# Assimilation of radar reflectivity

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# Convective-scale NWP at DWD: Plans for 2020

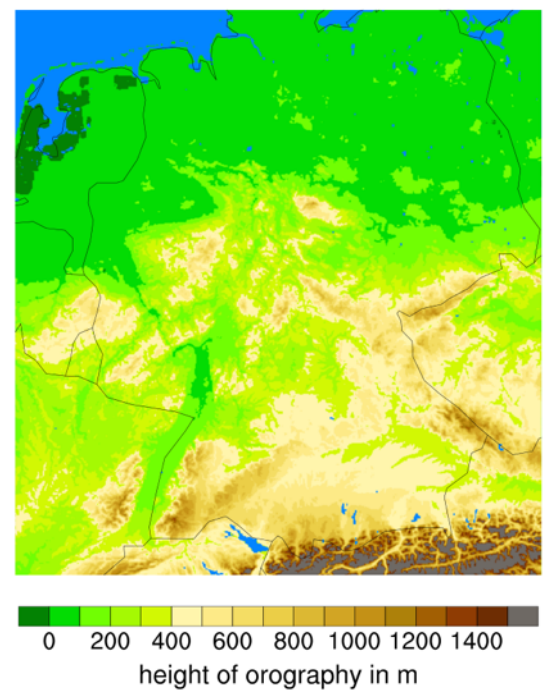
- **Storm-scale ICON-RUC-EPS:** hourly 12h ensemble forecasts based on short data cut-off (< 20 min); assimilation of 3D radar data, satellite (IR and VIS), Mode-S, etc.; 40 members for ensemble data assimilation and ensemble prediction.

- **Convective-scale ICON-LAM-EPS:** every 3 hours ensemble forecasts up to 48h

*Model domain of ICON-RUC and ICON-LAM; 2 km for the full domain and a 2-way nest with a grid spacing of 1 km for Germany.*

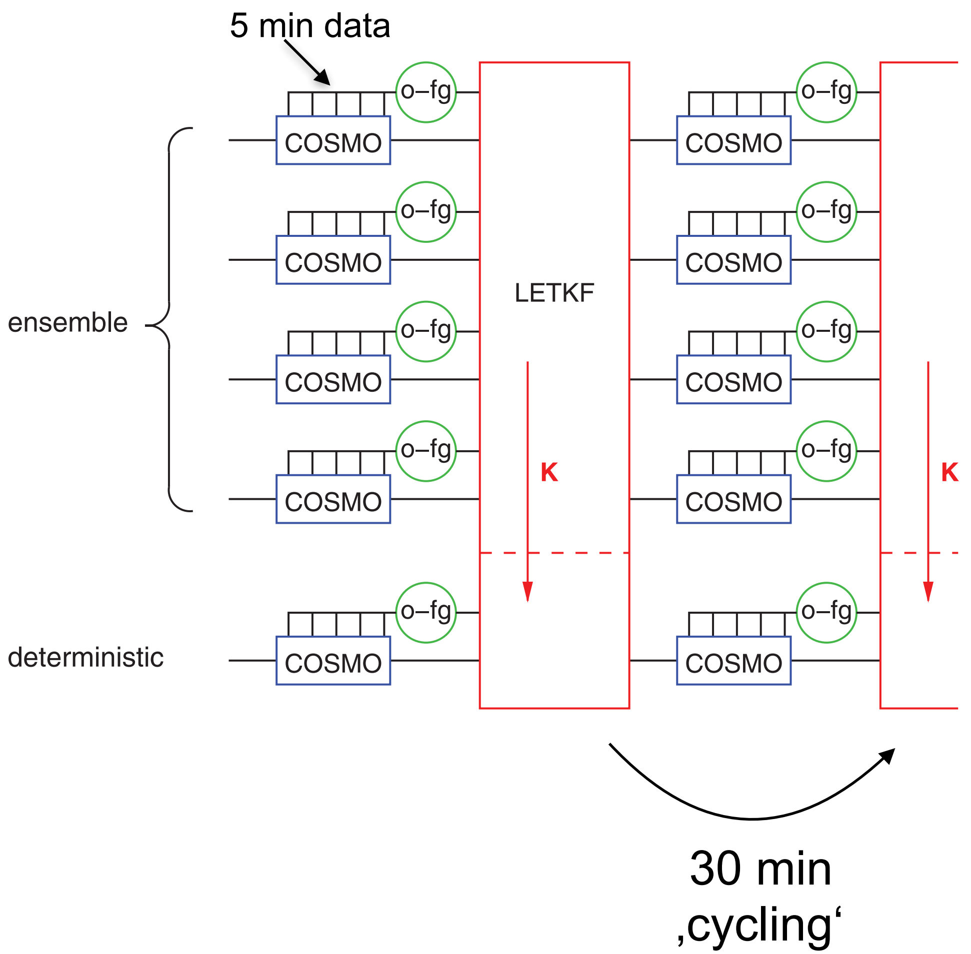
# A prototype experiment with the COSMO model

- COSMO model with 1 km grid spacing focusing on Southern Germany
- Two-moment microphysics with hail (Seifert and Beheng 2006, Blahak 2008)
- Data assimilation using LETKF with 3d radar reflectivity and radial velocity (Schraff et al. 2016, Bick et al. 2016).
- Assimilation with 40 ensemble members and 30 min cycling using 5 min radar data.
- Forecasts with 20 ensemble members for 6 hours.
- **Here without „Bubbles“ and without „dBZ transform“ instead focus on 1mom vs 2mom microphysics.**




*Model domain of COSMO1-RUC with a grid spacing of 1 km on a 700 x 750 grid.*

# Local Ensemble Transform Kalman Filter




- During the COSMO runs the model is compared with observations using a forward operator (o-fg).
- LETKF estimates new 3d fields of all model variables based on covariances in the ensemble members, e.g, how w and T correlate with dBZ.

**Caveats**:

- Works only if observations are well covered by ensemble.
- Non-gaussian statistics are not well represented.

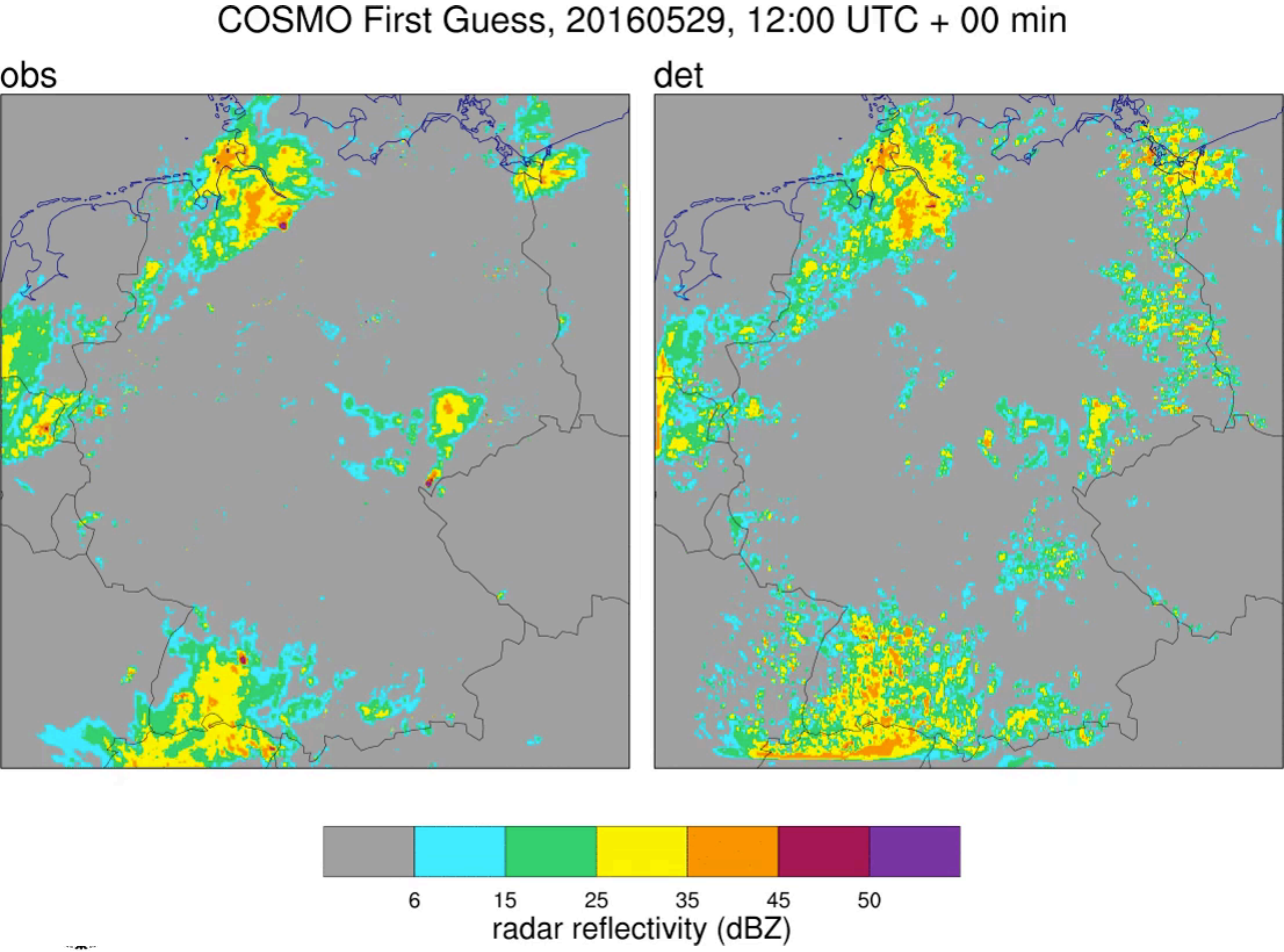
# LETKF and model settings

Model:

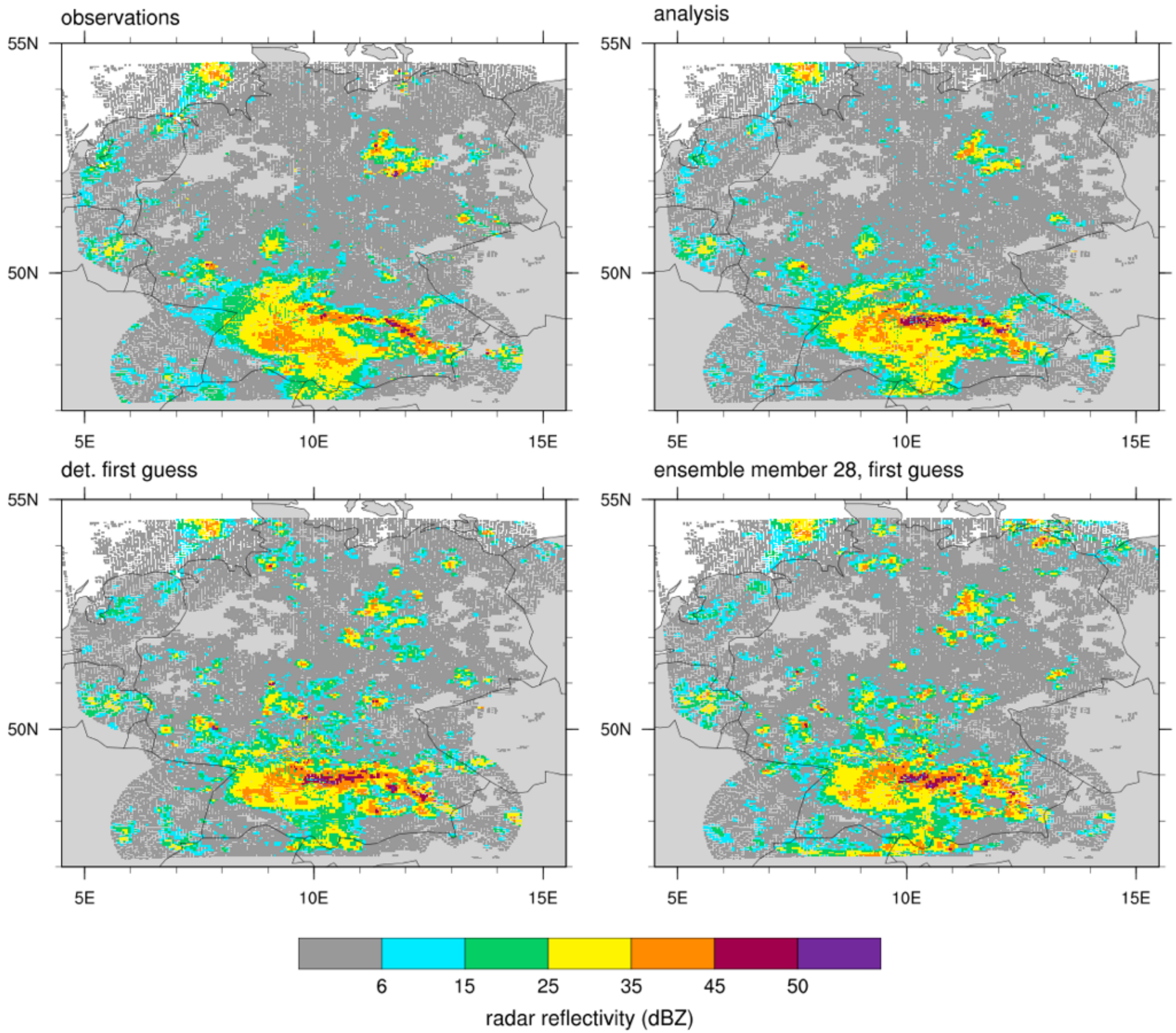
- 1 km grid (0.01 degree resolution), 65 vertical levels, dt = 7.5 s
- 2mom microphysics scheme vs 1mom (with COSMO-DE settings)
- shallow convection, numerics and turbulence as in COSMO-DE
- superobbing of radar data at 5 km resolution, every 5 min, full radar scan

LETKF:

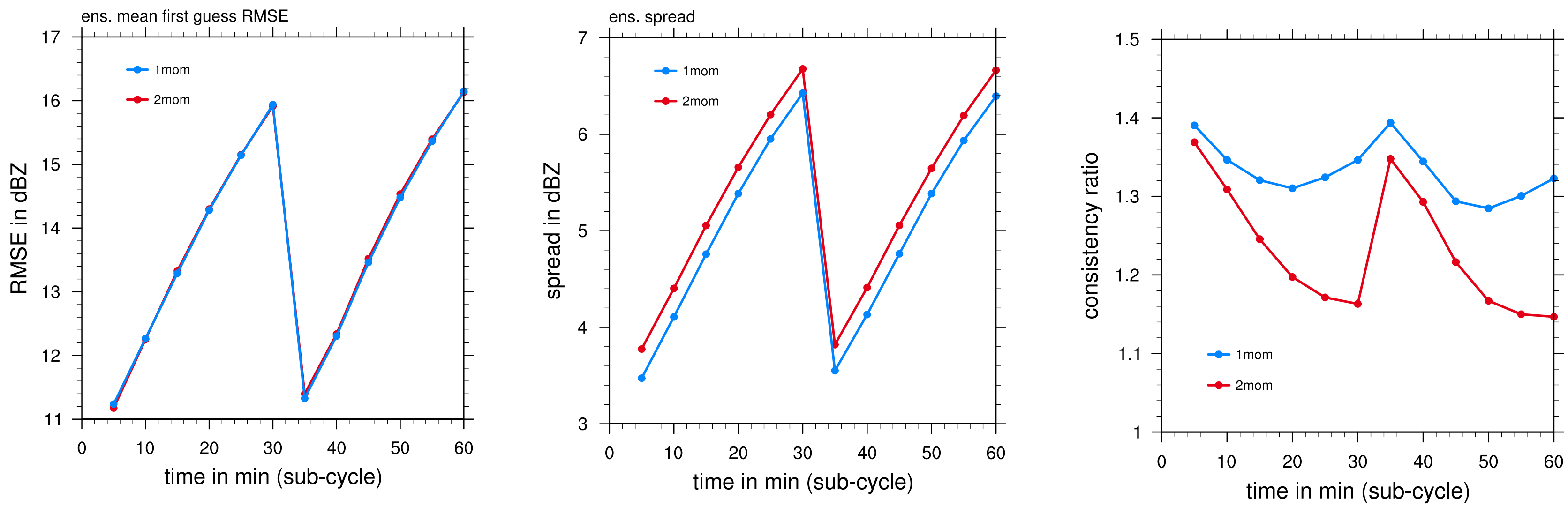
- RTPS with rtps_alpha=0.75
- refl_obs_error=10, radvel_obs_error=3, min_refl=0
- h_loc=5, v_loc=0.3 (for rvel and refl.)
- adap_rho=F, rho=1.0, sat_ad=T, hyd_bal=T, adap_R=F
- Additive perturbations (as in operational COSMO-DE)


COSMO First Guess, 20160529, 12:00 UTC + 00 min
obs
det
6
15
25
35
45
50
radar reflectivity (dBZ)

