DEPT of ATMOSPHERIC SCIENCE
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LARAMIE, WY 82071-3038
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REQUEST FOR WYOMING KING AIR SUPPORT

Rec'd:

Proj. No.:

A. IDENTIFICATION (2 contacts)

1. Name: **Bart Geerts** geerts@uwyo.edu	2. Title: Dr. Assistant Professor	3. Dept./Institution: University of Wyoming
4. Address: 16th & Gibbon Str., Laramie WY 82071	5. Phone: 307 766 2261	6. Date: 6/2004
7. Signature:	7. Signature:	

8. Other Persons and Their Responsibilities in Proposed Airborne Research: Rick Damiani

9. Project Title (about three words for identification purposes): **CuPIDO** (Cumulus Photographic Investigation and Doppler Observations)

10. Abstract (suitable for publication) of Proposed Program:

The campaign, to be conducted in the summer of 2005, intends to describe orographic cumulus development during the morning hours at the meso-γ scale as well as the cloud scale, with an emphasis on boundary-layer evolution and the effects of entrainment, detrainment, and glaciation on individual convective towers that tend to develop in succession and culminate in the cumulonimbus stage. Questions on the cloud scale surround the evolution of cumulus buoyancy, i.e. its generation by latent heat release and its erosion by entrainment. On the meso-γ scale, the key questions regard the modification of convective available potential energy (CAPE) by topographically-induced convergence and surface heat fluxes, the modification of the mid-tropospheric detrainment layer by successive cumulus pulses, and the generation of precipitation-induced cold pools.

To address these questions, CuPIDO aims to field the following observational facilities: stereo digital cameras (under direction of Dr. J. Zehnder, ASU), several standard portable automated mesonet (PAM-III) stations, several integrated surface flux facility (ISFF) stations, one mobile and one stationary up/down GPS/Loran Atmospheric Sounding System (GLASS), and the Wyoming King Air with Wyoming Cloud Radar (WCR).

11. Importance of the Proposed Airborne Measurements to the Research Project (total, half, small part, etc.):

The King Air is the only aircraft to participate in CuPIDO, and it is essential. In the past half-century several field studies of cumulus dynamics have been conducted by means of aircraft making in situ measurements, and also by means of ground-based precipitation radars. These studies form the basis of our current conceptual representations of entrainment. Entrainment remains the least understood factor in cumulus development.

With the WCR aboard the King Air, we have the ability to place flight-level observations, collected while penetrating a cumulus, in the context of radar-derived echo and velocity field within large sectors of the cumulus, at a resolution of 40 m or better, in both vertical and horizontal planes. This combination constitutes a powerful tool for the study of fundamental cumulus dynamics. In particular, the WCR reveals entrainment events at various scales in the airflow and echo fields. Close proximity aircraft data allow us to assess the thermodynamic and cloud microphysical characteristics of these events. Other than the investigations of processes at the cloud scale (flight legs 10-15 km long), we also will conduct flight patterns at the mountain scale (flight legs 30-40 km long) (see below).

12. Previous Airborne Research Experience of Requesting Scientist (list all previous NCAR/RAF, Wyoming and other aircraft-supported research):

Geerts: GALE, TOGA-COARE, TEFLUN, TRMM-LBA, IHOP, ROLLS, (RICO)
Damiani: IHOP, HiCu_02, HiCu_03

If needed, use additional sheets for answers.

13. List of Publications Resulting from Past Flight Support:

Geerts:

- Geerts, B., G.M. Heymsfield, L. Tian, J.B. Halverson, A. Guillory, and M.I. Mejia, 2000: Hurricane Georges' landfall in the Dominican Republic: detailed airborne Doppler radar imagery. *Bull. Amer. Meteor. Soc.*, **81**, 999-1018.
- Heymsfield, G.M., B. Geerts and L. Tian, 2000: TRMM Precipitation radar reflectivity profiles compared to high-resolution airborne and ground-based measurements. *J. Appl. Meteor.*, **39**, 2080–2102.
- Geerts, B., and Y. Dawei, 2004a: Classification and characterization of tropical precipitation based on high-resolution airborne vertical-incidence radar. Part I: Classification. Submitted to *J. Appl. Meteor.*, in press.
- Geerts, B., and Y. Dawei, 2004b: Classification and characterization of tropical precipitation based on high-resolution airborne vertical-incidence radar. Part II: Radar and ice scattering signatures of hurricanes vs land-based storms. Submitted to *J. Appl. Meteor.*, in press.
- Geerts, B. and Q. Miao, 2004a: Vertical velocity bias of echo plumes in the convective boundary layer, detected by an airborne mm-wave radar. *J. Atmos. Ocean. Tech.* , accepted.
- Geerts, B. and Q. Miao, 2004b: Flight behavior of small insects in the atmospheric convective boundary layer, as detected by an airborne Doppler radar. Part I: Observations. *Envir. Entom.*, accepted.
- Geerts, B. and Q. Miao, 2004c: Flight behavior of small insects in the atmospheric convective boundary layer, as detected by an airborne Doppler radar. Part II: A simple model. *Envir. Entom.*, accepted.
- Geerts, B., R. Damiani, D. Leon, and S. Haimov, 2004: Fine-scale vertical structure of a cold front as revealed by airborne radar. *Mon. Wea. Rev.* , in preparation.
- Geerts, B. and Q. Miao, 2004d: Vertical velocity and buoyancy characteristics of echo plumes in the convective boundary layer, detected by a profiling airborne radar. *Bound-Layer Meteo*., in preparation.

Damiani:

- Damiani, R., 2004: Doppler retrieved vorticity structures in developing cumulus and entrainment implications. *J. Atmos. Sci.*, in preparation.
- Damiani, R., Haimov, S., and G. Vali, 2004: Velocity fields in cumulus derived from airborne dual-Doppler measurements. In 14th International Conference on Clouds and Precipitation,Bologna, IT, June 18-23,2004. ICCP.

14. After flight operations are complete, how long do you anticipate will be required for data analysis? Explain.

6 months or less for the production of a quality-controled product;
2-3 years for the analysis leading to publications.

15. Where and when do you expect the results of the airborne observations to be published?

Within 3 years, in Monthly Weather Review, Atmospheric Research, Journal of the Atmospheric Sciences, Boundary Layer Meteorology, or Journal of Geophysical Research

16. Educational Activities: Anticipated Student Involvement:

This proposal calls for the participation of a PhD-level student during the field phase. The King Air aircraft is too small to seek active undergraduate student participation in the airborne operations in CuPIDO. However, if the deployment of GLASS and PAM facilities is supported, then we will coordinate with NCAR ATD to write an REU (Research Experience for Undergraduates) proposal to fund at least two University of Wyoming undergraduate students in the field, in order to install and run the facilities.

B. RESEARCH SPONSOR

1. Name of Sponsor: National Science Foundation	2. Contract Officer: NSF: *S. Nelson*
3. Address: *NATIONAL SCIENCE FOUNDATION Mesoscale Dynamic Meteorology, 4201 Wilson Blvd. Arlington, VA 22230*	4. Contract Identification: N/A

5. Funding:

[proposal to be submitted] Approved Pending X

6. Approximate Amount Budgeted for Research Pertaining to this Proposed Airborne Measurement Program:

Univ. of Wyoming proposal: NSF $427,064 ;
Zhender's group at the Arizona State University is already funded.

C. OTHER AVIATION FACILITIES

What other sources of research aviation support have been contacted, if any?; List Hourly Operating Cost:

none

D. FLIGHT OPERATIONS

1. Preferred Flight Period (please use a separate sheet for each flight period)

We are requesting 31 days of operation, anytime between 1 July and 31 August 2005

2. Type of Aircraft Required: *UW King Air*
3. Number of Research Flights Required: **60 hours**

4. Estimated Duration of Each Flight: 4 hours	5. Number of Flights Per Day: generally one flight per day	
6. Preferred Base of Operation: *Tucson AZ*	7. Alternate Bases: *Marana Airpark AZ*	8. Is Laramie acceptable? *No*
9. Average Flight Radius from Base: 50 km	10. Desired Flight Altitude: 500 – 25,000 ft AGL	
11. Particular Part(s) of Day for Flights: All flights are in the morning, generally between 7 am – 1 pm LT	12. Statistically, how many days during specified period should be acceptable for flight operations? Most days	

13.Sketch or Describe Desired Flight Pattern(s). State Priorities and Estimate Number of Flights for Each.

