(some) KENDA activities at DWD

- Ultra Rapid Data Assimilation (URDA)   (WG1)

  Zoi Paschalidi, Walter Acevedo (Roland Potthast)

- GPS Slant Total Delay   (Task 2.2)

  Michael Bender

Motivation

autonomous driving ⟵ depends strongly on weather conditions!

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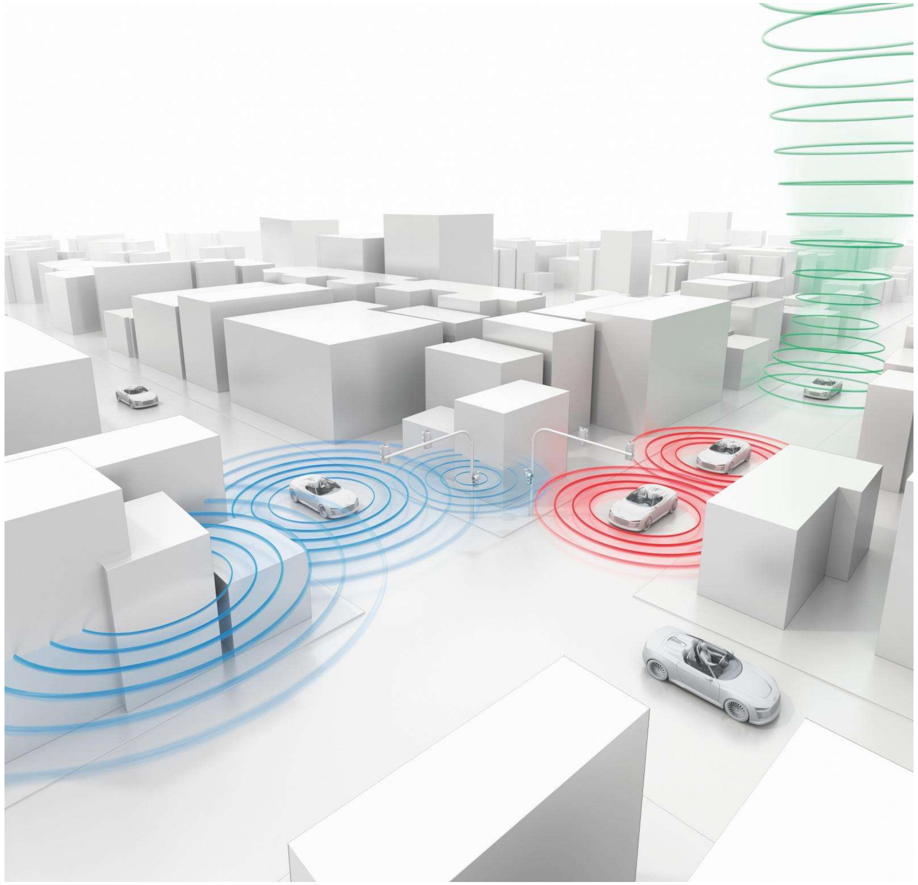
Outline

- new observation sources
- Ultra-Rapid DA (URDA) algorithm
- experiments with KENDA system
- perspective



Source: AUDI AG

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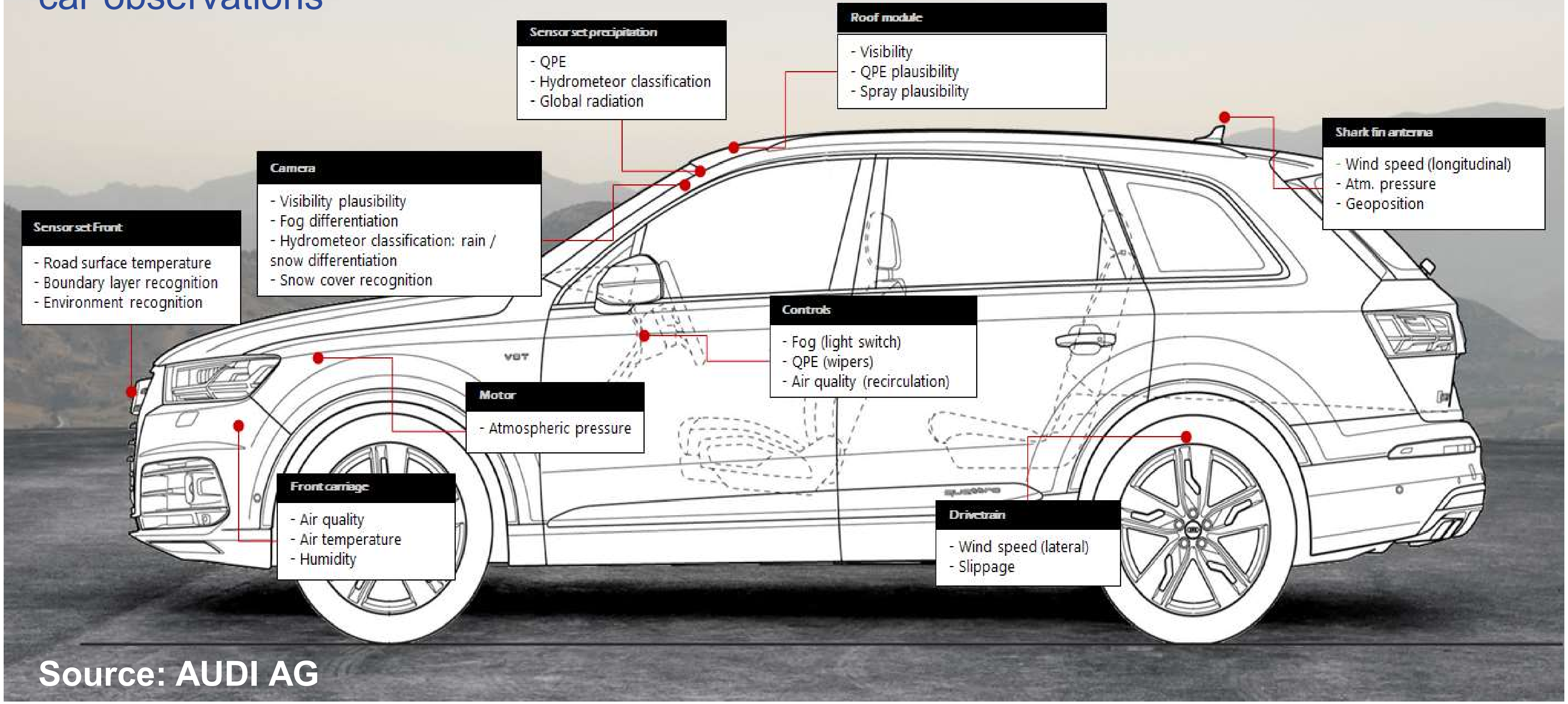
car observations



legal issues to make data available → currently data only from 1 car

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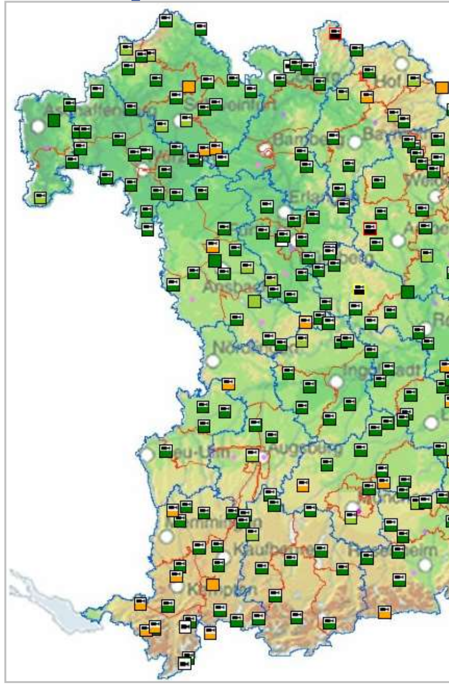
Road Weather Stations

Source: Bavarian Administration

measured variables

- road temperature
- road condition
- air temperature
- dew point
- temperature at 30 cm depth
- precipitation type
- precipitation intensity
- wind direction
- wind velocity
- visibility



285 stations in Bavaria (Jan. 2017)

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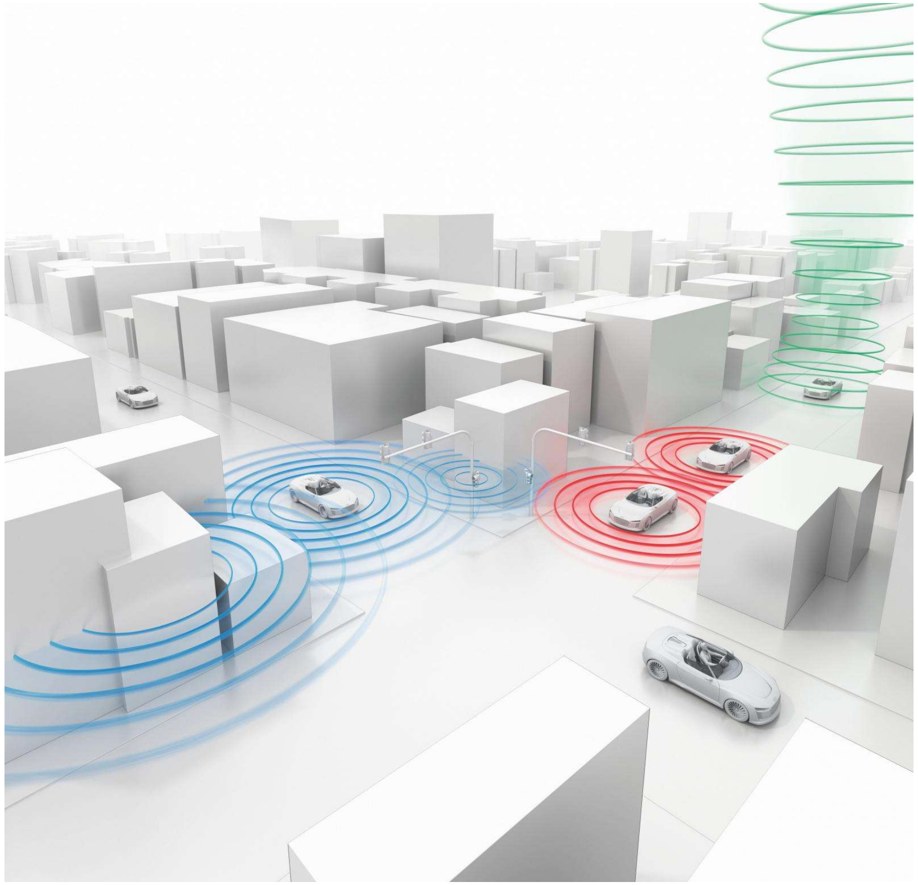
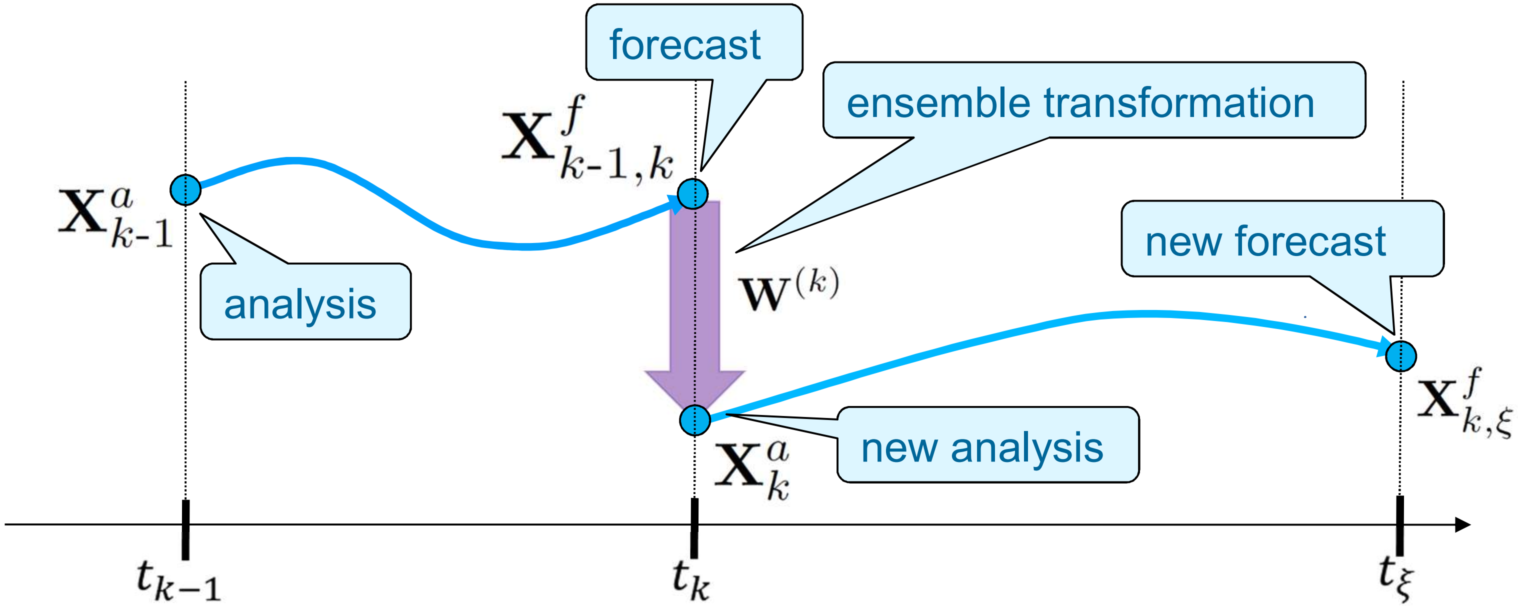


