AUSTRALIAN BUREAU OF METEOROLOGY SUPPORT FOR THE SOUTHERN OCEAN CLOUDS RADIATION AEROSOL TRANSPORT EXPERIMENTAL STUDY (SOCRATES) – A CASE STUDY IN SCIENCE-TO-SERVICES

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1. OVERVIEW

-A good weather service underpins the safety and efficiency of air operations-

Weather forecasters and Antarctic pilots alike lack confidence in airframe icing warning skill over the Southern Ocean and Antarctica. This is in part due to the unique nature of high southern latitude clouds being misrepresented in weather models; and in part due to the dearth of in-situ observations which help constrain satellite remote sensing errors and help build experience-based knowledge of cloud phase, liquid water density and therefore icing severity. The shortcomings in the warning service ultimately cause greater potential for aircraft to (1) operate in more hazardous areas than expected or alternatively to (2) run less efficient operations because aircraft are diverting around cloud fields whose icing severity has been overestimated.

The Australian Bureau of Meteorology (the Bureau) worked with a team of atmospheric scientists out of Hobart, Australia for six weeks in early 2018 to collect cloud, aerosol and precipitation data over the Southern Ocean during a research project called the Southern Ocean Clouds, Radiation, Aerosol Transport Experimental Study (SOCRATES). Inter-alia, the campaign allowed the Bureau to assess warning skill and consider techniques for airframe icing warning improvement.

2. THE SOCRATES FIELD CAMPAIGN

The SOCRATES campaign took place between 15 January and 24 February 2018 with an operations center in Hobart, Tasmania. The campaign used the American National Science Foundation and National Centre for Atmospheric Research (NSF/NCAR) HIAPER (High-performance Instrumented Airborne Platform for Environmental Research) Gulfstream V aircraft. Fifteen flights in total were conducted over the Southern Ocean. The aircraft carried a suite of instruments including radar, lidar, radiometers, cloud droplet probe, and dropsondes. Although many clouds were studied, the focus of the campaign was on the cold sector clouds of baroclinic cyclones.

Additional instrumentation were on-board the R/V Investigator and at Macquarie Island and there were overflights of above both. Intensive meteorological observations were also taken on-board the RSV Aurora Australis for a cooperating project.

See:
https://www.eol.ucar.edu/field_projects/socrates

3. THE BUREAU'S HIGH LATITUDE WARNING RESPONSIBILITIES AND INTEREST IN SOCRATES

The Bureau is responsible for the provision of severe icing warnings (SIGMET) to aircraft operating in the Melbourne Flight Information Region (FIR), an area that extends across and

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beyond the Australian mainland down to the South Pole (fig 1).

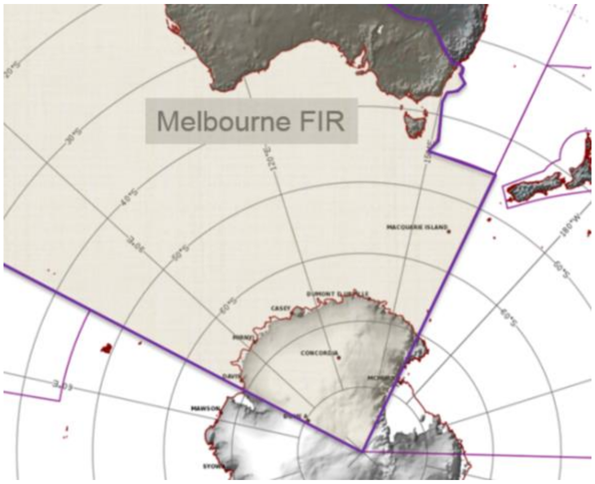

Figure 1 Melbourne Flight Information Region

The Bureau's National Operations Centre (NOC), located in Melbourne, is responsible for issuing severe icing warnings at all flight levels over the maritime and Antarctic areas of the Melbourne FIR, as well as the Australian mainland airspace above 10000ft. The overwhelming bulk of their service is focused on the main large jet flight corridors across mainland Australia and those transiting to Africa, Asia, the America's and Europe. The NOC services very few flights over the high southern latitudes, with less than 20 Antarctic inter-continental flights serviced in 2017. Unsurprisingly, icing reports from pilots (PIREPS) operating at the high latitudes are next to non-existent.

