Improvements on the Assimilation of radar reflectivities (P3)

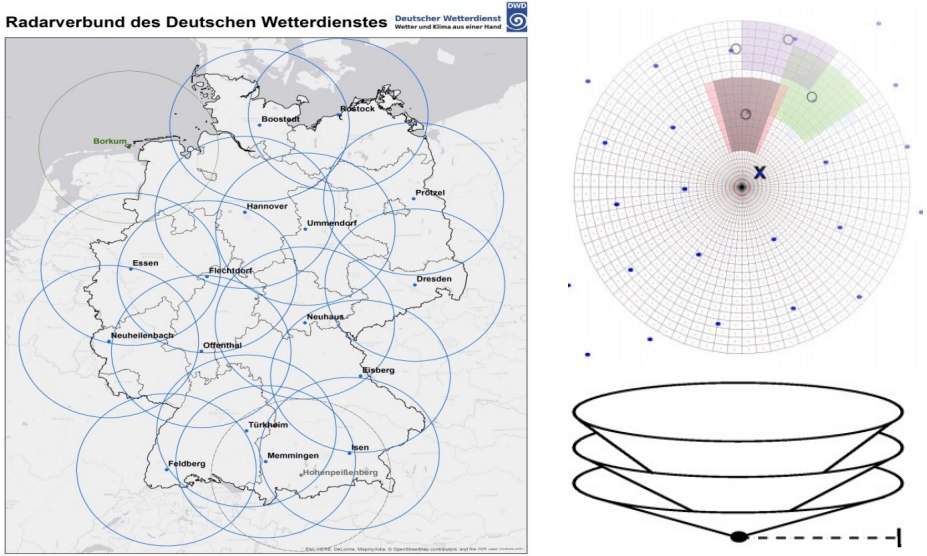
K. Vobig, R. Potthast

RealPEP

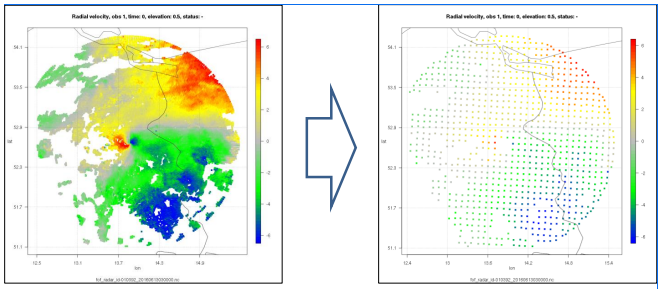
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

Radar Network of the DWD



Radar network of DWD (left); generation of superobservations (upper right); volume scan modus (lower-right)



Original Data *Superobing (~ 10 km)*

- 16 **Dualpolarization Radars** with 3D-Volume scans every 5 minutes
  - radial winds (**RW**)
  - reflectivities (**REFL**)
  - dual polarization moments (**DP**)
- generation of **superobservations**
  - average over specific volume
  - makes handling of large data sets feasible

Radar-related Projects at DWD

- assimilate **2D REFL** based on **latent heat nudging** ✔
- assimilation of **3D-Volume** Radar data via LETKF and EMVORADO (by Blahak and Zheng)
  - assimilation of Radar **RW** ✔
  - assimilation of **REFL** ✔
- assimilation of Radar-derived **objects** and seamless integration of Radar objects into nowcasting and short-range NWP
- **Jana Mendrok** works on extending EMVORADO to simulate **DP** (✔)
  - enables **direct** assimilation of DP
  - alternatively: “indirect” assimilation of DP via derived hydrometeor mixing ratios (→Lucas Reimann)

