DC-8 Inlet/Instrument Characterization Experiment (DICE)

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DICE Summary

The INTEX-NA mission will be conducted in summer 2004 and focus upon gaining a better understanding of the exchange of chemical and particulate species between the North America continent and the global troposphere. To prepare for the mission, the NASA Tropospheric Chemistry Program has reserved a block of DC-8 flight hours during May 2003 for use in testing instruments and sampling procedures. We propose to conduct tests during this flight series to compare and characterize the passing efficiency of aerosol inlet probes, inter-compare measurement techniques, and evaluate the in-flight performance of a number of new and existing aerosol sensors that may be included within the aircraft's INTEX-NA instrument payload. For the inlet tests, the shrouded diffuser (SD) probes used during previous missions aboard the DC-8 and P3-B for bulk aerosol collection and optical property measurements will be mounted on the aircraft in close proximity and plumbed into both individual and common manifolds to deliver sample to a variety of aerosol sizing and scattering instruments. Aerosol characteristics will be determined from samples delivered by the probes during flights designed to encounter air masses containing dust, sea salt, and regional haze. These data will be examined to determine the relative penetration of particles through the probes as a function of diameter, composition and aircraft operational parameters. The absolute passing efficiencies of the inlets will be constrained by comparing the airborne measurements of aerosol size and composition with those obtained on a tower operated at a location near NASA Dryden and also by comparing vertical profiles of humidity-corrected aerosol extinction with differential aerosol optical depths provided by a new multi-wavelength sun photometer instrument. Results of the study will be used to evaluate the impact of inlet losses on previous DC-8 data sets, guide development of more efficient inlets for high-speed aircraft, and to help establish aerosol measurement objectives for INTEX-NA.

The proposed instrument/sampling method inter-comparisons will explore the causes for differences observed between aerosol parameters measured aboard the DC-8 and P-3B during TRACE-P and help to ensure that a consistent set of aerosol composition, optical and microphysical measurements are collected aboard the two aircraft during INTEX-NA. Particular emphasis will be placed on comparing aerosol absorption sensors, bulk aerosol ionic composition measurement techniques, and optical sizing probes. The absorption instrument tests will involve making a side-by-side comparison of measurements from the Particle Soot Absorption Photometers (PSAPs) that were deployed aboard the P-3B and DC-8 during TRACE-P and evaluating their response to changes in pressure, humidity, and high ambient loading of non-absorbing aerosols. Tests of the aerosol composition measurement techniques will involve comparing the particle collection efficiencies of the filter and PILS sampling techniques as a function of aircraft altitude and predominant particle size and type. For the optical spectrometer tests, we will deploy a set of externally-mounted, aerosol spectrometer probes aboard the aircraft to evaluate their performance relative to each other and to a laser optical particle counter (OPC) and aerodynamic particle sizer (APS) operating behind the shrouded diffuser inlet probes. The external instruments will include Particle Measuring Systems FSSP-100 and FSSP-300 forward scattering spectrometer probes, the new Droplet Measurement Technologies,

Cloud, Aerosol and Precipitation Spectrometer, and the new University of Hawaii miniature OPC. Tests will focus upon determining the effective sample volumes for the probes and in elucidating their sensitivities to aircraft airspeed and attitude and particle shape, size, and composition.

Finally, a number of new instruments and sampling techniques are under development that could enhance our ability to characterize aerosols from airborne platforms. Those that will potentially be tested include: a tandem differential mobility analyzer; a three-wavelength, particle soot absorption photometer; a combined optical/aerodynamic particle sizer; a small, two-wavelength aerosol lidar suitable for deployment on the P-3B; a new filter technique that facilitates rapid collection of samples for organic and elemental carbon analysis; and a new scanning sun-photometer capable of yielding aerosol optical depths and column concentrations of chemical species. The flight plans designed to test aerosol inlets and sample varying aerosol populations to challenge instruments for inter-comparison purposes will provide an ideal opportunity to evaluate the performance of these systems over a broad range of aircraft operating conditions and aerosol loadings.

Background and Justification

Aerosols are now recognized as having significant impacts upon both regional and global climate and atmospheric chemistry. Indeed, their direct and indirect effects on radiative forcing represent the major uncertainty in predicting global climate change [Boucher, 2002]. Aerosols appear to play an important role in the hydrologic cycle through affecting cloud droplet size and the probability of precipitation [Lohmann, 2002]. Aerosols also provide an atmospheric reservoir for low volatility species and surface area upon which heterogeneous chemical reactions can occur. The main sources of aerosols in the U.S. are urban/industrial/transportation processes, coal-fired power plants, biomass burning and advective fluxes from upwind regions.

