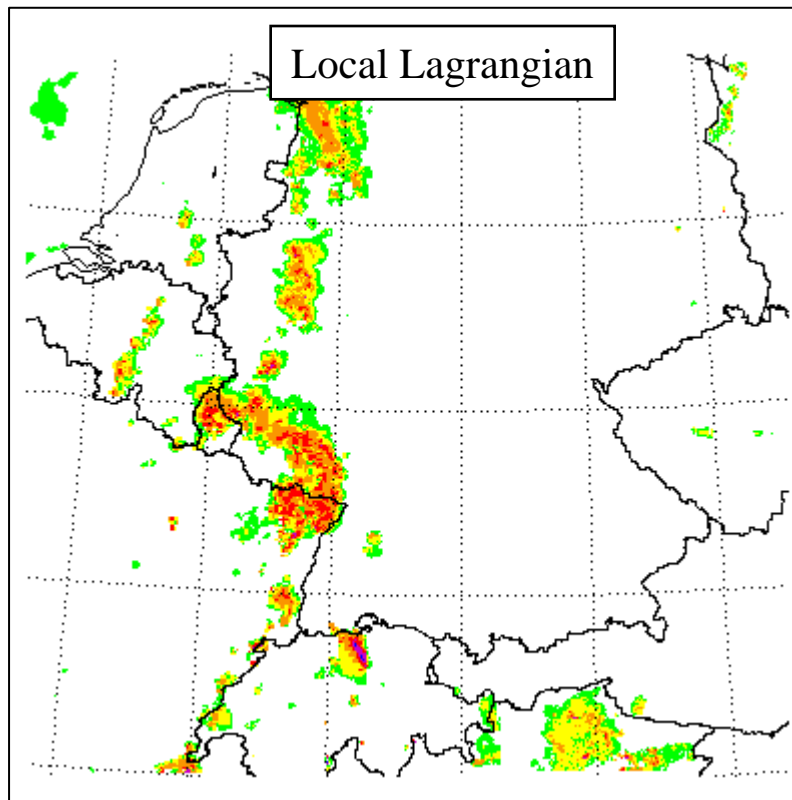
Kober and Tafferner, 2009

## Local Lagrangian:

temporal evolution of precipitation field is correlated to spatial variability

## Local Lagrangian:

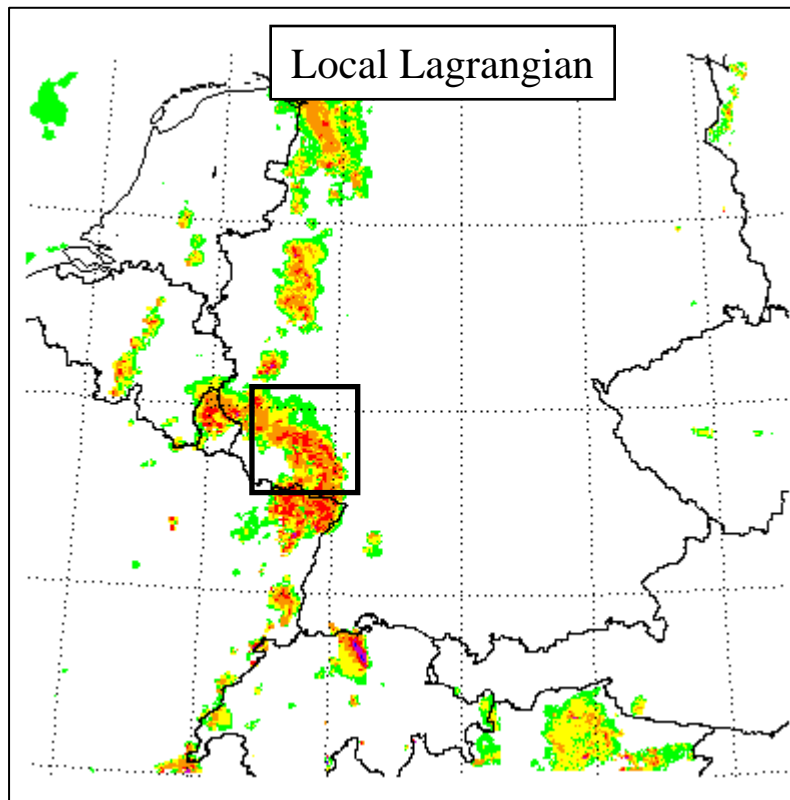
temporal evolution of precipitation field is correlated to spatial variability



# Probabilistic forecasts in Rad-TRAM

## Local Lagrangian:

temporal evolution of precipitation field is correlated to spatial variability



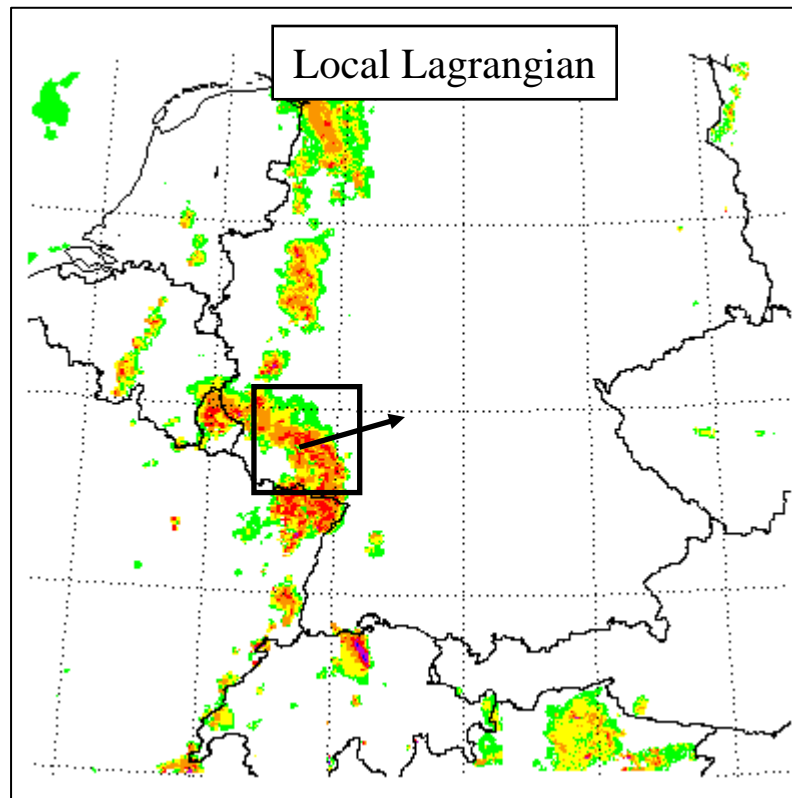
- fraction of pixels  $> 19\text{dbZ}$  in search area



# Probabilistic forecasts in Rad-TRAM

## Local Lagrangian:

temporal evolution of precipitation field is correlated to spatial variability

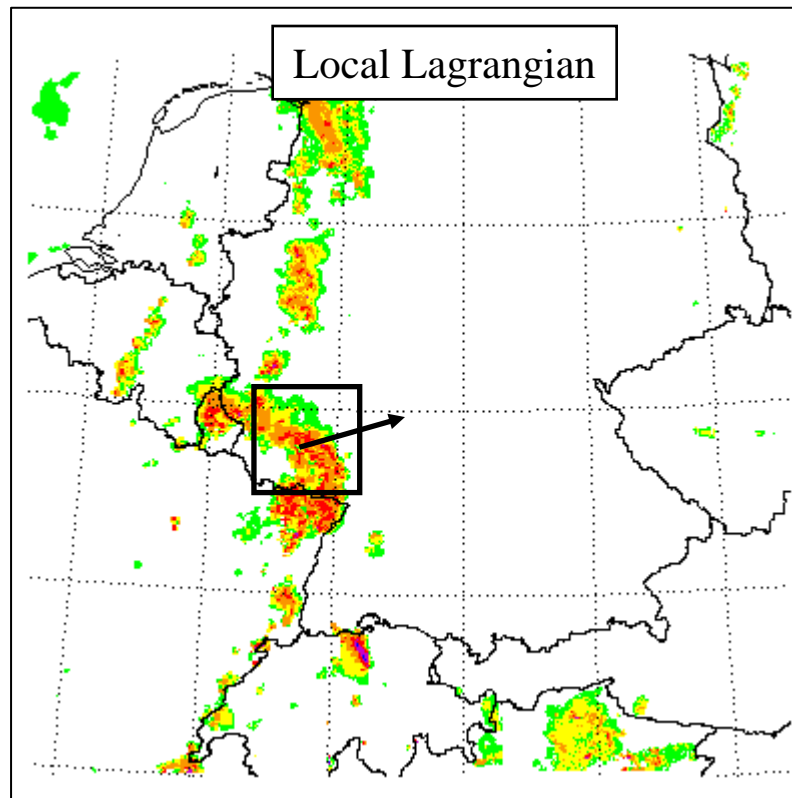


- fraction of pixels  $> 19\text{dbZ}$  in search area
- shifting with displacement vector
- interpolation with triangulation

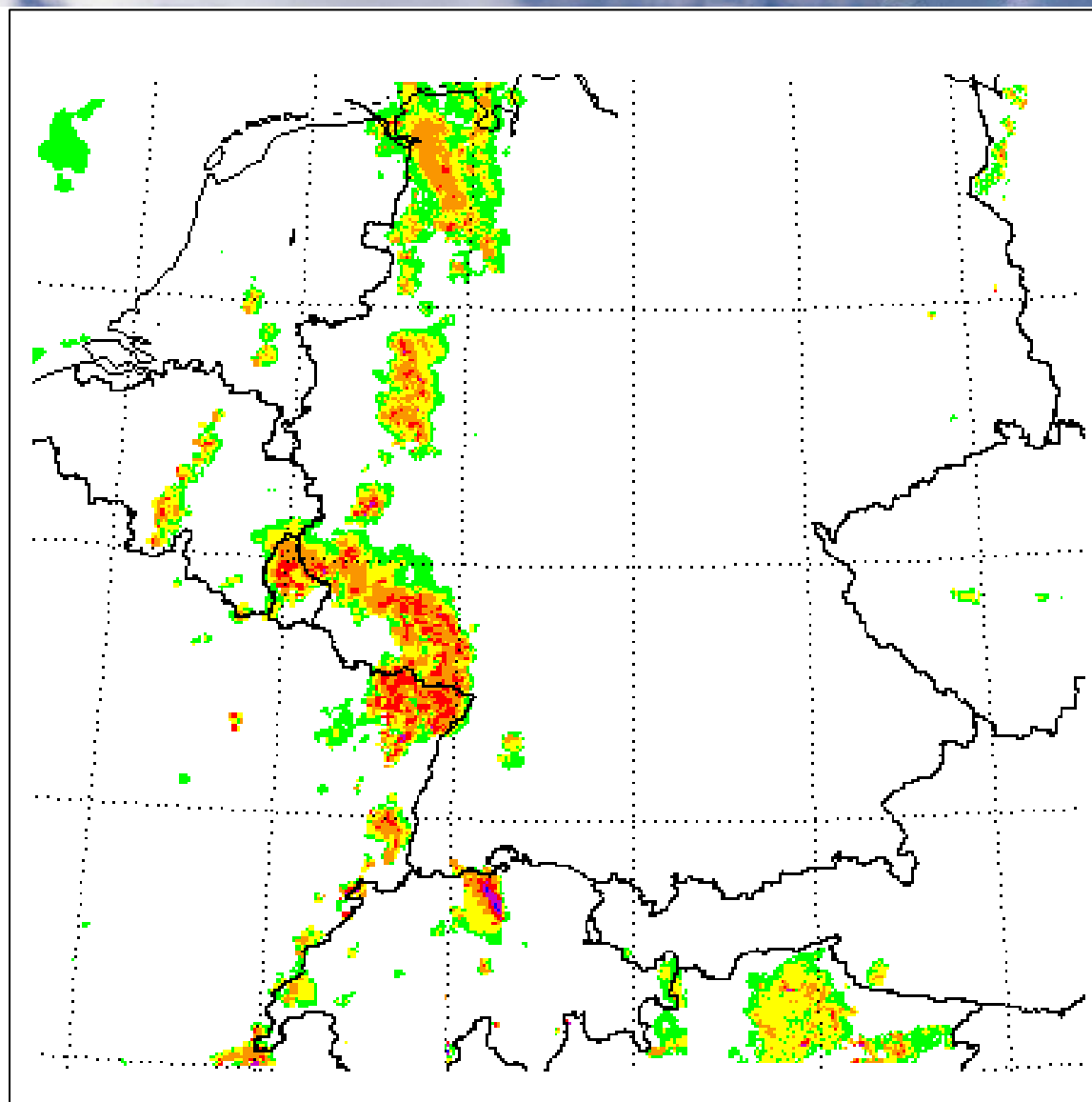
# Probabilistic forecasts in Rad-TRAM

## Local Lagrangian:

temporal evolution of precipitation field is correlated to spatial variability



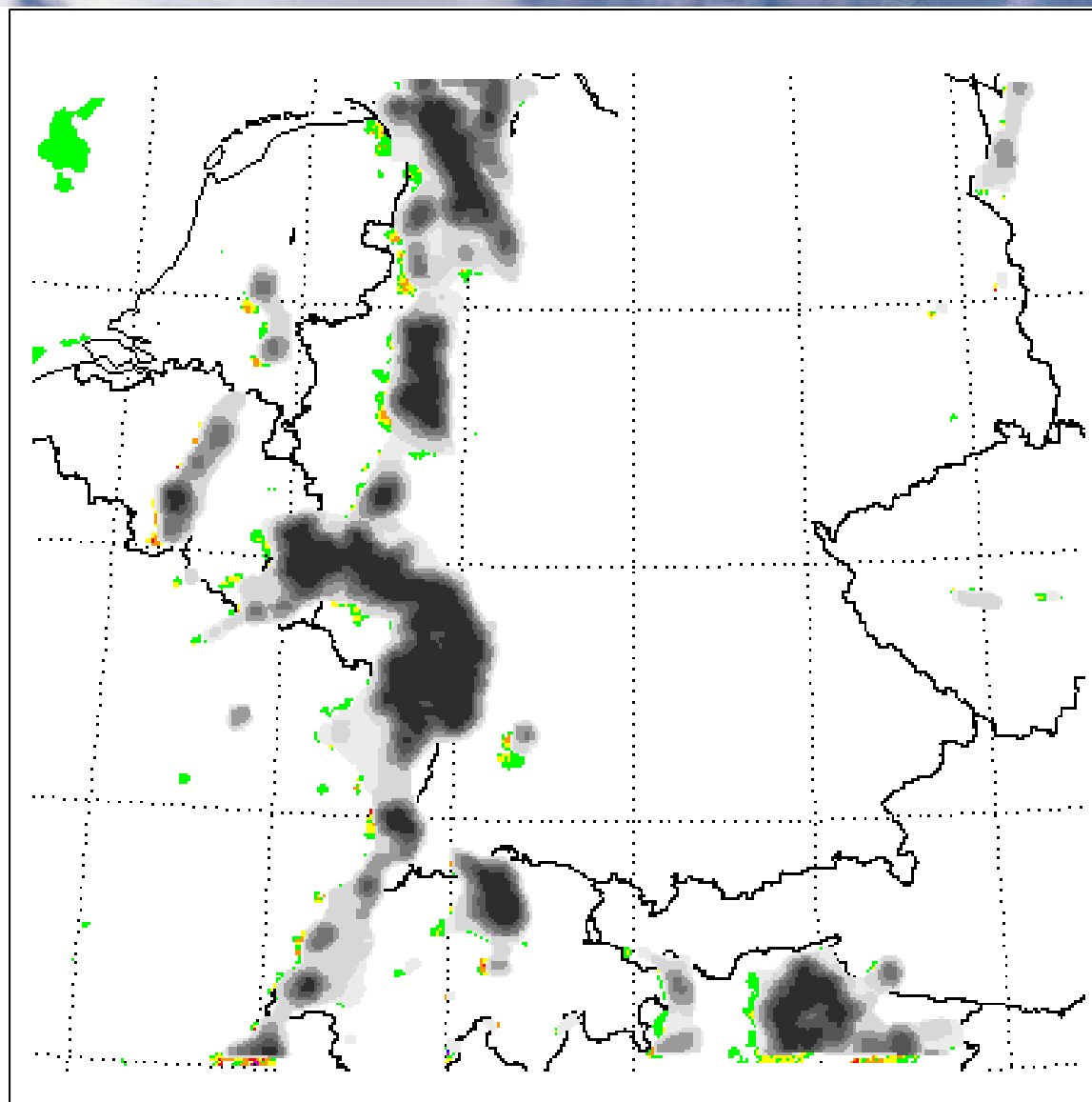
- fraction of pixels  $> 19\text{dbZ}$  in search area
- shifting with displacement vector
- interpolation with triangulation
- size search area  $\sim$  lead time
- forecasts up to 8 hrs in 15min steps



7 19 28 37 46 55 dBZ



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

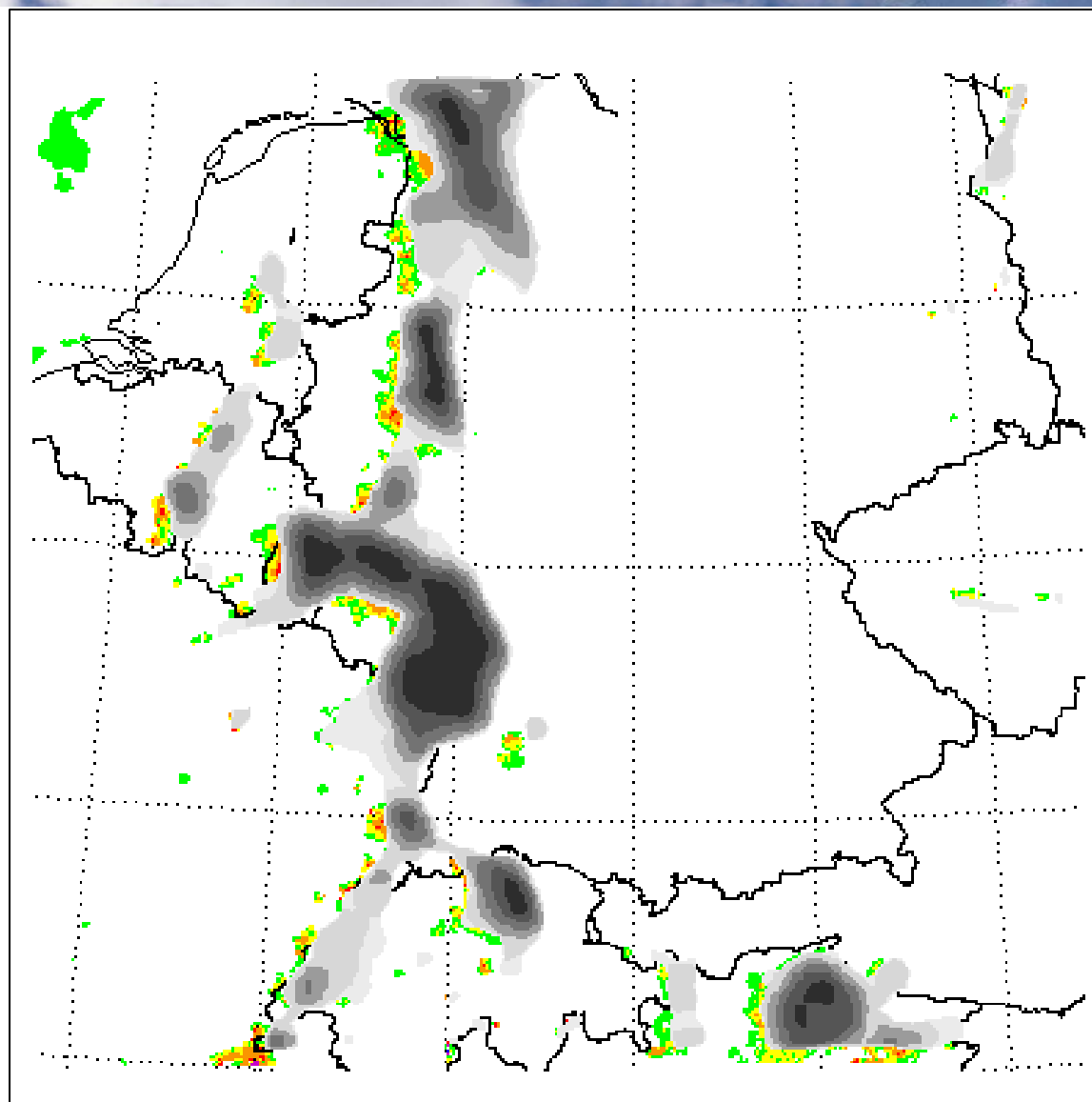


$\tau = 15\text{min}$



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft



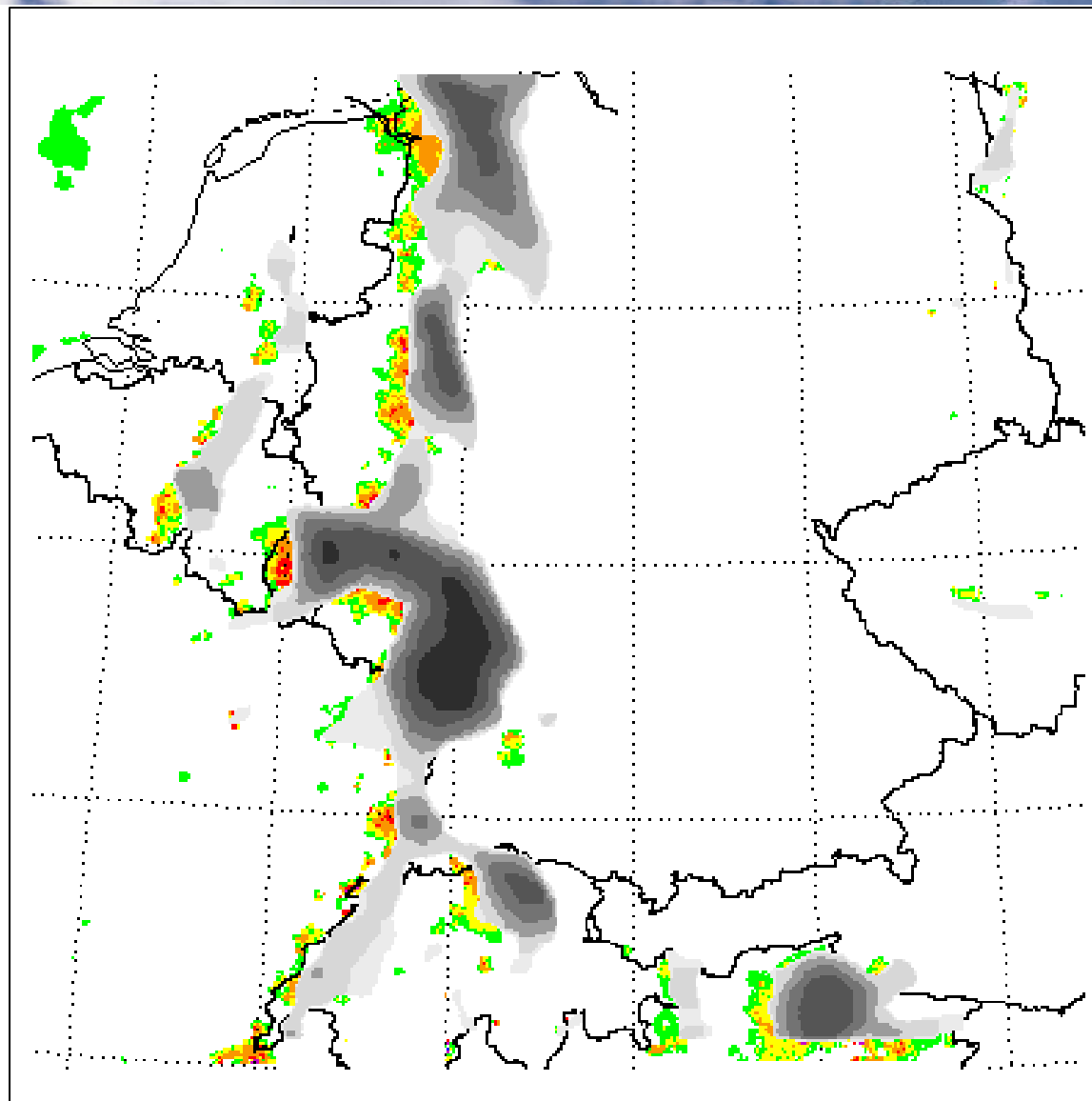


$\tau = 30\text{min}$



Deutsches Zentrum  
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in der Helmholtz-Gemeinschaft



