Object-based verification of radar reflectivities on the convective scale

COSMO General Meeting
09.09.2019 – 12.09.2019

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Why do we define (radar) objects?

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

We talk about **a** thunderstorm, thought as a complex unit with various attributes – not as a collection of pixels

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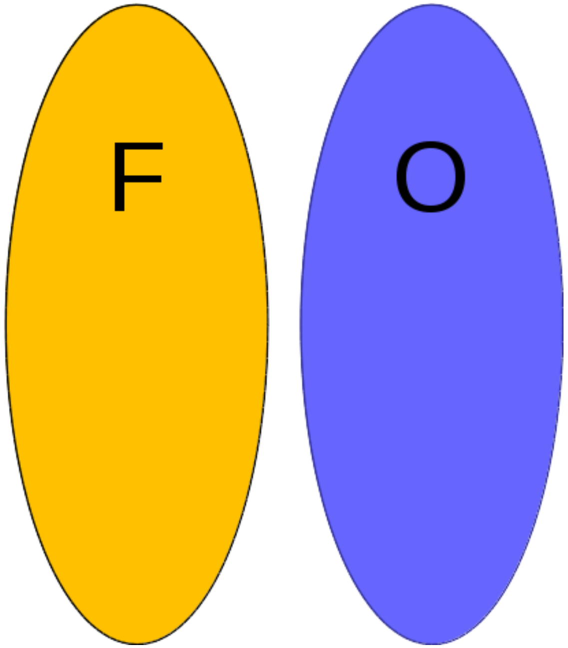
Why do we verify (radar) objects?

Double-Penalty problem



Objects will:

- Allow **distance metrics** as quality measure
- Allow to connect to other properties (amplitude, shape, lightning,…)
- Reduce amount of data

Total Interest & Median of Maximum Interest

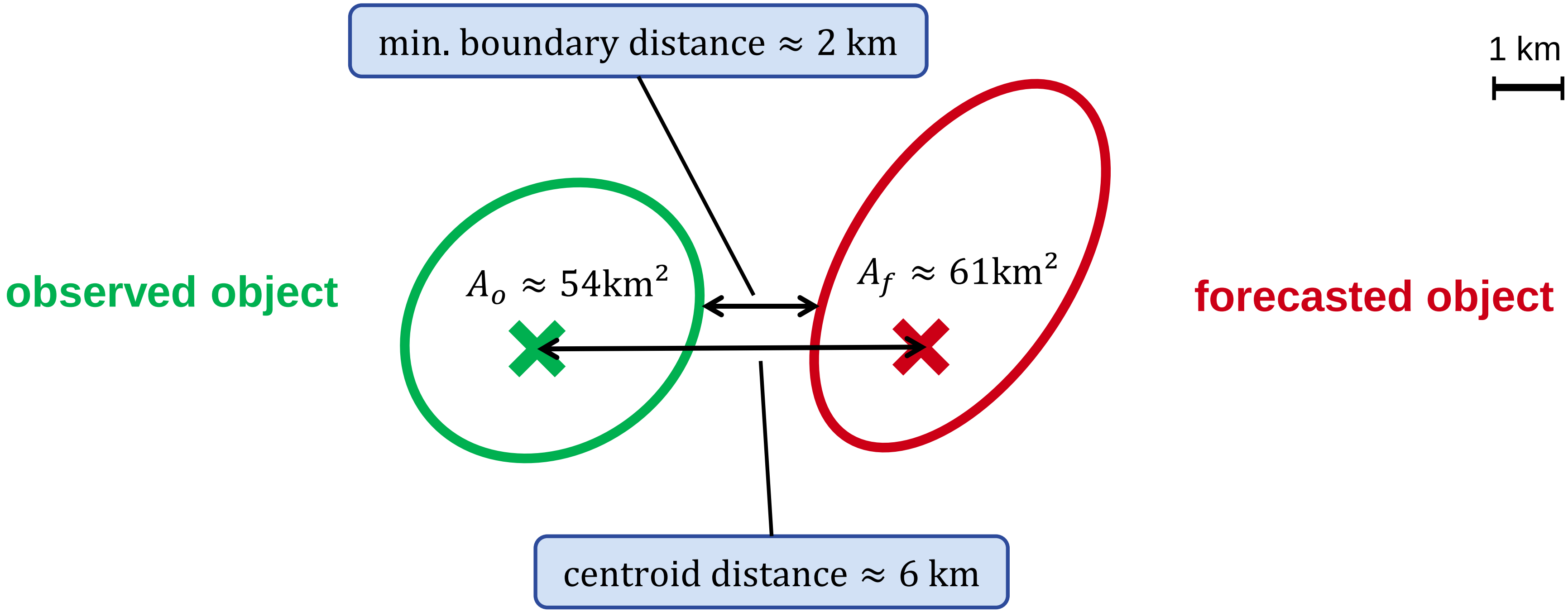
The Method for Object-based Diagnostic Evaluation (MODE) Applied to Numerical Forecasts from the 2005 NSSL/SPC Spring Program

C.A. Davis, B.G. Brown, R. Bullock & J. Halley-Gotway

- ➔ a **Fuzzy-Logic** algorithm that compares several attributes of forecast and observed objects (or features)
- ➔ a **total interest** describes how similar both objects are
- ➔ the **median of maximum** interest as a metric for overall forecast quality
- ➔ <u>However:</u> stratification on distinct attributes possible
- ➔ <u>Idea:</u> should better **mimic** the decision process of a forecaster

