

ISDAC Flight Planning Document

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I. Introduction

This document outlines flight profiles to be flown by the National Research Council of Canada Convair during ISDAC. This flight planning document compliments the ISDAC Science Overview Document (SOD) that describes the scientific justification for ISDAC and the principal science questions it is addressing.

Section II summarizes the operations plan that governs the timing for the weather briefings and go/no-go decisions in the field. The roles of the planning and management teams are also described. Section III describes the basic flight profiles and the meteorological conditions in which they will be flown. The flight descriptions are arranged in sub-sections according to the location where they will be flown: a) describes missions or components of missions in the vicinity of Barrow; b) describes components of missions during transits to and from Barrow; and c) describes coordinated flying with other aircraft in the vicinity of Fairbanks or Barrow. The approximate number of each flight profile needed to adequately address ISDAC science goals is also estimated. Section IV summarizes the science questions that will be addressed with each of the flight scenarios and identifies the key instrumentation needed for each. Section V provides a mission “scorecard” that we can use in the field to track which science goals have been addressed during which flight profile.

II. Flight Planning and Mission Execution

Proper execution of the flight plans will require careful planning and implementation in the field. This task will be especially daunting given the complex environment of the Arctic and the physical separation of project participants between Barrow, Fairbanks and possibly other locations. In the following paragraphs, we outline the general flight planning and mission execution approach that will be followed during the experiment.

It is important that the flight planning process for ISDAC be as open as possible. However, recommended flight profiles will be made by a small

group of individuals with the discussion facilitated by the AVP chief scientist Greg McFarquhar, who is also a Co-PI for ISDAC and the AVP technical director, Beat Schmid. In addition to Greg McFarquhar and Beat Schmid, the flight decision-making group will include the following people or their designated representative: Steven Ghan (ISDAC PI) and/or Dan Cziczo, Hans Verlinde (NSA Site Scientist), John Hubbe or Jason Tomlinson (PNNL), Walter Strapp and/or Alexei Korolev (Environment Canada) and Mengistu Wolde and/or Dave Marcotte (National Research Council Canada).

It is anticipated that the meteorological conditions will be reviewed the day prior to a mission by the flight decision-making group, with an objective to determine whether the air crew will be on-call for a flight the next day, and to provide a first cut flight plan for the mission. A decision to alert the flight crew to prepare for a flight will be made at an early meteorological briefing on flight-day, utilizing the most up to date measurements from the ARM site. The flight plan will be modified if appropriate to reflect recent conditions over the site, and a briefing of the NRC pilots will be then given by the NRC/EC flight director. Takeoff will be no earlier than 2 hours after this meeting, so there is still significant time to follow the weather and issue a final 'go/no-go' decision to the NRC/EC flight director approximately 30 minutes before takeoff. After the first flight, if necessary or practical the NRC/EC flight director will contact the flight decision-making group in Fairbanks from the ground in Barrow for further guidance for the second mission.

The NRC/EC flight director will be carefully briefed by the flight decision-making group before the flight on the highest priority objectives of the day, and will thereafter have authority to make common-sense modifications to the flight plan based on real cloud conditions observed in the air, and any operational/instrument issues that might affect the data set.

Forecasting support will be provided by the NSA Site Scientist Team from Penn State. They will lead the weather briefings and discussions that are summarized in Section II.b. The instrument mentors will be responsible for the calibration of their instrument, integration with the platform, operation during the campaign, removal of the instrument from the platform, data processing, and data archiving.

b. Briefing and planning schedule:

It is anticipated that the following schedule will be followed:

Day Before Flight

15:00 day before flight (while airplane is potentially in air). Meteorological briefing for all ISDAC participants

15:30 flight decision-making group; if next day is suitable, preliminary flight plan produced.

Day of Flight

06:00 meteorological briefing for flight decision-making group; official flight plan produced;

07:00 alert all flight crew and instrument support of possible flight; brief NRC pilots on expected mission profile; pull aircraft out of hangar

07:15 all crew and support on aircraft preparing for mission

09:00 doors closed, all non-crew members off the aircraft – final ‘go/no-go’ decision from flight decision-making group

09:30 takeoff Fairbanks

11:10 commence measurements over ARM site

12:30 landing Barrow after flight #1

12:45 NRC/EC flight director contacts flight decision-making group in Fairbanks for guidance on second flight

13:30 doors closed

14:00 takeoff Barrow for flight #2

14:18 -14:36 A-Train overpasses near Barrow ([April 1, 3, 10, 12, 17, 19](#)) or start measurements over ARM site without A-Train

16:50 start transit back to Fairbanks

18:30 land Fairbanks

19:00 Flight debrief and plans for next day announced/discussed

The above schedule requires a crew day of a little over 12 hours, the maximum recommended crew-day for the NRC pilots. In this regard, there will be little opportunity to extend the period on the ground at Barrow to wait for more favourable cloud conditions.

III. Generic Flight Profiles

There are basically 3 different locations/conditions in which the Convair will be flown during ISDAC: a) missions or components of

missions in the vicinity of Barrow; b) components of missions during transits between Barrow and Fairbanks; c) coordinated flying with other aircraft in the vicinity of Barrow or Fairbanks. The different flight scenarios are described separately for each. Each mission during ISDAC will include combinations of the flight profiles that are described below.

a. Flights in the Vicinity of Barrow

When the Convair is operating in the vicinity of Barrow, the following flight profiles will be flown:

- i) Spiral profiles over the ARM site at Barrow
- ii) Legs flown at constant horizontal altitude in cloud
- iii) Legs flown at constant horizontal altitude outside of cloud
- iv) Missed approaches at the Barrow airport
- v) Porpoising maneuvers (i.e., ramped ascents and descents)

These flight profiles are described separately below. Discussions will take place the day before each mission to determine what combination of these profiles will be put together on the same flight day.

The following rules will apply to the minimum altitudes that the aircraft may be flown at under the conditions noted below:

- (1) ***For flights over the ARM site:*** In VFR (non-cloudy) conditions, the minimum flight altitude, when pilots agree that conditions of the day are adequate (based on visibility, surface wind, surface texture, cloudbase height and texture, ambient lighting texture, set against pilots' familiarity with the area and/or route) would be 500' above ground (assuming that the immediate area around the Barrow site has no population or buildups) and otherwise 1000' above ground. In IFR (cloudy) conditions, the minimum altitude will be the Minimum Safe Altitude (MSA) for Barrow Airport (as yet not determined due to unavailability of the Barrow Airport approach charts, but the MSA would not be lower than 1600' AMSL, based on examination of air route planning charts , and could quite possibly be higher). Missed approaches into Barrow airport could get us lower in the vicinity of the airport, but not over the Barrow site. In some cloudbase conditions, it might be possible to proceed VFR , after establishing visual conditions on an approach to Barrow Airport and cancelling IFR, to and over the Barrow site or offshore, and

operate as low as 500', as long as the pilots feels that the conditions of the day are adequate (as described above).

- (2) ***For flights between Deadhorse and Barrow, and for any other low-level flights offshore:*** IN VFR conditions, flights could be conducted at 500', if the pilots agree that the conditions of the day are adequate (see above for the influencing factors) and possibly lower , again depending upon conditions . In IFR conditions, the lowest level flight altitude offshore (at least 5 nmiles offshore at all times) would be 1500' above the sea surface. If IFR conditions, the lowest flight altitude for the overland route between Deadhorse and Barrow would be 2000' AMSL for the direction of flight, 3000' for Barrow to Deadhorse, using the LF/MF air route G16 over land (a 30 deg dogleg). The minimum IFR altitude for the direct Deadhorse to Barrow route would be 6000' MSL.

a.i Spiral Profiles over the ARM site at Barrow

Many ISDAC science goals require profiles of atmospheric parameters over ARM's remote sensing site at Barrow (71°19'23"N 156°36'32"W). Because observations of aerosols require horizontally long level legs, the spiral profiles will concentrate on the acquisition of in-situ cloud observations. Thus, the location of clouds (particularly horizontally extensive boundary layer clouds such as stratus, stratocumulus, altocumulus and altostratus) will dictate the altitude ranges of the spirals. For ISDAC, the meteorological conditions will impact the timing of the profile (as is typical for a field project). However, deviations from the predetermined profiles will be made when hazardous flight conditions exist or due to aircraft control restrictions. Due to the ubiquitous nature of clouds over Barrow, we anticipate clouds will typically be present over the NSA.

The lower and upper altitude of the spirals cannot be determined a priori because it is dictated by the altitudes of cloud layers. The location of the cloud layers will be determined from on-board radar or visual observations or from the remote sensors at the ARM NSA site. Then, the spirals should be ideally conducted between an altitude 100 m below cloud base to 100 m above the highest layer of horizontally extensive cloud (e.g., 100 m above stratus, stratocumulus, altocumulus or altostratus, but spirals will not continue to cirrus altitudes). The profiles should be flown in an Eulerian fashion (i.e., centered over fixed location of Barrow site) rather

than a Lagrangian fashion (i.e., advecting with the background wind). The rate of ascent or descent should be between 2 to 4 m s⁻¹ depending on the thickness of the cloud so that the ascent/descent lasts between 5 and 10 minutes. The radius of curvature should be as tight as possible and one edge of the spiral should be centered over the ARM NSA site; the other edge of the spiral should be in the downwind direction so that the cloud is sampled in-situ AFTER it passes over the NSA site. The profiles can be flown in either an ascending or descending fashion. It does not matter whether the spirals are flown in clockwise or counter-clockwise fashion.

