Federal Ministry
of Transport and
Digital Infrastructure

Added value to VAAC guidance for Germany by secondary observations and model simulations using COSMO-ART

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Structure

- Motivation in Germany
- Sources for Decision Making in addit. to VAAC Guidance
  - Observations
  - Dispersion Modelling
- Operational Example
- Conclusions & Visions

Motivation in GER

Similar to other countries in EUR, during the ash crisis in 2010 and demanded from German politics, GER realized an action plan to cope with (*future*) VA crises:

(1) Provision of additional proof for the existence of VA in the atmosphere by

- **airborne data**
- **special evaluations of the (new) German ceilometer network**
- **better and improved utilization of SAT data**

(2) Confirmation of the position of VA clouds by qualifying/using the operational German dispersion model COSMO-ART for VA *(orig. for aerosols/react.trace gases radioactivity + pollen)*

(3) Support to Decision making to ATM via improved/validated SIGMETs → NOTAMs

Why not simply using VAAC advisories stand-alone?

In order to minimize traffic delays in the intensely used German (European) airspace, aviation MET warnings/forecasts of DWD have to be more detailed and specific compared to the provisions of ICAO Annex-3:

- Need for better temporal and spatial accuracy/reliability of VA forecasts
- Improved / accelerated exchange of information (forecasts and observations) for increased efficiency of the warning system
- in analogy to operational NWP, an assessment and potential reduction of forecast uncertainty may be reached by using “ensembles” of results, be it from one single NWP system or from comparison of the results of several systems → in case of deviations, weighting by knowledged experts is needed
- **In GER**, this process is legally regulated and performed by DWD

It turned out that improvements and reduction of uncertainty may be considerable, when additional sources of information → **“2nd sources”** *(in addit. to VAACs info)* are taken into acccount!

2nd sources:
(1) Airborne Measurements of VA

Stand-by contract with Hochschule Düsseldorf ***(Prof. K. Weber)***

- availability of **Flight Design CT** in **< 20 h**
- basic equipment for **Diamond DA 42 / Flight Design CT** (VA Mass concentr., SO_2 + CO)

(2) Techn. arrangement with enviscope GmbH for the measurem. of VA or alternat. radioactive material

- basic equipm. for **Learjet** (**radioactivity**) + for **Learjet** and **Partenavia** (VA, SO_2 + O_3)

FH D
Fachhochschule Düsseldorf
University of Applied Sciences

Airplane Flight Design CT with wing pod

Flight Design CT

- **Ceiling: up to 9000m**
- **range: 1500 km**
- **Speed: 330 km/h**

- service ceiling: 7000m
- range: 1500 km
- speed: 90 - 260 km/h

Diamond DA 42 MPP

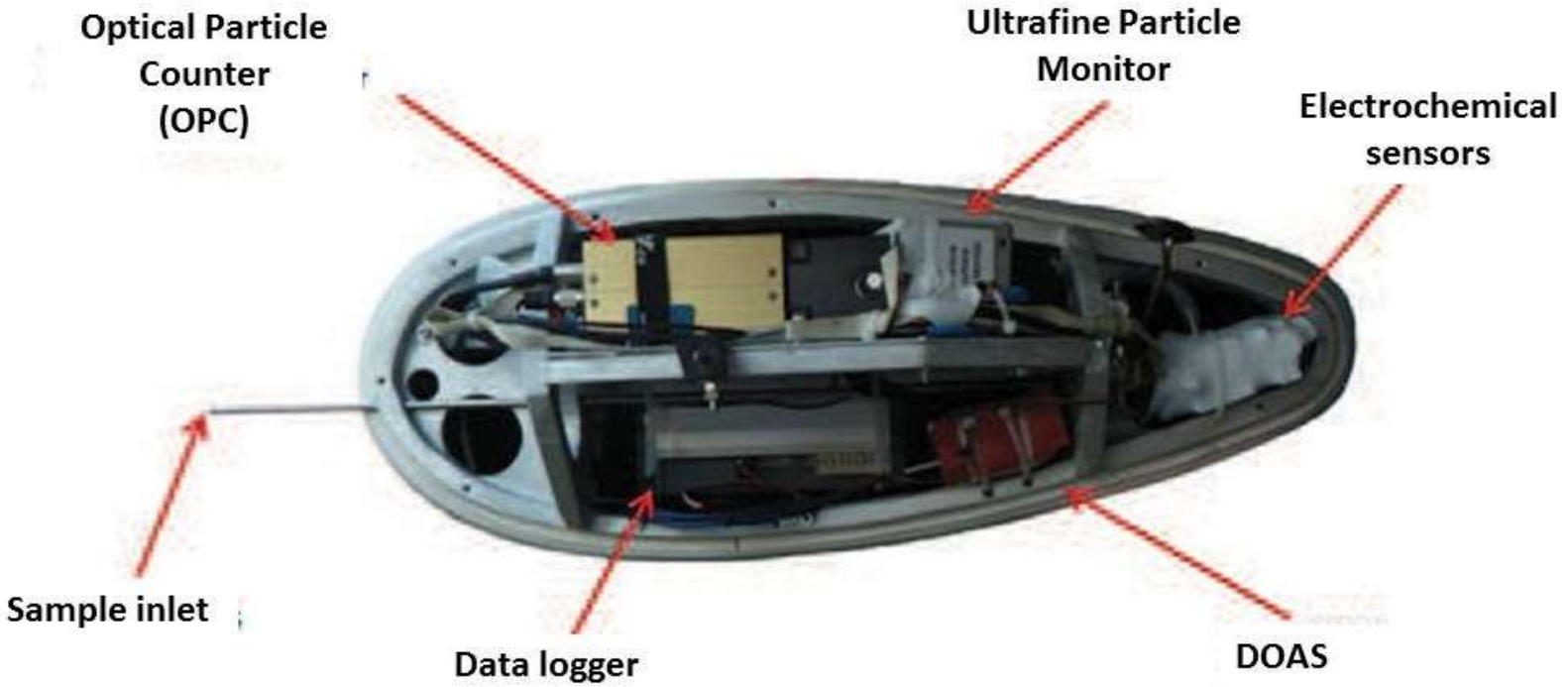
(1) Airborne Measurements of VA

FHD
Fachhochschule Düsseldorf
University of Applied Sciences

Forschungs- und Entwicklungsschwerpunkt
„Umweltmesstechnik in der Luftreinhaltung"
Prof. Dr. Konradin Weber

Airplane Flight Design CT with wing pod

Sensor pod of HS Düsseldorf



(1) Airborne Measurements of VA

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University of Applied Sciences

Optical Particle Counter

Output:

- Particles will be sorted into 31 size classes
  - Lower cut-off: 0.25 µm
  - Higher cut-off: 32 µm
- Conversion of particel number distributions into mass concentrations [µg/m³]
  - PM10
  - PM2.5
  - PM1.0

→ **real-time data transmission via Iridium SAT**

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(1) Airborne Measurements of VA

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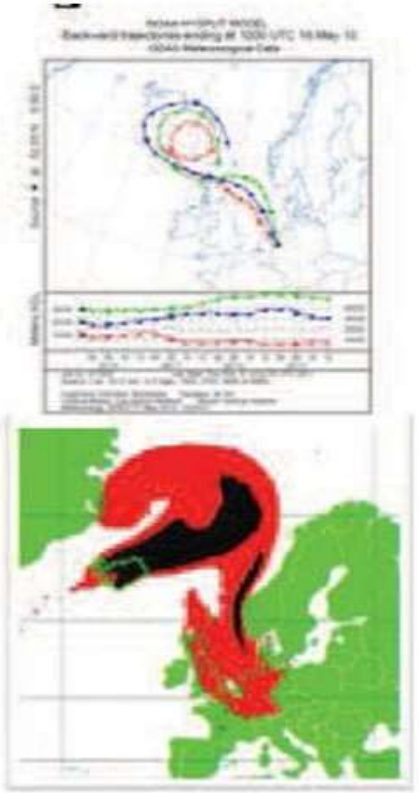
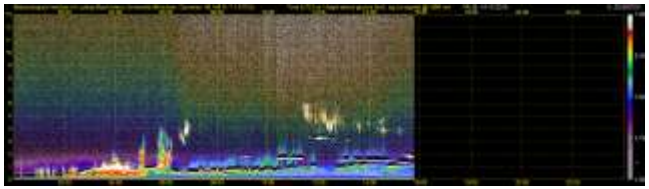
Monitoring flights across Germany during eruption of Eyjafjallajökull



Flight on behalf of DWD and BMVBS, 18th of May, 2010
in total 14 research flights across northwestern Germany

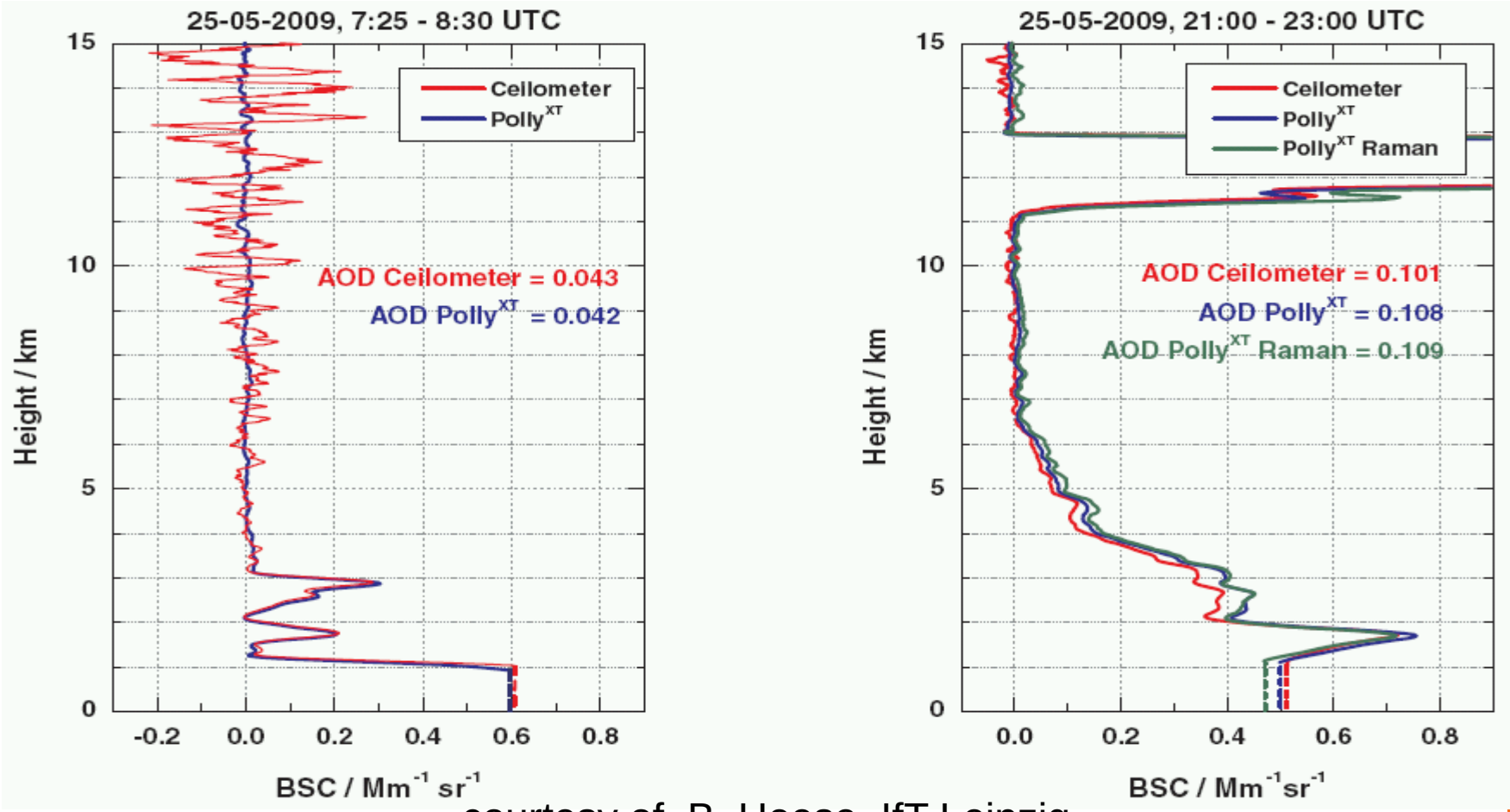
2nd sources:
(2) DWD-Ceilometer Lufft CHM15k



