Commercial Microwave Link (CML) Data Assimilation with the LETKF

Prepep Conference – 19.03.2025

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

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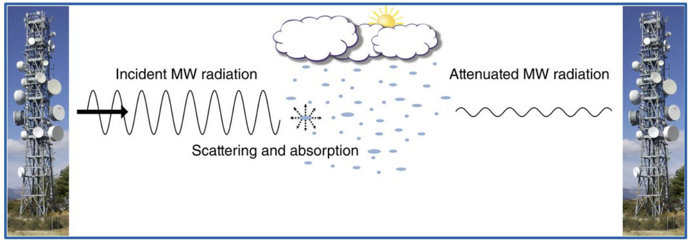
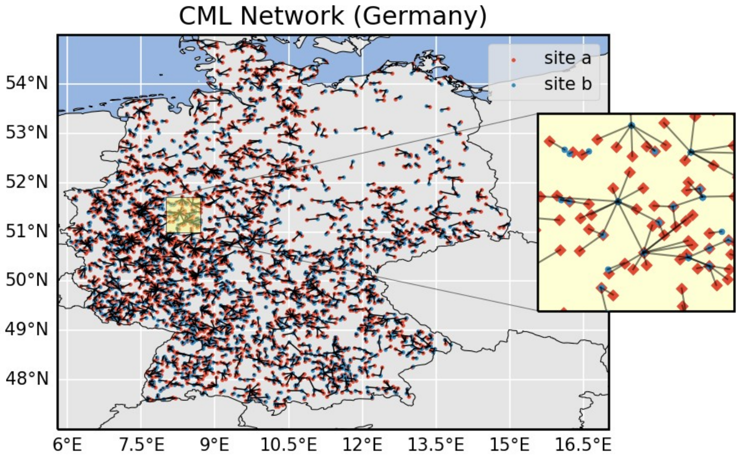
- …