In the event that air traffic control restrictions make it impossible to fly these spirals directly over the Barrow site, the spirals can be flown in a cloudy region directly downwind of the NSA site (ideally we do not want to fly upwind because we do not want to seed the cloud before it is remotely sensed by the ground-based equipment, but it is possible to fly the spirals upwind if that is where the clouds are). As noted above, the minimum altitude for spirals will be of the order of 1600' above ground in cloudy conditions over the ARM site, or 1500' MSL offshore. A missed approach into Barrow airport would be required to profile lower.

Because acquisition of in-situ cloud data during these profiles are central to many of the ISDAC objectives, we would like to fly as many as these profiles as possible (at least 2 during each flight) in the widest variety of meteorological conditions possible.

a.ii: Legs flown at constant horizontal altitude within cloud

Some level legs will be flown through cloud at a constant altitude to acquire information on the horizontal variability of cloud properties and to provide sufficient sampling of residual aerosol behind the CVI. These legs can either be at a single horizontal altitude or at a series of altitudes in a stair-step pattern of ascending or descending altitude. The first legs should be flown through layers dominated by ice water so that samples of ice crystal residuals can be collected behind the CVI before ice potentially clogs the inlet. It will be especially useful to collect data at altitudes that are anticipated to have the highest liquid water contents (these altitudes being determined from earlier stair-step patterns, spiral profiles, or in absence of other information just below cloud top). During the project, legs should be flown in both the along wind and cross wind directions (or alternatively, along coast and cross coast) to give a better measurement of the spatial

distribution of the cloud microphysical properties and to help remove or characterize the effects of land vs. ocean (ice/leads); the meteorological conditions will dictate what type of horizontal legs are flown on an individual day. Some legs should be preferentially flown downwind of the ARM site so that the in-situ data are collected after the cloud layer has been remotely sensed by the ARM site to avoid seeding effects. The legs should be 10-15 km (2 – 3 minutes long) to provide adequate sampling of the residual particles behind the CVI. When legs are flown at several altitudes, the first leg should be ~ 100 m above cloud top. Subsequent legs should be conducted at vertical steps of 50 to 150 meters depending on the depth of the cloud. The transition from one altitude to another one should be conducted along enroute descent with the vertical speed approximately 3m/s to 5m/s. The last horizontal leg is conducted near the level of sublimation of ice particles, identified from the onboard radar, or if the precipitations fall to the ground, then at the lowest allowed altitude, or no lower than 300 to 600 meters (depending on temperature) below the cloud base of the mixed phase layer. It is also possible to conduct the stair-step pattern starting at the bottom and working to top of cloud.

Additional horizontal legs are needed that are oriented perpendicular to the coastline. The Convair should start at Barrow and fly 50 km at a constant altitude north perpendicular to the coastline in order to sample the gradient of cloud properties. These flight profiles are especially desirable later in the project when the ice has moved away from the coast (we expect larger gradients then). The flights inward and outward flights should be conducted at alternate altitudes (one 100 to 200 m below cloud base and another at mid-level) to get information on the gradient of cloud properties at multiple levels. One such leg should be flown when the sea ice is at the coast as a baseline. Once the ice has moved further from the coast, multiple such legs are desired to statistically determine how cloud properties vary with distance away from the coast. The position of the sea ice will be monitored both from visual observations from the Convair flight scientist and from any remote sensing data available.

a.iii: Legs flown at constant horizontal altitude outside of cloud

Some legs need to be flown above and below cloud to sample key atmospheric properties that cannot be well measured inside cloud (and also to determine what these quantities are outside of cloud). These quantities include aerosols, ice nuclei, humidity, temperature and spectral radiance.

The orientation of these legs with respect to the surface site is not as important as for the cloud legs. However, the legs are envisioned to be between 60 to 75 km long (10 to 15 minutes long) because longer time periods are required for measuring the CCN concentrations; the lines for the CCN observations do not necessarily have to be straight legs but should be flown at a single altitude. Measurements of aerosols in stably stratified layers and especially below the cloud are required to meet the science objectives. Horizontal legs over water or a flat surface are also required for the radar calibration maneuvers. Because the minimum altitudes over land are high, it is possible that the data acquired will be biased to oceanic regions; however, such legs are the only possible way of obtaining aerosols under cloud.

Additional horizontal legs are needed that are oriented perpendicular to the coastline. The Convair should start at Barrow and fly 75 to 100 km at a constant altitude below cloud base north perpendicular to the coastline in order to sample the gradient of aerosols, humidity and temperature. These flight profiles are especially desirable later in the project when the ice has moved away from the coast (we expect larger gradients then). The flight inward could be conducted at an altitude above cloud top. One such leg should be flown when the sea ice is at the coast as a baseline. Once the ice has moved further from the coast, multiple such legs are desired to statistically determine how aerosols and humidity vary with distance away from the coast in a variety of meteorological conditions.

These legs through clear air should generally precede flight profiles (spiral or horizontal legs) through cloud so that the effects of icing on the aerosol sampled through the aerosol inlet is minimized.

a.iv Missed approaches at Barrow airport

When the spiral profiles or horizontal legs below cloud cannot be flown over Barrow because the cloud base is too low, missed approaches should be flown at the Barrow airport to gain information on the vertical structure of the clouds and aerosol. Although it is recognized that the conduct of the missed approaches may be in large pre-determined by ATC, there are certain features desired if operationally possible. The missed approach should start at the lowest altitude sampled during the other flight profiles (typically the lowest altitude that is allowed for flight away from the airport, i.e., 500 m) and continue down to the lowest possible altitude that

can be safely flown (i.e., we want to get a complete profile including cloud and below cloud to the surface because we want to sample the aerosol and the precipitation falling from the cloud and reaching the ground). The descent rate for the missed approach should be approximately 2 m s^{-1} to match the climb/descent rate of the spiral profiles (or whatever aircraft operations dictate). The length of the missed approach is set according to the descent rate and altitude at which the missed approach starts.

The missed approaches should be flown on all operation days when a low cloud base precludes the spiral profiles from reaching at least 100 m below cloud base. At least one, and preferably two, missed approaches should be completed on each such day so that we obtain a vertical profile of cloud and aerosol properties covering their entire depth. In the event that the missed approaches take longer than about 20-30 minutes (i.e., the aircraft is vectored a long way from the air field), we will have to restrict ourselves to one missed approach per flight leg.

a.v: Porpoising maneuvers (i.e., ramped ascents and descents)

In some cases it may be desirable to fly series of ramped ascents and descents through cloud to sample the vertical and horizontal structure of cloud and other parameters in cases where spirals cannot be flown. Here, we envision porpoising from above cloud to as close to ground as possible to sample the horizontal and vertical variability (descend at a rate of approximately 5 m s^{-1}). The length of the porpoising leg should be long enough so that we get at least one combination of ramped ascent and descent throughout the cloud.

b. Flight patterns to be flown during transits to/from Barrow

We envision that the Convair will be transiting either to or from Barrow when it is not operating in the vicinity of Barrow or flying coordinated legs with other aircraft (however, these flight profiles could be flown outside the vicinity of Barrow even if the Convair was not transiting to or from Barrow). The following flight profiles may be flown during the transit legs from Barrow to Fairbanks (in general, the Convair will fly straight to Barrow from Fairbanks in order to maximize time on station so such patterns are not envisioned during the transit from Fairbanks; in general, time over Barrow will be maximized so science legs will only be flown during transit from Barrow to Fairbanks if conditions over Barrow are

such that none of the science objectives can be met through further sampling over Barrow):

- i) Legs flown at constant horizontal altitude in cloud
- ii) Legs flown at constant horizontal altitude outside of cloud
- iii) Porpoising maneuvers (i.e., ramped ascents and descents)
- iv) A-train evaluation legs

It should also be emphasized that measurements during the transit must be carefully evaluated to ensure that the mission objectives over the ARM site are not compromised. For example, excess airframe icing will negatively affect later measurements, and could delay a second flight. Excessive times at low altitudes or altitude changes could lengthen the mission would reduce the time for sampling in the vicinity of Barrow. Transit time from Fairbanks to Barrow is assumed to be approximately 1.75 hours, and should not be lengthened without the agreement of the flight decision-making group. These flight profiles are described separately below.

i) Legs flown at constant horizontal altitude in cloud

Some level legs will be flown through cloud at a constant altitude to acquire information on the horizontal variability of cloud properties and to provide sufficient sampling of residual aerosol behind the CVI. These legs can either be flown at a single horizontal altitude or at a series of altitudes in a stair-step pattern of ascending or descending altitudes during the flights between Barrow and Fairbanks. The first legs should be flown through layers dominated by ice water so that samples of ice crystal residuals can be collected behind the CVI before it becomes clogged with ice. It will be especially useful to collect data at altitudes that are anticipated to have the highest liquid water contents (these altitudes being determined from earlier stair-step patterns, spiral profiles, or in absence of other information just below cloud top). The runs in supercooled liquid cloud should be restricted to the return transit because if a lot of icing occurs on the first transit it could impact other parts of the mission over Barrow.

