ITCT 2K2 Science Plan

(March 5, 2002)

I. Introduction and Overview

ITCT 2K2 is a field mission scheduled for the spring of 2002 to investigate the composition of air masses along the Pacific coast of North America. The particular focus is on the influence of anthropogenic emissions on the ozone and aerosol composition. This field program is part of the Intercontinental Transport and Chemical Transformation (ITCT) research activity of the International Global Atmospheric Chemistry (IGAC) Program.

II. Prelude to ITCT 2K2

There is ample evidence for the impact of long-range transport of ozone, fine particles, and their precursors over the Pacific. The long-range transport of dust particles from Asia has been extensively documented [Prospero et al., 1985; Duce et al., 1980; Xiao et al., 1998]. Several studies have investigated the transport and photochemical processing of anthropogenic emissions and the impact of these processes on the ozone and aerosol compositions. Studies conducted in the north Pacific region whose findings may be particularly important for planning and interpreting the ITCT 2K2 study include the following.

Point Arena Study - During April and May, 1985 measurements of ozone and its photochemical precursors were conducted on the northern California coast at Point Arena. Parrish et al. [1992] found that levels of O_3, peroxyacetyl nitrate (PAN), nitric acid (HNO_3) and the light alkanes were enhanced during periods when trajectory analysis indicated rapid transport from Asia. Effective lifetimes of O_3 and PAN in the marine troposphere were derived from the correlation of the levels of these compounds with the ratios of the alkanes.

CITE 2 Study - The NASA GTE program conducted an instrument intercomparison study over the Western U.S. and the adjoining Pacific Ocean [Hoell et al., 1990]. This mission was primarily devoted to instrument intercomparison, but also collected a summertime data set in the ITCT region.

MLOPEX Studies - The Mauna Loa Observatory Photochemistry Experiment (MLOPEX) was conducted during May and June 1988 [Ridley and Robinson, 1992] and during four one-month long intensive periods in each season of 1991/1992 [Atlas and Ridley, 1996] in the central North Pacific on Hawaii. These studies characterize the seasonally varying composition of this remote region of the troposphere with regard to ozone, its precursors and other photochemical products. Hess [2001] analyzes the spring time results with respect to the transport and photochemical processing of the measured species.

PEM-West Studies - The NASA GTE program conducted two field studies to study chemical processes and long-range transport over the northwestern Pacific Ocean. The first of these, Pacific Exploratory Mission-West A (PEM-West A), was conducted in the fall (September-October, 1991 [Hoell et al., 1996]) and the second, PEM-West B, in the spring (February-March, 1994 [Hoell et al., 1997]). These two missions have characterized the outflow of anthropogenic emissions from the Asian continent. PEM-West B will be of particular utility

in aiding the interpretation of the results from ITCT 2K2, since it was conducted in the same time season of the year.

PEM-Tropics B - The NASA GTE program has also conducted two missions to study the remote tropical Pacific region under contrasting chemical and transport conditions. The second of these, Pacific Exploratory Mission-Tropics B (PEM-Tropics B), was conducted in the spring (March-April 1999 [Raper et al., 2001]) and the first, PEM- Tropics A, in the late summer (August-September, 1996 [Hoell et al., 1999]). PEM-Tropics B, conducted in the same season as ITCT 2K2, included a number of flights over the tropical north Pacific where they observed a complex mix of pollution influence, including some from North America.

PHOBEA - The Photochemical Ozone Budget of the Eastern North Pacific (PHOBEA) program has made ground and aircraft based measurements of ozone, aerosols and precursors along the northwest U.S. Pacific coast [Jaffe et al., 2001]. These measurements are beginning to establish a multi-year record of anthropogenic influence in this region.

TRACE-P - The NASA GTE program recently completed a third field study in the West Pacific region: the Transport and Chemical Evolution over the Pacific (TRACE-P). It took place in March-April 2001. The objectives of TRACE-P are: (1) to better understand and quantify the export of environmentally important gases and aerosols, and their precursors, from the Asian continent; and (2) to better understand the processes controlling the chemical evolution of the Asian outflow over the western Pacific.

ACE-Asia - IGAC has planned a series of Aerosol Characterization Experiments (ACE) that integrate in-situ measurements, satellite observations, and models to reduce the uncertainty in calculations of the climate forcing due to aerosol particles. ACE-Asia (http://saga.pmel.noaa.gov/aceasia/), is the fourth in this series of experiments. One component of this study was an intensive field study designed to quantify the spatial and vertical distribution of aerosol properties, the processes controlling their formation, evolution and fate, and the column integrated clear-sky radiative effect of the aerosol (conducted in April-May, 2001).

BIBLE - The Biomass Burning and Lightning Experiment (BIBLE) Phase C, was conducted by the Japanese Earth Observation Research Center (EORC), National Space Development Agency of Japan (NASDA) in the Western Pacific during December 2000 (IGACtivities Newsletter No. 20, March 2000). The measurements provide data supplemental to the TRACE-P mission. The goal of BIBLE is to study tropospheric chemistry (natural and anthropogenic processes) in the tropical Asia/Pacific region. Measurements of ozone, ozone precursors and other photochemical quantities were made.

