Improving convective systems at short-leading times: assimilation of 3D radar reflectivities with COSMO- KENDA, and the two-moment scheme

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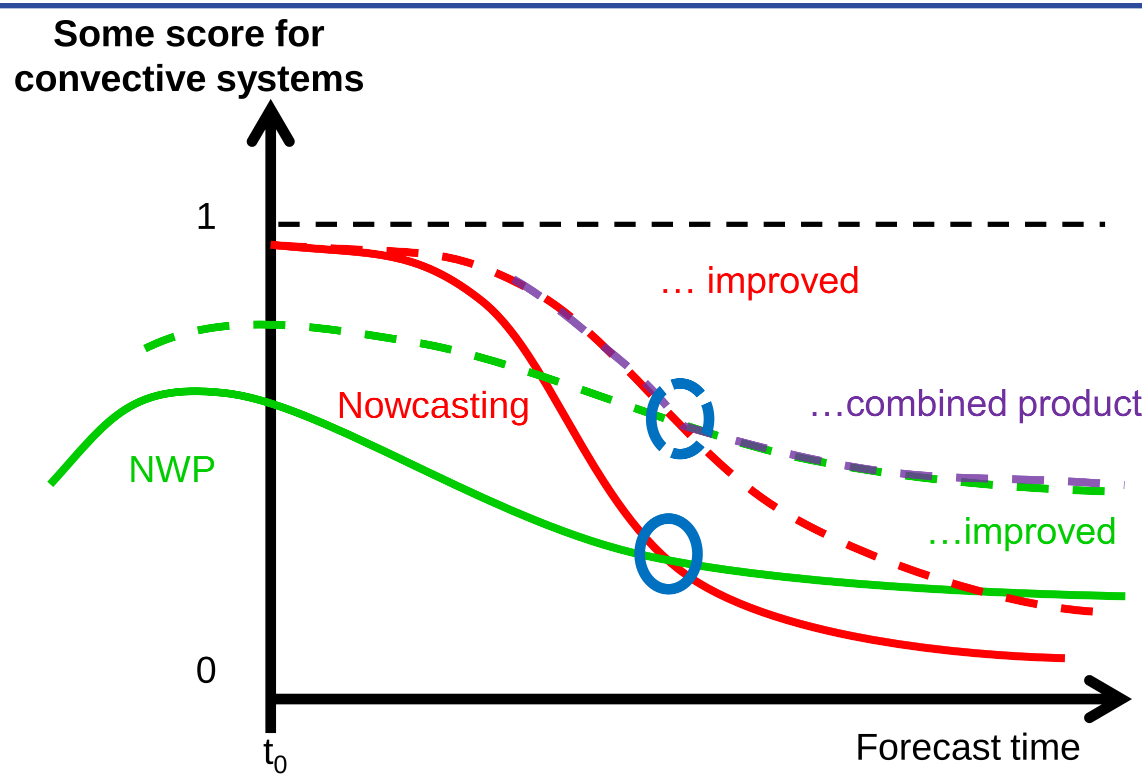
The SINFONY Project



Picture from U. Blahak

- In order to create a product that combines Nowcasting and NWP product, we need to bring NWP closer to the radar observations, specially at the analysis time t_0
- At the same time we cannot degrade the quality of the NWP

Direct Assimilation of Reflectivities

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- ➔ The assimilation of radar reflectivities in COSMO is performed via Latent Heat Nudging (LHN).
- ➔ LHN heats/cools the atmosphere based on the comparison of model precipitation and the radar-precipitation scan.
- ➔ The assimilation system COSMO-KENDA can **directly assimilate 3d radar scans**. COSMO-KENDA is currently used in DWD to assimilate all other observation systems.
- ➔ COSMO-KENDA corrects the hydrometeors specific densities based on reflectivity measurements. It has thus the potential to produce a more realistic reflectivity picture at analysis time, which could help for the **seamless transition between Nowcasting and NWP**.

Our tool: Basic Cycle (BACY)

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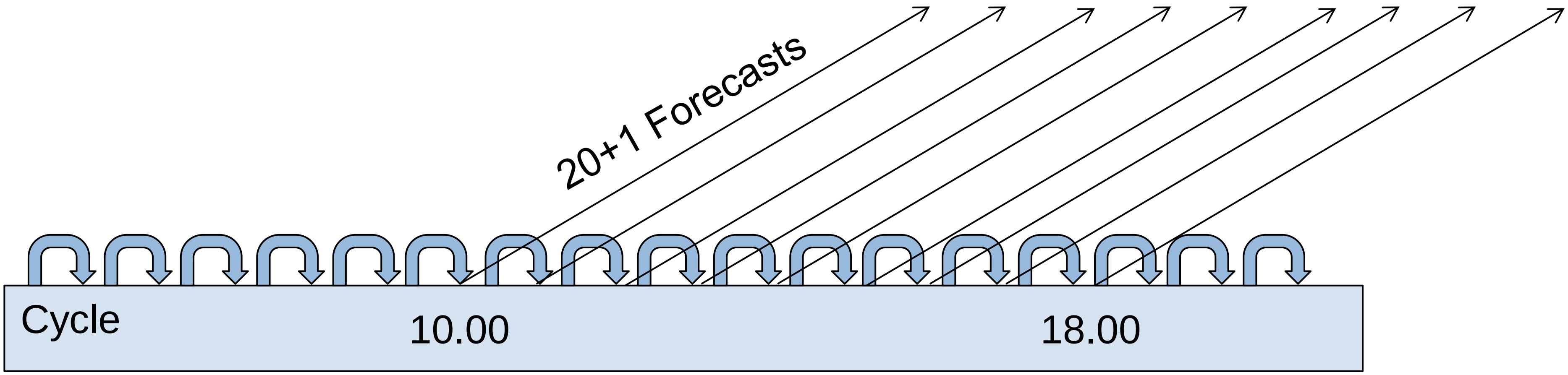
- 1h Cycle with hourly forecast during the convective period (10 -18). The forecasts run for 6 hours.
- COSMO-DE setup with version 5.4h.
- Assimilation with 40 ensemble members. Forecasts with 20 ensemble members.
- Simulations from 27.05.2016 until 02.06.2016 (7 days): In total 1323 forecasts (not independent)
- We evaluate the data during the experiment. No need to save huge amount of data.



What we have learned

- Spatial Averaging: we use "**superobbed**" data with a spatial resolution of 10 km.
- **Temporal Thinning**: we assimilate only the radar scan measured at the analysis time (every hour). All other radar scans (every 5 minuets) are not used.
- Cycling of TKE, and not reinitializing it every hour, has shown a positive effect.
- Ensemble inflation: in our setup relaxation to prior spread (RTPS) is better than relaxation to prior perturbation (RTPP).
- Observation error quantified based on Desrozier statistics.

Scores based on reflectivities

- We use scores based on radar composites as calculated by the forward operator. Improving score based on reflectivities can help to bridge the gap between Nowcasting and NWP.

- The Fraction Skill Score (**FSS**) assess, the skill of predicting convection at **a spatial scale (**here 30 km) for a given threshold (Roberts & Lean, 2008)

- The **Brier Score** measures the accuracy of the probability prediction of an **ensemble** for a given threshold. Not very reliable for rare events (very high reflectivities).

COSMO-KENDA vs LHN (Reflect verif.)

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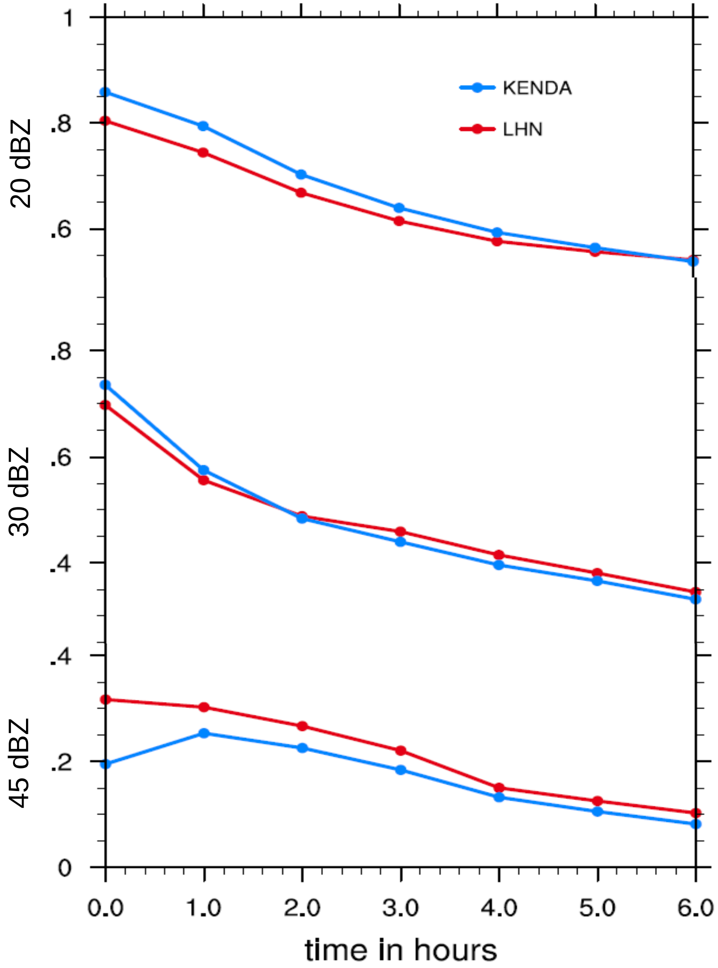
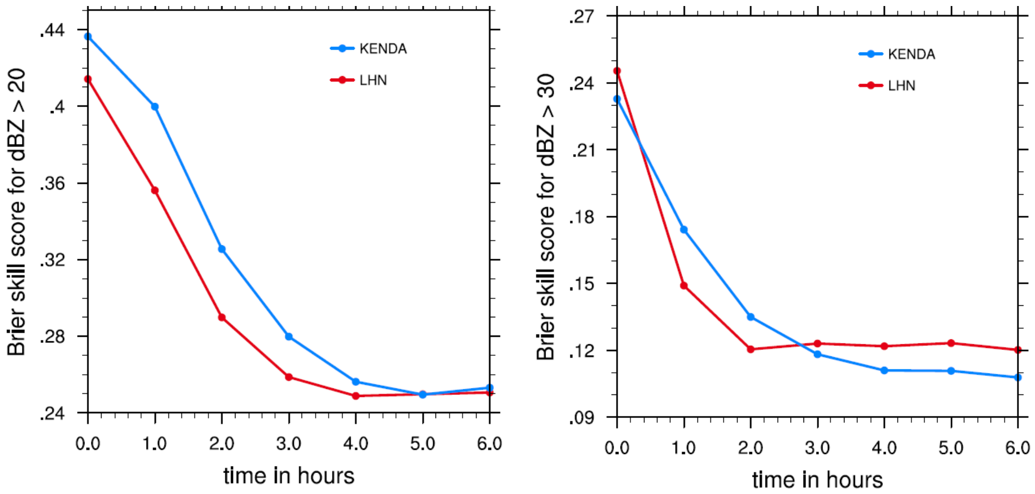
FSS (deterministic)