The NASA Global Tropospheric Experiment (GTE) INTEX-NA experiments planned for summer 2004 and spring 2006 will investigate the import and export fluxes, regional sources and sinks, and chemical transformation of both aerosol and trace-gas species over the North American continent. To accomplish these tasks, INTEX-NA will deploy the NASA DC-8 and P-3B aircraft instrumented with remote and in situ sensors to various coastal and interior sites within the U.S. to acquire large-scale vertical and horizontal measurements of important atmospheric constituents and parameters. These data will in turn be coupled with satellite observations and used in conjunction with photochemical and transport models to gain a better understanding of the exchange of trace species between the continents and overriding atmosphere. In order to link aircraft observations to satellite products derived from optical measurements it is important to adequately characterize aerosol sizes that contribute to these optical properties.

In view of the great uncertainties associated with the spatial distribution and sources and sinks of aerosols and recognizing the important roles that aerosols play in atmospheric processes, INTEX-NA will place a much higher priority upon characterizing particulate matter than any previous GTE mission. Measurements of fine/ultra-fine condensation nuclei, aerosol size distribution, bulk aerosol composition (inorganic and organic), black carbon/aerosol absorption/scattering and backscatter profiles are all assigned priorities of 2 (very important) or higher aboard both the P-3B and DC-8.

The particulates that will be encountered during INTEX will likely arise from a variety of sources and exhibit a wide range of physical and chemical properties. Aerosols associated with fossil fuel combustion and in situ formation processes will generally be less than a micron in size and relatively easy to capture and characterize from airborne platforms. Those arising from vigorous biomass burning, surface erosion, and cloud evaporation and outflow will often be much larger (up to ~5 um) and hence more difficult to aspirate into the aircraft because of inertial and turbulent losses within the sampling inlets [i.e., Sheridan et al., 1998]. The relative importance of sampling large aerosols aboard the DC-8 is supported by measurements obtained by during the SUCCESS experiment in May 1996 over the central U.S. Here, Talbot et al., [1998] found that aerosol loading at high altitudes (6 to 12 km) was dominated by crustal material lofted by convective activity occurring over the Western States. Because INTEX-NA phase A will be conducted during summer, we can anticipate that mid to upper tropospheric air masses sampled during the mission will similarly be impacted by convective outflow containing dust and other large aerosols. These aerosols may contribute significantly to aerosol optical properties and mass if drought conditions persist in the western states or if large forest fires are burning during the experiment period.

Because the P-3B has been used in previous GTE missions to probe the marine boundary layer and low level continental plumes, its in situ aerosol instrument payload has received significantly more attention, particularly in the area of physical property measurements, than that flown on the DC-8. Capitalizing on technology developed for other slow-flying, low altitude aircraft such as the NCAR C-130, measurements of aerosol number, size and volatility along with particulate absorption and scattering have been successfully recorded aboard the P-3B in the PEM-Tropics and TRACE-P missions. Comparable measurements were included aboard the DC-8 for the first time during TRACE-P, but were only partially successful due to inlet losses and a sensitivity of some instruments to changes in pressure and humidity. Bulk aerosol composition measurements have been made aboard both aircraft for the last several missions, but only for inorganic species and then with relatively poor temporal resolution for mid- to high-altitude sampling. Elemental carbon, EC, measurements have not been made upon either aircraft although aerosol absorption coefficients were determined on both aircraft during TRACE-P and the size distribution of nonvolatile particles (dust, soot, or sea salt) have been recorded on the P-3B since the PEM-TROPICS A mission. Regarding remote sensors, the DC-8 includes the UV-DIAL system that has provided reliable nadir and zenith backscatter profiles at two wavelengths since the inception of the GTE program. Remote aerosol measurements have not been included aboard the P-3B in GTE missions, although the aircraft has an optical port suitable for accommodating a nadir-viewing telescope. Sun photometers for measuring column aerosol extinction and wavelength dependence (priority 3 for both aircraft) were not included within any previous GTE payload.