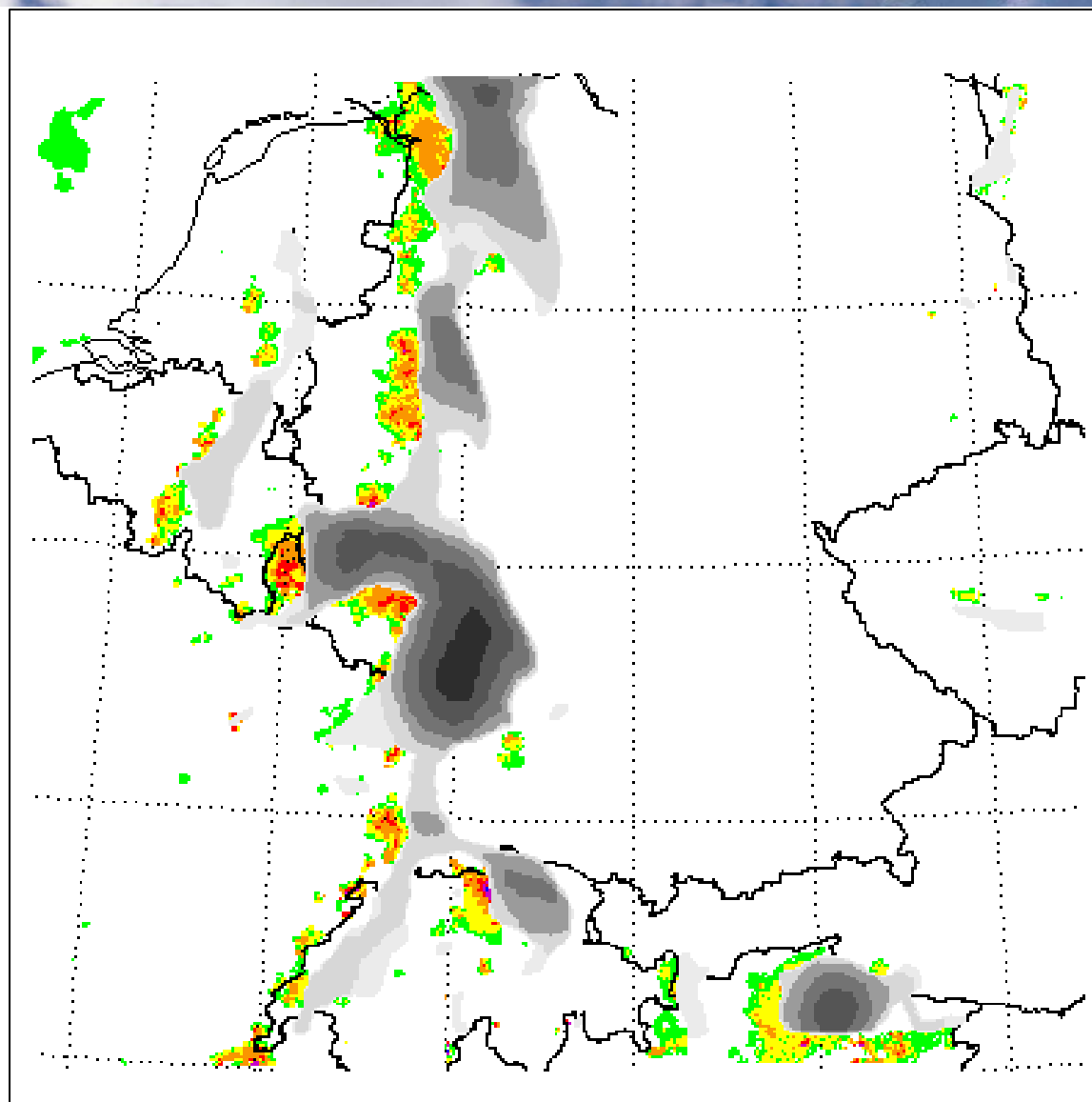


$\tau = 45\text{min}$



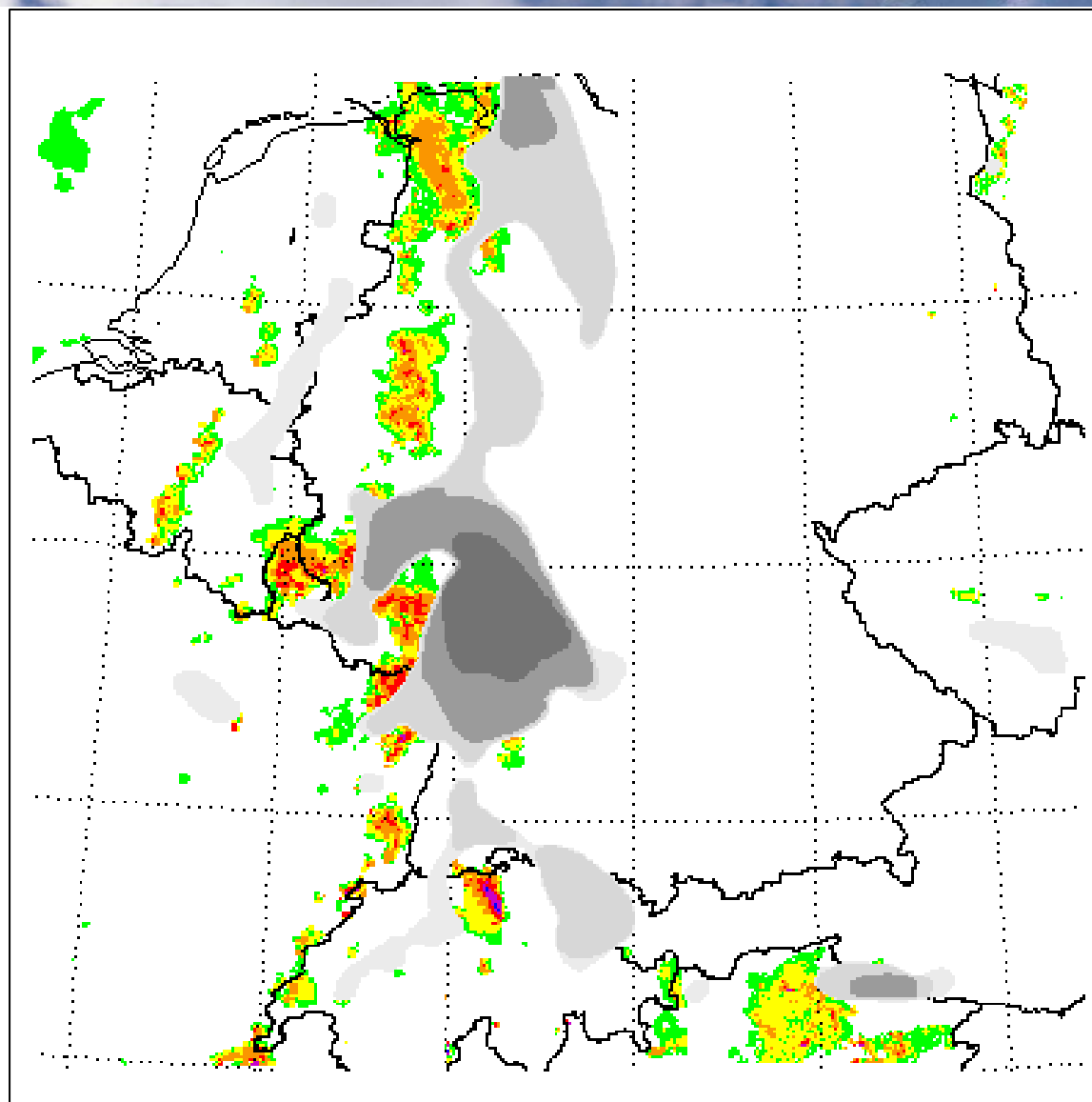
Deutsches Zentrum  
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$\tau = 60\text{min}$





$\tau = 120\text{min}$



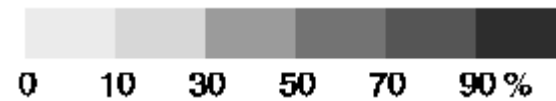
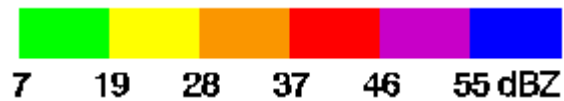
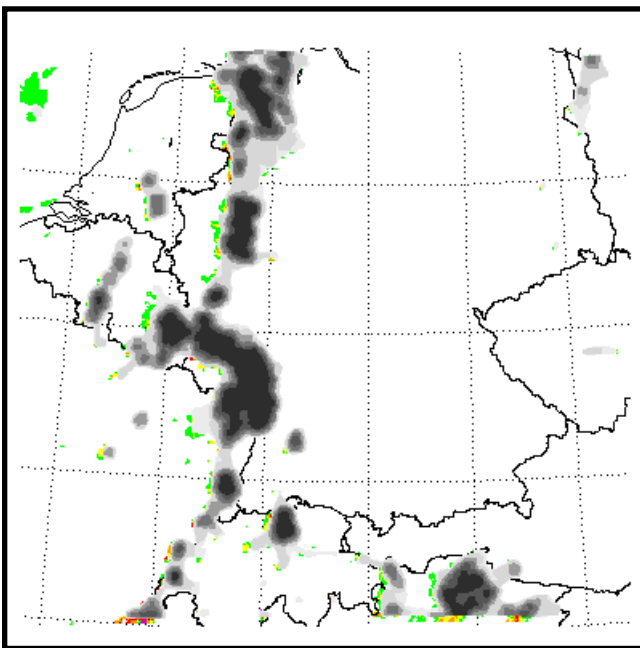
Deutsches Zentrum  
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# Rad-TRAM: for 12.08.2007 23:15UTC

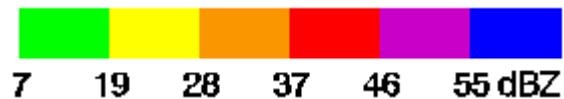
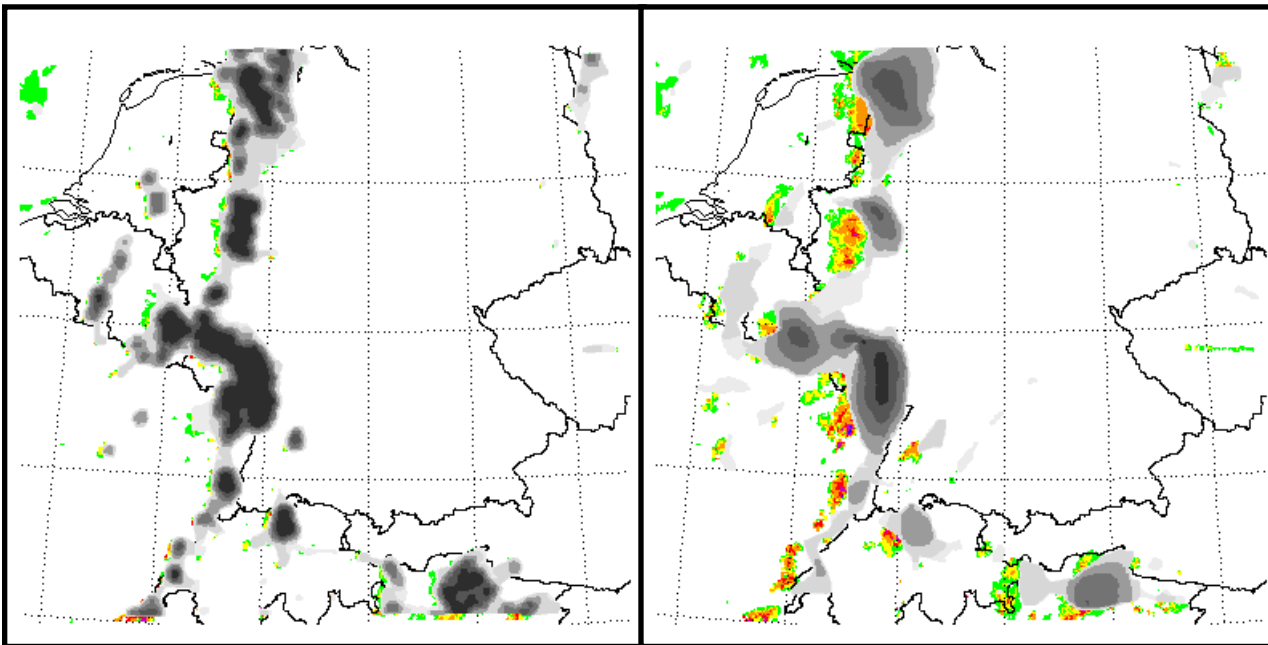
15 min forecast  
based on 23:00  
observation



# Rad-TRAM: for 12.08.2007 23:15UTC

15 min forecast  
based on 23:00  
observation

60 min forecast  
based on 22:15  
observation

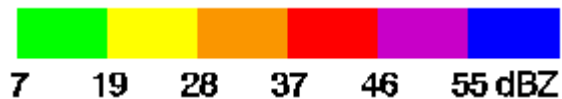
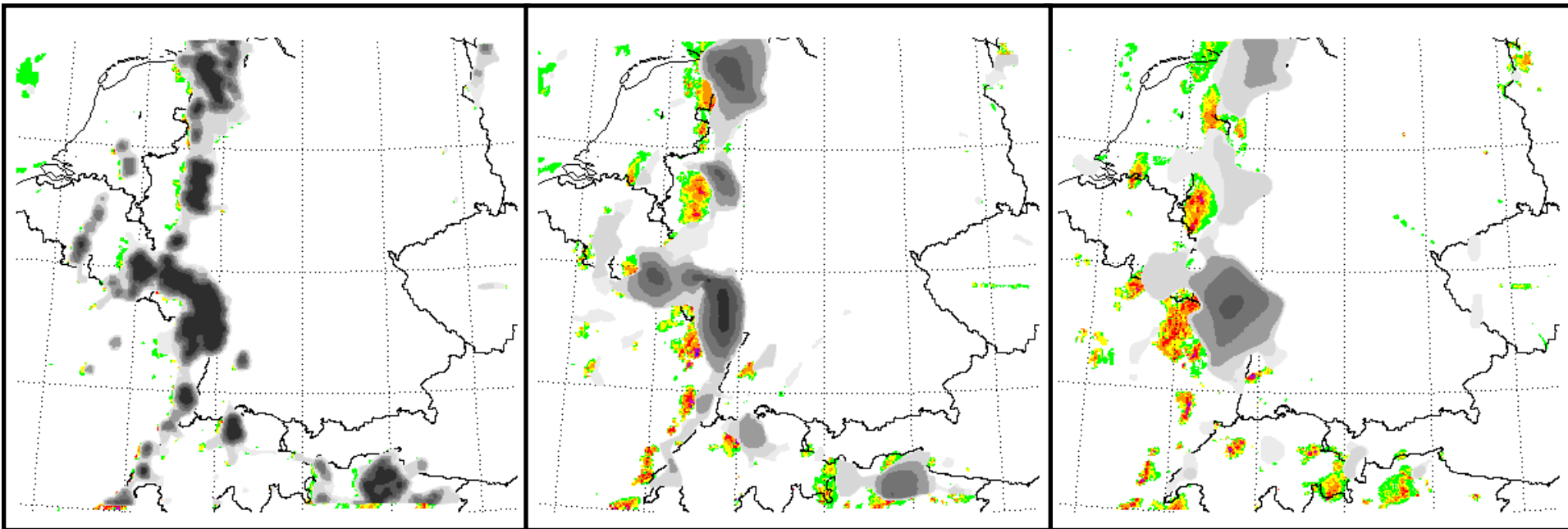


# Rad-TRAM: for 12.08.2007 23:15UTC

15 min forecast  
based on 23:00  
observation

60 min forecast  
based on 22:15  
observation

120 min forecast  
based on 21:15  
observation





# **2. Methods**

## **Derivation of probabilities**

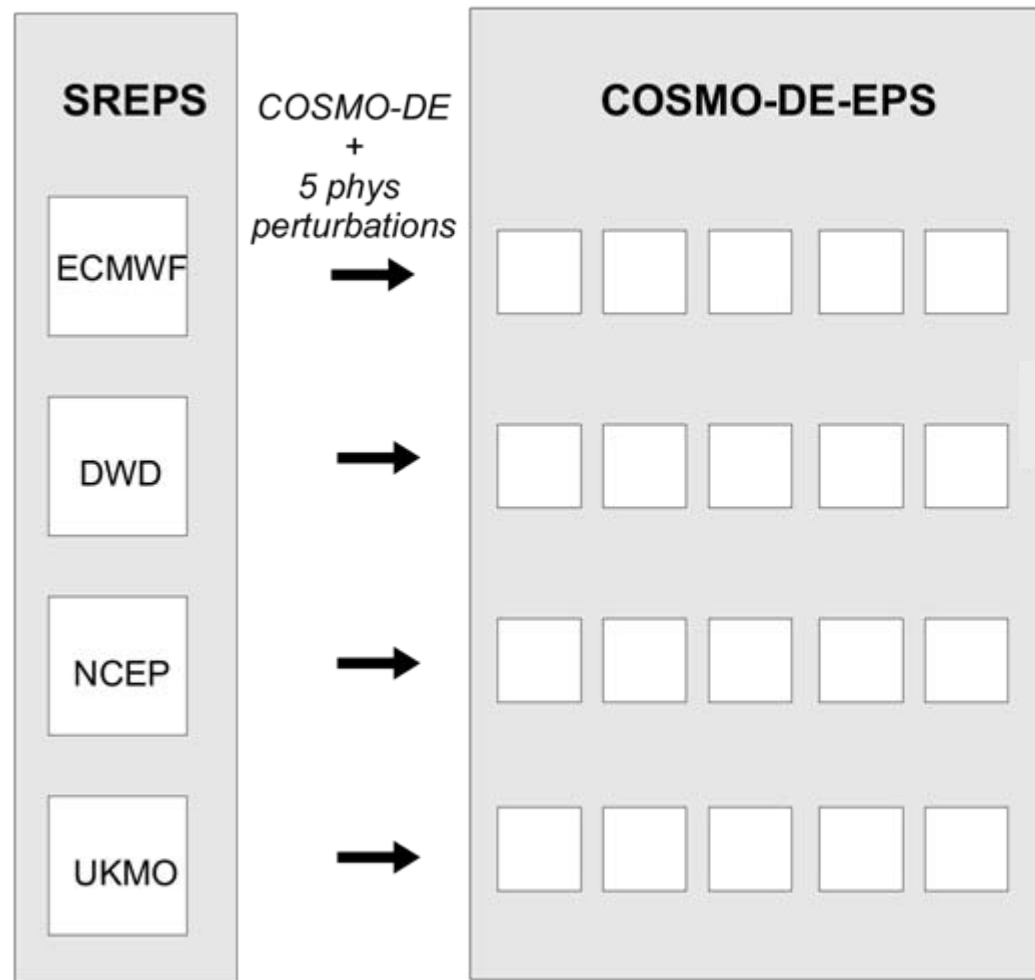
### **NWP: COSMO-DE-EPS**



experimental ensemble of DWD based on COSMO-DE:

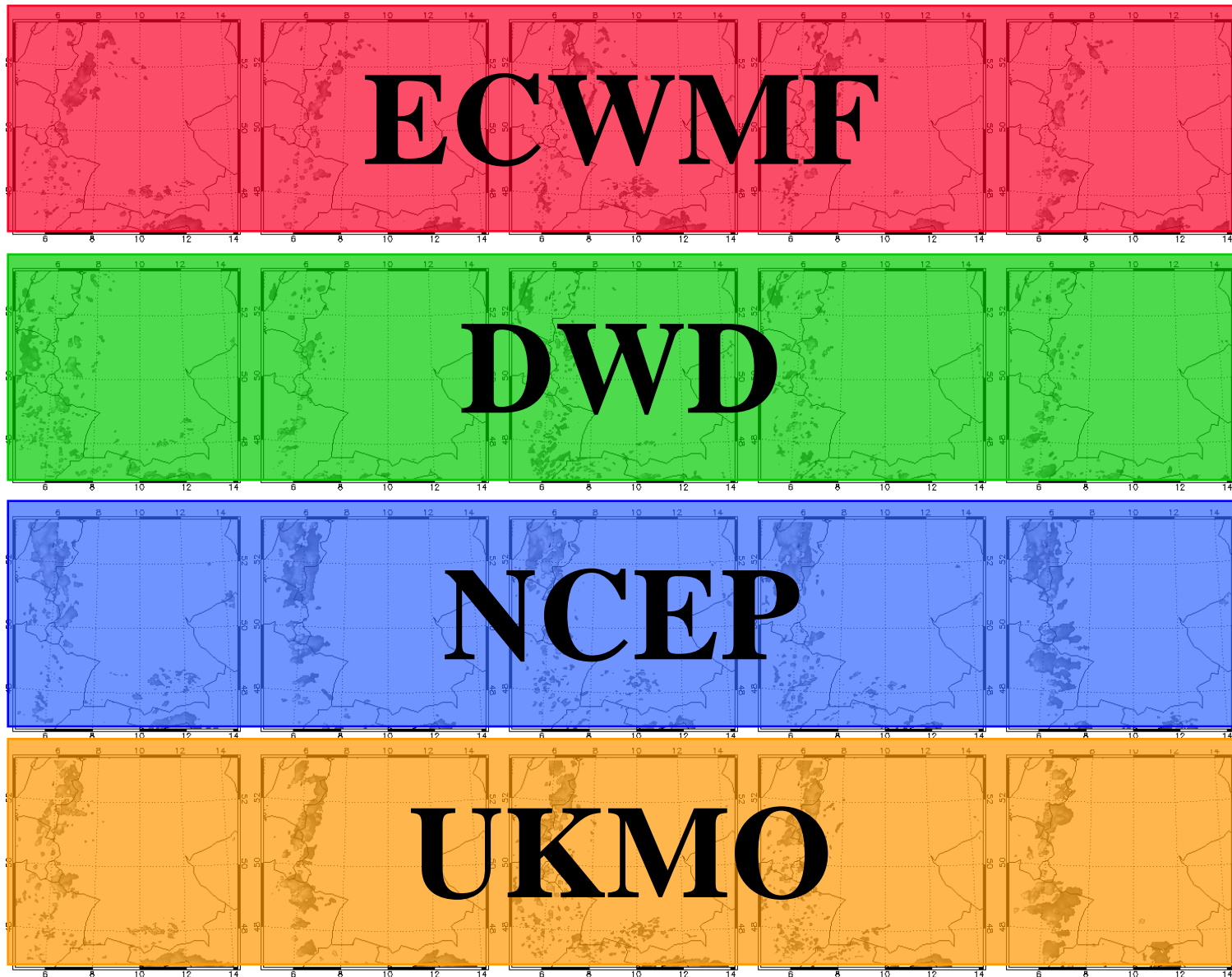
- 20 members
- 2.8 km horizontal resolution
- no parameterization of convection
- 24h forecast started at 0 UTC
- instantaneous synthetic radar reflectivity

# Schematic overview



# experimental COSMO-DE-EPS

12.08.2007  
23:15 UTC



Deutsches Zentrum  
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Gebhardt, 2010

12.08.2007  
23:15 UTC

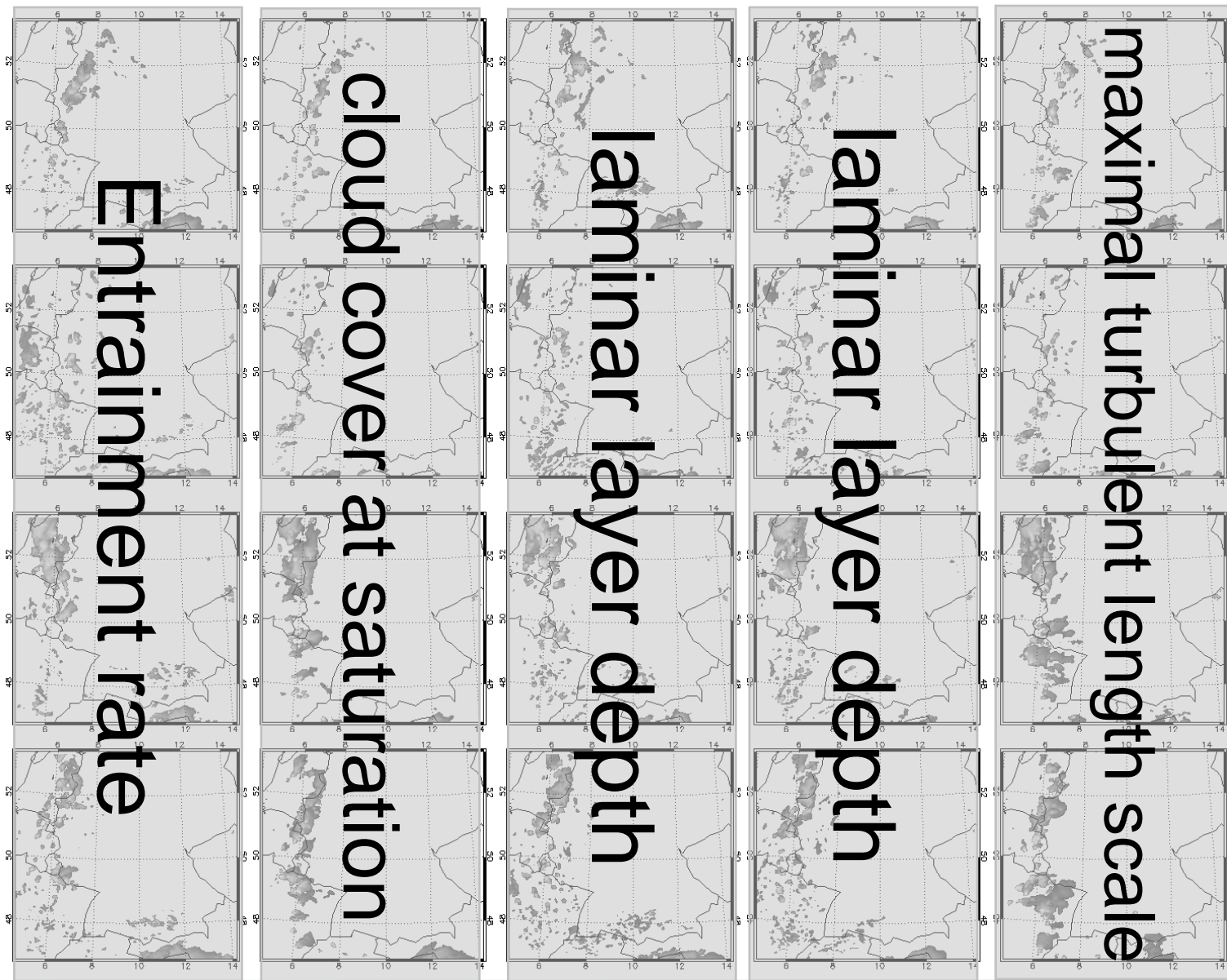




Table I. List of parameter perturbations in COSMO-DE-EPS.

