Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Modelling the Volcanic Ash Episode: Experiences with COSMO-ART

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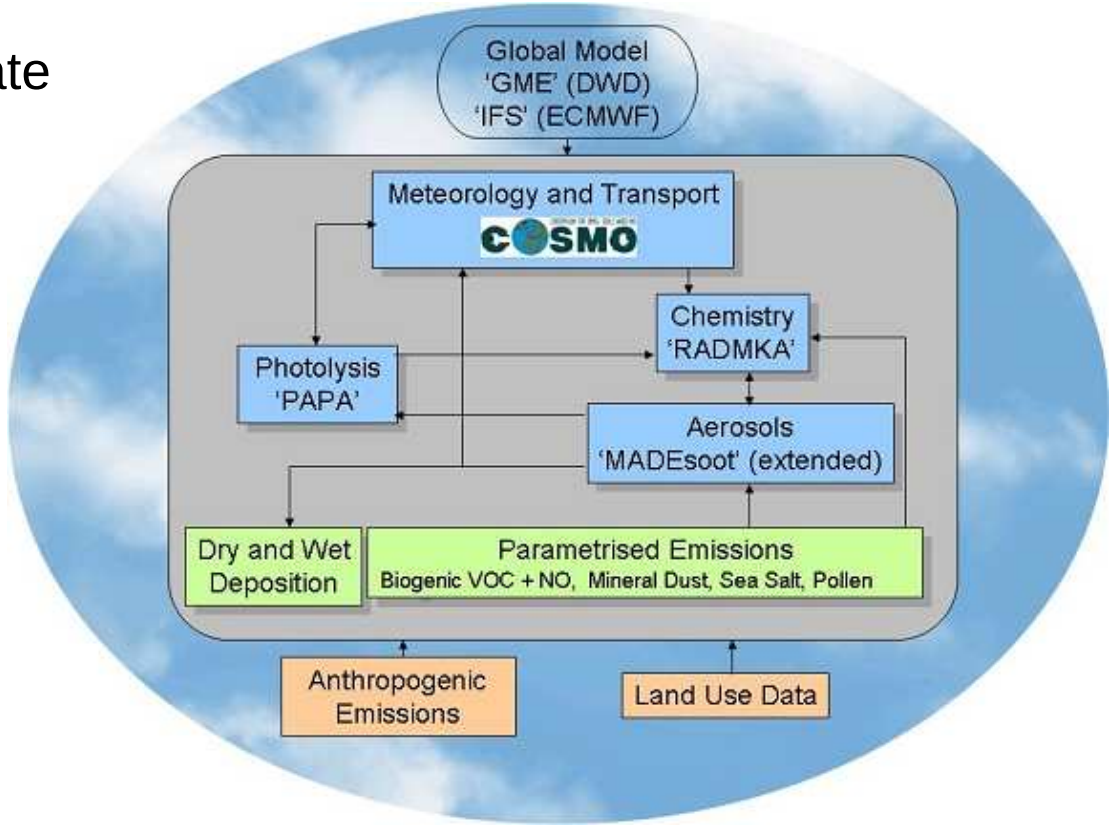
Karlsruhe Institute of Technology

COSMO-ART (Aerosols and Reactive Trace gases)

- Institute for Meteorology and Climate Research - Troposphere Research Bernhard and Heike Vogel
- Current application at DWD: Forecast of birch pollen
- Forecast of the volcanic ash episode of Eyjafjalla (using a modified pollen module)



Simulation Runs, Physical Processes (I)

- Experiment 7592 (Exp-A)
  - Period from 14.04.2010 00 UTC to 20.04.2010 00 UTC (144 hours): Simulation driven by COSMO-EU analyses (initial and boundary data)
  - From 20.04.2010 00 UTC daily 00 UTC and 12 UTC forecasts (78 h)
  - Line source at the location of the volcano (variable source height und -strength) 6 particle classes with diameters of 1, 3, 5, 10, 15 and 30 micrometer were emitted (each of them with the same density and source strength)
  - Advection, turbulent diffusion, sedimentation
- Experiment 7595 (Exp-B)
  - Period from 14.04.2010 00 UTC to 23.04.2010 00 UTC (216 hours): Simulation driven by COSMO-EU analyses
  - From 23.04.2010 00 UTC daily 00 UTC and 12 UTC forecasts (78 h)
  - … dito
  - Additional processes: turbulent dry and wet deposition

Simulation Runs, Physical Processes (II)

- Experiment 7804 (Exp-C)
  - … as 7595 (Exp-B)
  - Additional process: convective transport
- Experiment 7814 (Exp-D)
  - … as 7804 (Exp-C)
  - 80 model layers (instead of 40, especially more in the PBL)
- Experiment 7879 (Exp-E)
  - … as 7804 (Exp-C)
  - From 14.04.2010 00 UTC daily 00 UTC, 12 UTC "normal" (i.e. driven by GME data) forecasts (78 h) and 06 UTC, 18 UTC forecasts (48 h)

Remark: As the exact source strength is not known,
the **absolute** values of the simulated concentrations are not comparable to observed ones!

Physical Processes (III)

- Advection: centered differences (2nd order) – HE / VI
  (as q_v and q_c in Leapfrog core, which was still operational in April 2010)
- Vertical turbulent diffusion: prognostic TKE scheme
- Horizontal diffusion (4th order): coefficient = 0.5 (as for q_x)
- Sedimentation („gravitational dry deposition“): implicit vertical advection with $w + w_{sed}(D_{Ax},\varphi_A)$
- Turbulent dry deposition at the surface (lowest model layer)
- Wet deposition due to precipitation

$$c_{A_x} = c_{A_x} - 2\Delta t \cdot 3\frac{N}{kg \cdot m}\left(P_R^{CON} + P_R^{GSP}\right)c_{A_x} \qquad \text{mit } c_{A_x} \text{ in } \left[\frac{\mathrm{N}}{\mathrm{m}^3}\right]$$

- Convective transport in the Tiedtke massflux scheme

Variation of source height and -strength (new dataset every 6 h)

14.04.2010 00 UTC -	0.0000	40
14.04.2010 06 UTC -	0.5455	17
14.04.2010 12 UTC -	0.5455	17
14.04.2010 18 UTC -	1.0000	17
15.04.2010 00 UTC -	1.0000	17
15.04.2010 06 UTC -	0.8182	12
15.04.2010 12 UTC -	1.0000	10
15.04.2010 18 UTC -	0.8182	11
16.04.2010 00 UTC -	0.6364	15
16.04.2010 06 UTC -	0.7273	14
16.04.2010 12 UTC -	0.7273	14
16.04.2010 18 UTC -	0.7273	14
17.04.2010 00 UTC -	0.8182	11
17.04.2010 06 UTC -	0.8182	11
17.04.2010 12 UTC -	0.8182	11
17.04.2010 18 UTC -	0.8182	11

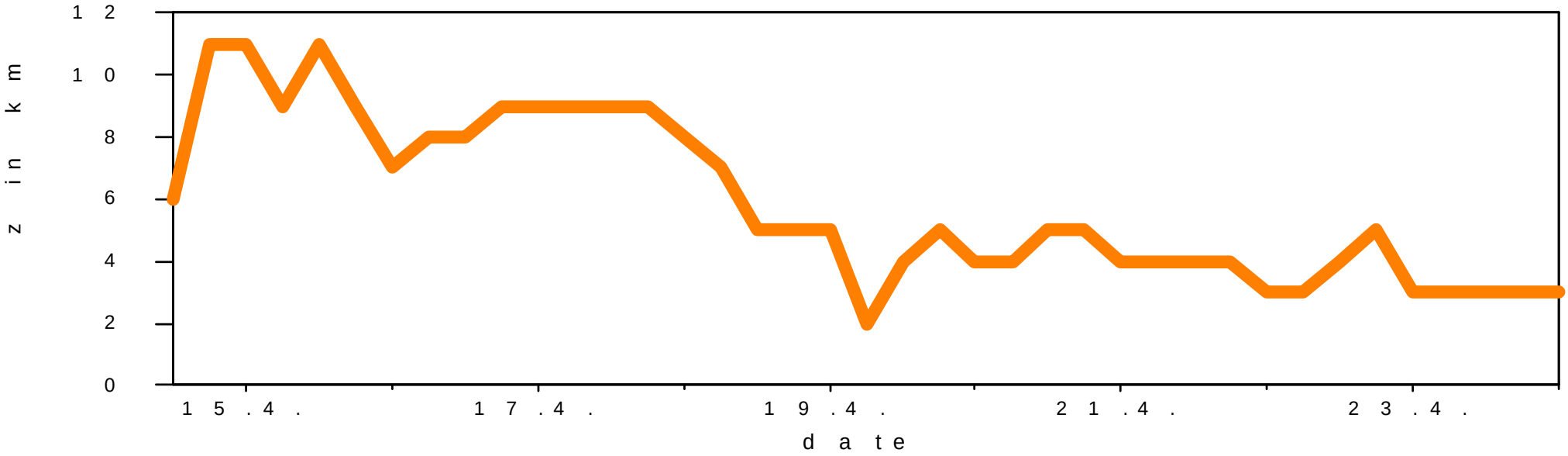
2nd col.: factor [0.0,1.0]

