3D Radar Data Assimilation in ICON-D2 and COSMO-D2 using KENDA

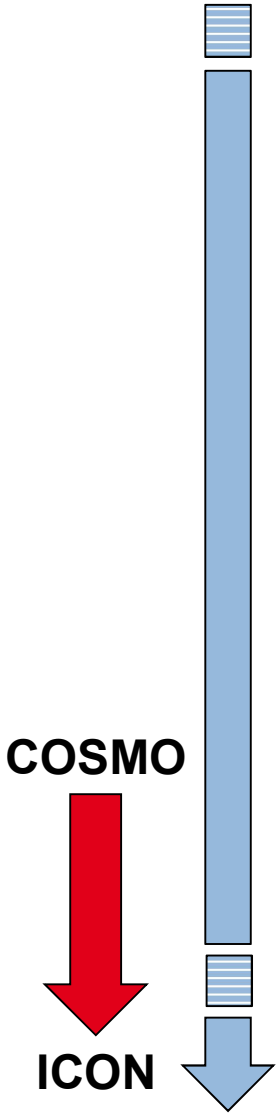
COSMO General Meeting 2020
Working Group 1 / KENDA-O Session

03.09.2020

Klaus Stephan & Christian A. Welzbacher
E. Bauernschubert, T. Bick, U. Blahak, C. Koziar, K. Khosravian, H. Lange, A. De Lozar, R. Potthast, H. Reich, A. Rhodin, C. Schraff, A. Seifert, G. Zängl, Y. Zeng and many more

“History” of 3D Radar Data Assimilation in vicinity of DWD

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



2010-13: Y. Zeng & D. Jerger, EMVORADO in COSMO @ KIT

2013-16: U. Blahak & Y. Zeng, EMVORADO in COSMO @ KIT/LMU

2013-16: T. Bick et al., 3D Radar reflectivity assimilation @ Bonn

Seit 2016: A. Seifert & A. De Lozar @ SINFONY

2016-18: E. Bauernschubert & K. Stephan @ SINFONY

2018/06-10: *First attempt of radial Winds in COMSO parallel routine*

2017-19: C. Welzbacher & A. De Lozar @ SINFONY

Since 2017: K. Stephan & C. Welzbacher and KENDA-Team @ FE12 - SINFONY

Since 2018: K. Khosravian @ IVS-Unwetter-Forschung

Since 2019: U. Blahak, EMVORADO in ICON

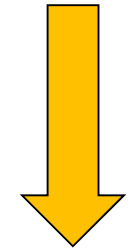
Since 03/2020: Radial Winds in COSMO-D2 Routine

Since 06/2020: Reflectivities in COSMO-D2 Routine

Since 06/2020: Radial Winds & Reflectivities in ICON-D2 Parallel-Routine

+ Work by A. Rhodin (DACE), H. Reich (KENDA), Development for BACY, NUMEX-Team, …

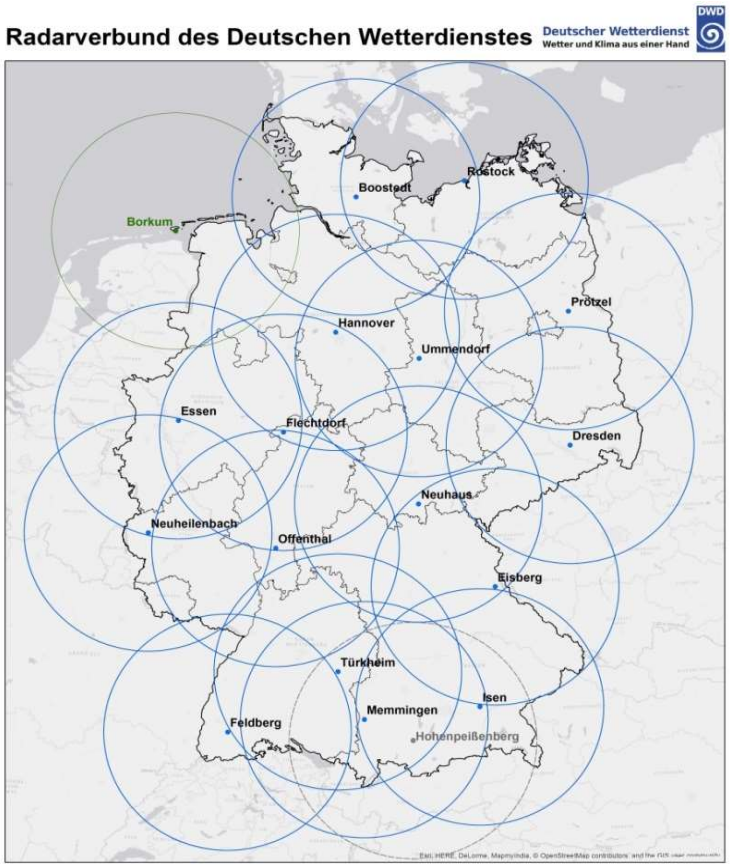
(Pre-) Operational Start in ICON-D2 & SINFONY



Radar Network & Model domain (D2)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- **Systems:**
  17 Doppler C-Band
- **Observables:**
  Reflectivity, radial wind, polarimetric moments
- **Temporal resolution:**
  Volume scan + terrain-following precipitation-scan every 5 min.
- **Spatial resolution:**
  1° azimuthal angular
  10 elevations (0.5° to 25°)
  1 km radial (up to 180 km)



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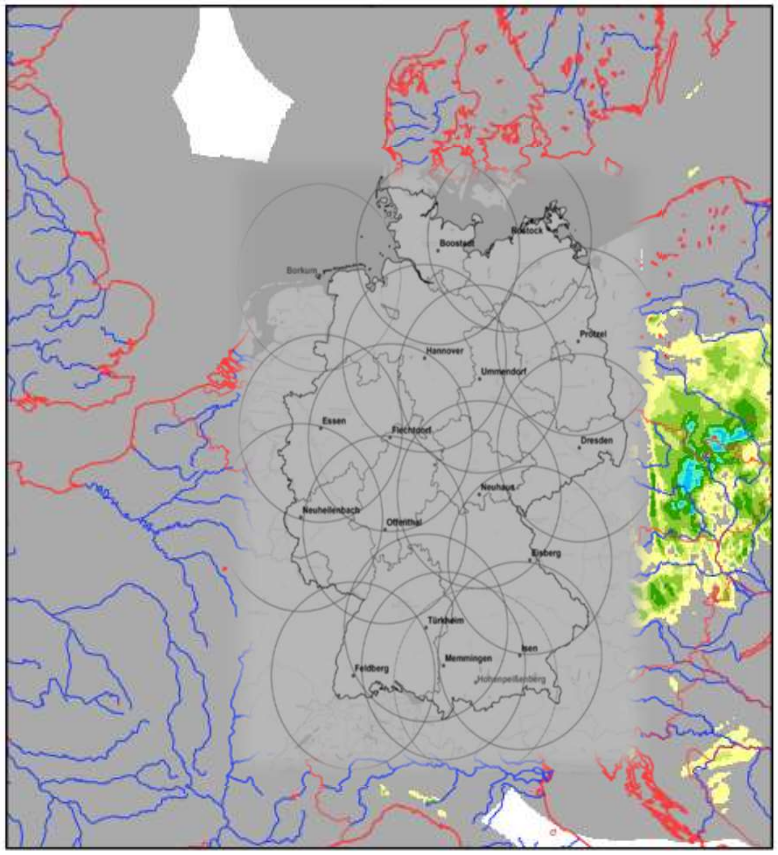

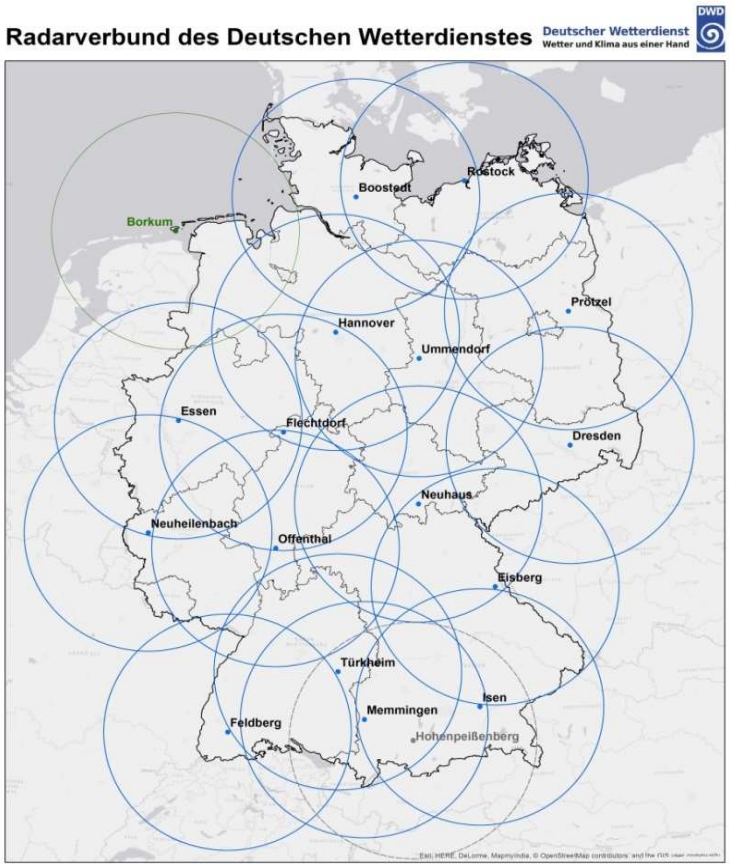

COSMO-D2-KENDA

- P-Suite CD2 2018: Radial Winds →
- Quality Control (ObsErr): Radial Winds
- Routine 03/2020: Radial Winds
- Routine COSMO-D2 06/2020: Radial Winds + Reflectivities + LHN

Also need to test in ICON

Also test in COSMO

ICON-D2-KENDA

- Setup of DA and Model

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→ Klaus

P-Suite CD2 2018: Radial Winds First attempt

06/2018 to 10/2018

Settings in COSMO Parallel Suite

- COSMO:
  - LHN active
  - loldturb is on
- EMVORADO
  - MIE scattering by lookup tables
  - Attenuation is applied
  - DeAlising of Radial Winds
  - Superobbing (radius 10 km)
- LETKF
  - Localization (0.3 logP in vertical and 16 km in horizontal)
  - Inflation (3D radar data are considered in adaptive inflation)
  - RTPP is on
  - Observation error profile estimated by Desrozier method (radialwind)
- Observation
  - Using of 3 elevation of radial wind (0.5, 1.5 and 3.5°)
  - Applying only observations at analysis time (hourly update)

Scores against SYNOP for 40 days in Autumn 2018

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

DD [degree]

FF [m/s]

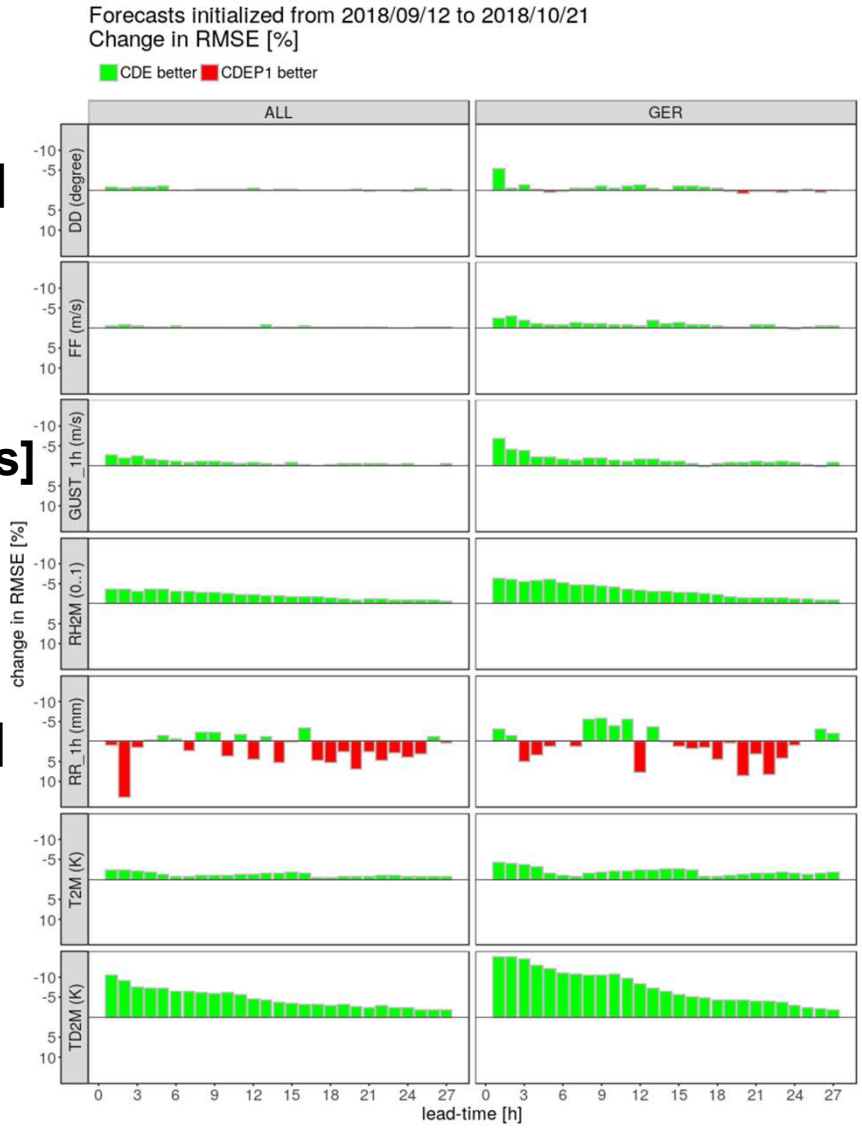
GUST_1h [m/s]