In order to achieve INTEX-NA experiment objectives, it is not only important to install extensive sets of aerosol instruments aboard the two aircraft, but to ensure that the instruments provide a seamless set of measurements over all operational conditions. This has not been the case in previous experiments. For example, during TRACE-P several instrument inter-comparison flight legs were conducted wherein the DC-8 and P-3B flew in wingtip-to-wingtip formation at altitudes between the surface and 6 km (Moore et al. submitted manuscript). On some or all of the flight legs, significant differences were seen between the measurements of aerosol optical parameters, size distributions, and composition recorded aboard the two aircraft. In some cases, the disagreement arose from differences in inlet cut sizes and transmission efficiencies. For example, aerosol scattering coefficients recorded aboard the two aircraft were in general agreement at high altitudes where ambient loading was dominated by sub-micron aerosols, but DC-8 values were considerably lower for boundary layer samples where super-micron sized, sea salt particles accounted for a large fraction of the aerosol extinction. Better agreement was seen between the two measurements in cases where dust particles were sampled in dry, elevated layers, suggesting that humidity played a role in determining the DC-8 inlet passing efficiency. For aerosol absorption measurements, values from the two aircraft were comparable during boundary layer sampling but diverged at higher altitudes apparently because the DC-8 instrument was sensitive to changes in pressure and humidity. Aerosol size distributions recorded aboard the aircraft by optical techniques were comparable for small sizes ($< 0.5\ \mu m$), but showed differences for particles measured by open cavity spectrometer probes mounted external to the aircraft cabin. Finally, aerosol ionic composition measurements obtained from filters and a mist chamber on the DC-8 and by the particle-in-liquid technique on the P-3B at times showed differences that could not be accounted for by differences in the size range of collected particles.

A number of important steps should be taken to resolve the sources of differences that were evident between measurements recorded aboard DC-8 and P-3B during TRACE-P and to prepare new and evolving aerosol sensors for inclusion within INTEX-NA instrument payloads.

First, the collection efficiencies of the aircraft aerosol inlets (see Table 1) must be characterized for anticipated flight and sampling conditions. In this regard, the shrouded inlet probe used by the University of Hawaii to characterize aerosol optical properties and size distributions aboard the P-3B during TRACE-P was included as part of the PELTI (Passing Efficiency of the Low Turbulence Inlet; http://raf.atd.ucar.edu/Projects/PELTI/) experiment conducted aboard the NCAR C-130. Using arrays of identical aerosol instruments on each sampling manifold and a total aerosol sampler as an absolute reference, PELTI examined the transmission efficiency of a variety of inlets as a function of particle size and composition as well as aircraft operational parameters. Results of the study suggest that the UH probe is relatively efficient at transmitting dust particles out to

~5 μm and can be corrected for the losses to yield size distributions out to a few μm beyond that. It also collected ~50% of sea salt particles during runs through the marine boundary layer, much better than the 20% mass passing efficiency of the carefully designed "Community Aerosol Inlet" that was used aboard the C-130 during previous aerosol sampling experiments. Because the NCAR C-130 and NASA P-3B have an almost identical flight envelopes, the inlet calibrations performed one can be directly transferred to the other, but not to the DC-8 which flies over a much greater range of airspeeds and altitudes.

Table 1. Inlets Proposed for Characterization during DICE

Inlet	Previous Use	Group
(2) Shrouded Diffusers	DC-8 TRACE-P, PEM-Tropics	New Hampshire
Small Shrouded Diffuser	DC-8 SOLVE-II	Langley
Shrouded, Solid Diffuser	P-3B TRACE-P, PEM Tropics; C-130 ACE	Hawaii

Secondly, the various instruments/sampling methods that were employed aboard the DC-8 and P-3B during TRACE-P that exhibited differences for measurements of certain parameters should be directly inter-compared on the same airborne platform, extracting samples from the same inlet manifolds. Candidate instruments/methods for the comparisons are the soot photometers, optical sizing probes, and aerosol composition techniques (see Table 2). The performance of these instruments should be examined over the range of conditions and aerosol loadings that are anticipated for the INTEX deployment with an emphasis on delineating disagreements that arise from sampling different aerosol size ranges and those that are due to performance differences inherent to the instruments or measuring techniques themselves.

Table 2. Candidate Instrument/Methods for In-flight Inter-comparisons

Measurement	Instrument	Group
Aerosol Absorption/Soot	DC8 PSAP	Langley
	P-3B PSAP	U. Hawaii
Aerosol Composition	Filters/Mist Chamber	U. New Hampshire
	PILS IC	Georgia Tech
Optical Particle Counters	FSSP-100, FSSP-300, CAPS, PCASP	Langley
	OPC, Mini-OPC, FSSP-300	U. Hawaii

Finally, new or modified sensors (see Table 3) that will potentially be included in the INTEX instrument payloads should flight-tested to identify possible problems and avenues for improvement. Tests of in situ instruments should be conducted on samples delivered by well-characterized aerosol inlets and be supported by simultaneous measurements of aerosol size, composition, and optical properties as well as meteorological variables and aircraft positional parameters. For profiling or column-measurement instruments, vertical profiles of corresponding in situ parameters should be recorded through highly scattering layers of several different aerosol types to provide data for validating the remote observations.

