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Developing and deploying new sensors for in-situ monitoring of clouds

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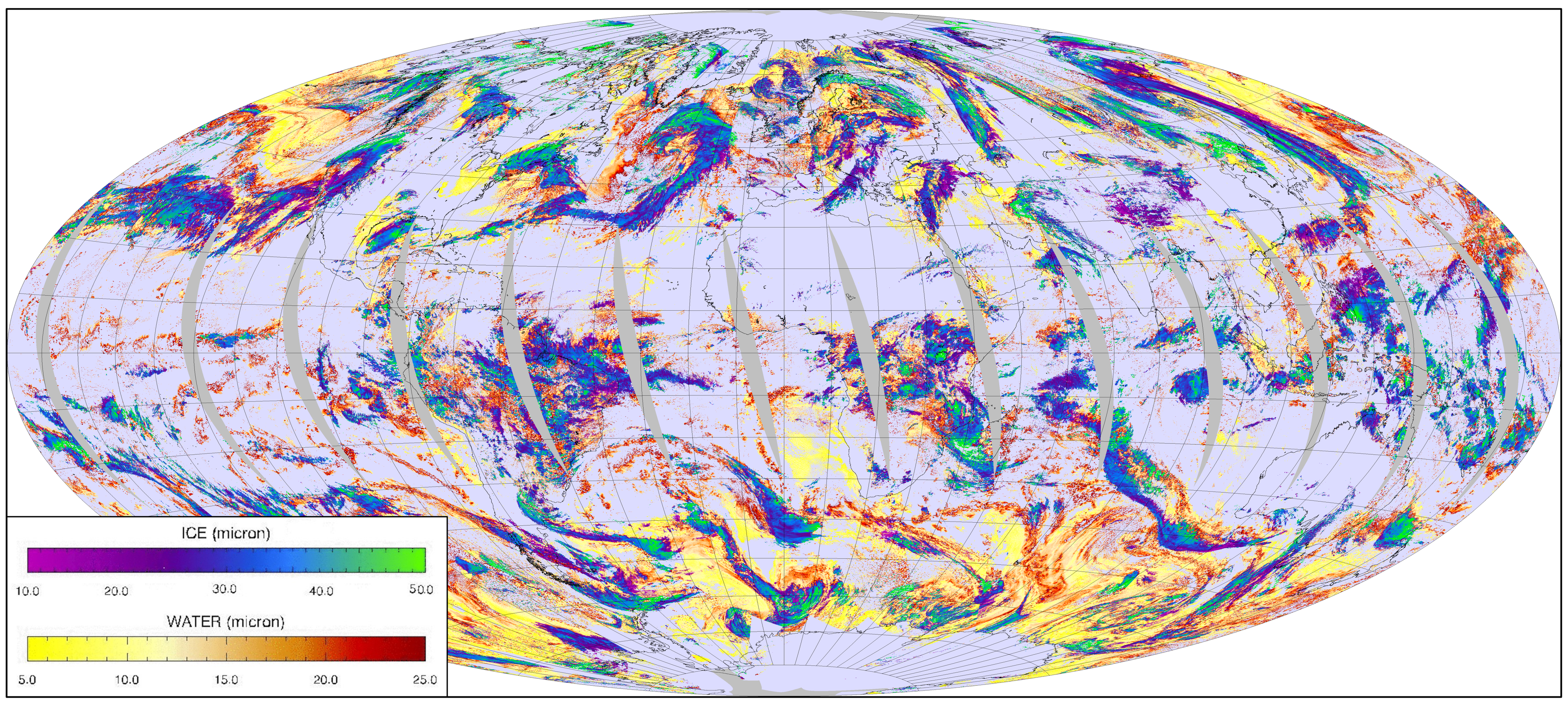
Background

Additional to cloud physics research, **in-situ measurement of cloud droplet size distribution** (from within clouds) is a requirement across climatological and meteorological communities.

In-situ measurement of cloud is used to validate satellite (and ground) remote sensing algorithms that can retrieve ***global cloud data product*** [1].

