Tests on cloud initialisation with AROME over Austria and Germany

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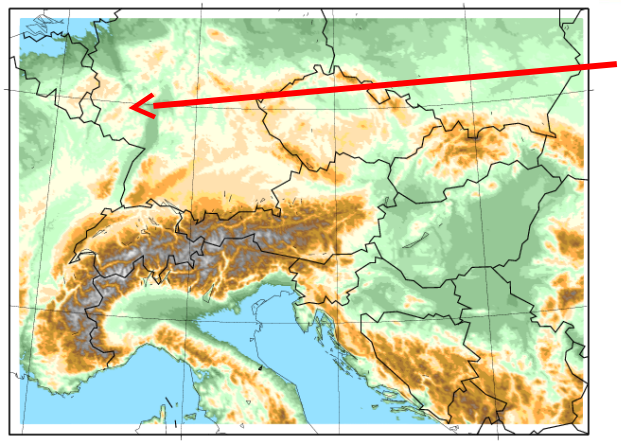
ICE-CONTROL Project: forecasting icing on windfarm windturbines



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

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

$C = rh_{max} - (rh_{max} - rh_{min})\sin(\pi\frac{p}{p_s})$ 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 T_m such that buoyancy is conserved

original version:

$q_0 \equiv q_m$

$T_0 \equiv T_m$

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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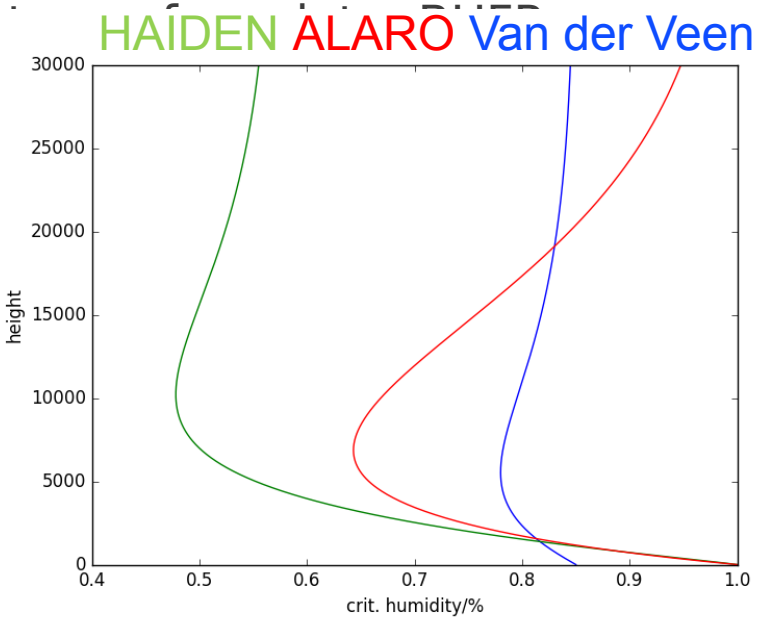
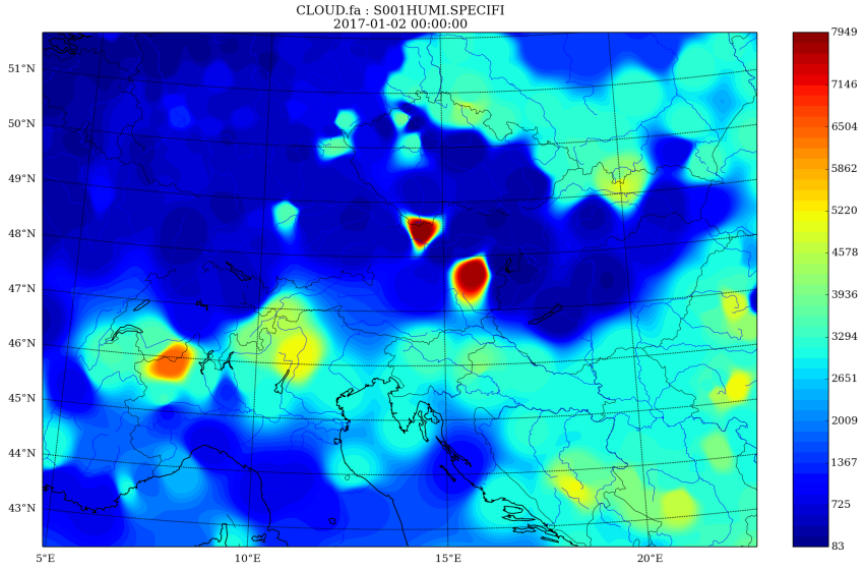
Cloud nudging – code modifications

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

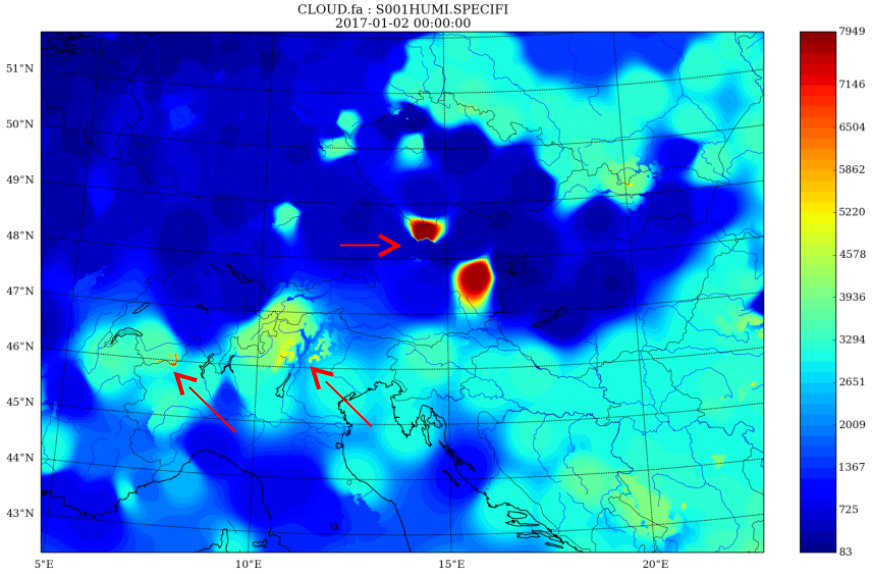
- Start from: Pre-processor „getcloudinfo“ trunk r14912 40h1, main routine: branch 38h1.2, adapted to cy40t1 export
- Several timeslots: ->run pre-processor once per slot save observations to different vertical level in FA file: S001->S003, modify also: mf_phys.F90
- satellite projection adapted to Austrian d[illegible] >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
- take optional saturation equation from Goff-Gratch to get qsat (water and ice)
- Random perturbation generator for obs
- Use spread for cloud base estimation



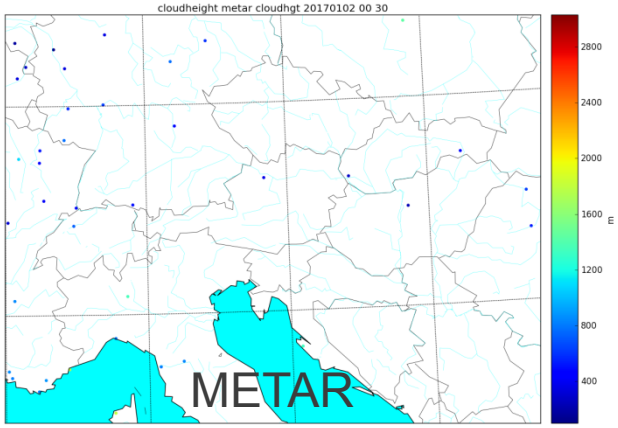
Cloud base above sea level from interpolated surface stations
2nd January 2017 00UTC

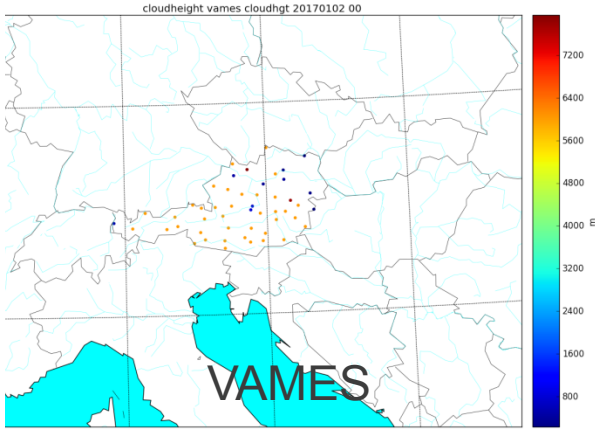


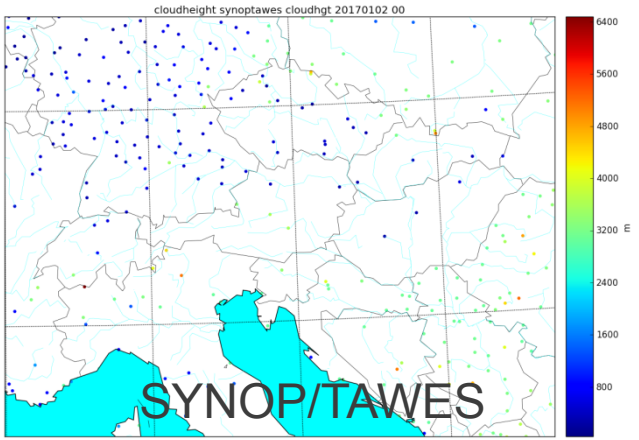
$$w = \frac{1}{d^6}$$



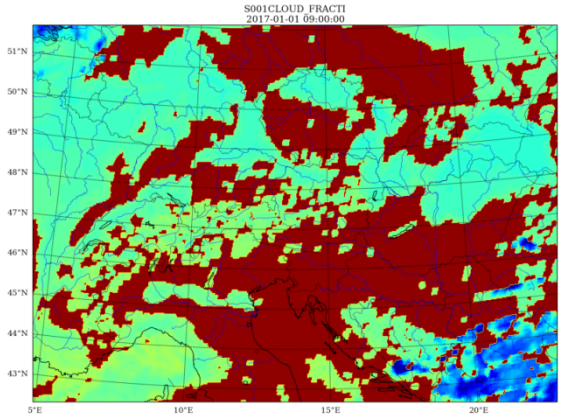
$$w = \frac{1}{(d+\frac{\Delta z}{5})^6} \text{ if } \Delta z > 250m$$



