Calibration with MOS at DWD

ECMWF Calibration Meeting
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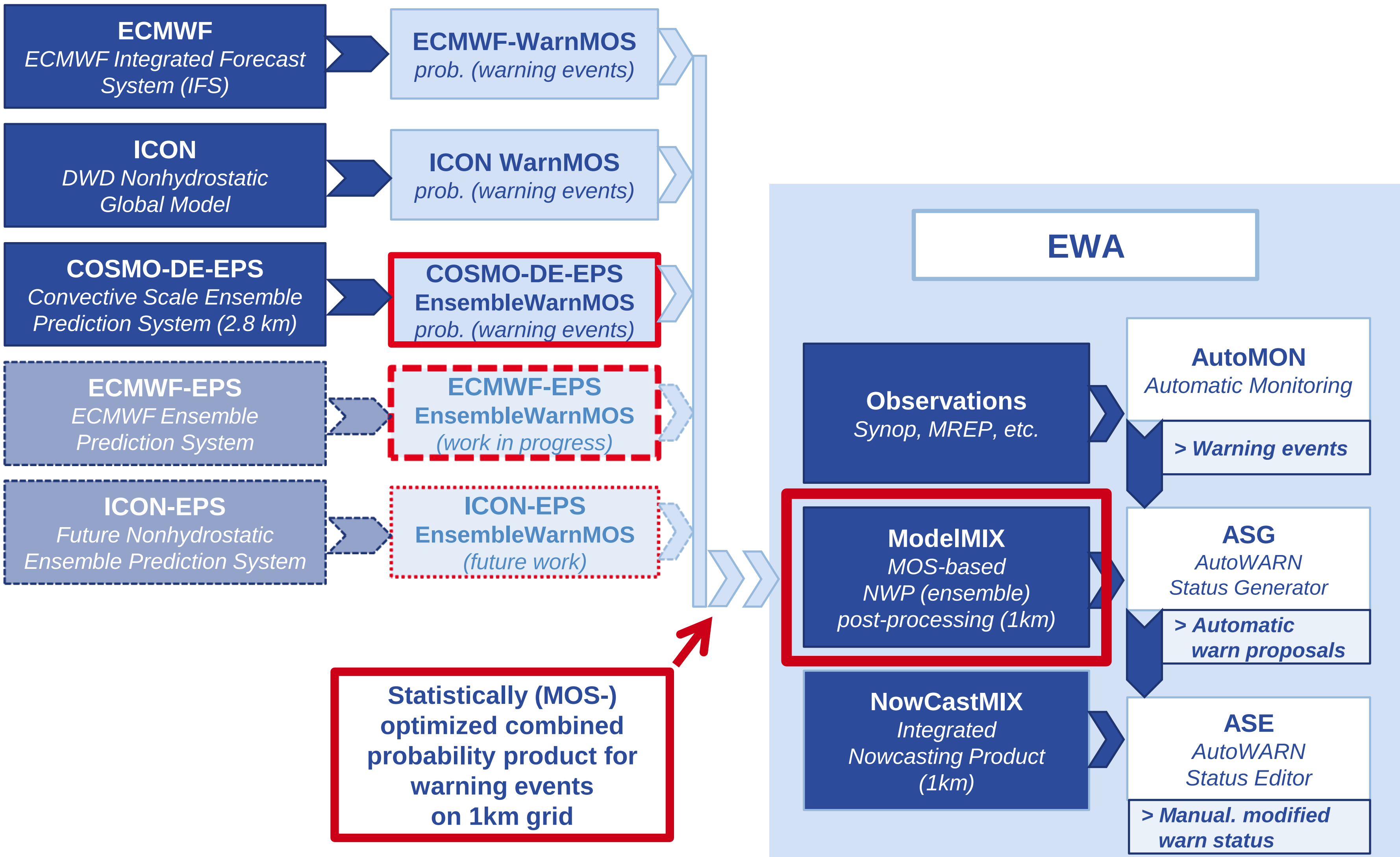
Deutscher Wetterdienst

Calibration with MOS at DWD

- Outline
  - Overview of MOS Systems at DWD
  - Ensemble MOS
  - ModelMIX: MOS of MOS
  - Ensemble MOS for ECMWF-EPS (TIGGE/THORPEX data)
    - Verification
  - Bonus

EWA: ModelMIX
decision support for weather warnings

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



MOS Systems at DWD

- **Operational Systems at DWD**
  - **ICON-MOS, ECMWF-MOS, MOS-MIX**
    global, medium scale, at synoptic stations, based on ICON and IFS/ECMWF
  - **ICON-WarnMOS, ECMWF-WarnMOS, WarnMOS-MIX**
    provides 27 warning criteria on 1x1 km grid for Germany
  - **AUTO-TAF** spezialised forecasts for airports
  - **CellMOS** nowcasting thunderstorms on advecting cells (Lagrange)

  - ***Ensemble-MOS, ModelMIX*** *(in development, based on WarnMOS)*
    calibration of ensemble forecasts (COSMO-DE-EPS, ECMWF-EPS, ICON-EPS)

Ensemble-MOS

- Enhancement of MOS Systems for Ensembles
  - apply for COSMO-DE-EPS and EZMW-EPS (later ICON-EPS)
  - optimization, calibration and interpretation using synoptical observations
  - ensemble products as model predictors
    - ensemble mean and stddev (quantiles, etc.)
    - surrounding of stations (mean and stddev of surrounding)
  - linear regression for continuous forecast elements (e.g. 2m temperature)
  - logistic regression for probabilistic forecast elements (e.g. prob(RR>15mm))
  - use of long time series, e.g. 3 years for COSMO-DE-EPS
  - multistation approach (9 climatological cluster in Germany, currently redesigned)
  - multi time equations for extreme and rare events
    (wind gusts, precipitation with high thresholds)
  - gauge adjusted radar data alternatively to precipitation observations
  - forecast of forecast errors, forecast uncertainty

MOS: stepwise linear and logistic regression

- provide set of predictors, e.g. model forecasts, observations, derived predictors (e.g. sqrt RR, Rel_Div_10m, CAPE index, etc.)
- select predictor with highest statistical correlation to predictand
- select further predictors correlated to residuum, as long as statistically significant
- **example: 2m temperature**
  - based on 3 UTC issue of COSMO-DE-EPS

```
99903 Issue=02:00z +001:00
TTT Season: spr

Name     Lin Reg  1         Co     Wgt
-----------------------------------
T_G_MS                    0.05       5
TD_2M_LS                 -0.02       2
TTT(-1)Obs                0.88      78
Td(+0)StF                 0.08       7
  …
-----------------------------------
Const. =    -5.2    RMSE    =     6.28
```

forecast time: 1h

  - *_MS: medium scale: 28 km*
  - *_LS: large scale: 54 km*
  - **Co:** coefficient of regression
  - **Wgt:** normalised weigth of predictor in equation
- 1 equation for each predictand (about 160), cluster (9), forecast time (21), season (4), issue of EPS(8)

