Investigation of cloud-droplet activation process during EUCAARI-IMPACT

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Airborne microphysical measurements onboard the SAFIRE ATR-42 during IMPACT

The research flights of SAFIRE ATR-42 aircraft during EUCAARI IMPACT field campaign encompassed a range of in-situ aerosol measurements, cloud-droplet size spectrometry, and vertical wind measurements. The resulting dataset is used here to study cloud-droplet activation - a process in which the size spectrum of droplets at cloud base is determined by the characteristics of aerosol and the air supersaturation (linked with its vertical velocity). Two flights flown in air of contrasting aerosol characteristics (figs 2 & 3) were chosen:

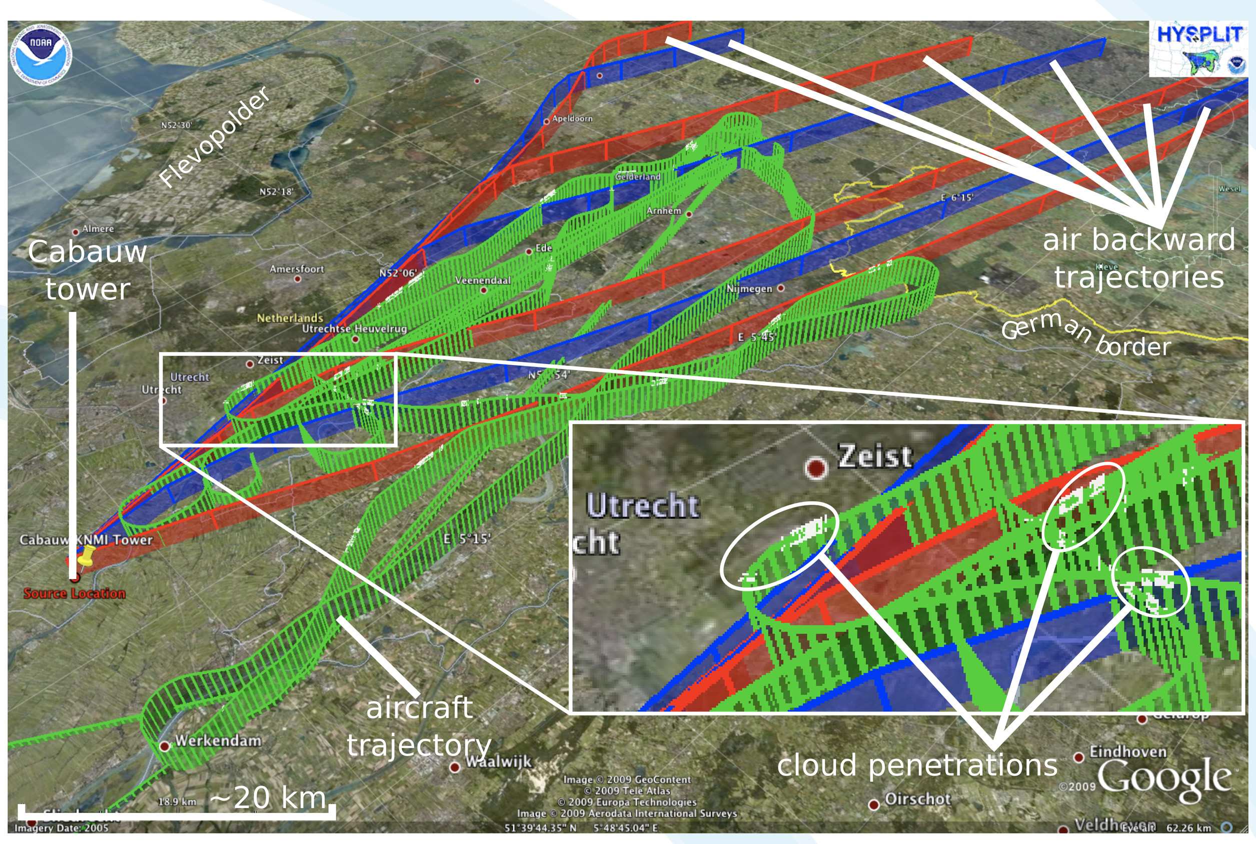
- RF49, May 13th: flown over The Netherlands in polluted continental air, $\sim$ 5 minutes of penetrations of Cu clouds (fig. 1)
- RF51, May 15th: flown over the North Sea in relatively pristine marine air, $\sim$ 50 minutes of penetrations of a deck of Sc clouds (fig. 2)

