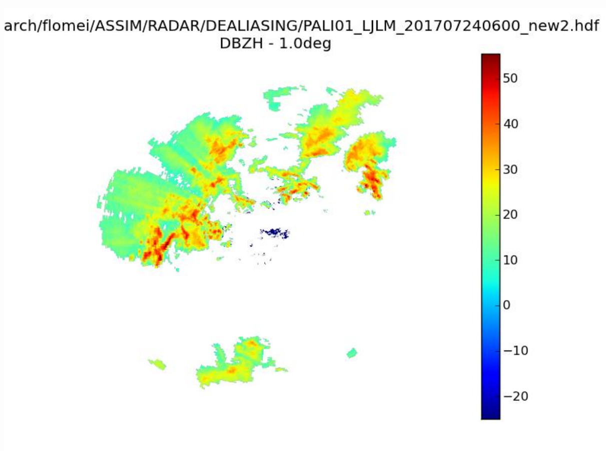
News on radar assimilation

Florian Meier, Lukas Tüchler

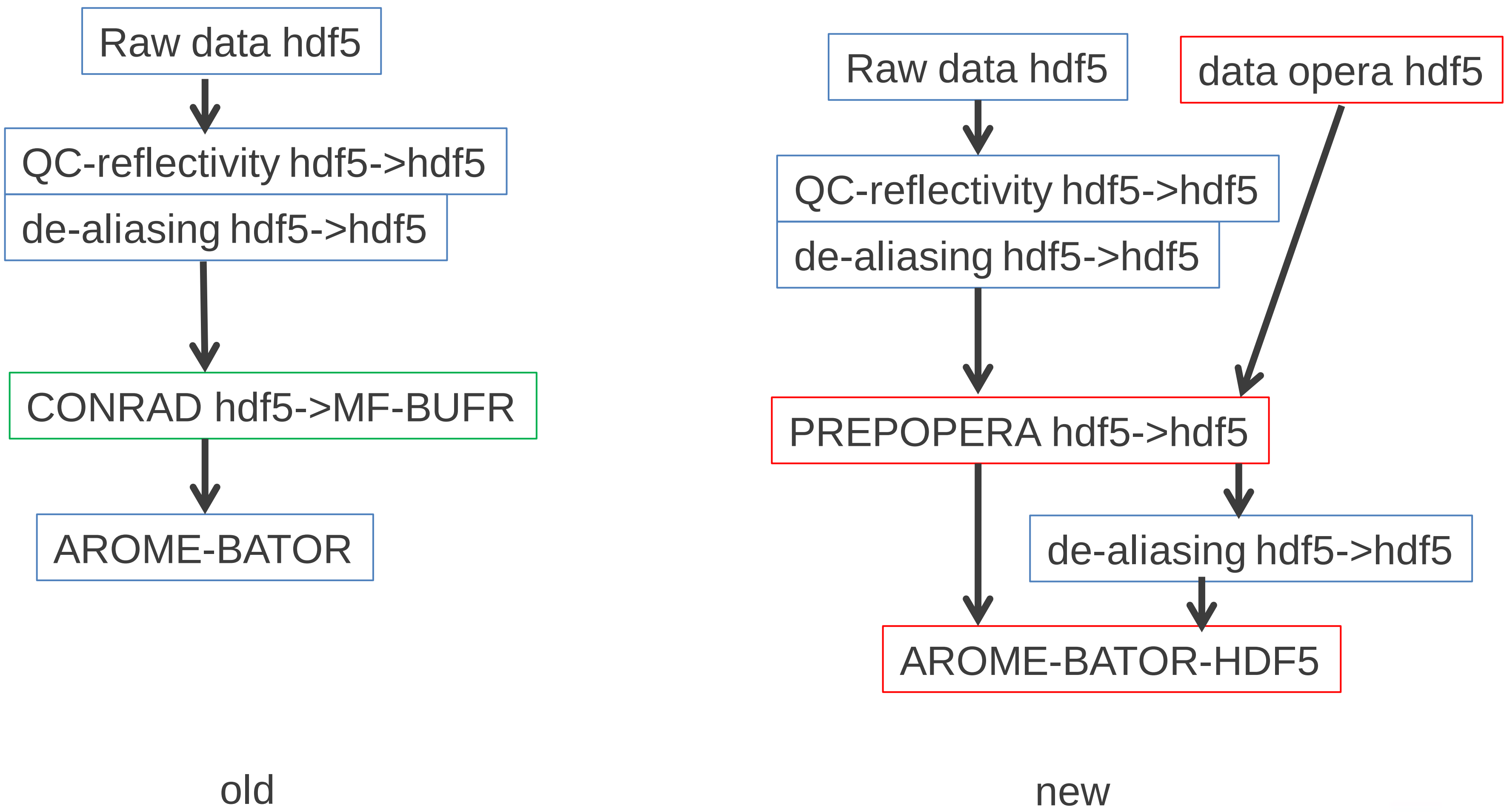


FFG Austrian Research Promotion Agency

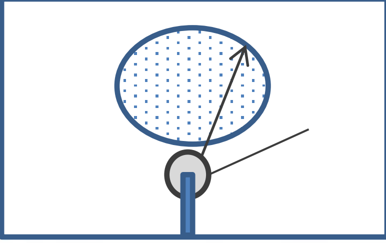
austro CONTROL

ZAMG Zentralanstalt für Meteorologie und Geodynamik

New version of radar data pre-processing



Modification of Harmonie BATOR-RADAR-HDF-5 reader and prepopery.py



- Directly reads polar volume data in HDF5 format as it is delivered via OPERA

- Adaptation of pixel interpolation to columns of pixels:
  - calculate lat, lon, altitude of lowest elevation pixels
  - Interpolate for each azimuth pixels of higher elevations by nearest neighbour method to the same column
  - In case of Hungarian OPERA data (number of azimuth values not the same for different elevations) take pixel of nearest ray
- Adaptations for slightly differences in OPERA data for different countries
- Add pre-thinning ZSAMPL_RADAR as in bufr-reader -> needed for more than 5 stations

<u>HARMONIE: Prepopera.py:</u>

run before BATOR: super obbing, skip overlaping elevations, add some missing information for individual radars:
antenna gain, pulsewidth, wavelength, sensitivity for LACE-countries + Germany + Southern Poland using OPERA-webportal and WMO radar page informations
-> still some missing informations especially sensitivity of many countries

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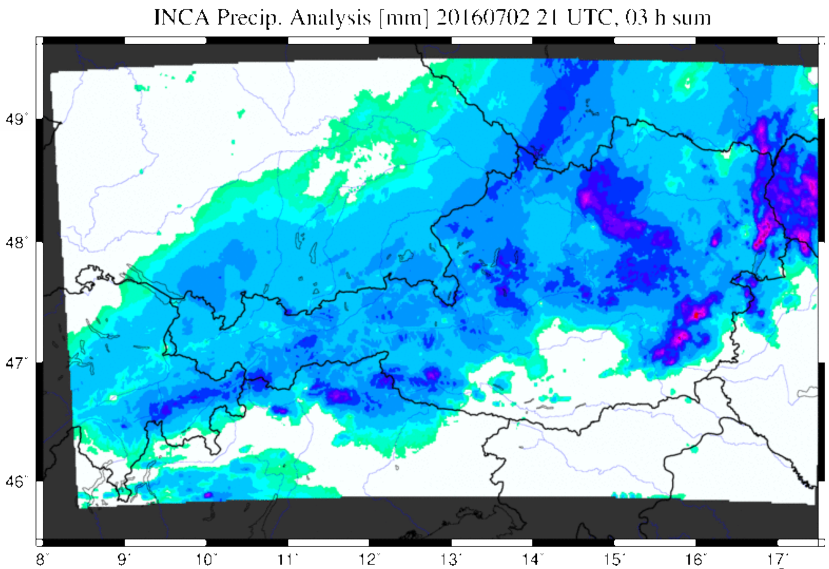
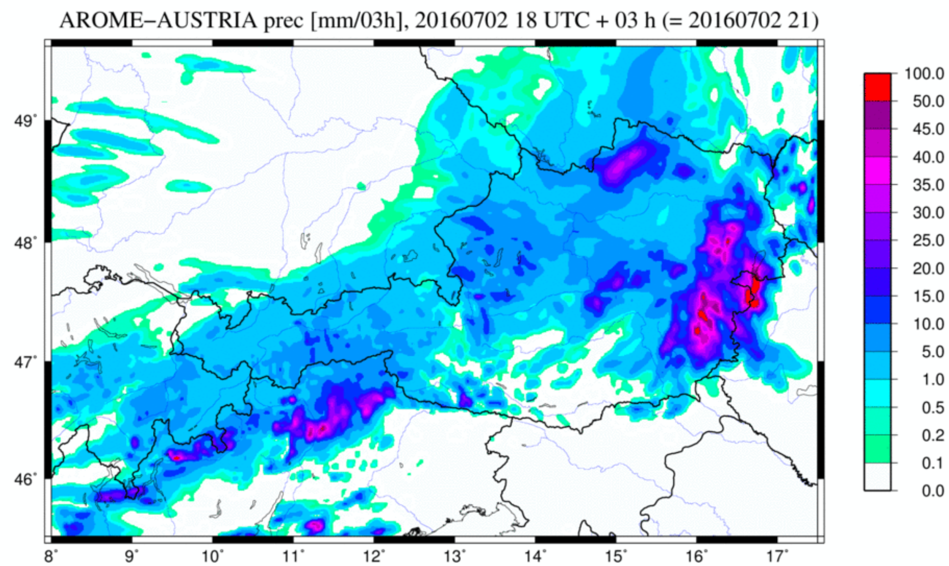
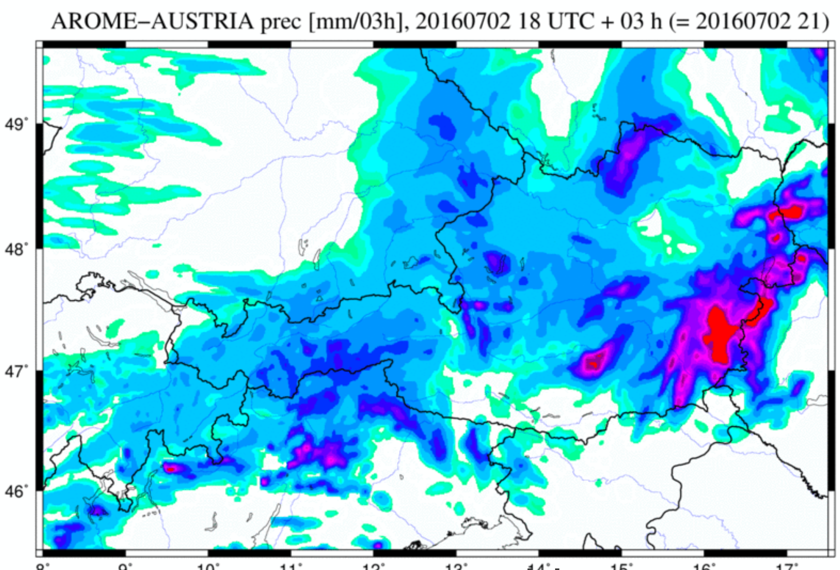


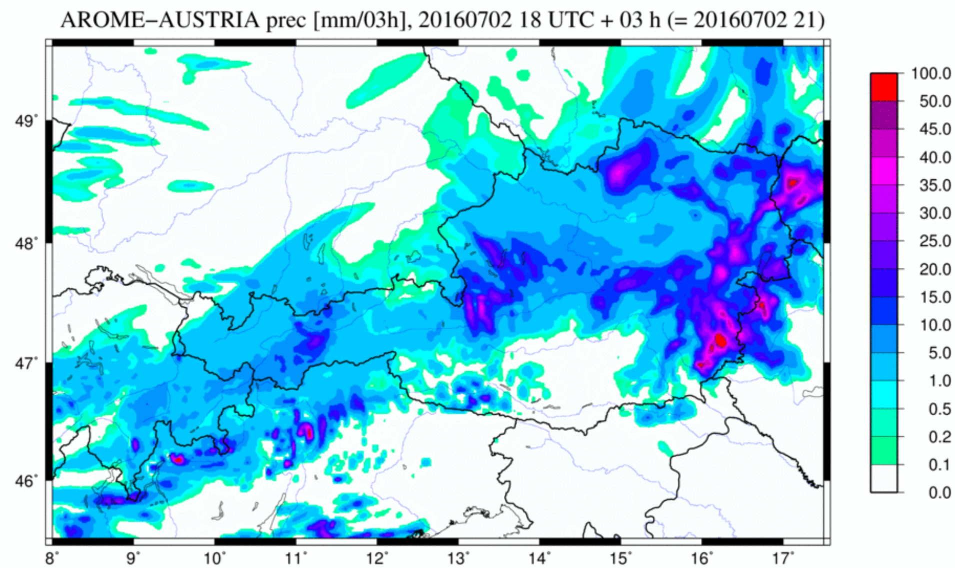
INCA 20160702 18UTC+3h



AROME no RADAR



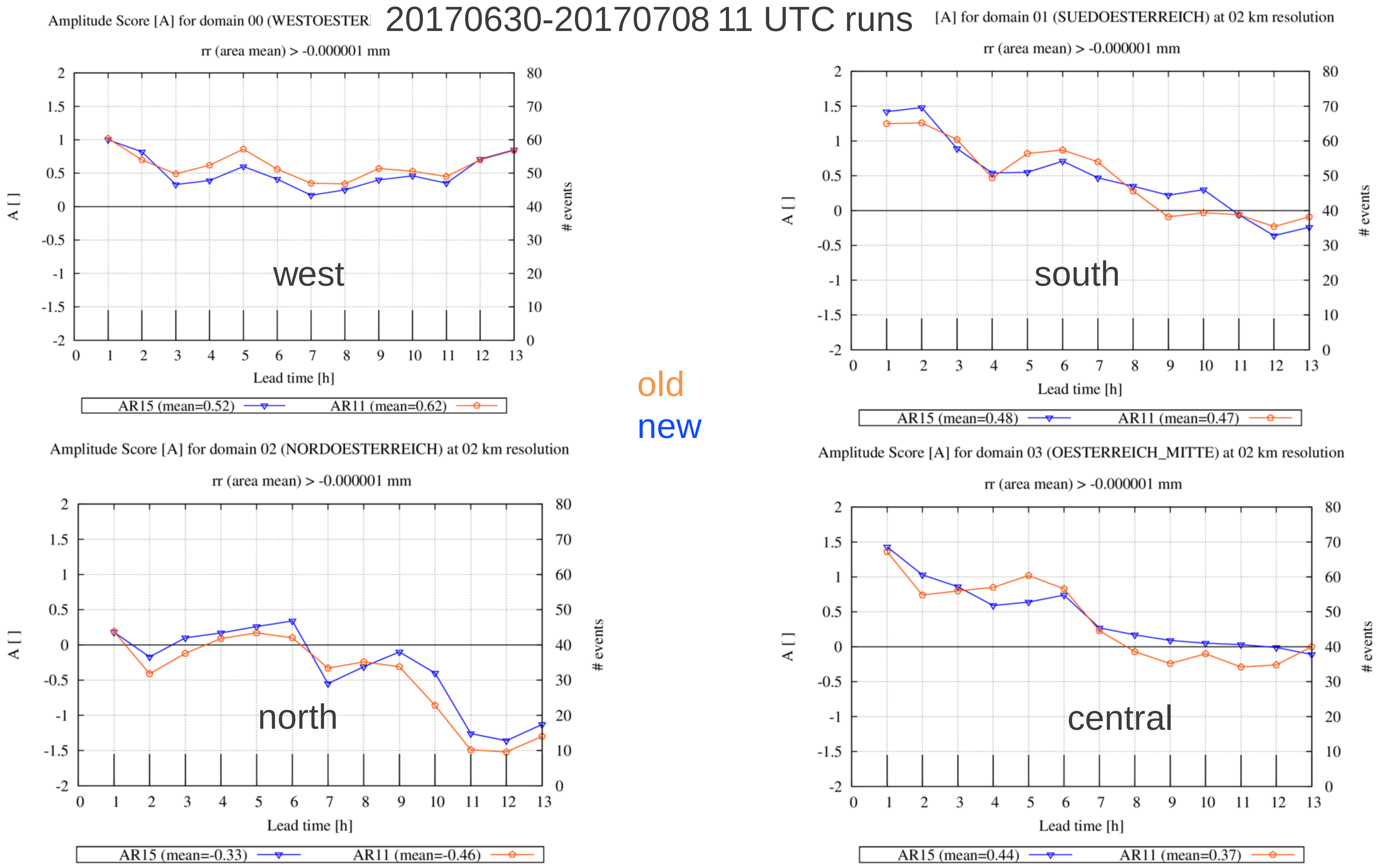
RADAR old



RADAR new

Time series comparison AROME-RUC new vs old radar

20170630-20170708 11 UTC runs



Time series comparison AROME-RUC new vs old radar

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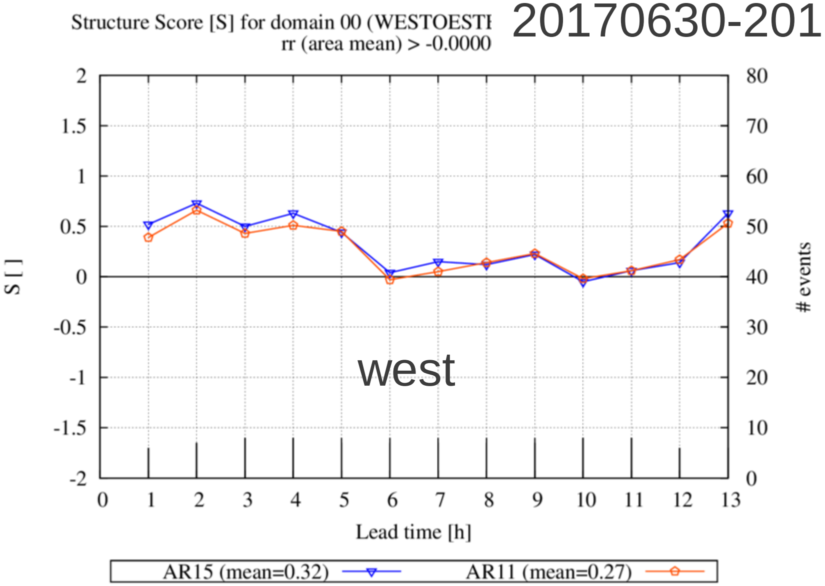
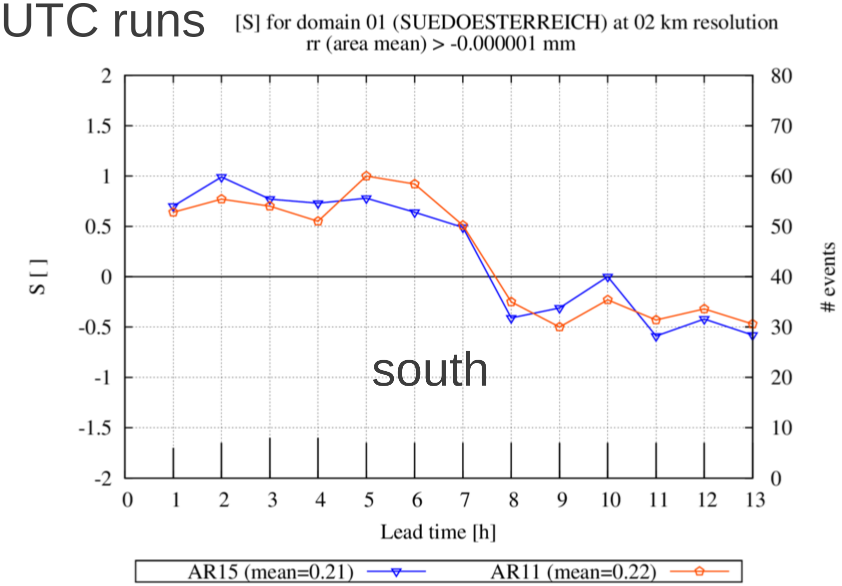
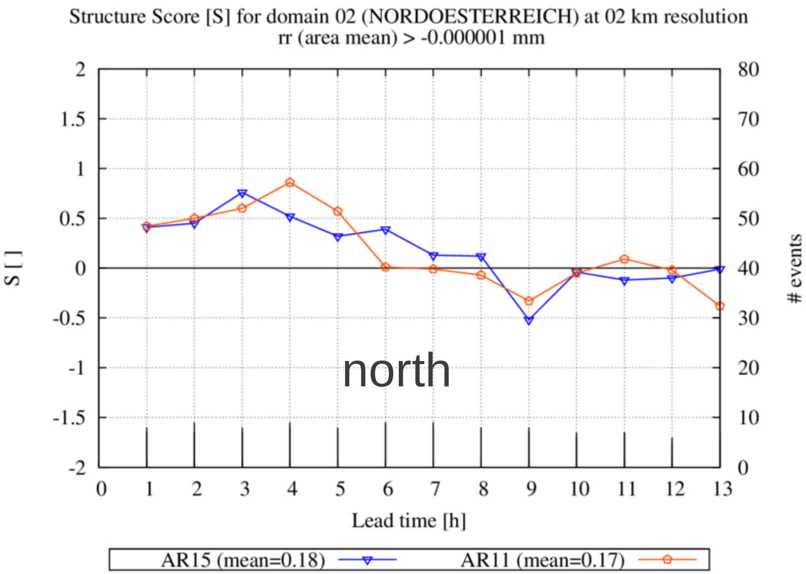
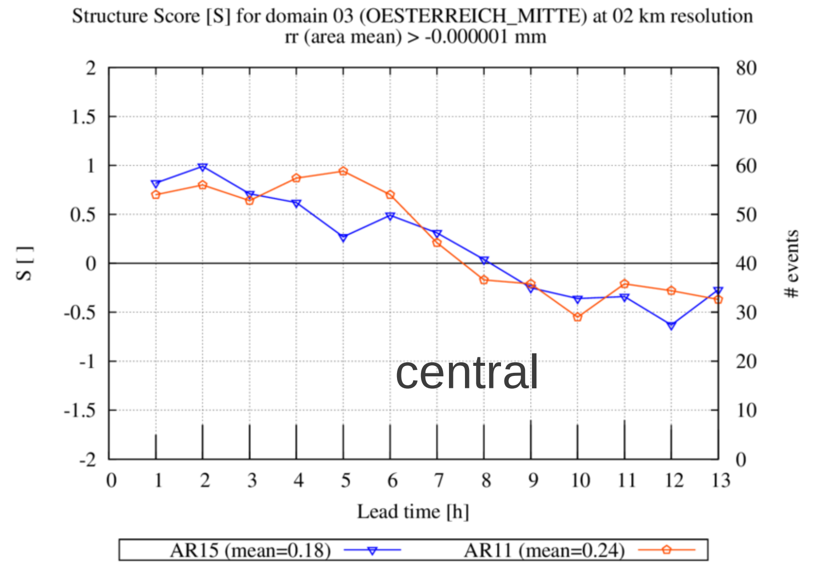