- **63 ceilometers** Lufft CHM15k in GER
- diode-pumped **Nd:YAG** – 1064nm
- **> 1000(!) systems** in EUR → ***WMO-GALION***
- aerosol profiles **~0.4 - 15 km**
- resolution: **~1 min**

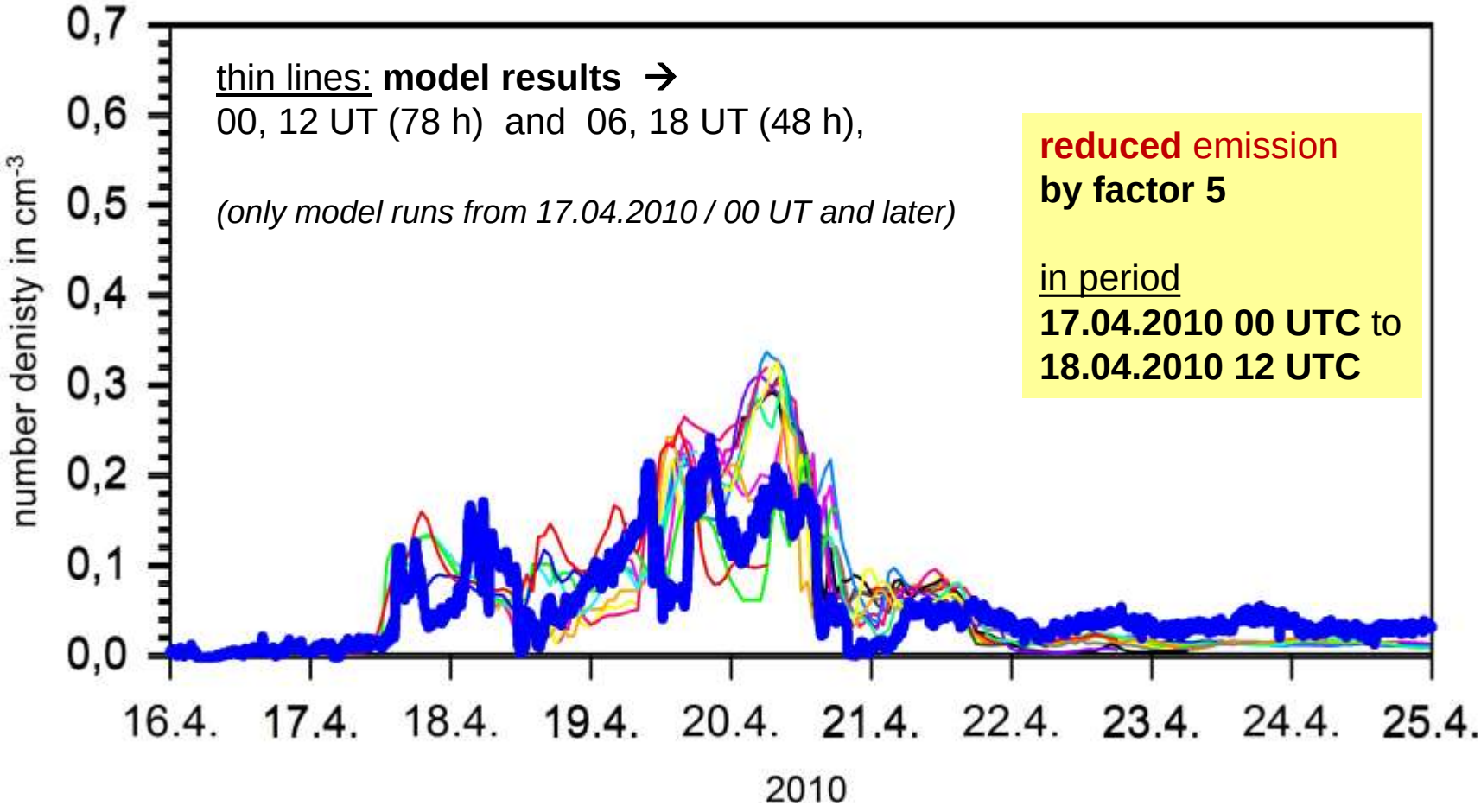
Future concept → calibration of ceilometers by real lidars for reduction of uncertainties

Ceilometer validation @IfT Leipzig (Mai 2009)



courtesy of B. Heese, IfT Leipzig

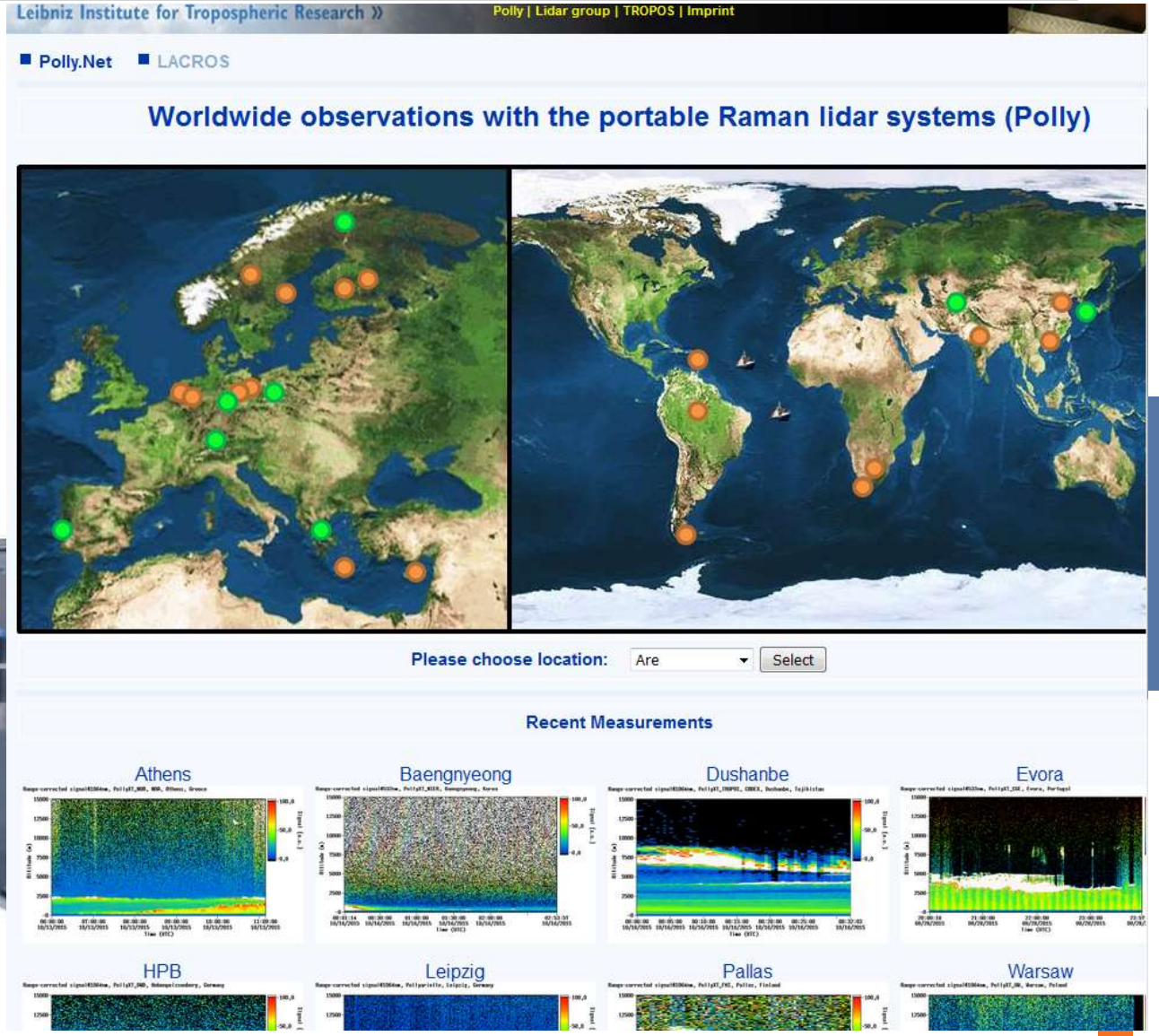
Comparison of scaled number concentrations (model results) with observations at MO Hohenpeißenberg *(Flentje et al. 2010)*



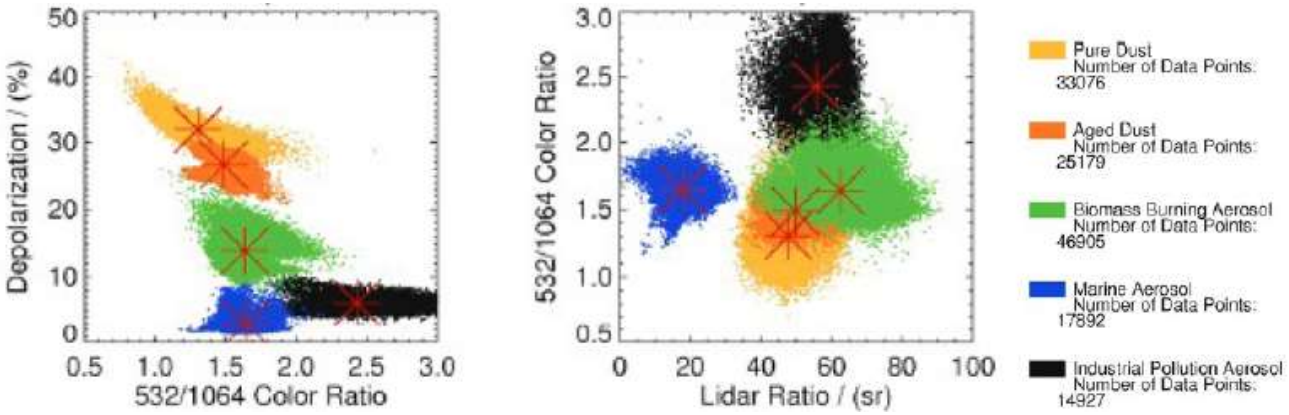
2nd sources → (real) Lidar

http://polly.tropos.de/

- 1 system e.g. operationally available at **DWD MOHp**



Detection of aerosol scattering.....