The orientation of the legs is dictated by the closest route between Fairbanks and Barrow to minimize the transit time. The legs will be most useful on the north side of the mountains where legs can be flown in horizontally extended boundary layer stratus, stratocumulus, altostratus or altocumulus. When legs are flown at several altitudes, the first leg should be ~ 100 m above cloud top (see flight pattern b.ii below). Subsequent legs

should be conducted at vertical steps of 50 to 150 meters depending on the depth of the cloud with each leg approximately 3 minutes long (10 to 15 km) to provide adequate sampling of the residual particles behind the CVI. The transition from one altitude to another one should be conducted along enroute descent with the vertical speed approximately 3m/s to 5m/s and after the descent another 3 minutes should be flown at constant altitude. The last horizontal leg is conducted near the level of sublimation of ice particles, identified from the onboard radar, or if the precipitations fall to the ground, then at the lowest allowed altitude, or no lower than 300 to 600 m (depending on temperature) below the cloud base of the mixed phase layer. It is also possible to conduct the stair-step pattern starting at the bottom and working to top of cloud. During the flight, the on-board scientists should note the approximate altitude of a layer with the largest supercooled water contents. After the series of altitudes are flown, a longer leg of approximately 10 minutes (30 km) should be flown in this layer, making note that the instruments are not icing up. This leg can be shortened and/or the sampling will be aborted if the icing accretion on the aircraft can not be managed by any one or more of the aircraft ice protection systems.

b.ii: Legs flown at constant horizontal altitude outside of cloud

Some legs need to be flown above and below cloud to sample key atmospheric properties that cannot be well measured inside cloud (and also to determine what these quantities are outside of cloud). These quantities include aerosols, ice nuclei, humidity, temperature and spectral radiance. During the transits, time should be spent measuring atmospheric quantities both in stratified layers and below cloud. These legs are envisioned to be between 60 and 75 km long (10 to 15 minutes long) because longer time periods are required for measuring the CCN concentration. Measurements of aerosols in stably stratified layers and especially below the cloud are required to meet the science objectives. These legs should generally precede legs through cloud to minimize the effects of icing on the aerosol inlet. It is also noted that below-cloud runs will generally not be possible during transit unless they are immediately after the Barrow measurements on the second flight, or if the cloud is an elevated layer. As previously mentioned the Convair cannot transit at low altitudes for significant periods of time in order to maximize the on-station time over Barrow.

b.iii: Porpoising maneuvers (i.e., ramped ascents and descents)

To provide a survey of the vertical structure of the atmosphere while enroute between Fairbanks and Barrow it will be useful to fly a series of ramped ascents and descents through the atmosphere to sample the vertical and horizontal structure of cloud and aerosol. Here, we envision porpoising from above cloud to as close to ground as possible to sample the horizontal and vertical variability (descend at a rate of approximately 5 m s⁻¹). A series of porpoising legs can be flown during the transit legs. In addition, as previously mentioned, these porpoising maneuvers will only be flown if there is sufficient flight time because porpoising uses a lot of fuel and thereby limits on-station time. These maneuvers may be possible on the return transit to Fairbanks if time permits.

c. Coordinated flying with other aircraft

We envision that we will be flying coordinated with other aircraft ((NASA P-3B, DC8 and B200, NOAA WP-3D) and flying satellite evaluation legs to answer relevant science questions. In this section, the relevant coordinated flight profiles are listed.

i) A-train evaluation legs

There are several overpasses of the A-train on a leg that roughly passes between Barrow and Fairbanks, with overpass times approximately between 1400 and 1430 local time (Optimal overpass days are April 1, 3, 10, 12, 17 and 19, with April 5, 8 and 21 also representing possibilities). On these legs, the Convair will either fly a straight line leg above, below or within cloud or a spiral descent over the NSA Barrow site (depending on which product/retrieval is deemed most suitable for evaluation given the cloud conditions) at the time of the overpass. If a straight leg is flown it would be flown at the same orientation as the overpass line and would be approximately 15 minutes long to get sufficient sampling of clouds/aerosols. The spiral descent/ascent would be at a rate between 2 to 4 m s⁻¹ so that the boundary layer cloud could be sampled in approximately 15 minutes. It is expected that these evaluation legs will be flown in coordination with other aircraft as outlined in subsequent coordinated profiles.

ii) Comparison of cloud/aerosol data with NOAA WP-3D

These comparisons will be conducted in the vicinity of Barrow or the Beaufort Sea where there are no obstruction hazards or near the base at Fairbanks. Legs will be flown at constant altitude either inside of

cloud (for cloud microphysics comparisons) or outside of cloud (for aerosol comparisons). Two waypoints will be identified (preferably in direction parallel to wind, or parallel or perpendicular to the coastline) and the Convair and NOAA WP-3D will alternately fly these way points, with the planes separated by air traffic control. Once the first aircraft has completed a constant altitude leg, it will ascend to higher altitude after which time the second aircraft will complete the leg at the altitude previously occupied by the first aircraft. This will be repeated for a series of different altitudes. Because of horizontal inhomogeneities in clouds especially and because the different aircraft can never sample the exact same cloud element, the coordination described above should be sufficient to intercompare many aspects of instrument performance (e.g., the impact of shattering producing small crystals, cloud mass and extinction closure, etc.). It is also proposed to perform precision instrument approaches slantwise through cloud layers, for example to Barrow, again separated by air traffic control.

iii) Comparison of cloud/aerosol data with NASA DC8

We will use similar intercomparisons as outlined in ii) above. There will be a particular focus on performing these intercomparisons in cloud.

iv) Coordinated flights between Convair and B200

We will fly coordinated flights during the A-train overpasses described above with the B200 flying at 28,000 feet, well above the location of the Convair. On other flights in the vicinity of Barrow, the Convair and B200 will coordinate with the Convair and the Barrow flying the same legs (with the same way points) with the B200 at 28,000 feet and the Convair either within, above or below the cloud. When the Convair is executing spiral ascents/descents over Barrow, the B200 can fly figure 8 flight patterns centered over the location of the spiral ascent/descent. For flights not in the vicinity of Barrow, the Convair and B200 can still fly coordinated, but the Convair will be flying along a single transect towards/from Fairbanks.

v) Coordinated flights between Convair and NASA P-3B

Because the NASA P-3 has instruments for measuring the broadband solar Albedo, the infrared irradiance of clouds, and the SSFR for retrieving optical thickness and effective radius the coordinated flying

between the NASA P-3B and Convair is envisioned to be similar to that described in iv) where the NASA P-3B is well above cloud and the Convair either just above cloud, within cloud or below cloud. In addition, the NASA P-3B will also fly just above the cloud to measure the aerosol optical depth above cloud and to get the aerosol optical depth between cloud top and the altitude where the SSFR does its cloud retrieval measurements. When the NASA P-3B is flying just above cloud and in coordination with the Convair, the Convair will ideally complete its above cloud leg and then when it descends to within cloud, the NASA P-3B will start its above cloud leg, the separation between aircraft being dictated by air traffic control. Alternatively, the Convair would complete its above cloud leg after the NASA P-3B has finished its just above cloud leg; however, the first scenario is preferable so that the Convair can make its above cloud measurements before the aerosol inlet is potentially clogged up by supercooled water.

In the event that any coordination is required to intercompare in-situ observations, the coordination would follow that outlined in ii) above.

SECTION IV: Science Objectives for Different Mission Profiles

1 Cloud Mission Profiles

1.1 Identifying thermodynamical conditions for maintaining mixed-phase clouds

Point of Contact: Alexei Korolev

Science Motivation/Hypothesis: The main objective is to study the conditions required for maintaining long-lived mixed phase clouds. Mixed phase clouds are considered to be condensationally unstable and are eventually expected to turn into ice-only clouds. However, the observation of long-lived mixed phase stratiform cloud layers conflicts with this theoretical proposition. Recent theoretical analyses (Korolev and Field, 2007) have proposed *the necessary and sufficient conditions* required for the dynamic forcing, which may result in indefinite maintenance of mixed phase stratiform cloud layers. The study of the mixed-phase maintenance will be conducted through the measurements of microphysical and thermodynamical properties of mixed-phase long-living cloud layers and deep ice clouds with its following comparisons with the theoretically estimated conditions required to maintain mixed phase.

Measurement Objectives: To address the objective posed above the microphysical and thermodynamical characterization of the cloud layer should be conducted above, inside and below mixed-phase layer. The underneath characterization should be extended few hundred

meters below cloud base. The mission will require both in situ measurements and airborne remote sensing.

The Key Measurements are:

- In-situ microphysics: droplet and ice particle size distributions, IWC, LWC, extinction coefficient, onboard radar.
- Thermodynamics: turbulent fluctuations, water vapor, temperature, wind speed and wind direction.

The measurements of vertical turbulent fluctuations are critically important for these measurements. The measurements of turbulence should be conducted along horizontal flight legs.

General Aircraft Flight Profiles:

Option 1 (long-living mixed-phase layer): Typically long-living (more than 2-3 hours) mixed-phase layers are represented by horizontally extended boundary layer St , Sc or midlevel As , Ac . After identifying such layer from visual and onboard radar observation, the aircrew initiates along wind straight horizontal legs, 10-15km (2-3min) long, stacked at several altitudes. The first leg is conducted approximately hundred meters above the cloud top. The following legs should be conducted with vertical steps 50 to 150 meters, depending on the depth of the cloud. The transition from one altitude to another one should be conducted along enroute descent with the vertical speed approximately 3m/s to 5m/s. The last horizontal leg is conducted near the level of sublimation of ice particles, identified from the onboard radar, or if the precipitations fall to the ground, then at the lowest allowed altitude, or no lower than 300 to 600 meters (depending on temperature) below the cloud base of the mixed phase layer. After the last leg the aircraft performs enroute (preferred) or spiral ascent to the cloud top. Estimated time to accomplish one cycle: 30-45min depending on the cloud depth.

Option 2 (embedded mixed phase layers): Embedded mixed phase layers are typically occur in deep $Cs-Ns$ or $As-Ns$ associated with frontal systems. Identifying the embedded mixed phase clouds from the onboard radar is not always successful. However they can be easily detected during a vertical sounding. After identifying the mixed-phase layer proceed with the flight pattern in Option 1. The number of the flight legs below the base of the mixed-phase layer should be limited to five with the vertical step 100 meters. Estimated time to accomplish one cycle: 30-45min depending on the cloud depth.

Option 3 (ice clouds): After identifying a continuous deep ($\Delta Z > 1\text{km}$) ice cloud from the onboard radar, perform straight legs stacked at 5 altitudes with the vertical step 100 meters. Estimated time to accomplish one cycle: 30min depending on the cloud depth.

