Assimilation of 3D Radar Data and Derived Objects on the Convective Scale with an Ensemble-based Data Assimilation System

ICCARUS

**20th of March 2019
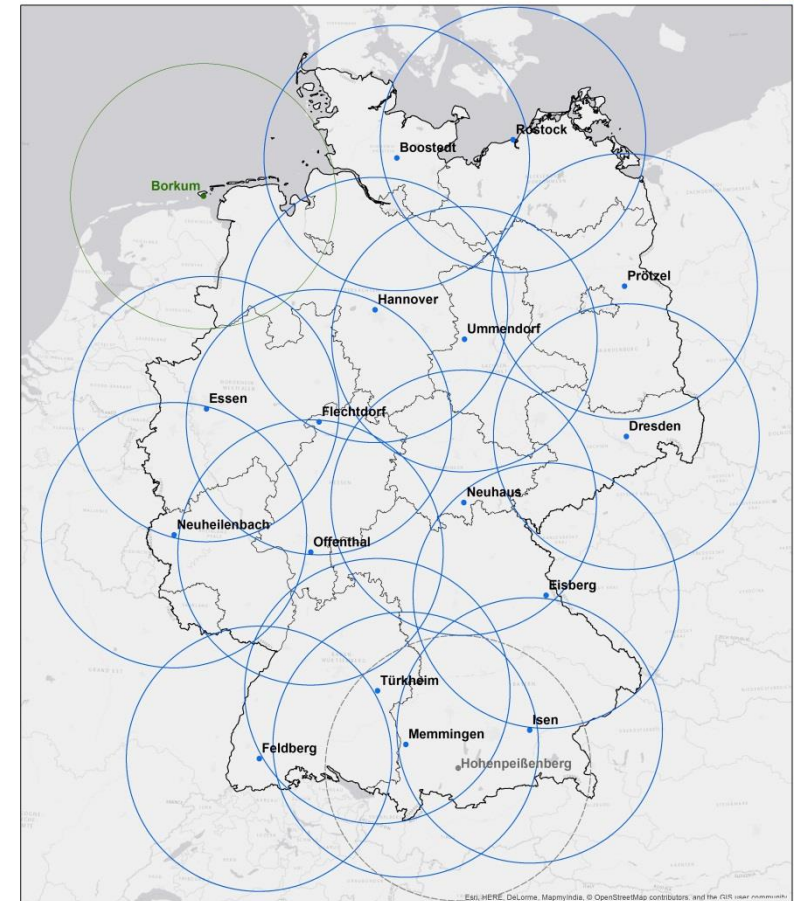Deutscher Wetterdienst, Offenbach**
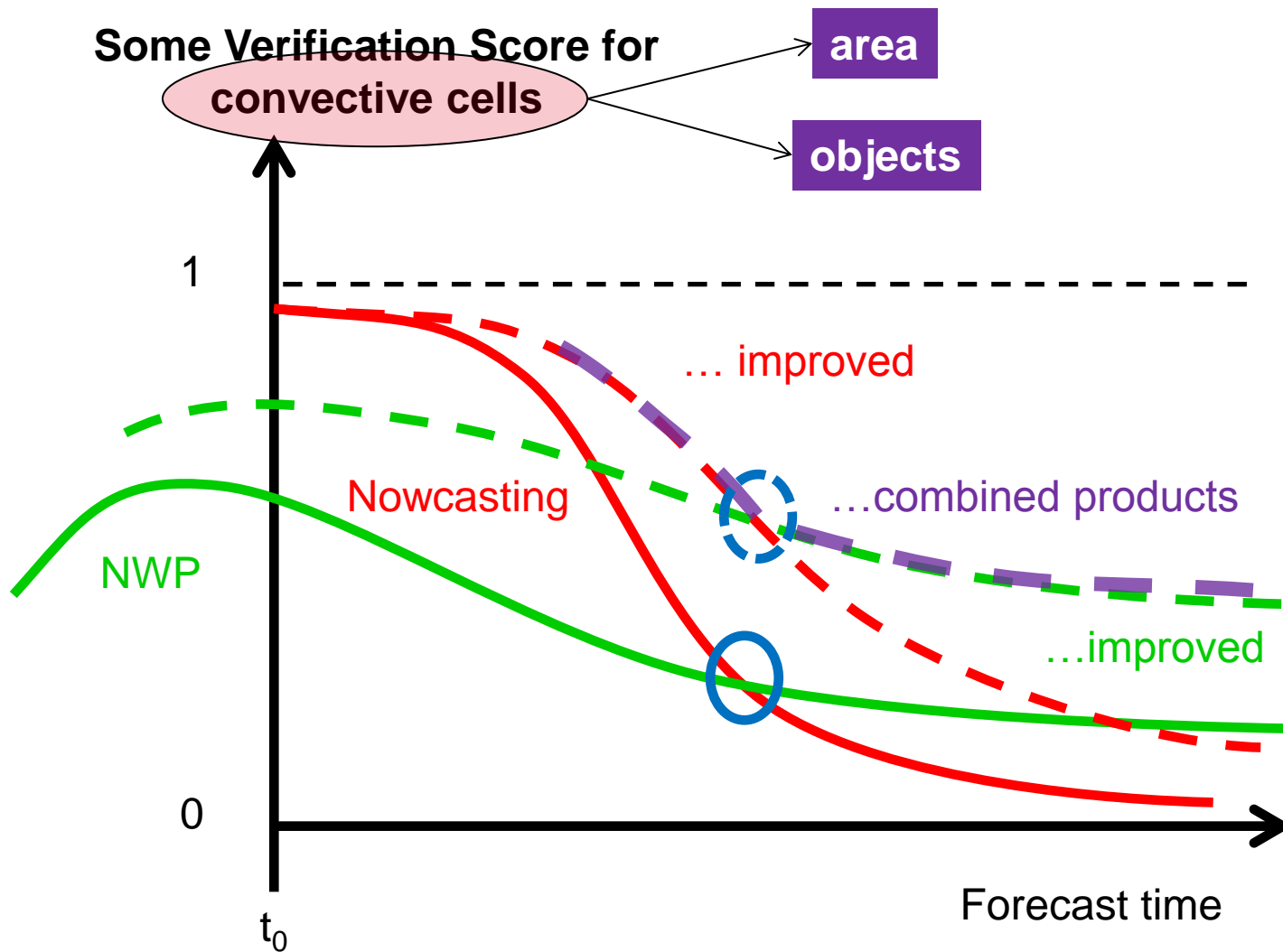
Christian A. Welzbacher
Data Assimilation, Deutscher Wetterdienst

