JK blending method in AROME 3D-Var

ENDI KERESTURI, YONG WANG, FLORIAN MEIER, FLORIAN WEIDLE, CHRISTOPH WITTMANN

ZAMG - ZENTRALANSTALT FÜR METEOROLOGIE UND GEODYNAMIK

Motivation

- **Ensemble Jk method (submitted to QJRMS)**
- **Include large scale information from global model**
  - Superior data assimilation
  - Better treatment of larger scales
  - Guidard and Fischer (2008), Gustafsson et al. (2018)
- **Mismatching perturbations coming from driving model with those generated by limited area model (LAM)**
  - LBCs perturbations vs ICs perturbations

State of the art

- **Digital filter blending method**
  - Brožková et al. (2001), Bučanek and Broškova (2017)
  - Low-pass digital filter -> blend a large-scale analysis with small scales of LAM
  - ALADIN-LAEF
- **Include global model information directly into limited area variational assimilation**
  - *Jk* blending method
  - Proposed by Guidard and Fischer (2008)
  - Adopted to HIRLAM by Dahlgren and Gustafsson (2012)

Theoretical background – Jk 3DVAR

- **Cost function:**

$$J(x) = \underbrace{\frac{1}{2}(x - x_b)^T B^{-1}(x - x_b)}_{J_b} + \underbrace{\frac{1}{2}(y - Hx)^T R^{-1}(y - Hx)}_{J_o}$$

- **Cost functionin Jk blending method**

$$J(x) = J_b + J_o + \underbrace{\frac{1}{2}(x - x_{ls})^T V^{-1}(x - x_{ls})}_{J_k} = J_b + J_o + J_k$$

Model setup

- **LAM: AROME model (2.5L90) cy40**
  - ZAMG's operational configuration
  - **3D-Var** - Conventional observations (AMDAR, SYNOP, PILOT, TEMP, SHIP, EUROPROFILERS) plus GEOWIND and ASCAT
  - ZAMG's operational B-matrix
  - 6-h continuous assimilation cycles
- **Driving model: ECMWF EPS control (18L91)**

Jk configuration

- **Namelist switches**
  - LEJK = TRUE # *main Jk switch*
  - ALPHAKT ~ 1 # *amplification factor for Jk temperature term*
  - ALPHAKVOR ~ 1 # *amplification factor for Jk vorticity term*
  - ALPHAKDIV ~ 0.1 # *amplification factor for Jk divergence term*
  - ALPHAKQ ~ 0.01 # *amplification factor for Jk humidity term*
  - ALPHAKP = 1 # *amplification factor for Jk pressure term*
  - PRESINFJK = 100500 # *Jk activated above pressure level*
  - PRESUPJK = 98000 # *Jk fully active above pressure level*

Humidity problem

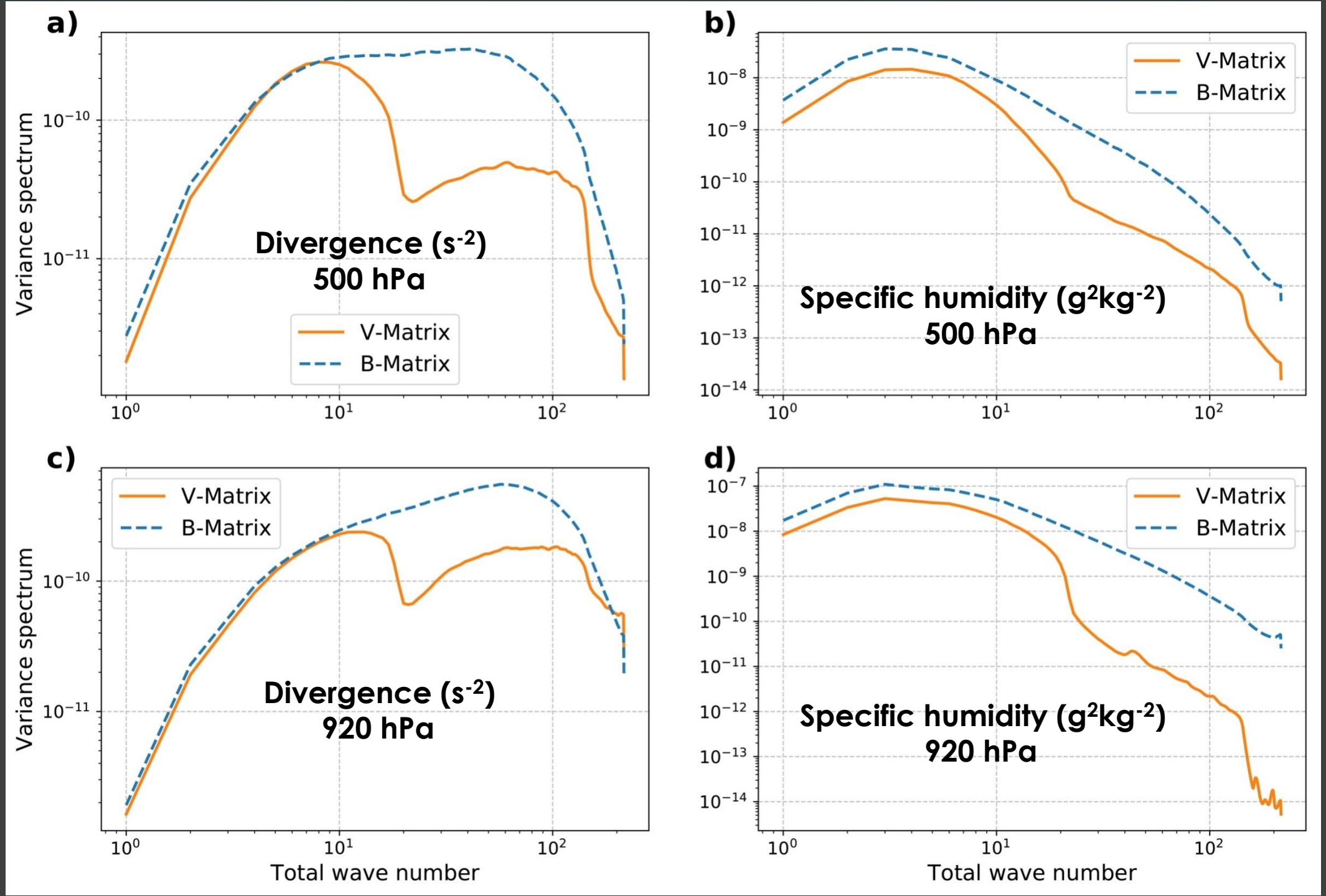
- **Jk code was written for ALADIN (humidity is spectral)**
  - Gridpoint humidity in AROME
  - Humidity gp -> sp (Epygram)
  - LSPRT = FALSE

