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RealPEP-P3:
Assimilation of Hydrometeor Mixing Ratios Derived from Dual-Polarimetric Radar Observations with KENDA

UNIVERSITÄT BONN
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METEOROLOGIE

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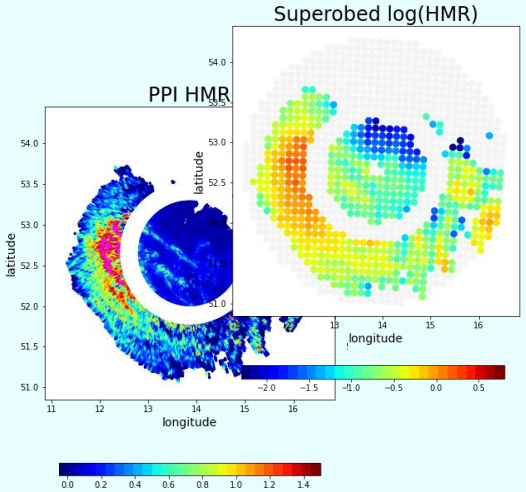
Hypothesis and General Approach

Hypothesis

The assimilation of hydrometeor mixing ratios (**HMRs**) derived from dual-polarimetric radar observations in NWP models improves precipitation forecasts with respect to the assimilation of radar reflectivity (**REFL**)

NWP Model + 

➡ **Improved precipitation forecast**

General Approach

A. Derivation of HMRs from DWD's dual-polarimetric C-band radar network
B. Spatial averaging of derived HMRs to super-observations (**superobing**)
C. Definition of a suitable observation error for data assimilation
D. Assimilation of superobed HMRs with KENDA in DWD's convective-scale model ICON-D2
E. Evaluation of predicted hourly precipitation accumulations with DWD's RADKLIM QPE product (FSS, BSS)

Derivation of HMRs

Consideration of HMRs through liquid water content (**LWC**) and ice water content (**IWC**)

- Hybrid LWC-estimator below melting layer following *Reimann et al. 2021*

  LWC(ZH, ZDR) **if ΔPHIDP<5deg**

  LWC(AH) **if ΔPHIDP>5deg and ZH<45dBZ**

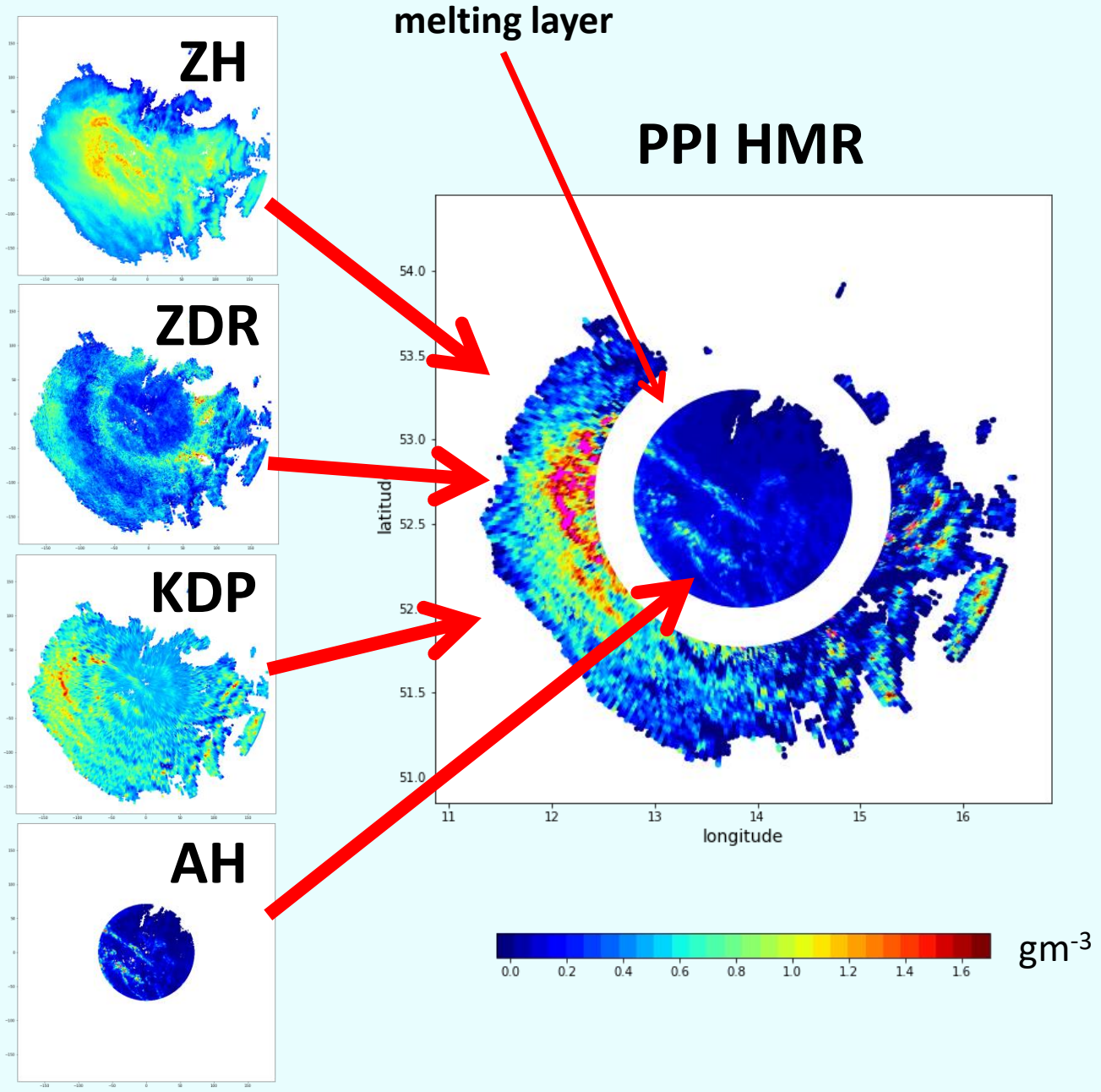
  LWC(KDP) **if ΔPHIDP>5deg and ZH>45dBZ**