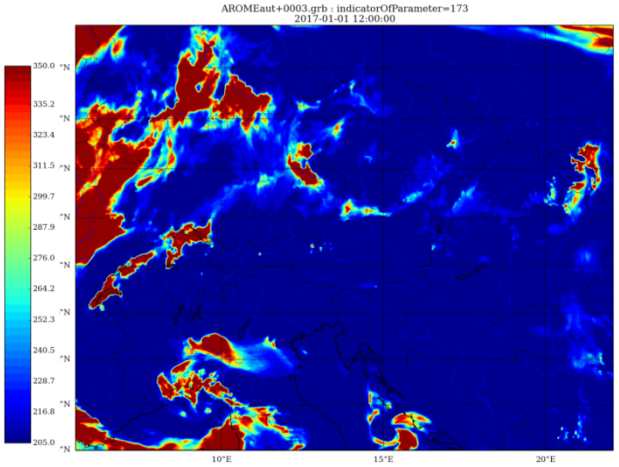


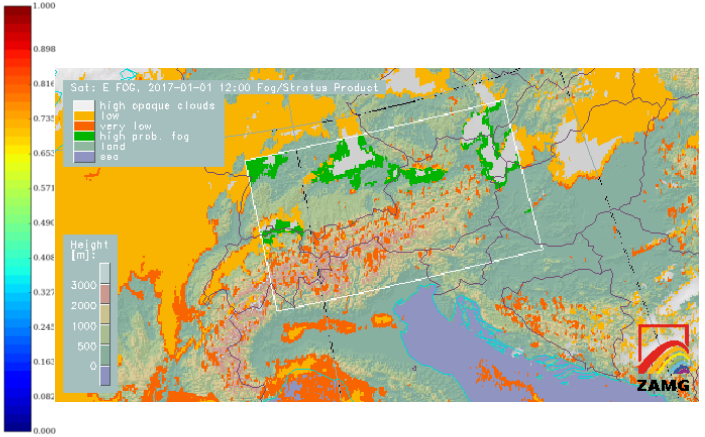


Cloud nudging 1st January 2017 09UTC+3h

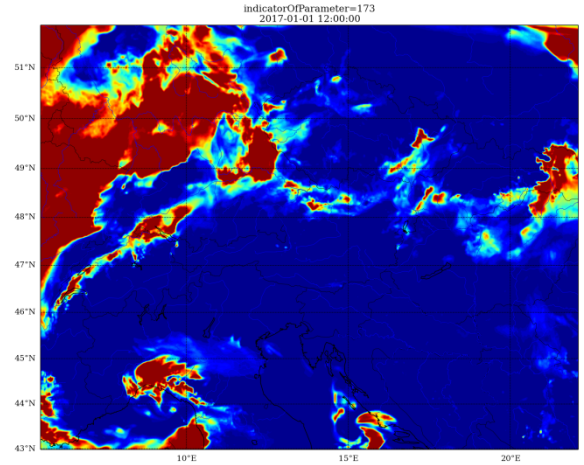


MSG-CTT/K 12UTC

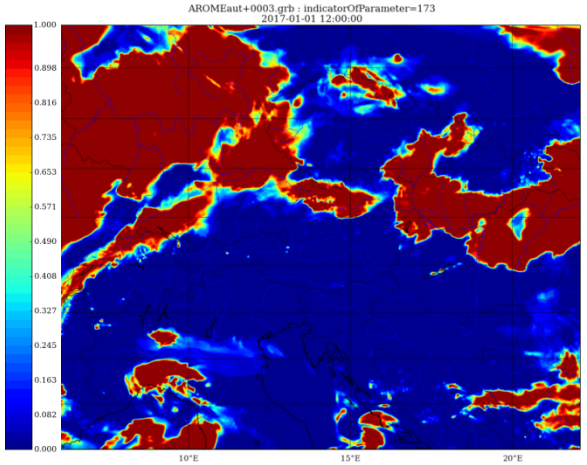




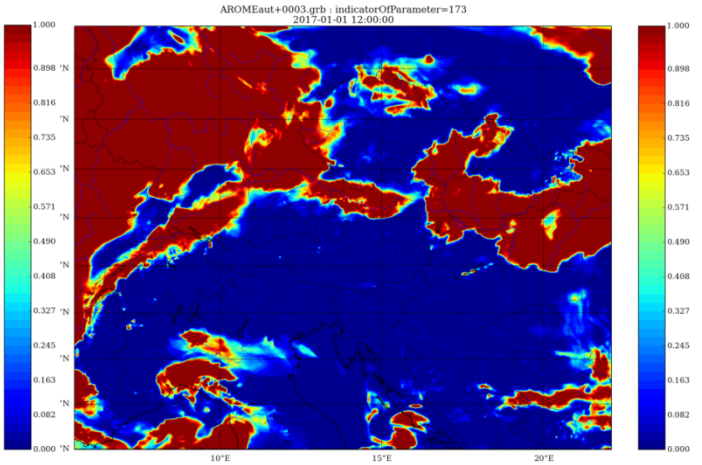
AROME low clouds reference



AROME+Van der VeenT0



AROME+Van der Veen0/0.5/1



AROME+Haiden

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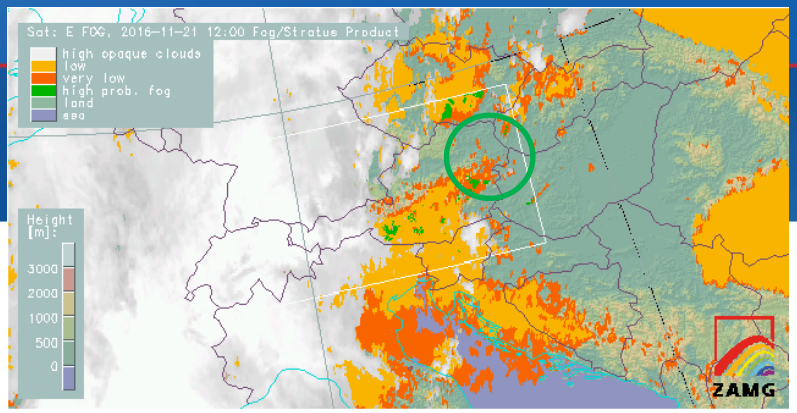
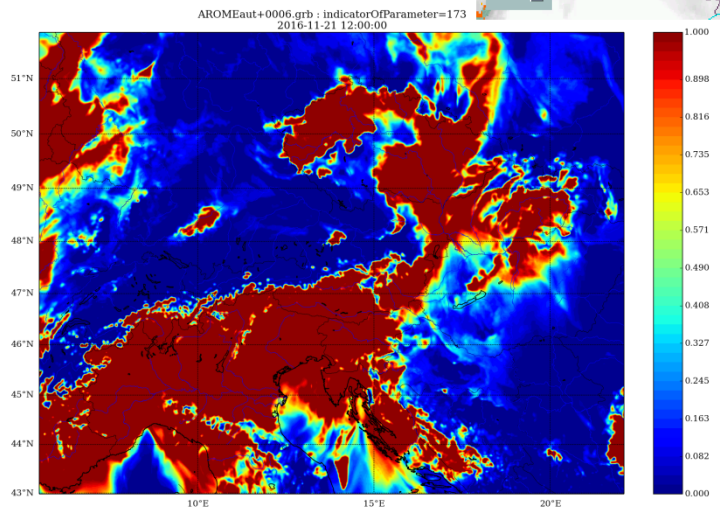
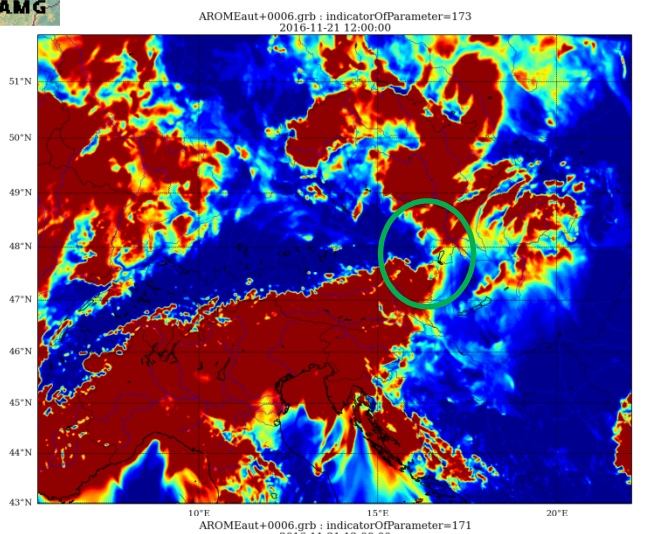