- **Volcanic ash**
- dust *(sahara, agriculture, …)*
- smoke
- Pollen
- from urban industry *(mixed aerosol)*
- … etc.

Depolarisation provides:

→ ***form of particles***

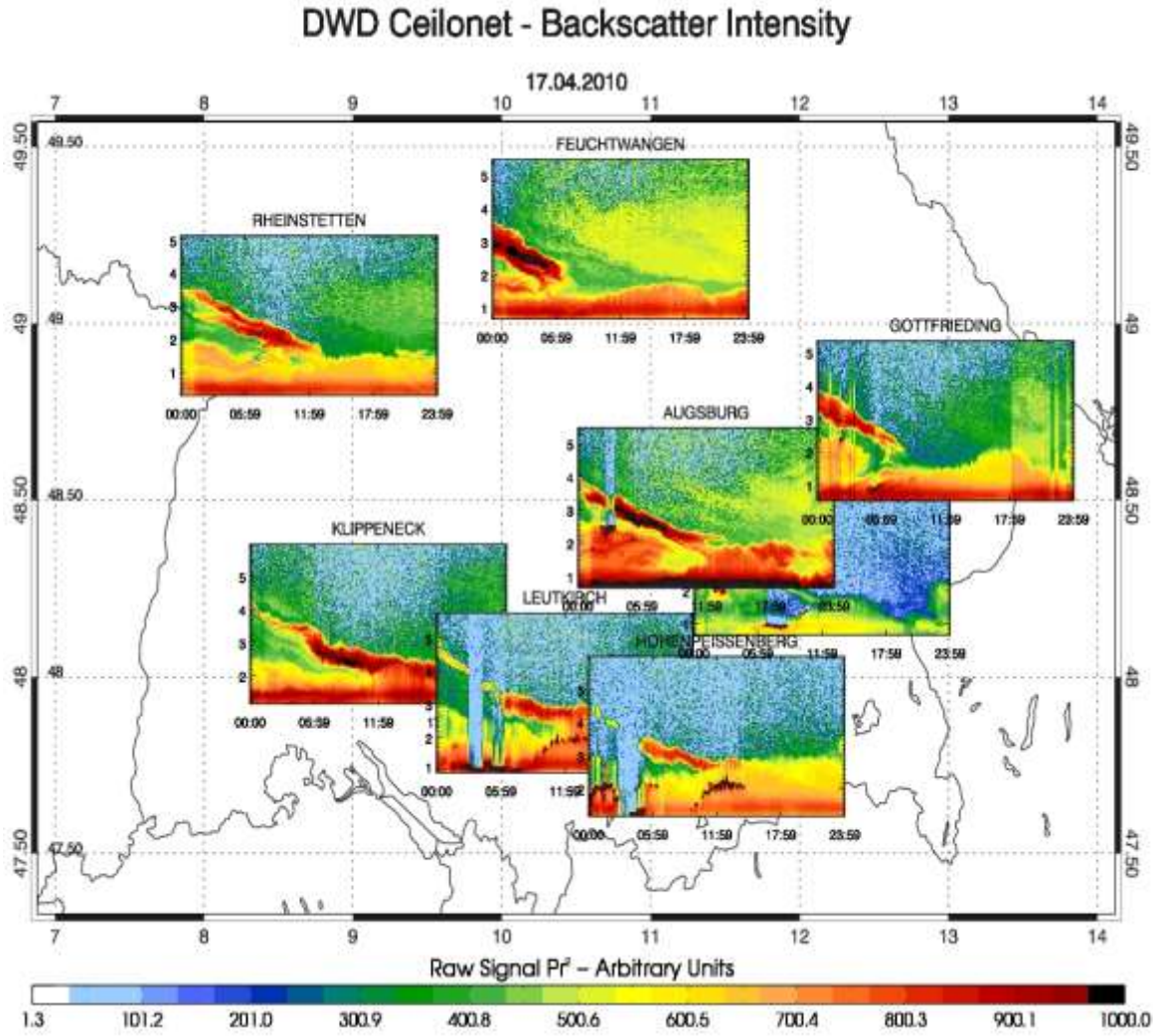
→ ***Phase*** → ***type of particle***

Detection of volcanic ash, April 2010
→ Eyjafjallajökull

Operation. practice

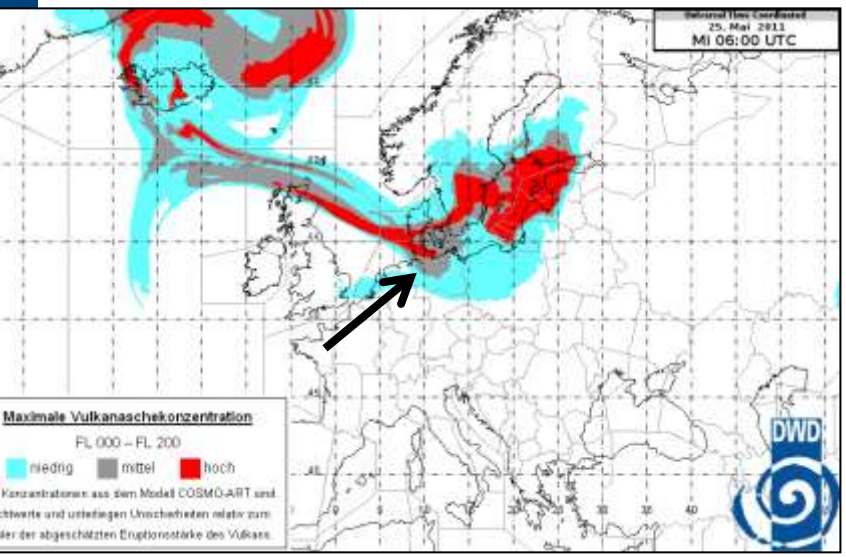
April 17, 2010

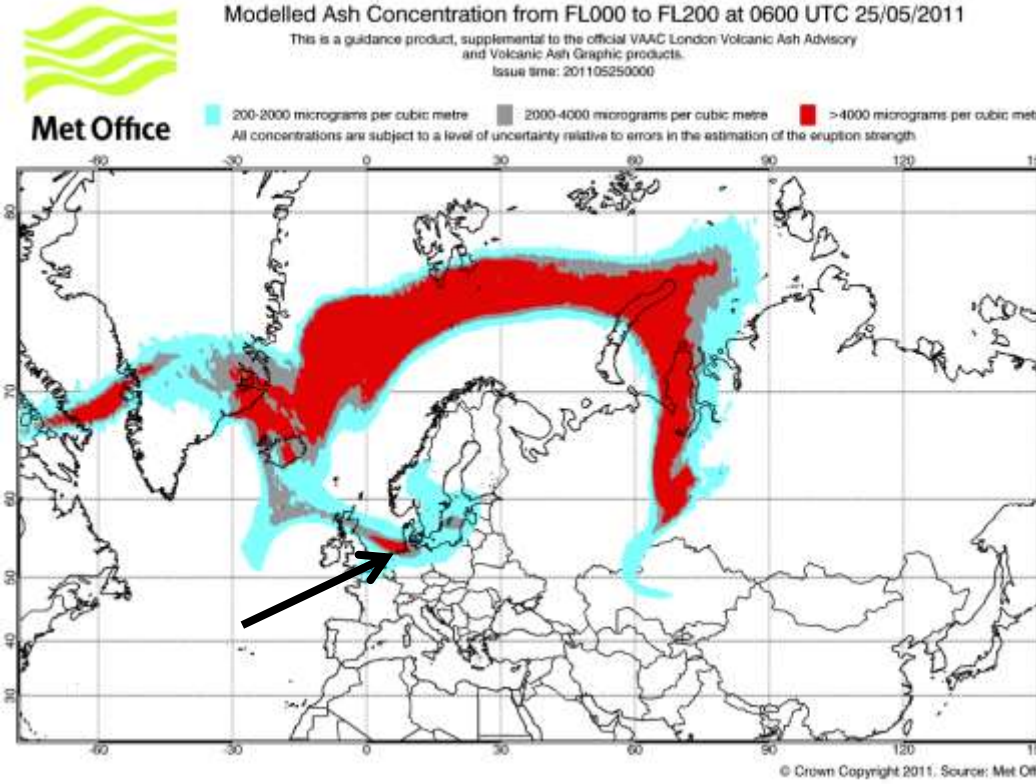
- coherent layer of VA ≈ 3-2 km
- VA entrainm. finally into the PBL
- sloped ash layer by sinking
- similar layering observable at neighbouring stations



