OMI Validation Opportunities from the AVE January 2006 Validation Campaign

San Jose Airport, Costa Rica

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http://cloud1.arc.nasa.gov/ave-costarica2/

1 Introduction

This document serves to present the OMI validation opportunities as identified for the AVE January 2006 airborne validation campaign, aimed to perform validation measurements for the NASA EOS Aura satellite. Such opportunities are derived from the intended payload, the geolocation of the deployment and the aircraft involved. General considerations on correlative data needs from airborne validation campaign for the validation of the data products of the OMI instrument aboard Aura are presented in document PL-OMIE-KNMI-535 [1]. General considerations on correlative data needs for OMI validation are presented in document TN-OMIE-KNMI-469 [2]. The validation requirements as discussed in the White Paper on OMI Science Goals and Validation Needs [3] update those listed in the Aura Validation Plan and highlight the validation capabilities that need development. Validation opportunities as identified for the previous AVE campaigns can be found in references [5 - 7]. The most recent write-up of general OMI validation priorities can be found in [8].

2 The January 2006 AVE Campaign

The January 2005 AVE Campaign will take place from San Jose Airport, Costa Rica, from 17 January - 09 February 2006. The campaign has been named CR-AVE, for Costa Rica Aura Validation Experiment. From this location the NASA owned WB-57 aircraft is operated which will carry an impressive amount of instrumentation on 5-6 hour flights up to 18 km altitude over more than 4000 km range. Please visit the dedicated campaign website: http://cloud1.arc.nasa.gov/ave-costarica2/ for more up to date information.

2.1 Payload instruments

The suite of instruments that will be on board of the WB-57 research aircraft during the January 2006 CR-AVE flights is presented in Table 1. Instrument details and payload location can be found in Chapter 5 of this document. From the payload overview it is clear that CR-AVE focuses on the water household of the upper troposphere – lower stratosphere (UTLS). Particularly the large set of in-situ instruments aimed at water and water vapor proves this point. However, there will also be substantial set of remote sensors flown, providing vertical column, and vertical profile data on atmospheric trace gases, atmospheric pollutants, and aerosols. In Table 1 the instruments that will provide OMI validation with interesting correlative data are color coded.

2.2 Campaign Schedule

The campaign schedule is depicted in Figure 1. During the deployment in Costa Rica, the WB-57 will fly two different payloads named “In situ” and “Remote”. The names denote the emphasis on the type of instruments per payload although there are several instruments that will fly on both payloads. The OMI validation team expects that with the remote sensor payload many long range straight and level flight will be performed to cover as much of the Aura ground track as possible. The OMI validation team also expects that with the in-situ payload the emphasis will be on characterizing the vertical distribution and transport of atmospheric species, with emphasis on the UT-LS region of the atmosphere.

Being a nadir remote sensor aboard EOS-Aura, the validation of OMI data products will benefit most from the long range “straight and level” flights with the remote sensors aboard the WB-57 providing correlative data across and along track on column integrated atmospheric trace gases and aerosols. Covering as much surface area as possible of the OMI swath enhances the statistics of comparisons and the amount of variability encountered. However, OMI validation will also benefit from in-situ measurements performed at various altitudes in the atmosphere, particularly measurements in the planetary boundary layer of atmospheric pollutants and aerosols. Furthermore, OMI retrievals will benefit from the recordings of the vertical profiles of atmospheric pollutants and aerosols. Although current retrieval schemes employ advanced profile climatologies, these profiles remain to be assumptions whereas the true state of the atmosphere might differ too much for the retrieved OMI data products to be sufficiently accurate.