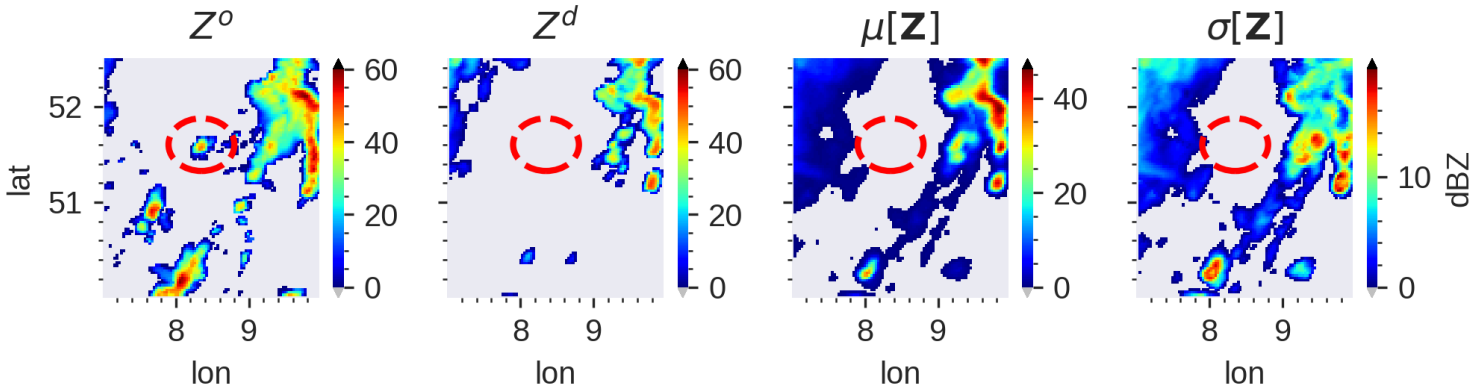
Radar-related Projects at DWD

- assimilation of nowcasted information[(1)]
  - tested assim. of nowcasted information via LETKF (based on oscillator model / Lorenz 63 model system)
  - positive impact of assimilating nowcasted information demonstrated
  - first tests assimilating nowcasted states (REFL) with KENDA
- overall topic here: improve assimilation of REFL via targeted covariance inflation[(2)] (TCI)

[(1)]: R. Potthast et al., MWR, (2022), accepted for publication
[(2)]: K. Vobig et al., https://doi.org/10.1002/qj.4157, (2021)

TCI – Motivation & Basics

TCI: Motivation



- even for large discrepancies between observed/simulated REFL LETKF might still produce small increments
- problem: very small ensemble spread $\sigma[\mathbf{Z}] \ll 1$
- approach: increase spread via (additive) targeted covariance inflation (TCI)

TCI: Basics

- assume correlation of Z with model variable Ψ

$$Z_i'(\mathrm{r}) = Z_i(\mathrm{r}) + \alpha_{\mathrm{TCI}}\left(\Psi_i(\mathrm{r}) - \mu[\Psi(\mathrm{r})]\right)$$

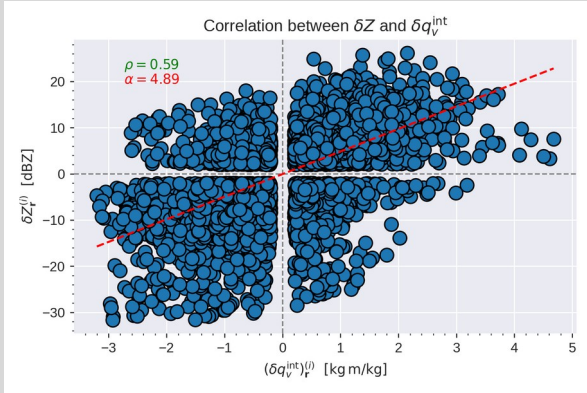
- α_{TCI} serves as scaling factor for “strength” of TCI
- using vertically integrated q_v for ψ

$$q_v^{\mathrm{int}}(\lambda, \mu, l_0, l_1, \beta) \equiv \int_{\mathcal{A}} \mathrm{d}\lambda' \mathrm{d}\mu' \; f_\beta(\lambda' - \lambda, \mu' - \mu) \int_{h(l_0)}^{h(l_1)} q_v(\lambda', \mu', h)\mathrm{d}h$$

- overall idea:
  - spread of q_v “imprinted” onto spread of Z
  - assim. “favors” members with more humidity: additional q_v (q_r,q_s,...) increments via corr.
  - model generates reflectivity (possibly...)

integral details

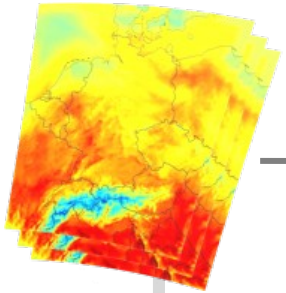
- β: strength of running mean factoring in time uncertainty
- l_0, l_1, β determined via optimization of corr. coefficient

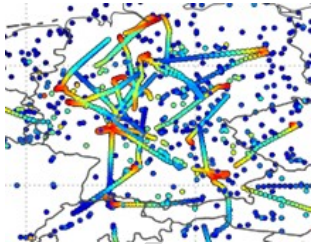


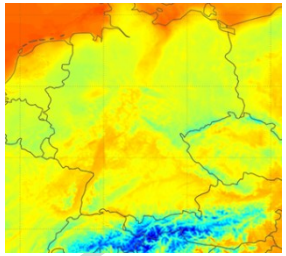
corr. coefficient

- several thresholds for data filtering and process determination
- α_{TCI} ⇝ “slope” of correlation