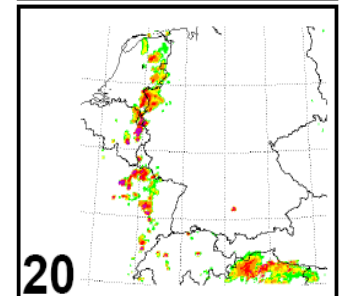
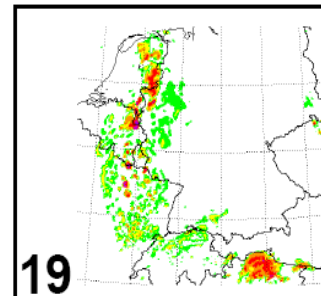
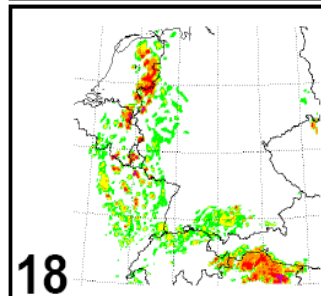
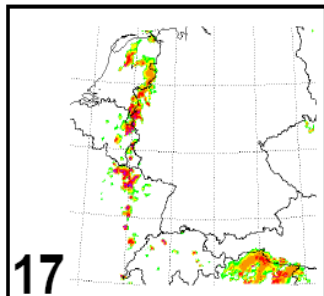
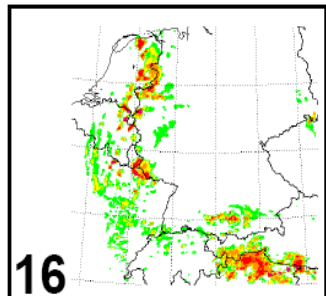
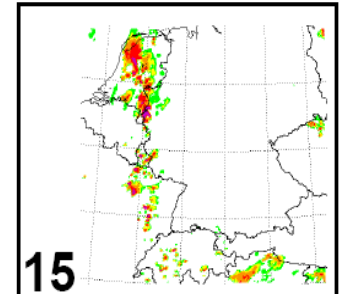
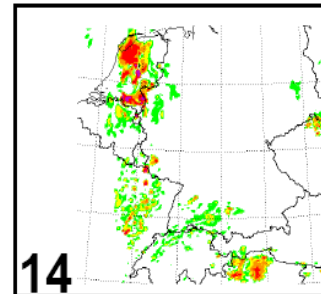
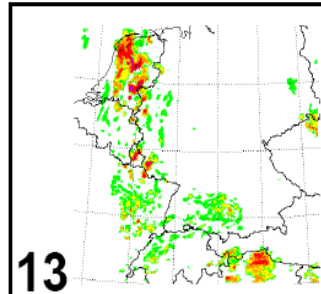
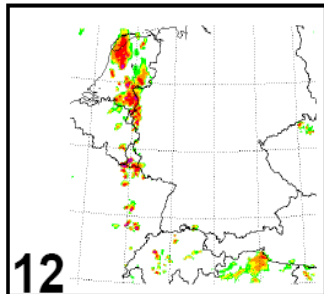
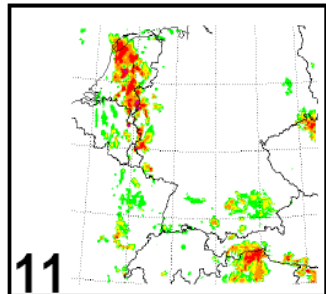
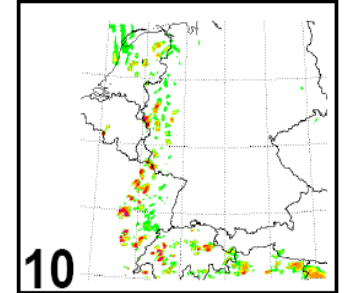
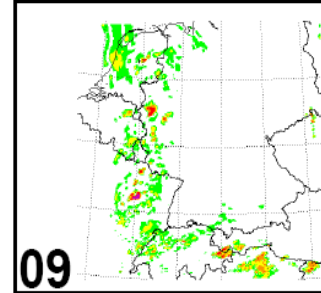
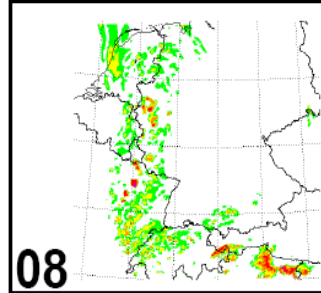
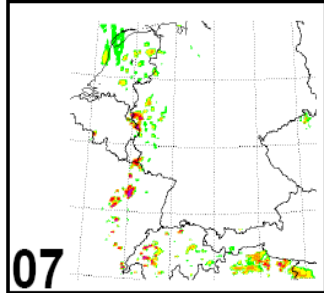
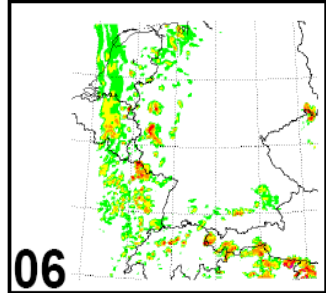
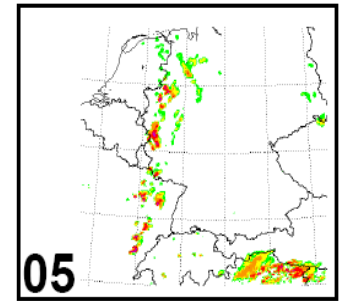
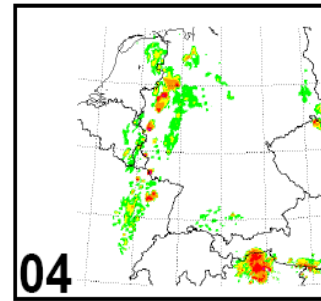
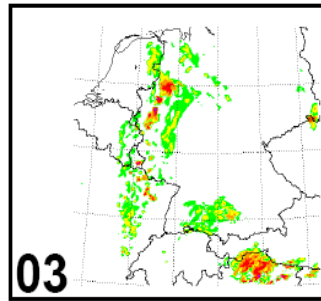
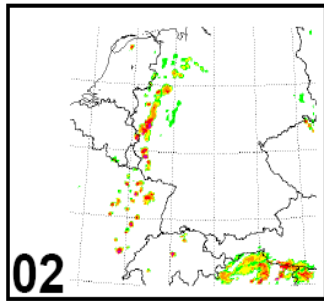
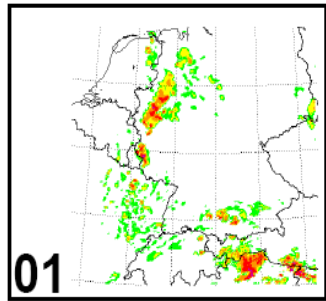
parameter	description	perturbed	default
entr_scv	entrainment rate of shallow convection	0.002	0.0003
clc_diag	subscale cloud cover given grid-scale saturation in the turbulence scheme	0.5	0.75
rlam_heat	scaling factor of the laminar sublayers for scalars	50	1.0
rlam_heat	scaling factor of the laminar sublayers for scalars	0.1	1.0
tur_len	asymptotic mixing length of turbulence scheme	150	500

➔ Perturbation of parameters that influence the formation of precipitation:

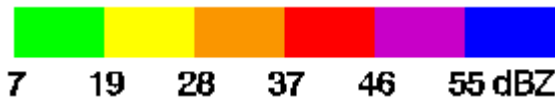
boundary layer-, turbulence- & shallow convection parameterization

➔ **Goal: Maximize the variability in the precipitation forecast**

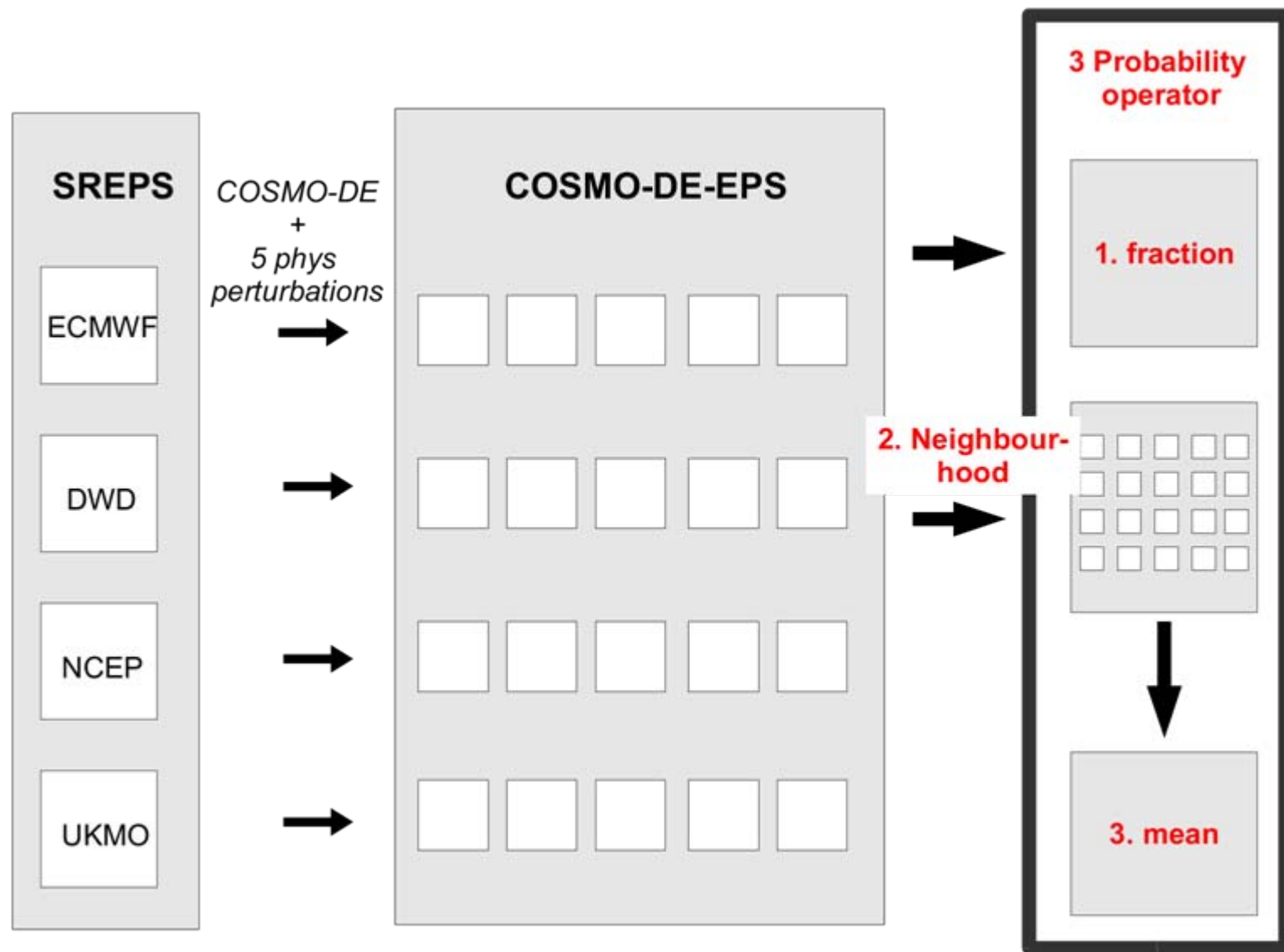
# COSMO-DE-EPS – synthetic radar reflectivity 850 hPa



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft



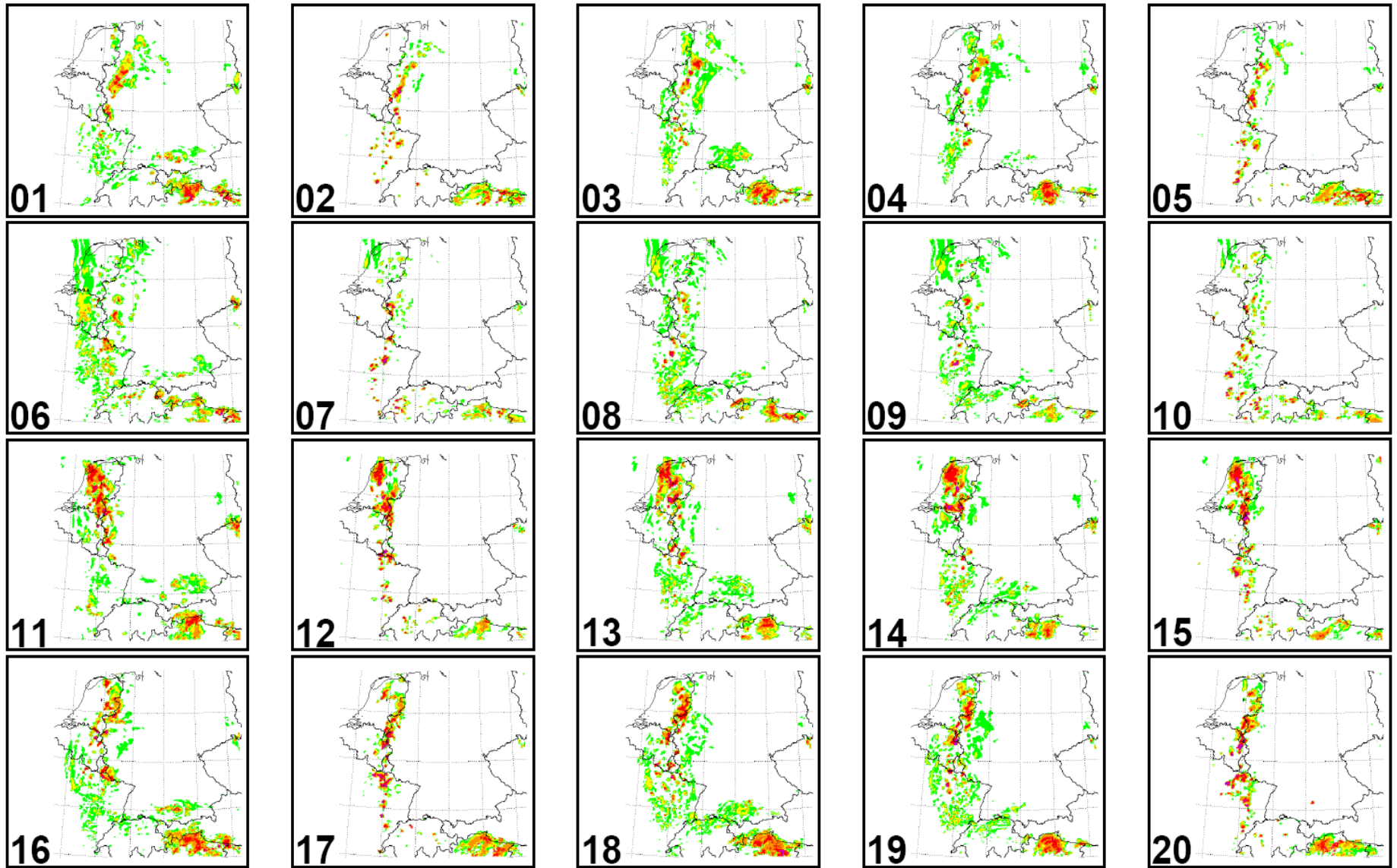
# Schematic overview



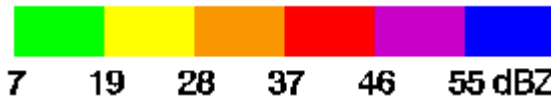
## 1. Traditional method: **fraction**



# COSMO-DE-EPS – Fraction

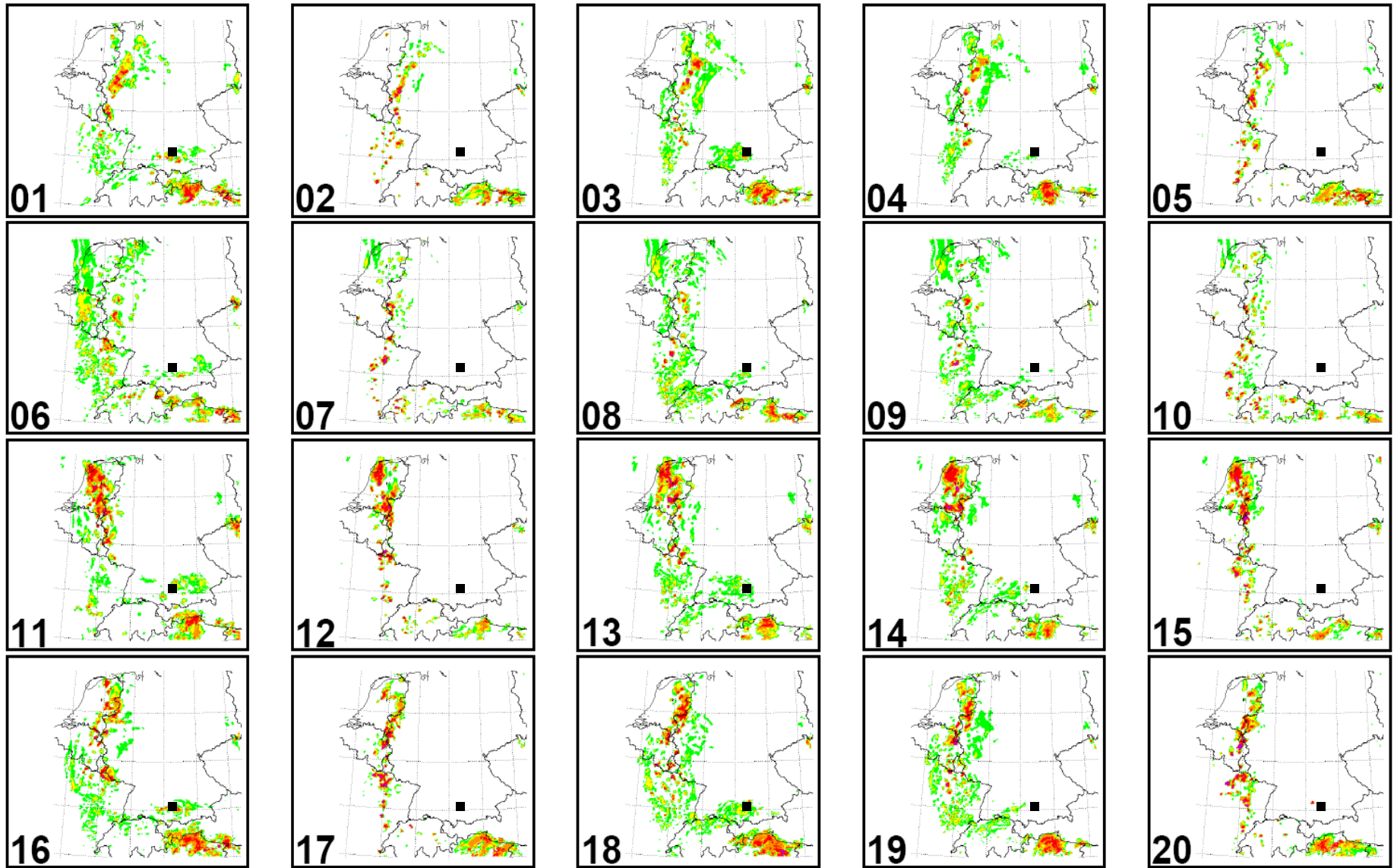


Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
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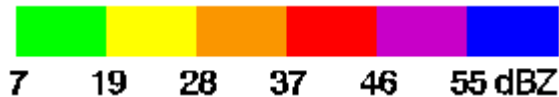




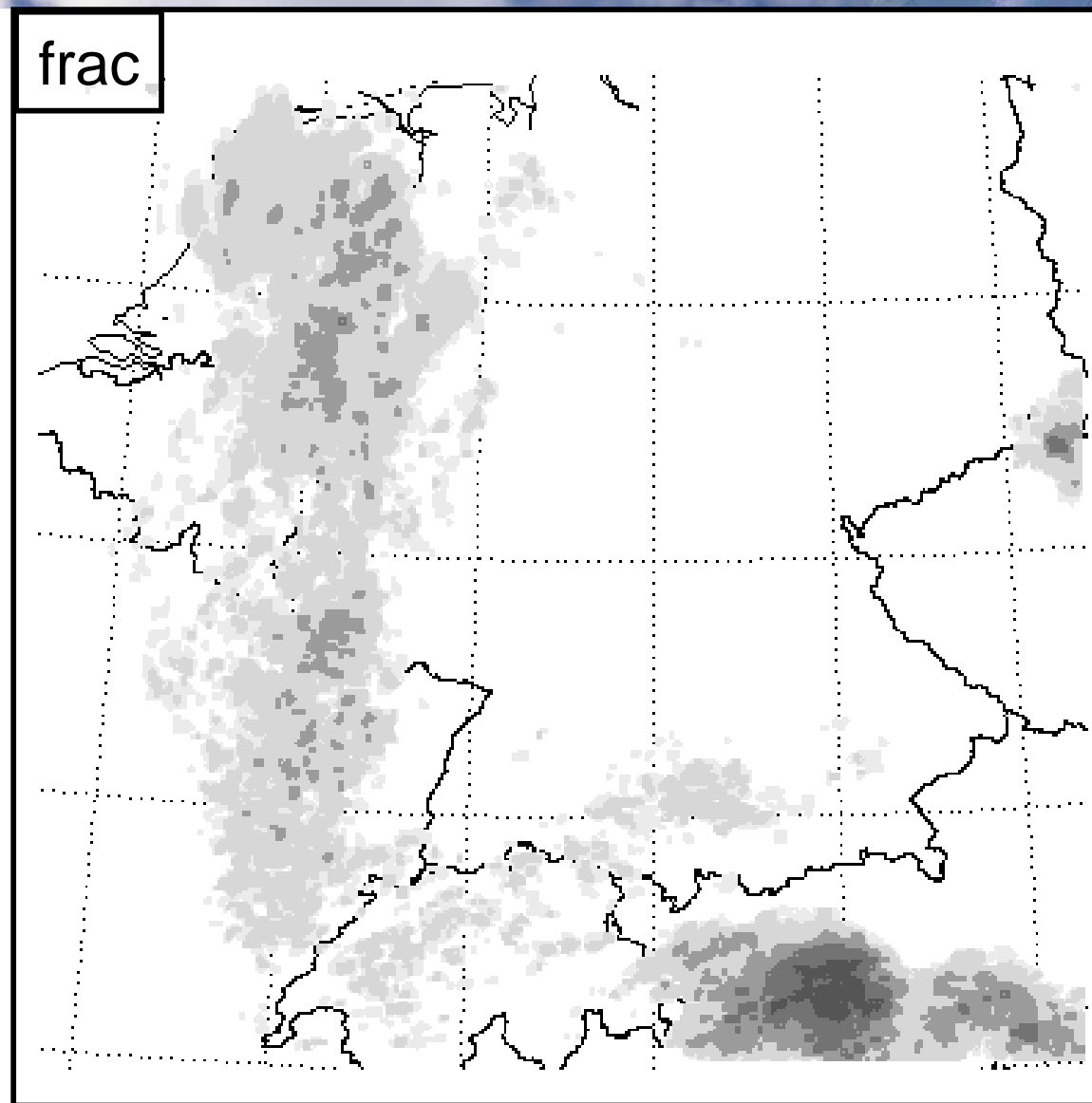
# COSMO-DE-EPS – Fraction



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# COSMO-DE-EPS – Fraction



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

0 10 30 50 70 90 %

# Probabilistic forecasts with COSMO-DE-EPS

1. Traditional method: **fraction**
2. Treating every members as deterministic solution:  
→ **neighbourhood - method** (Theis et al., 2005)



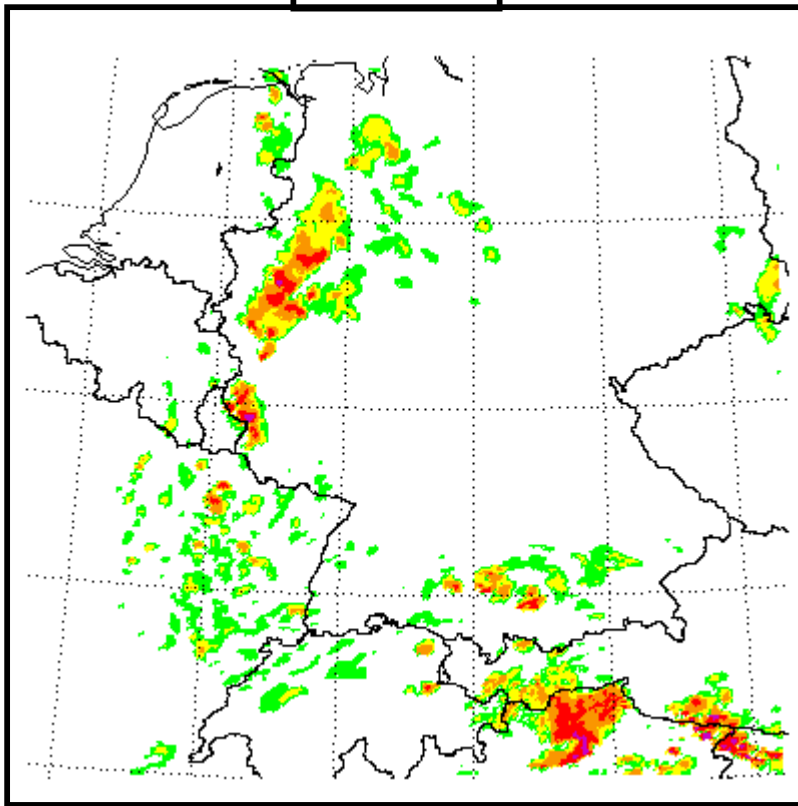
## **Spatial neighbourhood :**

Uncertainty in time and space is considered through spatial variability

## Spatial neighbourhood :

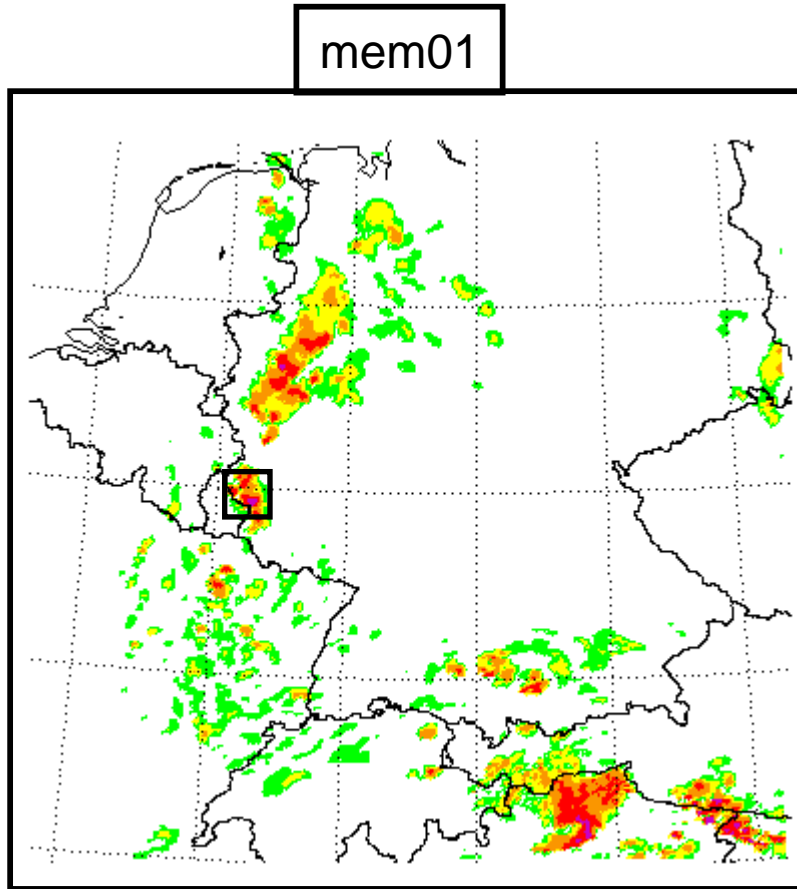
Uncertainty in time and space is considered through spatial variability

mem01



## Spatial neighbourhood :

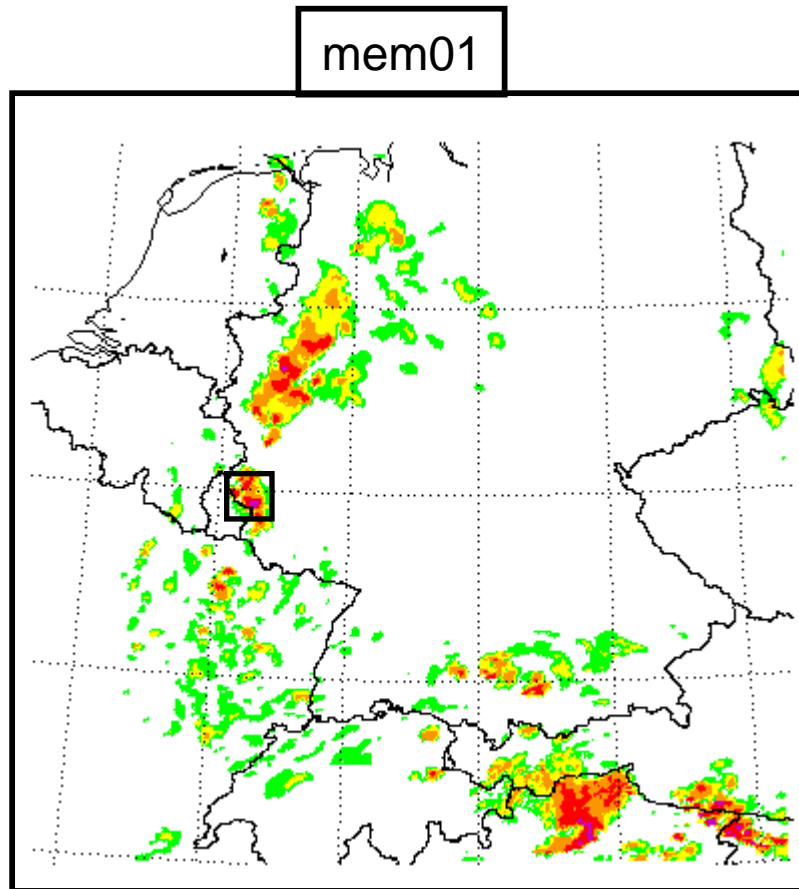
Uncertainty in time and space is considered through spatial variability