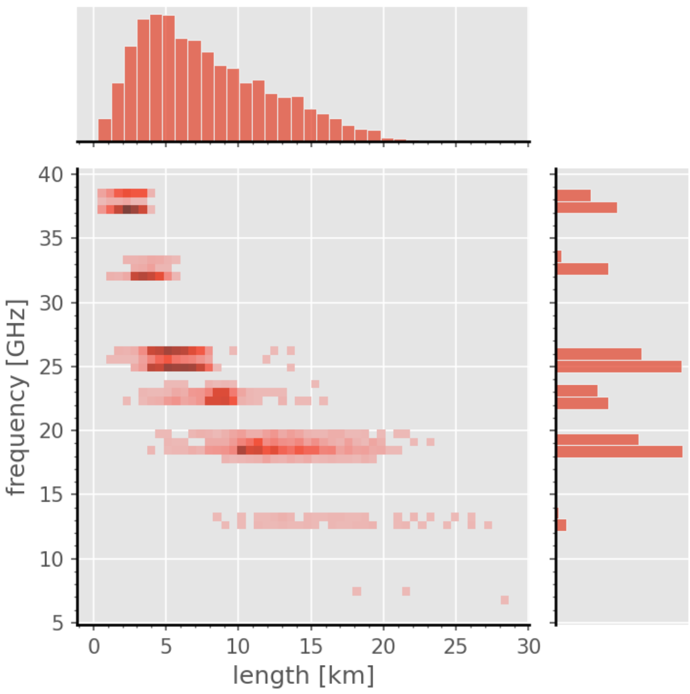
CML Basics: Motivation & Overview I

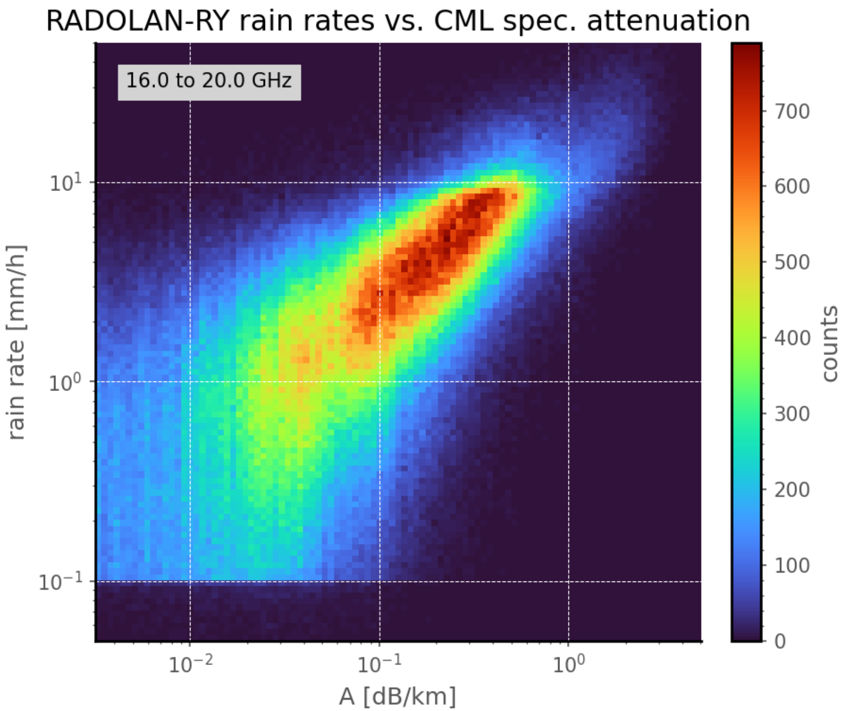
- overall **objective** here: **data assimilation** (DA) of **Commercial Microwave Link** (CML) data in NWP models for **improving QPF**
  - (How much) does it improve QPF?
  - How does it compare to Radar DA?
- CMLs employed for the **interconnection** of (commercial) **cell phone towers**
- transmitted radiation may be attenuated by, e.g., raindrops → **CML attenuation** carries information about atmospheric conditions between two towers
- ~4000 CMLs in current dataset for June 2019 with resolution of 1min





CML Basics: Overview II

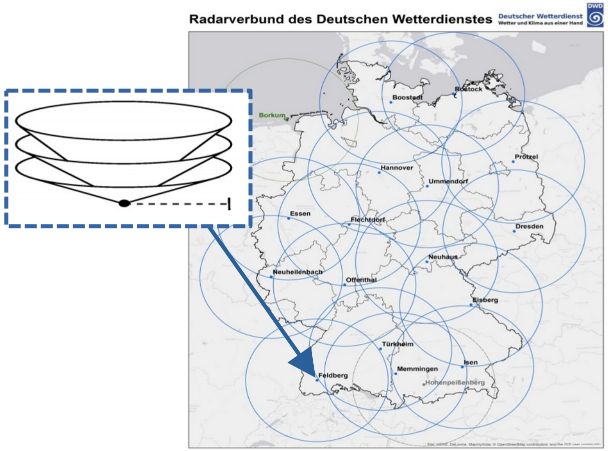


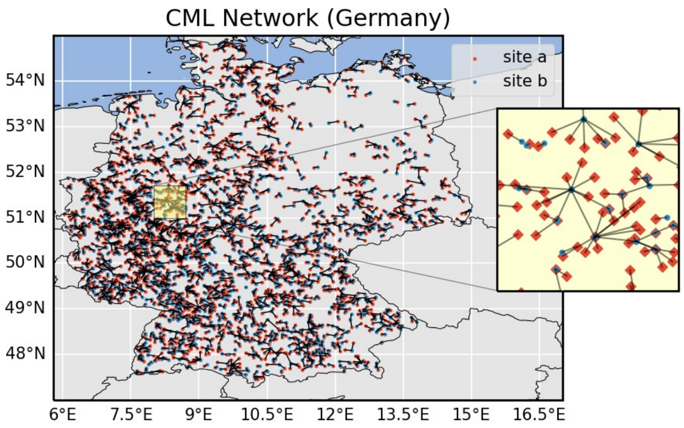


- CML frequency above DWD Radar frequency (~5GHz)
- use **path-integrated specific attenuation** A (unit dB/km) for DA
- direct relationship of A with rain rate via **power law**