It is preferable that these flights be conducted over the ARM site so that additional measurements of turbulence can be obtained from the ARM cloud radar. This would also be advantageous for evaluating the cloud radar vertical velocity measurements, such an evaluation not having been done yet to the best of our knowledge. However, these flight patterns can also be done elsewhere if conditions are appropriate provided horizontal legs of a few minutes long (to get measurements of turbulence) can be made inside and underneath a mixed-phase layer.

Repetitions Necessary:

Ideally 2-3 repetitions for options 1 and 2.

Weather Conditions:

Frontal cloud systems

Synergy with other missions:

Ground-based remote sensing validation
Statistical characterization of mixed phase clouds

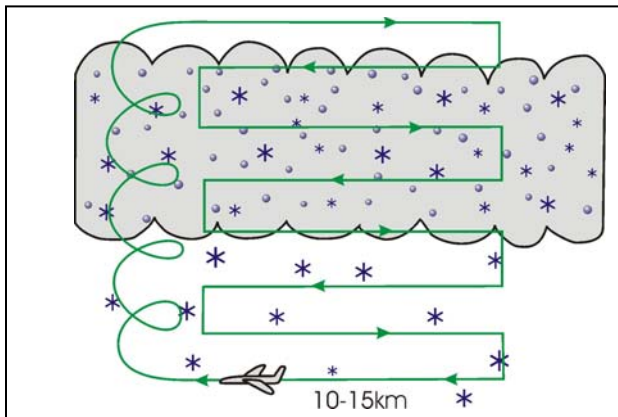
Critical instruments:

Nevzorov LWC/TWC probe, CSI, FSSP, OAP-2DC, OAP-2DP, RICE, Extinction probe, Licor, Rosemount 858, airborne radars (Ka-band and NAWX)

Reference

Korolev, A.V. and P.R. Field, 2007: The effect of dynamics on the formation of mixed phase clouds (theoretical consideration). *J.Atmos.Sci.*, in press

Flight Profile: a..iii); b.i)



Proposed flight pattern for the Convair 580 to study turbulence and microphysics of mixed phase clouds.

1.2 Statistical characterization of microphysics and thermodynamics of mixed-phase clouds

Point of Contact: Alexei Korolev, Walter Strapp, Hans Verlinde, Greg McFarquhar and Mengistu Wolde

Science Motivation: Characterize microphysical and thermodynamical properties of mixed phase clouds. Identify differences in occurrences of mixed phase clouds in Arctic (from the present study) and midlatitude clouds (from the past studies). Determine the spatial variability of cloud microphysical properties and vertical velocities, and determine how the variability depends on cloud type and synoptic classification. The main targets are: (a) statistical characteristics of the liquid water fraction, (b) statistical characterization of relative humidity, (c) statistical characterization of the extinction coefficient in clouds with the different phase composition, (d) statistical characterization of the total water contents, (e) statistical characterization of the total number of droplets, total number of ice crystals and effective radii of water droplets and ice crystals, (f) statistical characterization of different parameters that describe the shapes of the size distributions, and (g) statistical characterization of vertical velocities. After obtaining these data, there will be an attempt

made to relate the spatial variability of the cloud microphysical quantities and vertical velocities to the cloud type and synoptic classification and to determine the evolving role of aerosol in the variability of cloud properties.

Measurement Objectives: Vertical profiles of clouds over NSA ASRF as well as clouds encountered during transit flights between Fairbanks and Barrow suits perfectly well this objective. In-situ microphysics, dynamics, radiation and thermodynamics, particle size distribution, TWC, LWC, IWC, extinction/integrated cross-sectional area, vertical motion, turbulence and water vapor will be sampled. Radars will operate in side-looking mode to provide horizontal context when acquiring measurements in vicinity of Barrow. The NAWX radar with side looking and polarimetric capabilities will also be a useful tool for extending what is measured at the aircraft altitude to many kilometers away.

General Aircraft Flight Profiles:

Option 1 (transit flights): After take off identify from the onboard radar the altitude and boundaries of clouds, if they exist. Conduct enroute repeated ascents and descents through the identified cloud layer. The vertical velocity of the aircraft during profiling should not exceed 5m/s, and horizontal velocity should not be more than 100m/s. If level legs are conducted in vicinity of Barrow, each leg should ideally be followed by a spiral to document the microphysical properties in the cloud.

Option 2 (vicinity or over NSA ASRF): After identifying coordinates and altitude of a cloud from the ground based and/or onboard radar and/or satellite imagery perform a spiral sounding through the whole cloud layer.

Repetitions Necessary:

Ideally 2 repetitions for options 1 and 2.

Weather Conditions:

Frontal cloud systems

Synergy with other missions:

Ground-based remote sensing validation
CloudSat, Calipso validation

Critical instruments:

Nevzorov LWC/TWC probe, CSI, King probe, RICE, Extinction probe, Licor, airborne radars (Ka-band and/or NAWX)

Flight Profile:

a.i), b.i)

Reference

Korolev, A.V., G.A. Isaac, S. Cober, J.W. Strapp, and J. Hallett, 2003: Microphysical characterization of mixed-phase clouds *Q. J. Roy. Meteor. Soc.*, **129**, 39-66
Korolev, A.V., and G.A. Isaac, 2006: Relative humidity in liquid, mixed phase and ice clouds *J.Atmos.Sci.*, **63**, 2865-2880.

1.3 Ground-based Remote Sensing Validation

Point of Contact: Greg McFarquhar, Hans Verlinde, Steve Ghan and Mengistu Wolde

Science Motivation/Hypothesis:

Evaluate/verify/intercompare the retrieval of vertical profiles of cloud microphysical properties from ground-based remote sensors with direct in-situ measurements of the retrieved quantities. The primary goal of this mission objective is to assess the uncertainty of cloud properties derived from retrieval algorithms (microphysics and radiative) from ground-based remote sensors including the BBHRP algorithms. Other objectives include the development of empirical relationships (i.e., mass- and area-dimensional relationships in cirrus) that are needed in these algorithms and to characterize the spatial variability of cloud microphysical quantities.

Measurement Objectives:

Profiles of in situ microphysics measurements of ice crystal and liquid size and shape distributions, and bulk measurements such as ice water content, liquid water content, total water content, integrated cross-sectional area and extinction in the vicinity of the ground site are needed. Profiles of radiation, thermodynamics, vertical motion, turbulence, water vapour and radiation also required. These in-situ measurements are required over the ACFR site, although occasional porpoising legs along CloudSat legs will meet satellite remote sensing requirement. Remotely sensed radar reflectivity and Doppler velocity (if available), lidar backscatter, upwelling and/or downwelling radiative quantities such as flux and narrowband measurements are required in vicinity of ground site. The G-band radiometer (similar to the ARM ground-based system) and the airborne NAWX radar will also be useful for remote sensing validation and retrieval algorithm work.

General Aircraft Flight Profiles:

In-situ aircraft will spiral up/down over Barrow (Eulerian) and then fly series of level legs (approximately 50 km) centered at the location of the ground site where the legs would be made at cloud top, and then descend into 3 or 4 more levels with legs either with/against ambient wind (exact locations and levels should include mid-cloud and near base, but exact altitudes chosen depending on clouds observed on particular day); following stair-step pattern, in-situ aircraft will fly 3-4 Eulerian spirals to determine how much cloud properties over ground site are changing with time.

Repetitions Necessary:

Need at least 2 flights specifically dedicated to this objective where 3 to 4 spirals and at least 1 stepped profile is executed during each flight.

Weather Conditions:

Ideally would want to sample clouds with a variety of structures and phases (also include single-layer boundary layer clouds and clouds occurring in multiple layers, especially those with mixed-phases). Ideally this flight plan will be done in clouds without a complex horizontal structure so that it is easier to relate the in-situ observations to the radar observations by considering advection terms. For clouds with a complex horizontal structure, the observations are still useful because it contributes to the development of a

statistical database for comparing in-situ observations with remote sensing retrievals and does not bias the statistics of such comparisons to cases with simpler horizontal structures.

Synergy with other missions:

Small particles

Instrument Intercomparison

Critical Instruments:

CAPS, CVI, CPI, FSSP-100, 2DC, 2DP, 2DS, Extinctionmeter, CDP, (CIN)

1.4 Remote Sensing Validation – CloudSat and Calipso

Experimental Objective: Compare measurements from Convair cloud and aerosol in-situ and remote sensing instrumentation to CloudSat and Calipso

Point of Contact: Walter Strapp, Alexei Korolev, David Hudak, Howard Barker, Peter Liu (EC) and Mengistu Wolde (NRC)

Science Motivation/Hypothesis:

In the spring of 2006, the CloudSat W-band radar and the Calipso lidar were launched into space to join an existing train of satellites with an array of instruments designed to make global measurements of the atmosphere, including clouds and aerosols. The remote sensing and in-situ instruments on the Convair 580 aircraft are highly suited for making validation measurements of the satellite mounted CloudSat W-band radar and Calipso lidar. Data products provided by the CloudSat and Calipso satellites include profiles of liquid water and ice water, cloud base and cloud top, and effective radius of particles. Several airborne measurement programs have already been performed to compare to CloudSat and Calipso data products, including a study of winter clouds in the winter of 2006/2007 in Ontario using the Convair 580 aircraft. The ISDAC project offers a unique opportunity to extend this effort in arctic clouds and aerosol layers.