- Hybrid IWC-estimator above melting layer following *Carlin et al. 2021*

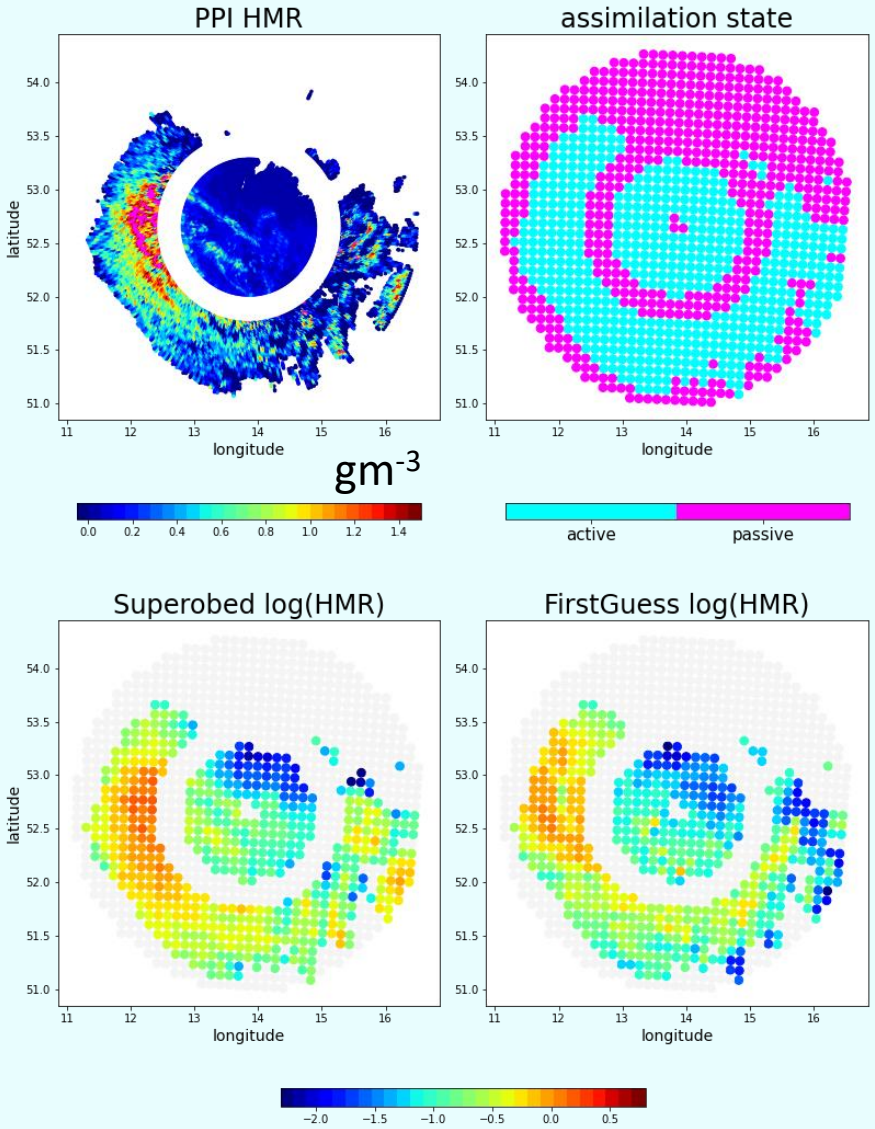
  IWC(ZH, KDP) **if ZDR<0.4dB**
  (Bukovcic et al. 2018, 2020)

  IWC(ZDR, KDP) **if ZDR>=0.4dB**
  (Ryzhkov and Zrnic 2019)

- No HMR-estimation within melting layer!



Preparations for HMR Assimilation



Data preparations

- HMR data have too high resolution (~1 km) compared to ICON-D2 analysis grid (~10 km)
  - ➢ Elevation-wise spatial pie-piece averaging of HMR PPI to Cartesian grid of ~10 km resolution (superobing)
- Superobed HMRs assimilated on log-scale (as REFL at DWD)
- By means of large German DSD data set:
  - ➢ Lower threshold of **-2.3** for log(HMR), all values below assume that value (corr. to 0dBZ threshold at DWD)
  - ➢ Observation error for log(HMR) of **0.5** (corr. to 10dBZ REFL error used at DWD)
- First guess log(HMR) derived from prognostic model variables moist air density (DEN) and rain water/ snow water mixing ratio (QR/QS)

Assimilation Strategy

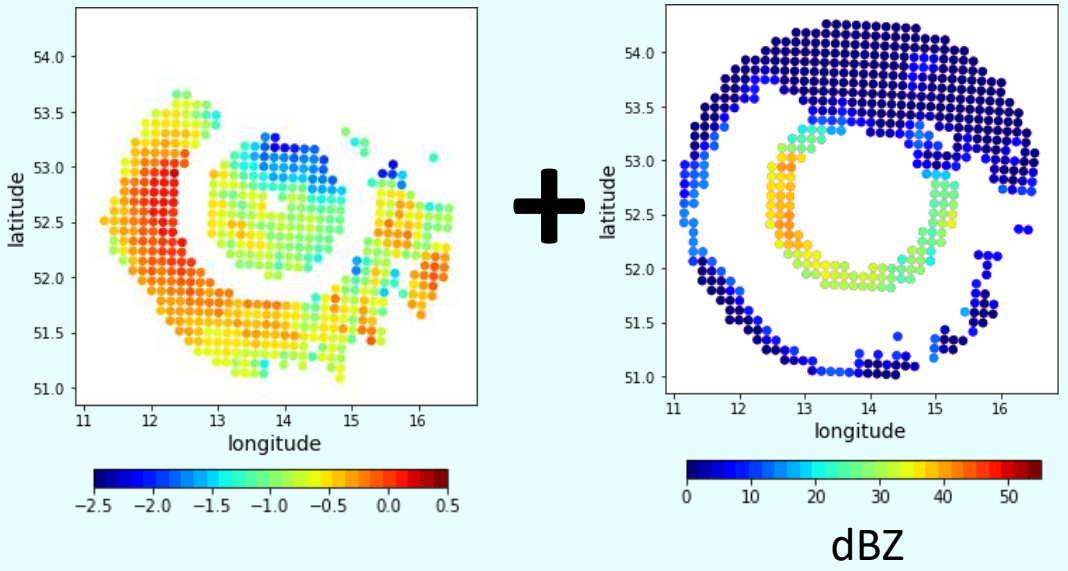
Problems with HMR assimilation:

1. HMR data only usable if of sufficient quality (RHOHV>0.85/0.90)
   - ➢ No HMR data available in low intensity precipitation far from the radar or no-precipitation region
2. HMR estimators LWC(ZH,ZDR) & LWC(AH) contain reflectivity
   - ➢ Assimilation of HMRs on top of REFL not straightforward due to non-zero co-variances

A first solution:

1) Assimilation of HMRs where HMRs are trustworthy + assimilation of REFL where HMRs are not trustworthy
2) Comparison with assimilation of REFL at all superobing positions in 1)