RH2M [0..1]

RR_1h [mm]

T2M [k]

TD2M [k]



15 .. -15 % Change in RMSE

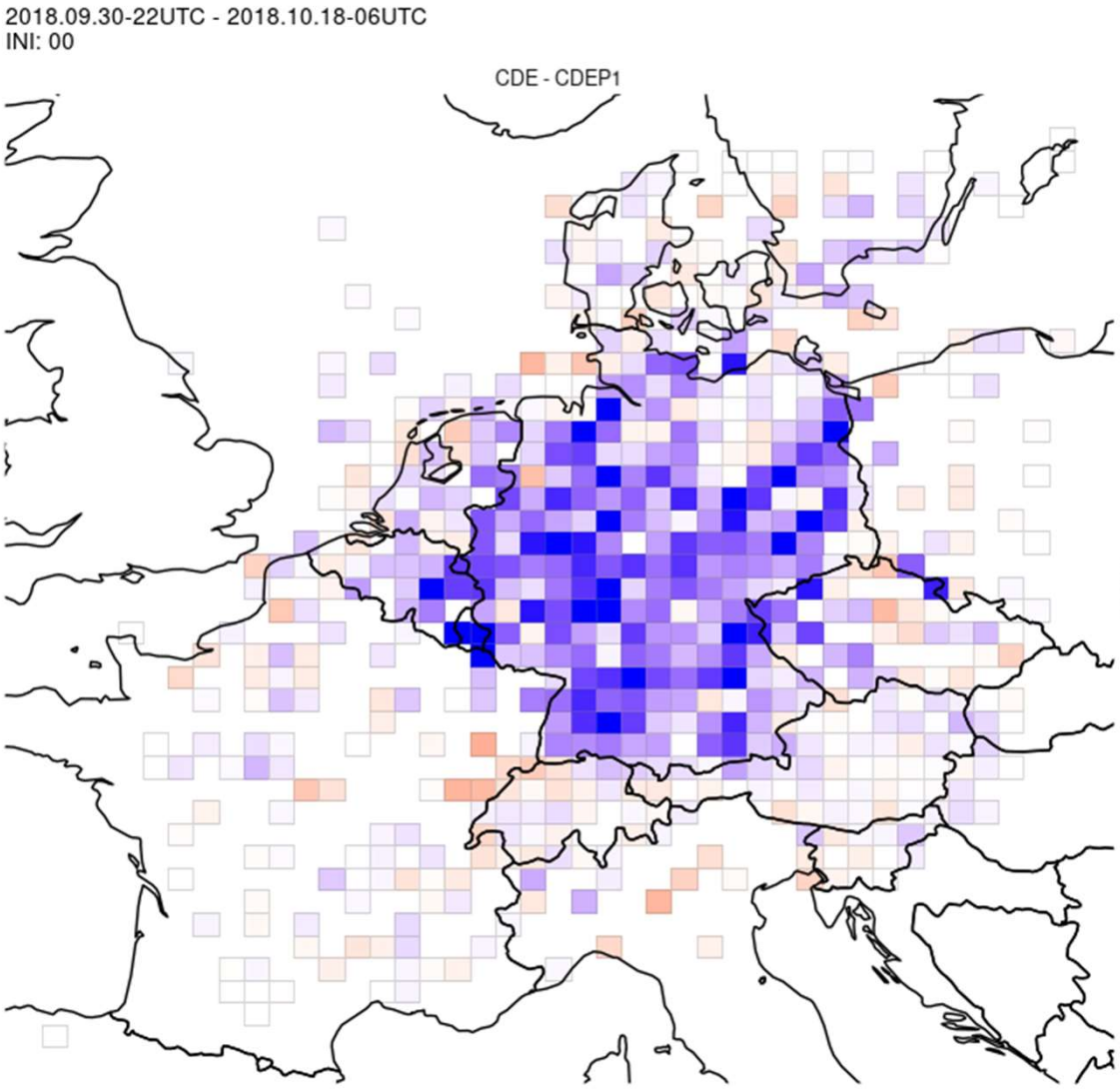
Left: whole D2-Domain
Right: Germany

Routine better

Parallel routine better

Scores against SYNOP for 20 days in Autumn 2018

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



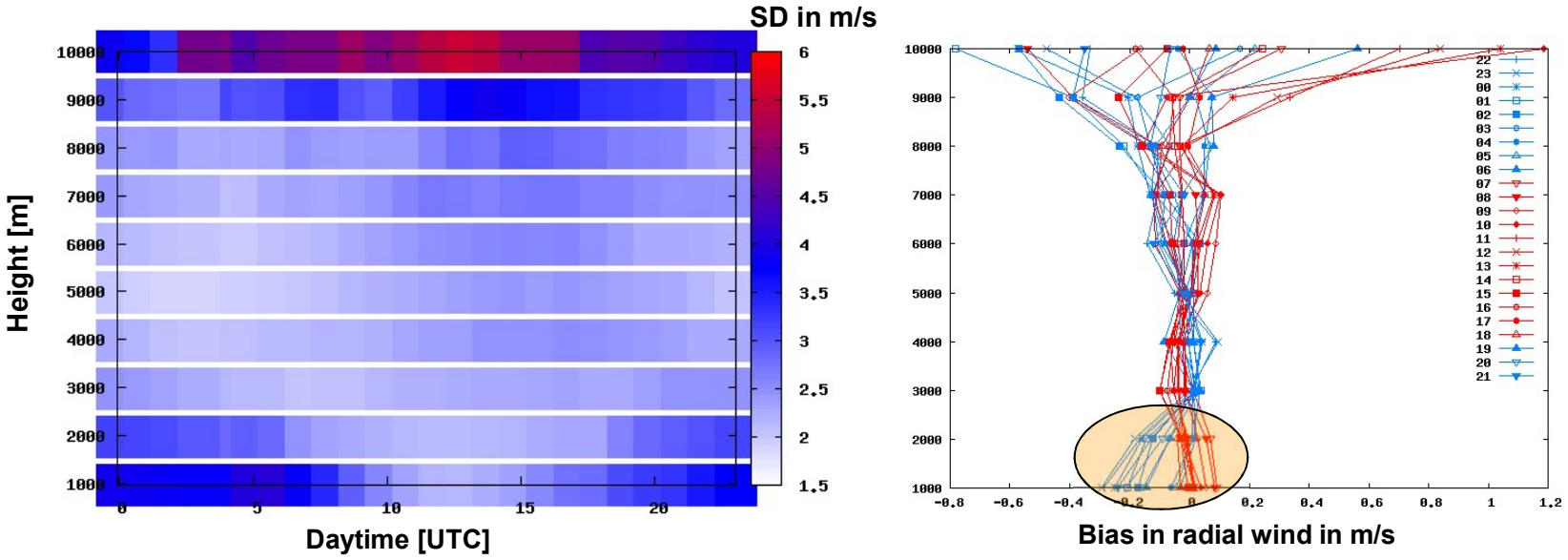
Change in SD of TD2M after 1h lead time

Parallel routine better

Routine better

Detrimental effect mainly over Germany, where RW are assimilated

Investigation for the reason



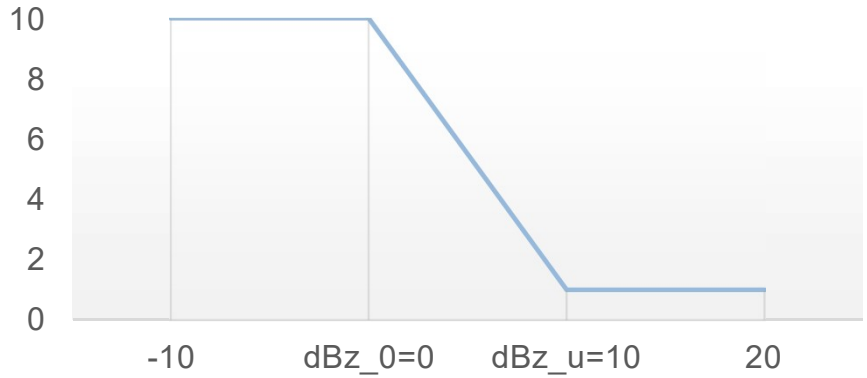
Standard deviation and Bias in radial wind for September 2018

Potential causes for problems:

1. Nocturnal model bias in horizontal wind (known for COSMO model)
2. Measuring of radial winds are more accurate when associated reflectivity is higher (known from radar technicians)

Solution

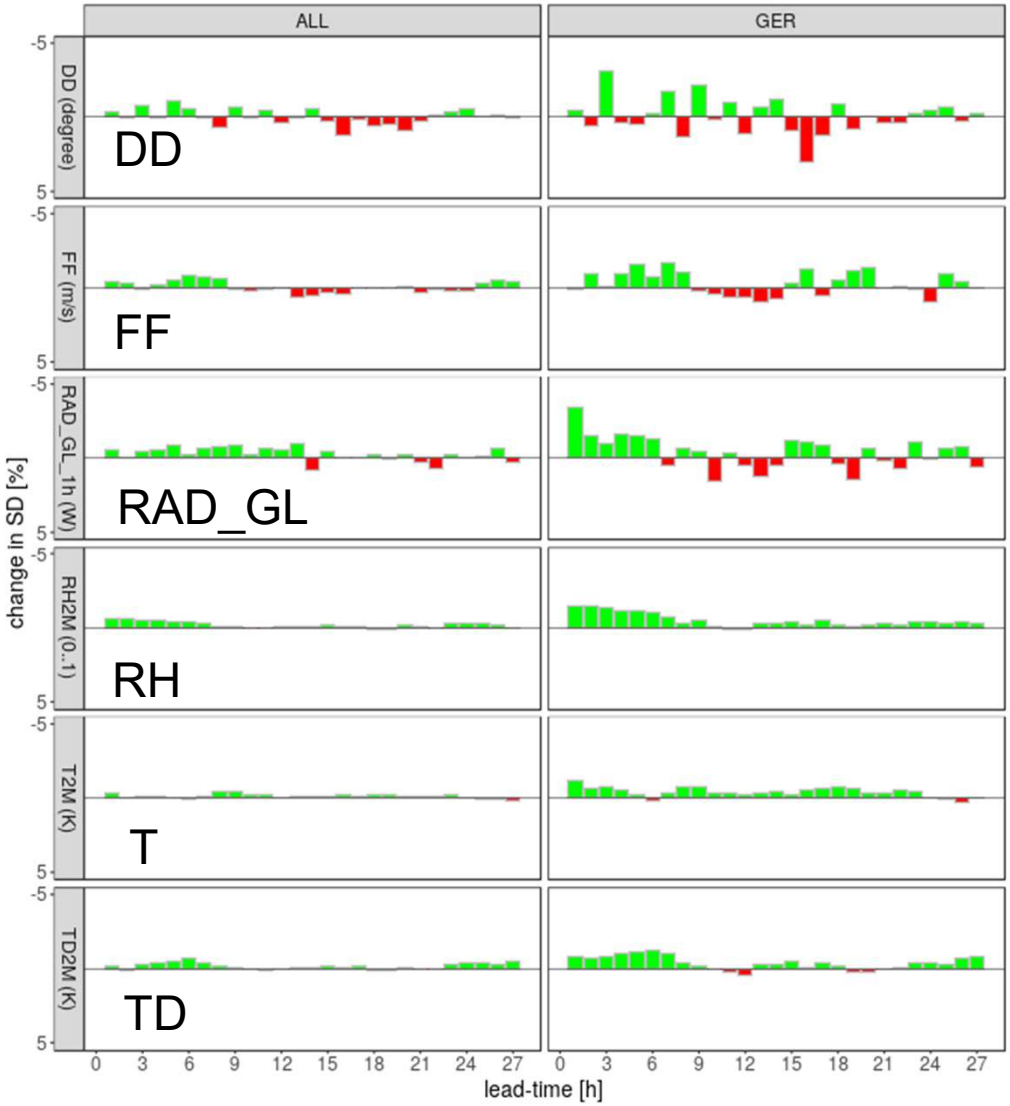
- Increasing of observation error for radial wind depending on measured reflectivity, implemented in EMVORADO (set itype_obserr_vr to 1 or 2):
  - Z > 10 dBz : take the error as defined in LETKF (i.e. by Desrozier or standard value 2.5 m/s)
  - Z <= 0 dBz: multiply common error with 10 (randomly choosen)
  - Z in between linear change:
    - the values of
      - Upper and lower Z
      - Maximal factor can be set via namelists



  - The observation error is increase within LETKF by multiplying the external given values (set luse_eo_factor=.true. and &OBSERR obstype='RADAR, …).