3rd col.: uppermost model layer -
constant emission profile below, no emission above

k	p_0 (hPa)	z (m)	Δz (m)
1	30.00	22184.5	2808.0
2	50.18	19807.4	1946.2
3	70.88	18062.0	1544.5
4	92.36	16634.0	1311.5
5	114.84	15307.8	1161.0

k	p_0 (hPa)	z (m)	Δz (m)
21	624.48	3837.7	443.8
22	659.37	3408.4	414.8
23	693.40	3007.8	386.3
24	726.35	2635.5	358.3
25	758.01	2291.1	330.6

model layers of COSMO-EU



VAAC (Volcanic Ash Advisory Centre), MetOffice UK

➔ Modell: NAME III (Numerical Atmospheric dispersion Modeling Environment)
http://en.wikipedia.org/wiki/NAME_(dispersion_model)

Features and capabilities of NAME:
NAME (in its current NAME III version) is a **Lagrangian air pollution dispersion model** for short range to global range scales. It employs 3-dimensional meteorological data provided by the Met Office's Unified National Weather Prediction Model. Random walk techniques using empirical turbulence profiles are utilized to represent turbulent mixing. In essence, NAME follows the 3-dimensional trajectories of parcels of the pollution plume and computes pollutant concentrations by Monte Carlo methods — that is, by direct simulation rather than solving equations. NAME uses a puff technique when modeling dispersion over a short range which shortens the time needed to compute the pollutant concentrations at the receptors. The model has the capability to calculate: the rise of buoyant plumes; deposition of pollution plume components due to rainfall (i.e., wet deposition); dry deposition; plume chemistry focusing on sulphate and nitrate chemistry; plume depletion via the decay of radioactive materials; the downwash effects of buildings. The model can also be run 'backwards' to generate maps that locate possible plume originating sources.

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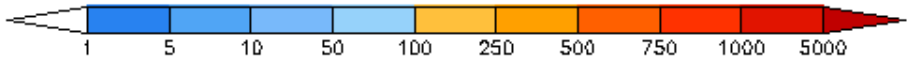
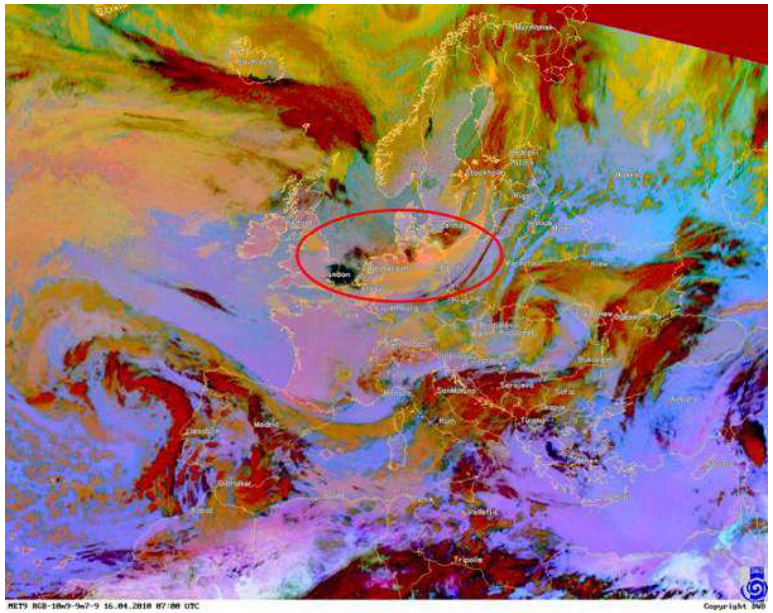
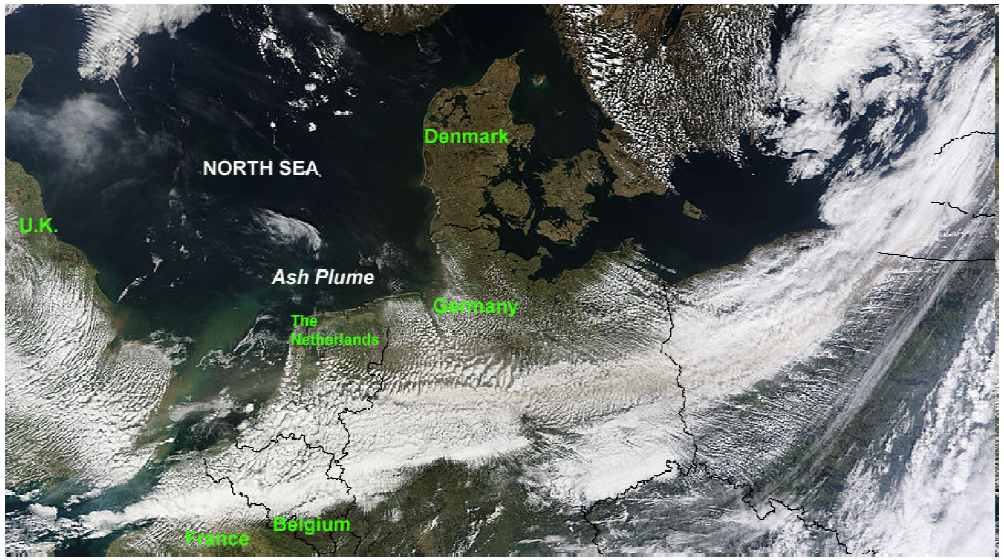
Concentration field of the 1µ ash class
for 16.04.2010 09 UTC (vv=57 h)
in model layer 16 (approx. 6500 m):

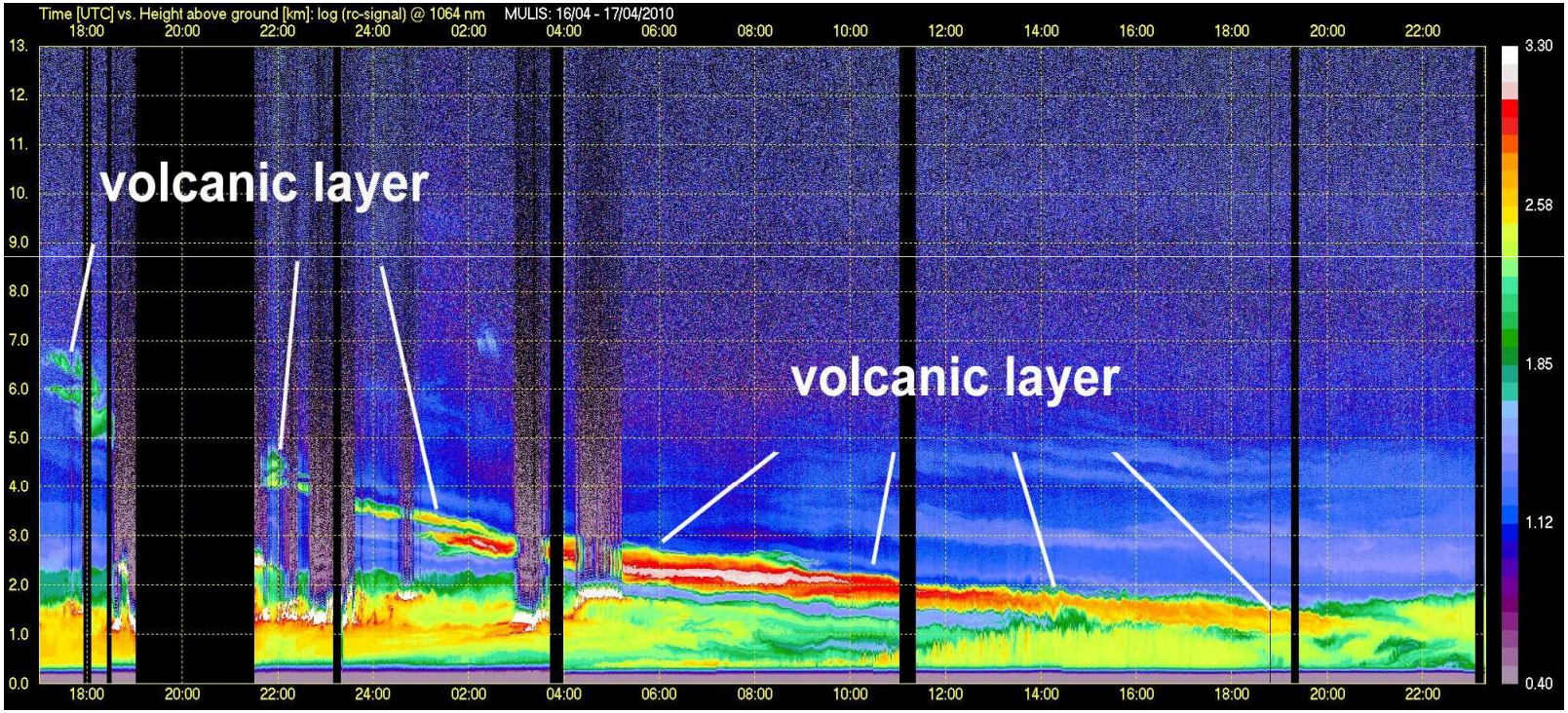


[N/m^3]