- Fraction of pixel  $> 19$  dBZ in search area

## Spatial neighbourhood :

Uncertainty in time and space is considered through spatial variability

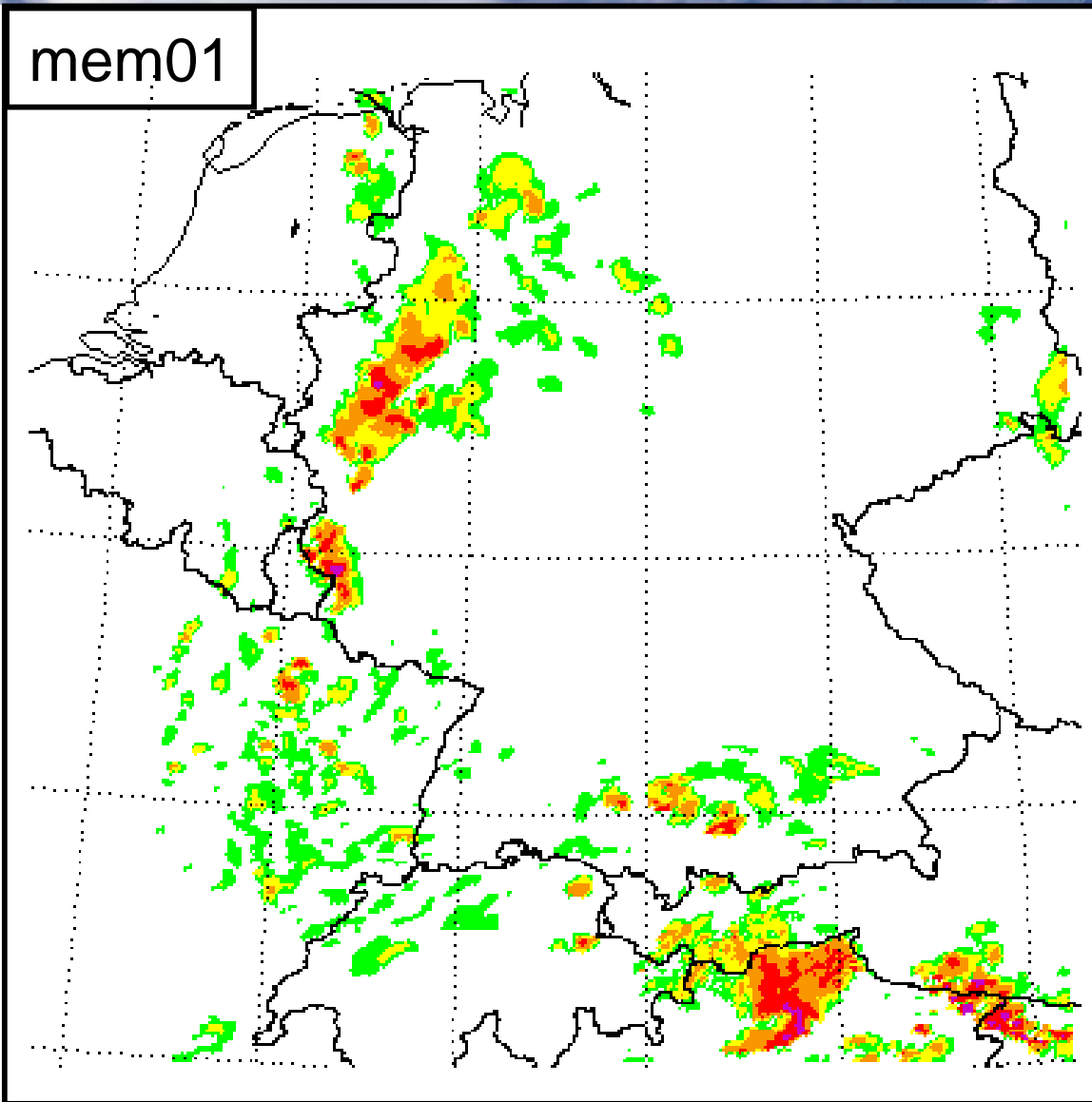


- Fraction of pixel  $> 19$  dBZ in search area
- no displacement
- constant search area size

# COSMO-DE-EPS – neighbourhood method

mem01

12.08.2007  
23:15 UTC

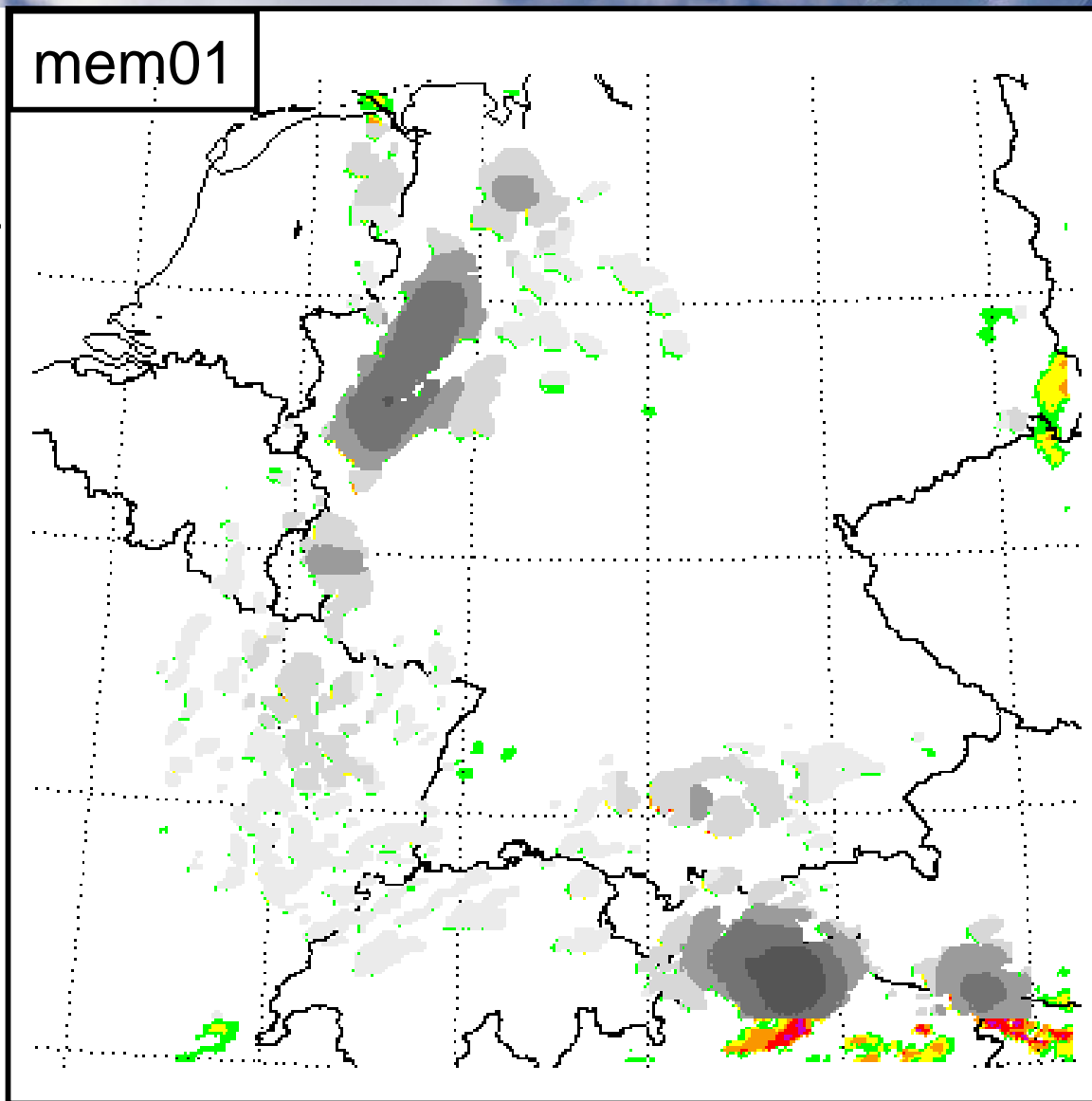


Deutsches Zentrum  
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# COSMO-DE-EPS – neighbourhood method

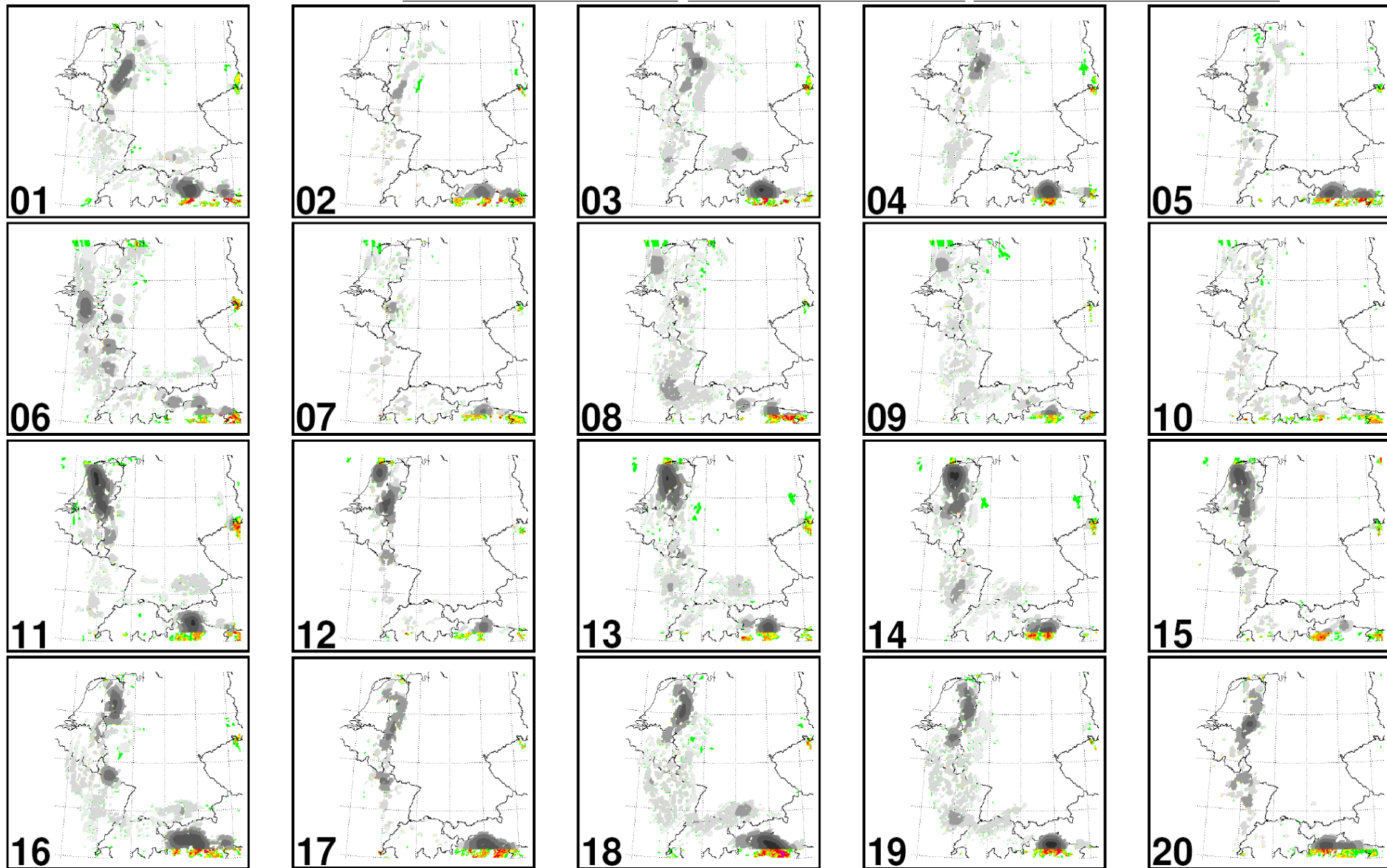
mem01

12.08.2007  
23:15 UTC



Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
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# COSMO-DE-EPS – neighbourhood method



DLR

Deutsches Zentrum  
für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft



7

19

28

37

46

55 dBZ



0

10

30

50

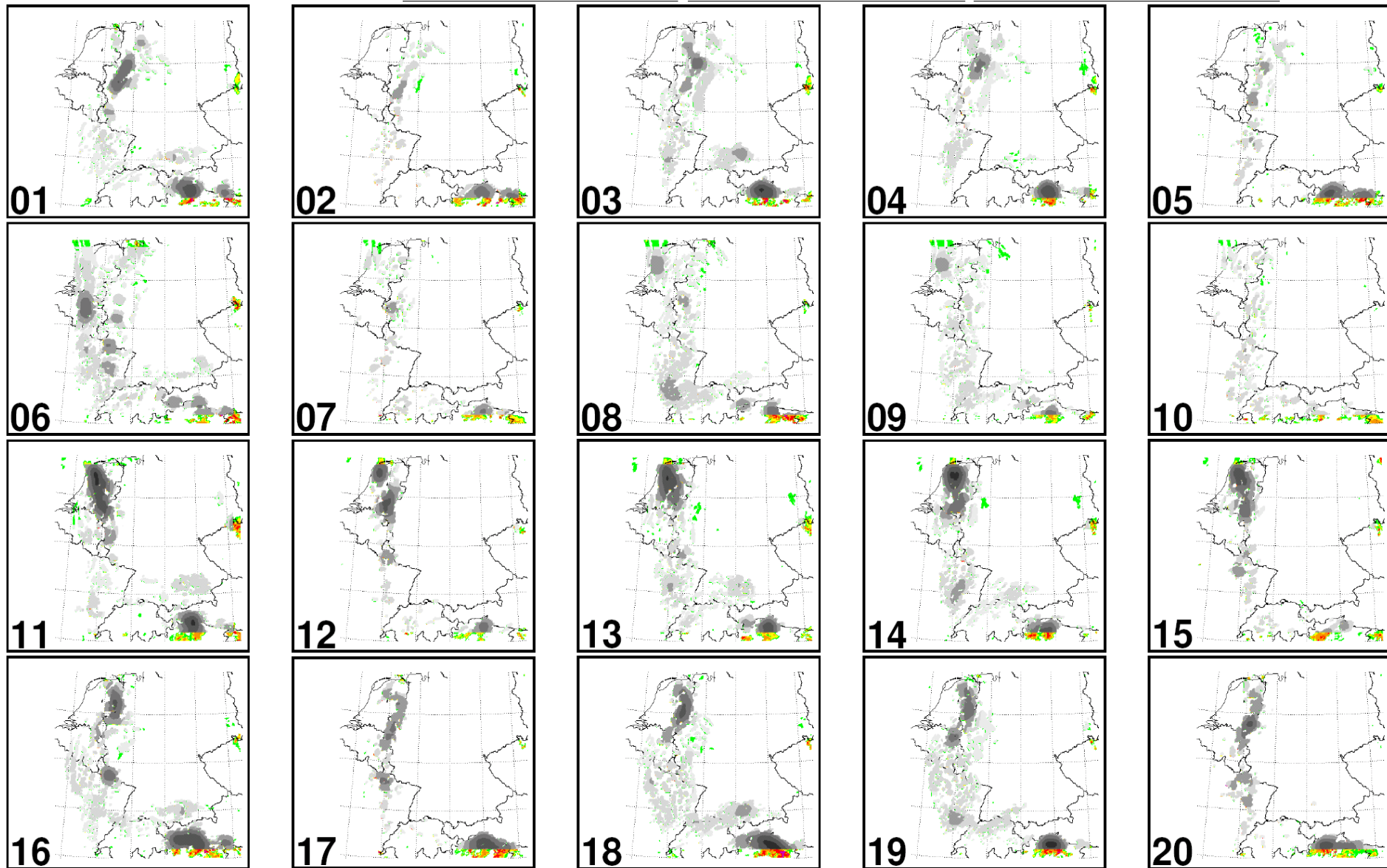
70

90 %

1. Traditional method: **fraction**
2. Treating every members as deterministic solution:  
→ **neighbourhood - method** (Theis et al., 2005)
3. Mean of neighbourhood members: **mean**



# COSMO-DE-EPS – mean of neighbourhood members

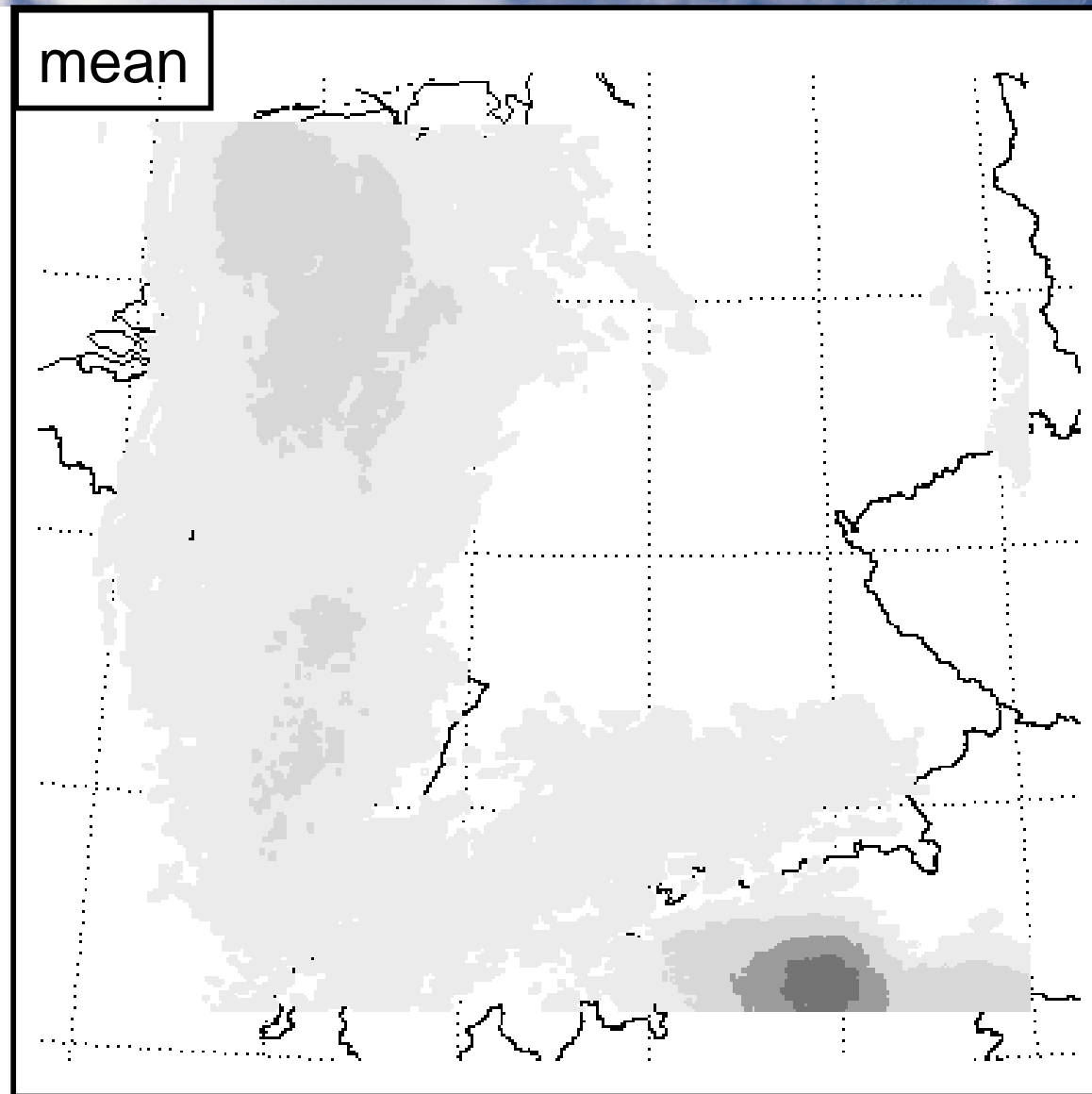


Deutsches Zentrum  
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7 19 28 37 46 55 dBZ 0 10 30 50 70 90 %

# COSMO-DE-EPS – mean



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# Probabilistic forecasts with COSMO-DE-EPS

1. Traditional method: **fraction**

2. Treating every members as deterministic solution:

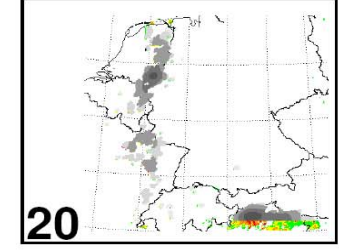
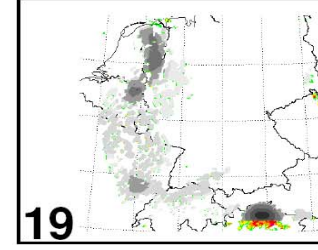
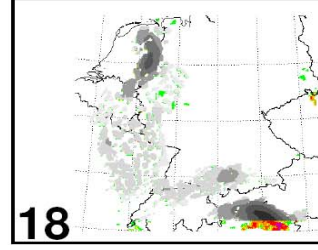
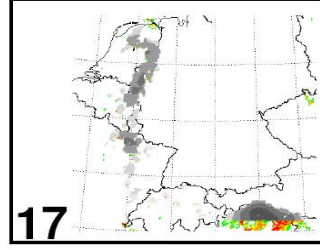
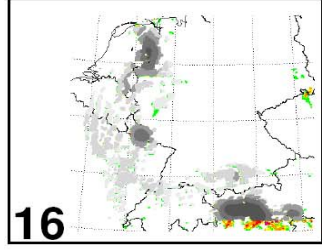
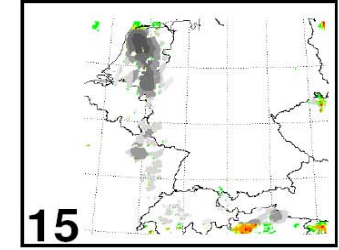
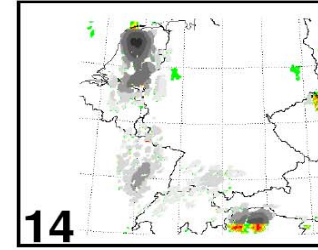
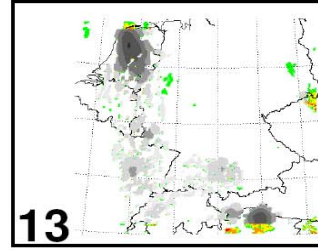
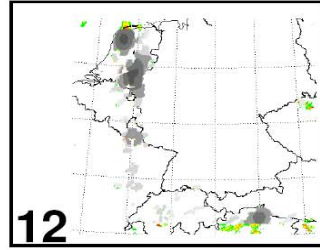
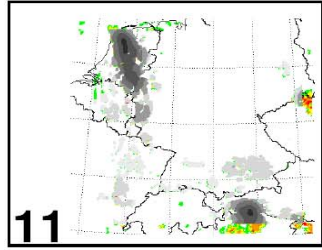
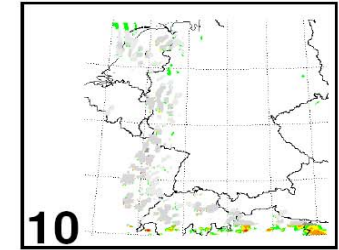
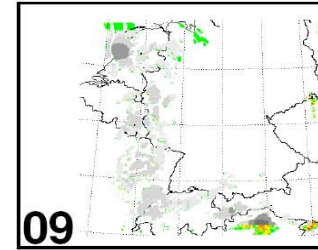
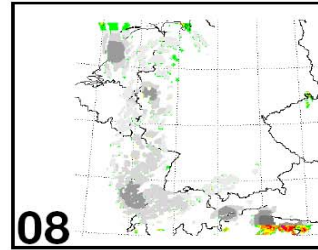
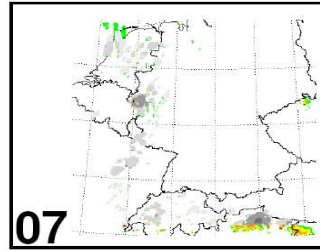
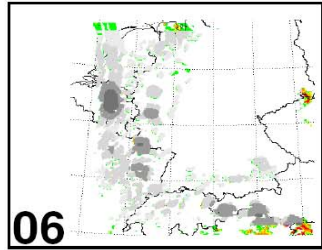
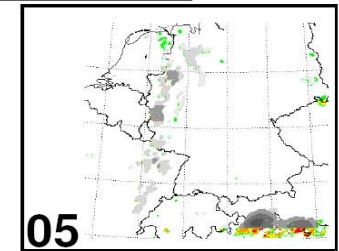
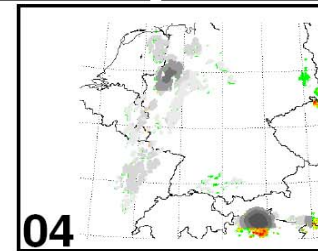
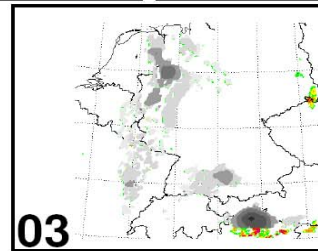
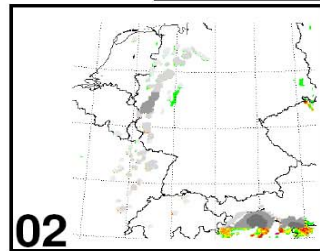
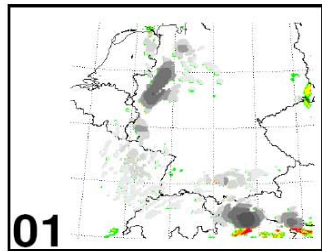
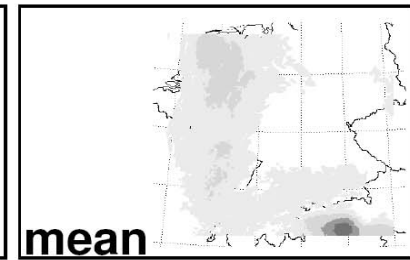
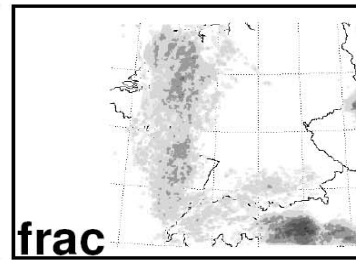
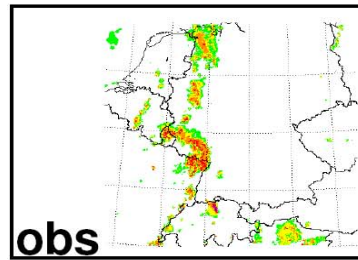
→ **neighbourhood - method** (Theis et al., 2005)