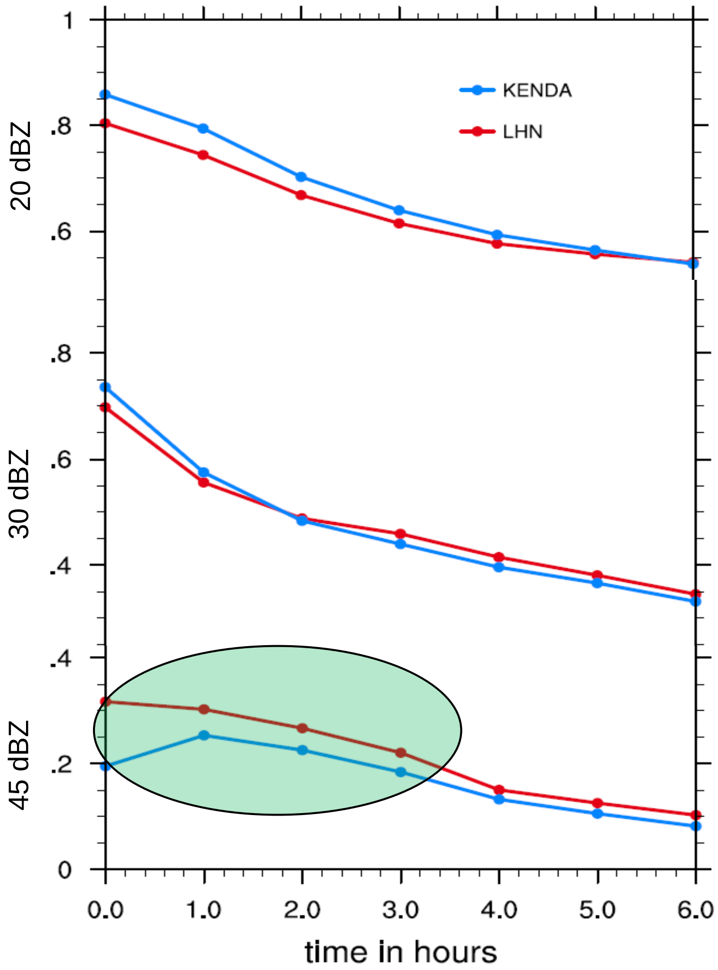
Brier skill score (ensemble)



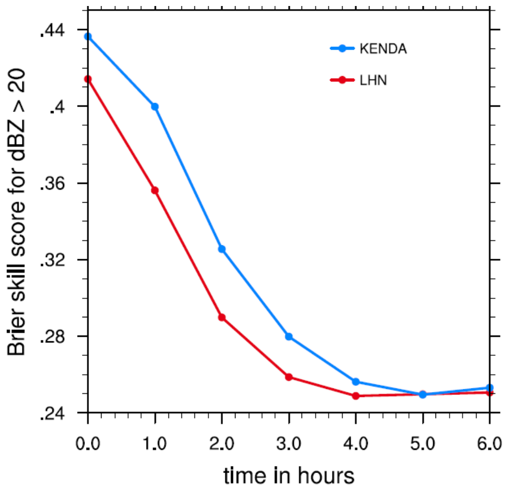
- ➔ KENDA shows a small advantage in the first two-three forecast hours.
- ➔ Higher reflectivities seem to be better captured by LHN. Specially strong thresholds over 45 dBZ are much better.

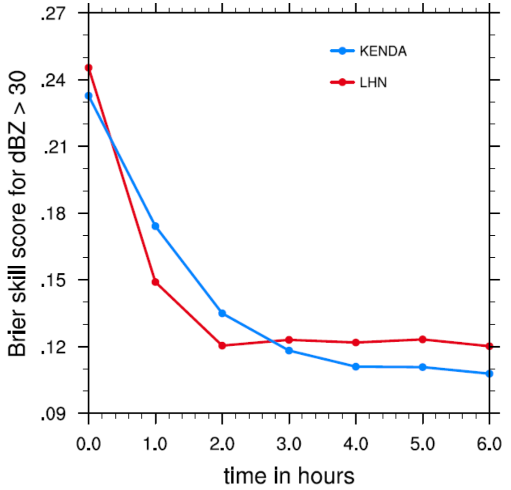
COSMO-KENDA vs LHN (Reflect verif.)

FSS (deterministic)



Brier skill score (ensemble)

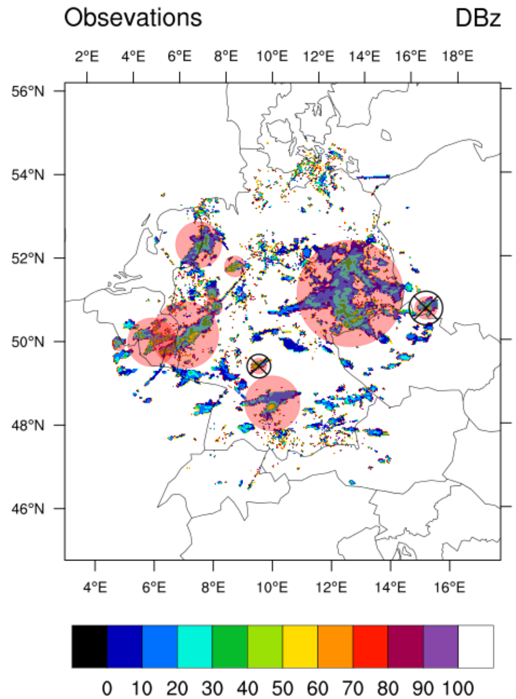


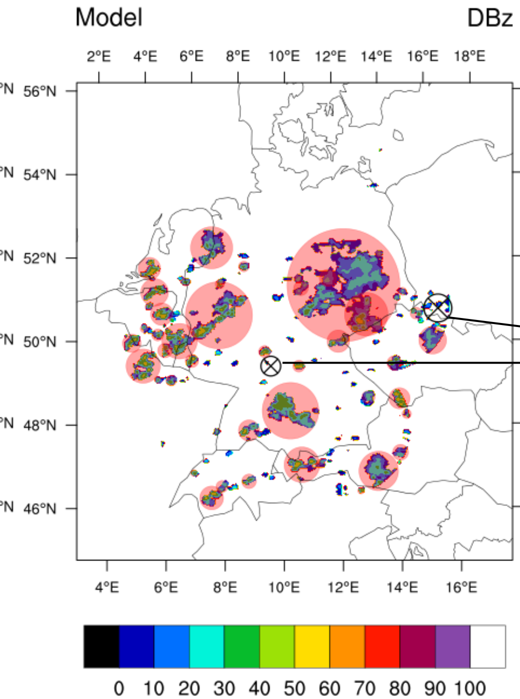


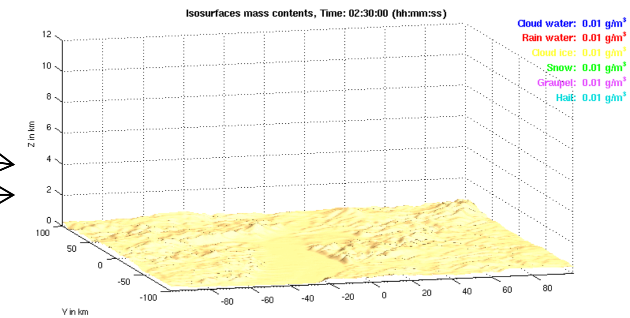
➔ KENDA shows a small advantage in the first two-three forecast hours.