E. Bauernschubert, U. Blahak, R. Feger, A. de Lozar, R. Potthast,
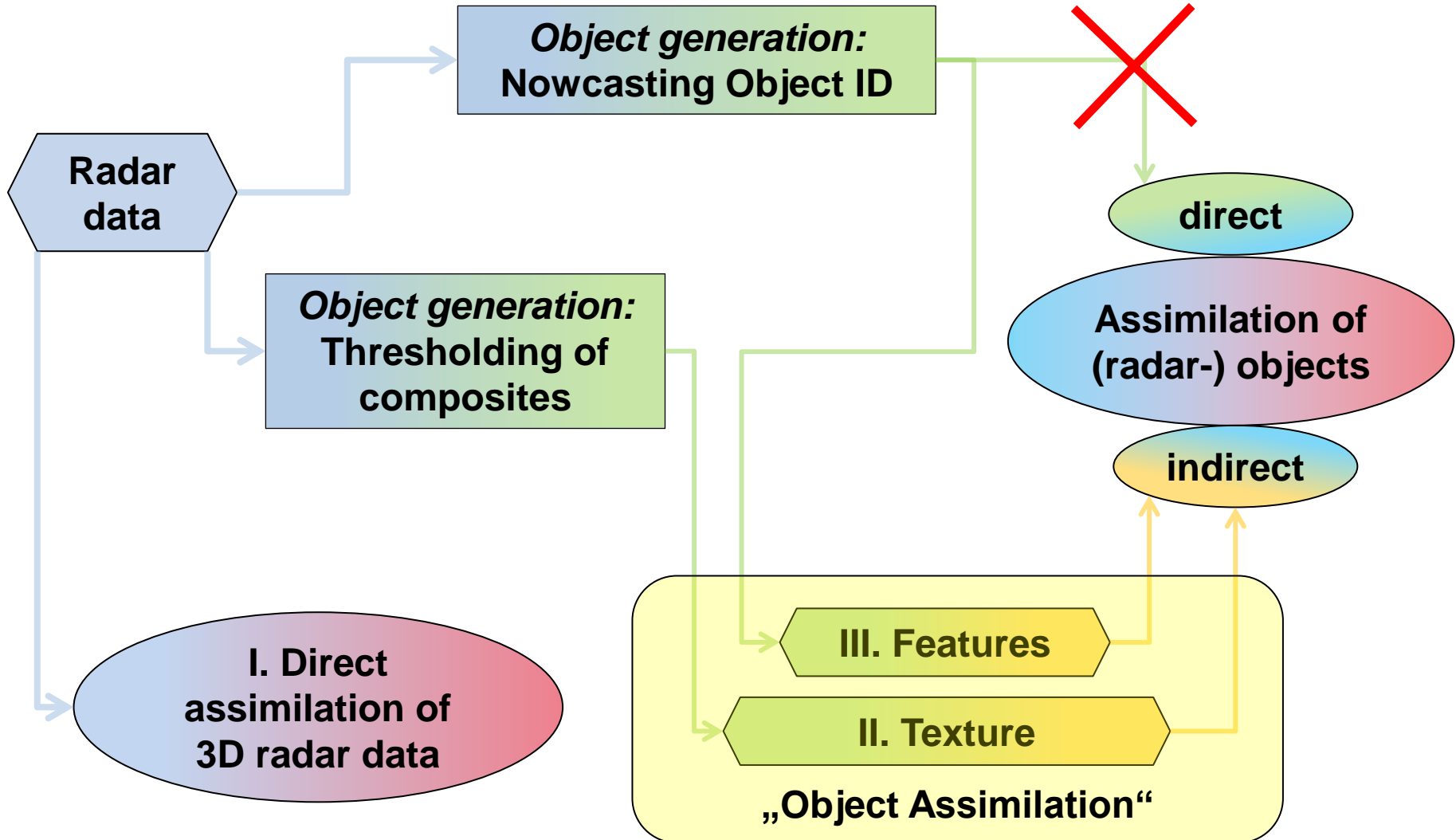C. Schraff, K. Stephan, M. Werner

Observations from Radar Network

➢ **Systems:**
17 Doppler C-Band Radars

➢ **Observables:**
Reflectivity, radial wind, polarimetric moments

➢ **Temporal resolution:**
Volume scan + terrain-following precipitation-scan every 5 minutes

➢ **Spatial resolution:**

1° azimuthal angular
10 elevations (between 0.5° and 25°)
1 km radial (up to 180 km)


Radarverbund des Deutschen Wetterdienstes

Legende
• operationelles Verbundradar
• Qualitätssicherungsradar
• Ausfallsicherungsradar (Ersatz für Radarstandort Emden)
— 150 km Abdeckungsradius

0 20 40 80 120 160
Kilometer
Maßstab 1:3.000.000
Stand: 07.03.2018 © GeoBasis-DE / BKG 2017

Some Verification Score for *convective cells* → **area**

→ **objects**

1

… improved

Nowcasting

…combined products

NWP

…improved

0

t_0

Forecast time

Overview: Assimilation of Radar Data

DA-System: KENDA

KENDA[#]: **4D-LETKF[†]** (conventional data + **3D radar data / derived objects**) [+ **LHN[*]**]
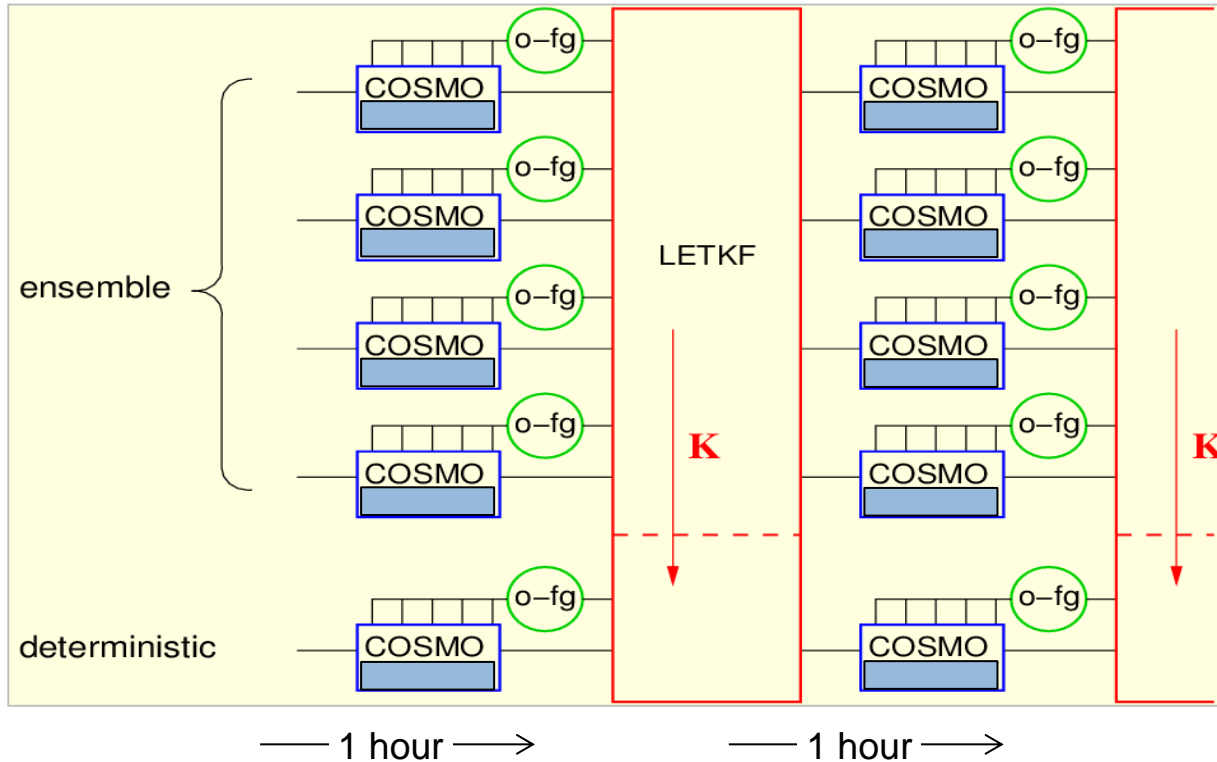
x(t): state vector in model space