3. Mean of neighbourhood members: **mean**

→ **22 probabilistic forecasts  
based on COSMO-DE-EPS**

# COSMO-DE-EPS

23:15 UTC







## **2. Data and Methods**

-

# **Calibration of model forecasts**



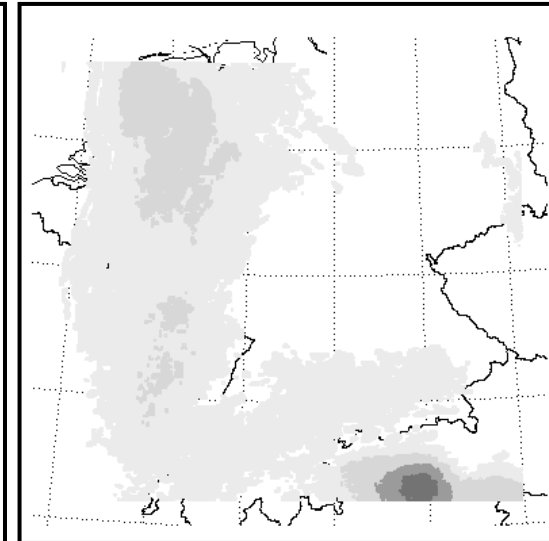
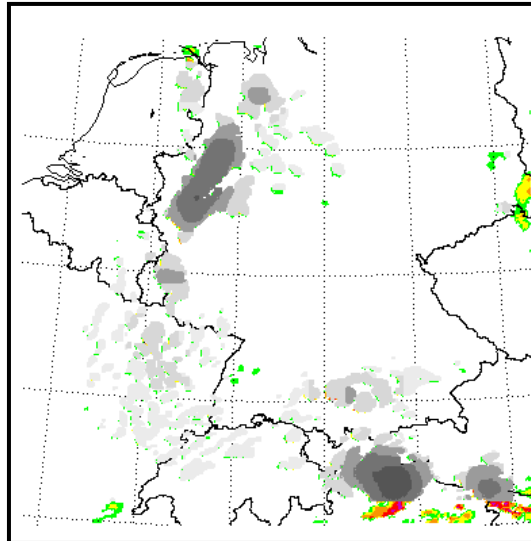
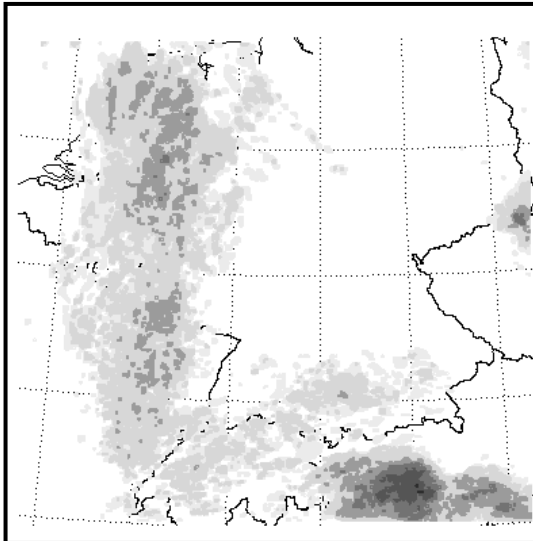
# Effect of Calibration (Reliability diagram statistics method)

frac

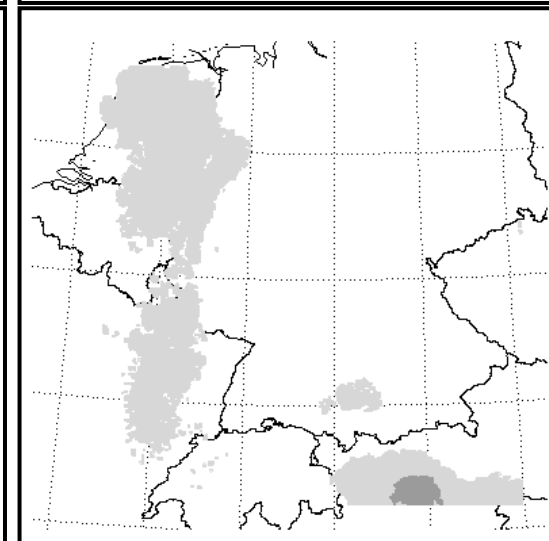
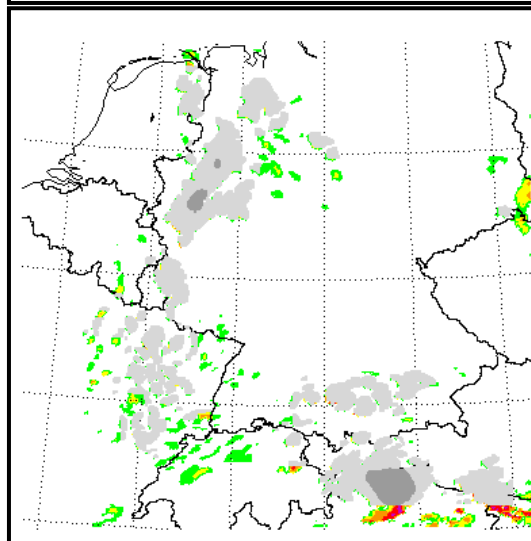
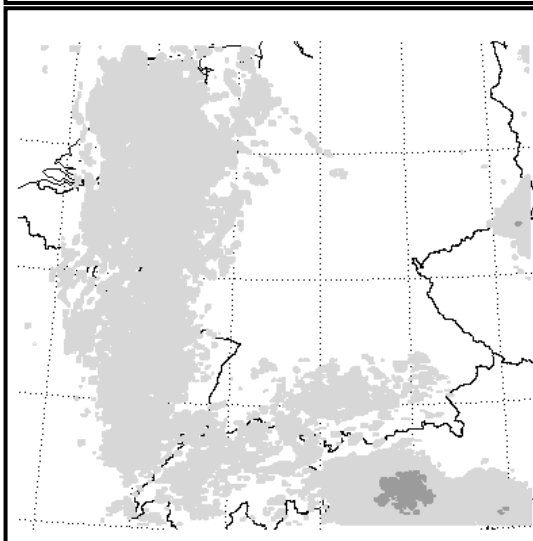
mem01

mean

before

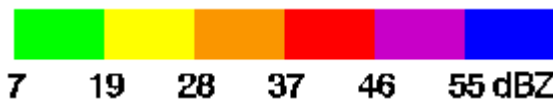


after



DLR

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für Luft- und Raumfahrt  
in der Helmholtz-Gemeinschaft





## 3. Forecast Quality



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für Luft- und Raumfahrt e.V.  
in der Helmholtz-Gemeinschaft

# Quality measures

- ⇒ **Brier Score and its decomposition**
- ⇒ **Reliability diagrams**
- ⇒ **ROC-curves**
- ⇒ **CSRR** (Conditional Square root of Ranked Probability Score)



time frame: 08.08.2007 – 16.08.2007

1. Development of skill with time (time series)
2. Development of skill with lead time

in the following: calibrated model forecasts

time frame: 08.08.2007 – 16.08.2007

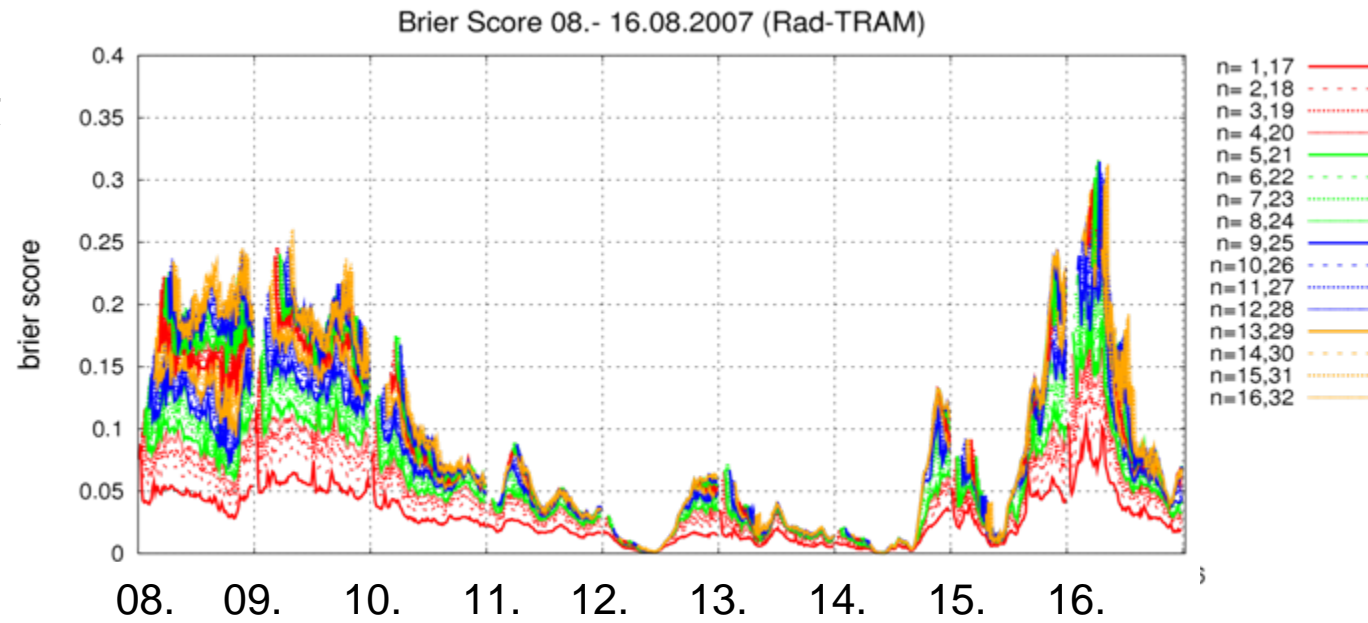
## 1. Development of skill with time (time series)

## 2. Development of skill with lead time

in the following: calibrated model forecasts

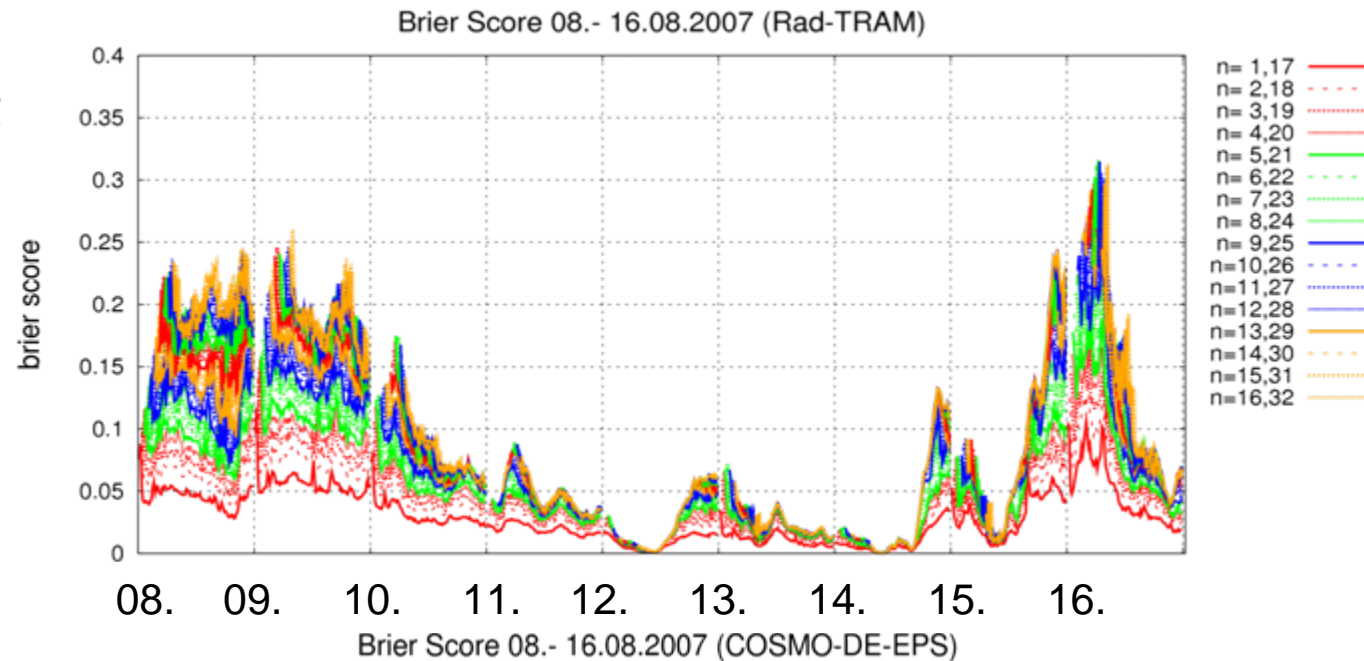
# 08. - 16.08.2007 – time series – Brier score

lines denote different  
lead times

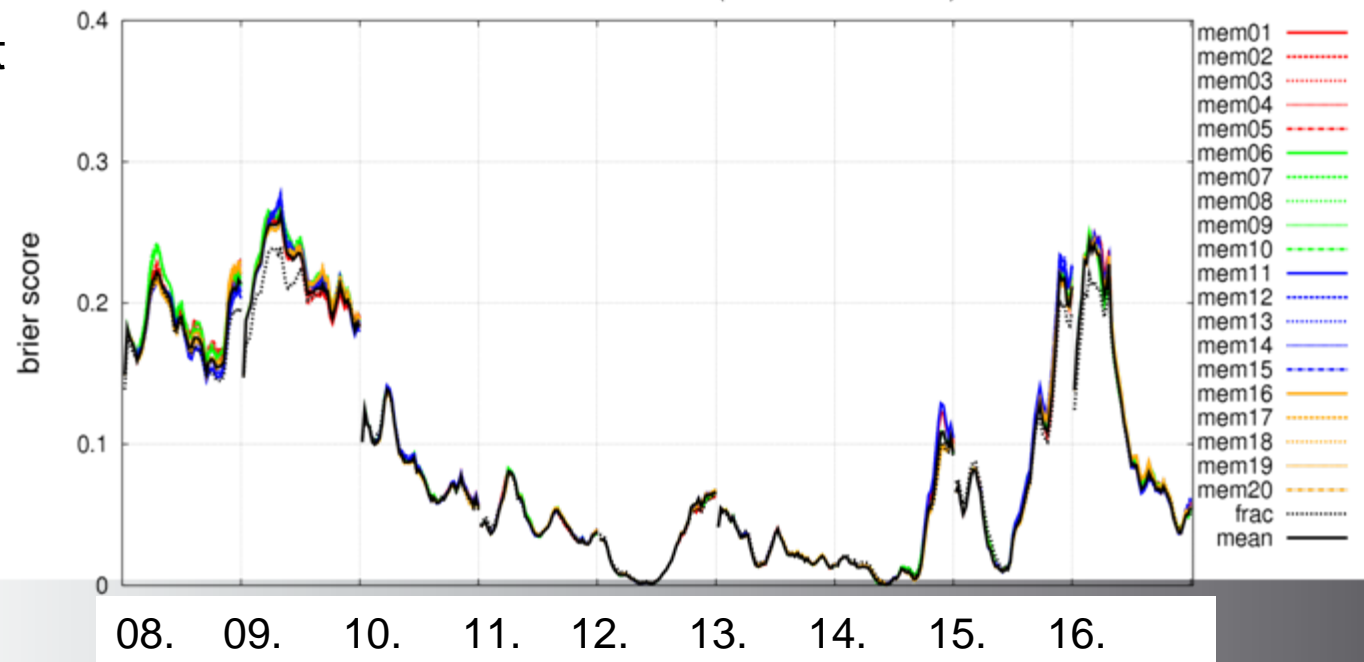


# 08. - 16.08.2007 – time series – Brier score

lines denote different lead times

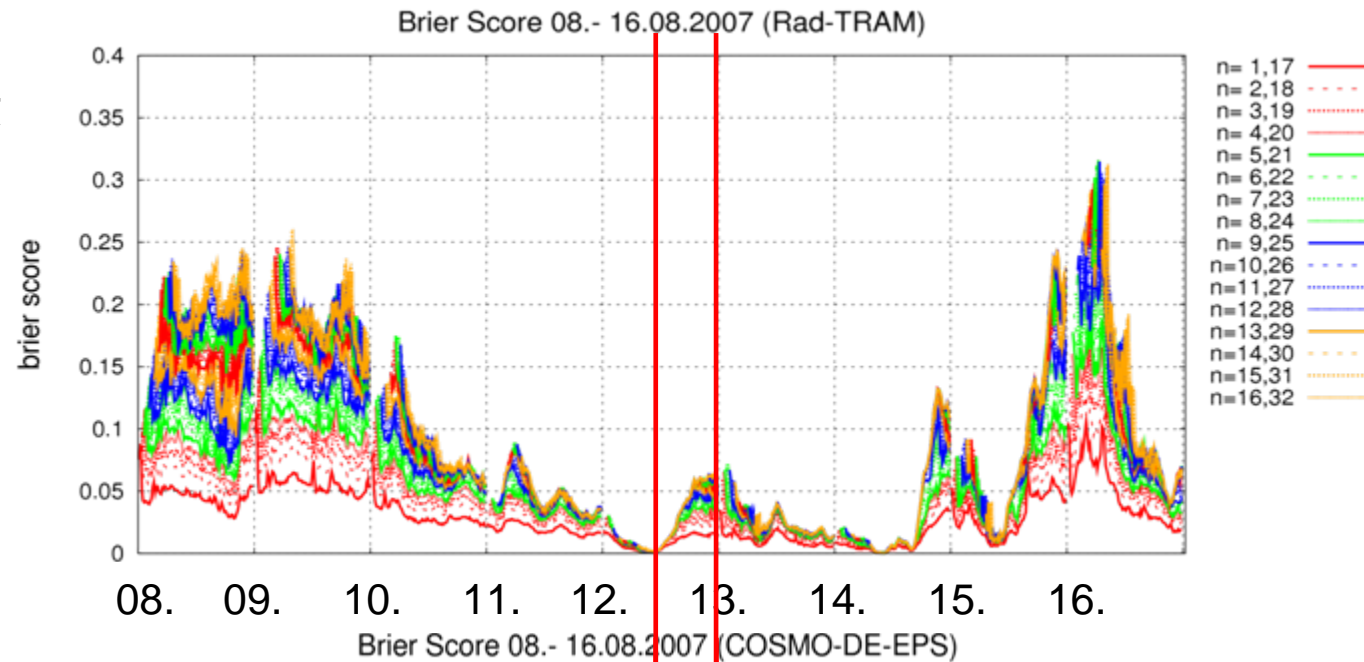


lines denote different methods

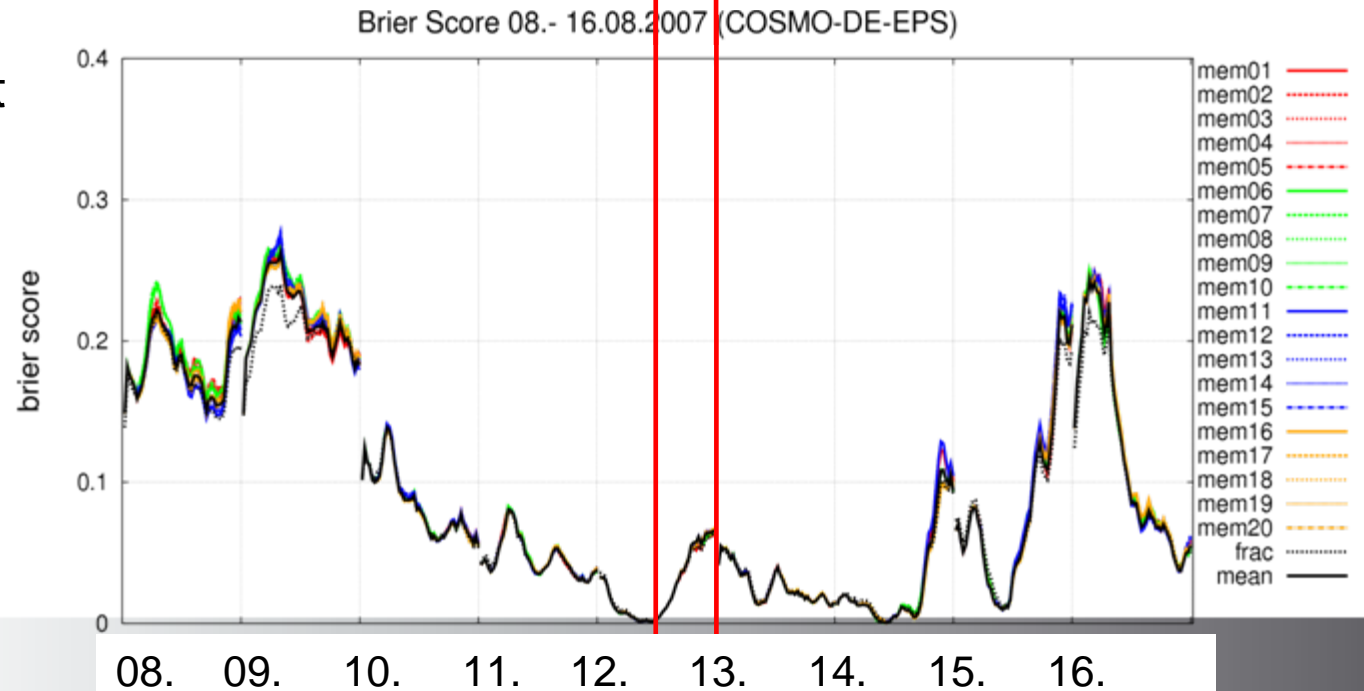


# 08. - 16.08.2007 – time series – Brier score

lines denote different lead times

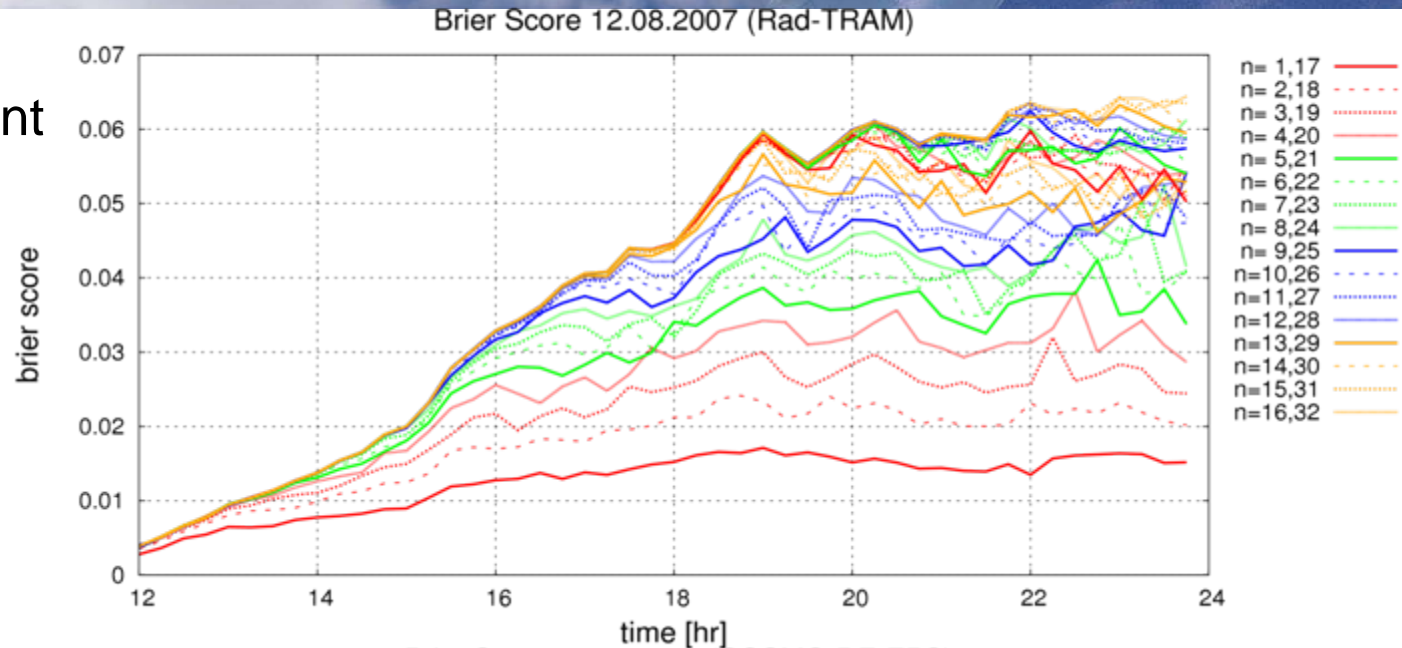


lines denote different methods

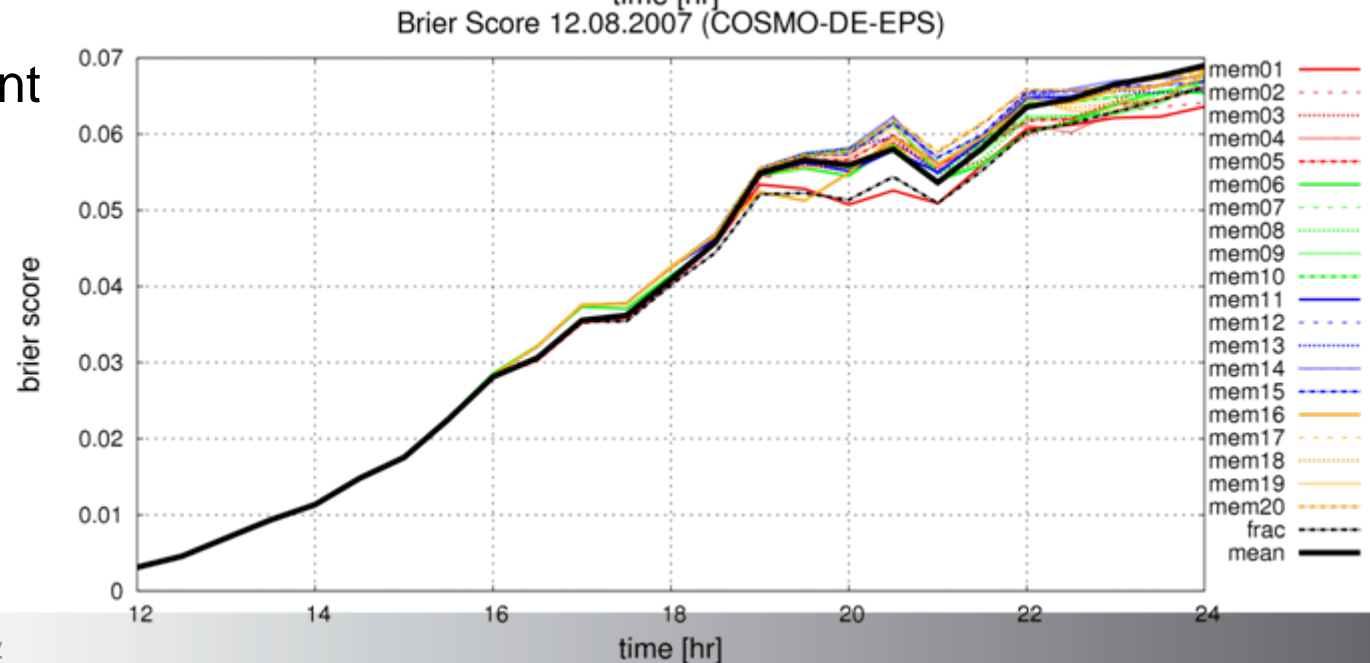


# 12.08.2007 – time series – Brier score

lines denote different lead times



lines denote different methods



time frame: 08.08.2007 – 16.08.2007

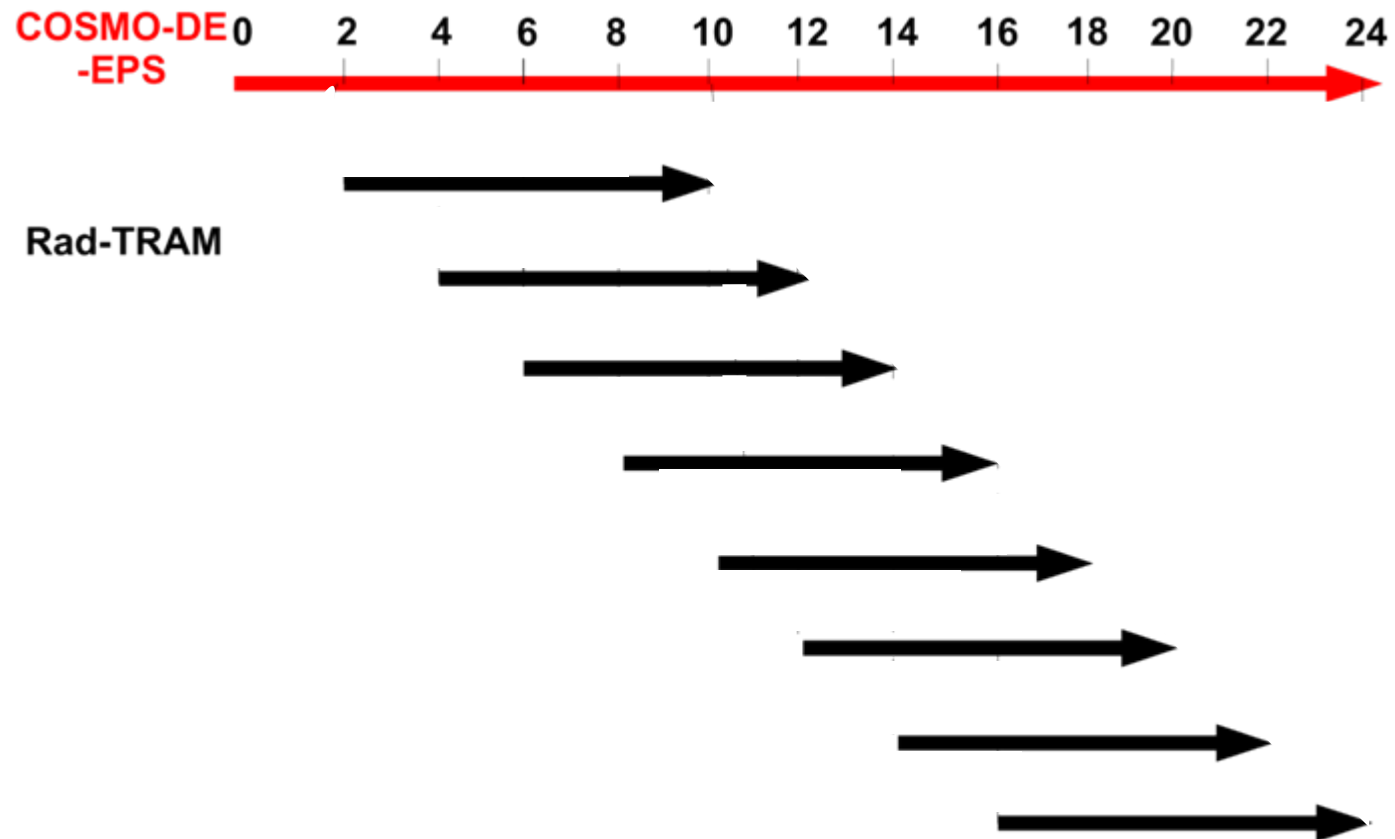
1. Development of skill with time (time series)