old

new





Time series comparison AROME-RUC new vs old radar

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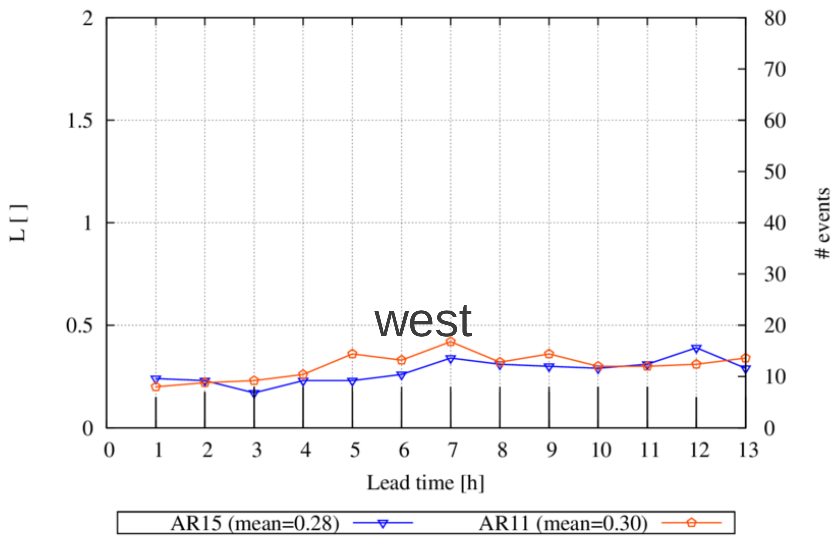
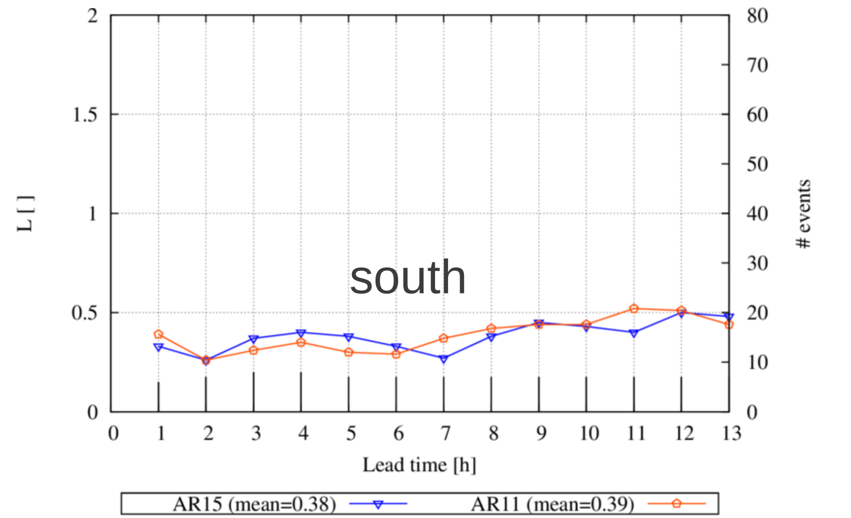
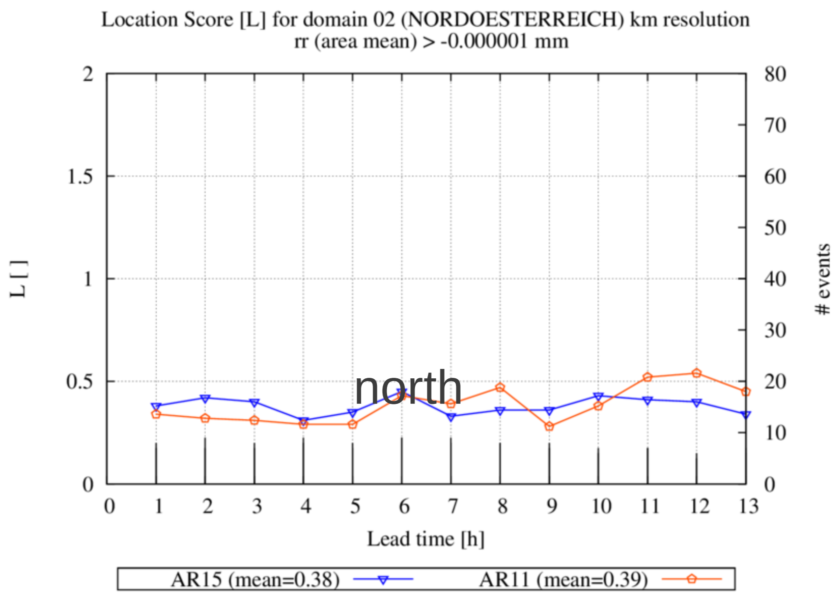
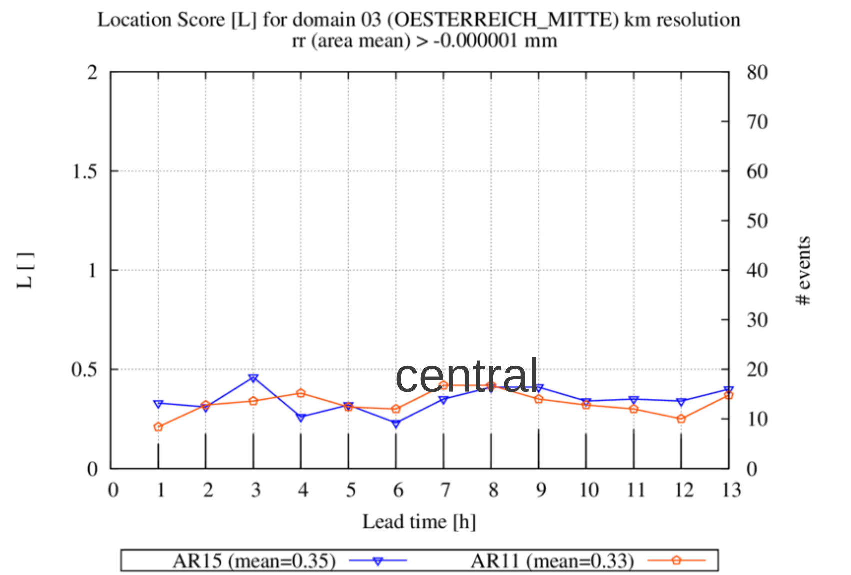




old

new



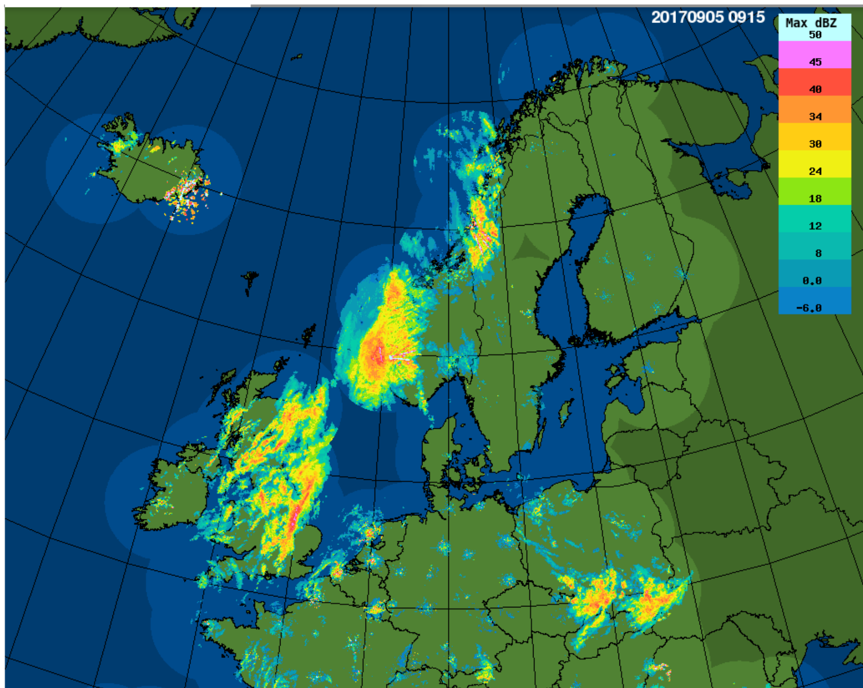


OPERA volume radar data from OIFS server

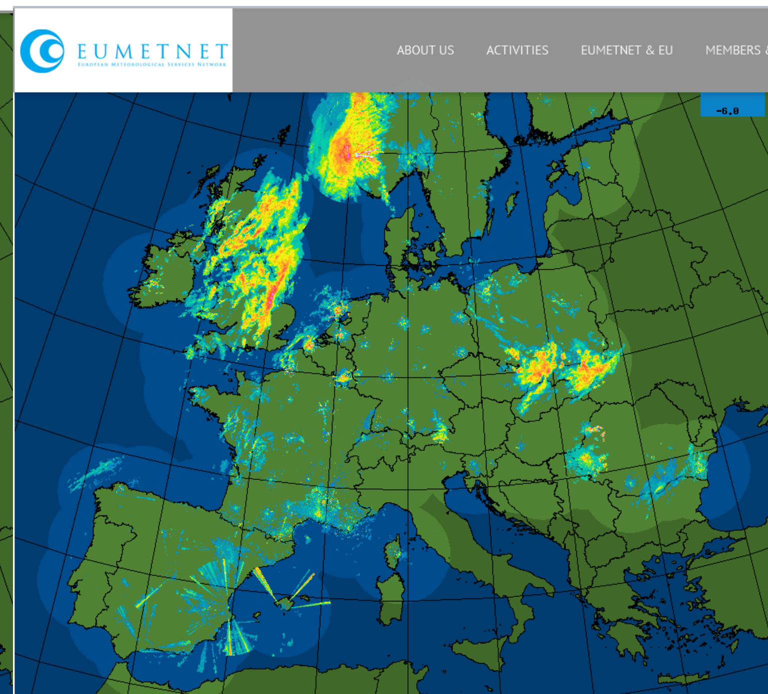
In principle one radar format for many European countries (ODIM-HDF5)

with Doppler wind, raw reflectivity, 4 quality flags (fmi.ropo.detector.classification speckle, mf.satfilter, SMHI beam blockage, pl.imgw.quality.qi_total), QC controlled reflectivity,

every 15min, quite early available, data from 19 countries about 126 radars, but….



OPERA composite



OPERA radar data from OIFS server

1. France and Germany: coded real values, strange „no data“ values, other countries: integer values 0-255*gain + offset
2. Germany + CZ + SK: several datasets for one elevation else one elevation = one HDF5 dataset
3. Hungary: number of rays differs for different elevations
4. No data from Austria, Italy, Switzerland, Romania, Bulgaria, Bosnia,
5. Some stations only reflectivity, from some countries not all stations
6. Some additional information like wavelength, radar constant etc. missing or differently coded
7. Different Nyquist-Speed -> more or less strong aliasing problems; only Germany not problematic (60m/s), but standard prepopera.py rejects all Doppler wind because of 1. and the elevation overlap filter

<u>However:</u> about 34 stations within Austrian AROME domain:

1x Be, 9x De, 9x Fr, 2x CZ, 4x PL, 2x SK, 2x HU, 2x SI, 2x HR, (1x SRB)

+ 5x bilateral exchange 4x AT, 1x IT, (2x SI, 2x DE)

de-aliasing on top seems to be benefitial (does not work yet for DE+CZ because of 2.)

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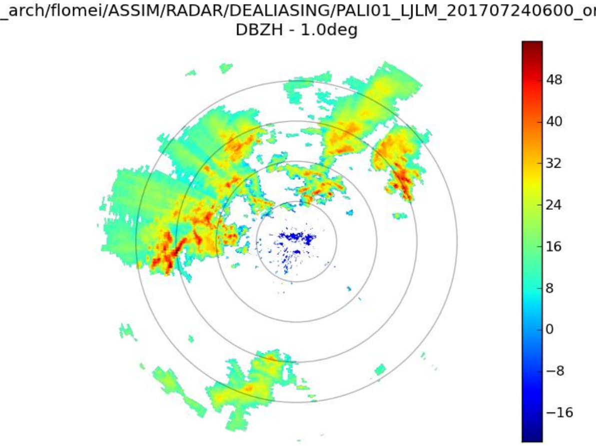
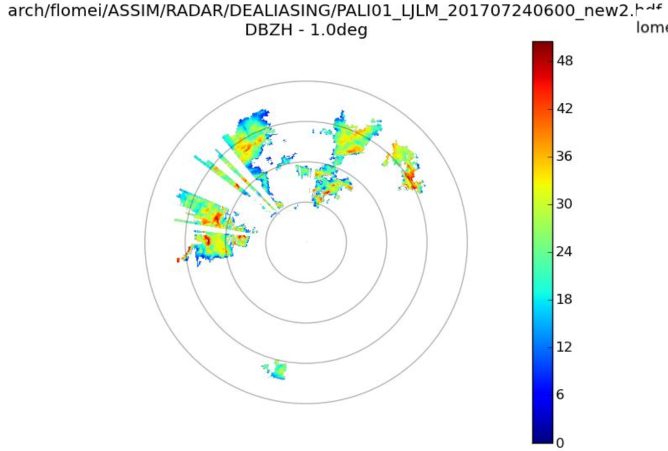
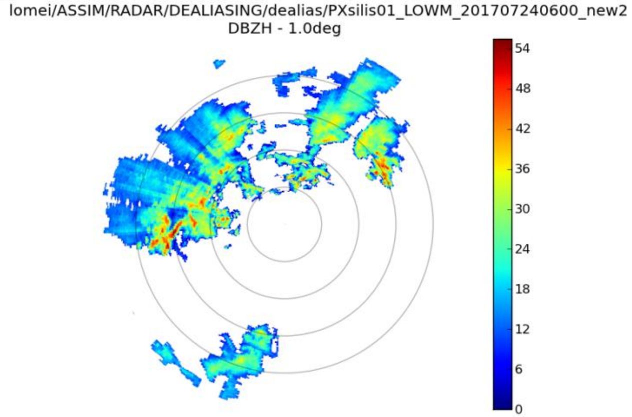
Example 20170724 06UTC radar Ljubljana