PEACE - The Pacific Exploration of Asian Continental Emission (PEACE) mission, also conducted by EORC/NASDA, will provide data complementary to TRACE-P. PEACE will make measurements of the seasonal excursion of the continental outflow from Asia. PEACE-A, to be conducted in January 2002, will provide an evaluation of the ozone budget at 20-45°N in winter. PEACE-B will be conducted in early May 2002, concurrently with ITCT 2K2. Ozone levels in the lower troposphere reach maximum in April-May in East Asia. Measurements of

ozone and its precursors in this time period will greatly contribute to an improved understanding of chemical processes causing spring ozone maximum.

III. ITCT 2K2 Goals

A. Characterize the chemical composition of the air masses coming ashore at the U.S. West Coast, and determine the relation to the sources and sinks of ozone and aerosols.

B. Explore the composition of these air masses as they are transported inland, and investigate the alteration in composition associated with the addition of emissions from U.S. West Coast sources.

IV. Specific ITCT 2K2 Science Questions:

The ITCT 2K2 Study is primarily an exploratory mission. These specific science questions are meant to give a general framework for mission planning. Answering them should be possible in the context of one intensive field program, and will be a first step toward answering the more general science questions discussed in the overall ITCT White Paper.

A. Is it possible to discover relationships between in situ measurements that allow the contribution to the composition associated with emission from each source to be identified and quantified? Will measurements of trace chemicals or aerosol chemical composition provide elemental and/or chemical speciation fingerprints for different source classes or source regions?

B. What mechanisms control the export of emissions from Asia, Mexico-Central America, and North America to the North Pacific Ocean? Preliminary analysis of TRACE-P results indicate that biomass burning emissions are primarily lofted by convection over south Asia, while anthropogenic emissions from east Asia are transported both aloft due to frontal passage and within boundary layer outflow following frontal passage.

C. What processes are inherent in these export mechanisms that significantly affect the ultimate fates of emissions exported from the various continental regions? Convection and some of the frontal lofting outflow likely involves more scrubbing of soluble species than boundary layer outflow, while the latter may be more influenced by dry deposition.

D. How does the composition of the anthropogenic emissions change during transport, and what is the effect upon ozone, aerosols and other photochemical products? How do ratios of aerosol composition, e.g. sulfate to nitrate or organic carbon to Ca, compare to those observed in the outflow regions during TRACE-P, ACE-Asia and PEACE-B? Do measures of photochemical aging – propane/ethane, acetylene/CO – provide useful indicators to follow evolution of primary emissions and/or aerosol parameters?

E. What are the magnitude and ultimate impact of emissions from commercial shipping and air transport in the Pacific? Can we carry out ship plume evolution studies to quantitatively determine the rates of transformation and removal of the emitted species? How do these rates compare with plume dispersal rates in the marine boundary layer?

F. Can we find evidence of influence from continental sources upwind of Asia (Europe, Tropical regions, or globally circulated North American emissions)? Do measures of photochemical aging – propane/ethane, acetylene/CO – provide useful indicators of source continent?

V. Facilities and Tools

A. Long-range transport forecasts and predictions; real-time data feeds

The Aeronomy Laboratory will acquire meteorological and satellite data feeds (GOES-West and GMS5 geostationary infrared and water vapor), and will assume responsibility for P3 flight planning. A variety of 3D chemical transport models from regional to hemisphere to global scale will be run in forecast mode to facilitate the flight planning. Forecasting activities include:

- Two three-dimensional tracer models used to forecast long-range transport and transformation of ozone and aerosols, their precursors and other trance chemicals. .
- Particle dispersion model that will utilize forecast wind fields to transport and disperse a passive tracer that is scaled to northern hemisphere CO emissions.

It is planned that each model will make forecasts available to the mission coordinators through their web sites; it will be a high priority to have a spokesperson for each forecast to be in the field to interact with mission coordinators.

B. NOAA WP3 Aircraft

The NOAA WP-3D aircraft will deploy a wide array of instrumentation for the in situ measurement of gaseous and aerosol parameters plus radiation and remote aerosol sensing by LIDAR. It will operate from Monterey CA (Figure 1). Appendix 1 lists the planned WP-3D instrumentation and Appendix 2 illustrates sample flight plans. 100 flight hours have been allocated to the program. Given that about 20 will be used in transit flights between Tampa and Monterey, there will be approximately 80 field flight hours. We expect this to correspond roughly to 10 to 14 research flights of 6 to 8 hours duration. The aircraft is currently scheduled to transit from Tampa to Monterey on April 19 and to remain in Monterey until approximately May 22.