➔ Higher reflectivities seem to be better captured by LHN. Specially strong thresholds over 45 dBZ are slightly better, but skill is very low for both.

Triggering convection with bubbles







- We trigger warm bubbles in regions where the radar composite shows a convective cell, but there is none in the model. We check every 15 minutes.
- Bubbles warm a region ~10x10kmx2km with averaged heating rate ~0.001 K/s, during 15 minutes.
- This is not latent-heat nudging. Once the bubble is triggered, the convective cell is free to evolve depending on the local meteorological conditions. Some bubbles do not develop into a convective cell.

KENDA vs LHN (Now with bubbles.)

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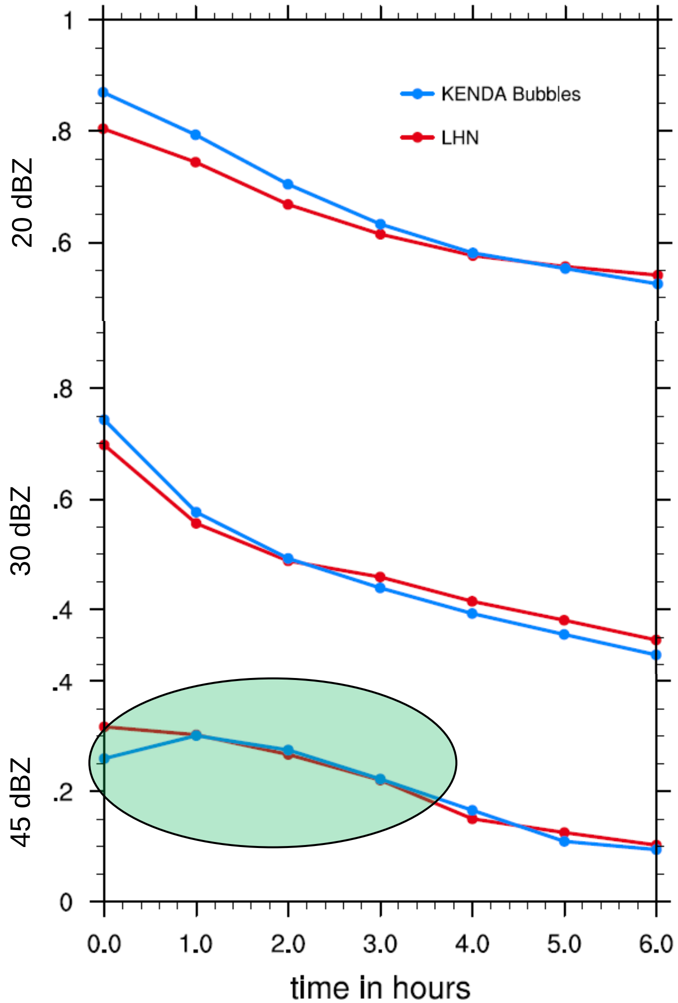
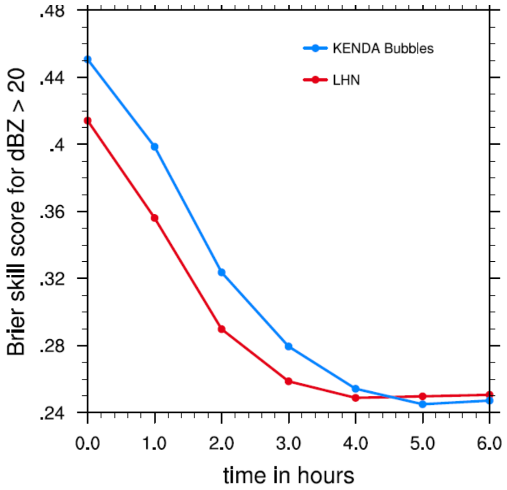
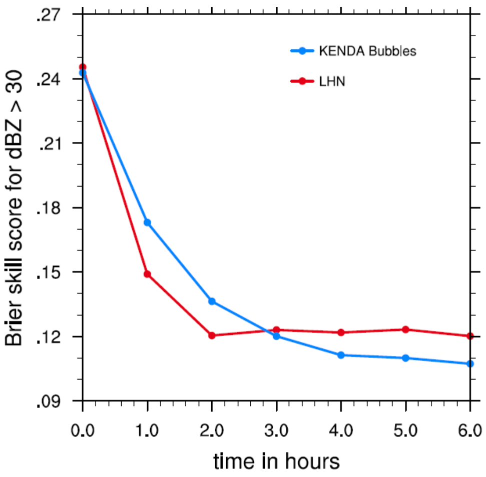
FSS (deterministic)





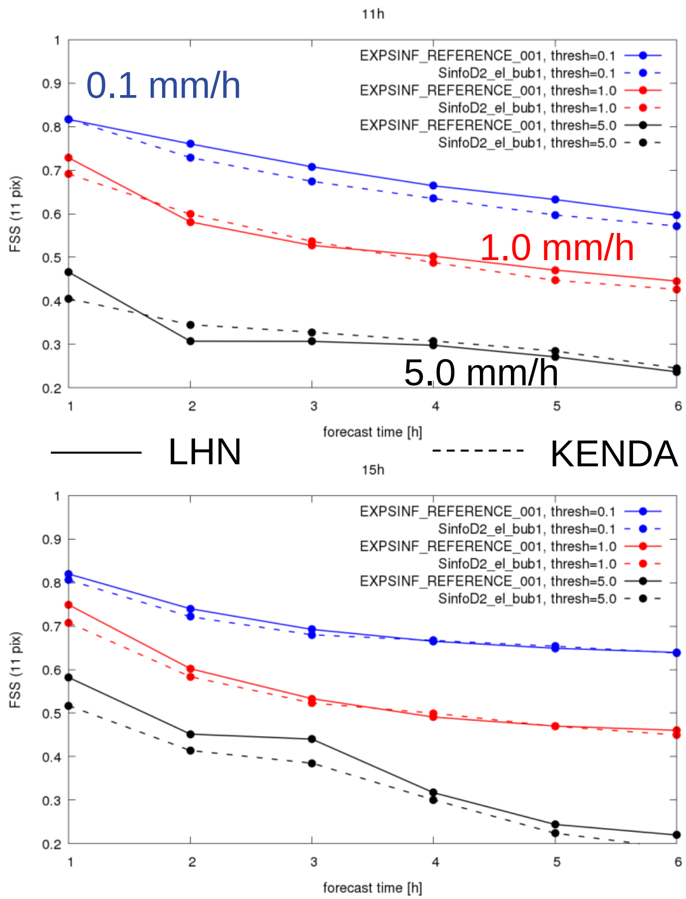


➔ Bubbles can correct the high reflectivities in KENDA making in comparable to LHN.

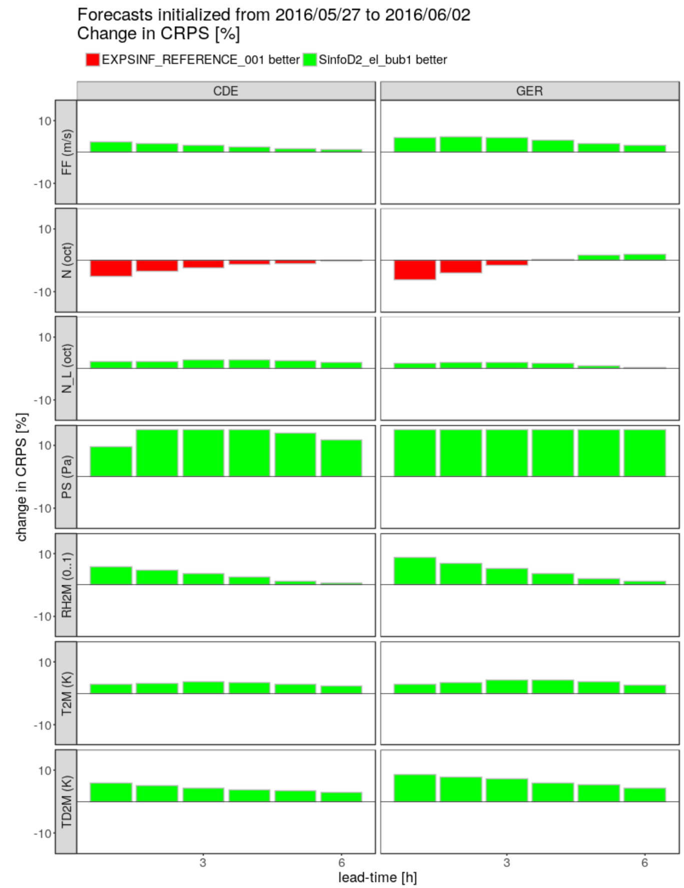
➔ All other scores change very little.

Standard verification

Precipitation verification (FSS)



Surface Stations verification (CRPS)



➔ KENDA performs better for the surface verification. LHN performs slightly better for precipitation.