Forward operator (e.g. EMVORADO [Zeng2016])

H(x,t): **model equivalent in observation space**

K: Kalman gain for ensemble mean

[#][Schraff2016], [†] [Hunt2007], * [Stephan2008]
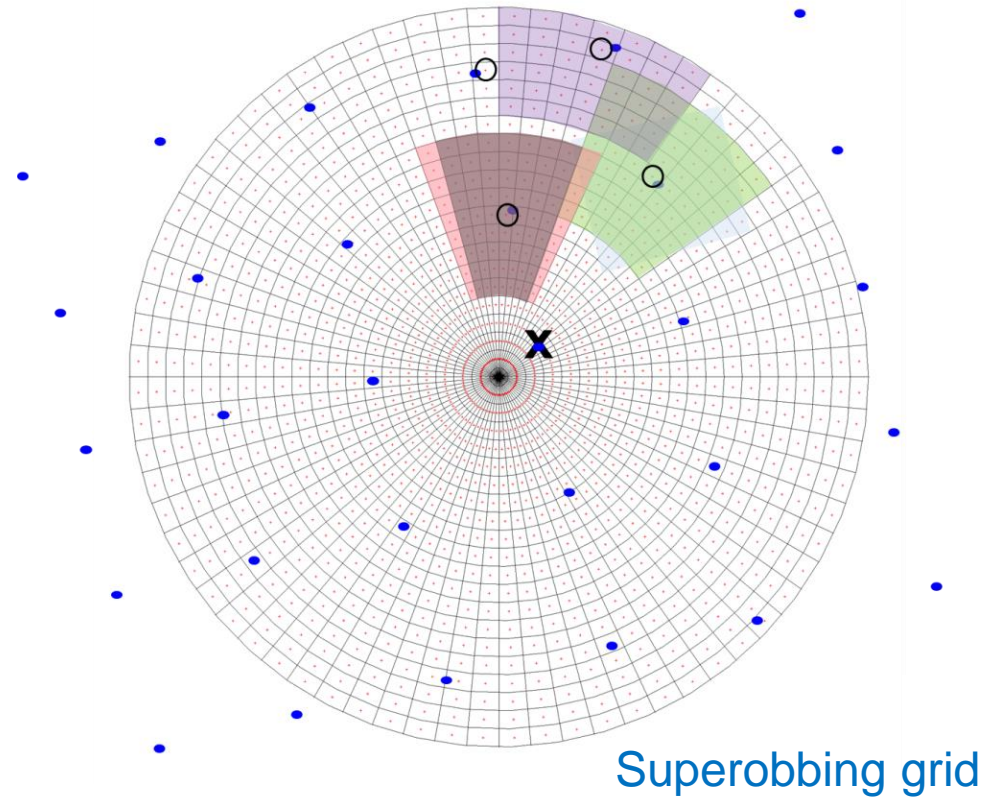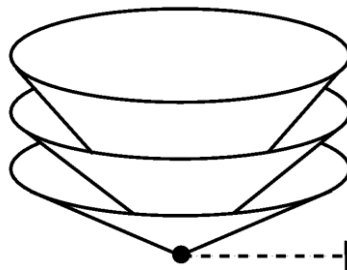
I. Direct assimilation of 3D radar data

- Full 3D radar data similar [Bick2016]
- Height & elevation dependent observation error by statistics [Desroziers2005]
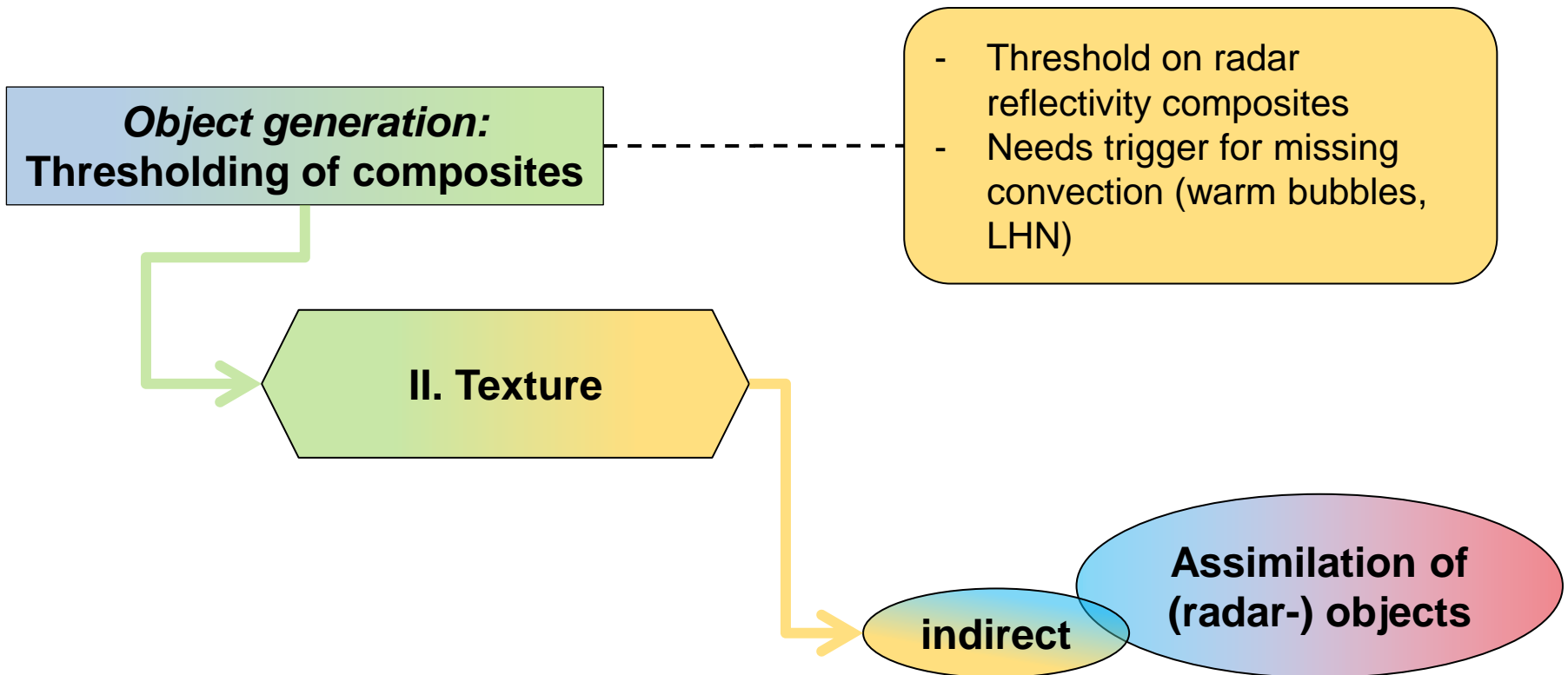- Needs trigger for missing convection (warm bubbles, LHN)

Assimilated Observations

Observables:
Reflectivities

Temporal resolution:
every 60 minutes (analysis time)