The goal of this ongoing research is to assess the closure between the measured physicochemical aerosol properties (figs 2 & 3) and the measured drop size distributions (figs 4 & 5).
The aerosol instrumentation of the aircraft included externally-mounted PCASP spectrometer, and a chain of internally-mounted instruments:

- two pairs of optical (GRIMM OPC) and scanning mobility (SMPS) aerosol size spectrometers (one pair connected through a heater set at 280°C - dashed lines in the figs 3 & 4)
- Cloud Condensation Nuclei Counter (CCNC) (DMT CCN spectrometer operated at a single supersaturation, green lines in figs 5 & 6)
- TSI 3025 and TSI 3010 Condensation Particle Counters (CPC)
- Aerosol Mass Spectrometer

Results from out-of-cloud measurements near cloud base using PCASP, 2×OPC and 2×SMPS are summarised in figures 3 and 4 (vertical bars indicate minimum-maximum ranges of measured values).
Results of cloud-droplet size spectrometry made using the FSSP-100, are summarised in figures 5 & 6 – a set of percentiles of measured liquid water content (LWC) and drop concentration (CDNC) is indicated for each considered height level, together with statistics from CCNC measured near cloud base.
Vertical air velocity was measured using a 5-hole gust probe integrated in the radome of the aircraft.

RF49 - 2008-05-13



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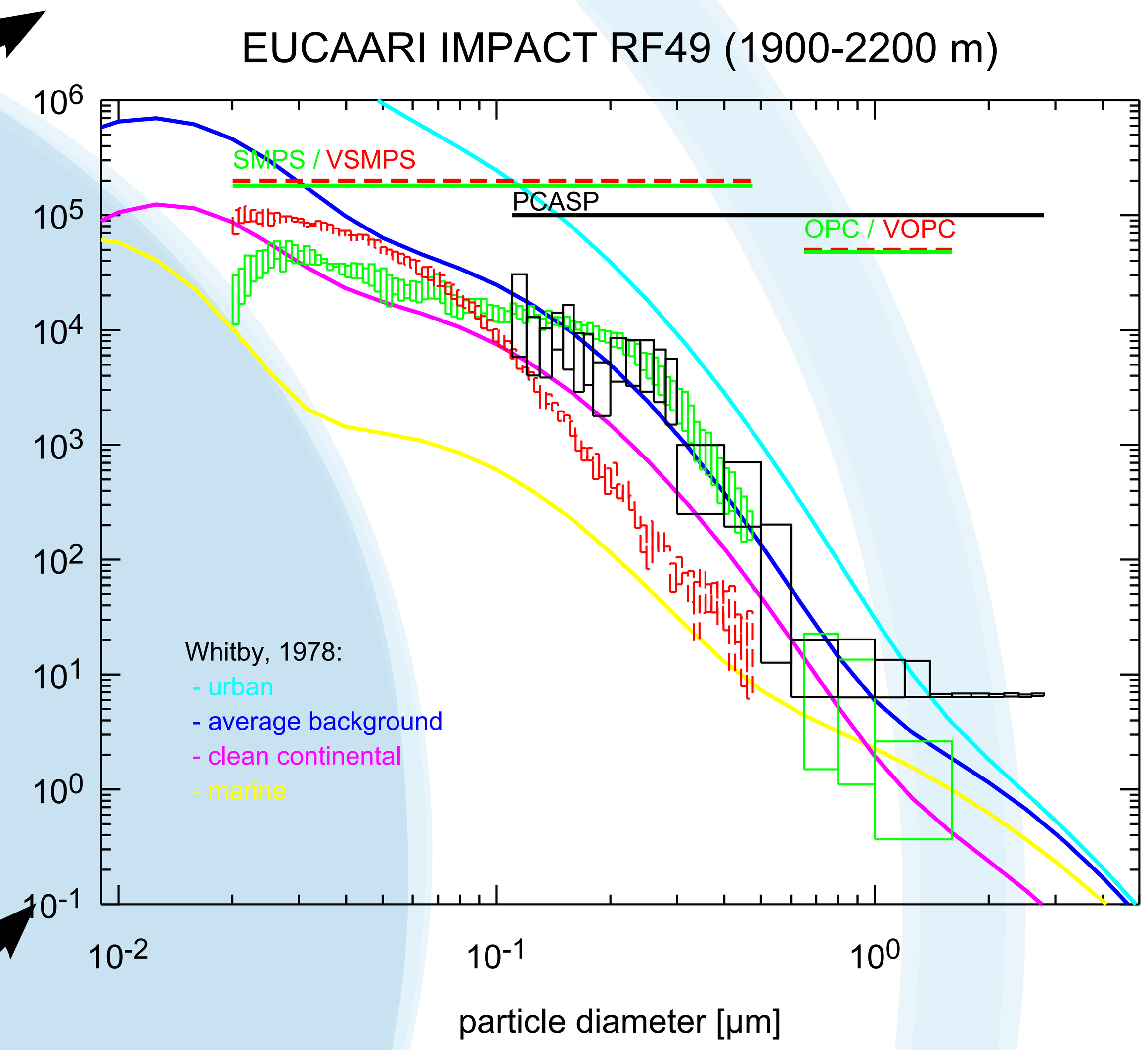