Fog (cloud that forms without the rising of air) in-situ process studies are used in developing forecast capability for more accurate **hazardous fog weather warning** [2].



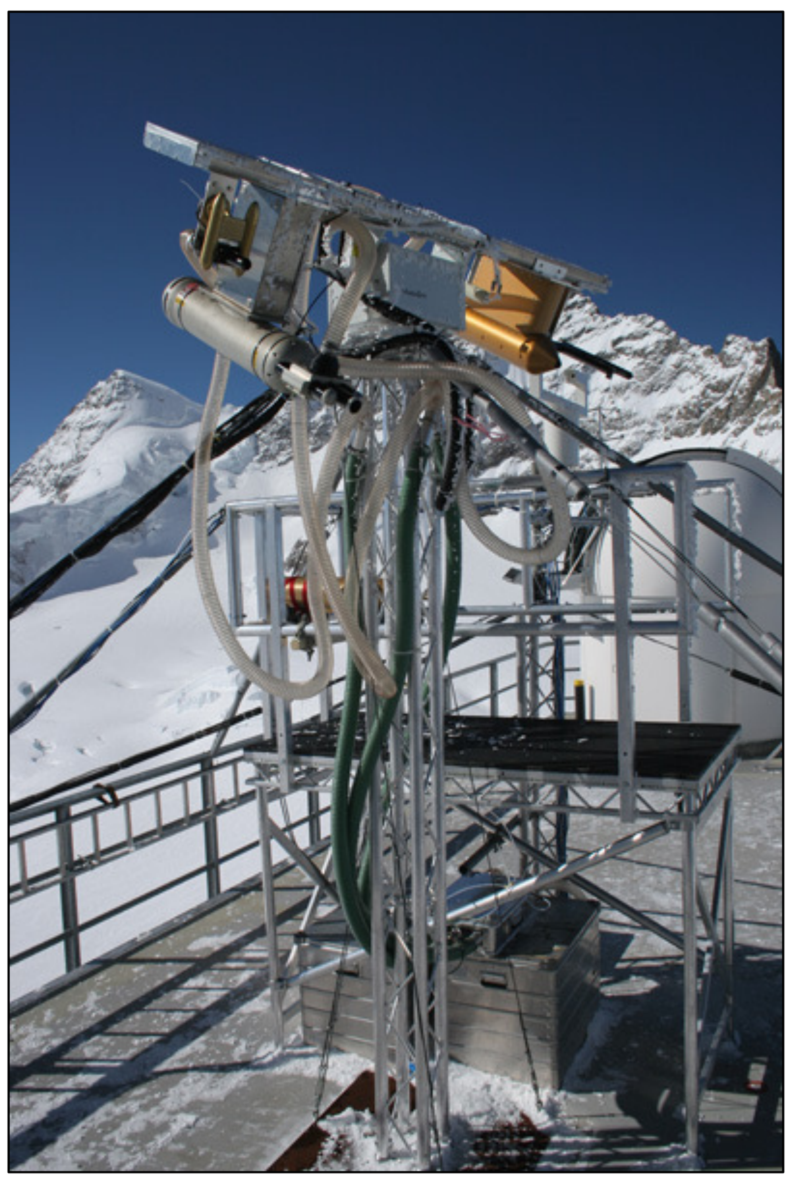
***Global cloud data product* is used to more accurately forecast the climate** – Cloud Effective Radius (CER; a measure of average cloud droplet size) can be retrieved over Earth daily by the MODIS satellites (NASA); the raster shows CER (5 km^2 average per pixel) retrieved by *Aqua* on 2023-03-14 [3].