Measurement Objective:

The CloudSat and Calipso satellite will pass over the Alaska area several times per week, providing vertical cross sections of radar reflectivity at 94 GHz, and lidar backscatter ratios at two wavelengths. Several data products are provided by the CloudSat/Calipso data processing group. The Convair-580 has the opportunity to validate the gross features of the CloudSat W-band radar using its own more sensitive W-band/X-band radar (NAWX), and its Ka-band radar. Perhaps more importantly, it possesses sophisticated instrumentation such as bulk LWC, IWC, and TWC measurements, and particle spectrometers, to validate CloudSat and Calipso algorithms describing the properties of clouds and aerosol layers. The G-band radiometer (similar to the ARM ground-based system) and the airborne NAWX radar will also be useful for remote sensing validation and retrieval algorithm work.

Flight Profiles:

The ISDAC flight programs will include routine 1.75 hour transit flights back and forth between Barrow and Fairbanks. If properly timed, these transit flights can be used to make valuable validation measurements for CloudSat. Two simple flight patterns are suggested. In the first case (Type 1), there will be a minimum impact on ISDAC other than the coordination of transit flight time and some additional transit time in order to transit to the CloudSat flight track. In the second case, a one-hour addition to the transit is used to study a feature along the line.

Type I: Transit between Fairbanks and Barrow will be timed so that a the Convair-580 aircraft can pick up the CloudSat track shortly after takeoff, and run an appropriate length of the track between Barrow and Fairbanks coincident at some point with the overpass of the satellite. This would be a direct transit down the line with no reversal of course.

Depending on the cloud conditions, the aircraft may on some occasions fly above or below cloud to get good remote sensing comparisons, or on other occasions fly in cloud to get in-situ validation data. The aircraft may ‘porpoise’ through the cloud layer depth to get validation of vertical profiles, or occasionally remain near cloud top to get validation of effective radius measurements. It is likely that the flight director would make this decision based on pre-flight guidance, and on real-time measurements taken onboard the aircraft. The same flight plan could be done without clouds to measure aerosol layers for comparison to Calipso. This flight plan would add approximately 0.5 hours to the standard Fairbanks-Barrow transit.

Type II: The Convair-580 aircraft would again pick up the CloudSat track shortly after takeoff. In this case an interesting cloud feature along the line with a scale size of the order of 40 nmiles would be identified by pre-flight weather guidance, and the takeoff time would be chosen so as to be at that location on the CloudSat track approximately 30 minutes before the overpass. The aircraft would then probe this 40 nmile section of the track for 30 minute prior to until 30 minutes after the overpass, performing in-situ profiles and down-the-track legs. Some adjustment of the aircraft track may be performed to account for cloud translation. This flight plan would add approximately 1-1.75 hours to the standard Fairbanks-Barrow transit.

Repetitions necessary:

As often as the ISDAC PIs can accommodate. This is an opportunity to take advantage of flight time that may not otherwise provide any scientific value.

Weather Conditions:

Ideally, moderately shallow (1-2 km) liquid, mixed-phase or glaciated cloud layers, with both sub-Cloudsat and above-CloudSat minimum detectable reflectivity (-28 dBZ), and with cloud bases higher than the minimum IFR en-route altitude. In the case of Calipso validation, mid level cirrus layers, and visible pollution layers would be most interesting. Relatively stratiform cloud or aerosol layers would be preferable to highly variable layers.

1.5 Instrumentation Studies

Experimental Objective: To improve our understanding of cloud measurement accuracy using measurements during transit flights

Point of Contact: Walter Strapp, Alexei Korolev and Greg McFarquhar

Science Motivation/Hypothesis:

Many of the science questions we seek to address with ISDAC data are dependent on knowledge of the bulk and size resolved cloud properties measured with in situ aircraft probes. In spite of new advances in instrumentation over the past decade, many of the same problems plaguing older instrumentation remain, and new problems continue to be discovered. Furthermore, the uncertainty, precision, and statistical representativeness of these measurements are substantial and difficult to establish. Whereas many old instruments have been extensively characterized and weaknesses documented, the performance of many new instrument has not had the benefit of similar characterization and documentation. Some of these problems, such as the accuracy of small ice particle measurements and the accurate separation of liquid and ice particles in mixed-phase clouds, limit our ability to make progress on fundamental issues dependant on knowledge of cloud microphysical properties. Thus, it is highly desirable that data be acquired in a variety of cloud conditions so that the performance and derived quantities of a variety of probes can be tested. In this way, it is hoped that some uncertainties and better understanding of the measurements used to answer the other science questions will be obtained.

Measurement Objective:

The Convair-580 aircraft will carry a complement of both well-characterized older technology instruments, and lesser characterized newer instruments with presumed superior performance in some areas. Some instruments will be modified specifically to mitigate certain problems such as shattering of ice particles and contamination of measurements by subsequent measurement of shatter debris. A variety of hot wire probes and a counterflow virtual impactor will all measure cloud measure total water content, providing an array of measurements to provide comparative performance data. A variety of small particle imaging probes will provide the same type of comparative performance data to assess the improvements provided by the newer technologies, thereby helping to provide information on the accuracy of past measurements with older probes.

Most ISDAC flights will provide a certain amount of instrument comparison data. However, the specific science objectives of the missions may not offer the flexibility for optimum flight patterns for instrument studies. In this mission, it is proposed to take advantage of uncommitted portions of transit flights between Barrow and Fairbanks to do instrument-specific performance studies.

The primary goal of this experiment is to intercompare size-resolved concentrations and bulk moments of the size distributions (e.g., ice and water mass contents) measured by a variety of probes on the aircraft. The specific science questions we seek to address with this objective are, 1) How do measurements of concentrations of small ice crystals (with maximum dimensions less than 100 μm) vary between different probes in a range of conditions (can we fly at a range of true air speeds?); 2) What is the impact of shattering on tubes of some of the in-situ particle samplers and how does this vary with varying

conditions and true air speed?; and 3) How much do concentrations/mass contents vary between probes operating in similar size ranges (especially as a function of phase of the cloud)?

Flight Profiles:

The objective would be to use uncommitted portions of transit flights between Fairbanks and Barrow to perform instrument performance testing. The onboard radar can be used to identify interesting cloud layers to perform such testing, or alternatively onboard observers may identify interesting cloud layers by eye. The aircraft would be directed to perform appropriate maneuvers for the specific instrument tests (e.g. porpoises through cloud depths or straight and level runs through cloud, speed runs, pitch and yaw excursions etc.). If time permits, and if particularly favourable cloud conditions are encountered for such performance testing, the direct transit may be interrupted to linger in the area to prolong the testing before resuming direct transit to the destination. Ideally these flights will also be flown in conjunction with ground-site measurements or satellite overpasses to allow for further comparison with retrieval products.

Repetitions necessary:

As often as the ISDAC PIs can accommodate. The intercomparisons between Fairbanks and Barrow represent an opportunity to take advantage of flight time that may not otherwise provide any scientific value.

Weather Conditions:

Currently, this is being proposed mainly for cloud studies. For each instrument sub-experiment, suitable weather conditions may vary. It is likely that a series of sub-experiments could be devised that would make use of almost any cloud conditions. Similar experiments should be designed for aerosol instrumentation. Several (>2) reasonable events should be observed during the Experiment; in particular, we should try to repeat measurements in clouds with varying extinction coefficients, with varying phases and with varying structures (e.g., single-layer versus multi-layer clouds); 2 different altitudes should be sampled for each event.

Synergy with other missions:

Ground-based validation
Small particle measurements
A-Train algorithm validation

Critical instruments:

FSSPs, CDP, CAPS, CSI, Nevzorov LWC/TWC, Water Vapor, CPI, , 2D-S, PMS 2D probes, Korolev extinction probe, CIN

1.6 Small Particles in Mixed-Phase and Ice Clouds

Point of Contact: Greg McFarquhar, Alexei Korolev, Walter Strapp

Science Motivation/Hypothesis:

The number concentrations of small ice crystals, with maximum dimensions less than approximately 100 μm , in mixed-phase clouds and in ice clouds, are very poorly known because conventional in-situ microphysical probes do not well measure these small crystals at typical aircraft speeds. Past studies have reached contradictory conclusions on the importance of these small crystals to total number concentration, projected area, extinction and mass of clouds. This is one of the key unknown questions in cloud microphysics. These small crystals have unknown effects on microphysical properties, such as ice crystal effective radius and mass-weighted fall speeds, and on radiation and hence are poorly represented in parameterizations for large-scale models. Assumptions in some ground-based and satellite retrievals also rely on assumptions about typical numbers of small ice crystals that have not been well validated. The primary objective of this mission is to characterize the number of small particles (maximum dimensions less than approximately 100 μm) that occur in mixed-phase and ice-phase clouds and to determine whether or not past measurements of high small ice crystal concentrations are instrument related (e.g., it has been hypothesized that artificially high concentrations of small crystals may be associated with shattering of large ice crystals on some probe tips). As a secondary objective, it will be examined if the role of small ice crystals is related to the location of the measurements (altitude, phase, liquid water fraction, temperature, humidity, etc.)

Measurement Objective:

To address the role of small ice crystals in microphysical and radiative properties, it is important to acquire in-situ measurements of ice crystal size distributions covering the complete range of possible particle sizes, measurements of bulk properties of the size distribution (e.g., mass content, extinction/integrated cross sectional area) obtained independently from measurements of the size distributions and preferably coincident retrievals of these bulk quantities from ground-based or satellite instruments.