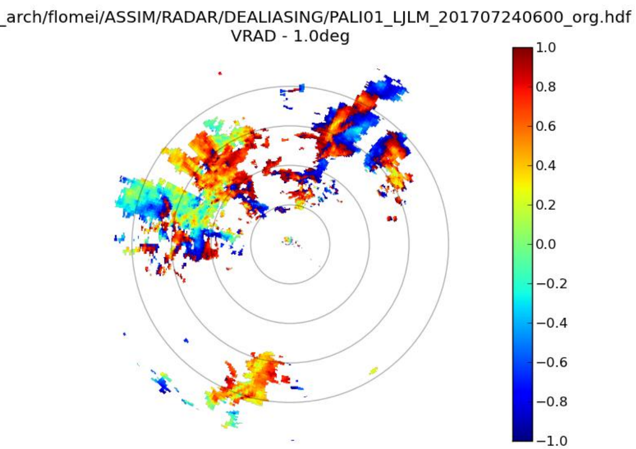


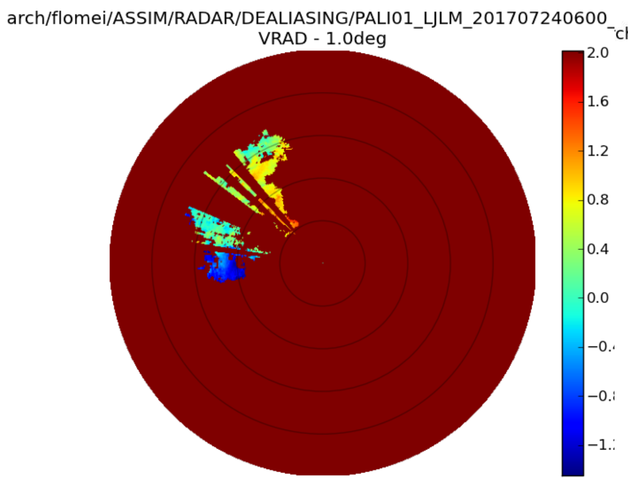
reflectivity

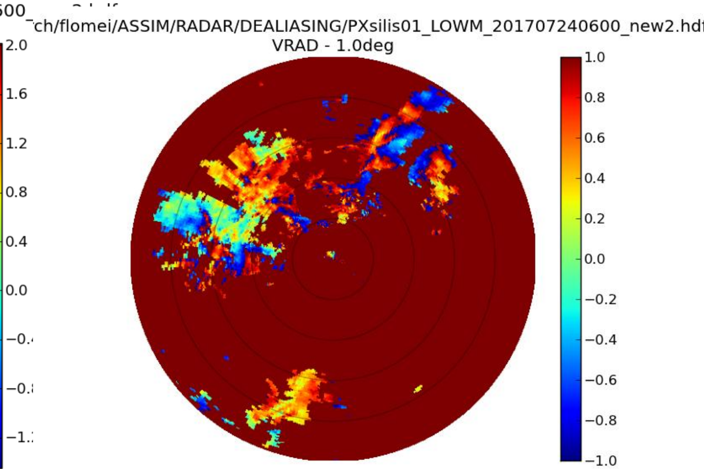
raw

QC-ZAMG

QC-OPERA

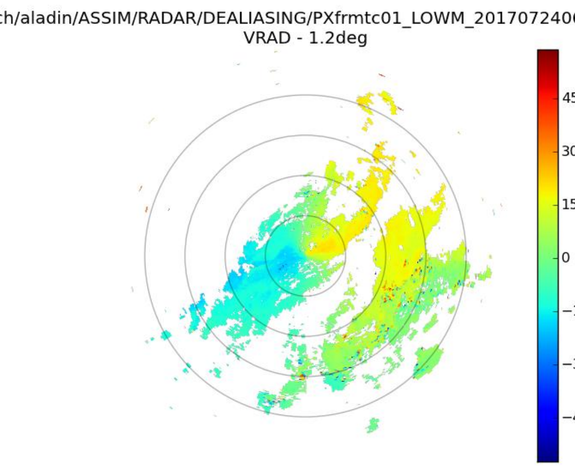




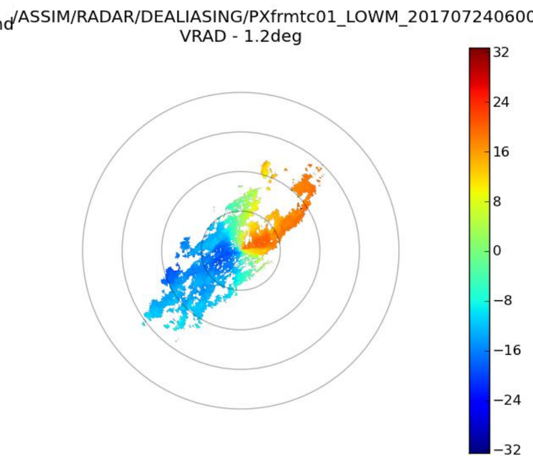


Doppler wind

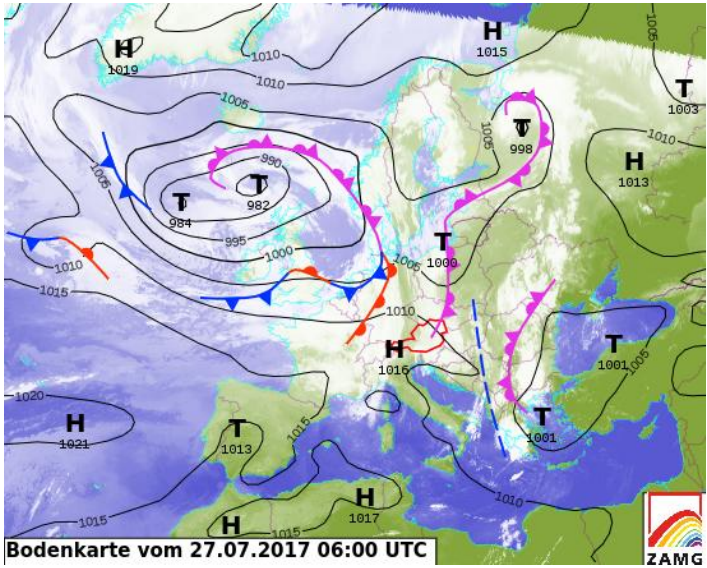
Example 20170724 06UTC

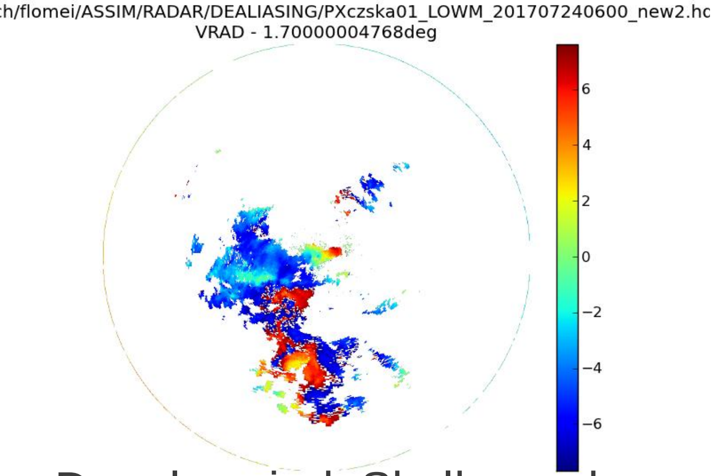


Doppler wind frmtc

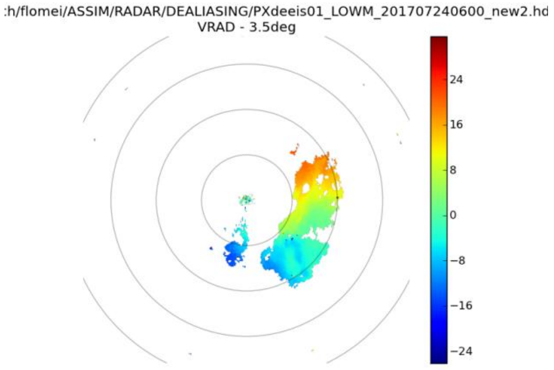


Doppler wind de-aliased frmtc





Doppler wind Skalky czska



Doppler wind Eisberg deeis

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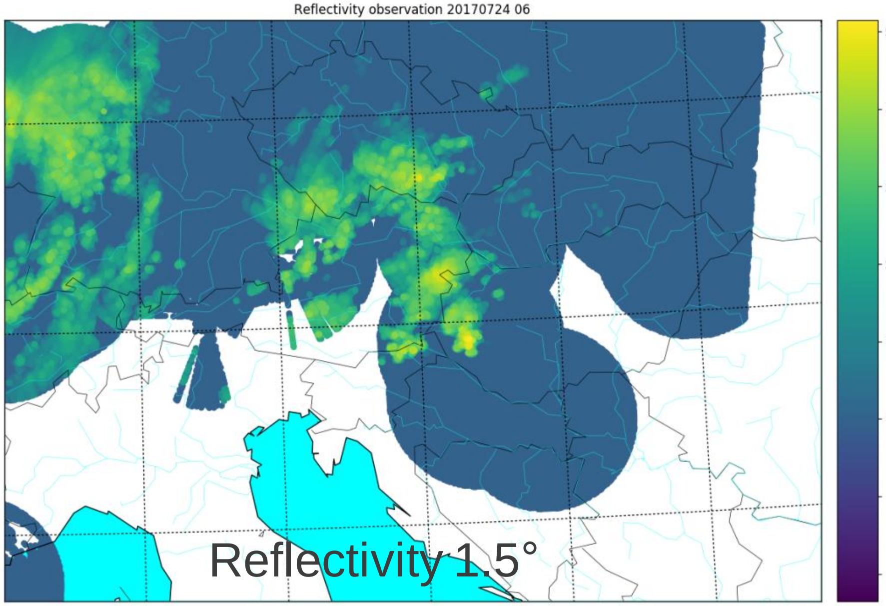
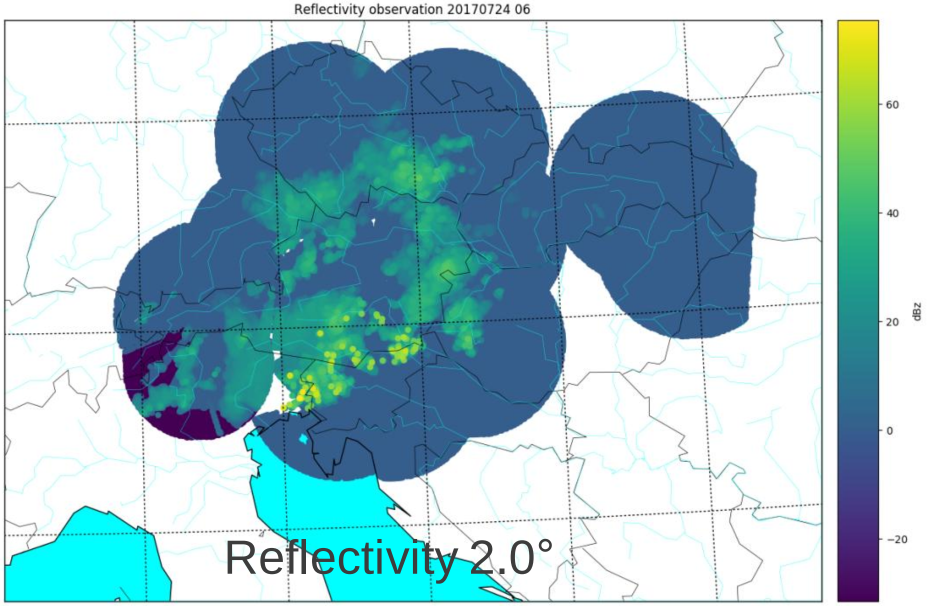
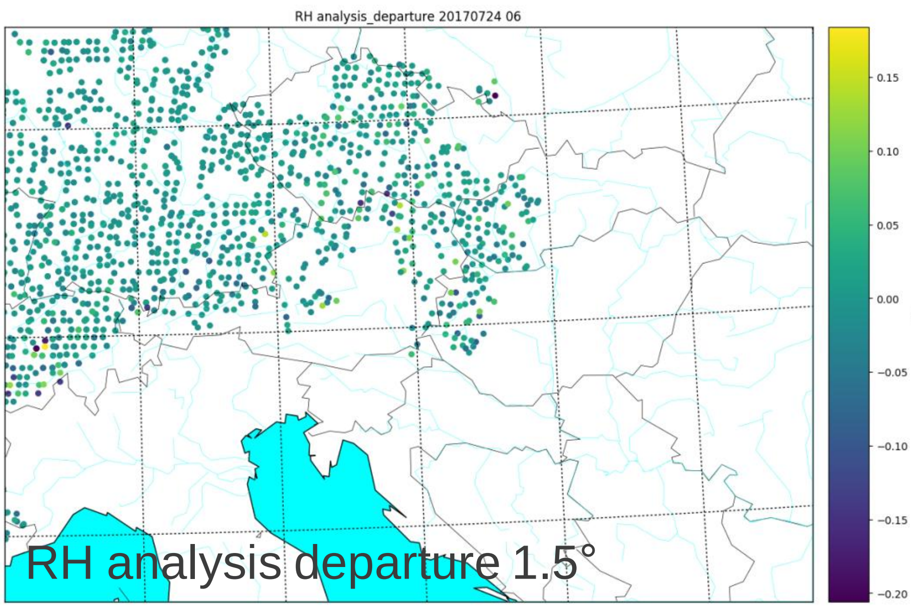
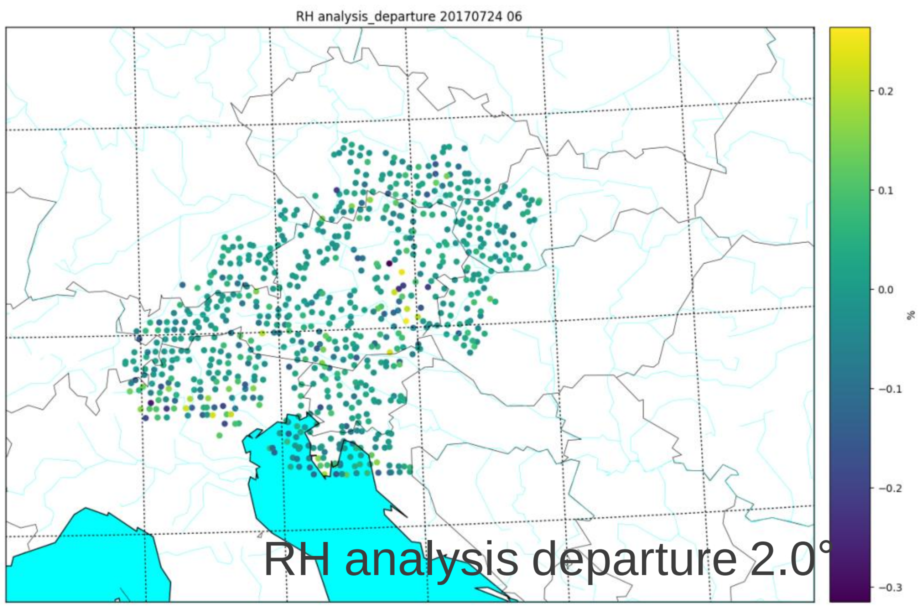
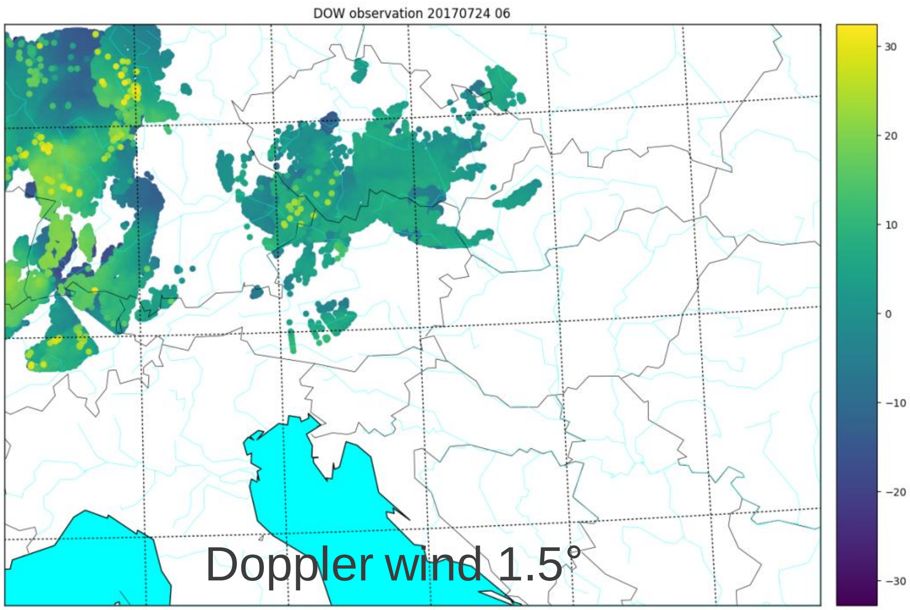
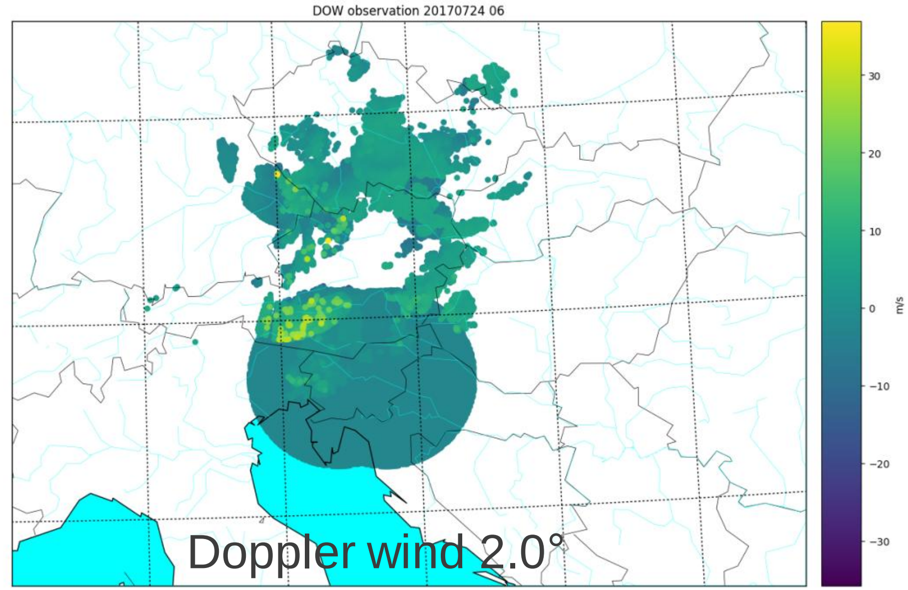

Reflectivity observation 20170724 06
Reflectivity 1.5°
50
40
30
20
10
0
−1
−2

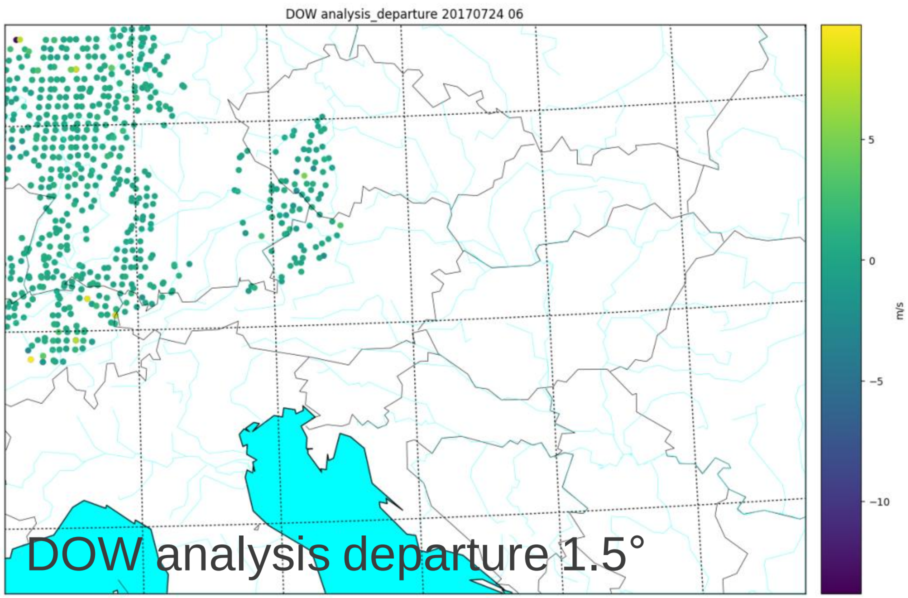

Reflectivity observation 20170724 06
Reflectivity 2.0°
60
40
20
0
−20
dBz

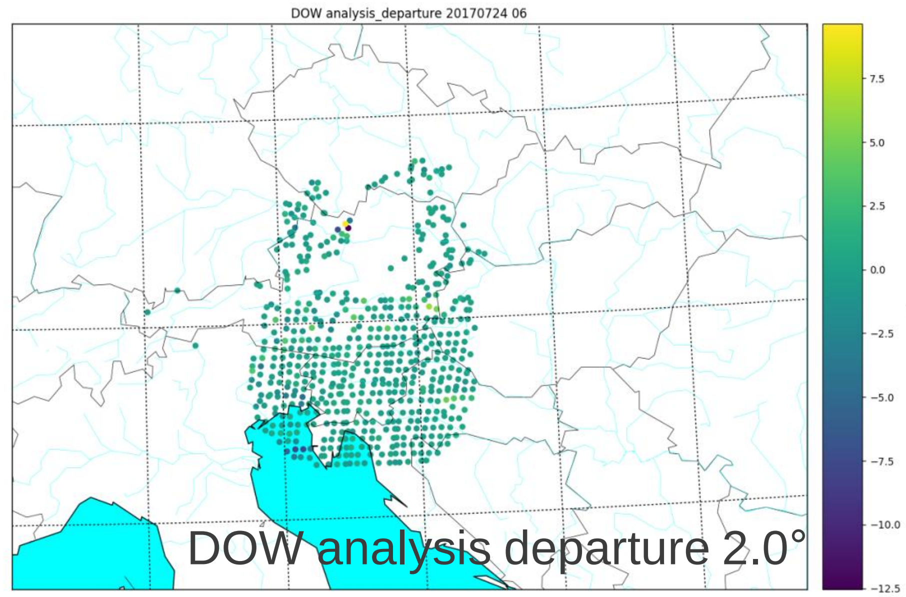

RH analysis_departure 20170724 06
RH analysis departure 1.5°
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20


RH analysis_departure 20170724 06
RH analysis departure 2.0°
0.2
0.1
0.0
−0.1
−0.2
−0.3
%


DOW observation 20170724 06
Doppler wind 1.5°
30
20
10
0
−10
−20
−30

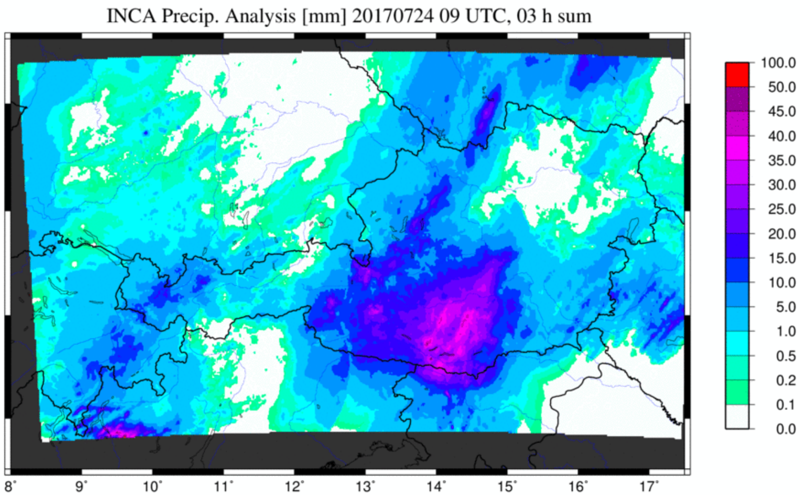

DOW observation 20170724 06
Doppler wind 2.0°
30
20
10
0
−10
−20
−30
m/s


DOW analysis_departure 20170724 06
DOW analysis departure 1.5°
5
0
−5
−10
m/s

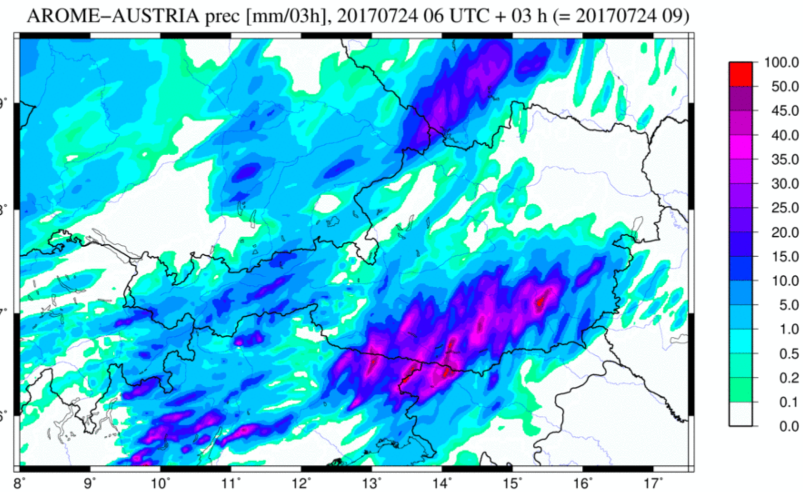

DOW analysis_departure 20170724 06
DOW analysis departure 2.0°
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−12.5
m/s