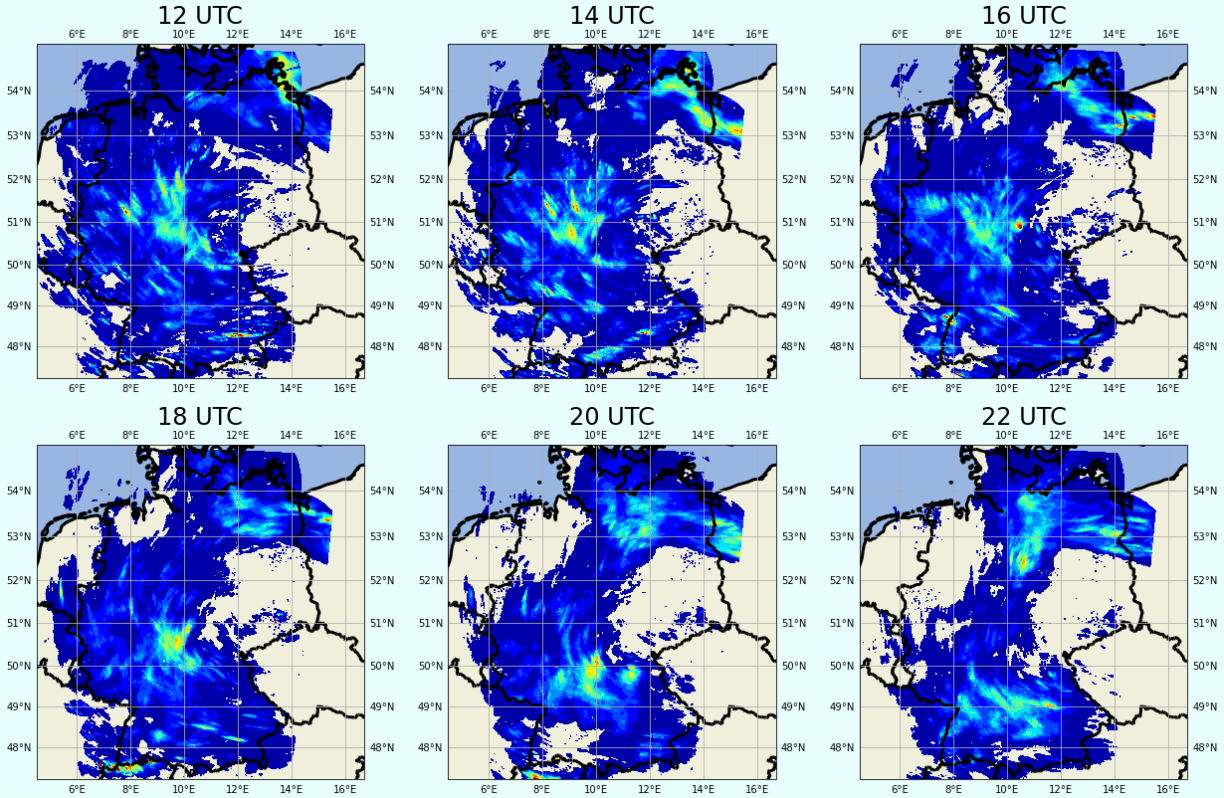
Superobed log(HMR) + **Superobed REFL**



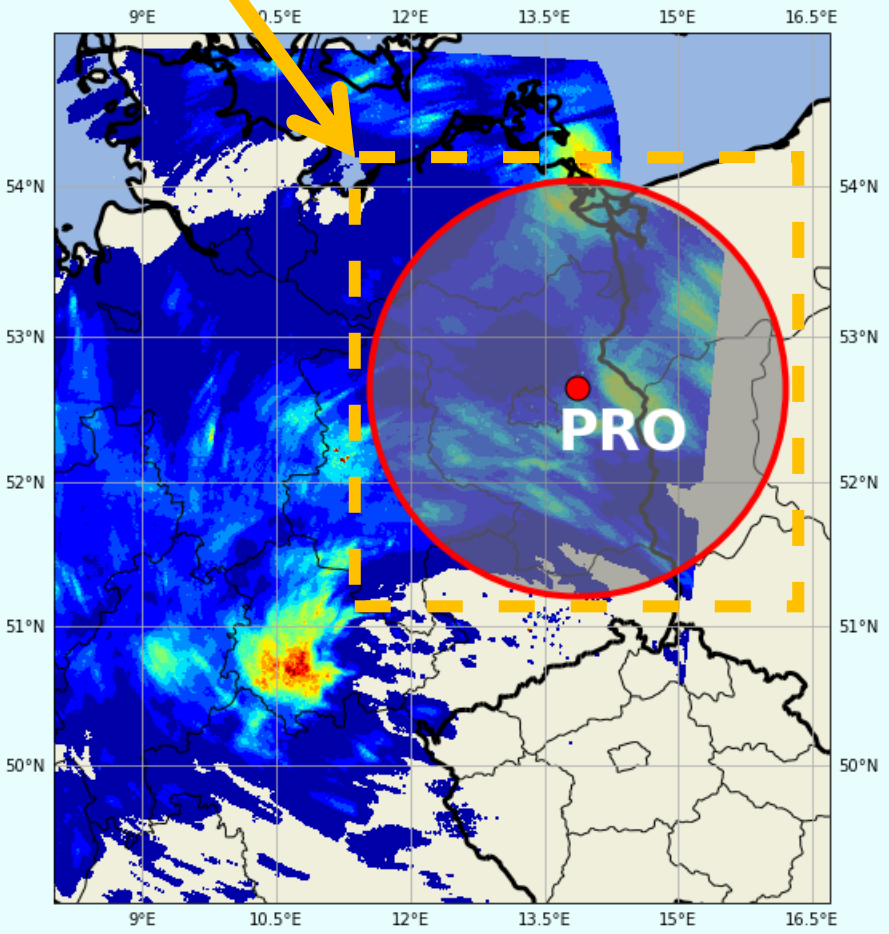
Assimilation Test Case

Considered precipitation event:

- Intense stratiform event on 25-07-2017
- Lasting the full day over full Germany
- Event caused flooding in Bode catchment



Evaluation region



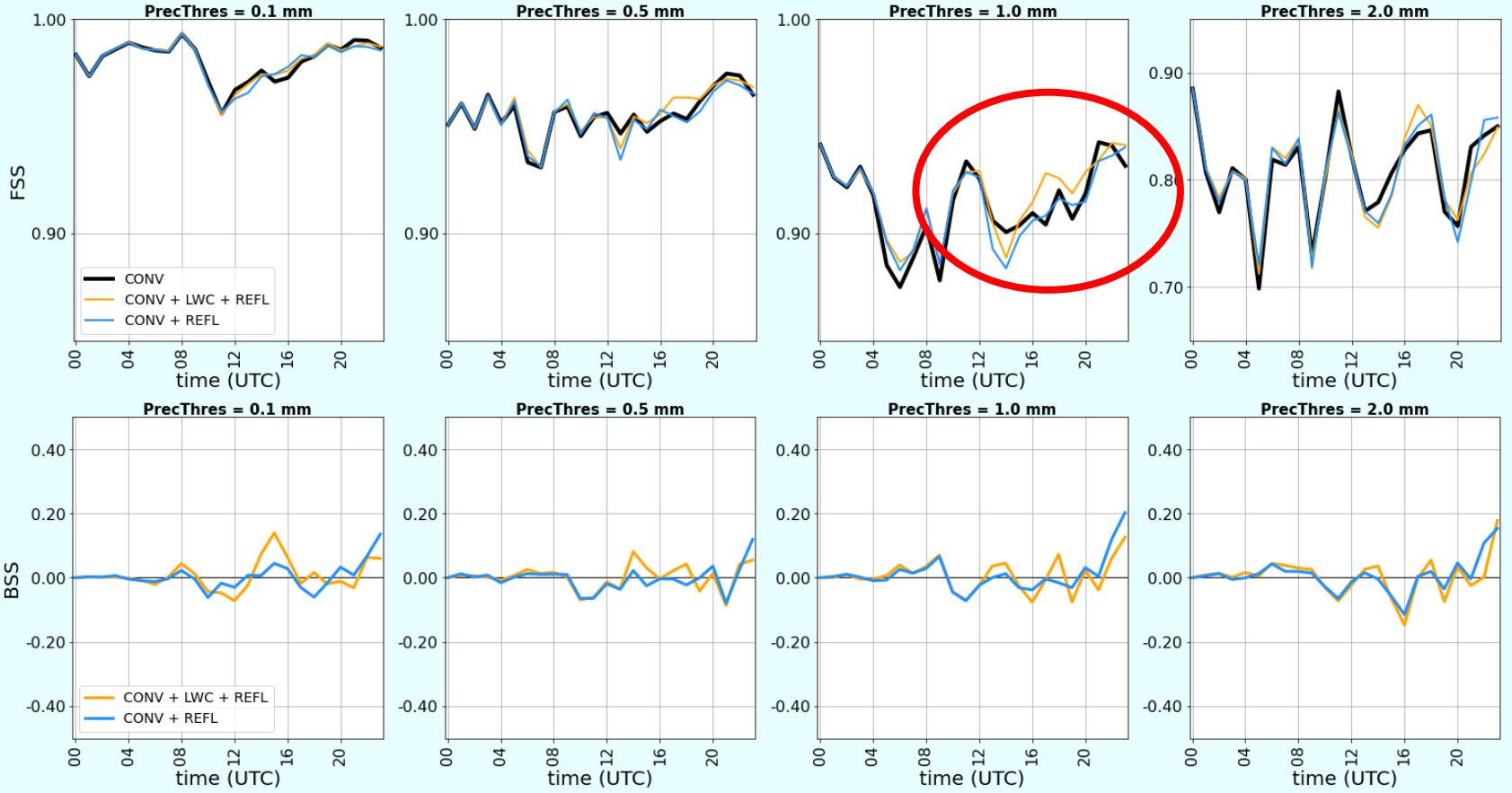
Test assimilation:

- Only ONE radar PRO is assimilated
- Elevations 1.5°, 3.5°, 5.5°, 8.0° and 12.0° are assimilated (as operational for REFL)

Results

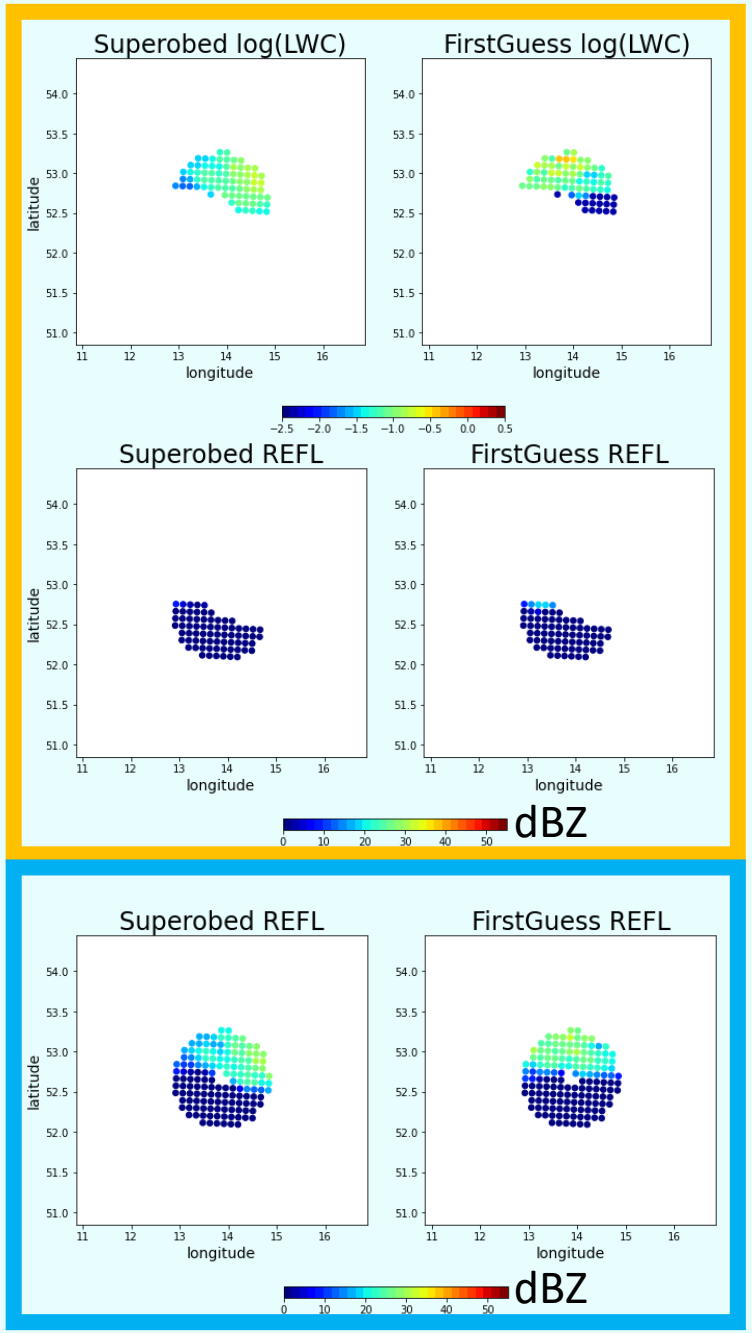
LWC Assimilation

FirstGuess (1h-forecast) evaluation of hourly precipitation accumulation



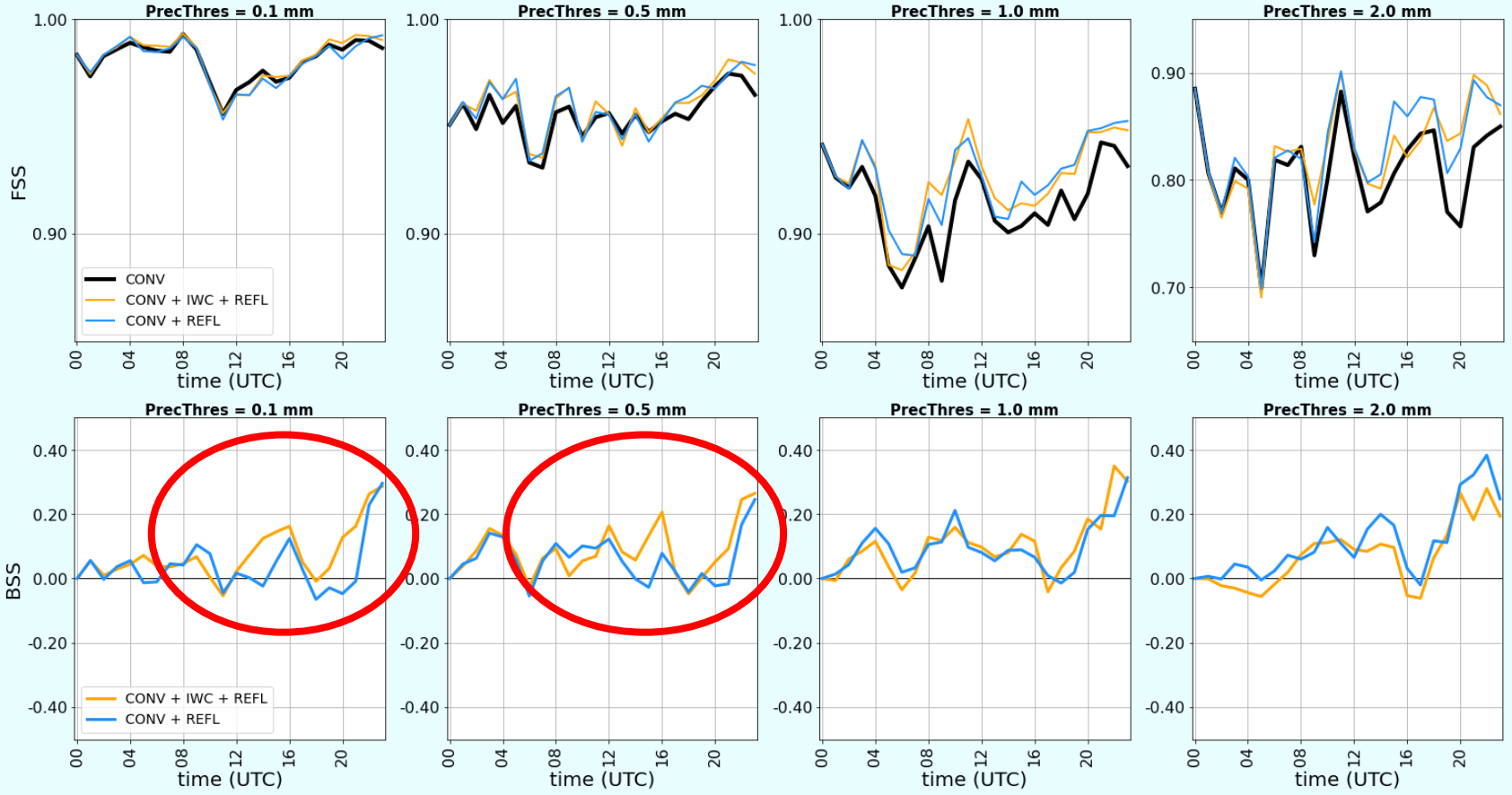
Findings: Both colors comparable; orange better in FSS 0.5/1.0mm in second half of day; orange better in BSS 0.1/0.5mm for some hours in second half of day

