Investigation of marine boundary layer and clouds with remote sensing instruments at Mace Head, MHDCloud

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Introduction and motivation

There has been extensive research on the properties of clouds, their formation and evolution, as clouds are responsible for redistributing water and are a major component in the global energy budget. Aerosols can modify cloud properties and further research is required to understand this aerosol-cloud interaction. Cloud layers within the well-mixed boundary layer are directly influenced by ground and ocean based anthropological and natural cloud condensation nuclei (CCN) sources. Turbulent mixing within the atmospheric boundary layer provides a mechanism for transporting gaseous and particulate matter, and is a significant factor in a variety of processes (e.g. gas exchange between the atmosphere and soil/ocean, aerosol nucleation, cloud formation). For many of these processes, an important parameter to determine is the mixing-level height, MLH, which is the top of the atmospheric region in constant contact with the surface through turbulent mixing (White et al., 2009).

Liquid cloud layers, such as stratocumulus or cumulus, at the top of the boundary layer can then be separated into two distinct groups:

- Coupled, where the cloud layer is present within or at the top of the mixed layer
- Decoupled, where the cloud layer is above the MLH

For cloud layers that are coupled with the surface, we assume that the aerosol properties measured at the surface are representative of the atmospheric column within the mixed layer, whereas this assumption may no longer be valid for decoupled cloud layers. By combining ground-based remote-sensing and in-situ aerosol observations we can investigate the propensity for coupling - decoupling of liquid cloud layers with the surface, and evaluate the conversion of boundary-layer CCN into cloud droplets. Any differences in coupled or decoupled cloud properties can also be evaluated.

Continuous measurements of the boundary layer structure at high temporal resolution are still sparse. Various methods have been derived to retrieve atmospheric layers from lidar and ceilometer data (e.g. O'Connor et al., 2010; Milroy et al., 2011; Barlow et al., 2011). Single-channel elastic-backscatter lidars and ceilometers are only capable of measuring the backscatter signal from aerosol particles and hydrometeors, which allows detection of aerosol layers (Milroy et al., 2011). However, it is uncertain how reliably MLH can be diagnosed from aerosol layers alone. A method is available for determining MLH based on the dissipation rate of turbulent kinetic energy (Barlow et al., 2011) derived from the vertical motion of air (O'Connor et al., 2010). As there is no commonly agreed way to retrieve boundary layer structure, a comparison of measurement techniques and methods is required.

Scientific objectives

The objectives of the measurement campaign with a Doppler lidar at the Mace Head research infrastructure were to study marine boundary layer and its associated clouds, and facilitate on-going aerosol and atmosphere-ocean exchange research at Mace Head by:

1) comparing methods for retrieving the marine boundary layer structure (O'Connor et al., 2010; Milroy et al., 2011),
2) investigating coupling and decoupling of marine stratocumulus clouds within the boundary layer,

3) investigating the potential for interaction between marine aerosol particles and clouds coupled within the mixed layer.

Reason for selecting site

As a large fraction of the Earth's surface is covered by oceans, understanding marine boundary layer dynamics and clouds is essential. The research infrastructure at Mace Head in Ireland is ideal for investigating the marine boundary-layer as it is located on the western shore of the North Atlantic Ocean and has a wide marine sector (ca. 120°). The site at Mace Head operates a suite of remote sensing (Mira-36 Doppler cloud radar, Vaisala and Jenoptik ceilometers, HATPRO microwave radiometer) and ground-based in-situ instruments for continuous monitoring of cloud and aerosol properties. However, information on atmospheric dynamics in the boundary layer is not currently available, and therefore, deployment of a Doppler lidar would provide added value to the already comprehensive dataset collected at the site.

Method and experimental set-up

The Finnish Meteorological Institute (FMI) deployed a 1.5-µm wavelength Doppler lidar equipped with a depolarisation channel (Halo-Photonics, Pearson et al., 2009). This instrument measures the backscatter signal and Doppler velocity from aerosol particles, drizzle, rain, cloud droplets and ice crystals. The FMI lidar was co-located with the permanent remote sensing instruments at Mace Head and operated continuously for approximately 25 days during February and March 2012.

During the campaign, the Doppler lidar was set to measure in vertical stare mode, with vertical profiles of horizontal wind obtained from the Doppler Beam Swinging technique at ten-minute intervals. In vertical stare mode, the Doppler velocity from aerosol targets, which have no appreciable terminal fall velocity, provides a direct measurement of the vertical air motion within the boundary layer. From this, the dissipation rate of turbulent kinetic energy is derived (O'Connor et al., 2010), from which the mixing layer height can be determined (e.g. Barlow et al., 2011); we can then investigate the relative frequency of whether stratocumulus and cumulus clouds are coupled or decoupled within the boundary layer.

