Name of research institute or organization:

University of Manchester, Centre for Atmospheric Science

Title of project:

CLACE-2014_UK (project “INUPIAQ” funded by UK NERC)

Project leader and team:

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Project description:

The University of Manchester INUPIAQ project contributed to the joint CLACE-2014 multi-national experiment held at Jungfraujoch (JFJ) (below left and right in close-up) in January-February 2014.

The aims of the Manchester contribution were to:

1. Provide a comprehensive data set of aerosol and cloud microphysics measurements.

2. To use the measurements obtained (along with the measurements of collaborating institutes) as input to an explicit cloud-aerosol interaction model (ACPIM), developed in Manchester, to use the model to undertake a series of sensitivity studies for the purpose of identifying and understanding the important processes occurring within the aerosol-cloud system at JFJ, thus highlighting processes which might need inclusion/modification in other state-of-the-art models, such as the Met. Office Unified Model (MetUM) and WRF (Weather Research and Forecasting Model).

3. Identify ice processes that impact cloud evolution significantly.

4. To determine whether observations in previous CLACE experiments e.g. the observed very sharp transitions between ice and liquid clouds [Choularton et al. 2008] are due to changes in aerosol chemical composition, in particular in Cloud Condensation Nuclei (CCN) or Ice Nuclei (IN) properties.

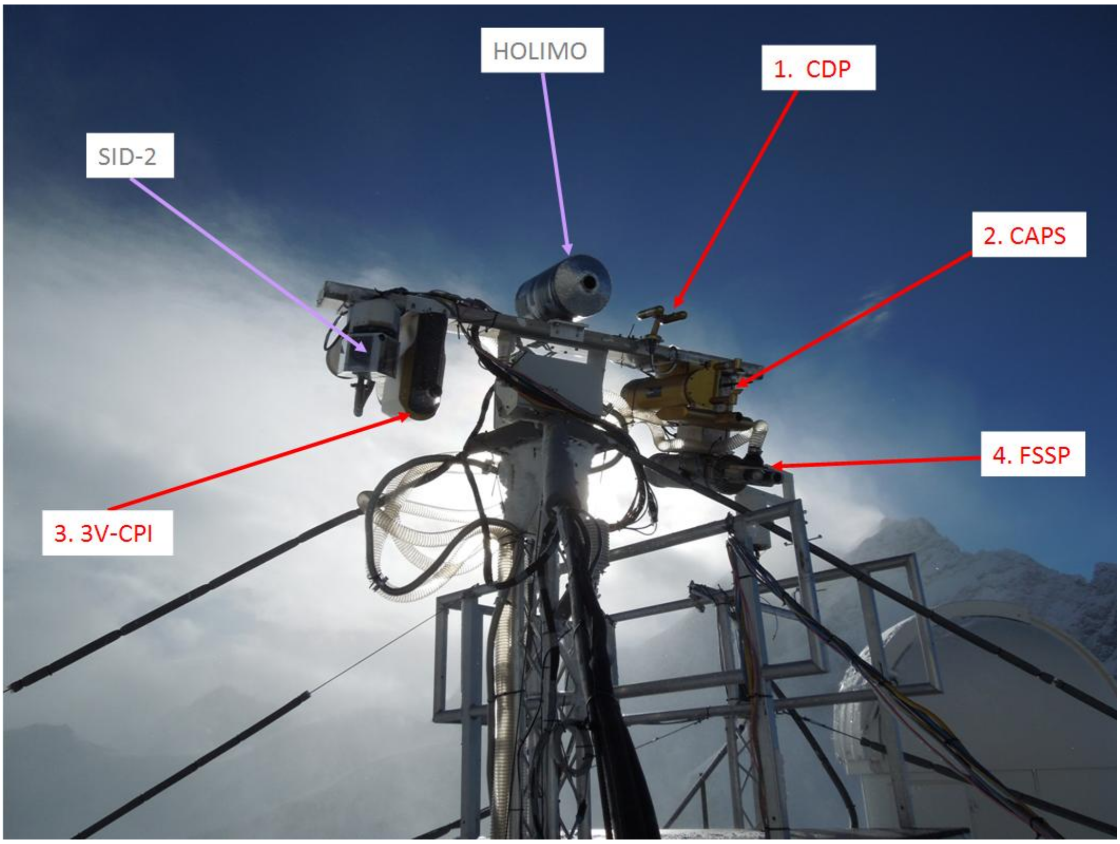
To meet these aims of understanding the development of the ice phase in JFJ clouds and to understand in particular how aerosols are linked to this, the University of Manchester contributed to the 2014 experiment by 1) deploying a suite of instrumentation at the site to: Measure liquid and ice phase cloud particle size distributions (from which cloud liquid and ice phase water contents could be calculated - although the former was also to be measured directly); Record images of cloud drops and ice particle habits (ice crystal shapes/type); Accurately measure the local 3-D wind vector; Measure the biological cloud residual particle concentrations. 2) Making measurements of the precursor aerosol at the lower mountain site Schilthorn which is generally below cloud. 3) To study the cloud formation and air parcel dynamics close to the summit using a LIDAR system deployed below cloud at Kleine Scheidegg. And 4) post experiment, to work on quality assuring the data, followed by data interpretation and work to model the cloud evolution using the detailed cloud models (e.g. ACPIM developed in Manchester) together with WRF.

