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TWP-ICE Operations Plan

P May
C Jakob
G McFarquhar
J Mather
J Mace

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ARM
CLIMATE RESEARCH FACILITY

TWP-ICE Operations Plan

Peter May, Jim Mather, Christian Jakob, Jay Mace, Greg McFarquhar
With contributions from many people

Overview

The TWPICE experiment will take place from January 21, 2006 through February 13, 2006. During this period, there will be a substantial ground and sea based component as well as NASA, ARM, ARA and UK aircraft. The UK aircraft will also be participating in an experiment in Darwin during November-December 2005. This earlier experiment also involves aircraft associated with the European SCOUT program and the routine remote sensing activities around Darwin. There is some overlap with the November/December activities, particularly the logistics at the RAAF base where the laboratory space, communications costs, and other costs that involve all groups will be shared.

In November 2004, a planning meeting was held in Darwin which focused on identifying logistics issues and tasking groups of people to address those issues. Toward this end, four working groups were established to tackle specific experiment components. Those groups along with their (co) chairs are:

Ground based network (Mather)
Logistics (Hollis/Atkinson)
Forecast support (Jakob)
Aircraft operations (Mace/McFarquhar)

These groups are responsible for collecting information relevant to their areas. This document distills information collected from these groups and is organized by the major functional components of the experiment.

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Experiment Management

TWP-ICE is a complex experiment in which multiple aircraft will have to be coordinated in complex meteorological conditions. It will be of the utmost importance that a clearly defined management structure is in place so that there is a protocol for making decisions about how experiment objectives will be met. For this purpose, we have created a science committee whose main task will be aircraft mission selection during the IOP itself. Once the IOP begins, ground based activities will be mostly routine with the exception of the ship's cruise pattern that will have to be coordinated with aircraft missions. Each of the major groups taking part in the experiment are represented on the science committee so that the scientific objectives of each group are represented in the decision making process. The members of the science committee are nominally:

Peter May (BOM/Science committee chair)
Greg MacFarquar (ARM UAV)
Jay Mace (ARM/NASA)
Graham Stephens (NASA Cloudsat)
Jim Mather (ARM)
Tim Tooman (ARM)
Jorg Hacker (ARA)
Dave Winker (NASA Calipso)
Kieth Bower (ACTIVE)
Geraint Vaughan (ACTIVE)
Christian Jakob (BOM)
Dave Starr (NASA/Aircraft management)
Ed Zipser (U. Utah/Aircraft management)

It will be the responsibility of the committee chair to mediate discussions and organize meetings associated with mission planning.

For each mission, a mission scientist will be selected from a few members of the science committee. The mission scientist will ultimately be responsible for deciding what mission will be flown on a given day and how a mission should be modified (including canceling a mission) after taking input from other members of the science committee and from forecast support. Details of this mission process are provided under the Aircraft Operations section.

Contacts

Science and infrastructure

Brad Atkinson	b.Atkinson@bom.gov.au	04 2797 5725
Kieth Bower	keith.bower@umist.ac.uk	
Frank Bradley	Frank.Bradley@csiro.au	
Lori Chappel	l.chappel@bom.gov.au	08 8920 3892
Jorg Hacker	jorg.hacker@flinders.edu.au	04 1885 7115
Andrew Hollis	a.hollis@bom.gov.au	04 0675 4681
Christian Jakob	c.jakob@bom.gov.au	04 0675 4680
Chuck Long	chuck.long@pnl.gov	04 0675 4686
Jay Mace	mace@met.utah.edu	04 0675 4689
Jim Mather	jim.mather@pnl.gov	04 0675 4678
Peter May	p.may@bom.gov.au	04 0675 4679

Greg McFarquhar	mcfarq@atmos.uiuc.edu	04 0675 4687
Peter Minnett	pminnett@rsmas.miami.edu	(On Southern Surveyor)
Jan Nystrom	jvnystrom@fastmail.fm	04 0675 4683
Mike Reynolds	michael@rmrco.com	(On Southern Surveyor)
Scott Seibold	scott@twinotter.com	
Dave Starr	david.starr@nasa.gov	04 0675 4682
Graham Stephens	stephens@atmos.colostate.edu	
Nigel Tapper	nigel.tapper@arts.monash.edu.au	
Matt Tomczak	matthias.tomczak@flinders.edu.au	(On Southern Surveyor)
Tim Tooman	tooman@sandia.gov	04 0675 4691 (92-96 for Proteus team)
Geraint Vaughan	Geraint.vaughan@umist.ac.uk	04 1649 8292
Ed Zipser	ezipser@met.utah.edu	04 0675 4684

Aircraft logistic support

Cheryl Welden	cwelden7@hotmail.com
Rhona Godward	rgodward@paspaley.com.au

Forecast Support (Jakob)

Weather forecast support – Experiment planning will rely heavily on obtaining the latest information on atmospheric conditions. Forecast resources are expected to include obtaining up to date weather information and personnel to provide expert interpretation of these data.

The lead forecaster for TWP-ICE will be Lori Chappel from the BOM regional office in Darwin. Lori will be dedicated to the experiment for its duration. Lori or her assistant will provide daily weather briefings which will be held at Charles Darwin University.

General weather products can be obtained from the BOM web site:

http://www.bom.gov.au/weather/nt/
More detailed weather charts can be obtained through the experiment forecast web page:

http://dods.bom.gov.au/twpice/browser/

This site is password protected, contact Peter May, Jim Mather, or Christian Jakob for the log-in information.

The page is a plotting tool with access to an up to date archive including forecast products from the BOM LAPS model, satellite images, upper air data and images from the ARM cloud radar.

Existing Surface Network

The Darwin ARM Site (Mather)

A description of the Darwin ARM site and instruments operated there can be found at:

http://www.arm.gov/sites/twp/darwin.stm/

While all of the ARM instruments will be important for TWP-ICE, the key critical instruments will be the remote sensors used to determine cloud microphysical properties. These instruments are:

Millimeter Cloud Radar (MMCR): 35 GHz, vertically pointing radar

Micropulse Lidar (MPL); Elastic scattering lidar operating at 532 nm

Microwave Radiometer (MWR): Two-channel radiometer used for integrated column water

Atmospheric Emitted Radiance Interferometer (AERI): Multichannel Infrared radiances

Contact for the ARM site instruments is Jim Mather.

Guest instruments at the Darwin ARM Site

VHF Broadband Digital Interferometer Lightning Detector (Kawasaki)

PI: Zen Kawasaki
Department of Communications Engineering, Osaka University
Phone +81 6 6879 7690
FAX +81 6 6879 7774
e-mail zen@comm.eng.osaka-u.ac.jp
http://www1a.comm.eng.osaka-u.ac.jp/~lrg/

Status: The lightning detection system was installed the week of 13 December 2004. This system produces 3-dimensional location of lightning channels with very good time and spatial resolution to produce maps of the lightning discharges. The system has significant range dependence so that the best quality data is within approximately 25 km of the base stations. Beyond this range, the detection efficiency decreases.

54.1 MHz profiler (Vincent)

Bob Vincent has installed a small 54 MHz profiler at the Darwin ARCS site. Profilers in this frequency range use antenna arrays that can be 50 m on a side or larger but this array is only 16 m on a side.

PI: Bob Vincent
School of Chemistry and Physics
North Terrace
University of Adelaide, SA 5005
+61-8-8303-5758 (T)
+61-8-8303-4384 (F)
robert.vincent@adelaide.edu.au

Alternate Contact: Andrew Mackinnon,
Department of Physics
University of Adelaide
Tel: +618 8303 3875
Fax: +618 8303 4384
Mob: +61(0)411 024 713
Andrew.mackinnon@adelaide.edu.au

Passive Microwave profiler (Crewell/Loehnert)

A 14 channel microwave radiometer for measuring boundary layer temperature and humidity profiles and cloud optical properties will be installed at the ARM site prior to the start of operations.

Contact:Susanne Crewell
University of Munich
+49 (0) 89 / 2180-4210
crewell@meteo.physik.uni-muenchen.de

Student who will look after this syetm in the field is Mario Mech: [mario@meteo.physik.uni-muenchen.de]

Two channel solar radiometer (Pavloski)

A two-channel, narrowband, vertically pointing shortwave radiometer for retrieving cloud properties.

Contact: Chuck Pavloski

Penn State University
1-814-863-3094
pavloski@meteo.psu.edu

BOM precipitation radars (May)

The BMRC will be operating the polarimetric weather radar during the experiment. It collects and archives the raw polarimetric data and transmits reflectivity and Doppler velocity for operational displays as well as polarimetric based microphysical classifications for web displays.

The radar collects a sequence of a long range scan (out to 400 km), a volume scan within 150 km, a vertical “cloud” scan and RHI scans over the ARM and Bureau profiler site. During aircraft operations, a radar engineer will be on site and it will be possible to organize additional RHI scans in the areas being probed by the aircraft.

The BoM also operates a Doppler weather radar that is used in real time. It also has a sequence of a long range scan followed by a volume scan. Both the long range and volume scans are displayed in the operation and web based display systems.

A third back up radar at the Darwin airport is also available if the operational radar fails.

Darwin Wind profilers (May)

The Bureau operates a 50 MHz profiler and in conjunction with the Aeronomy Laboratory of NOAA, a 920 MHz profiler at a site approximately 6 km from the airport. A NOAA S-band radar has also been installed at the profiler site by Chris Williams [christopher.r.williams@noaa.gov].

These systems will be operated routinely throughout the experiment.

Automated Weather Stations (AWS; May)

The Bureau operates a network of AWS stations. Loggers to collect 1 minute data will be added to these systems. The operational AWS data is displayed in real time.

An additional 10 BMRC systems will be deployed for the experiment.

Surface Flux Sites (Tapper)

The field experiment will have access to surface flux measurements across the domain, providing area-mean as well as landscape-specific values of heat, moisture and radiation fluxes. These measurements, provided by Monash University (Tapper and Beringer) will provide input to modelling as well as to fundamental moisture budget studies. TWP-ICE builds upon instrumentation established for the Savanna Fire Experiment (SaFE) and for a long-term hydrological study of the Daly River catchment, an area currently being cleared for agricultural purposes. The confirmed flux measurement sites are shown in Table 1.