Table 3. Candidate Instrument/Techniques for Flight Testing during DICE

Instrument	Measurement	Group
Filter/mist sampler	Organic Aerosol Speciation	New Hampshire
Three-Wavelength Soot Photometer	Soot/Aerosol Absorption	Hawaii
Tandem Differential Mobility Analyzer	Fine Aerosol Size Distributions	Hawaii
OPC section of APS	Accumulation(OPC) and Coarse Mode (OPC and APS) Size Distribution	Langley
Scanning Sun Photometer	Aerosol Optical Depth; Chemical Species Column Abundance	NCAR
Compact Aerosol Lidar	2-wavelength relative aerosol backscatter	Langley

Project Objectives and Questions to be Addressed

Because INTEX-NA is planned for summer 2004, the studies/tests recommended above must be conducted as soon as possible to have any impact on the planning of and preparation for the mission. For this reason, we propose to install instruments aboard the DC-8 during May or June of 2003 and conduct a series of flight test to 1) characterize aerosol inlets, 2) inter-compare instruments and sampling techniques and 3) test new and improved sensors and instruments. The tests and flight plans in DICE will address the following questions:

1) Inlet Characterization

- What are the size dependent differences of the inlet systems?
- How do these differences vary as a function of altitude, air speed, aircraft attitude (pitch, roll, yaw), relative humidity, and aerosol type?

- How do our sampling limitations impact our ability to establish the optical properties and constrain surface areas of the dust? Sea salt? Urban aerosols?
- Are there simple changes that we can make to increase the inlet cut sizes or make them more predictable?
- What impact do transport tubes and sampling manifolds have upon the integrity of aerosol populations?
- Is one inlet type preferable over others?
- Are there reasons to employ impactors or cyclones to place a known 50% cut size on certain measurements.
- Is an LTI needed in order to accurately sample large aerosols from the DC-8?

2) Instrument Inter-comparisons

- **Soot Instruments**: Do the aerosol absorption units (PSAPs) used on the DC-8 and P-3B yield fundamentally different measurements when operated under the same conditions. How do the performance of these instruments vary as a function of sample pressure, non-absorbing aerosol loading, and humidity. Can simple changes be made to improve their performance and sensitivity?
- **Optical Sizing Probes**: Are external sizing probes consistent with internal probes, tower measurements and column determinations of optical properties? Are they consistent with each other? Under what conditions are they most/least consistent?
- **Aerosol Composition**: How does the particle-in-liquid-spectrometer (PILS) instrument used on board the P-3B compare with the filter sampling system deployed aboard the DC-8? Can the differences found during TRACE-P be accounted for by differences in the size of particles sampled? Are the efficiencies of the techniques sensitive to altitude (pressure) and the relative solubility of the aerosol particles?

3) Instrument Tests and Characterization

- How well does the modified P-3B **Tandem Differential Mobility Analyzer** perform under the pressure and aerosol loading conditions encountered on the DC-8?
- How well does the **Optical Particle Counter section of an Aerodynamic Particle Sizer** (TSI-3321) perform under the pressure and aerosol loading conditions encountered on the DC-8. Is the optical sizing from this instrument consistent with performance of existing OPC's. More fundamentally, can aerodynamic sizes be related to optically effective sizes and or mass?
- How well does a modified **Three-wavelength, Particle Soot Absorption Photometer** operate in comparison to the single wavelength instruments operated on NASA aircraft in previous missions? Does it offer significant advantages?
- Can **organic aerosol** samples be efficiently captured for subsequent analysis by ground-based analytical instruments?
- How well does the new **Scanning Sun Photometer** system work aboard the DC-8? Where should it be mounted to suffer the least interference from aircraft

reflections and to provide the most useful observations? How well does its measurements compare with those from ground-based sensors? With in situ measurements performed aboard the aircraft in closure experiments?

- How well does the new **Compact Aerosol Lidar** work in airborne operation? Do the flight test suggest further improvements to increase its performance or utility? Can it be automated?

Participants

All GTE investigators that flew aerosol instruments/and or inlets aboard either the DC-8 or P-3B in TRACE-P have expressed an interest in participating in DICE. Table 4 provides a list of these groups, the instruments they plan to fly during DICE, and the objectives that they'll be on board to address. Note that New Hampshire, Hawaii and Langley will deploy inlets for characterization (objective 1), participate in instrument intercomparisons (2), and test new or improved instruments that will be proposed for INTEX-NA (3). Georgia Tech will participate by conducting in-flight inter-comparisons of aerosol composition provided by their PILS system with filter sampler/IC measurements determined by New Hampshire (2) and test modifications made to the system to improve its performance at high altitude (3). The Langley Aerosol Lidar will provide information to guide the in situ sampling for characterizing inlets (1) and will test the performance and operational readiness of the system they plan to propose for use on the NASA P-3B in INTEX (3). NCAR will deploy a sun photometer both for in-flight evaluation (3) as well as to provide differential, wavelength-dependent aerosol extinction measurements to facilitate closure experiments involving in situ optical sensors operating behind the test inlets (1).