Source: AUDI AG

standard sequential DA cycle



- forecast step : $\mathbf{X}^f_{k\text{-}1,k} = \mathcal{M}_{k\text{-}1,k}\mathbf{X}^a_{k\text{-}1}$
- analysis step (LETKF) : $\mathbf{X}^a_k = \mathbf{X}^f_{k\text{-}1,k\xi}\mathbf{W}^{(k)}$

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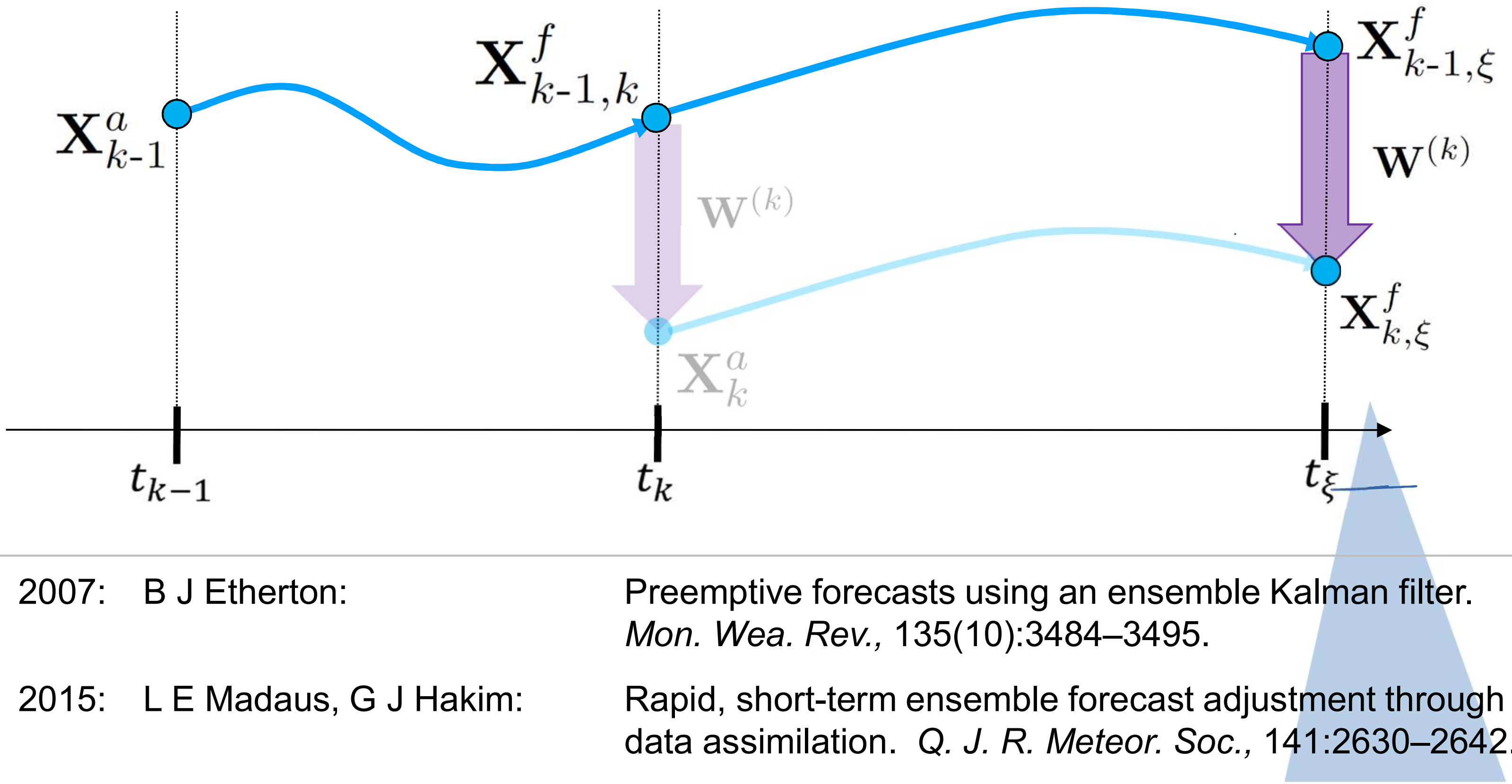
„Preemptive Forecasting" based on EnKF:



- 2007: B J Etherton: Preemptive forecasts using an ensemble Kalman filter. *Mon. Wea. Rev.,* 135(10):3484–3495.
- 2015: L E Madaus, G J Hakim: Rapid, short-term ensemble forecast adjustment through offline data assimilation. *Q. J. R. Meteor. Soc.,* 141:2630–2642.
- 2018: R Potthast, C A Welzbacher: Ultra rapid data assimilation based on ensemble filters. *Front. Appl. Math. Stat.* 4:45.

Properties:

Ultra-Rapid DA (URDA)

- equivalent to standard sequential DA for linear model and observation operator [Potthast & Welzbacher 2018]:
  → URDA applicable only for (very) short lead times (≤ ~ 1 – 3 h) for which
  - non-linearity is sufficiently 'small'
  - local transform matrix (of **L**ETKF) still applicable to forecast (i.e. the influence of obs remain within localisation area)

- applicable to several assimilation steps from different time intervals:

$$\mathbf{X}^f_{k,\xi} = \mathbf{X}^f_{k-n,\xi} \mathbf{W}^{(k-n+1)} \dots \mathbf{W}^{(k)}$$

- no model re-initialization / no additional forecast runs necessary
  → no need to update the whole model state;
  a reduced set of selected variables and grid points can be updated
  → very small computational costs

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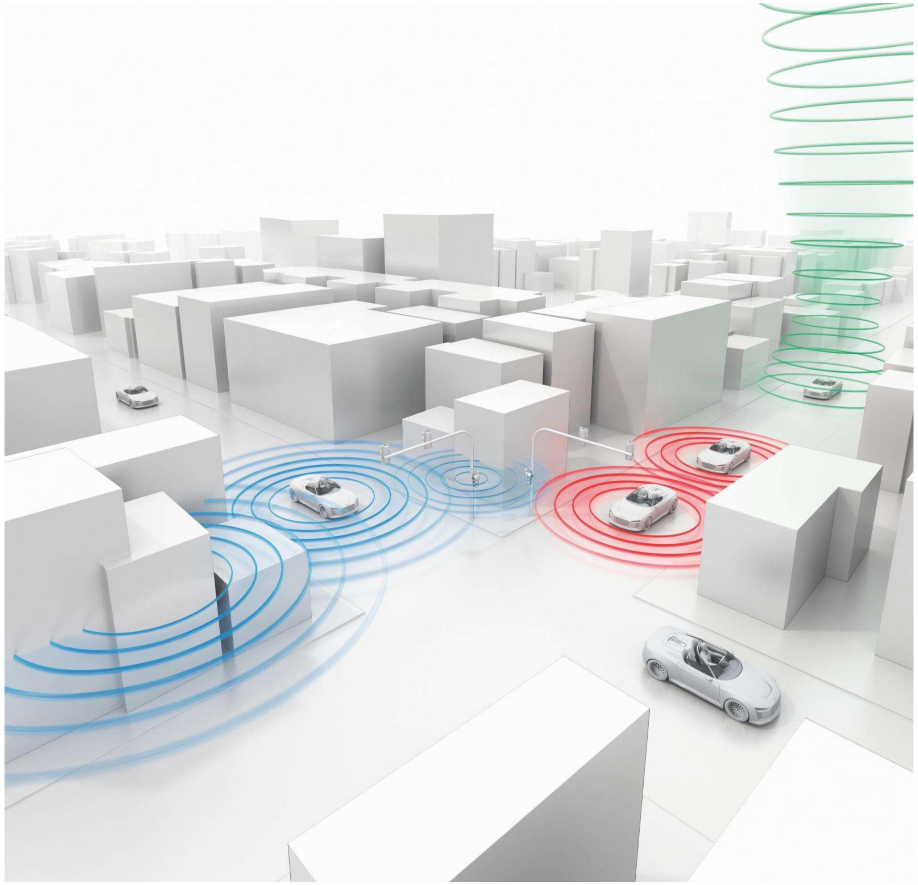

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URDA-KENDA Experiment

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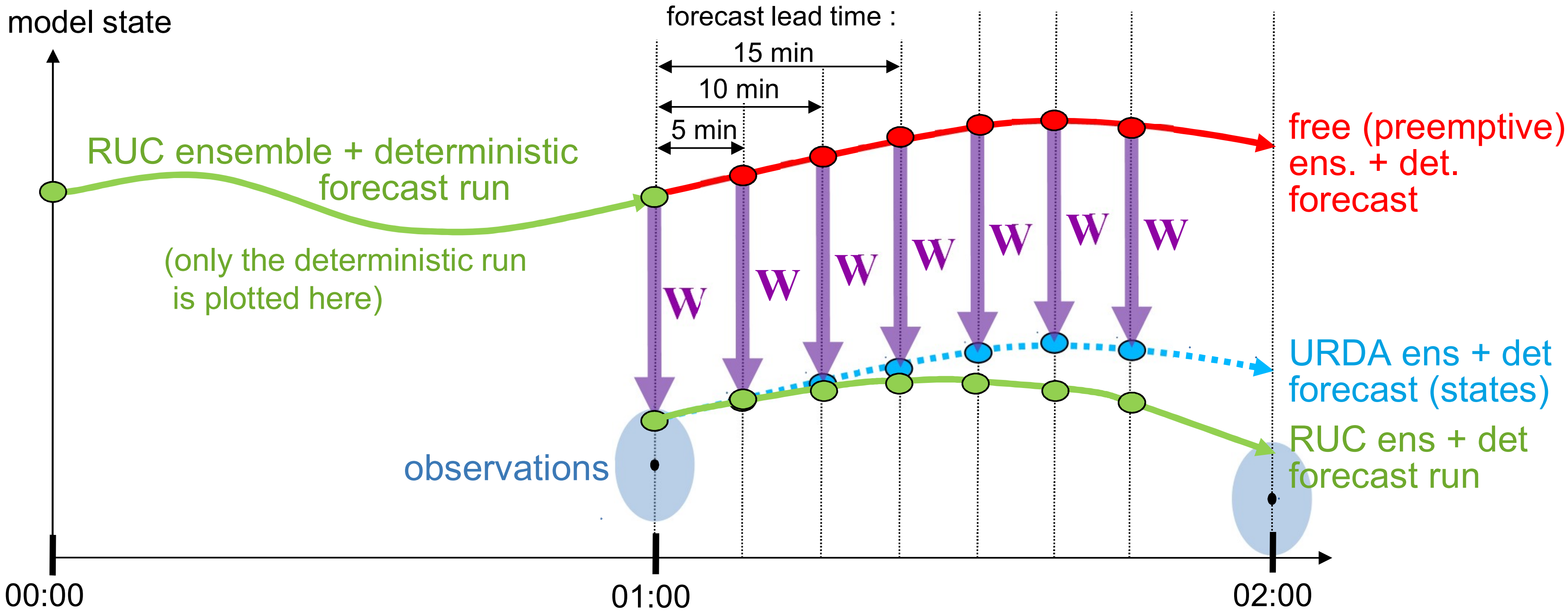
DWD