Table 1. Confirmed Surface Flux Sites (to operate for full TWP-ICE observational period, 16 January to 13 February)

Location	Lat/Long	Nature of Landscape	Instrumentation/Measurements
Darwin Harbour	12º 29.900'S 131º 53.200'E	Inshore waters	3-D eddy covariance system (sensible, latent heat flux, 20 min av.). Pyrgeometers/ pyranometers/net radiometer (net radiation, upward and downward directed short and longwave fluxes, including diffuse, 1 min av*.) Basic AWS
Howard Springs	12º 29.655'S 131º 09.143'E	Eucalypt open forest savanna with woollybutt, stringybark and a sorghum tall grass understory	3-D eddy covariance system (sensible, latent heat flux, 20 min av.). Pyrgeometers/ pyranometers/net radiometer (net radiation, upward and downward directed short and longwave fluxes, including diffuse, 1 min av*.) Basic AWS
Fogg Dam	12º 32.552'S 131º 18.413'E	Typical northern floodplain with sedges, rushes, grasses and scattered pandanus and gebang	3-D eddy covariance system (sensible, latent heat flux, 20 min av.). Pyrgeometers/ pyranometers/net radiometer (net radiation, upward and downward directed short and longwave fluxes, including diffuse, 1 min av*.) Basic AWS

Radiosonde Sites(Jakob)

The auxiliary radiosonde sites will be:

Cape Don Lat: (-11.3081 Lon: 131.7651) Northeast of Darwin
Phone: +61 (08) 8979 0030

Point Stuart Lodge Lat: (-12.5858 Lon 131.7609) East of Darwin and south of Point Stuart
Phone (08) 8978 8914

Garden Point (Lat -11.40891 Lon:130.41669) North of Darwin at the west end of Melville Island.
Phone number: To be added

Mount Bundy (Lat -13.2287 Lon: 131.1355) South of Darwin near Adelaide River
Phone 08 8976 7009

Detailed documentation of these sites is available on:

http://www.nt.bom.gov.au/ntregion/bmrc/TWP-ICE/twpice.shtml

RV Southern Surveyor

Latitude: 12.4S, Longitude: 129.8E

Teams at each site are being led by a retired Bureau of Meteorology observer. The remaining staff of the teams of 5 (4 on the ship) are students recruited from Universities in Australia, Germany and the US. Sondes will be launched every 3 hours beginning at 930 LT on Saturday, January 21 and concluding on February 13. The actual final launch time will be determined by ship operations and the time needed to unload equipment when it reaches port. The sonde teams are taking part in a 2 ½ day training sessions at the Bureau of Meteorology Training Annex in the suburb of Broadmeadows in Melbourne during the week of Jan 9. Helium will be used at each of the sites. Three sites (Cape Don, Garden Point, Mt Bundy) will launch 800 gm balloons while Pt Stuart and the ship will use 500 gm balloons.

The Bureau of Meteorology will also be launching 6 hourly soundings from the Darwin station. Kyoto University will be launching 6 hourly radiosondes from Bandung, Indonesia

Southern Surveyor (Jakob/Schulz/Bradley/Mather)

Contacts

Lead scientist: Matt Tomczak
Darwin Harbormaster: Bruce Wilson (8947-7201)
CSIRO Contact: Ron Plaschke

Schedule:

January 16	Loading begins 0630 (local time)
January 20	Depart Darwin
February 14	Return to Darwin
February 15	Unloading of equipment must be completed

Instruments:

Radiosonde station

PNNL Atmospheric Remote Sensing Laboratory (PARSL)

- Millimeter wavelength radar (94 GHz)
- Cloud/aerosol lidar (532 nm)
- Vaisala 25k ceilometer
- Two-channel microwave radiometer
- Infrared thermometer
- T/RH Probe
- Optical rain gauge

Surface radiation and fluxes
Precipitation
M-AERI
CTD profiles

Ship science crew

Simon Borlace (Flinders)
Melissa Coman
Connor Flynn (PNNL, PARSL)
Peter Minnett (U. Miami, M-AERI)
Wing Ng
Chuck Pavloski (Penn State University, PARSL)
Jerimiah Reynolds

Mike Reynolds (BNL, surface fluxes)
Eric Shulz (BOM)
Matt Tomczak (Flinders, lead scientist)
Alex Williams

Ship Communications

Communications from the ship will be limited. Staff on the ship will have access to email several times per day but data transmission will be kept to a minimum. Current plans are to transmit radiosonde temp messages for inclusion in model forecasts.

A satellite phone will be available for emergencies and for communications with the Dimona when it is flying in the vicinity of the ship.

Cruise strategy

The following is a notional cruise plan to achieve all the above objectives. As is often the case, it may need to be modified to suit the conditions we encounter on the day. For example, we are operating in a region and at a time when the dynamics of both ocean and atmosphere are expected to be quite complicated. The most severe problem from the flux measurement point of view would be lack of steady wind direction due to storm activity. So the plan should be understood as an indication of observational principles.

The ship will be deployed for 24 days at a location about 100 km west of Darwin. A suitable site will be selected, and the central Flinders mooring deployed. The ship will operate within a square box of side about 25km around this mooring, always beneath cover of the Darwin weather radar. There will be a short instrument and SeaSoar trial period within the box, during which two other moorings will be deployed at its perimeter. All these moorings are in shallow water, so deploying and retrieving them will take very little time.

There will then begin a cruise routine which will continue throughout the IOP. To minimize the effects of flow distortion and ship motion on the wind measurements, the best strategy to obtain continuous time series of air-sea fluxes is to steam slowly upwind without ship manoeuvers for as long as possible. At 2 kts the ship would travel from the mooring to the edge of the box in 3 hours on its “flux leg”. It would then deploy the SeaSoar in tow-yo mode and return to the mooring at 8kts on an “ocean structure leg” taking from 45min to 1hour. The ship would then turn and proceed again upwind which may, of course, have shifted direction. Note that in light winds flux measurements would be valid on the return leg – data would only be lost while the ship was turning. In a shifting wind situation, the flux leg may need higher speed to keep the relative wind within a reasonable sector over the bow, and the ship would cross the entire box in both directions.

The actual routine and timing will need to be determined after some experience, particularly of the SeaSoar handling. Throughout the cruise continuous measurements will be taken with the PARSL observatory, and radiosondes will be launched at three-hourly intervals. These will be closely scheduled, and it would be impractical, and unnecessary to try and synchronize the ship leg routines with launches. If a balloon is likely to coincide with either end of a leg, the turn will be delayed until the launch is completed. There will inevitably be other contingencies which affect the cruise timing, such as occasional CTD casts for comparison with the SeaSoar and ship's thermo-salinograph.

Of the aircraft flying during TWP-ICE, some will be measuring the state variables in the boundary layer, and surface fluxes. By observing spatial variability along the flight path, these complement the ship measurements and place them in the context of the whole experimental area. Experience with TOGA-COARE (Burns et al. 1999, 2000) tells us that confidence in the datasets is greatly enhanced by providing for careful intercomparisons between the measurements of ships and aircraft (flying as close as practical to the surface). Such comparison flights are scheduled in the experiment plan.

Aircraft Logistics (Jonas, Hollis)

Logistics team

Alf Jonas (ARA): Local contacts with RAAF
Andrew Hollis (BMRC): General logistical support

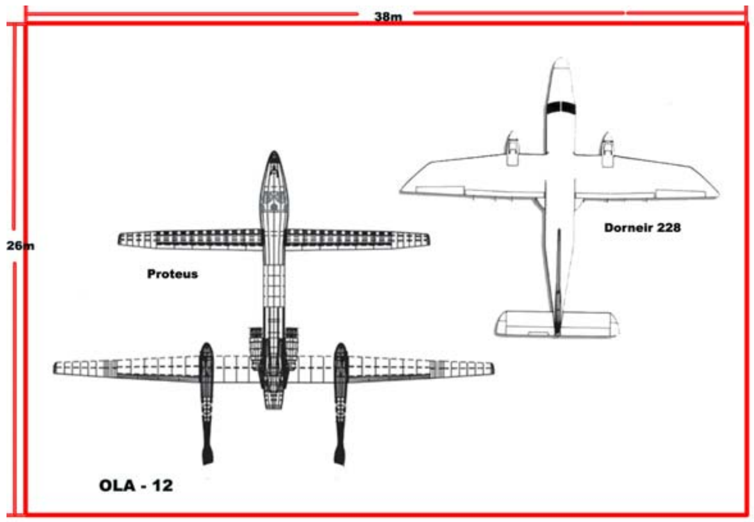
The aircraft will be stationed at the Darwin RAAF base. Logistics for the aircraft are being coordinated through Pearl Aviation. Our contacts at Pearl Aviation are Cheryl Weldon and Rhona Godward.

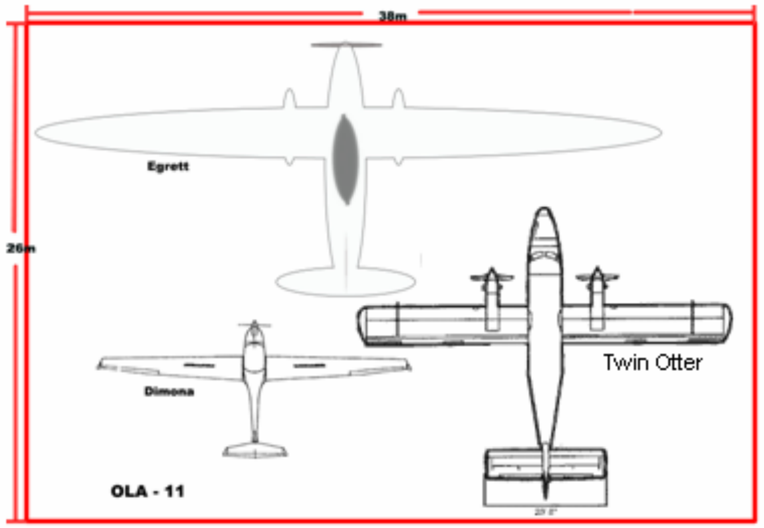
Hangarage

All aircraft, currently planned for this mission, will be able to fit into the available hangars on the Darwin RAAF base.

OLA-11 hangar could be shared by the Twin Otter, Dimona and the Egrett.
OLA-12 hangar could be shared by the Proteus and the D0-228.

Both these hangars have front and rear openings and these aircraft may be swapped around if working issues should require.





Communications

Brad Atkinson has arranged for high speed internet access to the RAAF base through Arafura connect. The service from Arafura will include the following:

- Bandwidth is on demand up to 10Mbit/s

- Arafura will provide a DHCP range of IP Addresses for each of the bunkers, the clients can plug in their own equipment, and Territory Technology Solutions will provide additional support as required.
- Arafura will supply 3 routers, one for each bunker, as long as each of the groups are not split across the bunkers.
- 24 hour support is available if required, service calls are logged with our office on 89476900, a technician will then be dispatched to carry out service as required. Additional charges apply for after hours work.
- No charge for data uploads
- Cost for data downloads is AU$0.12/Mbyte

With mission facilities widely dispersed across the RAAF, Darwin, & Northern Australia, cell phone communications will be required for all management and other designated personnel.

Aircraft Operations

Coordinators for Aircraft Mission Science: Jay Mace and Greg McFarquhar

Contact for each aircraft:

Proteus: Tim Tooman - tooman@sandia.gov , 925-294-2752
Will Bolton - wrbolto@sandia.gov, 925-294-2203

Egrett, King Air, Diamona:
Jorg Hacker - jorg.hacker@airborneresearch.com.au, +61-8-8182-4000

Mission selection and time lines (McFarquhar/Mace)

Introduction:

The overarching goals of TWP ICE are to characterize the physical and dynamical properties of the convective environment that compose the North Australian monsoon. The TWP ICE science plan describes these general objectives and the motivation for them in detail. The aircraft component of this experiment has three basic goals. The first of these is to characterize the properties of high level clouds associated with the various phases of the monsoon. A second objective of the aircraft component of TWP ICE is to observe the lower troposphere and the evolution of the convective boundary layer thermodynamic and physical structure including fluxes of water vapor and radiant energy. Another objective not unrelated to the others is the validation of remote sensing algorithms applied to ground-based and space-based observations. The validation objective is critical to the eventual scientific utility of TWP ICE because while aircraft data are detailed and valuable, the datasets created by aircraft are generally unable to fully characterize complex situations specifically or generally in a statistical sense while remote sensors operate continually and, over time, allow for reasonable statistical descriptions. Therefore, our default mission planning scenario will always be to locate aircraft missions over either the ARM ground site, over the ship-based remote sensors, both sites simultaneously, or under the A-Train satellites. The purpose of this document is to provide a set of working plans for implementation of the TWP ICE aircraft assets to address the various goals of the project.