The primary goals of the aircraft are to:

- Characterize chemical composition of lower troposphere with the aim of understanding processes that determine oxidant and aerosol loading that enter Western U.S.
- Investigate the influence of added North American emissions from the coastal regions as air masses are advected further inland.
- Investigate the processing of primary pollutants in ship plumes in the marine boundary layer.

C. Trinidad Head Ground Site

Trinidad Head is located just north of Eureka, CA (Figure 1.) This ground site is intended to:

- Characterize chemical composition of marine boundary layer at the U.S. West Coast.
- Provide linkage between composition measurements and radiative properties of the aerosols.
- Provide intercomparison opportunities, both between co-located surface instruments and between surface and aircraft instruments during aircraft flybys.

The Advanced GAGE (AGAGE) Program (http://cdiac.esd.ornl.gov/ndps/db1001.html), Ralph Keeling's group at Scripps Institution of Oceanography and the NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) currently conduct measurements this site. AGAGE measure CH_4, N_2O and a variety of halocarbons every ≈40 min. NOAA CMDL

currently launch weekly ozone sondes and plan to collect weekly flasks that are analyzed for a variety of tracer species including CO, CH_4, N_2O and 23 halocarbons.

For ITCT 2K2 these current measurements will be augmented with a variety of ozone and aerosol relevant species. Measurements that are planned include:

- VOCs-GC/FID/MS, $NO_{x,y}$, CO, CO_2, H_2, O_3, solar irradiance, met param
- Size resolved aerosol chemistry, Size resolved aerosol total mass, Aerosol light scattering and backscattering (450, 550, 700 nm), Aerosol light absorption (565 nm), Total aerosol number, Aerosol number size distributions (5-10000 nm), Aerosol optical depth (380, 440, 500, 675, 870 nm), Surface meteorological data, O_3, SO_2, Rn
- Aerodyne - Aerosol Mass Spectrometer
- Fast-response measurement of aerosol ionic chemical composition (PILS).
- DRUM Sampler

Tentative time schedule:

April 15 - Date for arrival of instruments
April 22 - Instruments all up and running
May 22 - End of intensive

D. PHOBEA2

The PHOBEA program will conduct a second field program in concert with ITCT 2K2. This program includes ground based and aircraft measurements. CO, O_3, NO_y, PAN, Aerosol light scattering and absorption, Rn, Hg, 24 hr aerosol loading (2 size cuts) and 24 hr semi-volatile organic compounds will be measured at Cheeka Peak Observatory, WA (Figure 1.) A small aircraft will collect vertical profiles of CO, O_3, non-methane hydrocarbons, and aerosol light scattering. Kotchenruther et al. [2001] illustrate a typical flight track.

E. Wind profiler network

The NOAA ETL Laboratory currently has a network of 915-MHz radar wind profilers deployed in California. We hope to fund the operation of four of them through the ITCT 2K2 study period. They are at northern coastal locations: Bodega Bay, CA (300 km south of Trinidad Head), Eureka (30 km south of Trinidad Head), Newport, OR (400 km north of Trinidad Head), and Cape Flattery, WA (near Cheeka Peak).

F. Mauna Loa and Barrow Observatories

The NOAA Climate Monitoring and Diagnostics Laboratory (CMDL) operates long-term atmospheric observatories at Pt. Barrow, Alaska and Mauna Loa, Hawaii. Presently, the measurements are aimed at climate forcing and ozone-depleting agents such as CO_2, CH_4, O_3, N_2O, CFC's, aerosols and solar incoming and upwelling radiation. In addition, persistent organic pollutants and mercury have been added recently at Barrow. Measurements at the observatories will be enhanced as part of the ITCT Program. During Spring 2001, a pilot intensive was held at Mauna Loa (Springtime TRansport of Effluents from Asia to Mauna Loa – STREAM) during which additional measurements such as continuous CO, persistent organic pollutants, mercury, nitrogen oxides, aerosol chemistry, and hydrocarbons (Proton Transfer Mass Spectrometry and GC-MS instruments) were conducted. The results of this pilot campaign will be used to evaluate possible observatory participation during ICT 2K2.

G. Post-mission analysis

The same 3D chemical transport models used in mission planning will be utilized for post-mission analysis. Additional post-mission analysis approaches will also be utilized including large eddy simulation of the role of stratocumulus clouds in the marine environment.

H. Emission inventory development

Current emission inventories need significant improvements, especially for Asia, Mexico and Central America. During ITCT 2K2, the focus will be upon further development of the Asian emission inventories.

VI. Coordination with Other Programs

A. ACE-Asia and TRACE-P

These two missions examined Asian outflow in the western North Pacific in the spring of 2001. Hence they have investigated one major continental source of ozone and aerosols. This source is expected to be upwind of the ITCT 2K2 study region much of the time. We will carefully follow their analysis and interpretation of the observations that were collected.