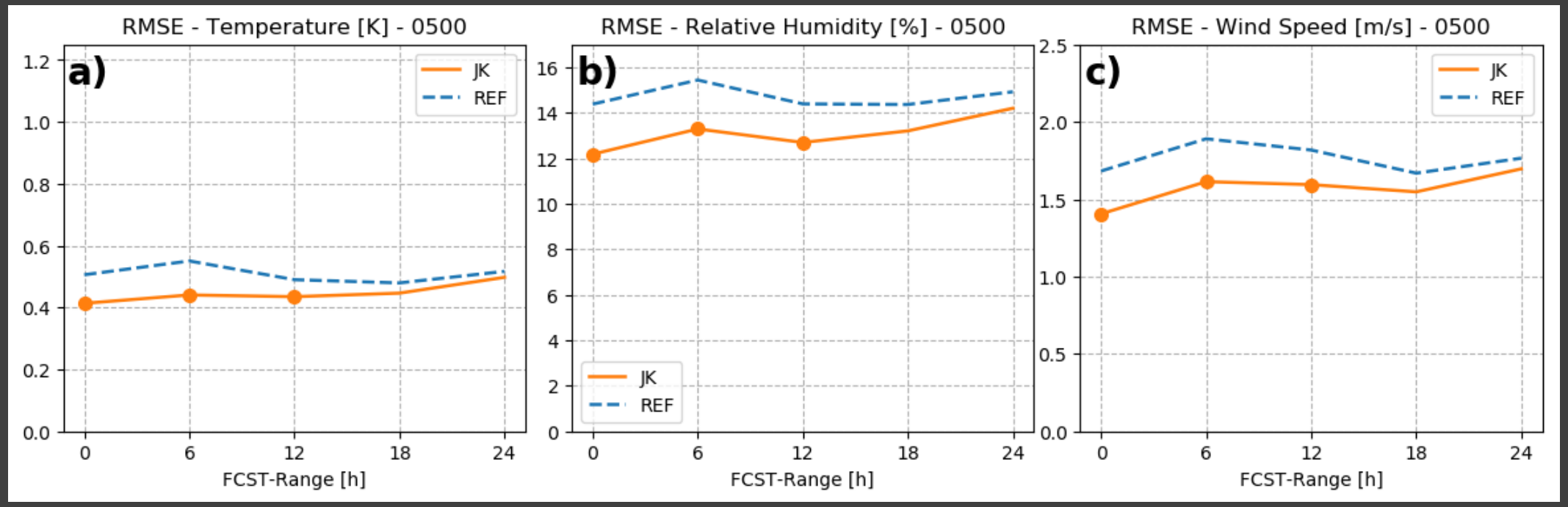
V-matrix calculation

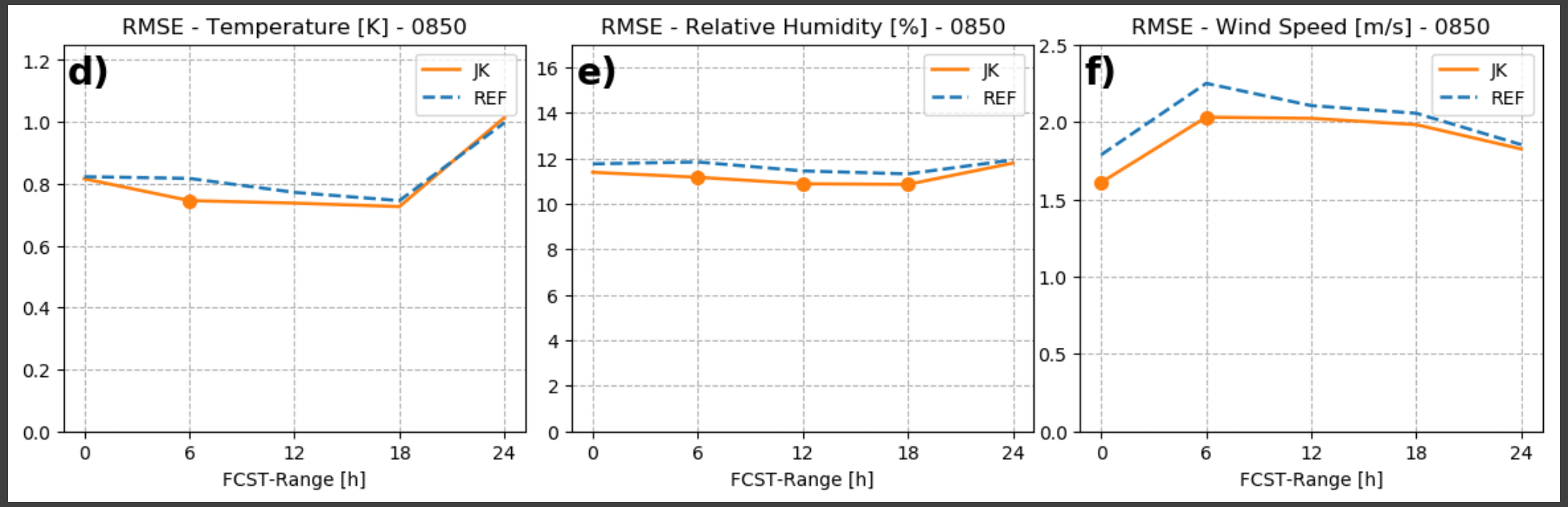
- **Ensemble method**
- **16 ECMWF EPS members (analysis)**
  - Interpolated to AROME domain
- **Two times per day (00 and 12 UTC) for two weeks in January, April, July and October**
  - Annual variability
- **Total of 896 differences**
- **Univariate formulation**

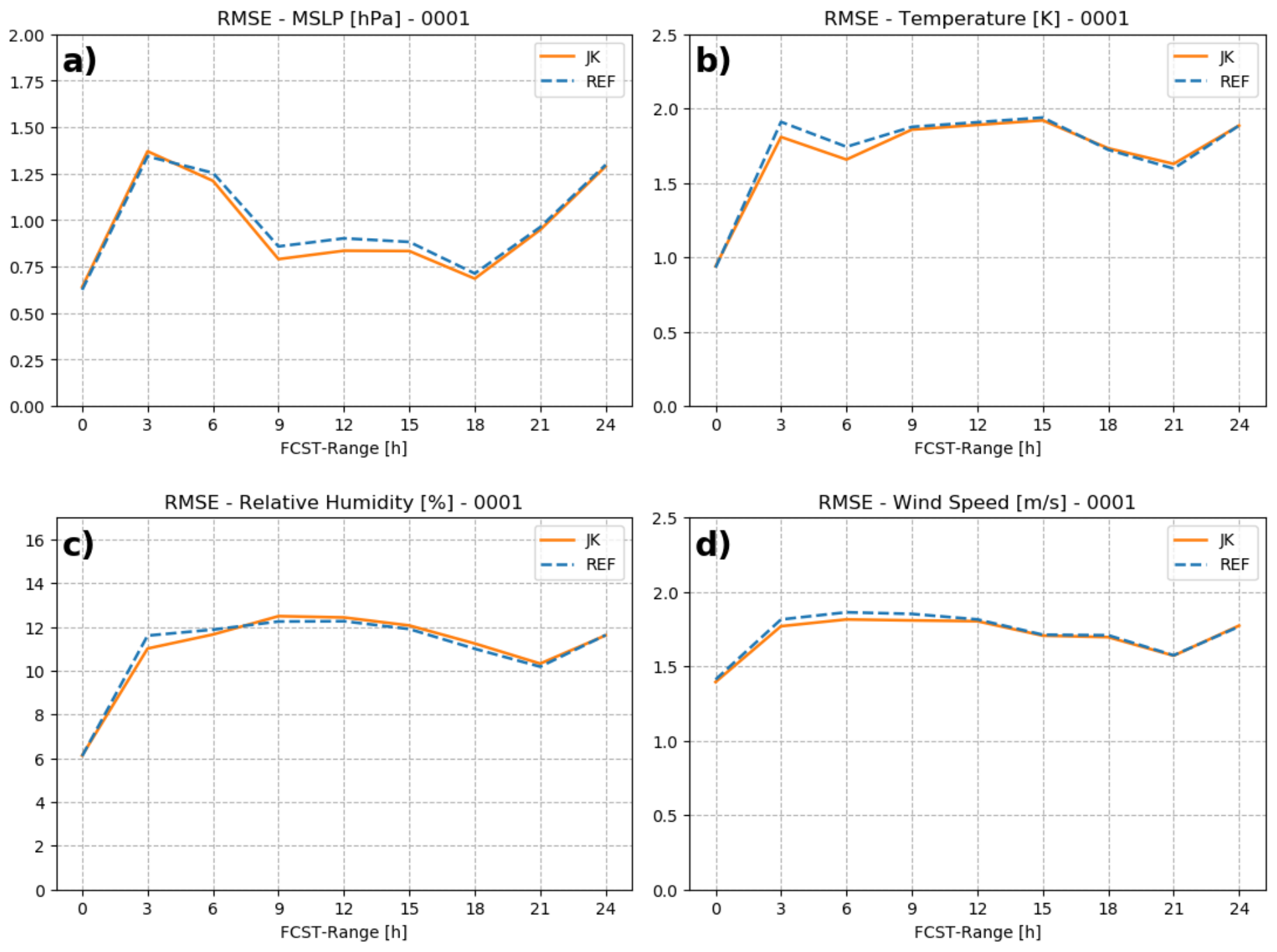
Scale selection

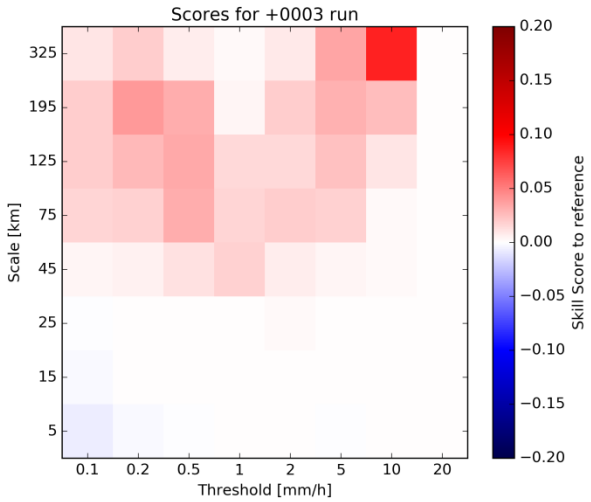
- **Truncation of J_k term**
  - Wave number for which horizontal error variance spectra, between LAM and global model, starts to diverge
  - NTRUNCJK = 8 ~ 135 km