We expect that the weather during the experiment, particularly during the active monsoon periods, will be complex and will challenge specific planning. Regardless, we use this document to construct a set of plans that will address the mission objectives identified in the science plan. The general meteorological situations during the experiment will be classified as either an active monsoon when the region around Darwin experiences a deep westerly flow in the lower troposphere with weak and widespread convection or a break period when active monsoon convection is well removed from Darwin and the region experiences diurnally driven afternoon thunderstorms that are stronger and show more organization than during the monsoon period. Within these general classifications, our planning will be dictated by where the convection is taking place, i.e. is the convection near or within the sounding array or is the convection well removed (several 10's to perhaps hundreds of km) from the sounding array? In the former situation missions designed to characterize the properties and evolution of anvils and the lower tropospheric convective environment will be our focus while during the latter situation, the characterization of the evolving properties of tropical cirrus (not necessarily associated with convection) will by our primary experimental objective. Given the broad objectives of ARM, both of these situations (anvils and cirrus) have equal merit as experimental targets since both have a significant impact on the global radiative energy budget.

Table 1 presents a breakdown of the experimental objectives that we wish to pursue within the broad mission types mentioned earlier and the aircraft assets that will be needed for each objective. Each of the experimental objectives in the table links to a more detailed description within this document that outlines the scientific motivation, the meteorological situation important to the objective, the aircraft assets and instruments that are critical to the objective, the number of repetitions and flights desired, which other objectives can be accomplished simultaneously, and default flight profiles that will best address the science questions posed. It should be kept in mind that not all experimental objectives will require full dedicated flights and often several objectives can often be addressed simultaneously or within the same flight.

Table 1.

Mission Type	**Experimental Objective**	**Proteus**	**Twin Otter**	**Dimona**	**Dornier**	**Egret**
Boundary Layer	Boundary Layer Recovery			X		
	Convective Boundary Layer Structure			X		
Anvil	Anvil Evolution	X	X			x
	Deep Anvil Characterization	X	X			x
Cirrus	Cirrus Evolution	X	X			x
	Small Particles in Cirrus	X	X			?
	Scattering Phase Function in Cirrus	X	X			x
Fluxes	Fluxes-Land			X		
	Fluxes-Ocean			X		
	Surface Spectral Albedo					
Validation	Cloudsat validation-Calibration and Detection	X	X			
	Cloudsat validation-Microphysics	X	X			
	Calipso Validaiton	X	X			
	Ground Based Algorithm Validation	X				
	In situ probe comparison	X				x

Table 2: Project Aircraft Capabilities

Aircraft	Duration (hours)	Early Ceiling	Late Ceiling	Air Speed	Max Range	Climb Rate	Descent Rate
Proteus							
Twin Otter	4 .5 (mission) + reserves	>10,000ft	>10,000ft	150 kts TAS			
Dimona	5 (mission) + reserves	>20,000ft	>20,000ft	60-105kts	~500NM	~500ft/m decreasing to above 10,000ft	>2,000ft/m
Egrett	4 to 5 (depending on flight profile)	~46,000ft	~49,000ft depending on weight and external sensors	Mach 0.36 at altitude	~1,000NM heavily depending on mission profile	~1,200ft/m decreasing above 20,000ft	>4,000ft/m
Dornier	4 to 5 (depending on flight profile)	15,000 ft	15,000 ft	Science: 70 m s^{-1}; Transit: 100 m s^{-1}		1500 ft/min to 750 ft/min as approach ceiling	

Flight Planning and mission execution.

Proper execution of the flight plans discussed in this document will require careful planning and execution of those plans by all involved. This task will be especially challenging during TWP ICE given the complex environment of the monsoon, the number of aircraft involved and the multiple objectives of the various groups and funding agencies involved in the mission. In the following paragraphs, we outline the general approach that will be taken during the experiment.

The planning and decision team:

It is important that the planning process is as open as possible so that ideas can be exchanged freely. However, decisions will be made by a smaller group of individuals with the discussion facilitated by the TWP-ICE mission scientist, Peter May. In addition to Peter May, the decision making group will include the following people: representatives from ARM (Jim Mather, Greg McFarquhar, Christian Jakob and Jay Mace); representatives from ARM UAV (Tim Tooman, Greg McFarquhar and Ken Black); aircraft mission direction personnel/convection experts (Dave Starr and Ed Zipser); representatives from ACTIVE (Keith Bower, Geraint Vaughan and Jim Whiteway); Jorg Hacker; a weather forecaster (Lori Chapell); and representatives from CloudSat (Graeme Stephens and Jay Mace) and CALIPSO (Dave Winker).

Briefing and planning schedule:

The briefing and planning schedule is outlined separately for two different scenarios. In Scenario 1, it is assumed that the planning day is a no-fly day and that the next day is a planned flight day. In Scenario 2, it is assumed that the planning day is also a flight day and then there will be a flight the next day. Scenario 1 will occur more frequently than Scenario 2 because it has been decided that flights will typically be conducted every other day (especially for the aircraft sponsored by ARM). However, when ideal monsoon conditions are present, there are possibilities for flights on success days. The ACTIVE team has also indicated that they will be occasionally flying on successive days.

Scenario 1 (Planning Day is no Fly Day with a flight anticipated on the next day).

Weather briefings for all hands will be conducted at 1600 local time at the University Lecture Theater. Christian Jakob has the responsibility for organizing the meeting and ensuring that it is conducted in a timely fashion. At the beginning of this meeting, the status of all aircraft and instruments will be reviewed. After this review, the forecaster will present the weather briefing. Following the weather briefing, the decision team will meet behind closed doors to debate the plans for the following day. Peter May has the responsibility for chairing this meeting and ensuring that it is conducted in a timely fashion. The participants will proceed to develop the flight objectives, operational areas and parameter spaces, time schedule, scrub criteria and schedule for the next day’s flight. If the weather is unsettled, it is possible to do this for an alternative flight mission as well; in this case the decision whether to fly the primary or alternate mission would be made the following morning prior to aircraft fueling and pay-load warm-up. At this meeting a mission scientist should be selected from the pool of those eligible as well as an assistant mission scientist. The pool of those eligible currently includes Peter May, Jay Mace, Greg McFarquhar, Keith Bower and Geraint Vaughan. At the end of the meeting the chair, Peter May, should poll the programmatic stakeholders for assent or objection. The final decision on participation of each platform will be made by that platform’s representative.

Following this meeting, the mission scientist and assistant mission scientist will head to the air base. The mission scientist will draw up detailed flight plans for the mission in consultation with the various programmatic and aircraft representatives. The flight scientist should be available as long as needed to answer questions and discuss the flight plans with the representatives of the different platforms. Baring major changes after meeting with the pilots, the mission scientist will complete the flight plans and make them available as soon as possible to all hands through a web site. If major changes to the flight plans are necessary, it is possible that a meeting with the planning and decision team will be reconvened (although the location of this meeting has not been set, it would likely be at the air base).

The exact schedule for the flight day will be determined by the lead-time required to allow the aircraft platforms to get ready for the mission (see Preliminary Operations Schedule below for the anticipated timeline for flight days). A meeting of the planning and decision team, chaired by the mission scientist, will be held at the air base at the earliest time in order for all aircraft to meet their takeoff schedule (3.5 hours before projected Proteus take off, 3 hours before Egrett/Dornier take off, 2 hours before Dimona take off). Following a briefing by the weather forecaster, the planning and decision team will meet and a go-no go decision will be made; if any modifications to the earlier identified operational parameters are necessary, these should be made as early as possible in this process. After one hour, this meeting must end in order to allow the aircraft crews time to prepare for the flight; the mission scientist is responsible for ensuring that the meeting ends in a timely fashion. Following the morning decision and planning team meeting, the convection experts (Ed Zipser and Dave Starr), the mission scientist and the weather forecaster will be available to meet with the pilots again as long as needed.

The flight management team that is selected for a specific flight (weather forecaster, mission scientist and assistant mission scientist, convection experts and programmatic representatives as summarized later) should head to the Bureau of Meteorology and be monitoring the weather starting 2 hours before the start of the flight. This will allow them to be in place to make a final go-no go decision, a decision to delay, and adjustment of operational parameters (way points, take off times, altitude of flight legs, etc.) in coordination with the aircraft representatives as the takeoff times approaches. Required lead times are necessarily aircraft specific. More details about the flight management strategy are included later.

Following aircraft landing, each program will hold its separate briefing to review the status of the platform and all the instruments, as well as getting feedback from the pilot on things that went well during the flight, and on things that could be improved. After all aircraft have landed, the flight management team will hold a final debriefing (at the Bureau of Meteorology) chaired by the mission scientist. It is possible that programmatic representatives (e.g., from ACTIVE and ARM UAV) will participate in this meeting by phone link.

Provided that the day after a flight is a no fly day, another debriefing meeting will be held the next day at 0900 at the University. This meeting will be open to all hands. The start of the meeting will center around operational concerns and platform/instrument status. Following this part of the meeting, the programmatic representatives may leave. Thereafter, a science discuss will continue until approximately 1100, where it will be reviewed whether the data that were collected on the mission were adequate for addressing the science goals that were proposed for the mission. A weather briefing would again be conducted at 1600 this day, assuming that the next day was to be a-fly day. Provided the next day was to be a flight day, these meetings would not be held and Scenario 2 below would be followed.