Example 20170724 06UTC

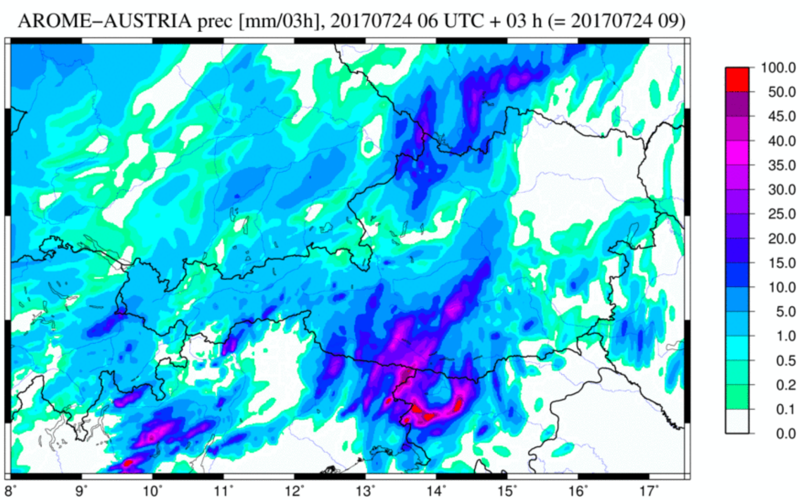
INCA



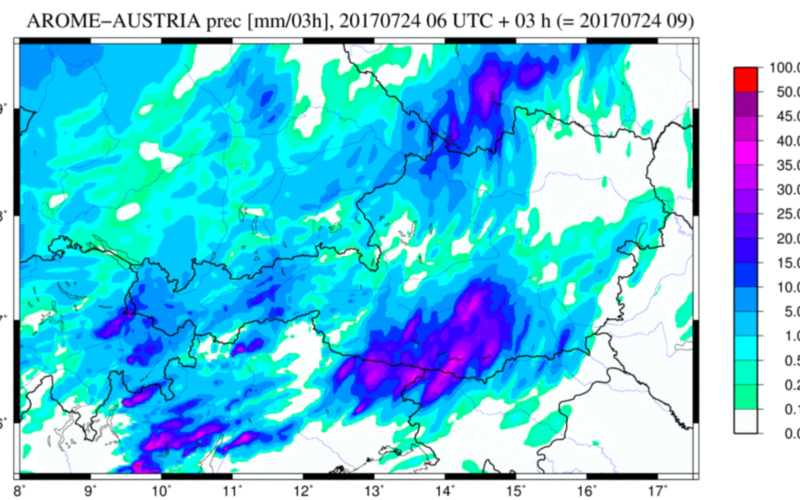
No RADAR



All RADAR



OPERA-only



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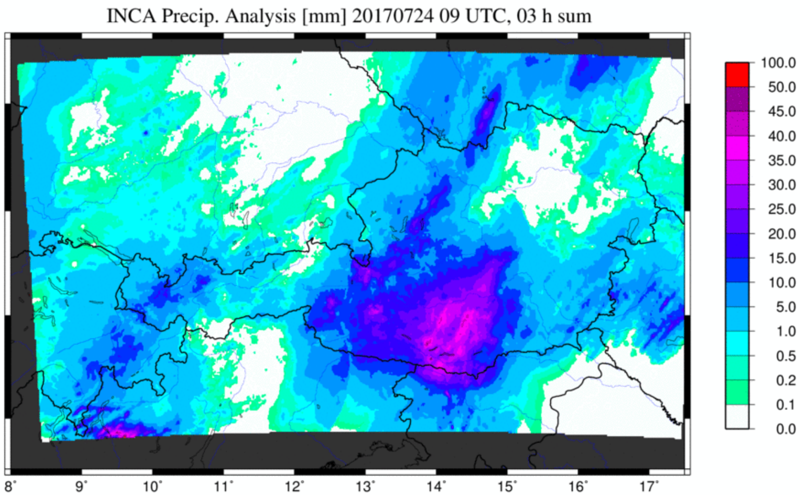
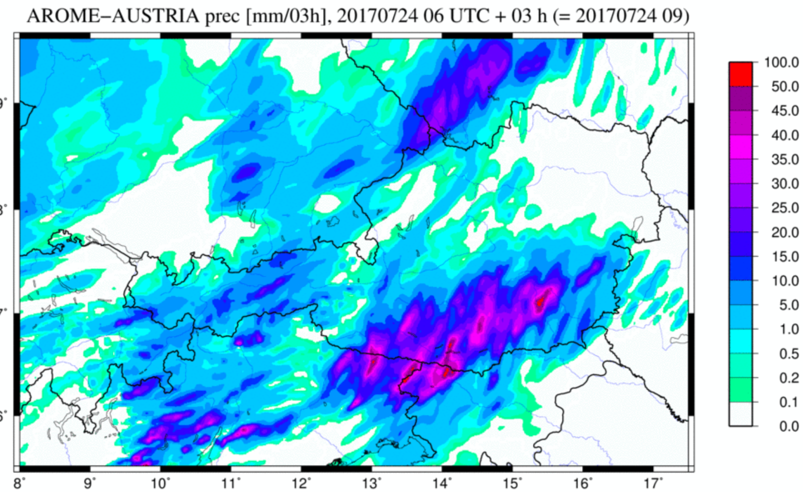
Example 20170724 06UTC

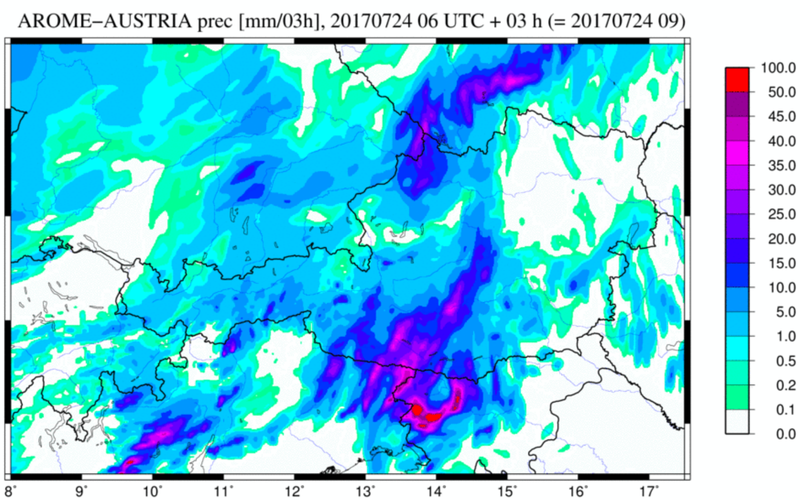
INCA



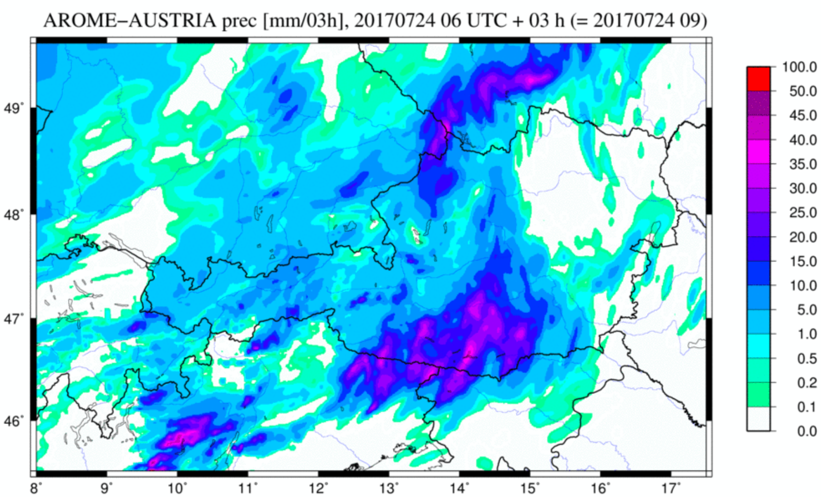
No RADAR



only bilateral exchange+AT



OPERA SI+DE+AT



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Conclusions

- HDF5-reader seems to deliver acceptable results now
- Pre-thinning is necessary for more RADAR stations (within BATOR or before?)
- Modified version of BATOR+PREPOPERA can handle all relevant OPERA data for Austrian domain
- Many slight differences in data format between countries
- de-aliasing is necessary; current version might be OK, but should be improved

  ->no solution for CZ, DE yet
- OPERA QC acceptable, but maybe additional QC flags should be considered (RLAN, climate, radar software flag)

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Belgium 2

Croatia 2

Danmark 5

Estonia 2

Finland 10

France 23

Germany 17

Hungary 2

Ireland 1

Norway 8

Poland 8

Portugal 3

Serbia 1?

Slovakia 2

Slovenia 2

UK 14

Modification of Harmonie RADAR-HDF-5 reader and prepopery.py

- Adaptation of pixel interpolation to columns of pixels

lowest elevation:

```
zdist(iobs) = nbin*xscale*1.0 (distance of pixel from radar)
zalt= sqrt(zdist(iobs)**2.+rae**2.+2.*rae*zdist(iobs)*sin(zelev*RPI/180.))-rae
zdist2  = rae*atan(zdist(iobs)*cos(zelev*RPI/180.)/(rae+zdist(iobs)*sin(zelev*RPI/180.)))
zlat(nbin,nray)   = asin(sin(vlat0*RPI/180.) * cos(zdist2/RA) +
          +cos(vlat0*RPI/180.)*sin(zdist2/RA)*cos(zazim(iobs)))*180./RPI
zlon(nbin,nray)  = vlon0 + atan2(sin(zazim(iobs))*sin(zdist2/RA)*cos(vlat0*RPI/180.), &
          &   cos(zdist2/RA)-sin(vlat0*RPI/180.)*sin(zlat(nbin,nray)*RPI/180.))*180./RPI
```

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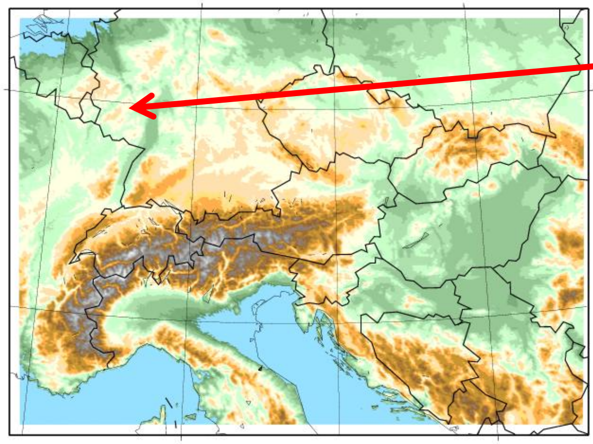
ICE-CONTROL Project: forecasting icing on windfarm windturbines



windfarm „Ellern“
in Soonwald/Hundsrueck
Germany

©Meteotest

- EDA-AROME forecasts
- Cloud assimilation
- SCADA-windturbine assimilation
- MODE-S assimilation

9th January 2017 14:20
126m wind turbine

Verbund AG:
windfarm operator
measurements,
evaluation
Thomas Burchhart,
Martin Fink

Meteotest private metservice
measurements, webcam
WRF-forecasts, icing model
Saskia Bourgeois,
René Cattin

University of Vienna, Meteo Dep.:
measurements/WRF-multiphysics
Lukas Strauss, Stefano Serafin,
Manfred Dorninger

Cloud nudging based on HARMONIE scheme (S. Van der Veen MWR 2013)

- Use NWC-SAF MSG cloud mask, cloud top temperature and cloud cover and cloud base height from surface stations (SYNOP/METAR/VAMES) to modify model humidity and temperature such that „model clouds“ are close to observed ones

$T_v = T(1 + 0.61q_m - q_l - q_i - q_r - q_s - q_g)$ get virtual temperature

$C = rh_{max} - (rh_{max} - rh_{min}) \sin(\pi \frac{p}{p_s})$ critical rel. humidity for cloud formation

$q_m = q_{sat}((1 - C)\sqrt{N} + C)$ If cloud cover N>0

$q_m = \min(q_m, C * q_{sat})$ If cloud cover N=0 or above/below cloud

→ New specific humidity

$T_m = T_v/(1 + 0.61q_m - q_l - q_i - q_r - q_s - q_g)$

change temperature *Tm* such that buoyancy is conserved

original version: $q_0 = q_m$, $T_0 = T_m$

Nudging: $q_{new} = q_{old} + \frac{q_m - q_{old}}{\tau}$, $T_{new} = T_{old} + \frac{T_m - T_{old}}{\tau}$

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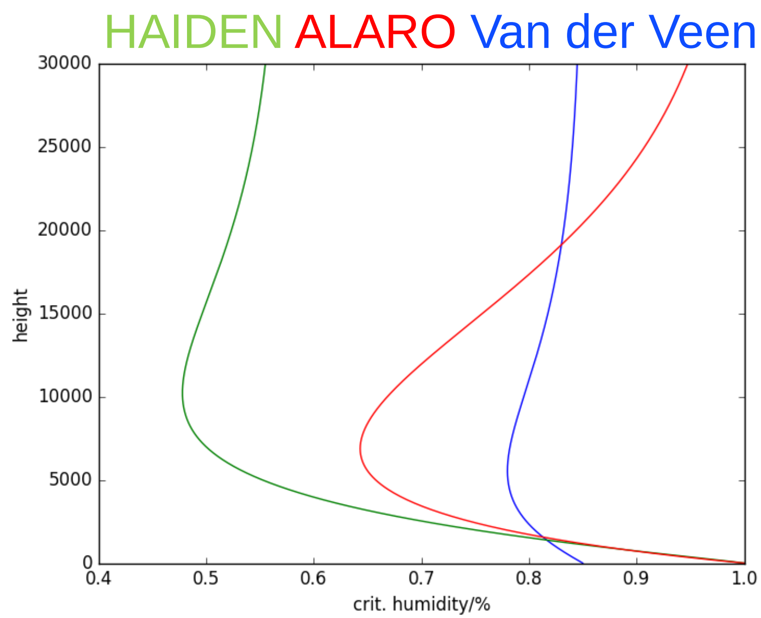
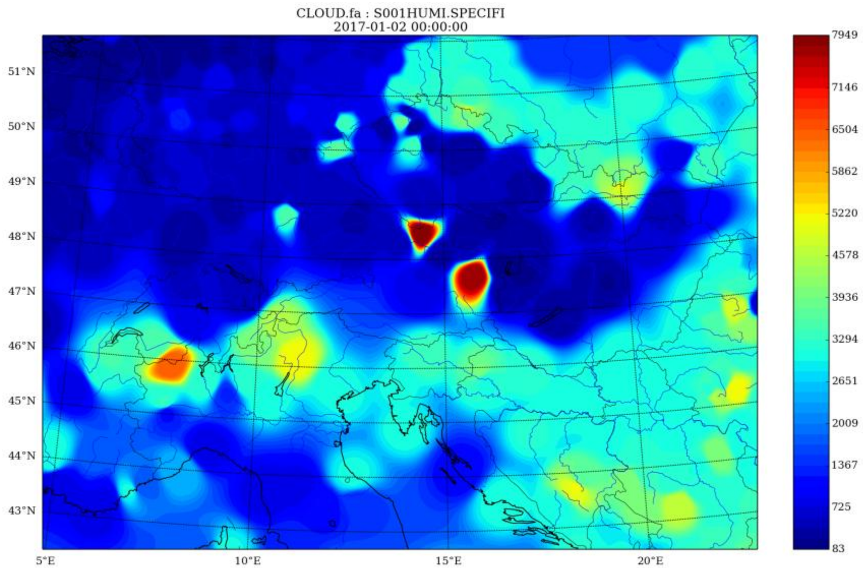
Cloud nudging – code modifications

OBS-> | GETCLOUDINFO PREPROC-> | OBS on GRID in FA-FILE-> | 001 |

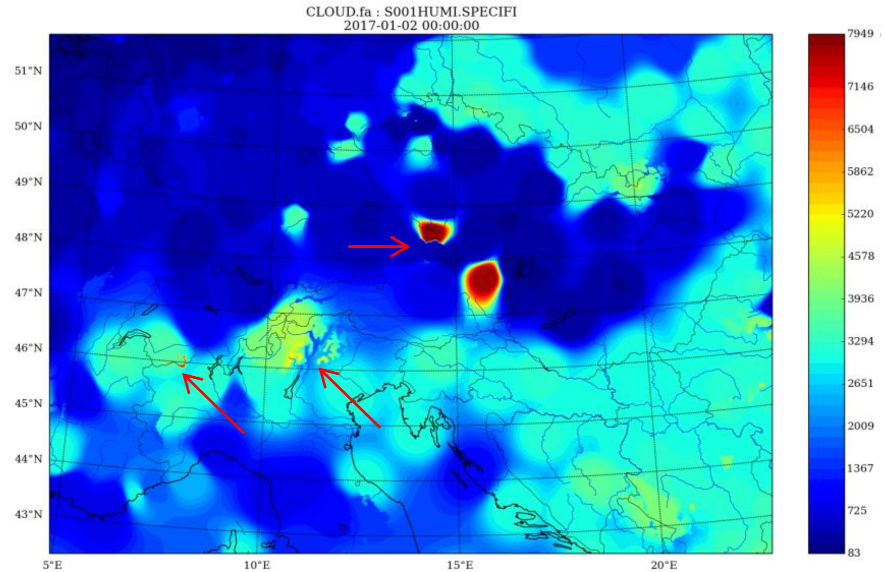
- Start from: Pre-processor „getcloudinfo“ trunk r14912 40h1, main routine: branch 38h1.2, adapted to cy40t1 export
- Several timeslots: ->run pre-processor once per slot save observations to different vertical level in FA file: S001->S003, modify also: mf_phys.F90
- satellite projection adapted to Austrian data, surface data: BUFR->ASCII
- Enable reading of NETCDF NWCSAF data (until now HDF5)
- add optional critical humidity profiles from ALARO/Haiden 2004
- Take orography into account for surface static
- take optional saturation equation from Goff-Gratch to get qsat (water and ice)
- Random perturbation generator for obs
- Use spread for cloud base estimation



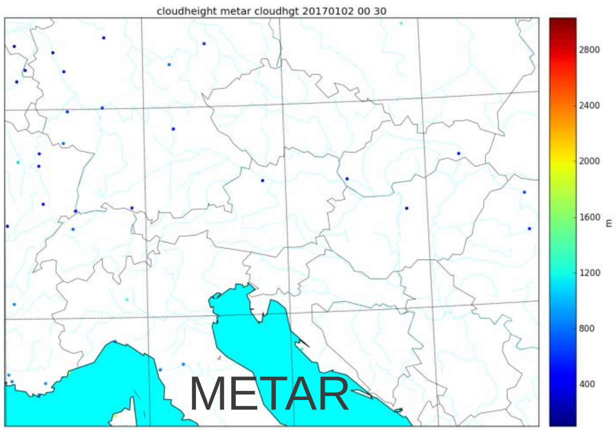
Cloud base above sea level from interpolated surface stations
2nd January 2017 00UTC