Flights will be dedicated to cloud scale as well as meso-γ scale investigations of orographic cumulus development. At this stage we foresee to utilize the available flight hours with an emphasis on the cloud kinematics, dedicating a larger portion of the flight segment to cloud penetrations and radar scanning mode fly-bys. However, depending on the type of convection and weather developments, we might extend a portion of the daily flight to better characterize the surface heat fluxes and the modification of the mid-troposheric environment by the successive cumulus pulses.

Temporal (rather than just statistical) sampling is essential to assess conceptual models of cumulus growth. Owing to the orographic locking of the convection, we should be able to perform multiple rapid scans of the same cloud. We plan to sample cumulus cloud with depths ranging from shallow (0.5- 2 km) to towering (congestus, up to ~ 4 km deep). If the cloud does not over-develop, but rather collapses in favor of new turrets, we will also be able to collect a statistically meaningful sample of numerous cloud features. The accurate planning of flight patterns is a key to the success of the experiment. In particular the next objectives dictate the rules of flight/cloud engagement:

1. Sounding, wind data and mesoscale box-pattern in the proximity of the area of operation
2. Characterization of the kinematics:
   - 2.1 Assessment of the main field structures in both vertical and horizontal planes, and of the coupling between the two planes
   - 2.2 Classification of flow properties with respect to vertical levels: several scanning passes at the same level and at least for four cloud levels: subcloud layer, cloud base, mid-depth, cloud top
3. Characterization of thermodynamic/microphysical quantities at different levels (subcloud layer, cloud base, mid-depth, cloud top)
4. Characterization of reflectivity structure variability within vertical and horizontal planes
5. Time Evolution

The King Air will be airborne prior to the initiation of convection in order to ferry to the estimated area of cloud formation. During the ferry the aircraft will execute a sounding up to about 3 km AGL and a low-level mesoscale circumnavigation of the mountain (**Fig 1**). The total estimated time to complete this segment of the mission is approximately 30 minutes (100 km circle around the mountain, see Fig 1).