MOS: stepwise linear and logistic regression

- provide set of predictors, e.g. model forecasts, observations, derived predictors (e.g. sqrt RR, Rel_Div_10m, CAPE index, etc.)
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- select further predictors correlated to residuum, as long as statistically significant
- **example: 2m temperature**
  - based on 3 UTC issue of COSMO-DE-EPS

```
99903 Issue=02:00z +019:00
TTT Season: spr

Name     Lin Reg  1       Co     Wgt
-----------------------------------
T_2M_MS                 0.12      11
TD_2M_MS                0.05       4
TTT(-24)Obs             0.05       4
TTT(-1)StF              0.77      65
Cos_Dag                 0.02       2
  …
-----------------------------------
Const. =  -11.3   RMSE    =   13.47
```

forecast time: 19h

  - *_MS: medium scale: 28 km*
  - *_LS: large scale: 54 km*
  - **Co:** coefficient of regression
  - **Wgt:** normalised weigth of predictor in equation
- 1 equation for each predictand (about 160), cluster (9), forecast time (21), season (4), issue of EPS(8)

Forecast of Forecast Errors (of MOS forecast)

- compute regression of any forecast element
- use MAE of residuum as predictand
- compute regression of this predictand
- **example: MAE of 2m temperature**
  - based on 12 UTC issue of ECMWF-EPS (TIGGE/THORPEX data, 4 variables)

```
99906 Issue=12:00z +024:00
TTT Season: win

Name     Lin Reg  1         Co     Wgt
-----------------------------------
temp                      1.04      88
Cos_Dag                   0.07       3
temp_dev                  0.04       3
Sin_3*Dag                 0.01       3
wind                     -0.16       3
-----------------------------------
Const. =    -2.5    RMSE    =    10.90
```

T2m

```
99906 Issue=12:00z +024:00
E_TTT Season: win

Name     Lin Reg  1         Co     Wgt
-----------------------------------
temp_dev                  0.05      37
wind                     -0.19      29
temp                     -0.02      18
Sin_3*Dag                -0.01      16
-----------------------------------
Const. =     9.3    RMSE    =     7.10
```

MAE of T2m

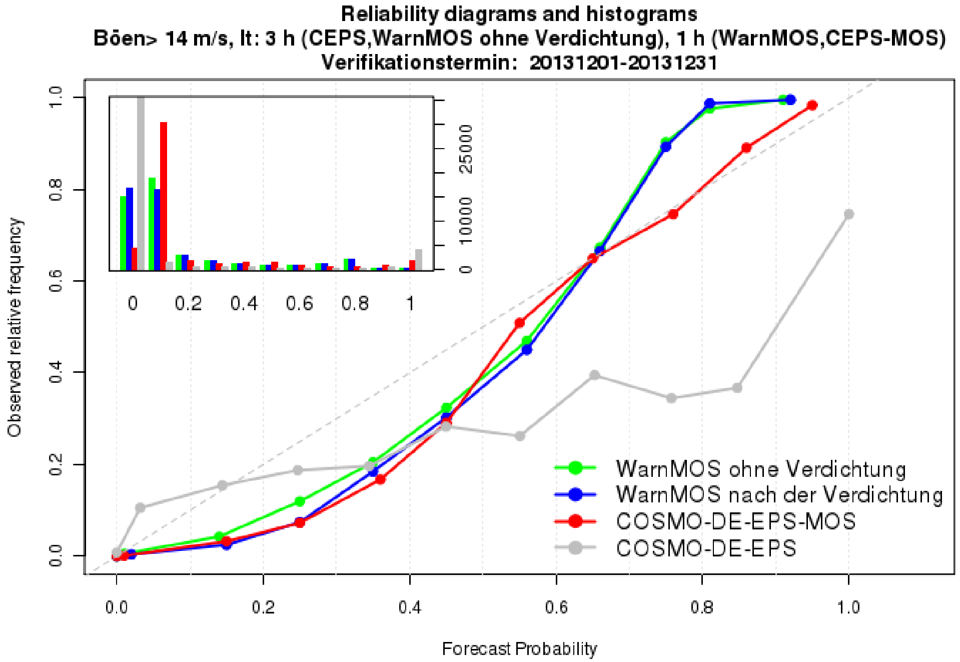
- *temp:* *ensemble mean of temperature*
- *temp_dev:* *standard deviation of ensemble*

stddev is increased and calibrated
(stddev = MAE/0.8 for Gaussian distribution)