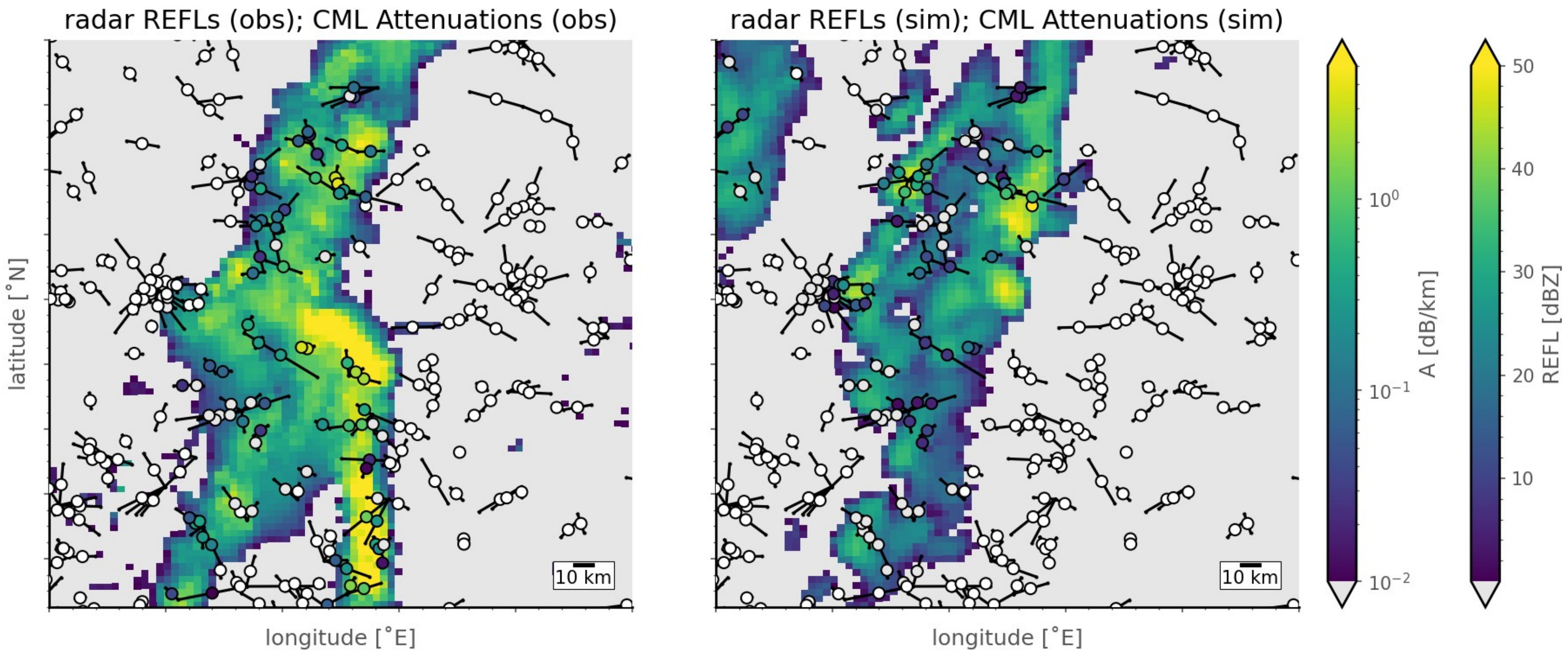
CML Basics: CML Simulations

- employ radar forward operator **EMVORADO** for computing **simulated CML attenuations A**
- differences between **Radar and CML**:
  - Radar: 17 stations, many azimuths, few elevations, frequency ~5 GHz
  - CML: ~4000 “stations”/sender, individual azimuth/elevation (only one per station) and frequency within 10 – 40 GHz
- each CML sender is interpreted as a single Radar station with **individual** lat/lon/level, azimuth/elev. of ray, frequency, etc.
- perform EMVORADO run based on ICON-D2 model fields