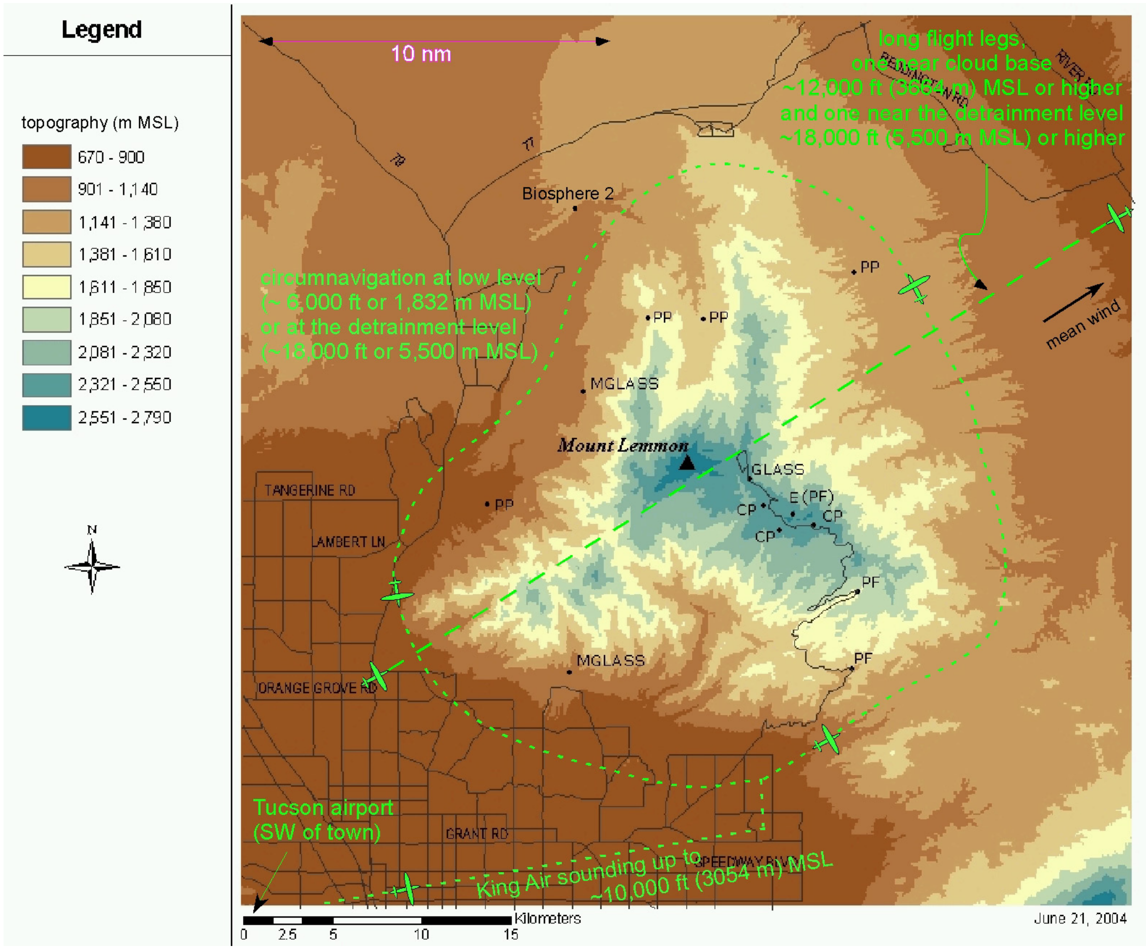


Fig 1. Flight patterns aimed at describing the interaction between orographic cumuli and their meso-γ scale environment.

The convection is usually locked on preferential topographic areas and develops in stages: shallow-to-deep-convection transition usually spans across three hours. This will give ample margin of operation for the aircraft to collect extensive data before departing the area due to electrification and lightning safety concerns.
In *the initial stages of evolution* the continental cumuli will likely be only marginally detectible by the WCR, and the strategy is to characterize the *subcloud layer* with *cross-wind passes at about 200 m below cloud base*, mostly relying on on-board instruments (**Fig 2**). Estimated flight-segment required time: *10-15 minutes*. The WCR will be run in up/down profile mode (scanning a vertical plane above and below flight level) that allows, in case of scatterers such as insects or other types of debris be present, to verify the occurrence of buoyant plumes and the continuity of updrafts from the surface up into the cloud. The thermodynamic assessment of the subcloud air mass will be used in post-processing in an effort to predict the adiabatic liquid water path and micro-physical quantities against the real data coming from penetrations across the cloud. Entrainment assessment calculations will also rely on these data.

The *next phase consists of penetrations at 200 m above base*. The WCR will be run in side-down profile and side-forward/ down/ up modes, scanning a vertical plane above and below the aircraft and a starboard horizontal one. We foresee to find good data for droplet activation problem closure and to be able to characterize the kinematics of cloud base (convergence, updraft strength and location). Estimated flight segment time: *10 minutes* (~4 2'-legs).

As the cloud develops into a weak congestus, passes along the same line will be executed near cloud top in VPDD mode. Then if the tower out-climbs the aircraft there will be chances to perform *HPDD passes grazing the edges alternated by VPDD or side-down modes* (see Fig 2) penetrating the cloud. Estimated required time: *20 minutes*.
With the cloud at a congestus stage, a further up/down/side penetration and/or DPDD will be executed at the same altitude, likely a *mid-depth level*. Then the aircraft will climb again to the top of the tower and complete passes in VPDD and HPDD. Estimated required time: *20 minutes*. Alternating between HPDD and VPDD, an up/down WCR view is needed for the spatial collocation of the various features in the horizontal plane with respect to the updraft/downdraft regions. All flight legs should maintain the same orientations, along the shear vector if shear is present.

In case of multiple mid-size towering clouds, the operation might be repeated once. Both at an early and at a late stage, 40 km long legs will be flown at two levels, one near cloud base and one at the estimated level of maximum detrainment, in order to assess how the cumuli affect the environment (Fig 1).