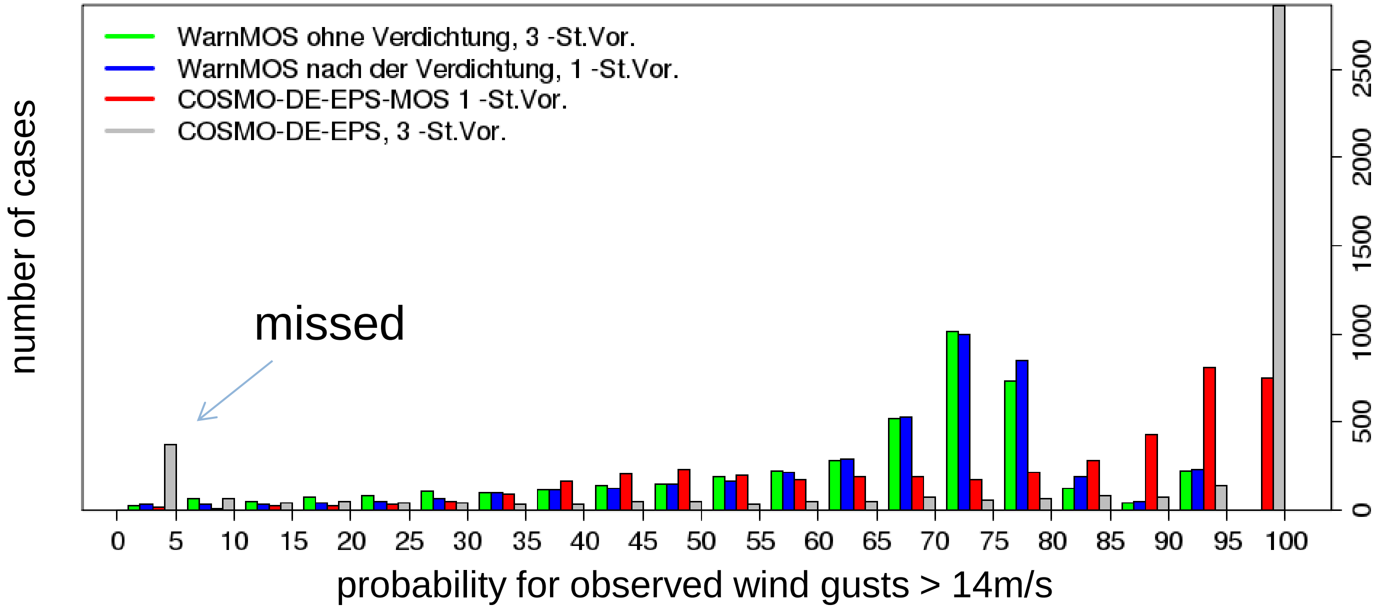
Calibration of wind gusts > 14m/s

Impact of logistic regression

- reliability diagram for 3-hourly forecasts
  - COSMO-DE-EPS (not calibrated, grey) shows significant overforecsting for high probabilities.
  - MOS with linear regression (blue, green) shows underforecasting for high probabilites.
  - Ensemble MOS with logistic regression (red) is correcting, however not yet perfectly. Still overforecasting for small probabilities (problem found).



threshold probabilites for observed wind gusts > 14m/s



- ➔ 3-hourly forecasts (december 2013)
- ➔ COSMO-DE-EPS-MOS runs two hours after COSMO-DE-EPS, forecast time is two hours less, therefore

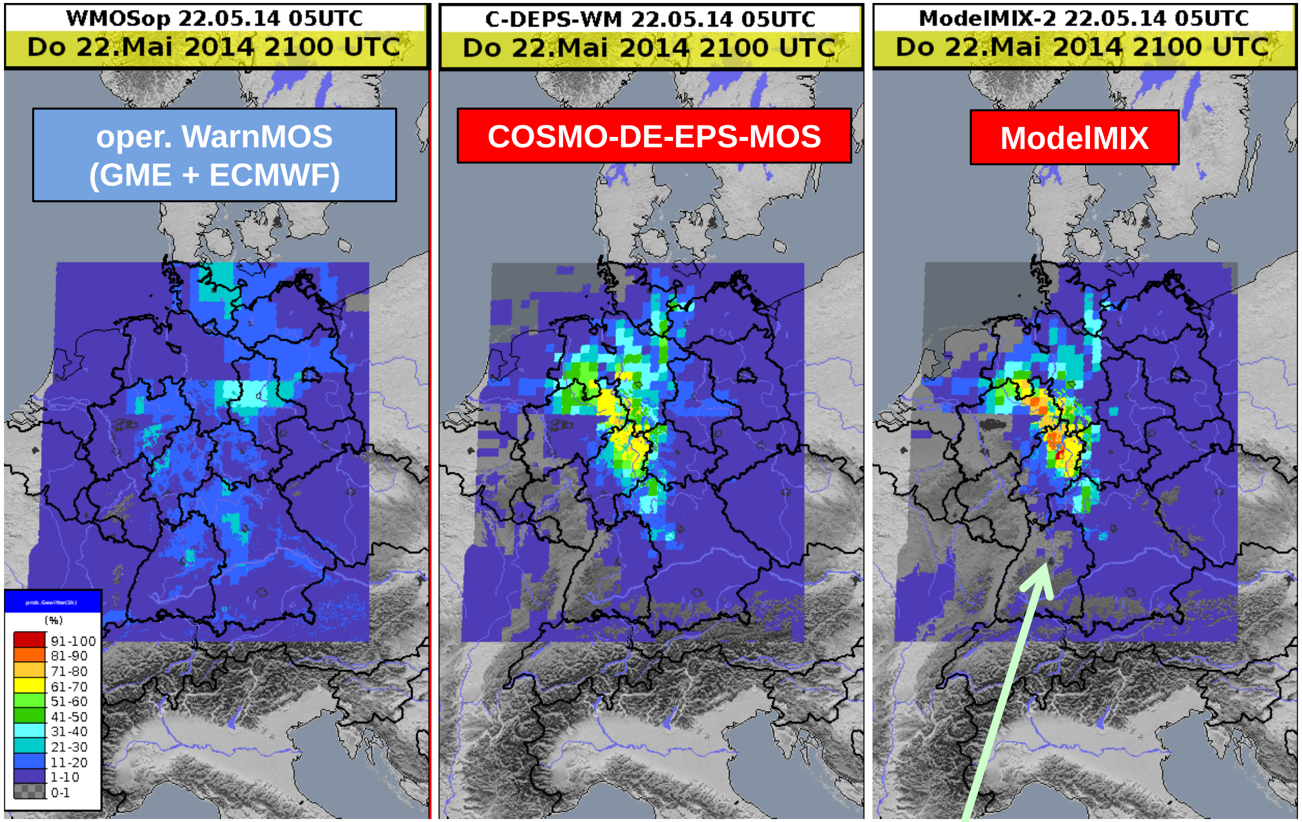
- ➔ COSMO-DE-EPS (grey) has many cases with probability 0, despite observed wind gusts >14m/s
- ➔ COSMO-DE-EPS-MOS corrects „U-shape“ of COSMO-DE-EPS

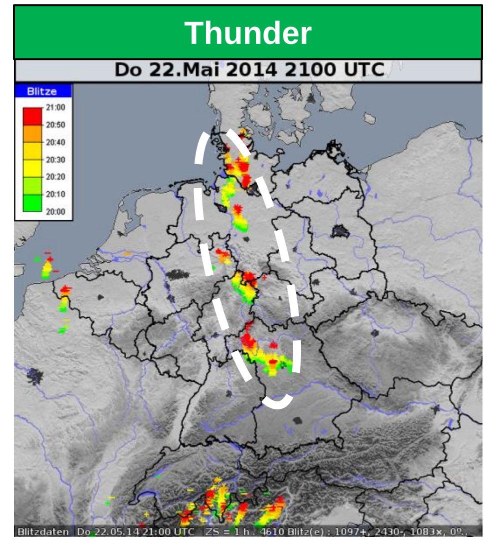
ModelMix – MOS of MOS

- combination of MOS systems
    - ICON-WarnMOS
    - ECMWF-WarnMOS
    - COSMO-DE-EPS-WarnMOS
    - ECMWF-EPS-WarnMOS
    - …
  - statistically optimal combinations
  - consistent probabilitstic products for warning criteria
  - at locations of stations and on 1km-grid