- RUC = Rapid Update Cycle → 1-hrly LETKF DA cycle
- assimilated obs: only conventional (Synop, radiosondes, aircraft)

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URDA-KENDA Experiment

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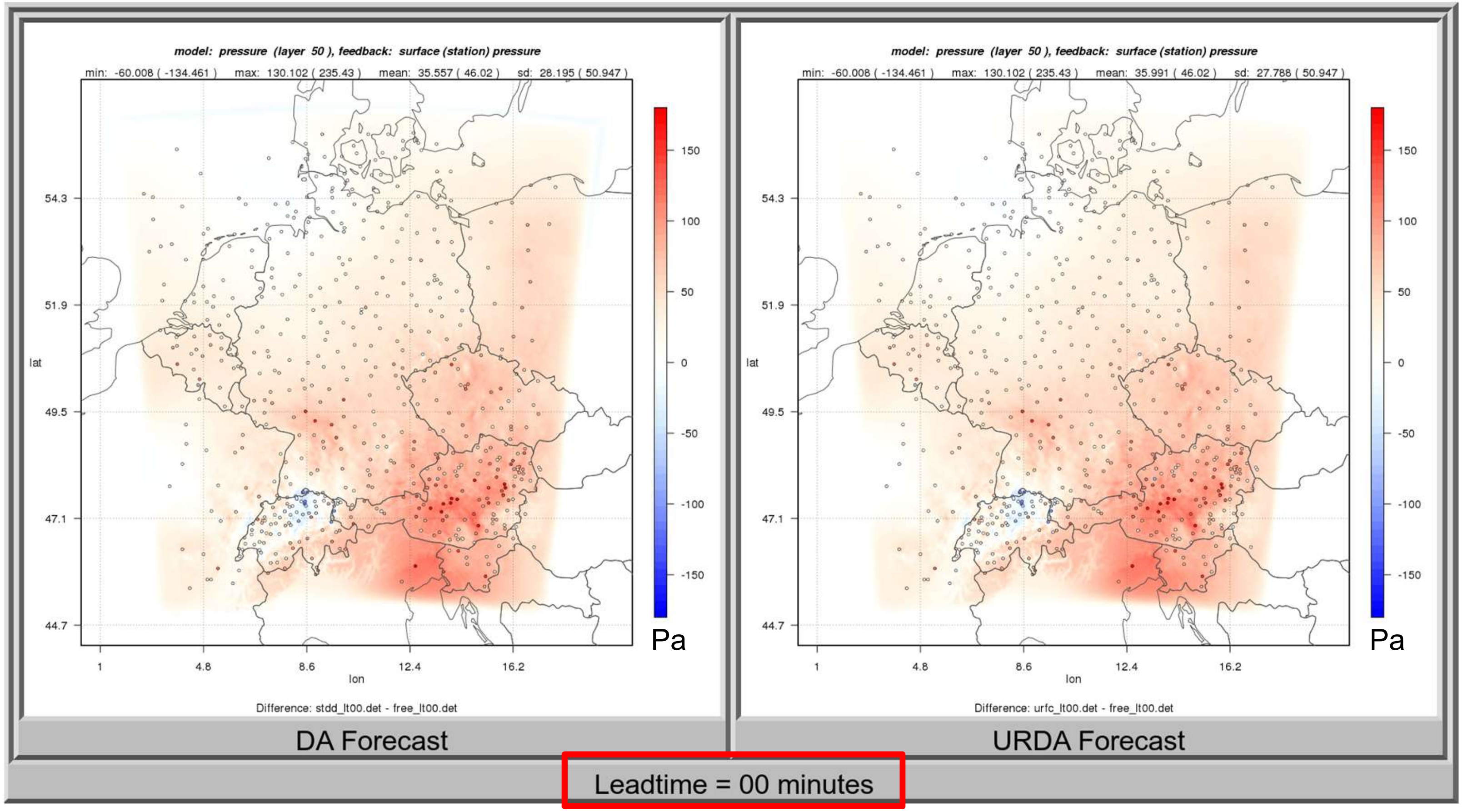
surface pressure differences



RUC minus free (det.) forecast

URDA minus free (det.) forecast

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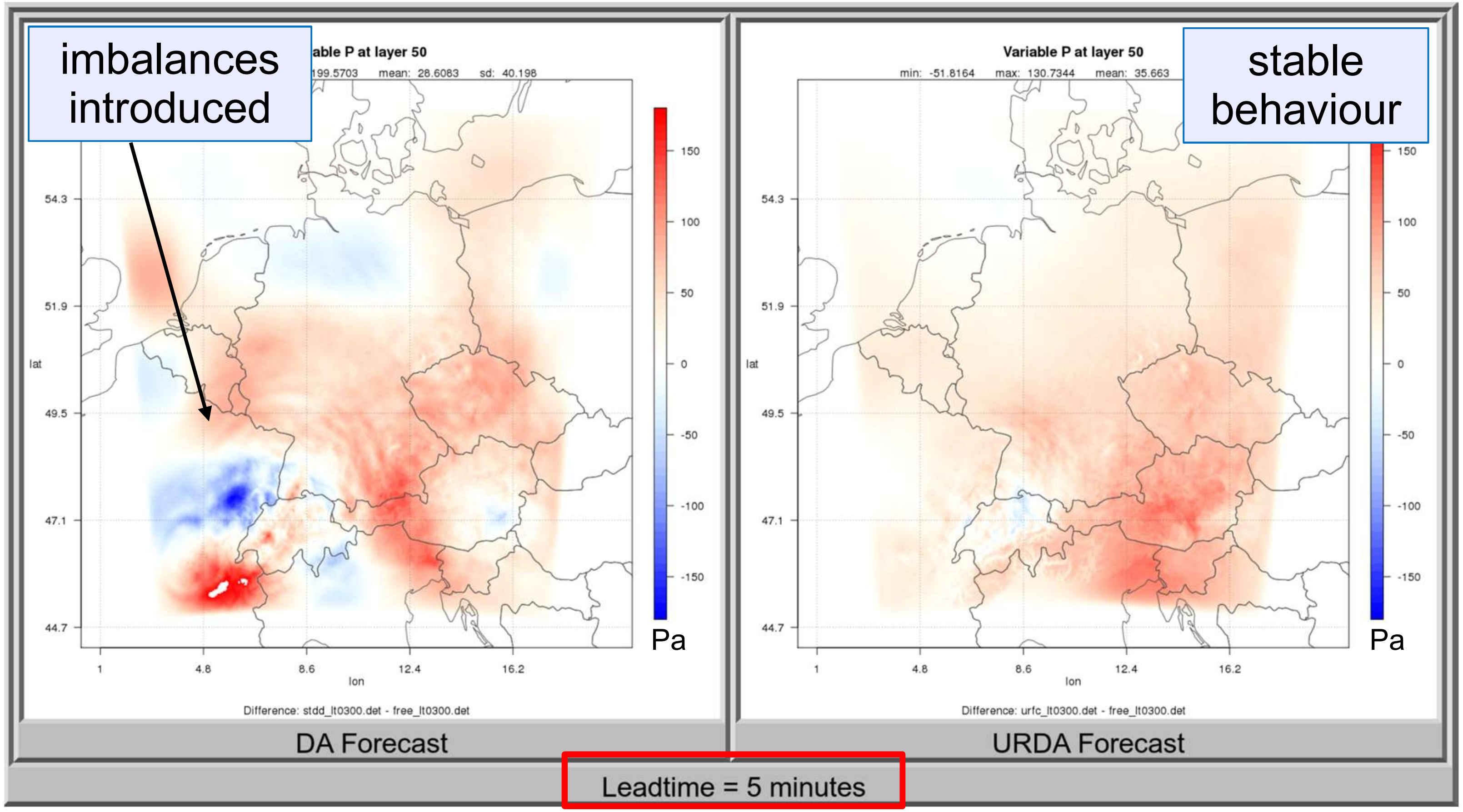
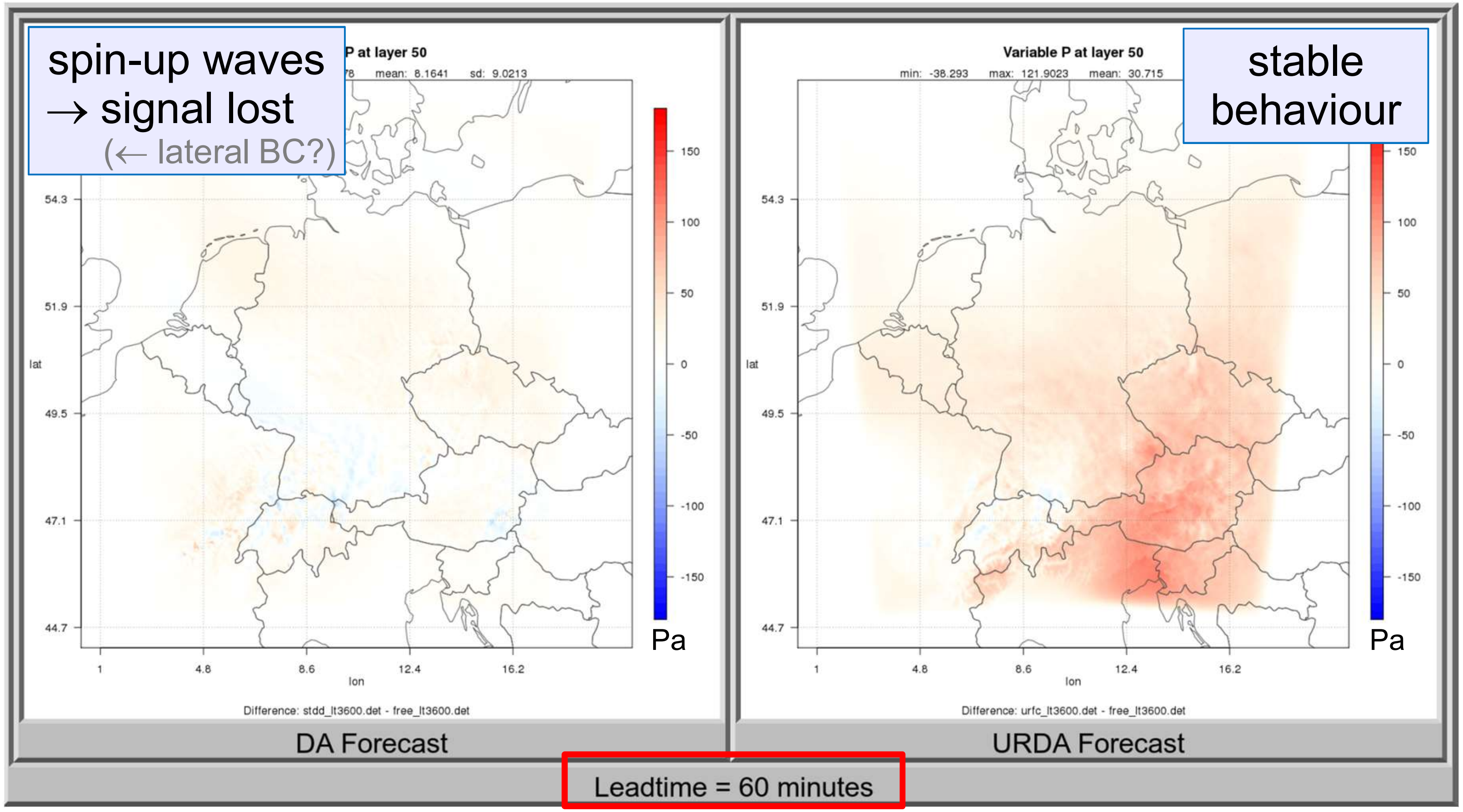
surface pressure differences