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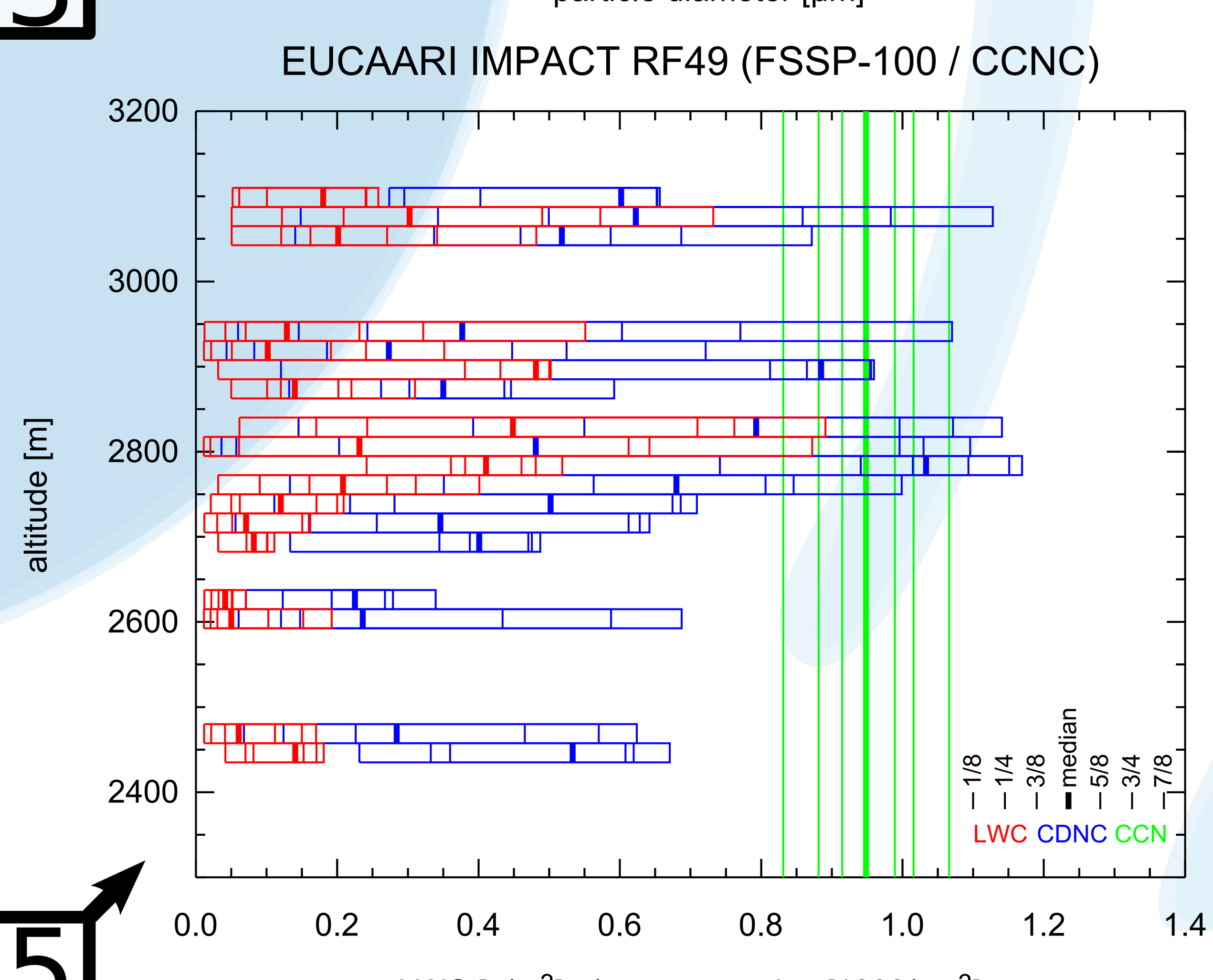