Table 4. Potential DICE Participants

Research Group	Instruments	Objective		
		1	2	3
Langley (Anderson)	PSAP, OPC/APS, PCASP, FSSP, CAPS, Neph	X	X	X
Hawaii (Clarke)	PSAP, APS, OPC, FSSP, mOPC, TDMA, Neph	X	X	X
New Hampshire (Dibb)	Filters, Mist Chamber, OC sampling	X	X	X
Georgia Tech (Webber)	PILS		X	
Langley (Browell)	Aerosol Lidar	X		X
NCAR (Shetter)	Sun Photometers, Radiometers	X		X

Experiment Approach and Instrument Installations

The aircraft instrument payload, rack placements and flight plans are designed to optimize our ability to address the aerosol inlet characterization and instrument inter-comparison objectives of DICE. Instruments placed on board the aircraft primarily for test purposes will be given a lower priority and mounted in non-interfering locations.

Our primary approach in testing the inlets will be to collect aerosol size, composition, and optical property measurements behind each of the inlets at varying aircraft air speeds and attitudes and inlet sampling velocities (i.e., isokinetic, subisokinetic, and superisokinetic) in the vicinity of an instrumented tower. Then, using the tower measurements as an absolute standard, we can then derive the 50% cut size for the inlets as functions of aerosol type and sampling condition. The tower will likely be located adjacent to the runways at Edwards Air Force Base, a region of heavy dust particle loading. To characterize the inlets over a broader range of aerosol types, air speeds, and altitudes, measurements of aerosol optical properties recorded downstream of each inlet will be compared with differential, wavelength-dependent aerosol extinction measurements provided by the scanning sun photometer (See Figure 1 for example). This approach will allow us to assess the inlets' passing efficiency in conditions that will potentially be encountered during INTEX-NA, i.e., sampling over a broad range of altitudes in air masses containing photochemical smog, sea salt aerosols, and elevated dust plumes.

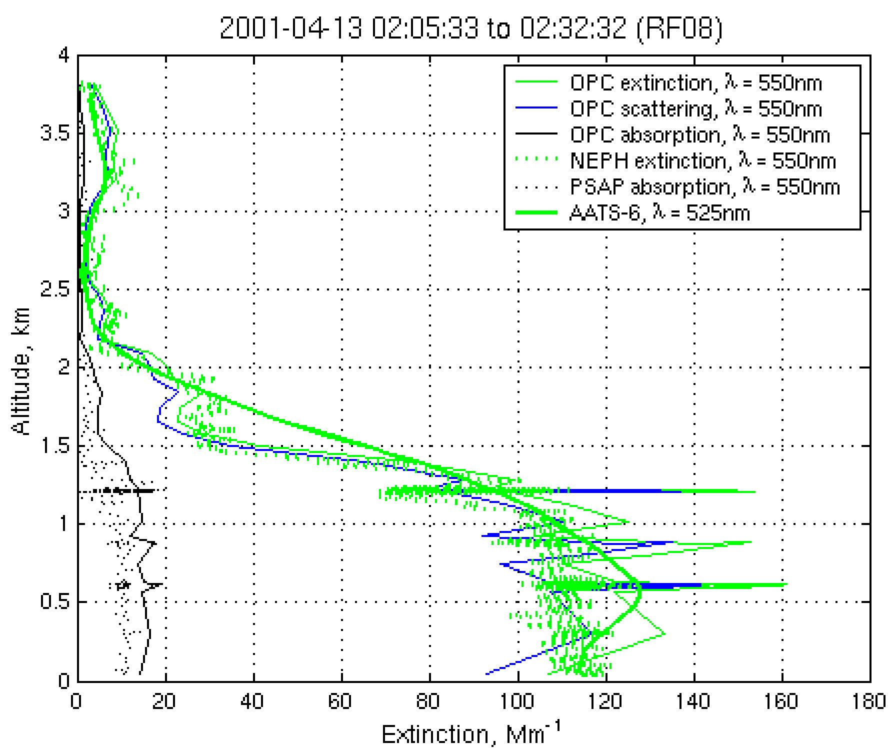

Figure 1. Results of a closure experiment conducted aboard the NCAR C-130 during ACE-Asia. The ATTS-6 extinction data were calculated by differentiating aerosol optical depth with respect to altitude.