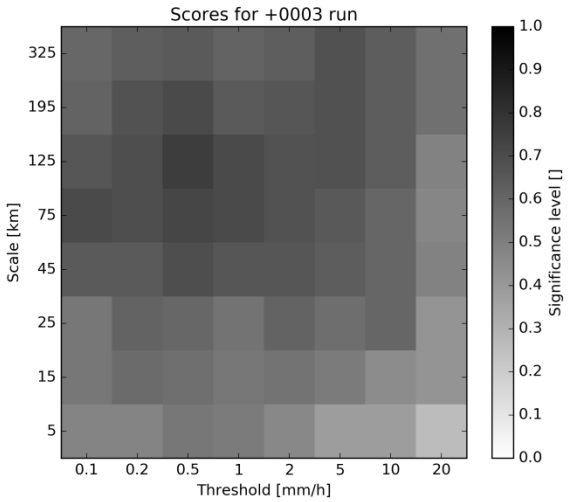

a)
Divergence (s^{-2})
500 hPa
V-Matrix
B-Matrix
Variance spectrum
b)
Specific humidity (g^2kg^{-2})
500 hPa
c)
Divergence (s^{-2})
920 hPa
Total wave number
d)
Specific humidity (g^2kg^{-2})
920 hPa

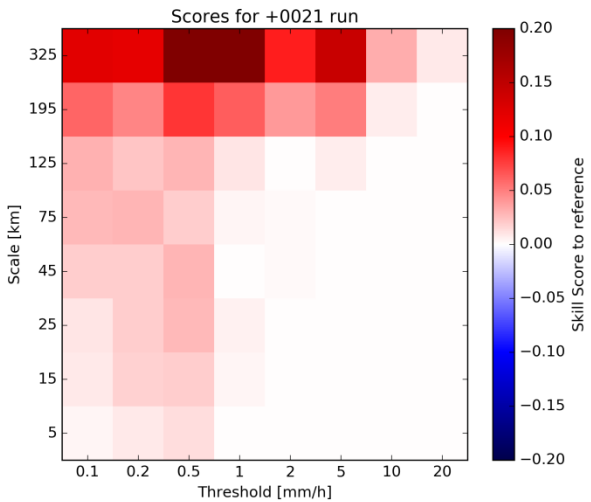

RMSE - Temperature [K] - 0500
a)
JK
REF
FCST-Range [h]
RMSE - Relative Humidity [%] - 0500
b)
JK
REF
FCST-Range [h]
RMSE - Wind Speed [m/s] - 0500
c)
JK
REF
FCST-Range [h]

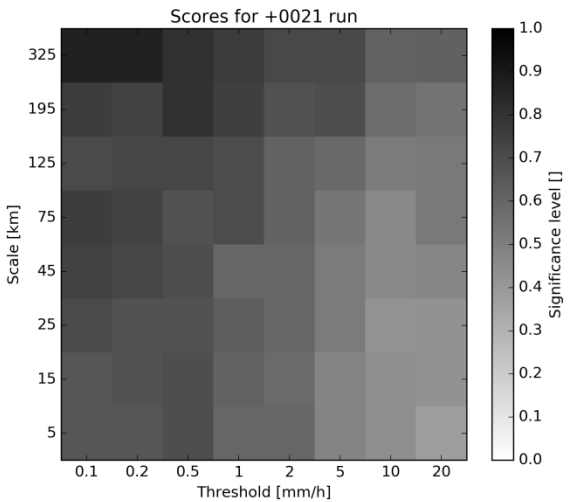

RMSE - Temperature [K] - 0850
d)
JK
REF
FCST-Range [h]
RMSE - Relative Humidity [%] - 0850
e)
JK
REF
FCST-Range [h]
RMSE - Wind Speed [m/s] - 0850
f)
JK
REF
FCST-Range [h]

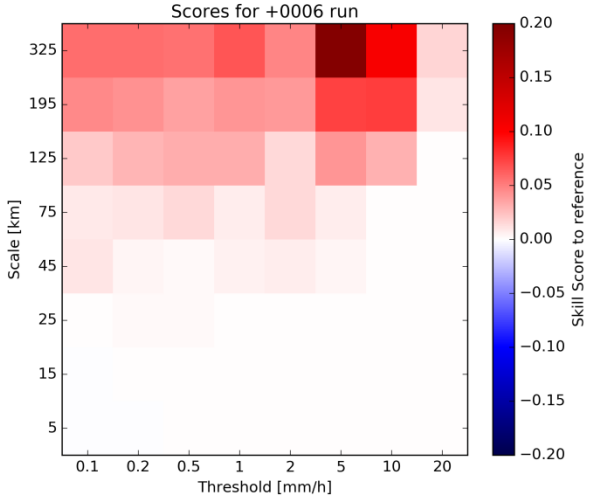

RMSE - MSLP [hPa] - 0001
a)
JK
REF
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
3
6
9
12
15
18
21
24
FCST-Range [h]
RMSE - Temperature [K] - 0001
b)
JK
REF
2.5
2.0
1.5
1.0
0.5
0.0
0
3
6
9
12
15
18
21
24
FCST-Range [h]
RMSE - Relative Humidity [%] - 0001
c)
JK
REF
16
14
12
10
8
6
4
2
0
0
3
6
9
12
15
18
21
24
FCST-Range [h]
RMSE - Wind Speed [m/s] - 0001
d)
JK
REF
2.5
2.0
1.5
1.0
0.5
0.0
0
3
6
9
12
15
18
21
24
FCST-Range [h]

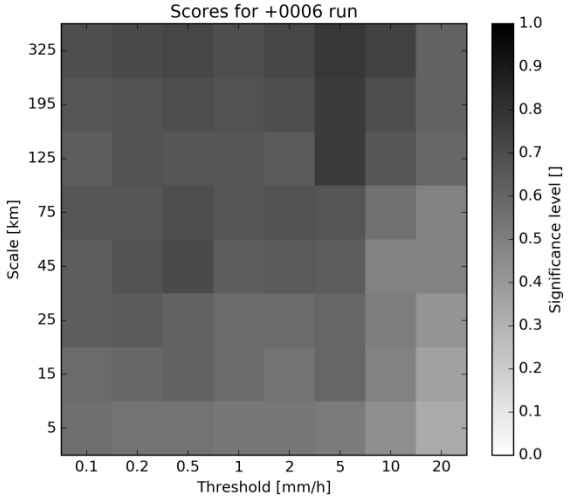

Scores for +0003 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Skill Score to reference
0.20 0.15 0.10 0.05 0.00 −0.05 −0.10 −0.15 −0.20

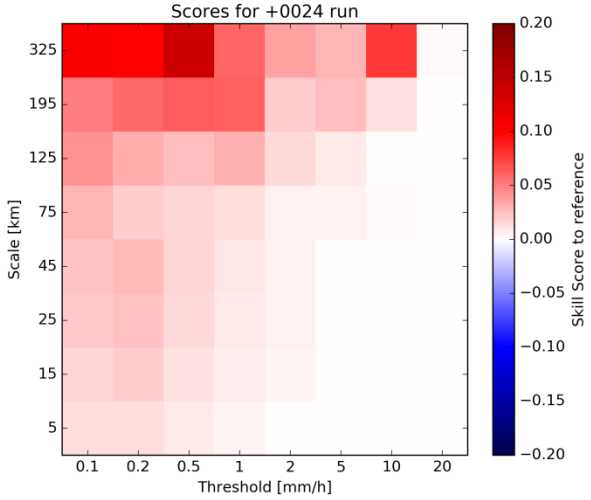

Scores for +0003 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Significance level []
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0