RUC minus free (det.) forecast

URDA minus free (det.) forecast

surface pressure differences



RUC minus free (det.) forecast

URDA minus free (det.) forecast

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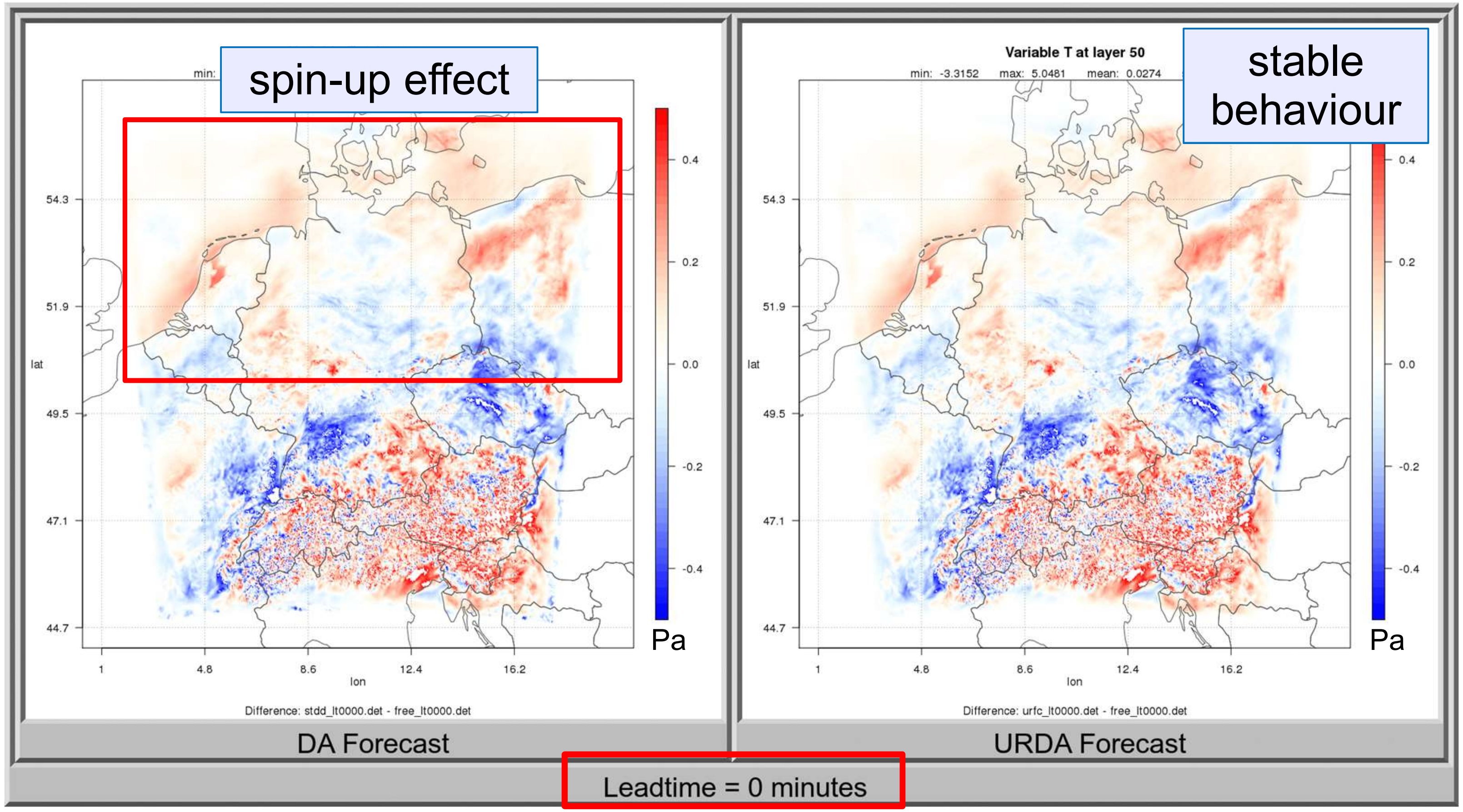
temperature differences at lowest model level



RUC minus free (det.) forecast

URDA minus free (det.) forecast

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URDA-KENDA Experiment

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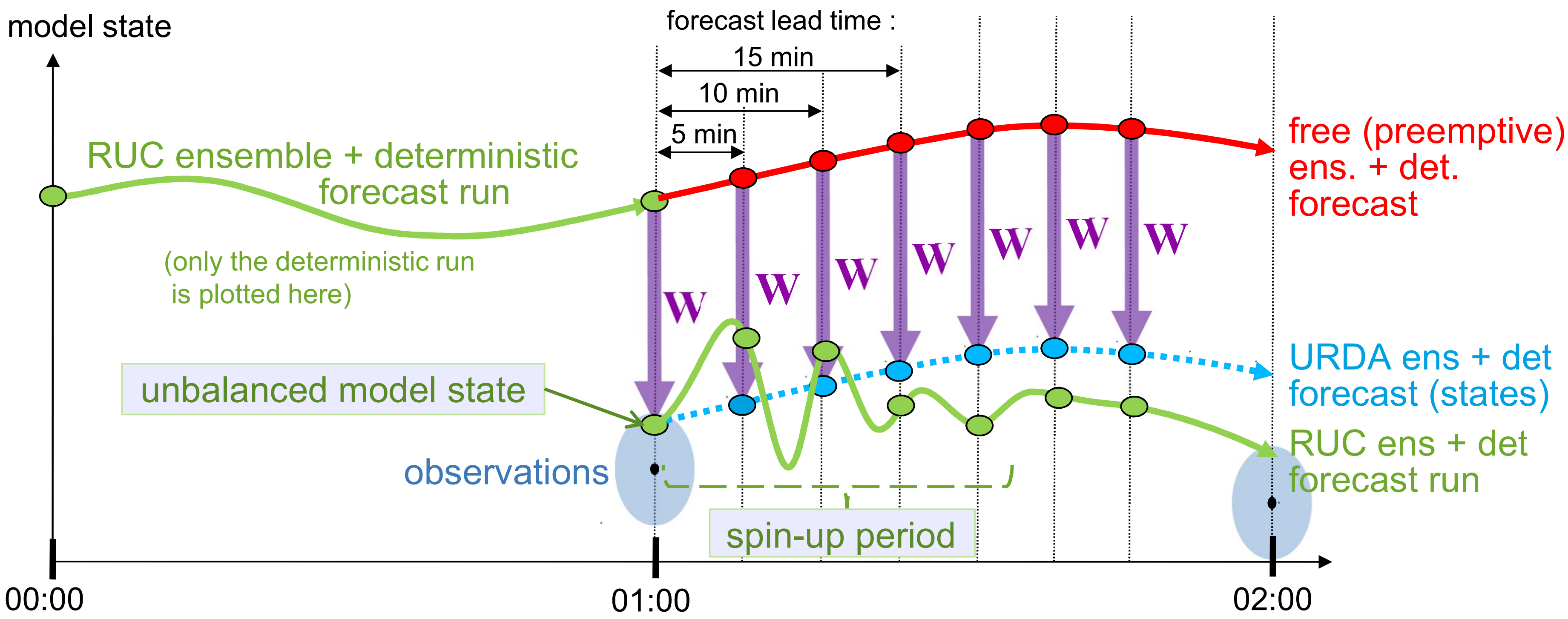
DWD



- RUC = Rapid Update Cycle → 1-hrly LETKF DA cycle

- model re-initialization in RUC introduces imbalances
- URDA can beat RUC for short forecast times

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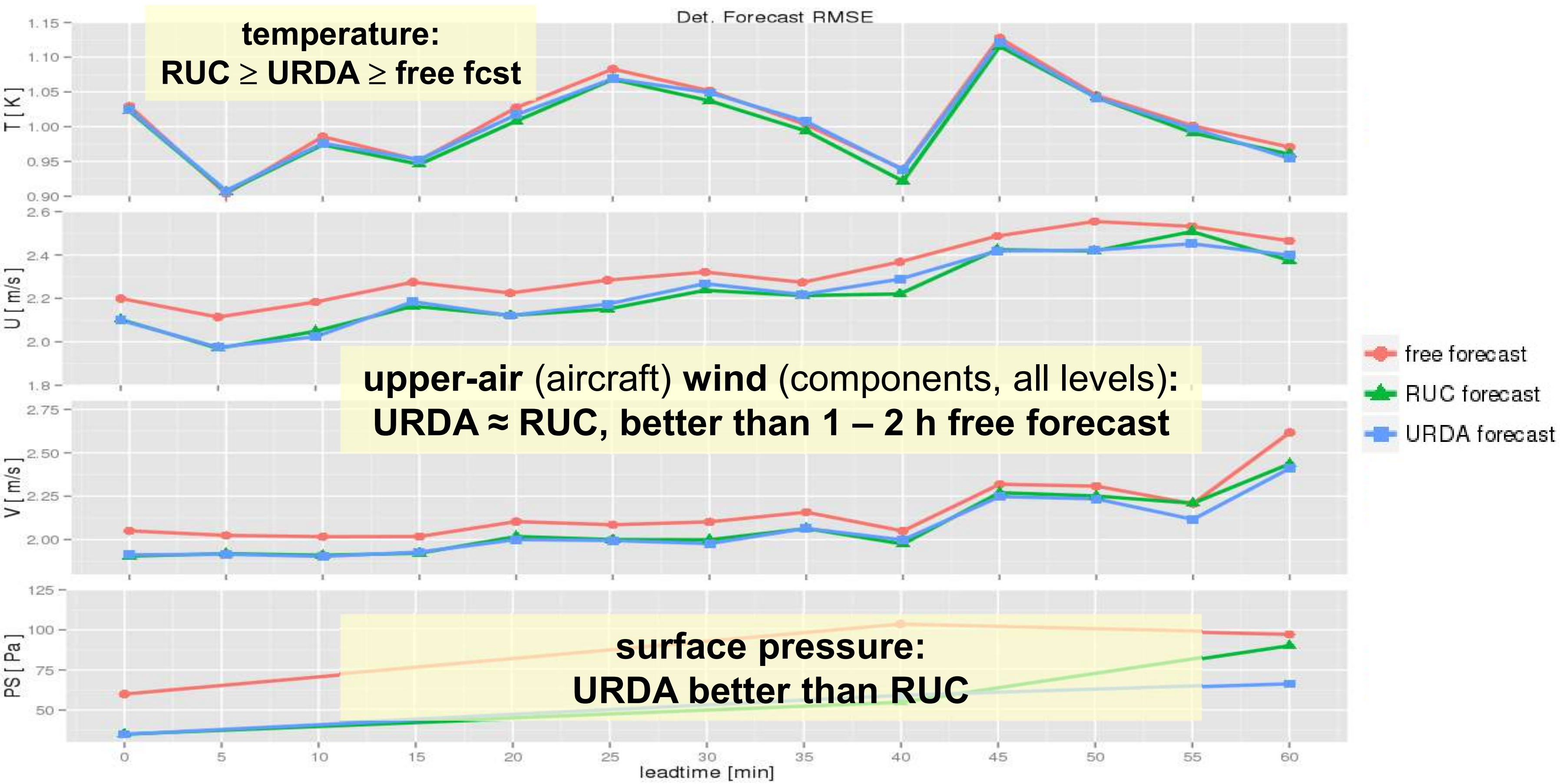
RMSE vs. lead time



assimilating Synop pressure + radiosonde + aircraft + wind profiler data

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Conclusions and Perspective

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1. **URDA** shows great potential for very short lead times:
   - strongly reduced computational cost
   - frequently updated and rapidly available
   - quality comparable to RUC for short lead times, no spin-up effects