# 20160529, 18:00 UTC, elev. = 0.5°

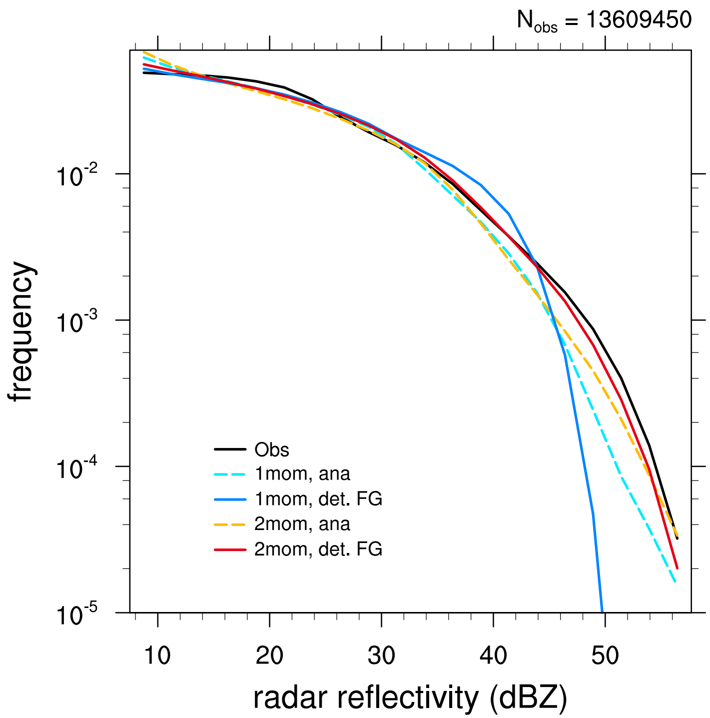


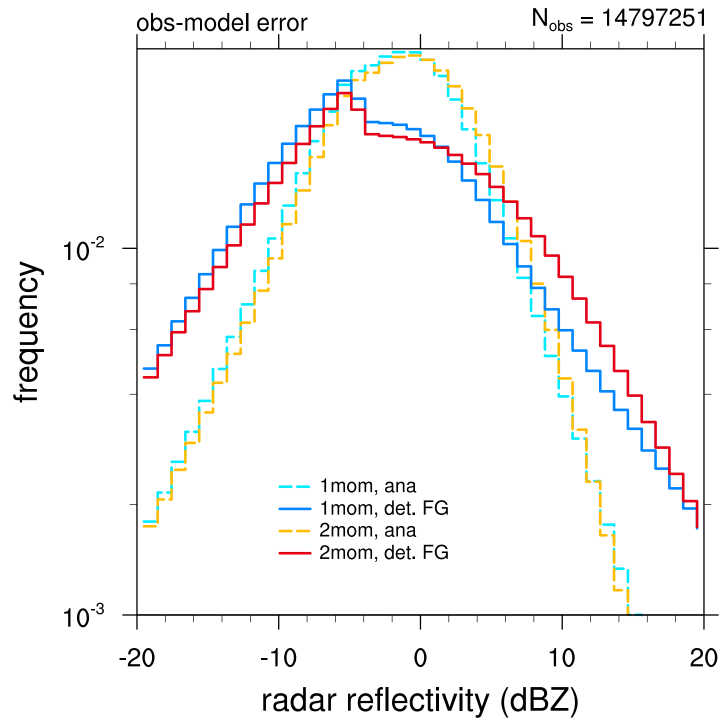
# LETKF results




- No significant difference in first-guess or analysis RMSE
- More spread with 2mom microphysics
- Hence, improved consistency ratio with 2mom microphysics.

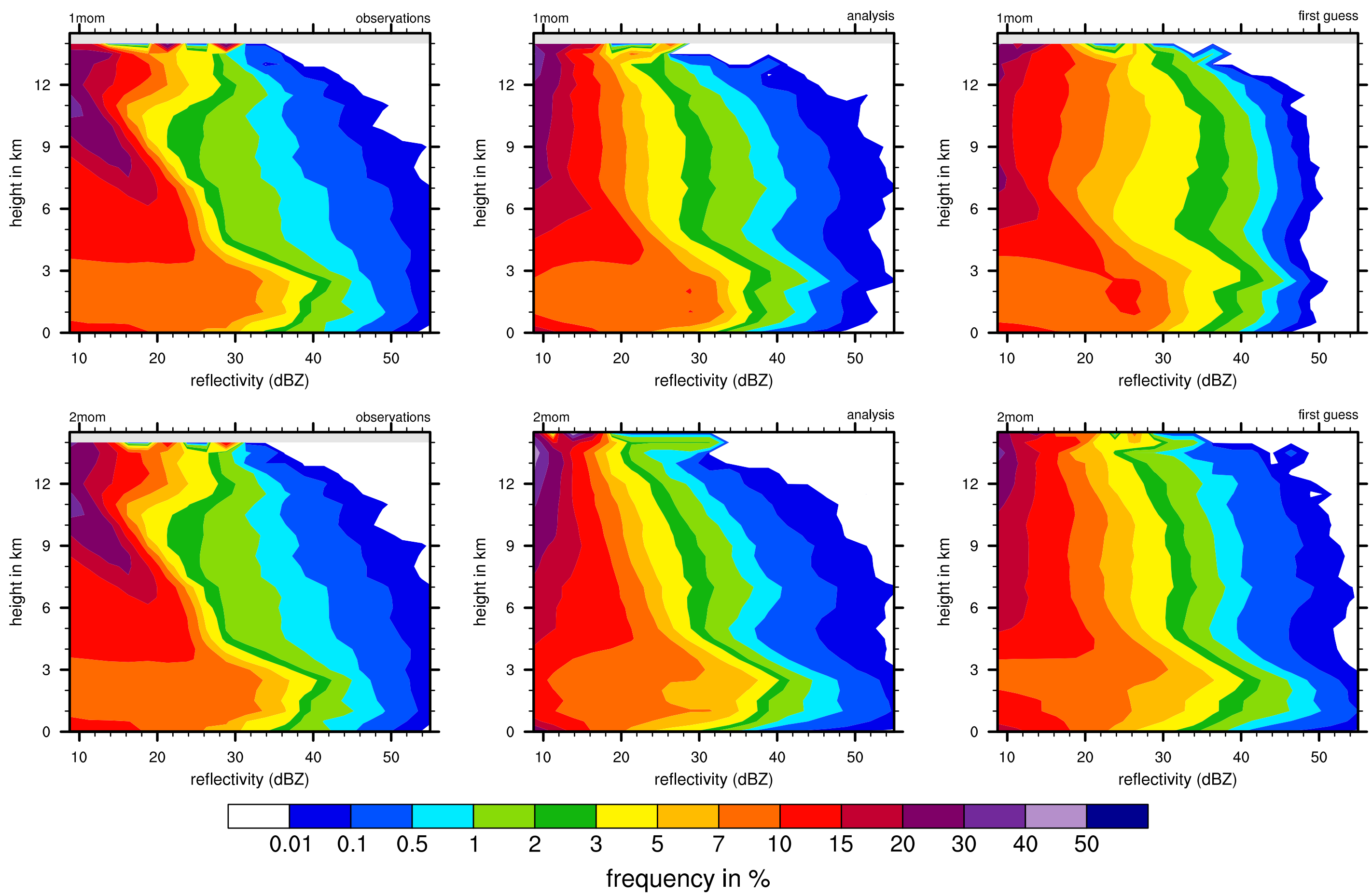
# Histogram of dBZ



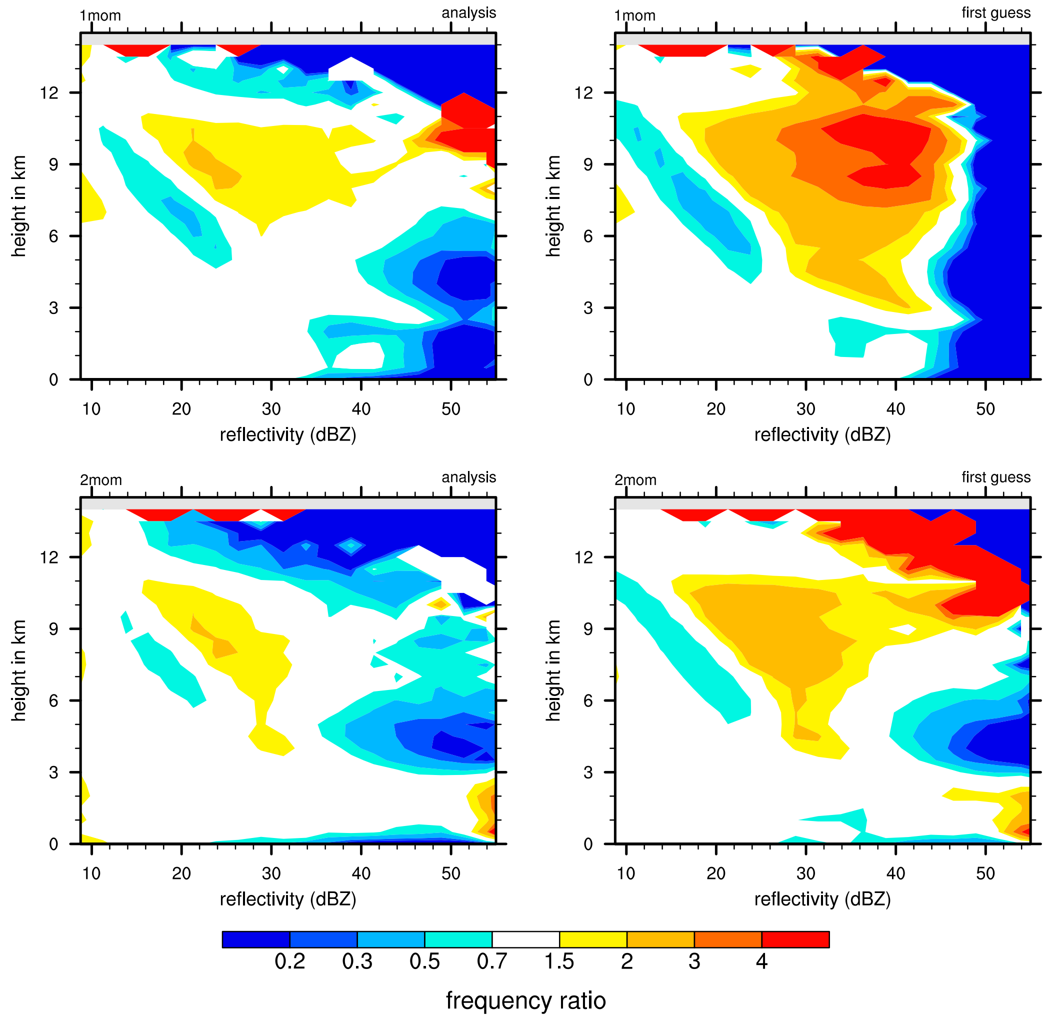

- The 2mom microphysics is much close to the observed dBZ statistics.
- Operational 1mom microphysics misses everything above 45 dBZ.
- LETKF analysis improves 1mom, but deteriorates 2mom statistics.

