LHN in ICON-LAM

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Klaus Stephan

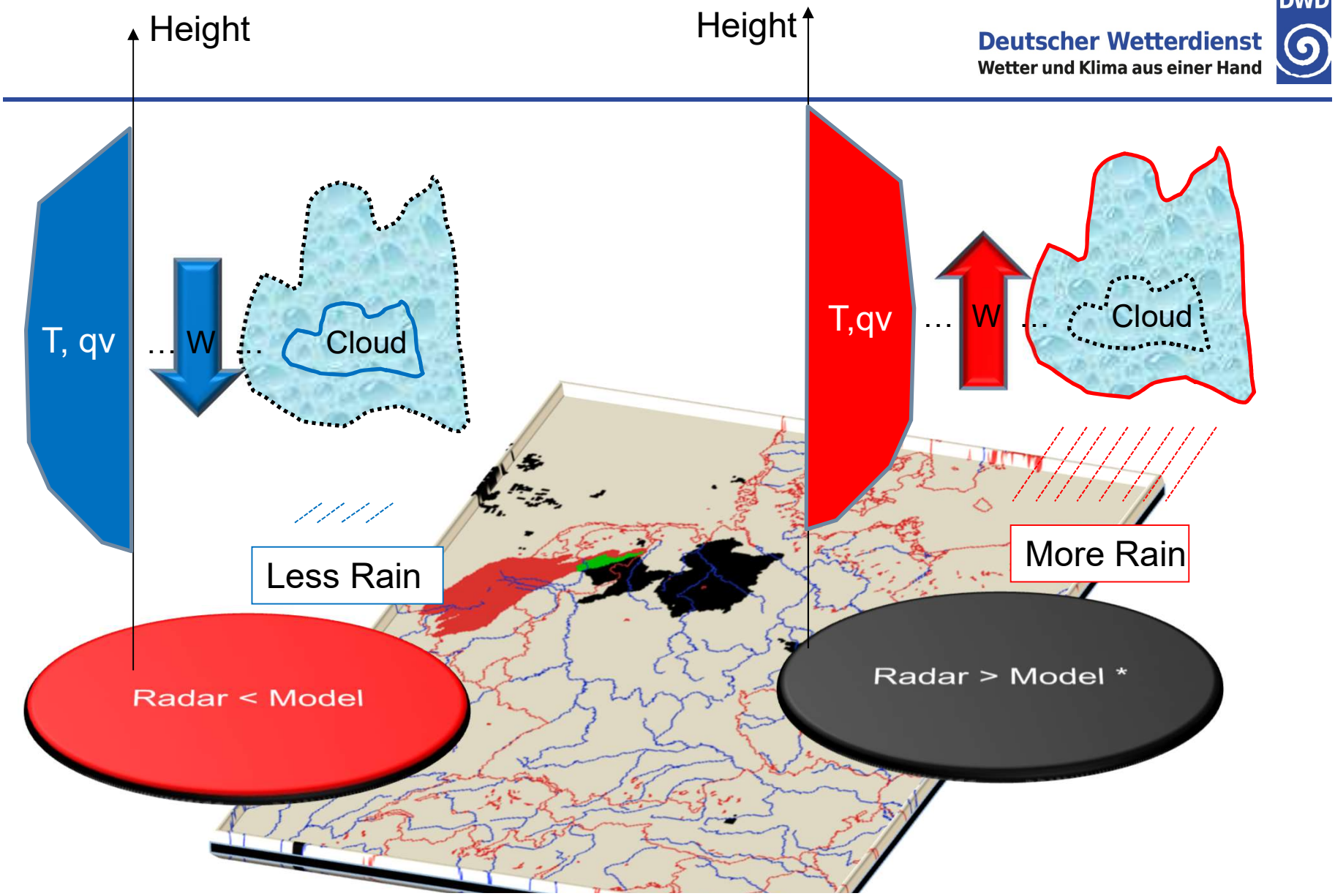
Outline

- Motivation and brief description of LHN
- Technical aspects for applying LHN
- Pro & Cons of LHN concerning ICON-LAM
- (OPERA)

Motivation

- Apart from assimilation of 3d radar reflectivity and radial winds a 2d composite of radar derived precipitation is assimilated via latent heat nudging.

- Pro:
  - not all 3d volume data are available yet, at least for German model domain
  - LHN triggers cells in the entire ensemble and therefore helps assimilating 3d volume data
  - LHN corrects amount of precipitation within the model, avoiding a drying out
- Cons:
  - LHN adopts the dynamical structure during assimilation, but may lead to imbalances which may lead to spin down effects and different model bias
  - Radar observation error are almost not accounted for



* If model has no suitable precipitation at the target grid point, a more suitable nearby grid point is searched (COSMO).
If no point can be found, an artificial temperature profile is used for the scaling.

Latent Heat Nudging

Basic Assumptions:

- vertically integrated latent heat release $\propto$ vertically integrated precipitation flux within each model column
- relation is similar in model and nature
- relation is linear and constant in any meteorological situation

$$T_{LH,obs} = RR_{obs}\frac{T_{LH,mod}}{RR_{mod}} = \frac{RR_{obs}}{RR_{mod}}T_{LH,mod} = \beta T_{LH,mod}$$

$$\frac{\partial T}{\partial t} = F(X,t) + \alpha\left(T_{LH,obs} - T_{LH,mod}\right) = F(X,t) + \alpha\left(RR_{obs} - RR_{mod}\right)\frac{T_{LH,mod}}{RR_{mod}}$$

In addition increments of specific humidity are added (optionally but recommended) to remain relative humidity constant (***lhn_hum_adj***)

Technical aspects (1)

- LHN is applied at any integration step between (***nlhn_start*** and ***nlhn_end***)
- $T_{LH,mod}$ is collected from all processes associated with latent heat release within every integration time step, separately.
- α: nudging coefficient (***lhn_coef***), which decides how much of the increment is added. Setting to „0“ means no increment is added, but all monitoring is available
- β: ratio between observed precipitation and a model equivalent (RR_{mod}). RR_{mod} can be surface precipitation or a vertical mean of the precipitation flux (***lhn_qrs***). This accounted for temporal evolution of precipitation within model column. The extent of the vertical average is a tuning property (***rqrsgmax***). We have to avoid a bias between this equivalent and the model precipitation itself.
- β will be limited by ***fac_lhn_up*** and ***fac_lhn_down***. As closer β is limited too 1 as lower an increment will be.
- We recommend to restrict increments to model levels, showing a positive latent heat release (***lhn_incloud***)
- The increment itself can also be limited by ***abs_lhn_lim*** and ***lhn_limit***.

Technical aspects (2) (almost new since ICON)

- In case of too little precipitation simulated, an artificial temperature profile can be applied (***lhn_artif, tt_artif_max, zlev_artif_max, std_artif_max***).
  - In COSMO still a searching for a more suitable neighbouring grid point will be applied first (***lhn_search***)
- Take into account only moisture increments (***lhn_no_ttemp***)
- Take into account only artificial temperature profile (***lhn_artif_only***)
- Scale ***abs_lhn_lim*** with height using a Gaussian function (same function as defined for artificial temperature profile) by ***lhn_limitp*** instead of ***lhn_limit***

- LHN routine may provide more diagnostic output (***lhn_diag***) within YULHN (COSMO) or lhn.log (ICON). Herein also an online verification against the radar data can be provided between ***nlhnverif_start*** and ***nlhnverif_end***.

Technical aspects (3) (concerning observations)

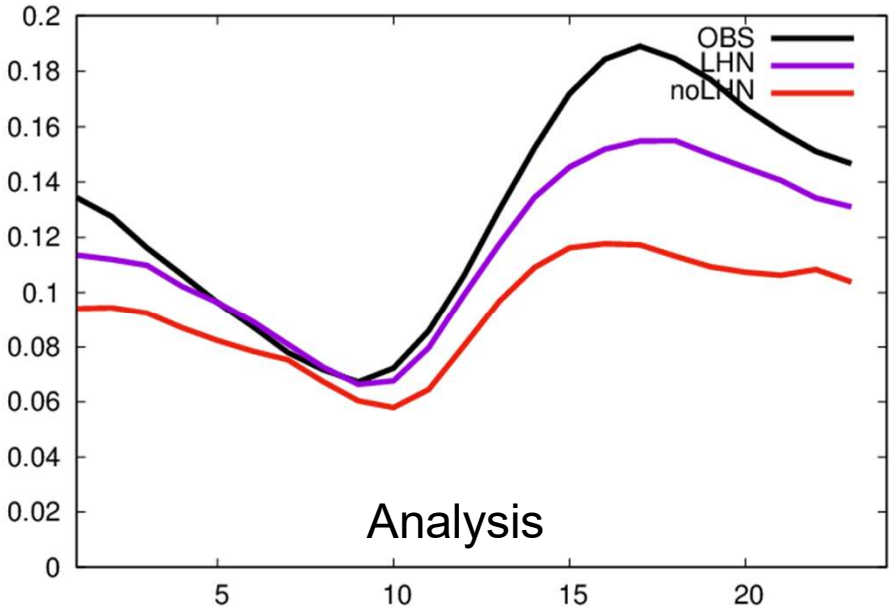
- Radar data has to be interpolated to model grid (i.e. aggregation in space). Both radar and model can be smoothed spatially (***lhn_relax, nlhn_relax***)
- Radar data are interpolated in time between observations (observation frequency has to be specified by ***lhn_dt_obs***)
- A detection for bright band can be applied, when a radar height information is given. (***lhn_bright, height_file***)
- A blacklist file can be applied (***lhn_black, blacklist_file***). This blacklist can be obtained by comparision against satellite products
- A spatial quality index can be applied (***lhn_squal***, not tested yet in ICON). The quality index has to be included within the ***radardata_file*** and is prepared in pre processing quality control