Observations should be obtained in ice-, mixed- and even liquid-phase clouds to test the performance of the probes. The key measurements needed to meet this objective are:

- In-situ measurements of particle size distributions covering the complete range of possible ice crystal sizes (CDP, CAS, FSSP, 2DS, 2DC, 2DP)
- Measurements from forward scattering probes both with and without protruding inlets and shrouds (CDP, CAS and FSSP)
- High-resolution images of ice crystals to help identify particle habits (CPI, CAPS, 2DC, 2DP), information helpful for deriving estimates of total mass content and bulk extinction optical depth from the in-situ size distributions
- In-situ measurements of extinction optical depth derived from extinction meter
- In-situ measurements of total mass content derived from cloud spectrometer and impactor (CVI) probe
- Remotely sensed extinction optical depth from lidar backscatter (either airborne or ground-based) and if possible, upwelling and/or downwelling radiative quantities such as flux and narrowband measurements
- Should be flown in conjunction with Terra and/or Aqua MODIS if possible for additional comparisons with satellite retrievals or in conjunction with measurements made at the ground-based sites

General Aircraft Flight Profiles:

In-situ aircraft (Convair) flies either level legs, porpoises or spirals to obtain good data base in variety of conditions from all the probes

Coordinated lidar backscatter measurements from NSA.

If lidar from ground-based site used for lidar backscatter, an approximately 5 to 10 minute leg (60-100 km) should be flown with/against ambient wind over ground-based site; altitudes of cirrus can be radioed to Proteus pilot to help select the flight altitudes especially if thin cirrus layer present

- If coordination with Terra/Aqua possible, two end-points for run selected such that flight leg is flown parallel to overpass of satellite and 10 to 15 minute leg will be flown in this orientation
- Observations in variety of phases (liquid-, mixed- and ice-) required throughout the campaign

Repetitions Necessary:

Several repetitions (10 to 20 representative samples) should be made as this is crucial question in cloud and radiation physics, comparisons made with ground-based lidar Range of phases and cloud conditions should be sampled.

Observations can be acquired as component of other missions

Weather Conditions:

- Ideal situation would be uniform thin cirrus in a single layer.
- Both thin and thick cirrus layers should be sampled

Synergy with other missions:

- Ground-based validation
- A-Train algorithm validation
- In-situ probe intercomparison

Critical Instrumentation:

- CAPS, CVI, CPI, FSSP-100, 2DC, 2DP, 2DS, Extinction meter, CDP, (CIN)

1.7 Spatial Scale of Mixed-Phase Cloud Variability

Point of Contact: Greg McFarquhar and Mengistu Wolde

Science Motivation/Hypothesis:

Many past studies have suggested that mixed-phase clouds consist of a clustering of phases, whereby there are packets of liquid and ice that appear with very small spatial scales between them. Although the existence of such clusters has been established, the nature of the mixing between the clusters or the spatial scales of the clusters have not been well established.

Measurement Objective:

To address the spatial scales of these clusters and the nature of the mixing between water and ice in mixed-phase clouds, it is important to fly horizontal legs in mixed-phase clouds at a variety of altitudes. Further, it is needed to make these observations in both multi-layer and single-layer clouds to determine the degree to which seeding from upper layers affect the mixing of phases in the lower layer clouds. The key measurements needed to meet this objective are:

- In-situ measurements of particle size distributions covering the complete range of possible ice crystal sizes (CDP, CAS, FSSP, 2DS, 2DC, 2DP)
- Measurements from forward scattering probes both with and without protruding inlets and shrouds (CDP, CAS and FSSP)
- High-resolution images of ice crystals to help identify particle habits (CPI, CAPS, 2DC, 2DP), information helpful for deriving estimates of total mass content and bulk extinction optical depth from the in-situ size distributions
- In-situ measurements of extinction optical depth derived from extinction meter
- In-situ measurements of total mass content derived from cloud spectrometer and impactor (CVI) probe
- The frequency of the measurements required for this objective would be approximately 10 Hz for the synchronous probes.
- The NAWX radar with side looking and polarimetric capabilities will also be a useful tool for extending what is measured at the aircraft altitude to many kilometers away.

General Aircraft Flight Profiles:

- In-situ aircraft (Convair) flies level legs in a variety of conditions with mixed-phase clouds to characterize the clustering, spatial scaling and mixture of the phases
- Ideally, some of the horizontal legs should be flown perpendicular to the coastline (e.g., 50 km) to determine what the gradient of cloud properties along the coastline is (MPACE observations and modelling studies have suggested that this is an important factor to consider, especially when the ice moves away from the coastline later in the spring)
- Flights should also be conducted in both cross-wind and along-wind directions
- If coordination with Terra/Aqua possible, two end-points for run selected such that flight leg is flown parallel to overpass of satellite and 10 to 15 minute leg will be flown in this orientation
- Observations in variety of phases (liquid-, mixed- and ice-) required throughout the campaign

Repetitions Necessary:

- Several repetitions (10 to 20 representative samples) should be made to try and better understand this spatial scaling
- Range of phases and cloud conditions sampled
- Observations can be acquired as component of other missions

Weather Conditions:

- Ideal situation would be mixed-phase clouds, both occurring in a vertically continuous layer and in multiple layers
- Sample at a variety of altitudes and layers within the clouds

Synergy with other missions:

- Ground-based validation
- A-Train algorithm validation
- In-situ probe intercomparison

Critical Instrumentation:

CAPS, CVI, CPI, FSSP-100, 2DC, 2DP, 2DS, Extinction meter, CDP, (CIN)

1.8 Cloud extinction closure.

Point of Contact: Greg McFarquhar and Alexei Korolev

Science Motivation: Cloud extinction closure consists of comparing the measured cloud extinction with that calculated from Mie or other theories using the measured size distribution of cloud particle number and shape. This provides a test of Mie and other theories for warm, ice, and mixed-phase conditions. Cloud extinction closure has rarely been achieved?

Measurement Objective: Sample the cloud in stratified layers known to be warm, ice, or mixed phase. Critical measurements: cloud extinction, cloud particle size distribution 0.5-5000 microns, cloud particle shape 100-1000 microns. Perform separate closure for warm, ice, and mixed phase conditions.

General Aircraft Flight Profiles: a.i, a.iv, a.v, b.i, b.iii. Horizontal track or spirals through multiple levels of cloud for 5-10 minutes each.

Repetitions Necessary: 3

Weather Conditions: stratiform cloud is preferred

Synergy with other Flight Objectives: Can be combined with cloud modeling and with ice nucleation objectives. Strong connection with cloud water closure.

Critical Instrumentation: CAPS-CAS, CAPS-CIP, 2DS, 2DP, CIN, 2DC, extinction meter

1.9 Cloud water closure.

Point of Contact: Greg McFarquhar, Alexei Korolev and Walter Strapp

Science Motivation: Cloud water closure consists of comparing the measured bulk cloud water with the cloud water calculated from the integration over the measured cloud particle size distribution. This provides an important check on our cloud particle and bulk measurements.

Measurement Objective: Sample the cloud in stratified layers known to be warm, ice, or mixed phase. Critical measurements: Total water content, cloud particle size distribution 0.5-5000 microns, cloud particle shape 100-1000 microns. Perform separate closure for warm, ice, and mixed phase conditions.

General Aircraft Flight Profiles: Horizontal track through multiple levels of cloud for 5-10 minutes each.

Repetitions Necessary: 3

Weather Conditions: stratiform cloud is preferred

Synergy with other Flight Objectives: Can be combined with cloud modeling and with ice nucleation objectives. Strong connection with cloud extinction closure

Critical Instrumentation: CAPS-CAS, CDP, FSSPs, CAPS-CIP, 2DS, 2D2-C, 2DP, CVI, Nevzorov LWC/TWC, PMS King

1.10 Scale dependency of ice crystal number concentration for cloud-climate modeling applications: emphasize on dynamics

Point of contact: Gultepe, Girard, Isaac, Liu

Science Motivation: Earlier work by Gultepe et al (2001) suggested that small particle concentration is important to obtain various physical/dynamical parameterizations and to understand relationships between N_i and dynamical/thermodynamical parameters e.g. vertical air motion, RH_i, and T. Without the knowledge of small N_i e.g. particles size less than 100 micron, earlier parameterizations used in literature become not applicable for climate/cloud studies. Development of scale dependent N_i parameterizations is needed for applications related to various cloud systems.

Measurement objectives: Aircraft flight patterns should represent various meteorological events from a few hundreds meter up to 100 km. To obtain statistically significant microphysical parameters, constant flight legs should not be less than 30 km (5 min duration). Flights should be done at various T and RH levels, and specifically for T < 20C within the cloud.

General aircraft flight profiles

- i) Constant altitude level flights over 30 to 50 km length stack up within the cloud. At least 4 legs within the cloud; 1 close to base within the cloud, 1-2 within the cloud, 1 close to cloud top.

- ii) Eulerian Spirals over the Barrow site for vertical variability in the related parameters. In ideal case, before and after the constant flight legs.
- iii) Clear air segments (30-50 km) above, below, and around the cloud system if it is possible.
- iv) If an ice fog forms over the NSA site, lowest flight levels or missed-approach flight patterns will be very useful for inter-comparisons. In this case, a few flights legs at the lowest level (300 feet) are considered to be very important.

Synergy with other missions: Small particles, scale effects, Ni parameterizations

Weather conditions: BL clouds, ice clouds, clouds over ocean and land, shear/turbulent environments

Critical instruments: DMT CVI, FSSP-100, FSSP-300, 2DC, 2DS, CIP, extinction meter, PCASP, RH, T, and Rosemount Radom probe wind measurements

1.11 Cloud cover parameterizations

Point of contact: Gultepe, Isaac, Girard

Science Motivation: Cloud cover parameterizations include large uncertainties; 1% change in cloud cover in fact can balance greenhouse warming effect. With new data sets we will analyze the Ni, TWC, IWC, Nd for various thermodynamical conditions and develop a cloud cover parameterization for modeling applications.

Measurement objectives: Longer legs are better to be used for cloud cover (Cr) parameterization. For this reason, various cloud microphysical parameters will be included from the flight legs. Especially, measurements from the transit flights can be very applicable for parameterization development.