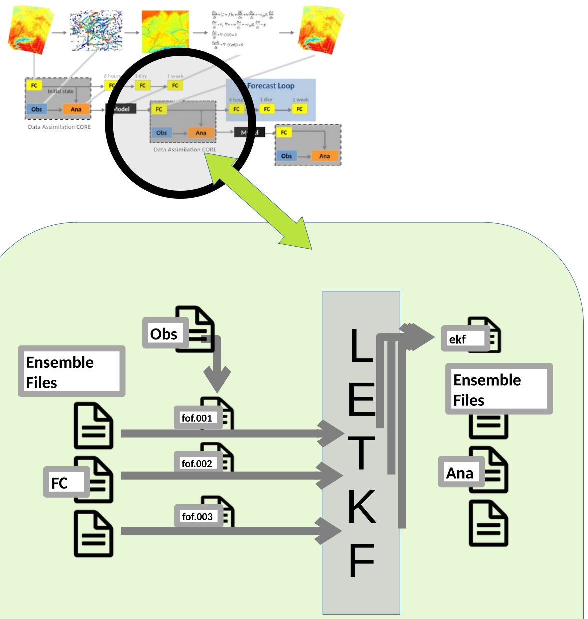
CML Basics: Radar vs. CML



- comparison of **obs. (left)** and **sim. (right)** radar REFLs and CML A
- results seem **plausible** (especially simulated attenuations)

CML Basics: LETKF DA System

- LETKF DA → construct “feedback” files
  - contain **all data relevant** to LETKF assimilation, including **observations + sim. model equivalents** (for **each ensemble** member)
  - employ **EMVORADO** for computing simulated CML attenuations
- built system for construction of CML feedback files:
  - perform all necessary data **(pre-)processing steps**: EMVORADO calculations, temporal superobbing, ...
  - **implemented** (mostly) in Python
  - **integrated into BACY** → realistic/full-scale DA exps.



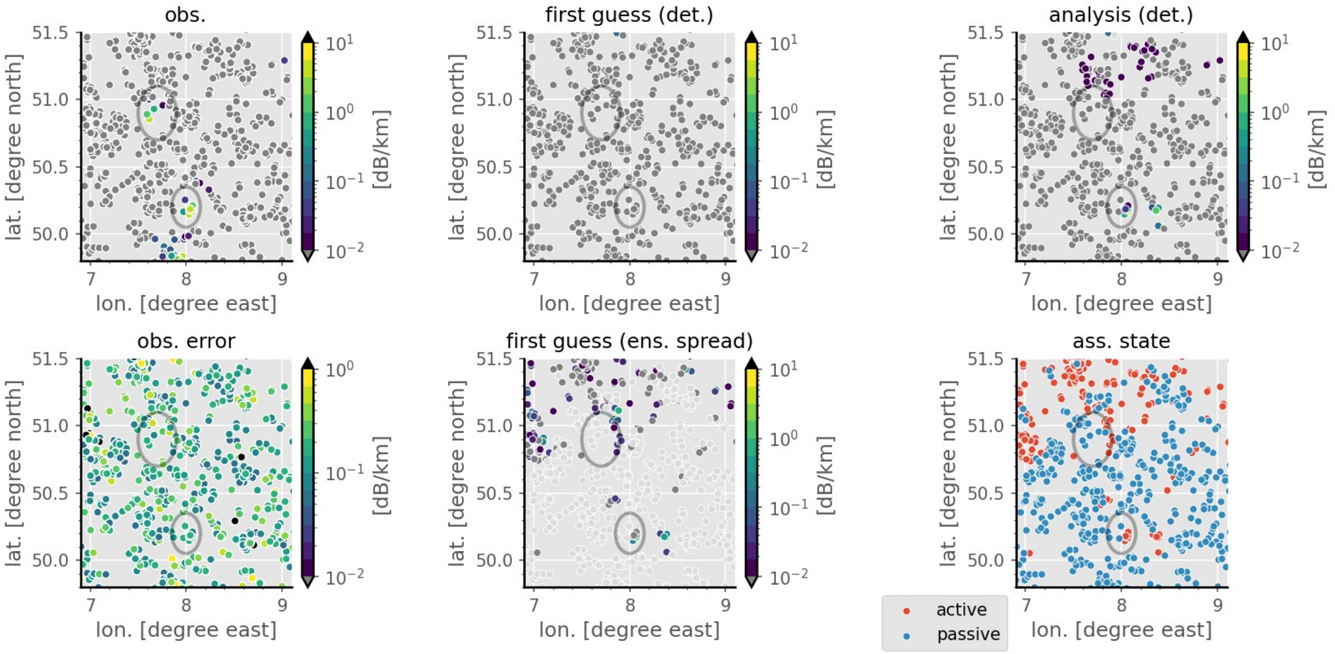
- fof.*: sim. + obs. quantities of ens. members
- LETKF produces increments depending on innovations + Kalman gain