High reflectivities are not yet good

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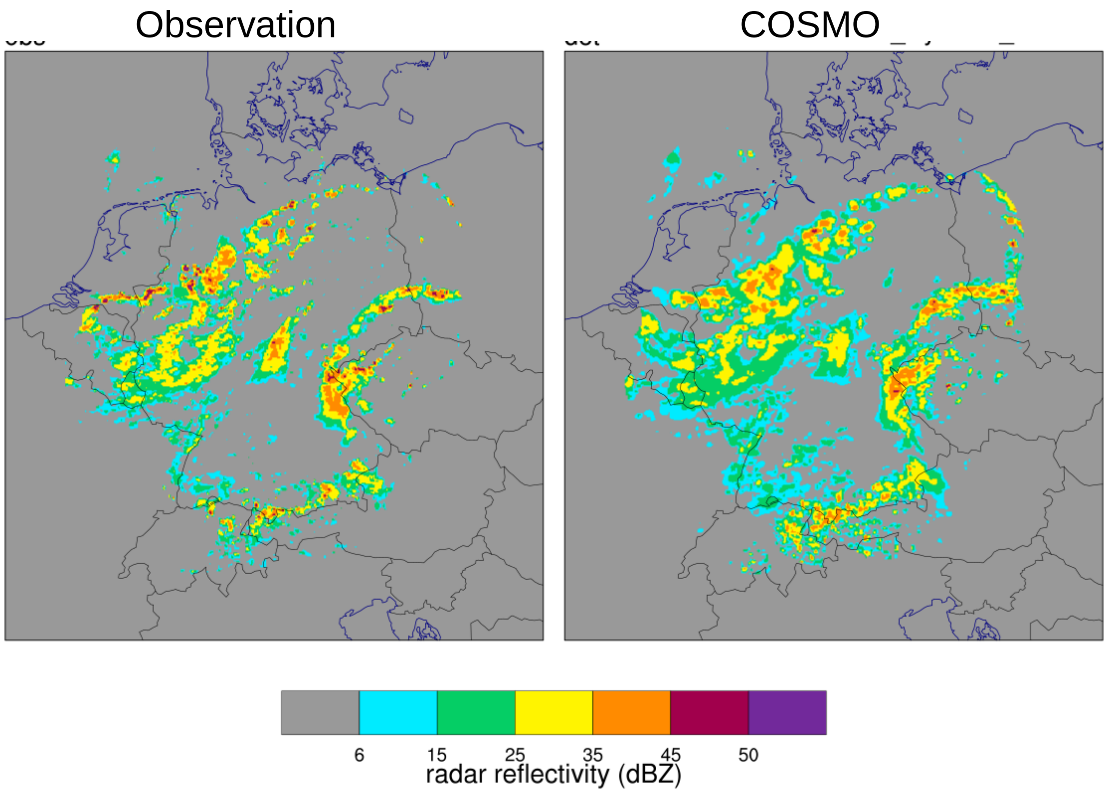

- ➔ The model produce too few cells with high reflectivities (over 30 dBZ), and therefore the scores are worst.
- ➔ This might be a problem of the model physics (specially the micropysiscs).

2-Moments-Scheme

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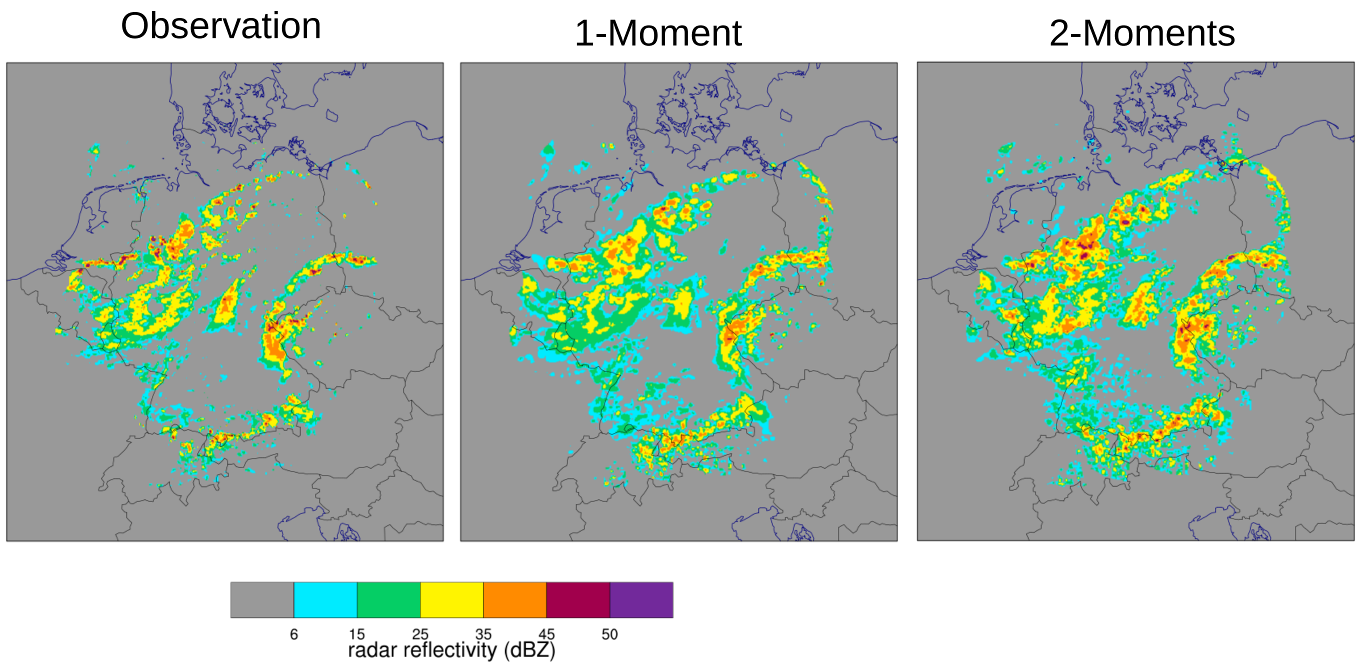
- We use to 2-Moments-Scheme (Seifert and Beheng 2006)

- The 2-Moment-Scheme consider the number of hydrometeors (N) and their specific density (q) as prognostic variables: this allows for the combination of few, very large hydrometeors that produces high reflectivities.



2-mom improves high reflectivities

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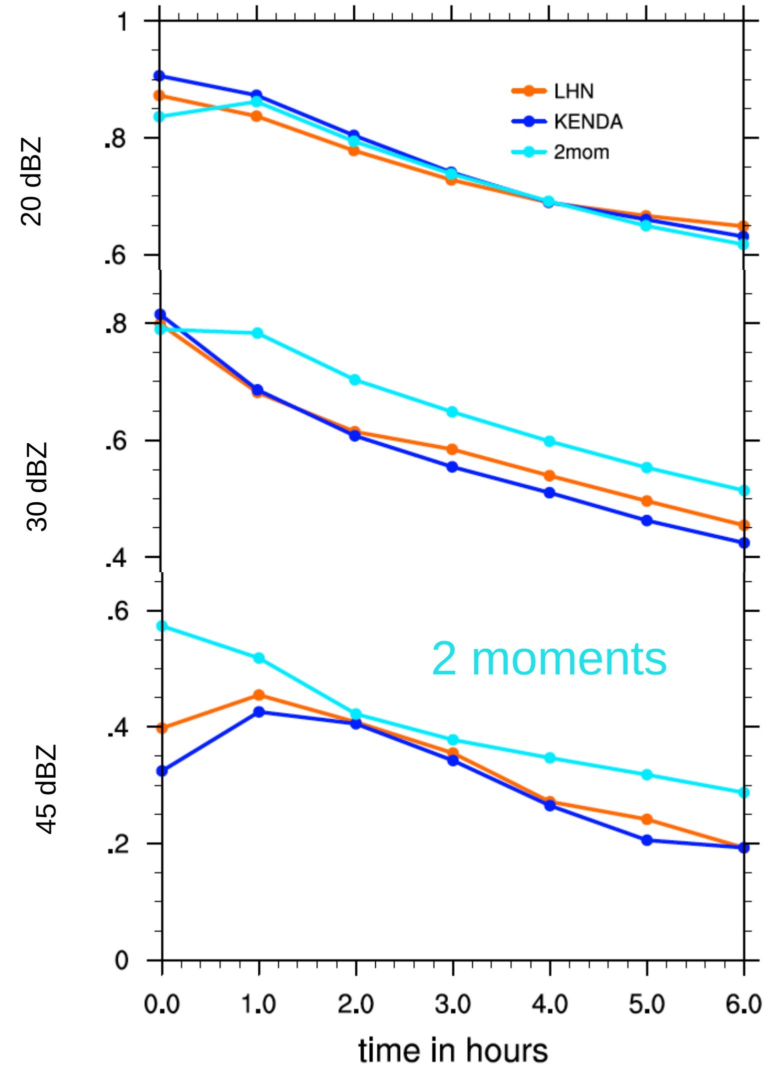
- ➔ The two-moment scheme shows better scores for higher reflectivities, probably as a result of the more realistic physics.
- ➔ Two-Moment simulations show however reduced skill in the standard verification for both synop and temp.
- ➔ The scheme is not tuned. Optimization is still possible.
- ➔ Fundamental problem in LETKF when estimating many more variables? What to do with number densities?