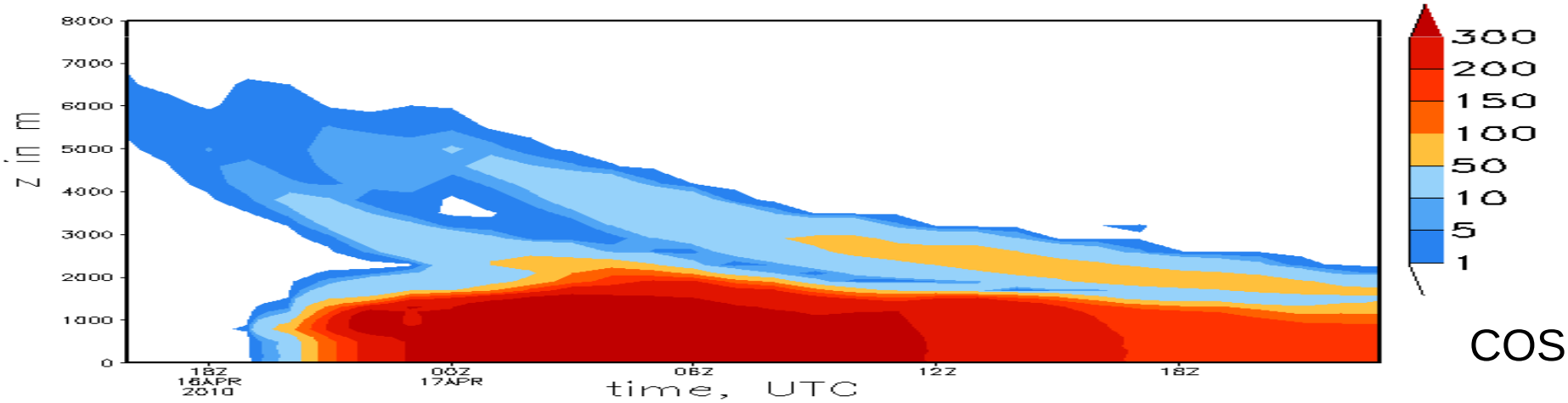




Satellite images at approx. same time:

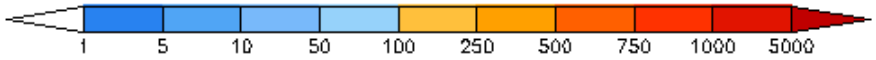


Lidar
Uni München



COSMO-ART

Exp-C (216 h driven by analyses)
1 µm particel in model layer 30 (ca. 1000m)



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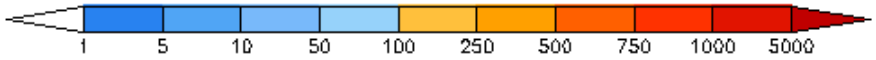
… dito, i.e. Exp-C after 66 hours forecast



Deutscher Wetterdienst
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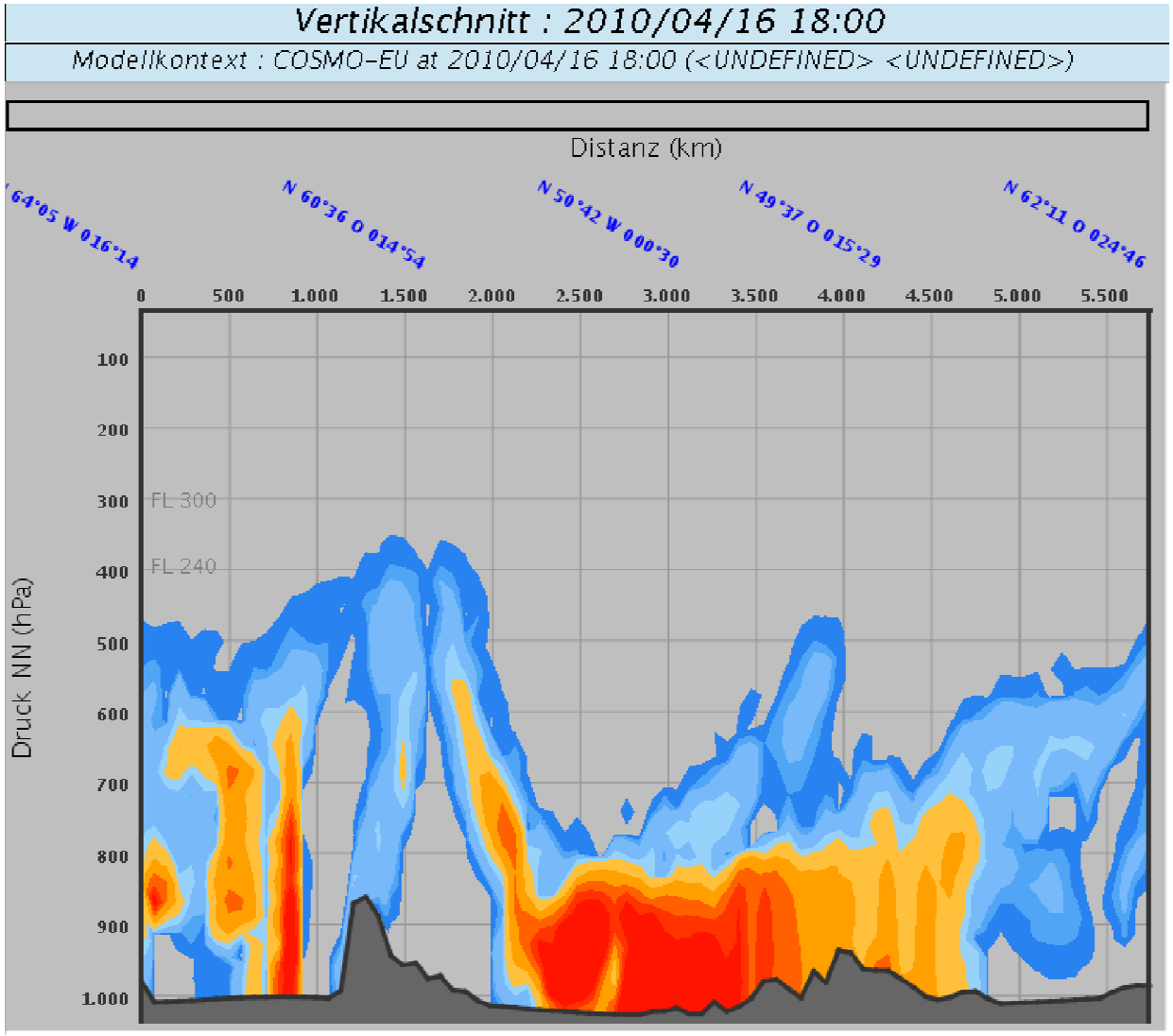
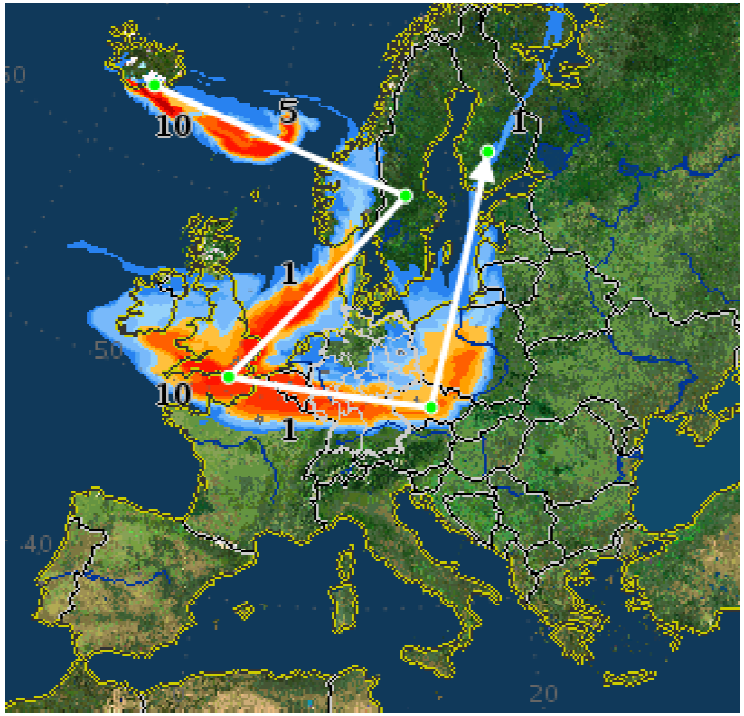
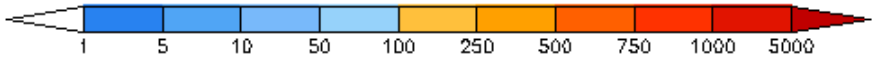


