OBSERVATION IMPACT ON THE CONVECTION-PERMITTING SCALE USING AN OBSERVATION-BASED VERIFICATION METRIC

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INTRODUCTION

Goal:

- Impact of observations in the pre-operational regional LETKF DA system (KENDA)

Current improvement:

- Verification with independent observations (instead of the model analysis)

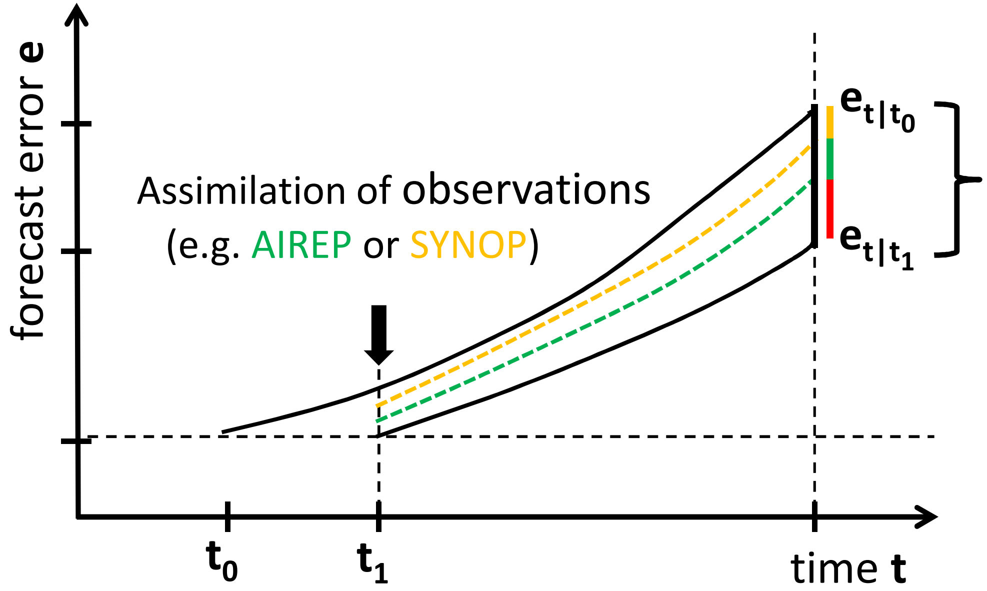
Why observation impact?

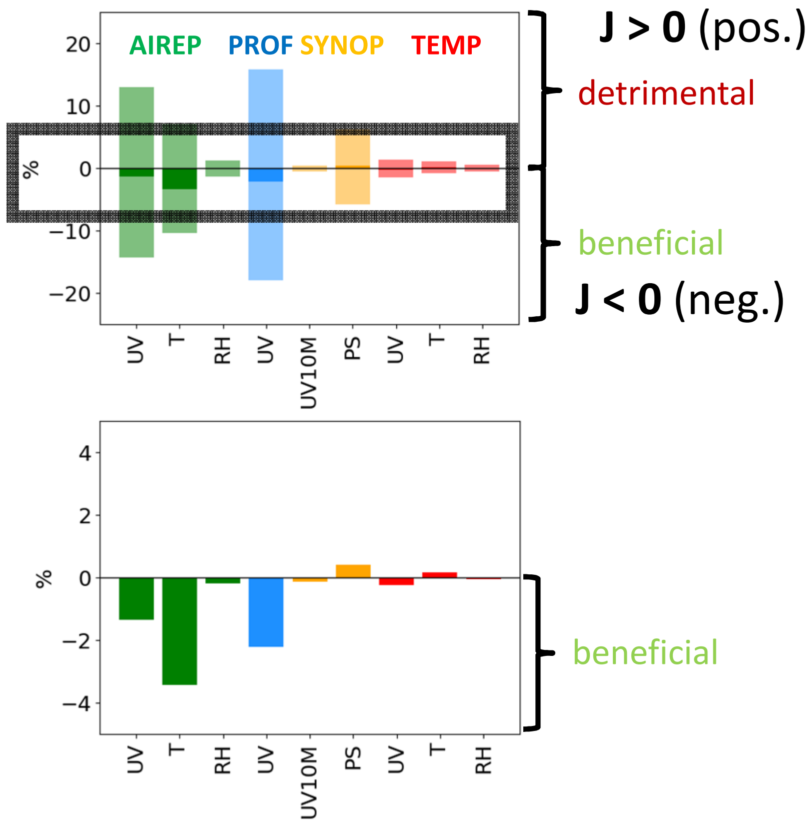
- Detect issues with individual observations
- Optimizing the observing, data assimilation and forecasting system