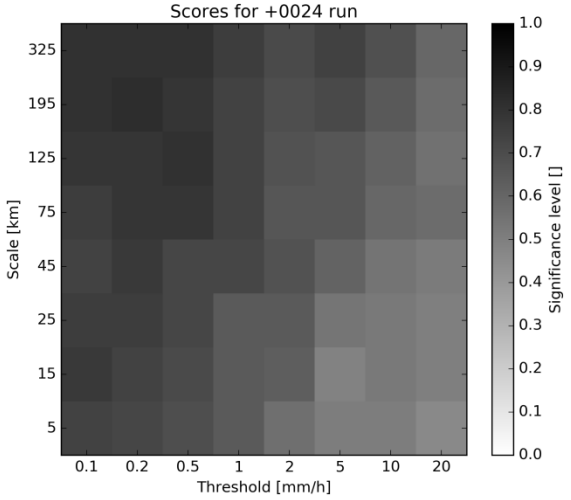

Scores for +0021 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Skill Score to reference
0.20 0.15 0.10 0.05 0.00 −0.05 −0.10 −0.15 −0.20

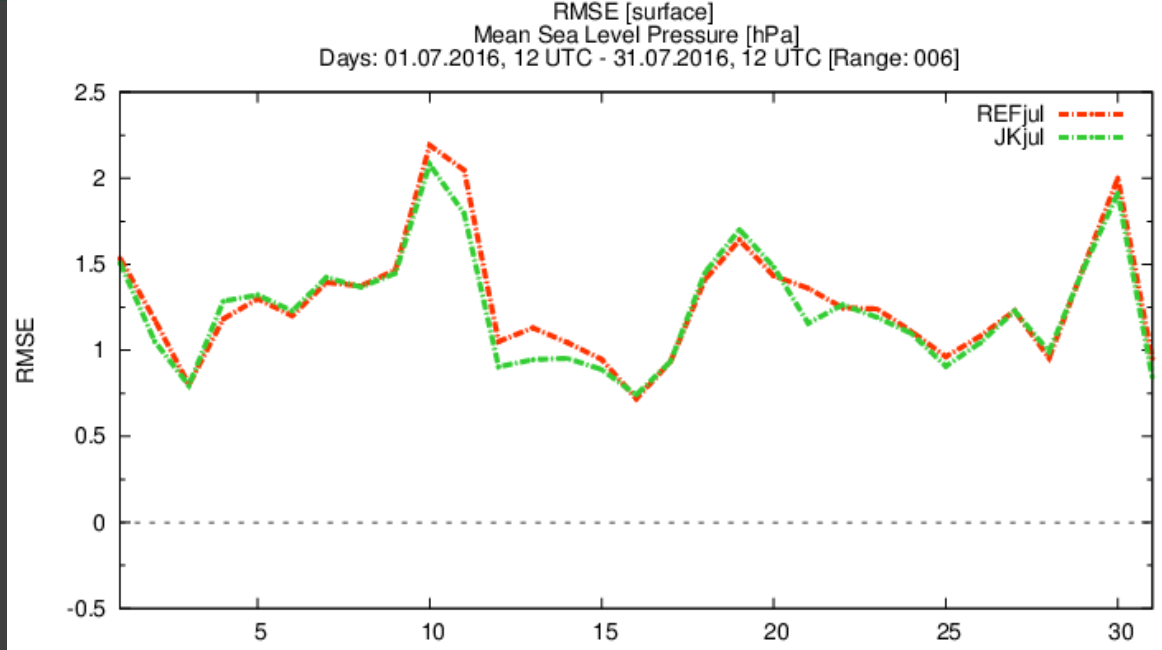

Scores for +0021 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Significance level []
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0

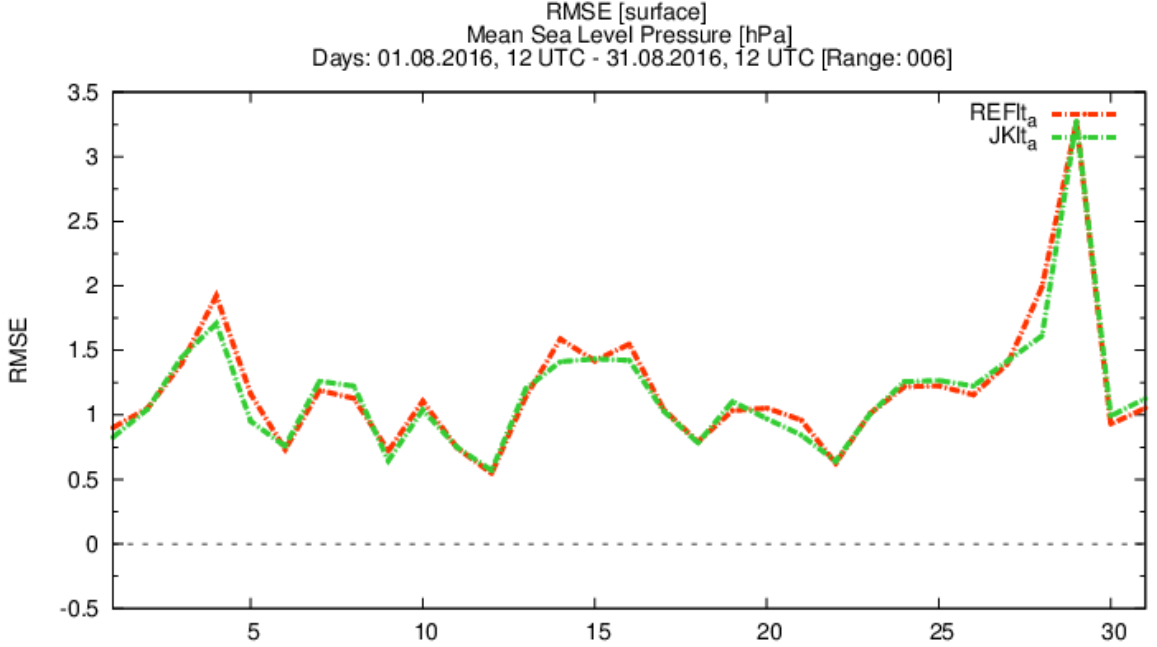

Scores for +0006 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Skill Score to reference
0.20 0.15 0.10 0.05 0.00 −0.05 −0.10 −0.15 −0.20

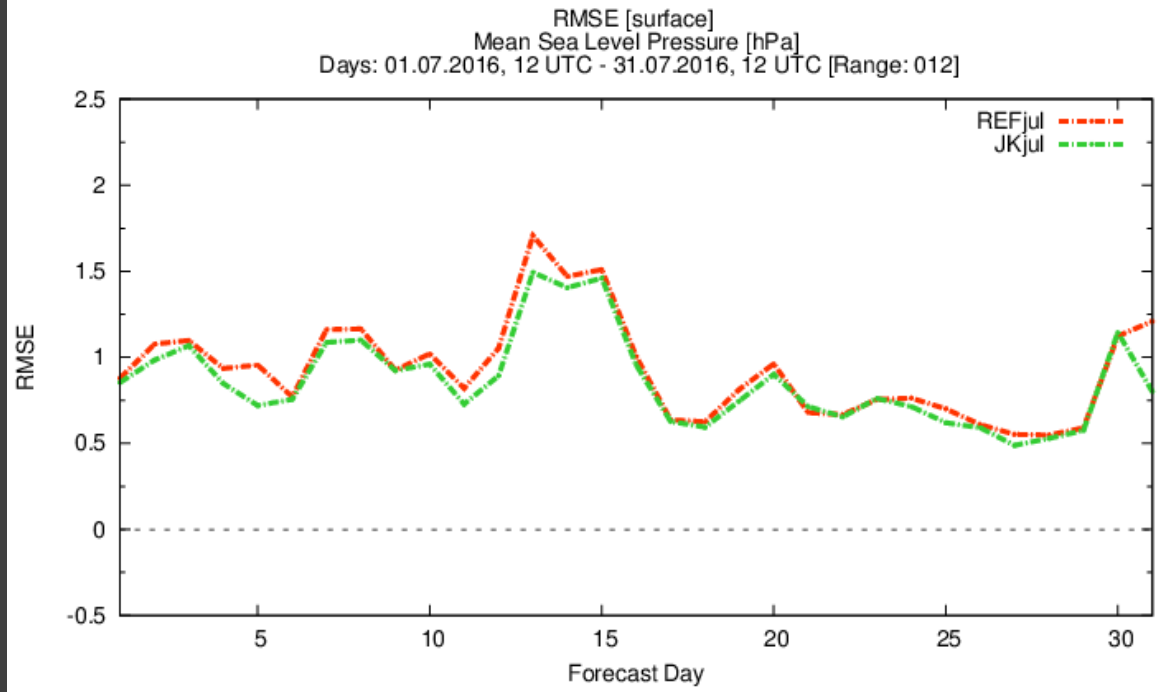

Scores for +0006 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Significance level []
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0