The aircraft will divert back to base when the convection becomes deep (cumulonimbus) or lightning is observed. One more mountain circumnavigation will be performed if conditions permit. In case of initial turrets dissipating in the early phases there will be opportunities to sample multiple events to accumulate statistical data, increasing the flight time at a given altitude.

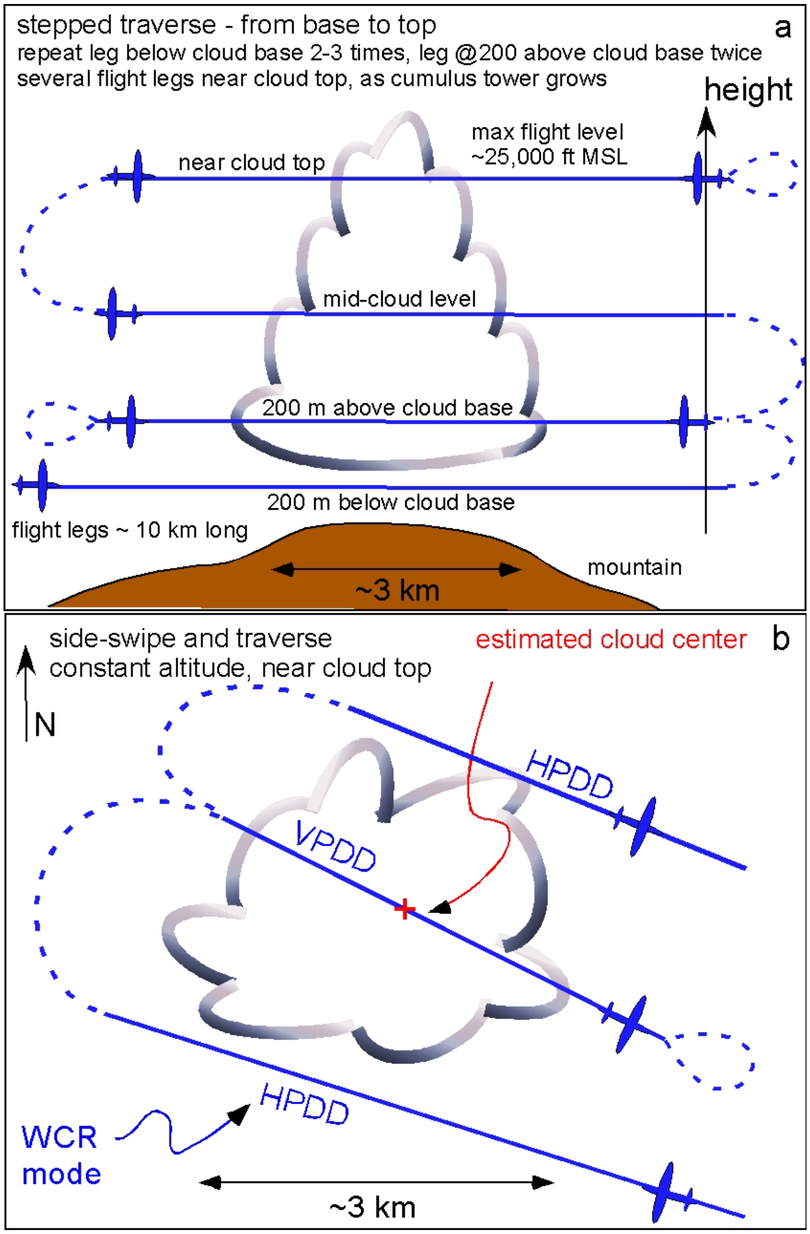


Fig 2. Flight patterns aimed at studying fundamental cumulus dynamics. (a) Vertical transect showing a stepped traverse; (b) Combination of traverses and side-swipes, with the WCR in vertical and horizontal plane dual Doppler (VPDD and HPDD), respectively.