VA Concentration Charts of UKMO & DWD

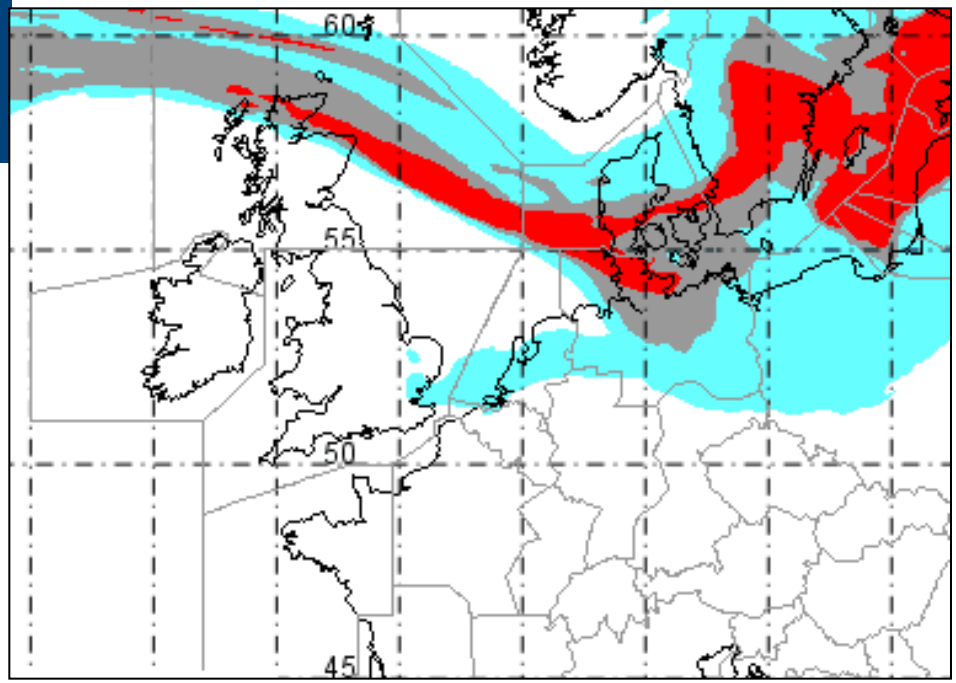
→ Grimsvötn event 2011



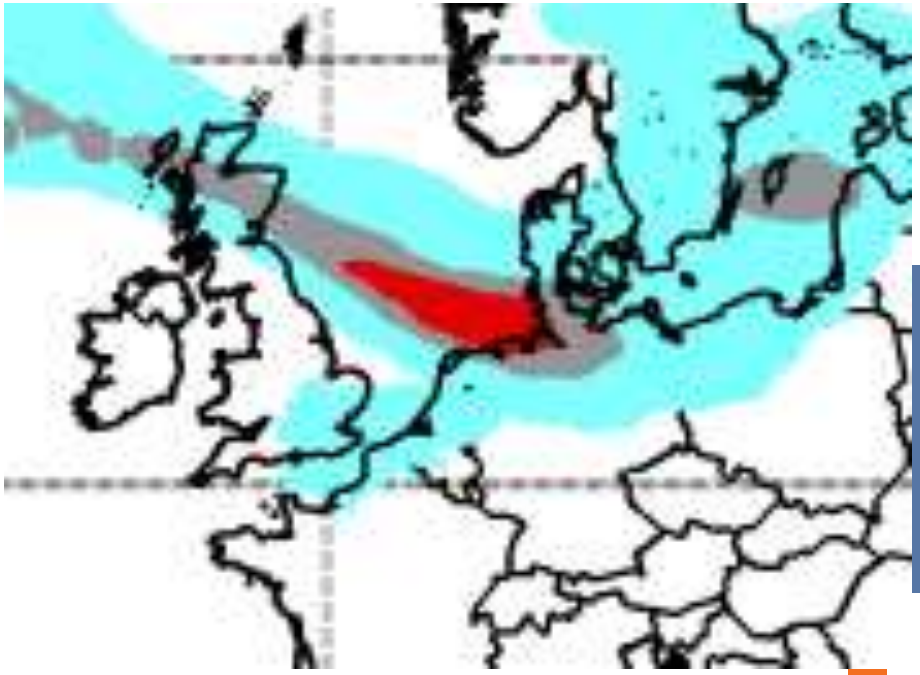


+ 6 h forecasts of VA *(Ash Concentration for 0600 UTC 25/05/2011)*
model runs of 25.05.2011 / 00 UTC at DWD ***(COSMO-Art, left)*** and from **VAAC-L**

VA Concentration Charts of DWD and VAAC-L

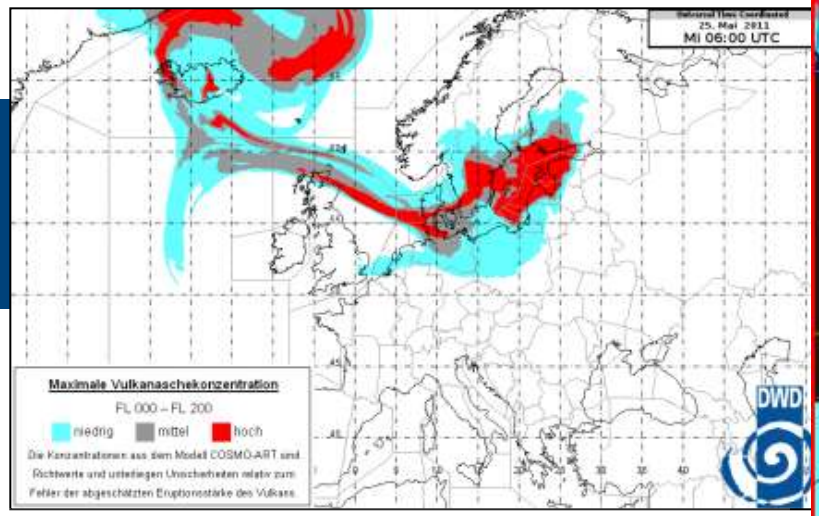


DWD

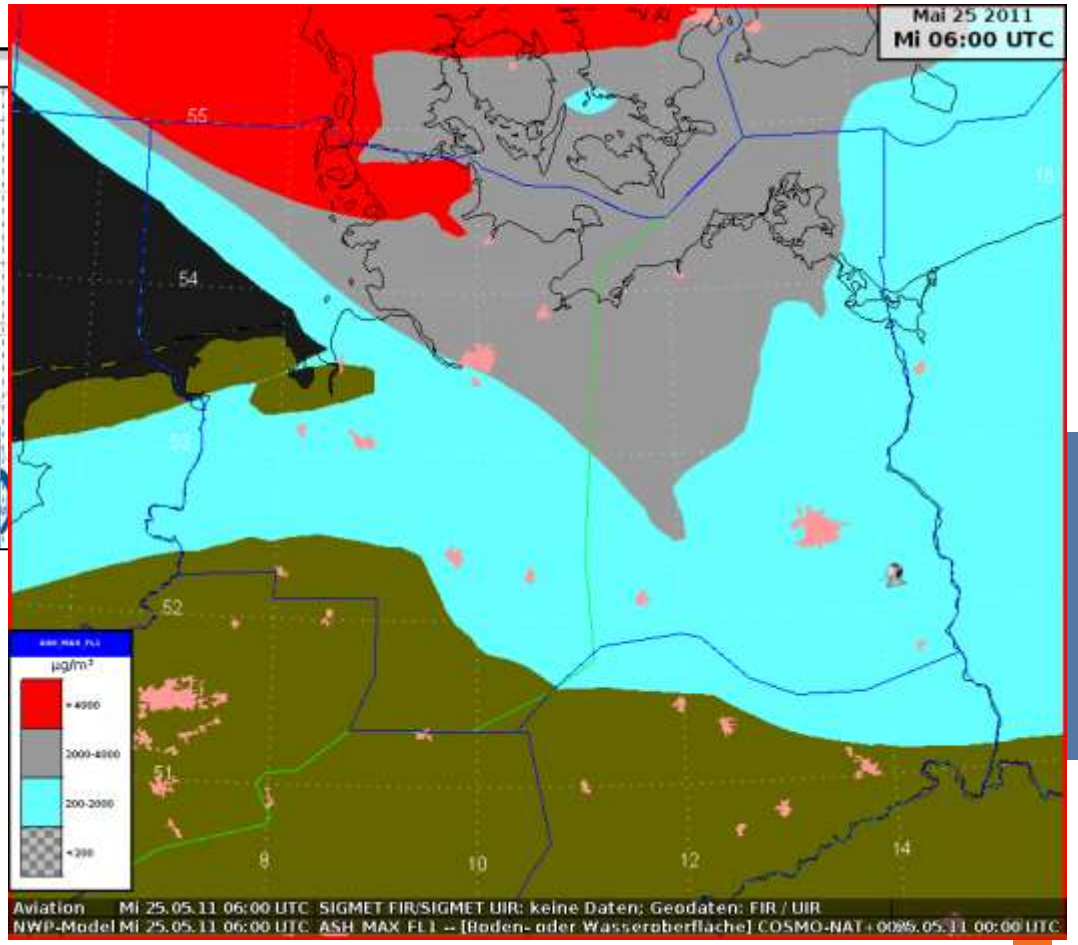


VAAC-L

DWD COSMO-Art VA products



Operation. forecast 25.05.2011/ 0600 UT



- Grimsvötn showed that 2nd information may provide crucial additional value
- **Expert weighting** mandatory for all available sources of information

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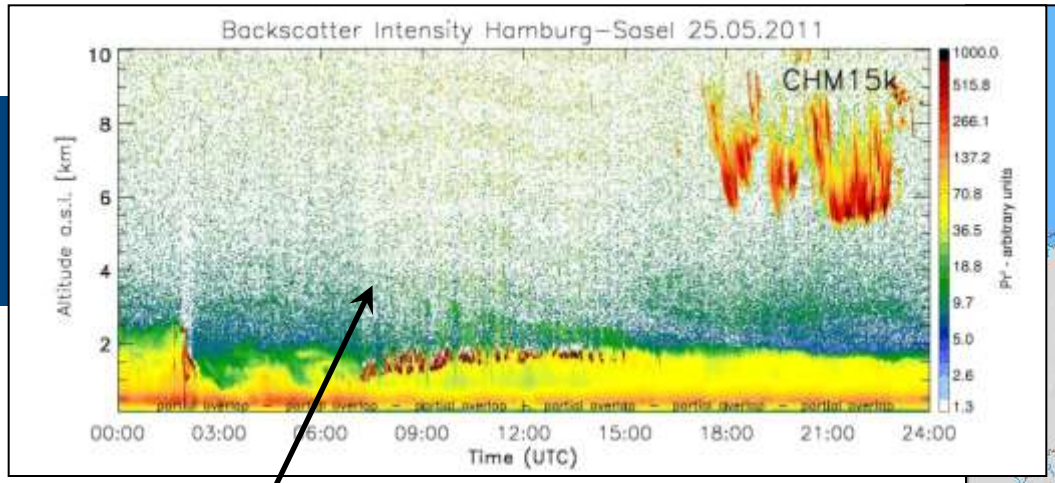
VA Ceilometer in Germany



- hardly noticeable back scattering over Hamburg during Grimsvötn event
- manual evaluat. of VA concentrat. → < 200 µg/m³

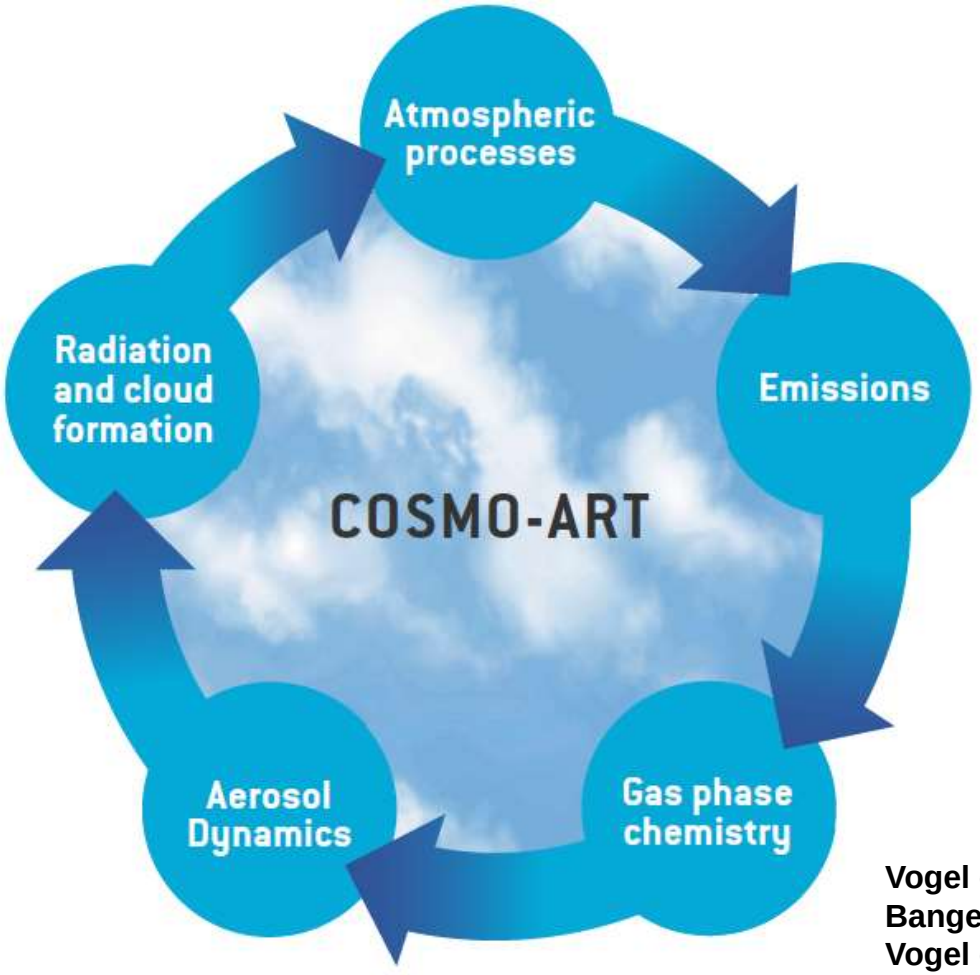
→ **operation. proof for COSMO-ART by ceilometer data**