Calculate the attributes

➔ <u>given</u> is an arbitrary object pair



$$\text{area ratio} = \frac{\min(A_o, A_f)}{\max(A_o, A_f)} \approx 0.88$$

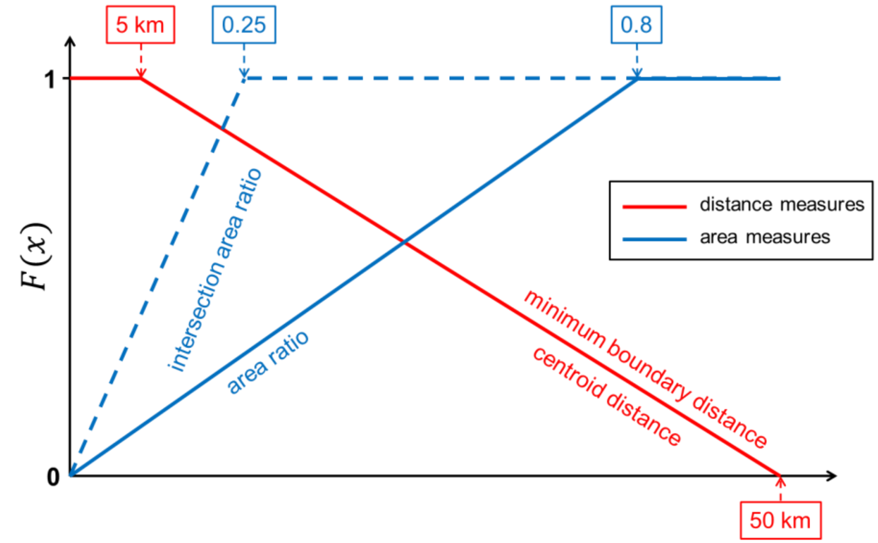
$$\text{intersection area ratio} = \frac{A_{intersect}}{\mathrm{mean}(A_o, A_f)} = 0$$

Build the interest for each object pair j

<u>Weight w of attributes:</u>

cent. dist (**28%**),
min. bound. dist. (**40%**),
area ratio (**19%**),
intersection ratio (**13%**)

<u>Interest function F:</u> includes limits for each attribute



Object pair j

$$I_{i,j} = c_i w_i F_{i,j} \quad [0,1]$$

<u>Attributes i:</u>

centroid distance,
minimum boundary distance,
area ratio,
intersection ratio

<u>Confidence c:</u> for each attribute

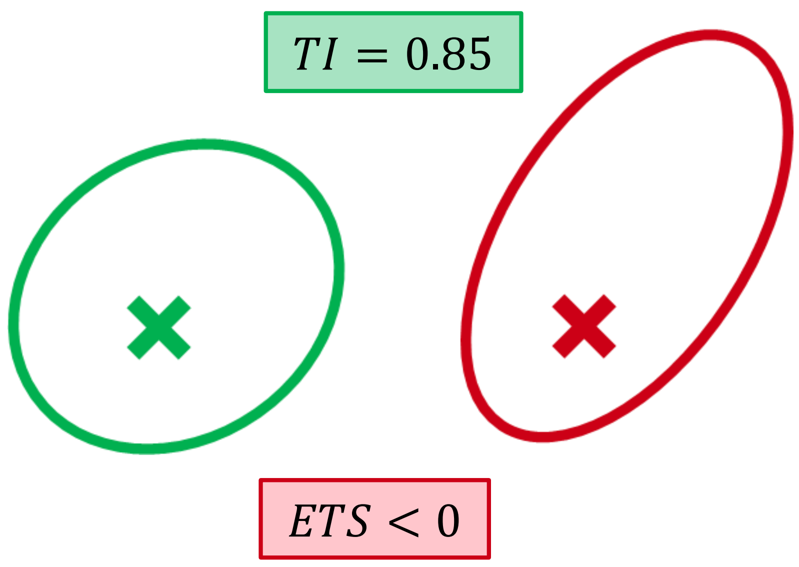
e.g. small centroid distance is less meaningful
if area ratio is greatly different → $c = \text{area ratio}$

Note: values taken from Davis et al., empirically determined for US domain.

Build the total interest (TI)

➔ sum up to „total interest“ for each object pair *j*

$$TI_j = \frac{\sum_{i=1}^{M} I_{i,j}}{\sum_{i=1}^{M} c_i w_i}, [0,1], M - \#\text{attributes}$$



Median of Maximum Interest (MMI)

- ➔ sum up to „total interest“ for each object pair *j*

$$TI_j = \frac{\sum_{i=1}^{M} I_{i,j}}{\sum_{i=1}^{M} c_i w_i}, [0,1], M - \#\text{attributes}$$

- ➔ doing this for each possible combination of object pairs:

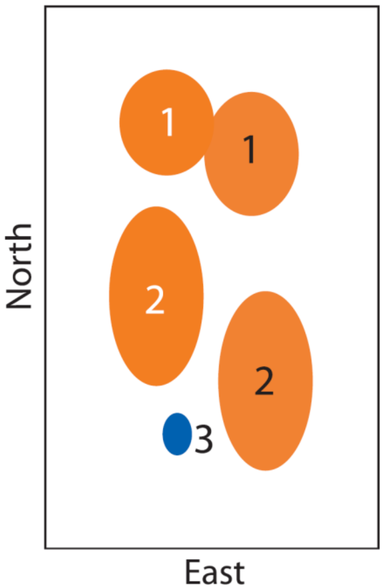


figure from Davis et al. (2009)

Total Interest Matrix

Forecast \ Observed	1	2	max:
1	0.90	0.75	0.90
2	0.50	0.80	0.80
3	0.40	0.55	0.55
max:	0.90	0.80	