NWP: Assimilation Cycle





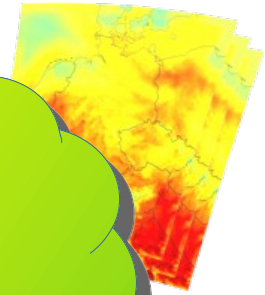


$$\frac{\partial v_n}{\partial t} + (\zeta + f)v_t + \frac{\partial K}{\partial n} + w\frac{\partial v_n}{\partial z} = -c_{pd}\theta_v\frac{\partial \pi}{\partial n}$$

$$\frac{\partial w}{\partial t} + \vec{v}_h \cdot \nabla w + w\frac{\partial w}{\partial z} = -$$

$$\frac{\partial \rho}{\partial t} +$$

$$\partial \rho$$



TCI algorithm
"lives" here

6 hours 1 day 1 week

FC FC FC FC

Initial state

Obs Ana Model

Data Assimilation CORE

6 hours 1 day 1 week

FC FC FC FC

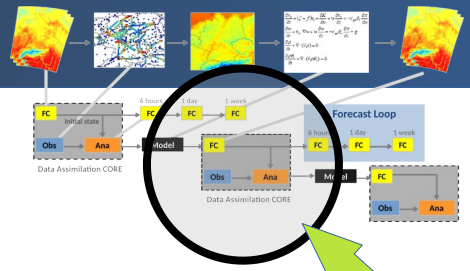
Obs Ana Model

Data Assimilation CORE

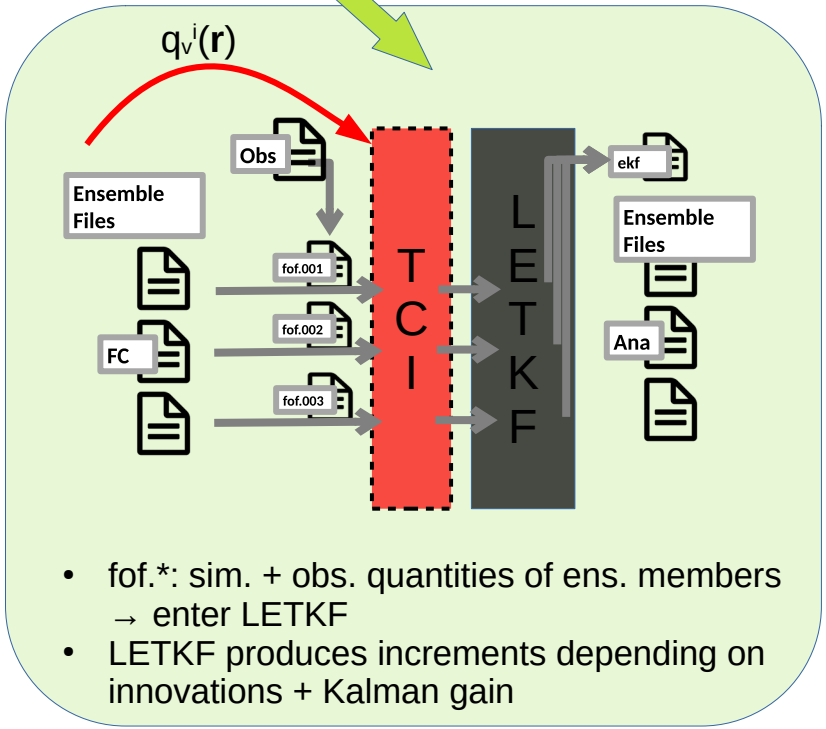
FC

Obs Ana

TCI: Technical Steps

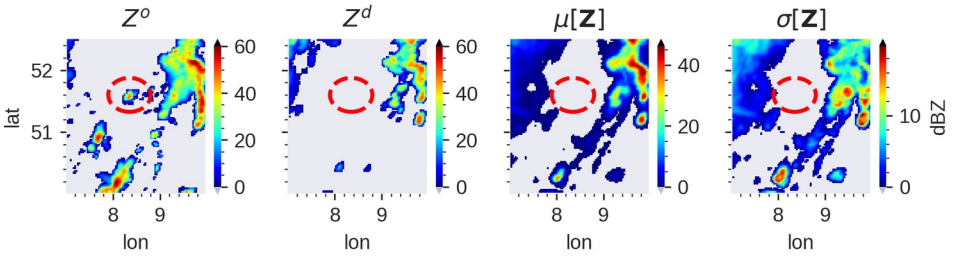


- implemented via **pre-processing feedback (fof) files** before entering the **LETKF**
- apply TCI algorithm and **alter simulated Z** in feedback files
- each member processed separately
- use altered feedback files as input for LETKF



TCI – Single-Observation Experiments

Single-Observation Experiment



- study effects of TCI in single-observation (SO) experiment
  - assimilating only single reflectivity at (51.60°,8.35°,1035m) for 2019-06-03 at 12 UTC
  - data from Radar station Flechtdorf at elevation angle 0.5°
  - other observation set to ‘passive’ within feedback files
- relevant changes to “default” BACY settings
  - obs. error reduced to 2 dBZ
  - vertical localization increased to v_{loc}=10.3
  - no multiplicative cov. inflation / no relaxation to prior perturbation