→ **decision making against VAAC guidance in this case**

→ **immediate opening** of closed airspace

From Measurements to Forecasts

COSMO-ART → Aerosols and Reactive Trace gases



Concept:

- **online coupled.**
- **identical methods applied for all scalars (temperature, humidity, concentrations of gases, and aerosols) to calculate transport processes.**
- includes the treatment of deep convection *(Tiedtke scheme)*
- **modular structure.**

Vogel et al., 2009
Bangert et al., 2012
Vogel et al., 2014
Rieger et al., 2014

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Quantitative forecast of the VA mass concentration

6 particle classes

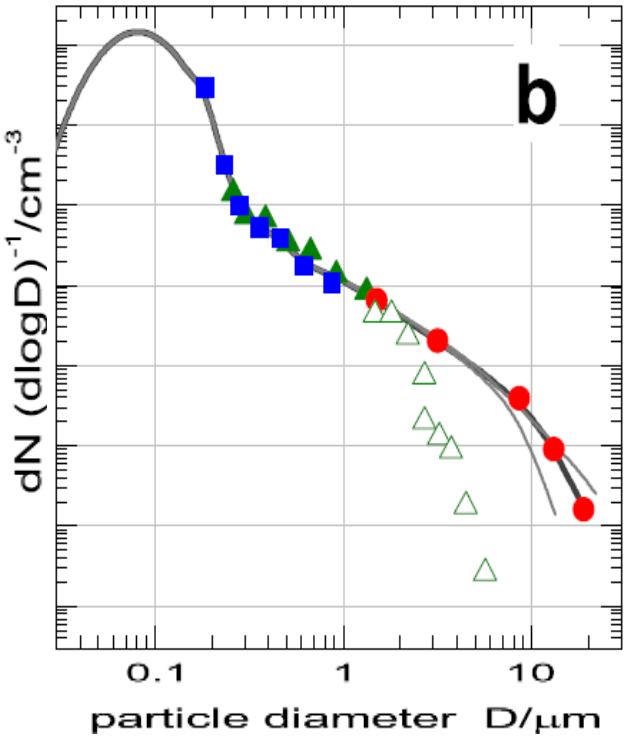
$$c^m = \sum_{i=1}^{6} w_i \cdot c_i^N$$

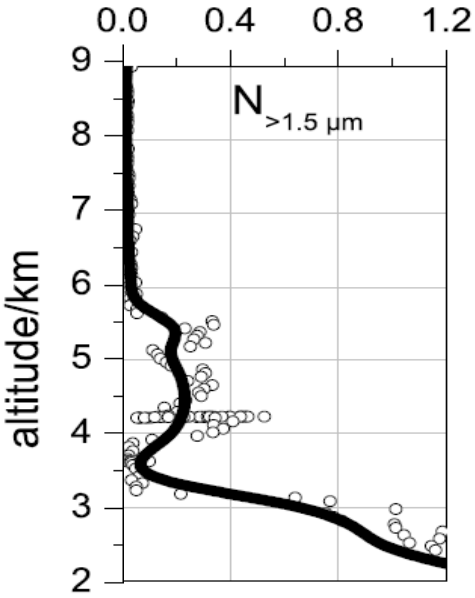
mass concentration

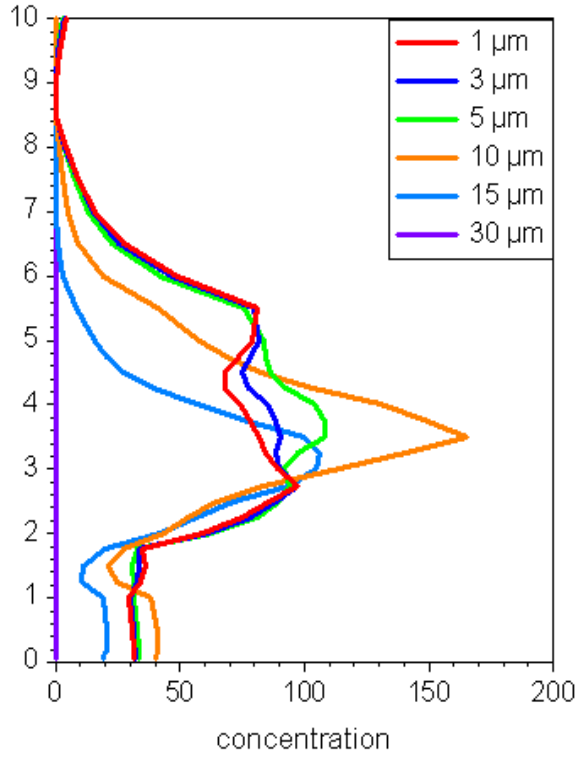
number concentrations

weighting factors…

….based on aircraft measurements in April / May 2010 *(Schumann et al. 2011)*







- **meas. particle size distrib.** (**left**: near the volcano)
- **number concentration** (profile near Leipzig)

COSMO-ART (**grid point: Leipzig**)

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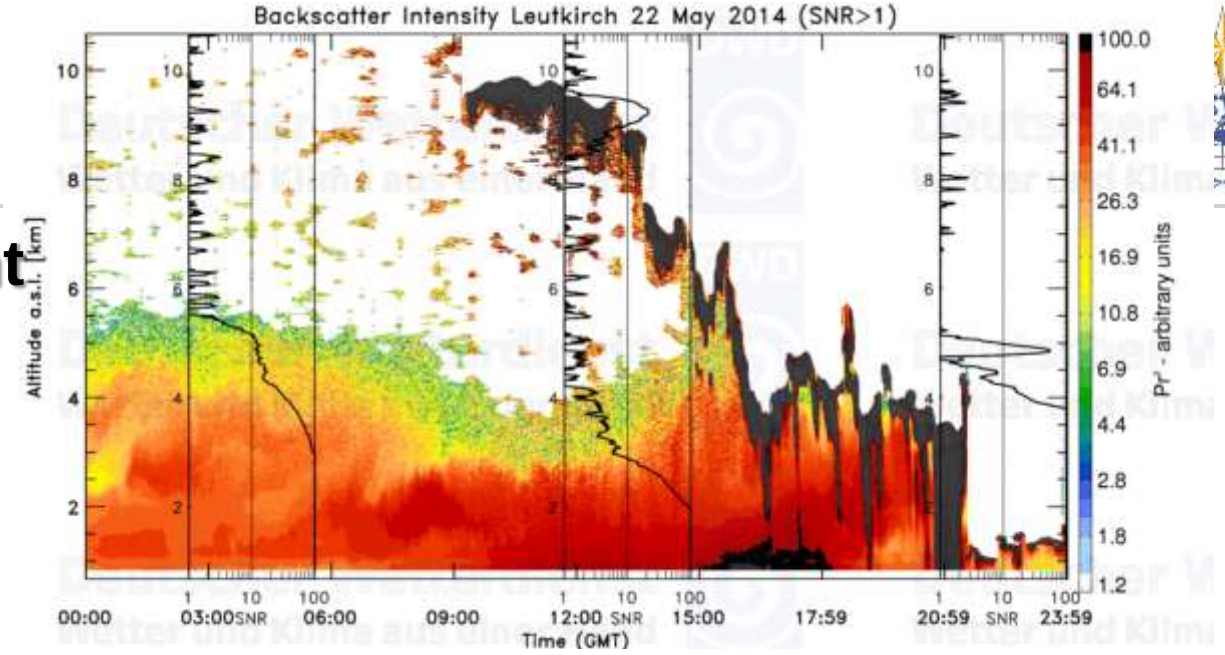
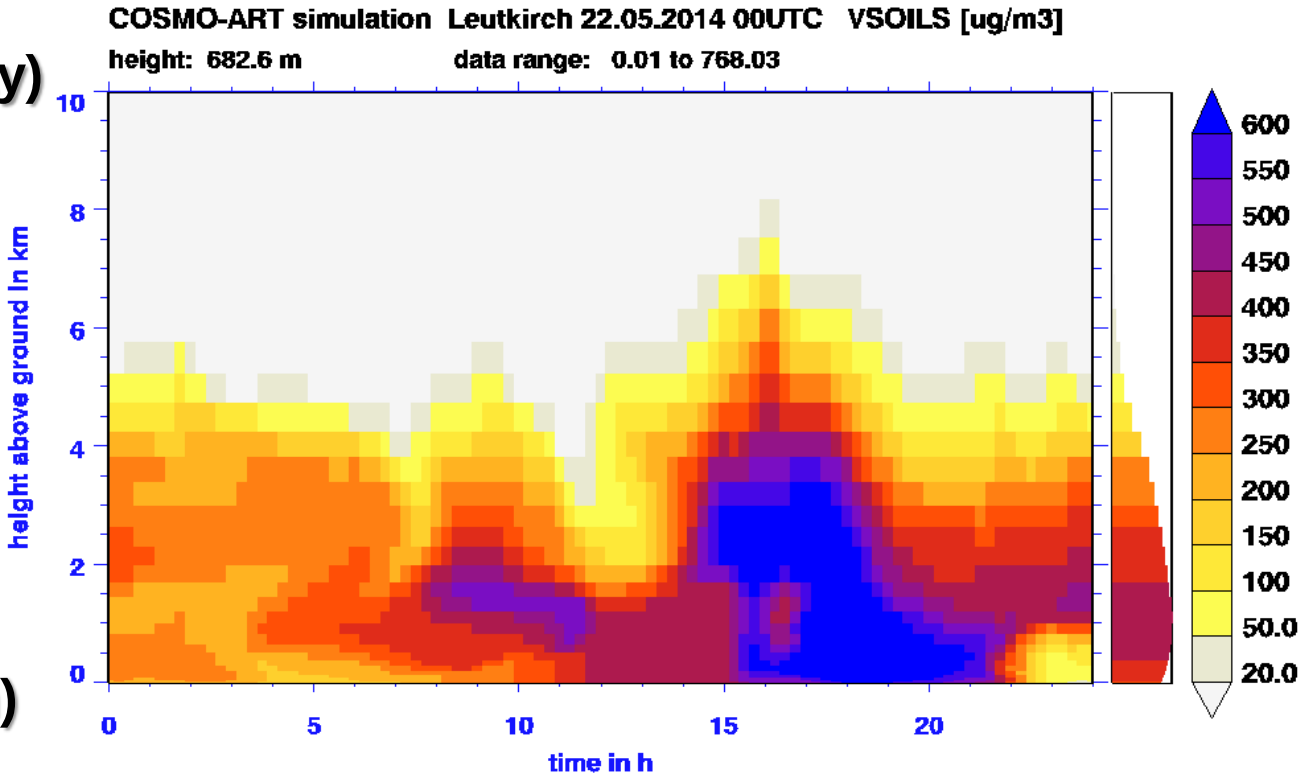
Mineral Dust Event in May 2015