ModelMIX: Thunderstorm

Probability for thunderstorm +16h





Combination of MOS forecasts → signal for thunderstorm is enhanced

ModelMIX: weights of the individual MOS Systems

- mix of 2 x COSMO-DE-EPS-MOS, GME-MOS und ECMWF-MOS (latest issues)
- relative weights according to linear regression
- **example: T2m** – all seasons, alle forecast times up to 21h, all stations

Aus-gabezeit	C-EPS 00h	C-EPS 03h	C-EPS 06h	C-EPS 09h	C-EPS 12h	C-EPS 15h	C-EPS 18h	C-EPS 21h	GME 00h	GME 12h	EZMW 00h	EZMW 12h
02h	74%							3%		2%		21%
05h	24%	54%							6%			16%
08h		21%	62%						3%			14%
11h			35%	44%					2%		19%	
14h				29%	53%				1%		17%	
17h					30%	49%				8%	13%	
20h						18%	62%			6%	14%	
23h							4%	62%		2%		32%

ModelMIX: weights of the individual MOS Systems

- mix of 2 x COSMO-DE-EPS-MOS, GME-MOS und ECMWF-MOS (latest issues)
- relative weights according to linear regression
- **example: FX/1h>25kn** – all seasons, alle forecast times up to 21h, all stations

Aus-gabezeit	C-EPS 00h	C-EPS 03h	C-EPS 06h	C-EPS 09h	C-EPS 12h	C-EPS 15h	C-EPS 18h	C-EPS 21h	GME 00h	GME 12h	EZMW 00h	EZMW 12h
02h	39%							28%		7%		25%
05h	8%	44%							24%			24%
08h		6%	53%						16%			25%
11h			13%	45%					13%		30%	
14h				10%	52%				10%		38%	
17h					10%	49%				22%	18%	
20h						11%	59%			14%	16%	
23h							13%	54%		4%		29%

ModelMIX: weights of the individual MOS Systems

- mix of 2 x COSMO-DE-EPS-MOS, GME-MOS und ECMWF-MOS (latest issues)
- relative weights according to linear regression
- **example: RR/1h>15mm** – all seasons, alle forecast times up to 21h, all stations

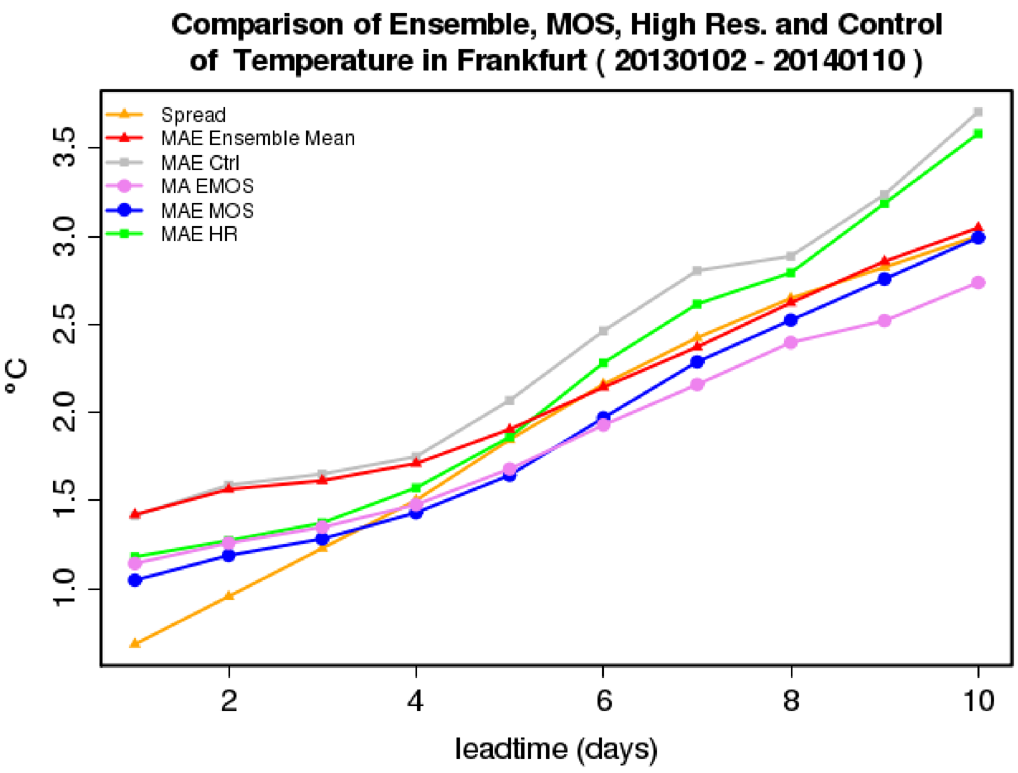
Aus-gabezeit	C-EPS 00h	C-EPS 03h	C-EPS 06h	C-EPS 09h	C-EPS 12h	C-EPS 15h	C-EPS 18h	C-EPS 21h	GME 00h	GME 12h	EZMW 00h	EZMW 12h
02h	54%							22%		14%		11%
05h	31%	45%							17%			7%
08h		43%	44%						6%			7%
11h			30%	43%					9%		17%	
14h				22%	57%				8%		13%	
17h					34%	35%				20%	11%	
20h						26%	56%			8%	9%	
23h							25%	43%		10%		22%

Ensemble-MOS for ECMWF-EPS

- TIGGE/THORPEX data
  - 36 TIGGE stations
    - 50 ensembles, 1 high resolution run
    - 2m temperatur, mean wind, cloud coverage, 24h precipitation
      - observations as predictands
      - ensemble products, mean, stddev as predictors
    - training sample 2002-2012 (10 years)
    - free forecasts for 2013
      - variables and errors (smoke plumes, „Rauchfahnen“)
      - verification

EnsembleMOS for ECMWF-EPS

Verification of 2013 – 2m temperature errors



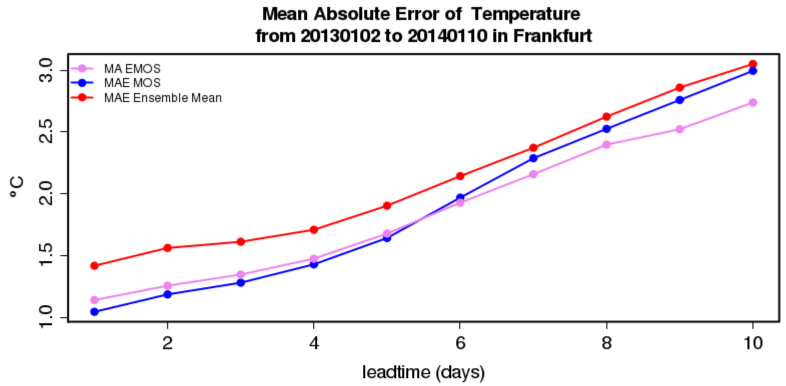
Frankfurt

MAE MOS: MOS Errors (blue)
MA EMOS: Estimated Errors (pink)