14. How many scientific observers will you require on each flight?

- flight scientist
- instrument engineer will operate WCR and King Air data systems
- graduate research assistant (essential only if the WCR electronic fast switching capability is not yet in place)

E. SCIENTIFIC PAYLOAD

1. LIST OF STANDARD WYOMING SENSORS

VARIABLE	INSTRUMENT	RANGE (1)	ACCURACY (2)	RESOLUTION (1)
Air Temperature	Reverse flow (Minco element)	-50 to +50?C	0.5?C	0.006?C
Air Temperature	Friehe	-50 to +50?C	0.5?C	0.006?C
Dewpoint Temp.	Cambridge Sys Model 137C3	-50 to +50ºC	1.0ºC > 0ºC 2.0ºC < 0ºC	0.006ºC
Mag. Heading	King KPI 553/Sperry C14-43	0 - 360°	1°	0.02°
Static Pressure	Rosemount 1501	0 - 1,080 mb	0.5 mb	0.003 mb
Static Pressure	Rosemount 1201FA1B1A	0 - 1,034 mb	0.5 mb	0.06 mb
Geometric Alt.	Stewart Warner APN159 Radar Alt	60,000 ft	1%	0.24 ft
Geometric Alt.	King KRA 405	2,000 ft	3% < 500 ft 5% > 500 ft	0.48 ft
Pitot - Static	Rosemount 1332	0 - 85 mb	0.2 mb	0.005 mb
Turbulence	MRI Turbulence Meter	0 - 10 $cm^{2/3}s^{-1}$	0.5 $cm^{2/3}s^{-1}$	0.1 $cm^{2/3}s^{-1}$
Azimuth from Sta.	King KNR615 VOR	360°	1°	0.02°
Distance from Sta.	King KNR705A DME	200 nm	0.4 km	0.1 nm
Lat./Long.	Tremble 2000 GPS	± 90º Latitude ± 180º Longitude	100 m(3)	1.72 x 10^{-4} deg.
Lat./Long.	Honeywell Laseref SM	± 90º Latitude ± 180º Longitude	0.8 mm/hr (50% CEP); 1.66 mm/hr (95% CEP)	1.72 x 10^{-4} deg.
Ground Velocity	Honeywell Laseref SM	0 - 4,095 kts	1 m/s after correction	0.0039 kts
Vertical Velocity	Honeywell Laseref SM	± 32,768 ft/min	1 m/s after correction	0.03125 ft/min
Pitch/Roll Angle	Honeywell Laseref SM	± 90? Pitch ± 180? Roll	0.05? (4)	1.72 x 10^{-4} deg.
True Heading	Honeywell Laseref SM	180°	0.2º (4)	1.72 x 10^{-4} deg.
Differential Pressure	Rosemount 858AJ/1332	± 15°	0.2°	0.00375°
Liquid Water Cont.	Bacharach Model LWH (JW)	3 g/m^3	0.2 g/m^3 or 10%	0.0002 g/m^3
Liquid Water Cont.	In-House CSIRO-Hot Wire	3 g/m^3	0.2 g/m^3	0.0003 g/m^3
Icing Rate	Rosemount 871FA	0.5 cm/trip	N/A	0.0004 cm
Engine Torque		2,230 ft/lb.		0.2 ft/lb.
Event Markers	In-House (10/Station)			1 sec.
Video Record	Forward looking camera, and voice recording			

2. STANDARD INSTRUMENT GROUPINGS - Available by Request (Justify Request)

Cloud Particle Spectrometers X **Requested**

VARIABLE	INSTRUMENT	RANGE (1)	ACCURACY (2)	RESOLUTION (1)
Cloud Drop Spect.	PMS FSSP	0.5 - 45 μm		0.5 - 3 μm (5)
Cloud Part. Spect.	PMS 200X (1DC)	12.5 - 185.5 μm		12.5 μm
Hydrometeor Spect.	PMS 2DC	25 - 800 μm		25 μm
Hydrometeor Spect.	PMS 2DP	200 - 6,400 μm		200 μm

Boundary Layer Turbulent Flux X **Requested**

VARIABLE	INSTRUMENT	RANGE (1)	ACCURACY (2)	RESOLUTION (1)
H_2O and CO_2 Vapor	LICOR 6262 Gas Analyzer	0 - 75 mb (H_2O) 0 - 3,000 ppm (CO_2)	1% ± 1 ppm @ 350 ppm	0.1 mb 1 ppm