B. PEACE-B

The Pacific Exploration of Asian Continental Emission (PEACE) mission is being conducted by the Earth Observation Research Center, National Space Development Agency of Japan (EORC/NASDA) in the western North Pacific. The second phase of this project (PEACE-B) will take place during the ITCT 2K2 study period. We plan to closely coordinate with this study in two regards:

- The forecast models that we will rely upon for flight planning, we hope to make available to the PEACE-B flight coordinators and to compare their observations with the forecasts in near real time to provide a check on the reliability of the forecasts.
- We will seek opportunities to sample air masses in the eastern North Pacific that PEACE-B sampled in the western North Pacific. Such trans-Pacific, quasi-Lagrangian studies may provide opportunities to more definitively investigate photochemical transformations of air masses during intercontinental transport.

The primary research platform of PEACE-B is the Japanese Gulfstream II aircraft. Appendix 3 lists the G-II instrumentation and Appendix 4 illustrates the tentative flight route. Tentative dates for research flights are April 22 - April 28, May 5 - May 18, 2002. Currently we are discussing collaboration details including coordination of flight schedules, exchange of model forecasts, field data, and final data, and conducting a joint data workshop.

VII. ITCT 2K2 Operational Schedule

A. Model Forecasts will be made by several groups. They will be accessible on web sites for ITCT 2K2 and PEACE-B participants. Each PI will archive forecasts to compare with post-analysis.

B. First-look data - These data are for forecast evaluation and planning purposes only. They will be held confidentially. A password protected ftp site has been established as a data repository. Access will be limited to the ITCT 2K2 and PEACE-B science teams. Posting

data for a defined set of species and from intercomparison periods will have highest priority. These data will include:

- **Continuous aircraft measurements** - Posted within 24 hr. of end of flight - will include CO, O_3, NOy, Aerosol number density (> ≈0.4μ) and CN when available.
- **Continuous ground measurements** - Posted within 48 hr for selected species of particular interest and more extensive postings for intensive periods

C. Preliminary data - These data are for preliminary analysis prior to the data workshop

- Posted by August 15, 2002 on password protected ftp site.
- NASA GTE or NASA Ames Format will be used. Tools developed for TOPSE may be used.
- First data merges for each aircraft and each ground site will be completed by August 22 - Updated merges with routine notification will follow.
- Model products (concentrations along flight tracks, time series) will be included in this archive.
- Final aircraft data will be made available to study participants 90 days after completion of field study

D. Final Data Archive – We will use the NASA/NARSTO archives.

E. First Data Workshop – To be held at University of Washington-Bothell in late October or early November, 2002.

F. Data Workshop with PEACE-B – Will be combined with our first data workshop in Washington if possible.

G. Public Data Release – Scheduled for June 1, 2003

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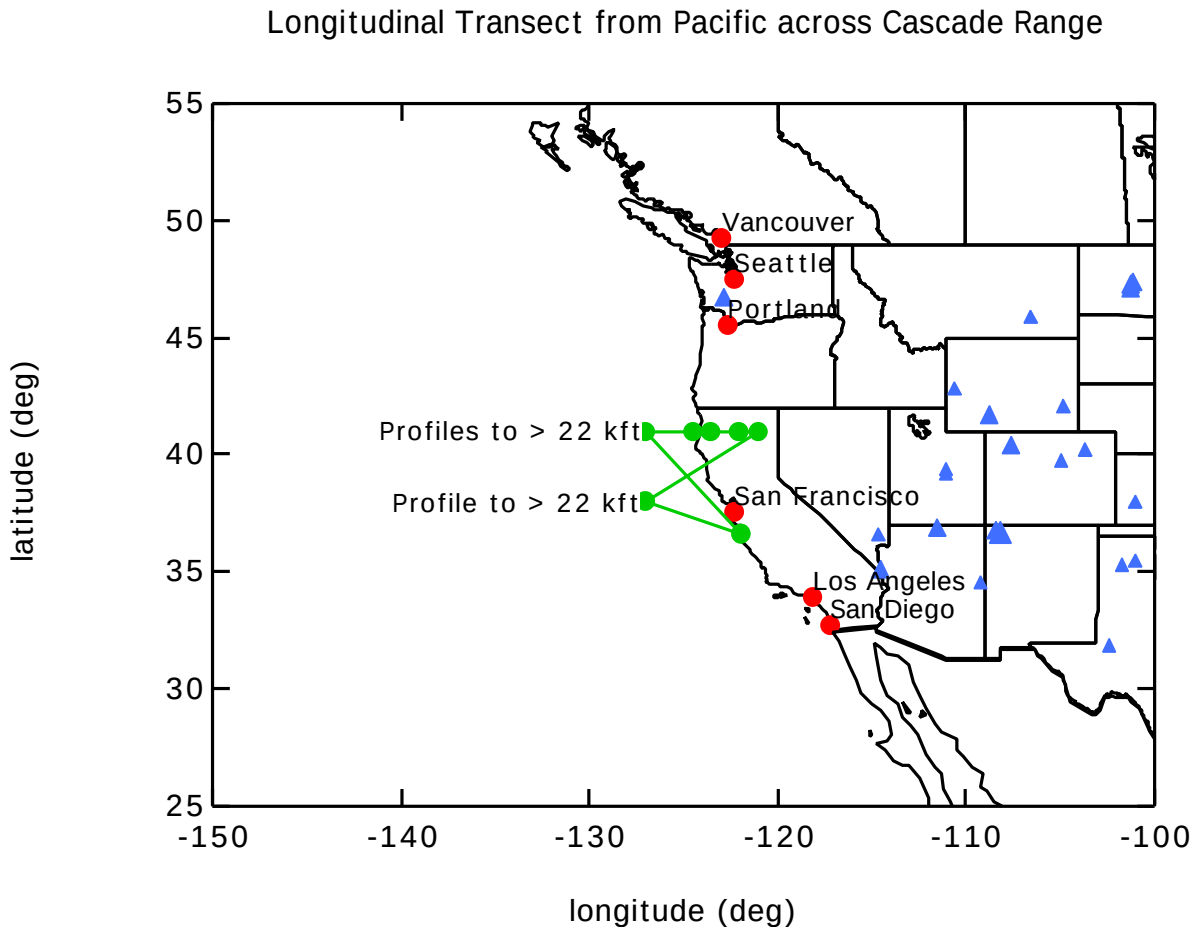
Appendix 1. ITCT 2002: NOAA WP-3D INSTRUMENTATION LIST