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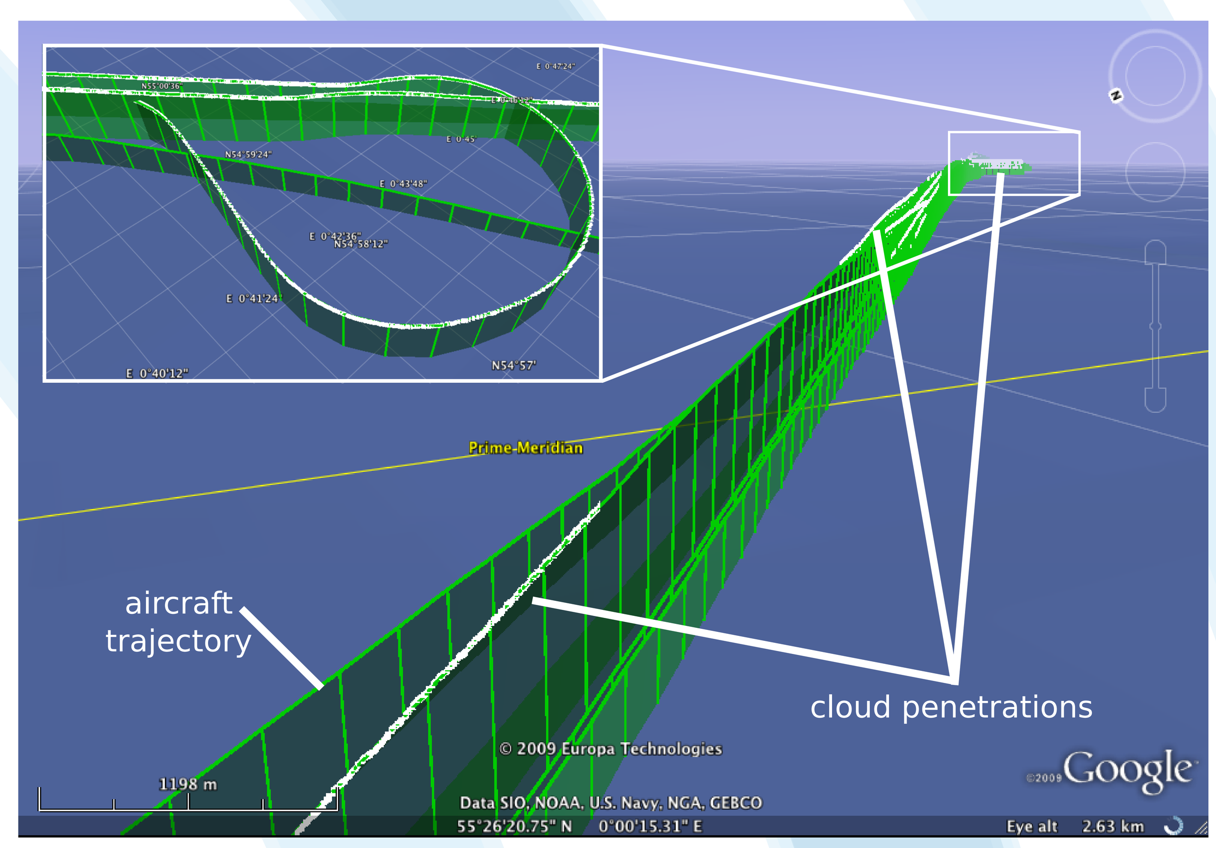
RF51 - 2008-05-15