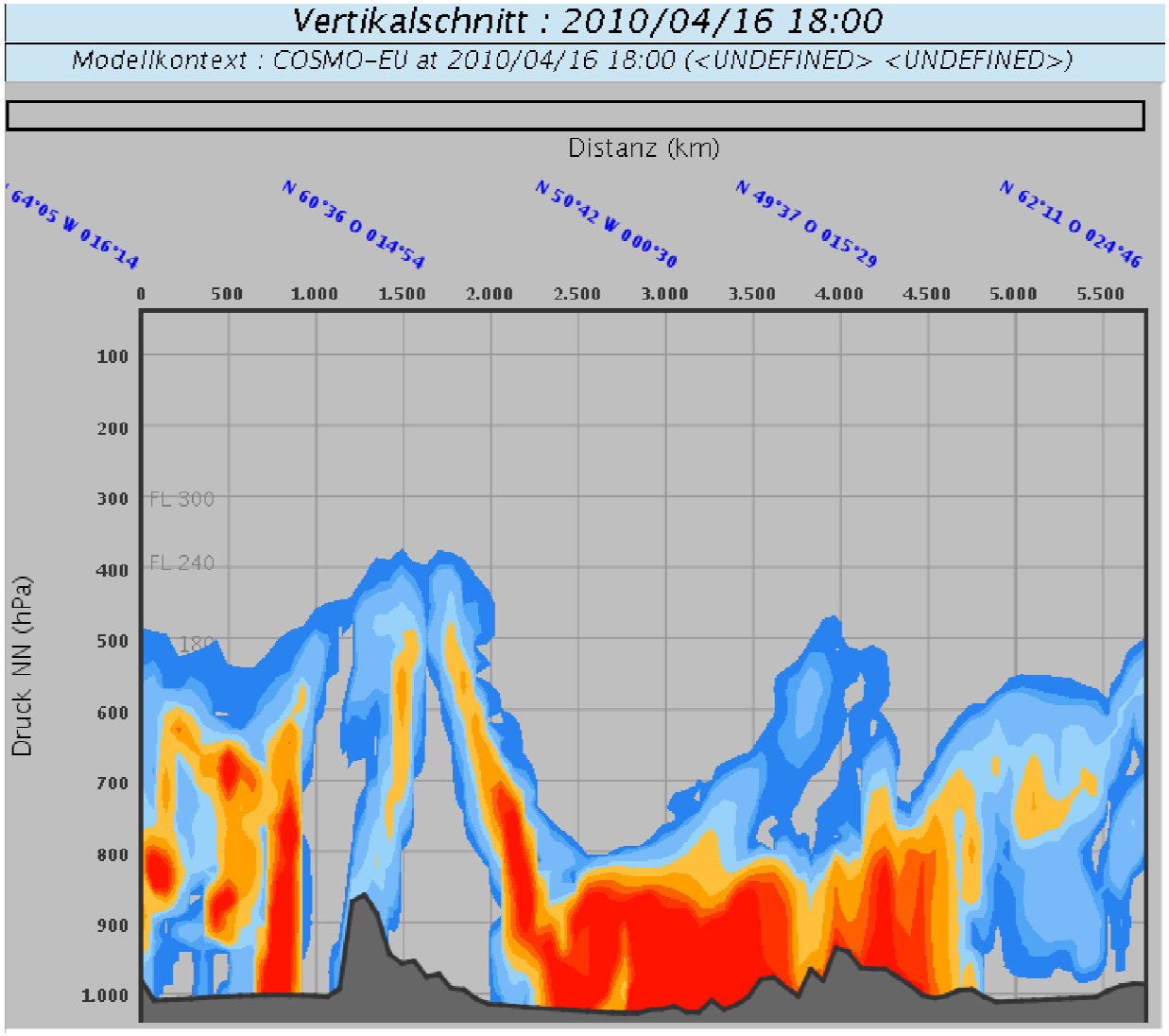
Visualization in NinJo: Cross-Section Layer



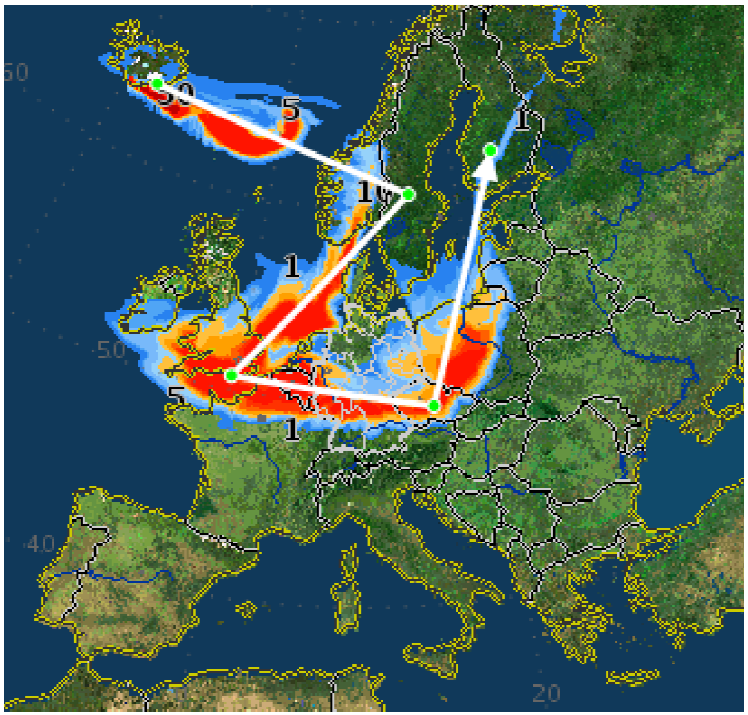
Exp-D (80 layers) after 66 hours forecast