	Instrument	Product
Remote Sensing	ACAM	O3 (ozone), NO2 (nitrous oxide), SO2 (sulphur dioxide), BrO (bromine oxide), CHCO (formaldehyde) and aerosols
	CAFS	UV/VIS actinic flux, O3 (ozone) column
	COSSIR	cirrus cloud parameters
	CPL	cloud height, cloud fraction
	CRS	reflectivity of and Doppler velocity in clouds
	MTP	temperature profiles
	Scanning-HIS	upwelling IR radiance, O3 (ozone) profile
In situ	2DS	aerosol and cloud particles properties
	ALIAS	HCl, (hydrogen chloride) NO2 (nitrogen dioxide), CH4 (methane), N2O (di-nitrogen oxide), CO (carbon monoxide), water isotopes
	Argus	CO (carbon monoxide), CH_4 (methane), N_2O (Nitrous Oxide)
	CAPS	aerosol and cloud particles properties
	CIMS	HNO3 (Nitric Acid), HCL (hydrochloric acid)
	CO2	CO2 (carbon dioxide)
	CPI	cloud particle images
	CSI	cloud particle properties
	Frost Point	in situ air humidity
	FCAS	aerosols
	H2O	water vapor
	ICOS	water isotopes
	JLH	atmospheric H2O (water) vapor
	MACS	aerosols
	MMS	navigation
	NMASS	aerosols
	O3/CH4	O3 (ozone), CH4 (methane)
	PALMS	
	PANTHER	CH3COCH3 (acetone), PAN, H2, CH4 (methane), CO (carbon monoxide), N2O (nitrous oxide), SF6 (sulfur hexafluoride), CFC-11, CFC-12, halon-1211
	PT	Ambient pressure (p) and temperature (T)
	SP2	
	WAS	CFC

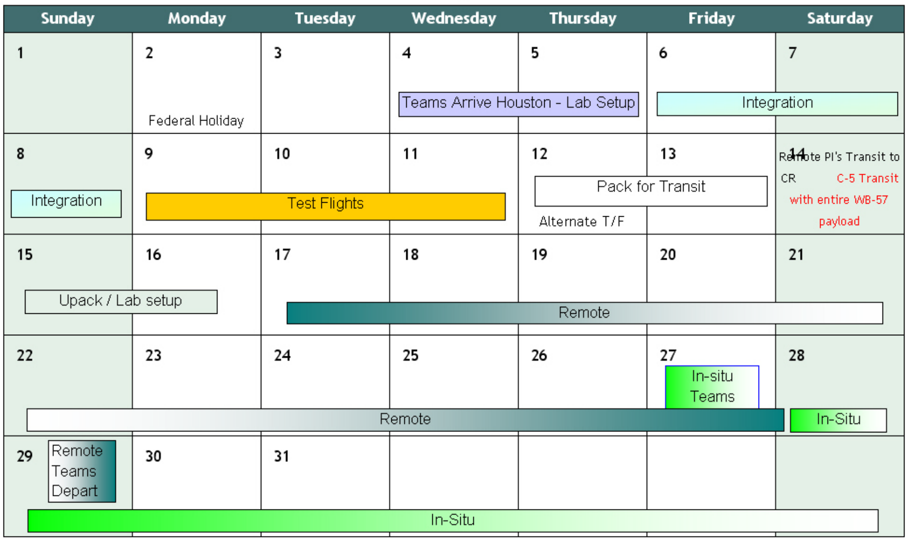
Table 1: Tentative WB-57 payload for the June 2005 AVE campaign (of interest to OMI.)

3 Validation opportunities

At the time of writing, nitrogen dioxide (NO2) is the species of highest interest in the atmospheric science community as an indicator of anthropogenic activity, namely combustion processes (industry, transport), and a key component of air pollution. Under polluted conditions, the tropospheric contribution to the total NO2 column may be comparable to the stratospheric contribution. The tropospheric NO2 column is subject to large spatial and temporal variability, particularly near sources such as power plants, cities, and highways. In addition, accurate knowledge of the NO2 altitude distribution is needed for accurate total column retrievals. For an accurate validation of OMI total NO2 column under polluted conditions, the spatial variability as well as the altitude distribution of NO2 should be sufficiently measured.