Data for validating the sun photometer measurements will be obtained by performing low passes over Aeronet Sites (e.g., http://aeronet.gsfc.nasa.gov/) at Rodgers Dry Lake (34oN, 117oW), San Nicolas Island (33oN, 119oW), and Table Mountain (34oN, 117oW). These sites are equipped with Cimel Sun Photometers that make continuous measurements of aerosol optical depth (AOD) at 340, 380, 440, 500, 670, 870, and 1020 nm. Vertical soundings will also be performed over the Rodgers Dry Lake so that the in situ measurements of aerosol optical parameters can be integrated and compared with the ground-based AOD measurements.

Table 6. Racks or Installations Needed to Address DICE Objectives 1 and 2

Rack/Installation	Instrument	Parameter
New Hampshire	* Filter Sampler	Aerosol Composition
	* PILS	Aerosol Composition
	Nephelometer/impactor	Scattering Coefficient
	OPC/Aerodynamic Particle Sizer	Size Distribution
Hawaii	* Filter Sampler	Aerosol Composition
	* PILS	Aerosol Composition
	PSAP	Aerosol Absorption
	(2) Nephelometers	Size Distribution
	OPC and Aerodynamic Particle Sizer	Size Distribution
Langley In Situ	*Filter Sampler	Aerosol Composition
	OPC/Aerodynamic Particle Sizer	Size Distribution
	*PSAP	Scattering Coefficients
	Nephelometer	Scattering Coefficients
NCAR	Scanning Sun Photometer	Extinction Coefficients
Ground Station	* Filter Sampler	AOD/Aerosol Composition
	Nephelometer/impactor	Scattering Coefficients
	*PSAP	Aerosol Absorption
	HSLAS	Size Distribution
	Aerodynamic Particle Sizer	Size Distribution
	Sun Photometer	Aerosol Optical Depth

* Instruments that are also being intercompared

The instrumentation that will be required for the inlet tests is listed in Table 6. Note that some of these instruments are also on board for inter-comparison purposes. Our plan will be to locate the in situ sensor racks on either side of the DC-8 center aisle in the forward half of the cabin. The "low-boy" rack needed to support the sunphotometer will be placed in the rear of the aircraft and the sensor head mounted in an upward-looking, 62^o port. The two identical New Hampshire inlets will be mounted in their usual location, i.e, in the 62^o zenith port across the aisle from the mission director's console. The "New Hampshire" rack will be mounted just aft these inlets in a position selected to minimize the bends in and length of transport tubing. The Langley and Hawaii inlets will be mounted on opposite sides of the aircraft, in the same relative airframe positions and will be plumbed into individual sampling manifolds on adjacent racks (see Table 6 for a list of instruments). The individual manifolds on each rack will be plumbed into a common sampling manifold mounted on the Hawaii rack so that air from any of the four inlets can be diverted and sampled with a single set of aerosol instruments. Use of a common manifold will also facilitate in-flight comparisons of the aerosol instruments and help remove differences in instrument performance as a source of uncertainty in the inlet characterizations.

The ground-based instruments will likely be mounted within an environmental enclosure located at the base of the sampling tower. Air samples will be drawn in through a side-facing inlet--directed into the prevailing wind--and delivered to a sampling manifold through a large-diameter metallic pipe. Although probably unnecessary due to the dry desert conditions, air delivered to the instrument will be heated to maintain a relative humidy of < 40%. Instrument operation and filter collection will be automated so that measurements can be made continuously throughout the DICE experiment period.
The instruments located in the three racks and on the tower will yield common measurements of optical sizing over the range from 0.5 to 10 μm, aerodynamic sizing from 0.8 to 20 μm, submicron and total aerosol scattering coefficients, and aerosol composition. In addition, the Hawaii/Langley rack aboard the aircraft will yield total and sub-micron multi-wavelength scattering coefficients, optical size distributions extended down to 0.1 μm, and aerosol absorption coefficients. These added parameters will be used to calculate aerosol extinction at multiple wavelengths to allow evaluation of inlet performance by comparison to extinction derived from the on board scanning sun photometer.