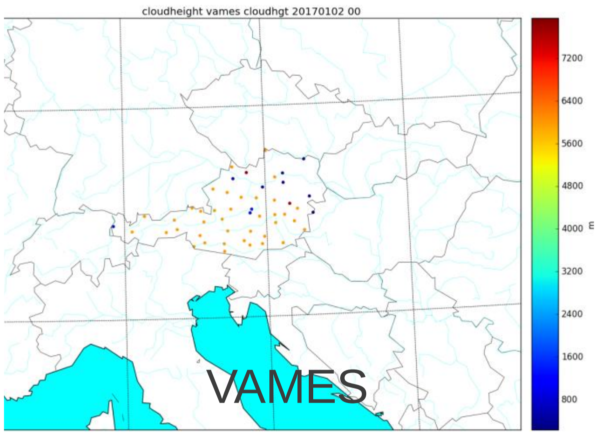


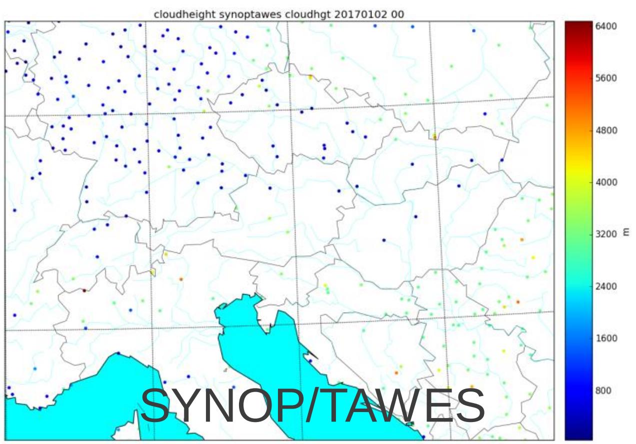
$$w = \frac{1}{d^6}$$



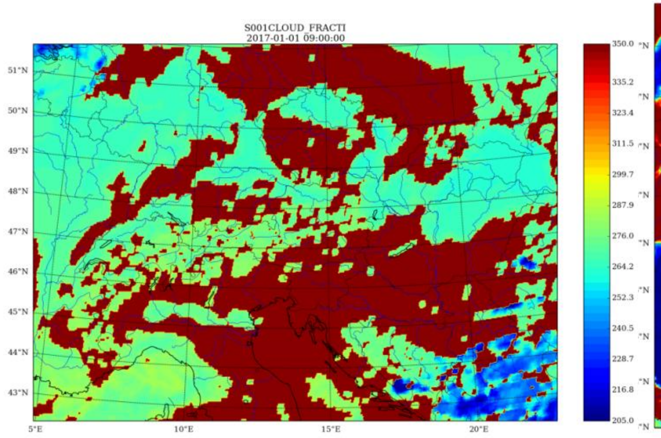
$$w = \frac{1}{(d+\frac{\Delta z}{5})^6} \text{ if } \Delta z > 250m$$



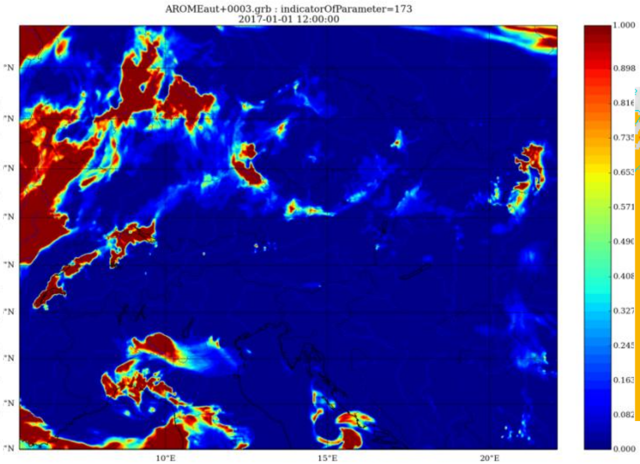


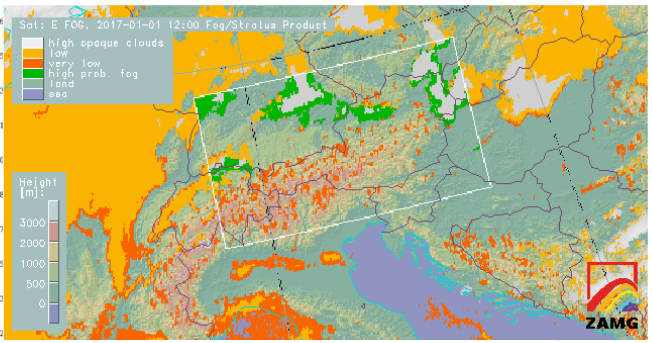


Cloud nudging 1st January 2017 09UTC+3h

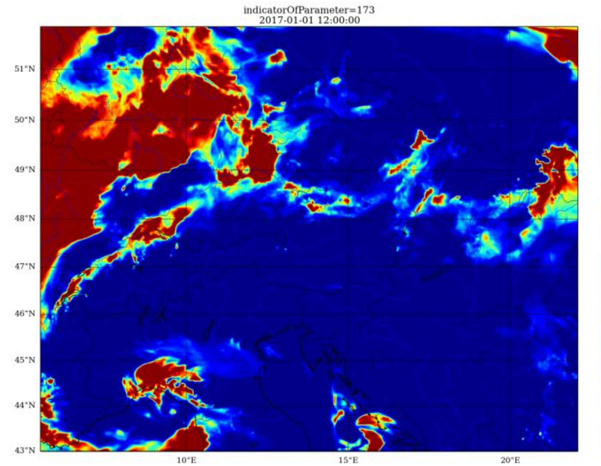


MSG-CTT/K 12UTC

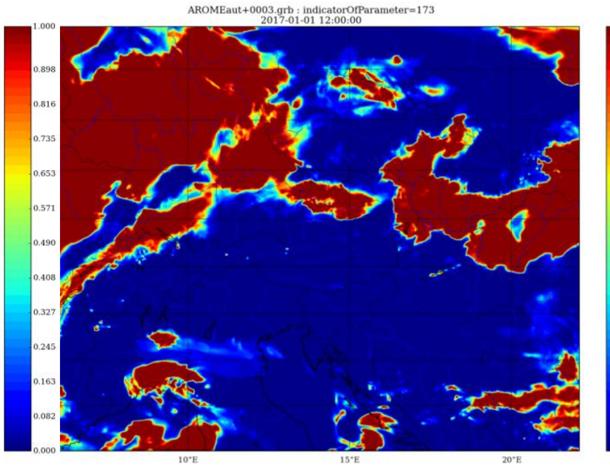




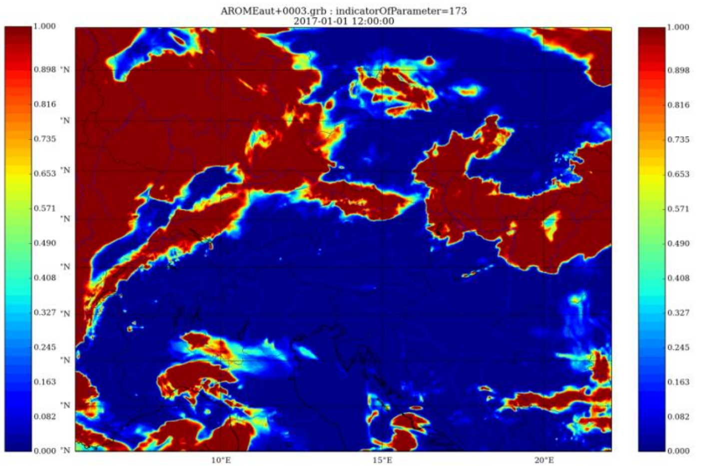
AROME low clouds reference



AROME+Van der VeenT0



AROME+Van der Veen0/0.5/1



AROME+Haiden

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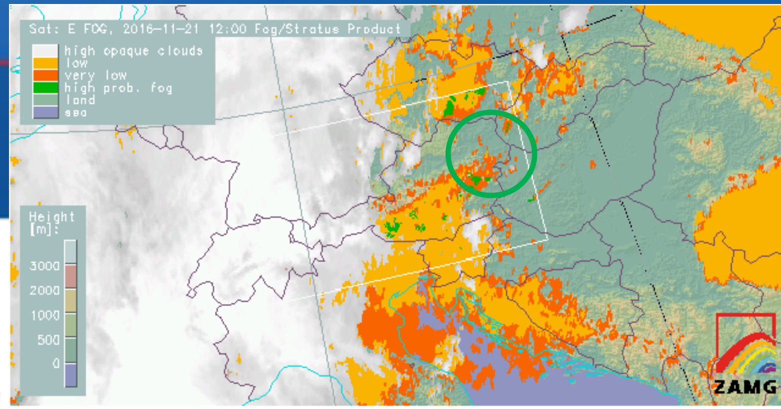
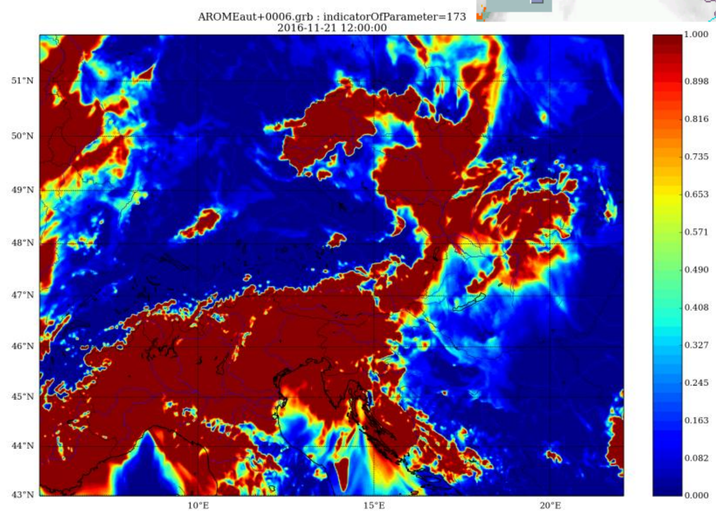
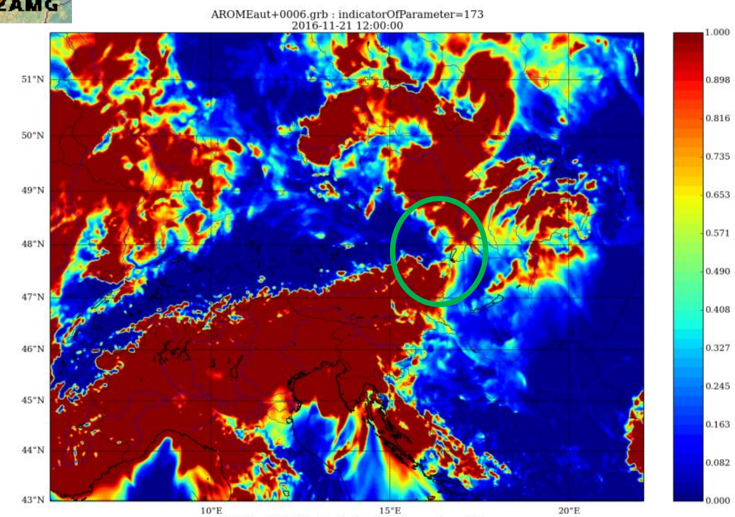