SO Exp.: Correlations and Increments

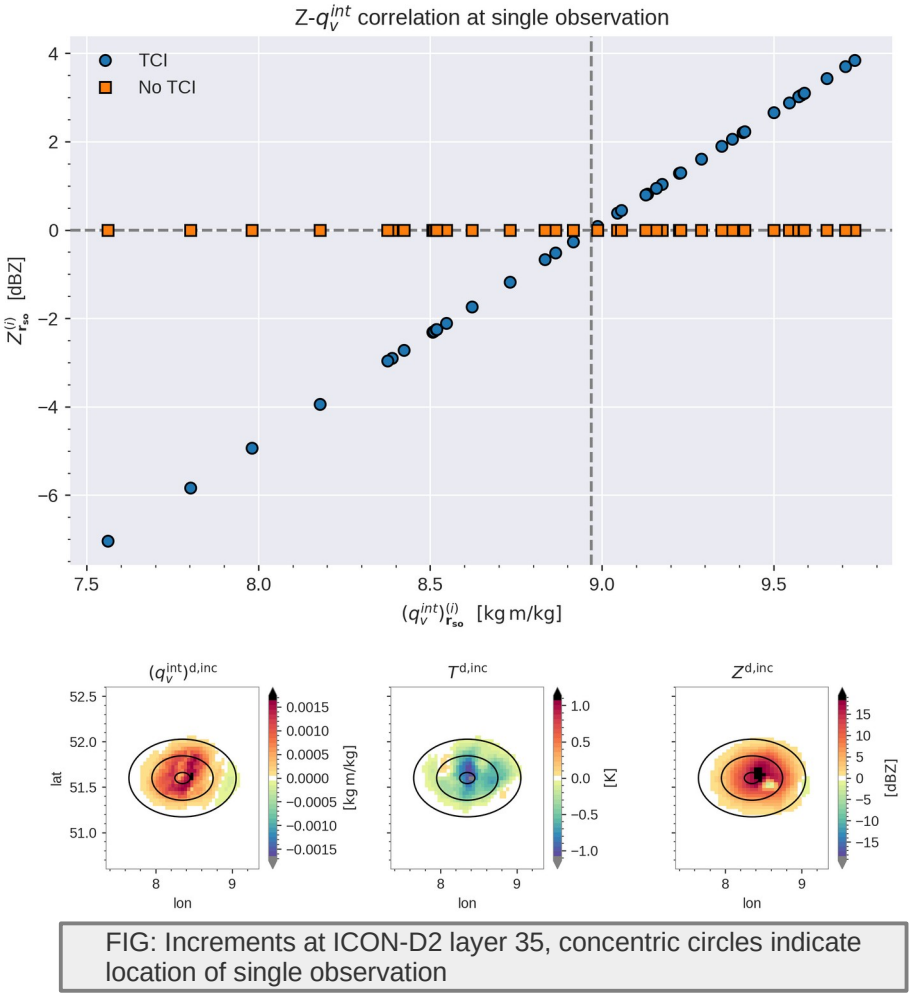
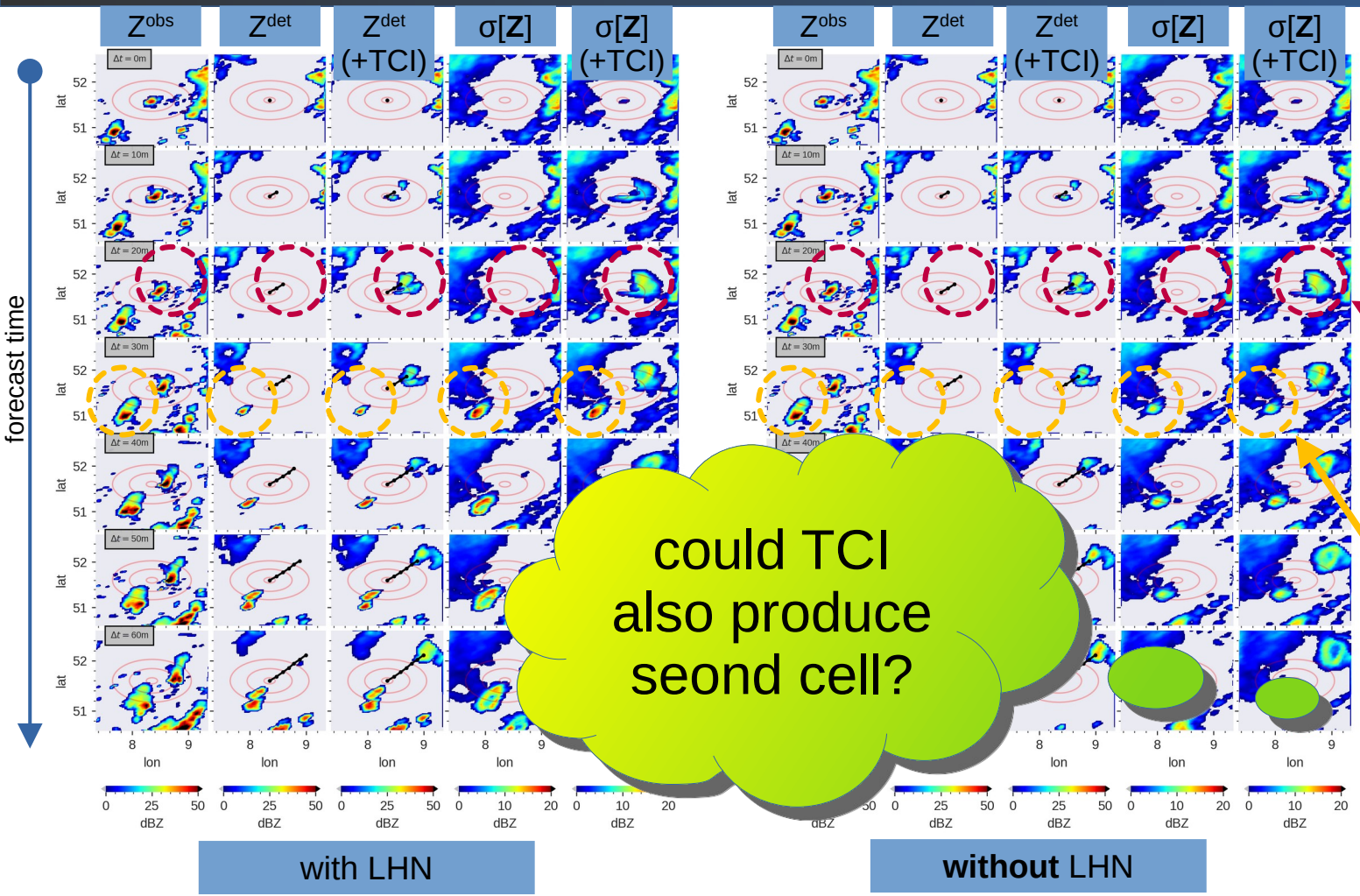