AROME-REF

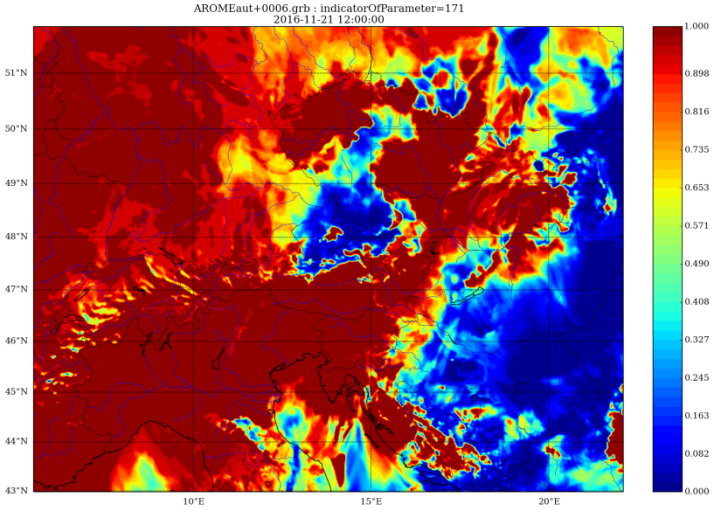
AROME-CLOUDMASK



2016112106
+6h

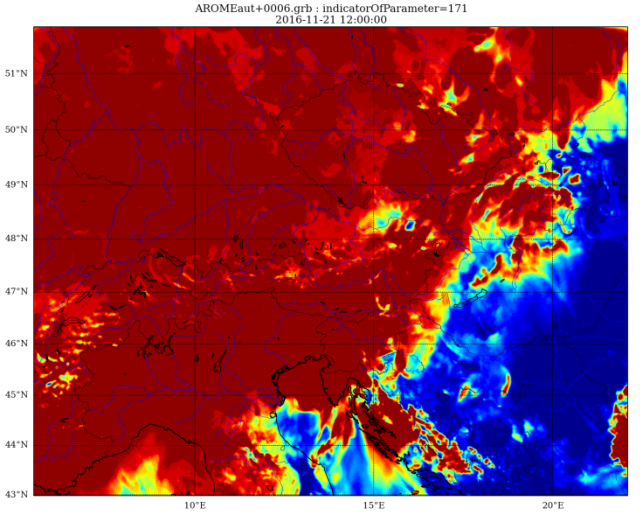


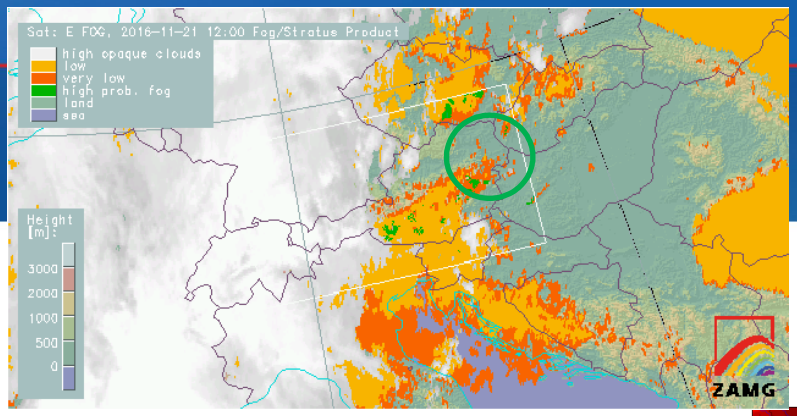
low clouds
improved



total clouds

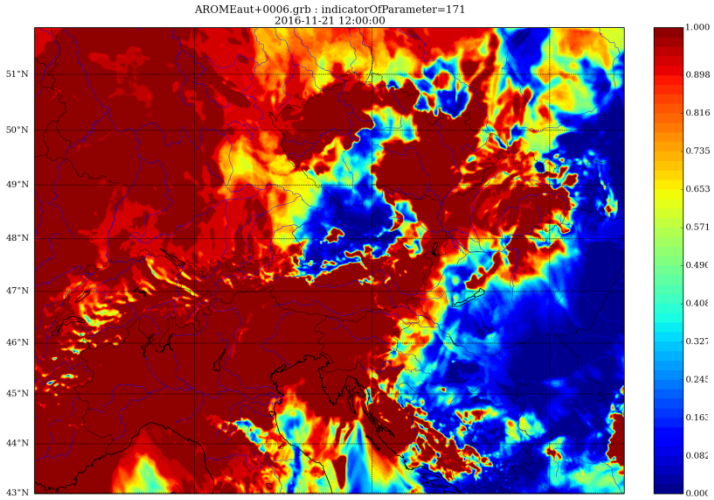
too much total clouds





AROME-REF

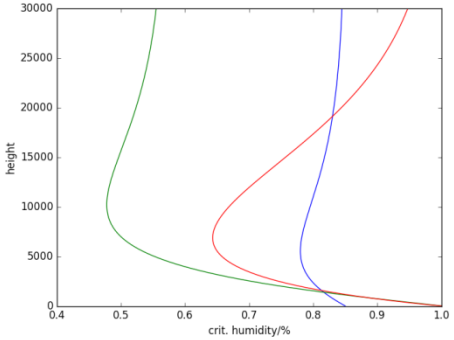
AROME-HAIDEN

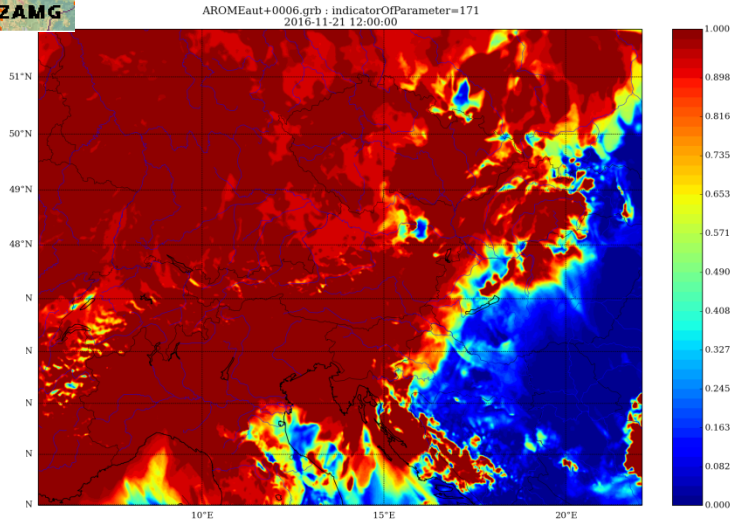


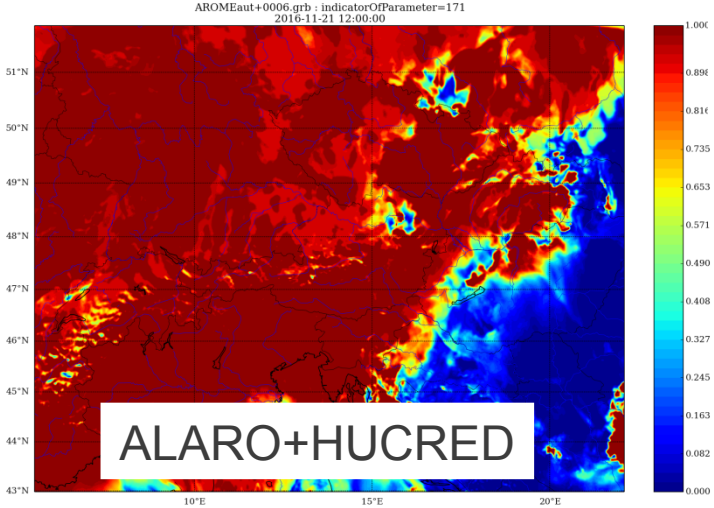
2016112106
+6h

total clouds

HAIDEN ALARO Van der Veen

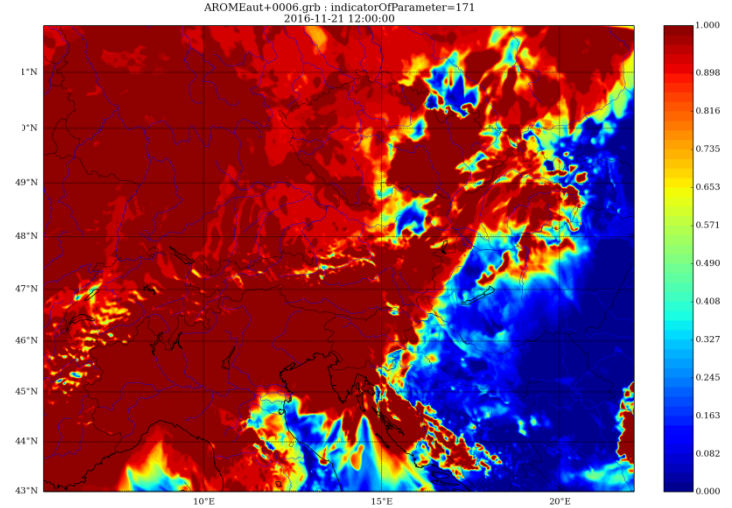




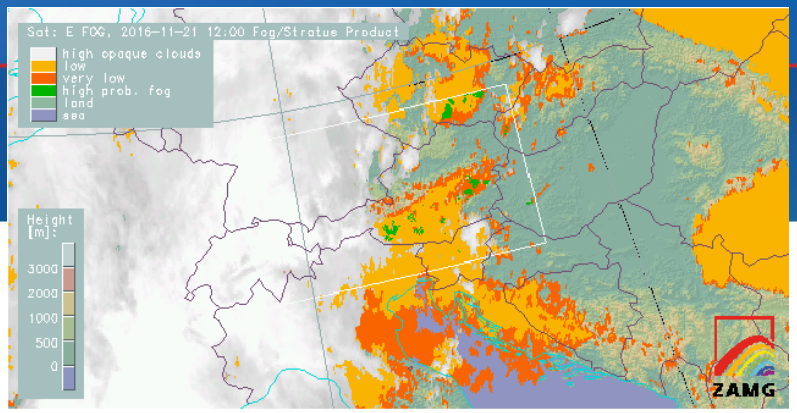


ALARO+HUCRED

using also
saturation over ice
for qsat calculation

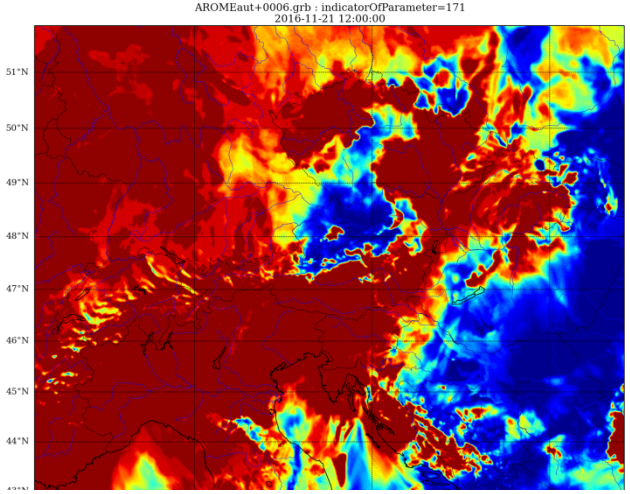