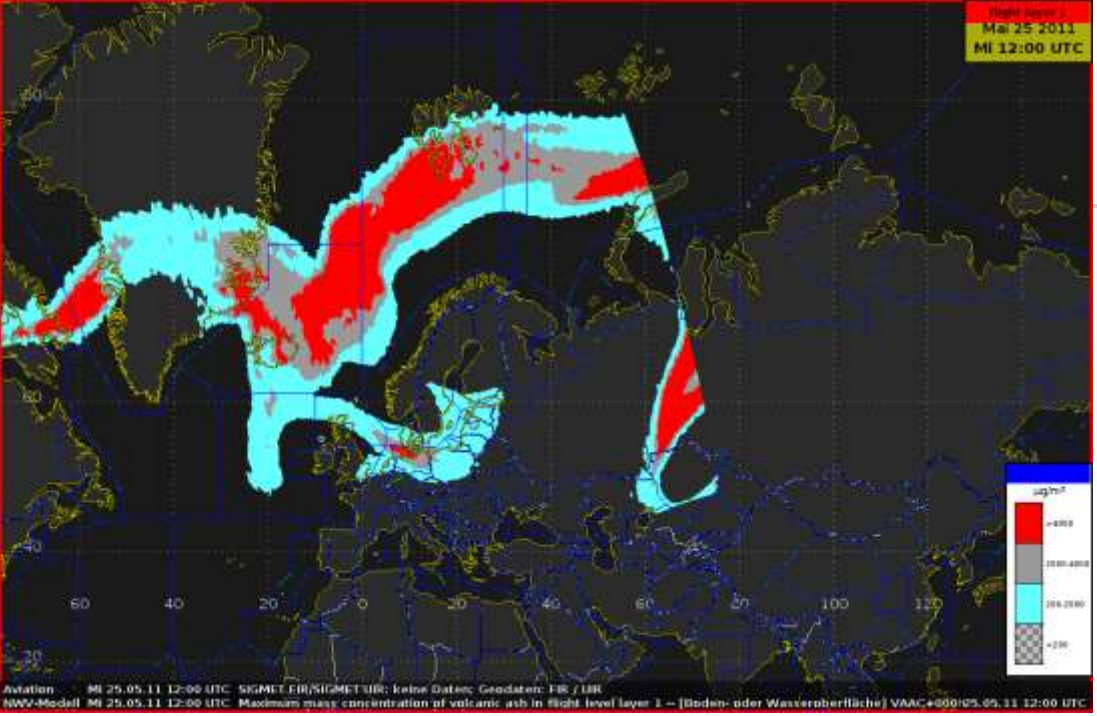
Observation from Ceilometer (Backscatter Intensity)



COSMO-ART Simulation (Mass Concentration)



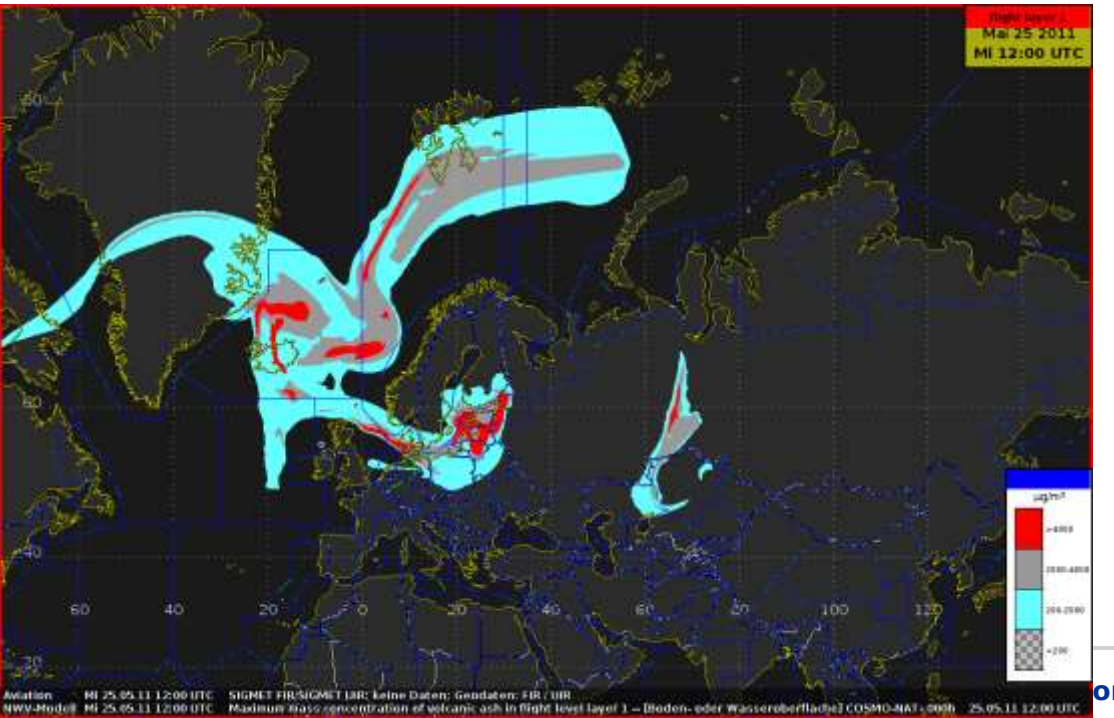
Grimsvötn – May 2011



NAME (VAAC London)

Maximum value in last six hours**?**!

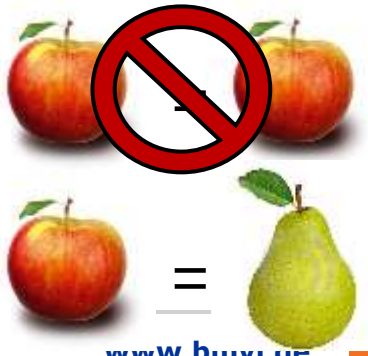
Post processing:
up to **factor 10.0** at higher altitudes to account for unresolved ash peaks!
(in a vertically stretched grid)



COSMO-ART (KIT & DWD)

Instantaneous values!