Flight Schedule:

The table below presents a list of milestones for each aircraft, specified in hours:minutes relative to the take-off time for each aircraft. The take-off time T and the landing time L will most likely differ for the various platforms and hence are designated as follows: TP and LP for Proteus take off and landing times; TDi and LDi for Dimona take off and landing times, TE and LE for Egrett take off and landing times; TDo and LDo for Dornier take off and landing times, and TO and LO for Twin Otter take off and landing times. Not all aircraft will be involved in every mission. The forecast presentation and decision meeting will be set at the earliest needed time when considering the schedules of all aircraft. DB denotes day before

Preliminary Operations Schedule

1600 DB: Weather briefing for all hands at University Lecture Theater (Jakob chairs)
1630 DB: Decision team meets behind closed doors to draft flight plans for next day at University; mission scientist and assistant mission scientist selected for flight (May chairs)
1700 DB: Mission scientist & assistant mission scientist go to air base to meet with aircraft crew and draw up detailed flight plans.
DB: Dornier fuels
TBD: Model output ready for evaluation (may be earlier if needed by other platforms involved in coordinated mission); This evaluation should be conducted at the earliest of the following times: TP-4:30, TE-4:00, TDo-4:00, TDi-2:00, TO??
TBD: Forecast presented to planning/decision team; decision meeting chaired by flight scientist. This meeting should be conducted at the earliest of the following times: TP-3:30, TE-3:00, TDo-3:00, TDi-1:00, TO??
First take-off – 2hours: Flight management team arrive at Bureau of Meteorology to prepare for directing flight
TDo-4:00 Power up AMS (only needed for first flight of day; rest of payload turned on during power up)
TP-2:30: Fly/No-fly decision for Proteus
TP-2:30: Proteus fuels
TE-2:00: Fly/No-fly decision for Egrett
TDo-2:00 Fly/No-fly decision for Dornier
TP-1:30: Proteus payload turned on
TDi-0:05 Fly/No-fly decision for Dimona
LP+0:30: Debrief meeting for Proteus crew at air base
LDo+0:30 Debrief meeting for Dornier crew at air base
LE+0:30 Debrief meeting for Egrett crew at air base
Last landing +0:30: Final debriefing of flight management team with participation of all aircraft representatives (at Bureau with some aircraft teams participating by phone)
Last Landing +1:00: Weather briefing when next day is possible flight date (Bureau Office)
Last Landing +1:30: Decision team meets behind closed doors (Bureau office)

1100 next day Mission debrief session at CDU lead by mission scientist unless there are back to back flights.

L+24 hours: Mission scientist should document accomplishments of mission for posting to the experiment web site

Scenario 2: Consecutive Fly Days

If there is a possibility for consecutive fly days, this should be identified as soon as possible (i.e., at the 1630 DB meeting of the decision/planning team). This will allow the aircraft crews to be ready for and prepare for the scenario of consecutive flight days. In the scenario for consecutive flight days, the same timeline and operations procedure is followed for the day before the first flight and for the day of the first flight up to and including the landing of the aircraft. However, a different procedure is followed once the aircraft have landed. One half to one hour after the last aircraft has landed, there will be a meeting of the decision/planning team meeting chaired by Peter May at Charles Darwin University. The first part of this meeting will consist of updates on the status of the different instruments and platforms; it is critical that the aircraft representatives provide as much feedback as possible on the flight that has been just conducted to help with planning for the next day's mission. Following these updates, a weather briefing will be provided to all hands. After the weather briefing, the decision/planning team will meet behind closed doors to draft flight plans for the next day, and a mission scientist and assistant mission scientist for the next day will be selected. The timing of the next day's mission will also be set at this meeting. Immediately after this meeting, the mission scientist will meet with the aircraft representatives to draft detailed flight plans, and will be responsible for making these flight plans available to all parties through a web site. The timeline for the 2nd flight day will then follow the scheduled drafted above.

Flight Execution:

In order to accomplish the science objectives outlined in this proposal, it is necessary that the aircraft platforms work together in a synergistic fashion. When possible, changes to predetermined flight plans made by individual platforms should be made in consultation with an operations team to assess the impact on the science objectives. The operations team will be selected to accomplish the goals of each flight the day before the mission is flown. The operations team for flight execution is formulated in order to allow each agency to have control and to be the principle communicator with their aircraft, but at the same time allowing coordinated scientific changes to predetermined flight plans to be made in reaction to changing meteorological conditions. It is envisioned that the aircraft operations team will operate in the following manner.

After the planning and decision team has established flight plans for a particular day and aircraft have departed, access to the established operations center at the Bureau of Meteorology will be controlled to ensure that the operations team can execute the flight plans as proposed with the minimum distraction. Aircraft guidance from the operations team should be of two sorts. The first kind is emergency guidance with a 2-3 minute decision cycle to warn aircraft of a quickly developing and threatening situation. Should this be used, then something is going awry and a flight abort should be strongly considered. The second kind is change guidance and has a 10-15 minute decision cycle.

This sort is invoked when the meteorological situation is changing in a reasonably well-understood manner and the best scientific data can be extracted from the evolving situation by repositioning aircraft maneuver points. It is important that the cycle time for change guidance not be shorter than 10 minutes to insure that the guidance is considered and not reactionary.

The operations team at the Bureau of Meteorology will consist of a mission scientist and assistant mission scientist (selected at the previous days planning meeting whereby appropriate individuals are selected depending on mission to be flown), a weather forecaster (Lori Chapman), representatives from the ARM UAV program (Tim Tooman, or Ken Black), representatives from the ACTIVE program, and convection experts (Dave Starr, Ed Zipser and/or Peter May). Other individuals who will be interacting with the operations team include the flight scientists on the Twin Otter and Dornier and the Dimona pilot.

Because of the large number of individuals involved in the operations team, it is important that each member have a clearly defined role to allow any modifications to flight plans (i.e., aircraft guidance) to be made on a timely basis. We envision the roles of the members of the operations team as follows:

> **ARM UAV representative**: Communicates any desired changes in flight profiles (timing of legs, altitude of legs, speed/location of spiral descents, way points, aircraft coordination points, etc.) to the Proteus pilot. Remotely monitors payload functions and provides any useful quicklook data to the mission scientist (such as cloud conditions above the aircraft). Advises mission scientists of any aircraft issues (e.g., fuel availability, instrument failure) that may play a role in proposed changes to flight profiles.
>
> **ACTIVE representative**: As for the ARM UAV representative except as relates to Egrett and Dornier.
>
> **Weather Forecaster:** Responsible for monitoring convection and weather conditions, provides updates to mission scientists and convection experts.
>
> **Convection Experts**: Responsible for working with weather forecaster to monitor cloud and convection, working with mission scientist to suggest modifications to flight profiles (way points, timing of legs, altitudes of legs, aircraft coordination points, etc.) needed to accomplish the science goals
>
> **Mission Scientist and Assistant Mission Scientist:** Responsible for communicating with convection experts/weather forecaster and formulating any needed modifications to flight profiles. Communicates/discusses changes with ARM UAV/ACTIVE representatives, flight scientist on Twin Otter and Dimona pilot and then reformulating changes in collaboration with convection experts in accordance with aircraft issues (fuel availability for suggested changes, practicality of suggested changes, etc.)

Flight scientists on Twin Otter/Dornier: Communicates with the mission scientist, advising mission scientist of conditions that he is observing and any aircraft/instrument issues Twin Otter/Dornier are experiencing. Communicates any suggested flight changes to pilot and provides feedback on changes to mission scientist.

Pilot on Dimona: Plays similar role to flight scientist on Twin Otter

Detailed mission plans are listed in appendix 1 of this document.
Additional information regarding the UK consortium (ACTIVE) is available at:
http://personalpages.manchester.ac.uk/staff/geraint.Vaughan/Active/active.htm

Communications/Data Transfer (Atkinson)

Data archival and dissemination during (and after) the experiment – Develop a complete plan for how data will be distributed. This will include real time distribution of some products during the experiment as well as access to archived data during the experiment and afterward.

Key products to be made available in near-real time for mission planning and analysis:

Millimeter radar reflectivity and velocities
Lidar backscatter
C-Pol radar echoes at various altitudes
Satellite images – possibly overlaid on radar echoes
Sounding profiles
Model forecasts

Data transfer between ground sites – images, small files, larger files?

Communications – among all the surface sites as well as the ship.

Develop web page for dissemination of information. There should be a central site where people can go for experiment forecasts, aircraft schedules, preliminary results (eg radar images of certain cases).

Data archival – during experiment and ARM IOP data base

Health and Safety(May/Atkinson/Noonan)

Medical services lists

Emergencies: 000 (equivalent of US 911)

Evacuation plans from remote localities
Dangerous Animals: Crocodiles, jelly fish (potentially deadly and common – believe the warning signs), venomous snakes (assume all snakes are potentially deadly), wild pigs, dingoes, water buffalo ….

Use insect repellant in evenings, particularly at remote sites.

Swimming Risks : Do not swim in creeks or at the beach. This is EXTREMELY hazardous. Pools only.

Heat issues: The temperature and humidity conditions in Darwin at this time of year are extreme. Care needs to be taken with respect to hydration and heat. This is particularly so for personnel working out doors or people exercising as heat stroke is a potential hazard. If working outside, people should drink several litres of water per day.

Lightning: Many of the storms in the area are highly electrically active. Follow guidelines shown in the Bureau poster to minimize risks.

Driving Left hand side of the road. NO left hand turns at red lights.

Contingencies

Tropical Cyclone in general area

Forecasters to take lead in a watching brief to advise on likely impacts. That is, will the TC directly affect the area and if this is possible on what time scale.

Tropical Cyclone threatens Darwin

With a 72 hour forecast indicating that a TC will affect the area, preparations for evacuation of personnel and aircraft will begin.

With a 48 hour forecast indicating that a TC will affect the area, personnel at the remote sites will be evacuated to Darwin. The aircraft will be re-located to Cairns/Alice Springs.

External Interactions(May)

There are various organizations that are either providing logistic support or some form of regulatory approval for the experiment operations. These, along with their current status, include:

Royal Australian Air Force

Approval has been given at the ministerial level for RAAF to support the experiment logistics.
Contacts on base are:
Warrant Officer Will Van deWyre (321BCP@defencegov.au)(08)89235593
Flt Lt Paul Morrison (paul.Morrison@defence.gov.au) (08)89238838
Flt Lt Diane Jackson . (Diane.Jackson@defence.gov.au) (08)89235573

All staff entering base first need to check in at security to obtain temporary passes. Photo-ID passes will need to be obtained as soon as possible from the visitor office.

Air Services Australia

Air traffic control (ATC): have been notified of the experiment are happy with the arrangements. May briefed ATC operations in Brisnae in October on the planned operations. This will be coordinated through the Bureau's Weather and Ocean Services Branch which is responsible for liaising with Air Services and their branches.
NOTAM to be issues prior to IOP regarding frequent soundings.
Contacts at ATC (Brisbane) are Rob Mitchell (rob.Mitchell@airservicesAustralia.com) Ross Layther (ross.layther@airservicesAustralia,com). For complex flight operations, such as instrument intercomparison flights, it is recommended that the operations supervisor be contacted directly at least 2 hours before flights.

The operations supervisor number is (07-3866 3314). Flight notification is required at T-2 hrs.

Low level operations may be under the control of the Darwin tower which is staffed by RAAF personnel.

CSIRO

Experiment time for the RV Southern Surveyor is approved and fitted into the cruise schedule

APPENDIX 1 Flight profiles

Mission Type: Boundary Layer (3.10 of science plan)

A. Experimental Objective: Quantify rate of boundary layer recovery in post-convection cold pools

Point of Contact: Peter May, Ed Zipser

Science Motivation/Hypothesis: The recovery of the boundary layer after convective activity is poorly constrained. Conditions thought to favor more rapid recovery include stronger surface winds/fluxes and weaker subsidence. The critical need is measurement of the vertical profiles of state parameters and fluxes at various stages of the recovery process.

Measurement Objectives: Examine the profiles through the boundary layer after storms have left the area by flying several stacked legs.

