Ash particles and ice clouds during the Eyjafjalla eruption: Lidar observations and model simulations

CHRISTIAN ROLF, MARTINA KRÄMER AND CORNELIUS SCHILLER

Forschungszentrum Jülich, Inst. für Chemie und Dynamik der Geosphäre 1 (ICG-1), Germany (email: c.rolf@fz-juelich.de)

LIDAR OBSERVATIONS OF THE EYJAFJALLA ASH CLOUD OVER JÜLICH WITH CORAL

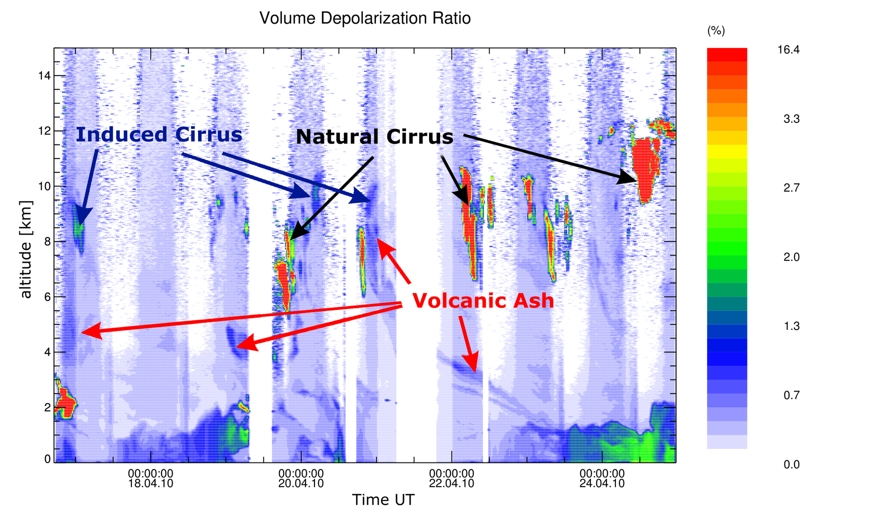
CORAL (**C**loud **O**bse**R**vation with **A**tmospheric **L**idar) description:

- Leosphere ALS 450
- Laser @ 355 nm (UV)
- 20 pulses per second
- Laser energy / duration per pulse: 16 mJ / 4 ns
- Altitude: 0.4 - 15 km
- 2 polarization channels: Determination of depolarization
- Resolution: 1 min in time (typically), 30 m in altitude

Depolarization δ shows the derivation from a sphere

$$\delta(r) = C \cdot \frac{I_{perpendicular}(r)}{I_{parallel}(r)}$$

Depolarization measurements of the Eyjafjalla ash cloud (16.04. - 24.04.2010)



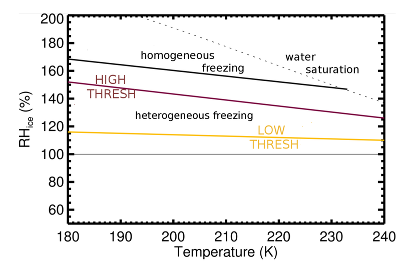
ECMWF BACKWARD TRAJECTORIES

Calculation of ECMWF backward trajectories, when CORAL detects Ice / Ash:

- ECMWF analysis data (medium range weather forecast)
- Trajectories show where the airmasses originate
- Important quantities: time, temperature, pressure and humidity
- ECMWF data often shows a dry bias of H_2O in upper troposphere
- For model simulations: Use of maximum humidity along the trajectory

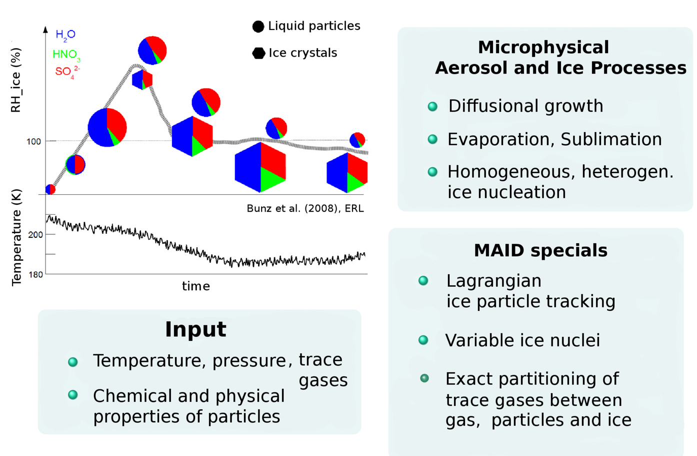
MODEL SIMULATIONS

- Simulation of ice formation along the trajectory, temperature noise $0.3 - 0.5\ K$
- Initial water: maximum ECMWF humidity
- Two senarios:
  - ➤ Clean without ash $IN = 0.01\ cm^{-3}$, high freez. treshold
  - ➤ Polluted with volcanic ash $IN = 15\ cm^{-3}$, low freez. treshold



hom. freezing: Koop et al. (2000), Nature
het. freezing: Kärcher et al. (2006), JGR
freezing thresholds: Gensch et al. (2008), ERL