Spatial resolution:
10 km superobbing

Trigger:
Warm bubbles if missing cells

Superobbing grid

Object generation:
Thresholding of composites

- Threshold on radar reflectivity composites
- Needs trigger for missing convection (warm bubbles, LHN)

II. Texture

indirect

Assimilation of (radar-) objects
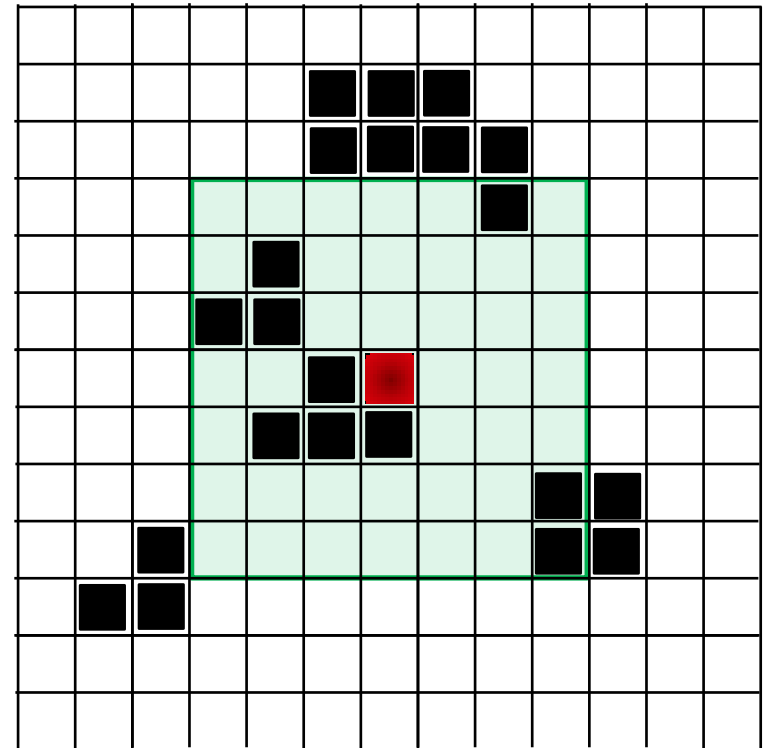
Texture assimilation - idea
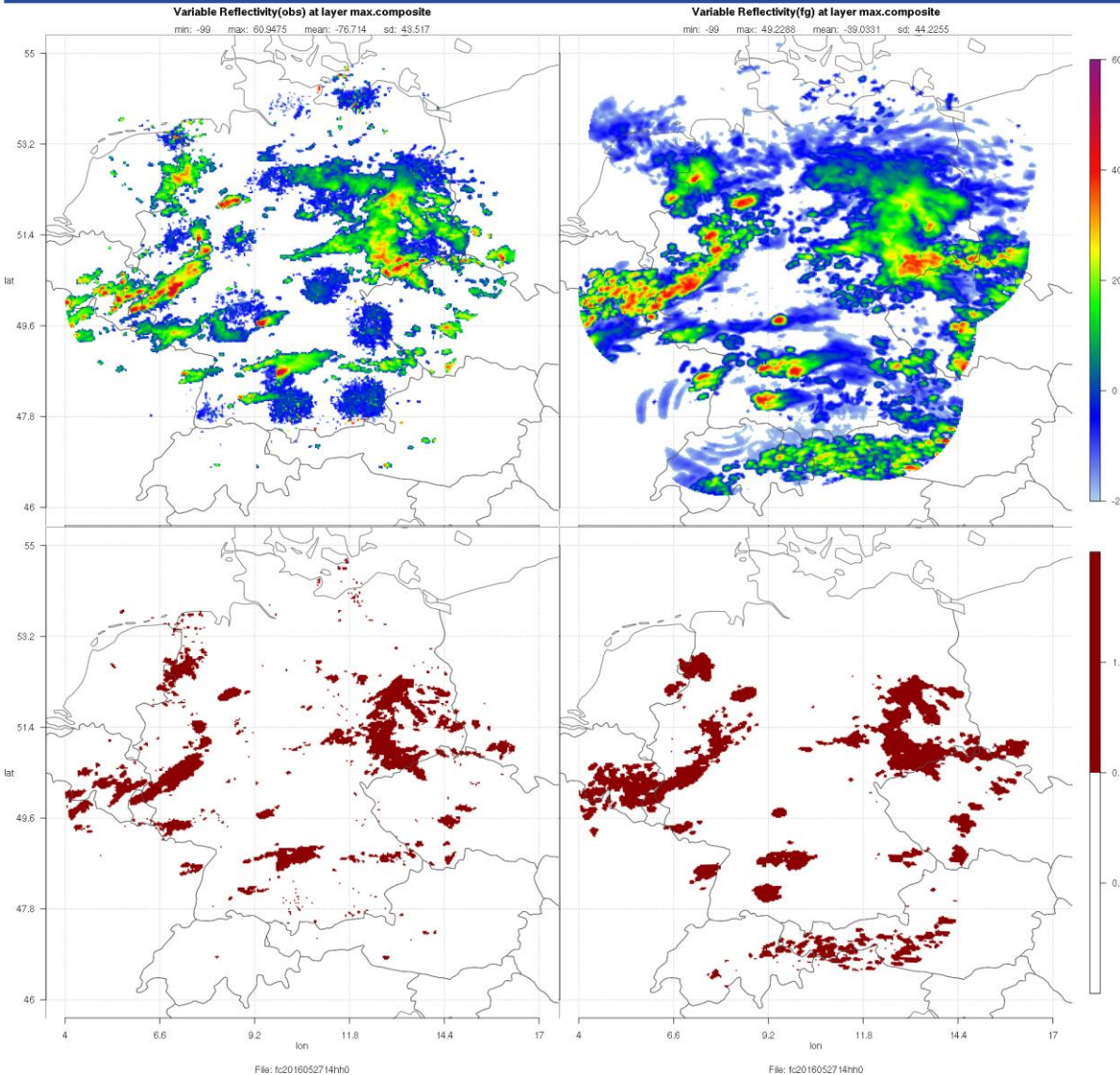
Normalized counts (observation)   **Normalized counts (model equivalent)**
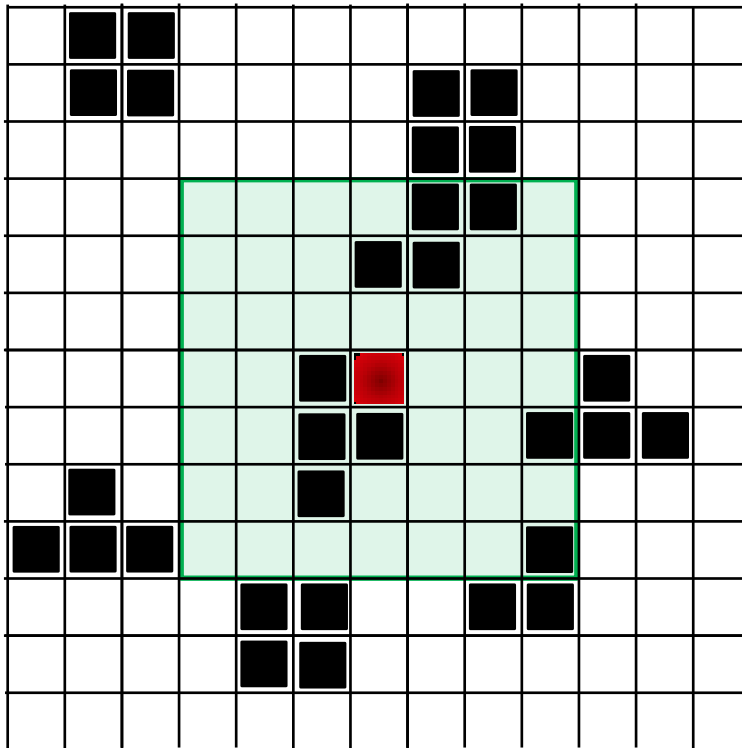
■ = fulfils condition (e.g. reflectivity > threshold)
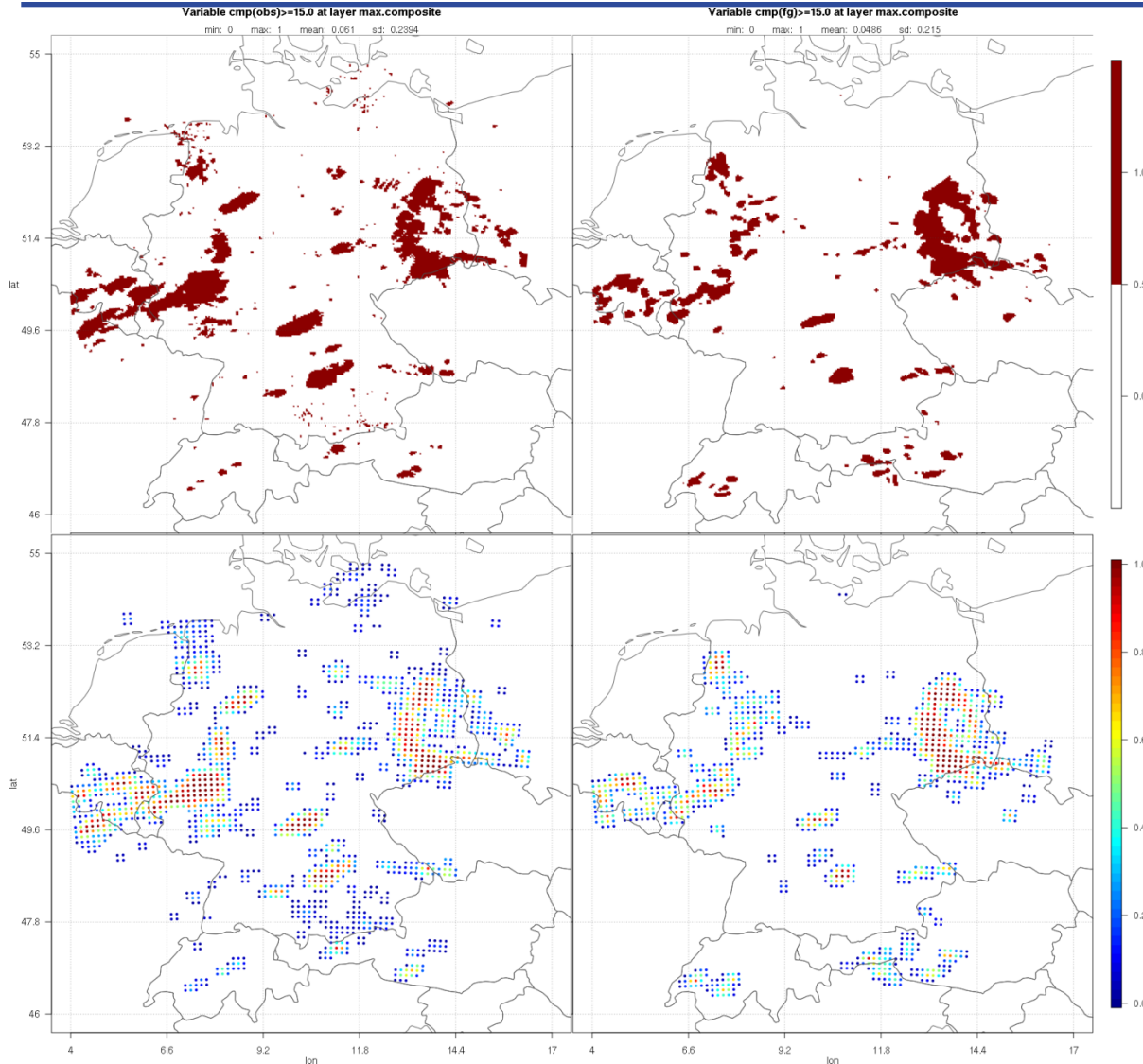
→ Observation: normalized number of ■ in **box** = p(■)