EnsembleMOS for ECMWF-EPS

- Verification of 2013 – 2m temperature errors

Frankfurt



MAE MOS: MOS Errors (blue)
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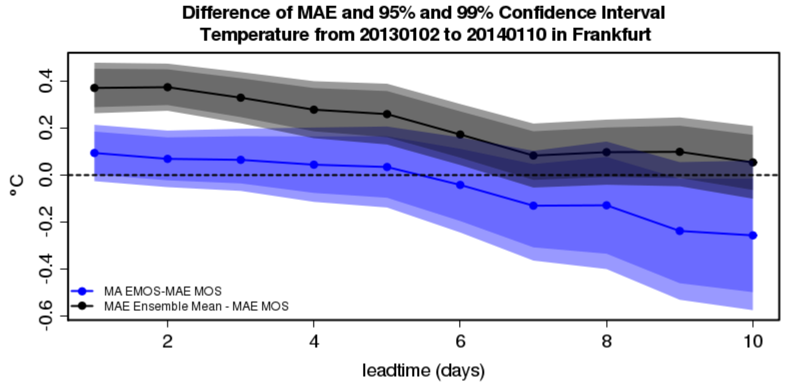


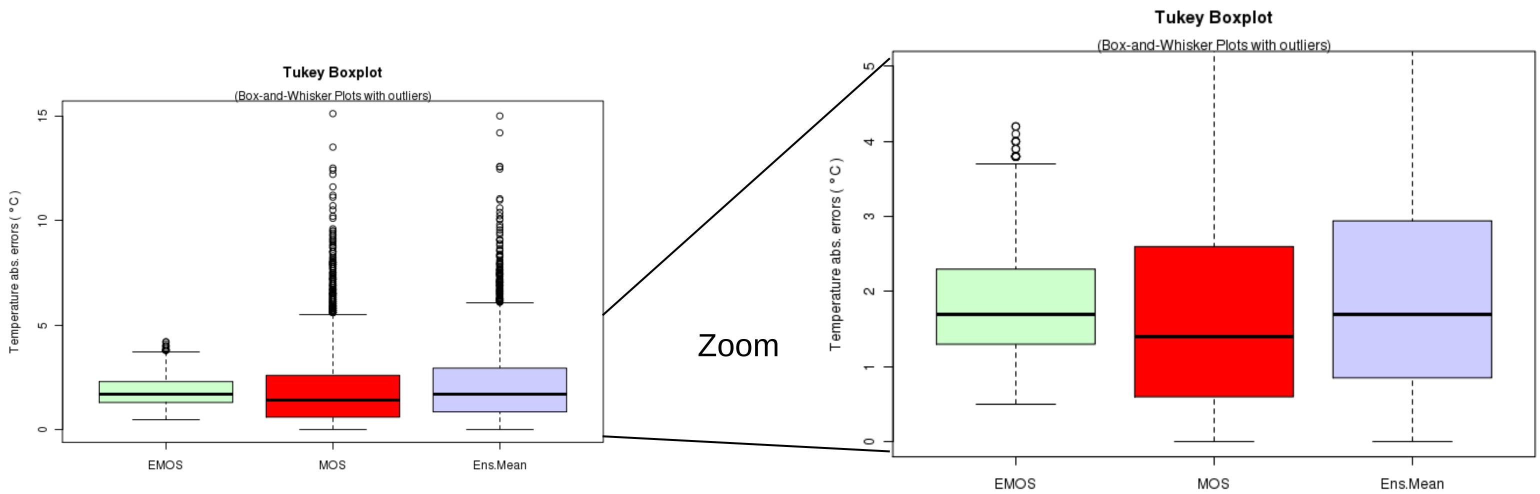
Ensemble-MOS (black):
significantly better until day 6

Estimated-True Errors (blue):
no significant difference

EnsembleMOS for ECMWF-EPS

■ Verification of 2013 – 2m temperature errors

Frankfurt



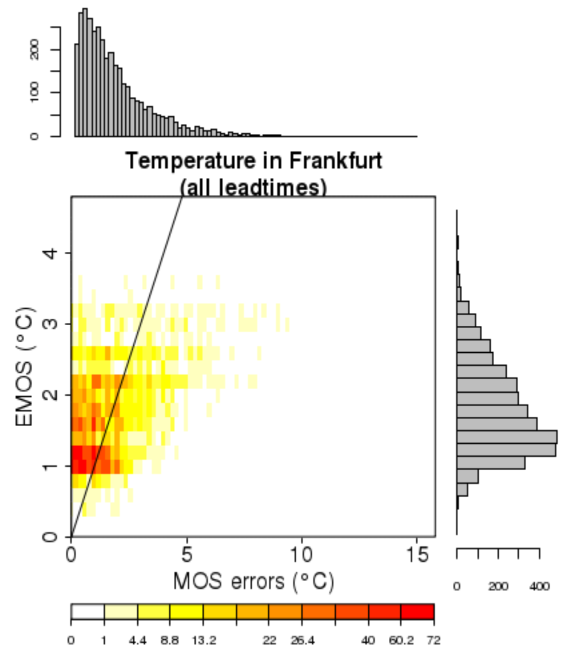
Ens. Mean: Errors of Ensemble Mean
MOS: Errors of MOS
EMOS: Estimated Errors of MOS