The instruments/methods that will be inter-compared during DICE are listed in Table 2 above. Note from Table 6, that the aerosol composition measurements provided by New Hampshire and Georgia Tech will be inter-compared on two racks aboard the aircraft. In terms of aerosol absorption measurements, the Langley and Hawaii instruments will be mounted in a single rack and derive samples from a common manifold. The OPC that was used on board the P-3B during TRACE-P will be installed in the Hawaii rack and the size distributions it yields will be inter-compared with those provided by the Langley Passive Cavity Aerosol Spectrometer Probe (PCASP) mounted on the aircraft right wing-tip. An inter-comparison of open cavity aerosol optical particle counter measurements will be made possible by mounting the Hawaii and Langley Forward Scattering Spectrometer Probes (FSSP) in canisters on the left wing-tip, the Langley Cloud Aerosol and Precipitation Spectrometer in the remaining canister on the left wing, and the Hawaii mini-OPC on a window plate. The electronics for the external sensors will be mounted in the Hawaii and Langley instrument racks.

Instruments deployed primarily for test and evaluation purposes (see Table 4) will be located either in the rear of the aircraft or within empty space in racks supporting the DICE inlet characterization and instrument inter-comparison objectives. The Langley compact lidar system telescope will be mounted over the nadir viewing port typically occupied by the UV-DIAL system during GTE missions. Tests of the organic aerosol collection technique will be conducted on New Hampshire's instrument rack as will altitude sensitivity tests of the new tandem OPC/APS of Langley. The multi-wavelength PSAP and tandem differential mobility analyzer will be mounted in the Hawaii and extract air from the Hawaii sample manifold.

Experiment Schedule

DICE will be conducted at Dryden Flight Research Center (DFRC) during the May/June, 2003 time frame. Inlets and racks will be shipped to Dryden at least one week prior to this date so that inspections by the DFRC staff can be completed before upload begins on the 5th. Downloading of instruments must be completed by June 6th to avoid conflict with the next scheduled DC-8 experiment. We anticipate that instrument integration aboard the aircraft and tower, preliminary calibrations/instrument inter-comparisons, and power-up/ground tests can be completed within the first two weeks of the experiment, leaving the remaining $2^{1/2}$ weeks open for the flight tests that are described below. A total of four data flights in addition to the initial shake-down flight are planned. Each data flight will be separated by at least two no-fly days to allow for data reduction and instrument calibrations.

Instrument Calibrations

An important activity during DICE will be establishing and maintaining calibration of the array of instruments used for characterizing the aircraft inlets. For this purpose, a calibration lab will be established and used to determine the size registration and concentration sensitivities of the optical and aerodynamic aerosol spectrometers used on the aircraft and tower. The lab facilities will include an aerosol classifier, vibrating orifice generator, and an aspiration generator to provide aerosols of known composition, refractive index, and size over the 0.01 to 20-µm diameter range. A multi-port sampling manifold will be installed on the outputs of these generators to allow simultaneous calibration and performance comparisons of the various sizing instruments. A portable aspiration generator will also be flown aboard the aircraft and plumbed into the common sampling manifold to make possible in-flight calibration checks.

Flight Plans

About 20 hrs of flight time are required to address DICE inlet characterization and instrument inter-comparison objectives. These are in addition to the 10 hrs of "piggyback" time that will be available from the LRR program that is sharing the DC-8 payload space with DICE. The flights will be conducted at or around midday, hopefully in clear sky conditions to make possible recording AOD data with the ground and aircraft-based sun photometers. Plans will generally include constant altitude legs of minimum 15-minute duration to make possible filter sample collection and frequent vertical profiles with 1000 ft/min ascent/descent rates to allow for comparisons between data from the in situ and remote sensing instruments. All flights will have inlet characterization as a primary or secondary focus. Table 7 lists the type and duration of missions envisioned. Note that the first flight will be devoted to testing the instrument and inlet systems. An issue will be whether the passive venturi pumping systems installed aboard the aircraft can provide sufficient flow to maintain isokinetic-sampling conditions in the test inlets. We will also use this flight to examine the flow and pressure changes induced in the aerosol sampling manifolds by valving flow between the individual and common manifolds. Our observations will be used to develop procedures for operating the test instruments and switching valves during the subsequent inlet tests.

Flights 2, 3, and 4 will focus upon obtaining inlet characterization data near the ground station and in sampling dust, sea salt aerosols, and urban/industrial emissions, respectively. Each mission will begin and end with low passes and profiles to 3 km over the ground station at Rodgers Dry Lake. In addition, we will make a low and high (>3 km) pass over the lidar/aeronet station at Table Mountain to obtain validation data for the lidar and on board sun photometer. Flight 2 will focus primarily upon characterizing the inlets while sampling dust in the vicinity of DRC. We will venture far enough out of the Edwards AFB control area to perform high altitude sampling legs (i.e., 8 and 12 km) and to operate the nadir-viewing lidar system. These legs will be flown to the south east of Edwards to obtain lidar curtain plots of the LA plume for use in designing the wall flights planned for mission 4.