CML Case Study: Setup

- **perform** single-time DA experiments (via BACY):
  - **single LETKF assim.** followed by **ICON-D2 model run**
  - assimilate **ALL available CMLs** at 2019-06-03T12:00
  - **branch off** from **“parent” BACY cycle** during which **only conventional data** was assim.: no Latent Heat Nudging (!), no radar DA, etc.
  - compare configs. **“exp_{none}”, “exp_{conv}”, “exp_{cml}”, “exp_{radar}”, “$exp_{conv+cml}$”**, ...
- **study** LETKF output, ICON increments, model dynamics, and Fractions Skill Score (FSS)
  - zoom into “interesting” regions exhibiting certain properties, like **large discrepancies** between obs. and sim. REFLs, **sizeable spread** for sim. REFLs, **“enough” CML stations**

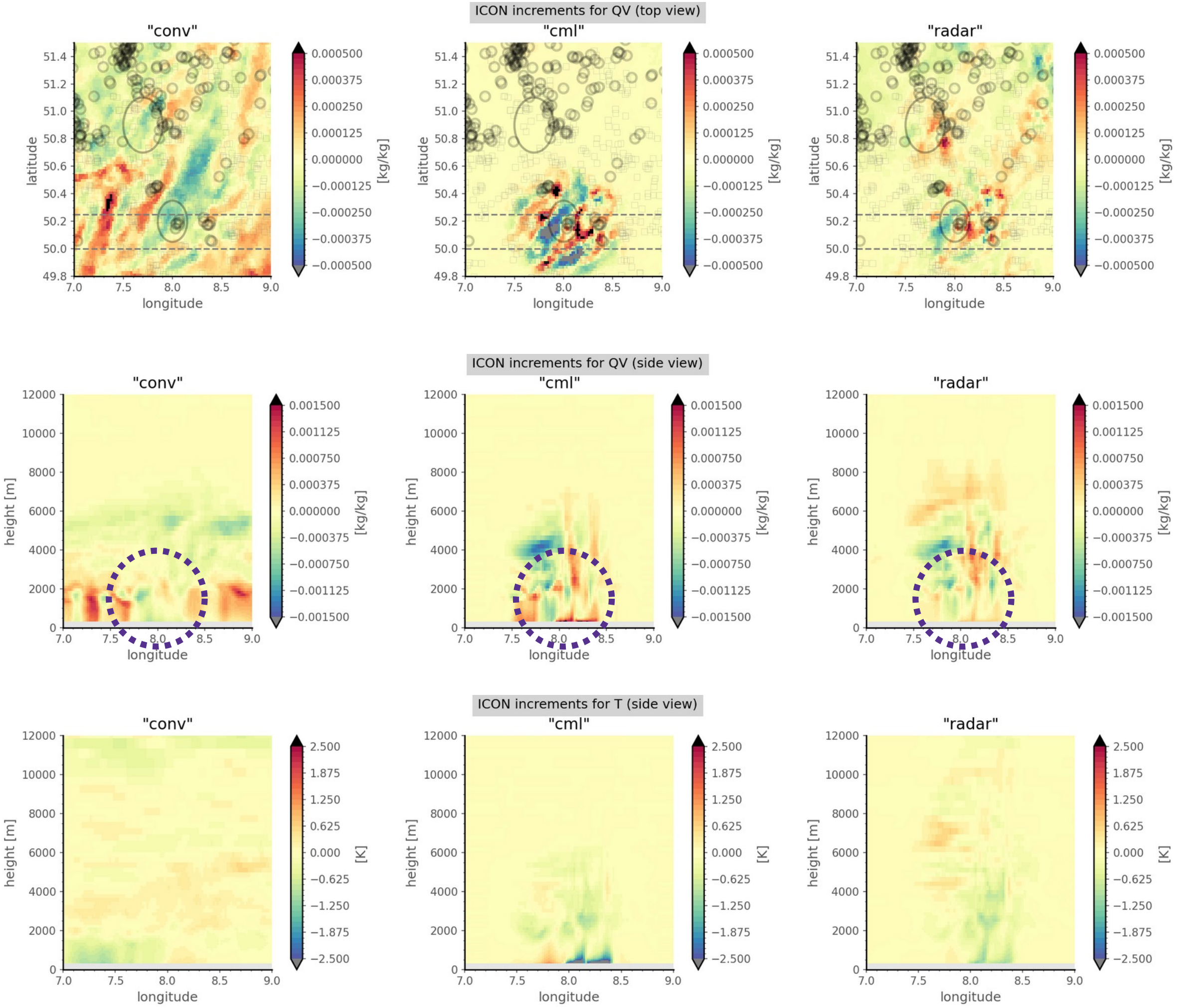
CML Case Study: LETKF Assimilation Results