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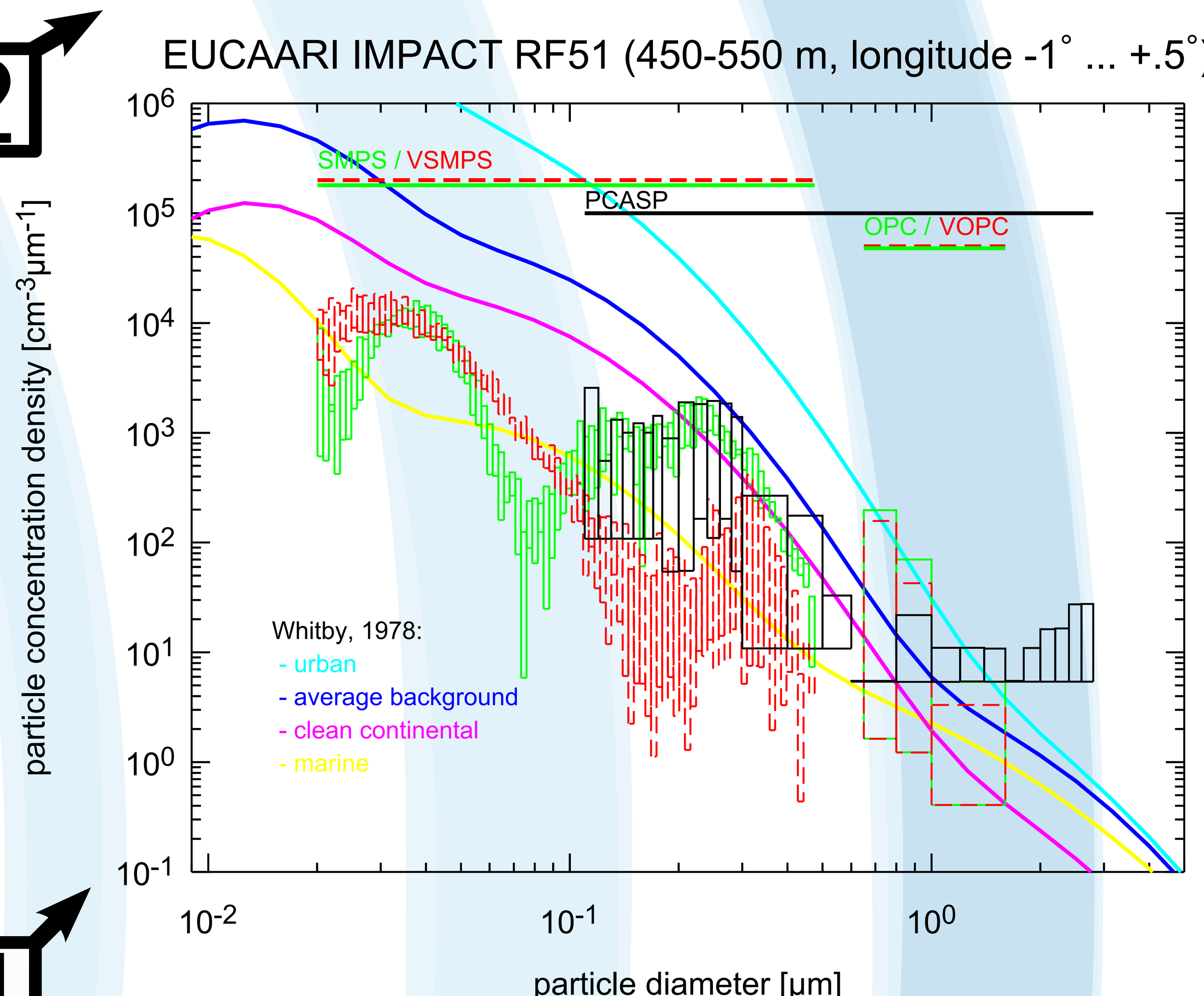