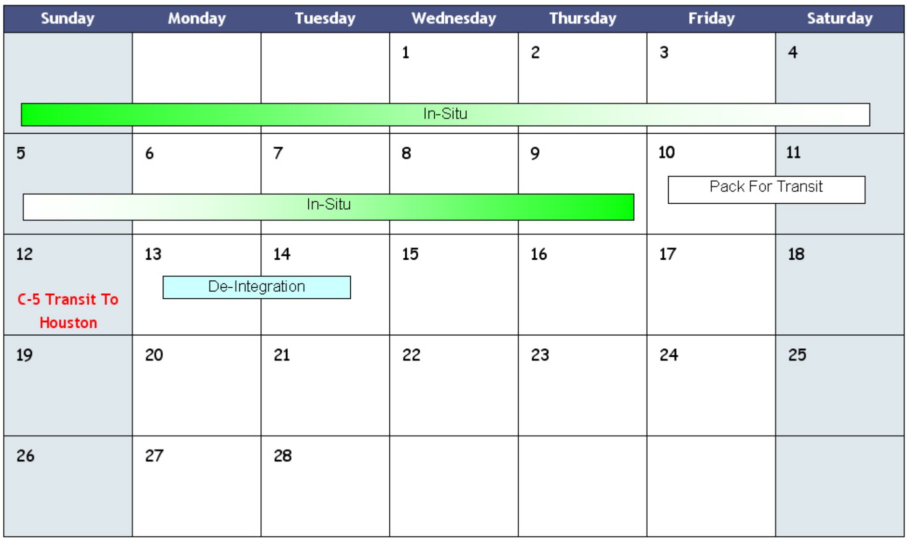
There are many sources of correlative data available for total ozone column validation. Ground based Brewer and Dobson instruments suffice for validation of total ozone column under unpolluted conditions. However, validation needs remain for the tropospheric part of the total column, and for total ozone column and tropospheric ozone column under polluted conditions.

January 2006



Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2 Federal Holiday	3	4 Teams Arrive Houston - Lab Setup	5	6 Integration	7
8 Integration	9 Test Flights	10	11	12 Pack for Transit Alternate T/F	13	14 Remote PI's Transit to CR C-5 Transit with entire WB-57 payload
15 Upack / Lab setup	16	17 Remote	18	19	20	21
22 Remote	23	24	25	26	27 In-situ Teams	28 In-Situ
29 Remote Teams Depart In-Situ	30	31				

February 2006



Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
In-Situ			1	2	3	4
5 In-Situ	6	7	8	9	10 Pack For Transit	11
12 C-5 Transit To Houston	13 De-Integration	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28				

Figure 1: CR-AVE Campaign schedule. Note that during this deployment there will be a separation between flying a remote sensing payload and an in situ payload, although several instruments will be aboard both payloads. Details can be found in Chapter 5 of this document.

It has been well recognized that aerosols play an important role in radiative forcing of the Earth atmosphere. However, the sign and magnitude of the forcing depends on the type of aerosols, their size distributions, and the altitude at which they reside in the atmosphere. Aerosols influence the retrieval of atmospheric trace gas species from satellite remote sensing observations. Uncertainties in aerosol abundances influence the (un)certainty of determining the airmass optically sampled and hence the vertical column amounts of atmospheric trace gases. There is a strong need for expanding aerosol observations towards covering more physical and scattering properties of the aerosol material, such as chemical type and physical size of aerosol material and their distributions. With this information the radiative transfer through the atmosphere during episodes of high aerosol loading can be better understood and trace gas retrievals can be made more accurate.