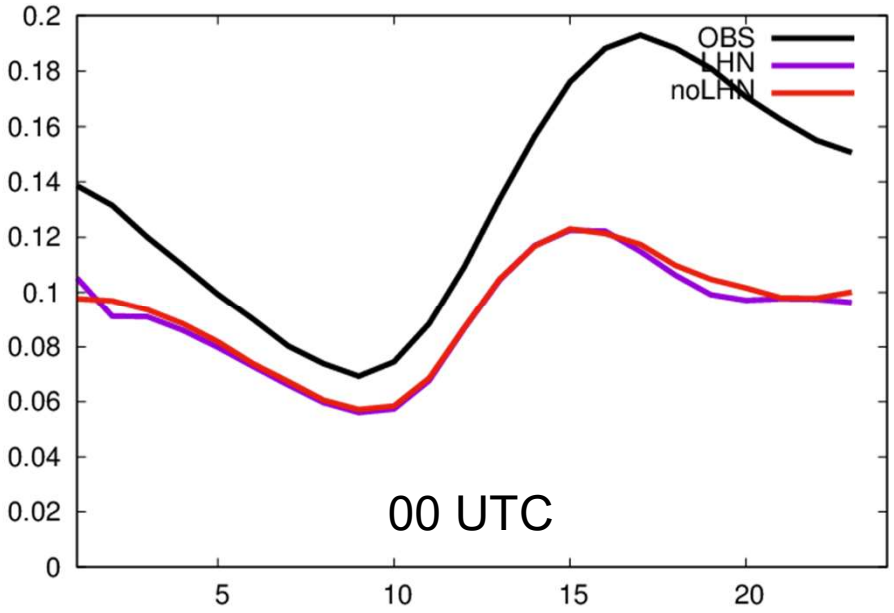
Pro & Cons

- Pro:
  - LHN corrects amount of precipitation within the model, avoiding a drying out of the soil
  - not all 3d volume data are applicable yet, at least for German model domain
  - LHN triggers cells in the entire ensemble and therefore helps assimilating 3d volume data
- Cons:
  - LHN adopts the dynamical structure during assimilation, but may lead to imbalances which may lead to spin down effects and different model bias
  - Radar observation error are almost not accounted for

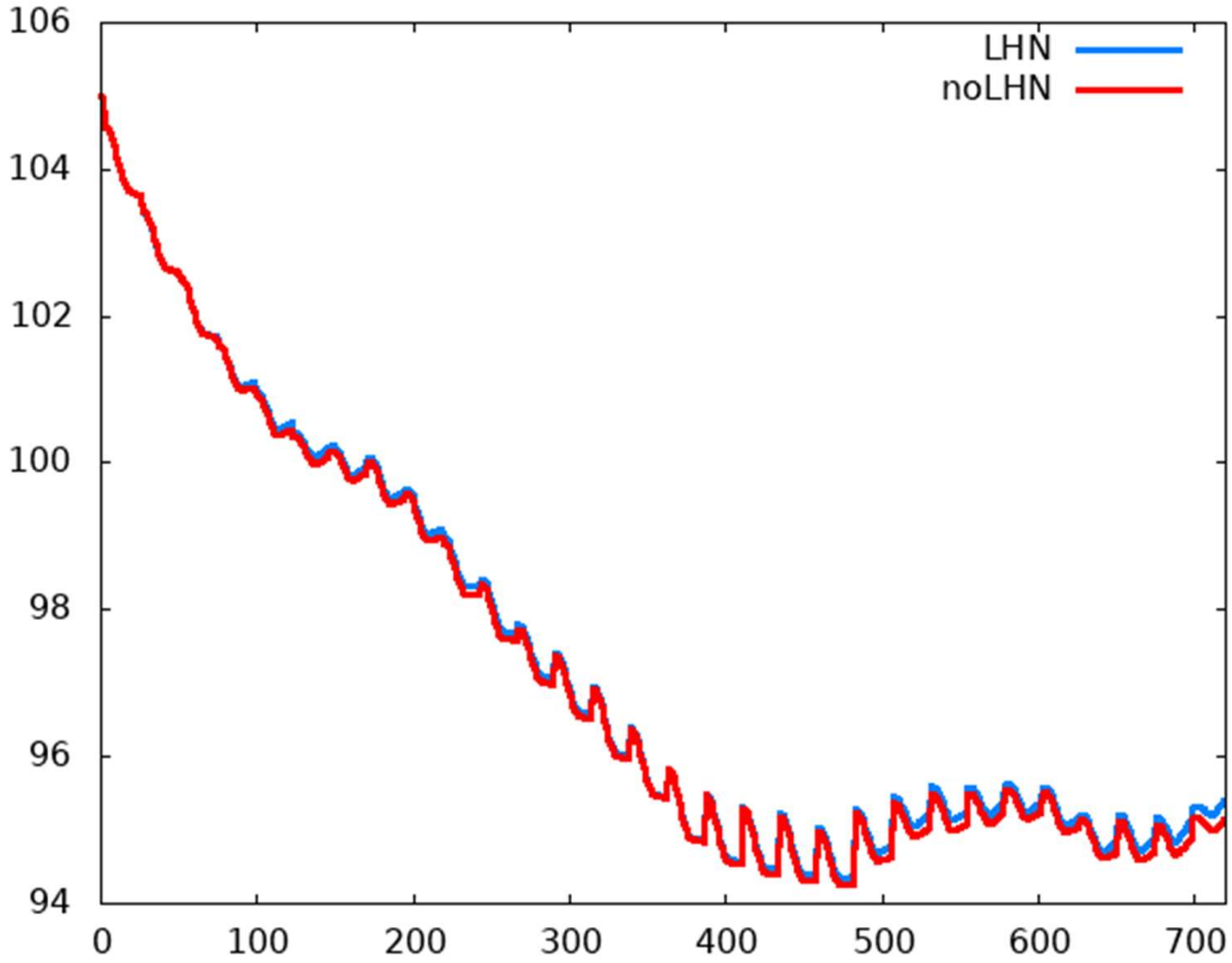
- **Comparison of two experiments, with and without LHN for June 2021**
  - Other setup very close to operational setup.