- In situ measurement of low level radiative, latent and sensible heat fluxes and vertical profile of state parameters in the PBL

General Aircraft Flight Profiles: Straight legs at 4 stacked altitudes: (100 ft, 250 ft, 500 ft 1500 ft (or near cloud base). If conditions permit this to be performed over or near surface flux sites using legs ~ 20 km and repeated, or ~ 50 km if spatial variability is large, sacrificing repetitions Other information to be used in defining tracks is the observation of the evolution of precipitation and outflow boundaries with the weather radar. Soundings to 5000 ft will be performed near the beginning and end of the on-station time.
Repetitions Necessary: ~ 4 (12 hrs). Ideally 2 over land and 2 over ocean.

Weather Conditions:

- Post storm in remnant cold pools.
- Day only

Synergy with other missions: Suitable follow on from cirrus missions where Dornier has been used to characterize the BL near the convection. Potential for back to back flights with D (what of pilot hour restrictions?)

Aircraft: Dimona
Critical measurements: radiative, sensible and latent heat fluxes; state variables.

B. Experimental Objective: Convective boundary layer structure

Point of Contact: Peter May, Ed Zipser

Science Motivation/Hypothesis: That the intensity of the convection is related to the thermodynamic structure of the boundary layer through the depth of the in-flow. Also, that the type of mesoscale organization is related to the low-level wind shear. In particular, both break season and monsoon BL storms will be sampled, to test the hypothesis that different characteristics of continental and oceanic storms are related to BL structure and forcing.

Measurement Objectives: Examine the profiles of the thermodynamic characteristics of the boundary layer, and low-level wind profiles in air feeding the convection. In situ measurement of low level radiative, latent and sensible heat fluxes and vertical profile of state parameters in the PBL

General Aircraft Flight Profiles: Straight legs at 4 stacked altitudes: (100ft, 250 ft, 500 ft 1500 ft (or near cloud base. Other information to be used in defining tracks is the observation of the outflow boundaries with the weather radar. Soundings to 5000 ft will be performed near the beginning and end of the on-station time a safe distance from the storms. The legs will approach the convective cells up to pilots' discretion regarding safety

Repetitions Necessary: ~ 4 (12 hrs). Ideally 2 over land and 2 over ocean.

Weather Conditions:

- During early part of storm lifetime
- Day only

Synergy with other missions: Suitable to associate with cirrus missions, so priority is given to those convective systems producing cirrus being sampled by the other aircraft. Possible that the Dornier could also fill this role

Aircraft: Dimona

Critical measurements: radiative, sensible and latent heat fluxes; state variables.

Mission Type: Anvil (See sect. 3.1 – 3.7 TWP ICE Science Plan)

A. Experimental Objective: Anvil Evolution (See Sections 3.1 and 3.2 of the TWP ICE Science Plan)

Point of Contact: Jay Mace

Science Motivation/Hypothesis: Of particular interest is the evolution of deep convective outflow into self maintaining cirrus layers. Understanding the processes governing this evolution is critically important for model validation and parameterization development. The specific science questions we seek to address with this objective are, 1) How do anvil cirrus evolve after detrainment from a cumulus tower? And 2) What are the physical mechanisms that govern this process? A primary goal of this objective will be to document,t with combined in situ and remote sensing data, aspects of the condensed water budget in the cloud system as it evolves. A fundamental question we would like to address is how much mass in the anvil is lost to lower levels and how much mass and what particle sizes survive into the downstream cirrus? A corollary to this question: Are new particles formed within the anvil as it ages?

Measurement Objectives: To address the questions posed above it is necessary to characterize the change in cloud microphysical properties of maritime/monsoon anvil outflow as it evolves over time/distance away from the convective source. The mission will require both in situ measurements and airborne remote sensing. The cloud system will be complicated enough that in situ data alone will likely not provide the breadth needed to answer the questions posed above although in situ data alone can document the evolution of the basic microphysical properties. The airborne remote sensing data (particularly radar) can provide sufficient context to address the questions posed above but only if certain evolving empirical relationships (Z-IWC, D-mass, D-Area) are supplied from in situ. Therefore, this experiment strongly relies on carefully coordinated in situ and remote sensing data for success. The Key Measurements are:

- In situ microphysics, dynamics, and thermodynamics particularly size distribution, IWC, extinction/integrated cross sectional area, vertical motion and turbulence, water vapor. **It is critically important that measurements of condensed mass, independent of imaging probes, be collected.**
- Remotely sensed radar reflectivity and Doppler velocity (if available), lidar backscatter.

- This mission should be flown in conjunction with ground-site measurements if possible. The ideal situation would be for convection within the flux array with anvil spreading over ground sites as the aircraft advect with the evolving cloud field.
- This objective would benefit very much from the availability of multiple in situ platforms (Egrett) that would either document the properties of a different location of the anvil or provide for extended measurements when the first aircraft runs out of fuel.

General Aircraft Flight Profiles:

- In situ option 1: In situ aircraft chooses an altitude within the anvil outflow as close to the convective source as deemed safe by the aircrew and initiates a cross wind racetrack 50 nm across the wind and 20 nm along the wind. During the downwind leg of the racetrack, the in situ aircraft should ramp down several thousand feet and fly the next across wind leg at a lower altitude. During the upwind leg the in situ aircraft should climb back to the original altitude before performing the next cross wind leg. The race track will shift laterally with the mean wind. If two in situ aircraft are available, the second altitude should be closer to cloud base/lower in the atmosphere so that the vertical flux of condensed water can be considered and empirical relationships at different altitudes can be determined. Orienting the in situ across the wind and stepping the racetrack along the wind will allow for documentation of the change of cloud properties with time.
- In situ option 2: In situ aircraft conducts a series of spiral ascent and descents within the cloud system
- In situ option 3: In situ aircraft initiates racetrack in opposite sense of the remote sensing aircraft, conducting consecutive legs at different altitudes to document cloud properties vertically. These racetracks can be stepped laterally as the cloud system evolves downwind. This would have the advantage of more coordinated data but would compromise the Lagrangian aspects of option 1.
- The goal of the remote sensing aircraft is to use mm radar and lidar to characterize the spatial properties (e.g. vertical mass flux as a function of height and time) of the cloud field as it changes with time. The Twin Otter will fly along wind racetracks ~50 nm along wind and ~20 nm across wind stepping along the wind as the cloud system evolves. The Twin Otter track should be coordinate with the in situ aircraft.

Repetitions Necessary:

- For the mission objectives to met, the anvil should be followed for several (> 2) hours.
- Several (>2) reasonable events should be observed during the Experiment

Weather Conditions:

- Ideal situation would follow an anvil system from its inception in deep maritime convection through a portion of its lifecycle as the anvil passed over the flux array and ground sites where quantities such as large scale vertical motion and moisture convergence in the upper troposphere could either be modeled or observed.
- This objective could also be pursued as part of a monsoon break system to compare with Crystal FACE and maritime/monsoon observations.

Synergy with other missions:

- Ground-based validation
- Deep anvil characterization
- Small particles in anvils

With the exception of the ground-based validation objective this mission should be the primary focus of an entire flight or a substantial portion of an entire flight if it is to be successful.

Aircraft:

- Proteus – Primary in situ platform.
  - Critical instruments: CAPS, CSI, Water Vapor, BAT, CPI, CIN
  - Flight Pattern: crosswind racetracks that step through the cloud layer. Pattern should shift laterally with the mean wind.
  - If anvil system passes over the ground site, conduct 10nm spiral over the ground-base instruments (see ground site validation mission)
- Twin Otter
  - Remote Sensor: Critical instruments mm radar, lidar
- Egrett
  - Potential Roles:
    - flown in conjunction with primary in situ platform at a lower or higher altitude
    - flown in series with primary in situ platform, sampling the evolving cloud system after the Proteus flight was completed
  - Critical measurements- CAPS, CPI,

B. Experimental Objective: Small Particles in Anvils

Point of Contact: Greg McFarquhar

Science Motivation/Hypothesis: The number concentrations of small ice crystals, with maximum dimensions less than approximately 100 μm, in anvils 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 and mass of anvil size distributions. 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 anvils 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, proximity to convection, age of anvil, formation mechanism of anvil-break period or active convection)

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. This mission will also benefit from the availability of multiple in-situ platforms to intercompare in-situ concentrations from instruments on different platforms, but also to assess if possible instrument measurement problems are dependent on the true air speed of the aircraft platform. 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
- High-resolution images of ice crystals to help identify particle habits (CPI, CAPS), 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 cloud integrating nephelometer (CIN)

- In-situ measurements of total mass content derived from cloud spectrometer and impactor (CSI) 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 (Proteus) chooses an altitude within anvil and flies an approximately 5 to 10 minute leg through thin uniform layer (porpoising in layer if thick enough)
- Coordinated lidar backscatter measurements required from either Twin Otter or ground-based site.
- 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
- Second in-situ aircraft (Egrett) ideally flies in close coordination to first in-situ aircraft to answer same set of questions
- If coordination with Terra/Aqua possible, two end-points for run selected such that flight leg will be parallel to overpass of satellite and 10 to 15 minute leg will be flown in this orientation

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 and airborne lidar
- Ideally should be conducted simultaneously with Egrett and Proteus aircraft
- Cirrus and anvils with range of optical depths should be sampled
- Observations can be acquired as component of other missions, but flight time dedicated to this objective within uniform thin cirrus should be made available

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
- Cirrus scattering phase functions

Aircraft:

- Proteus – Primary in situ platform.
  - Critical instruments: CAPS, CSI, CPI, CIN
  - Flight Pattern: Fly through uniform, thin single cirrus layer (porpoise if necessary) in coordination with other aircraft (Twin Otter, Egrett) providing lidar; flight pattern ideally with/against ambient wind to assist data interpretation if aircraft air speeds are different
  - If anvil system passes over the ground site, fly an approximately 5 to 10 minute leg (60-100 km) with against ambient wind over ground-based site; if A-Train overpass occurs, legs aligned to the satellite path should be flown
- Twin Otter
  - Primary Mission: Remote Sensor.
  - Critical instruments mm radar, lidar
  - Flight profile: Fly beneath the cirrus with lidar, mm radar pointing upwards; Flight should be coordinate with Proteus as much as possible and should be with/against ambient wind at the level of the cirrus; possibly provide flight altitudes to Proteus in real-time
- Egrett
  - Potential Roles: Fly as the in-situ platform in place of/coordination with the Proteus
  - Critical measurements- CAPS, CPI,

C. Experimental Objective: Deep Anvil Characterization - (See Sections 3.1-3.7 of the TWP ICE Science Plan)

Point of Contact: Dave Starr

Scientific Motivation/Hypothesis: The microphysical, radiative, and dynamical properties of heavy anvil that has recently been detrained from maritime/monsoonal convection is undocumented. These clouds are a key component of the earth's radiative balance due to their typical coverage, high albedo, and cold cloud tops. It is important that the properties of these clouds are documented adequately so that future modeling efforts of these complex cloud systems can be properly constrained with data.

Measurement Objectives: Sample the properties of deep, recently detrained ice layers from mature local monsoon convection - could be post-squall system but better if less dynamic and longer lasting, i.e., more circular system. Strongly prefer monsoon system but break system would also be useful but more difficult operationally.