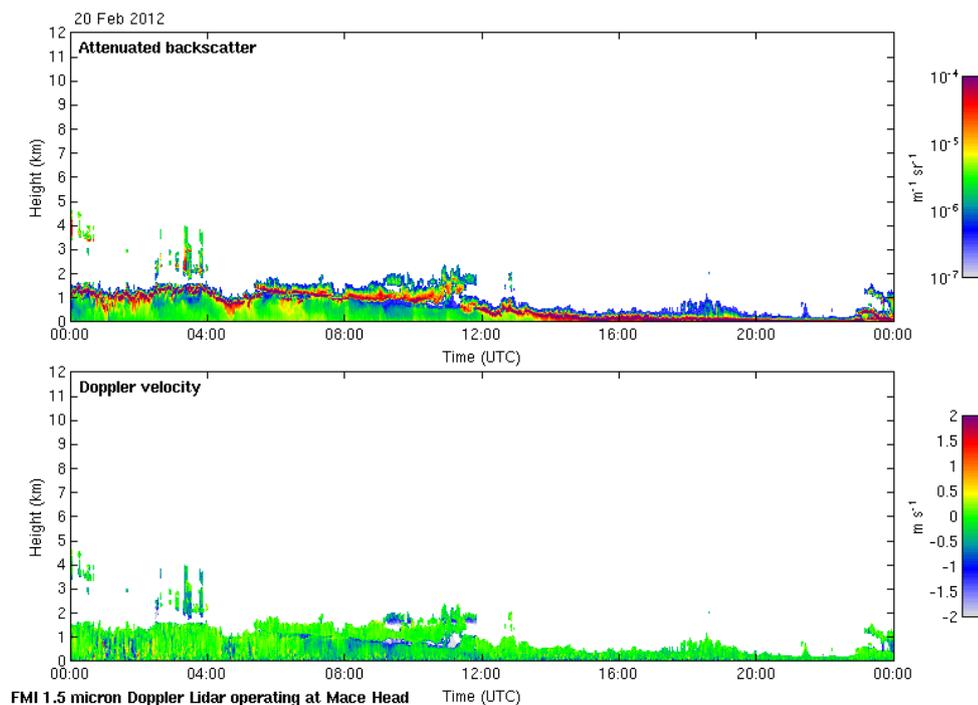## Preliminary results and conclusions

Figure 1. Time-height quicklook of vertical profiles of attenuated backscatter coefficient (top panel) and Doppler velocity (lower panel) at Mace Head, Ireland, on 20th February 2012.
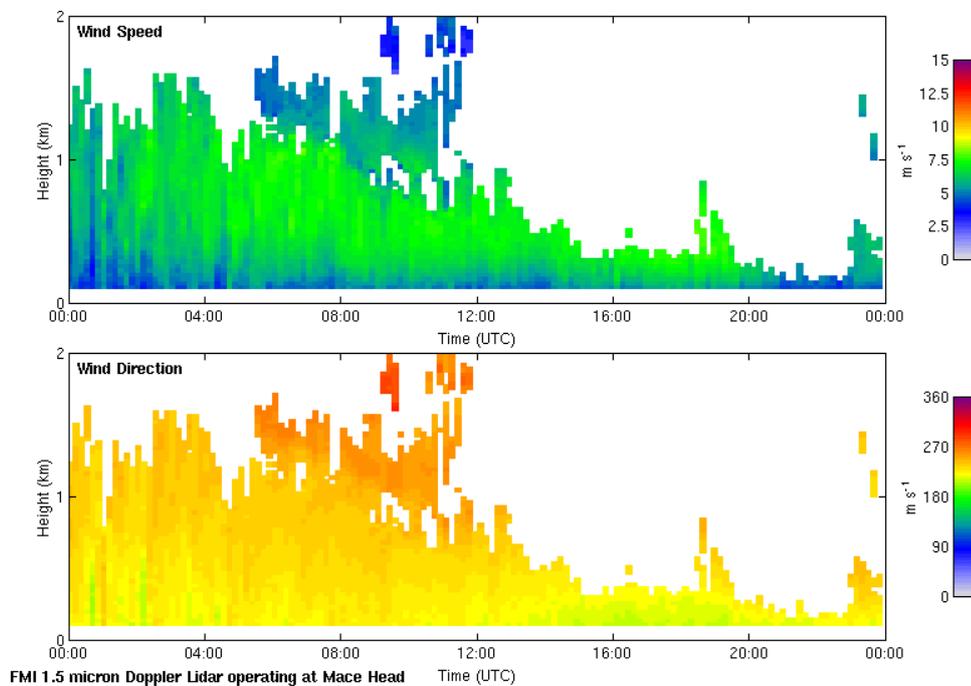
Figure 2. Time-height quicklook of horizontal wind speed (top panel) and wind direction (lower panel) at Mace Head, Ireland, for the same day as in Fig. 1. Note that the vertical axis has been modified relative to Fig. 1.

The measurement campaign at Mace Head has just finished and data analysis is currently on-going, thus, we only provide a preliminary view of the data here. A number of steps must be undertaken in the processing of the raw instrument data. The first step is to create profiles of backscatter and Doppler radial velocity in standard netCDF format with artifacts and other non-meteorological noise removed. An example daily quicklook plotted from the vertical profiles is shown in Fig 1. Horizontal winds are then obtained from the cleaned DBS profiles (an example is given in Fig. 2). Data for the entire campaign has been processed to this level. The next step is to derive the dissipation rate of turbulent kinetic energy, and determine MLH; currently in progress.

Once MLH has been determined, liquid cloud layers can then be classified as coupled or decoupled, and further characterised by means of cloud fraction, cloud thickness, liquid water content, drizzle and precipitation, cloud droplet number concentration; parameters provided routinely from Mace Head remote sensing observations. Comparison with surface in-situ aerosol measurements will then allow the investigation of the relationship between CCN and cloud droplets through parameters such as aerosol number concentration and hygroscopicity.

Outcome and future studies

In co-operation with researchers from NUI-Galway we will study the boundary layer structure for air masses which may have either marine or continental influence, and determine MLH from two different methods. This comparison is expected to guide future discussion on instruments and methods to achieve the best estimate for boundary layer structure through the EU COST programme EG/CLIMET.

We plan to publish at least two manuscripts in international peer-reviewed journals. Preliminary titles are:

1. Comparing methods to retrieve marine boundary layer structure.
2. Investigating the boundary layer structure for coupled/decoupled stratocumulus in the marine environment.

In addition, we will present and publish the results in the proceedings of upcoming conferences and workshops. This will also help publicise this dataset, with the intent that it is used within the wider ACTRIS community; we plan to collaborate with various groups to attempt to answer some of the major scientific questions concerning aerosol-cloud interaction.

References

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