Deutscher Wetterdienst
Wetter und Klima aus einer Hand



Visualization in NinJo: Cross-Section Layer



Comparison:
with / without wet deposition

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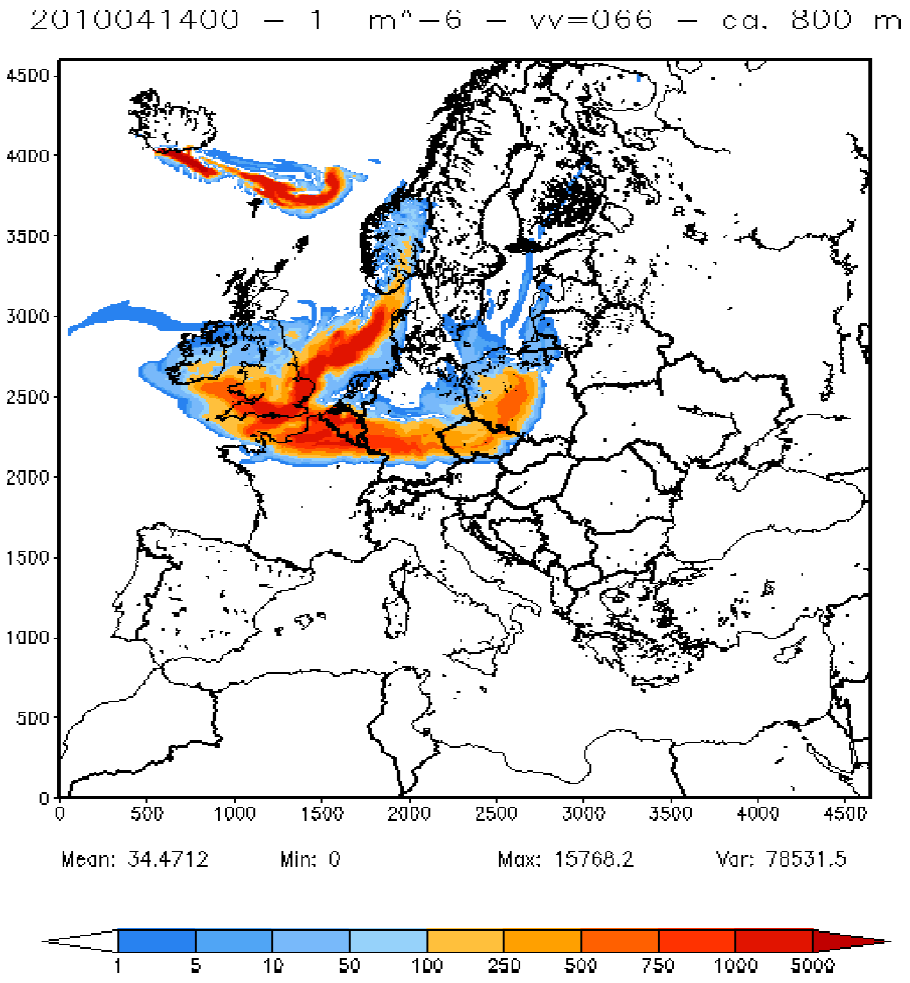
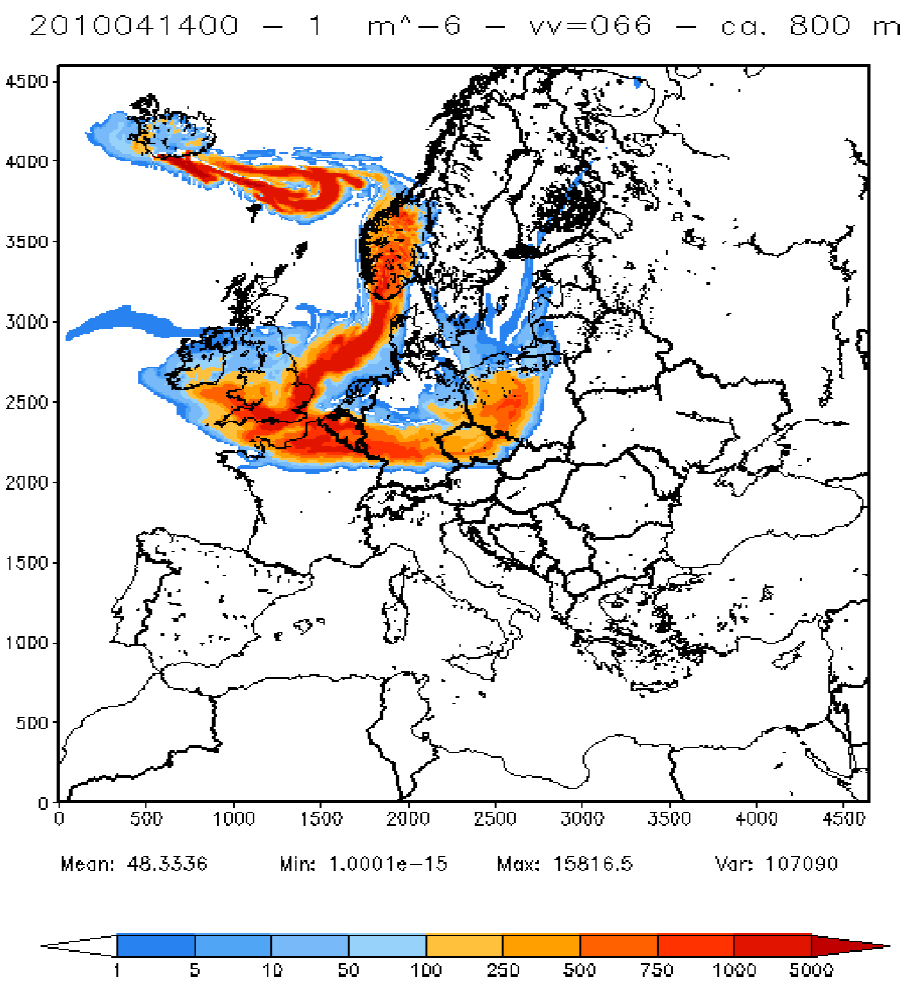


Exp-B



Exp-A

Comparison:
with / without wet deposition

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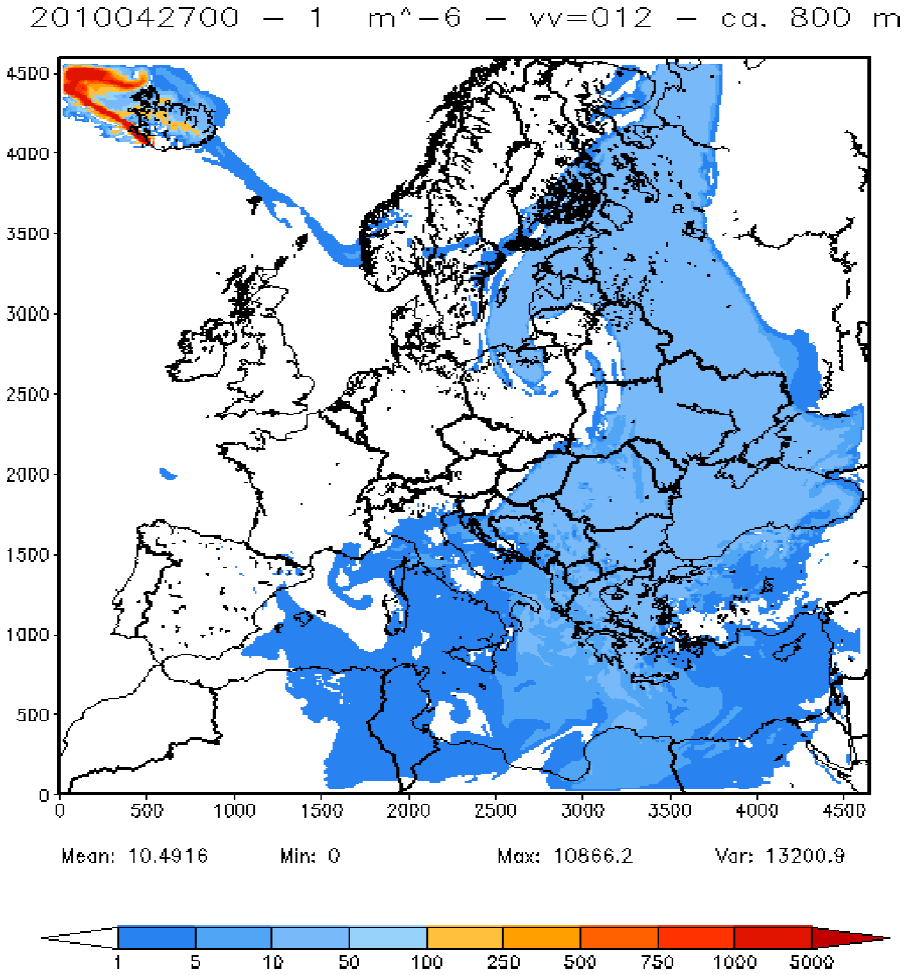
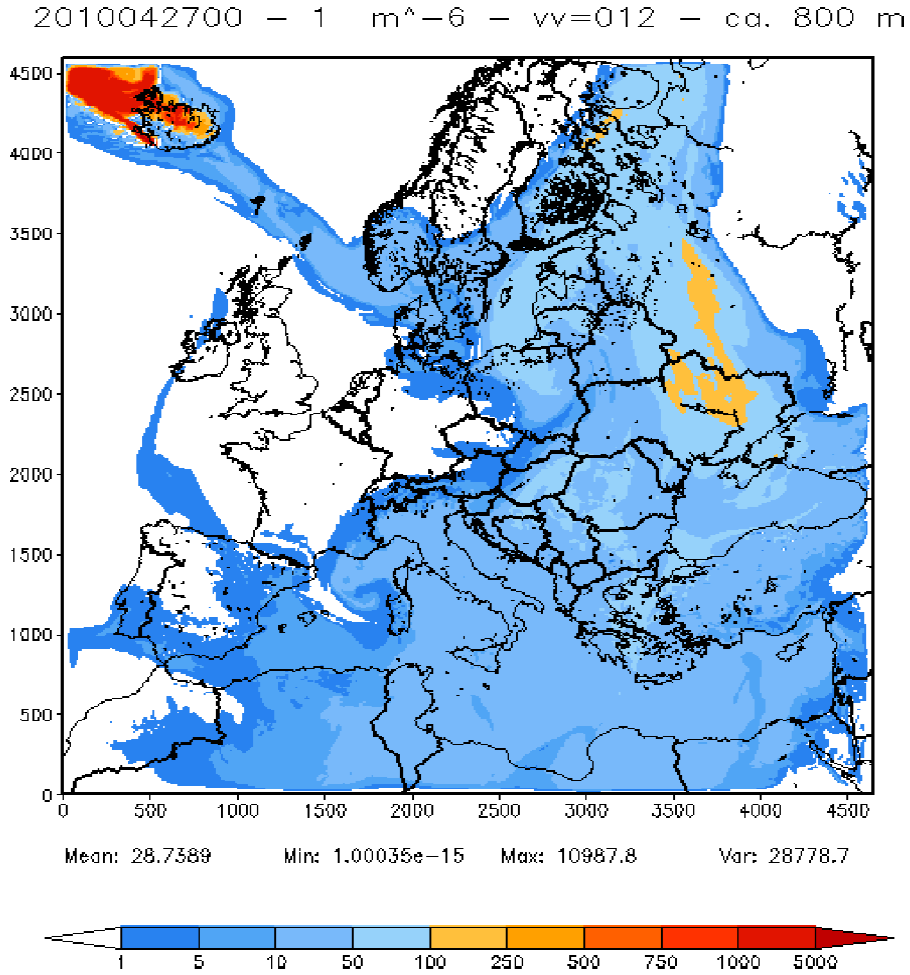