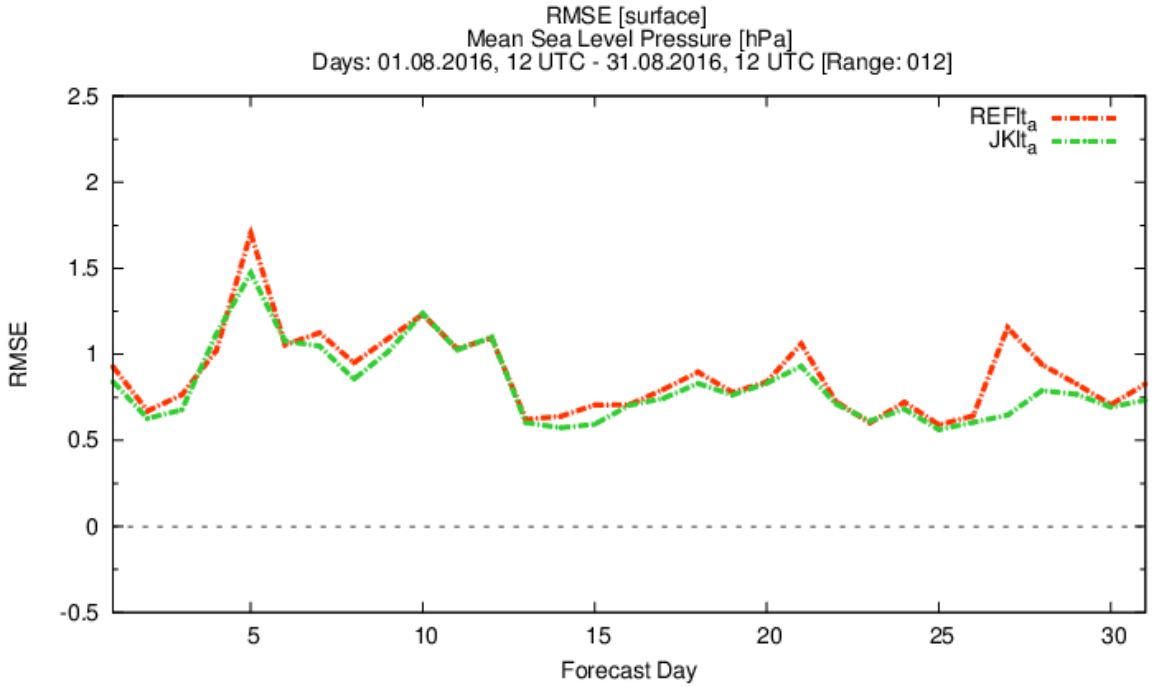

Scores for +0024 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Skill Score to reference
0.20 0.15 0.10 0.05 0.00 −0.05 −0.10 −0.15 −0.20

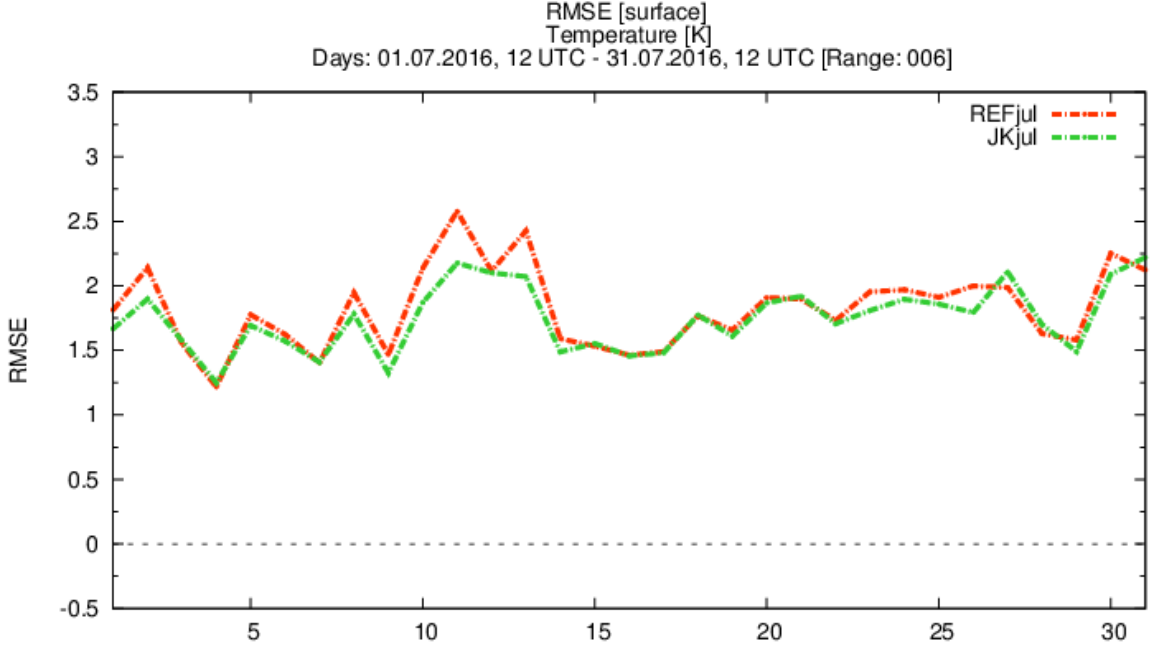

Scores for +0024 run
Scale [km]
325
195
125
75
45
25
15
5
0.1 0.2 0.5 1 2 5 10 20
Threshold [mm/h]
Significance level []
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0

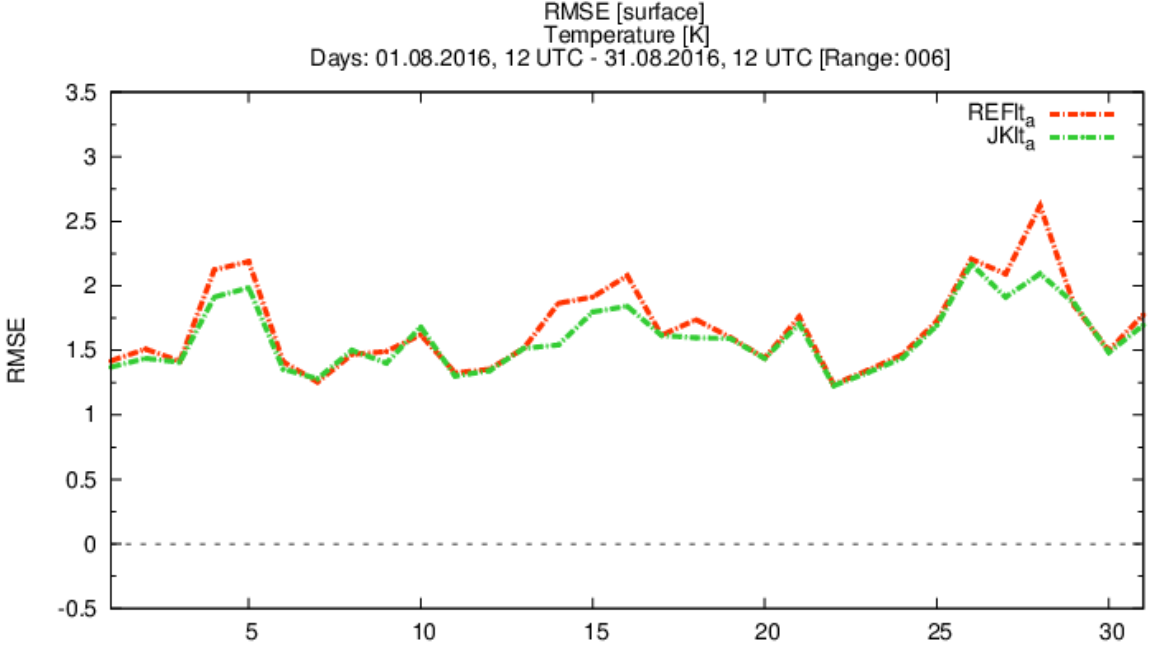

RMSE [surface]
Mean Sea Level Pressure [hPa]
Days: 01.07.2016, 12 UTC - 31.07.2016, 12 UTC [Range: 006]
REFjul
JKjul
RMSE
2.5
2
1.5
1
0.5
0
-0.5
5
10
15
20
25
30