- Microphysical/optical profiles in very heavy cirrus with significant self-maintenance
- secondary objective is to characterize the in situ cloud dynamical processes associated with re-generation over range of scales (1-10's km)
- Remote Sensing Aircraft: Radar reflectivity and Doppler velocity, lidar backscatter, upwelling and/or downwelling radiative quantities such as flux and narrowband measurements. This will be key for A-Train objectives even if no satellite overpass occurs during the flight.
- Should be flown in conjunction with ground-site measurements if possible. The ideal situation would be for convection within the flux array with anvil spreading over ground sites as the aircraft profile within the associated anvil.

General Aircraft Flight Profiles:

- Given the likely complexity of the monsoon environment with multiple convective towers detraining at multiple levels, vertical profiles (spirals) through the cloud system in conjunction with the ground-based remote sensors would be the primary objective.
- Stepped legs or racetracks could be utilized if appropriate.
- Multiple in situ aircraft would allow for better vertical sampling.

Repetitions Necessary:

- Duration of a flight should be sufficient to establish the statistical properties of the cloud field (2-3 hours of continuous sampling).
- At least 2 events should be observed during the Experiment

Weather Conditions:

- Ideally an isolated maritime or monsoon convective system 15-20 km east of the ground sites propagating eastward generating outflow that advects westward over the ground sites.
- Heavy outflow from break convective systems could also be pursued.

Synergy with other missions:

- Ground-based validation
- Small particles in cirrus
- A-Train algorithm validation
- Monsoon and Break Convection Characterization (Dimona fluxes and BAE146 missions)

Aircraft:

- Proteus – Primary in situ platform.
  - Critical instruments: CAPS, CSI, Water Vapor, BAT, CPI, CIN

    - Primary Flight Pattern: spirals over the ground-based instruments. This could also potentially include flights along the scanning pattern of precipitation radar since heavy anvil will be sampled.
    - Stepped level legs and/or racetracks to provide dynamical information that is important to document the temperature, humidity, and vertical air motion within the system for model validation.
- Twin Otter
    - Primary mission: Remote sensor. Critical instruments: mm radar, lidar
    - Primary Remote sensor flight profile: If the in situ aircraft are conducting spirals, the Twin Otter should fly a pattern that characterizes the spatial variability of the cloud field. The pattern could be as simple as an along-wind racetrack or as complicated as the flower-petal pattern used during MPace or ARESE.
- Egrett
    - Potential Roles: flown in conjunction with primary in situ platform at a lower altitude
    - Critical measurements- CAPS, CPI,

Mission Type: Cirrus (See 3.2 TWP ICE Science Plan)

A. Experimental Objective: Cirrus Evolution (See Sections 3.x of the TWP ICE Science Plan)

Point of Contact: Jay Mace

Science Motivation/Hypothesis: Do aged cirrus (cirrus not directly associated with convective outflow) continue to evolve through their life cycle or do they reach a steady state where perhaps radiative destabilization and supply of water vapor from below are balanced by crystal sedimentation? Understanding the processes governing this evolution is important for model validation and parameterization development. It is the goal of this objective to try to document specific aspects of the cloud field and its local environment that will assist in future modeling efforts of tropical cirrus.

Measurement Objectives: If we assume that the cloud field is in an approximate steady state condition, then we should be able to balance the upward flux of water vapor with the loss of condensate in the lower portions of the cloud. Our goal is to document these components of the water budget. Using the water vapor and turbulence probes on the Proteus one would ideally like to calculate the three dimensional flux convergence of water ($\nabla \bullet \vec{V}'q'$) into the cloud field. However, while documentation of the horizontal convergence of water vapor can be attempted by flying at constant altitude over a closed geographic region, the vertical flux convergence $\frac{\partial}{\partial z}(w'q')$ would likely be more obtainable from aircraft by conducting large (radius 10-20 km) slow spirals from several km below cloud base into the middle portion of the cloud layer.

Ground-based remote sensing data suggest that the IWC reaches a maximum in the middle third of the cirrus layer and then decreases toward cloud base. This decrease toward cloud base is likely due to sublimation of ice crystals. Documenting this process will require coordination between the in situ aircraft and the remote sensing aircraft below the layer. Because the cloud will contain substantial spatial variability, it is unlikely that in situ aircraft alone can address the sedimentation rate. Therefore, we will rely on the Twin Otter remote sensing measurements to provide the vertical and horizontal structure of the cloud field. The in situ measurements can supply important Z-IWC, D-Mass, and D-Area empirical relationships that will allow for accurate and targeted retrievals with the remote sensing measurements.

General Aircraft Flight Profiles:

- In characterizing the water budget, it is important that the Proteus obtain the most accurate statistics possible on the horizontal and vertical wind so that gradients can be calculated. Beginning several kilometers below cloud base, fly a box pattern approximately 20 km on a side where wings are straight and level during the entire 20 km section. After completion of each box, step upward 1000 feet and repeat until a predetermined altitude within the cloud layer is reached.

- Once the middle section of the cloud is reached begin a series of stepped race tracks matched to, but in an opposite direction of, the Twin Otter. Step the racetrack vertically upward through the cloud layer followed by a Lagrangian spiral once the cloud top or the maximum altitude is reached. Repeat the pattern while fuel and cloud allow reorienting the pattern with the motion of the cloud field.
- The Twin Otter should work in a circular pattern immediately below the Proteus pattern.
- Ideally, this mission would be flown in conjunction with ground site validation where ½ of the mission documents cloud field evolution and the other half conducts ground site validation.

Repetitions Necessary:

- For the mission objectives to met, the anvil should be followed for several (> 2) hours.
- Several (>2) reasonable events should be observed during the Experiment

Weather Conditions:

- The cirrus field examined should be extensive and persistent. Optimally, no intervening clouds should block view of the layer from the Twin Otter.
- This objective could also be pursued as part of a monsoon break system to compare with Crystal FACE and maritime/monsoon observations.

Synergy with other missions:

- Ground-based validation
- Small particles in cirrus
- A-Train algorithm validation
- airborne algorithm validation

Aircraft:

- Proteus – Primary in situ platform.
  - Critical instruments: CAPS, CSI, Water Vapor, BAT, CPI, CIN
  - If anvil system passes over the ground site, conduct 10nm spiral over the ground-base instruments (see ground site validation mission)

- Twin Otter
    - Remote Sensor: Critical instruments mm radar, lidar

- Egrett
    - Potential Roles:
        - flown in conjunction with primary in situ platform at a lower altitude
        - flown in series with primary in situ platform, sampling the evolving cloud system after the Proteus flight was completed
    - Critical measurements- CAPS, CPI,

B. Experimental Objective: Small Particles in Cirrus

Point of Contact: Greg McFarquhar

Science Motivation/Hypothesis: The number concentrations of small ice crystals, with maximum dimensions less than approximately 100 μm, in cirrus 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 and mass of anvil size distributions. This is one of the key unknown questions in cloud microphysics. These small crystals hence 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 cirrus 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, information on origin of cirrus, total optical depth of cirrus, 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. This mission will also benefit from the availability of multiple in-situ platforms to intercompare in-situ concentrations from instruments on different platforms, but also to assess if possible instrument measurement problems are dependent on the true air speed of the aircraft platform. 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
- High-resolution images of ice crystals to help identify particle habits, 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 cloud integrating nephelometer (CIN)
- In-situ measurements of total mass content derived from cloud spectrometer and impactor (CSI) 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 (Proteus) chooses an altitude within anvil and flies an approximately 5 to 10 minute leg through thin uniform layer (porpoising in layer if thick enough)
- Coordinated lidar backscatter measurements required from either Twin Otter or ground-based site.
- 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
- Second in-situ aircraft (Egrett) ideally flies in close coordination to first in-situ aircraft to answer same set of questions
- If coordination with Terra/Aqua possible, two end-points for run selected such that flight leg will be oriented parallel to overpass of satellite and 10 to 15 minute leg will be flown at appropriate orientation; if end-points need to be changed on the day of flight based on cirrus location, an effort should still be made to orient the aircraft parallel to satellite track

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 and airborne lidar
- Ideally should be conducted simultaneously with Egrett and Proteus aircraft
- Cirrus and anvils with range of optical depths should be sampled

- Observations can be acquired as component of other missions, but flight time dedicated to this objective within uniform thin cirrus should be made available

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
- Cirrus scattering phase functions

Aircraft:

- Proteus – Primary in situ platform.
    - Critical instruments: CAPS, CSI, CPI, CIN
    - Flight Pattern: Fly through uniform, thin single cirrus layer (porpoise if necessary) in coordination with other aircraft (Twin Otter, Egrett) providing lidar; flight pattern ideally with/against ambient wind to assist data interpretation if aircraft air speeds are different
    - If anvil system passes over the ground site, fly an approximately 5 to 10 minute leg (60-100 km) with against ambient wind over ground-based site; if A-Train overpass occurs, legs aligned to the satellite path should be flown
- Twin Otter
    - Primary Mission: Remote Sensor.
    - Critical instruments mm radar, lidar
    - Flight profile: Fly beneath the cirrus with lidar, mm radar pointing upwards; Flight should be coordinate with Proteus as much as possible and should be with/against ambient wind at the level of the cirrus; possibly provide flight altitudes to Proteus in real-time
- Egrett
    - Potential Roles: Fly as the in-situ platform in place of/coordination with the Proteus
    - Critical measurements- CAPS, CPI,

C. Experimental Objective: Cirrus Scattering Phase Functions

Point of Contact: Greg McFarquhar

Science Motivation/Hypothesis: In order to improve our understanding of the fundamental nature of cloud-radiation interactions (and to improve our representations of such processes in large-scale models), we require information about the mean single-scattering properties of cirrus clouds and how these properties vary depending on the location (altitude, geographic regime), formation mechanism of cirrus (generic vs. anvil cirrus, age of anvil, etc.) and other properties of cirrus (e.g., optical depth, geometric thickness, etc.). Previously, information on bulk scattering properties has been derived by combining in-situ observations of size and shape with libraries of shape and size-dependent single scattering properties or from bulk measurements of certain scattering properties (e.g., asymmetry parameter from cloud integrating nephelometer). By flying aircraft equipped with radiometers in banked orbits, it is also possible to make direct observations of scattering phase functions to compare against scattering phase functions derived from in-situ observations and bulk scattering properties measured by other instruments. When compared against existing scattering libraries, this should help determine the dominant habits present in the cirrus and provide information to assist with satellite retrievals of cloud properties.

Measurement Objectives: The primary goal of this mission objective is to make direct measurements of the cirrus scattering phase function and relate them to coincident in-situ measurements of particle sizes and shapes which can be used to independently estimate scattering phase functions and bulk scattering properties.