Correction of precipitation amount

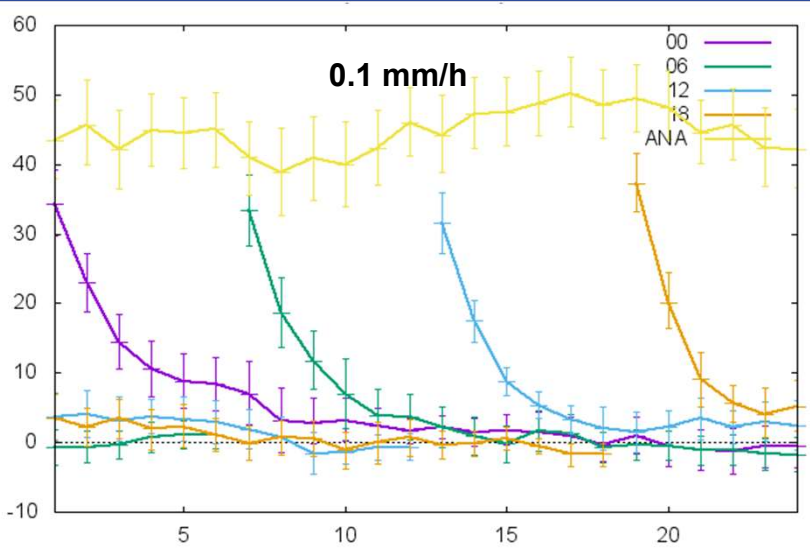


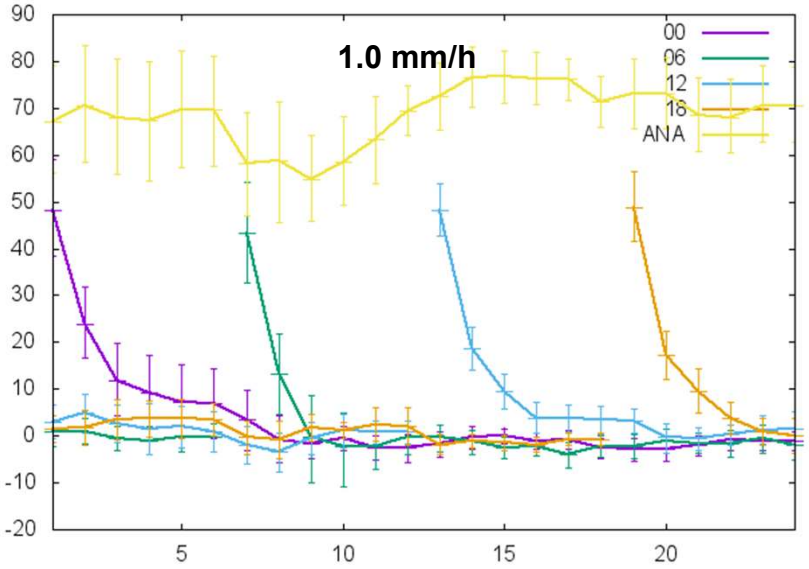


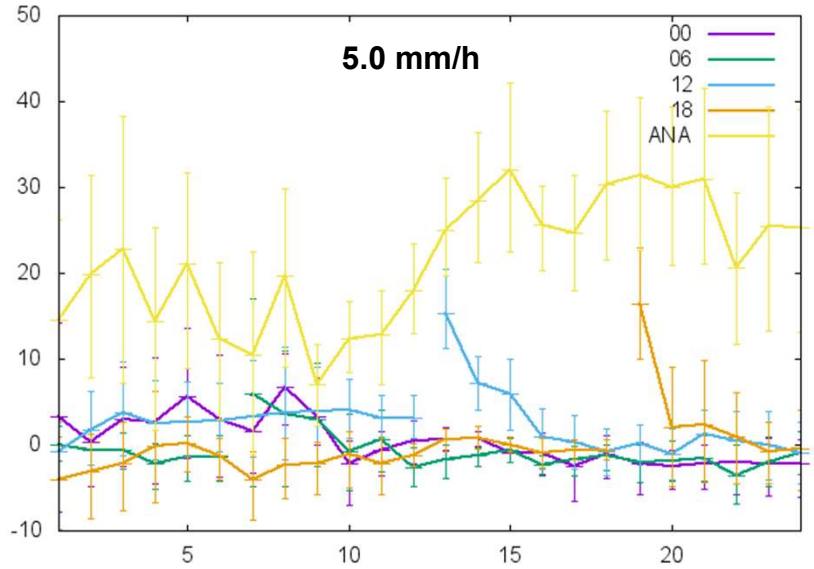
Influence on soil moisture (5th layer)

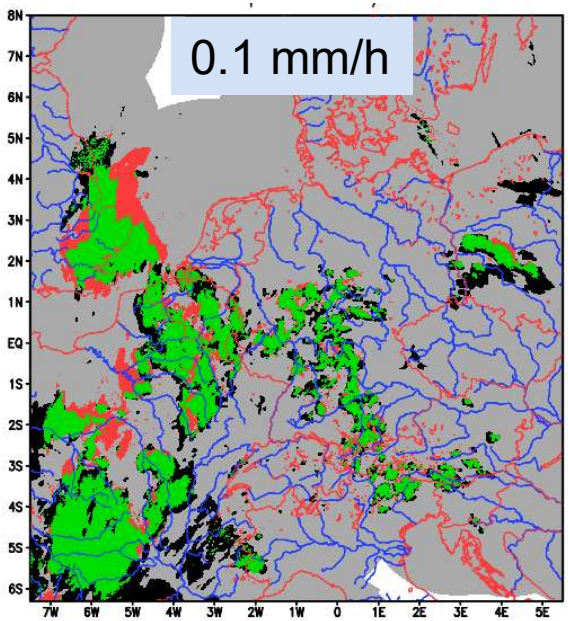


Improvement in FSS (11 grid points)

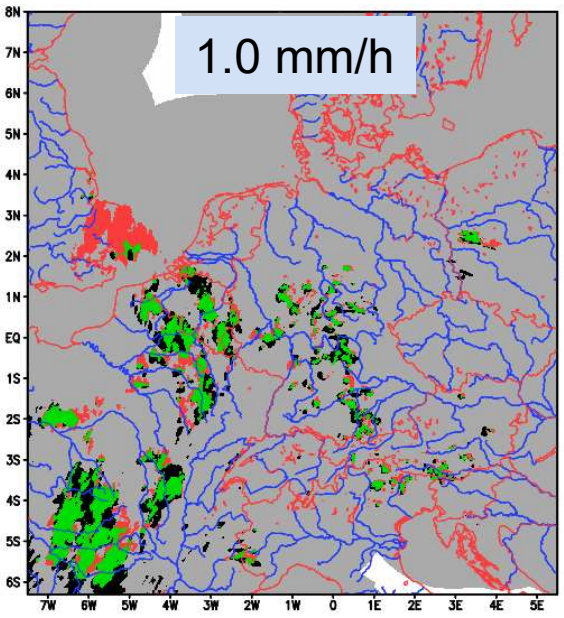




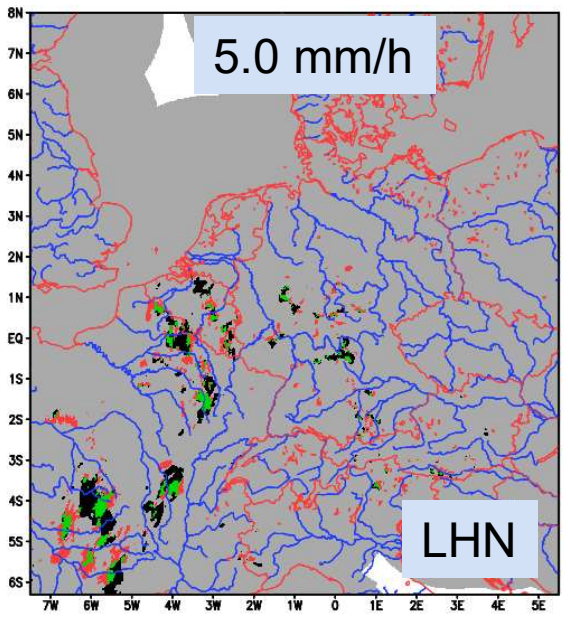




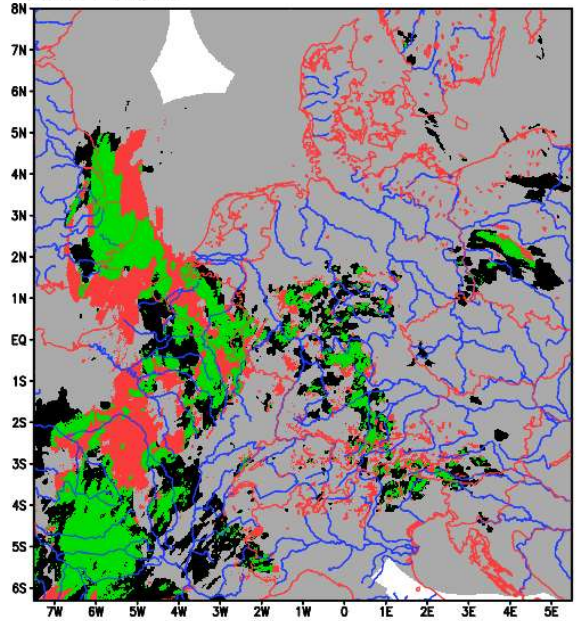
Radar: mean: 0.378 mm/h max: 72.19 mm/h
Model: mean: 0.337 mm/h max: 92.50 mm/h
missed (black): 33875 false (red): 16772 hits (green): 50249
ETS: 0.428 FBI: 0.796



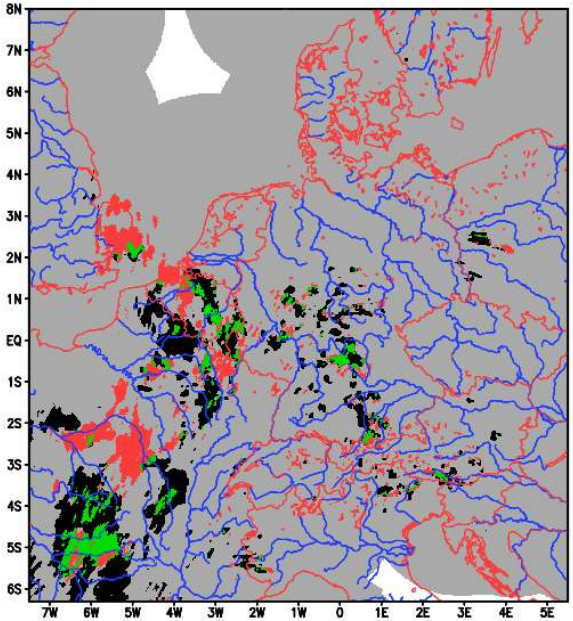
Radar: mean: 0.333 mm/h max: 72.19 mm/h
Model: mean: 0.306 mm/h max: 92.50 mm/h
missed (black): 14260 false (red): 11907 hits (green): 16832
ETS: 0.362 FBI: 0.924