QC of radial winds via reflectivity

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Change of SD for:

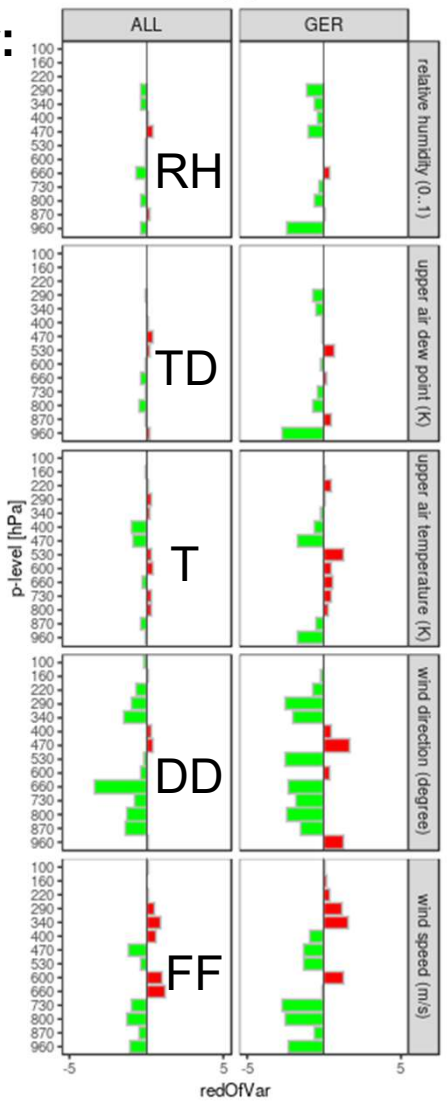
TEMP →

← SYNOP

Period:
02.06. to 25.06.19

Reference better
Reference + radial winds better

Assimilation of RW now ready for next parallel suite, running successfully within 2 month in winter 2019/2020



COSMO-D2-KENDA

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Also test in COSMO

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- P-Suite ICON-D2 06/2020: Radial Winds + Reflectivities + LHN

→ ***Christian***


Results are not good…
Why?
Results are good…
Why?

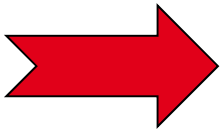
Details about Experiments

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- **ICON-D2**
  Cycle: hourly with KENDA-LETKF
- **Forecasts: 00, 06, 12, 18 UTC: 24h lead time deterministic**
- **Standard Observations and operators:**
  - Conventional observations including Mode-S
  - DACE@ICON with 3 time slices
  - LHN at all times (if indicated to be used)
- **LETKF:**
  - adap_rho = T ! adapt. rho infl
  - apply_rtpp = T ! Relaxation to prior perturbations
  - Binary: /lustre2/uwork/fe12bacy/bin/var3d-20191107-0289a0
- **ICON namelist settings:**
  - No qi, qr, qs, qg increments used
  - QC increments added to QC if already present at gridpoint and added to QV if not
  - No ensemble perturbations
- **Radar Observation settings → later**

Details about evaluation

- **obs_err_stat**
  - Used are AIREP, PILOT and TEMP for variables Relative Humidity (RH), Temperature (T) and Wind
  - FG (1h forecast, solid line) of special interest, Analysis = linearized analysis (dashed line)
- **Precipitation verification**
  - Compare fraction skill score of forecast precipitation for different thresholds
  - Evaluation for deterministic run with lead time 24h at 0, 6, 12 and 18 UTC
  - Forecasts interpolated to COSMO-D2 region used
  - Full D2 and “German” (i_start=235, i_end=540, j_start=160, j_end=570)
- **TEMP, SYNOP, AIREP verification (MEC)**
  - Only observations active in all experiments to be compared are used



„Only“ DET verification

Impact of radar data assimilation in ICON-D2-KENDA

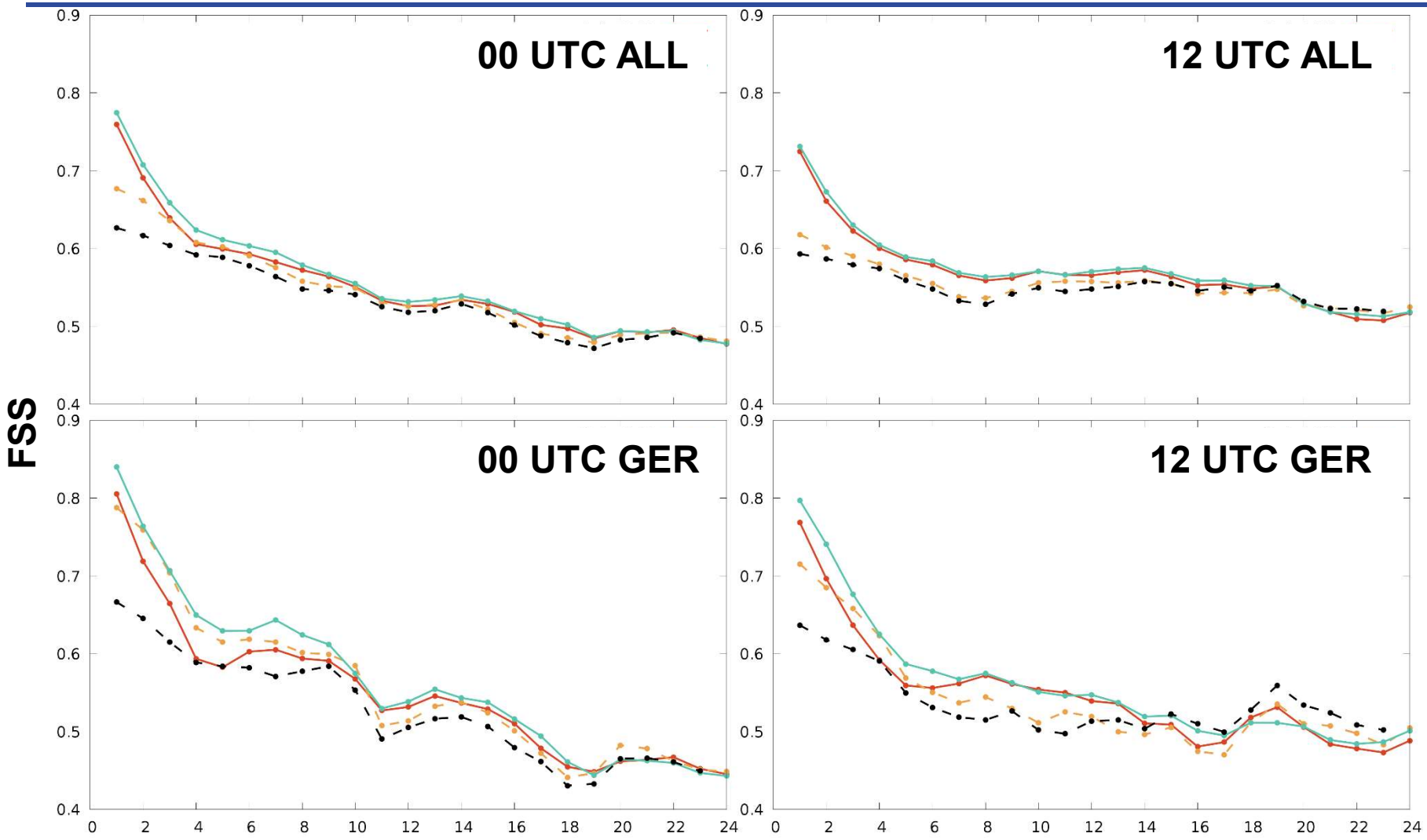
Summer experiments (June 2019)

Obs_err_stat: 01.06. 02UTC – 23.06. 00UTC
MEC Verification: 02.06. 00UTC – 23.06. 18UTC
Precipitation Verification: 02.06. – 22.06. (21 days)

- Using **no** radar data at all (ILAM_ONLINE_0639.2)
- **Only** using **LHN** (ILAM_ONLINE_06262)
- **Only** using **3D-Radar-Data** (ILAM_ONLINE_0639)
- Using LHN **plus** 3D-Radar-DATA (ILAM_ONLINE_0633)

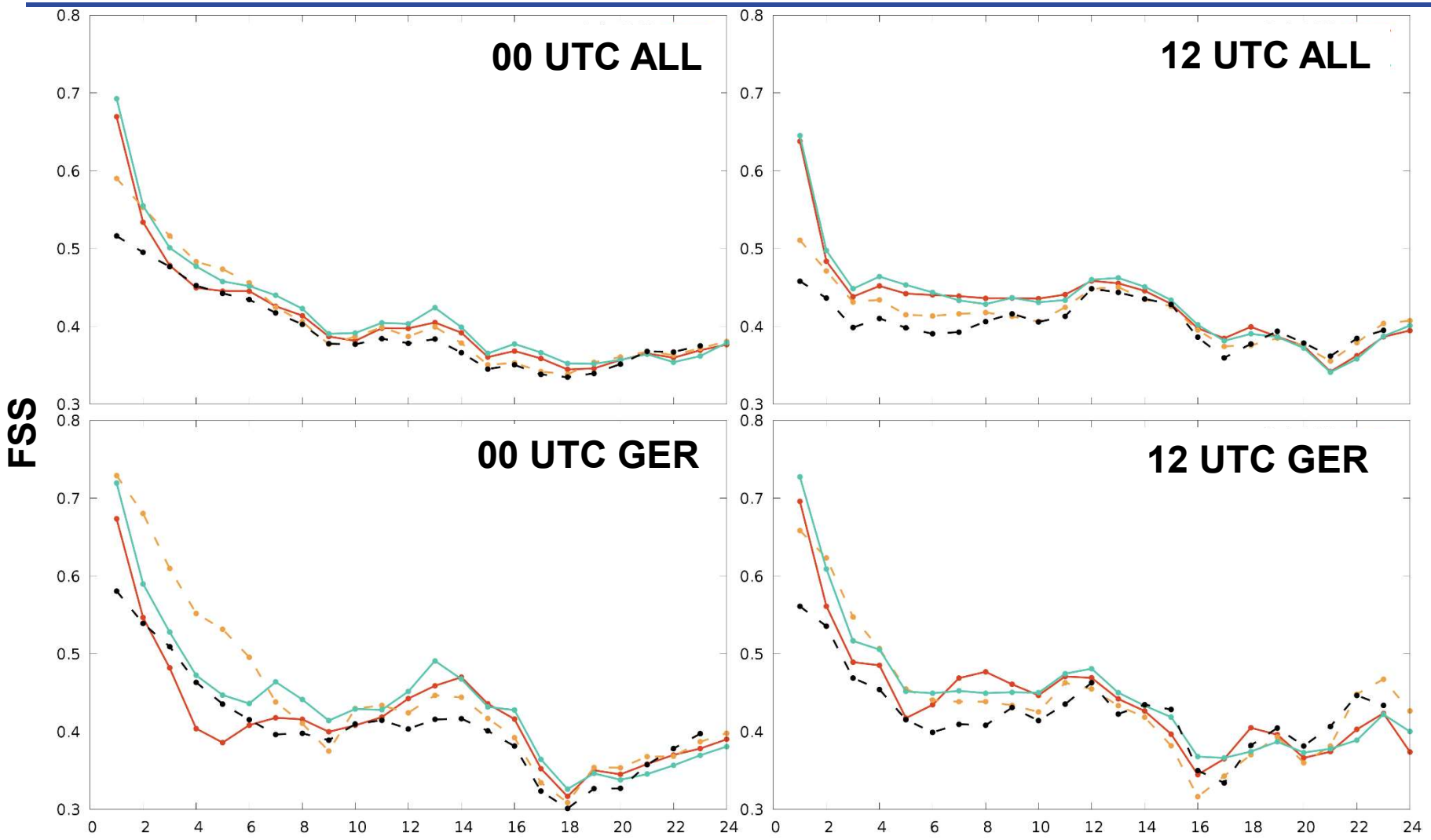
Impact of radar data: precipitation verification (0.1 mm/h , 11x11gp)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