- Measurements of scattering phase function using narrow field view of radiometers (Spectral Radiance Package, SRP) from Proteus flying below cirrus in banked orbits
- Alternately, scattering phase function should be derivable from measurements made by the diffuse field camera (DFC) on board the Proteus when flying in level orbit
- In-situ measurements of particle size and shape distributions (ideally from Egrett but is also possible to design flight profiles with Proteus) from which scattering phase function can be estimated for comparison with direct observations
- In-situ measurements of asymmetry parameter derived from cloud integrating nephelometer (CIN) on Proteus or other aircraft
- Remotely measured upwelling and/or downwelling radiative quantities such as flux and narrowband measurements (either airborne or ground-based)
- Should be flown in conjunction with MISR if possible for additional comparisons with multi-angle measurements or in conjunction with ground-based sites for comparison with ground-based retrievals

General Aircraft Flight Profiles:

- When only Proteus available, area of thin (to avoid multiple scattering complications) uniform cirrus will be selected; Proteus will fly banked orbit with as high as bank angle as possible beneath cirrus, executing two full turns to get sampling over as wide as range as possible; will also fly a couple of minutes along a level leg to make measurements of radiative fluxes below cirrus
- Thereafter, if Proteus is able to reach the level of the cirrus, Proteus will spiral up through cirrus in Eulerian fashion (or fly a level leg 5 to 10 minutes long if very thin cirrus) to measure size and shape distributions and bulk microphysical/single-scattering properties (g and β_e from CIN, IWC from CSI) of cirrus
- Thereafter, if Proteus is able to ascend above the cirrus, Proteus will fly 5 to 10 minute leg above the cirrus so that a complimentary measurement of scattering phase function can be made by DFC as well as measurements of the radiative fluxes above cirrus; if this can be scheduled with MISR overpass, the orientation of this leg would be set to match the orientation of MISR
- Depending on other objectives, Proteus will descend back through cirrus and fly another banked orbit to assess changes in scattering phase function that may have occurred during the time to make the other observations
- If additional in-situ aircraft available (Egrett), depending on the thickness of the cirrus layer it will fly either an Eulerian ascent through cirrus or 5 to 10 minute straight-line leg with/against the ambient wind to make the in-situ observations of particle shape and size distribution;
- 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

Repetitions Necessary:

- 2-3 repetitions in cirrus with varying extinction optical depths and with varying formation mechanisms

Weather Conditions:

- Ideal situation would be uniform thin cirrus in a single layer over the ocean.
- Very thick cirrus layer should be avoided to reduce complications from multi-scattering in analysis.
- Ideally cirrus should not be too high as data most valuable if can have coincident in-situ and single-scattering observations

Synergy with other missions:

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

- Small particle measurements

Aircraft:

- Egrett – Primary in situ platform.
    - Critical instruments: CAPS, CPI, DMT CDP
    - Flight Pattern: Fly 2 legs through uniform, thin single cirrus layer (porpoise if necessary) in coordination with other aircraft (Proteus); flight pattern ideally with/against ambient wind to assist data interpretation; legs approximately 5 to 10 minutes long (60 to 100 km) with mid-point of leg coinciding with location of banked orbit of upper level aircraft; alternatively, if cirrus thicker, could do an Eulerian ascent through cirrus over the mid-point of the banked orbit
    - If measurements in vicinity of ground site or MISR overpass, the leg should be centered at this location.
- Proteus
    - Primary mission: Radiative fluxes.
    - Critical instruments: DFC, Spectral Radiance Package, lidar and upwelling radiative fluxes, S-HIS
    - Remote sensor flight profile: Fly banked orbit with maximum bank angle that operational considerations allow. After completing banked orbit, should align with in-situ aircraft and fly straight leg (with or against ambient wind) of approximately 5 to 10 minutes long (60 to 100 km) to measure radiative fluxes below cirrus; when Proteus only aircraft involved, should perform the in-situ measurement strategy listed above, and if can climb above the cirrus, make measurements of radiative fluxes above cirrus and of scattering phase function with DFC
    - If measurements in vicinity of ground site or MISR overpass, the banked orbit and straight-line leg should be centered at this location and aligned to coincide with the MISR orientation

- Twin Otter
    - Potential Roles: Measure downwelling radiative fluxes beneath the cirrus and remotely sense its properties with mm radar and lidar to provide information on how microphysics affects radiation
    - Critical instruments: lidar, radiometers
    - Flight profile: fly beneath the cirrus in coordination with Proteus measuring cirrus with lidar and with radiometers.

Mission Type: Fluxes (See 3.6, 3.10 of TWP ICE Science Plan)

A. Experimental Objective: Compare ground-based and aircraft measurements of surface fluxes and test representativeness

Point of Contact: Peter May, Frank Bradley, Jorg Hacker

Science Motivation/Hypothesis: There is a need to inter-compare the airborne flux measurements with the ground and sea based measurements to allow the aircraft to assess the area averaged fluxes during flights and as a step to linking the continuous observations from the surface sites to estimation of the area averaged fluxes.
Spatial sampling and an estimation of spatial variability is required so that the surface fluxes measured at the ship can be generalized to the oceanic part of the experiment domain.
In turn the area averaged fluxes are required inter alia, for model boundary conditions.

Measurement Objectives: Perform flux inter-comparisons with sea based surface flux measurements for cross-validation of the measurements and as an input for studies of the spatial and temporal variations of the fluxes.

- In situ measurement of low level latent and sensible heat fluxes along with surface temperature and radiative observations.

General Aircraft Flight Profiles:

Low level straight flight along ocean leg beginning just north of Darwin to ship operational area and return. This will allow estimates of the spatial variability of the fluxes.

Low height (~ 100 ft) straight run measurement legs of approximately 10 km arranged as a square centred over the ship location. The legs will be along and cross wind. In the case of the ship this should be along the direction of the ship traverse during ship flux observations. We have to ensure that the ship is near the middleof its 3-hour upwind leg during the aircraft box pattern, which is easy
enough given about 2 hour's warning The box pattern should continue for 60 min.

Repetitions Necessary: Repeated as often as possible up to mission total hours of approximately 12.5 hours. This will allow five 2.5 hour missions.

Weather Conditions:

- For ship comparisons seeking moderate to strong winds with no convection nearby.
- Day only
- Ship: 4-8 m/s winds

Synergy with other missions: Stand alone measurement

Aircraft: Dimona
Critical measurements: radiative, sensible and latent heat fluxes;; radiative sea surface temperature; state variables. Coordination with ship.
Single engine operation at low altitude over water also requires continuous updating of aircraft status and accident plan.

Mission Type: Fluxes – Land (See section 4.6 of TWP ICE Science Plan)

A. Experimental Objective: Compare ground-based and aircraft measurements of surface fluxes and test representativeness

Point of Contact: Peter May, Nigel Tapper, Jorg Hacker

Science Motivation/Hypothesis: There is a need to inter-compare the airborne flux measurements with the ground and sea based measurements to allow the aircraft to assess the area averaged fluxes during flights and as a step to linking the continuous observations from the surface sites to estimation of the area averaged fluxes.
Spatial sampling and an estimation of spatial variability is required so that the surface fluxes measured at the ship can be generalized to the oceanic part of the experiment domain.
In turn the area averaged fluxes are required inter alia, for model boundary conditions.

Measurement Objectives: Perform flux inter-comparisons with ground based surface flux measurements for cross-validation of the measurements and as an input for studies of the spatial and temporal variations of the fluxes.

- In situ measurement of low level latent and sensible heat fluxes along with surface temperature and radiative observations.

General Aircraft Flight Profiles: Low level straight flight to grid flight pattern location.

Repetitions Necessary: Perform at least 3 grid flights that cover the northern flux sites. Two missions that cover the area around the southern flux site**.** Repeated as often as possible up to a mission total hours of approximately 15 hours. This will allow five 3 hour missions.

Weather Conditions:

- For land comparisons weak winds with clear sky preferred. Ideally some variations of conditions, but not active convection/outflows in the area
- Day only
- Land: Low wind conditions

Synergy with other missions: Stand alone measurement

Aircraft: Dimona
Critical measurements: radiative, sensible and latent heat fluxes; state variables. Coordination with land sites.

C. Experimental Objective: Assess surface spectral albedo and variability over land

Point of Contact: Chuck Long

Science Motivation/Hypothesis:

Measurement Objectives: Perform comparisons of broadband spectral flux and albedo measurements with ground based surface flux and albedo measurements for cross-validation of the measurements and to relate the spectral measurements to the spatial and temporal variations of the fluxes measured by the Dimona.

- Measurement of low level spectral and broadband radiative observations.

General Aircraft Flight Profiles: Low height (minimum allowable) along the same ideas as outlined in the Dimona "Verify ground-based measurements of surface fluxes" and "Estimate area averaged surface fluxes" Experimental Objectives. The idea is to relate the Dimona and surface measurements to similar spectral measurements, using the Proteus broadband measures as a transfer medium.

Repetitions Necessary: Repeated as often as possible as the Proteus missions allow. Ideally the flights would cover a range of solar zenith angles and cloud conditions. As many as opportunity and resources allow, given the secondary priority of this experimental objective. Some data is better than none at all.

Weather Conditions:

- A variety of non-precipitating cloudiness conditions, ranging from clear-sky to overcast.
- Day only
- non-precipitating

Synergy with other missions: This is not the priority goal of the overall experiment, but added as a "mission of opportunity" idea. For instance, could this be done piecemeal on takeoff and landings?

Aircraft: Proteus

Critical measurements: broadband and spectral upward and downward radiation

Mission Type: Validation (See sect 3.5 TWP ICE Science Plan)

A. Experimental Objective: Cloudsat Validation – Detection and Calibration - (See Sections 3.5 of the TWP ICE Science Plan)

Point of Contact: Jay Mace or Graeme Stephens

Science Motivation/Hypothesis: Cloudsat CPR with a vertical resolution of 250 m and a 1.5 by 2.5 footprint has a stated minimum detectable signal of -28 dbz. Hydrometeor identification is based on a statistical approach that attempts to identify cloud using the difference in the signal of a resolution volume from the expected instrument noise. Cloud properties are derived from this basic measurement combined, perhaps, with other data sources such as MODIS. It is critical to interpretation of Cloudsat data and products that in situ and remotely sensed validation data are collected in the tropical environment. This experimental objective will attempt to establish the validity of the CPR calibration and the cloud occurrence products derived from cloudsat, calipso and MODIS.

Measurement Objectives:

- This mission should be flown in close coordination with a cloudsat overpass where the in situ and remote sensing aircraft fly along the cloudsat ground track in clouds during the overpass.
- Remote sensing aircraft: Radar reflectivity, lidar backscatter.
- Microphysical properties (N(D), IWC, extinction) at some level within the cloud. Ideally, the in situ aircraft should fly in the upper third of the cloud layer where detection by the radar is less certain in order to map the microphysical properties near the detection threshold of the cloudsat radar.

General Aircraft Flight Profiles:
In situ and remote aircraft intersect the cloudsat ground track 15-20 minutes prior to the overpass and fly along the ground track cloud until 5 minutes after the overpass. The aircraft should then double back along the ground track. The in situ aircraft could either fly straight and level at an optimal altitude or the in situ aircraft could porpoise within the cloud. The porpoising should extend over at least 1500 m (3 cloudsat range resolution volumes). It would be particularly useful for the in situ aircraft to porpoise from the cloud top region to a thicker portion of the layer in order to validate the cloud detection algorithm.

Repetitions Necessary: At least 2 overpasses should be observed during the Experiment

Weather Conditions: Ideally a uniform cirrus layer with enough horizontal extent to be sampled for 20-30 minutes of flight time. This layer should be sufficiently thick to be sensed by the cloudsat radar (i.e. DbZe> -28. and ideally > -20.)