Why ensemble approximation of observation impact?

- Re-use of COSMO-KENDA ensemble
- Cheaper than data denial

METHOD





Goal: Contribution of different observations to the reduction of forecast error

METHOD

$$J(\boldsymbol{d}') \approx \frac{2}{N_e - 1} \boldsymbol{e}_f^d \cdot \boldsymbol{Y}_f^d \left(\boldsymbol{Y}_a^d\right)^T \boldsymbol{R}^{-1} \boldsymbol{d}'$$

J : Observation Impact

N_e: Number of ensemble member

$\boldsymbol{Y}_f^d$: Forecast ensemble in obs . space

$\boldsymbol{Y}_a^d$: Analysis ensemble in obs. space

$\boldsymbol{R}$: Observation error covariance matrix

$\boldsymbol{d}$: Innovation vector $\boldsymbol{d} = \boldsymbol{y_o} - \boldsymbol{y_b}$

$\boldsymbol{e}_f^d$: Forecast error

(Following Kalnay et al 2012)

(Reformulated by Sommer & Weissmann 2016)

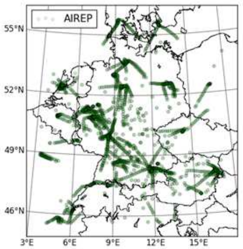
Method

$$e_f^d = \overline{H_{veri}\left(x_f^d\right)} - y_{veri}$$

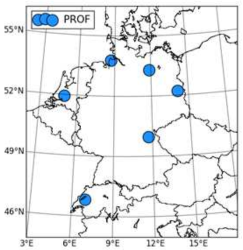
- e_f^d : Forecast error
- H_{veri} : Observation operator into verification space
- $x^d{}_f$: Model equivalent for verification
- y_{veri} : Observation used for verification

Conventional (UV/ T/ RH)

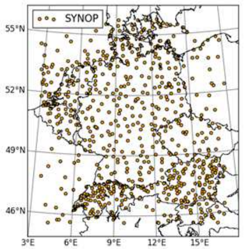
AIREP



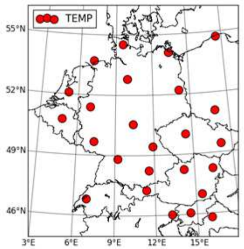
PROF



SYNOP

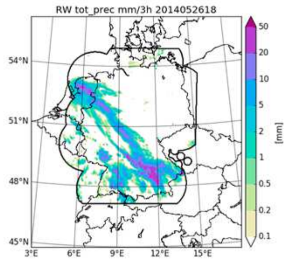


TEMP

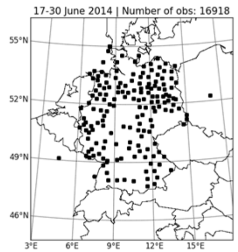


Remote Sensing (TOT_PREC)