Exp-B



Exp-A

Comparision with VAAC (MetOffice)

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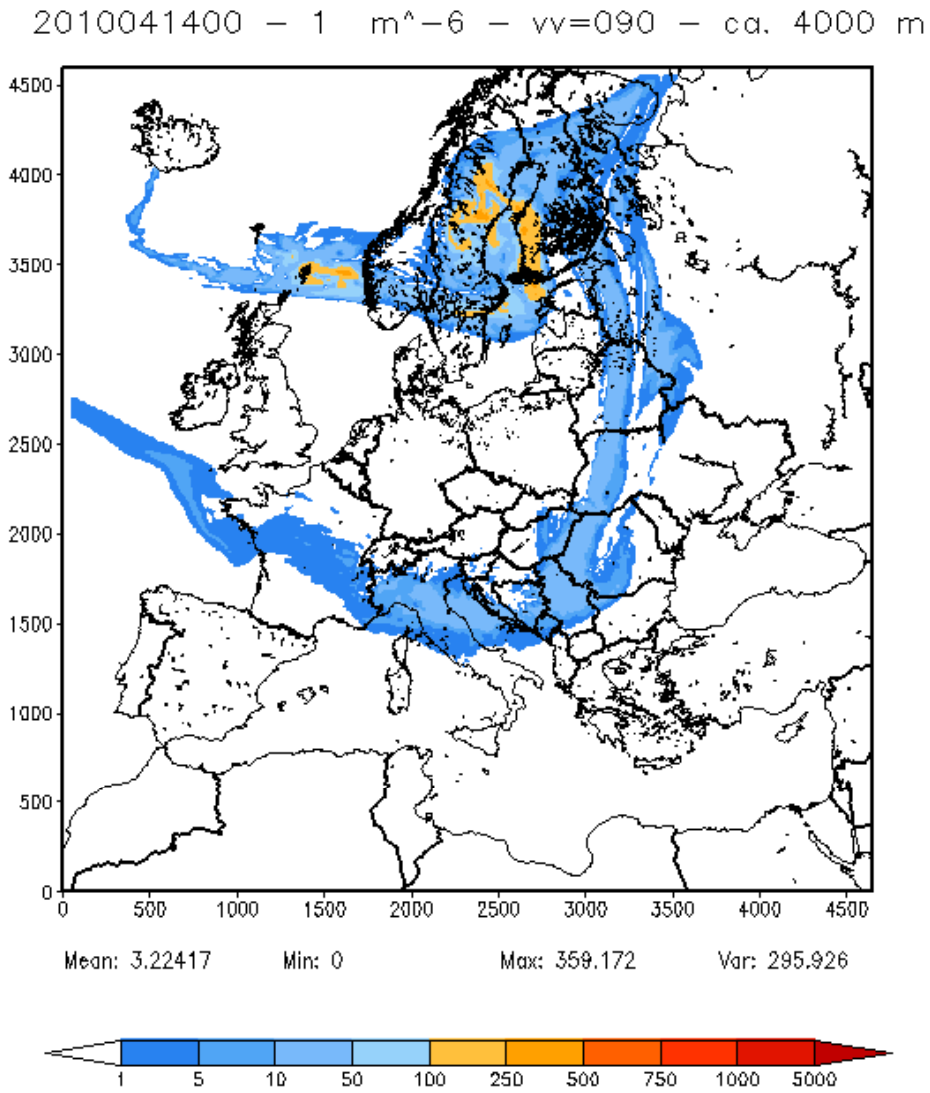
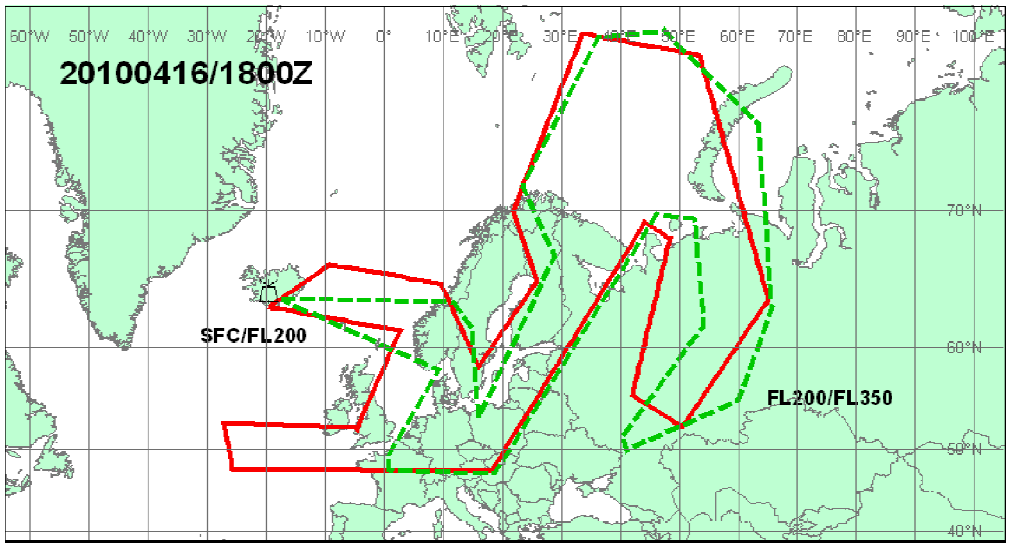
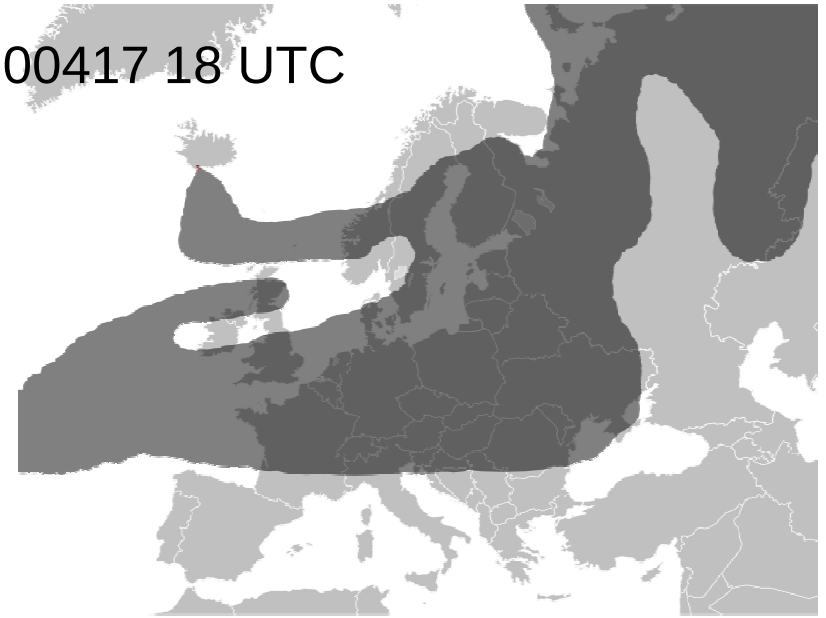