3.1 Nitrogen dioxide tropospheric column observations

The Airborne Compact Atmospheric Mapper (ACAM) spectrometer system will fly for the second time aboard the WB-57. System details can be found in chapter 4, section 5.2.1. If ACAM performs as expected, AVE flights with the ACAM spectrometer can provide estimates of the tropospheric NO2 column when large amounts of tropospheric NO2 are present. Performing such flights over pristine regions, such as the Pacific Ocean far away from localized sources and their outflow, provides us with a reference spectrum and a background estimate of the tropospheric NO2 column. Performing flights over the San Jose region and the Costa Rica coastal region should provide us with a map of the spatial variability of NO2 in polluted regions near cities and factories. Although at first the measurements may not be quantitative, even a qualitative map will be exciting to compare with maps of OMI tropospheric NO2 column observations. Given the high spatial resolution of ACAM, such flights can provide information on the spatial variability of NO2 at scales smaller than the OMI pixels. Also, if there is boundary layer SO2, it should be possible to measure that.

Flight Requirements:
- Fly along track over regions of low and high air pollution
- Fly near the tropopause for a clear separation of troposphere and stratosphere
- Fly at high altitudes to capture most of the OMI swath as possible.
- Capture the OMI swath near nadir.
- Capture the location of ground based Dobson and Brewer instruments

Opportunities:
- 0 High altitude overpasses over regions of low air pollution (Pacific Ocean reference)
- 0 High altitude overpasses over regions of high air pollution (San Jose city, industry, or power plants)
- 0 Moderate altitude overpasses over regions of high air pollution (San Jose city, industry, or power plants)

3.2 Atmospheric pollution

The payload for the Costa Rica AVE January ‘06 campaign contains instruments that together could provide a suite of measurements of atmospheric pollution. The CAFS instrument is able to measure the column amounts of ozone above and below the aircraft. The ACAM spectrometers are likely to provide us with column amounts of O3, NO2, and SO2 below the aircraft. The in-situ instruments FCASS and NMASS measure aerosols size distributions and chemical composition in the air mass sampled by the aircraft. ALIAS measures NO2 and there are several instruments characterizing clouds and aerosol particles along the way.

When cruising near the tropopause, the remote sensing instruments will yield estimates of tropospheric and stratospheric abundances. Crenellation flights down into the boundary layer offer the opportunity of sampling large parts of the troposphere and could in principle render limited information of profiles. Spiral flights with the in-situ payload could resolve the atmospheric pollutants and aerosols.

Flight Requirements:
- Fly along track over regions of low and high air pollution
- Fly near the tropopause for a clear separation of troposphere and stratosphere
- Perform crenellation flights down into the boundary layer particularly for aerosols sampling
- Perform spiral flights down into the boundary layer particularly for atmospheric pollutants sampling

Opportunities:
- 0 Spatial variability of atmospheric pollution over sources and outflow regions
- 0 Quantifying atmospheric pollution over sources and outflow regions
- 0 Aerosol physical properties and their distributions
- 0 Vertical profiles of atmospheric pollutants and aerosols by various instruments

3.3 Urban Scales

An interesting scientific question regarding OMI is whether the instrument is capable of measuring atmospheric pollution at urban scales. Such a capability offers the opportunity to pinpoint sources of pollution. Species involved are O3, NO2, SO2 and aerosols. For example, if there is a plume of highly polluted air that is roughly a kilometer wide and several OMI pixels long, ACAM will be able to capture the higher resolution details of the event and comparisons with OMI data will yield an estimate of the pinpointing capabilities of OMI. We could target a good coal burning power plant or heavy steel industry. A high altitude over flight of the San Jose region would let ACAM map it out.