Estimated Errors are usually too small, but show weaker outliers

EnsembleMOS for ECMWF-EPS

- Verification of 2013 – 2m temperature errors

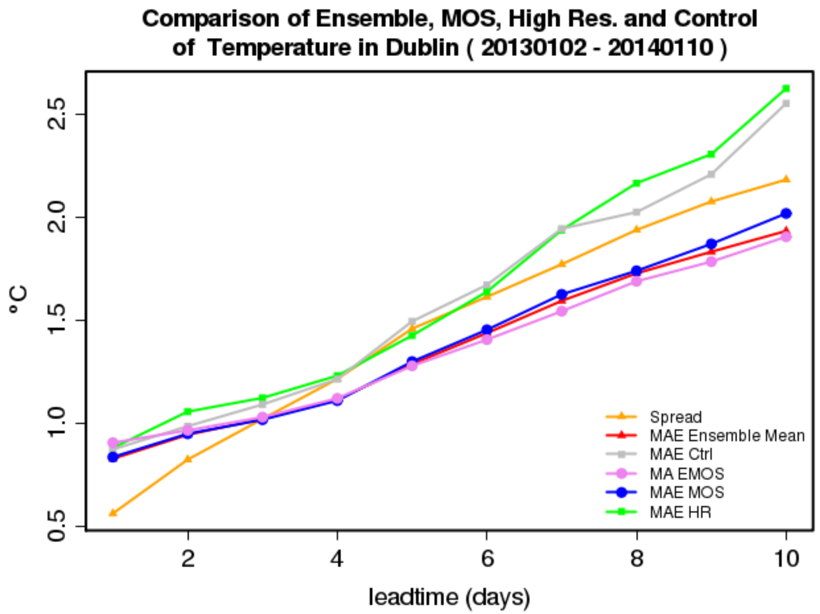
Frankfurt



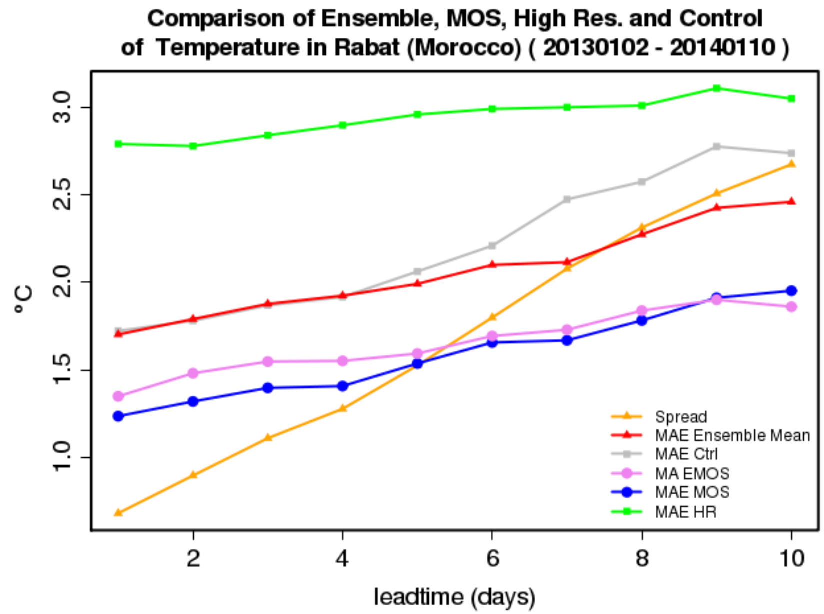
MOS: Errors of MOS
EMOS: Estimated Errors of MOS