Exp-C





Comparison: different model layers

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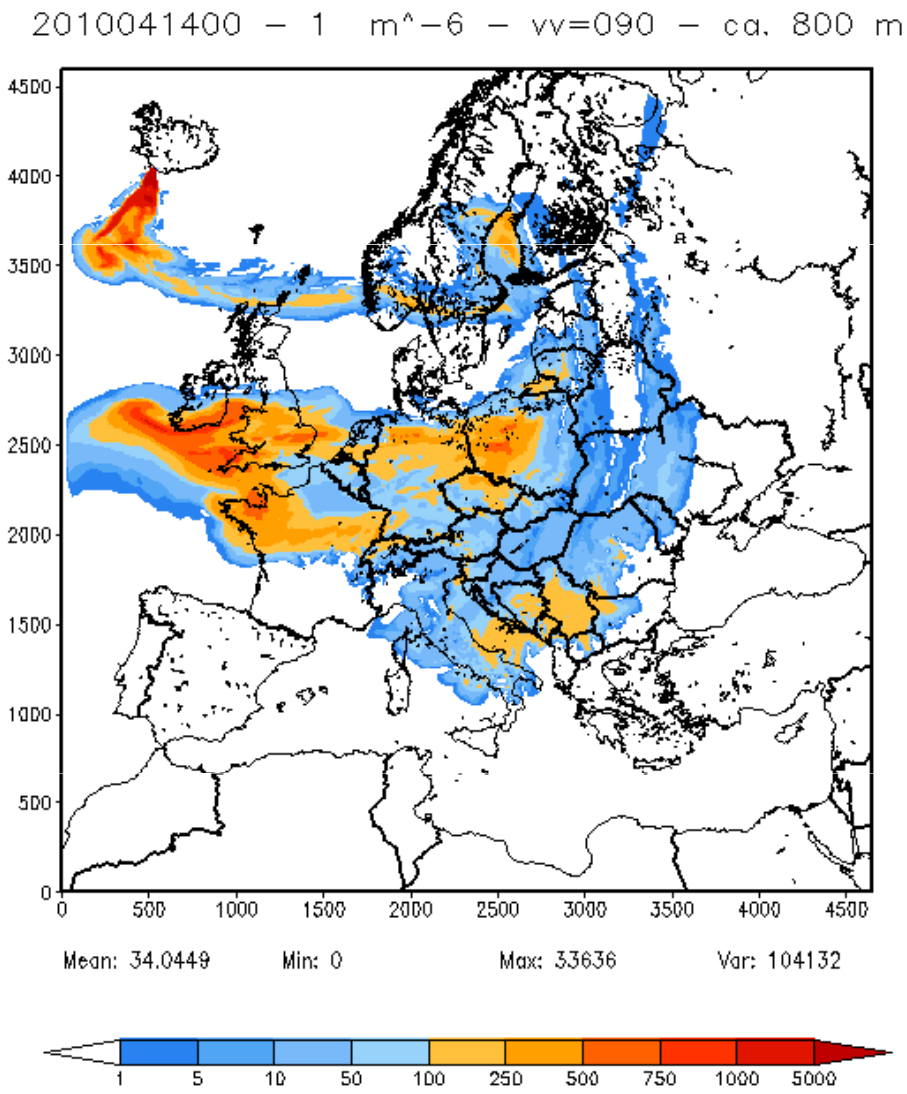