Conclusions

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- The assimilation of radar reflectivities with COSMO-KENDA shows promising results. In many scores it is better than latent-heat mudging (only one week).
- Warm bubbles seem to improve assimilation and forecasts of high reflectivity convective cells.
- The 2-moment-scheme shows better scores for higher reflectivities, probably as a result of the more realistic physics, but more work needs to be done.

Thank you!

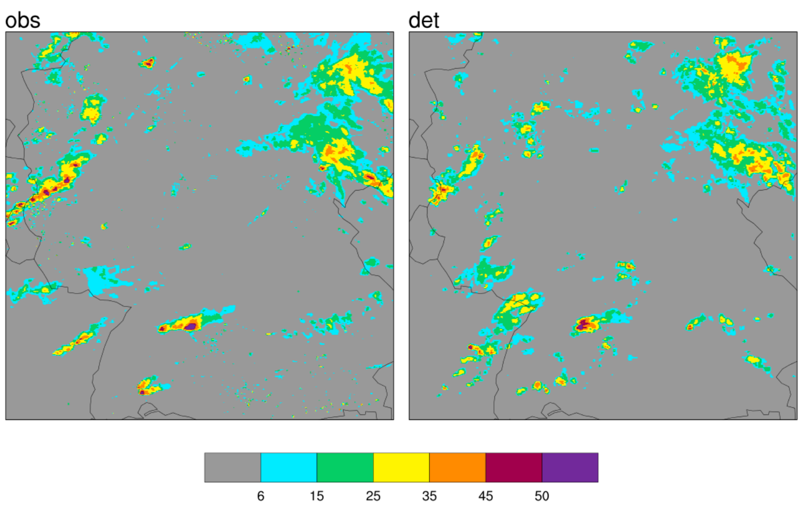
Movies??

Vielen Dank

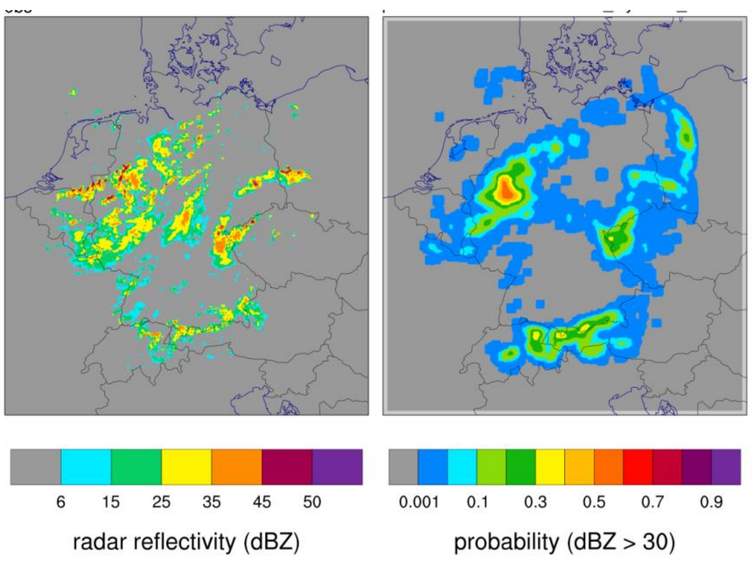
Ausblick

- Arbeiten mit COSMO-D1 auf 1 km Auflösung (A. Seifert)
- Verifikation vom Ensemble
- Umsteigen auf ICON-LAM
- Verbesserung der Modelphysik
- Noch bessere Assimilation für t=0? Vieleicht 15 min Cycle notwendig für die Nowcasting-NWP Verbindung

COSMO-D1



Wahrscheinlichkeit Plot, 5 h Vorhersage



Oberfläche Verifikation ?