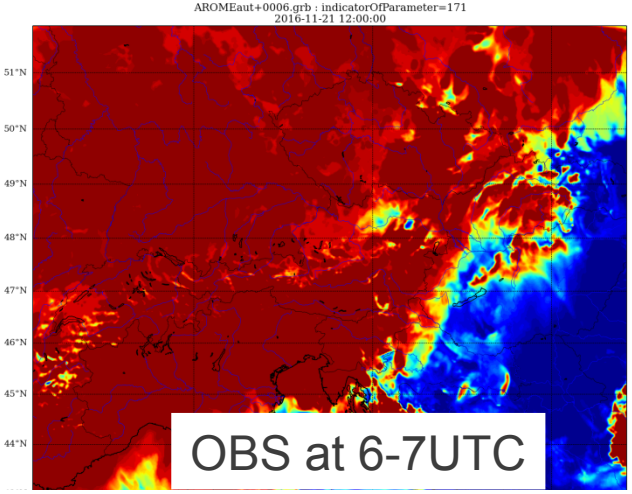
AROME-REF



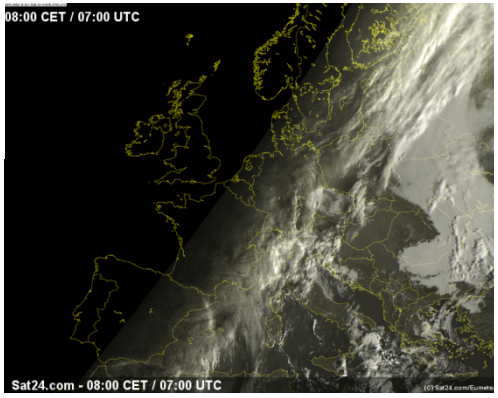
2016112106
+6h

Sunrise in Vienna
at 06:11UTC

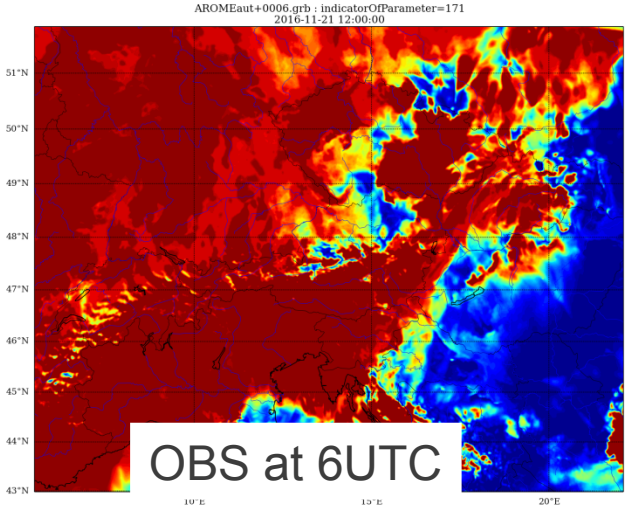




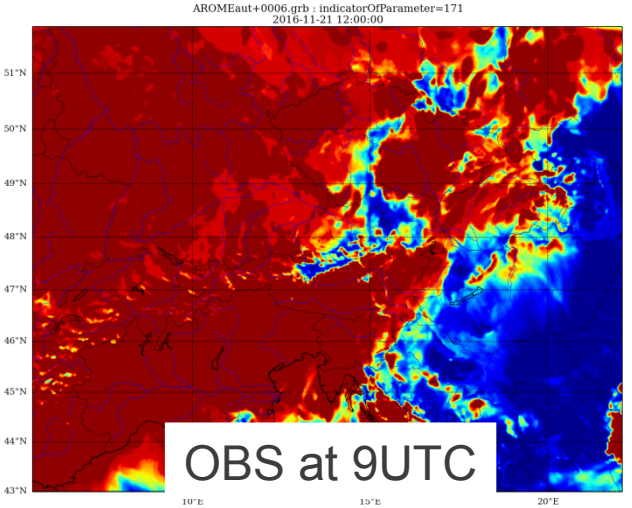
OBS at 6-7UTC



MSG-HRV 07UTC

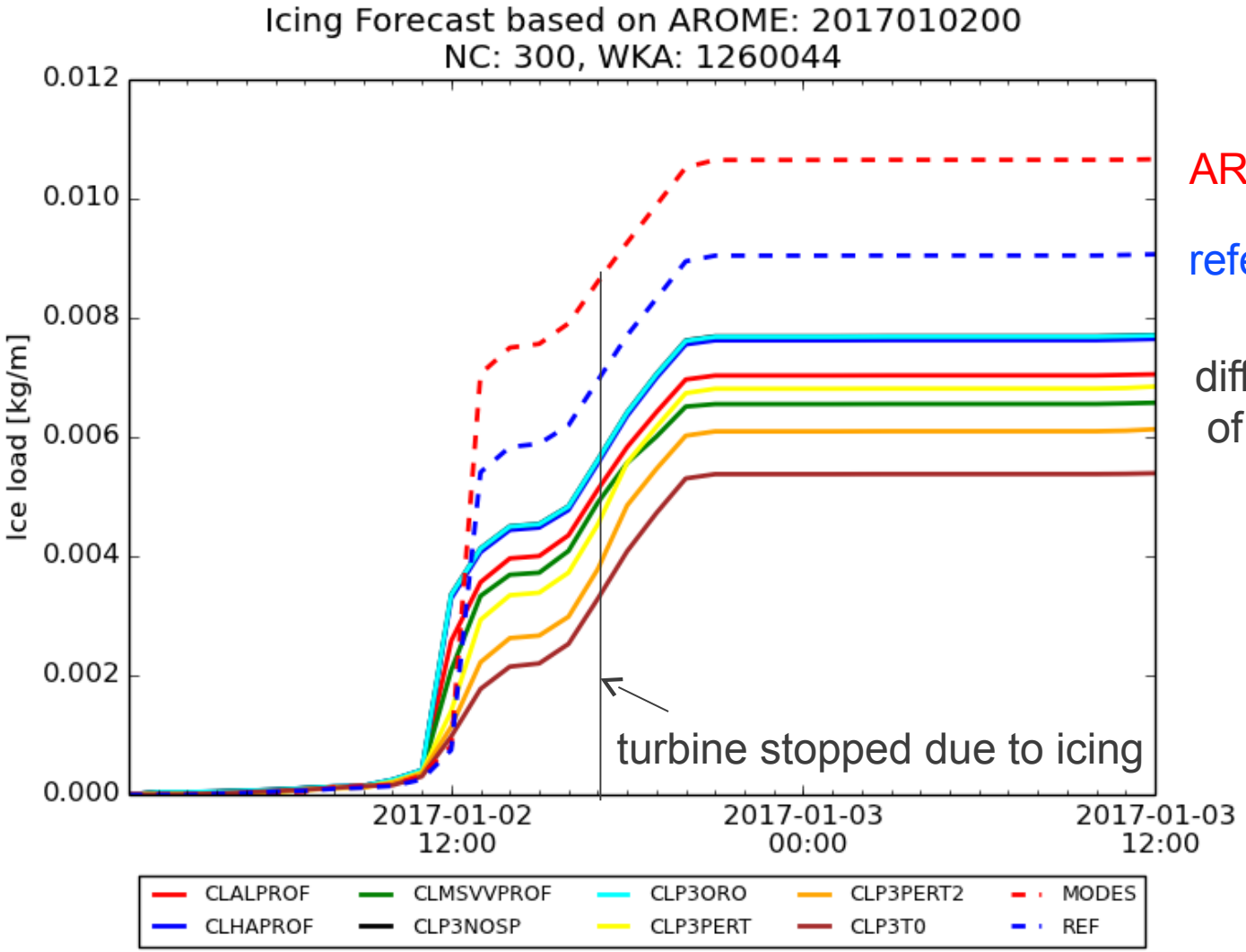


OBS at 6UTC



OBS at 9UTC

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



AROME+MODE-S

reference

different versions of cloud nudging

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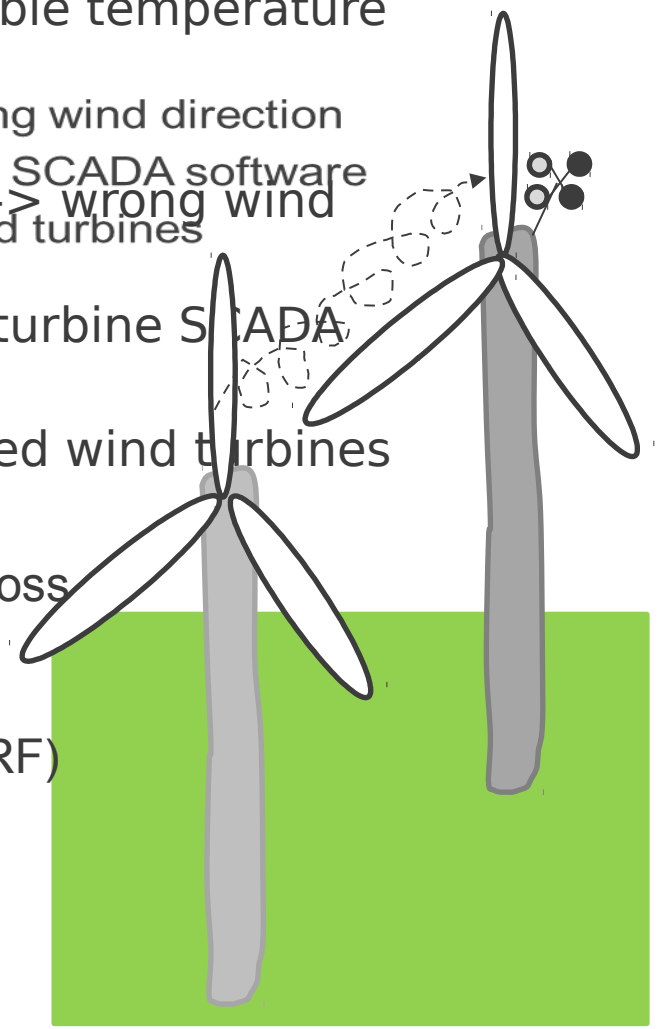
SCADA windturbine assimilation

- 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

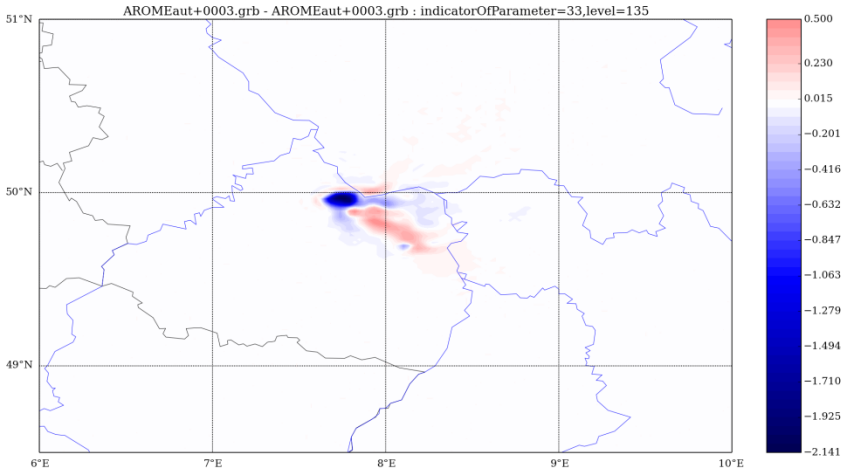


Possible solutions:

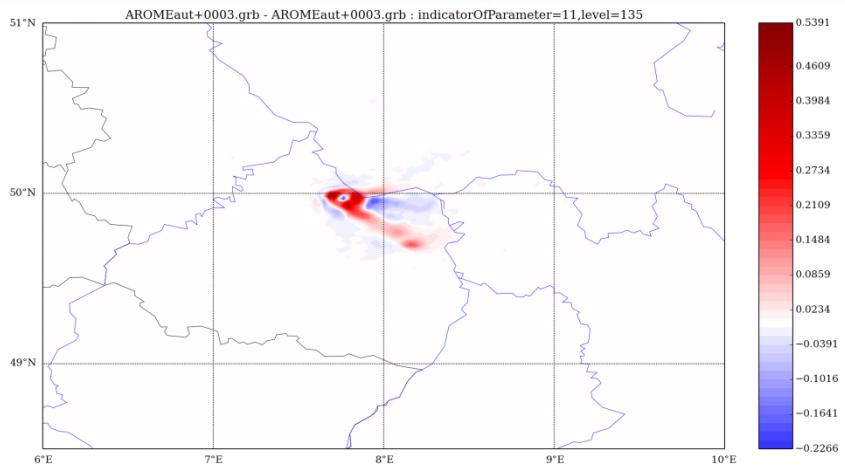
- Take only highest/single standing turbine data – data loss
- wind direction specific blacklisting
- bias correction from longer timeseries – variability?
- parameterise windfarm in model (Fitch et al. 2012, WRF) to reduce effect in the first guess

Supervisory Control and Data Acquisition

Parametrization of windfarms (21 Turbines)



Difference in U135m +3h



Difference in T135m +3h

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

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

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

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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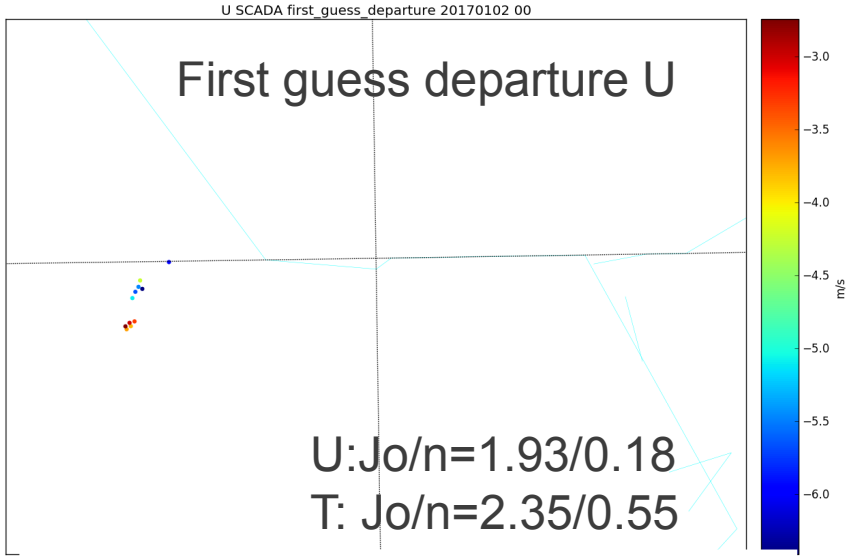
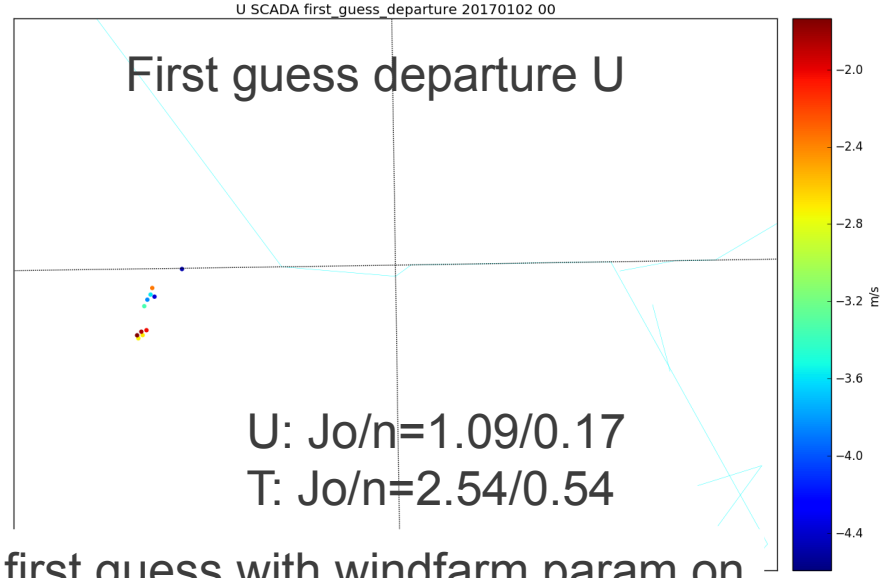
SCADA windturbine assimilation



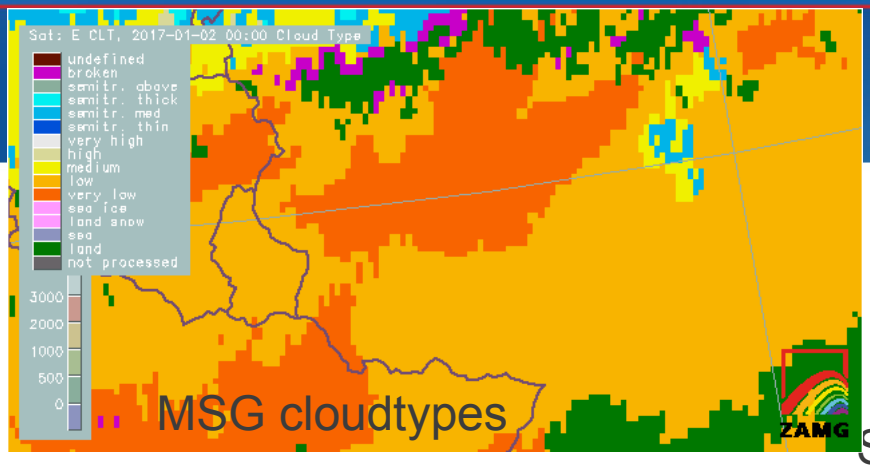
first guess with windfarm param off



first guess with windfarm param on

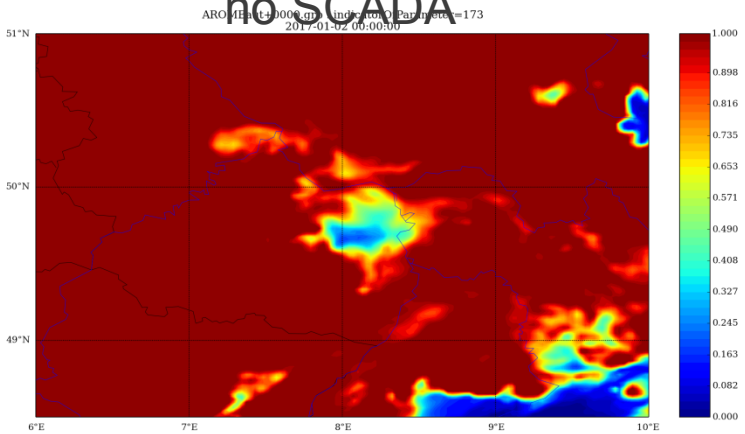
+3h forecast
Verified against
13 turbines

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

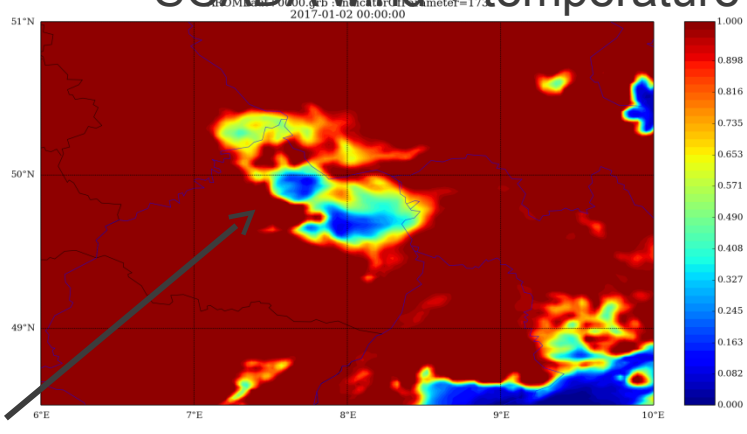


MSG cloudtypes

no SCADA



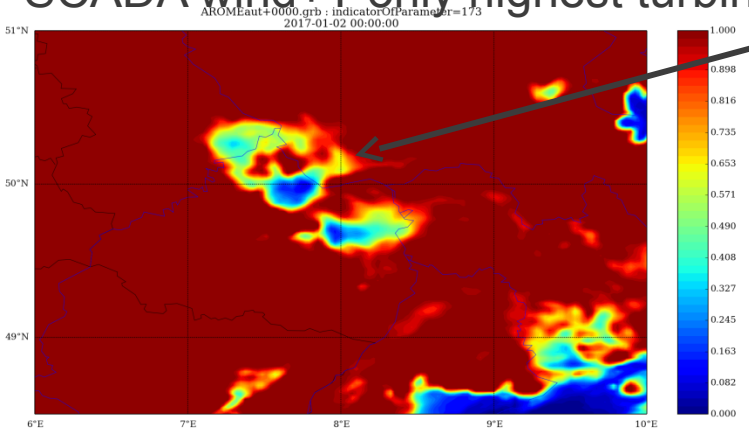
SCADA wind + temperature



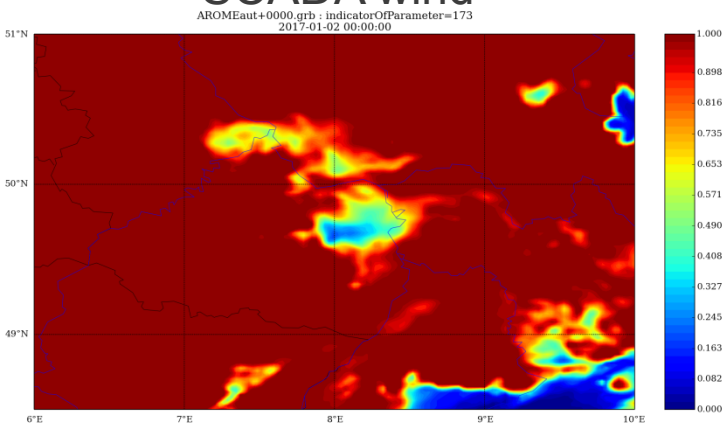
low clouds
2nd January
2017 00UTC+0h

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

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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

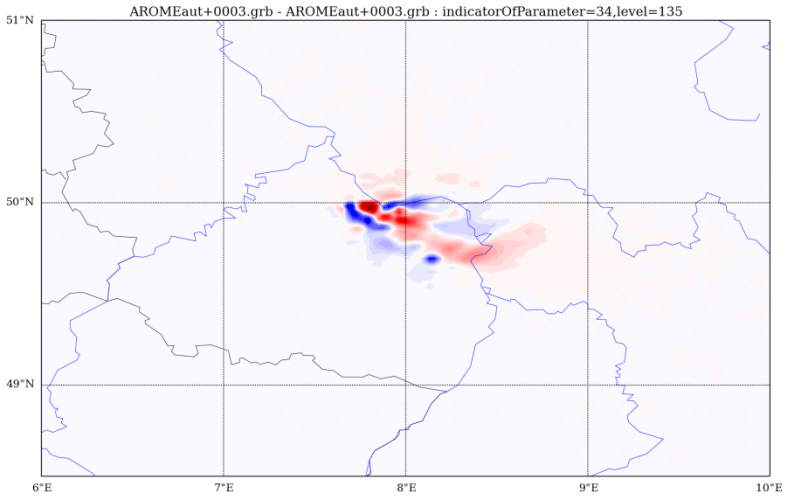
ALARO:
HUCRED=1.2
REFLRHC=150000.
TEQH=60.
RHCEXPDX=0.3
RDTFAC=1.0
SCLESPR=248000.
SCLESPS=2500.