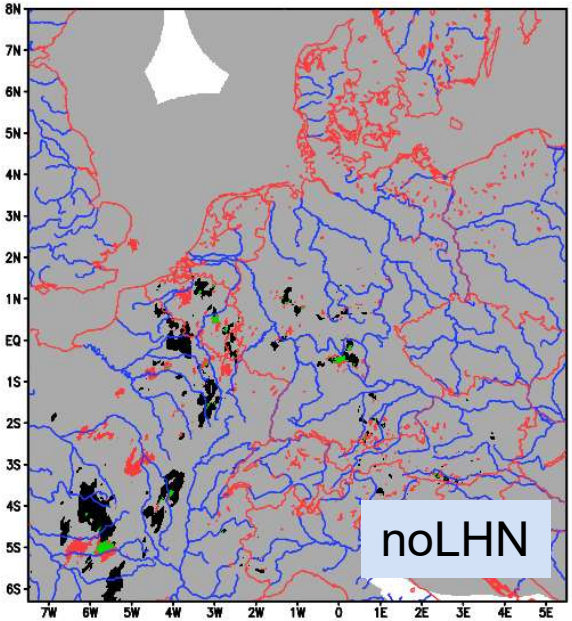
Radar: mean: 0.225 mm/h max: 72.19 mm/h
Model: mean: 0.210 mm/h max: 92.50 mm/h
missed (black): 6399 false (red): 6589 hits (green): 2828
ETS: 0.168 FBI: 1.020



Radar: mean: 0.378 mm/h max: 72.19 mm/h
Model: mean: 0.252 mm/h max: 93.63 mm/h
missed (black): 43532 false (red): 30343 hits (green): 40592
ETS: 0.271 FBI: 0.843

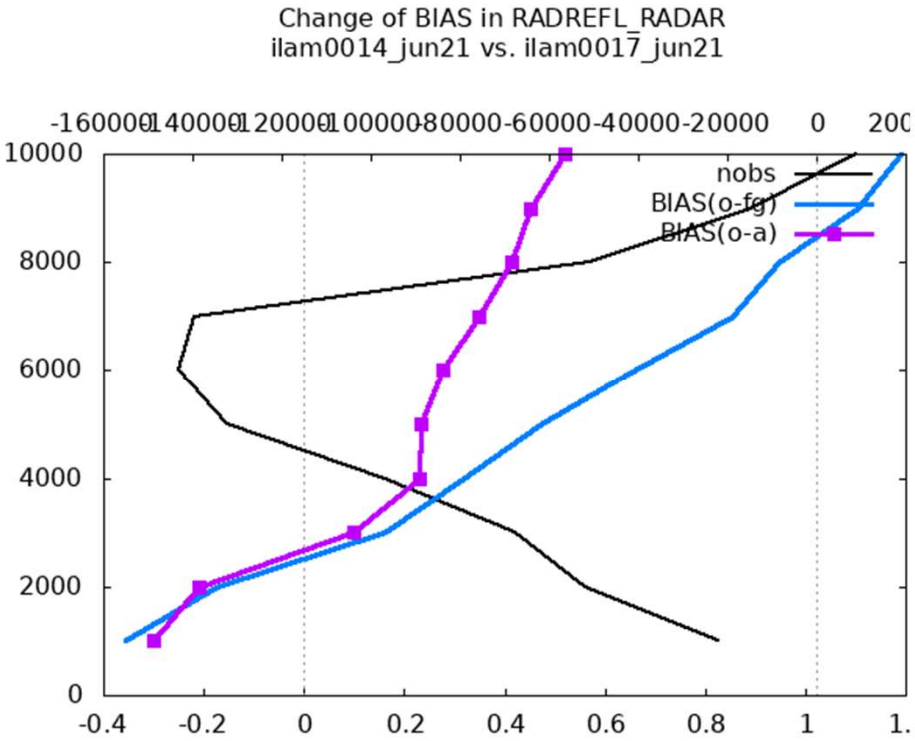


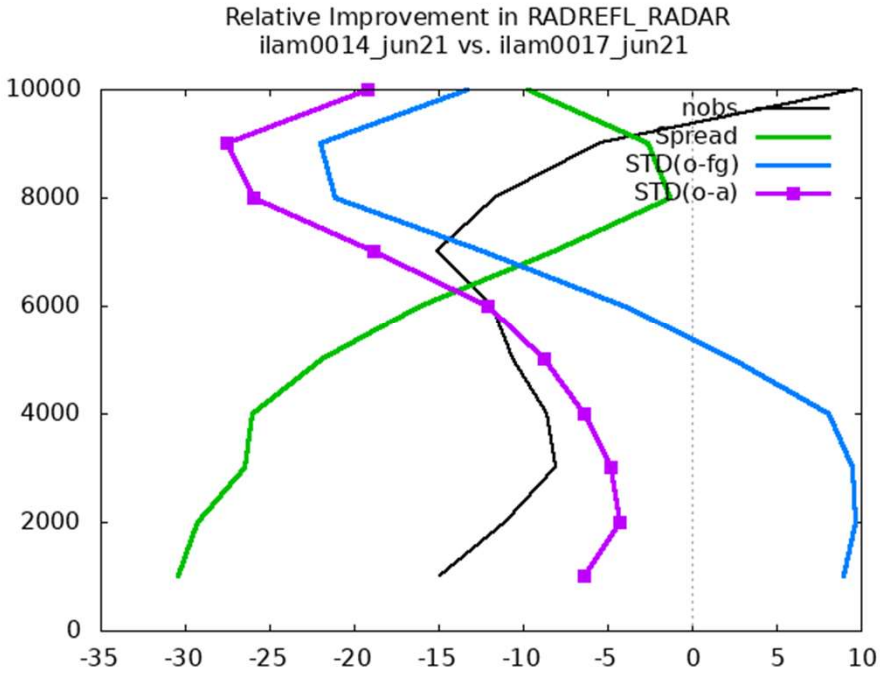
Radar: mean: 0.333 mm/h max: 72.19 mm/h
Model: mean: 0.210 mm/h max: 93.63 mm/h
missed (black): 24560 false (red): 14489 hits (green): 6532
ETS: 0.115 FBI: 0.676



Radar: mean: 0.225 mm/h max: 72.19 mm/h
Model: mean: 0.137 mm/h max: 93.63 mm/h
missed (black): 8578 false (red): 4808 hits (green): 649
ETS: 0.038 FBI: 0.591