Flight Requirements:

- Straight and level sampling of the San Jose region
- Focused sampling of industrial regions with point sources of pollution

Opportunities:

0 Flights over highly polluted regions with lots of ozone, NO2, SO2 and aerosols
0 Mapping the region with ACAM searching for point sources of pollution
0 Sampling of point sources of pollution with ACAM for comparisons with OMI (selected power plants)

3.4 Proof of instrument performance

During this campaign one needs to prove the suitability of the CAFS instrument for performing validation measurements of ozone partial columns. Analysis of the total ozone column data yielded by CAFS from the last three AVE campaigns shows that the performance of the CAFS instrument is not sufficient for use of the data for OMI validation. CAFS total ozone column shows a negative bias with respect to OMI total ozone column and adjusting the climatology to overcome this bias yields undesired tuning. Furthermore, the climatology will never be able to accurately represent the natural variability and the state of the atmosphere on the day of flight. The OMI team strongly suggests flying and analyzing the recordings of the lower hemisphere CAFS instrument as well as the standard upper hemisphere CAFS instrument.

The ACAM instrument flew aboard the WB-57 for the first time during the June 2005 AVE deployment. Although hampered by instrumental problems early in the campaign the instrument performed wonderfully well. However, analysis of the recorded data showed that retrieving sensible data from the recorded spectra was difficult, mainly due to the temperature instability of the instrument. Quantification of tropospheric NO2 column amounts and it variability has been not performed yet. The OMI team strongly suggests flying the ACAM instrument over regions of anthropogenic activity such as the San Jose city and the Pacific coastal regions to prove this capability.

4 Last year OMI observations over the Costa Rica region

With more than one year of OMI data at hand, the opportunity exists to explore the behavior and the composition of the atmosphere in the region as covered by the CR-AVE deployment by investigating the data recorded by OMI exactly one year ago. Given the identified OMI validation opportunities we limit the choice of OMI data products here to OMI RGB, OMI total ozone column, OMI total and tropospheric NO2 column.

OMI R(ed) G(reen) B(lue) images are distilled from the OMI VIS channel by narrow band integration of the Earth radiance intensity around carefully selected wavelengths in the OMI VIS channel and assigning histogram equaled red, green and blue color values, respectively. From these images one is able to recognize clouds and cloud patterns, open ocean, coast lines, deserts, ice sheets and pole caps, sun glint, dust storms and many more geophysical features. The image presented in Figure 2 reveals many of the mentioned features for the region of interest to the CR-AVE deployment. Coast lines are drawn following the 1993 CIA world map. Note the presence of large scale cloud structures and sun glint around the Yucatan peninsula.

In Figure 3 we show the total ozone field over the region of interest. At these latitudes and in this time of year the total ozone field shows little detail and little variability from day to day. The challenge here is to measure above high clouds, above open ocean and over land-sea transitions. The challenge is also to measure both stratospheric as well as tropospheric partial ozone column and come to agreement with OMI.

