Assessment of BCP and BCPD Aircraft Observations by Validation against Ice Water Content from the Nevzorov Probe.

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Motivation

The BCP and BCPD instruments were developed (Beswick et al. 2014, 2015 and Baumgardner et al. 2017) to allow the IAGOS (European In-service Aircraft for Global Observations) community to exclude periods the aircraft were flying in clouds from the measurements. The instruments are however capable of giving size resolved number concentration measurements of cloud particles and large aerosols such as e.g. dust particles. The particles are smaller than those that can be detected by the onboard RADAR and they can therefore provide warnings to pilots of dangerous flying conditions in real time which are typically found in deep convective clouds and their outflow regions. The warnings to pilots could avoid issues of engine roll back due to encounters with areas of high ice water content, air frame icing and sensor degradation due to high ice crystal concentrations. As several commercial airliners are fitted with BCP/BCPD instruments and have been flying for several years collecting a large database of encounters with ice clouds at cruise altitude and water and mixed-phase clouds during take off and landings. The collected measurement form a database which could create a very useful near global dataset of cirrus cloud properties encountered during flights for case-study comparisons with numerical weather prediction models and also satellite measurements as well as give a near global climatology of ice water content for weather and climate models. Cirrus clouds are important for climate modulation and can sometimes be difficult to measure with satellites.
The instrument has been shown to work well in liquid water clouds (Beswick et al. 2014, 2015, Baumgardner et al. 2017). Here we will report on the comparison of BCP and BCPD measurements on the FAAM BAe-146 aircraft with simultaneous measurements of ice water content using the Nevzorov probe (Korolev et al. 1998, 2013) to determine how well ice water content can be detected by the IAGOS BCP system.

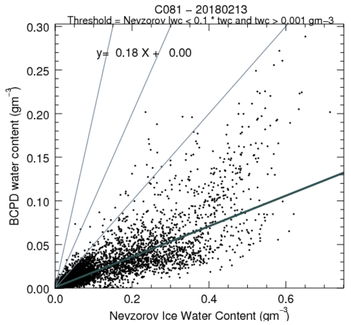
Measurements Used in this Study

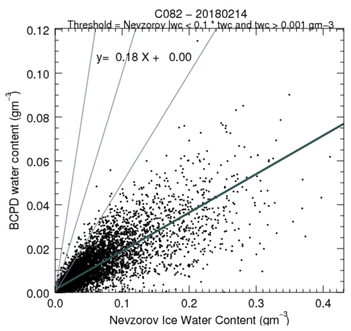
IAGOS - European In-service Aircraft for Global Observing Systems:
A fleet of 5 commercial airliners (Airbus A330/A340) have been flown on international routes that cross 5 continents with Particle backscattering optical spectrometers (the Backscatter Cloud Probe (BCP)) since 2011.
Backscatter Cloud Probe measurements:
The **IAGOS BCP** is mounted flush with the skin of the aircraft and measures the concentration and optical equivalent diameter of particles from 5 to 90. Data is accumulated every 4 seconds. The data can be post-processed through an inversion technique to provide. For the **Satellite study** an inversion technique (Beswick et al. 2014) was used with 20 seconds of accumulated measurements to provide accurate size distributions of number and mass concentration.
The **BCPD** was flown during the PICASSO field campaign on the wing-pylon of the FAAM BAe-146 aircraft. It measures particle number and size the same way as the **BCP**, but has additional polarisation information, that can distinguish between spherical and non-spherical particles (not used in this study).
For the **BCPD vs Nevzorov** study the measurements were used straight from the instrument.

BCPD Comparison with Nevzorov

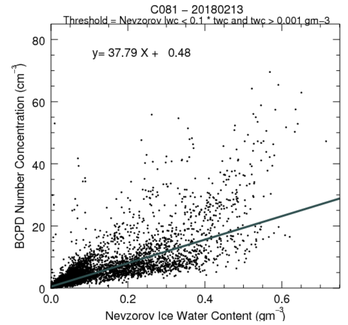
2 Picasso flights through frontal clouds over Chilbolton in the UK in February 2018
Nevzorov Ice Flag determined as LWC < 10% of Total Water Content and Total Water Content > 0.001gm-3

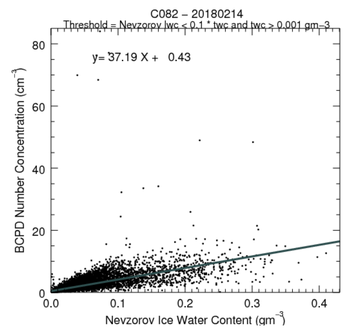
BCPD water content vs. Nevzorov Ice Water Content