Problem Statement

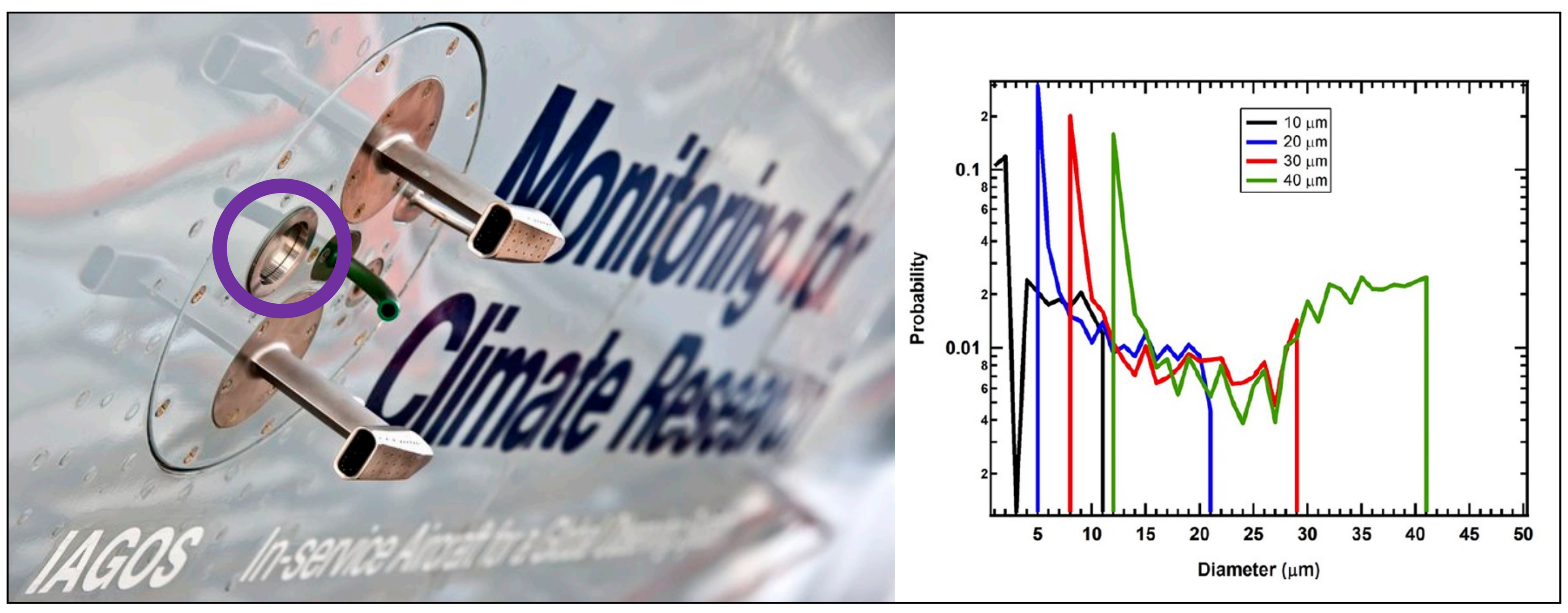
Availability of data on the microphysical properties of clouds is a **current limitation** in developing capability within meteorology and climatology [1][2].

In-situ sampling of cloud can be a **costly operation**, often necessitating the use of special aircraft and instrumentation that cannot provide **long-term data.**

Ground-based weather stations in contact with clouds, and **commercial aircraft** provide potential platforms for cloud monitoring, but most instrumentation is not suitable for these platforms, or too costly for widespread distribution [4][5].



Sphinx Observatory, Switzerland (3,571 m) – Costly aircraft cloud spectrometers require scaffolding and modification for ground-based use [6].



Cloud could be monitored from commercial aircraft – IAGOS (In-Aircraft Global Observing System) provides infrastructure for climate monitoring from commercial aircraft [7] and includes the Back-scatter Cloud Probe (**BCP**; **encircled**). The BCP detects cloud to accompany other instruments, but cannot measure size distribution accurately; the chart shows probabilities droplet size is misclassified if the signal is interpreted quantitatively [8].