Post processing: none



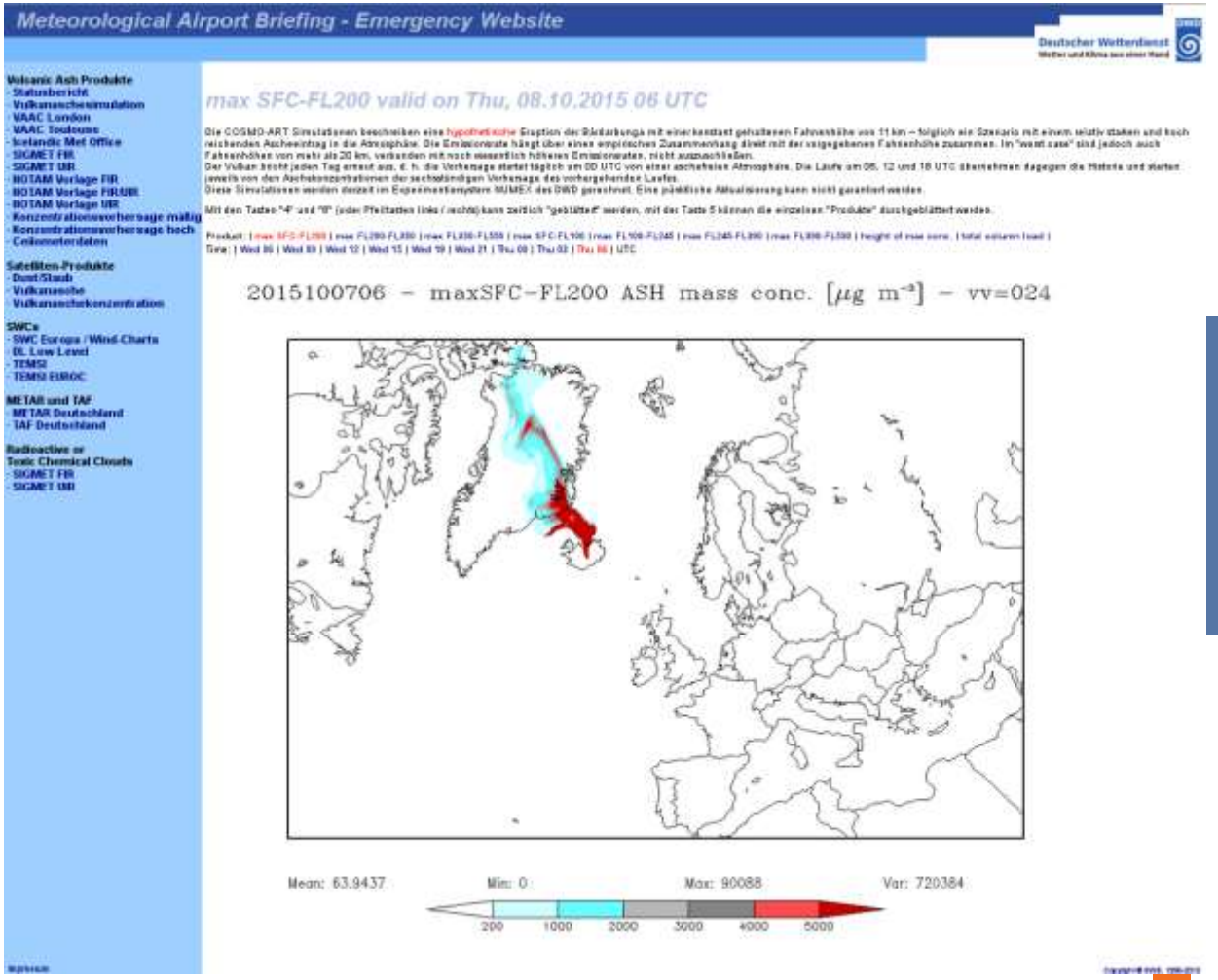
COSMO-ART in practice

DWD emergency website

….open to expert users after authorization

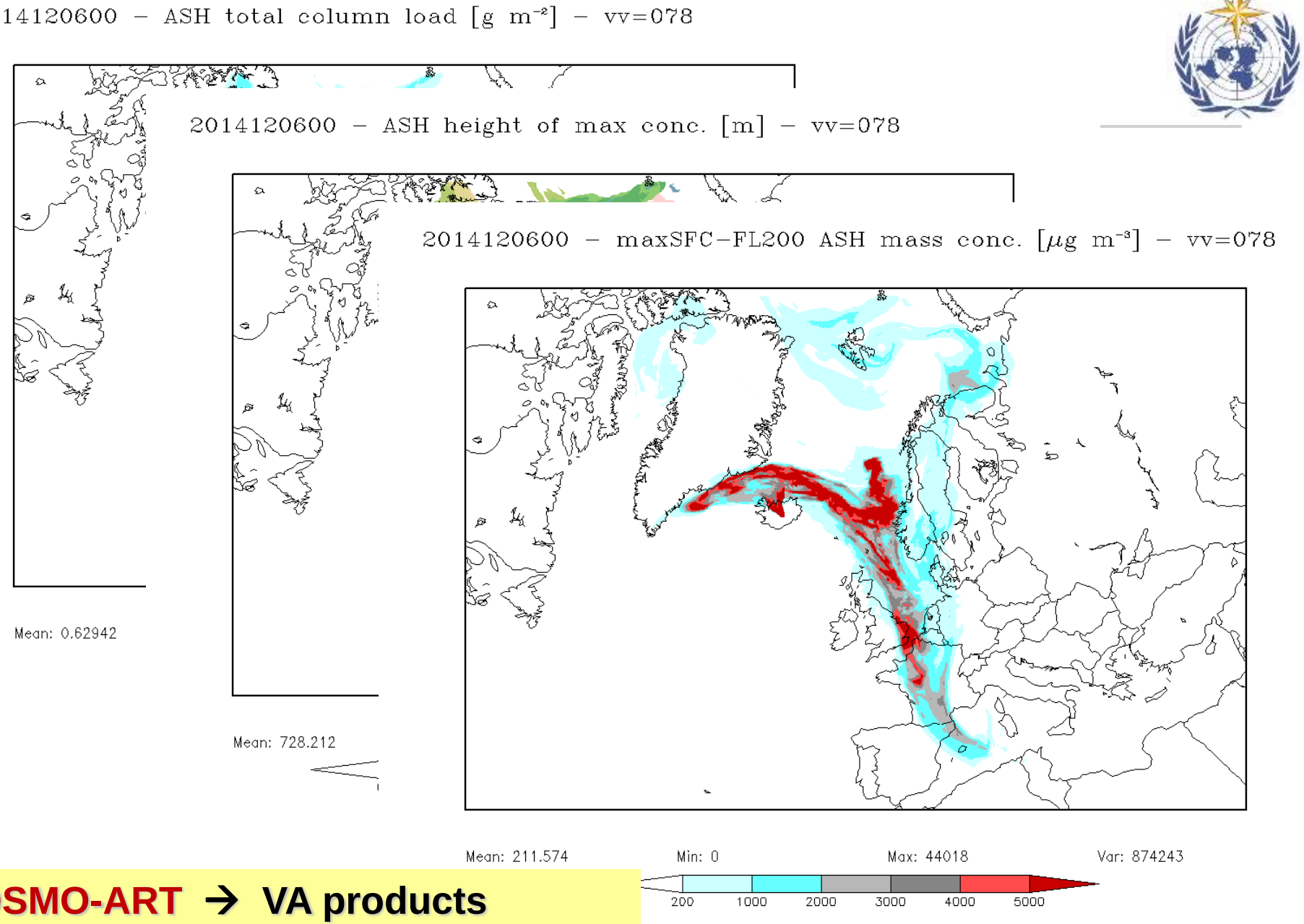
Daily forecasts with COSMO-ART at 00 and 06 UT:

- for a hypothetical eruption of Bardabunga
- starts anew 00 UT
- assumed plume height 11 km



Why / what?

- test of the production chain
- ….



COSMO-ART → VA products

(Hypoth. eruption of Bardarbunga / plume height 11 km

ICON - ART

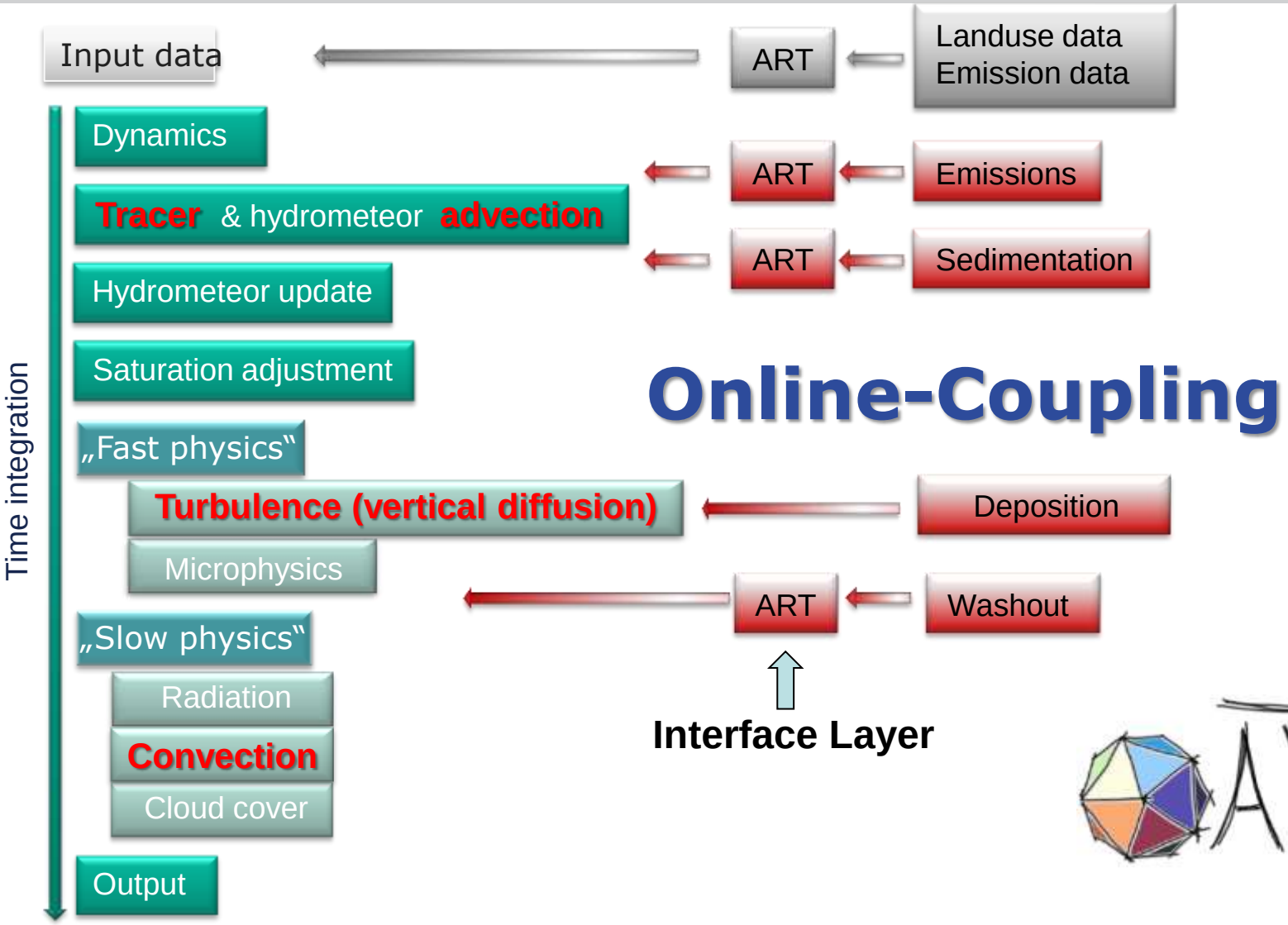
Switch from COSMO-ART to ICON-ART

ICON: ***Global* domain** → 2,9 million spherical triangles ($\Delta x \approx 13$ km)
Regional domain → $\Delta x \approx 6{,}5$ km

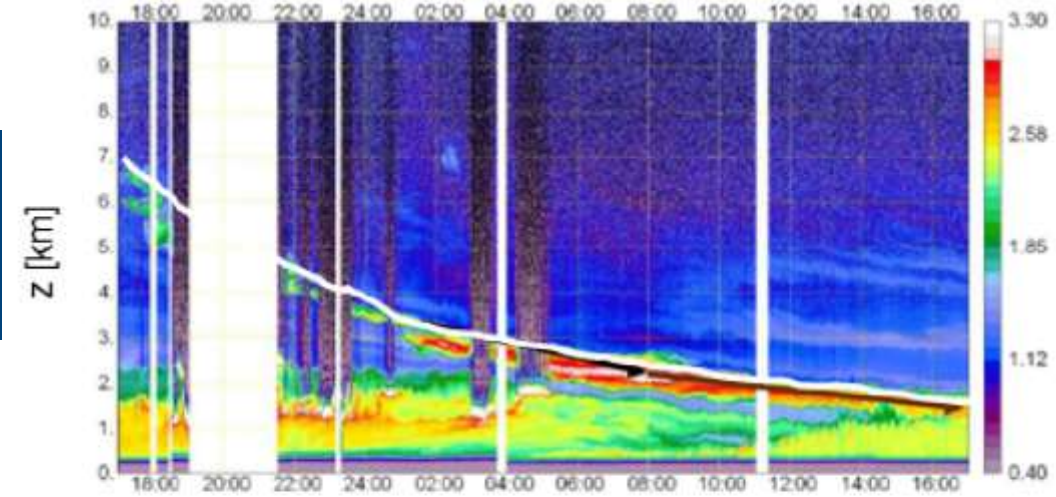
- Same diagnostic products are implemented in **ICON-ART**
- Validation and further development of **ICON-ART** is ongoing

→ *see also publication on ICON-ART 1.0* by **Rieger et al. (2014)**

ICON-ART

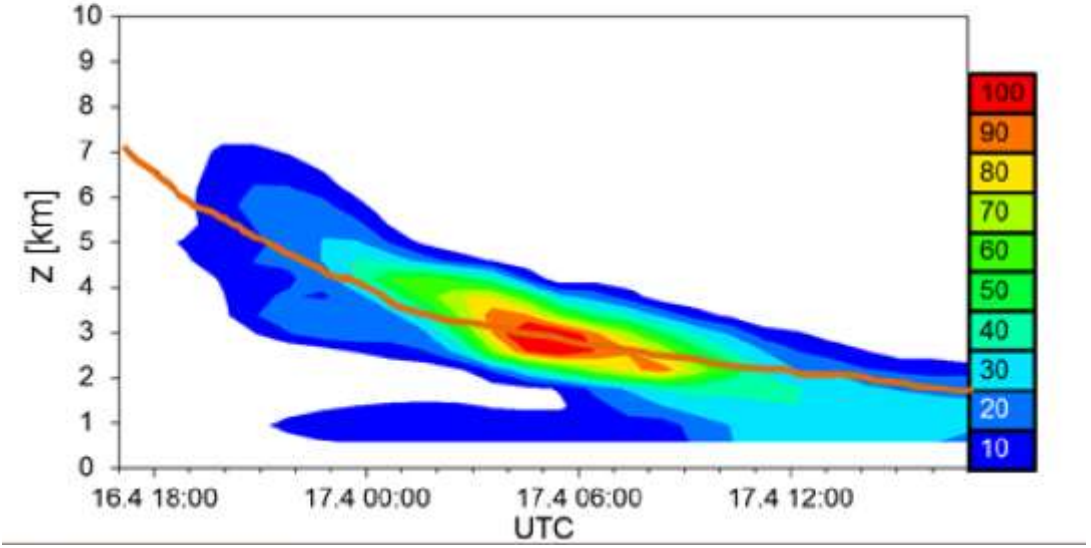

Input data
ART
Landuse data
Emission data
Dynamics
ART
Emissions
Tracer & hydrometeor advection
ART
Sedimentation
Hydrometeor update
Saturation adjustment
Online-Coupling
„Fast physics"
Turbulence (vertical diffusion)
Deposition
Microphysics
ART
Washout
„Slow physics"
Radiation
Convection
Cloud cover
Output
Time integration
Interface Layer

ICON-ART
Comparison with LIDAR



Top: Logarithm of range-corr. signal of MULIS at = 1064 nm at Maisach from **16 April 2010, 17:00 UT to 17 April 2010 17:00 UT** / 0…10 km a.g.