EnsembleMOS for ECMWF-EPS

- Verification of 2013 – 2m temperature errors



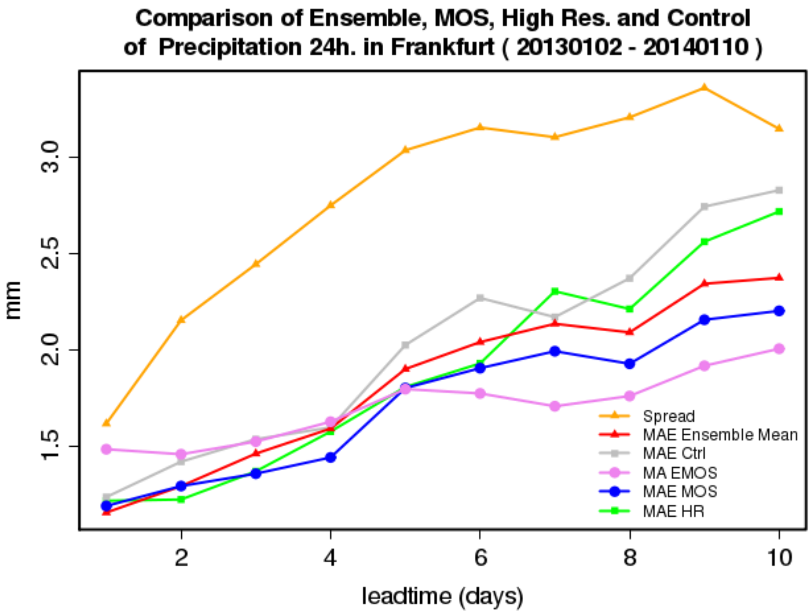
Dublin



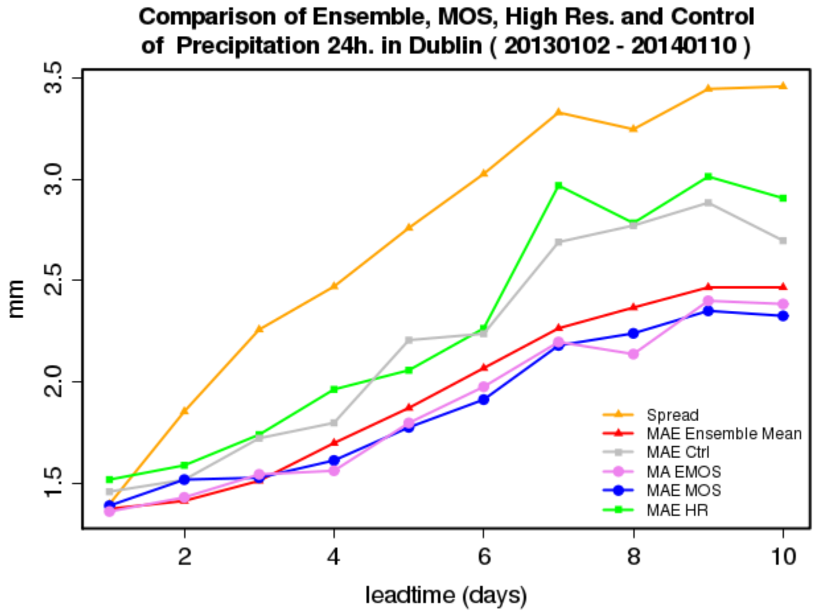
Rabat

EnsembleMOS for ECMWF-EPS

- Verification of 2013 – 24h precipitation errors



Frankfurt



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EnsembleMOS for ECMWF-EPS

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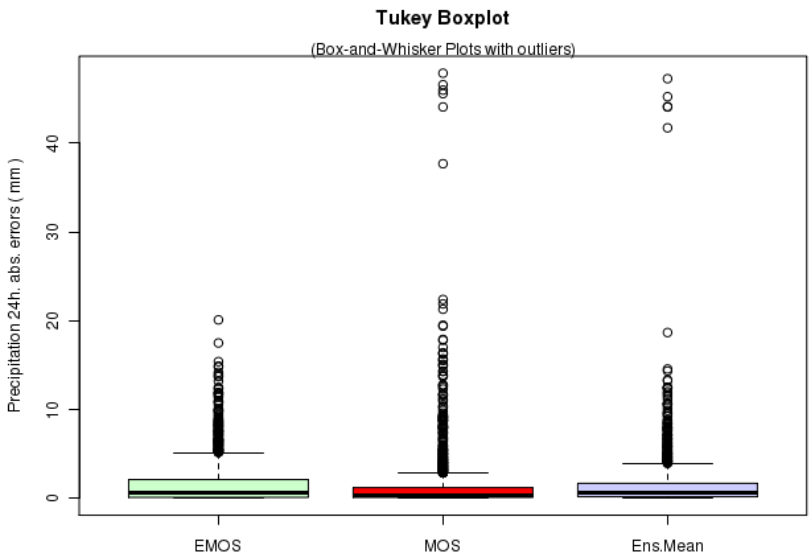
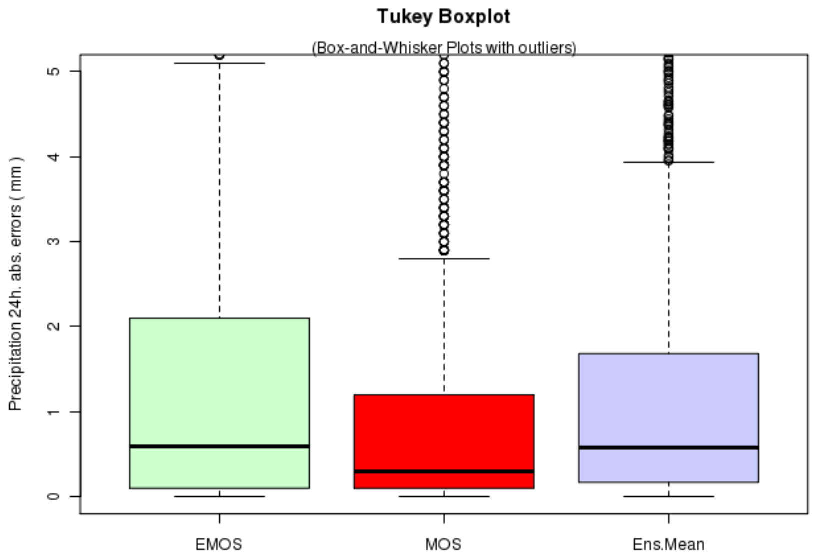
- Verification of 2013 – 24h precipitation errors