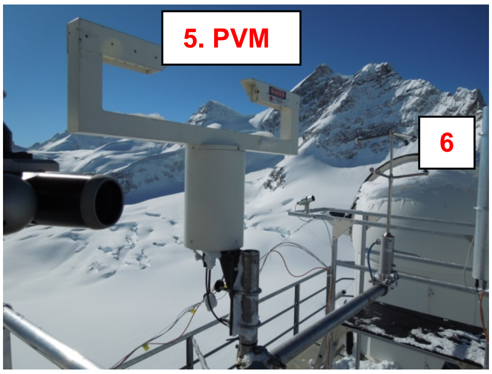
The major instruments deployed by the University of Manchester at JFJ and at * Schilthorn sites in early 2014 included:

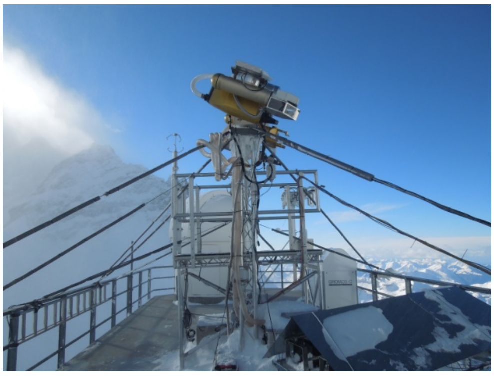
1) a DMT Cloud Droplet Probe (CDP-100) (to measure drop size distributions: 1-50um);
2) a DMT CAPS (Cloud, Aerosol and Precipitation Spectrometer) multi-probe consisting of a Cloud and Aerosol Spectrometer with depolarisation detection (CAS-depol) (measuring aerosol and cloud particle concentrations, 0.6um-50um) (includes a de-polarision back-scattered signal channel to differentiate liquid and ice particles), and a CIP-15G (Cloud Imaging Probe with15µm greyscale resolution - recording larger cloud particle images in the size range: 15-960um);
3) a SPEC 3-View Cloud Particle Imaging probe (3V-CPI) combining a fast response (10Hz) 2D Stereoscopic (2D-S) shadow imaging probe (10µm resolution over the range: 10-1280um) and a new high speed (400 frames per second) high resolution CCD CPI;
4) a PMS/DMT Forward Scattering Spectrometer (FSSP-SPP-100) measuring drop size distributions: (0.5-50um);
5) a Gerber Particulate Volume (PVM) monitor measuring cloud liquid water content directly;
6) a heated Metek Ultrasonic Anemometer, along with
7) Temperature and humidity sensors (NB items 6 and 7 duplicated at * the Schilthorn);
8) a Wavelength Integrating Bio-aerosol Sensor (WIBS) (a UV-LIF single particle spectrometer) for continuous detection/sizing of single biological particles in the cloud residual or aerosol population (sampling inside the Sphinx laboratory off the partner ISI or total aerosol inlets). NB for the first part of the project WIBS was deployed at * (the Schilthorn below cloud site);
9) * an Aerodyne Aerosol Mass Spectrometer (submicron non-refractory aerosol mass composition) (NB * deployed at the Schilthorn below cloud site);
10) * a DMT SP2 (Single Particle Soot Photometer) instrument for measuring black carbon aerosol and its mixing state (* at the Schilthorn site);
11) * a GRIMM (model 1.109) dust monitor optical particle counter measuring aerosol size distributions (size range 0.2-20 micron in 30 channels);
12) * a TSI APS (Aerodynamic Particle Sizer model 3321) aerosol optical particle spectrometer (aerodynamic size range 0.5-20 microns in 52 size bins);
13) * a remote controlled aerosol collection system on filters (2 stage Nuclepore filters; with 10 and 1.0 micron pore sizes) giving roughly super and sub-micron aerosol samples for offline analysis by ESEM and EDX methods;
14) * a BIRAL (PWS) Present Weather and visibility Sensor (HSS VPF-730) for measurement of local visibility conditions (i.e. clear/fog/cloud, rain/snow precipitation state at the Schilthorn);
15) * auxiliary fast response CO and O3 gas phase measurements for determining airmass connectivity with the JFJ site (by comparison with similar measurements made by collaborators at the JFJ summit);