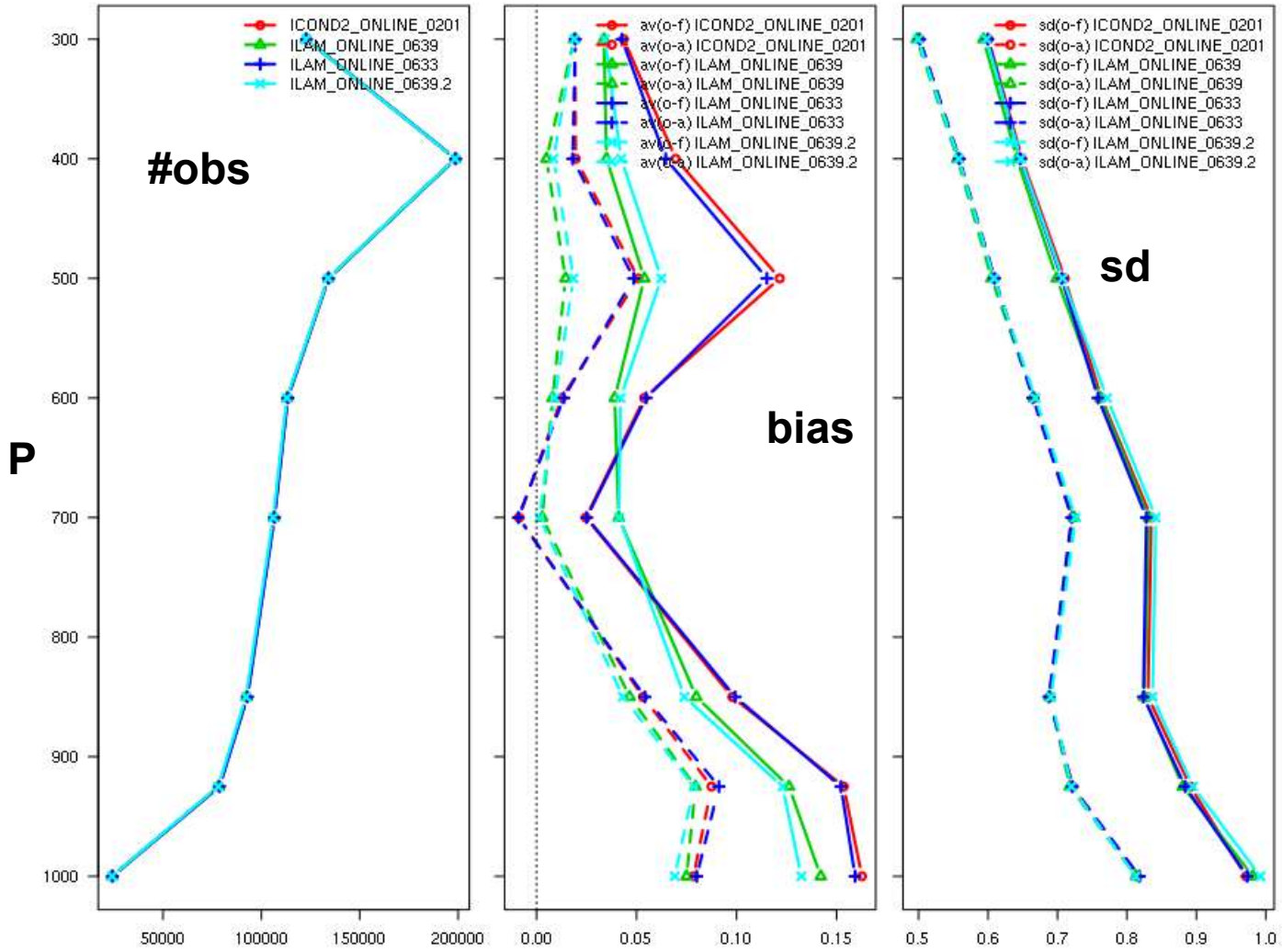
Impact of radar data: precipitation verification (1.0 mm/h , 11x11gp)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Impact of radar data: obs_err_stat (AIREP): T

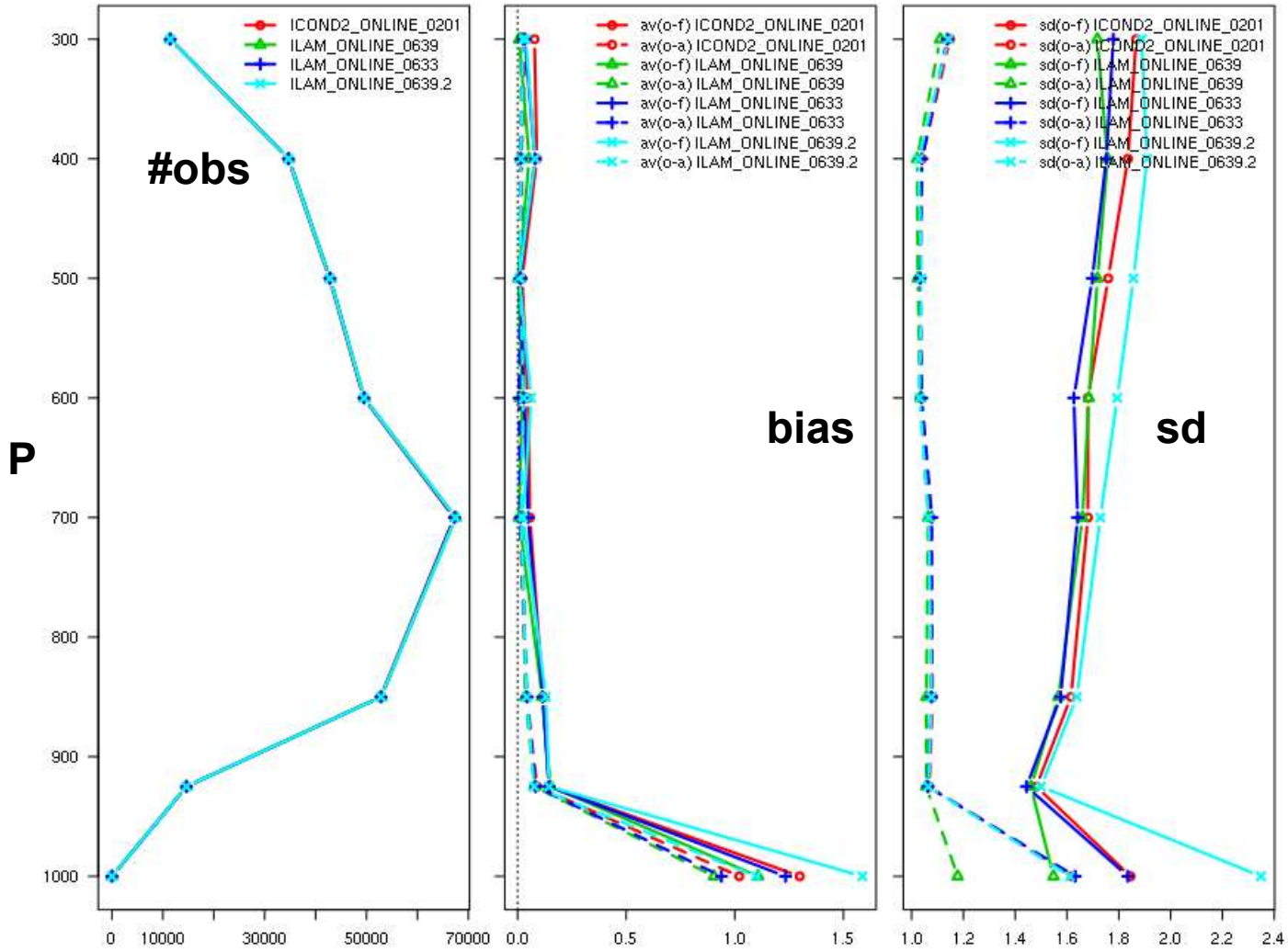
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



No radar --- only LHN --- only 3D radar --- LHN + 3DRadar

Impact of radar data: obs_err_stat (PILOT): WIND

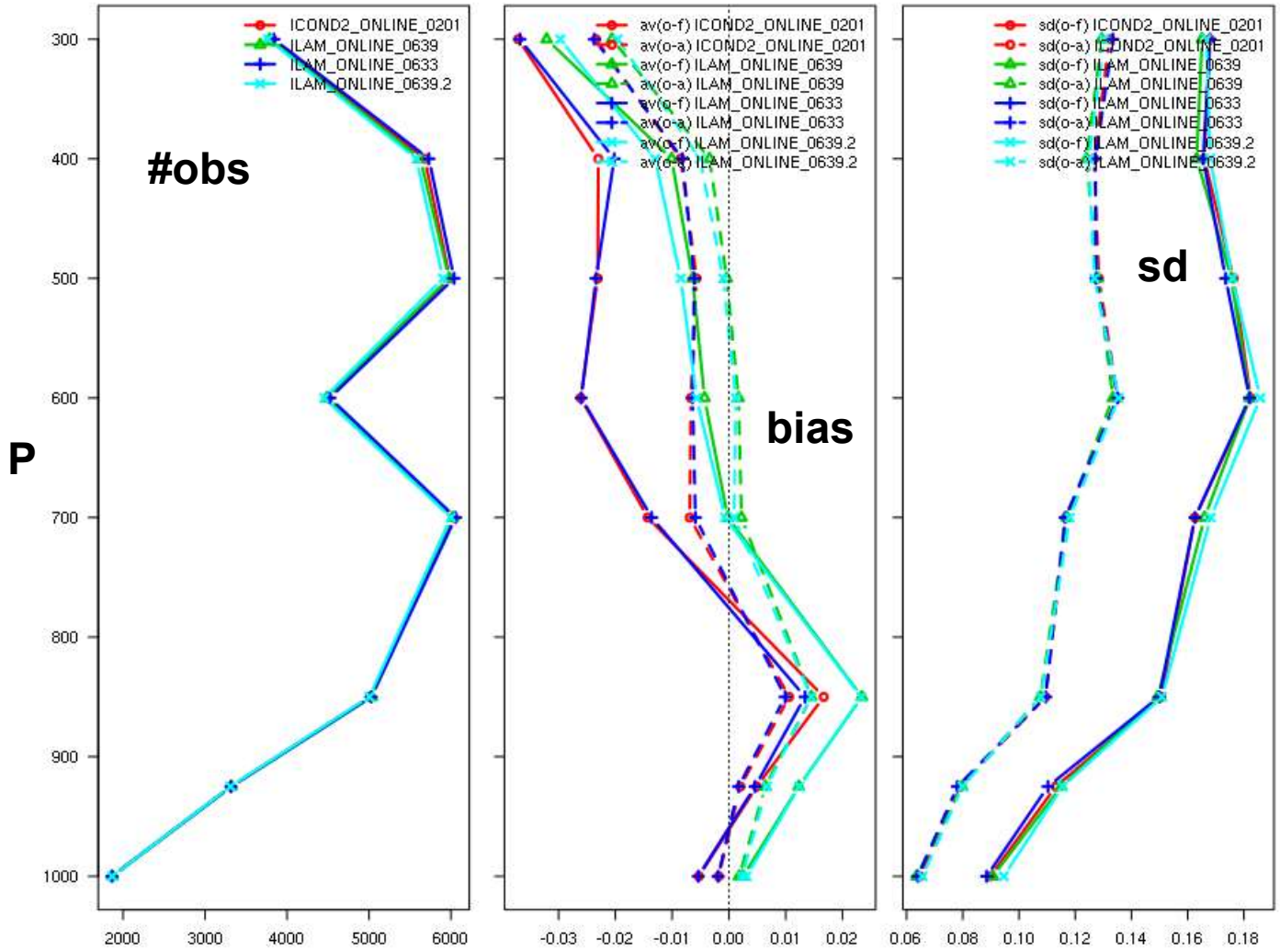
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