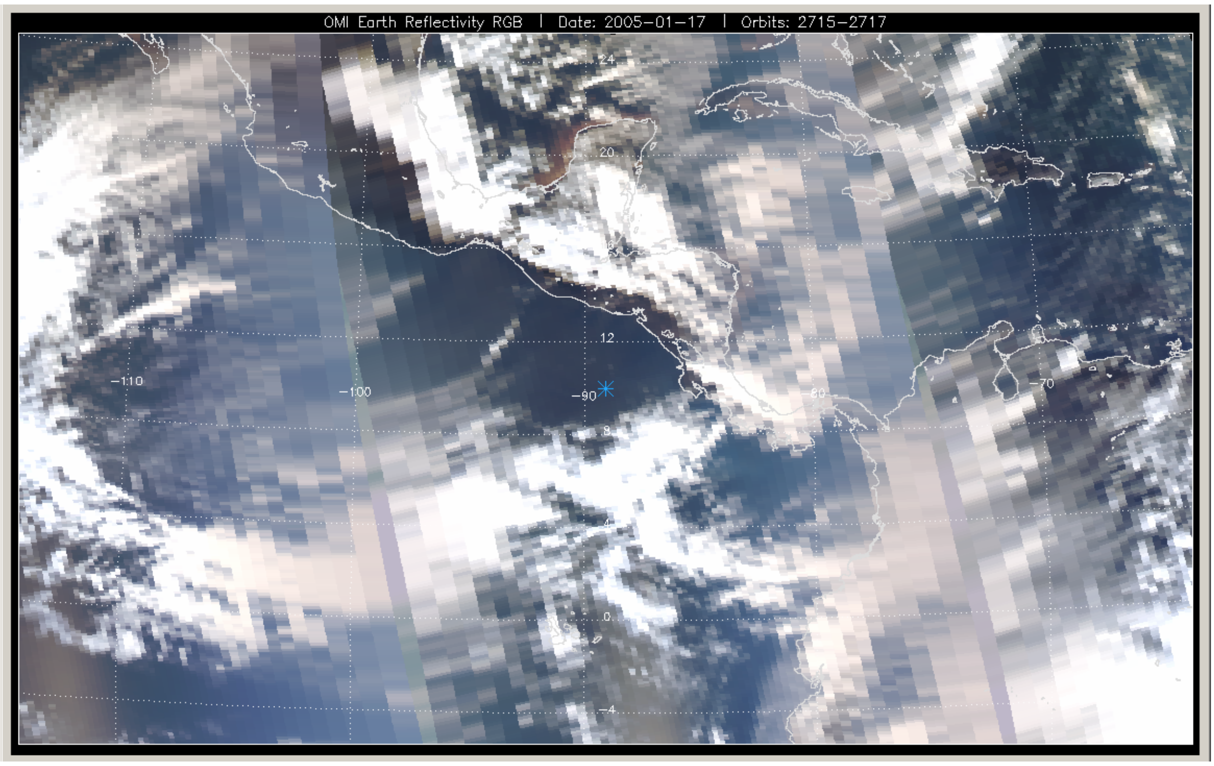


Figure 2: OMI RGB over Central America on Monday 17th of January 2005, Aura orbit 2715-2717. Note the presence of three orbits of OMI in this image.