Parameter	Time Resolution	Method	Det. Limit	Principal Imvestigator
Ozone (O3)	10 seconds	UV Absorption	1 ppbv	D. Parrish, J. Holloway; NOAA-AL
Ozone (O3)	< 1 second	NO/O3 Chemiluminescence	0.2 ppbv	D. Parrish, J. Holloway; NOAA-AL
Nitric Oxide (NO)	0.7 second	NO/O3 Chemiluminescence	20 pptv	T. Ryerson, D. Nicks; NOAA-AL
Nitrogen Dioxide (NO2)	0.7 second	Photolysis NO/O3 Chemilumin.	100 pptv	T. Ryerson, D. Nicks; NOAA-AL
Total Nitrogen Oxides (NOy)	1 second	Au Converter. NO/O3 Chemilum.	100 pptv	T. Ryerson, D. Nicks; NOAA-AL
Sulphur Dioxide (SO2)		Denuder Difference with S/O3 Chemiluminescence		T. Ryerson, D. Nicks; NOAA-AL
Nitric Acid (HNO_3)	1 second	Chemical Ionization Mass Spectrometer (CIMS)	100 pptv	A. Neuman, J. Nowak; NOAA-AL
Ammonia		CIMS		A. Neuman, J. Nowak; NOAA-AL
In-situ VOCs	depends on choice and # of species	Proton Transfer Reaction Mass Spectrometer	depend s on species	Joost de Gouw, C. Warneke NOAA-AL
Canister VOCs	< 1 min. at selected times	Canister Sampling, GC/FID, GCMS	‹ 10 pptv	E. Atlas, S. Donnelly, S. Schauffler; NCAR-ACD
Carbon Dioxide (CO_2)	0.1 second	NDIR	60 ppbv	D. Parrish, J. Holloway; NOAA-AL
Sulfur Dioxide (SO_2)	2 seconds	UV Pulsed Fluorescence	1 ppbv	D. Parrish, J. Holloway; NOAA-AL
Carbon Monoxide (CO)	1 second	VUV Resonance Fluorescence	1 ppbv	D. Parrish, J. Holloway; NOAA-AL
Hydroxyl Radical (OH)		CIMS		Greg Huey, Dave Tanner, Georgia Tech.
H_2SO_4		CIMS		Greg Huey, Dave Tanner, Georgia Tech.
PAN	every 2.5 min	Dir. Injection., GC/ECD	5 pptv	F. Flocke, NCAR-ACD J. Roberts; NOAA-AL
PPN	every 2.5 min	Dir. Injection., GC/ECD	5 pptv	F. Flocke, NCAR-ACD J. Roberts; NOAA-AL
MPAN	every 2.5 min	Dir. Injection., GC/ECD	5 pptv	F. Flocke, NCAR-ACD J. Roberts; NOAA-AL