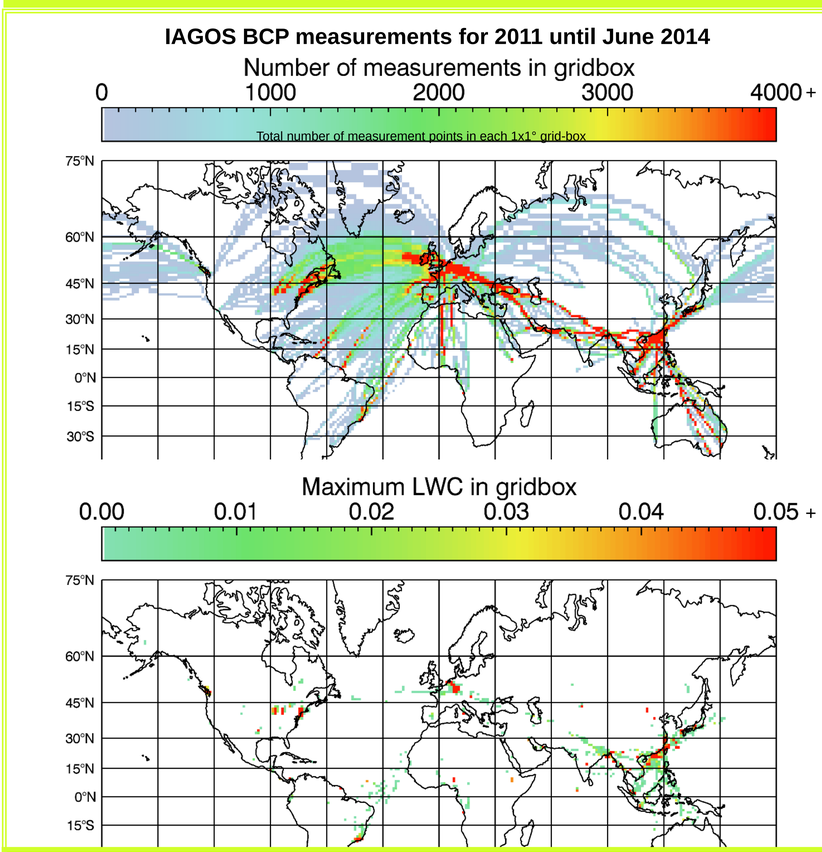
BCPD Number Concentration vs. Nevzorov Ice Water Content





Satellite Imagery from MSG SEVIRI available every 15 minutes:
The Met Office has two methods for identifying regions in satellite images with potential severe convection and/or overshooting tops. These areas may be associated with regions of high IWC.
The first method known as water vapour-infrared window brightness temperature difference (WV-IRW BTD) method and looks for signatures where very cold cloud tops yield upwelling radiances that are warmer in a water vapour band than in an infrared window channel (Schmetz et al., 1997).
The second method uses an infrared window channel alone and essentially looks for cold pixel clusters which show the infrared texture associated with the structure of an idealised overshooting convective top. Both methods are combined into the satellite product shown for the case below. Here pixels that pass the WV-IRW BTD test are yellow and those that pass both tests are coloured red.

Global Maps of IAGOS Measurements



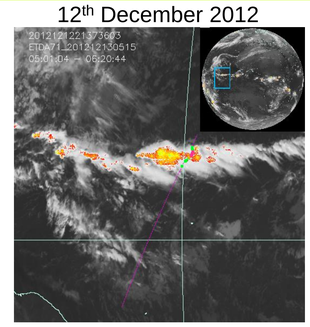
Conclusions

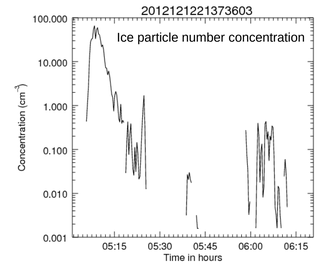
There is a correlation between BCPD number concentration and the Nevzorov IWC when in ice clouds. There is a better correlation between BCPD water content measurement and the Nevzorov IWC. Therefore the raw BCPD water content can be calibrated into representative IWC.
The analysis of ice particle number concentrations and ice water content from 15 selected commercial flights equipped with a BCP as part of the IAGOS instrument package show that there is a high correlation between ice particle number concentration, as well as ice water content, and the areas identified as highly convective in the satellite products. Regions with ice particle number concentrations above 1cm^{-3}, as measured by the BCP, are rarely encountered outside such areas. All the flights analysed had BCP concentrations in excess of 1cm^{-3} when passing through regions marked as highly convective in either satellite product. In addition, when the particle number concentration is in excess of 10 cm^{-3} the satellite images have shown highly convective areas in all of the cases investigated.

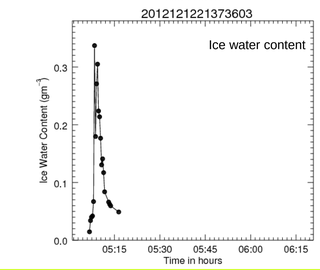
Comparison of IAGOS BCP Measurements and Met Office Satellite Product

These satellite image products have potential use as nowcast warning tools for pilots. BCP/D measurements can be used to validate Satellite products.

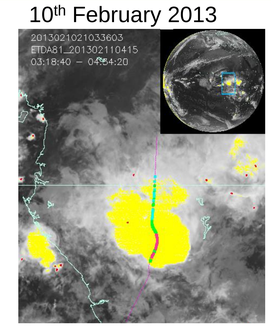
12th December 2012

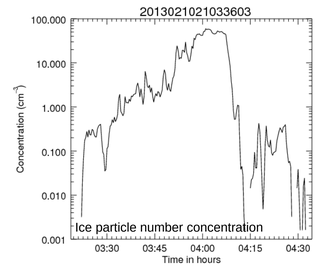


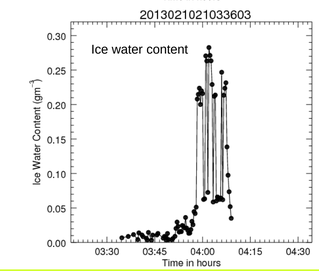




10th February 2013







Outlook - Future work may include:

- Further analysis of mass size distribution, effective diameter, MVD and extinction coefficient for comparison with these and newer satellite products
- Extension of the IAGOS event database, use of near-real time IAGOS data and inclusion of cloud size information
- Comparison of BCP data rather than BCPD data from the FAAM research aircraft from the Septex campaign with the Nevzorov and other ice-cloud measurements so as to estimate potential BCP underestimation of IWC due to non-detection of larger particles.
- Comparison of University of North Dakota BCP and Nevzorov data to further test robustness of relationship found in this study
- Expand study of satellite product to new Met Office product and new satellite regions
- Expand global maps to include more flights, number concentration, temperature and altitude constraints.

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