representation of relevant LETKF assimilation input/output data (from “ekfCML” file)

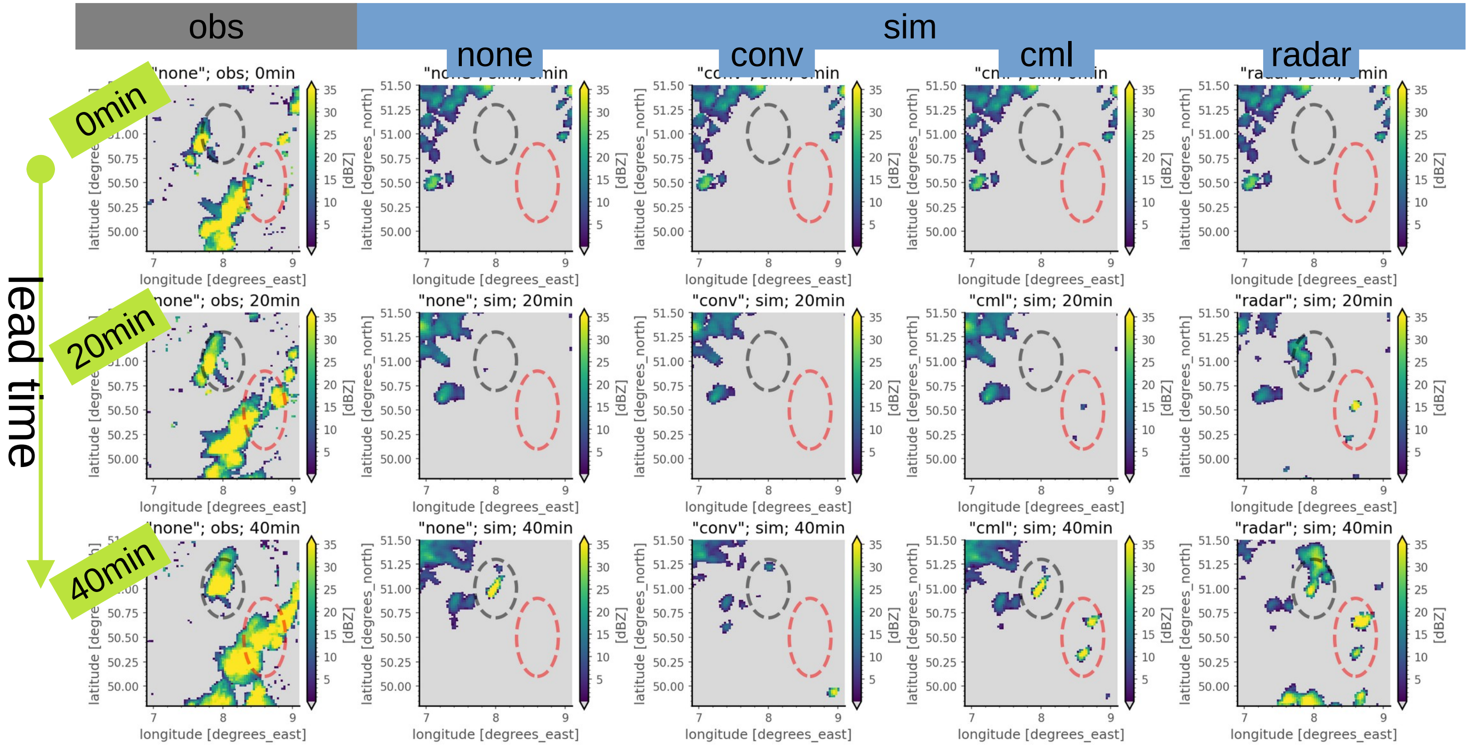


- **only assimilated CML** data here (“exp_{cml}”)
- dynamic obs. error: 1 dB / “CML length”
- first-guess check switched off
- vert. localization: 0.3
- horiz. localization: 16.0