No radar --- only LHN --- only 3D radar --- LHN + 3DRadar

Impact of radar data: obs_err_stat (TEMP): RH

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



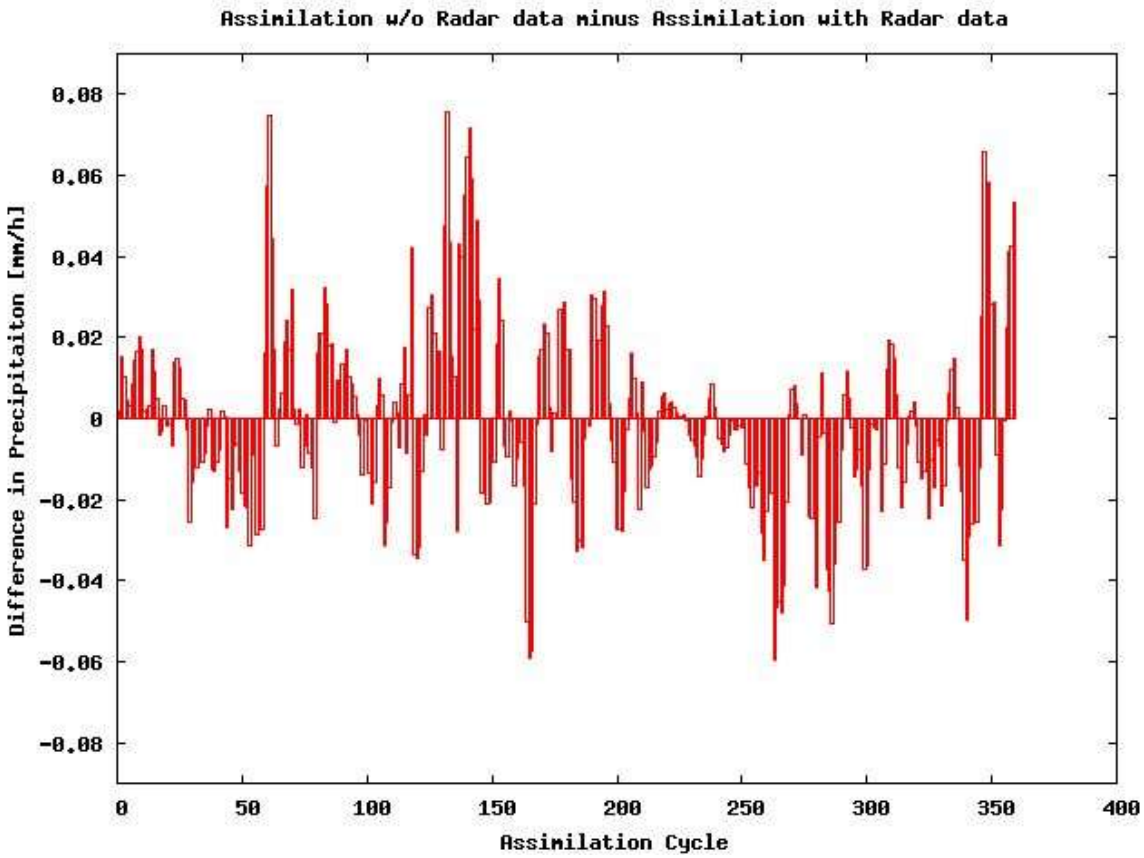
No radar --- only LHN --- only 3D radar --- LHN + 3DRadar

Total precipitation: no radar vs. all radar

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Sum of spatial-average:

- ➔ **0639.2: 34.2 mm**
- ➔ 0639: 34.8 mm
- ➔ 06262: 35.0 mm
- ➔ **0633: 35.1 mm**



„no radar – all radar“

Total precipitation: only LHN vs. all radar

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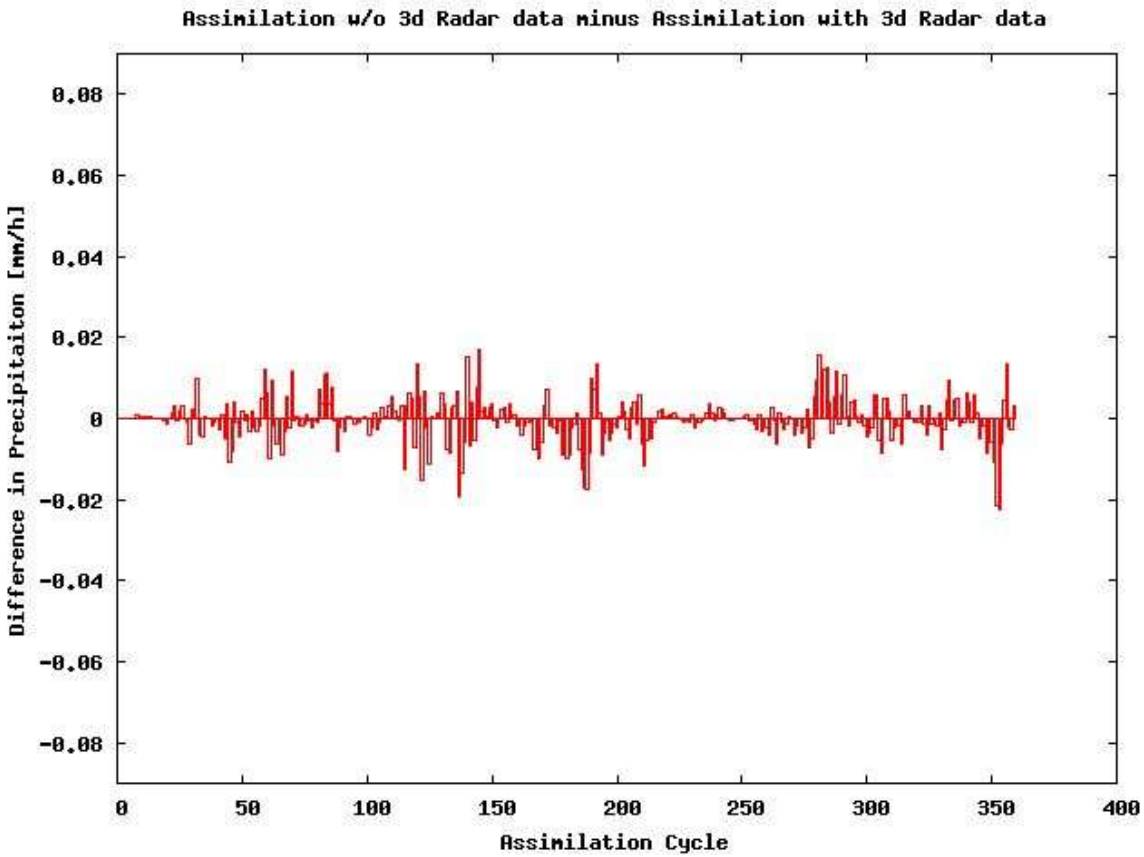