AROME-REF

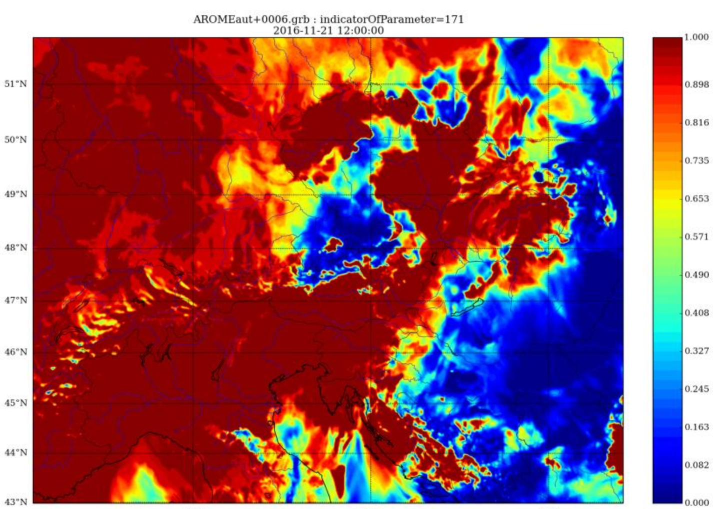
AROME-CLOUDMASK



2016112106
+6h

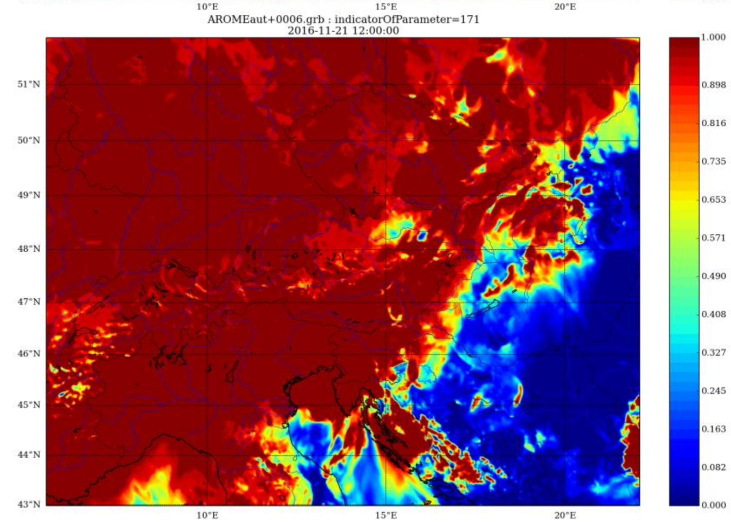


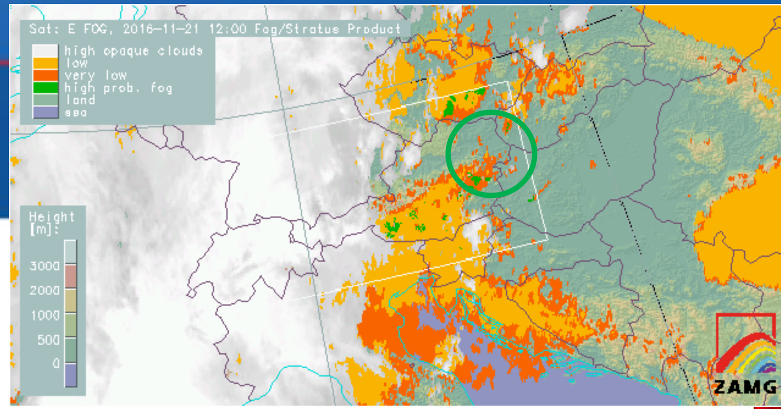
low clouds
improved



total clouds

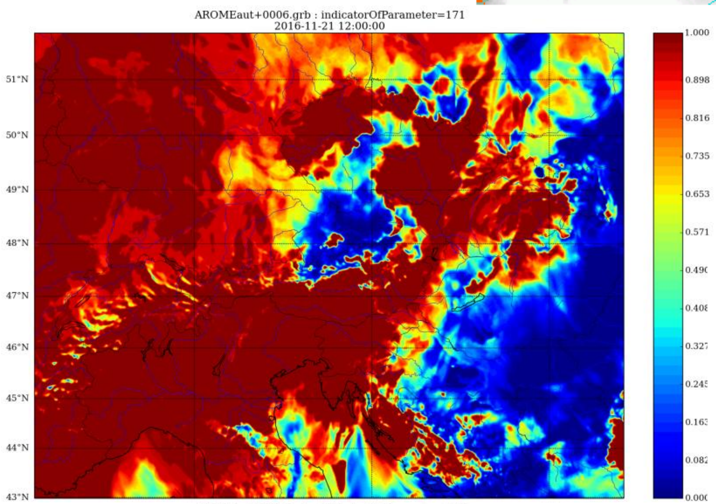
too much total clouds





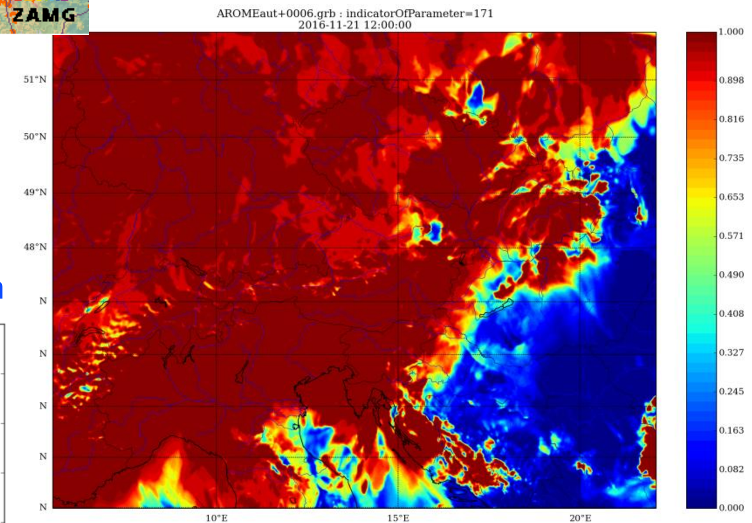
AROME-REF

AROME-HAIDEN

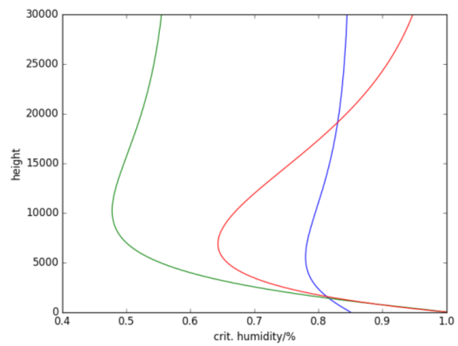


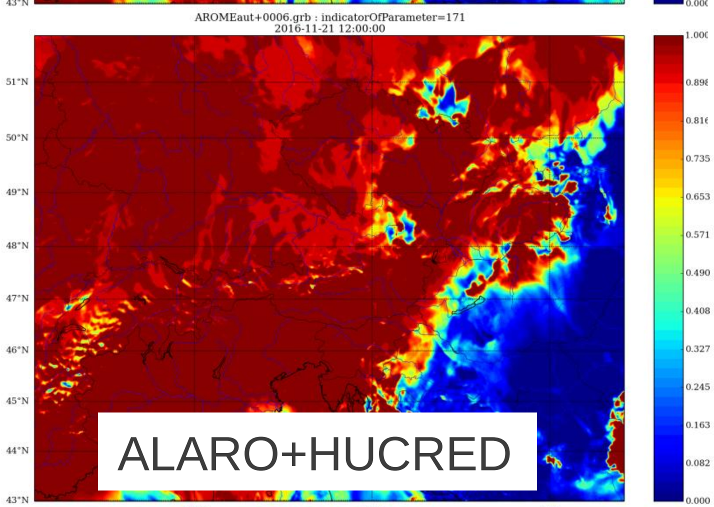
2016112106
+6h

total clouds



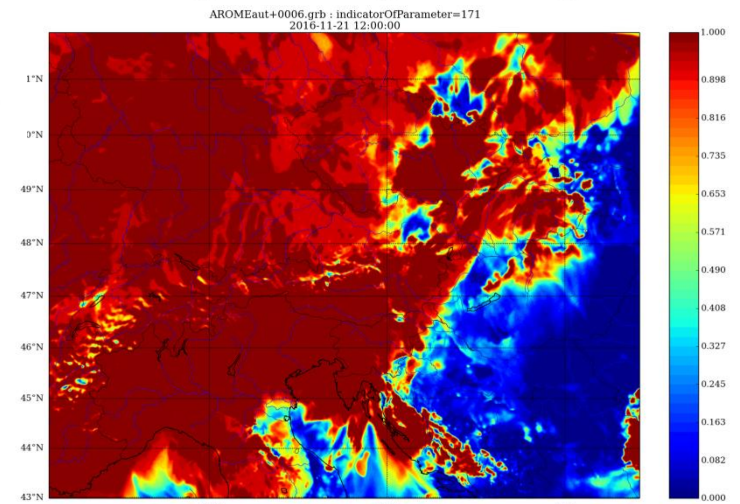
HAIDEN ALARO Van der Veen



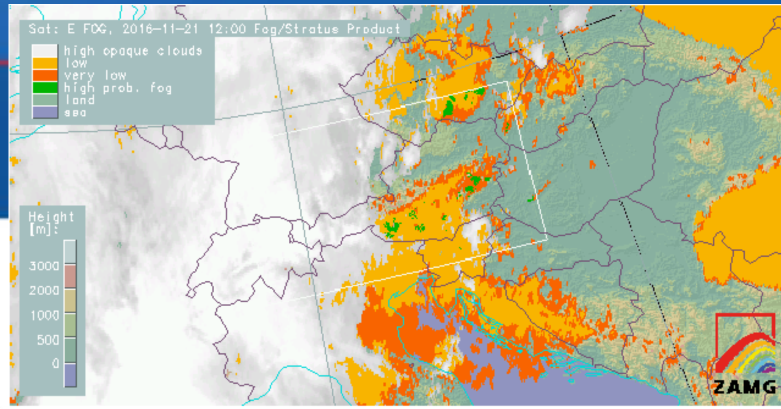


ALARO+HUCRED

using also saturation over ice for qsat calculation

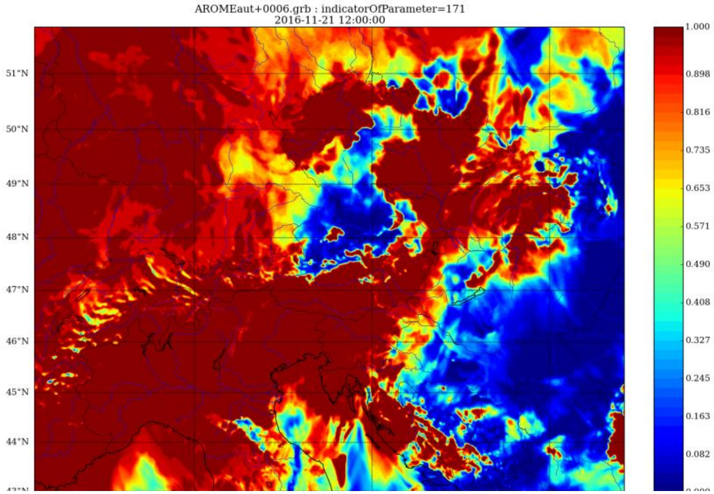


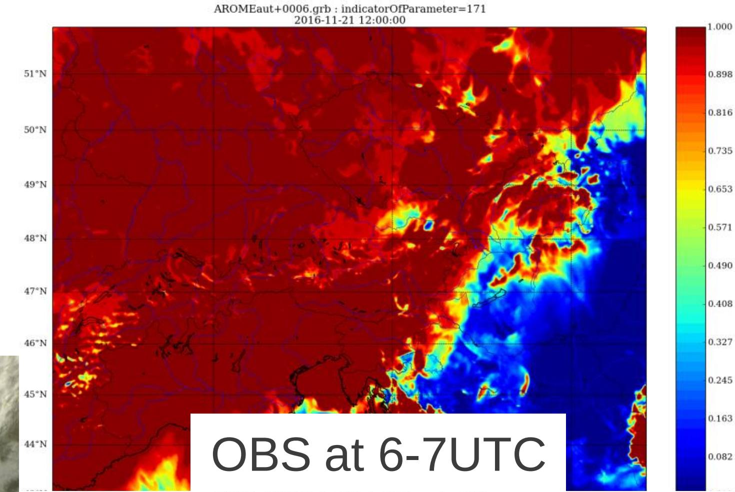
AROME-REF

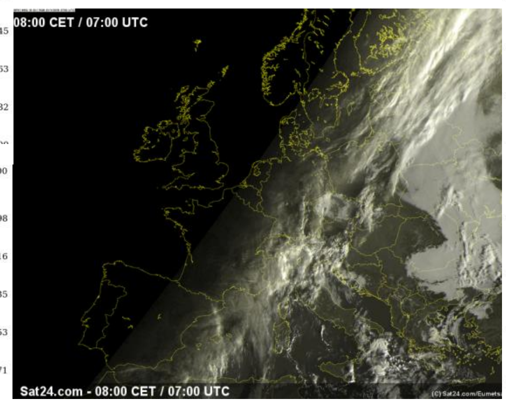


2016112106
+6h

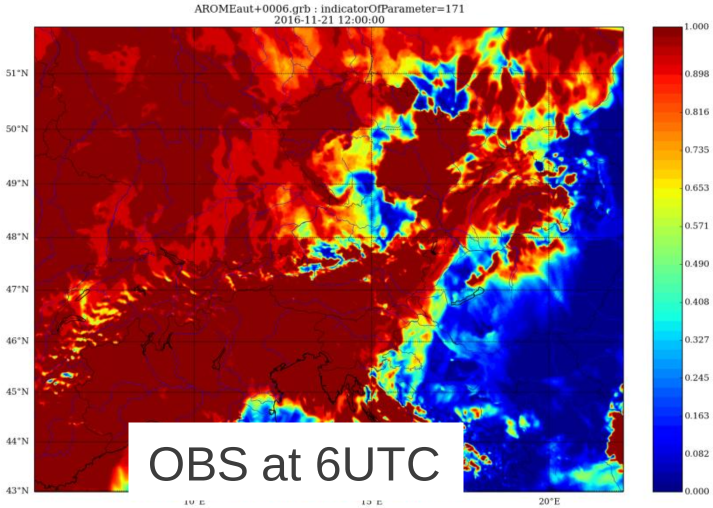
Sunrise in Vienna at 06:11UTC

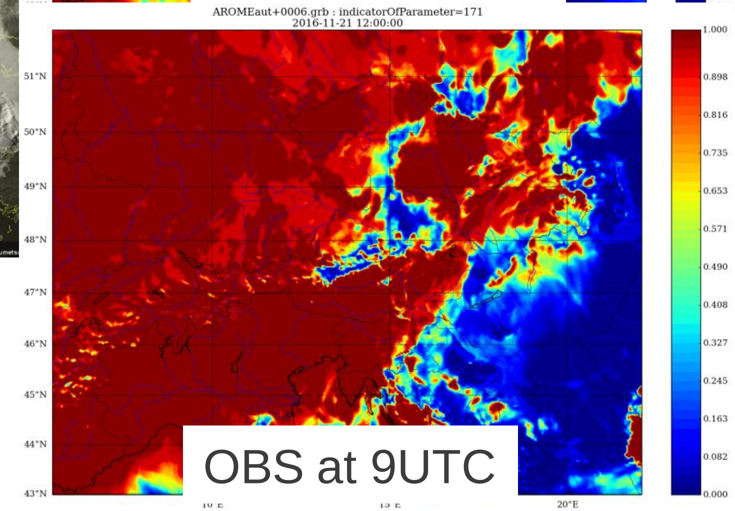




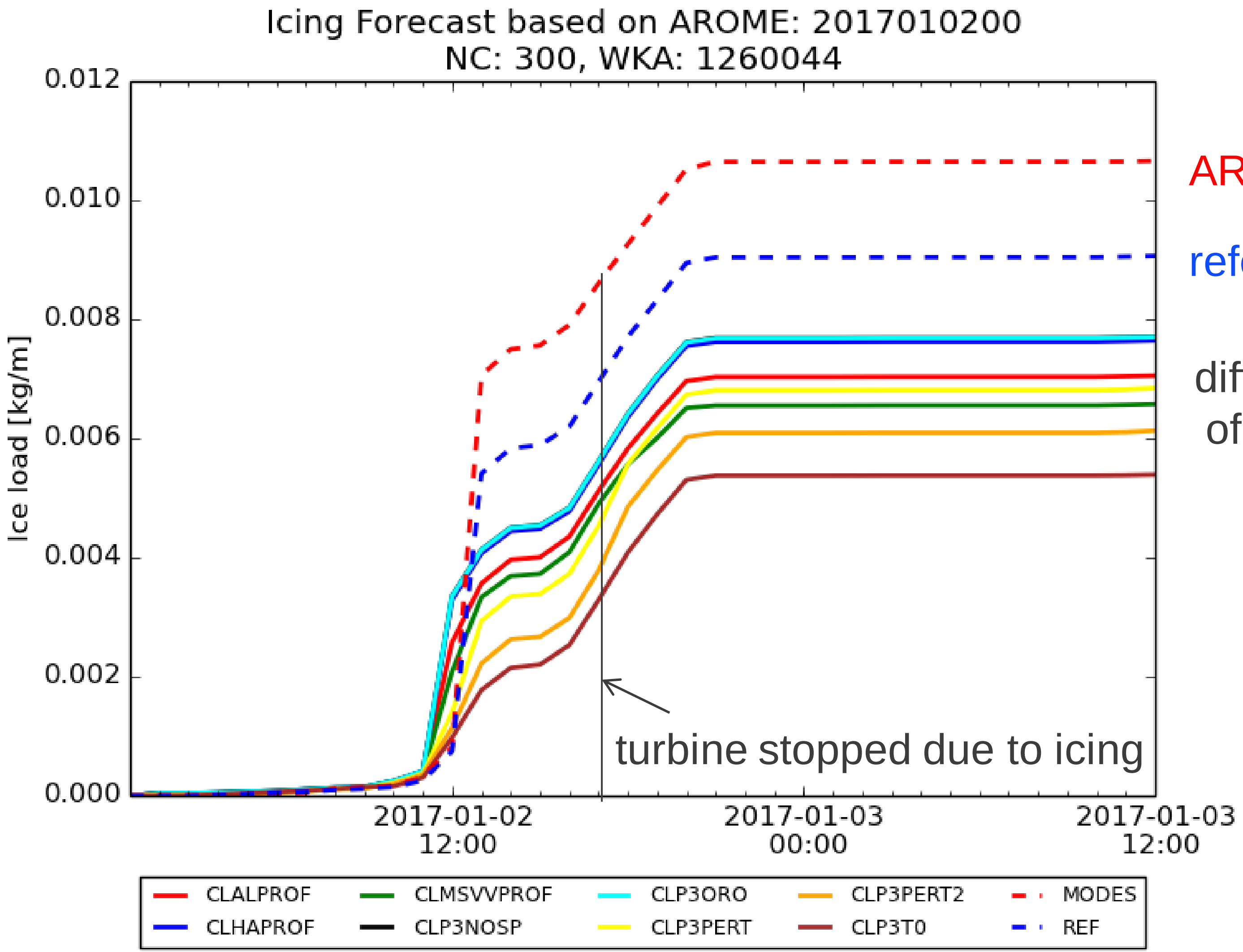


MSG-HRV 07UTC





Icing forecast with Makkonen model for Ellern windturbine 2nd January 2017



AROME+MODE-S

reference

different versions of cloud nudging

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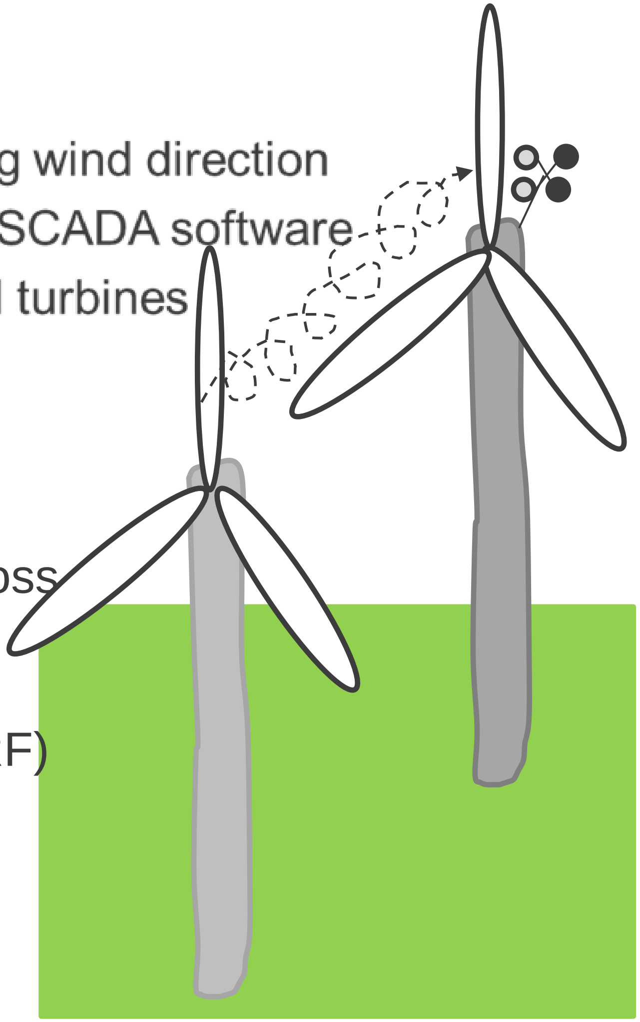
SCADA windturbine assimilation

- wind speed, temperature and gondola position/wind dir. at hub height
- Treat in AROME like one layer windprofiler enable temperature for obstype 6 ($\sigma_o = 1.41\ K; 1.89\frac{m}{s}$)
- put data to obsoul format
- Reject data, if turbine is not in working mode -> wrong wind direction
- speed is corrected for perturbation of flow by turbine SCADA software
- problem: airflow is also disturbed by neigboured wind turbines

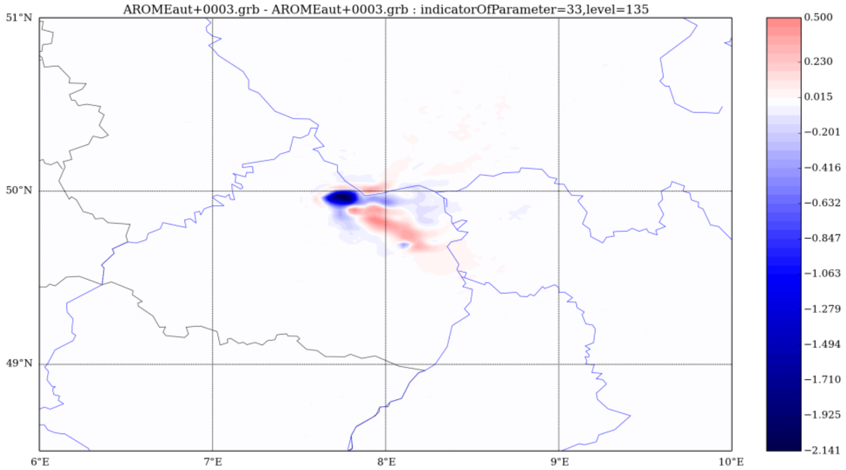
  ->the model „does not know" it ->bias



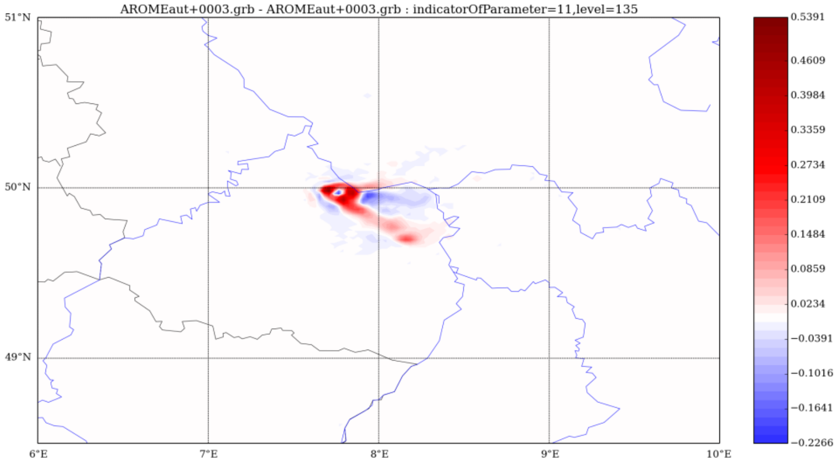
Possible solutions:

- Take only highest/single standing turbine data – data loss
- wind direction specific blacklisting
- bias correction from longer timeseries – variability?
- parameterise windfarm in model (Fitch et al. 2012, WRF) to reduce effect in the first guess

Parametrization of windfarms (21 Turbines)



Difference in U135m +3h



Difference in T135m +3h

$$\frac{dTKE_{ijk}}{dt} = \frac{0.5}{(z_k - z_{k+1})} N_{ij}\left(C_T\left(\left|\overrightarrow{v_{ijk}}\right|\right) - C_p\left(\left|\overrightarrow{v_{ijk}}\right|\right)\right)\left|\overrightarrow{v_{ijk}}\right|^3 A_{ijk}$$

$$\frac{du_{ijk}}{dt} = -\frac{u_{ijk}}{\left|\overrightarrow{v_{ijk}}\right|}\frac{0.5}{(z_k - z_{k+1})} N_{ij} C_T\left(\left|\overrightarrow{v_{ijk}}\right|\right)\left|\overrightarrow{v_{ijk}}\right|^2 A_{ijk}$$

$$\frac{dv_{ijk}}{dt} = -\frac{v_{ijk}}{\left|\overrightarrow{v_{ijk}}\right|}\frac{0.5}{(z_k - z_{k+1})} N_{ij} C_T\left(\left|\overrightarrow{v_{ijk}}\right|\right)\left|\overrightarrow{v_{ijk}}\right|^2 A_{ijk}$$

N_{ij}=turbines per area

C_T= thrust coefficient

C_P=power coefficient

A_{ijk}=area of model layer affected by turbine

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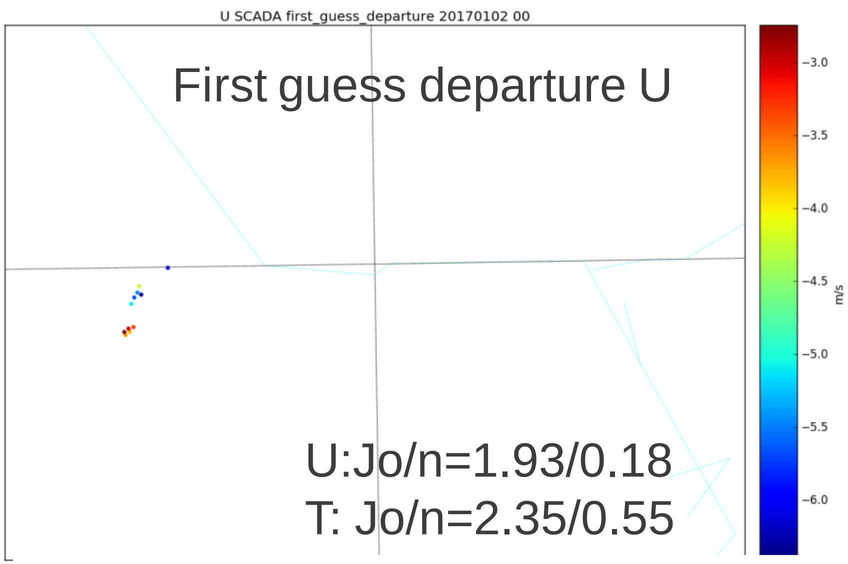
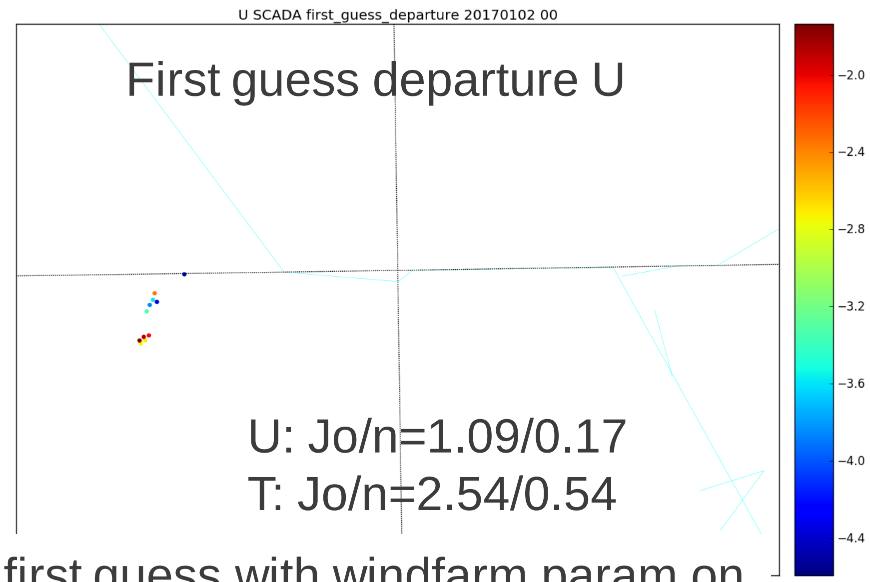
SCADA windturbine assimilation



first guess with windfarm param off

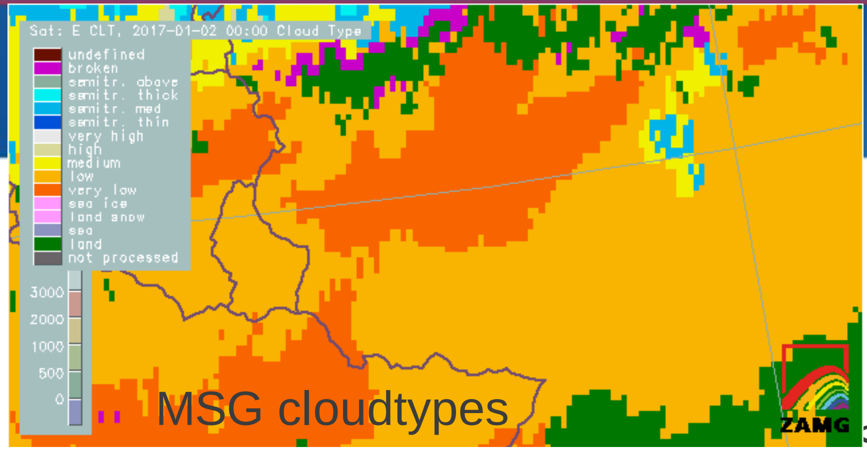


first guess with windfarm param on

+3h forecast
Verified against
13 turbines

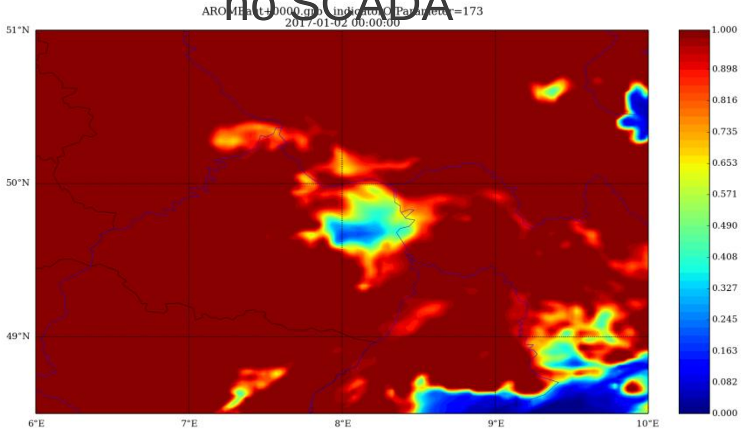
worse ->

EXP	BIAS U	BIAS V	BIAS T	BIAS FF	RMSE U	RMSE V	RMSE T	RMSE FF
REF	2.061	-4.570	0.420	2.329	2.530	2.590	1.038	2.603
ASSIM	1.743	-4.260	0.363	1.925	2.269	2.310	1.023	2.243
PAR	1.219	-3.977	0.189	1.337	1.723	1.759	0.982	1.630
COMB	1.24	-3.951	0.200	1.347	1.742	1.774	0.989	1.641
REF2	1.628	-4.177	0.233	1.791	2.043	2.091	0.979	2.024