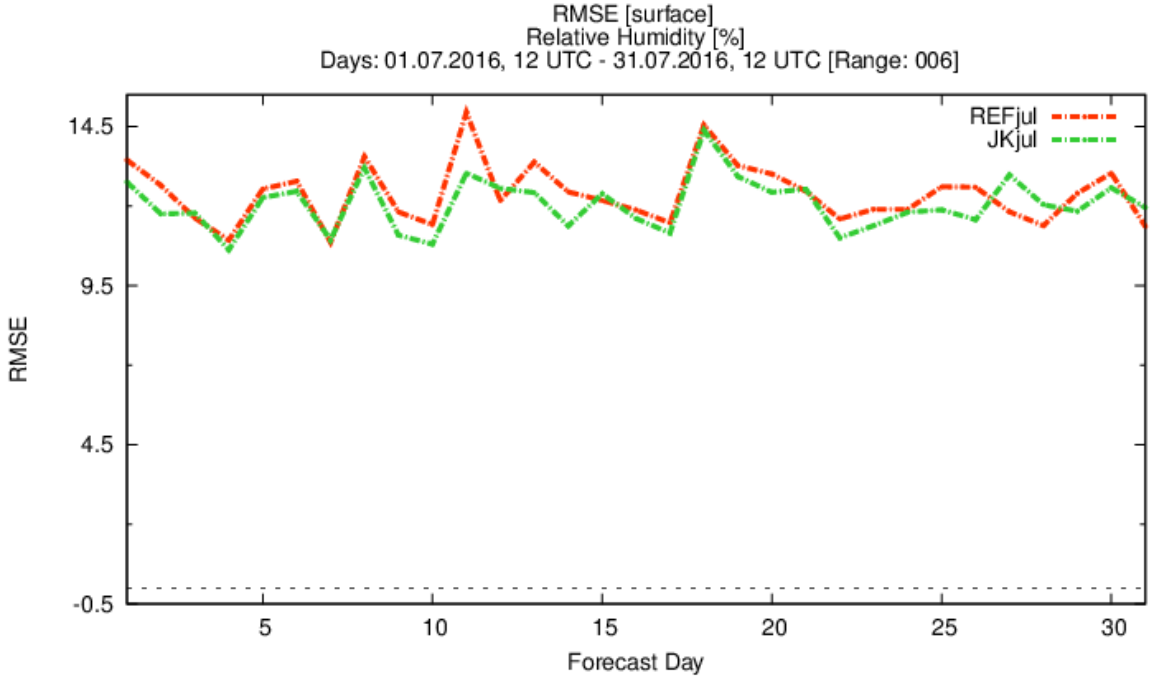

RMSE [surface]
Mean Sea Level Pressure [hPa]
Days: 01.08.2016, 12 UTC - 31.08.2016, 12 UTC [Range: 006]
REFlt$_a$
JKlt$_a$
RMSE
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
5
10
15
20
25
30

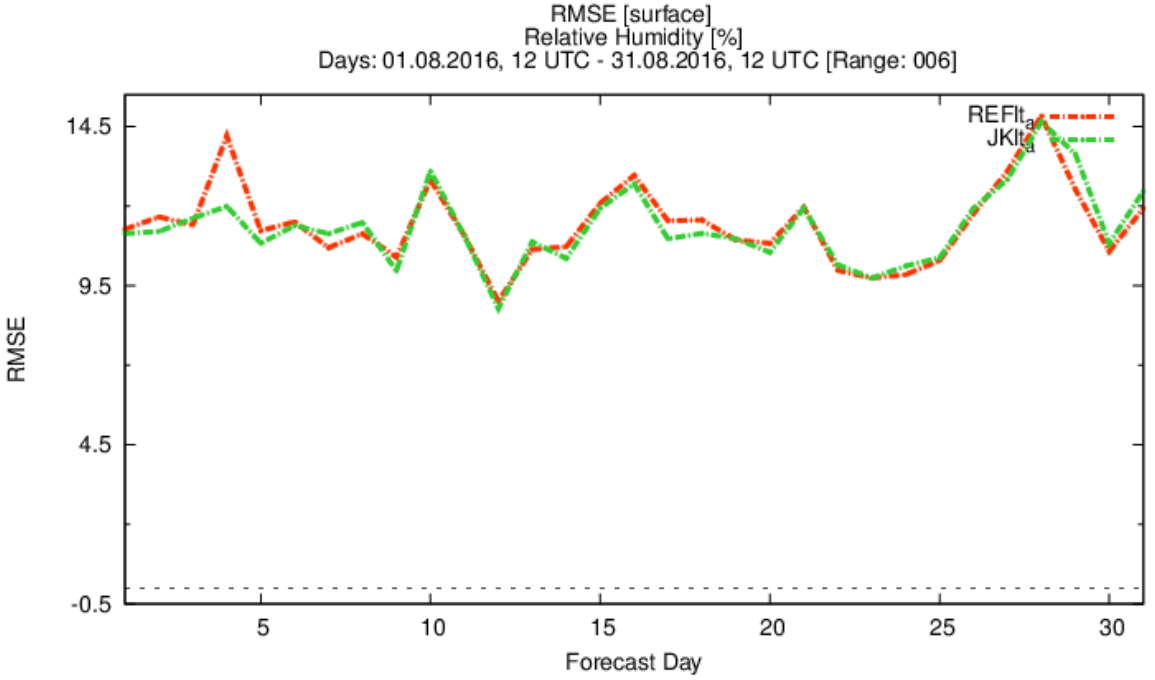

RMSE [surface]
Mean Sea Level Pressure [hPa]
Days: 01.07.2016, 12 UTC - 31.07.2016, 12 UTC [Range: 012]
REFjul
JKjul
RMSE
2.5
2
1.5
1
0.5
0
-0.5
5
10
15
20
25
30
Forecast Day


RMSE [surface]
Mean Sea Level Pressure [hPa]
Days: 01.08.2016, 12 UTC - 31.08.2016, 12 UTC [Range: 012]
REFlt$_a$
JKlt$_a$
RMSE
2.5
2
1.5
1
0.5
0
-0.5
5
10
15
20
25
30
Forecast Day