General aircraft flight profiles

Overall, longer constant flight legs during the project are suggested for data collection. There are no specific criteria to fly specifically into the clouds.

Synergy with other missions: Small particles, Scale effects, Cloud cover, IWC and TWC

Weather conditions: Mixed of various cloud types are needed for the analysis. Flights should not be always done for a specific cloud type.

Critical instruments: Nevzorov probes, FSSP-100, FSSP-100, 2DC, 2DP, 2DS, CIP, extinction meter, RH, T.

1.12 Ice fog microphysics and extinction: emphasis for in-situ validations

Point of contact: Gultepe, Liu, Girard, Isaac

Science Motivation: Ice fog microphysical and extinction measurements are important for various applications; 1) cloud-climate studies, 2) aviation applications, 3) nucleation, and 3) validation of aircraft in-situ based measurements and analyzing the results. Ice fog in fact is a cloud at the surface with no main dynamical disturbance. For this reason, various measurements at the surface will be used for parameterization development and in-situ validation.

Measurement objectives: Measurements at the surface will be done by the various instruments for ice particles and extinction measurements, and also at the higher levels (e.g. 300 m) by aircraft in-situ instruments. At the surface, measurements will be continuous during entire April. If aircraft flies into higher levels of ice fog, measurements can be tested against each other.

General aircraft flight profiles

- i. Flight segments (5-30 km) below the fog top height (~200 m), and around the fog system if it is possible.
- ii. If an ice fog forms over the NSA site, lowest flight levels or missed-approach flight patterns (as low as possible) will be very useful for inter-comparisons. In this case, a few flight legs at the lowest level (300 feet) are considered to be very important.

Synergy with other missions: Visibility, extinction, Small particles, Nucleation, Ni parameterizations

Weather conditions: BL ice clouds, high level ice clouds, clouds over ocean and land

Critical instruments: DMT CVI, FSSP-100, FSSP-300, 2DC, 2DDS, CIP, extinction meter, RH, T, and Rosemount radom probe wind measurements, UHSAS PCASP, SPLAT, CDFC, AMS and also various precipitation, extinction, and ice microphysical measurements.

1.13 Use of airborne atmospheric remote sensing systems for cloud physics studies

Point of Contact: Mengistu Wolde

Science Motivation:

- Retrievals of cloud microphysical properties (information on particle size, phase, type and water-ice content) using multiple airborne remote sensing systems (NAWX and G-band radiometer).
- o Characterization of cloud structures and processes
- o Aircraft hazard detection (turbulence, icing) using radar polarimetric and Doppler radar signatures
- o CloudSat validation

Measurement Objectives:

- NRC Airborne W and X-band Polarimetric Doppler Radar (NAWX)
Multi-frequency Polarimetric Doppler Radar
- Environment Canada Ka-band radar
- Prosensing G-band (183 GHz) radiometer
- Basic cloud physics and atmospheric state sensors

General flight patterns:

- Stacked horizontal legs at different altitudes starting from cloud top to below cloud base.
- Porpoising through a liquid layer for radar/radiometer retrievals using NAWX and 183 GHz radiometer.
- Radar calibration maneuvers: This will be done occasionally for few minutes over the water or over flat surface when the aircraft is not doing project specific tracks. Typically we do this during a return trip.

1.14 Aerodynamics Effects of In-flight Icing

Point of Contact: Anthony Brown

General Flight Profiles: Conduct aerodynamic characterization maneuvers, consisting of pitch-up maneuvers (1.5g/0.5g to 15 degrees nose-up and 10 degrees nose-down, respectively) and three-axis 2-3-1-1 small perturbation maneuvers, for the characterization of the effects of in-flight icing upon the aero plane's aerodynamic characteristics, whilst in icing accretion with airframe Ice Protection System (IPS) on and with delayed IPS activation (IPS OFF) for an acceptable period, which depends upon the accretion characteristics (rate and nature)

2. Aerosol or Aerosol-Cloud Science Objectives**2.1 CCN Closure**

Point of Contact: Steve Ghan, Don Collins and Peter Liu

Science Motivation: CCN closure consists of comparing the measured CCN concentration with the concentration calculated from the Kohler theory using measurements of size distributions of aerosol number and either composition or hygroscopicity. This provides a test of Kohler theory and of our ability to measure CCN. CCN closure has only recently been achieved due to advances in aerosol measurement technology, but has never been achieved in the arctic. The relatively polluted conditions expected during April above Barrow suggests that CCN closure can be achieved. This experiment is compromised by the absence of a DMA or HTDMA on the aircraft. These instruments are on the ground, which provides size and hygroscopicity measurements below cloud under all conditions except fog, but not necessarily near cloud base and within 500 m of the aircraft measurements only for missed approaches.

Measurement Objectives: Sample the aerosol in stratified layers below cloud layers. Critical measurements: CCN at a single supersaturation (0.2%), size distribution of aerosol number (100-1000 nm) and hygroscopicity (50-500 nm).

General Aircraft Flight Profiles: a.iii, a.iv, b.ii; Long horizontal tracks through homogenous aerosol layers below clouds with 10 minutes sampling time.

Repetitions Necessary: 3

Weather Conditions: Cloud-free layers.

Synergy with other Flight Objectives: Can be combined with any objective requiring hygroscopicity measurements below cloud, such as droplet number closure or cloud modeling.

Critical Instrumentation: CCN, DMA, HTDMA, PCASP.

2.2 Droplet number closure

Point of Contact: Steve Ghan and Hans Verlinde

To what extent do measurements at the surface of aerosol number concentrations, size distribution, and cloud-nucleating properties represent the properties of particles entering clouds at cloud base, and how does the measured cloud droplet concentration (size resolved) at the base of the (liquid) cloud correspond to the aerosol distributions? What is the response of the effective radius to environmental aerosol loading for warm clouds in the Arctic?

Droplet number closure consists of comparing the measured droplet number with that estimated from dynamic Kohler theory using measured updraft velocity and size distributions of measured aerosol number and hygroscopicity. This provides a test of our understanding of the droplet nucleation process. Closure has only recently been achieved due to improvements in aerosol measurement technology, and has never been achieved in the arctic. Closure will be challenging for ISDAC due to the weak updrafts expected in the stratified clouds.

Measurement Objective: Sample the aerosol in stratified layers below cloud. Sample droplet number and updraft velocity in lower part of cloud. Critical measurements: size distribution of aerosol number (50-1000 nm) and hygroscopicity (50-500 nm), droplet number and updraft velocity. Aerosol characterization, including total aerosol number concentration, cloud condensation and ice nucleus concentrations. Vertical air motion and turbulence, water vapor. Below and above cloud layers. During these legs radars will alternatively look up/down into the cloud layer.

General Aircraft Flight Profiles: a.iii, b.ii. Long horizontal tracks through homogenous aerosol layers below clouds with at least 10 minutes sampling time followed by either a

horizontal track just above cloud base or a spiral to document the microphysical properties in cloud.

Repetitions Necessary: 3

Weather Conditions: stratocumulus preferred for stronger updrafts

Synergy with other Flight Objectives: Can be combined with cloud modeling objective

Critical Instrumentation: DMA, HTDMA, PCASP, gust probe, CAPS-CAS

2.3 Cloud Modeling

Point of Contact: Steve Ghan and Ann Fridlind

Science Motivation: Cloud modeling consists of comparing measured clouds with clouds simulated by a numerical cloud model using measured aerosol and boundary conditions. This is the ultimate test of our understanding of clouds and their sensitivity to aerosol because it allows the clouds and circulation to respond to the aerosol. A variety of numerical experiments are needed to isolate differences between clouds during ISDAC and M-PACE due to differences in aerosol and boundary conditions.

Measurement Objective: Critical measurements: downward longwave at a level above all clouds of interest, precipitation at surface, and vertical profiles of cloud particle size distribution (0.5-5000 micron), liquid water content, ice water content, and cloud extinction, size distribution of aerosol number (10-3000 nm) and hygroscopicity (50-500 nm) below cloud, $IN(T, S_i)$. Also needed are vertical profiles of u, v, T, q and their horizontal advective tendency, surface temperature, and surface fluxes of sensible and latent heat; these can come from ECMWF analyses.

General Aircraft Flight Profiles: If possible, a 10 minute horizontal leg below cloud; if not, a 1 minute sample on a missed approach to the Barrow airport to get CCN concentration at one supersaturation. Follow this with 1-minute horizontal legs between and above cloud layers, then descend in vertical spirals above Barrow to sample clouds.

Repetitions Necessary: 10

Weather Conditions: any type of cloud with top below 3 km

Synergy with other Flight Objectives: strong connection to semi-direct objective. Most closure studies can be performed along with this experiment.

Critical Instrumentation: PCASP, HTDMA, CCN, CFDC, pyrgeometer, CSI, Nevzorov, King probe, CAPS-CAS, CAPS-CIP, 2DS, 2DP, cloud extinction probe

2.4 Semi-Direct Effect

Point of Contact: Steve Ghan and Ann Fridlind

Science Motivation: An additional mechanism for aerosol effects on clouds is through the radiative heating produced by absorption of sunlight. Although the sun is near the horizon at Barrow in April, it may shine long enough to produce a significant semi-direct impact on the energy balance by heating the air sufficiently to burn off clouds. This experiment is an extension of the cloud modeling experiment, adding the radiative heating by the aerosol.

Measurement Objective: Measure vertical profiles of absorption by aerosol at visible wavelengths.

General Aircraft Flight Profiles: Vertical spirals through clear air if possible.

Repetitions Necessary: 10

Weather Conditions: all cloud types with tops below 3 km

Synergy with other Flight Objectives: strong connection to cloud modeling experiment.