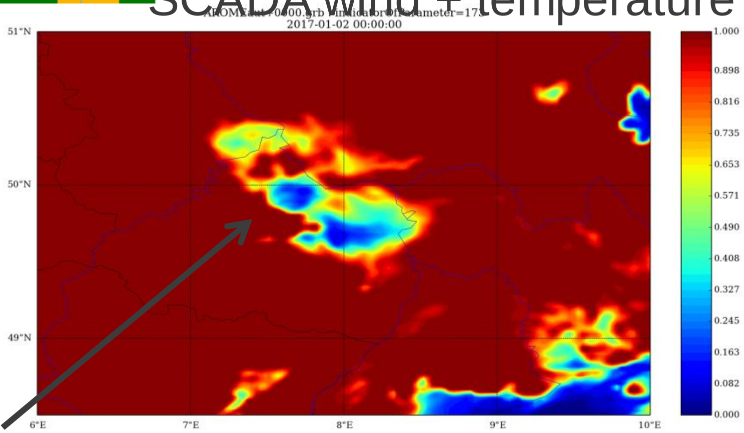
MSG cloudtypes

no SCADA



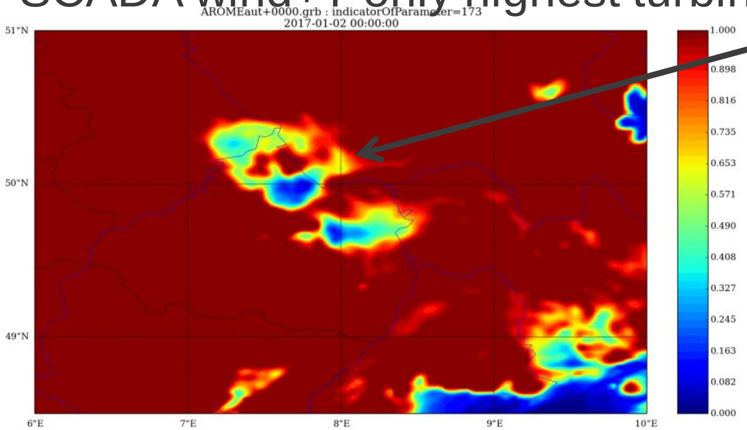
low clouds
2nd January
2017 00UTC+0h

SCADA wind + temperature

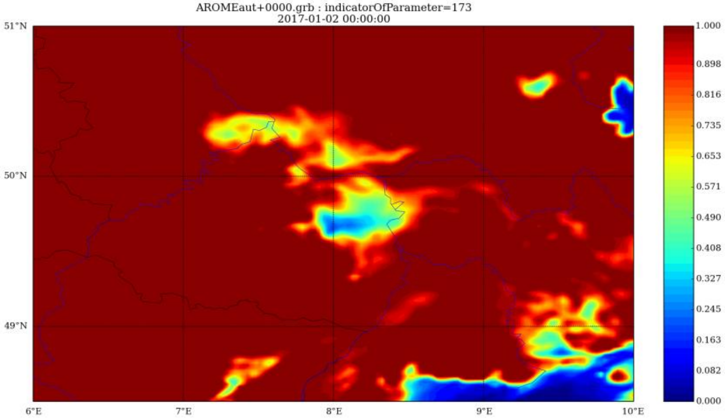


underestimation
of low clouds
due to temperature
assimilation

SCADA wind+T only highest turbine



SCADA wind



Conclusions

- cloud assimilation can improve low cloud cover significantly
- Nudging can add additional benefit to just modifying init file
- Cloud masking at sunrise might be problematic
- Slight differences for low clouds with different critical humidity profiles

- windfarm parameterization (Fitch et al. 2012) can reduce cost function and first guess departure of assimilated windturbine winds and improve 125m wind forecast
- windfarm assimilation led to slight improvement of 125m wind (1 case)
- subgridscale interaction of wind turbines needs additional effort
- wind turbine temperatures more problematic than wind ->low clouds dissolved in 2 cases ->re-define observation error
- longer timeseries, more cases for evaluation needed

HAIDEN:

LHUCN=F
HUCOE=0.7
HUTIL=1.3
NPCLO1=0
NPCLO2=1
HUCRED=1

ALARO:

LHUCN=T
HUCOE=1.4
HUTIL1=-0.6
HUTIL2=1.1
HUCRED=1

ALARO:

HUCRED=1.2
REFLRHC=150000.
TEQH=60.
RHCEXPDX=0.3
RDTFAC=1.0
SCLESPR=248000.
SCLESPS=2500.

RHMAX=0.85
RHMIN=0.78

```
CCC=1._JPRB-MAX( HUCOE*ZVETAF**NPCLO1*&
           & (1._JPRB-ZVETAF)**NPCLO2*&
           & (1._JPRB+SQRT(HUTIL)*(ZVETAF-0.5_JPRB)),1.E-12)
```

```
CCC=1._JPRB-MAX(1.E-12,HUCOE*ZVETAF*(1._JPRB-ZVETAF)/&
           & ((1._JPRB+HUTIL1*(ZVETAF-0.5_JPRB))*(1._JPRB+HUTIL2*&
           & (ZVETAF-0.5_JPRB))))
```

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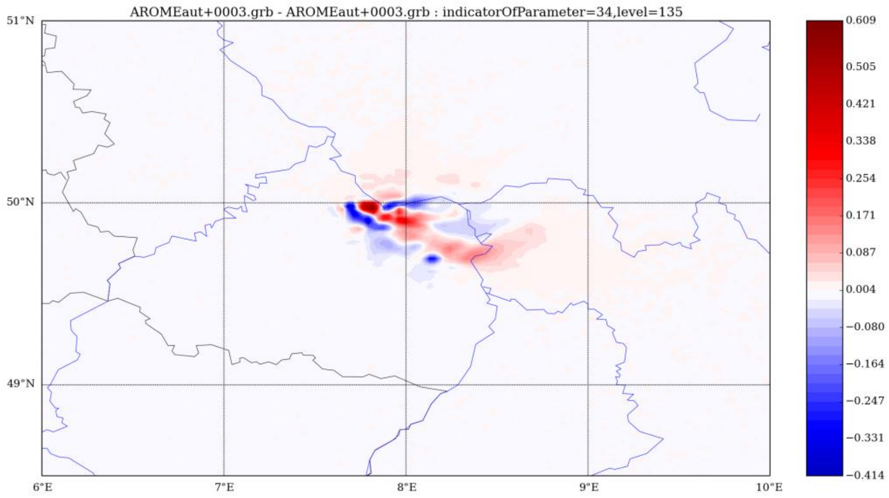
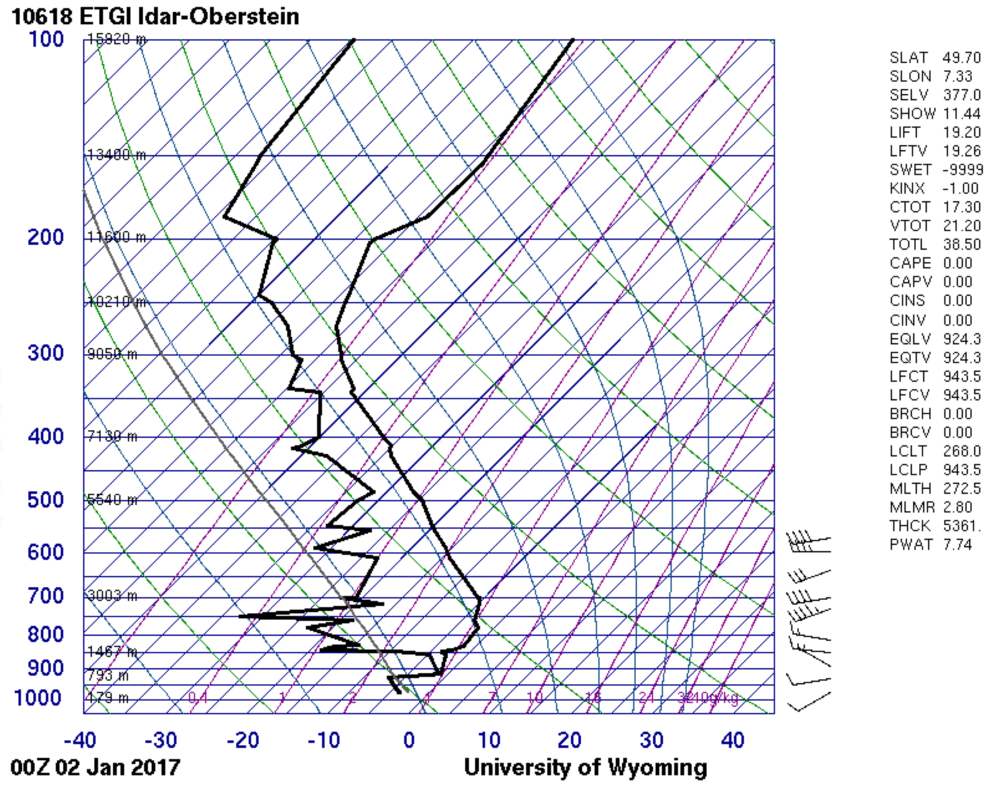
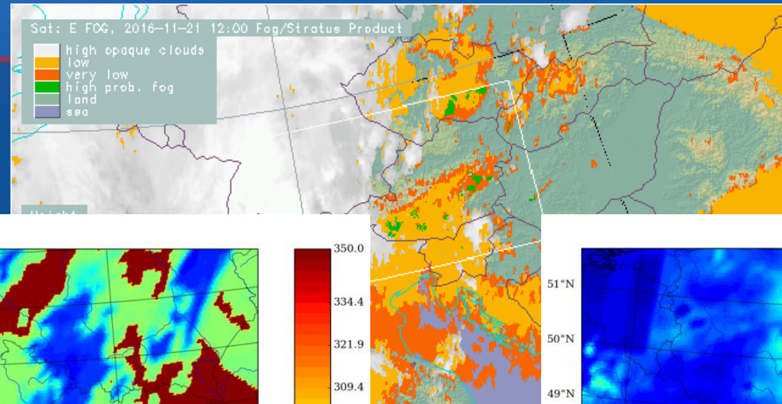
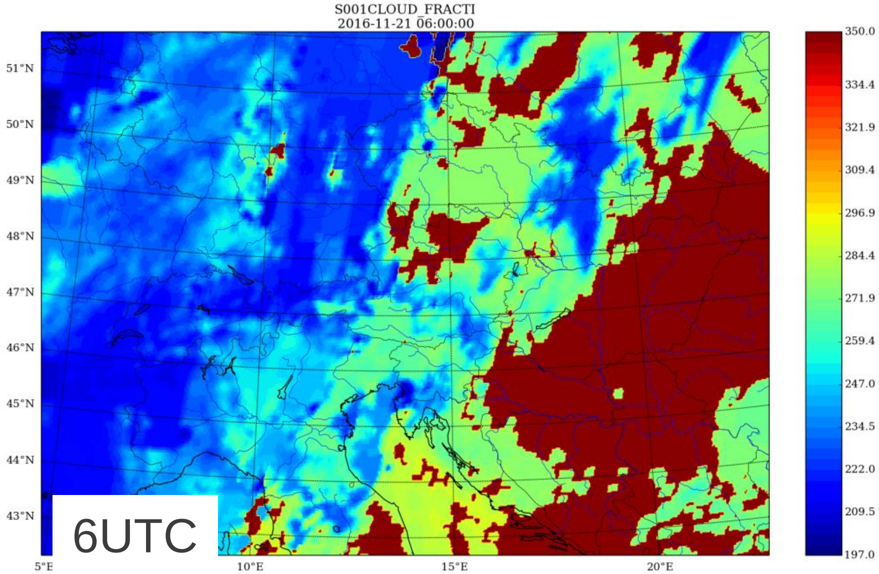
```
ZMESHEXP=(REFLRHC/(TEQH*PGM(JX)))**RHCEXPDX
            ZLESEFR=1.0_JPRB/SCLESPR
            ZLESEFS=1.0_JPRB/SCLESPS
            ! ZRMF comes from FONICE function
            ZRMF=1.0_JPRB-EXP( -(RTT-MIN(RTT,TM(JX,JK)))**2._JPRB
&
               & * (1.0_JPRB/(2.0_JPRB*(RDT*RDTFAC)**2._JPRB)) )
            ZLEN0=1.0_JPRB/(ZRMF*ZLESEFS+&
            & (1.0_JPRB-ZRMF)*ZLESEFR)
            CCC=((HUCRED*CCC+1._JPRB-
HUCRED)*ZMESHEXP+ZLEN0)/(ZMESHEXP+ZLEN0)
```

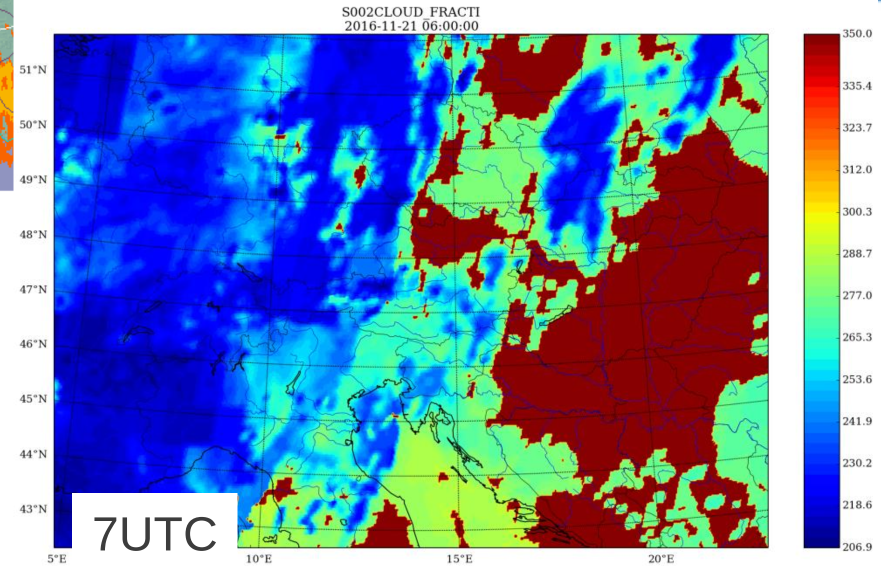




ZAMG
Zentralanstalt für Meteorologie und Geodynamik


Sat: E FOG, 2016-11-21 12:00 Fog/Stratus Product
high opaque clouds
low
very low
high prob. fog
land
sea


S001CLOUD_FRACTI
2016-11-21 06:00:00
6UTC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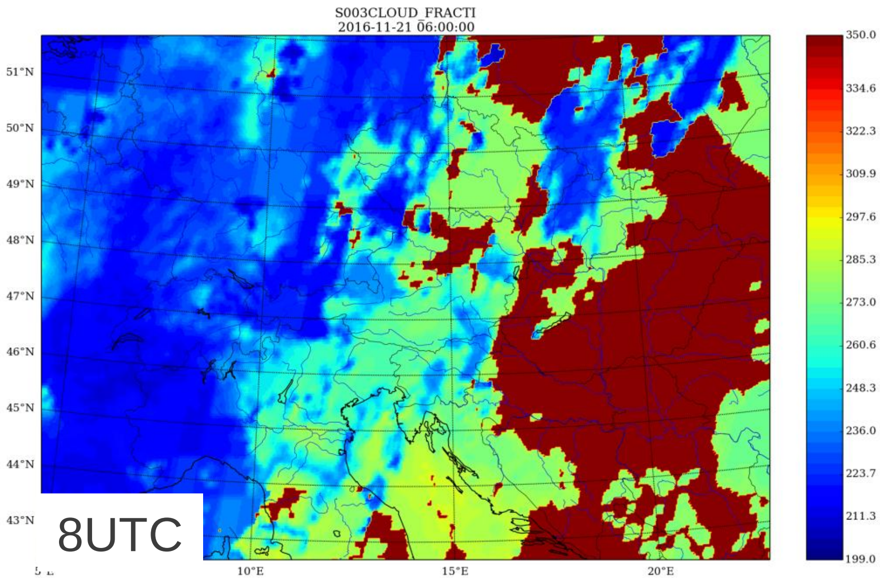
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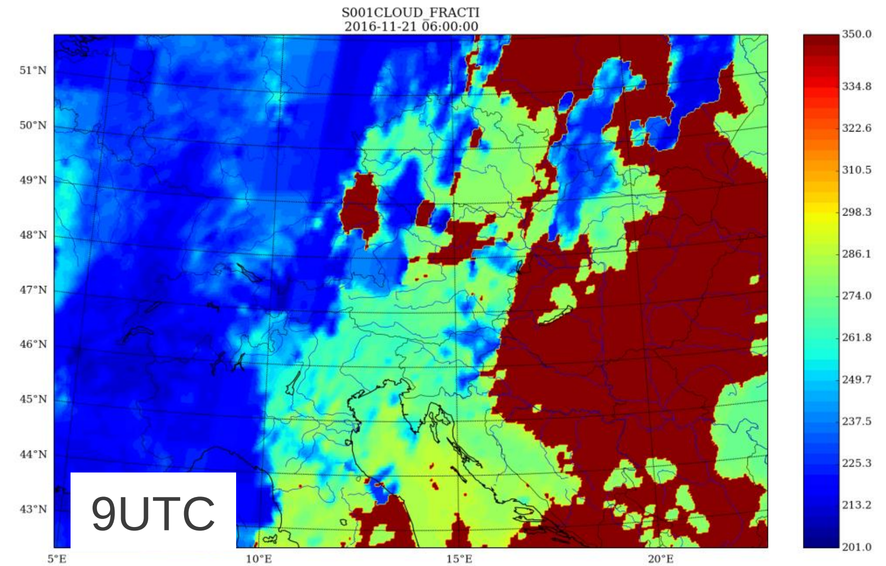
2016-11-21 06:00:00
8UTC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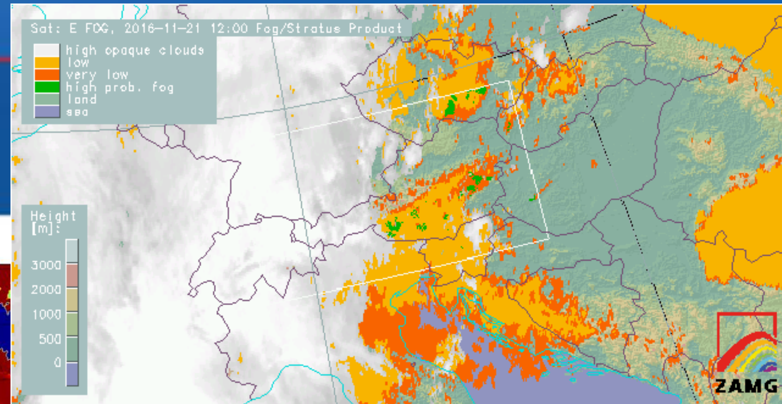
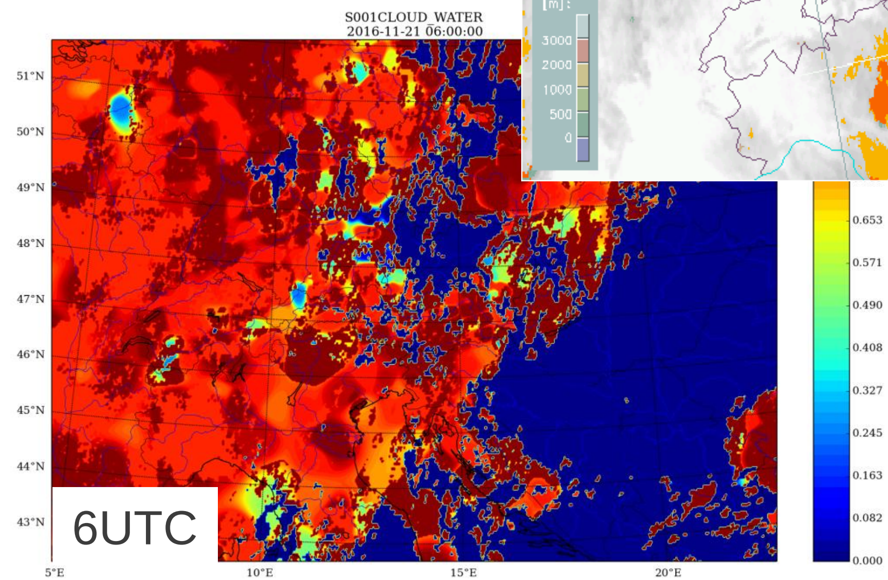
2016-11-21 06:00:00
9UTC