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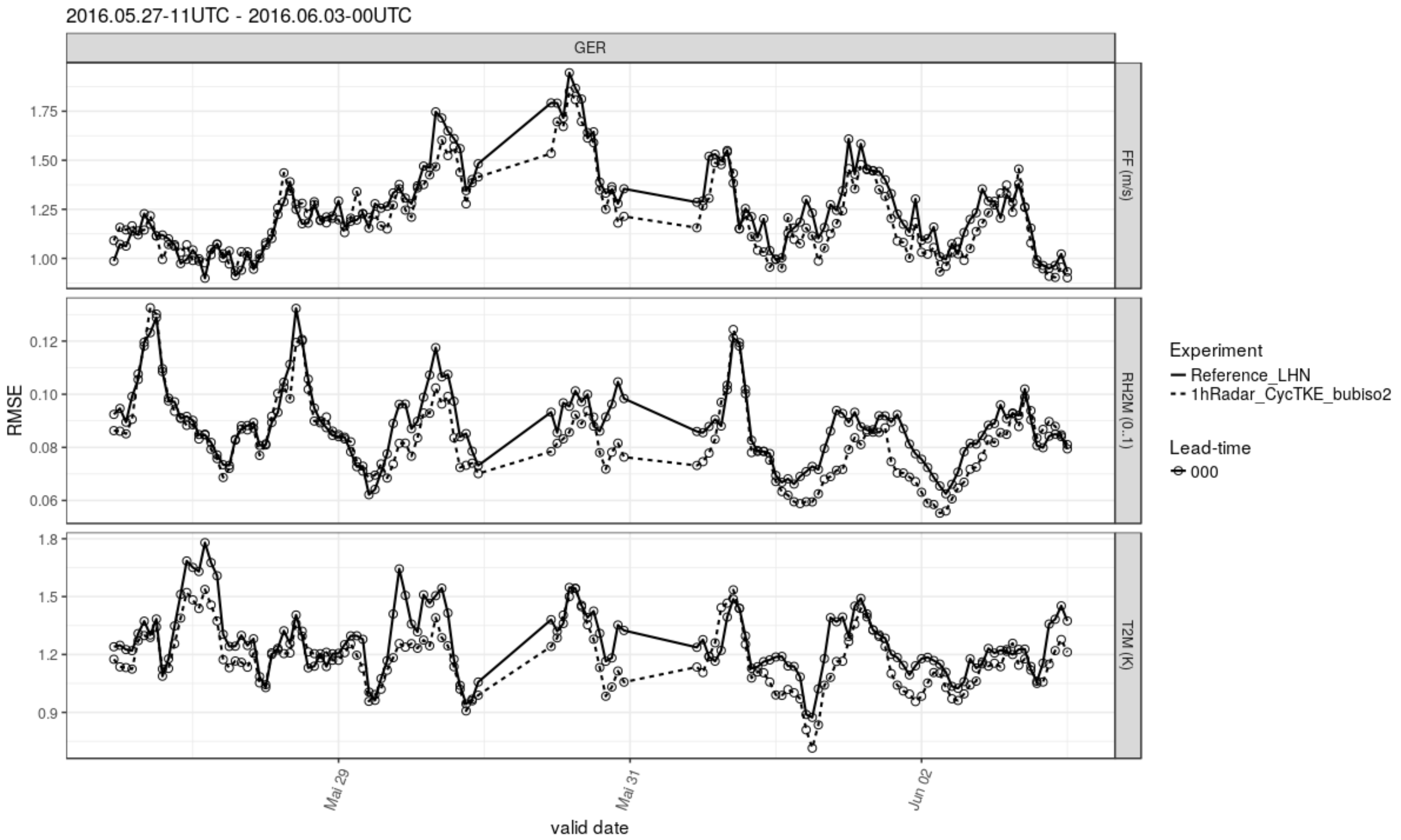
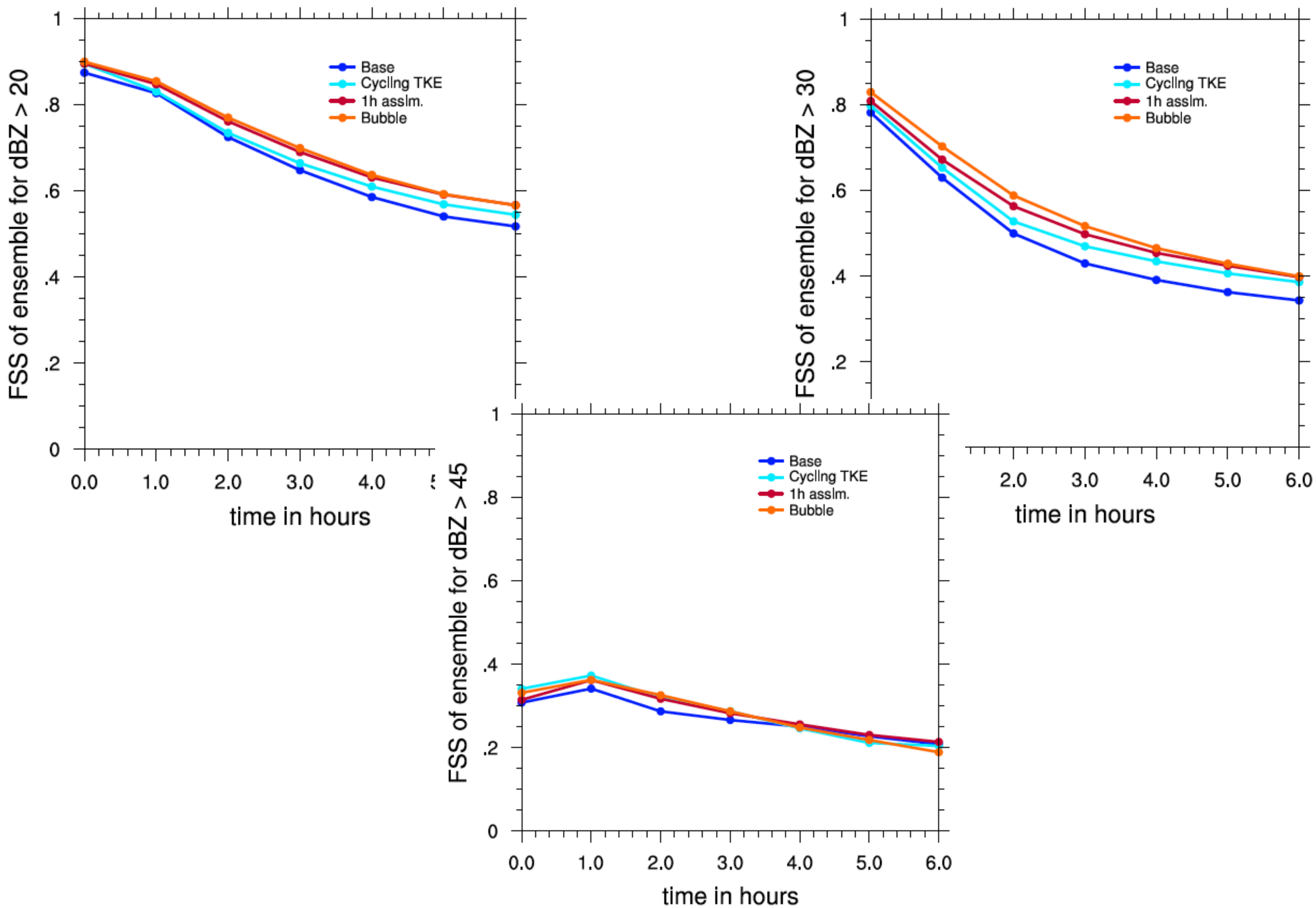
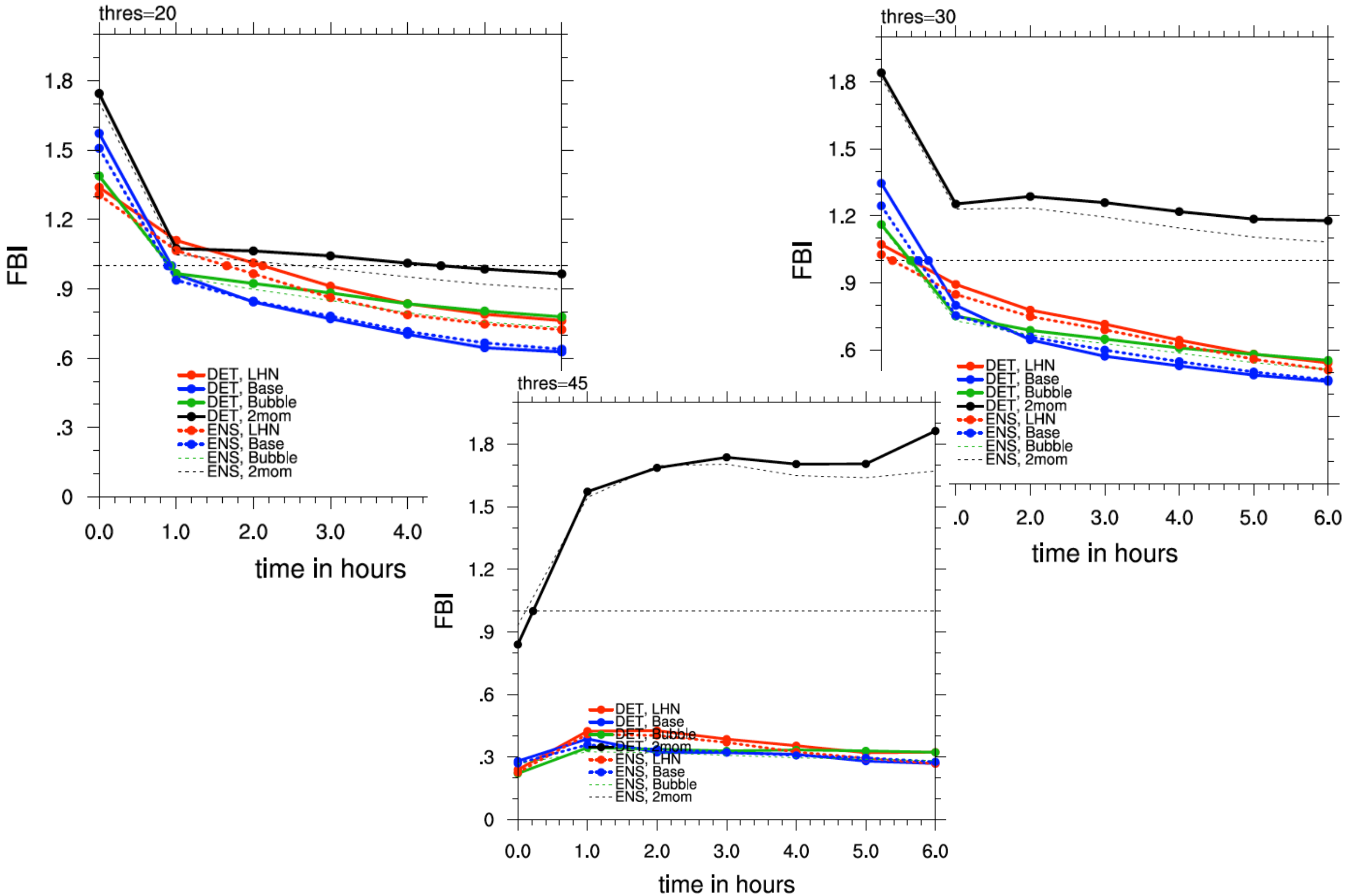


Step by step


FSS of ensemble for dBZ > 20
Base
Cycling TKE
1h assim.
Bubble
1
.8
.6
.4
.2
0
0.0
1.0
2.0
3.0
4.0
time in hours
FSS of ensemble for dBZ > 30
Base
Cycling TKE
1h assim.
Bubble
1
.8
.6
.4
.2
2.0
3.0
4.0
5.0
6.0
time in hours
FSS of ensemble for dBZ > 45
Base
Cycling TKE
1h assim.
Bubble
1
.8
.6
.4
.2
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
time in hours

Frequency bias



FSS Niederschlag (30 km)

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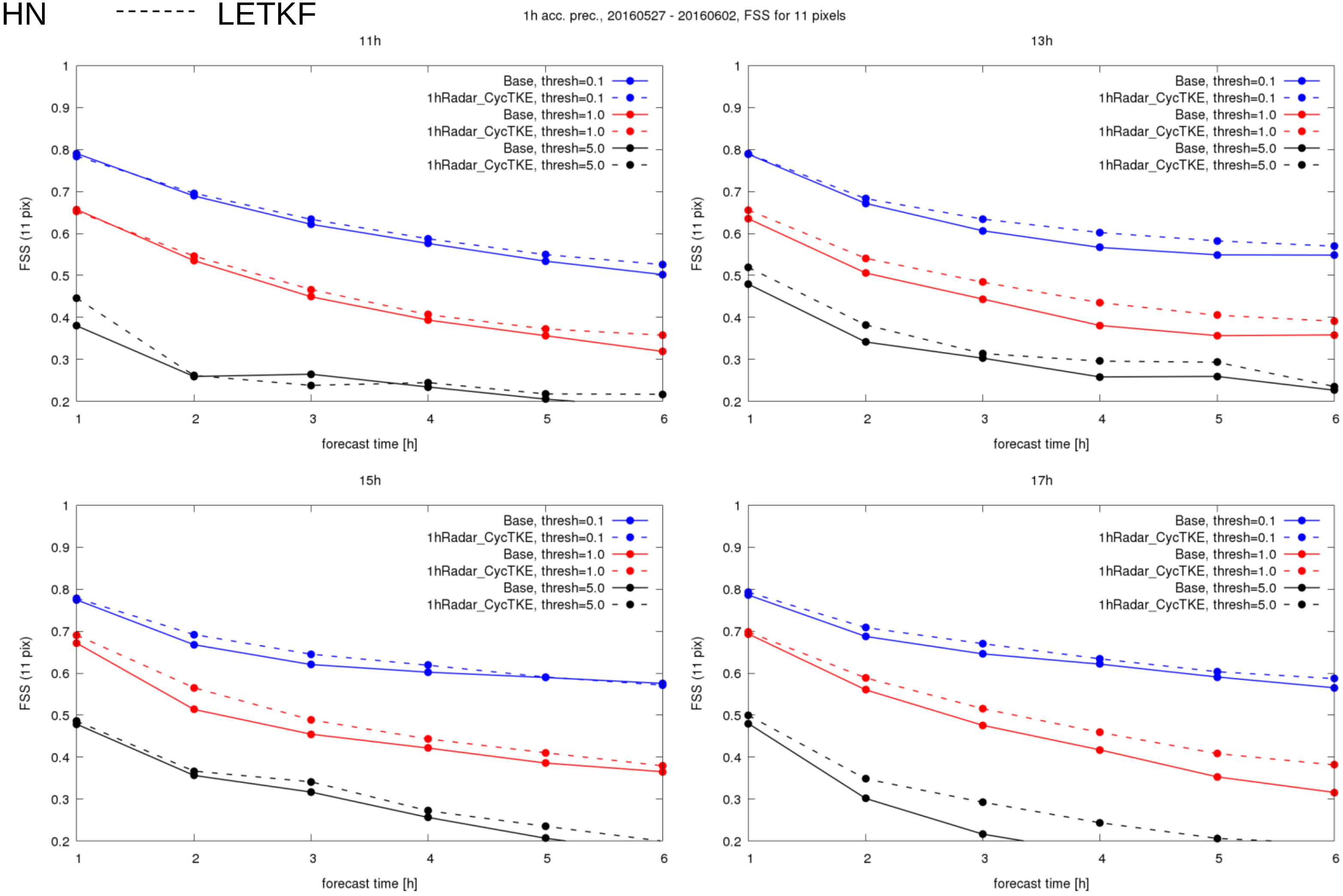
LHN ------- LETKF