*The thick **white line** shows the hand-drawn border of the top of the ash plume*



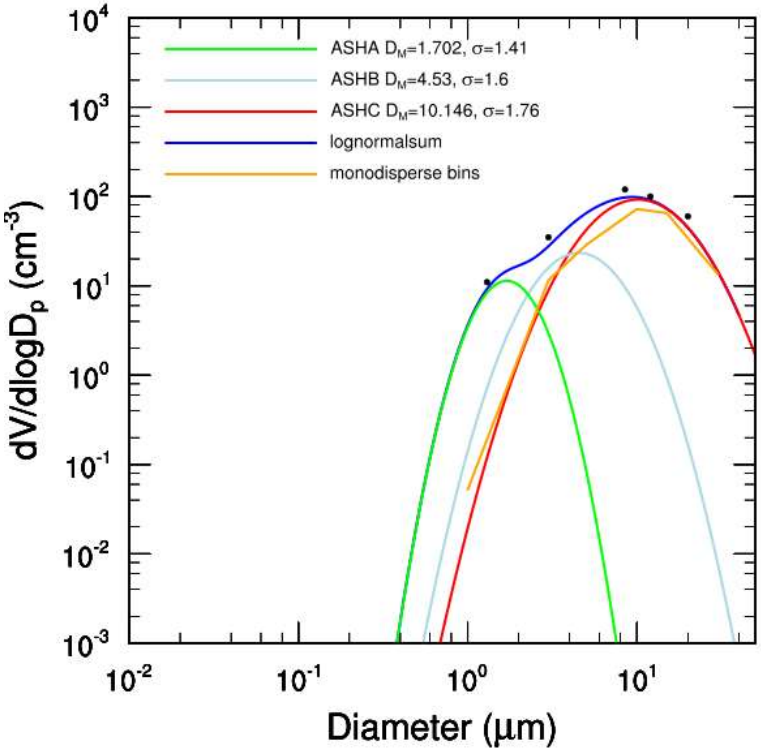
Bottom: Simul. cross sections in μm^{-2} m^{-3} for the size bins 1, 3, 5, 10, & 15 µm.

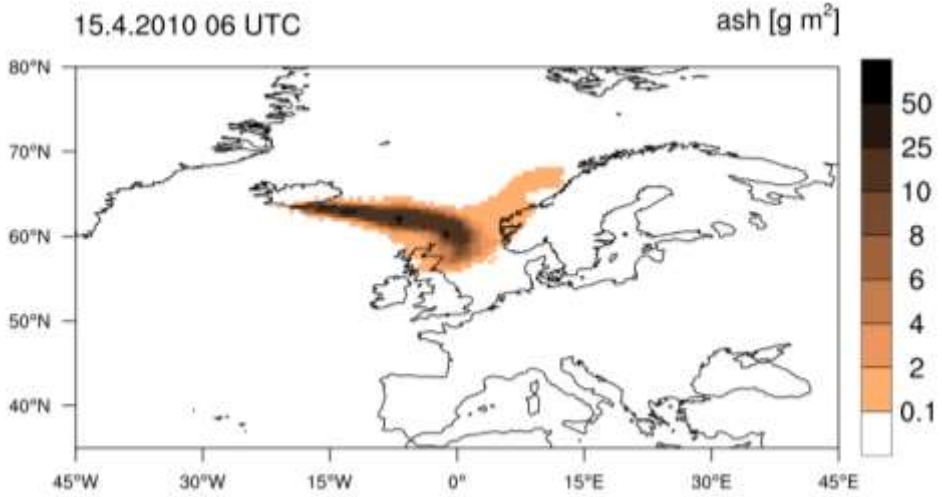
The brownish line is a copy of the white line shown above

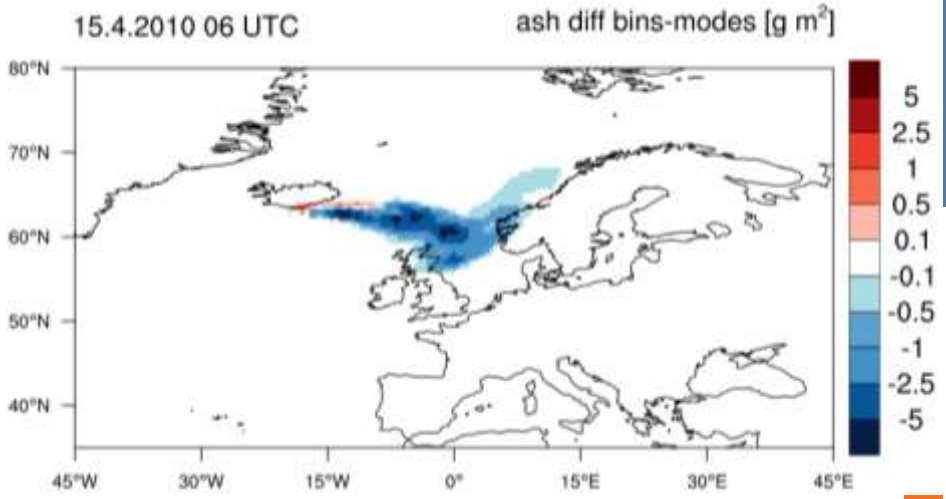
Other Developments for ICON-ART

Carolin Walter, Ph.D. thesis

- Real **Integration of observations** in VA **and SO_2 forecast**
- Sulfate formation and secondary aerosol
- Replacement of bins by modes
- Interaction with cloud formation







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Conclusions, Needs & Visions

What we have….

- good experience with **2nd–sources approach** in **GER**
  - … enables to reduce forecast uncertainties
  - … needs expert weighting of information (*no option for end-users*)
  - **GALION** = WMO's GAW Aerosol Lidar Observation Network of networks
    → includes national ceilometer networks → still mainly for cloud detection: *Airport STD*

- **What is still needed** (…*not yet available*)
  - International real-time data exchange from ceilometers *(and lidars)*
  - integration of national ceilometer networks into the GALION network
  - progress in algorithms for VA concentr. from ceilometers (→ "***TOProf***" and "**E-Prof**")
  - **For dispersion modeling**…..
    - **operat.** Lidar / ceilom. **forward operator**
    - implementat. of (real) data assimil. of measur. VA concentr./column load *(SAT, ceilom.+airb.data)*
- **VISION**
  - (Eulerian) Forecast of VA on base of assimilated measured data from space / ground at least in EUR
  - considerable reduction of ESP dependency

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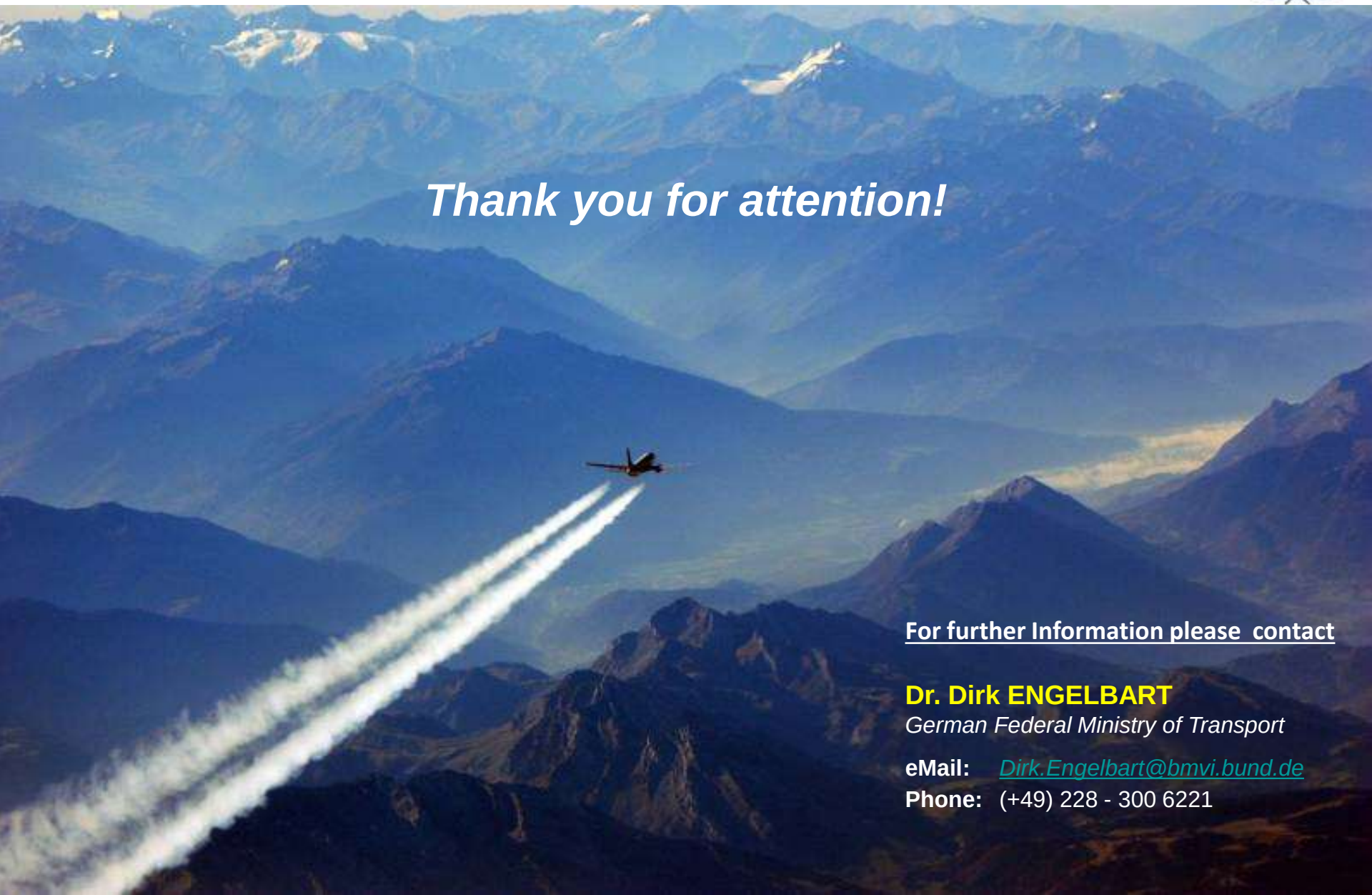

Thank you for attention!

For further Information please contact

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