PiBN, APAN	every 2.5 min	Dir. Injection., GC/ECD	10 pptv	F. Flocke, NCAR-ACD J. Roberts; NOAA-AL
Aerosol Single Particle Compostion		Particle Analysis by Laser Mass Spectrometry (PALMS)		Dan Murphy, Dave Thompson, NOAA-AL
Aerosol Bulk Ionic Compostion		Particle Into Liquid Sampling (PILS)		Rodney Weber, Georgia Tech.
Small Aerosol Concentration	1 sec, usually integrated to 10 sec	Nucleation Mode Aerosol Size Spectrometer	5 - 60 nm	C. Brock; NOAA-AL C. Wilson; U. of Denver
Aerosol Size Distribution	1 sec, usually integrated to 10 sec	Focussed Cavity Aerosol Spectrometer	0.07 - 1.2 µm	C. Brock; NOAA-AL C. Wilson; U. of Denver
Large Aerosol Concentration with LTI	1 sec, usually integrated to 10 sec	White Light Scattering (Climet & LasAir)	0.5 - 10 µm	C. Brock, Dan Murphy; NOAA-AL C. Wilson; U. of Denver
Vertical Aerosol Distribution		UV Backscatter LIDAR		M. Hardesty et al.; NOAA-ETL
Photolytic Flux	1 second	280-400 nm spectrally resolved Radiometer, Zenith & Nadir		R. Jakoubek; NOAA-AL
Broadband Radiation	1 second	Pyrgeometer	3.5 - 50 µm	NOAA-AOC
Broadband Radiation	1 second	Pyranometer	0.28 - 2.8 µm	NOAA-AOC
Water Vapor (H2O)		Tunable Diode Laser		Eric Richard, Ken Kelly, NOAA-AL
Water Vapor (H2O)	< 1 second	Lyman Alpha Absorption		NOAA-AOC
Air Temperature	< 1 second	Platinum Resistor	± 0.5 °C	NOAA-AOC
Dewpoint/ Frostpoint	≤ 3 seconds	Dew/Frostpoint Hygrometer	-75 - 50 °C	NOAA-AOC
Altitude	1 second	Barometric, Radar, GPS		NOAA-AOC
Position	1 second	GPS, INE		NOAA-AOC

Appendix 2. Sample WP-3D Flight Plans



Characterize trace gas profiles along a west to east from Pacific across coastal mountains to dry continental area.

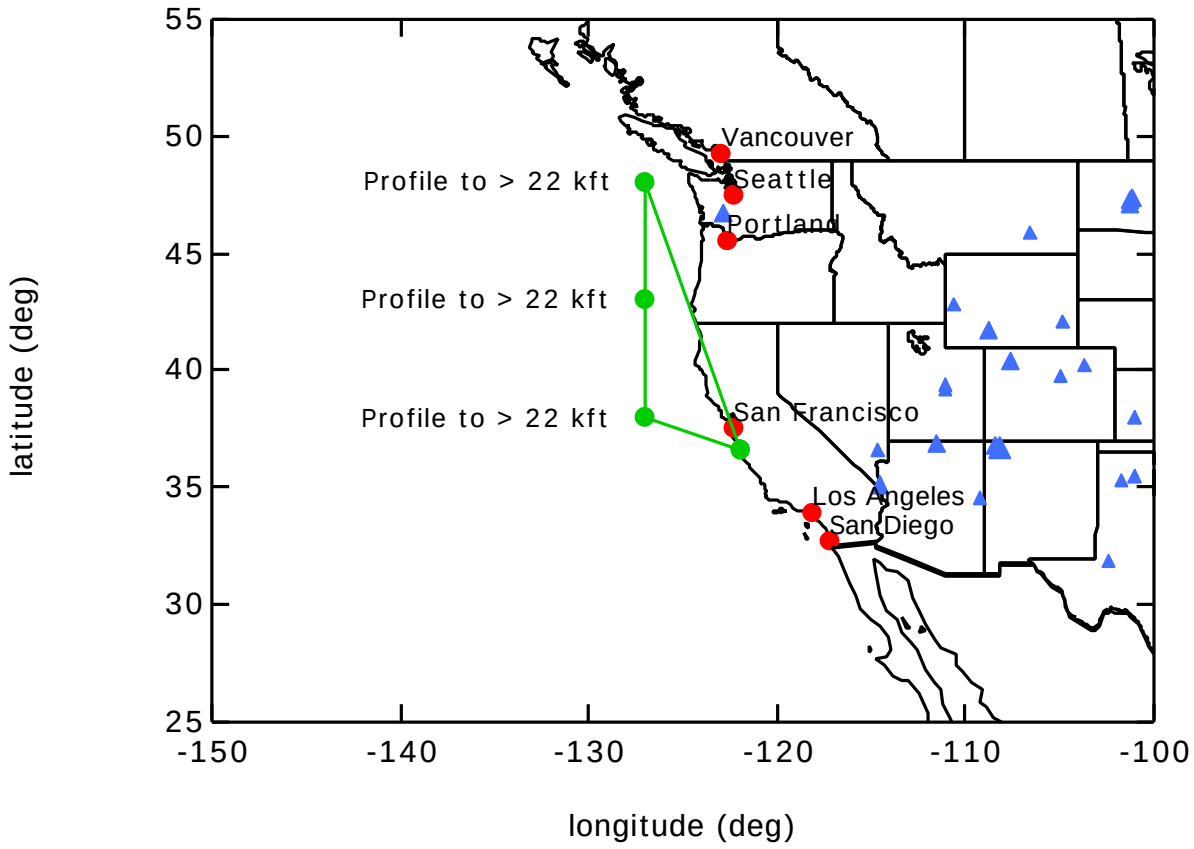
During transit between profiles study layers that were identified in profile in more detail. Return to altitude of prominent layer, define vertical extend and potential altitude gradient in dolphin flight pattern.
Estimated flight time is about 5.5 hours, constant altitude legs to better characterization of trace gas and aerosol distribution will be added.