Source: AUDI AG

2. **Observation operators** for **car observations** under development
   - modelling of dependency between meteorological state and car-microclimate; time- and spatial aggregation
   - car-dependent bias correction; quality control
   - data anonymization (legal issues)

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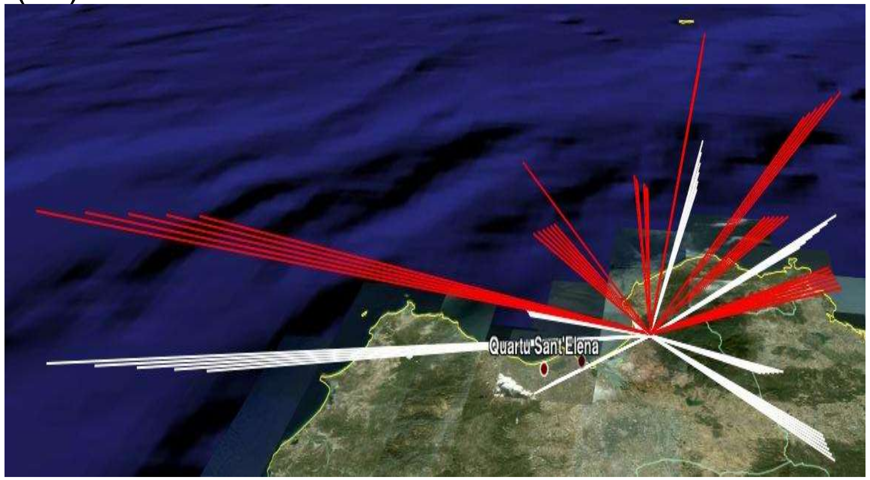
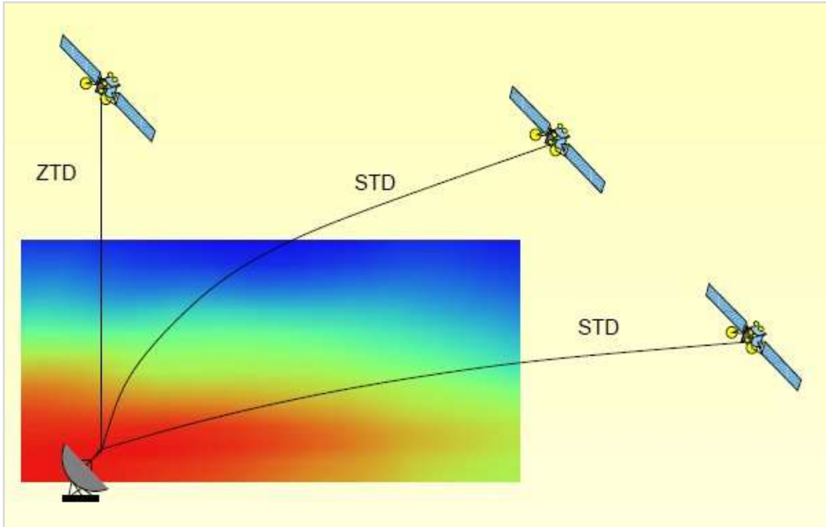
Task 2.2: GPS STD convective summer period

→ GPS (GNSS) Slant Path Delay : **humidity** integrated over (slant) path from ground station to GNSS (GPS) satellite, all weather obs

(45) GPS obs from 1 station / 9 satellites in 15 min.





- 300 stations in COSMO-DE domain
- STD (slant total delay), elevation ε = 5°– 90° → after thinning ~ 2000 obs/h
- ZTD (zenith total delay): mapping of delays to 1 zenith info, < 300 obs/h
- no clear positive impact → improved bias correction, bug fixes, etc.
- new experiment: assimilate ZTD + low-elevation STD (7° < ε < 25°)

Task 2.2: GPS STD
convective summer period

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radiosonde verification
25 May – 1 July 2016

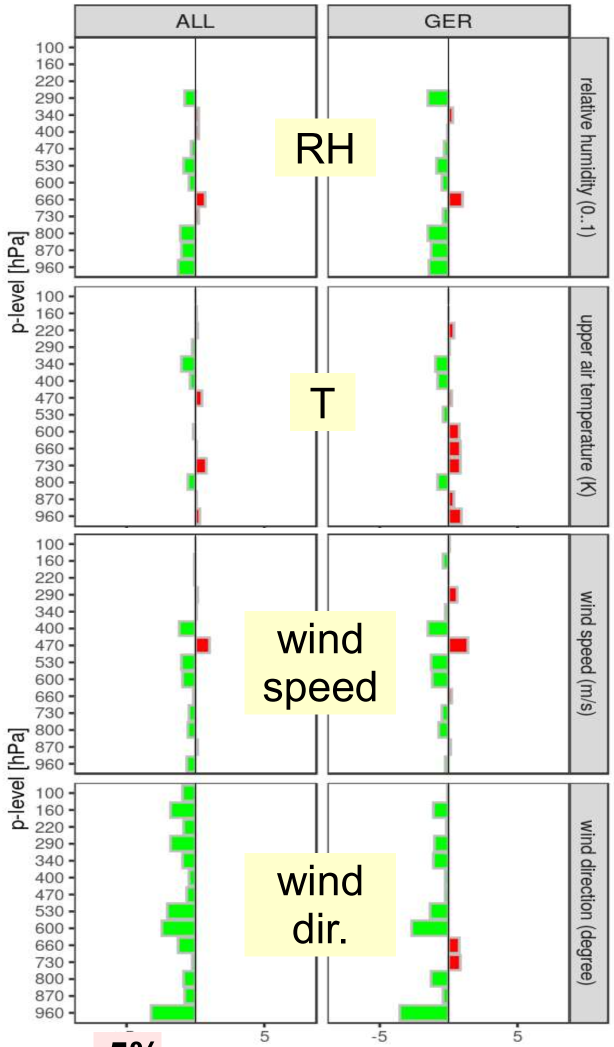
→ 5 weeks !