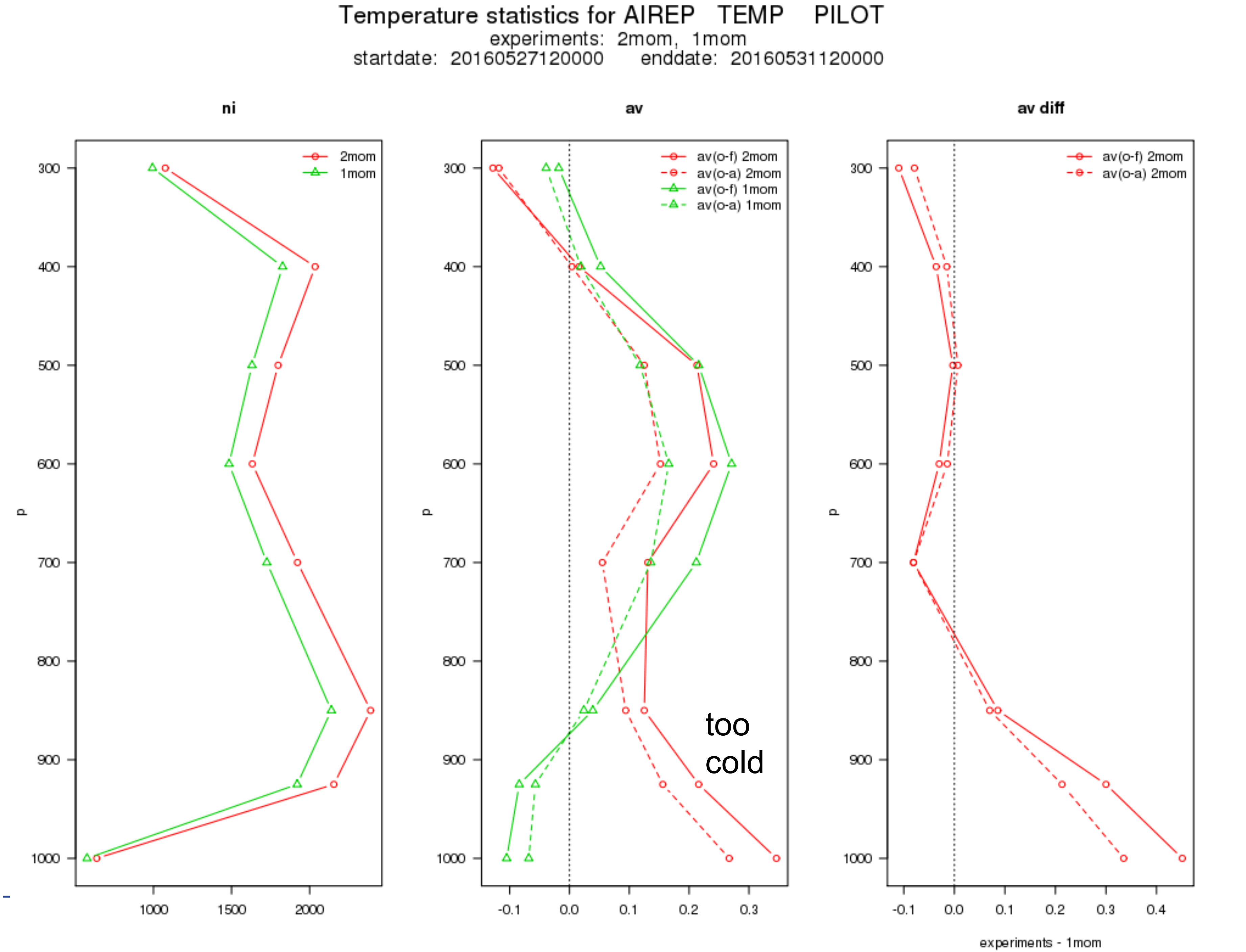
# CFADs (1d PDFs as function of height)



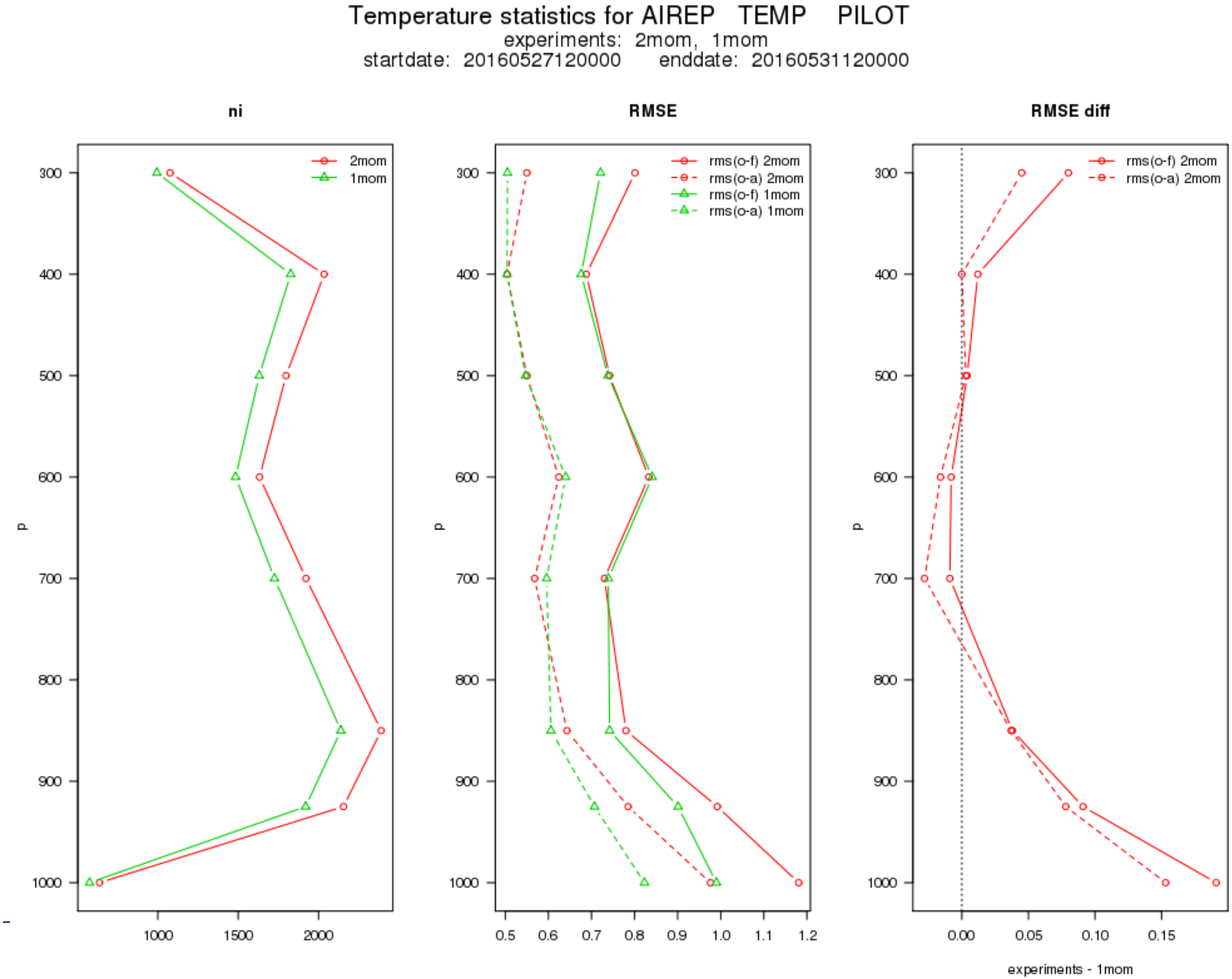
# Bias of CFADs

- First guess with 1mom shows positive frequency bias for moderate dBZ, but lack of high dBZ.
- First guess of 2 mom is much better than 1 mom.
- Analysis is similar for both microphysics schemes.