Median of all maximum interest values → <u>MMI</u>

So far so good, but…

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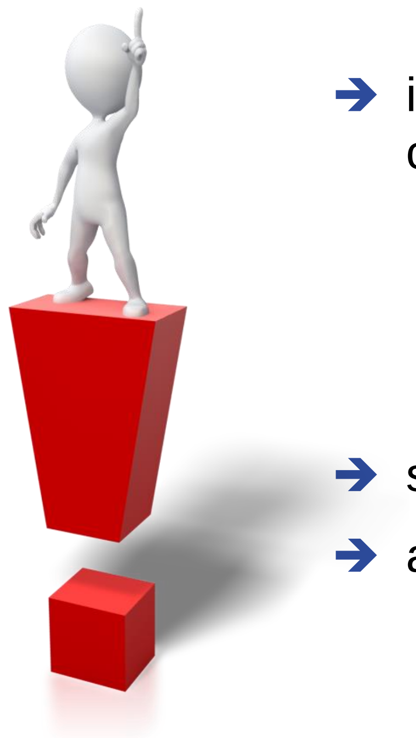

- ➔ interest values are highly depending on the appropriate choice of
  - ➔ limit parameters
  - ➔ weighting of attributes
  - ➔ confidence functions
- ➔ statistical study necessary to estimate parameters empirically
- ➔ and to finally provide specific „user setups“

This is where we want to start now!

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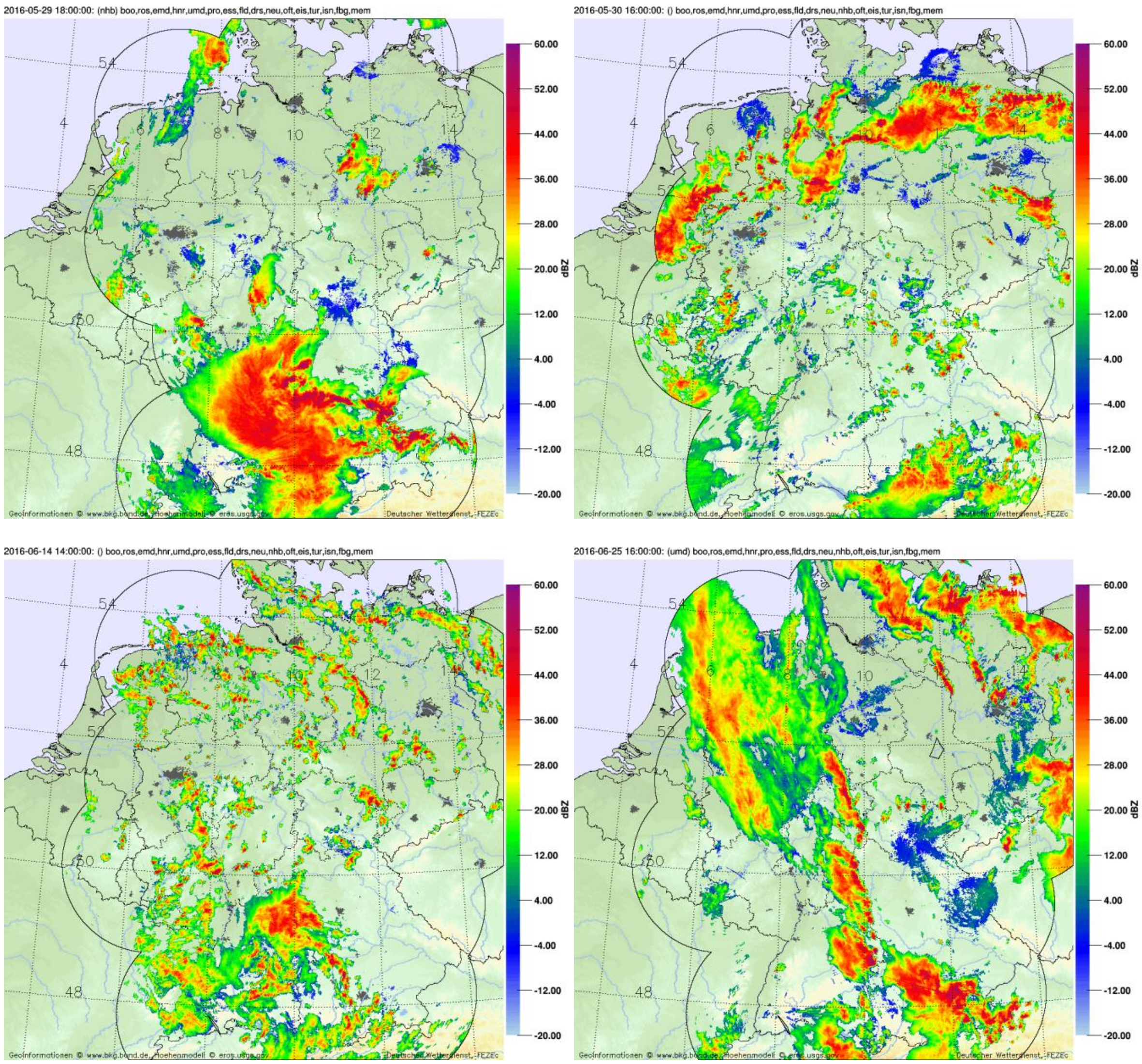
Test case period 26.5. - 25.6.2016



Time period with nearly permanent severe convective events,

but also some large-scale systems

Observation basis: DWD radar network

Simulation data basis (reflectivities)