Texture assimilation – idea

Variable Reflectivity(obs) at layer max.composite
min: -99   max: 60.9475   mean: -76.714   sd: 43.517

Variable Reflectivity(fg) at layer max.composite
min: -99   max: 49.2288   mean: -39.0331   sd: 44.2255

File: fc2016052714hh0

File: fc2016052714hh0

**Reflectivity scale: -20 … 60 dBZ**

- *Top:* **Maximum composite** at each model grid point
- *Bottom:* **Binary field** for Reflectivity ≥ 15 dBZ

- *Left:* **observation**
- *Right:* **model** (forecast)

- **Animation: forecast** (from hh=0 to hh=6 Δt=1h)

- **Start date:** 27.05.2016, 14UTC
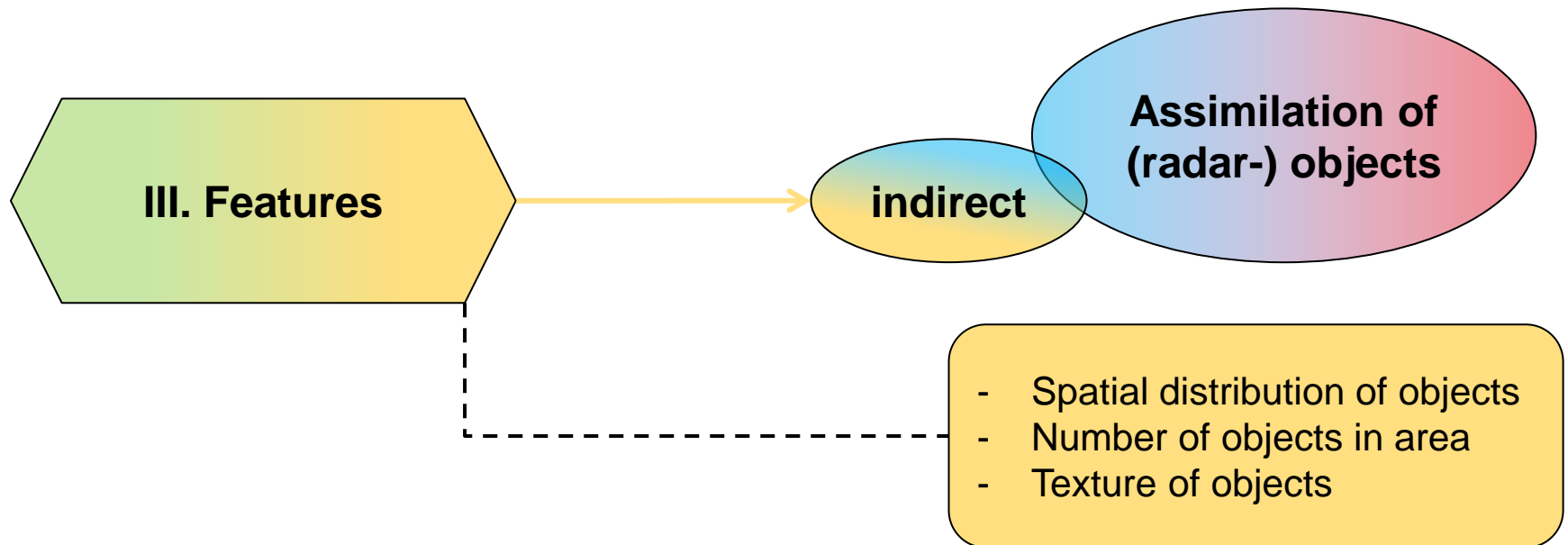
Texture assimilation – idea