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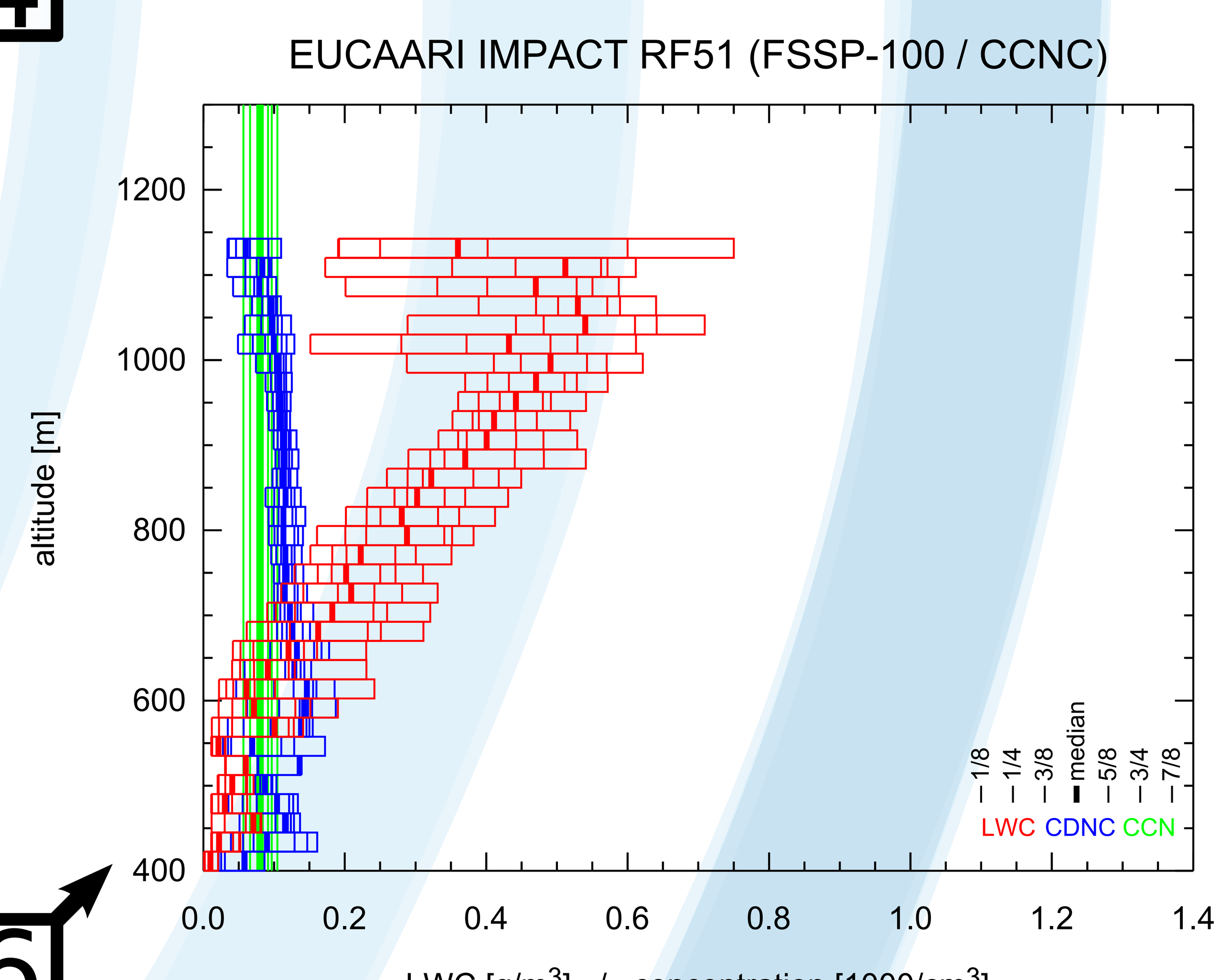