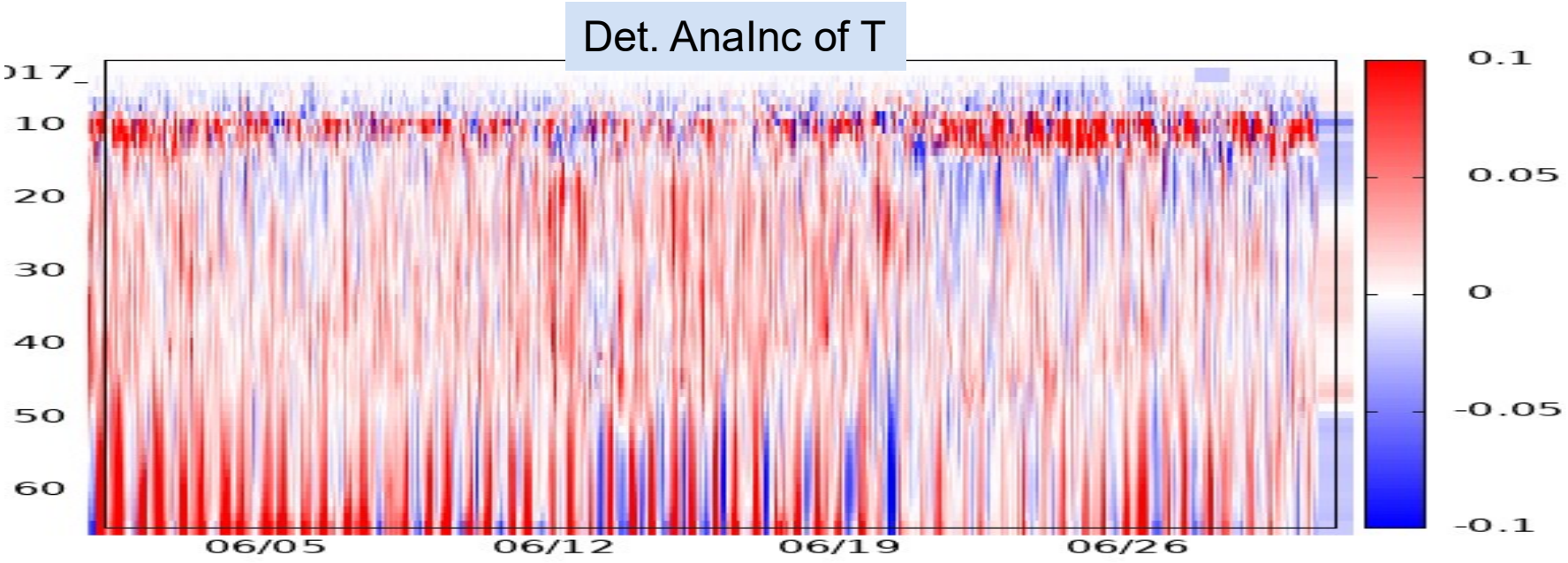
Benefit on 3d radar data assimilation

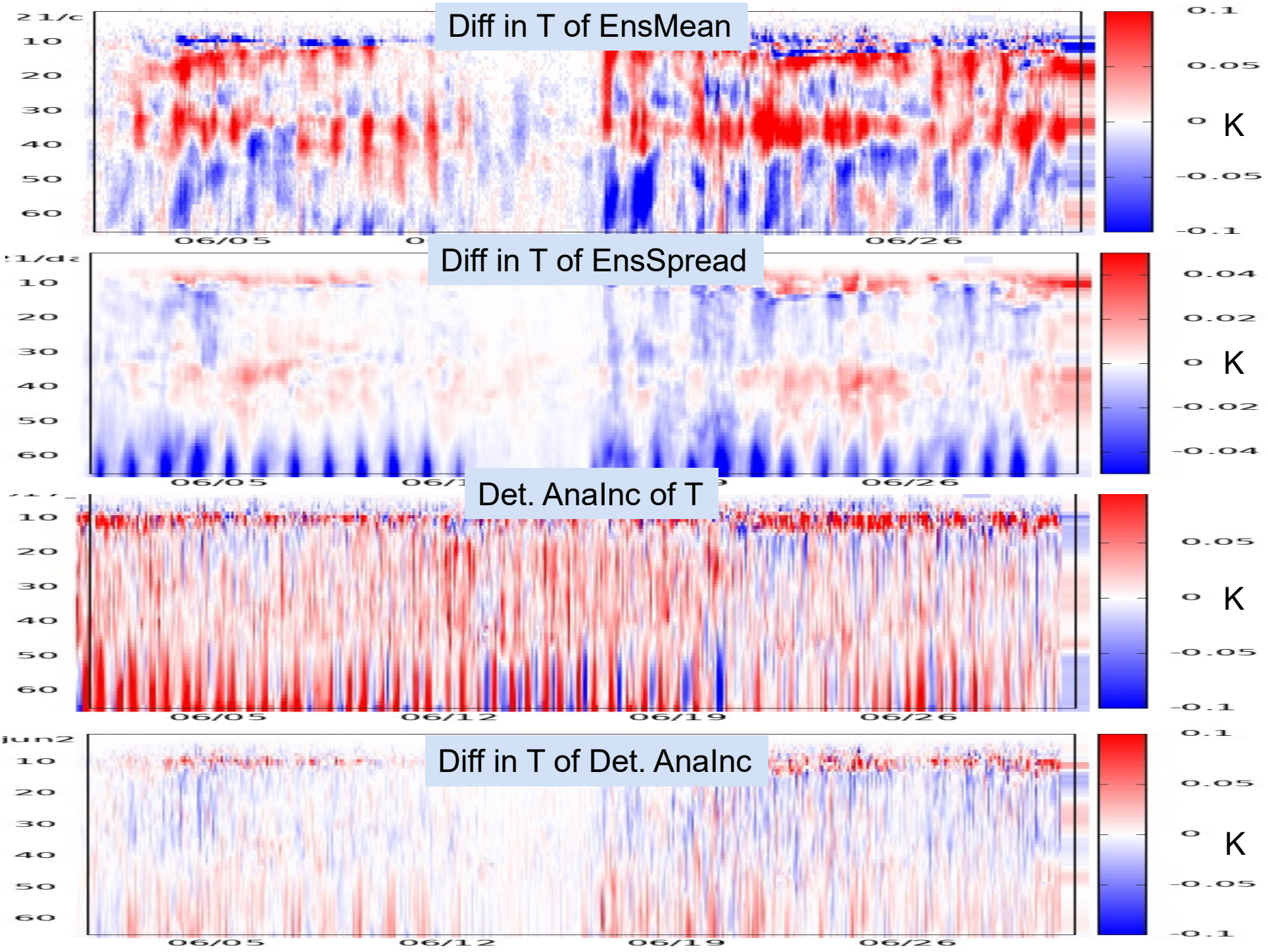


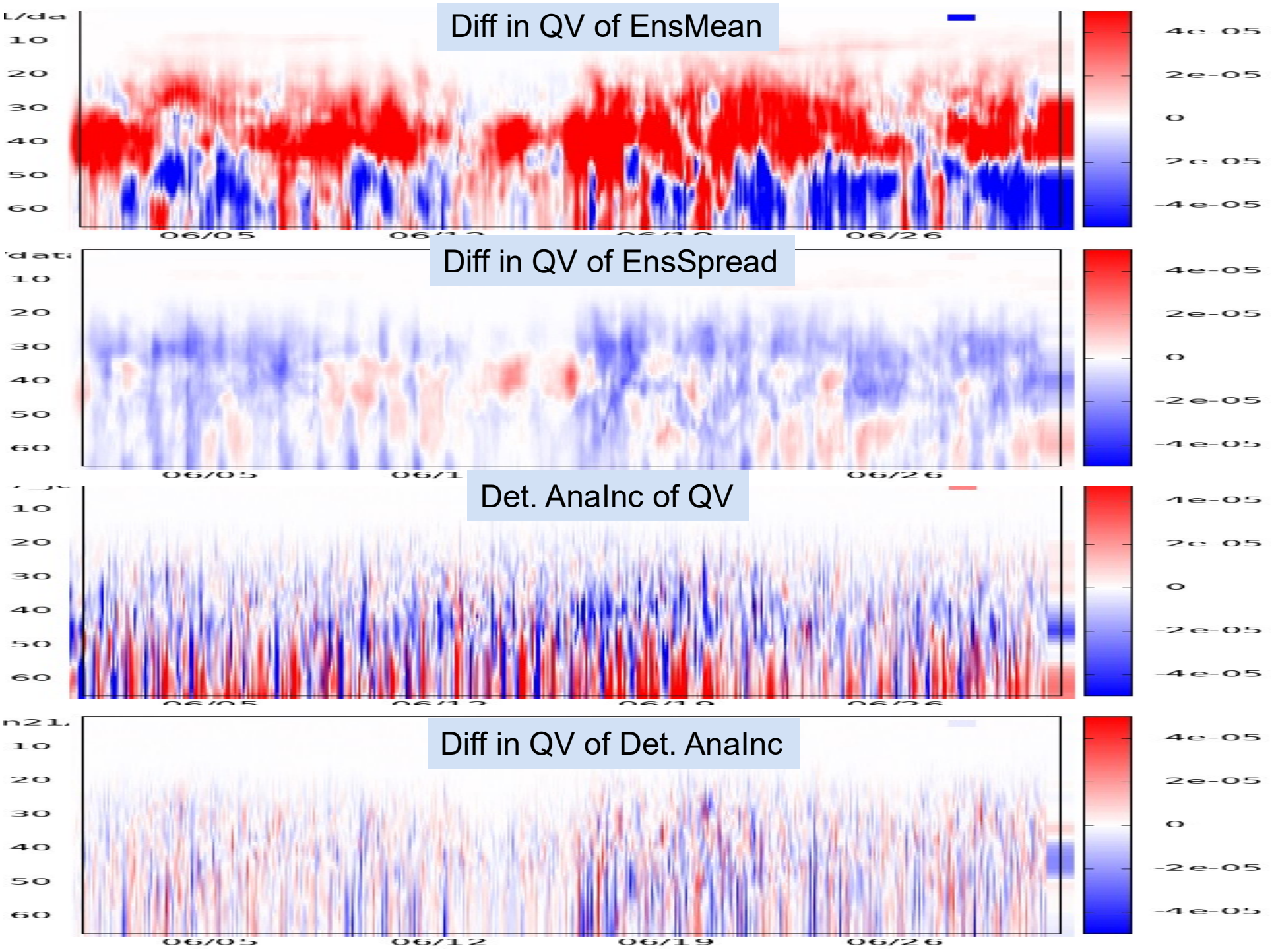


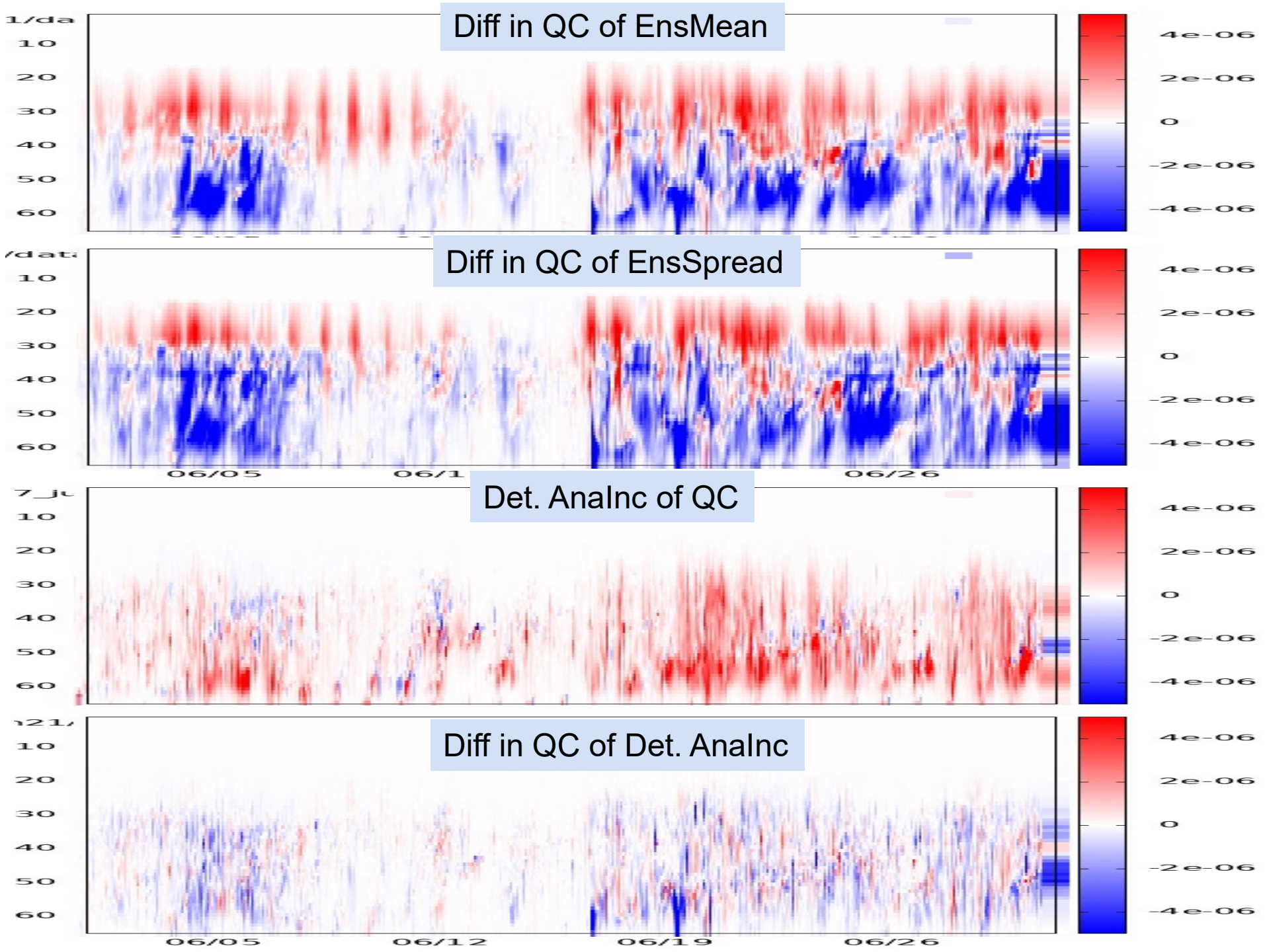
Influence of model state

- Evaluation of model state can be done in different ways.
  - Verification of analyses or forecasts against observations
  - Investigation temporal and spatial averages of meteorological parameter.
  - In terms of LETKF, this are Ensemble mean, ensemble spread and analysis increments




Diff in T of EnsMean
Diff in T of EnsSpread
Det. AnaInc of T
Diff in T of Det. AnaInc
10
20
30
40
50
60
06/05
06/12
06/19
06/26
0.1
0.05
0
K
-0.05
-0.1
0.04
0.02
-0.02
-0.04


Diff in QV of EnsMean
Diff in QV of EnsSpread