1.5° Elevation



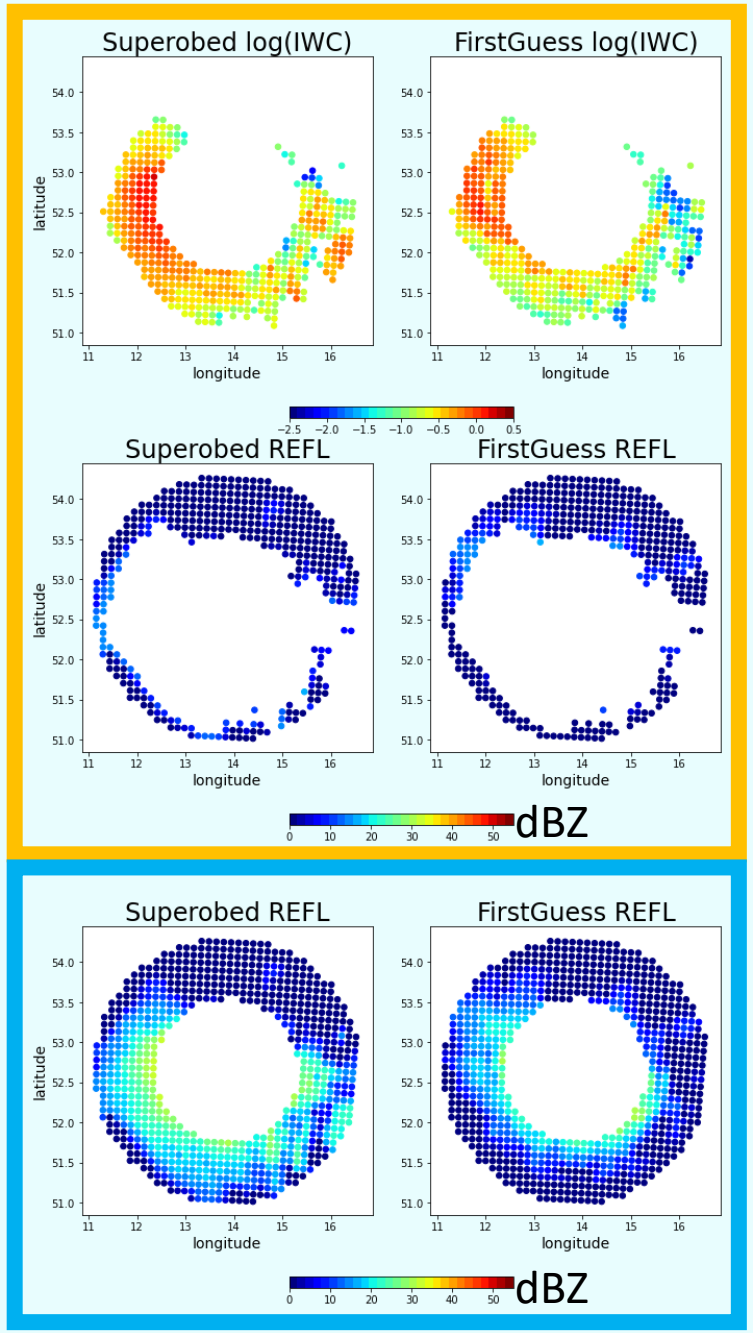
IWC Assimilation

FirstGuess (1h-forecast) evaluation of hourly precipitation accumulation



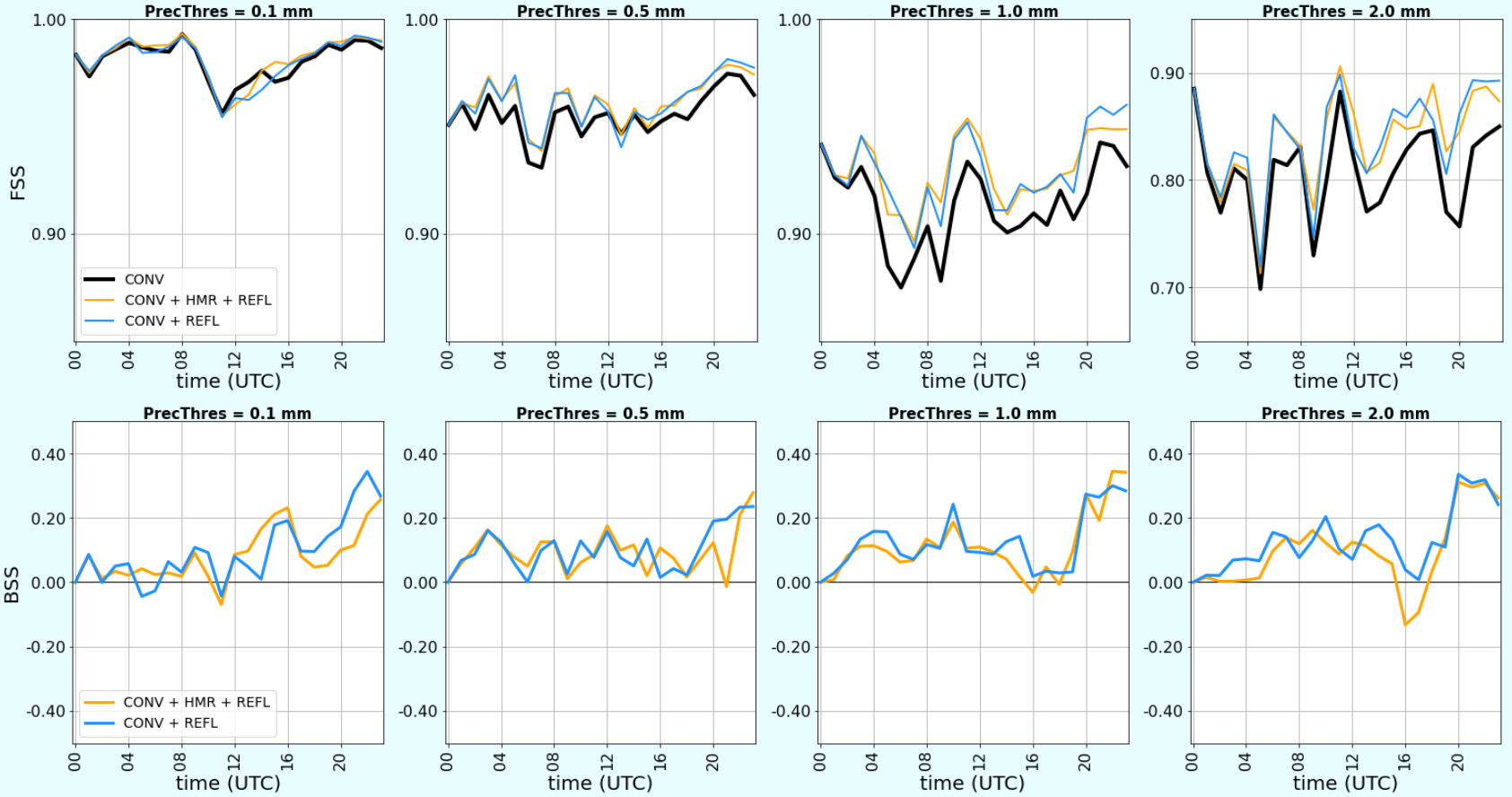
Findings: deterministic FSS comparable for both colors; orange curve BSS better for 0.1/0.5/1.0mm for second half of day; orange curve BSS worse for 2.0mm