Precipitation



GNSS Humidity

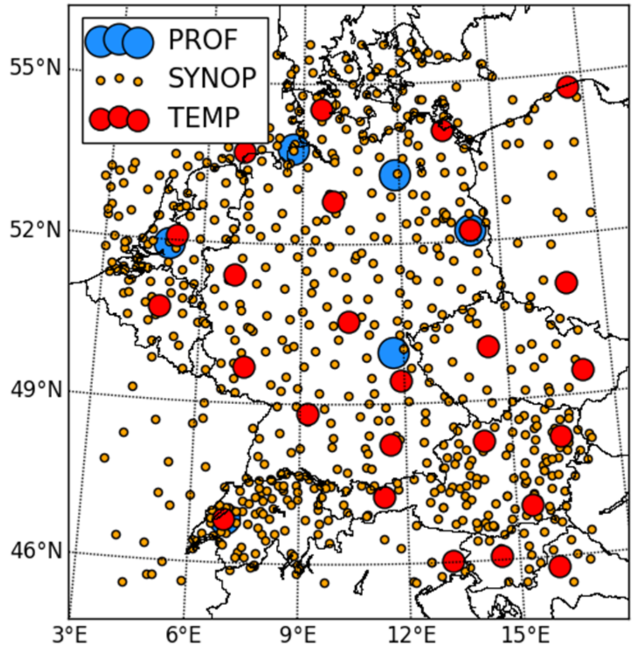


EXPERIMENTAL SETUP

Period:
- 36 days (288 cycles): 26. May – 30. June 2016
- Summer period with high impact weather events

Model:
- Regional COSMO-KENDA (LETKF) ensemble system of DWD *(40 members, 3h forecasts)*

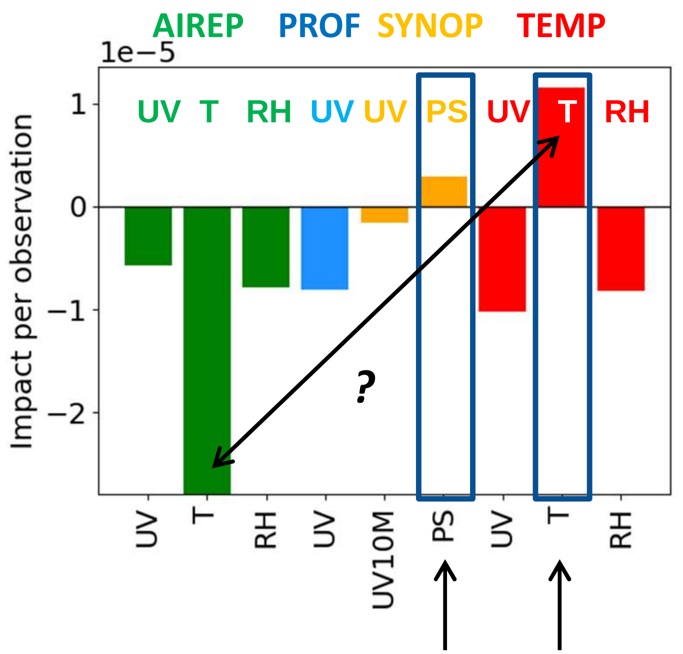
Setup:
- 1-day spin up & 3h-cycling
- Verification window: 1-3 h after analysis
- Operational setup of DWD except:
  - No adaptive localization
  - Inflation: With RTPP, without RTPS



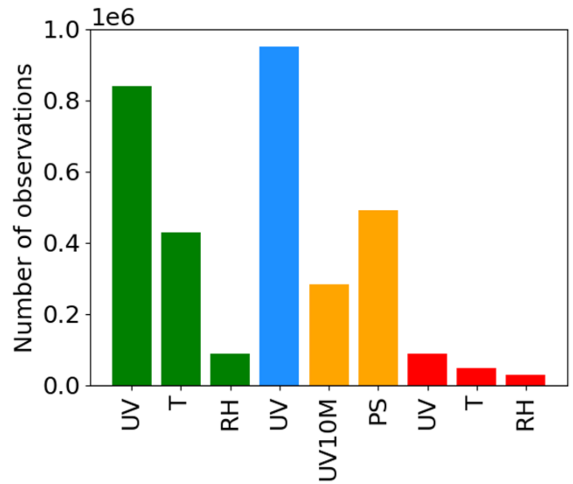
Stations of different observation types in the COSMO-DE domain