Det. AnaInc of QV
Diff in QV of Det. AnaInc
10
20
30
40
50
60
06/05
06/12
06/19
06/26
4e-05
2e-05
0
-2e-05
-4e-05


Diff in QC of EnsMean
Diff in QC of EnsSpread
Det. AnaInc of QC
Diff in QC of Det. AnaInc
10
20
30
40
50
60
06/05
06/12
06/19
06/26
4e-06
2e-06
0
-2e-06
-4e-06

Assimilation cycle against Observations

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

Radiosondes

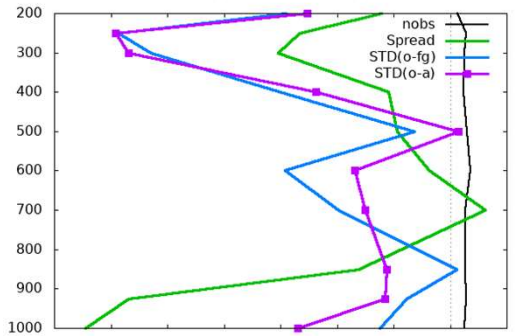
Aireps

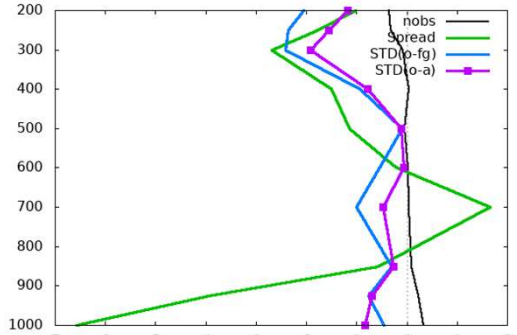
T

RH

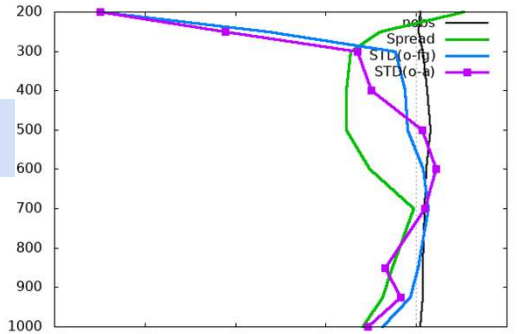
Wind

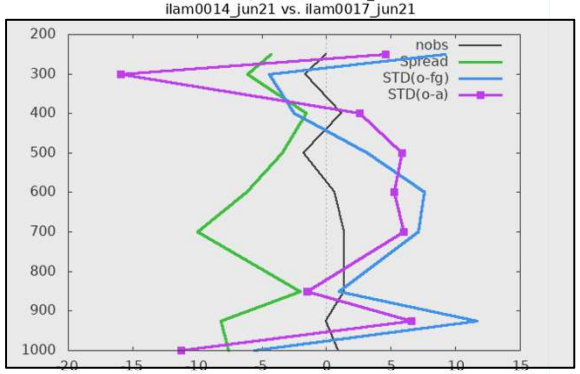
Pilot



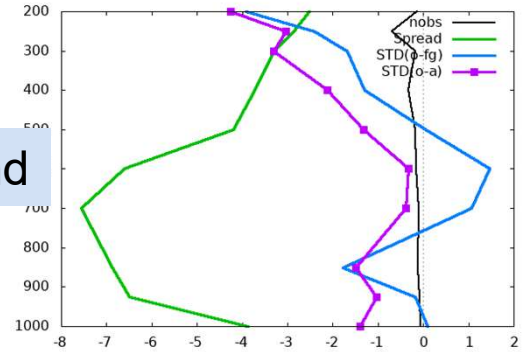


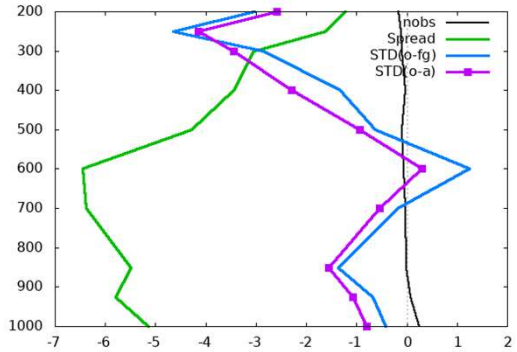
Relative Improvement in RH_TEMP
ilam0014_jun21 vs. ilam0017_jun21