The Bureau also maintains an Antarctic Meteorology Section in Hobart, who provide a bespoke service in support of all Australian Antarctic operations, including the ~20 inter-continental flights per year between Hobart and Casey Station and some 100 smaller fixed and rotary wing aircraft flights operating chiefly within East Antarctica. Such 'intra-continental' flying in Antarctica is typically undertaken under 'visual flight rules', that is outside of cloud masses, notably to avoid the hazards of both whiteout (loss of surface and horizon) and airframe icing.

Nevertheless, the Bureau's Antarctic Meteorology Section has over the years developed knowledge of significant icing threats, including:

1. Ice accumulation over an aircraft flying in cloud at -35C between Casey and Concordia stations (the flight was aborted);
2. Freezing rain from sub-zero degree Celcius clouds at Davis Station, halting helicopter operations; and
3. A short study of freezing fog at Wilkins Ice Runway revealed seven events over a 3 month period in summer 2016-17.

The Bureau's NOC and AMS teams worked closely with SOCRATES while in Hobart by facilitating daily flight planning and issuing warnings. This ensured a more safe and efficient running of the campaign and provided an unprecedented opportunity for the service providers to learn from this targeted flying campaign into Southern Ocean super-cooled clouds. It is noteworthy that Southern Ocean clouds regularly advect over Antarctic coastal and inland air operations.

3. SOCRATES FLIGHT PLANNING

SOCRATES scientists attended the Bureau's Hobart offices on a daily basis for the purpose of flight planning. The campaign was resourced to undertake around 15 flights over a 6 week period. The campaign had a number of objectives to address, so it was important that flights were not wasted on duplicate scenarios or conversely that unique opportunities be missed due to forced down-time for maintenance or pilot rest.

The flight briefings investigated current weather and forecast conditions out to 3-4 days ahead. A standard suite of satellite images, observations, plus maps and route cross sections of forecast winds, temperatures and relative humidity were routinely viewed. The group found that a novel combination of model simulations of infrared satellite imagery (synthetic IR) with skew-T/Log-P representations of vertical profile forecasts from target clouds (fig 2) were the stand out tools for quickly diagnosing cloud properties and identifying flight plans.

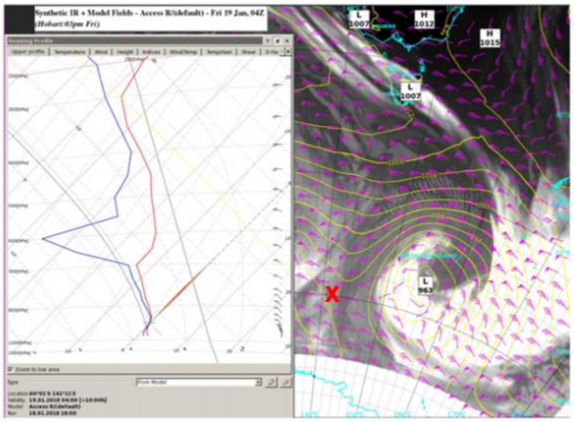

Figure 2. Synthetic Infra-red satellite image (model) with forecast skew T/Log P vertical profile at point x. The model predicts a saturated atmosphere from the surface to 700hPa level, between zero and -15 C.

4. LESSONS LEARNED AND FUTURE

A wealth of observations were gathered from the field campaign and these will take some years to be adequately analysed and interpreted. Some interesting observations and things learned during the campaign in relation to airframe icing warnings include:

1. Multiple cases of significant ice accumulation on the aircraft were observed in the cold sector of cyclones, including in strato-cumulus;
2. Supercooled liquid water was observed at temperatures as low as -33^{o}C;
3. Weather model guidance, including from ECMWF, ACCESS R, AMPS WRF and NCEP GFS often painted mid-level cloud bands as one continuous thick deck of high humidity where alternate cloud and dry layers were in-fact observed;
4. Severe icing conditions were observed and experienced in strato-cumulus (fig 3). Such scenarios, where water contents exceeded 1g/m^3, seemed associated with underlying convective cells;
5. Global and regional model representations of supercooled cloud liquid water content were too coarse to adequately inform forecasters of smaller areas of observed high airframe icing risk; and
6. Once adequately tuned to high southern latitude clouds, weather satellite algorithms could significantly address the paucity of cloud phase and cloud water density observations that are critical for adequate cloud representations in models as well as provide wide area icing potential advice to bolster user confidence.

Figure 3. Photo of airframe icing observed during flight RF09 at 0419 UTC, minutes after aborting a 10-min in-cloud leg and descending to lower altitude. Courtesy of Brian Rainwater, NCAR/EOL/RAF

6. ACKNOWLEDGEMENTS

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