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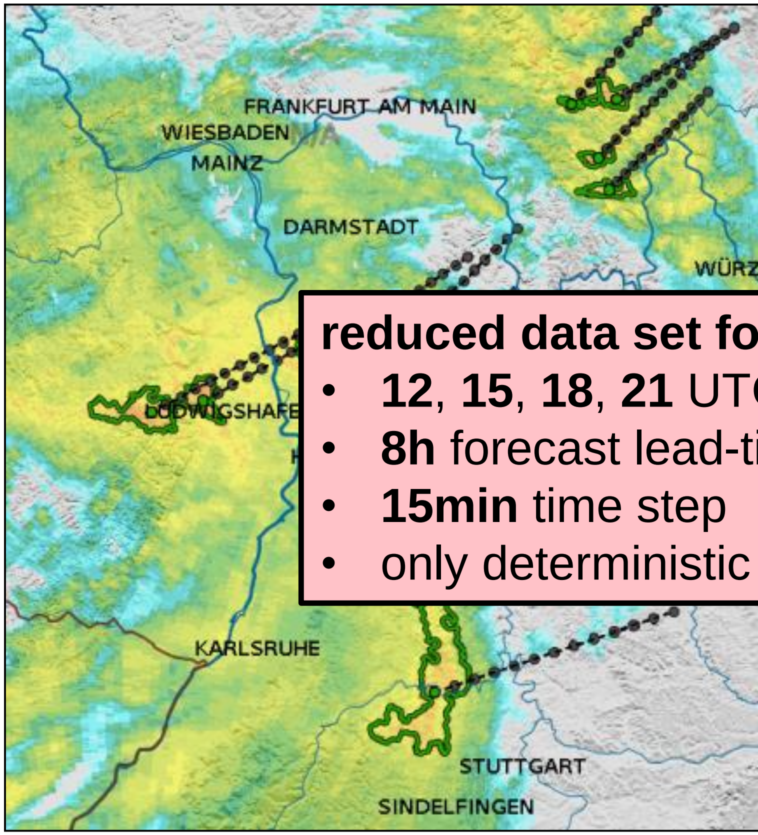
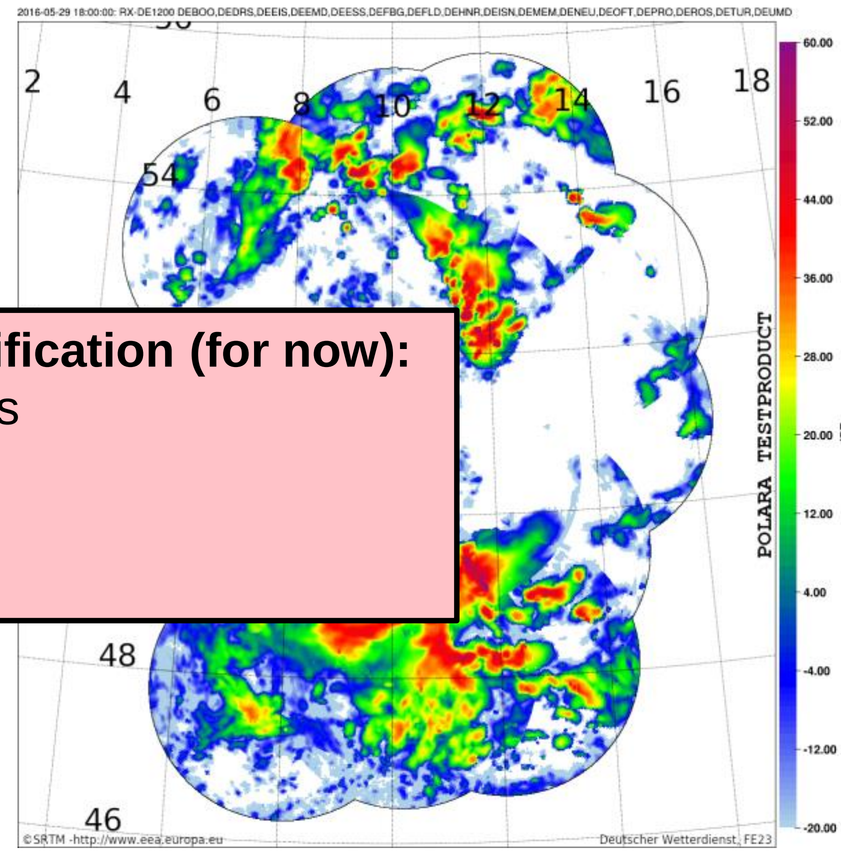
linear object nowcasting
currently (still) operational

COSMO-DE & EPS
assimilation radar reflectivities
2-moment scheme





reduced data set for verification (for now):

- **12**, **15**, **18**, **21** UTC runs
- **8h** forecast lead-time
- **15min** time step
- only deterministic

Radar forward operator (EMVORADO) simulates reflectivities on radar grid (see Zeng *et al*., 2016)

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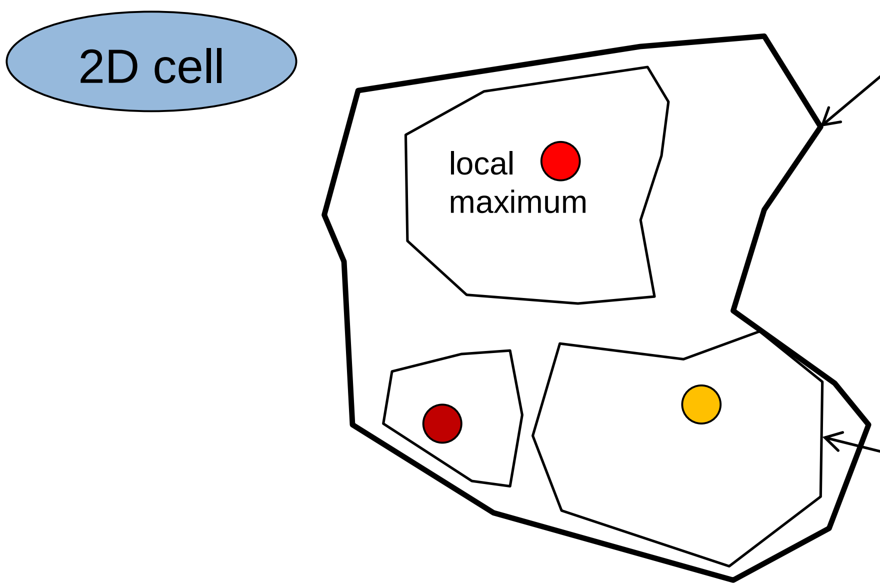
Identification of convective cells