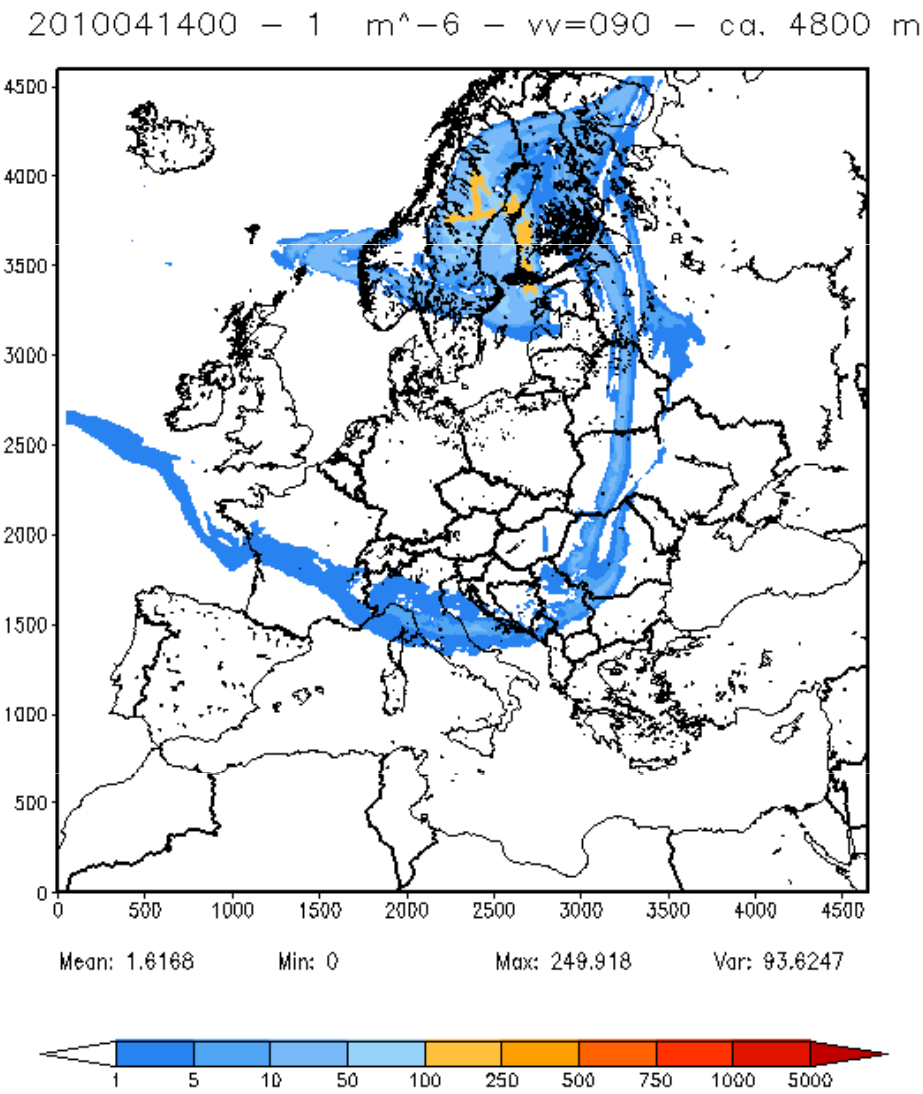

ca. 800 m

Exp-C

ca. 4800 m

Comarison: size of particles

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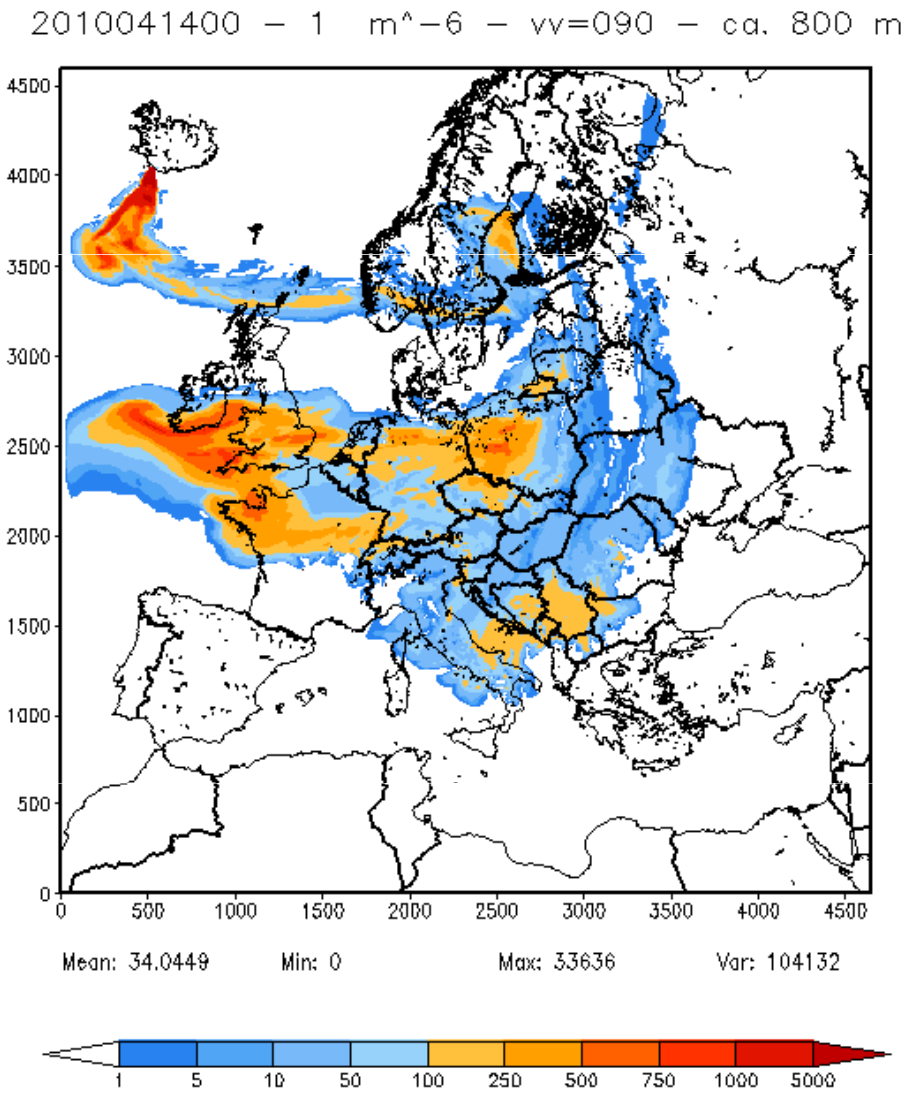
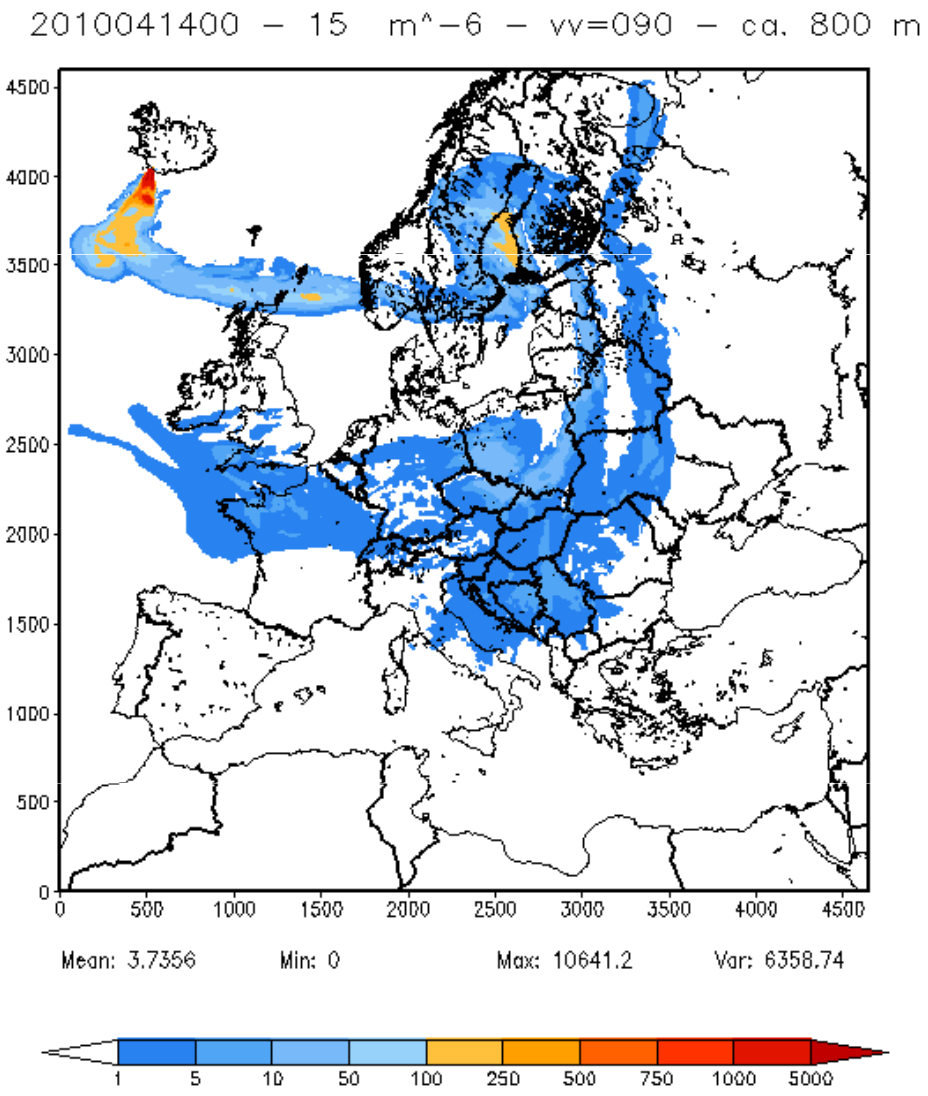




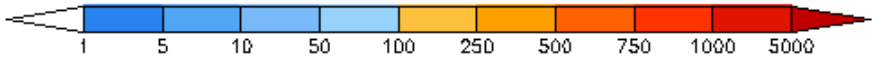
Exp-C

1 µm

15 µm

Exp-E (78 h / 48 h runs in forecast mode) - Date: 17.04.2010 12 UTC

1 µm particel in model layer 30 (ca. 1000m)



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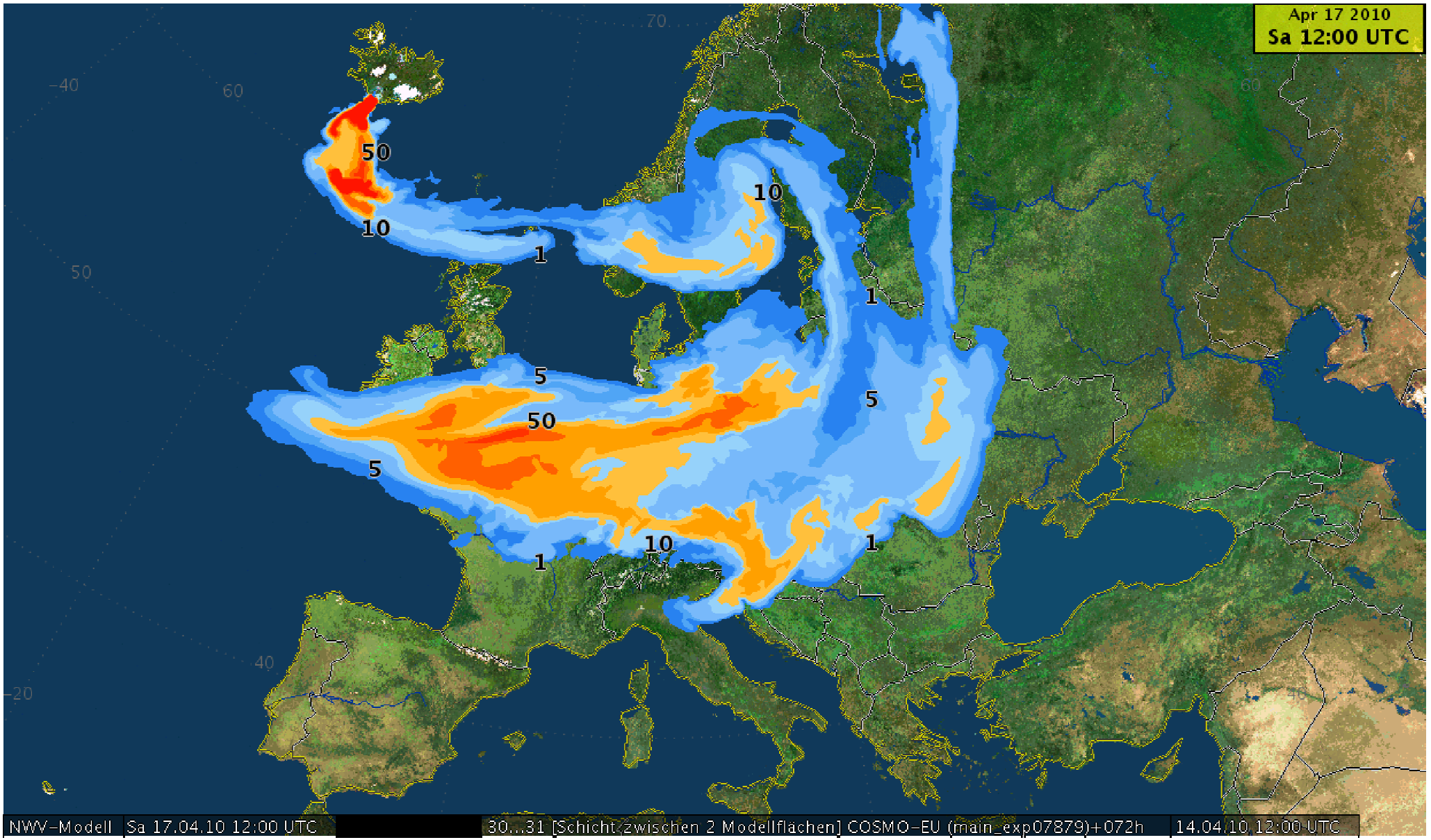

Summary and Preliminary Conclusions

- During the first days of the eruption volcanic ash was injected into the atmosphere up to 11 km.

- A comparison of the simulated ash-plume with the satellite picture shows: The model captures the horizontal distribution of the ash-plume quite well.

- The simulation results show the capability of an operational weather forecast model that is extended by aerosol processes to simulate the spatial and temporal distribution of volcanic ash. As the source strength will not be known in future eruption events only a combination of ground based and satellite borne remote sensing instruments together with in-situ observations and model results facilitates the work of decision makers during future events.

Outlook

- Simulations for a bigger (yet to be defined) model domain.
- Investigation of a source function (variable with height) which resembles better the ash plume.
- Switch to the new two-timelevel Runge-Kutta core and more sophisticated higher order advection routines for the scalar quantities.
  The coupling of the COSMO-ART modules is done… first tests are currently performed.
- Implementation of COSMO-ART in ICON.
  ICON will replace GME and COSMO-EU in the model chain of DWD.
  We thereby will have the possibility to perform global ICON-ART simulations with local mesh refinement.

Thank you!