„LHN – all radar“

Soil Moisture (W_SO) – First Guess

W_SO(1) no radar

W_SO(1) all radar

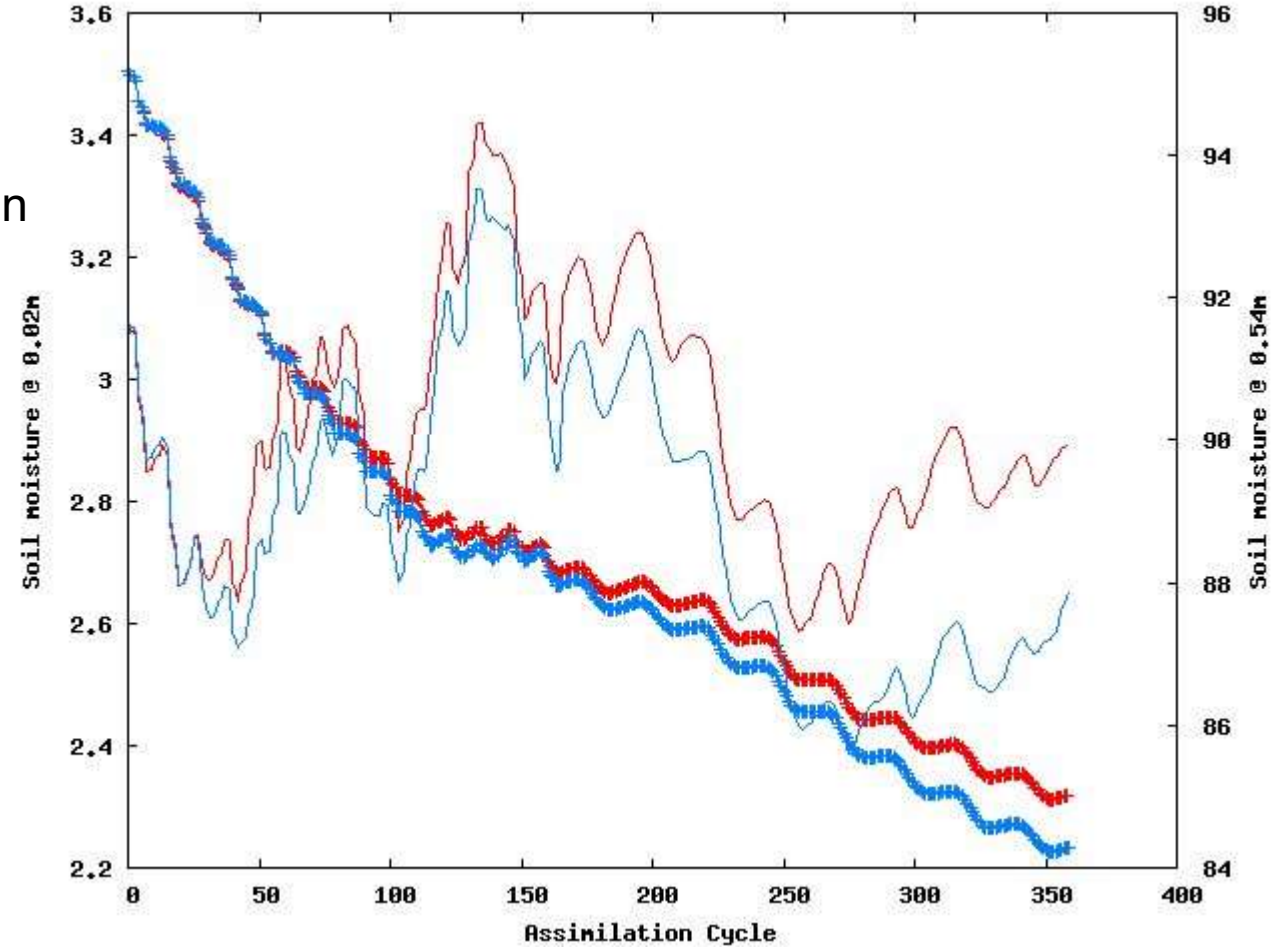
→ Reaction on precipitation

→ little impact on evapotranspiration

W_SO(5) no radar

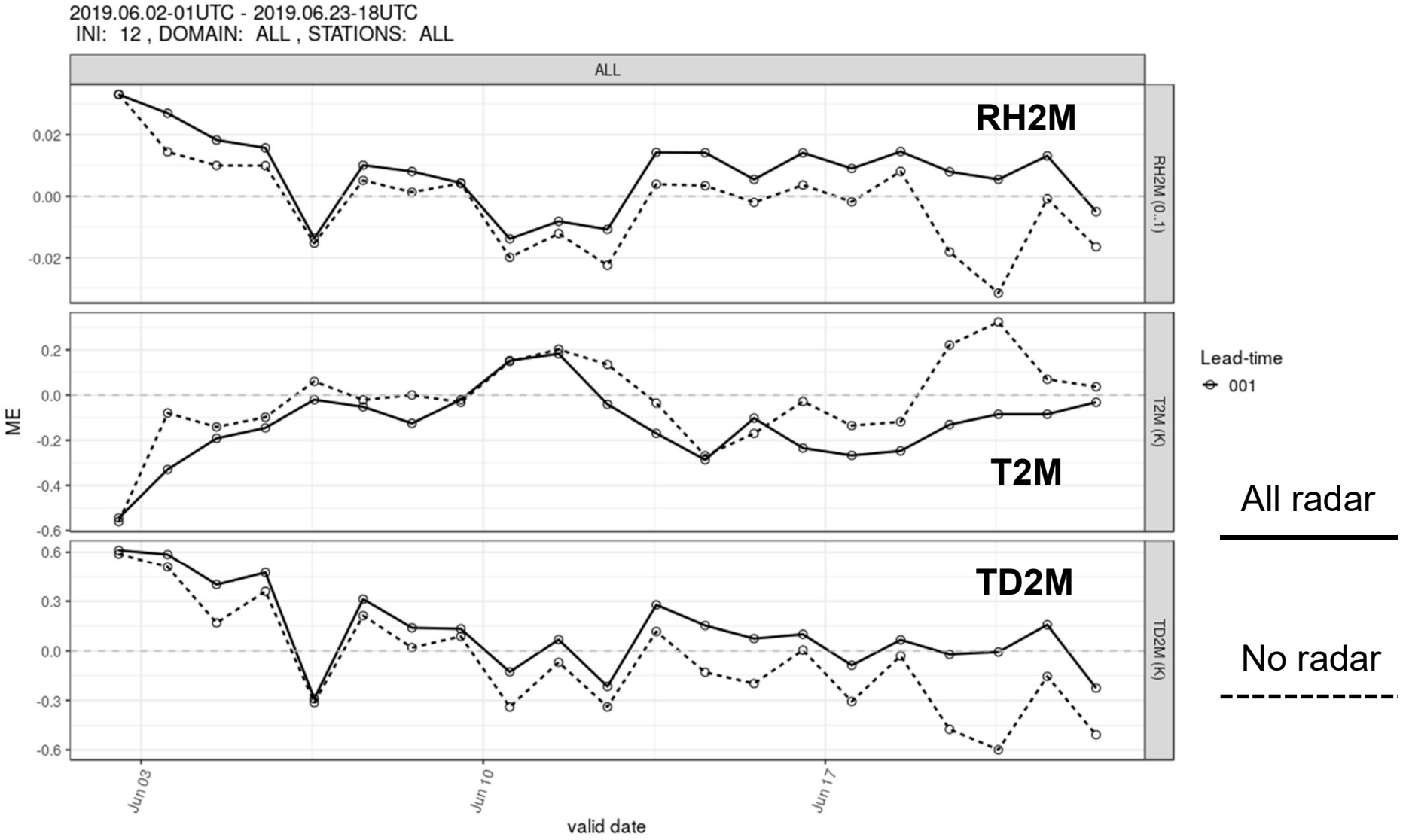
W_SO(5) all radar

→ large impact on evapotranspiration



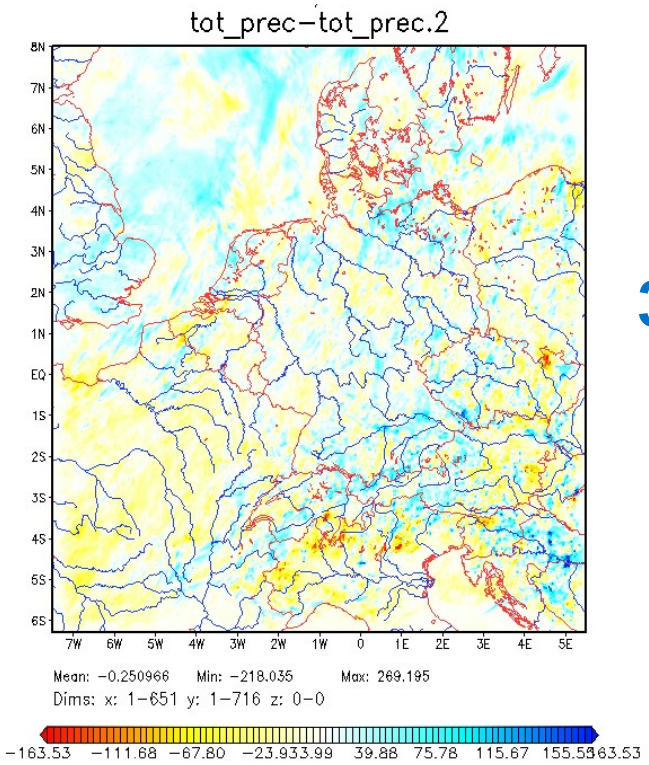
ME OF RH2M, T2M, TD2m @ Synop-Verification – 1h leadtime from det. forecasts

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

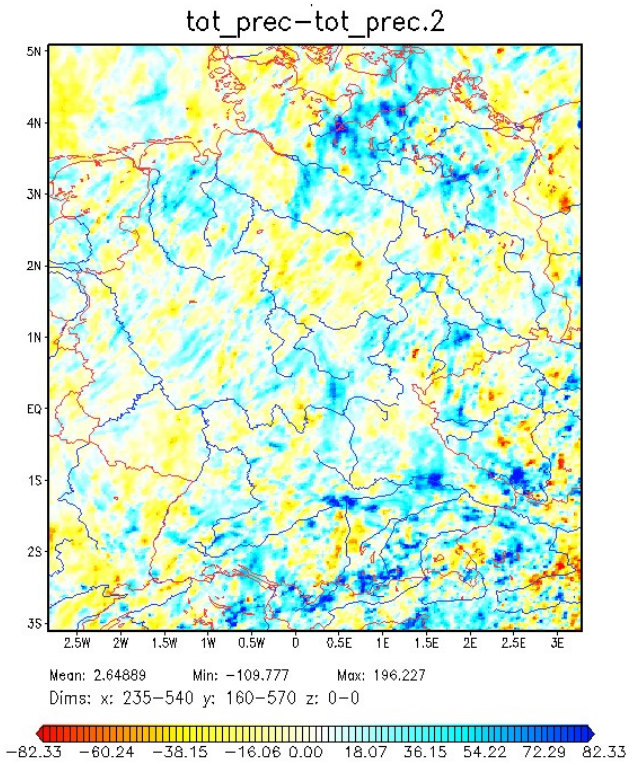


Total precipitation Difference of FG sums: Only 3D-Radar – only LHN

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



3D-Radar – LHN



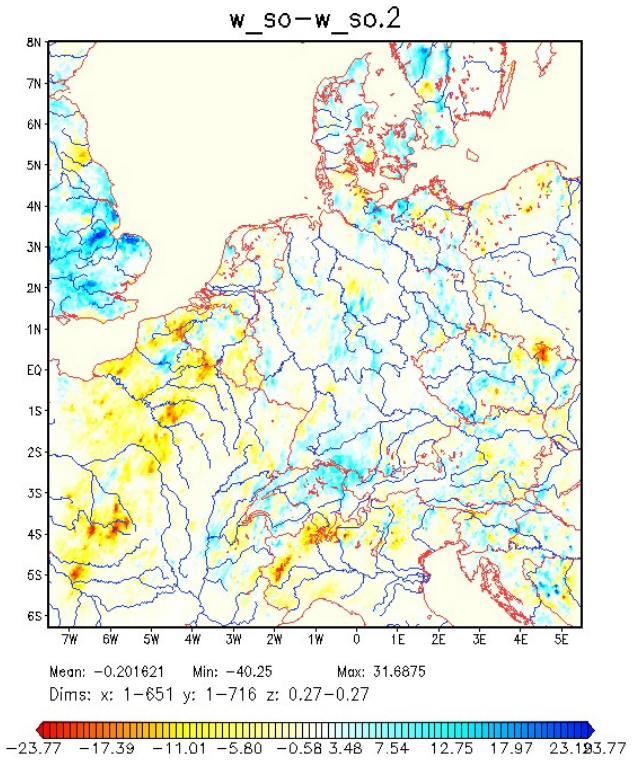
D2-Domain
Mean: -0.25 mm

Germany
Mean: 2.64 mm

More precipitation: **3D-Radar (+)**
LHN (-)

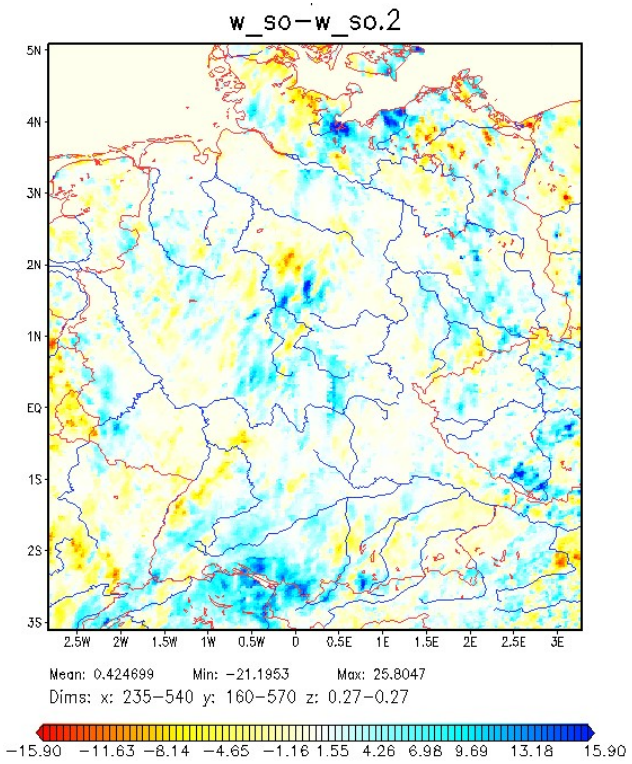
Soil moisture W_SO(5)
MEAN(only 3D-Radar) – MEAN(only LHN)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



D2-Domain
Mean: -0.20

3D-Radar – LHN

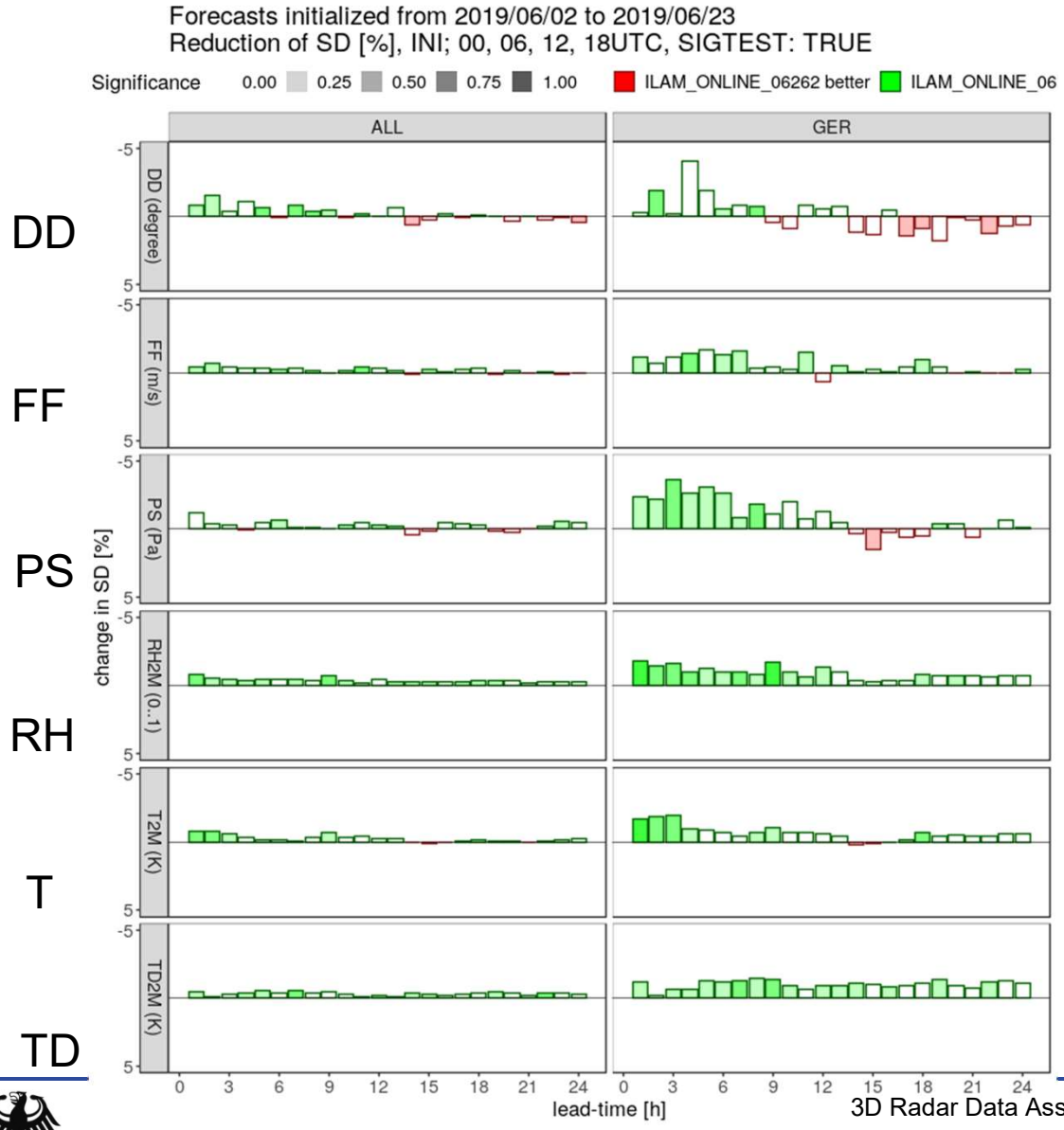


Germany
Mean: 0.42

3D-Radar drier (-) ---- LHN drier (+)