2. **Development of skill with lead time**

in the following: calibrated model forecasts

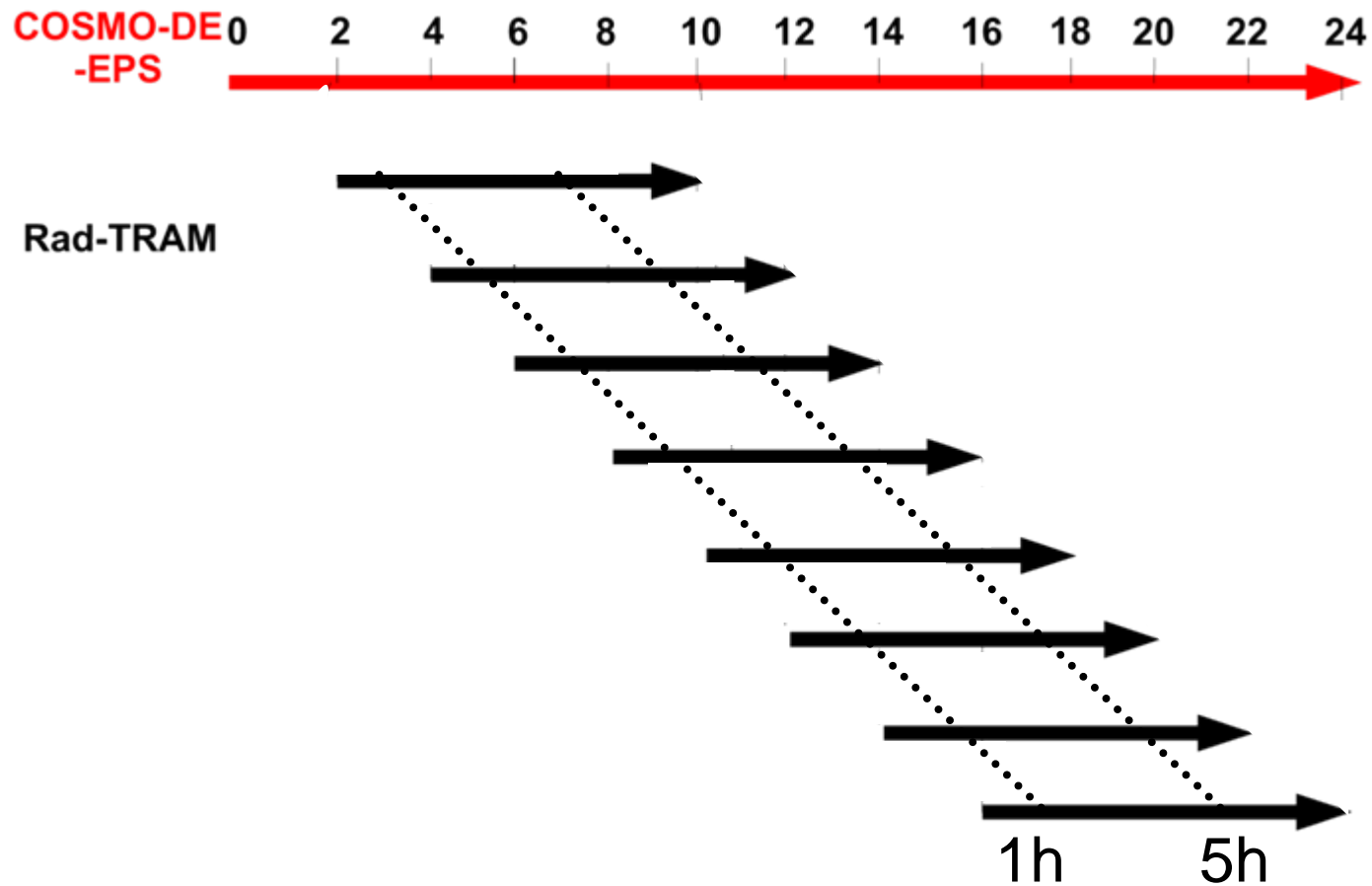


# Forecast skill with lead time

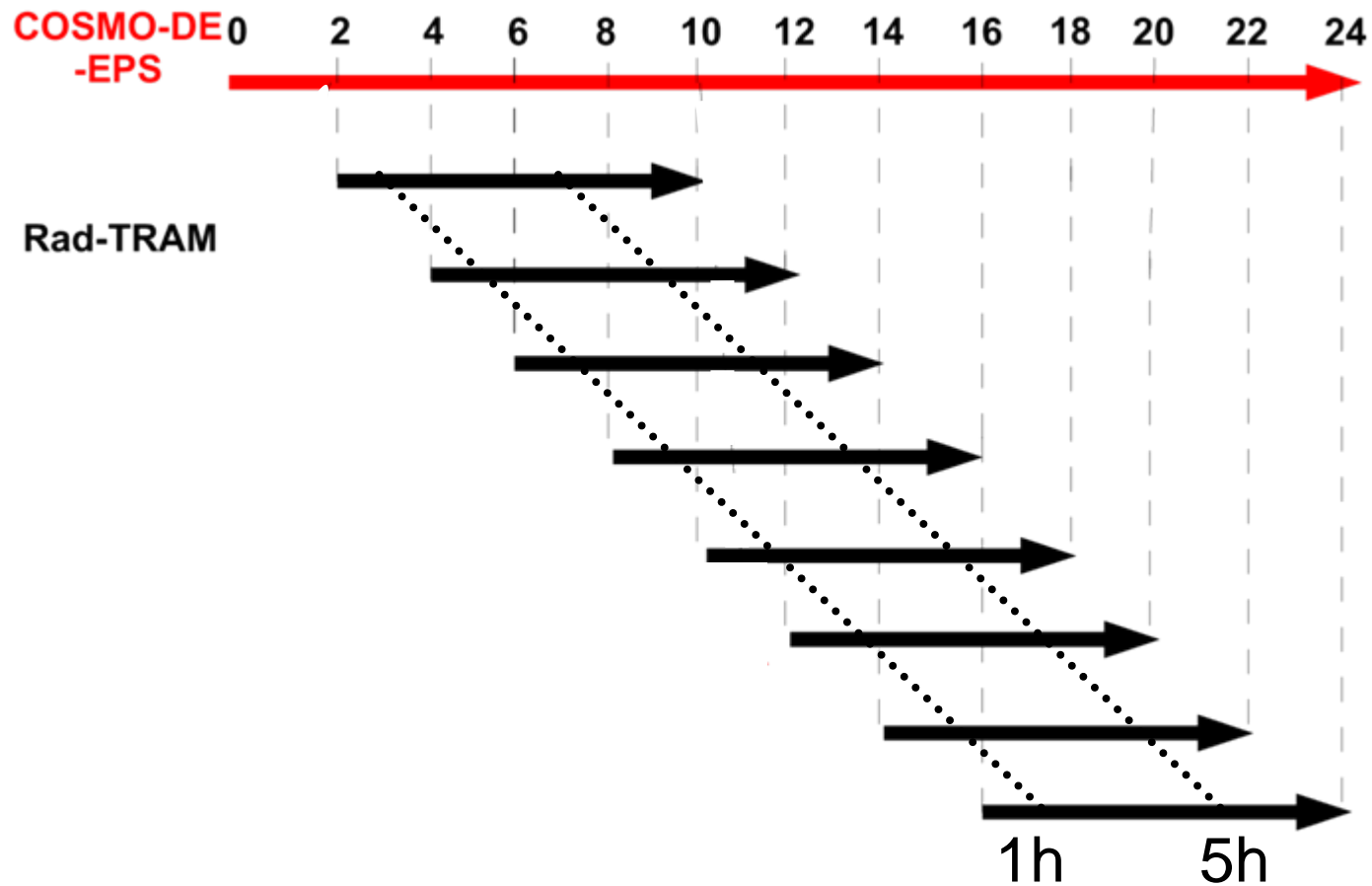




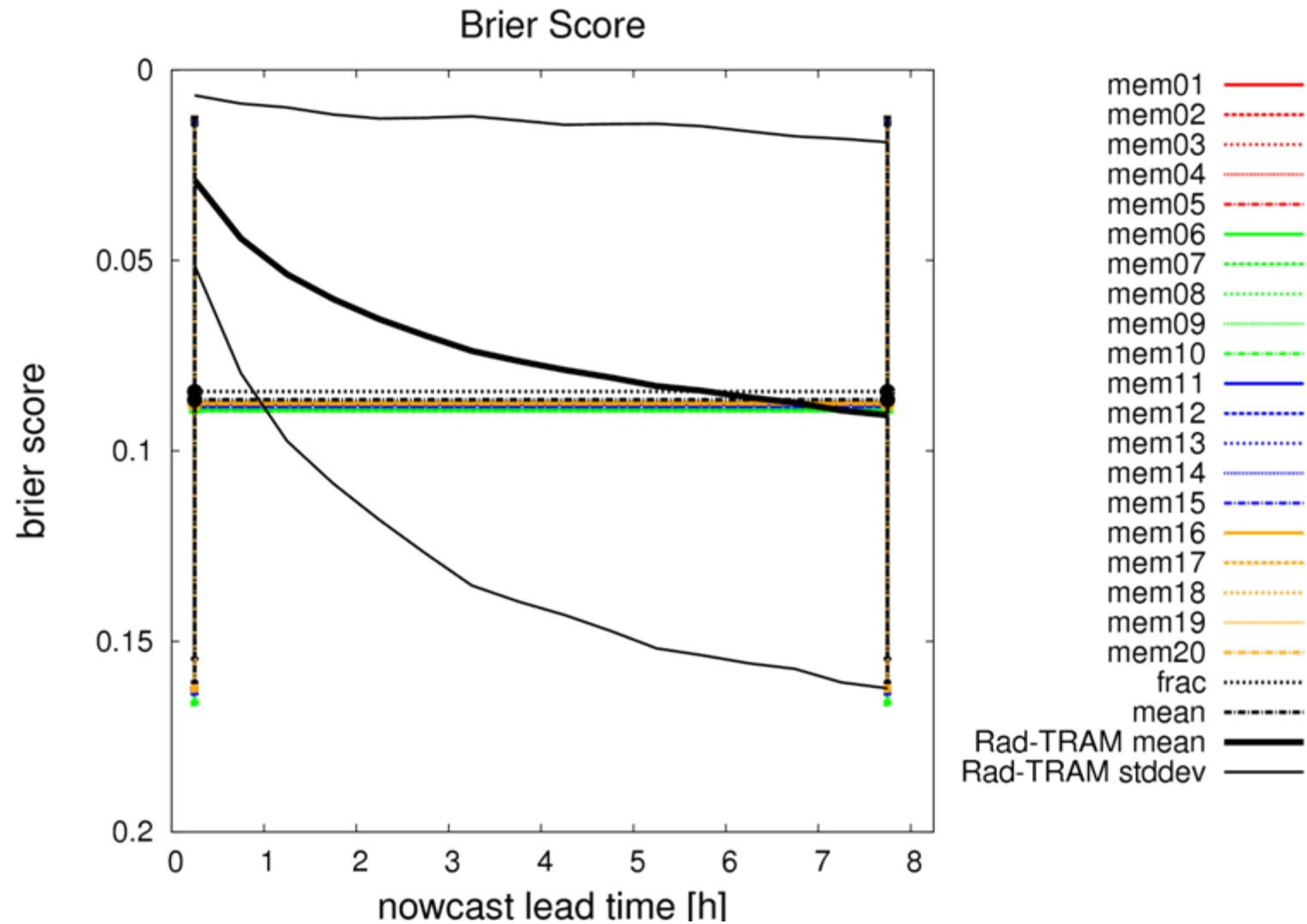
# Forecast skill with lead time



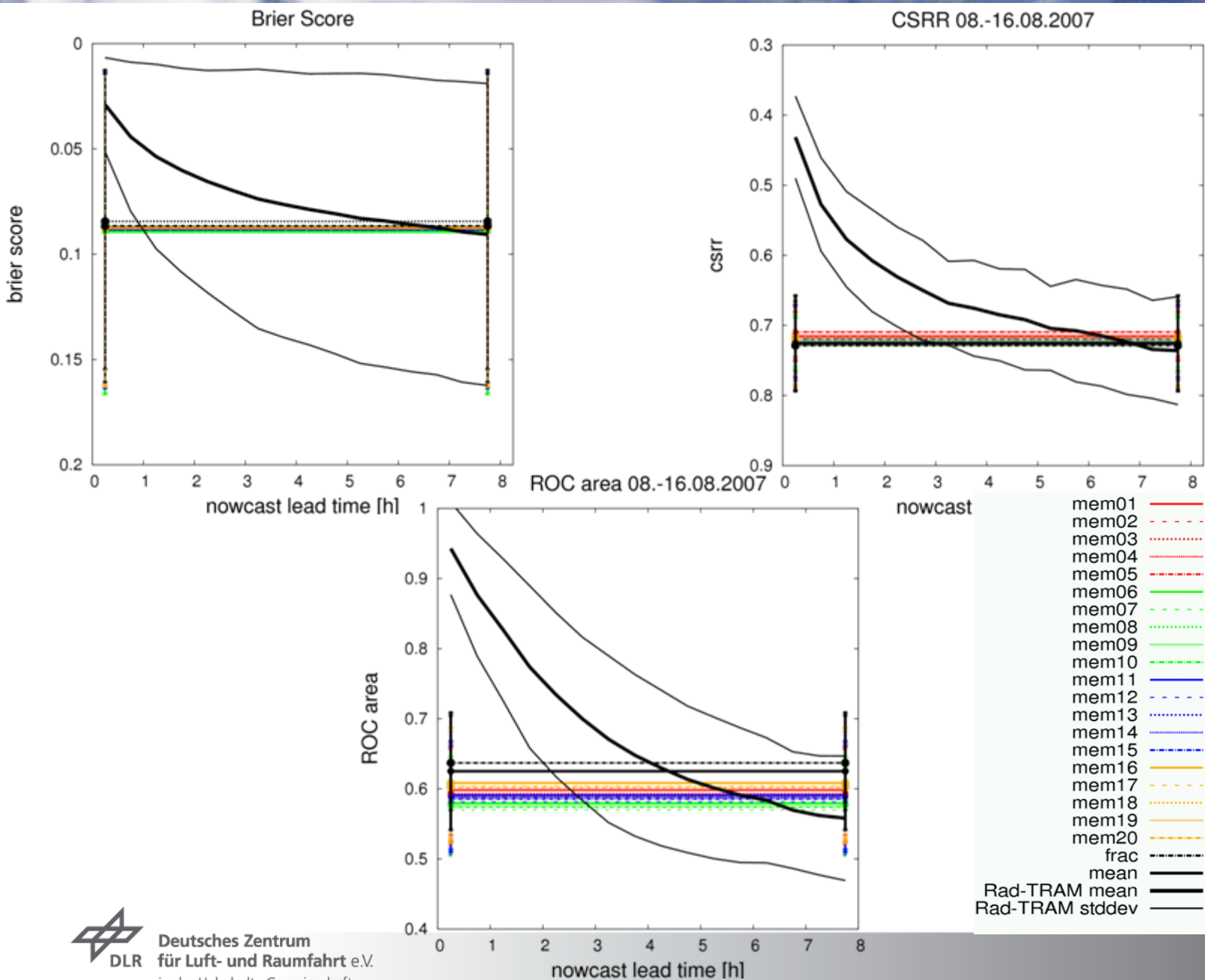
# Forecast skill with lead time



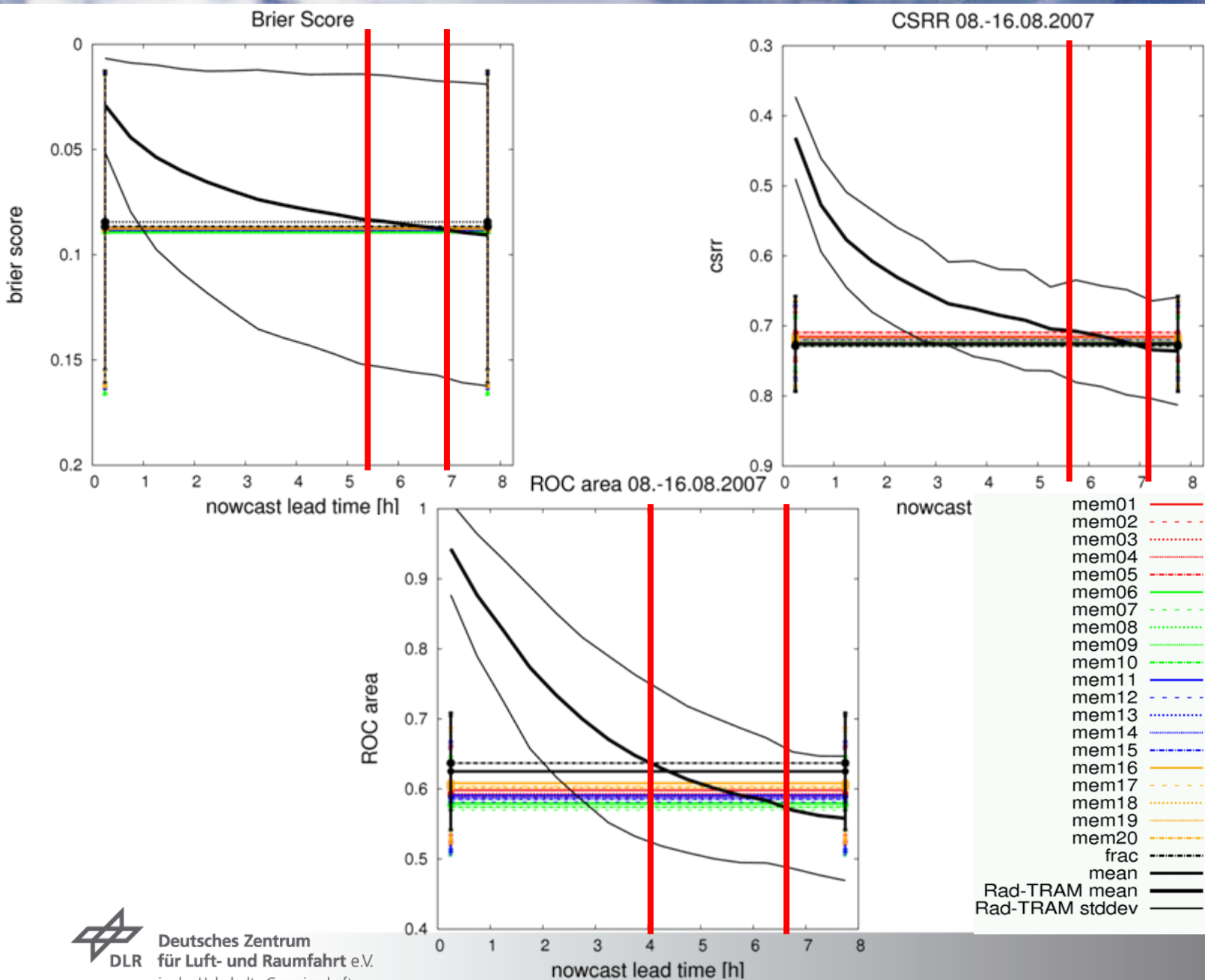
# Forecast skill with lead time



# Forecast skill with lead time



# Forecast skill with lead time





## 4. Blending of the forecasts

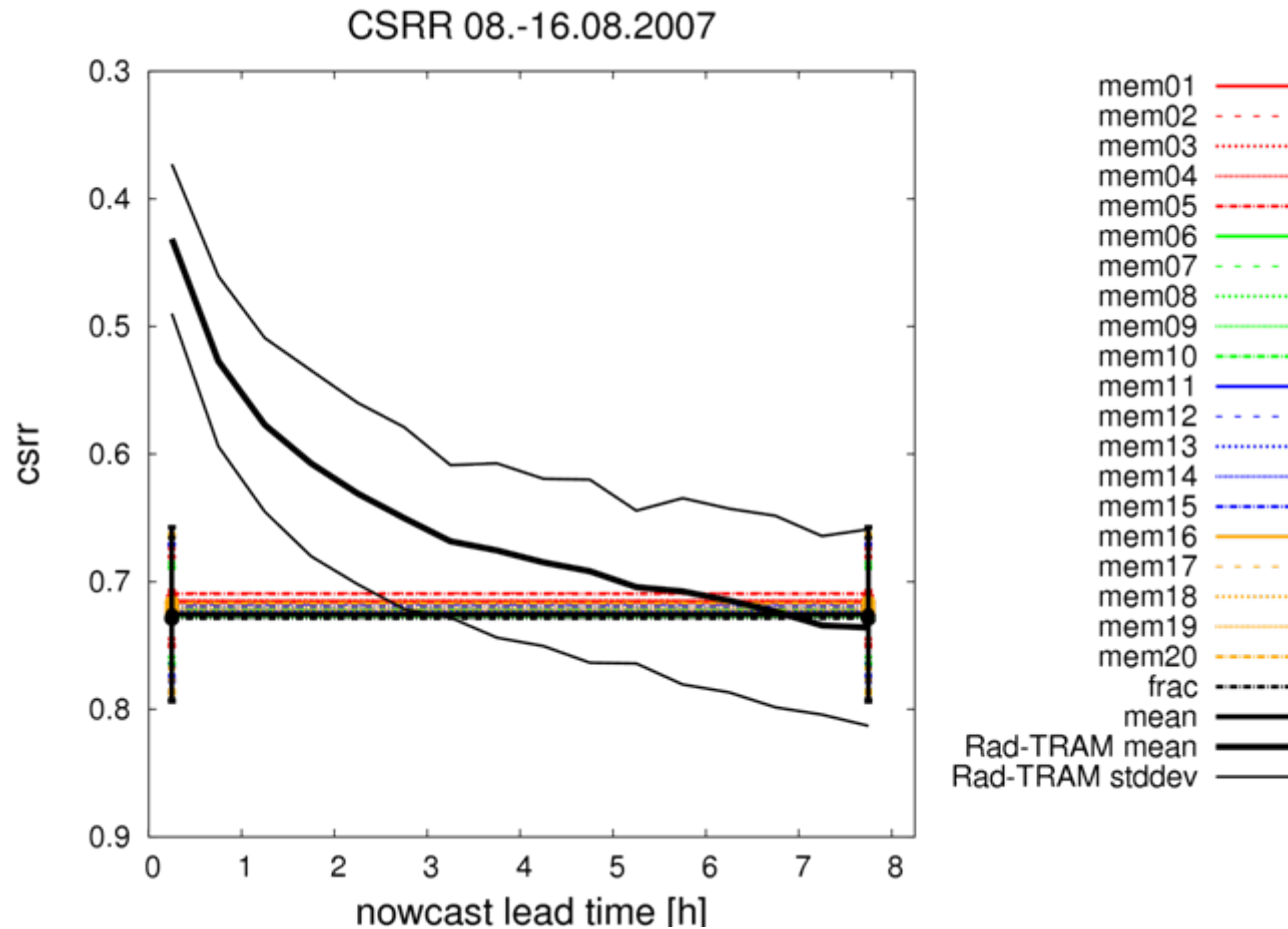


# Combination – methodology

Derivation of weighting functions for additive combination

# Combination – methodology

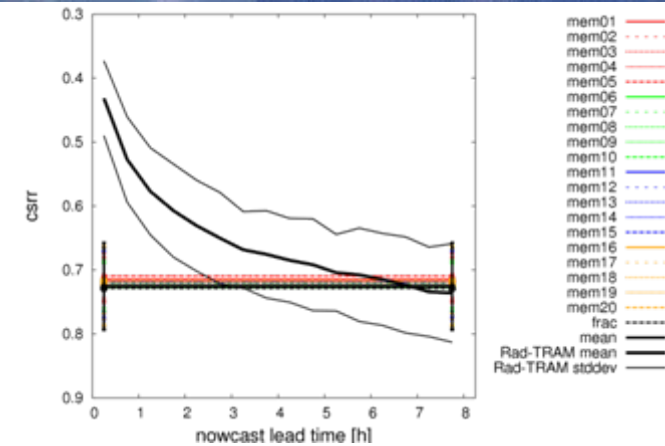
## Derivation of weighting functions for additive combination





Weighting function for Rad-TRAM:

$$w_r(\tau) = 2.11 - \frac{1}{1 - CSRR(\tau)^{2.8}}$$

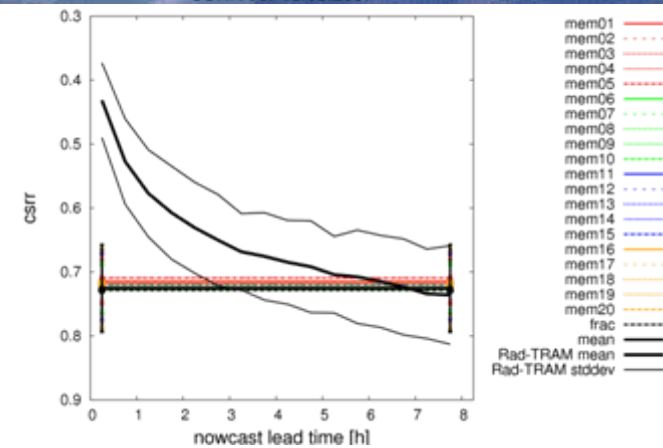


Weighting function for Rad-TRAM:

$$w_r(\tau) = 2.11 - \frac{1}{1 - CSRR(\tau)^{2.8}}$$

Weighting function for COSMO-DE-EPS:

$$w_c(\tau) = 1 - w_r(\tau)$$

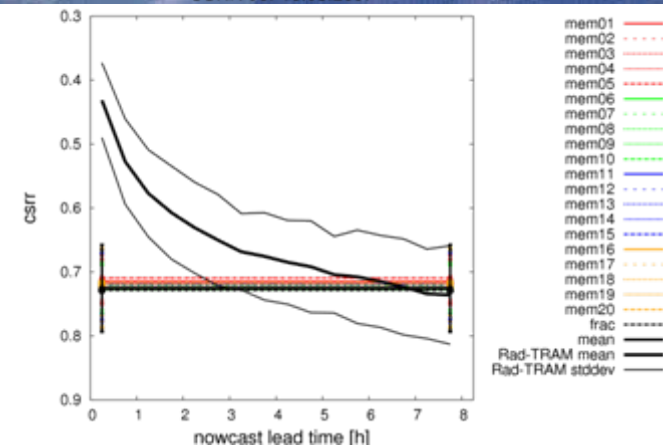


Weighting function for Rad-TRAM:

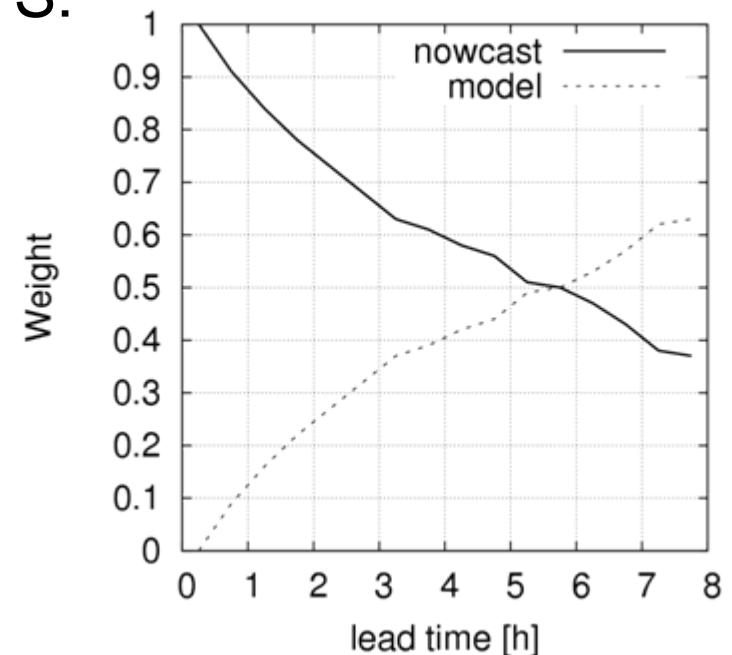
$$w_r(\tau) = 2.11 - \frac{1}{1 - CSRR(\tau)^{2.8}}$$

Weighting function for COSMO-DE-EPS:

$$w_c(\tau) = 1 - w_r(\tau)$$



Weighting functions

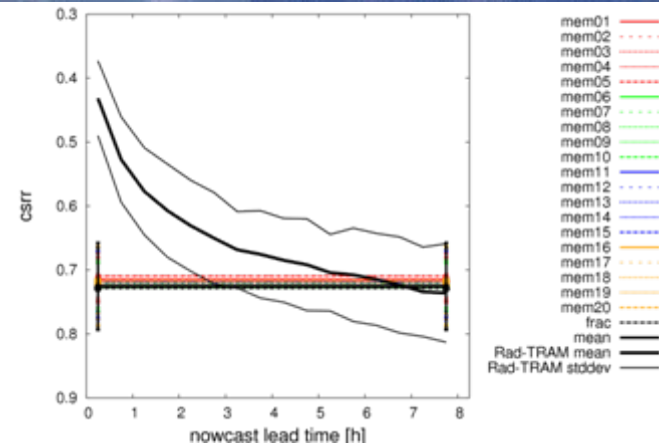


# Combination – methodology

CSRR 08-16.08.2007

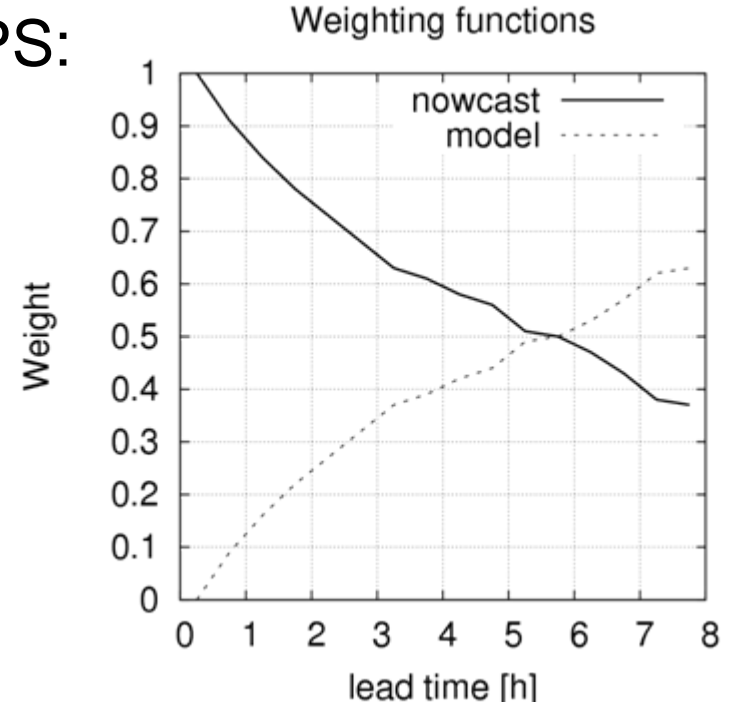
Weighting function for Rad-TRAM:

$$w_r(\tau) = 2.11 - \frac{1}{1 - CSRR(\tau)^{2.8}}$$



Weighting function for COSMO-DE-EPS:

$$w_c(\tau) = 1 - w_r(\tau)$$



$$P_{blend,i} = w_r(\tau) * P_{LL}(\tau) + w_c(\tau) * P_{EPS,i}$$

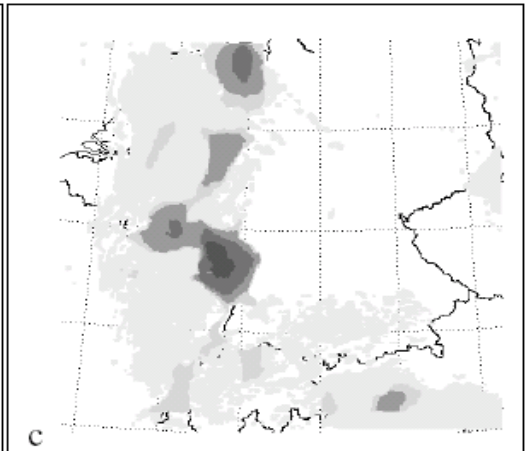
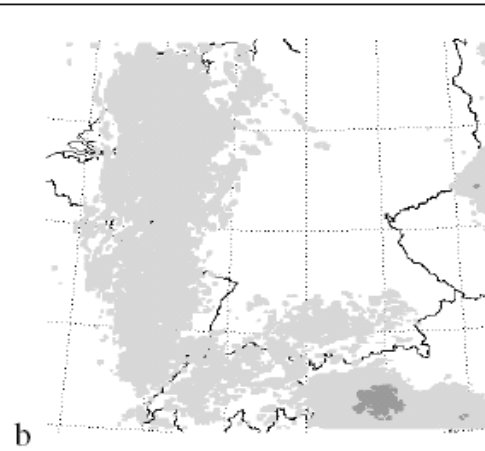
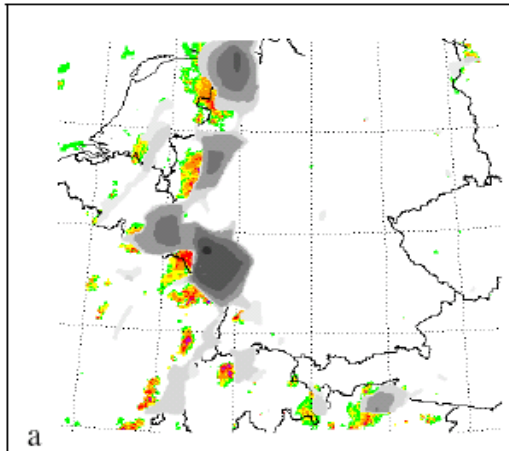
# Combination – example 12.08.2007

Rad-TRAM

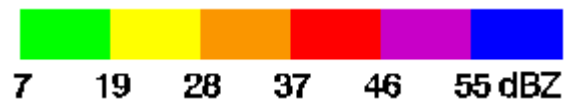
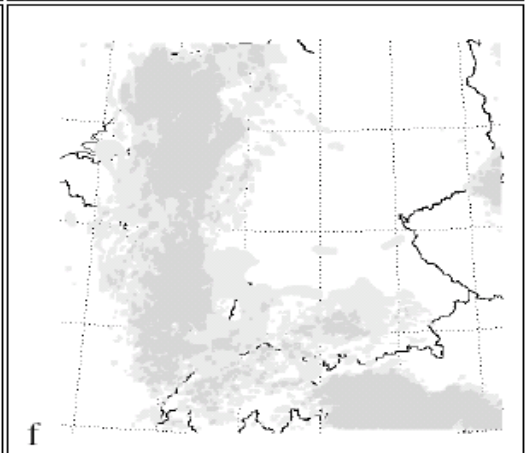
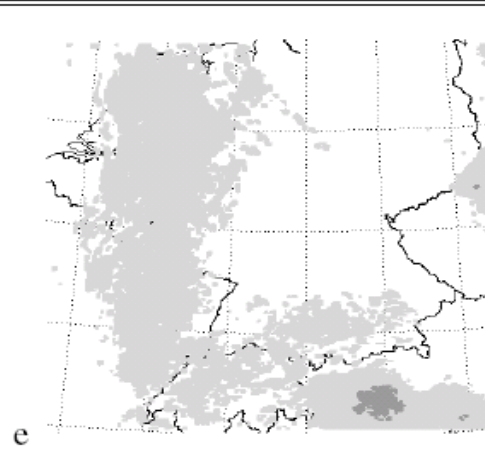
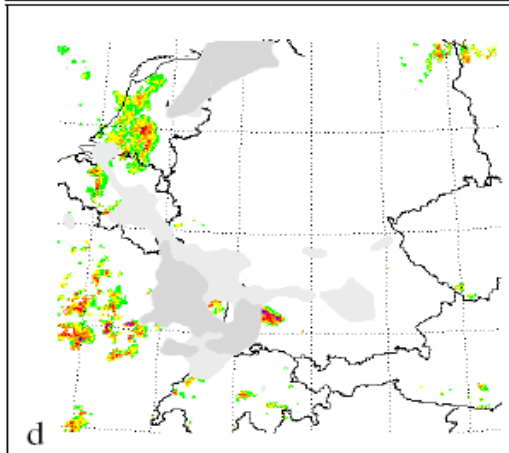
COSMO-DE-EPS  
fraction

Combination

$\tau = 1.25h$



$\tau = 7.25h$



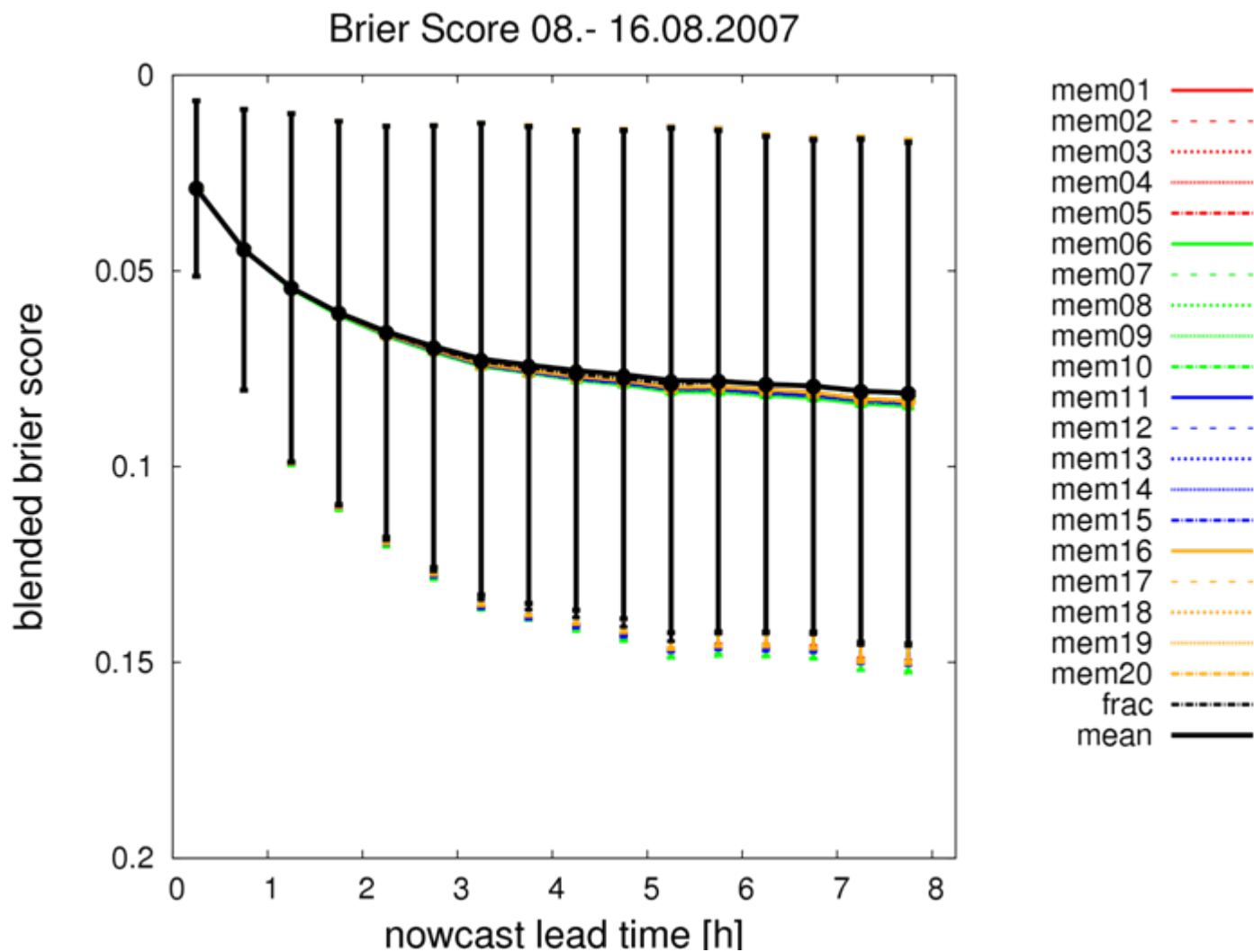
# Combination – forecast quality



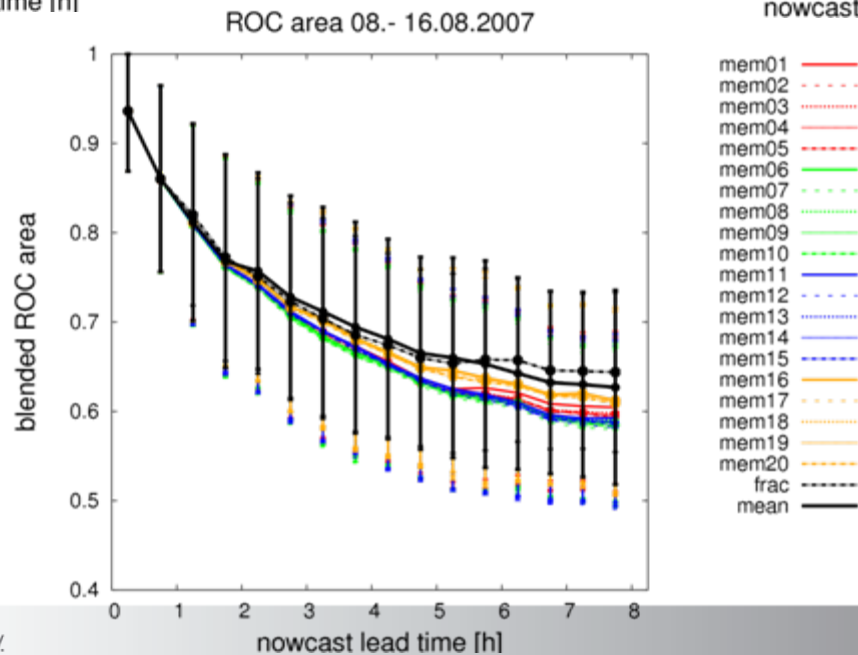
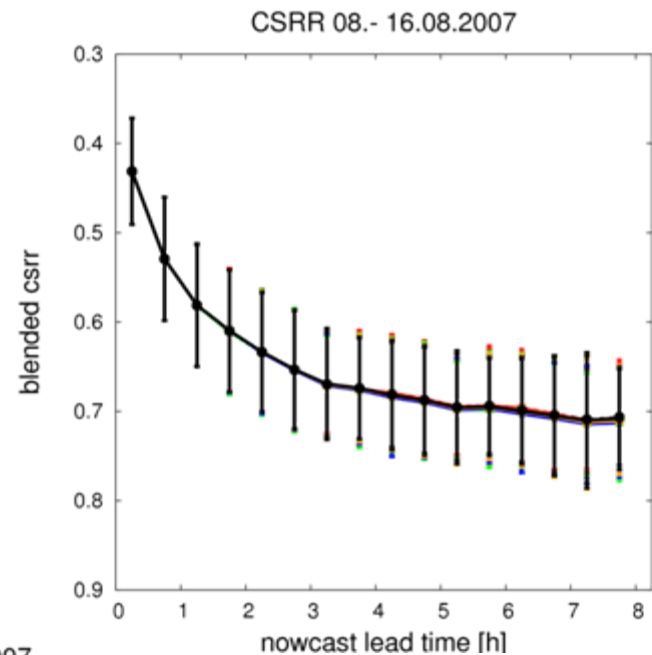
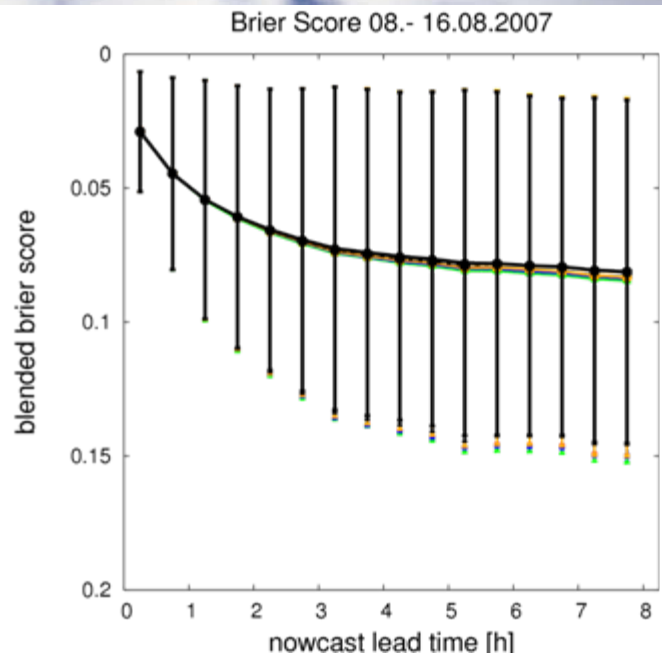
DLR

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in der Helmholtz-Gemeinschaft

# Combination – forecast quality

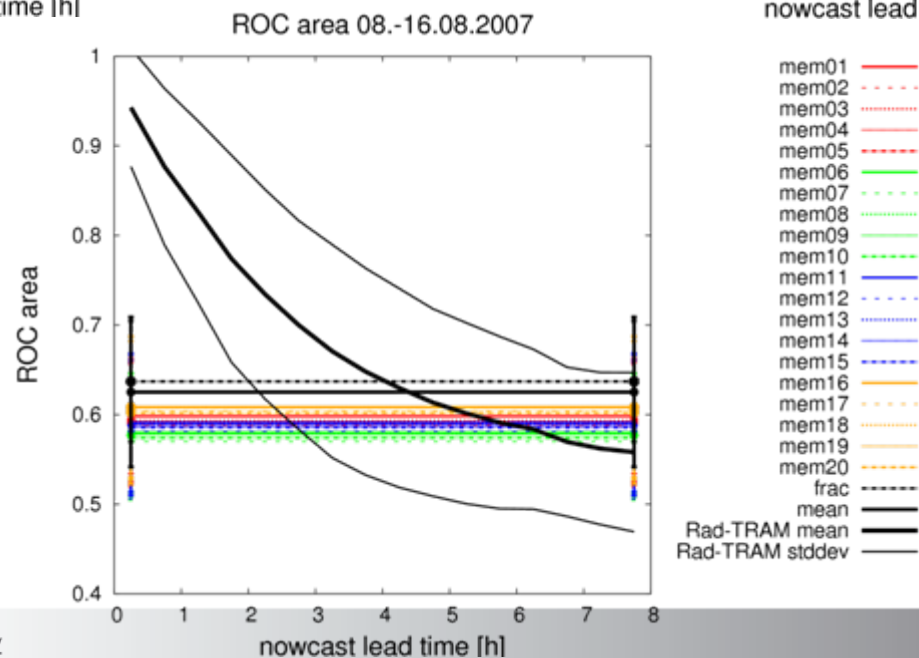
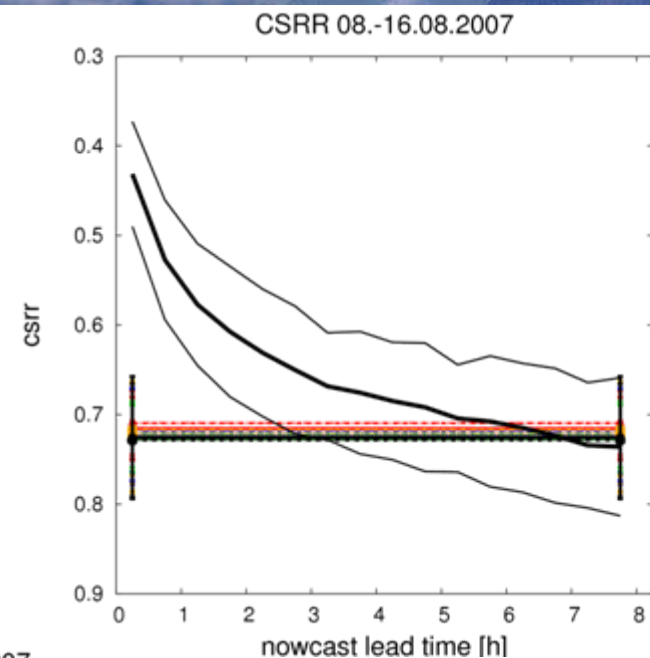
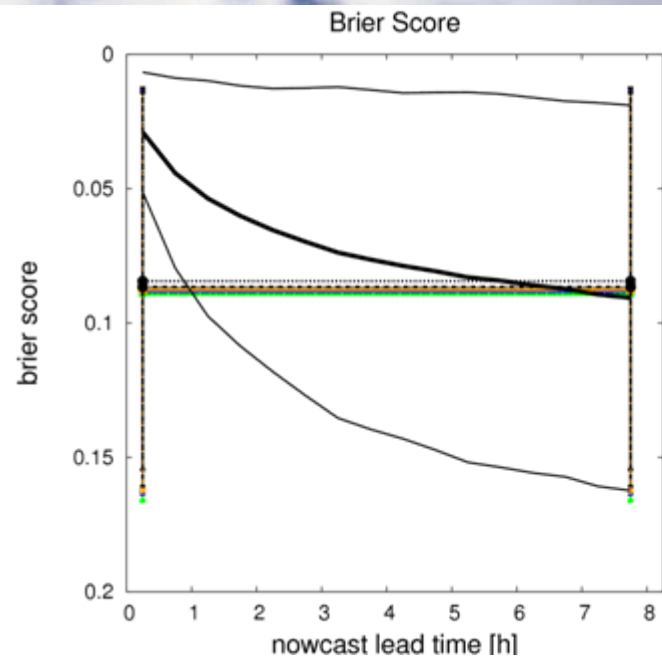


# Combination – forecast quality

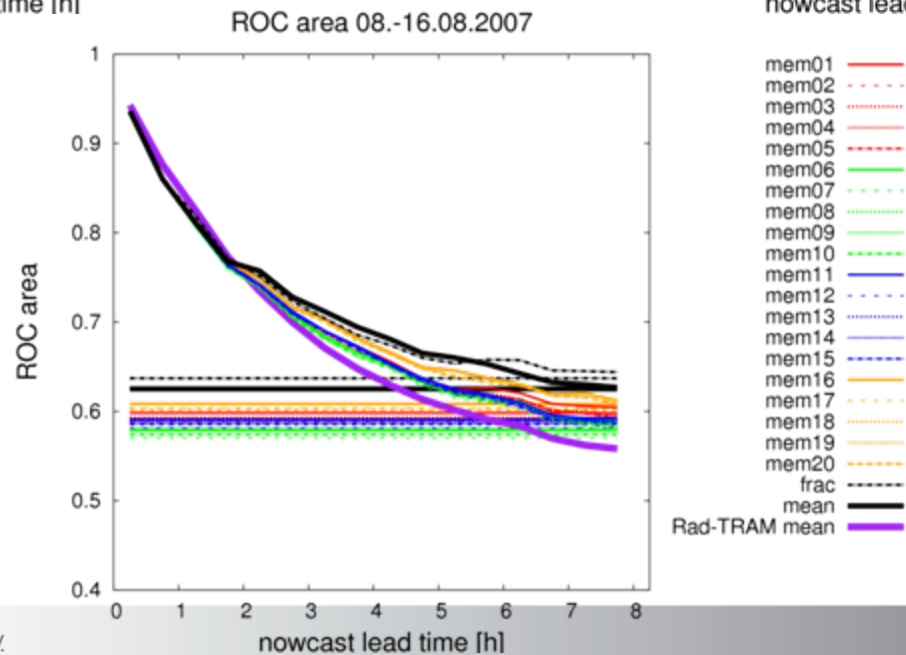
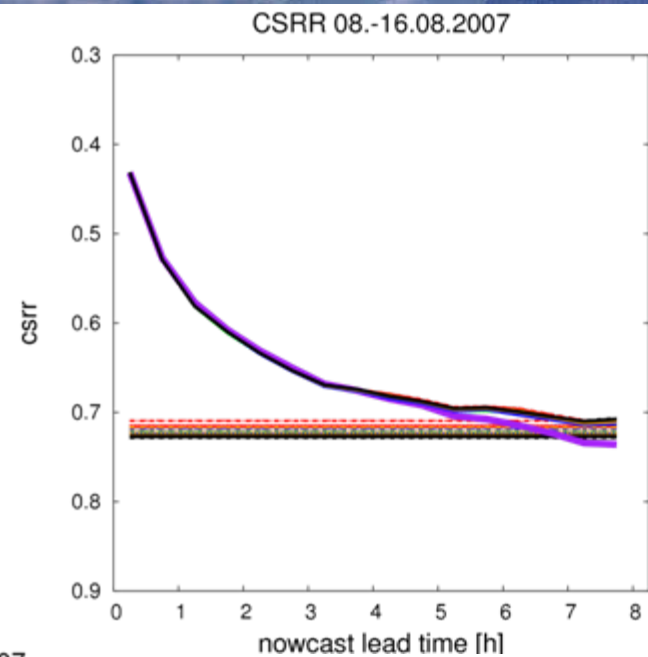
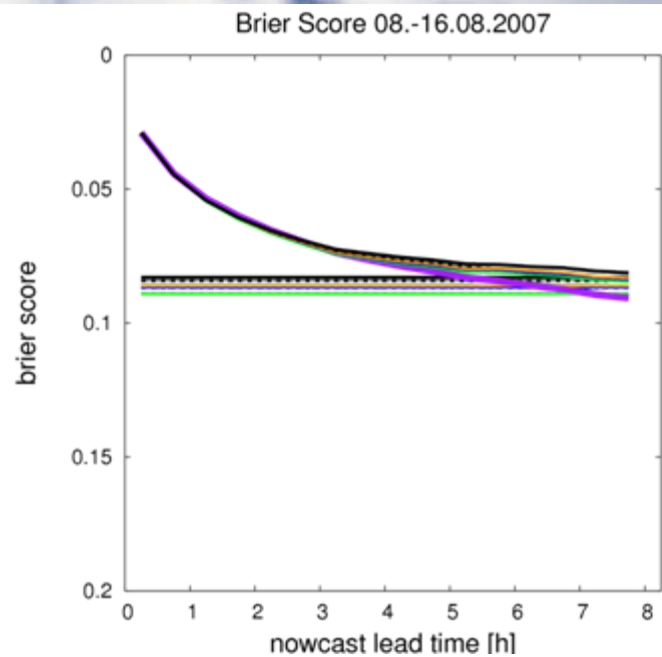