Sat: E FOG, 2016-11-21 12:00 Fog/Stratus Product
high opaque clouds
low
very low
high prob. fog
land
sea
Height [m]:
ZAMG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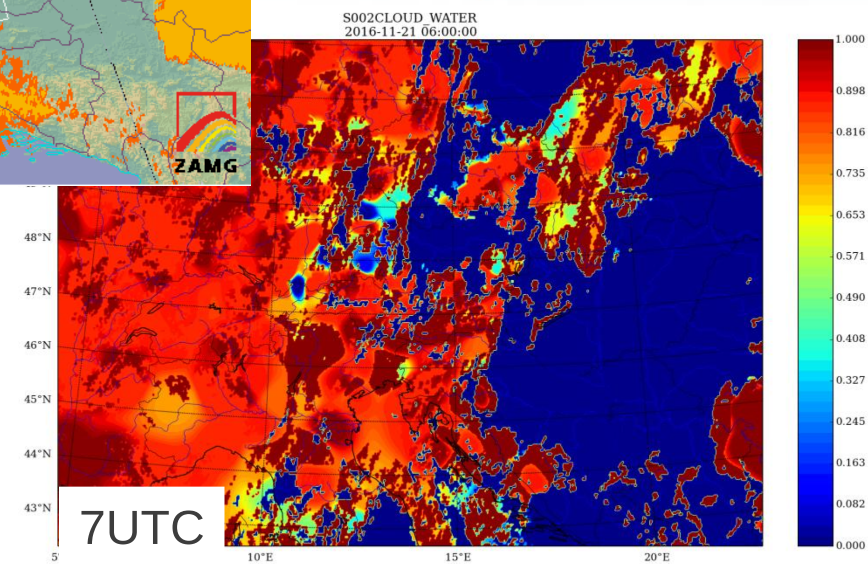
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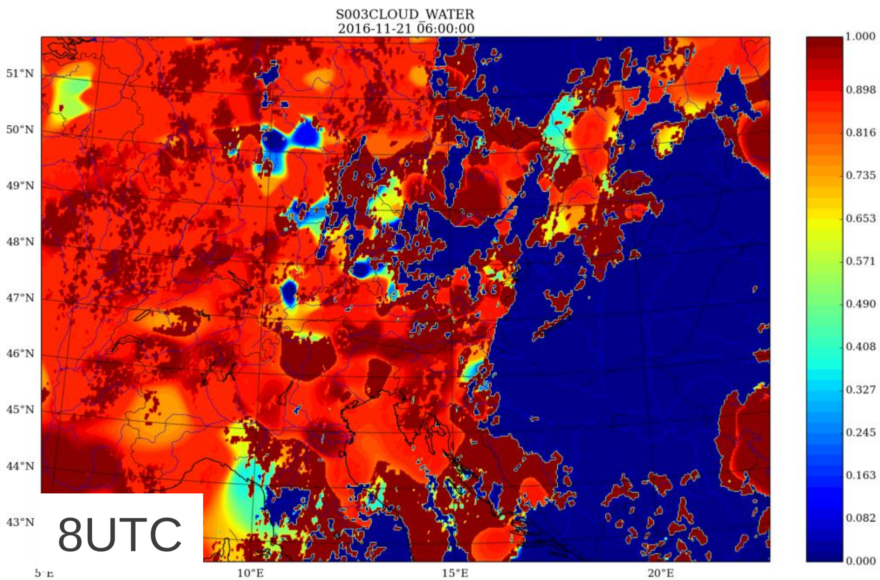
7UTC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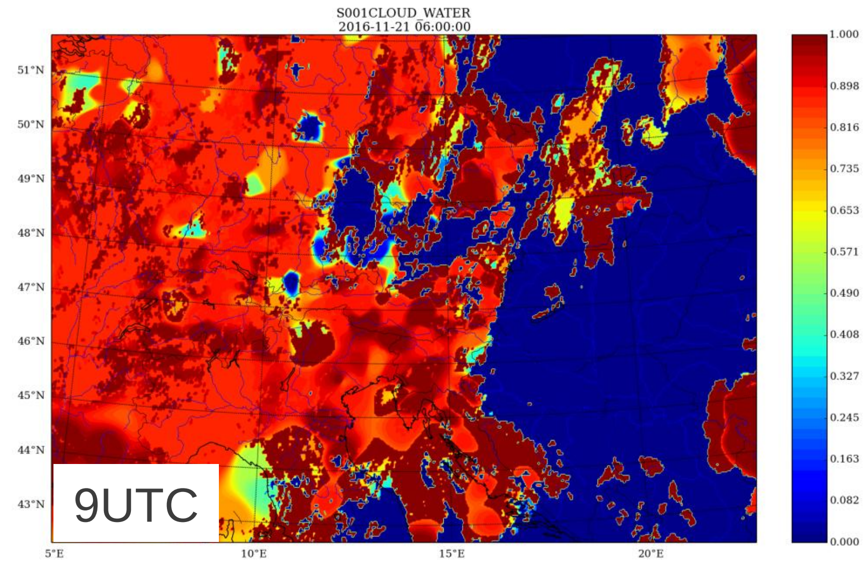
8UTC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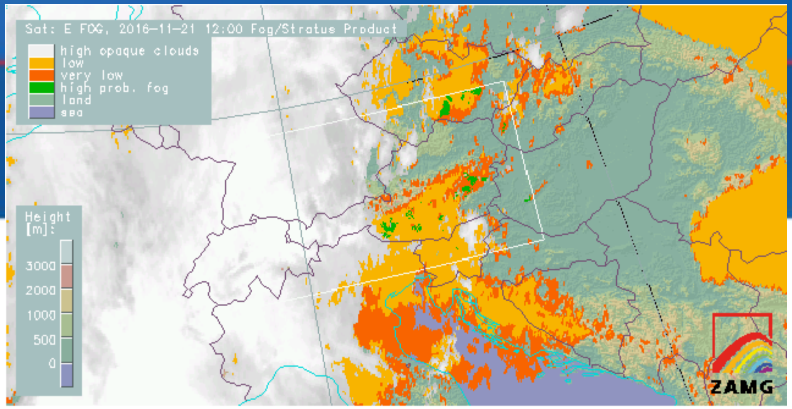
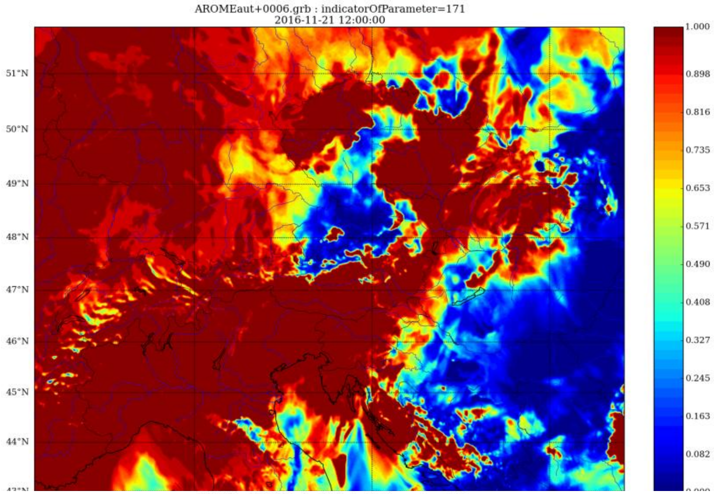
2016-11-21 06:00:00
9UTC

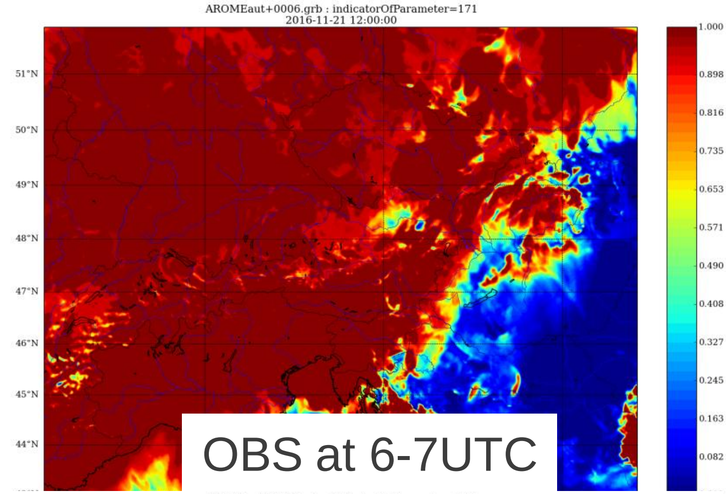


AROME-REF

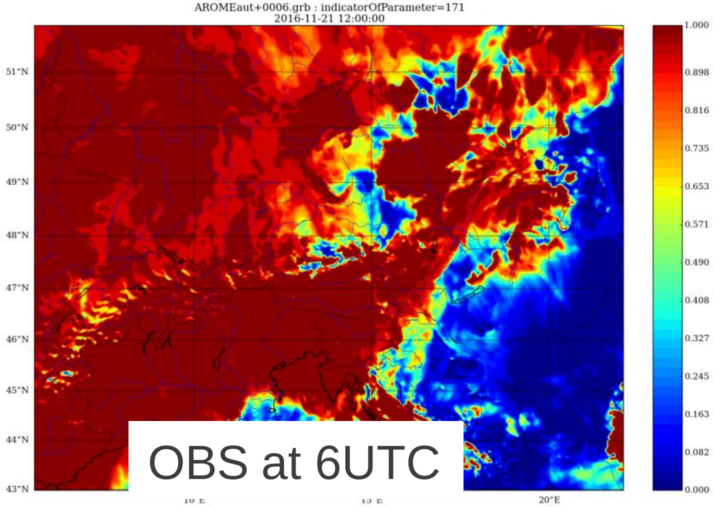
2016112106
+6h

Sunrise in Vienna at 06:11UTC!

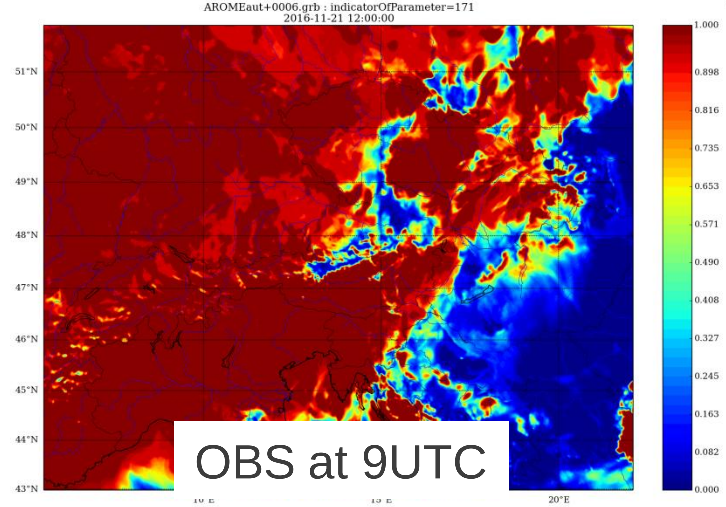




OBS at 6-7UTC

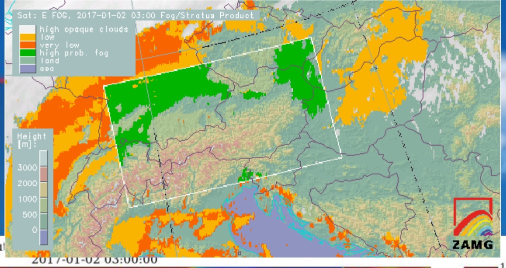


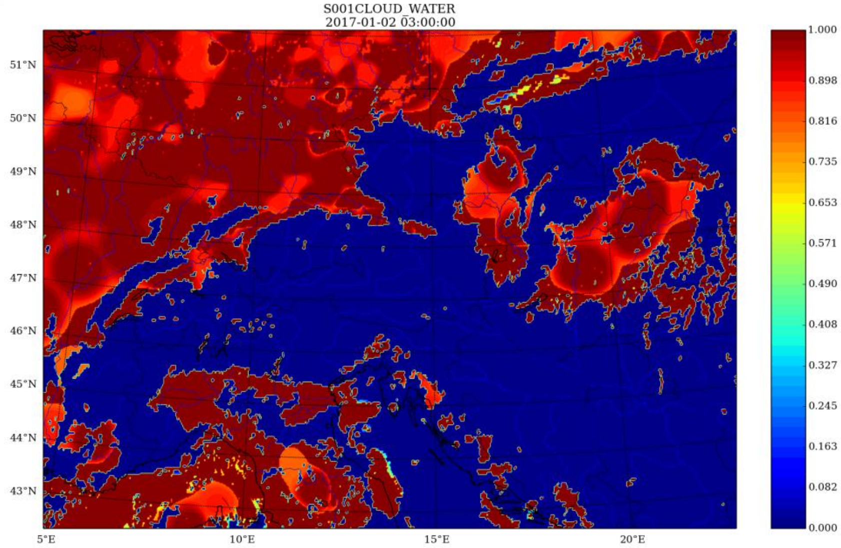
OBS at 6UTC



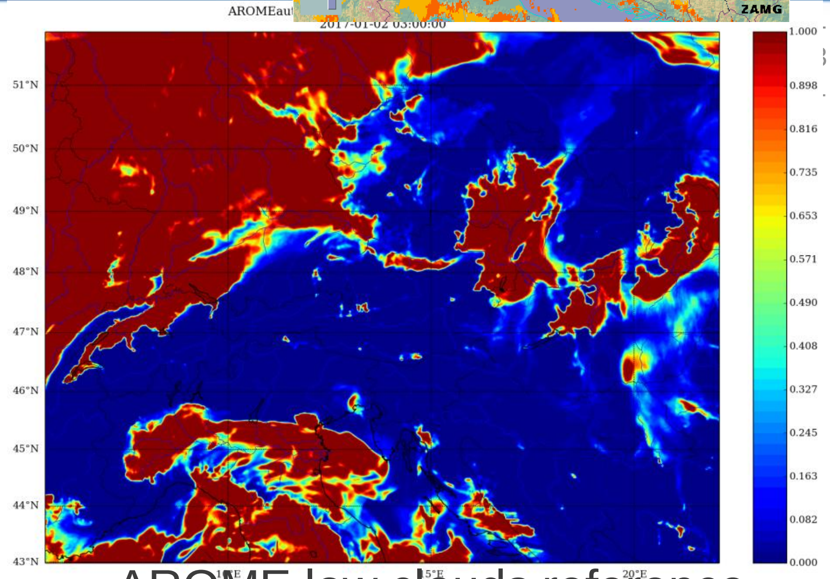
OBS at 9UTC

cloud nudging 2nd January 2017 00UTC+3h

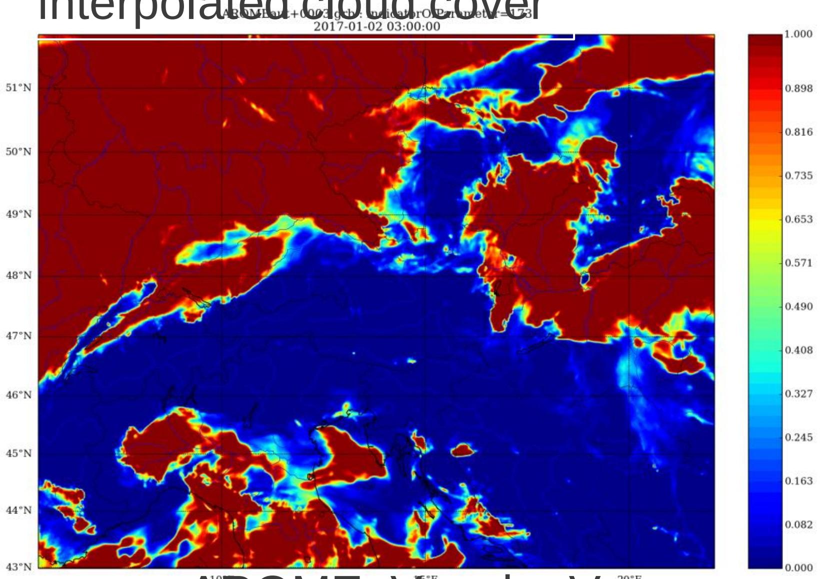




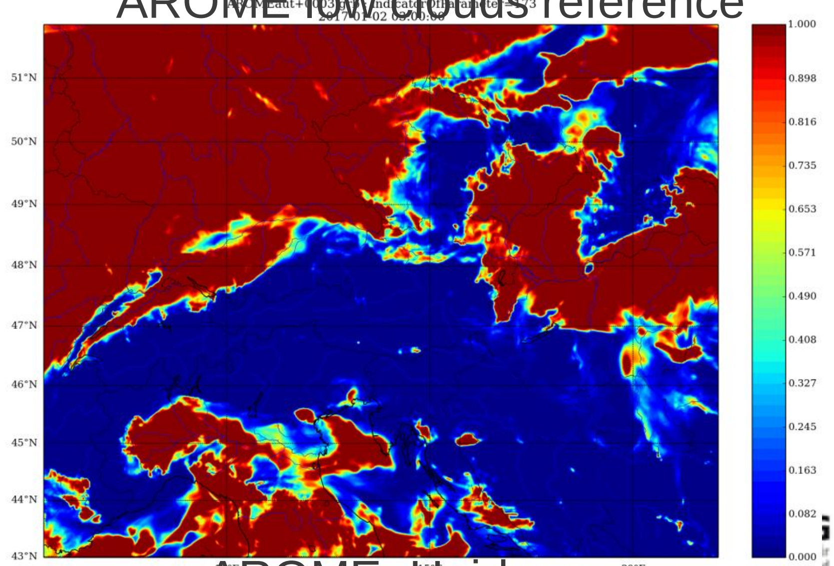
interpolated cloud cover



AROME low clouds reference



AROME+Van der Veen



AROME+Haiden