In-House product: KONRAD3D



Basic thresholding:

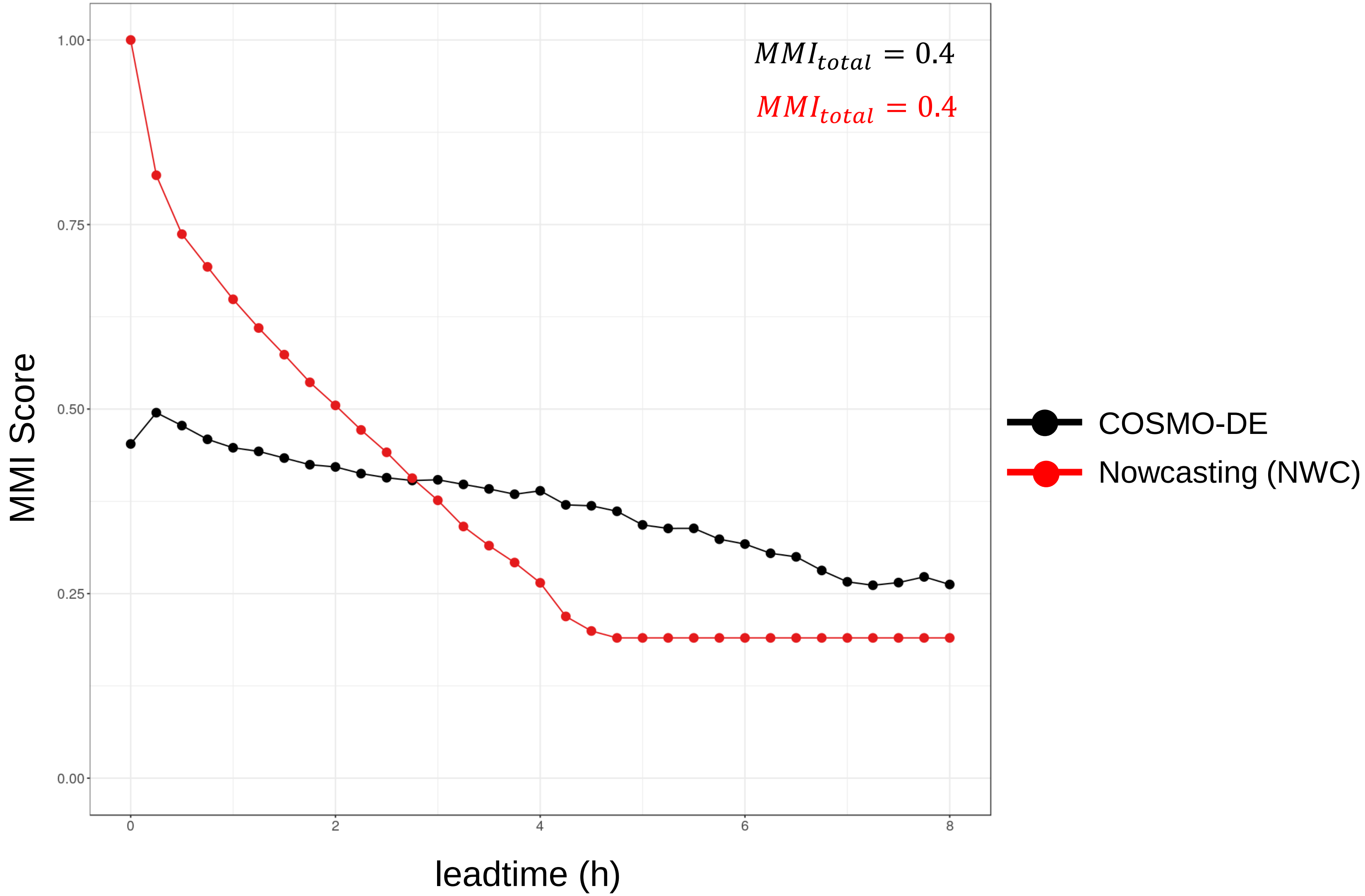
region of intense precipitation through thresholding
→ **here: 35 dBZ**

Adaptive thresholding:

A subcell must have a max-min difference of at least **7 dBZ**

- for each radar, each elevation → overlaying results in 3D cells
- Applied to both, observations and simulations