Air Temperature	Friehe Temperature Probe			
Radiation Sensors X **Requested**				
Pyranometer	Eppley PSP (0.285 - 2.8 μm)	0 - 1,400 W/m^2	5 W/m^2	0.08 W/m^2
Pyrgeometer	Eppley PIR (3.5 - 50 μm)	0 - 700 W/m^2	15 W/m^2	0.04 W/m^2
Radiation Pyrometer	Heimann KT-19.85 (9.6 - 11.5 μm)	-50ºC to 400ºC	0.5ºC	0.10º for 10 s

E. SCIENTIFIC PAYLOAD (con't)

3. NON-STANDARD INSTRUMENTS (available by prior arrangement)
Place an **X** beside the requested instruments. These instruments are not eligible for Deployment Funds

VARIABLE (Contact)	INSTRUMENT	RANGE[1]	ACCURACY[2]	RESOLUTION[1]
XX Cloud Radar (Vali/Kelly)	95 GHz			
CCN (Wechsler)	In-House/Automatic			
Hydrogen Peroxide (Snider)	In-House/Enzyme	0 - 20 ppbv	0.05 ppbv	0.001 ppbv
Ozone (Snider)	TECO 40	0 - 1000 ppbv	2 ppbv	0.1 ppbv
Visibility (Montague)	Nephalometer/Radiance M903	0 - 10^{-3}m^{-1}	2 x 10^{-6}m^{-1}	0.1 x 10^{-6}m^{-1}
XX CO_2 and H_2O Vapor (Kelly)	LICOR 6262 Gas Analyzer	0 - 75 mb (H_2O) 0 - 3,000 ppm (CO_2)	1% ± 1 ppm @ 350 ppm	0.1 mb 1 ppm
SF_6 Detector (Snider)	Scientech LBF-3	0 - 20 ppbv	0.01 ppbv	0.001 ppbv
XX NDVI sensor				

4. Justification for STANDARD INSTRUMENT GROUPS and for NON-STANDARD INSTRUMENTS

- *The WCR is to be included sine qua non.*
- *Turbulent flux (25 Hz) measurements are essential, given the high variability with cumuli.*
- *Radiation sensors will be used to detect clouds above or below flight level. This is important since the WCR does not detect the edge of thin clouds, and the King Air does not carry a lidar. Upward-looking IR is a 'poor-man's' way of determining cloud presence and estimating cloud base height, thereby complementing the WCR observations. Downlooking visible serves the same purpose, when flying high. The forward camera, aircraft observers' notes, and the stereo-photogrammetry data from Biosphere II site also serve this purpose.*
- *Cloud particle spectrometers are needed to document the microphysical characteristics of cloud droplets and hydrometeors in shallow to towering cumulus.*
- *The NDVI is less important. It is useful to estimate surface flux variations along the flight track. These fluxes are known to vary significantly with vegetation type (which varies with altitude over the mountain).*

Notes: (1) In units native to the instrument (4) Not considering static system misalignment
(2) In units of customary usage (5) Selectable
(3) Limited by reception

F. USER-SUPPLIED SCIENTIFIC PAYLOAD					
1. List Requirements of User-Supplied Scientific Payload.					
Instrument	**Weight**	**Size** (19" panel or other)	**Power Required** (watts, amps)	**Type of Power** (AC, DC, Hz)	**External Sensor Location** (if any)
none					

Justification for User-Supplied Payload

G. DATA RECORDING AND PROCESSING REQUIREMENTS

1. Summarize the scientific prerequisites (Hypotheses) leading to the Instrument Specifications stated in Part E (accuracy, frequency, etc.)