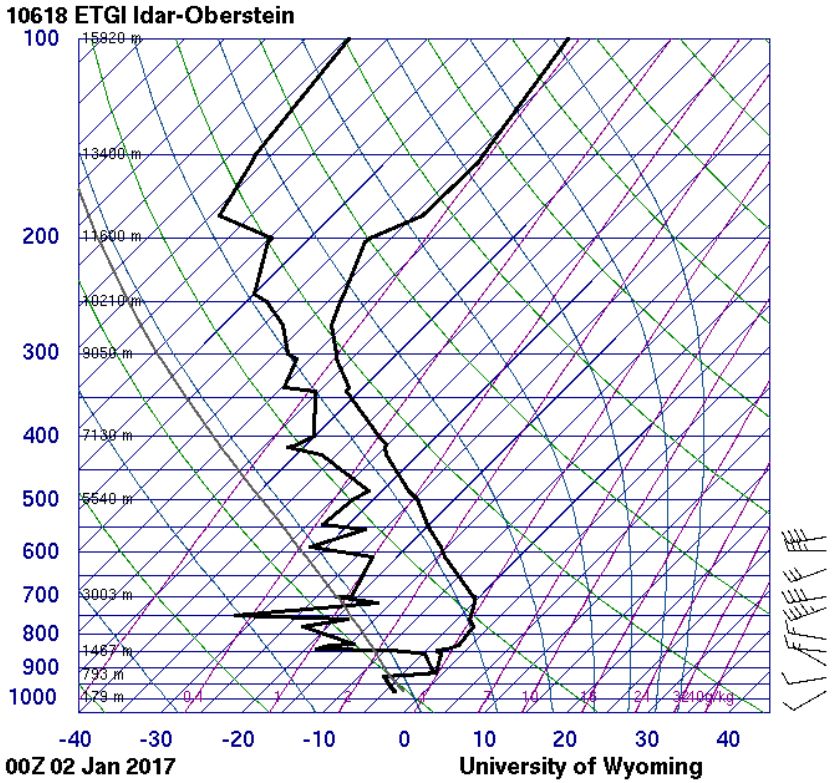
RHMAX=0.85
RHMIN=0.78

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

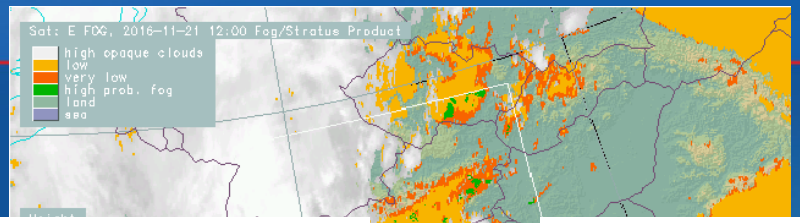
```
CCC=1._JPRB-MAX(1.E-12,HUCOE*ZVETAF*(1._JPRB-ZVETAF)/&
                & ((1._JPRB+HUTIL1*(ZVETAF-0.5_JPRB))*(1._JPRB+HUTIL2*&
                & (ZVETAF-0.5_JPRB))))
```

```
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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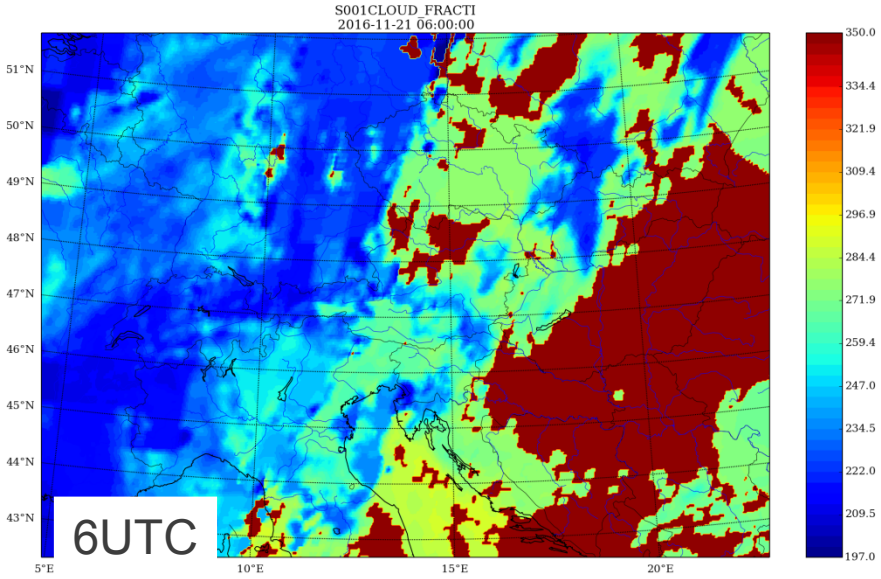
high opaque clouds
low
very low
high prob. fog
land
sea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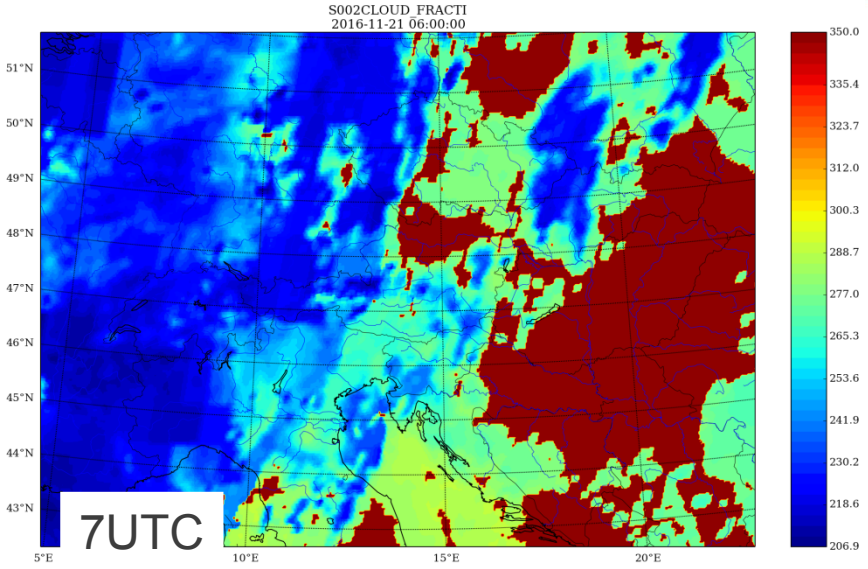
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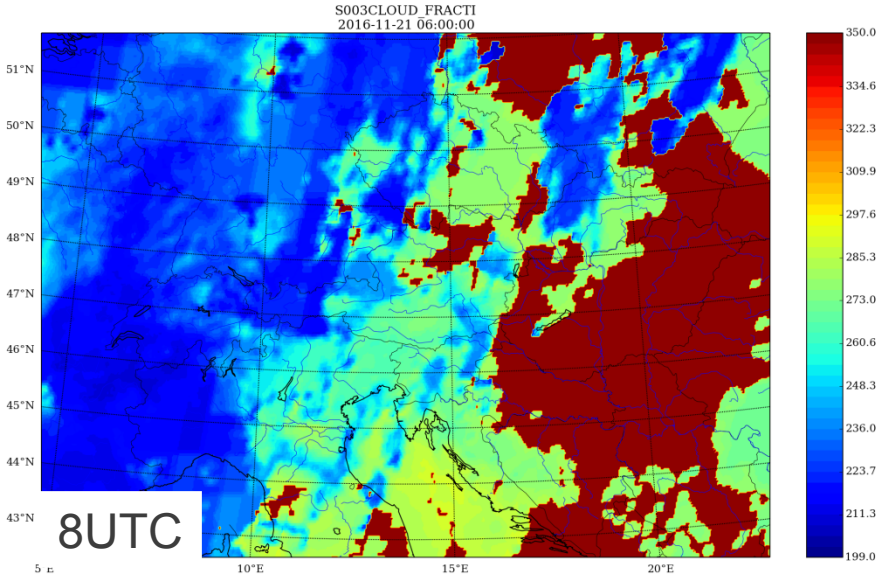