Verification over the entire period



However…

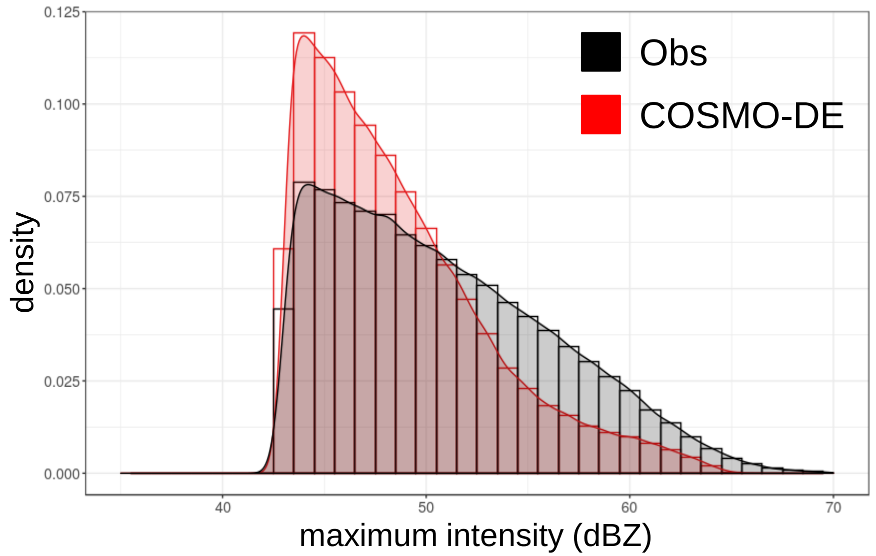
… is the comparison between observation and model forecast really fair?

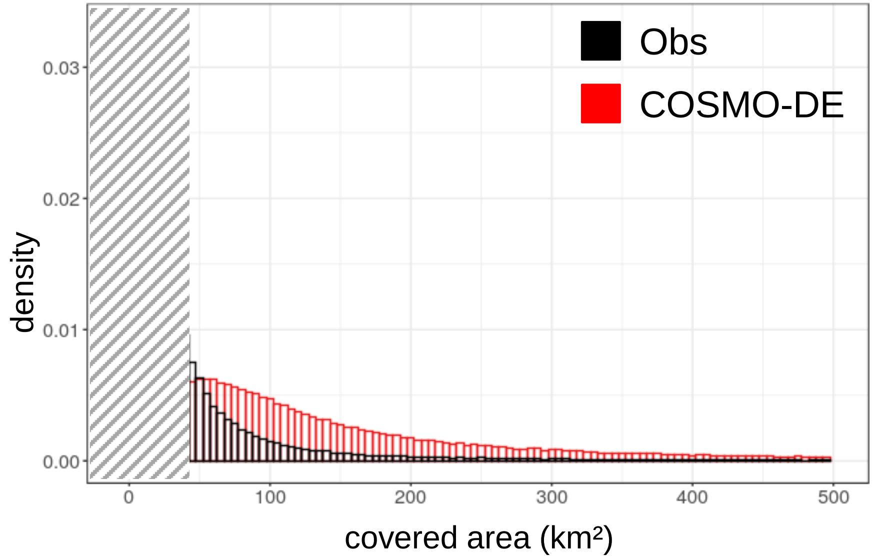
- far too many small objects in observation
- too many large objects in forecast

- Experiment: What happens to the MMI if we

1. exclude features with area < 50km² (effective model resolution)

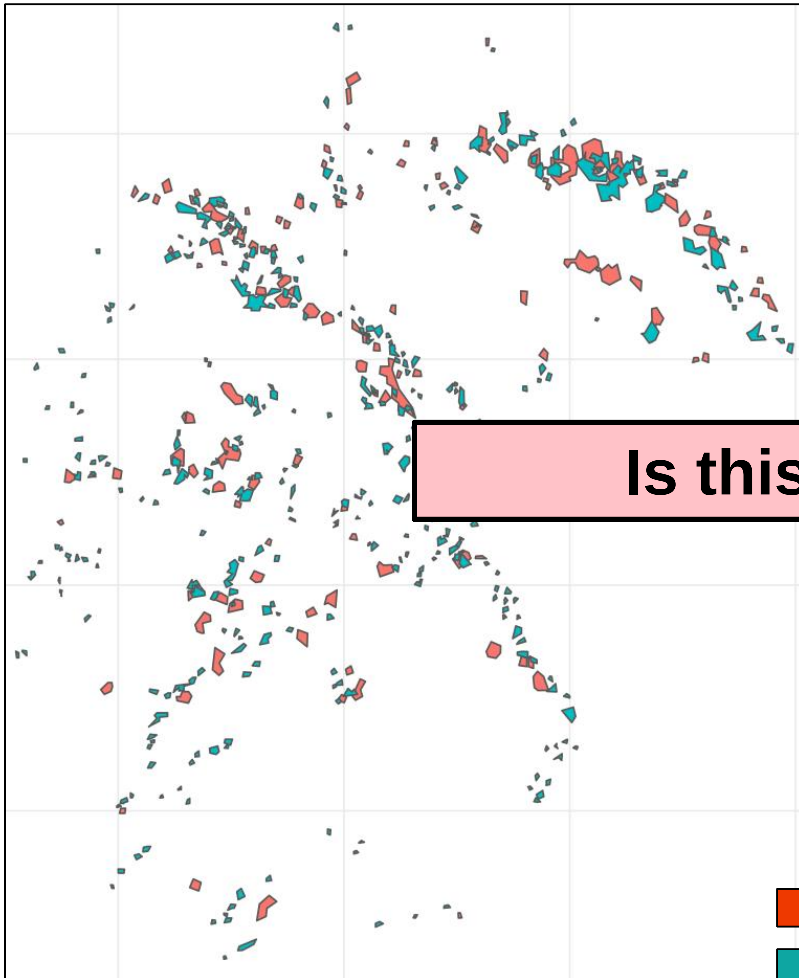
2. set 30 dBZ basic threshold to observed objects (instead of 35 dBZ)
   → results in larger observed objects