AVERAGE IMPACT PER OBSERVATION

Verification with conventional observations



Number of assimilated observations



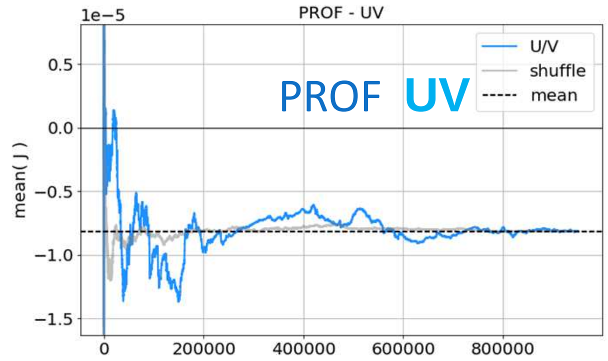
detrimental impact?

Questions:

- How reliable are the results? Sample size?
- Large differences between AIREP T and TEMP T?
- Detrimental impact for SYNOP PS and TEMP T?

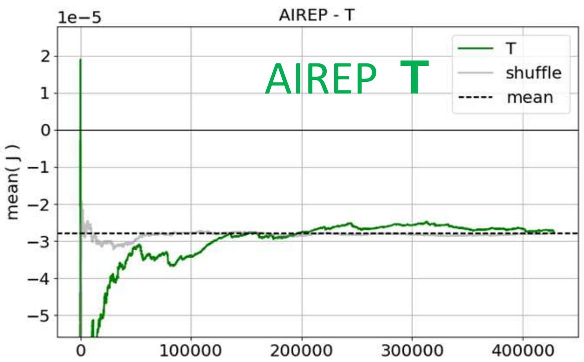
RELIABILITY

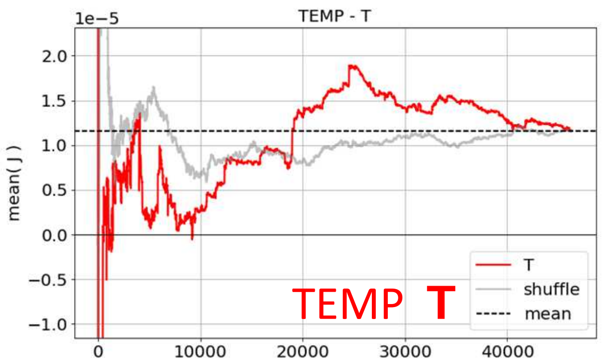
Ordered partial sum - (colored solid line)
Randomized partial sum - (gray solid line)
Mean impact - (dashed line)

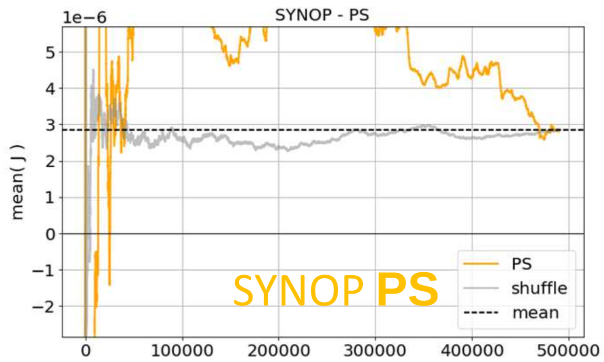


Questions: How reliable are the results? Sample size?