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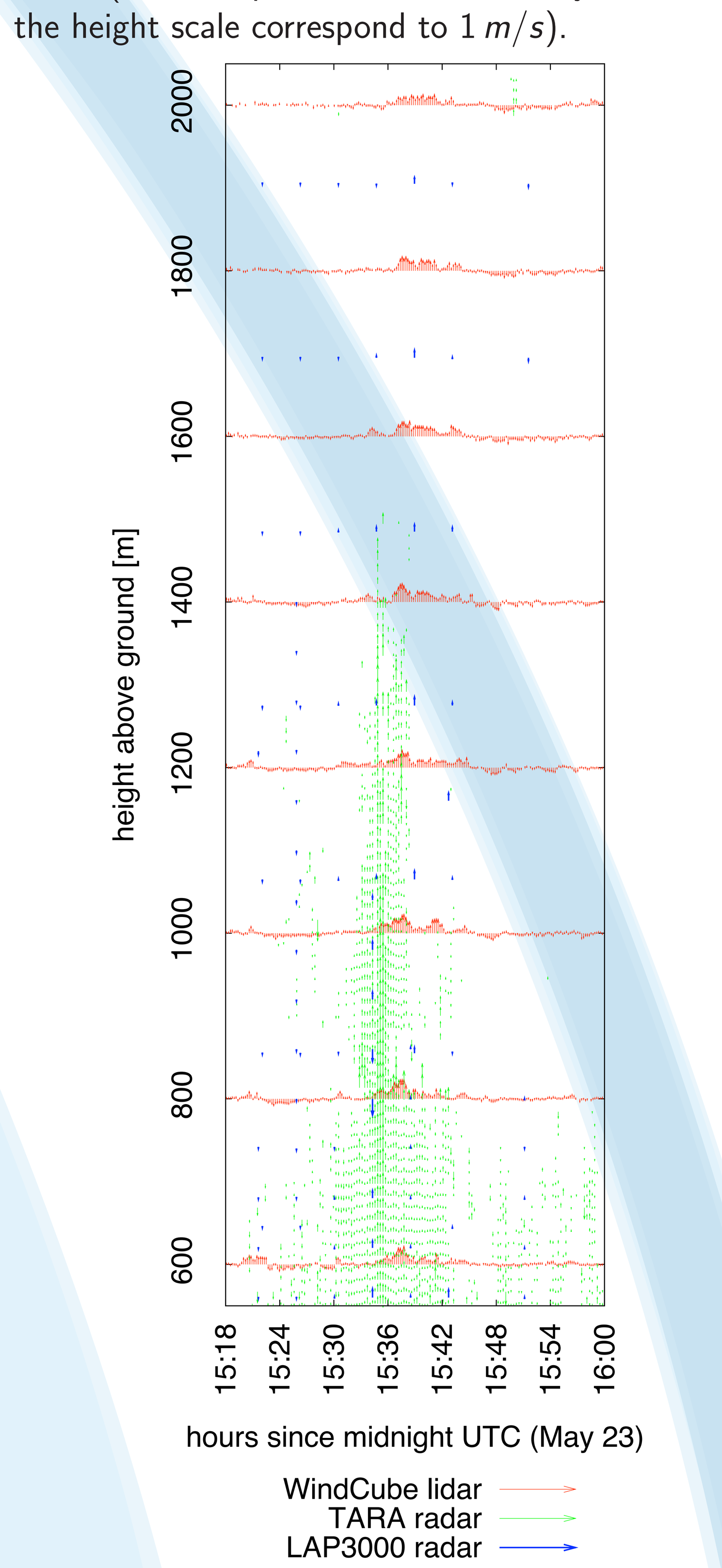
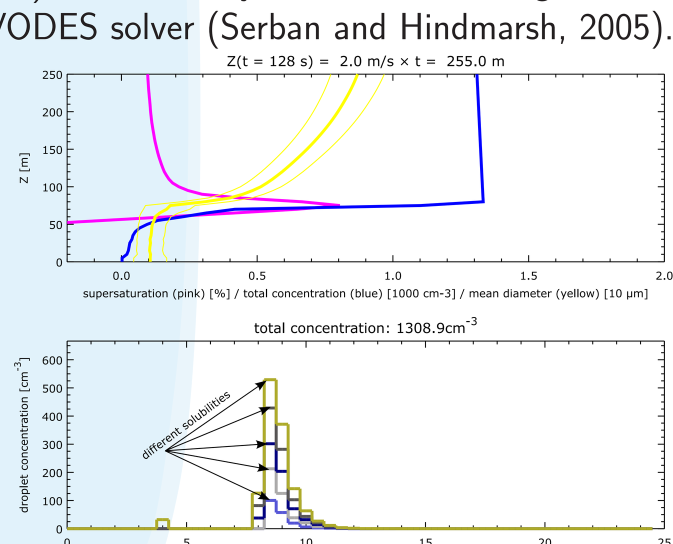
ground - based obs. @Cabauw