FIG: Increments at ICON-D2 layer 35, concentric circles indicate location of single observation

- without TCI: no spread in Z at single observation at all
- with TCI: spread in Z is produced
  - result: analysis produces increments for Z (linearized) and q_v

SO Exp.: Evolution of REFL



- ass. at 12 UTC followed by 1h free forecast
- “new” cell emerges consistent with observed cell
- second cell only with LHN (out of spatial reach of TCI)

TCI – Beyond Single-Obs Exps.

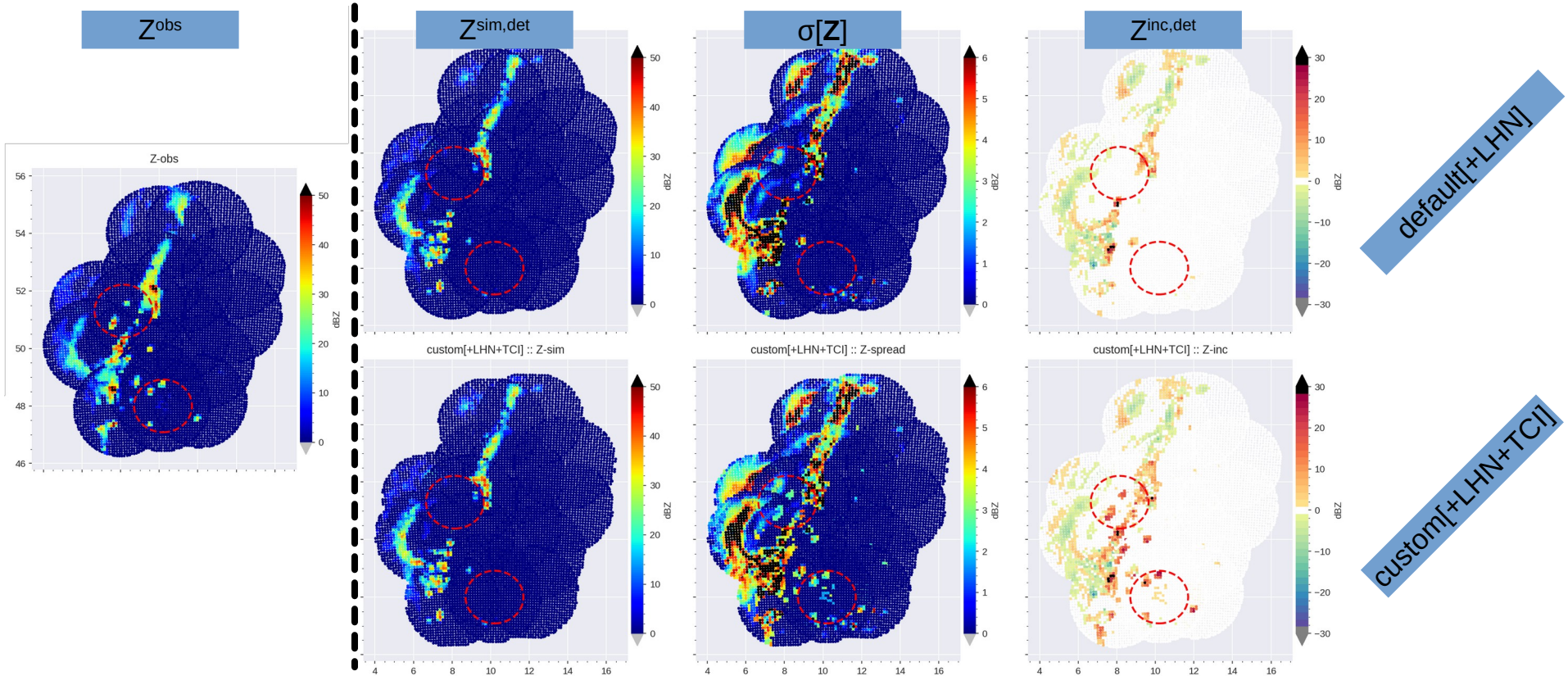
Multi-Observation TCI

- previously: studied effects of TCI in SO experiments
- now: study effects of TCI applied to all radar data
- as before: TCI is applied via modification of feedback files before entering LETKF machinery