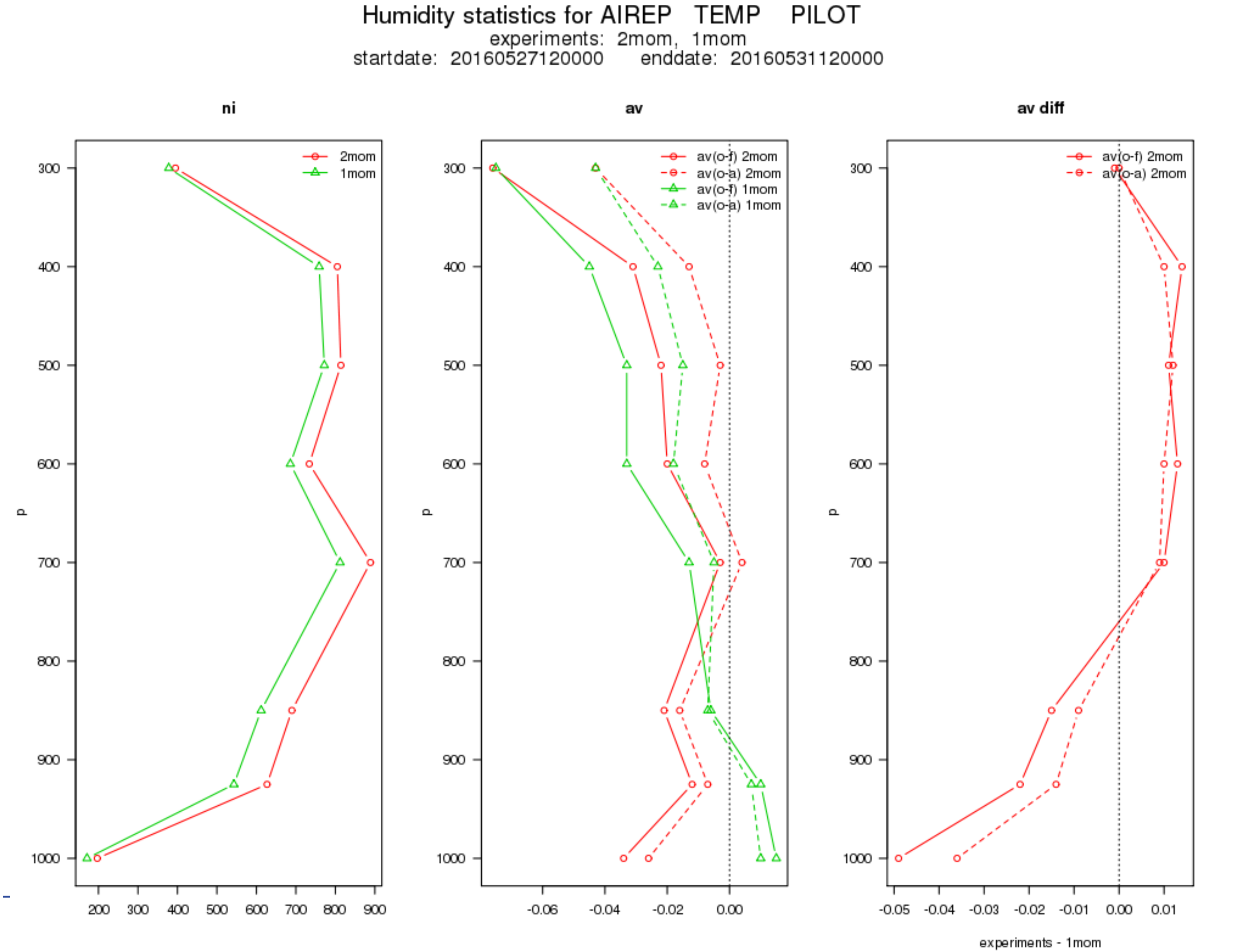


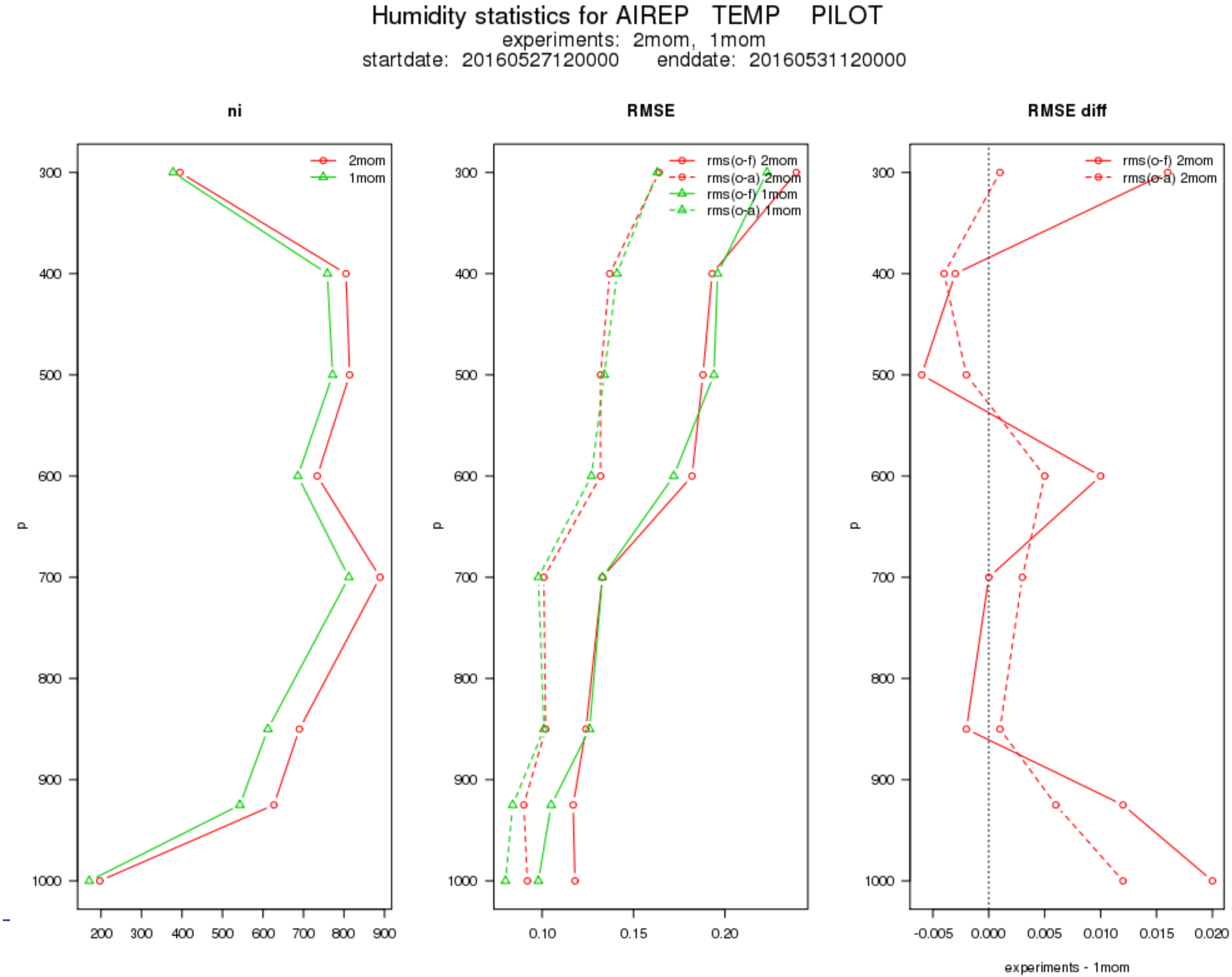


Temperature statistics for AIREP TEMP PILOT
experiments: 2mom, 1mom
startdate: 20160527120000 enddate: 20160531120000
ni
av
av diff
2mom
1mom
av(o-f) 2mom
av(o-a) 2mom
av(o-f) 1mom
av(o-a) 1mom
p
too
cold
experiments - 1mom



Temperature statistics for AIREP TEMP PILOT
experiments: 2mom, 1mom
startdate: 20160527120000 enddate: 20160531120000
ni
2mom
1mom
RMSE
rms(o-f) 2mom
rms(o-a) 2mom
rms(o-f) 1mom
rms(o-a) 1mom
RMSE diff
rms(o-f) 2mom
rms(o-a) 2mom
p
300
400
500
600
700
800
900
1000
1000
1500
2000
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
0.00
0.05
0.10
0.15
experiments - 1mom


Humidity statistics for AIREP TEMP PILOT
experiments: 2mom, 1mom
startdate: 20160527120000 enddate: 20160531120000
ni
av
av diff
2mom
1mom
av(o-f) 2mom
av(o-a) 2mom
av(o-f) 1mom
av(o-a) 1mom
p
experiments - 1mom