Variable cmp(obs)>=15.0 at layer max.composite
min: 0   max: 1   mean: 0.061   sd: 0.2394

Variable cmp(fg)>=15.0 at layer max.composite
min: 0   max: 1   mean: 0.0486   sd: 0.215

- *Top:* **Binary field** for Reflectivity ≥ Threshold
- *Bottom:* **Texture** for box 7x7 g.p., every 4th model g.p., threshold 15 dBZ

- *Left:* **observation**
- *Right:* **model** (<u>first guess</u>)
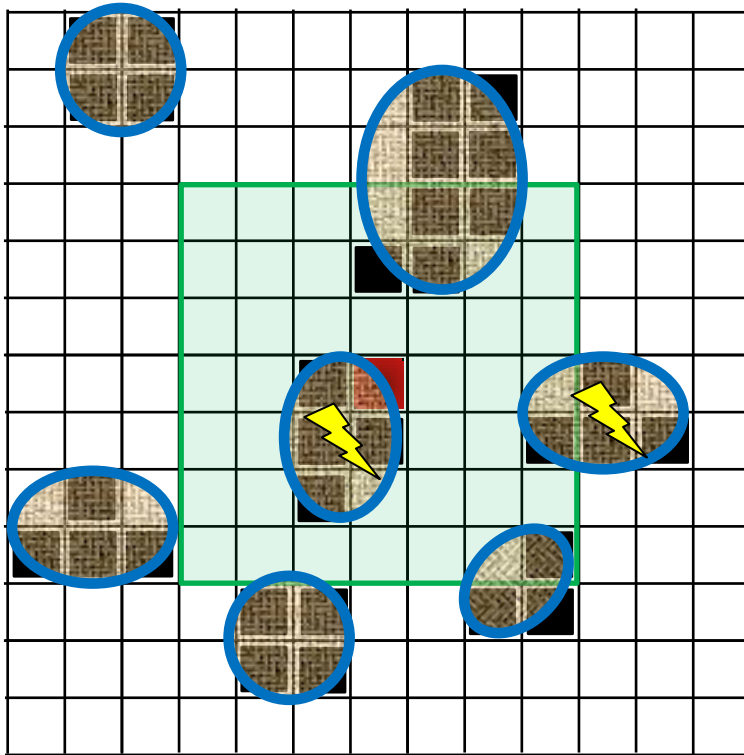
- **Date:** 27.05.2016, 14UTC + 1h
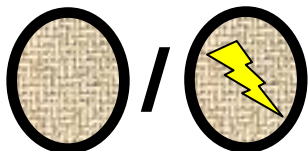
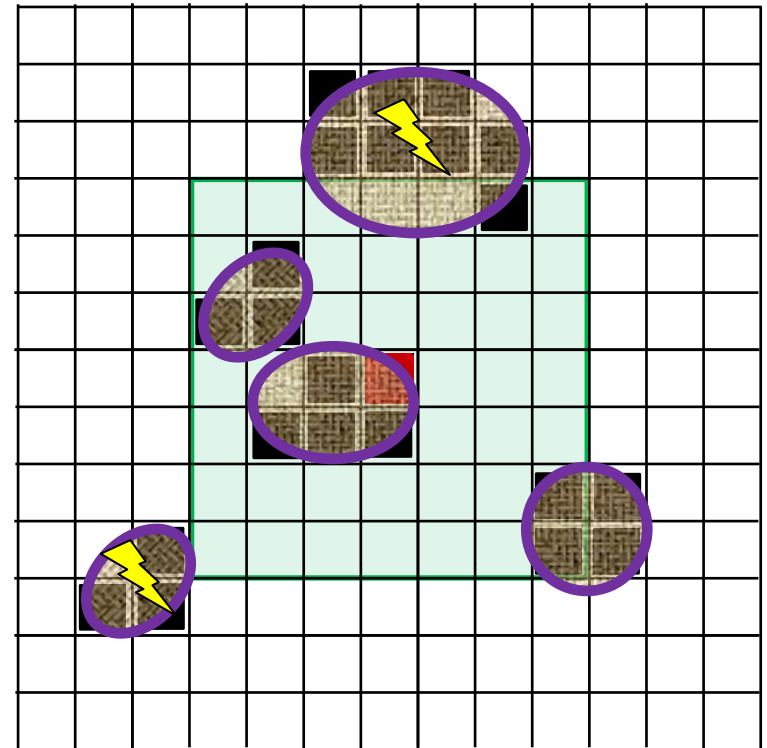# Texture assimilation – idea
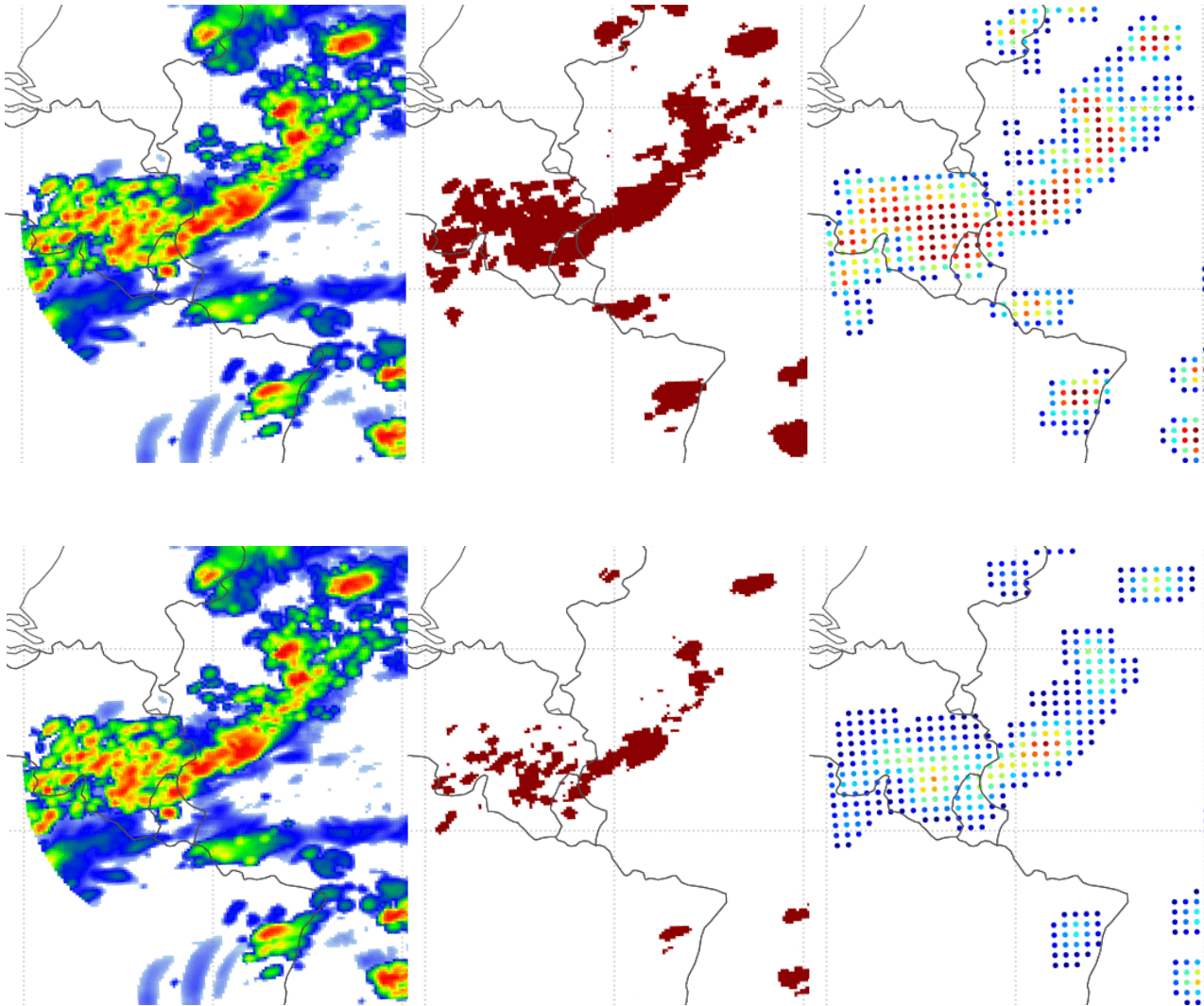
- *Top:*
  box 7x7 g.p.,
  animated threshold
  (15 to 35 dBZ ΔZ=5 dBZ)