The ability to place airborne in situ observations in the context of WCR-derived echo and vertical velocity information at ~40 m resolution, above, below, and to the side of the aircraft, constitutes a powerful synergy for cloud dynamical studies. In CuPIDO we aim to describe the vertical and horizontal structure of the airflow and cloud radar reflectivity fields within orographic cumuli, and relate the fine-scale cloud structure observations to flight-level measurements of microphysical and thermodynamic properties of these cumuli and their environment. We then aim to explore the linkages between the evolution of a cumulus tower, the evolution of successive cumulus towers, and the environment in which the cumuli initiate, deepen, glaciate, entrain, and detrain. Thus the hypotheses are twofold, but interconnected:

Hypothesis 1. The WCR data are of sufficient quality and accuracy that the echo and kinematic structure of orographic cumuli can be described at a scale of about 40 m, which is sufficient to resolve the primary entrainment processes. The WCR entrainment signatures can be interpreted in light of proximity in situ (flight-level) microphysical and thermodynamic data. The King Air/WCR combination is a novel approach to cumulus dynamics research, which has been based mostly on pencil-line aircraft observations and ground-based precipitation radar data. Our observations will yield new insights into the fundamental dynamical mechanisms controlling the evolution of cumuli.

Hypothesis 2. Cumulus convection over mountains has a significant impact on the environment in which orographic cumuli develop and decay. The King Air and WCR data will yield new insights into the synergy between towering cumulus convection and orographically-induced mesoscale circulations.

2. If nonstandard formats and/or data rates are required, how often are the measurements required? (Attach statement justifying the need for nonstandard rates as processing procedures. Nonstandard rates and formats will be considered as a special processing request.)

The standard formats (generally netCDF) are fine.

**Note: The standard media for data transfer is Exabyte magnetic tape.

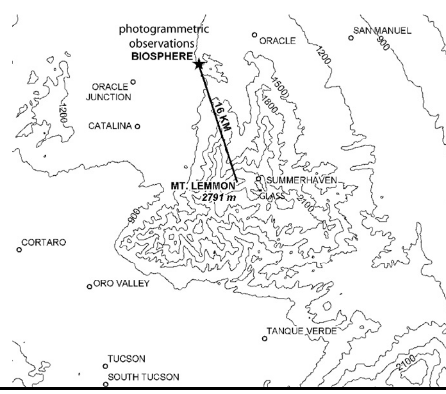
3. If additional processing is required, will it be done at NCAR? At WYO? **Yes**

4. Has request for computing services been sent to NCAR Computing Facility? **No**

H. OTHER SUPPORTING SERVICES

1. Will you require Air-Ground Communication? **YES** If so, what range? 50 km Specify location of base station and operating frequencies.

The King Air flight scientist should be able to communicate with the digital photogrammetry team at Biosphere II, located 16 km north of Mt. Lemmon (see Fig on the right). That team will coordinate the release of radiosondes and describe, in real-time, the visible evolution of cumulus clouds over the mountains. They will also be able to relay real-time weather information through web access (satellite, radar, lightning). Given the short range, 900 MHz Freewave telemetry communication may be sufficient.



2. Any special sensor calibration services required? No

3. What additional recording capability is requested? Explain below.

Voice Record Yes

Video Recording Yes (forward)

4. Will WYO Support be required in preparing special instruments for use on aircraft? (If so, specify type and lead time.) **no**

I. AIRCRAFT-GROUND SUPPORT NEEDS FOR USER-SUPPLIED INSTRUMENTATION

1. ON FLIGHT DAYS:

A.Preflight Needs (prior to takeoff):

Access 2 hrs.

Power 2 hrs.

B.Postflight Needs (after landing):

Access 2 hrs.

Power 2 hrs.

C.Special Support Needs:

2. NON-FLIGHT DAYS:

A.Routine Maintenance:

B.Special Support Needs:

Use the remaining space to provide any additional information which WYO may need to support this program:

There may be a concern about lightning, because although a lightning impact does not affect the King Air flight performance, it does require an expensive and time-consuming engine inspection. CuPIDO is aimed at shallow to towering cumuli that are more or less locked over the Santa Catalina Mountains. Cumulus traverses will terminate before the cumulonimbus stage is reached. At that stage, aircraft operations will cease (possibly after a final mountain circumnavigation). Similar missions have been flown before over the Magdalena Mountains in New Mexico, with the NCAR King Air (Blyth and Latham 1993). Because orographic cumuli grow gradually, and because they occur in isolation over the mountains, it is quite easy to assess when they will mushroom out to become cumulonimbi with lightning (A. Blyth, pers. comm.).