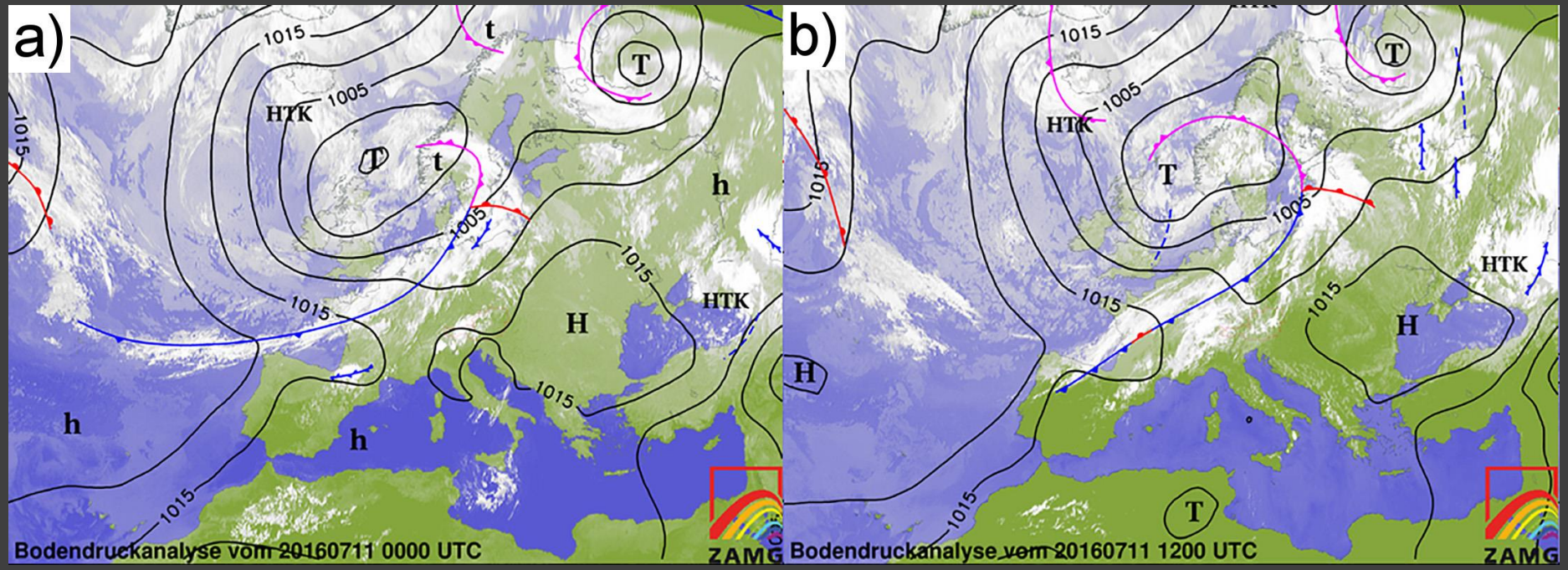

RMSE [surface]
Temperature [K]
Days: 01.07.2016, 12 UTC - 31.07.2016, 12 UTC [Range: 006]
REFjul
JKjul
RMSE
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
5
10
15
20
25
30

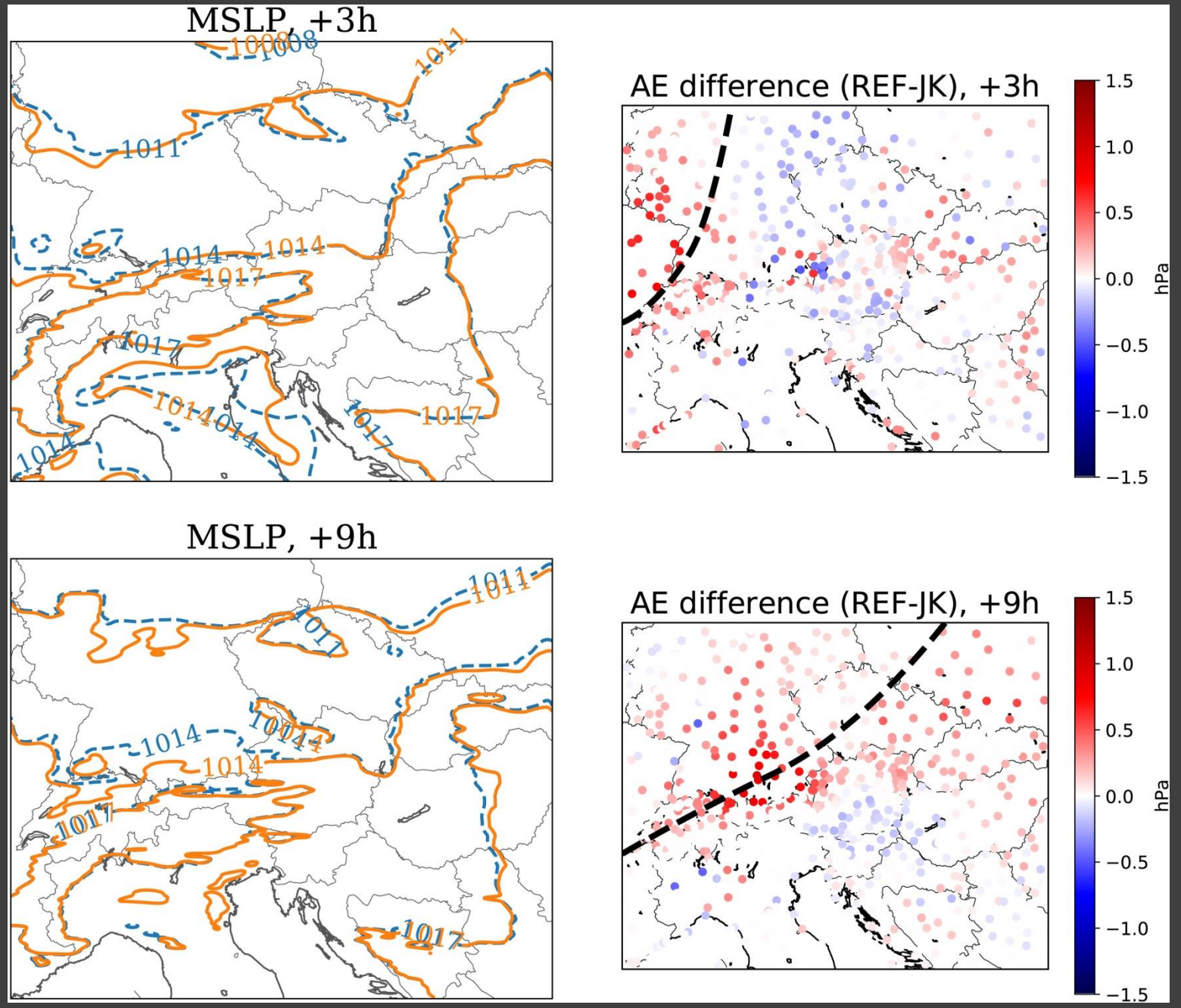

RMSE [surface]
Temperature [K]
Days: 01.08.2016, 12 UTC - 31.08.2016, 12 UTC [Range: 006]
REFlt$_a$
JKlt$_a$
RMSE
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
5
10
15
20
25
30


RMSE [surface]
Relative Humidity [%]
Days: 01.07.2016, 12 UTC - 31.07.2016, 12 UTC [Range: 006]
REFjul
JKjul
RMSE
14.5
9.5
4.5
-0.5
5
10
15
20
25
30
Forecast Day