Answer: Sample size is large enough

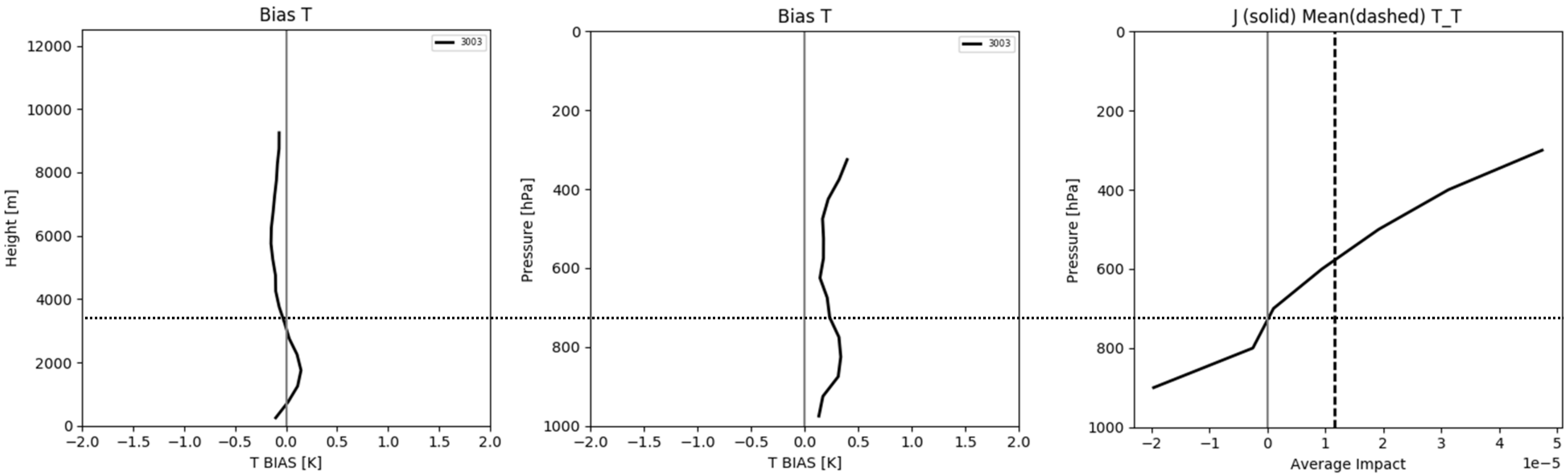






BIAS AS FUNCTION OF HEIGHT

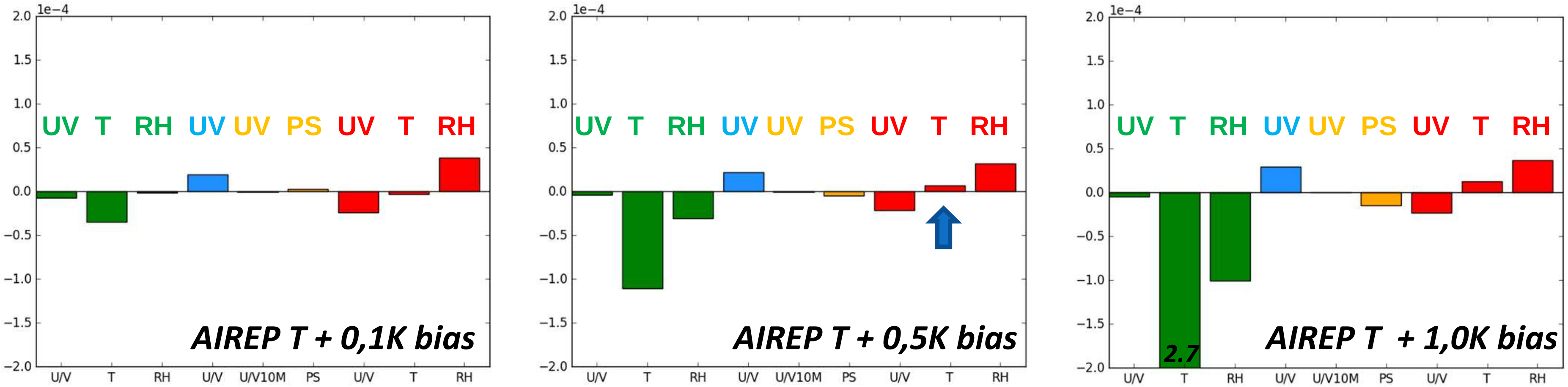
AIREP T bias | **TEMP T bias** | **TEMP T Impact**



Questions: Large differences between AIREP and TEMP T?