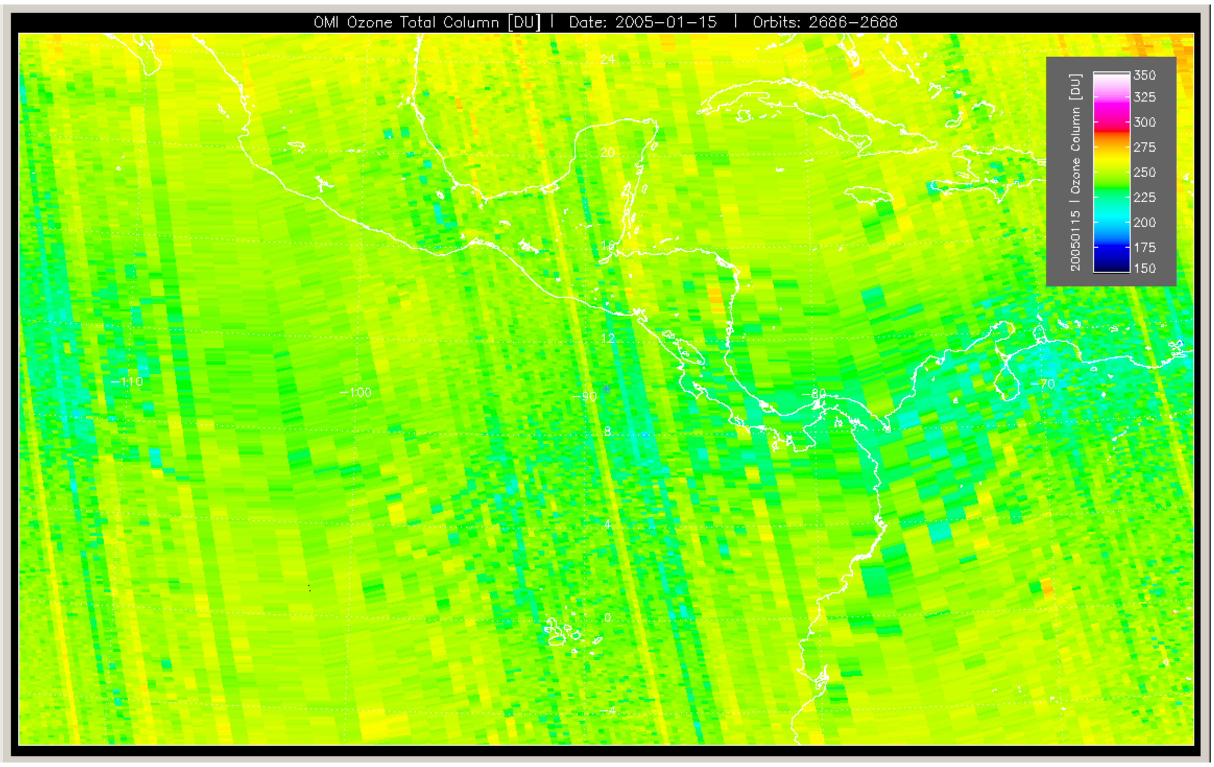


Figure 3: OMI total ozone fields over Central America on Monday 17th of January 2005, Aura orbit 2715-2717. Note the absence of strong variability over this region in this time of year.