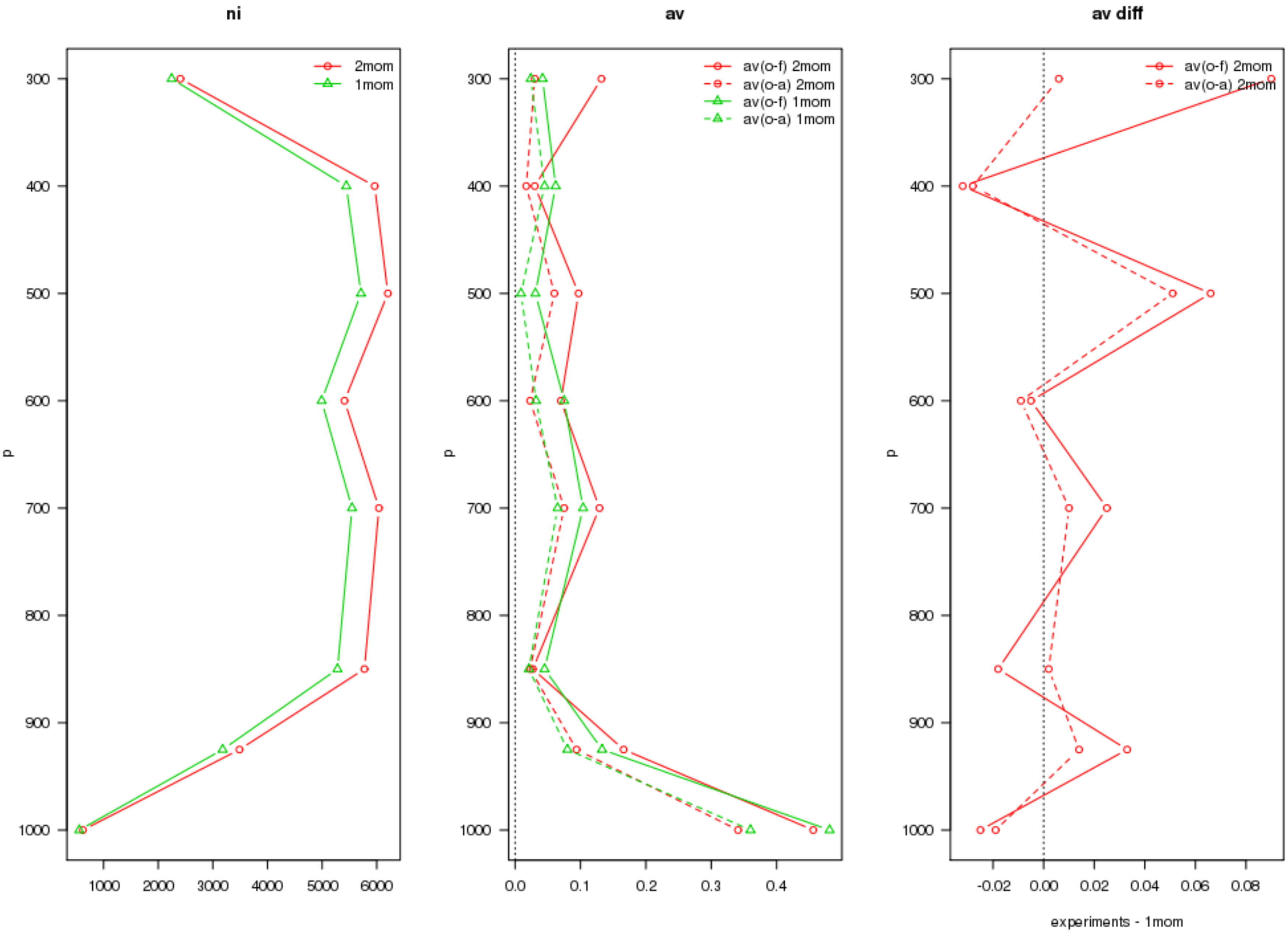


Humidity statistics for AIREP TEMP PILOT
experiments: 2mom, 1mom
startdate: 20160527120000 enddate: 20160531120000
ni
RMSE
RMSE diff
2mom
1mom
rms(o-f) 2mom
rms(o-a) 2mom
rms(o-f) 1mom
rms(o-a) 1mom
p
experiments - 1mom

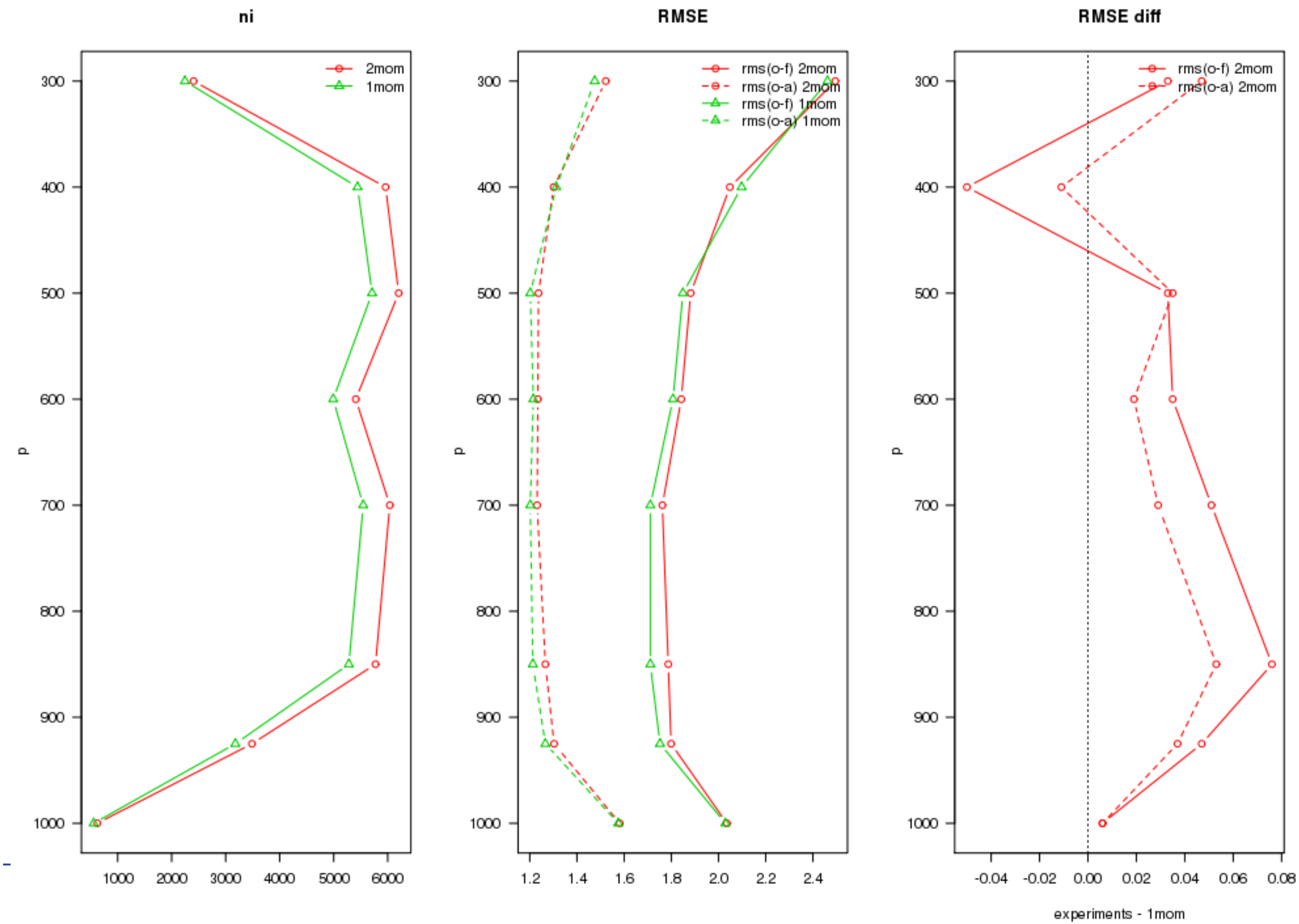
Wind statistics for AIREP TEMP PILOT

experiments: 2mom, 1mom

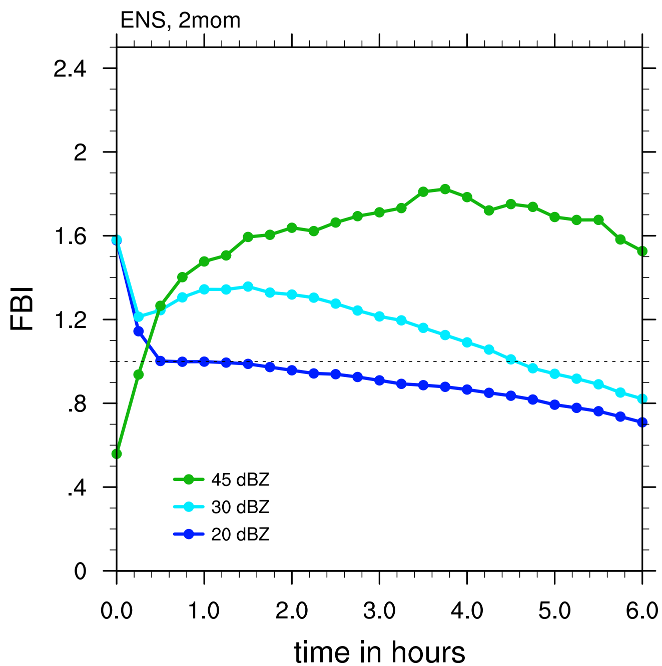
startdate: 20160527120000 enddate: 20160531120000

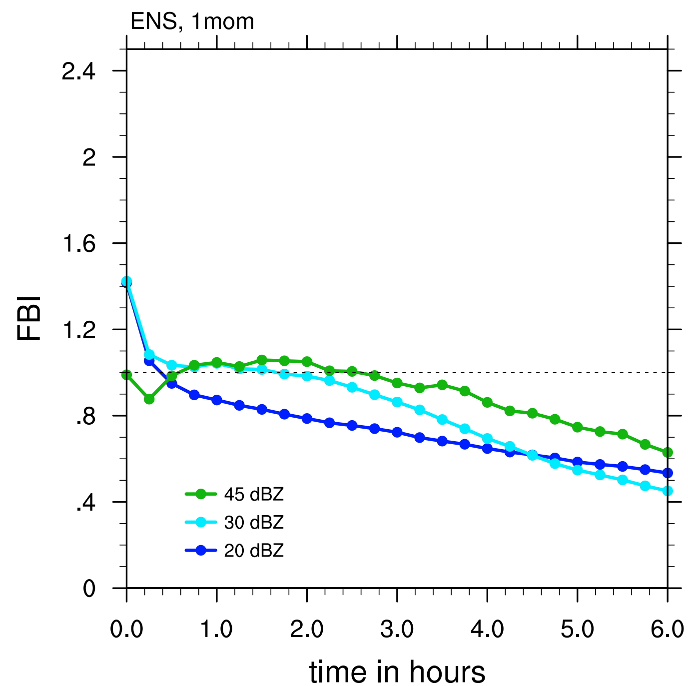


Wind statistics for AIREP TEMP PILOT
experiments: 2mom, 1mom
startdate: 20160527120000 enddate: 20160531120000