1.5° Elevation



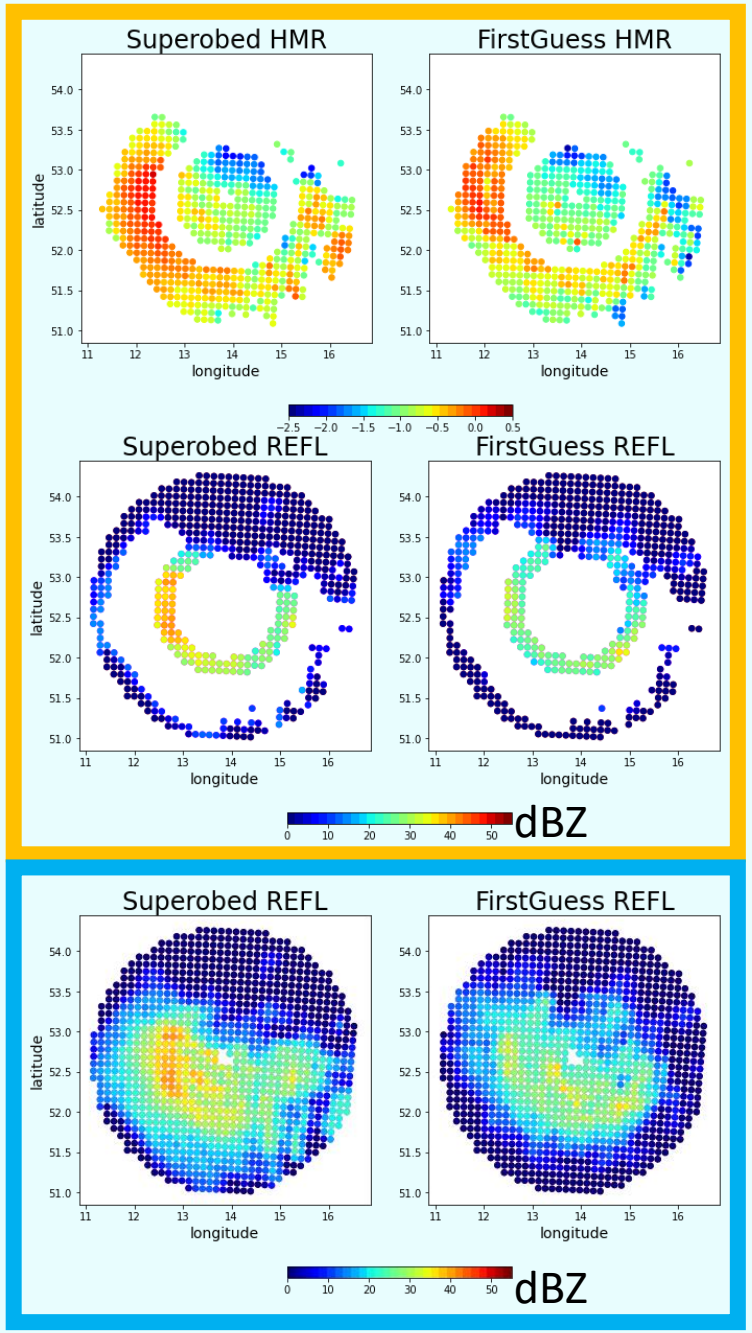
LWC+IWC Assimilation

FirstGuess (1h-forecast) evaluation of hourly precipitation accumulation



Findings: FSS curves comparable; no clear signal for BSS 0.1/0.5/1.0mm; blue curve BSS rather better for 2.0mm