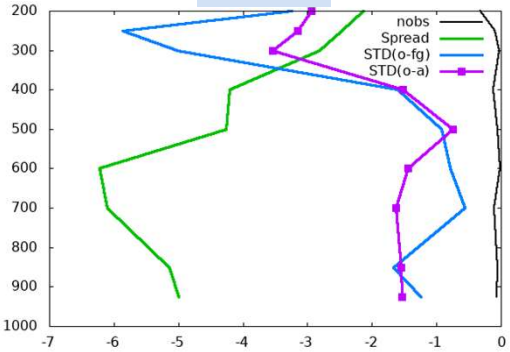




ilam0014_jun21 vs. ilam0017_jun21







- Slightly negative for LHN:
- Reduction in Spread and active observerations
- Increasing STD of both, Analyse and FG

Forecasts cycle against Observations

Wetter und Klima aus einer Hand

Synop

Wind

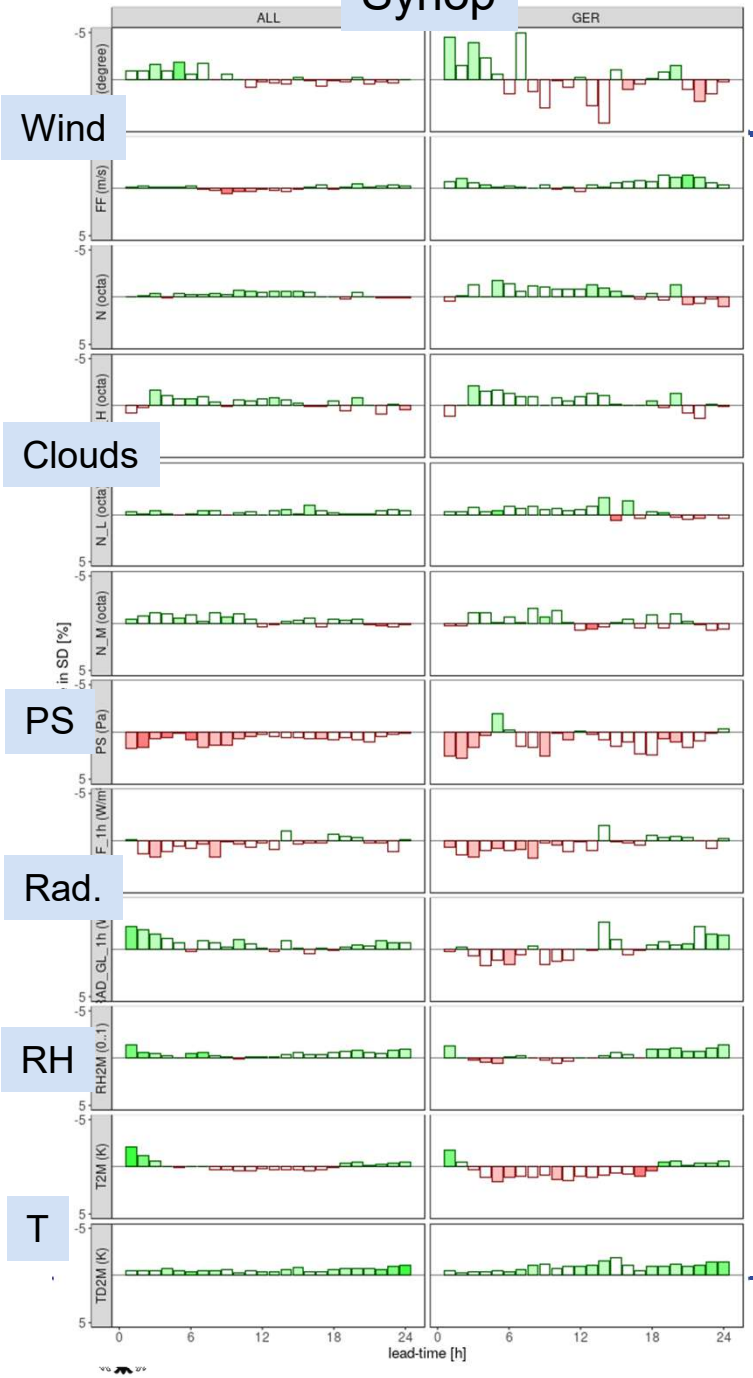
Clouds

PS

Rad.