Longitudinal Transects are planned for :
Northern Ca : Less inhabitated, signature of natural VOCs in aerosols, mineral aerosols over desert.

Latitude of Pt. Arena (39 N) connects to Blodgett Forest, Sacramento study, Lake Tahoe

Latitude of Monterey (36.5 N) : landuse contrast : marine, agricultural, dry Owens Lake and Death Valley.

Latitudinal Transect along the West Coast



Characterize trace gas profiles along a north to south gradient along the west coast.

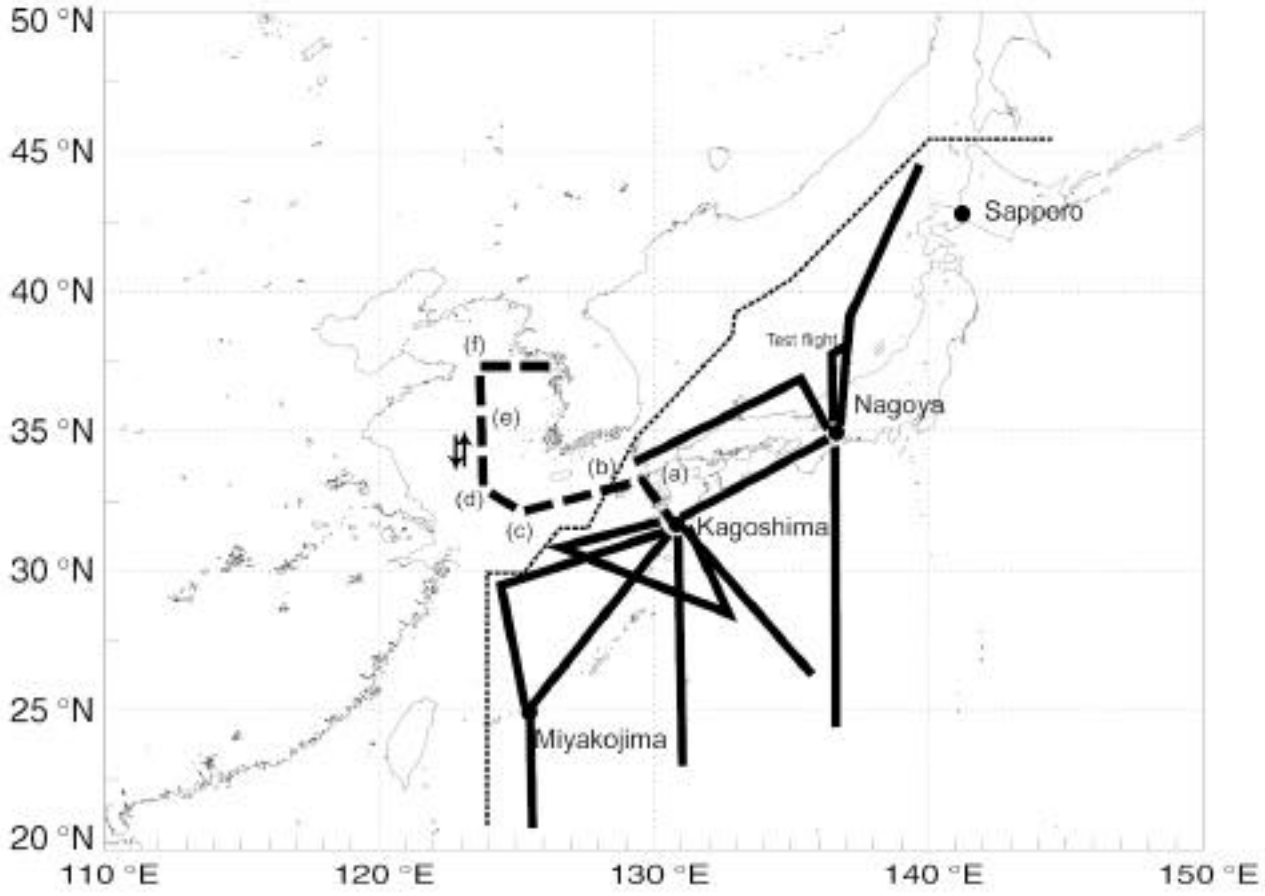
During transit between profiles study layers that were identified in profile in more detail. Return to altitude of prominent layer, define vertical extend and potential altitude gradient in dolphin flight pattern.