16) a Halo-Photonics Doppler aerosol LIDAR (a 1.55 µm eye-safe (Class 1M) scanning micro pulsed LiDAR, on loan from the NCAS AMF) measuring boundary layer dynamics and turbulence, wind and mixed phase cloud observations, looking vertically upwards, and at the cloud enveloping the JFJ summit and scanning down the northern valley side of JFJ, west towards the Schilthorn (NB deployed at the Kleine Scheidegg site just north of the JFJ ridge).

All instruments 1-7 were mounted externally on the JFJ terrace rooftop outside the Sphinx laboratory. Instruments 1-4 were mounted on an instrument crossarm (Main photo 1 below), which was able to rotate and tilt the cloud microphysics instruments directly into the ambient wind, automatically (as determined from the real-time sonic anemometer measurements). The crossarm and rotator were mounted on the top of a 3m (square) mast secured to the JFJ terrace rooftop (as illustrated in Photos 2-3), alongside an access platform. The PVM and sonic anemometer (Photo 2) were fixed to a horizontal bar from a separate (triangular) mast to the west of the rotator on the other side of the access platform. The temperature/humidity sensors were attached to the fixed rotator mast. The ETH HOLIMO holographic spectrometer and the KIT SID-2 instruments were also deployed on the Manchester crossarm in 2014 (located centrally on the top of the wing and at one below wing end position, respectively).

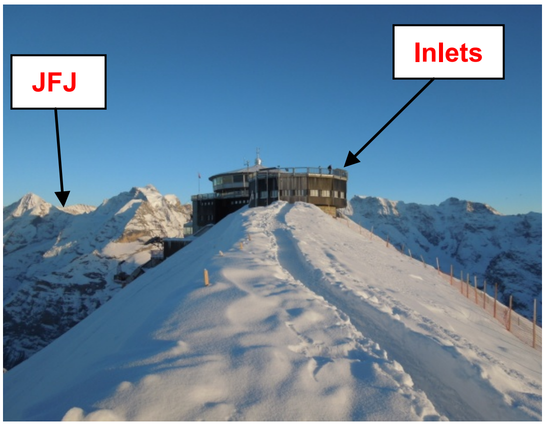




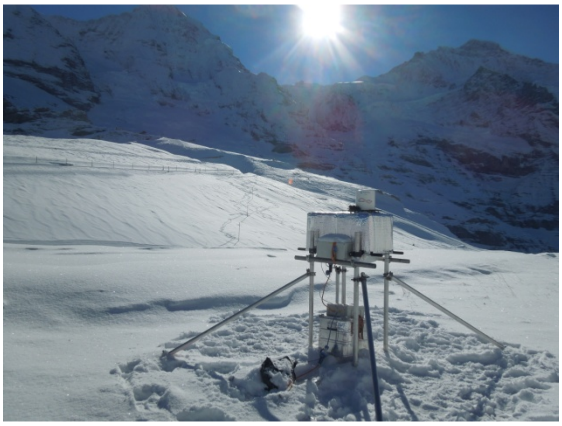


Instruments (1-4) are designed to be deployed on aircraft and hence normally sample cloud at aircraft speeds. Because of this, instruments with inlets (2a, 3 and 4) were aspirated by attaching tubing to the rear of inlets and sucking cloud through at controllable rates using vacuum pumps (located in the aluminium boxes beneath the platform) and a venturi control system. All instruments, particularly those with inlets, required constant attention during sampling to prevent significant build up of rimed ice in supercooled cloud conditions. During night-time this was not always possible when left unattended, and hence such icing incidents need careful removal during quality assurance of the data prior to analysis. All microphysics instruments were also calibrated at suitable intervals using known calibration standards (e.g. calibration glass spheres of known diameter for CDP, FSSP and CAS, or by the use of calibration filters in the case of PVM. The latter required frequent checks of the baseline and calibration span, to account for the gradual decline of optics cleanliness etc. *(this instrument has required significant correction for an intermittent electronic problem encountered in the field in 2014).*