RH

T

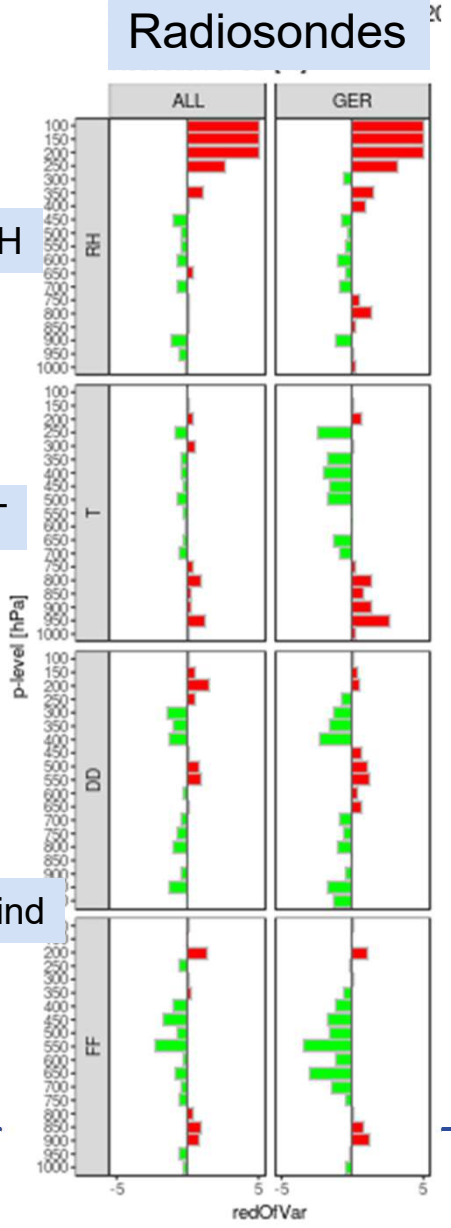


Radiosondes

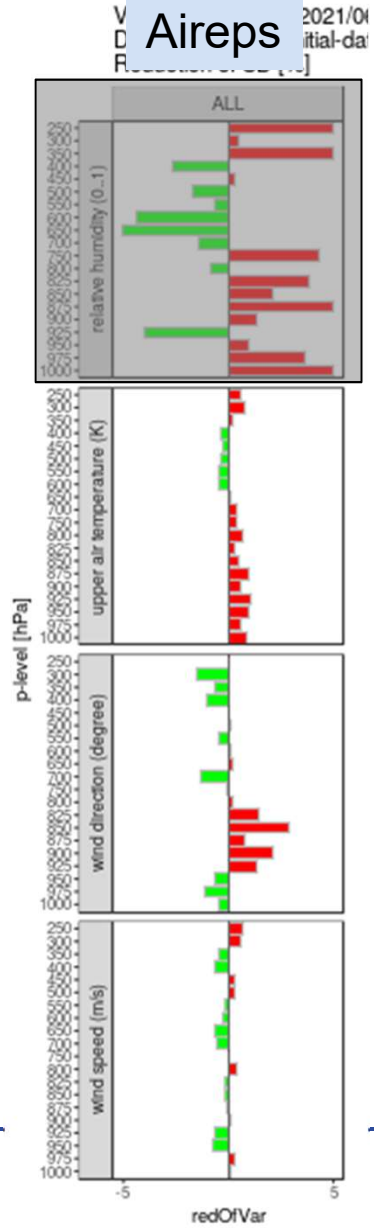
RH

T

Wind

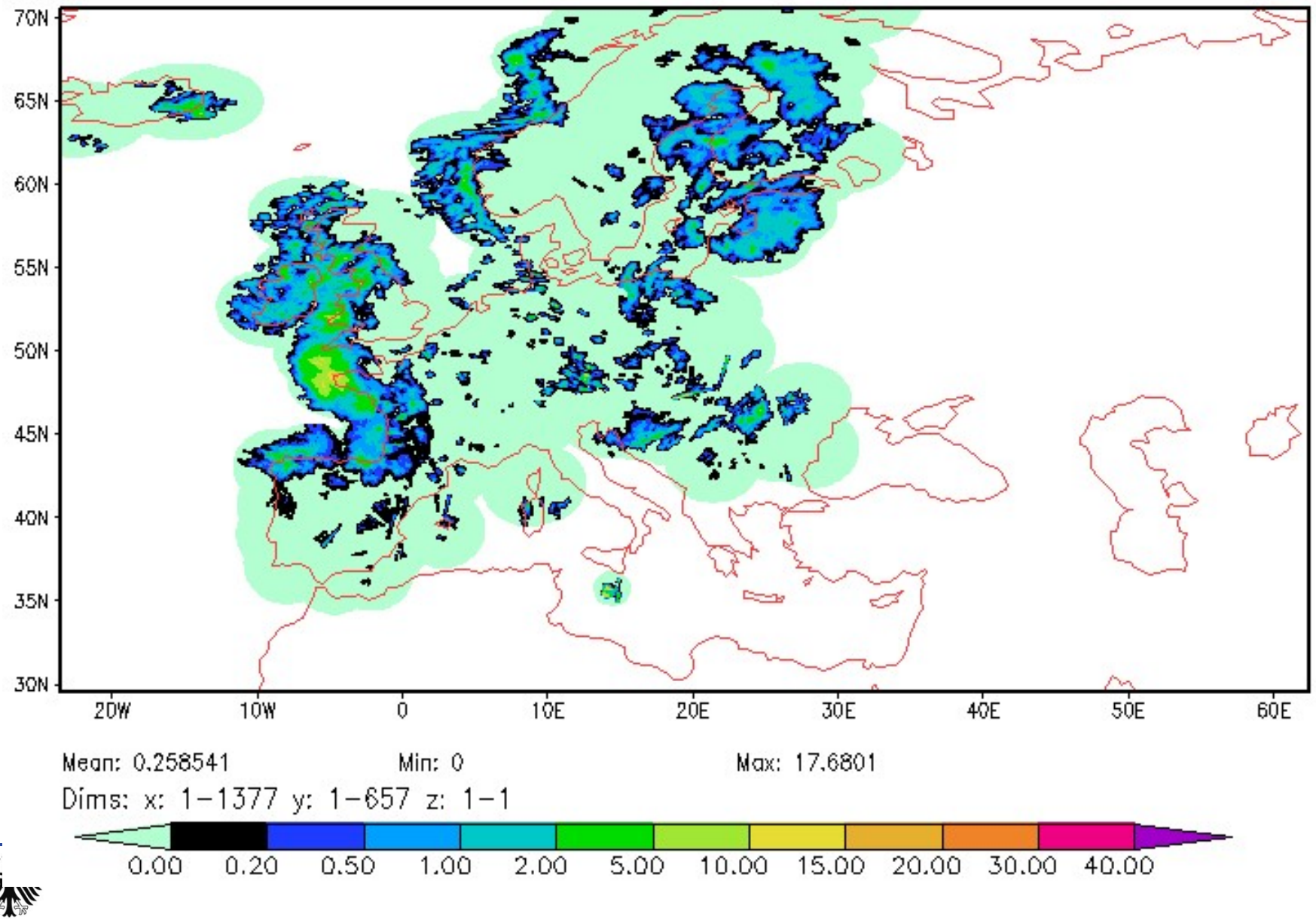


Aireps



Conclusion

- LHN in ICON LAM does improve precipitation during assimilation and within the first hours of free forecast. Socres remains longer than improvements in amount
- Effects on soil moisture less pronounced due to the relaxation to ICON-EU (every day at 3 UTC)
- LHN leads to cooling and drying within the boundary layer, a warming and moistinging further above.
- LHN leads to a reduction in spread
- Scores against observations are slightly negative for assimilation cycle but neutral too slightly positive for forecasts.
- Interaction with 2 moment scheme under development (too much graupel high above, stronger bias in surface precipitation and vertical precipitation flux.
- If you consider to apply LHN, you may think about using OPERA rain rate composite …


70N
65N
60N
55N
50N
45N
40N
35N
30N
20W
10W
0
10E
20E
30E
40E
50E
60E
Mean: 0.258541
Min: 0
Max: 17.6801
Dims: x: 1-1377 y: 1-657 z: 1-1
0.00
0.20
0.50
1.00
2.00
5.00
10.00
15.00
20.00
30.00
40.00

Here some facts

- Consists of about 150 radar stations all over Europe
  - Differ in age, manufacture, maintenance, post processings
  - Inhomogeneous quality
- Precipitation product is calculated from the best as possible reflectivity volume data. Data are weighted according to distance to composite grid point. So mainly the lowest elevation will win. Z is transformed to R be standard relation.
- Product available every 15 minutes and with 2x2 km² grid. A more frequent production is envisaged.
- ECMWF do not recommend using the data without further adjustments. DWD is using it in the almost outer areas of ICON-D2 domain, applying blacklisting and bright band detection

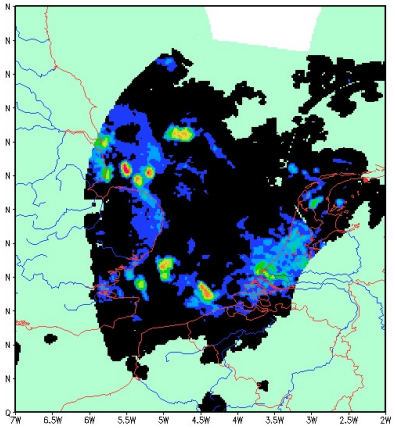
Forecast quality vs. data quality

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

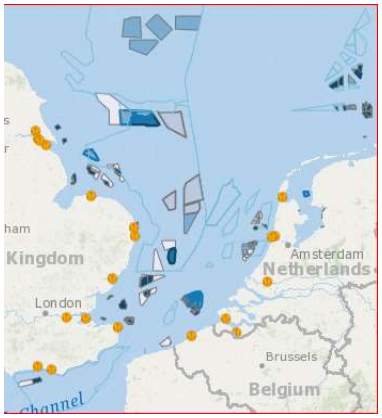
DWD

Satellite image

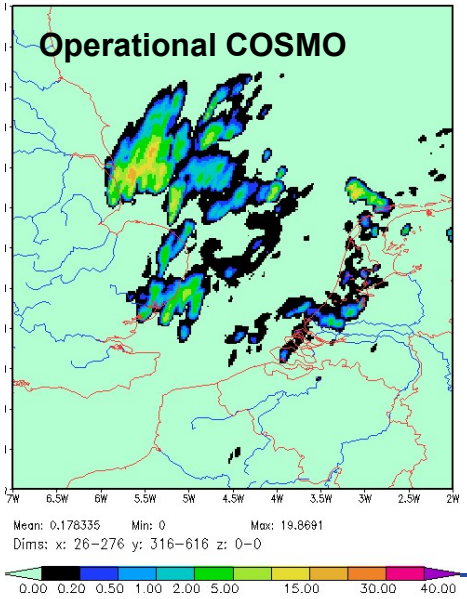
Dutch Radar



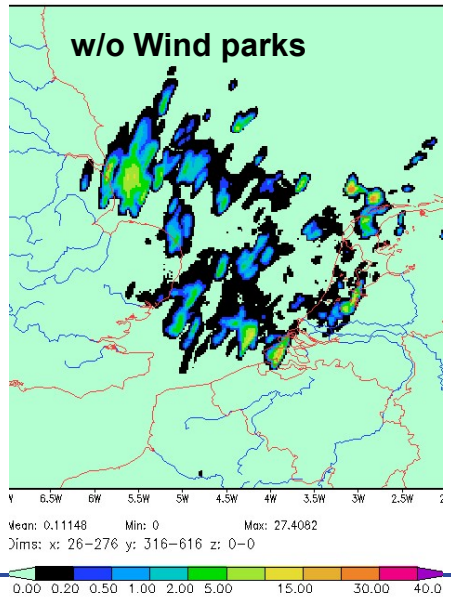
Offshore Wind parks



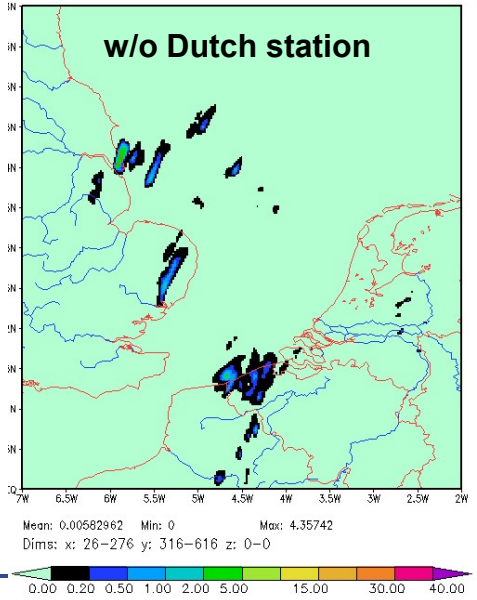
Operational COSMO



w/o Wind parks



w/o Dutch station



w/o LHN