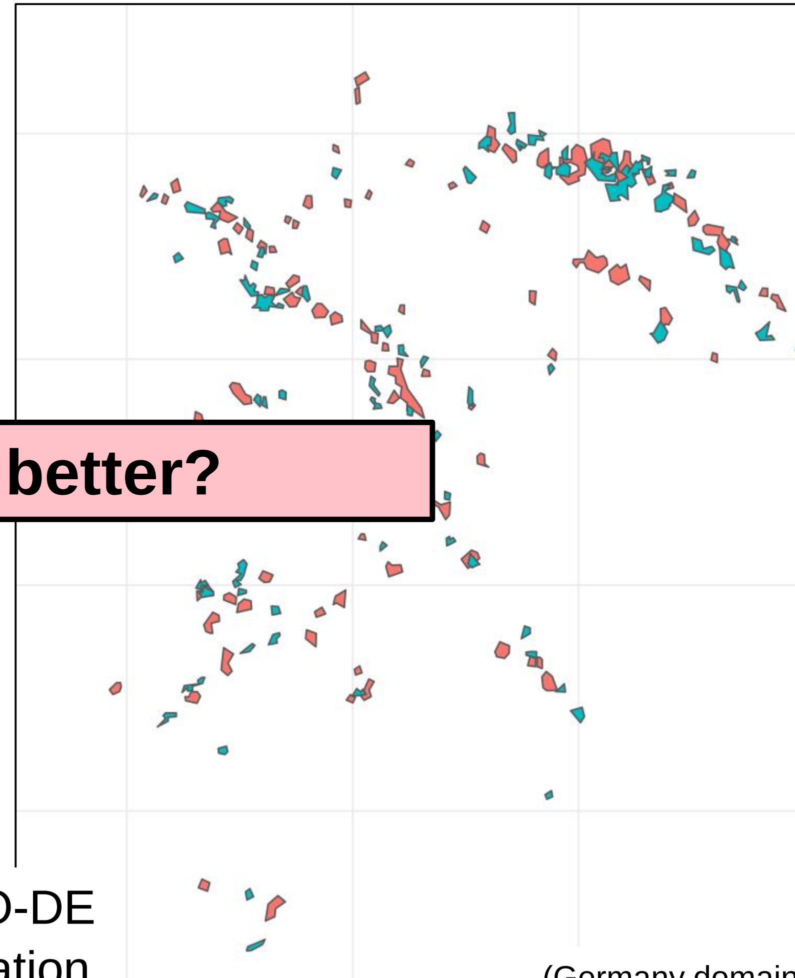


A qualitative comparison

all objects
30dBZ (obs) vs 35dBZ (model)



objects larger 50km²
30dBZ (obs) vs 35dBZ (model)



Is this much better?

COSMO-DE
Observation

(Germany domain)

What does the global verification say?

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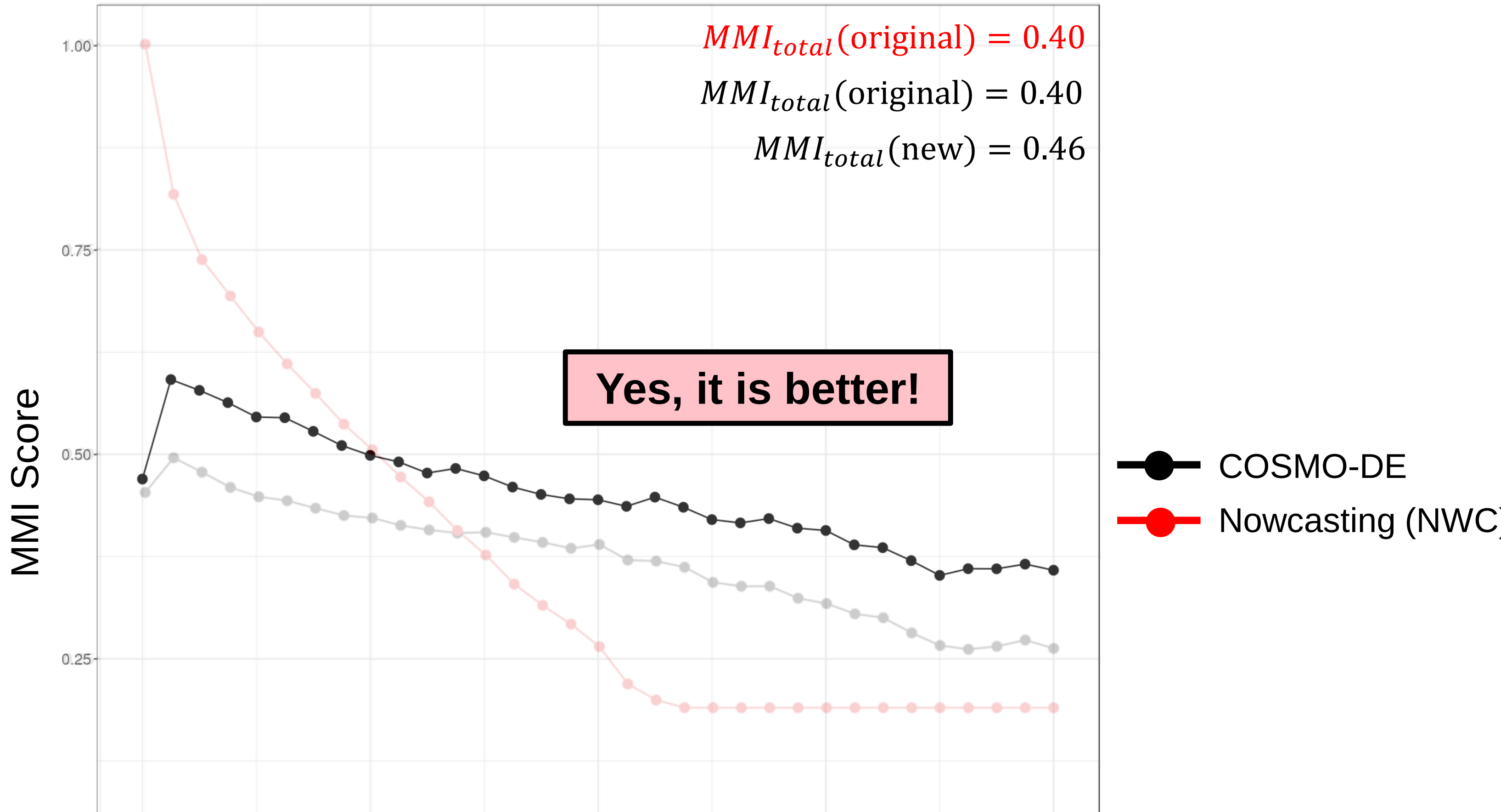