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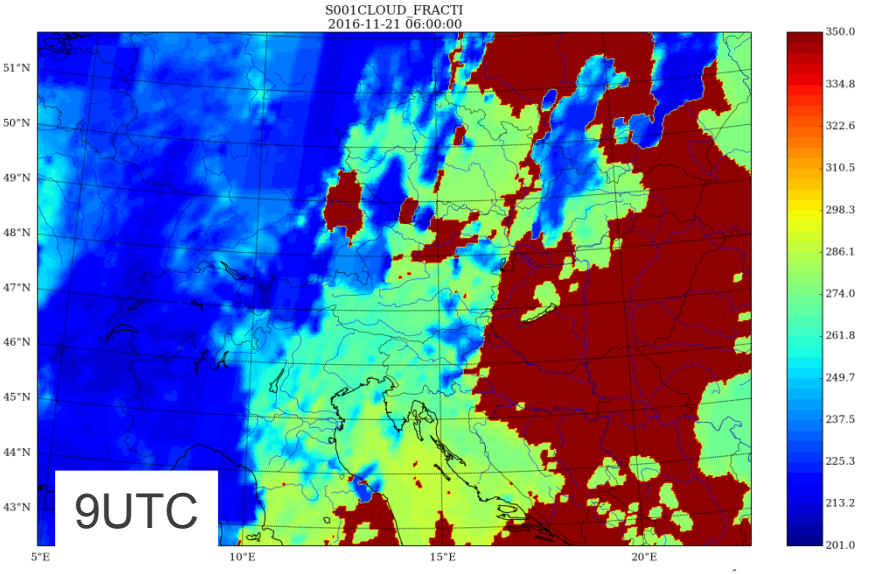
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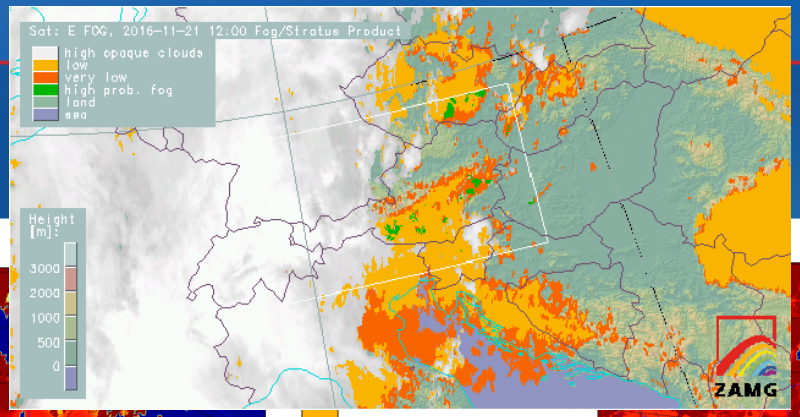
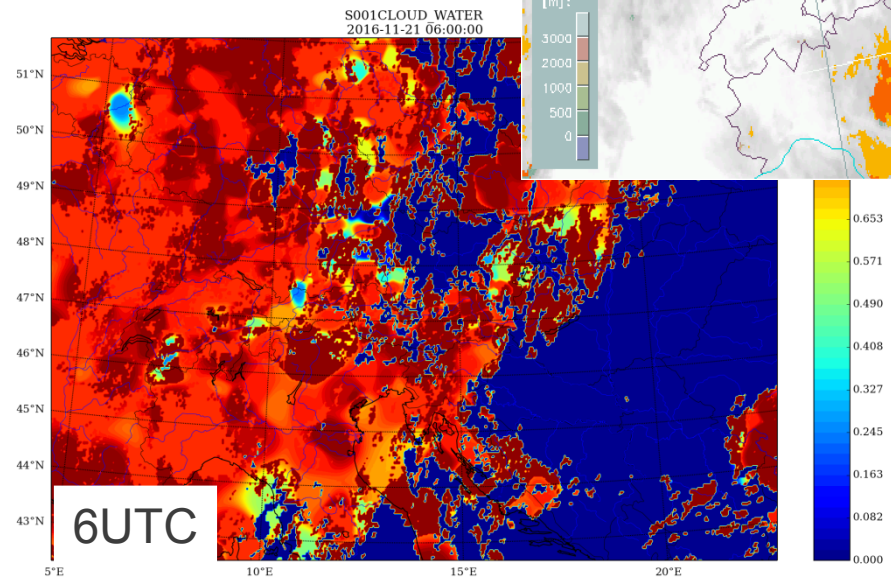

Sat: E FOG, 2016-11-21 12:00 Fog/Stratus Product
high opaque clouds
low
very low
high prob. fog
land
sea
Height [m]:
3000
2000
1000
500
0
ZAMG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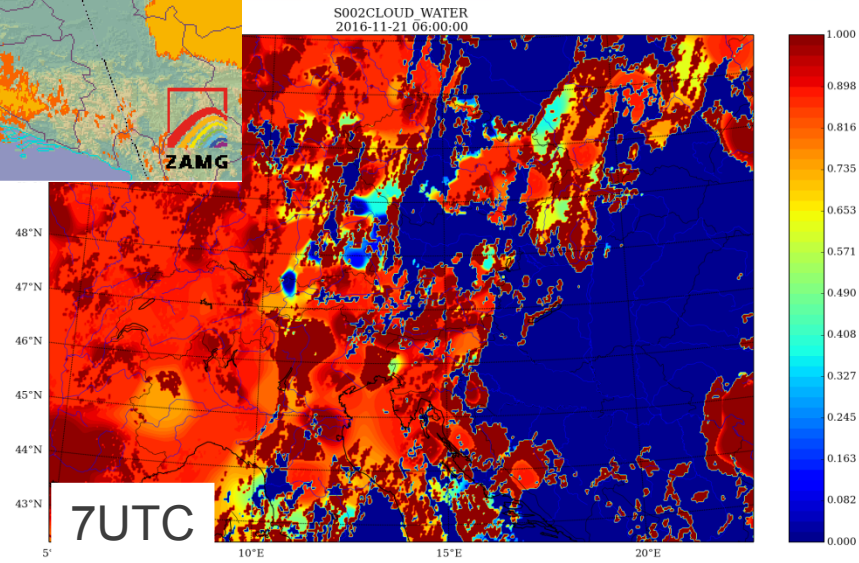
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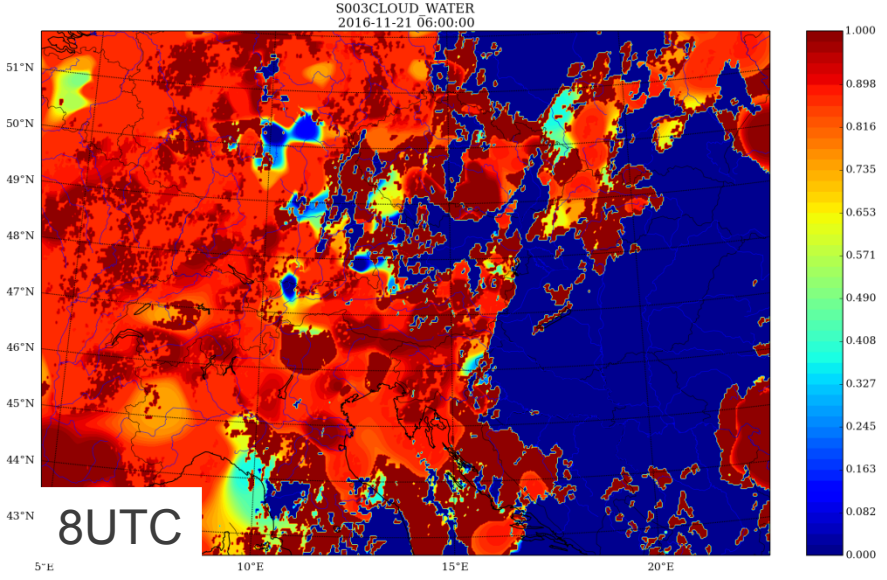
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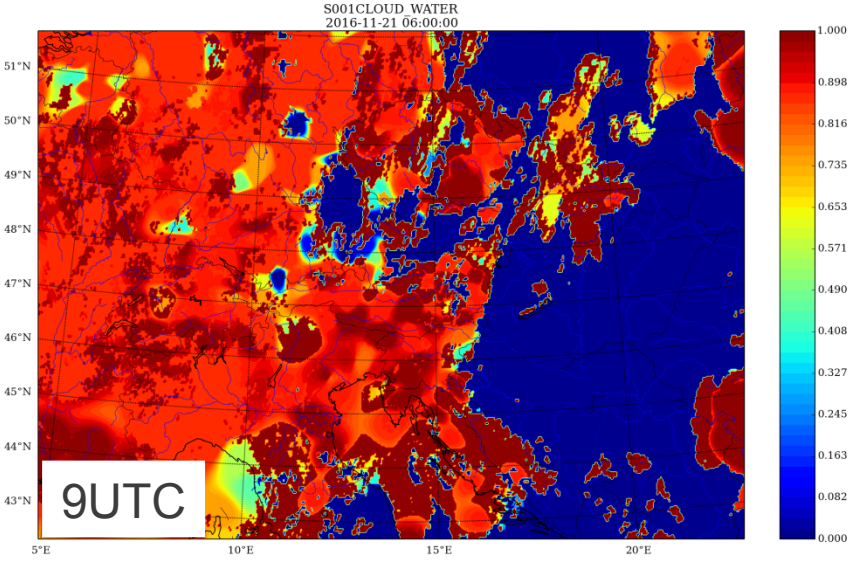
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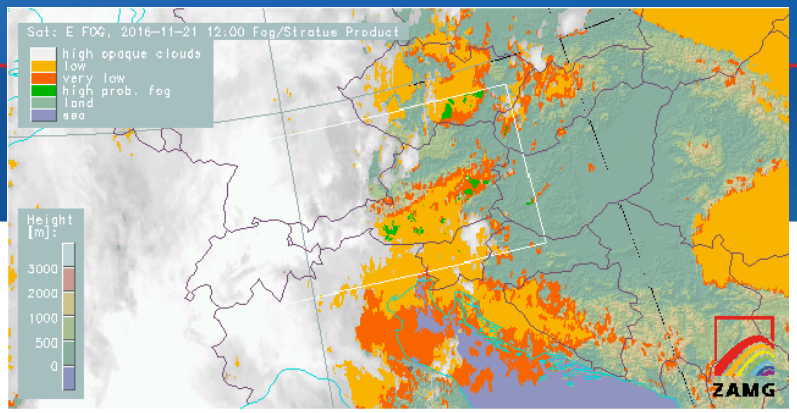