# Combination – forecast quality of components



# Combination – forecast quality

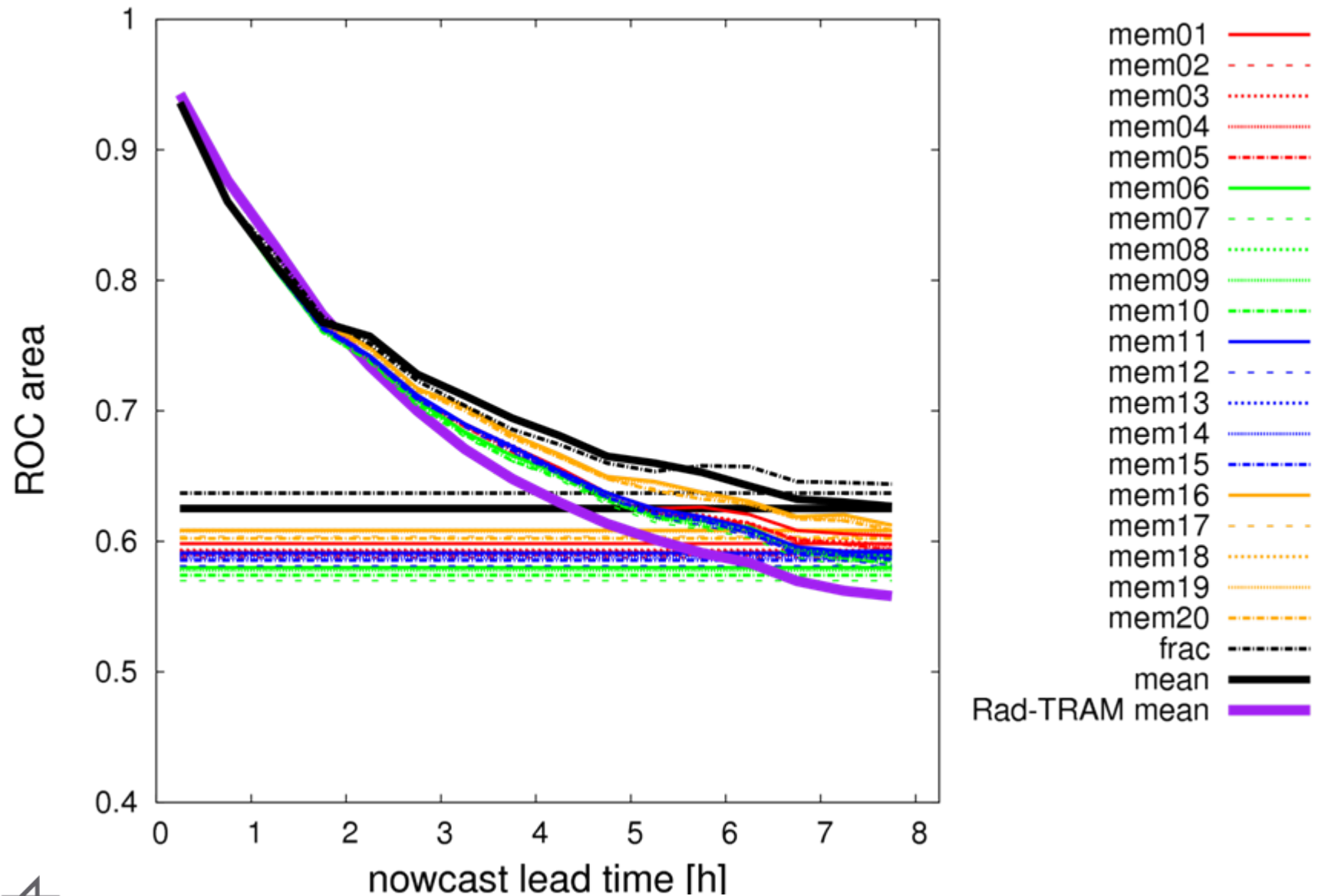


mem01 —  
mem02 - - -  
mem03 .....  
mem04 —  
mem05 - - -  
mem06 —  
mem07 .....  
mem08 .....  
mem09 .....  
mem10 .....  
mem11 —  
mem12 - - -  
mem13 .....  
mem14 —  
mem15 - - -  
mem16 —  
mem17 .....  
mem18 .....  
mem19 —  
mem20 - - -  
frac - - -  
mean —  
Rad-TRAM mean —



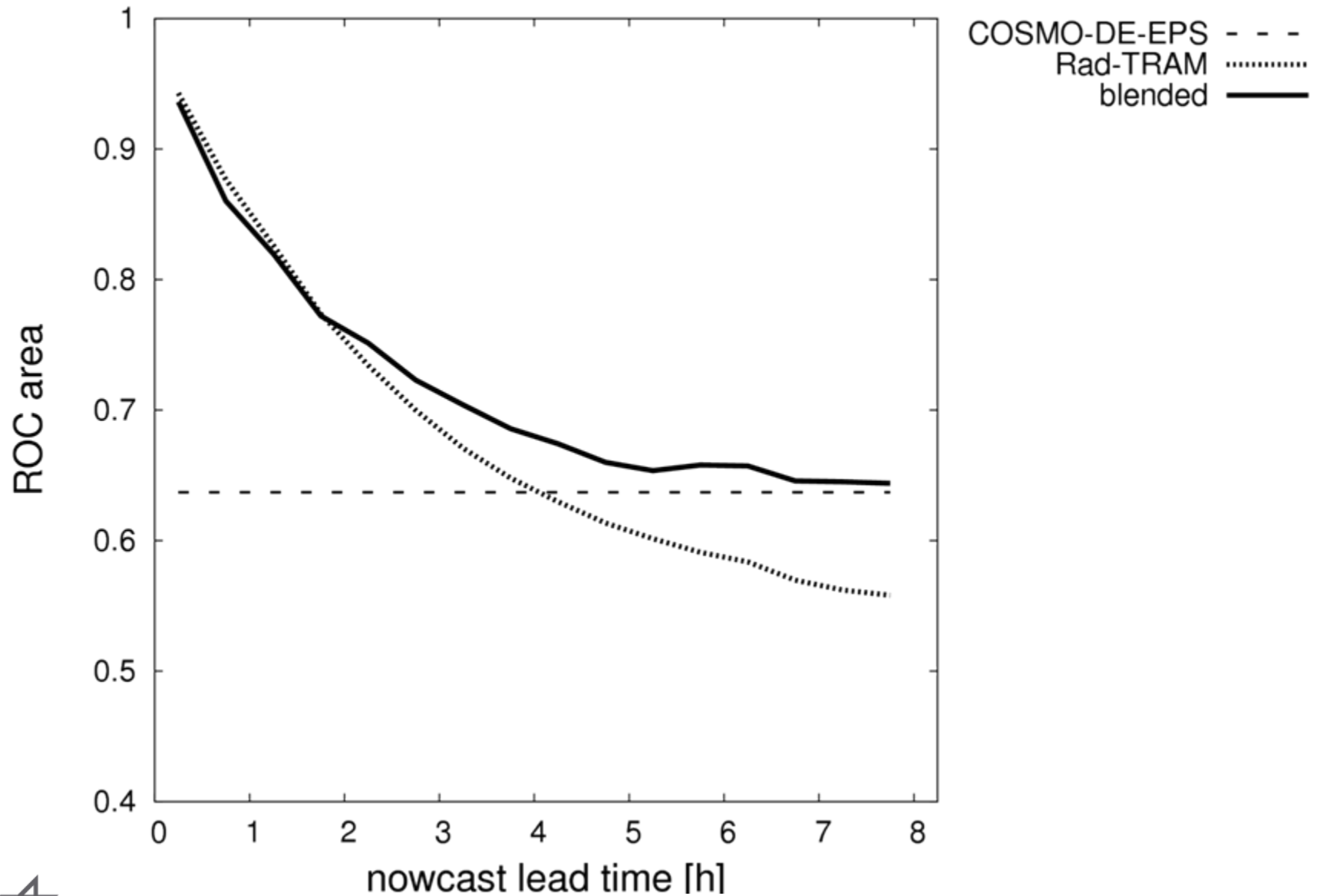
# Combination – forecast quality

ROC area 08.-16.08.2007



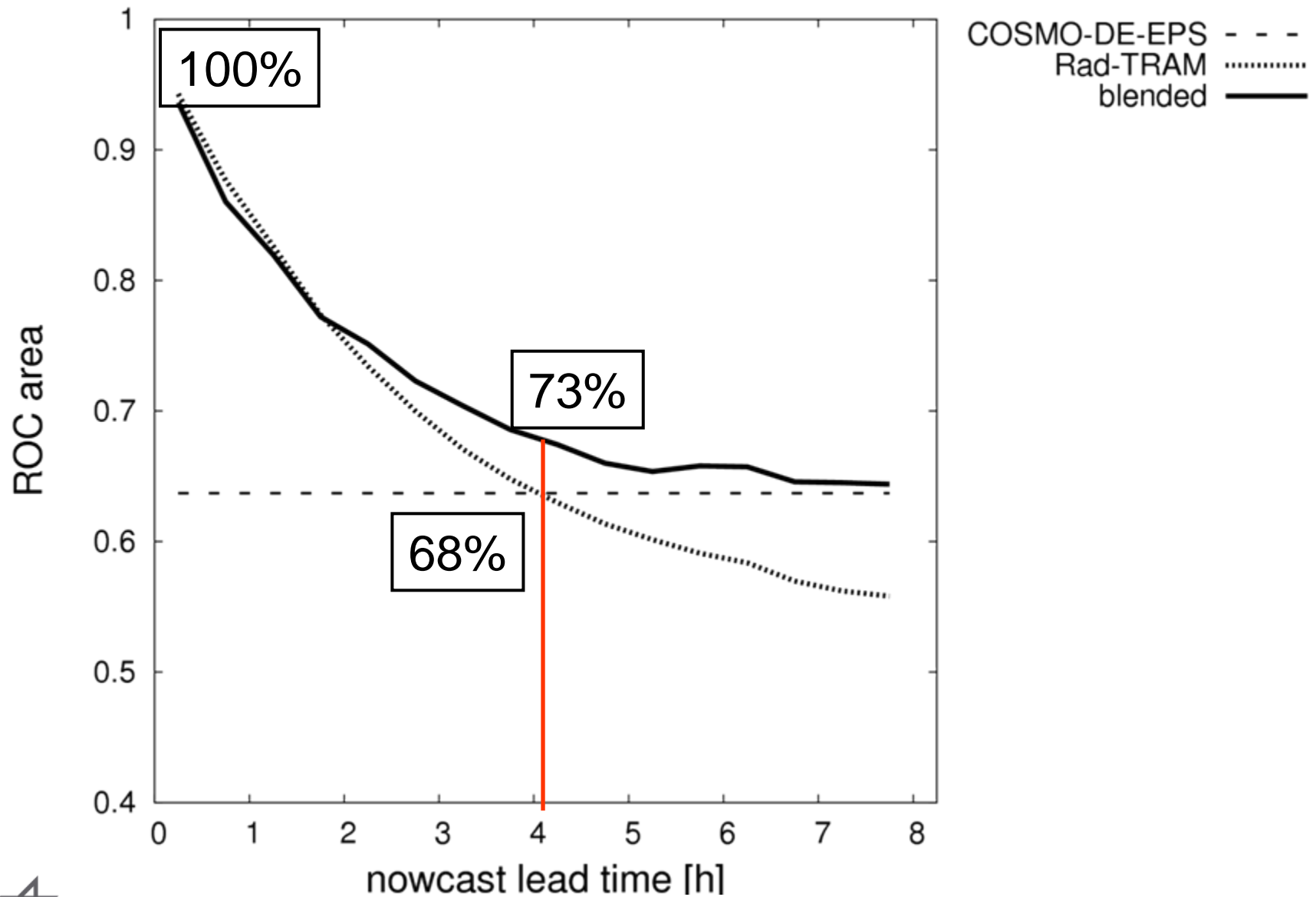
# Combination – forecast quality


ROC area 08.-16.08.2007



# Combination – forecast quality

ROC area 08.-16.08.2007





# 5. Conclusions & Outlook



# Conclusions

## 1. Methodology:

- calculation of probabilistic forecasts with nowcasting and NWP methods
- evaluation of forecast quality
- blending of forecasts



# Conclusions

## 1. Methodology:

- calculation of probabilistic forecasts with nowcasting and NWP methods
- evaluation of forecast quality
- blending of forecasts

## 2. Results:

- cross-over period between 5.5 und 7 hours
- blended forecast reproduces skill for short and long lead times
- improved skill through blending for the cross-over lead times





- Most potential for improvement: model forecasts

lead time dependent evaluation  
(time-lagged Ensemble)

- Most potential for improvement: model forecasts
    - lead time dependent evaluation  
(time-lagged Ensemble)
  - Rerun the study with larger amount of data:
    - analysis (calibration, derivation of weighting functions)  
within different meteorological regimes:
- Identification with convective time scale (Done et al., 2006)



End

-

Thank you for your attention!



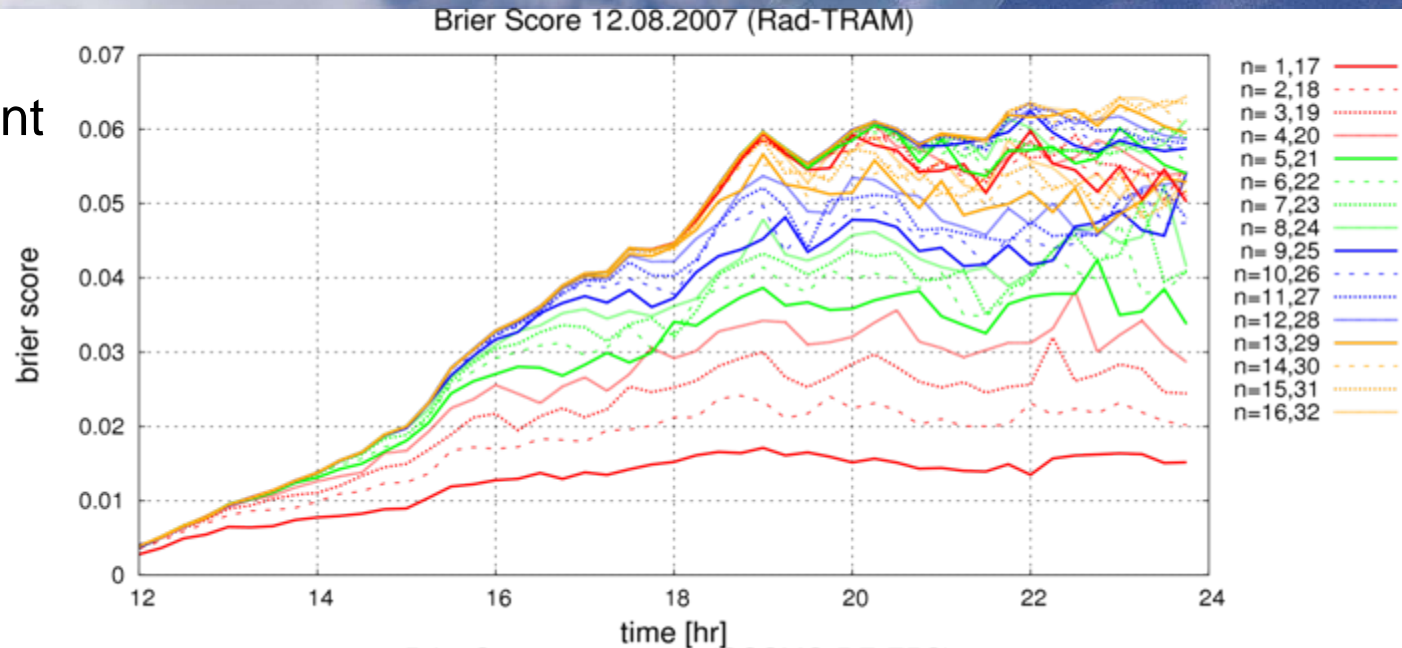


## 6. Further slides

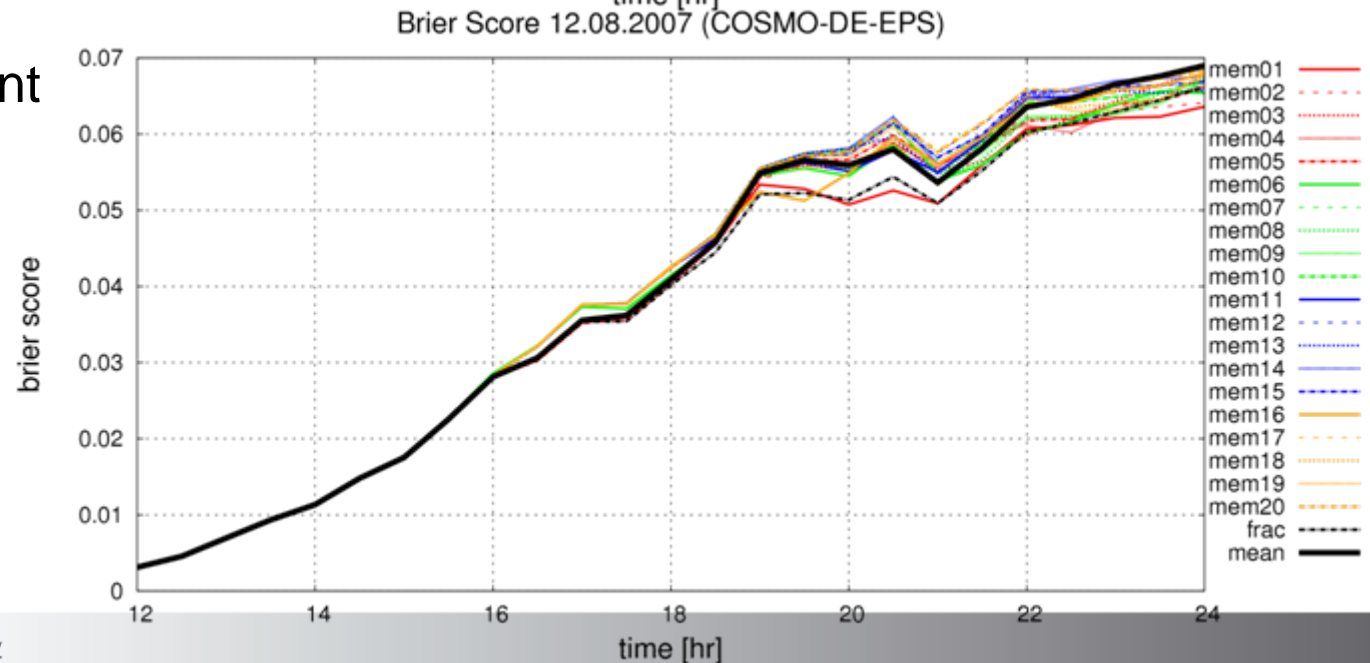


# 12.08.2007 – time series – Brier score

lines denote different lead times

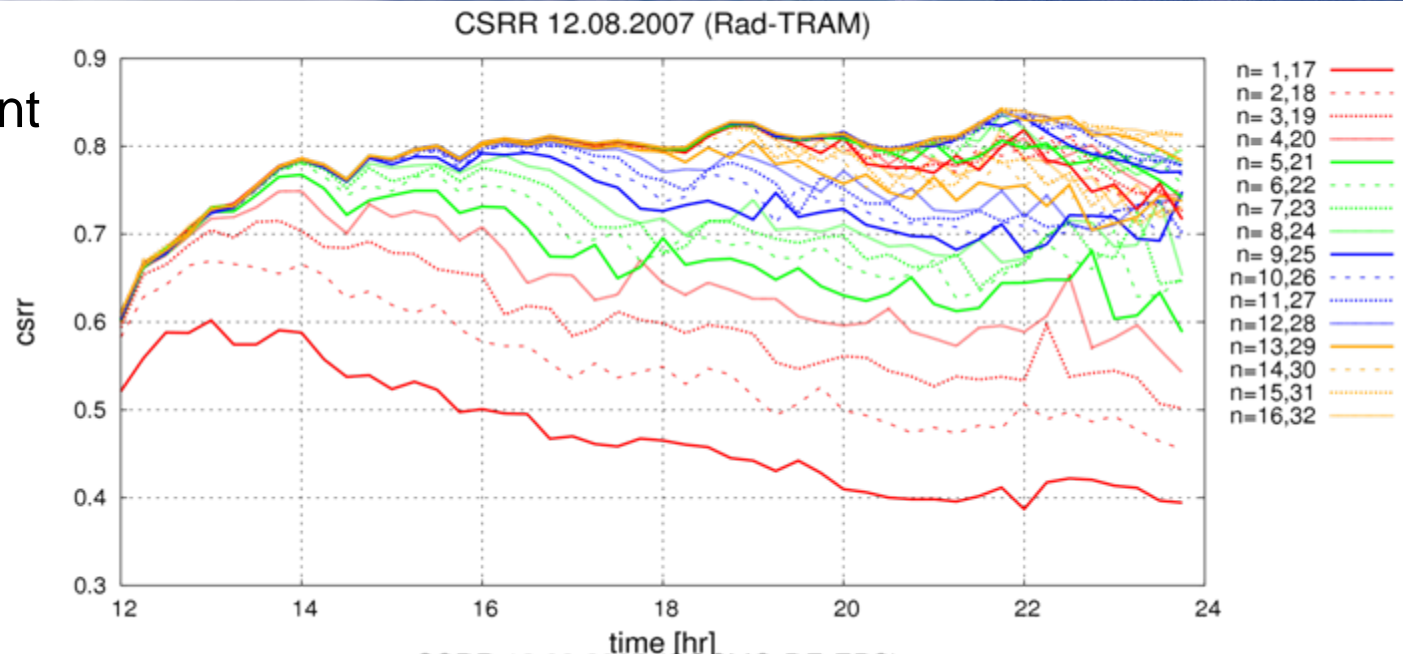


lines denote different methods

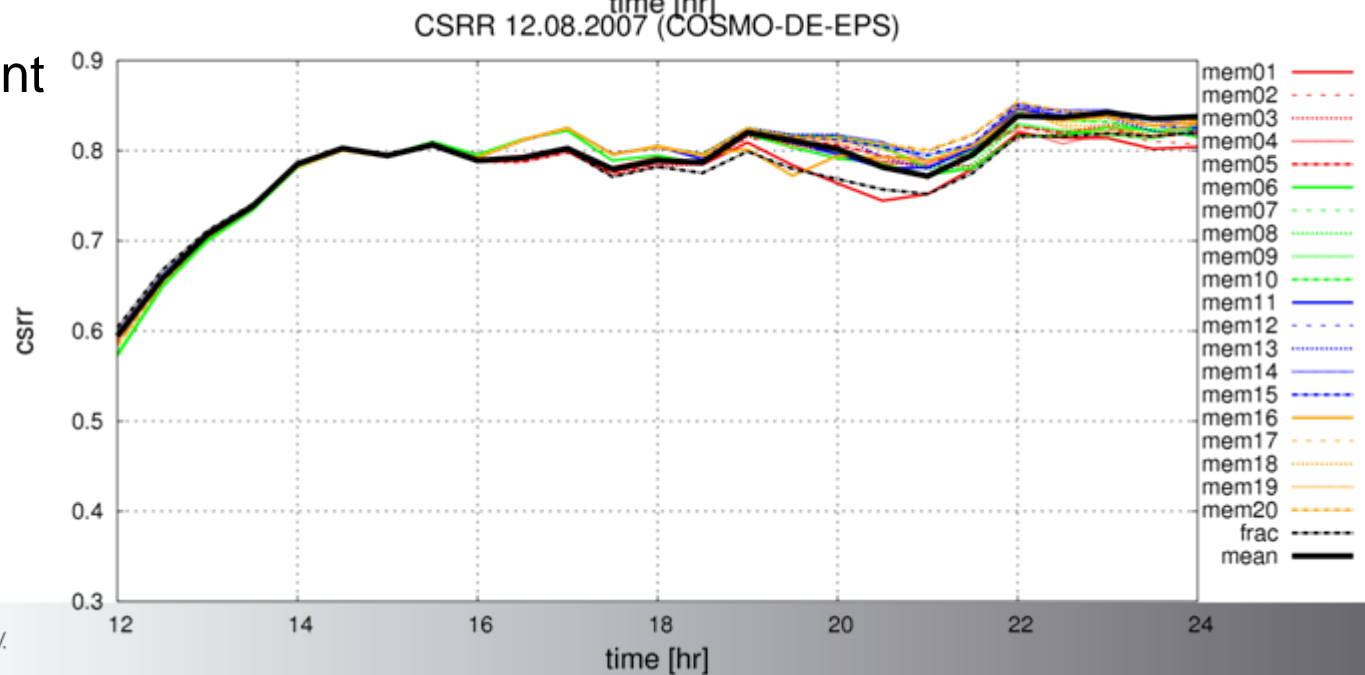


# 12.08.2007 – time series – CSRR

lines denote different lead times

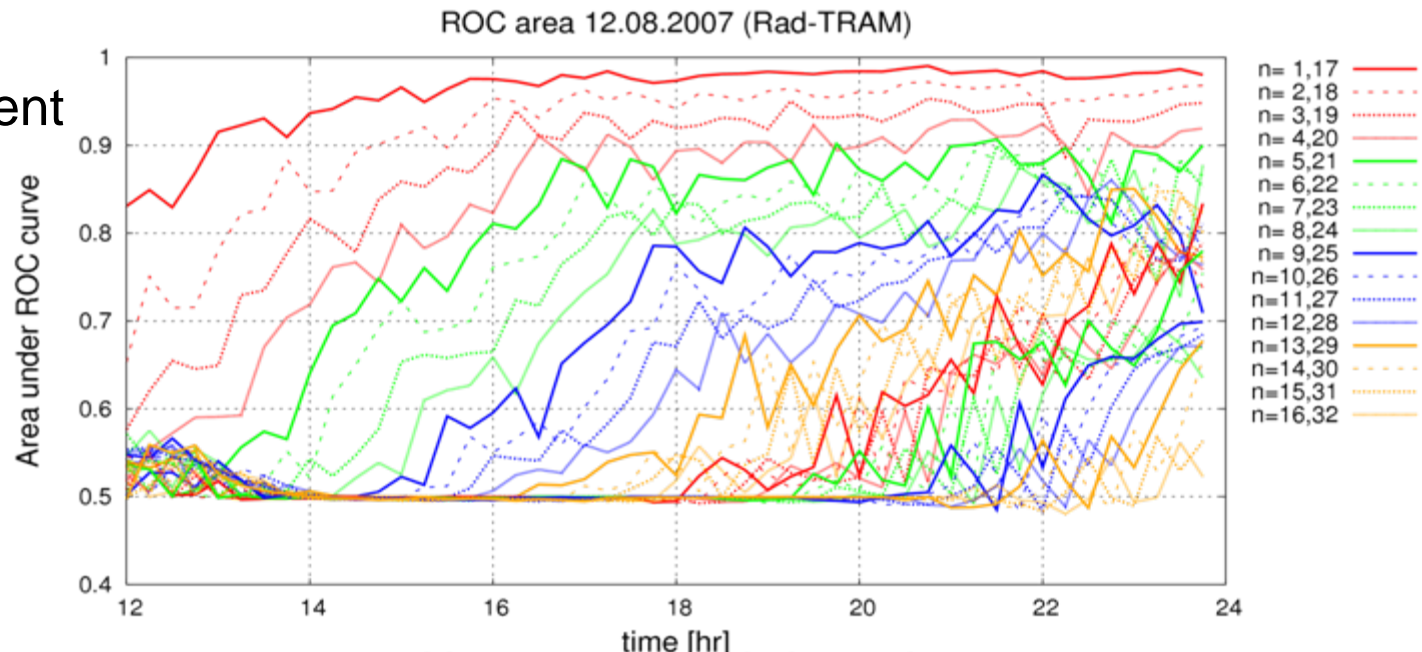


lines denote different methods



# 12.08.2007 – time series – ROC area

lines denote different lead times



lines denote different methods