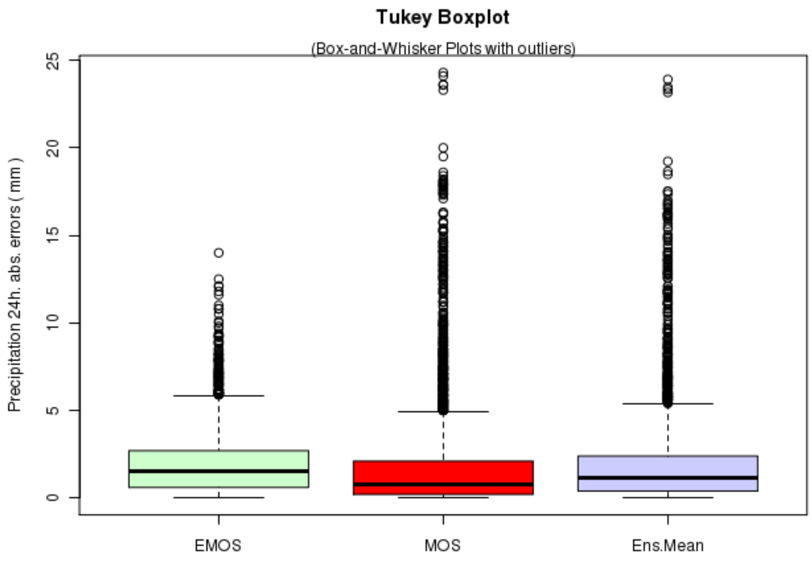


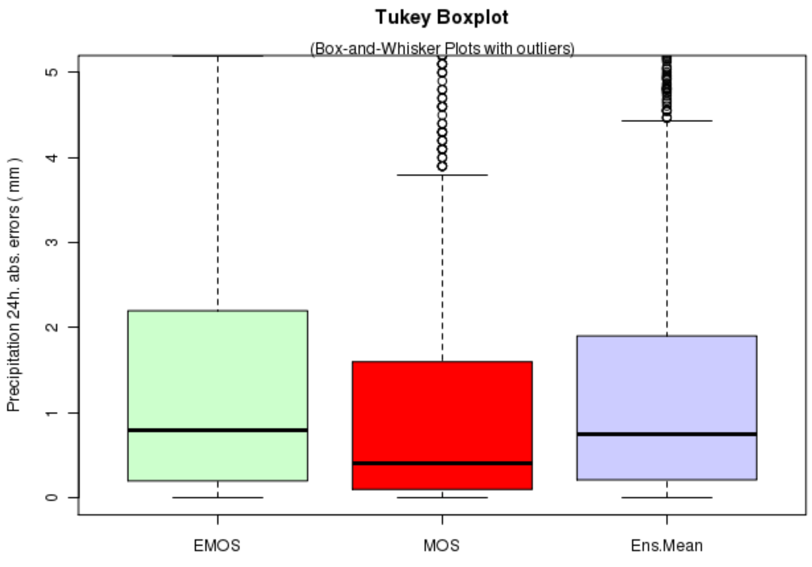


EnsembleMOS for ECMWF-EPS

Dublin

- **Verification of 2013 – 24h precipitation errors**

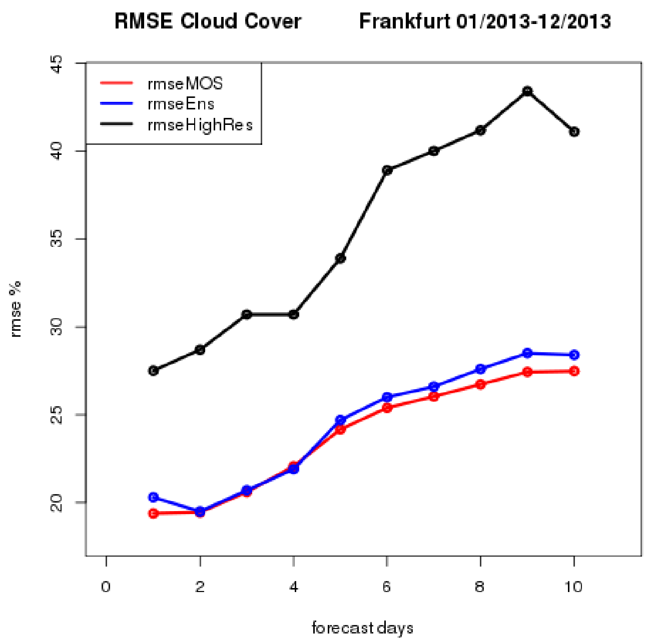


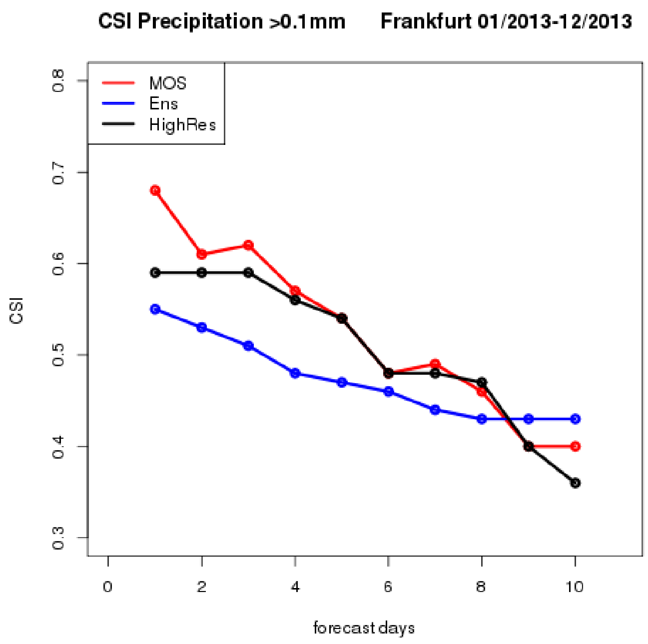


EnsembleMOS for ECMWF-EPS

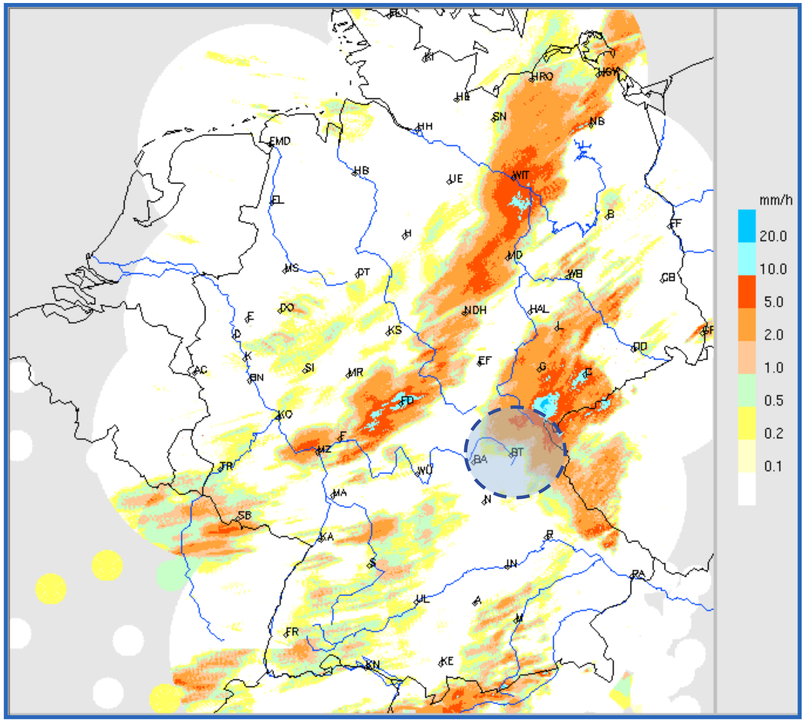
Frankfurt

- Verification of 2013 – cloud coverage and 24h precipitation (CSI, TS)





Gauge adjusted radar products as predictands (T. Hirsch)

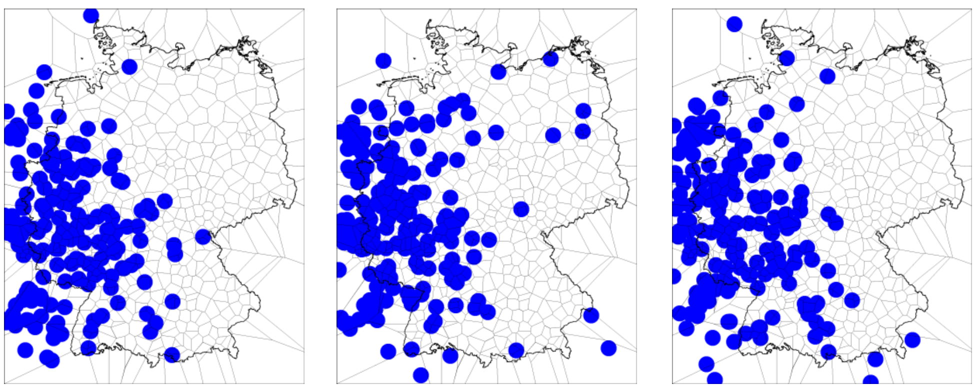


1-hourly estimation of precipitation (gauge adjusted at stations)

- Probabilities of Precipitation
  - P(RR>15 mm/ 1h)
  - P(RR>40 mm/12h)
- standard: synoptic observations
- idea: use **radar-data (RW, 1x1 km)**
  - surrounding of stations (r=8 km und 40 km)
  - relative frequencies of threshold exceedances in surrounding
- improved statistical sample
  - higher representativity
  - more extreme cases

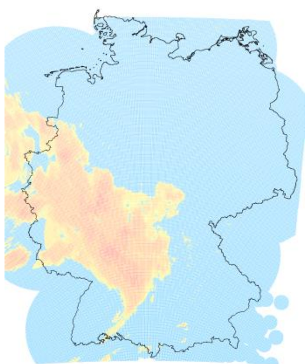
Area based probabilites

- Probability that an event occurs at least one time in any point of an area (for precipitation events currently)
- correct comparison between point observation (synop) and area mean (numerical model)
- derive area probabilites from point probabilites for arbitrary areas



3 of about 1000 Monte Carlo Simulations

Radar for validation



- Idea: place randomly circular precipitation cells so that the relative number of coverages match forecasted point probabilites at stations and count coverages for an arbitrary area.
- Reference: B. Krische, R. Hess, B. K. Reichert, V. Schmidt: "A probabilistic approach to the prediction of area weather events, applied to precipitation", Spatial Statistics, Elsevier, accepted 2015

Thank you for attention