Fraction Skill Score (Roberts & Lean, 2008)

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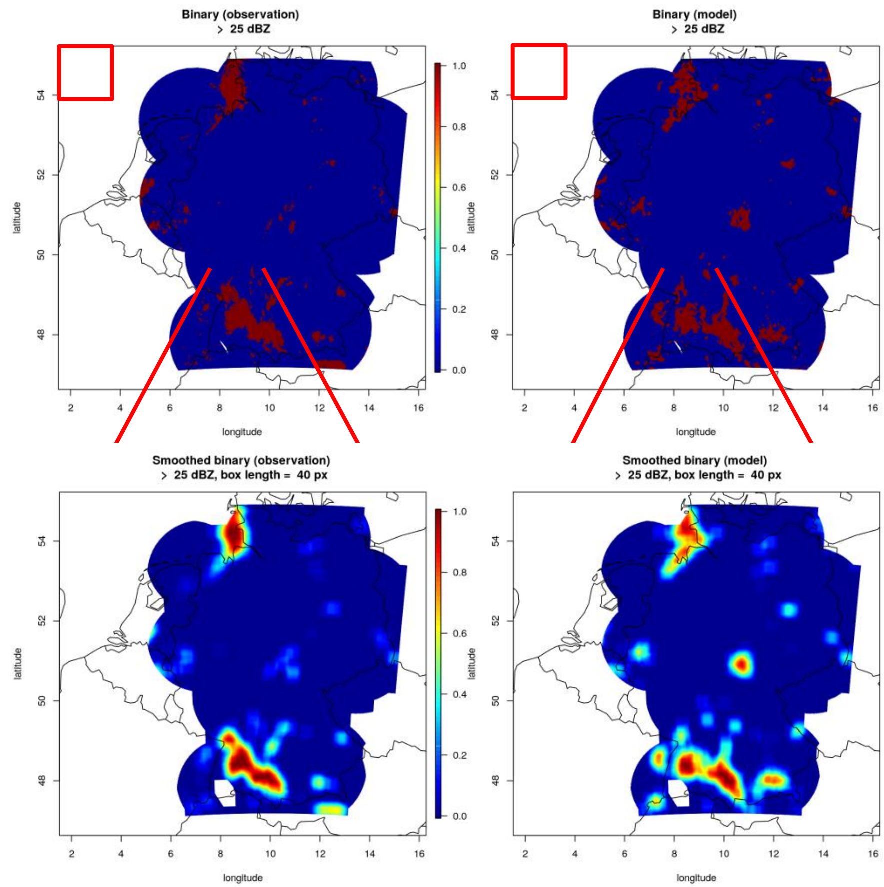
Wie wird der FSS berechnet?

1. Vorh. u. Beob. auf selben Gitter
2. Auswählen geeigneter Schwellwerte *S*
3. Konvertiere Vorh. u. Beob. in binäres Feld für jeden Schwellwert
4. Wähle Boxlänge und scanne das gesamte Gebiet pixelweise
5. Für jede Box:
   - ➔ zähle Pixel > *Schwellwert*
   - ➔ Teile durch Anzahl Pixel in Box
   - ➔ Ermittle Anteile
   - ➔ Erhalte geglättetes Bild mit Anteilen
6. Berechne Fraction Skill Score

$$FSS = 1 - \frac{\frac{1}{N}\sum_{i=1}^{N}(P_{fcst} - P_{obs})^2}{\frac{1}{N}\sum_{i=1}^{N}P_{fcst}^2 + \frac{1}{N}\sum_{i=1}^{N}P_{obs}^2}$$

7. Wiederhole Schritte 2 - 7 für unterschiedliche Schwellwerte und Boxlängen



$$FSS = 1 - \frac{\sum(P_f - P_o)^2}{}$$

Scores based on reflectivities

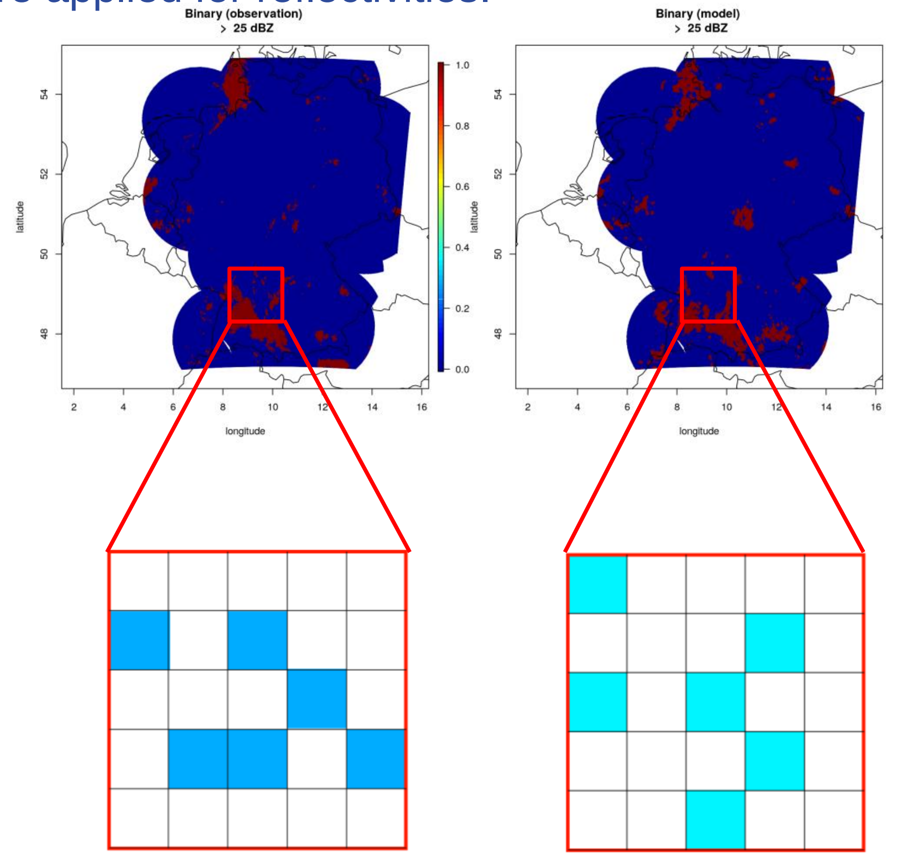
Fraction Skill Score (Roberts & Lean, 2008), here applied for reflectivities.

- The FSS assess the skill of predicting convection at **a spatial scale** for a given threshold (here 30 km).

$$FSS = 1 - \frac{\frac{1}{N}\sum_{i=1}^{N}(P_{fcst} - P_{obs})^2}{\frac{1}{N}\sum_{i=1}^{N}P_{fcst}^2 + \frac{1}{N}\sum_{i=1}^{N}P_{obs}^2}$$

- The Brier Score measures the accuracy of the probability prediction of an **ensemble**.