- prerequisites and effects of TCI application at **r**:
  - discrepancy between observed/simulated REFL
  - small ensemble spread
  - modify Z for all ensemble members via integrated q_v correlation

BACY Configurations

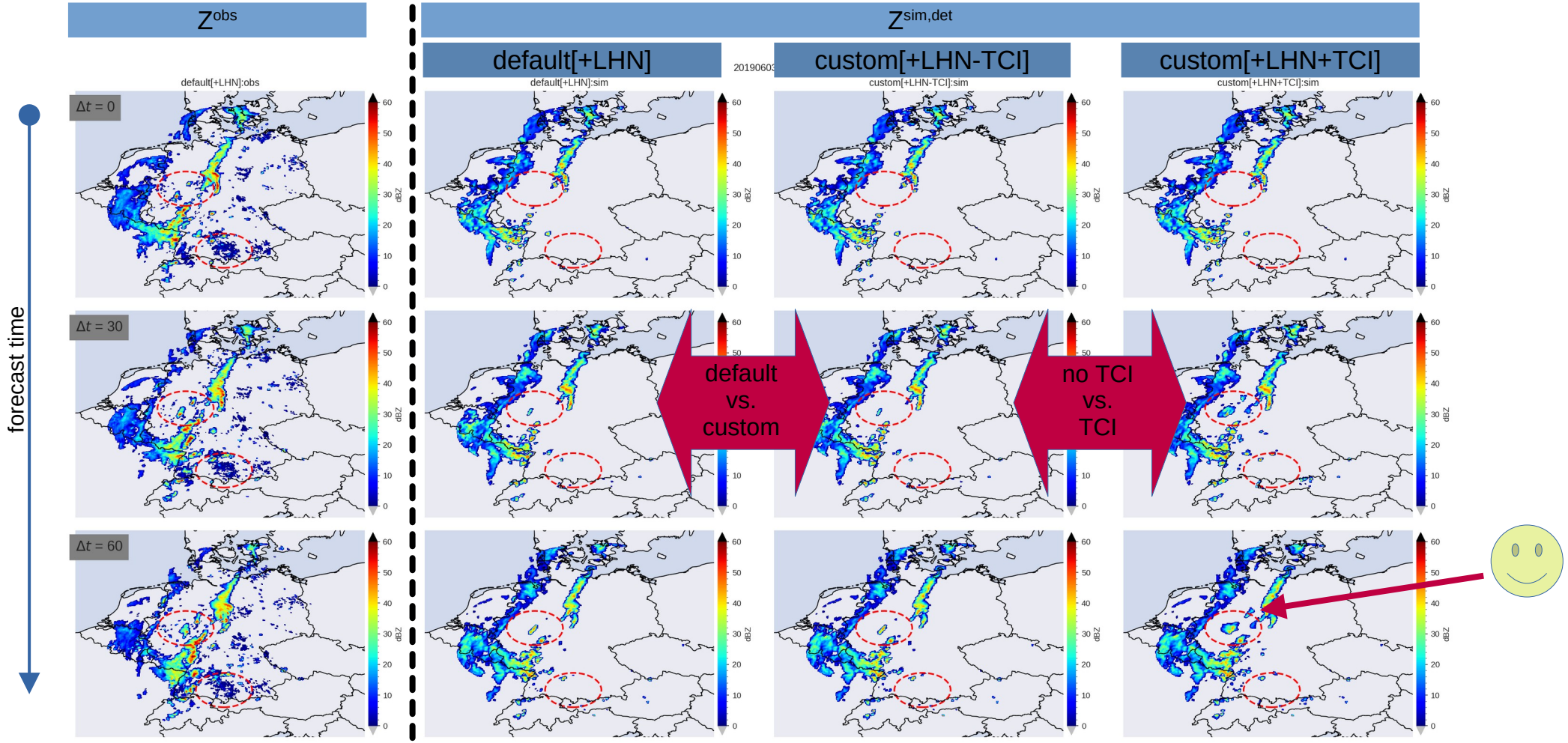
- “default”: (mostly) default BACY configuration
  - assimilation of conv. data and REFL (at several elevations)
  - LHN may be turned on/off [±LHN]
  - assimilation takes place on 2019-06-03 at t0 = 12 UTC
- “custom”: minor changes w.r.t. default configuration
  - serves as reference for assessing direct impact of TCI
  - increased first-guess check for REFL
  - TCI may be turned on/off [±TCI]