Mission 3 will again emphasize inlet tests over the ground station and passes over Table Mountain, but will include a number of straight and level legs above and within the MBL off the California coast and a vertical sounding over the San Nicolas Island Aeronet site. Approximately four, 15 minutes runs will be made through the MBL, punctuated by on either end by shallow vertical soundings so that the in situ scattering measurements can be integrated and compared with AOD values provided by the scanning sun photometer. At least two constant altitude legs of minimum 15 minutes duration will be conducted in the 5 to 10 km altitude range for instrument inter-comparison and characterization purposes.

Table 7. Summary of DICE Flight Plans

Flight	Mission Objectives	Duration
1	> Shake Down Flight; test pumps, inlet velocities, alignments, manifold valving systems, etc. > Perform low passes by ground station	2 hrs

2	> Perform low passes over ground station > Record up and down sounding over Rodgers Site > Make low and high altitude passes over Table Mtn (lidar and Aeronet Site) > Perform vertical sounding over Dryden > Do high altitude legs to examine instrument sensitivities	4 hrs
3	> Perform low passes over ground station > Do speed variations during transit to oceanic area > Conduct speed variations and sounding through MBL > Perform spiral profile near San Nicolas Island (Aeronet Site) > Low and High pass over Table Mtn > Down sounding over Rodgers Site with low passes	4 hrs
4	> Perform low passes over ground station > Do speed variations during transit to area east of LA > Do 4 altitude wall flight through LA plume > Perform spiral profile over desert east of LA > Low and High pass over Table Mtn > Down sounding over Rodgers Site	5 hrs
5	> Perform low passes over ground station > Do speed variations during transit to Monterey > Perform inter-comparison flight with NRL Twin Otter over ocean w/ MBL runs and vertical profiles. > Low and high pass over Table Mtn > Down sounding over Rodgers Site	5 hrs

Mission 4 will again incorporate passes over the ground station and aeronet sites for inlet characterization and instrument validaton purposes, but will have a secondary focus of testing the aerosol absorption and organic aerosol collection systems in areas heavily impacted by urban/industrial pollution. To accomplish this, a four-altitude wall pattern will be flown over eastern California, downwind of the LA basin. Flight levels for the wall will be selected by examining lidar images recorded during a high altitude pass over the study area. The wall be initiated by making a downward spiral into the PBL and followed by a sequence of ~20-30 minute constant altitude runs conducted perpendicular to the prevailing wind between selected waypoints. Upward spirals will be flown at each end of the track to examine the agreement between in situ and remote measurements of aerosol optical properties.

Mission 5 will again include an inlet characterization experiment over the ground station, but will primarily focus upon conducting in-flight instrument inter-comparisons with the CIRPAS Twin Otter operated by NRL. The Twin Otter will be carrying a payload of aerosol optical and sizing instruments and will have just finished a month-long deployment to the DOE Atmospheric Radiation Monitoring site in Oklahoma where it will have participated an experiment to assess the flight readiness of airborne aerosol absorption and extinction instruments. The specific measurements systems that will be compared between the two aircraft include aerosol absorption, scattering, and optical-based size distributions. The flight plan will include wingtip-to-wingtip profiles and constant altitude legs through the MBL and PBL. The DC-8 will also make passes by the NOAA aerosol monitoring site in Trinidad Head, CA, and conclude the flight with a low altitude pass over Owens Dry Lake and a vertical profile over Rodgers Dry Lake (Edwards).

Data Archiving and Mission Planning

The success of DICE is dependent upon having a quick turn-around of the aerosol sizing and scattering data collected behind each inlet to guide preparation and planning for the next test flight. We will thus have a minimum of two no-fly days between flights and place a heavy emphasis on archiving mission critical data within 24 hrs after each mission. A network and server will be set up at Dryden to accommodate submission of the data and daily meetings will be held each afternoon to discuss results from the previous mission, instrument status and future flight plans.

Experimenters will be required to archive final data collected in relation to DICE objectives 1 and 2 within 2 months after the end of mission. Files will be submitted in the GTE format to the archive at LaRC where they will maintained in pass-worded directory accessible by DICE investigators. Although we encourage their submission, there will be no archiving requirement for data collected from instruments flown purely for test and evaluation purposes.

Logistics

As noted above, the mission will be conducted at NASA DFRC during May of 2003. With few exceptions, each group will be supported to bring two researchers in the field for a period of 30-35 days. We will encourage participants to stay at the Visiting Officers Quarters on Edwards Air Force Base. This facility is located within 5 miles of the DC-8 hanger, has spacious rooms, and is priced at \$27 night^{-1}. Alternative accommodations can be found in Lancaster (35 mile drive) or Rosamond (20 miles).

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