AROME-REF



2016112106
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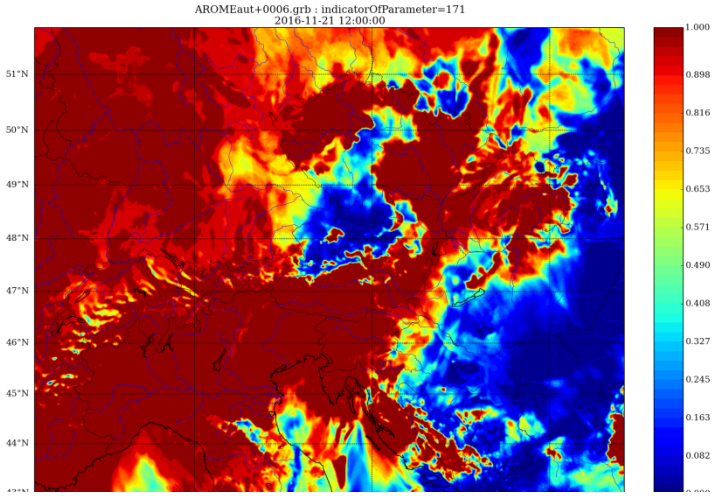
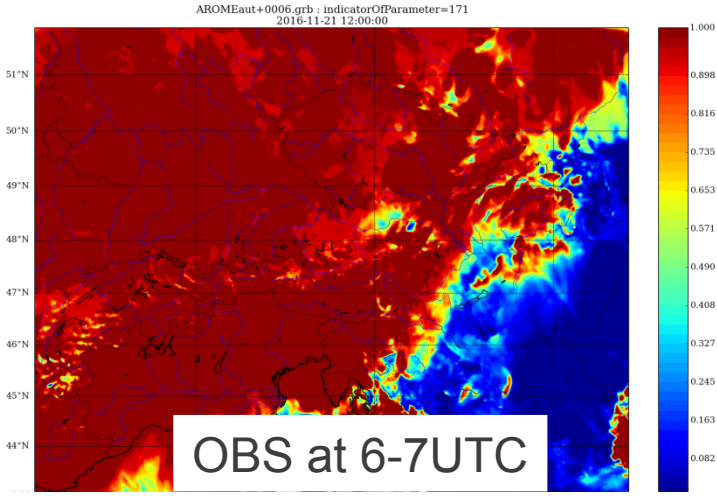
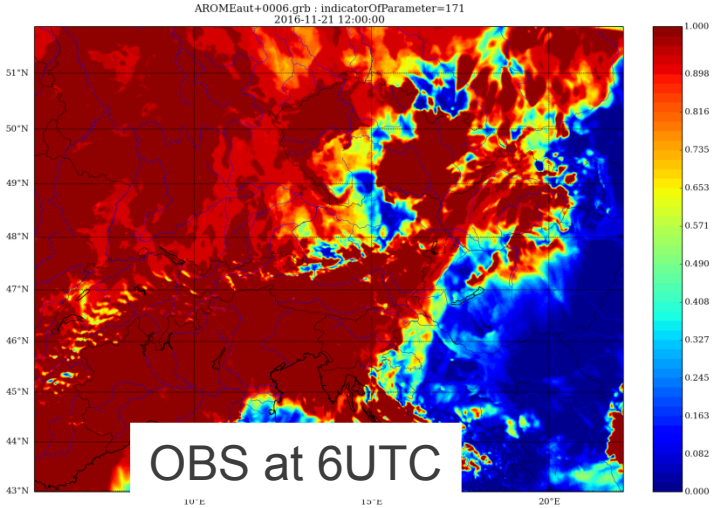
Sunrise in Vienna at 06:11UTC!





OBS at 6-7UTC



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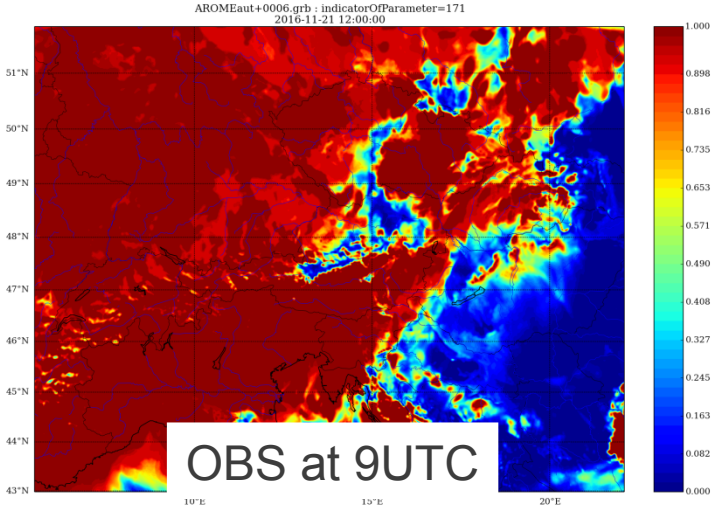
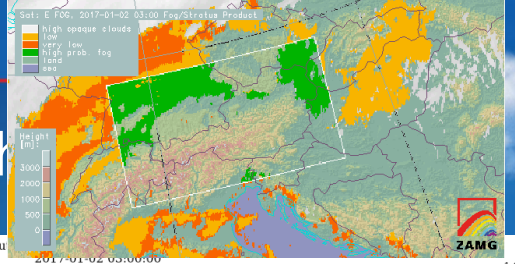
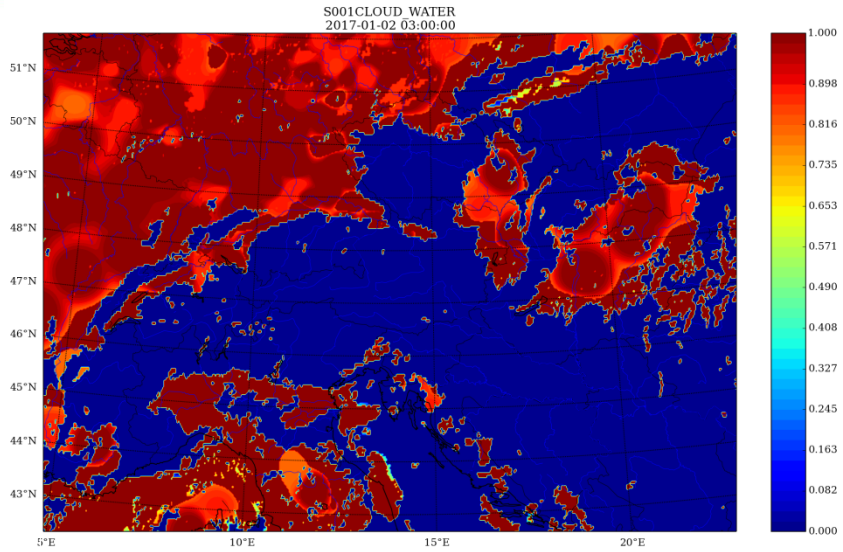


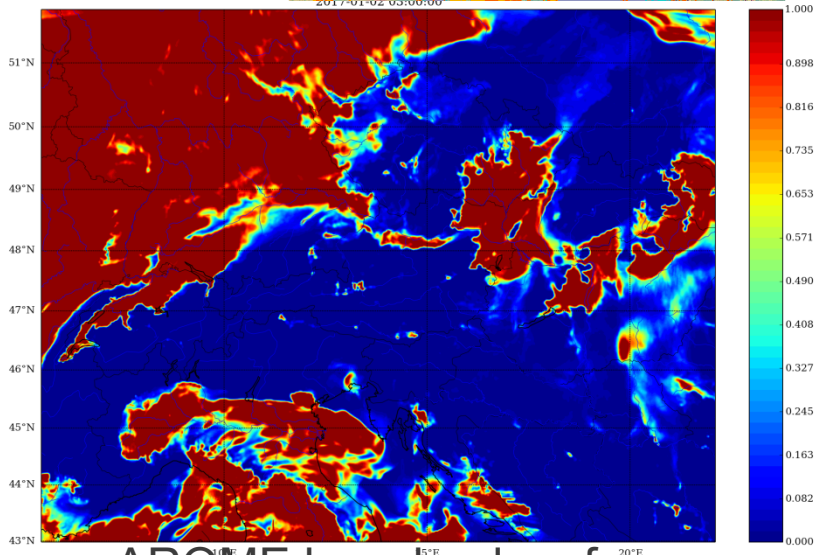
OBS at 9UTC

cloud nudging 2nd January 2017 00UTC+3h

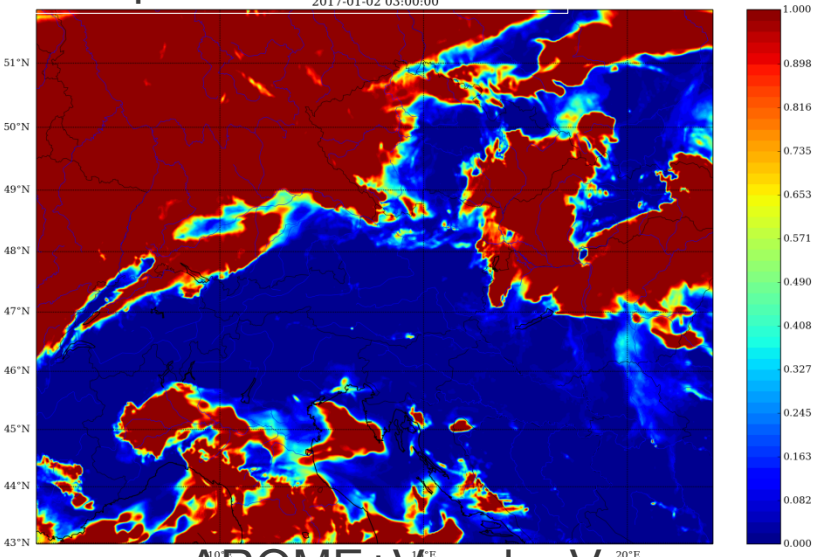




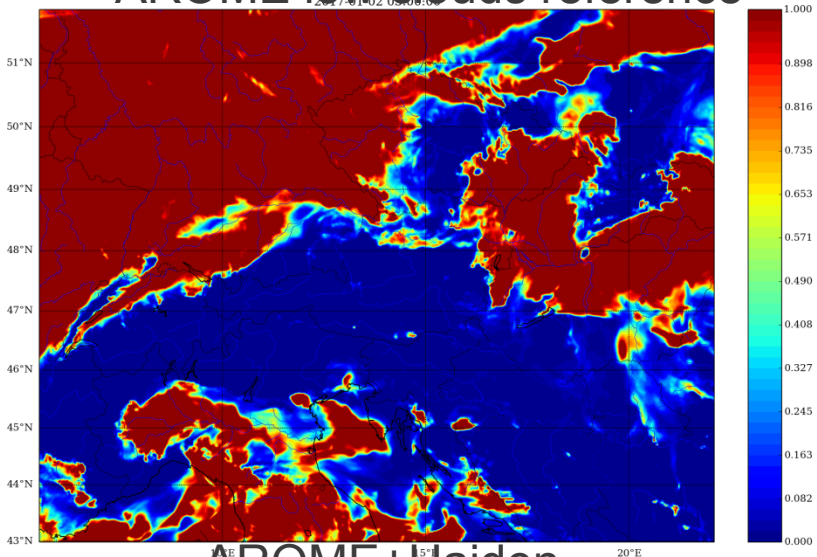
interpolated cloud cover



AROME low clouds reference



AROME+Van der Veen



AROME+Haiden