change in RMSE

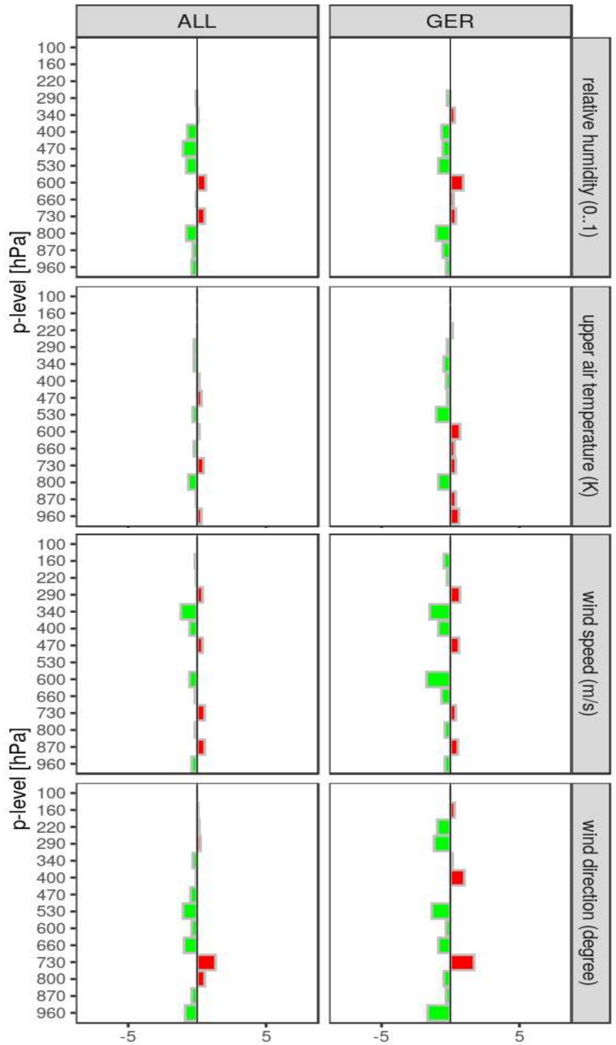
better

worse

STD + ZTD vs. no-GPS



STD + ZTD vs. ZTD



bias: only slight increase of wet bias

-5% significant at few levels /ini times

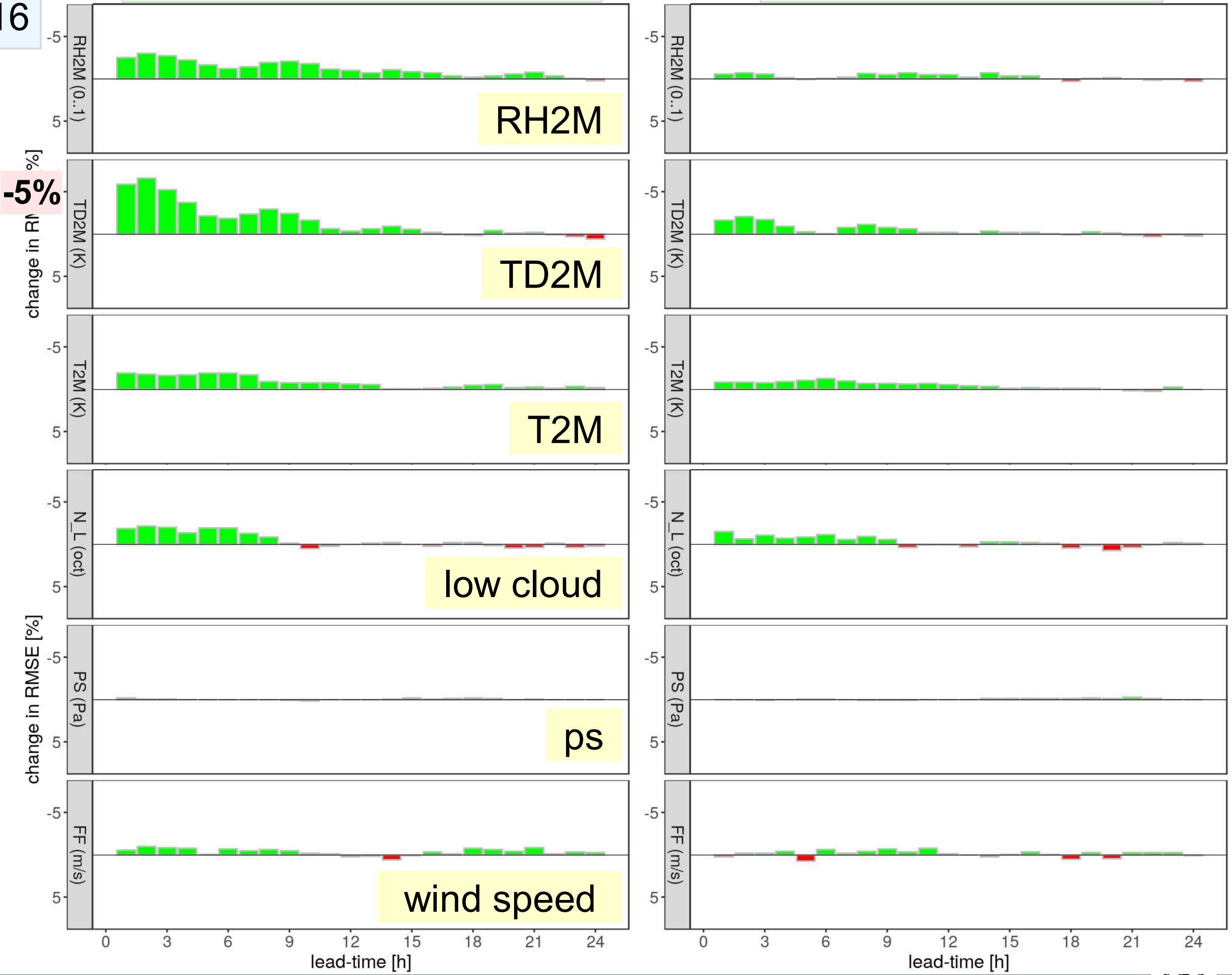
not significant

Task 2.2: GPS STD convective summer period

Synop verif. (GER)
25 May – 1 July 2016

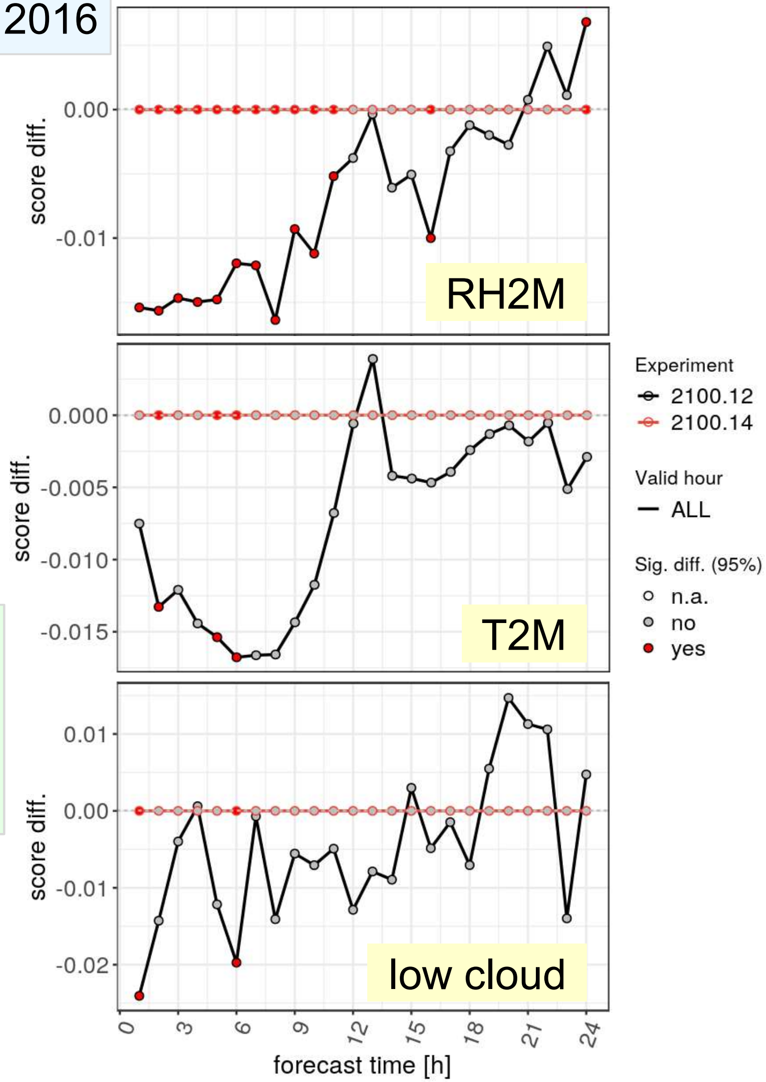
% change in RMSE

better
worse

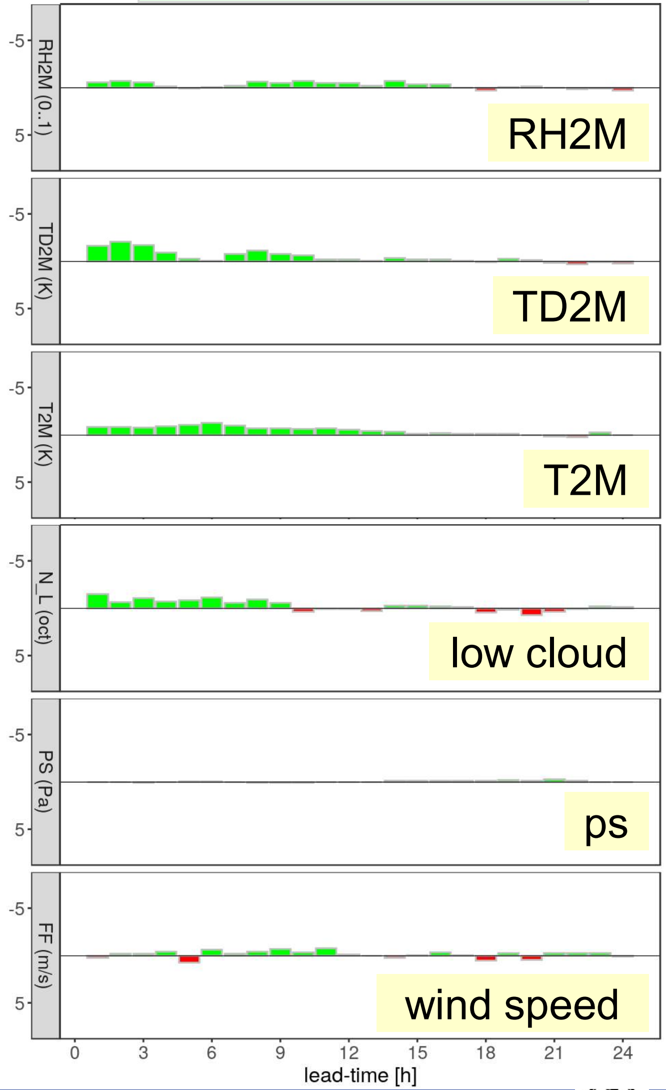


Synop verif. (GER)
25 May – 1 July 2016

6-UTC forecast runs



STD + ZTD vs. ZTD



improvements by STD over ZTD are occasionally significant

Task 2.2: GPS STD convective summer period

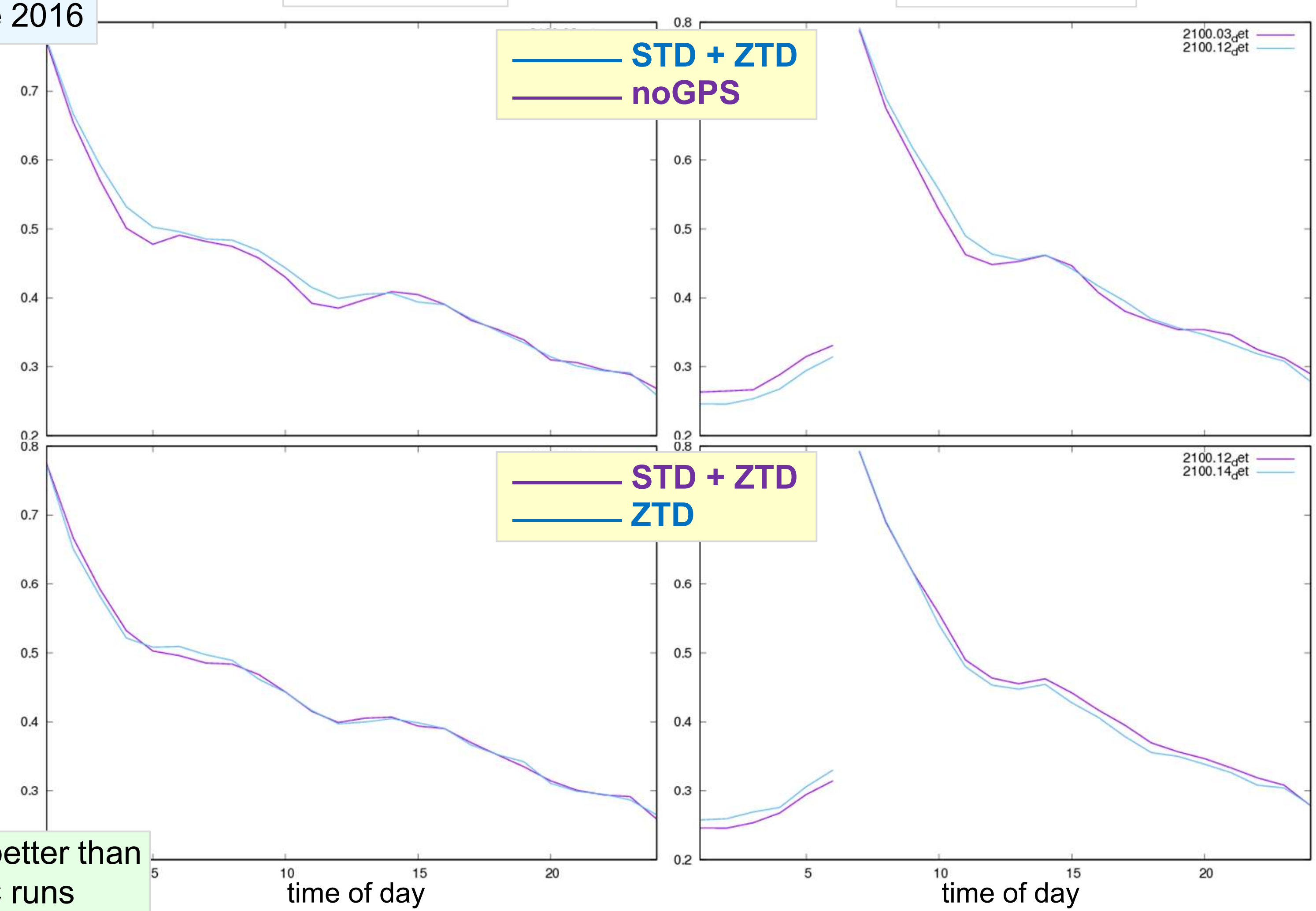
precip vs. radar
26 May – 28 June 2016

1-hrly precip FSS (30 km)

1 mm/h

0-UTC runs

6-UTC runs



STD + ZTD slightly better than
- noGPS 0-, 6-UTC runs
- ZTD 6-UTC runs

Task 2.2: GPS STD
winter period (with spells of low stratus)

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Dec. 2016

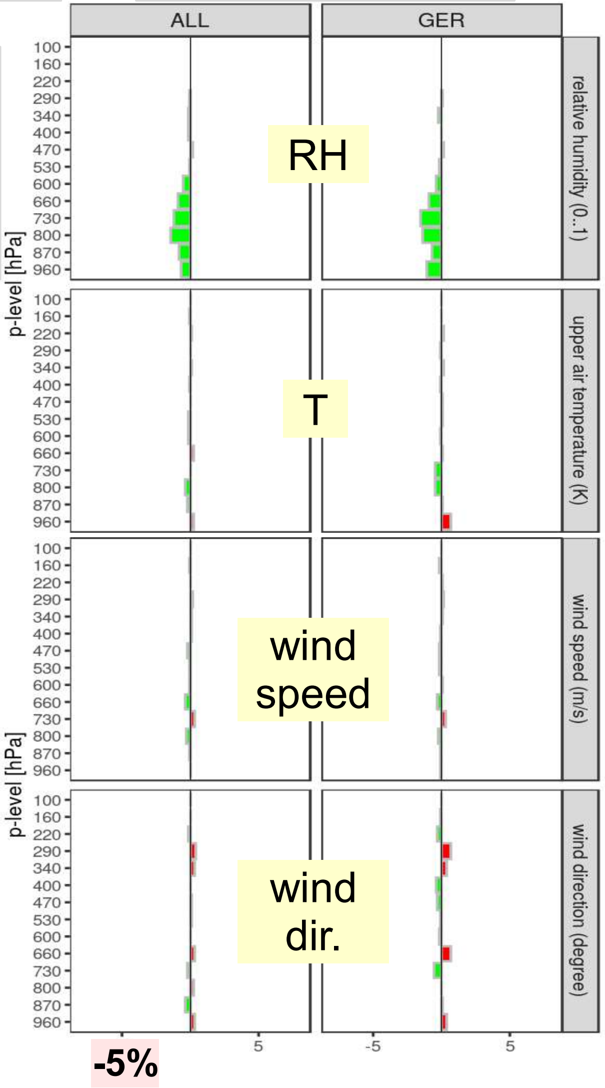
radiosonde verif.