The ground-based aerosol instrumentation at the Cabauw observatory was a superset of the instruments used inside the SAFIRE ATR-42 aircraft. Vertical wind was measured using multiple remote-sensing instruments including: the TARA and LAP3000 radars, and the WindCube lidar. An example of comparison of these results for a single updraft is presented below (arrows represent vertical velocity, 5 m on the height scale correspond to 1 m/s).

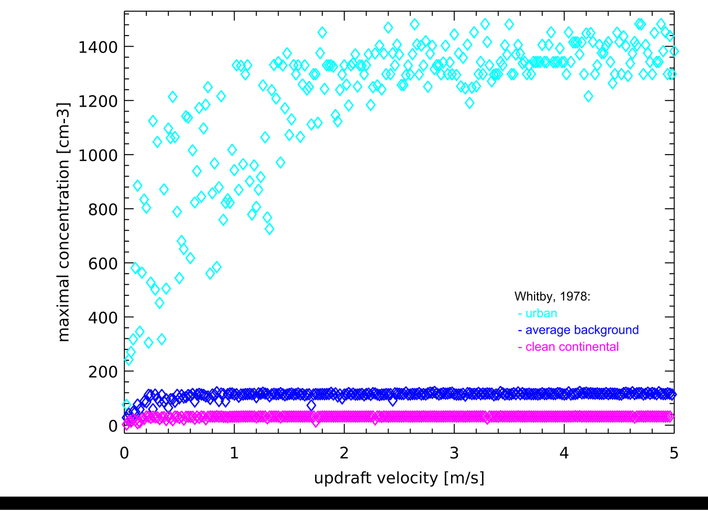


CCN activation modelling

An adiabatic air parcel model is used. The key model input parameters are: vertical air velocity (constant) and the aerosol size spectrum divided into bins of constant-in-time particle concentrations. The evolution of radius assigned to each bin is governed by a drop growth equation. The aim is to match the aerosol representation in the model with the range of measured aerosol physicochemical properties (presently we follow the description of Johnson, 1980). The ODE system is solved using the CVODES solver (Serban and Hindmarsh, 2005).



A summary of multiple simulations for three different aerosol settings (tri-modal lognormal spectra shown in figs. 3 & 4, defined after Whitby 1978 and used e.g. in Nenes et al., 2001), and different vertical velocities is show below. Results of such sets of simulations, matched with the measured velocity spectrum, is to be compared with statistics of in-situ-measured droplet-spectrum parameters.



Acknowledgements: Work done within the European Commission's 6. FP IP EUCAARI (European Integrated project on Aerosol Cloud Climate and Air Quality interactions) No 036833-2. SA and HP were supported by the Polish MNiSW grant 396/6/PR UE/2007/7. SA participation in the IMPACT field campaign was supported by the EC's FP6 ACCENT EU-Network of Excellence "Access to Infrastructures". Data provided by CNRM, LaMP, Leosphere, Météo-France, KNMI and TUDelft.

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Poster presented at the EUCAARI Annual Meeting 2009, November 2009, Stockholm, Sweden