1.5° Elevation



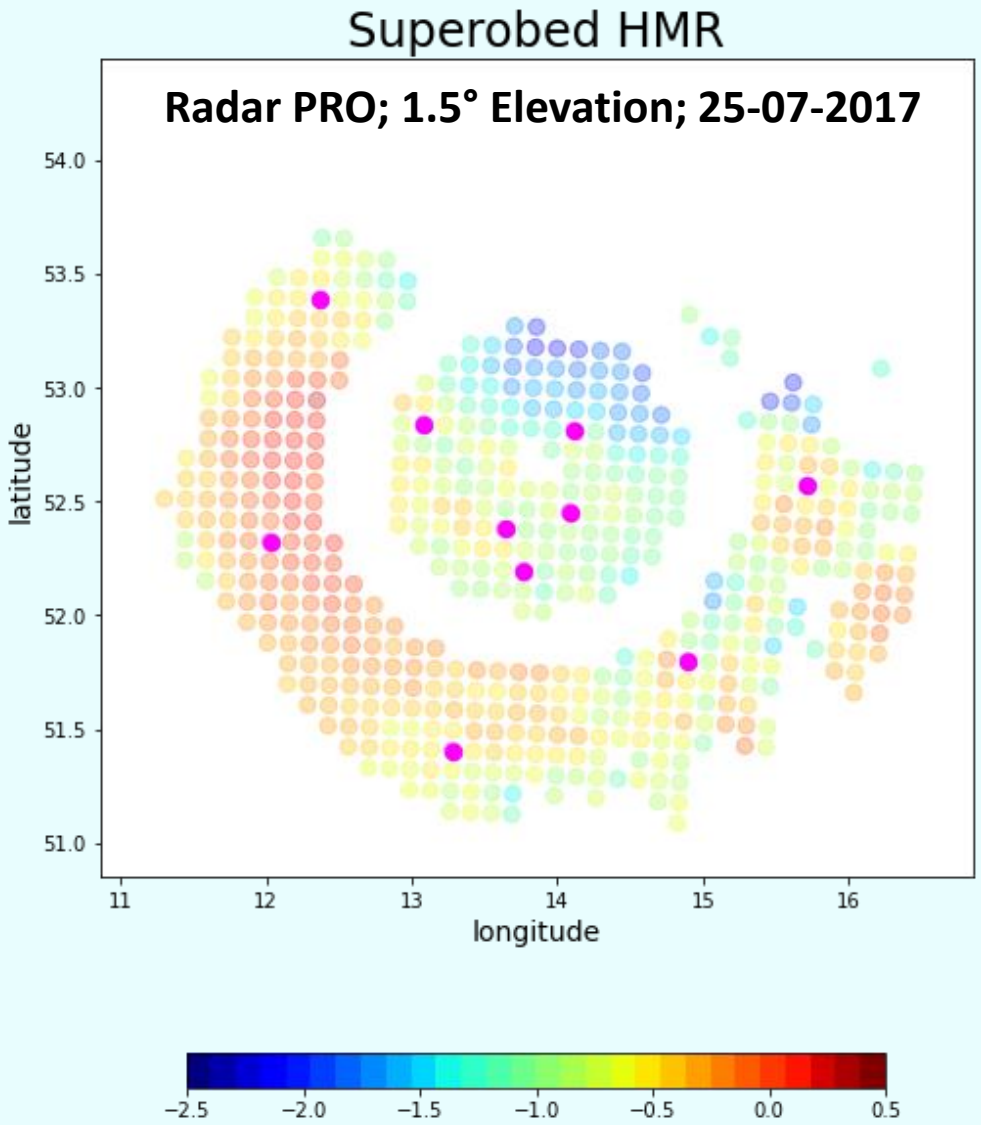
Single-Observation Experiments

Purpose:

- Yields HMR assimilation comparable analysis increments to REFL assimilation?
- If not: there may be analysis increment "jumps" in HMR+REFL assimilation between HMR and REFL superobing points
- Adjustment of chosen observation error may make analysis increments more similar

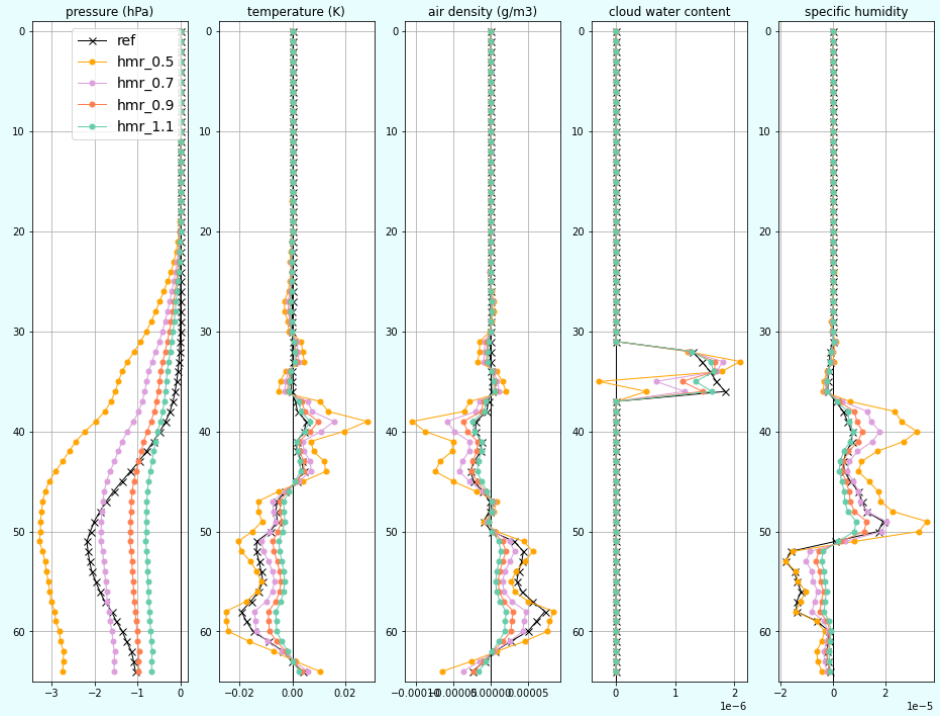
Strategy:

- Assimilation of only one single superobing point of radar PRO; no other observations assimilated!
- 5 Experiments performed for LWC region (magenta dots in right figure below melting layer)
- 5 Experiments performed for IWC region (magenta dots in right figure above melting layer)

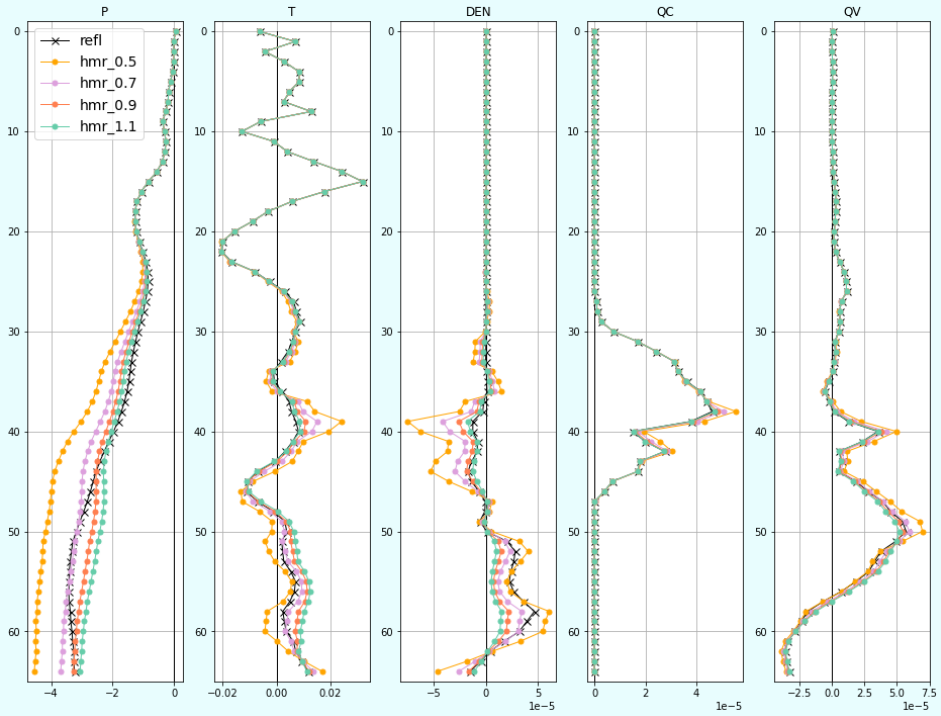


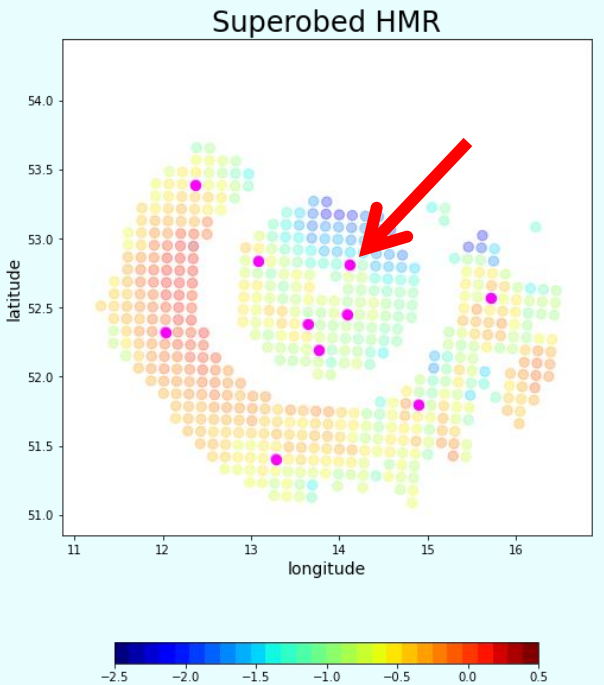
Single-Observation Experiments: LWC Point 1