- *Bottom:*
  threshold 30 dBZ,
  animated box
  (5 to 13 Δb=2)

- **Both: model equivalent**

- **Date:** 27.05.2016, 14UTC

III. Features → **indirect** **Assimilation of (radar-) objects**

- Spatial distribution of objects
- Number of objects in area
- Texture of objects

Feature assimilation - idea
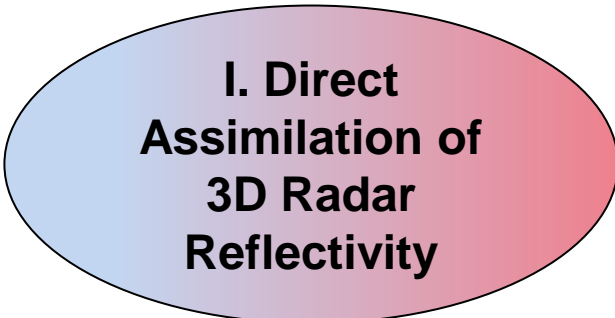
Counts (observation)

Counts (model equivalent)

⬭ / ⚡ = identified object (with collective/object attributes)

Results

I. Direct Assimilation of 3D Radar Reflectivity

vs.

II. Texture Assimilation
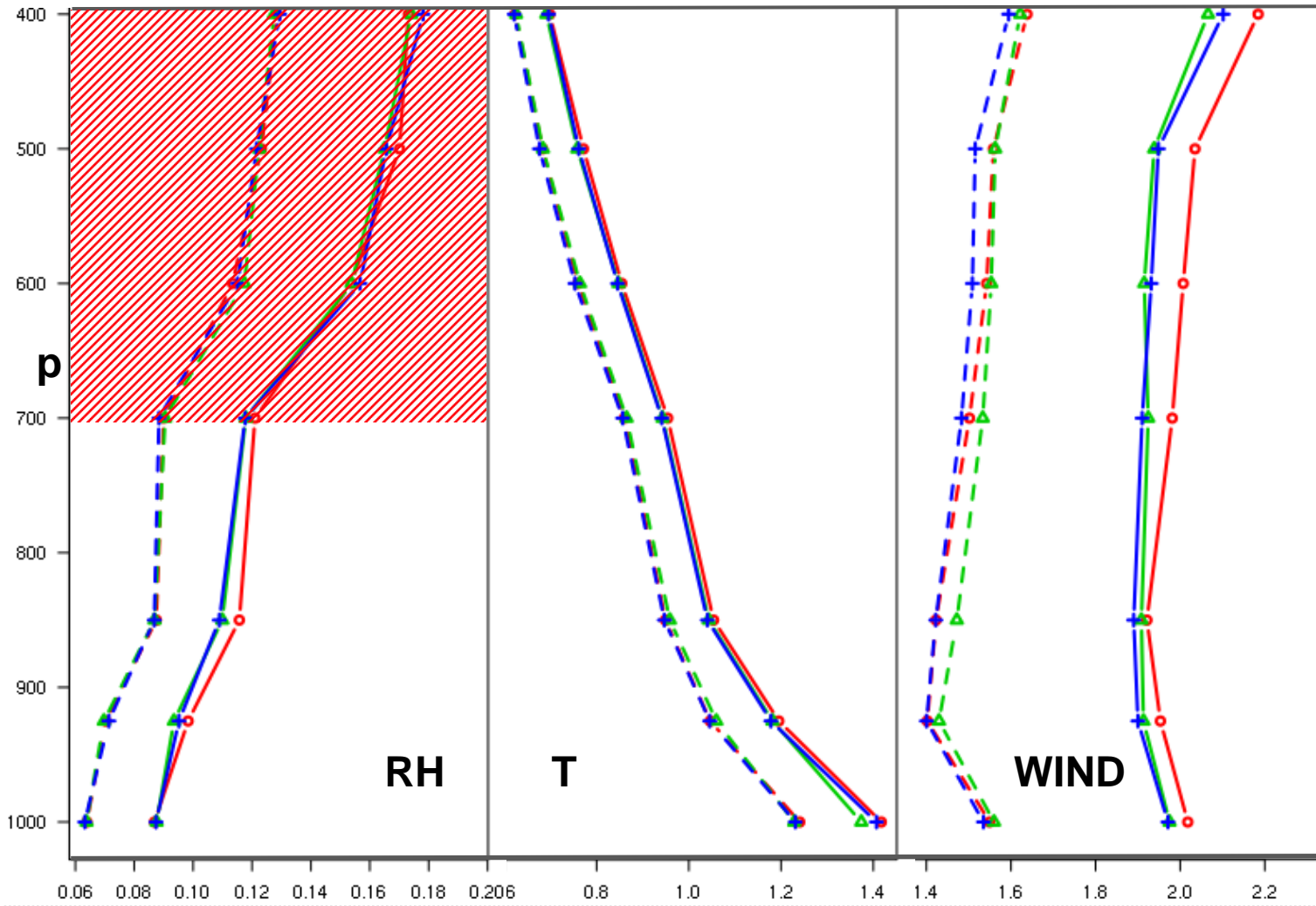
RMSE:

—— : first guess

---- : analysis

- **6 days**
- **hourly cycle**
- **40 member +**
  deterministic
- **verified obs.**
  same in all
  experiments
- **OBS: TEMP,**
  PILOT, AIREP