STD + ZTD vs. no-GPS

Synop verif (GER)

benefit significant at + 6 h

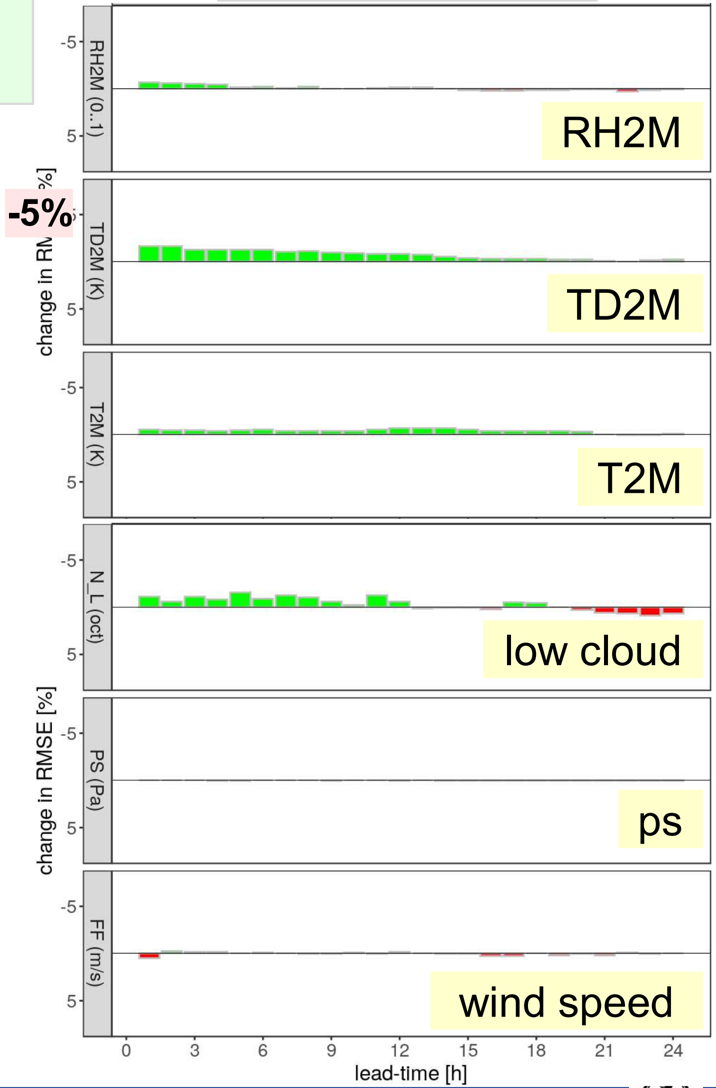
(in 6-, 18-UTC runs)



% change in RMSE

better

worse



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Task 2.2: GPS STD
winter period (with spells of low stratus)

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DWD

Dec. 2016

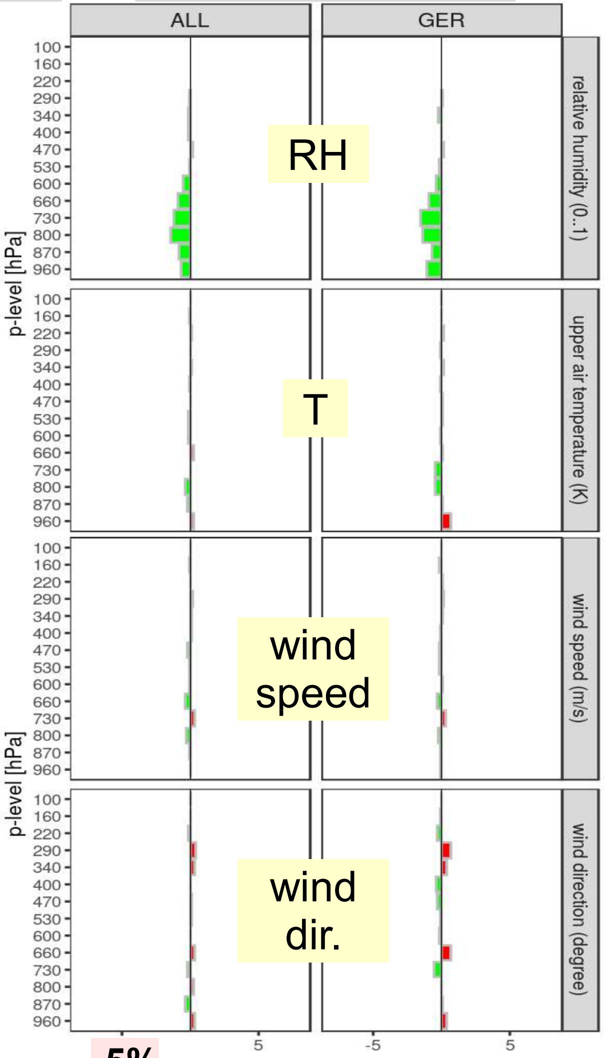
radiosonde verif.