Microphysical boxmodel MAID
(**M**odel for **A**erosol and **I**ce **D**ynamics)



Bunz et al. (2008), ERL, Gensch et al. (2008), ERL

OVERVIEW / RESULTS

The volcano Eyjafjallajökull in Island ejected a large ash cloud during its eruptions in April 2010. The cloud spreads out over central Europe in a period of 6 days and disrupted the air traffic.

Few days after the first eruptions, we detected the ash cloud with a backscatter lidar over western Germany, Jülich (50° 54' north, 6° 24' east). The lidar, called CORAL (Cloud ObseRvation with Atmospheric Lidar), measures optical properties (i.e. backscatter signals / extinction coefficient) and depolarization of aerosol particles at a wavelength of 355 nm in a high vertical resolution of 15 m. In the depolarization channel we can discriminate between cirrus clouds and aerosol particles. Cirrus clouds mostly create a high signal in the depolarization because of the ice crystal's asphericity. The ash cloud particles create a much smaller depolarization.

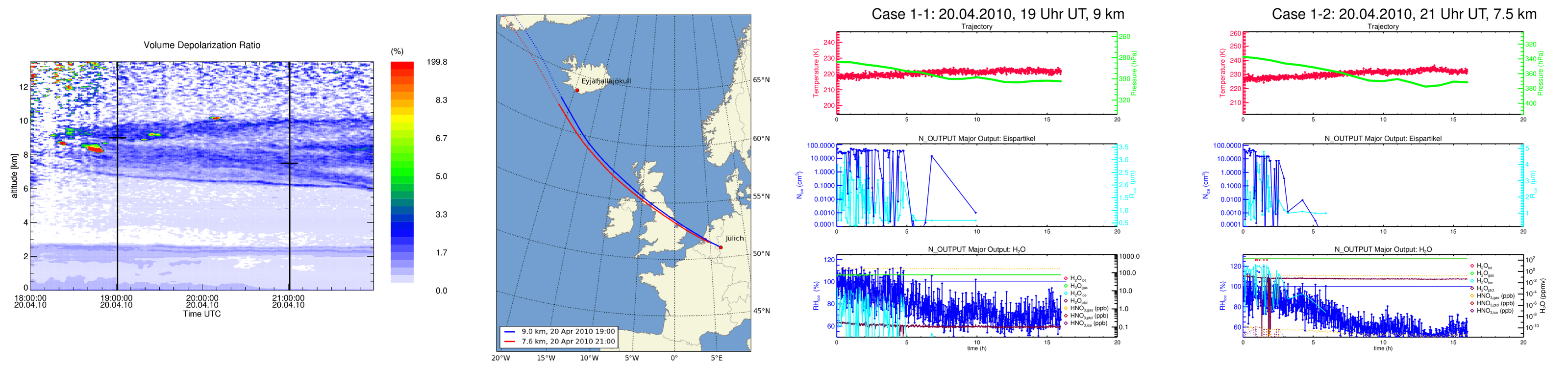
Periods with or without volcanic ash occured in dependence on the dynamical situation. During some periods, our measurements show ice formation on the ash particles. Here, we investigate four different types of observations: Pure volcanic ash, volcanic ash with ice spots, cirrus modified by volcanic ash and natural cirrus cloud. For each case we calculate ECMWF backward trajectories. With our detailed microphysical box model MAID (Bunz et al., 2008) we simulate the ice formation along these trajectories.

Results

- ➤ Combination of lidar measurement and simulation of ice formation
- ➤ Distinction between pure volcanic ash and thin cirrus clouds induced by ash possible
- ➤ Thin cirrus cloud formed on volcanic ash
- ➤ Volcanic ash strongly changes the microphysical properties