REFL: Assimilation

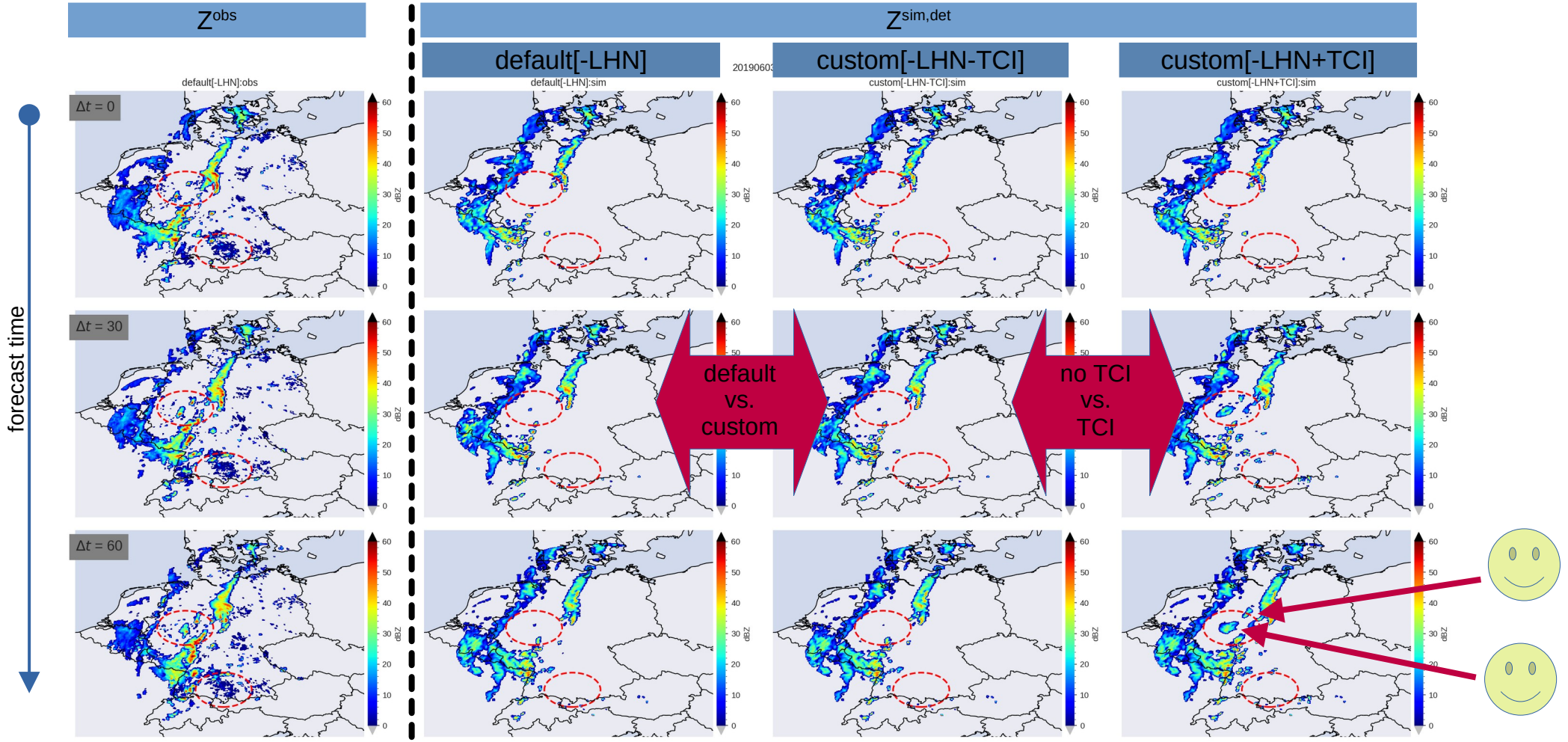


- TCI produces spread → additional increments for REFL

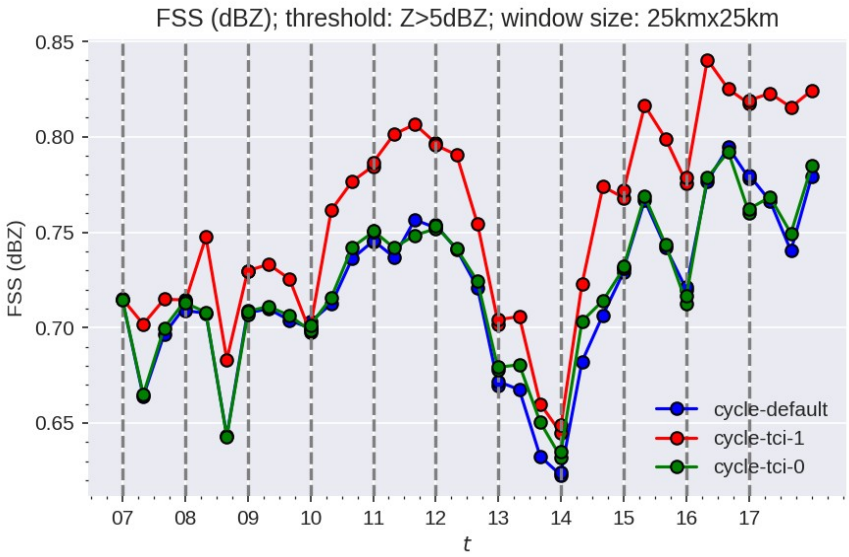
Evolution of REFL (with LHN)

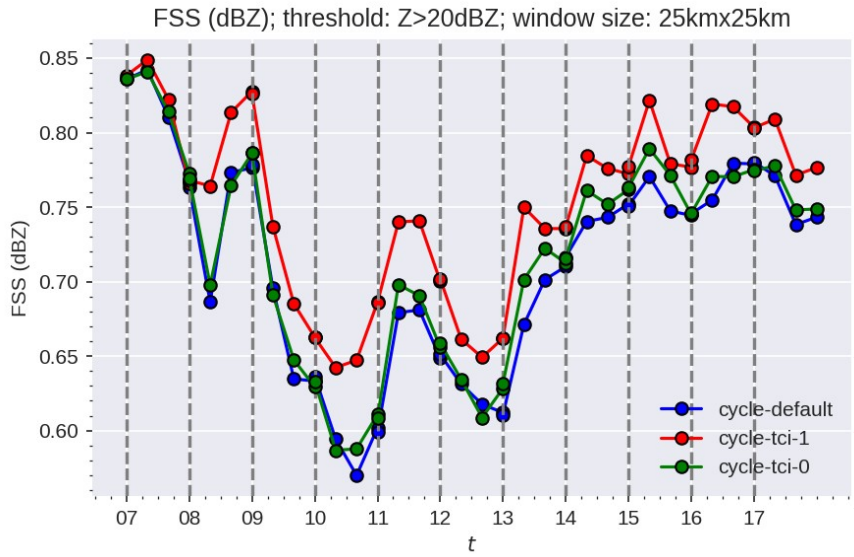


Evolution of REFL (without LHN)



Verification: Fractional Skill Score





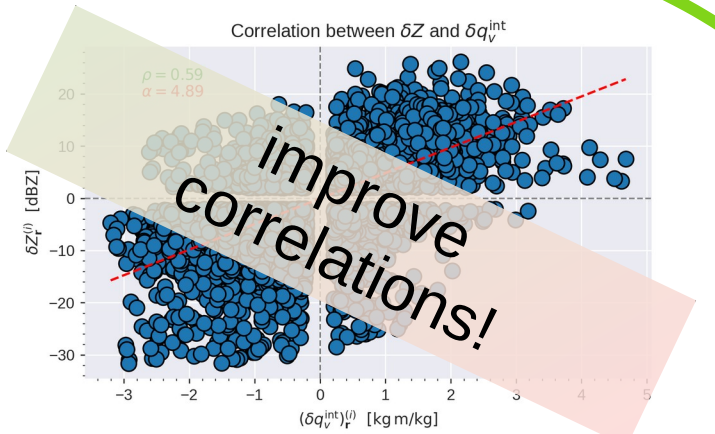
default[+LHN]
custom[+LHN+TCI]
custom[+LHN]

- performing cycle starting at 7 UTC
- TCI applied at each assimilation (hourly)
- FSS for two dBZ thresholds shown

positive impact of TCI on FSS

Summary and Outlook

- overall, TCI results are promising
  - production of “new” cells (consiste
  - positive impact on FSS
- AIREP/TEMP observation error
  - negative impact of TCI
  - contribution (positive/negative) to sta ent
  - time/spatial/process dependence of
- optimize the capturing and use of correlations of TCI method
  - better data filtering/pre-processing necessary
  - towards more “process-aware” TCI



Outlook

- assim. of information on convective initiation
  - employ total column water vapor obtained from satellite data
  - also apply TCI-like approach (?)
- assim. of data from Commercial Microwave links (CMLs)
- assim. of nowcasted states
  - employ advanced nowcasting for assim. nowcasted states (REFL) with KENDA

Thank you for your attention!