The median lowers the score significantly when we have too many small mismatched objects.
→ Big problem when considering convective events.

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Conclusion

- ➔ once tuned, the method has potential verifying objects with different attributes
- ➔ A summary score but stratification on distinct attributes possible

- ➔ Use more attributes (volume, cell-based VIL, …)
- ➔ What if no observed or no forecasted objects are detected (MMI not defined i.e. false alarms or misses are not punished)?
- ➔ How to compare to other methods, e.g. neighborhood?
- ➔ Making use of MODE matching capabilities to quantifiy forecast errors for different object attributes.
- ➔ **How to adapt the method to ensemble forecasts?** (Single member? Ok, but no real benefit. Restrictions for object comparison?)

A systematic analysis of the score and its behaviour to the single attributes will follow …

Thank you for your attention!

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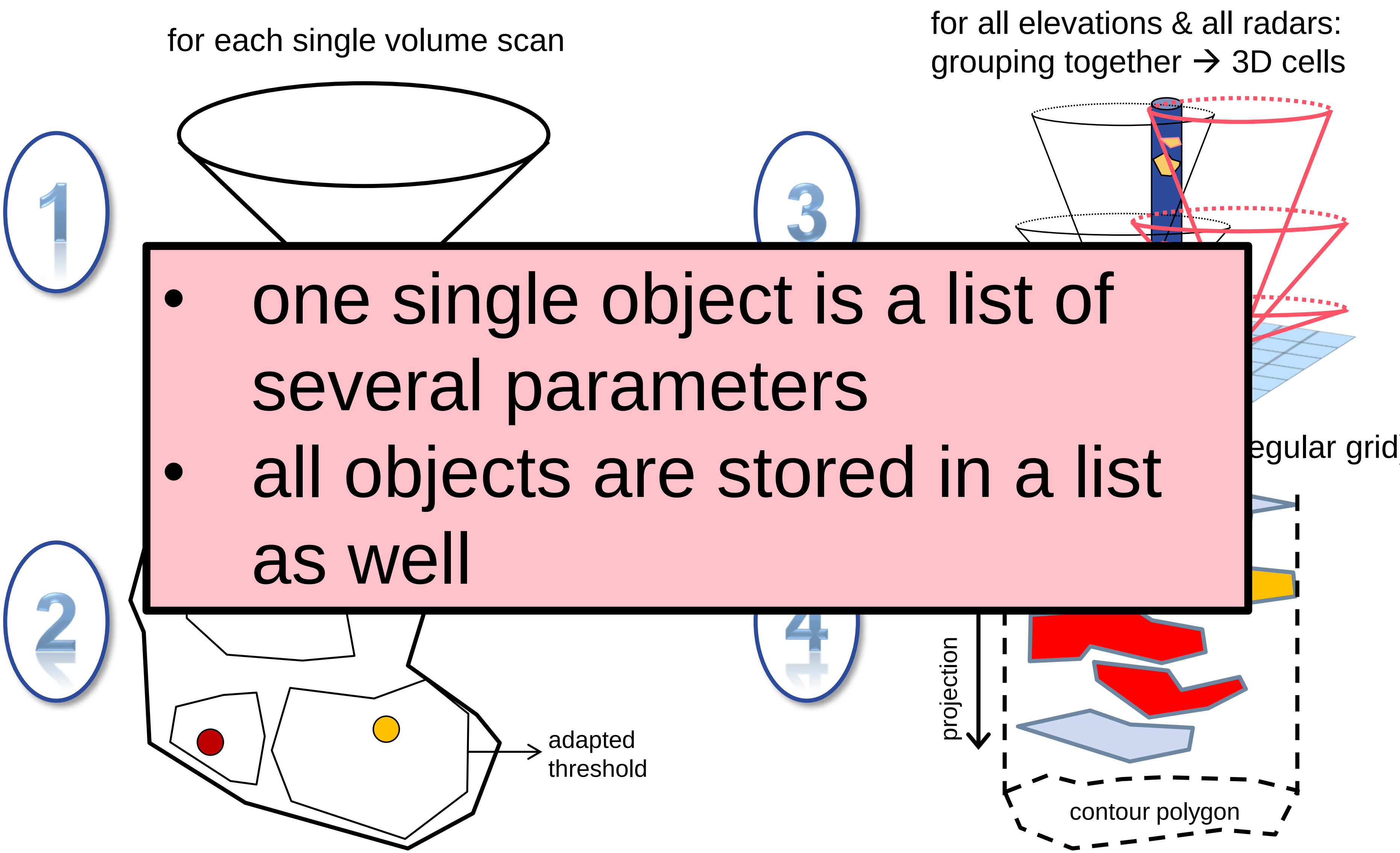
Appendix

From radar to objects: KONRAD3D



- one single object is a list of several parameters
- all objects are stored in a list as well