Critical Instrumentation: as for cloud modeling, plus PSAP and photoacoustic

2.5 Ice Crystal Nucleation

Point of Contact: Sarah Brooks

Science Motivation: Much is unknown about the composition and size of ice nuclei, particularly in the Arctic. IN concentrations were measured during M-PACE, and were found to be rarely at detectable levels. Although we expect higher aerosol mass concentrations during ISDAC, we don't know if IN concentration will be higher. If they are, we need to know why. This experiment will determine the composition of the ice nuclei by examining the residual aerosol behind a counterflow virtual impactor (CVI).

Measurement Objective: Given the much larger number concentrations of CCN vs IN, it is important to be sure that cloud water does not "contaminate" the ice crystals we wish to sample. Conditionally sample clouds dominated by ice by using measured total water and liquid water to identify ice clouds and icing probes to identify supercooled water. Sample aerosol behind CVI, using single particle mass spectrometer (SPLAT), aerosol mass spectrometer (AMS), and single particle soot photometer (SP2).

General Aircraft Flight Profiles: Horizontal legs through stratified ice clouds.

Repetitions Necessary: 10

Weather Conditions: stratiform completely glaciated cloud layers

Synergy with other Flight Objectives: can be combined with cloud closure experiments. Strong connection to next experiment

Critical Instrumentation: RICE, Nevzorov, CVI, SPLAT, AMS, SP2

2.6 Relation between IN and ice crystal concentration

Point of Contact: Greg McFarquhar

Science Motivation: M-PACE has shown that ice crystal number concentrations can far exceed the measured IN concentrations for measured temperature and supersaturations. However, the IN concentrations were near the detection limit for the CFDC. If IN concentrations are higher during ISDAC, the relationship could be examined with more confidence. Secondary production of ice crystals is expected to be less important for ISDAC than it was for M-PACE, so we expect better agreement between IN and N_i measurements for ISDAC.

Measurement Objective: Measurements of T , S_i , $IN(T, S_i)$ below and above ice cloud, crystal number within stratified ice cloud.

General Aircraft Flight Profiles: Horizontal legs of 15 minutes below, above, and lastly within ice clouds.

Repetitions Necessary: 10

Weather Conditions: Stratiform ice clouds

Synergy with other Flight Objectives: strong connection to previous experiment

Critical Instrumentation: Rosemont, LICOR, CFDC, SPEC CPI, CAPS-CAS, CAPS-CIP, 2DS, 2DP

2.7 Aerosol extinction retrieval

Point of Contact: Steve Ghan and Connor Flynn

Science Motivation: Evaluate the conditions in which the MPL retrieval of aerosol extinction works and when it does not.

Measurement Objective: Vertical profiles of measured aerosol scattering and absorption in clear air.

General Aircraft Flight Profiles: Vertical spirals directly over ARM site.

Repetitions Necessary: 5

Weather Conditions: clear column over ARM site

Synergy with other Flight Objectives: strong connection to CCN retrieval.

Critical Instrumentation: nephelometer, PSAP, photoacoustic

2.8 CCN retrieval

Point of Contact: Steve Ghan

Science Motivation: Evaluate the conditions in which the surface-based retrieval of CCN (Ghan and Collins, 2004; Ghan et al., 2006) works and when it does not.

Measurement Objective: Measurements of CCN concentration and aerosol size distribution at multiple levels above the ARM site.

General Aircraft Flight Profiles: Stacked horizontal legs of 1 minute each over ARM site.

Repetitions Necessary: 5

Weather Conditions: clear above ARM site

Synergy with other Flight Objectives: strong connection to extinction retrieval

Critical Instrumentation: CCN, DMA, PCASP, HTDMA

2.9 Ice crystal nucleation parameterizations and dehydration processes

Point of contact: Gultepe, Liu, Girard, Isaac

Science Motivation: Ice crystal number concentrations versus ice nuclei and total aerosol number concentrations will be analyzed and parameterized if a relationship exists. There are different processes for ice nucleation e.g. homogeneous and heterogeneous nucleation processes. Various in-situ aerosol measurements (SPLAT, AMS and SP-2) can help us better understand both refractory and non-refractory characteristics of ice nuclei. These results will be used in Canadian GEM model to study semi-direct effect and indirect effect of aerosols.

Measurement objectives: This will specifically be for ice cloud conditions, representing various cloud systems. Measurements need to be done both within and outside of the cloud at various T and RH conditions

General aircraft flight profiles

- i. Constant altitude level flights over 50 km length stack up (separated at 300 m at least) within the cloud. At least 4 legs within the cloud; 1 close to base within the cloud, 1-2 within the cloud, 1 close to cloud top.
- ii. Lagrangian Spirals in clear air and within the cloud
- iii. In ideal case, before and after the constant flight legs.
- iv. Clear air segments (30-50 km) above, below, and around the cloud system if it is possible.
- v. If an ice fog forms over the NSA site, lowest flight levels or missed-approach flight patterns will be very useful for inter-comparisons. In this case, a few flights legs at the lowest level (300 feet) are considered to be very important.

Synergy with other missions: Small particles, Nucleation, Scale effects, Ni parameterizations

Weather conditions: BL ice clouds, high level ice clouds, clouds over ocean and land, shear/turbulent environments

Critical instruments: DMT CVI, FSSP-100, FSSP-300, 2DC, 2DS, CIP, extinction meter, RH, T, and Rosemount Radom probe wind measurements, PCASP, UHSAS, SPLAT, CDFC, AMS, SP-2. Since we are flying in cloud, we will also be using the CVI (not the DMT CVI) to look at the residue from ice crystals.

2.10 Long Range Transport of Pollutants to the Arctic Troposphere

Point of contact: Shao-Meng Li, Richard Leatch, Anne Marie Macdonald, Kurt Anlauf, Walter Strapp, Peter Liu

Science objective: The primary scientific objective will be the long range transport of pollutants to the Arctic, the cloud processing of pollutants in the Arctic, aerosol optical closure, contributions to CCN closure, and contributions to the overall ISDAC scientific objectives.

Measurement objectives: To investigate long range transport of pollutants from lower latitudes to the Arctic, including

General aircraft flight profiles: a series of vertical profile measurements from surface to 20 kft, ascending or descending over Barrow/Fairbanks

Repetitions necessary: yes

Weather conditions: clear sky preferred

Synergy with other missions: impact of long range transport on the Arctic chemistry including aerosols; results complement those of the other missions

Critical instruments: CO, Hg, O₃ (gaseous pollutants), AMS, SP2 (aerosol pollutants), UHSAS (particle number size distribution), CPC (aerosol number concentration)

2.11 Cloud processing of Hg in the Arctic Troposphere

Point of contact: Shao-Meng Li, Richard Leitch, Anne Marie Macdonald, Kurt Anlauf, Walter Strapp, Peter Liu

Science objective: The primary scientific objective will be the long range transport of pollutants to the Arctic, the cloud processing of pollutants in the Arctic, aerosol optical closure, contributions to CCN closure, and contributions to the overall ISDAC scientific objectives.

Measurement objectives: To understand the potential effects of cloud (liquid and solid phase clouds) on the transformation of Hg in the atmosphere.

General aircraft flight profiles:

- i. pre-cloud (cloud base) air Hg and CO measurements
- ii. in-cloud interstitial Hg and CO vertical profiles
- iii. LWC and cloud droplet size distribution vertical profiles
- iv. Updraft velocity measurements at cloud base and in cloud

Repetitions necessary: yes

Weather conditions: cloudy situation, both liquid phase and solid phase clouds

Synergy with other missions: the flight plan will be the same as those planned for other ISDAC missions; no separate flights are needed

Critical instruments: Hg(g), CO (gaseous pollutants), Nevzorov probe (LWC), FSSP100 (cloud droplet size distribution), 3-D wind (updraft velocity measurements)

2.12 Aerosol optical closure in the Arctic Troposphere

Point of contact: Shao-Meng Li, Richard Leitch, Anne Marie Macdonald, Kurt Anlauf, Walter Strapp, Peter Liu

Science objective: The primary scientific objective will be the long range transport of pollutants to the Arctic, the cloud processing of pollutants in the Arctic, aerosol optical closure, contributions to CCN closure, and contributions to the overall ISDAC scientific objectives.

Measurement objectives: To characterize optical property closure of aerosols in the Arctic

General flight plans: no specific plans needed

Repetitions necessary: yes

Weather conditions: clear sky preferred

Synergy with other missions: the objectives will be completed while other missions are carried; no specific mission flights are necessary for these objectives

Critical instruments: PSAP (absorption), Nephelometer (scattering), UHSAS/FSSP300 (aerosol number size distribution), AMS/SP2 (aerosol chemistry size distribution), SPLAT (size distribution of aerosol dust components), CPC (aerosol number concentration)

2.13 Contributions to CCN closure studies and aerosol activation studies

Point of contact: Shao-Meng Li, Richard Leaitch, Anne Marie Macdonald, Kurt Anlauf, Walter Strapp, Peter Liu

Science objective: The primary scientific objective will be the long range transport of pollutants to the Arctic, the cloud processing of pollutants in the Arctic, aerosol optical closure, contributions to CCN closure, and contributions to the overall ISDAC scientific objectives.

Measurement objectives: to make critical measurements necessary to complete CCN closure studies in clear air, and complete studies on aerosol activation in clouds

General flight plans: profiles in clear air, pre-cloud (at cloud base), in cloud measurements coupling to CVI

Repetitions necessary: yes

Weather conditions: stratus clouds

Synergy with other missions: these objectives are already incorporated in the main missions of the ISDAC program

Critical instruments: UHSAS and PCASP-100x (aerosol number size distribution), AMS (aerosol chemical size distribution) on ambient or after CVI, SP2 (size distributed soot carbon), SPLAT (size distribution of aerosol dust components) and CCN.