Impact of radar data: surface verification (reduction of sd)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



DD

FF

PS

RH

T

TD

Scale: -5 to 5%

Only LHN better

LHN + 3DRadar better

Impact of radar data: TEMP verification (reduction of sd)

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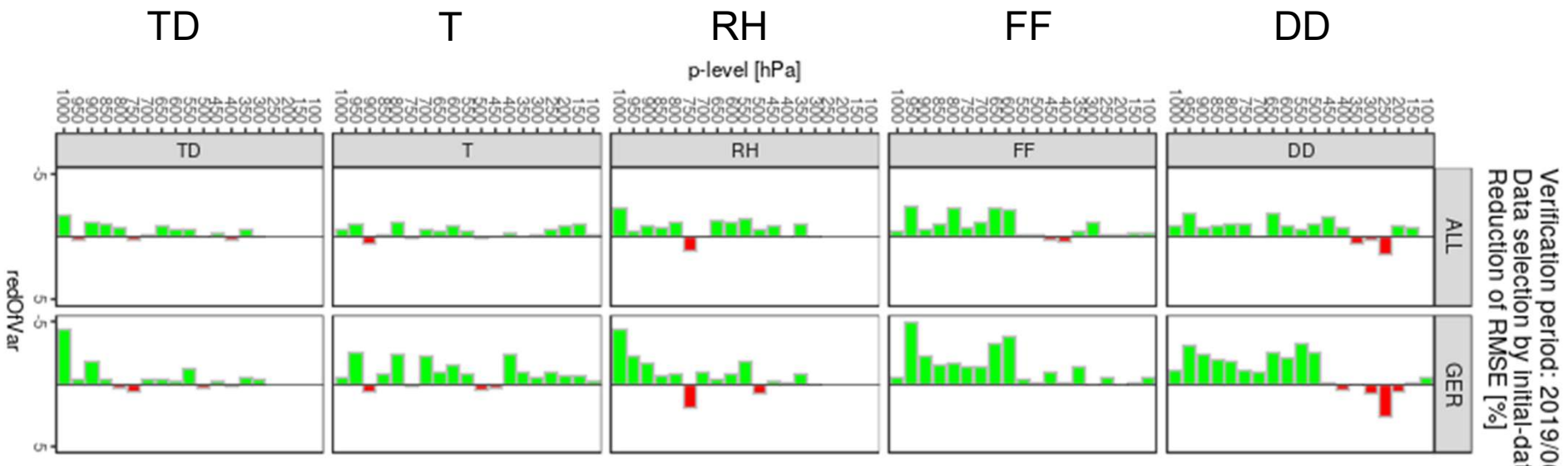
Wetter und Klima aus einer Hand



Scale: -5 to 5%

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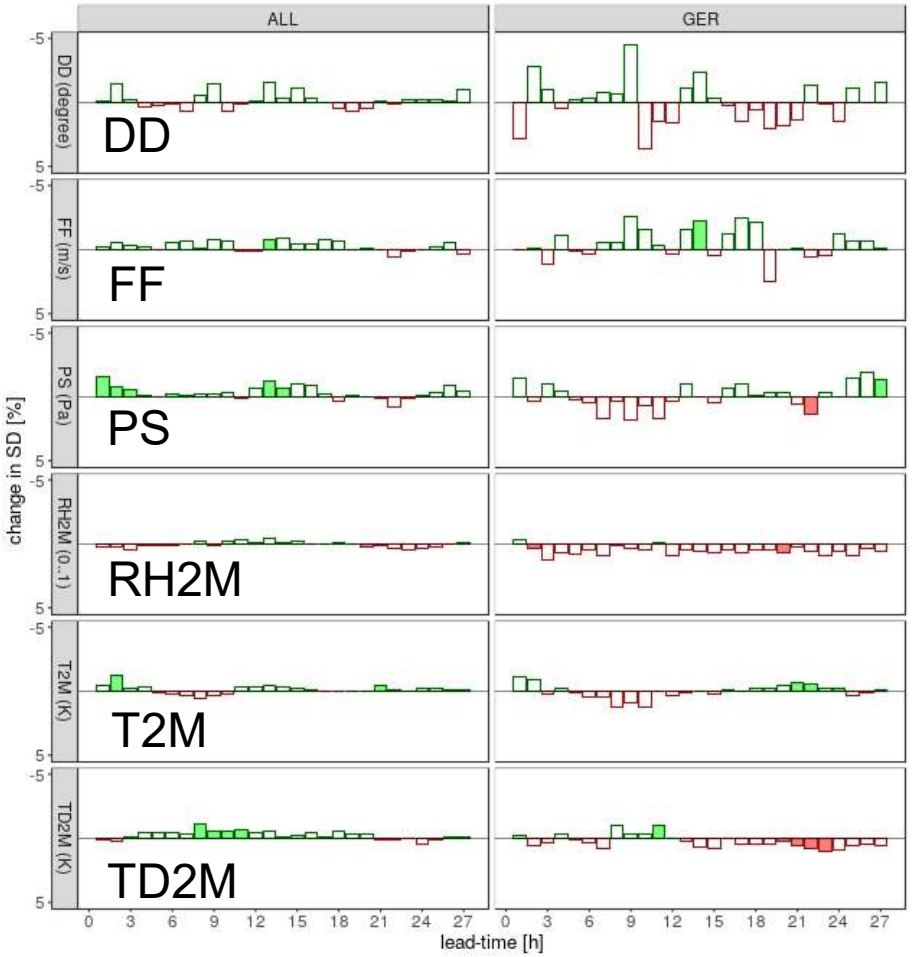
→ ***Klaus***

Routine COSMO-D2 06/2020: Radial Winds + Reflectivities + LHN

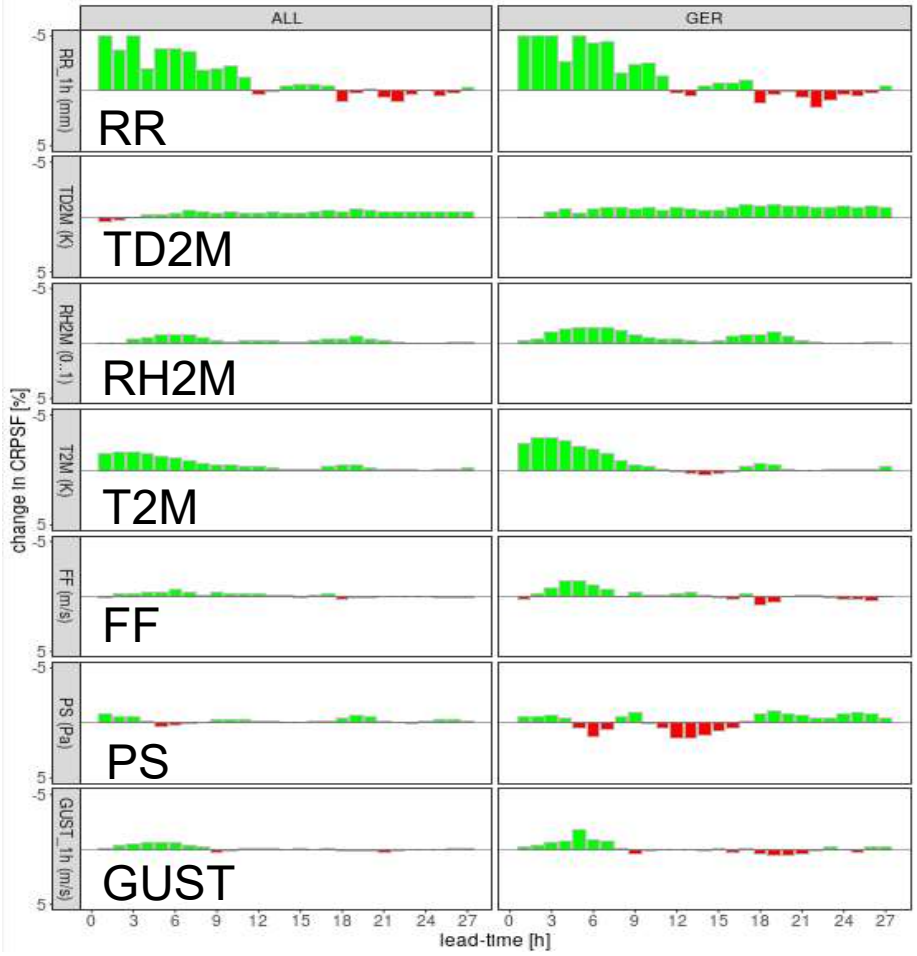
SYNOP-Verification (det & EPS, 01.06.-12.06.)

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

„ROUTINE“ vs. „ROUTINE“ + Reflectivity



SD (+/-) RMSE (+)



CRPS (+)

Upper-Air-Verification (det & EPS, 01.06.-12.06.)

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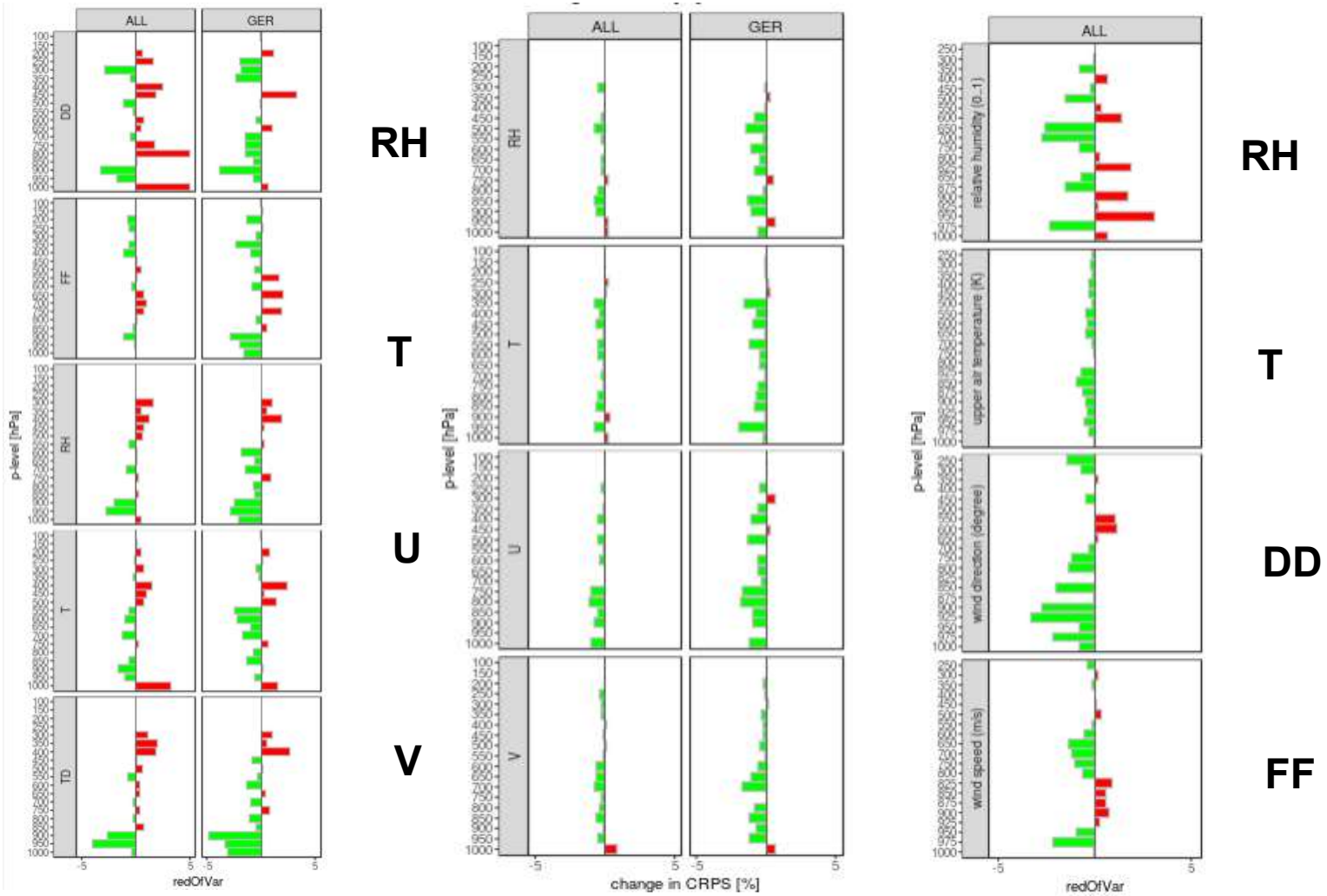
Wetter und Klima aus einer Hand