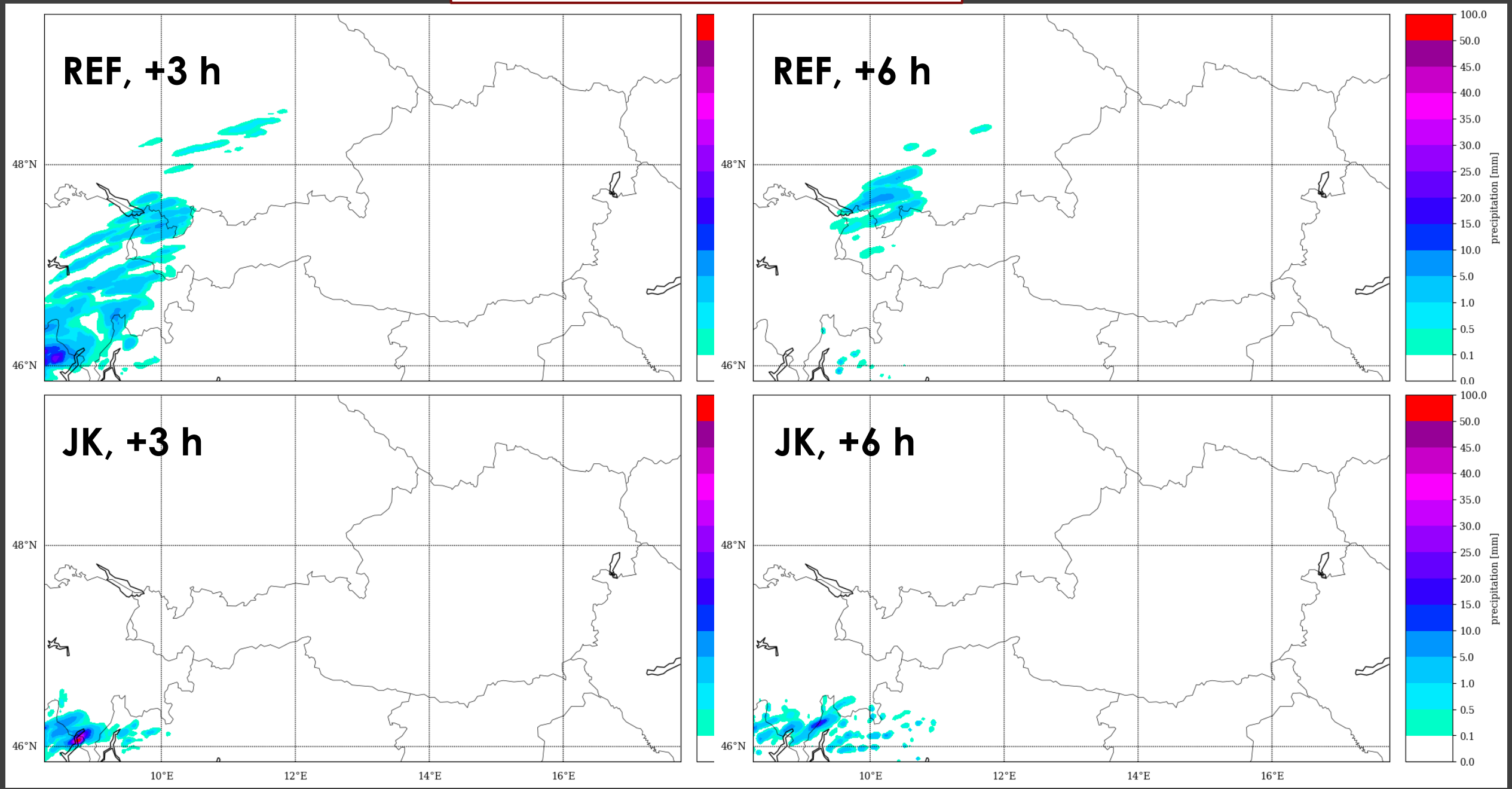

RMSE [surface]
Relative Humidity [%]
Days: 01.08.2016, 12 UTC - 31.08.2016, 12 UTC [Range: 006]
REFlt$_a$
JKlt$_a$
RMSE
14.5
9.5
4.5
-0.5
5
10
15
20
25
30
Forecast Day

Case study: 11. 7. 2016.

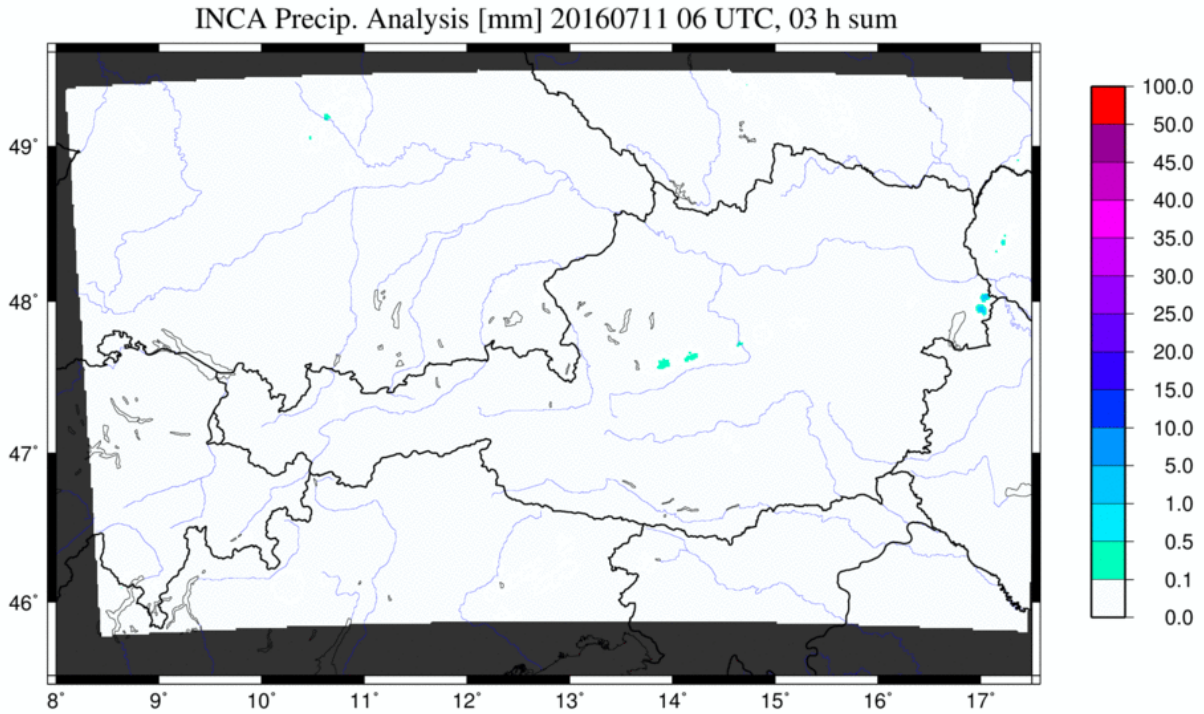


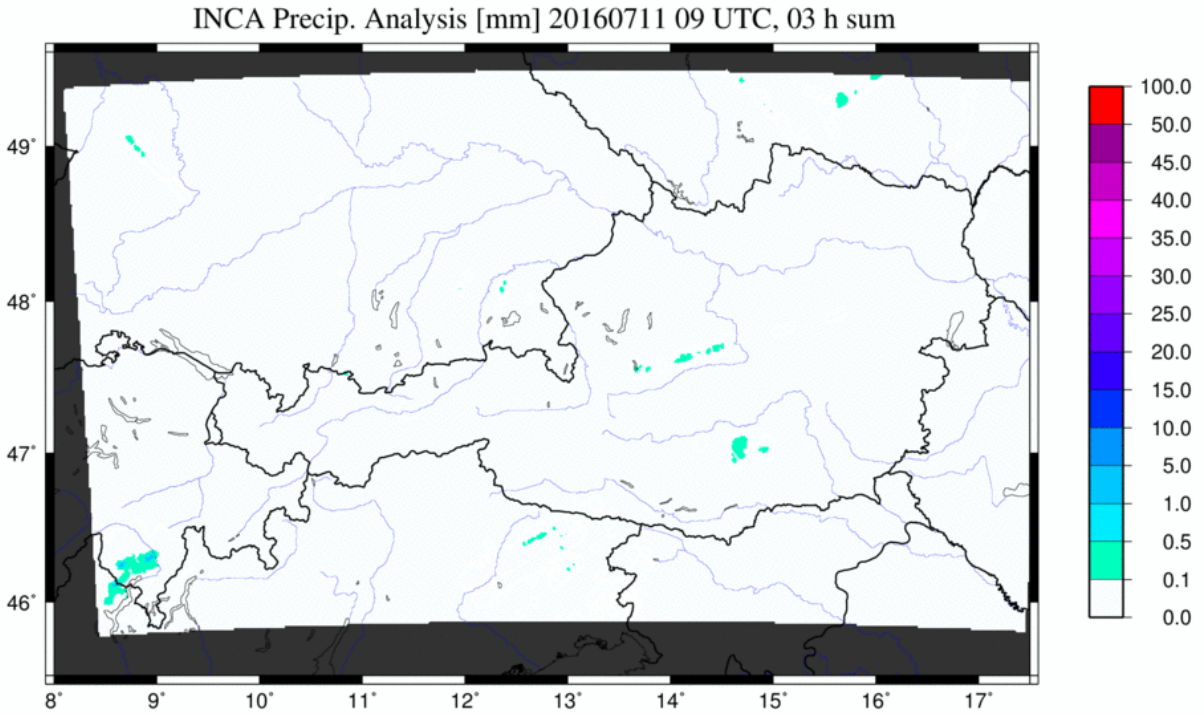

MSLP, +3h
1008
1008
1011
1011
1014
1014
1014
1017
1017
1014
1014
1017
1017
AE difference (REF-JK), +3h
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
hPa
MSLP, +9h
1011
1011
1014
1014
1014
1017
1017
AE difference (REF-JK), +9h
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
hPa

Started at 11. 7. 2016. at 00 UTC



Observations





Conclusion

- **Global model information included into convection permitting ensemble 3DVAR**
- **Positive impact on upper air variables**
- **Positive impact on surface pressure and precipitation**
- **Improved model performance in some situations**
- **Future plans**
  - Test Jk in ALADIN/HR
    - Deterministic environment