RH   **T**   **WIND**

3D Reflectivity   **Texture [(T=30,B=11),(T=20,B=7)]**   **No Radar Data Assimilation**

Forecast Verification (reflectivity)

3D Reflectivity

Texture [(T=30,B=11),(T=20,B=7)]
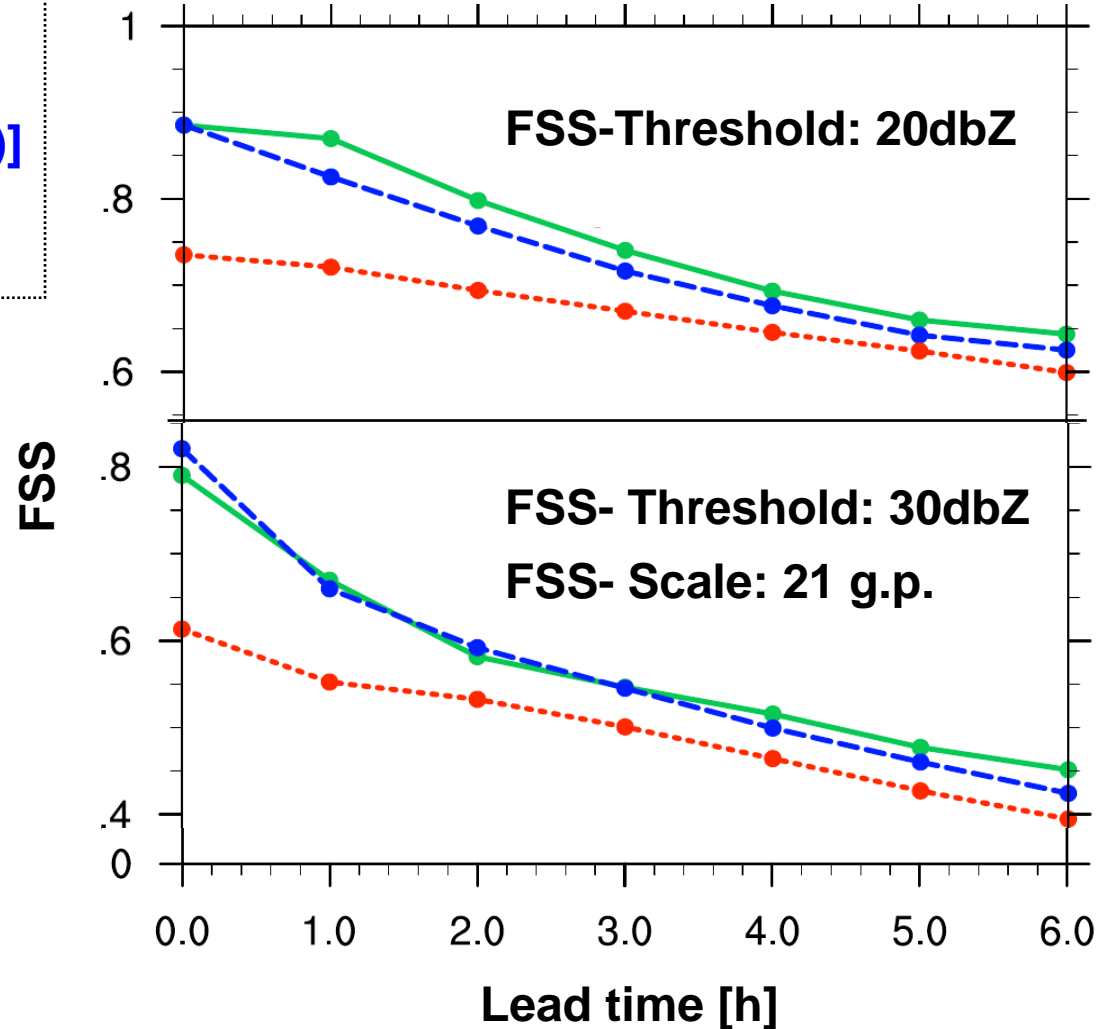
No Radar Data Assimilation

6 days, 27.05.-01.06.2016

6h forecasts, hourly 10-18 UTC, deterministic run

Fraction Skill Score
[Roberts & Lean, 2008]

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

FSS-Threshold: 20dbZ

FSS- Threshold: 30dbZ
FSS- Scale: 21 g.p.

FSS

Lead time [h]

Conclusions

1. *Direct assimilation of 3D radar data (reflectivity)*

+ Positive in FG (RH, wind)*

**+** Positive in reflectivity/precipitation(not shown) up to 0.2 in FSS over 6h*

2. *Texture*

+ Neutral(RH,T), positive(Wind) in FG*

+ Almost equal skill in FSS

+ Assimilation of multiple scales/thresholds

? Vertical localization, proper metric

- Loss of information (smaller threshold)

3. *Features (future)*

+ No matching of objects, reducing double penalty

? Vertical localization, proper metric

- Double counting, potential loss of information

* compared to no radar data assimilation
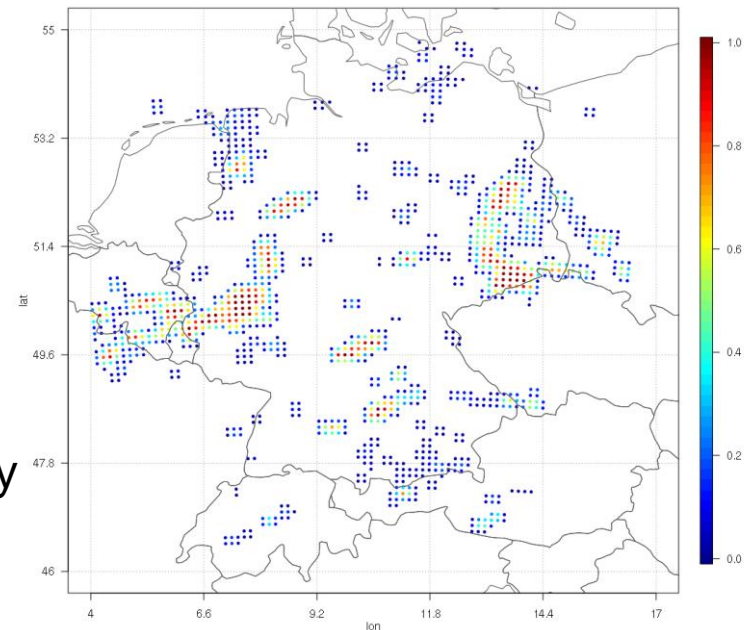
Thank you for your attention

Gracias por tu atención

Bedankt voor uw aandacht

Grazie per l'attenzione

شكرا لاهتمامكم

Merci de votre attention

Danke für Ihre Aufmerksamkeit

ご清聴ありがとうございました

Obrigado pela sua atenção

Takk for din oppmerksomhet

Kiitos huomiostasi

谢谢你的关注

ขอบคุณสำหรับความสนใจของคุณ

Спасибо за внимание

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[Bick2015]:   doi 10.1002/qj.2751

[Desroziers2005]:   doi 10.1256/qj.05.108

[Hunt2007]:   doi j.physd.2006.11.008

[Roberts & Lean, 2008]: doi 10.1175/2007MWR2123.1

[Schraff2016]:   doi 10.1002/qj.2748

[Stephan2008]:   doi 10.1002/qj.269

[Zeng2016]:   doi 10.1002/qj.2904