STD + ZTD
vs.
no-GPS

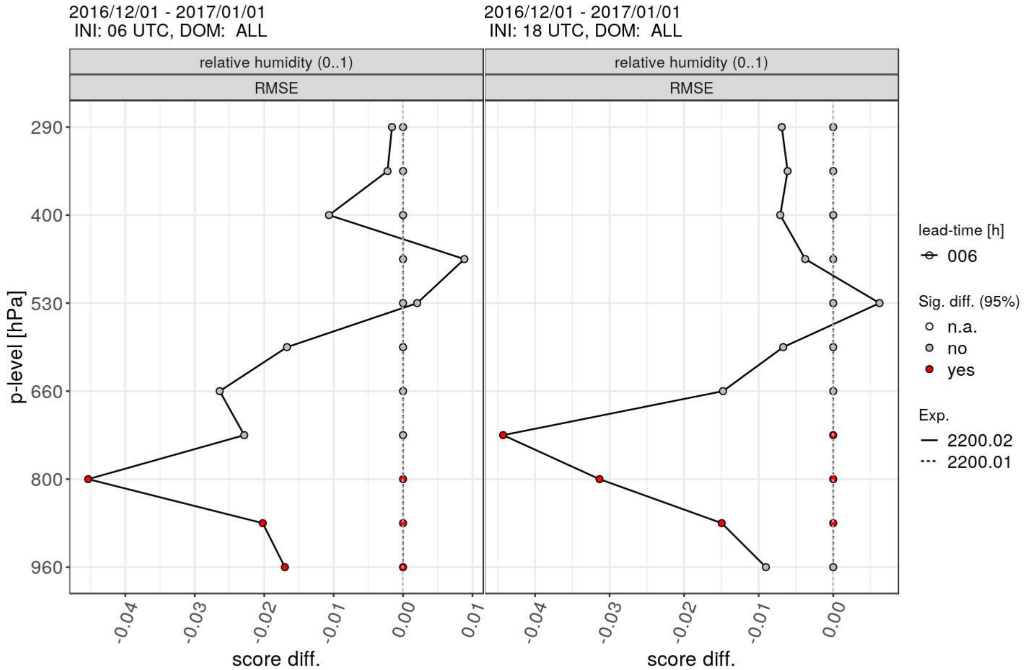
% change in RMSE

better

worse



-5%

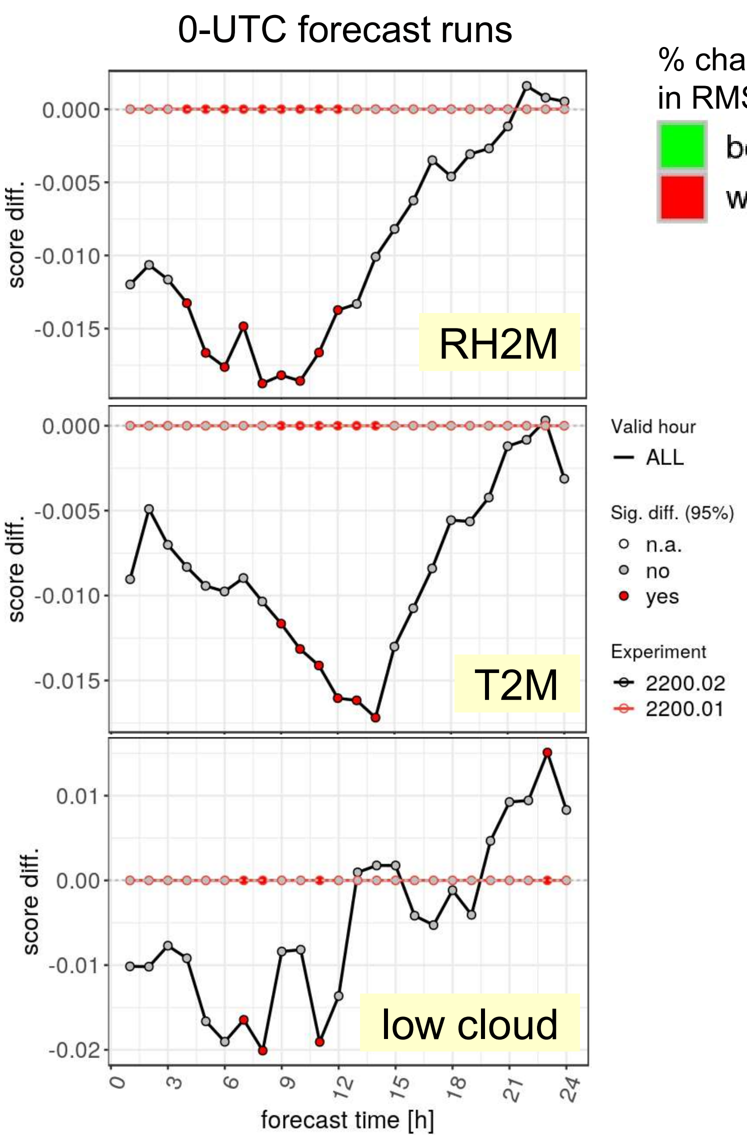


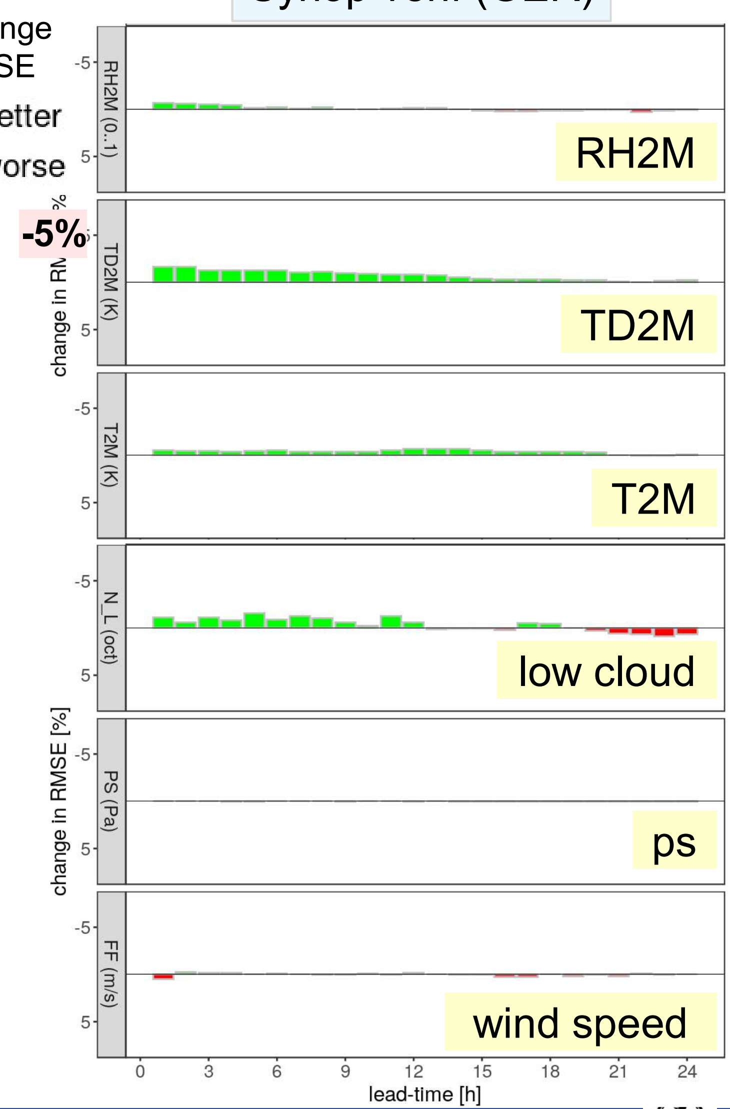
+ 6 h, below 700 hPa:
RMSE reduction significant, by 2 – 4 %
(in 6-, 18-UTC runs)

Task 2.2: GPS STD
winter period (with spells of low stratus)

Dec. 2016

STD + ZTD
vs.
no-GPS





improvements by STD + ZTD are occasionally significant

Task 2.2: GPS STD
winter period (with spells of low stratus)

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correct cloudy / correct cloud-free / missed events / false alarms / undefined (observed higher cloud)

GPS STD exp. **rejects**:
- **1 wet RH more at 10954, 11 Z**
- 1 ~wet RH less at 10868, 11 Z
- 1 wet RH more at 10771, 11 Z
- 1 wet RH more at 10393, 11 Z
- **1 cold T more at 06610, 12 Z**
- 1 wet RH less at 11520, 12 Z
- **1 cold + wet more, 10618, 17 Z**
- 1 dry RH less at 10238, 17 Z

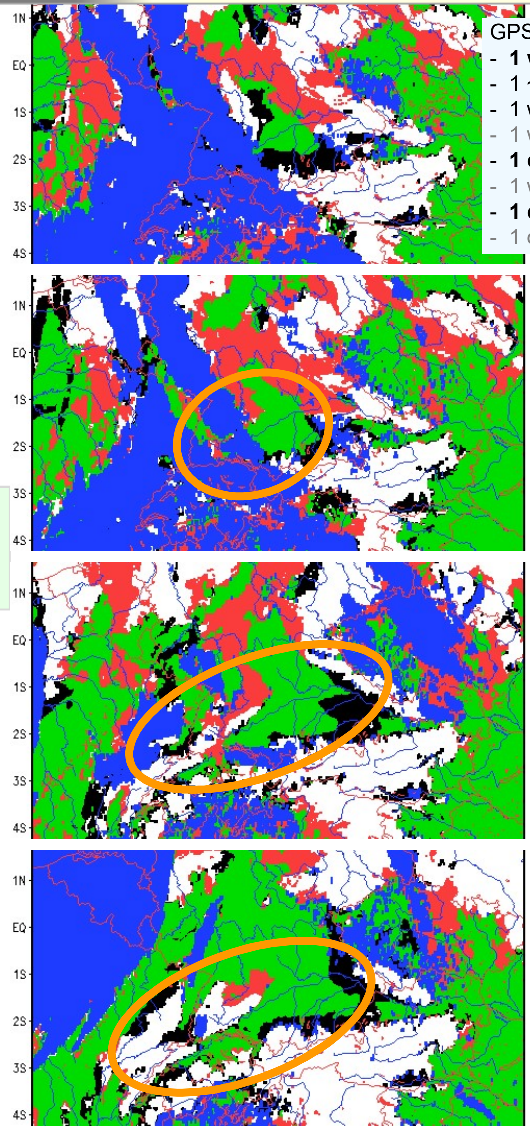
20 Dec. 2016, 12 Z + 06 h

20 Dec. 2016, 18 Z + 01 h

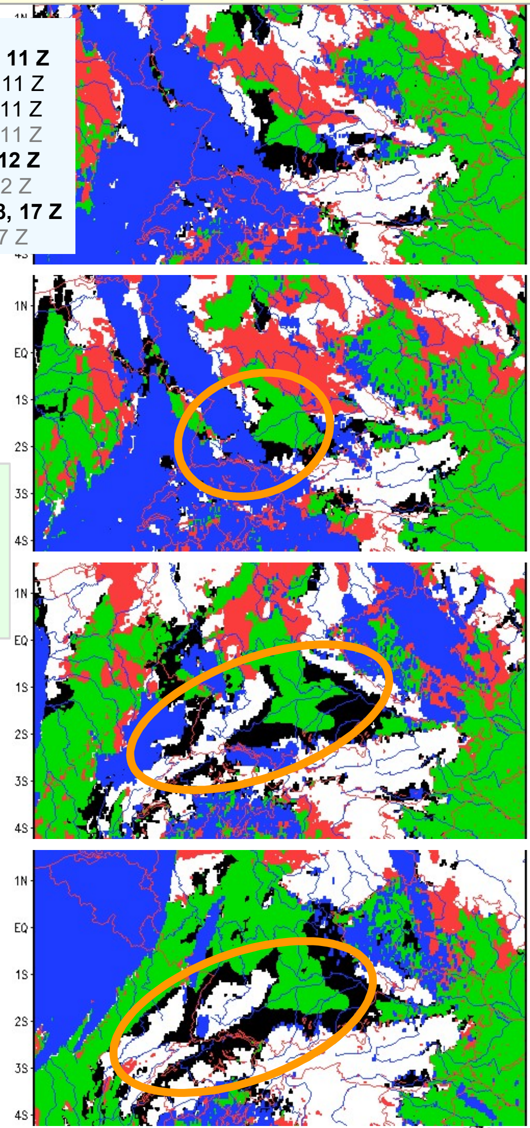
20 Dec. 2016, 18 Z + 06 h

20 Dec. 2016, 18 Z + 12 h

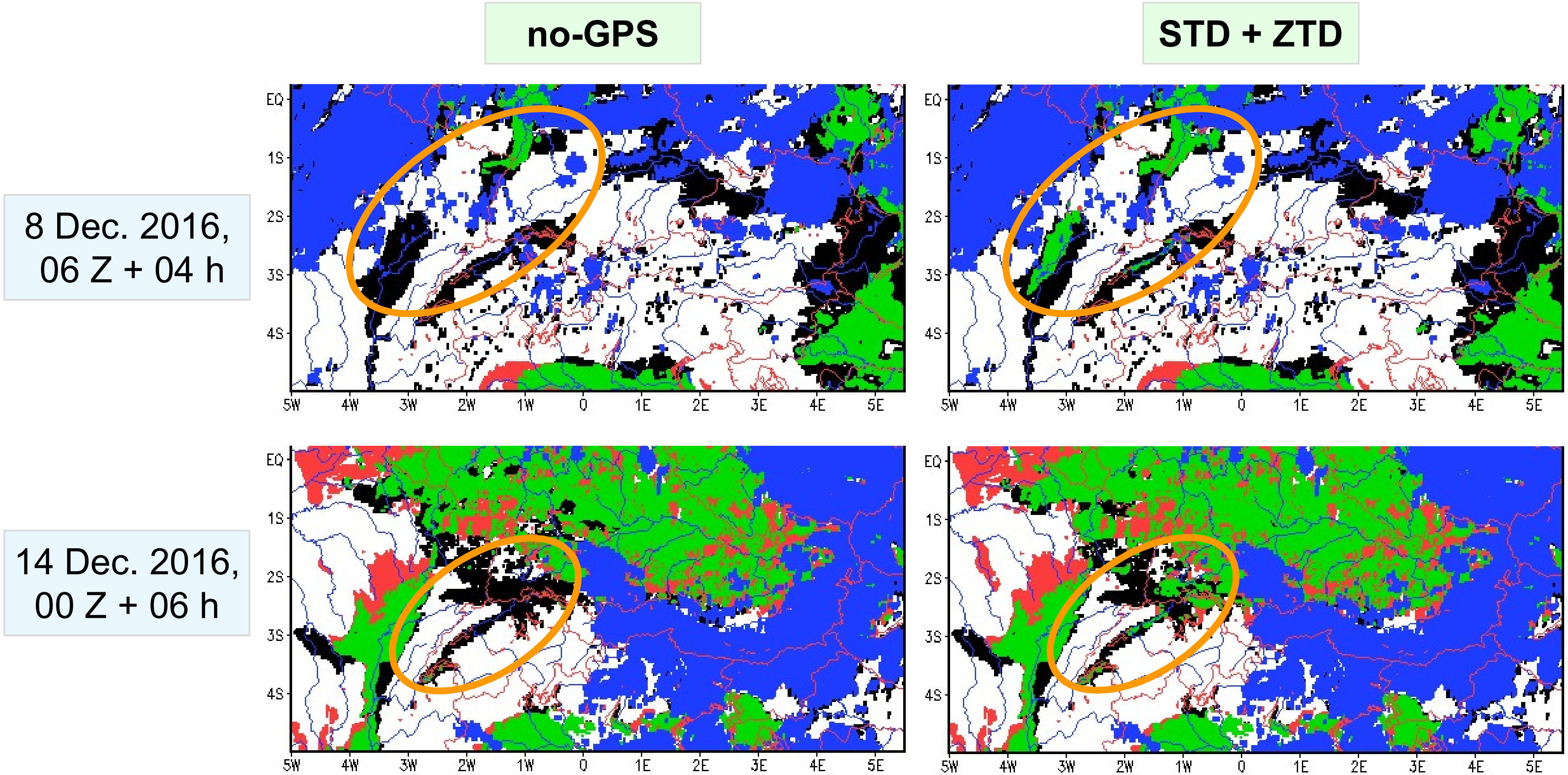
no GPS



STD + ZTD



Task 2.2: GPS STD
winter period (with spells of low stratus)



Task 2.2: GPS STD summary

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- experiments with combined assimilation of ZTD + low-elevation STD
  - small but consistent positive impact (summer)
  - slightly better than use of ZTD alone
  - no major problems with low stratus
    (which was a problem for nudging of GPS-derived integrated water vapour IWV)

    (improved first guess check for radiosonde T, q (already operational at MeteoSwiss)
    will likely mitigate 1 negative case)
- technical work being done towards operational use (e.g. BUFR format)
- further experiments required with COSMO-D2,
  still option to (try to) make it operational for COSMO (but not very likely due to limited resources)