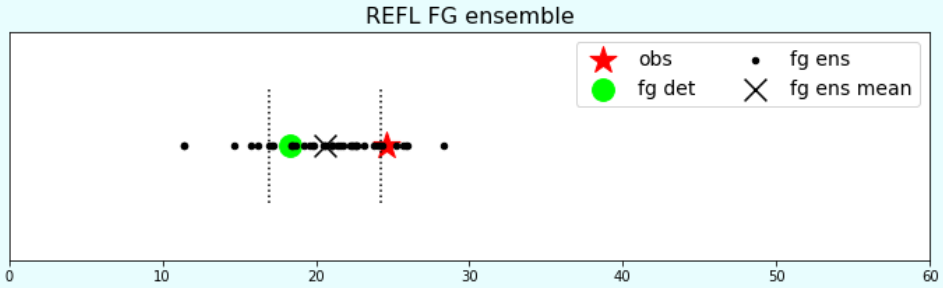
deterministic increment | pro_015_132

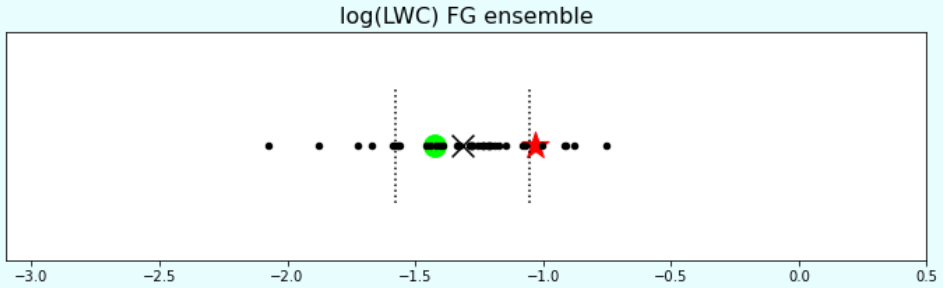


ensemble-mean increment | pro_015_132









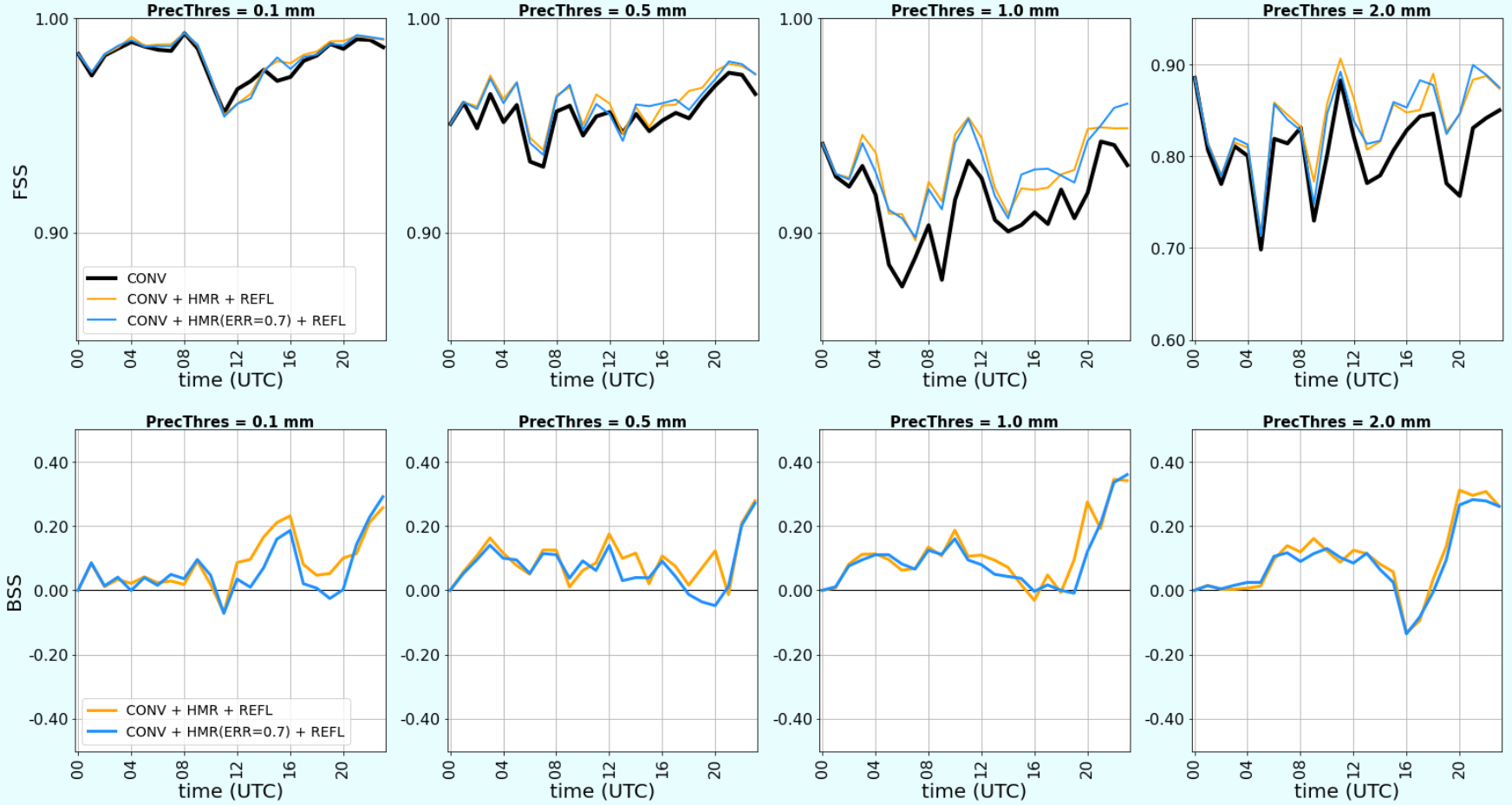
Most suitable error: 0.7

Single-Observation Experiments: Résumé

The single-observation experiments show:

- LWC observation error of 0.5 seems slightly too small
- More suitable value for LWC seems to be **0.7**

- No clear tendency from the 5 IWC-experiments regarding observation error
- The same value of 0.7 as for LWC is chosen for IWC



BUT: Forecast gets worse with adjusted error! ….

Summary & Near Future Work

Summary

- Assimilation of HMRs overall results in similar forecast skills as the assimilation of radar reflectivity
- There is evidence that the assimilation of HMRs can improve precipitation forecasts
- Single observation experiments show:
  A. The chosen observation error for LWC may be too low
  B. It is yet not clear if the chosen observation error for IWC is suitable
  C. Assimilation with an adjusted observation error for LWC & IWC results in worse precipitation forecast

Near Future Work

- Investigation needs to be expanded to more/different radars and synoptic situations to yield a clearer picture of HMR's influence
- Investigation of forecasts with longer lead time (MAIN runs in BACY)

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Thanks for your attention!

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