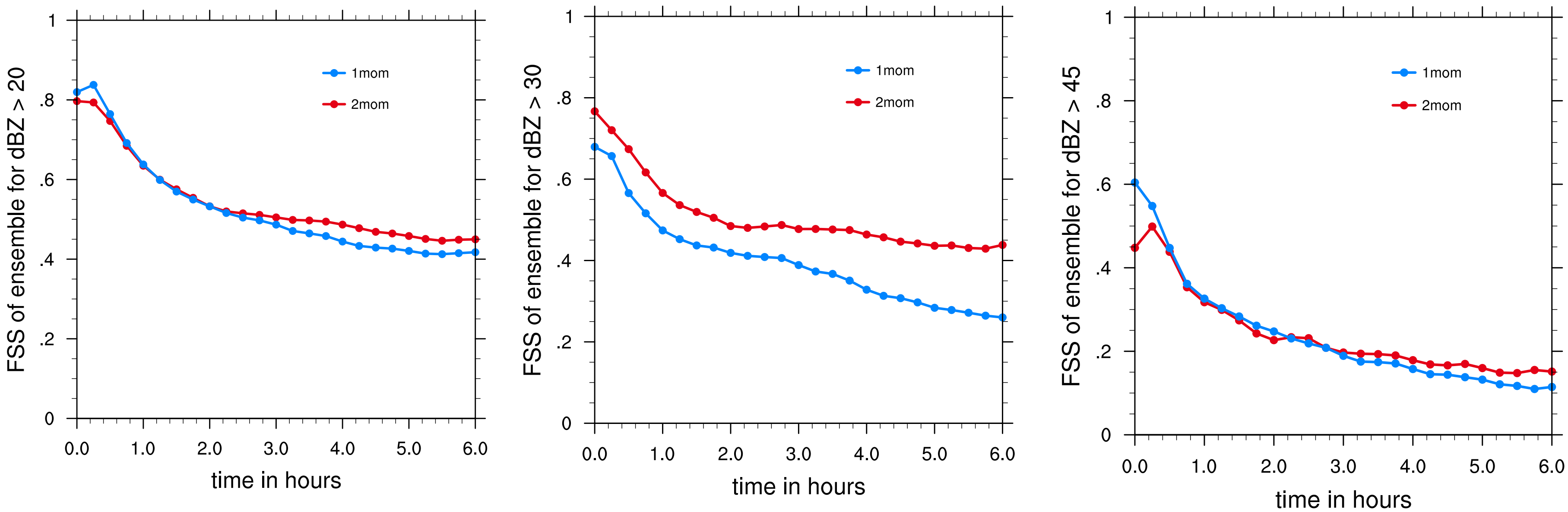
# Forecast scores (for 3 days, 12, 13, 14 UTC + 6 h)




- 2mom overestimates the frequency of 30 and 45 dBZ, 1mom seems to better
- Compensating errors in case of 1mom. The model simulations too many convective cells.

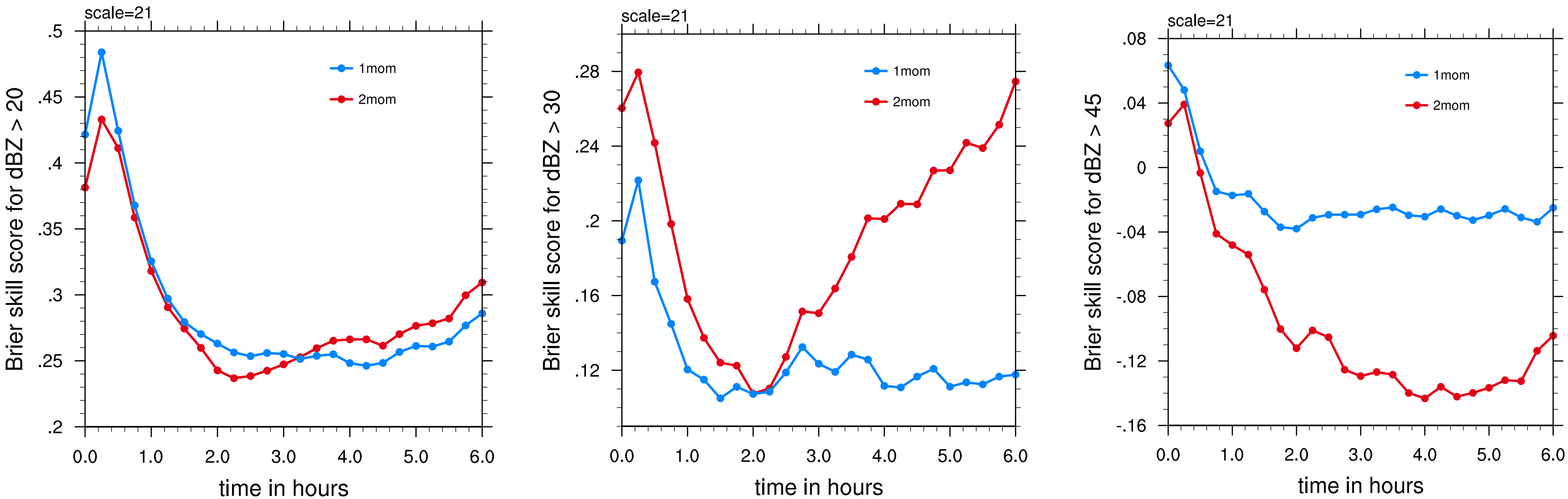
# Forecast scores (for 3 days, 12, 13, 14 UTC + 6 h)




- In the Fraction Skill Score the 2mom scheme shows some improvement for 30 dBZ, but not for 20 dBZ where the 1mom is well calibrated, and 45 dBZ where both have low skill.

(FSS at a scale of 21 grid points, roughly 20 km)

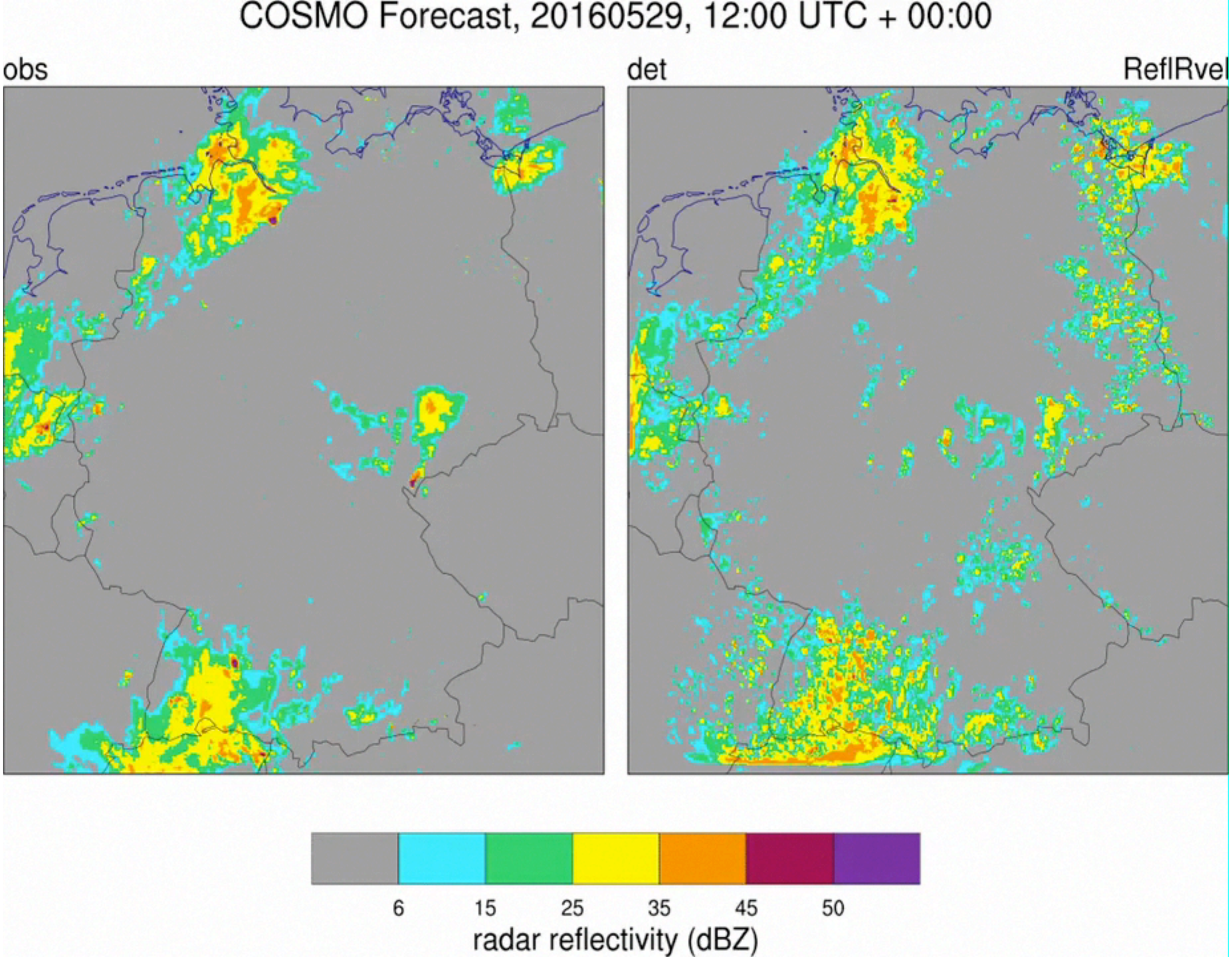
# Forecast scores (for 3 days, 12, 13, 14 UTC + 6 h)