$$BS = \frac{1}{N}\sum_{t=1}^{N}(f_t - o_t)^2$$



$P_{obs} = 6/25$ $P_{fcst} = 6/25$

Abbildung von M.Hoff

Improving the TKE Cycling

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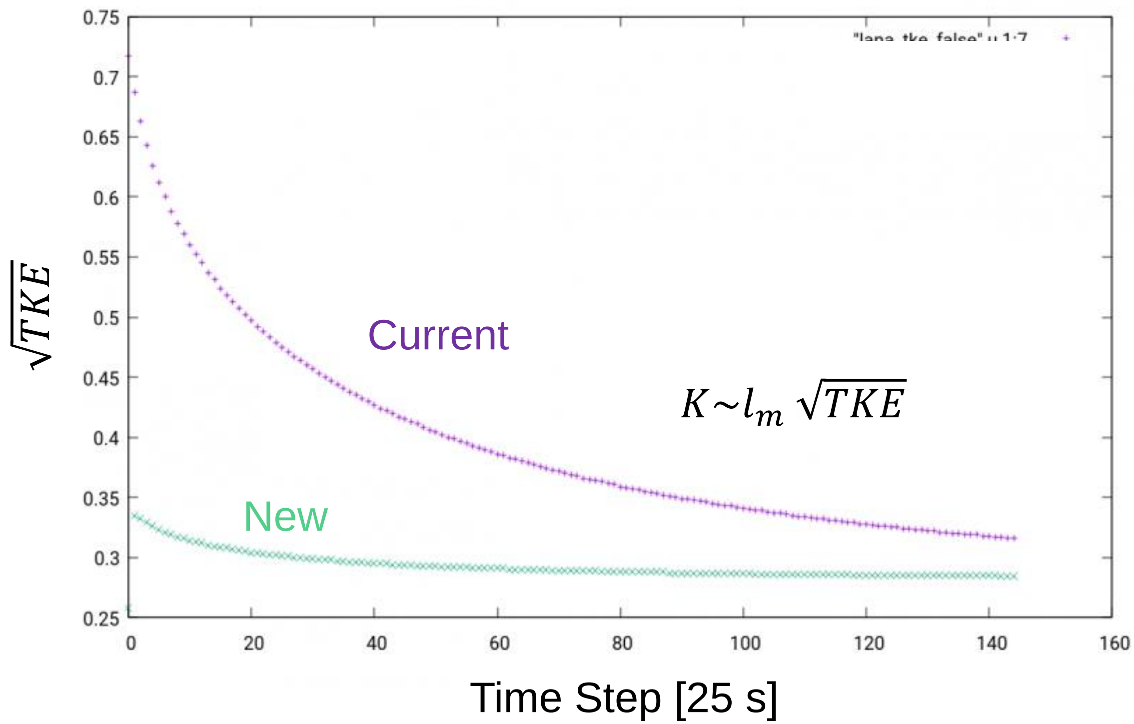

- ➔ TKE is currently initialized at each COSMO start, which happens every cycle (each1h)
- ➔ The LETKF is a local procedure that produces too much shear, and therefore too much TKE.
- ➔ TKE is now **cycled** (no initialization)
- ➔ At the same time the turbulent mixing length scale was set to a more physical value (von ℓ_m = 150 m zu ℓ_m = 500 m)

Assimilation nur stündlicher Daten

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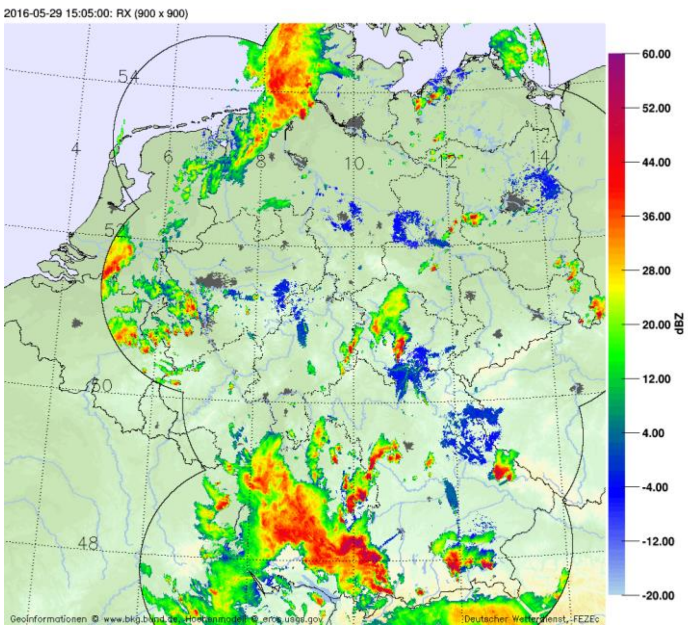
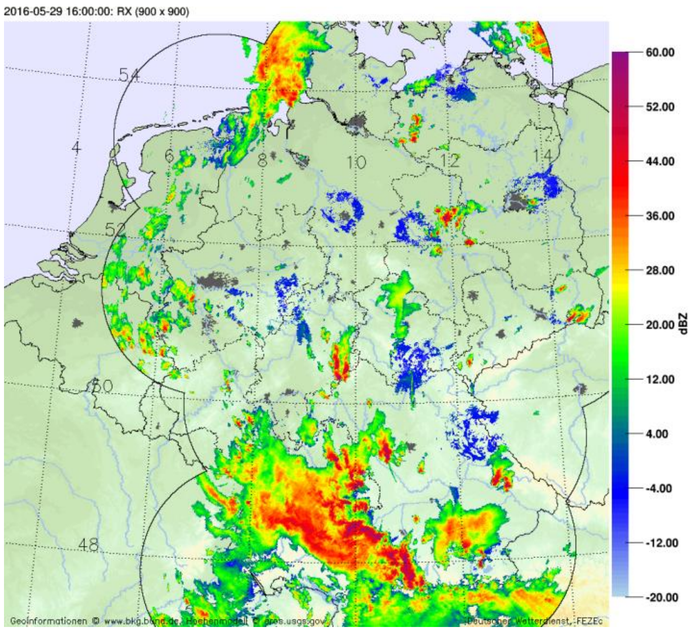
- ➔ Wir assimilieren jetzt die Radardaten nur für die Analysezeit (statt alle 5 Minuten)
- ➔ Das ist eine Datenreduktion **um Faktor 12**, die für Radar-Winde schon einen positiven Effekt gezeigt hat
- ➔ Wir benutzen auch die neuen, korrigierten Radardaten



5 min Daten



1 h Daten

Precipitation verification

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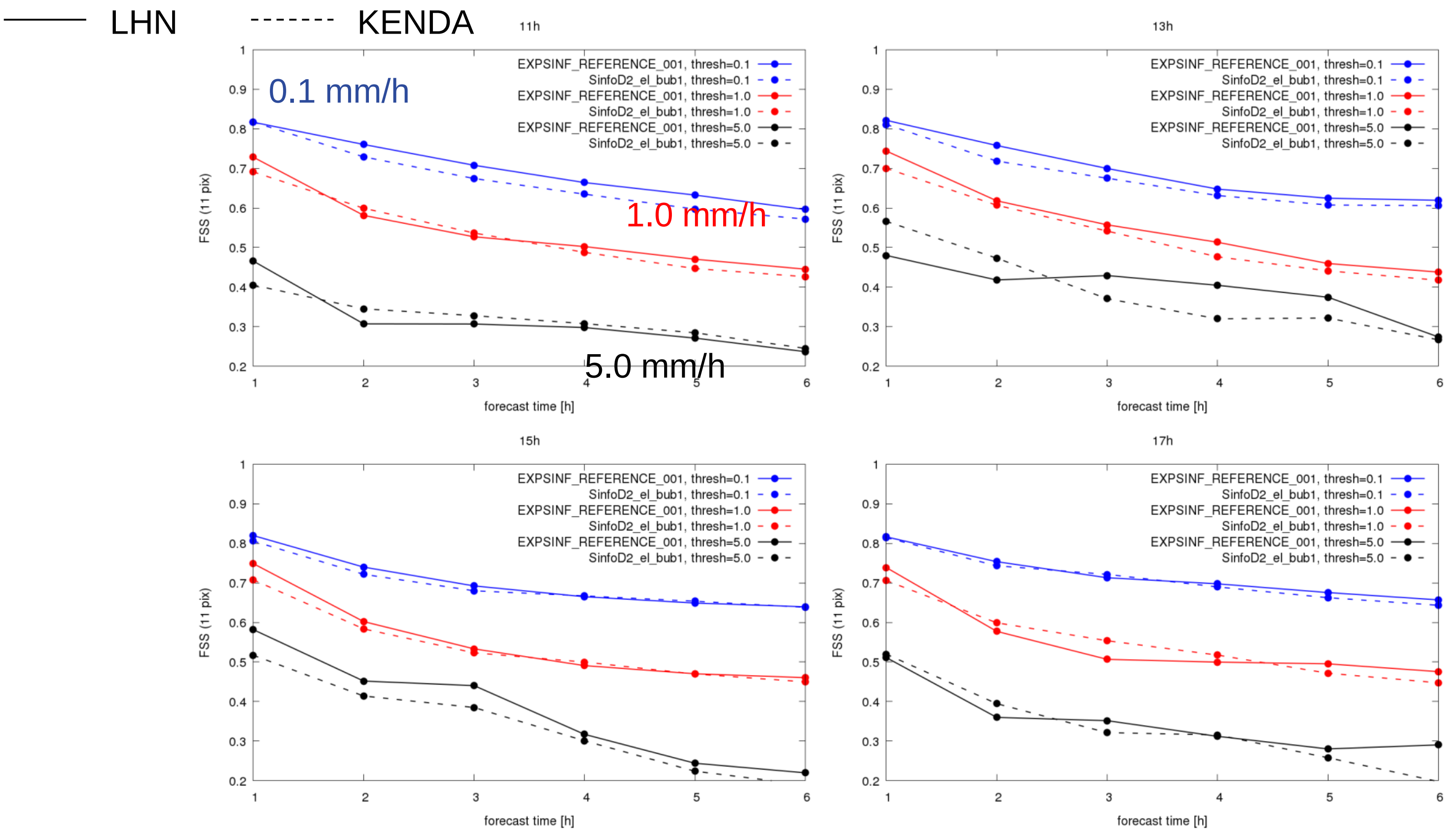

- ➔ In Gegenteil zu LETKF, LHN versucht Niederschlag direkt zu verbessern.
- ➔ Trotzdem, der neue LETKF zeigt eine leichte Verbesserung für 1 mm/h. Kein signifikanter Unterschied für die anderen Schwellwerte.