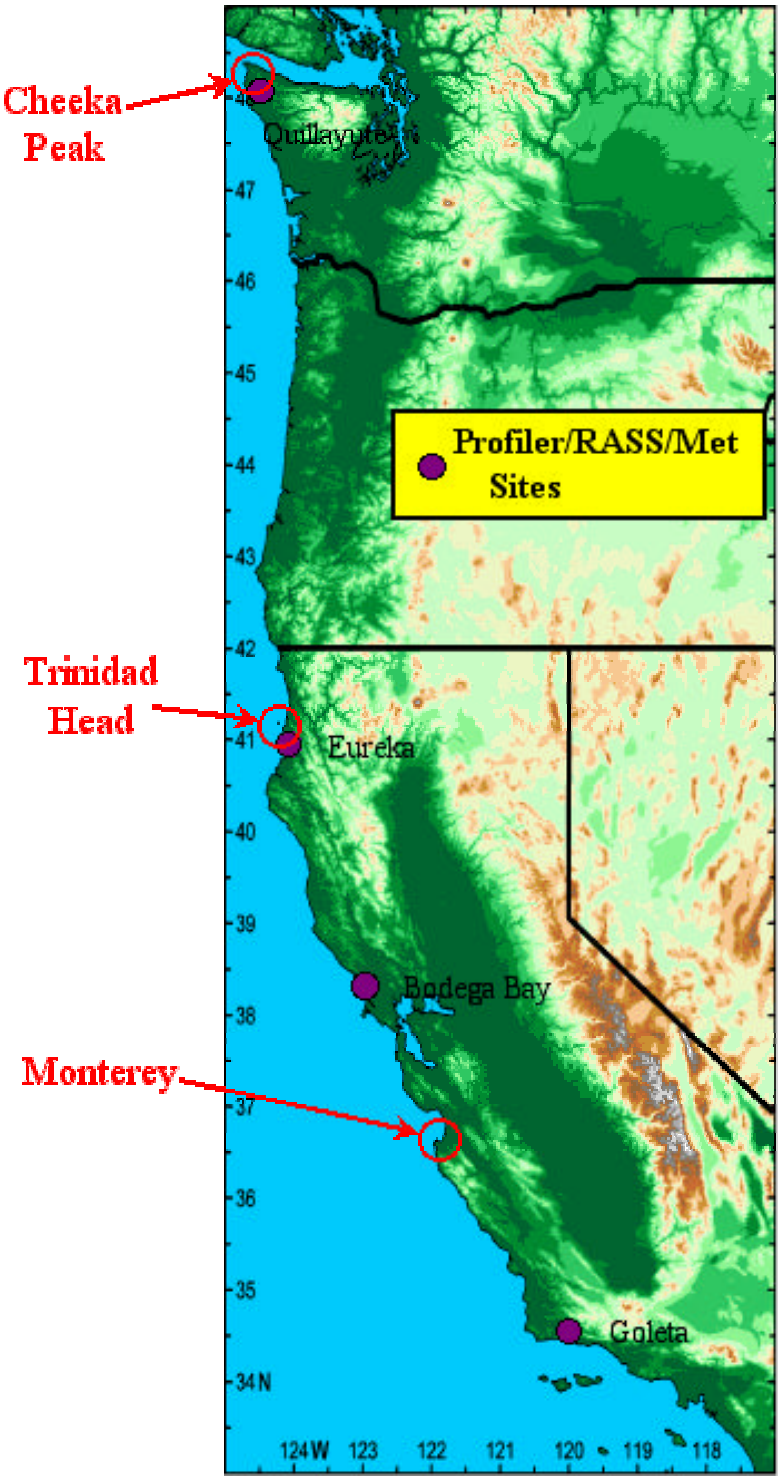
Estimated flight time is about 8.5 hours, thus giving an illustration of the potential latitudinal coverage of the P3.

Appendix 3. PEACE-B Gulfstream II Instrumentation List

Species/items	Techniques	sampling time interval
O_3	UV absorption	1 s
NO, NO_2, NO_y	Chemiluminescence	1 s/10s/1s
CO	Resonance fluorescence	1 s
CO_2	IR absorption	1 s
H_2O	Dew/frost point hygrometer	1 s
NMHCs (C_2-C_{10})	Grab sample/GC	5 min
Halocarbons (C_2-C_{10})	Grab sample/GC	5 min
Alkylnitrates (C_1-C_4)	Grab sample/GC	5 min
Aerosol size distribution	Multiple-Angle Aerosol Spectrometer Probe (MASP)	1 s
Condensation nuclei (CN)	Butanol CN countor	1 s
Black carbon	Aethalometer	10s
J(NO2)	Filter radiometer	1 s
$J(O^1D)$	Filter radiometer	1 s
SO_2	Pulsed UV Fluorescence	20s
SO_2	Backscatter UV/DOAS	1s

Appendix 4: Tentative PEACE-B Gulfstream II Flight route




Cheeka Peak
Trinidad Head
Monterey
Quillayute
Profiler/RASS/Met Sites
Eureka
Bodega Bay
Goleta
47
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34 N
124 W
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Figure 1