„ROUTINE“ vs. „ROUTINE“ + Reflectivity



TEMP, SD | TEMP, CRPS | AIREP, SD

Current settings related to radar data assimilation

Radar Observation Settings

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Default settings for **radial winds** (online):
  - *0.5°, 1.5° and 3.5° elevation*
  - Reflectivity dependent obs_error (between 2.5 and 25 m/s)
    → factor calculated within EMVORADO
  - v_loc=0.3
  - No data below 600m (in exps: 300m)
- Default settings for **reflectivities** (online):
  - *1.5°, 3.5°, 5.5°, 8.0° and 12.0° elevation*
  - Obs_err=10 dBZ (constant)
  - v_loc as for conventional obs
  - No data below 600m
  - Reflectivities <0 dbZ set to 0 dbZ
  - Attenuation simulated
  - First guess check with factor 10
- Default settings for **both**:
  - Superobbing 10km
  - h_loc=16km
  - No data above 9000m (in exps: 10000m)

Studies by Elisabeth Bauernschubert and Klaus Stephan (mainly Desroziers)

Idea by Klaus, employed by Uli (@EMVORADO) and Elisabeth (@DACE)

Educated guess → have „homogenous“ coverage (1st elevation: clutter)

Default value, using Desroziers → no clear signal (interplay with adap_rho)

Prevents e.g. large T increments near ground

Radar Observation Settings

- Default settings for **radial winds** (online):
  - *0.5°, 1.5° and 3.5° elevation*
  - Reflectivity dependent obs_error (between 2.5 and 25 m/s)
    → factor calculated within EMVORADO
  - v_loc=0.3
  - No data below 600m (in exps: 300m)
- Default settings for **reflectivities** (online):
  - *1.5°, 3.5°, 5.5°, 8.0° and 12.0° elevation*
  - Obs_err=10 dBZ (constant)
  - v_loc as for conventional obs
  - No data below 600m
  - Reflectivities <0 dbZ set to 0 dbZ
  - Attenuation simulated
  - First guess check with factor 10
- Default settings for **both**:
  - Superobbing 10km
  - h_loc=16km
  - No data above 9000m (in exps: 10000m)

Ground clutter identified with Desroziers and other techniques

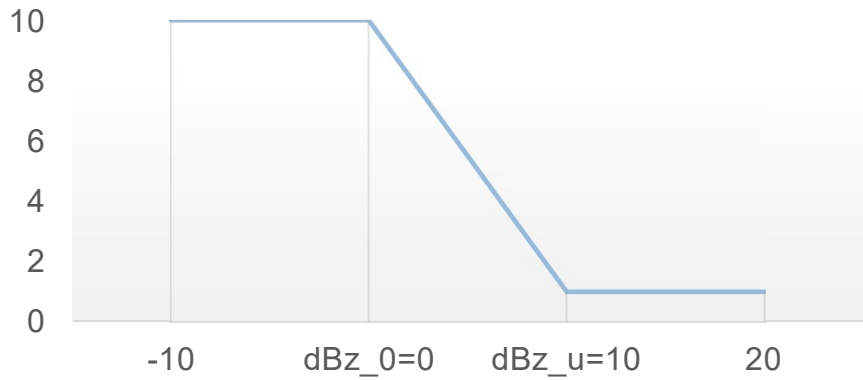
Avoid large increments in LETKF & reduce FG-spread

Rejection also depends on obs_error, no clear signal

Related to grid resolution and correlation length

Model for obserr @ emvorado

- Relative error (= factor to be multiplied by LETKF with given value for obs_err_radvel) written to fof-file
- Factor different from 1.0 for Z<10 dbZ
- Variables to be set in EMVORADO-nml (in up-to-date src):
  - itype_obserr_vr
  - baseval_obserr_vr
  - maxval_obserr_vr
  - ramp_lowdbz_obserr_vr
  - ramp_highdbz_obserr_vr



QC possibilities:

- Perform superobbing as usual, then calculate factor for obserr
- take function for obserr also into account to calculate radvel superobservation (itype_obserr_vr = 2)

Settings@LETKF-nml:

- ***luse_eo_factor = .true.*** (in &RADAR_OBS)
  → use e_o from EMVORADO fof-File as factor to multiply e_o-PROFILE
- ***Do <u>not</u> use:***
  radvel_obs_error = 3. ! radar radial wind obs error
- ***Specify obs_error via profile:***
  &OBSERR obstype='RADAR' codetype=0 1 3 quantity='radvel' table='extern'
  scale=1.0
  err= 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 2.50 /
  → Radar radial winds: use fixed profile to work with luse_eo_factor

Regarding inflation:

- Radar observations used for adaptive multiplicative inflation
  - Could be switched off, not straight forward
  - Observation error plays an important role
- Relaxation to prior perturbations (RTTP) is used (alpha=0.75)

Settings@EMVORADO:

- Attenuation is simulated in EMVORADO (lextdbz = .true.)
  → yet observations are corrected, gives no clear picture in experiments
- supob_lowthresh_z_obs=0.0,
- supob_lowthresh_z_sim=0.0,
- supob_vrw=10.0, ! (m/s) upper threshold for stddev of radial wind values within a superobbed bin to accept the superobbing value

Regarding v_log:

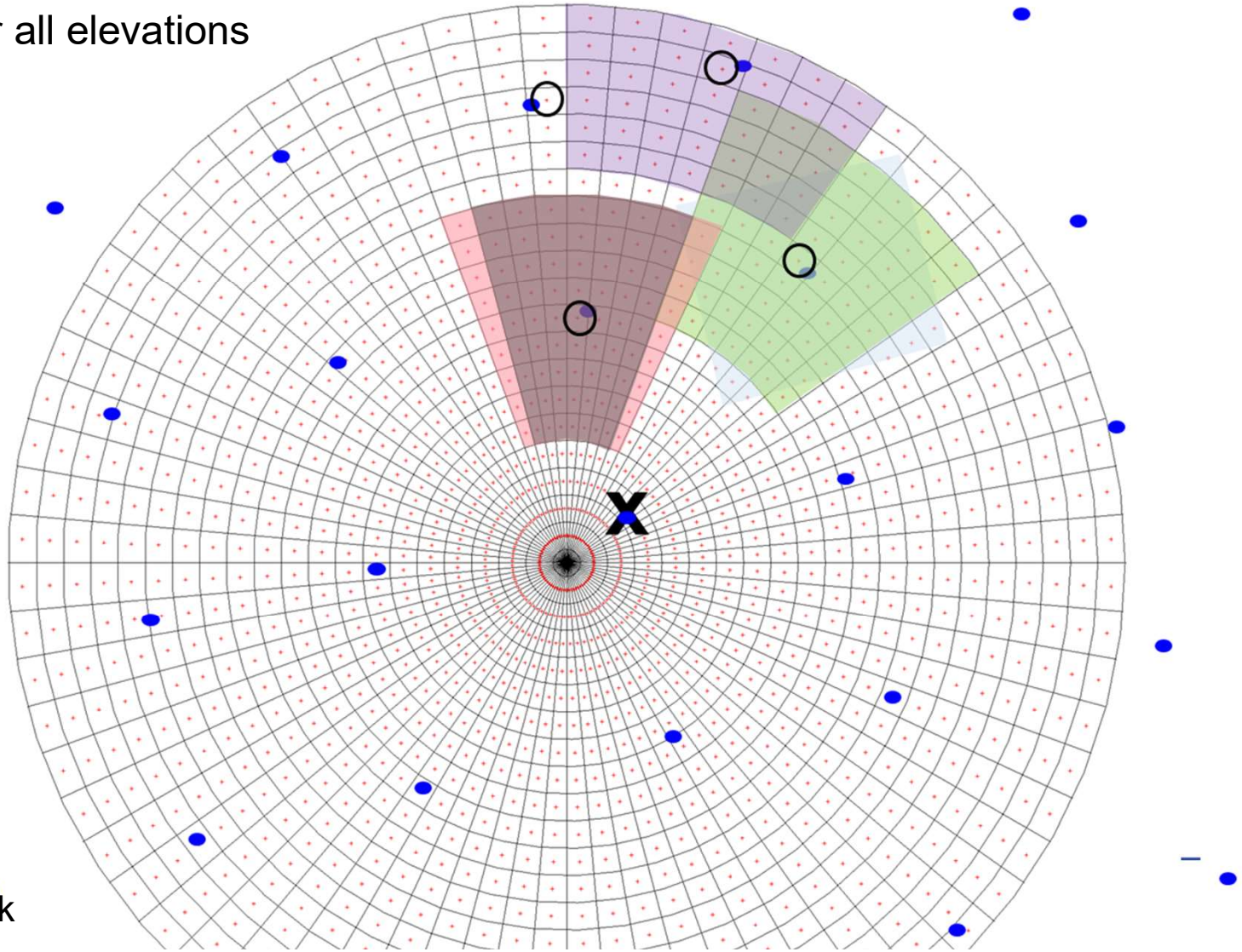
From KENDA Paper: *"In the experiments of this study, the vertical localization scale increases with increasing height in the range 0.075–0.5 in terms of the logarithm of pressure"*

Superobing of radar data

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

- Superobing in the horizontal:
- Same **grid** for all elevations

2D PPI grid



By U. Blahak

List of Experiments – June 2019

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

Exp-ID	duration	3D Radar Refl / Radvel	Base experiment	LHN	Comment
ILAM_ONLINE_0626	4 weeks	N / N		Y	
ILAM_ONLINE_06262	3 weeks	N / N	*0626	Y	Bug not act.
ILAM_ONLINE_0627	3 weeks	N / Y	*0626	Y	
ILAM_ONLINE_0631	3 weeks	N / Y (10 ele.)	*0627	Y	
ILAM_ONLINE_0633	3 weeks	Y / Y	*0627	Y	
ILAM_ONLINE_0635	3 weeks	N / Y (10 ele.)	*0631	Y	“no” v_loc
ILAM_ONLINE_0636	3 weeks	Y / N	*0626	Y	
ILAM_ONLINE_0638	3 weeks	Y / Y	*0633	N	FG-chk 10σ
ILAM_ONLINE_0639	3 weeks	Y / Y	*0633	N	
ILAM_ONLINE_0639.2	3 weeks	N / N	*0633	N	
ILAM_ONLINE_0640	3 weeks	Y / Y	*0633	Y	no att., 10σ
ILAM_ONLINE_0641	3 weeks	Y / Y	*0633	Y	10σ

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ILAM_ONLINE_0639.2	3 weeks	N / N	*0633	N	
ILAM_ONLINE_0640	3 weeks	Y / Y	*0633	Y	no att., 10σ
ILAM_ONLINE_0641	3 weeks	Y / Y	*0633	Y	10σ

→ Using more elevations for radial winds is slightly benificial (computing time)
→ Using the „default“ vertical localization does not improve the result

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ILAM_ONLINE_0636	3 weeks	Y / N	*0626	Y	
ILAM_ONLINE_0638	3 weeks	Y / Y	*0633	N	FG-chk 10σ
ILAM_ONLINE_0639	3 weeks	Y / Y	*0633	N	
ILAM_ONLINE_0639.2	3 weeks	N / N	*0633	N	
ILAM_ONLINE_0640	3 weeks	Y / Y	*0633	Y	no att., 10σ
ILAM_ONLINE_0641	3 weeks	Y / Y	*0633	Y	10σ

→ Increasing the allowed deviation for the FG-check of the reflectivities is neutral
→ Disableing the simulation of attenuation does not give a clear signal