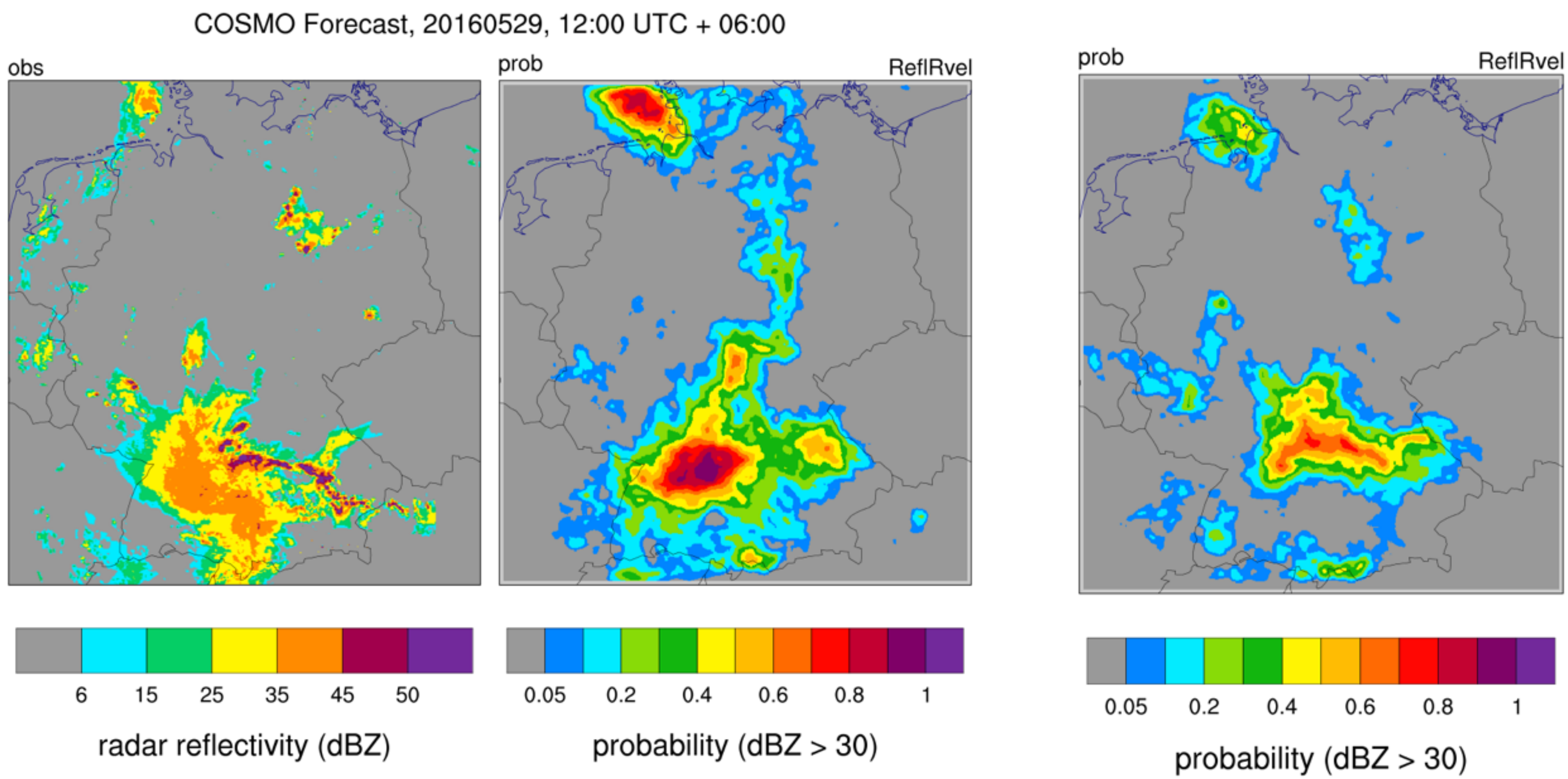

- In the Brier score the 2mom scheme shows some nice but weird behavior for the 30 dBZ threshold. For 45 dBZ it is still better to predict nothing as the 1mom scheme actually does.

(reference in this BSS is a zero probability forecast)

# Braunsbach flooding on 29th May 2016

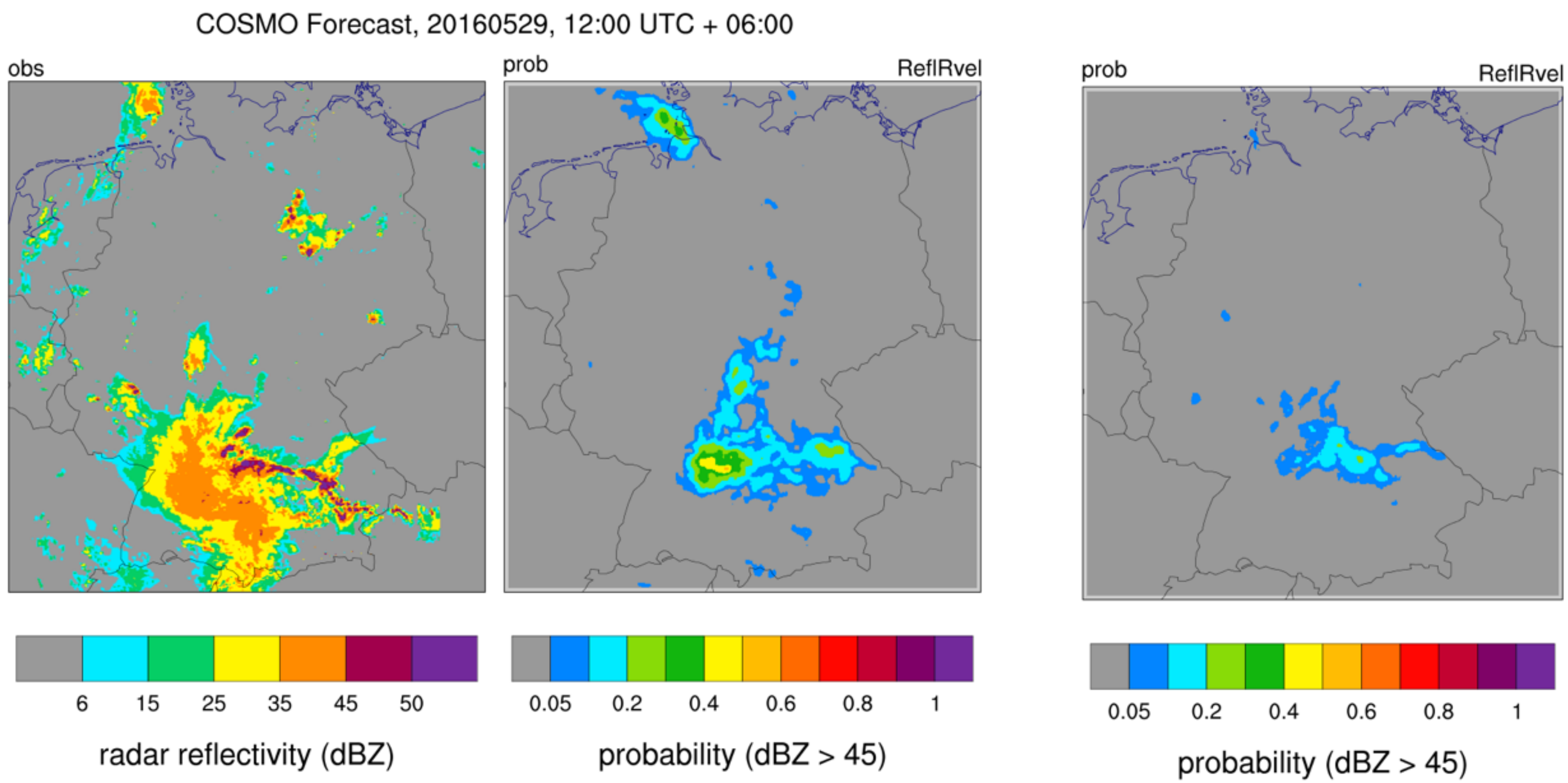


COSMO Forecast, 20160529, 12:00 UTC + 00:00
obs
det
ReflRvel
6
15
25
35
45
50
radar reflectivity (dBZ)

# Braunsbach flooding on 29th May 2016




**2mom forecast** **1mom forecast**

# Braunsbach flooding on 29th May 2016




**2mom forecast** **1mom forecast**

# Conclusions:

- The LETKF works reasonably well for the assimilation of radar reflectivity.
- Some advantages with 2mom microphysics scheme, but still room for improvement, e.g., cold bias in PBL (too strong cold pools?).
- Forecasts for the Braunsbach event look promising.

# Planned work for next 12 months (incl. Alberto)

- Careful analysis of effect of „bubbles“ and „dBZ transform“
- Improvement of 2mom scheme for „stratiform regions of convective systems“ and „cold bias“,
  … but would like to have IR and VIS satellite (at least passive) otherwise the improvements for dBZ might deteriorate the cloud structures seen by the satellite.
- Horizontal diffusion for 1 km COSMO model.
- OSSE-like test with idealized supercell to better understand practical predictability in the LETKF-based system.