Finally, the bio-aerosol spectrometer (WIBS (8) (initially deployed at the Schilthorn) was deployed internally to the Sphinx laboratory, and sampled off either the “ISI” or “Total aerosol” inlets in 2014, in conjunction with the KIT WIBS instrument. All measurements from the external cloud microphysics instrumentation were logged on systems set up within the Sphinx laboratory workshop, together with the controls for the crossarm rotator (and alongside the HOLIMO and SID-2 logging computers of ETH and KIT).



The aerosol instruments housed within the apartment at the Schilthorn site (photo, above left) sampled from a bespoke total aerosol inlet set up on the corner of the “James Bond” terrace (see photos above, right & left), alongside the Present Weather Sensor (PWS), sonic anemometer and T and RH measurement pole. All instruments were logged locally within the Schilthorn apartment (below the inlets), although the measurements were also observable remotely via the internet. O3 and CO instruments were provided with suitable but separate sample lines, from the same sampling pole. All sample lines were lagged and maintained at chosen controlled temperatures to avoid unknown sampling artefacts.



The Halo Photonics LIDAR, (photo above left - directly in front of, and here down-sun of JFJ, and photo above right – in the middle of the bottom of the picture - with Eiger to right, and JFJ beyond that - out of shot) was deployed on the Jungfraubahn train shed roof at the Kleine Scheidegg and logged internally, but was communicated with remotely via a wireless internet connection. Scanning patterns were designed to investigate the dynamics of the airflow into/out of the JFJ sampled clouds and along the northern side of the JFJ ridge west towards the Schilthorn, as well as determining the dimensions of the sampled cloud and aerosol layers.

Results:
The intended outcome of the University of Manchester contribution to CLACE-2014 is a comprehensive data set of aerosol and cloud microphysics measurements, enabling detailed cloud model sensitivity studies to be undertaken which aim to aid identification and increase understanding of the important processes occurring within the aerosol-cloud system, highlighting processes which need inclusion in other state-of-the-art models, such as the UK Met. Office Unified Model (MetUM).

The analysis and interpretation of these data collected during CLACE_2013 and 2014 are proceeding now that we have funding from NERC, but these activities are in their early stages and are not yet final or ready for presentation/publication. Preliminary analysis of data from the microphysics probes suggests that ice crystal number concentrations observed are often much higher than the ice nucleus (IN) concentrations observed locally (or likely to be present), and higher than predicted IN concentrations from measured aerosol numbers. These results strongly suggest that a secondary ice particle production process is operating in the cloud system. Work is proceeding to identify and quantify the processes contributing to the observed ice crystal number concentration. The preliminary work has been written up in the format of a draft paper in the University of Manchester PhD thesis of Gary Lloyd (one of the investigators present during the campaign). However, the work is currently ongoing.

Key words:

Ice microphysics, mixed phase cloud, ice nucleation

Internet data bases:

Currently raw data storage is on a local (in Manchester) mirrored data server while quality assurance and analysis is on-going. When completed, data will be transferred to (and will, within one year of uploading, be publically available) at the British Atmospheric Data Centre (BADC). Worked up data has also been stored on a joint CLACE data base for direct access by CLACE-2014 collaborating scientists.

Scientific publications and public outreach 2014:

Theses

Lloyd, G., The origin of the ice phase in clouds, PhD Thesis, University of Manchester, 2014.

We have also contributed to papers in preparation or submitted led by other members of the consortium. We intend to produce papers from Manchester in collaboration with colleagues at other institutions, on the themes of fluorescent aerosol measurements from the WIBS instruments (within and outside major dust events); on the origin of the very high ice crystal concentrations observed at JFJ, and their implications for precipitation formation in the observed clouds - probably both observations and modeling based papers.

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