❶ PURE VOLCANIC ASH

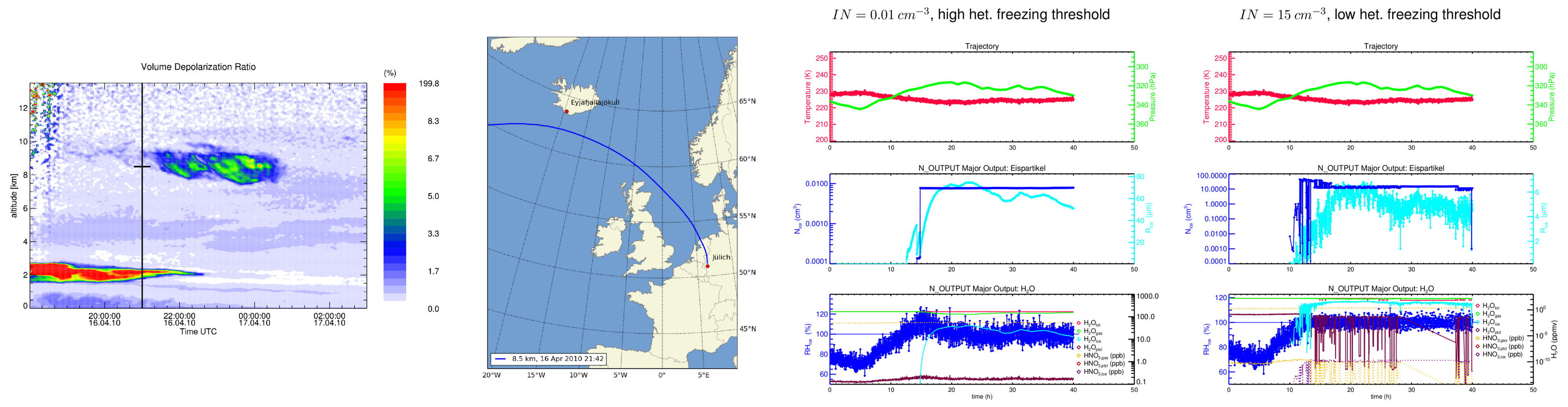
MAID-Simulation with volcanic ash
$IN = 15\ cm^{-3}$, low het. freezing threshold



- Lidar depolarization shows a increased signal
- Low RH_{ice} ⇒ no ice formation
- ➤ Pure volcanic ash was seen by the lidar
- ➤ Volume depolarization of the volcanic ash layer is $\delta = 2\,\%$ (aer. depol: 15%)

❷ CIRRUS MODIFIED BY VOLCANIC ASH

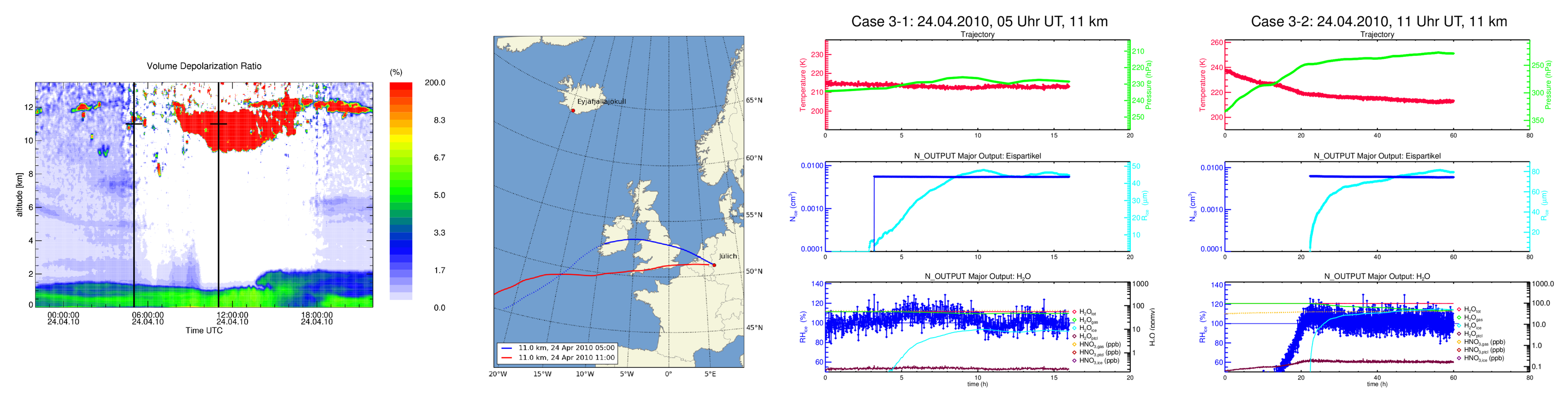
MAID-Simulation Case 2-1: 16.04.2010, 21 Uhr UT, 8.5 km



- Small lidar depolarization signal around $5\,\%$ (aer. depol: 10%) indicate small spherical ice particles
- Ice particles much smaller within volcanic ash
- ➤ Thin cirrus cloud formed on volcanic ash
- ➤ Volcanic ash strongly changes the microphysical properties

❸ NATURAL CIRRUS CLOUD

MAID-Simulation without volcanic ash
$IN = 0.01\ cm^{-3}$, high het. freezing threshold



- In both cases: High lidar depolarization signal around $30.\,\%$ indicate big aspheric ice particles
- Trajectories don't come from the volcano Eyjafjalla
- MAID simulation without ash also shows big ice particles with $R_{mean} = 75\ \mu m$
- ➤ Natural thick cirrus cloud