Synergy with other missions:

- Calipso validation
- Because this objective would consume only approximately 1 hour of flight time, this objective could be combined with other experimental objectives.

Aircraft:

- Proteus – Primary in situ platform.
  - Critical instruments: CAPS, CSI, Water Vapor, CPI, CIN
  - Primary Flight Pattern: Level leg within a thick portion of the cloud or porpoising through the cloud top region into the thicker portion of the cloud.
- Twin Otter
  - Primary mission: Remote sensor. Critical instruments: mm radar, lidar
  - Primary Remote sensor flight profile: Fly along the cloudsat ground track.

B. Experimental Objective: Cloudsat Validation – microphysical and radiative properties

Point of Contact: Jay Mace, Graeme Stephens

Science Motivation/Hypothesis: The A-train measurements primarily consisting of the cloudsat radar reflectivity, the calipso lidar backscatter, and the Aqua MODIS radiances and reflectances will be used to derive cloud properties using retrieval algorithms. We have a rare opportunity to create a data set with which these algorithm results can be compared.

Measurement Objectives: Unlike the "Cloudsat Validation – Detection and Calibration" objective, the primary focus of this exercise will be validation of the retrieval algorithm results. Many of the algorithms being applied to the A-Train data retrieve properties of the cloud layer such as optical depth and ice water path. The only way these layer mean properties can be adequately validated is by conducting spirals through the cloud layer over a period of time that straddles the satellite overpass. The primary platform for this objective would be the Proteus with its more extensive array of microphysical probes.

General Aircraft Flight Profiles: Ideally a reasonably uniform and extensive cirrus field would be targeted and the in situ aircraft would plan to be midway through a spiral descent as the satellite passes over the aircraft. During the overpass instant it would be ideal for the Twin Otter and remote sensors to be directly below the in situ aircraft flying along the satellite ground track. Ideally the in situ aircraft would have completed a spiral up through the layer prior to the overpass so as to document any variability in the cloud layer.

Repetitions Necessary: This objective should be attempted 2-3 times during the experiment in both thin and thick cirrus conditions.

Weather Conditions: A uniform cirrus layer over water with no lower clouds would be ideal.

Synergy with other missions: This objective should only take up approximately 1 hour of flight time and can therefore be combined with other objectives as appropriate.

Aircraft: Proteus is the primary platforms of interest.

Critical measurements: CAPS, CPI, CSI, CIN

C. Experimental Objective: CALIPSO Validation (see section 3.5 of TWP-ICE Science Plan)

Point of Contact: Dave Winker, Chip Trepte

Science Motivation/Hypothesis: CALIPSO lidar with a vertical resolution of 60 meters and a 100-m diameter footprint has a detection sensitivity corresponding to a backscatter coefficient of about 2E-3 /km/sr, and about 5E-4 /km/sr with averaging. Cloud properties are derived from calibrated 532 nm returns and the depolarization state of the backscattered 532 nm signal.

Measurement Objectives:

Several different versions of this mission can be flown (detailed in Flight Profiles), involving in situ and remote sensing aircraft. The objective is to acquire lidar profiles within cirrus, or cirrus anvils, coincident with in situ profiles of cloud microphysics. Ideally, the mission is flown in close coordination with a CALIPSO overpass, with the two aircraft flying along the CALIPSO ground track (which is identical to the CloudSat groundtrack) during the overpass. CALIPSO retrievals rely on assumptions on ice particle microphysics. Therefore, characterization of the size distribution, habit, and relationships between IWC and extinction within a variety of tropical cirrus (fresh and aged anvil, subvisible, etc.) is needed.

General Aircraft Flight Profiles:

Option A) Remote aircraft intersects the CALIPSO ground track 15-20 minutes prior to the overpass and flies along the ground track until 5 minutes after the overpass. The aircraft should then double back along the ground track (??). Ideally, the in situ aircraft profiles cloud microphysical properties at the point where CALIPSO and the remote sensing aircraft intersect. The remote sensing aircraft could also porpoise within the cloud (as for CloudSat) or fly level legs within the cloud (though it may be difficult to fly at a level within the cloud which is sensed by both CALIPSO and CloudSat).

Option B) If no CALIPSO overpass is available, coordinated flights of remote sensing and in situ aircraft as described in (A).

Option C) Microphysical profiles from in situ aircraft data coincident with ground-based uplooking lidar (when cirrus is transparent).

Remote Sensing aircraft: two-wavelength depolarization lidar, preferably downlooking and able to fly at least 2 km above cloud tops. Uplooking lidar useful for transparent cirrus. Cloud profiling radar and infrared multiband radiometer desirable.

In situ aircraft: microphysical properties: particle size distribution, shape, extinction, IWC

Repetitions Necessary: Same as for CloudSat validation? (at least 2 overpasses)

Weather Conditions: Ideally, a uniform cirrus layer with enough horizontal extent to be sampled for 20-30 minutes of flight time. A range of cirrus is desired, from thin, subvisible cirrus (to test detection limits) to deep, opaque anvil cirrus (to validate extinction retrievals).

Synergy with other missions:

- Ground-based validation
- Small particles in cirrus
- Anvil evolution
- Aura and CloudSat validation
- Because this objective would consume only approximately 1 hour of flight time, this objective could be combined with other experimental objectives.

Aircraft:

- Proteus– Primary in situ platform.
  - Critical instruments: CAPS, CSI, Water Vapor, CPI, CIN
  - Flight Pattern: prefer spiral through upper layers of cloud, near CALIPSO coincidence point; or porpoising along CALIPSO ground track through upper region of cloud into the thicker portion of the cloud.
  - If anvil system passes over the ground site, conduct 10nm spiral over the ground-base instruments (see ground site validation mission)
- Twin Otter
  - Remote Sensor: Critical instruments (for overlying transparent cirrus): uplooking lidar
  - Flight profile: underfly Proteus to obtain coincident lidar and in situ measurements
- Egret
  - Potential Roles: flown in conjunction with primary in situ platform at a lower altitude. Having a second in situ platform like the Egret would add significantly to this objective.
  - Critical measurements- CAPS, CPI

D. Experimental Objective: Ground-based Remote Sensing Validation

Point of Contact: Jay Mace

Science Motivation/Hypothesis: Evaluate/verify/intercompare the retrieval 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. 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:

- In situ microphysics measurements of ice crystal size and shape distributions, bulk measurements such as ice water content and extinction, and water vapor in the vicinity of the ground site.
- Remotely sensed radar reflectivity and Doppler velocity (if available), lidar backscatter, upwelling and/or downwelling radiative quantities such as flux and narrowband measurements in vicinity of ground site.

General Aircraft Flight Profiles:

- In-situ aircraft will spiral up/down over ground site (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.
- The remote sensing aircraft will fly a series of Figure 8 patterns centered on the ground-based site where the pattern is parallel/perpendicular to ambient wind at level of cirrus; legs should be approximately 20 km long. Remote sensing and in situ aircraft should be coordinated to maximum degree possible when passing over ground-based site.

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 cirrus generated from a variety of different formation techniques (aging anvils, anvil associated with break-type/monsoonal convection, etc.)

Synergy with other missions:

- Deep anvil
- Small particles in cirrus
- A-Train algorithm validation
- Aging anvil (to be addressed as follow on mission)
- Remote measurements of scattering phase function

Aircraft:

- Proteus – Primary in situ platform.
    - Critical instruments: CAPS, CSI, Water Vapor, BAT, CPI, CIN
    - Flight Pattern: staircase pattern (~50 km) that step through the cloud layer (top, middle, and base). Central coordinate should be over the ground-based site and legs should be with/against the ambient wind; Eulerian spirals: start at top of cloud layer and spiral through to bottom of cloud layer directly over ground-based site; descent rate should be set so that each spiral takes on the order of 10 minutes
- Twin Otter
    - Remote Sensor: Critical instruments: mm radar, lidar
    - Remote sensor flight profile: Figure 8 patterns centered on the ground-based site where each leg is either parallel or perpendicular to the ambient wind at the altitude of the cirrus.
- Egrett
    - Potential Roles: Act as an in-situ platform either in addition to or in place of the Proteus (e.g., increase the time of the mission or increase the number of altitudes that can be sampled)
    - Flight Profile: Similar to Proteus; if both aircraft are in air for a thicker cirrus, this would allow two levels of cirrus to be sampled at the same time improving the vertical resolution
    - Critical measurements- CAPS, CPI

E. Experimental Objective: In Situ Probe Comparison

Point of Contact: Greg McFarquhar

Scientific Motivation/Hypothesis: Many of the science questions we seek to address with TWP ICE are dependent on knowledge of the bulk and size resolved cloud properties measured with in situ aircraft probes. It is well known that the uncertainty, precision, and statistical representativeness of these measurements are substantial and difficult to establish. Thus, it is highly desirable that some time be devoted to intercompare the size-resolved and bulk measurements of in-situ microphysical properties made by probes on the different aircraft. 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 Objectives: The primary goal of this mission is to intercompare size-resolved concentrations and bulk moments of the size distributions (e.g., ice mass content) measured by a variety of probes on different aircraft platforms. 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 aircraft platforms flying 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 true air speed?; and 3) How much do concentrations/mass contents vary between identical probes installed on different aircraft flying through the same cloud (especially when flying at different air speeds)?

General Aircraft Flight Profiles:

- A target cloud, ideally horizontally uniform cirrus, should be selected for analysis (clouds with a variety of different properties should be selected in order to better understand instrument performance, e.g., anvil, aged anvil and generic cirrus should be selected, with a variety of different geometric and optical thicknesses); the most desired clouds are horizontally uniform so that minor differences in time and space observations of the different platforms are not significant
- Measure the same cloud in-situ with multiple aircraft as closely located as allowed by safety considerations; aircraft should fly 10 minute legs through the cirrus, with/against the ambient wind
- Should be flown in conjunction with ground-site measurements or satellite overpasses if possible to allow for further comparison with ground-based retrieval products

Repetitions Necessary:

- Several (>2) reasonable events should be observed during the Experiment; in particular, should try to repeat measurements in cirrus with varying extinction coefficients and from different formation mechanisms (e.g., aging anvil versus generic cirrus); 2 different altitudes should be sampled for each event.

Weather Conditions:

- Ideal situation would be horizontally uniform cirrus (either aging anvil or generic cirrus)

Synergy with other missions:

- Ground-based validation
- Small particles in cirrus
- A-Train algorithm validation
- Intercomparison of other species (water vapor, chemical species)

Aircraft:

- Proteus– One in situ platform.
    - Critical instruments: CAPS, CSI, Water Vapor, CPI, CIN
    - Flight Pattern: Two 100 km legs near middle of cirrus cloud layer with or against the ambient wind.
    - If cirrus passing over the ground site, should fly flight legs over ground system parallel to ambient wind.
- Egrett – Second in situ platform
    - Critical instruments: CAPS, CPI, DMT CDP
    - Flight pattern: See Proteus(with time/space separation determined from safety considerations)

Critical measurements- A complimentary instrument should be operating on each platform.