CML Case Study: LETKF Increments



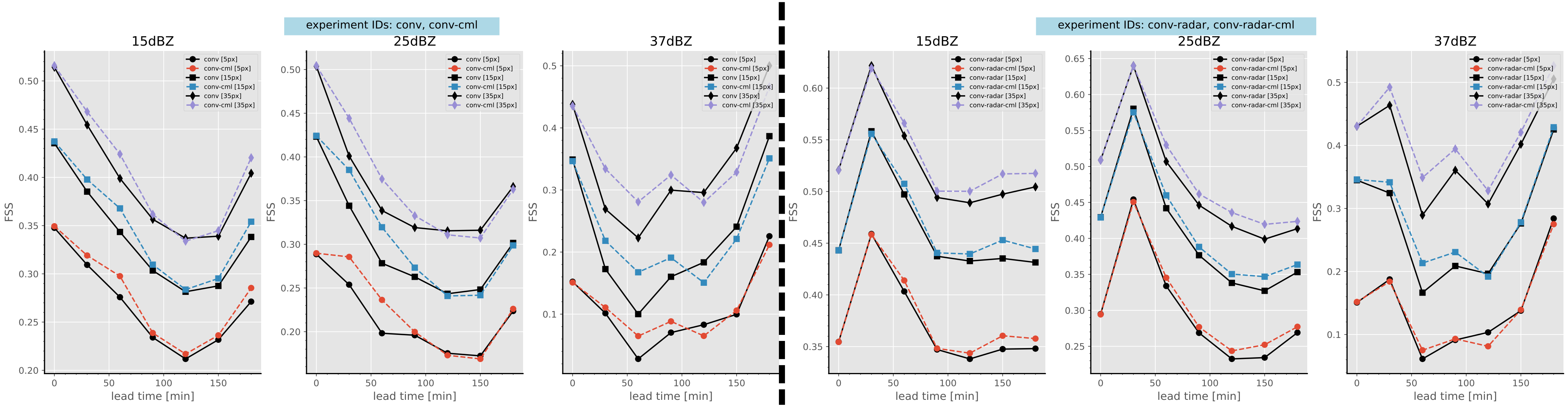
- depiction of LETKF **increments** for QV and T
- reduced 3D to 2D fields via mean along height dimension (→ **top view**) or lat. dimension (→ **side view**)
- result:
  - clear **differences** of conv. and CML DA
  - CML and radar DA **similar**



visualization of radar REFLs (dbzcmp) at 1.5°

- accurate **initiation of convection**
- clear **positive impact of CML** DA (w.r.t. conv. DA)
- CML DA **similar to radar DA**
- **interesting**: conv. data seem to “block” REFL generation

CML Case Study: Fractions Skill Score (REFLs)



fractions skill score (FSS) w.r.t radar REFLs over complete domain

- CML DA **consistently improves FSS** by up to about 10%
- CML DA brings improvement even **on top of conv.+radar** DA
- however, impact of **radar DA much more pronounced** than CML DA

Summary & Outlook

- set up system for **simulating and assimilating CML** data
- **case study** comparing results of **single-time DA** and subsequent model run for different configurations
  - short-term REFL verification shows **accurate initiation of convection**
  - FSS for REFLs **improved by up to 10%**
  - overall, already **clear improvement** for these **non-cycled experiments**
- <u>next steps:</u>
  - conduct **longer-term fully-cycled BACY** experiments and study CML impact on FSS, observation error statistics, ...
  - general quality control, spatial thinning/superobbing
  - **further study** impact of parameters like obs. error, localization, etc.

Thank you for your attention!