Answer: Opposite temperature biases for AIREP T & TEMP T affect impact estimation

SENSITIVITY TO BIASES

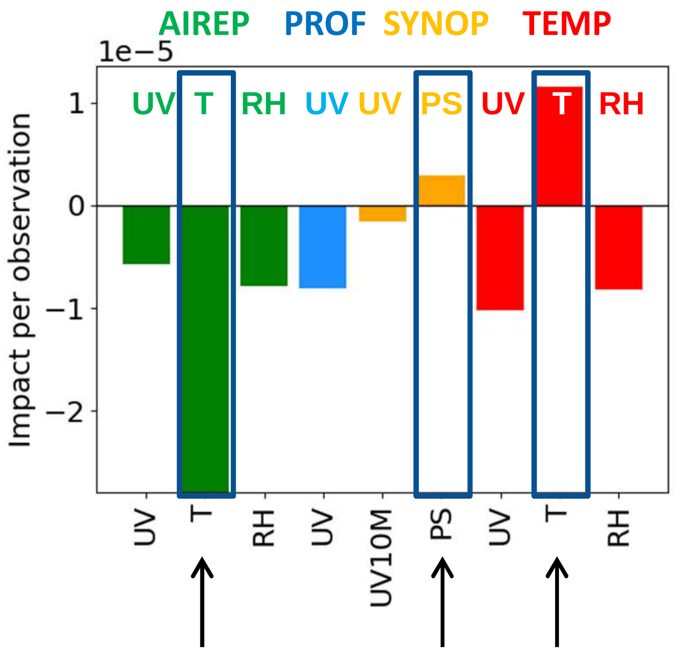


Sensitivity of the estimated observation impact to a simulated AIREP temperature bias:

→ Biases can affect impact approximation (valid for any kind of verification)

Average Impact per Observation

Verification with conventional observations



Results affected by biases

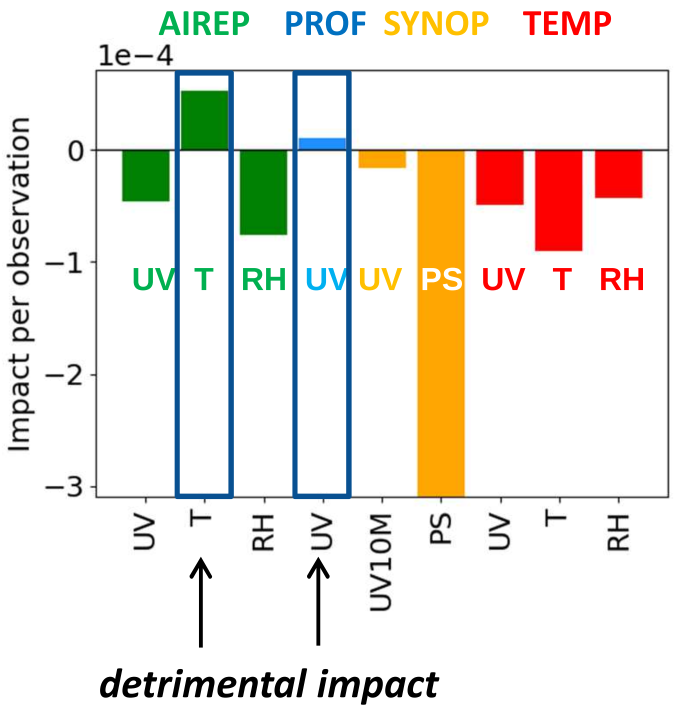
Issues:

- Biases
- Arbitrariness of verification metric
- Self verification

Solution:

→ **Independent observations for verification**
e.g. remote sensing observations

Verification with precipitation observations



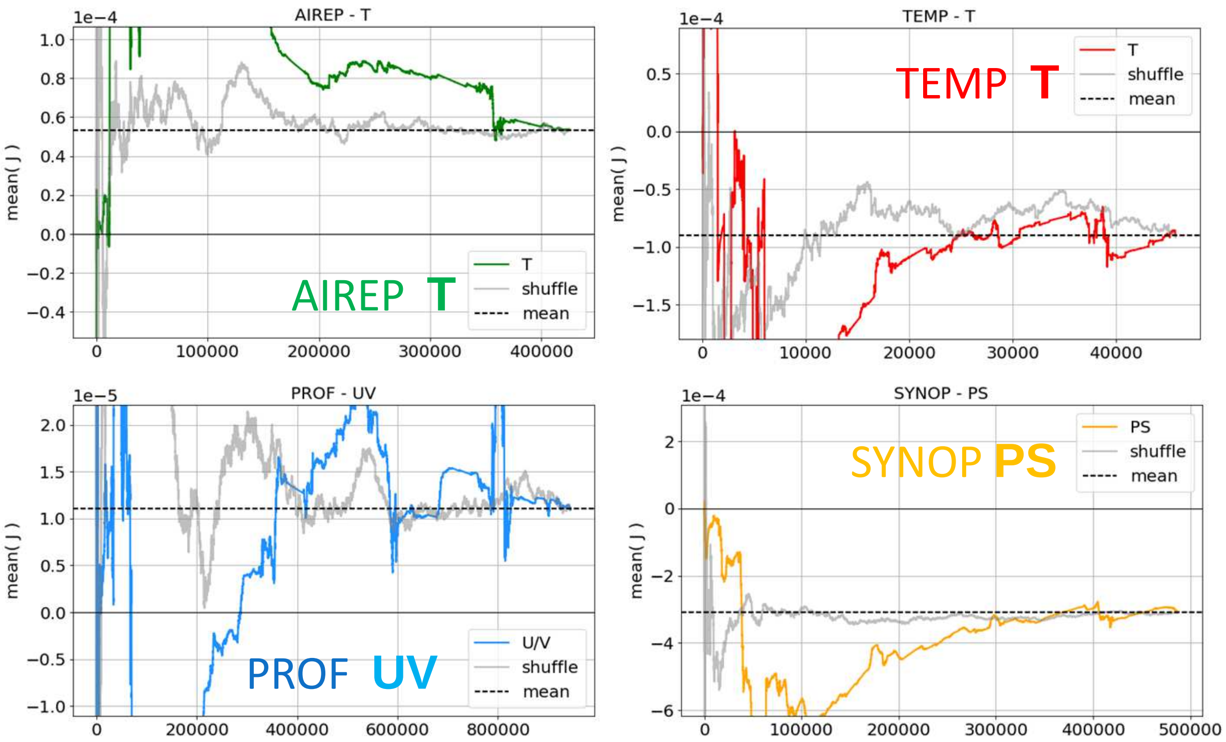
Verification with precipitation:

- Surface pressure & sounding temperature with largest beneficial impacts
- Aircraft temperature with detrimental impact
  Wind profiler with neutral impact

Question:

- What about model biases?
- How reliable are the results?

RELIABILITY



Question:
How reliable are the results?

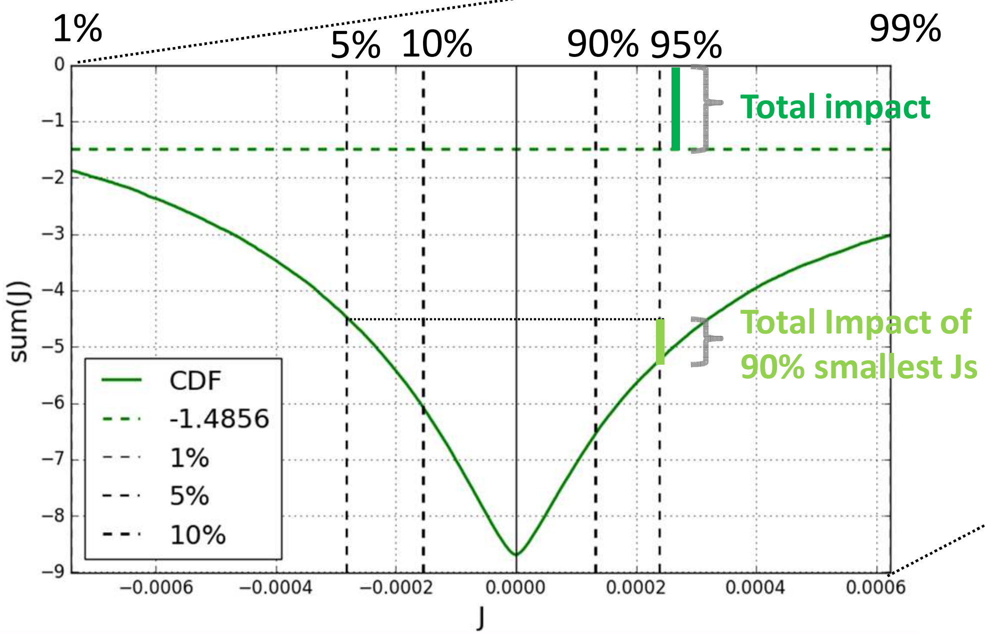
Answer:
Sample size is large enough
for most observation types