Aims

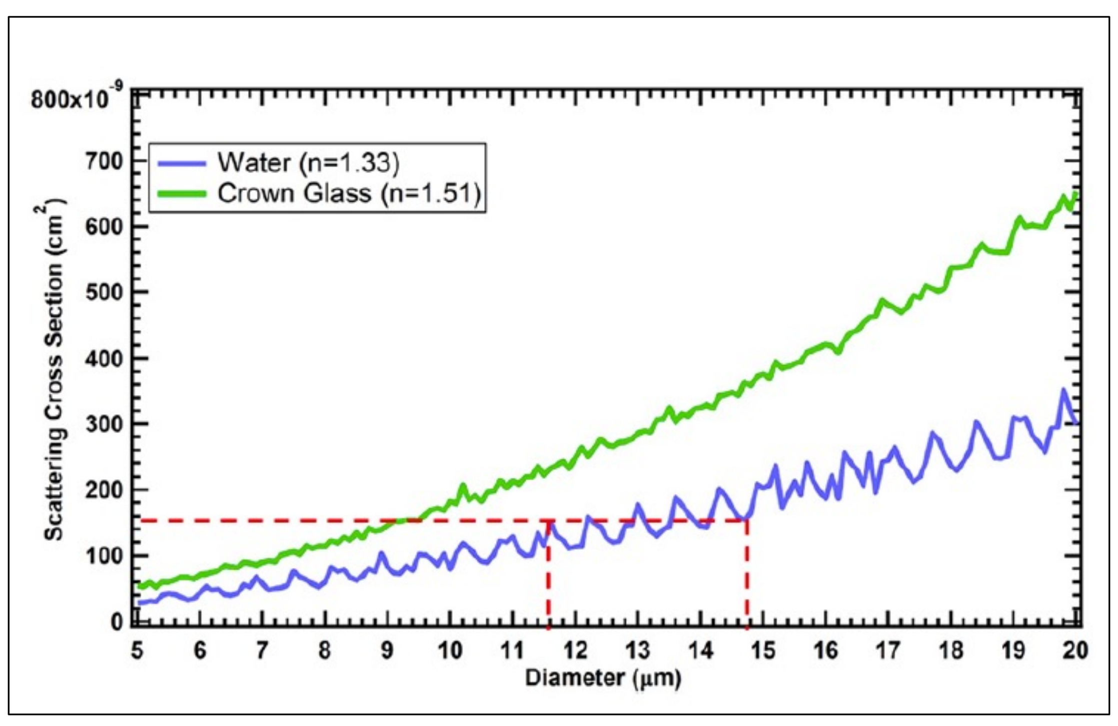
- Design a **low-cost sensor for in-situ measurement of cloud droplet size distribution**, suited to use from monitoring platforms.
- Develop and assess a prototype for **ground-based monitoring** use at Holme Moss Meteorological Observatory, University of Manchester (524 m).

Methodology and Challenges

Light scattering is the predominate technique used to measure cloud droplets in the size range of 2-50 microns.

An **iterative experimental and theoretical approach** will be used to discern the most suitable light scattering configuration for a low-cost monitoring sensor before rapid prototyping.

Tolerances in rapid prototyping techniques present challenges in developing a sensor of required precision, accuracy and stability; simplicity of design will be prioritised and scope of use continuously reviewed during the development process.



Non-monotonic light scattering relationships can present measurement challenges – Mie theory relationship between scattered light intensity and droplet size, shown for a BCP configuration with an example of non-injectivity (in dashed red) [8].

References

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[2] Price, J. D. et al., 'LANFEX: A Field and Modeling Study to Improve Our Understanding and Forecasting of Radiation Fog' (2018), doi.org/10.1175/BAMS-D-16-0299.1
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[4] Doulgeris, K et al., 'In Situ Cloud Ground-Based Measurements in the Finnish Sub-Arctic: Intercomparison of Three Cloud Spectrometer Setups' (2020), doi.org/10.5194/amt-13-5129-2020
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[8] Beswick, K. et al., 'The Backscatter Cloud Probe – a Compact Low-Profile Autonomous Optical Spectrometer' (2014), doi.org/10.5194/amt-7-1443-2014