-> Results are representative
for summer period

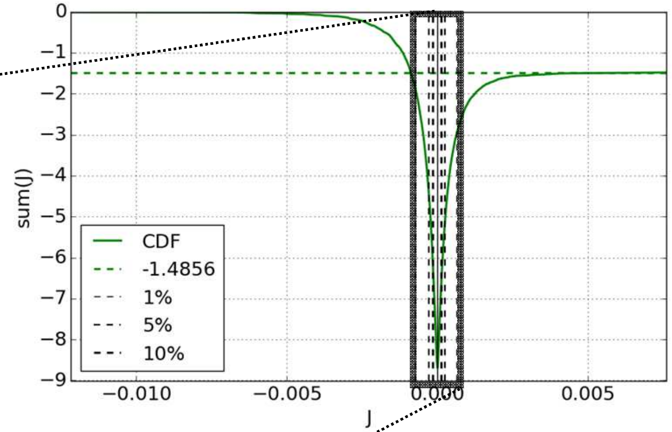
Ordered partial sum - (colored solid line)
Randomized partial sum - (gray solid line)
Mean impact - (dashed line)

DISTRIBUTION – CDF

Question: Is the small number of observations with extreme impact values important?



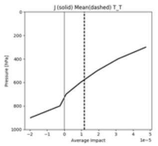
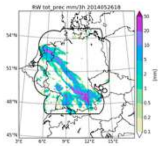
Cumulative Distribution Function (CDF)



AIREP U/V

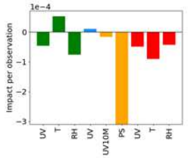
Answer: The 10% most extreme impact values contribute as much as smallest 90%

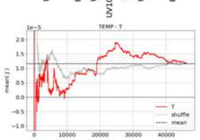
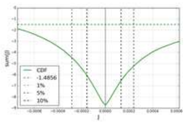
SUMMARY

Approach:

- Issues: Biases, self verification, arbitrariness of verification metric
  -> Bias-free, independent and representative set of observations
  for verification required (e.g. remote sensing)
- Method is enhanced to verify with independent remote sensing observations
  -> Precipitation (radar RW/EW) & Humidity (GNSS)



Results for summer experiment:

- Surface pressure & sounding temperature with largest beneficial impacts
- Aircraft temperature & wind profiler show detrimental & neutral impacts
- Sample size is large enough, results are representative
- 10% most extreme impact values are as important as smallest 90%

LITERATURE

Kalnay, E. et al. 2012: A simpler formulation of forecast sensitivity to observations: Application to an ensemble transform Kalman filter. Physica D, 230: 112-126. DOI: 10.3402/tellusa.v64i0.18462

Sommer, M. and M. Weissmann, 2014: Observation Impact in a Convective-Scale Localized Ensemble Transform Kalman Filter, *Q. J. R. Meteorol. Soc., 140, 2672–2679.* DOI: 10.1002/qj.2343

Sommer, M. and M. Weissmann, 2016: Ensemble-based approximation of observation impact using an observation-based verification metric. *Tellus A.* DOI: 10.3402/tellusa.v68.27885