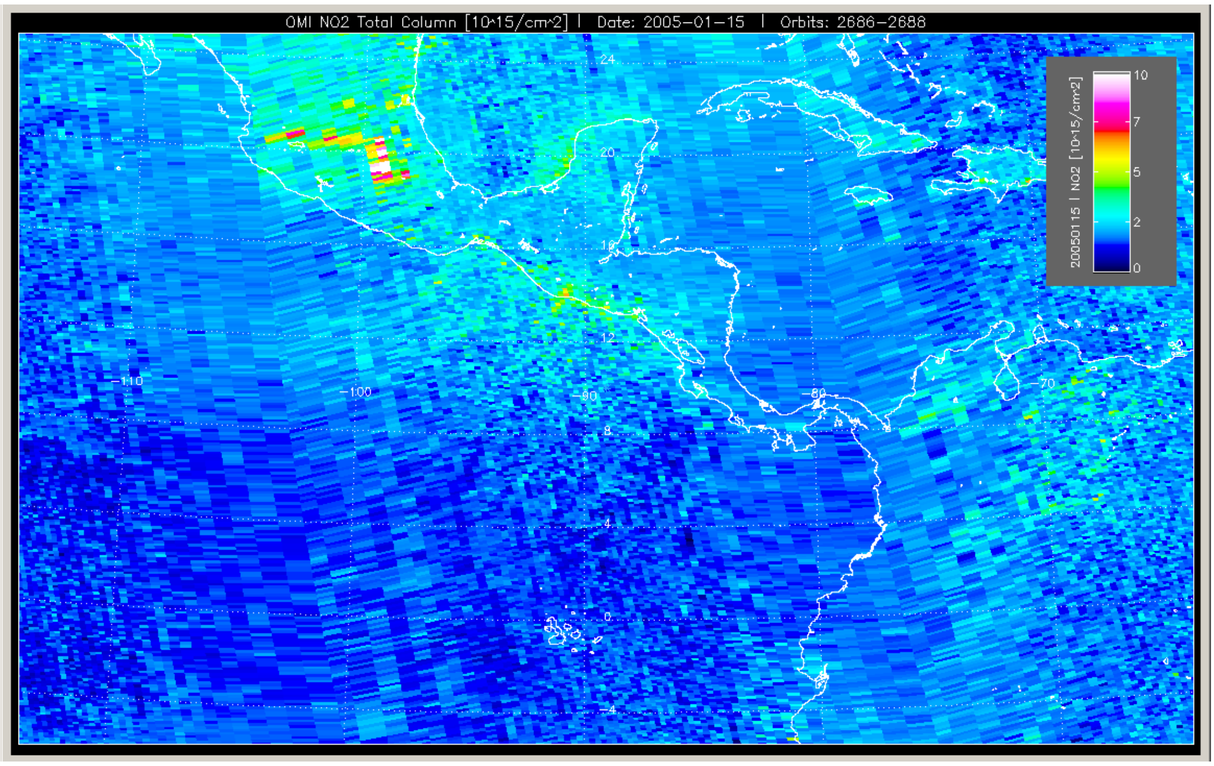


Figure 4: OMI total NO2 fields over Central America on Monday 17th of January 2005, Aura orbit 2715-2717. Note the location of populated areas indicated by increased values.

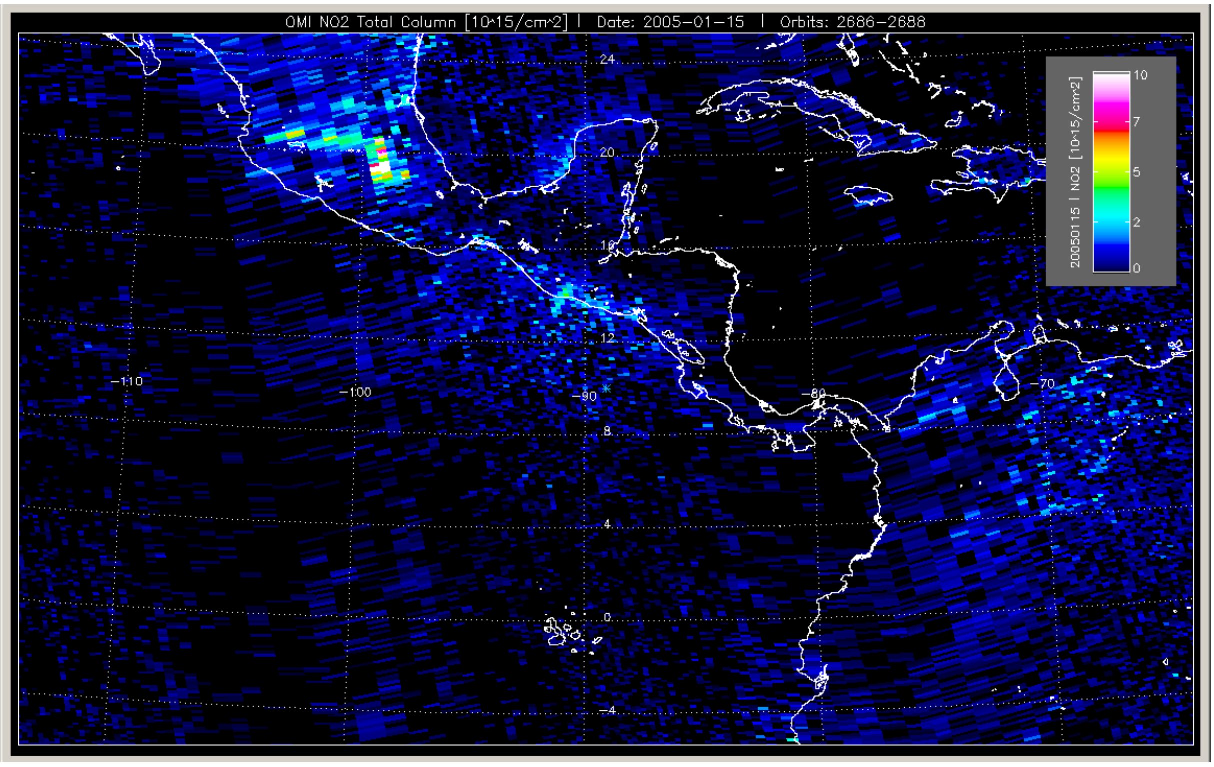


Figure 5: OMI tropospheric NO2 fields over Central America on Monday 17th of January 2005, Aura orbit 2715-2717. Note the location of the Mexico City Metropolitan and several other cities.

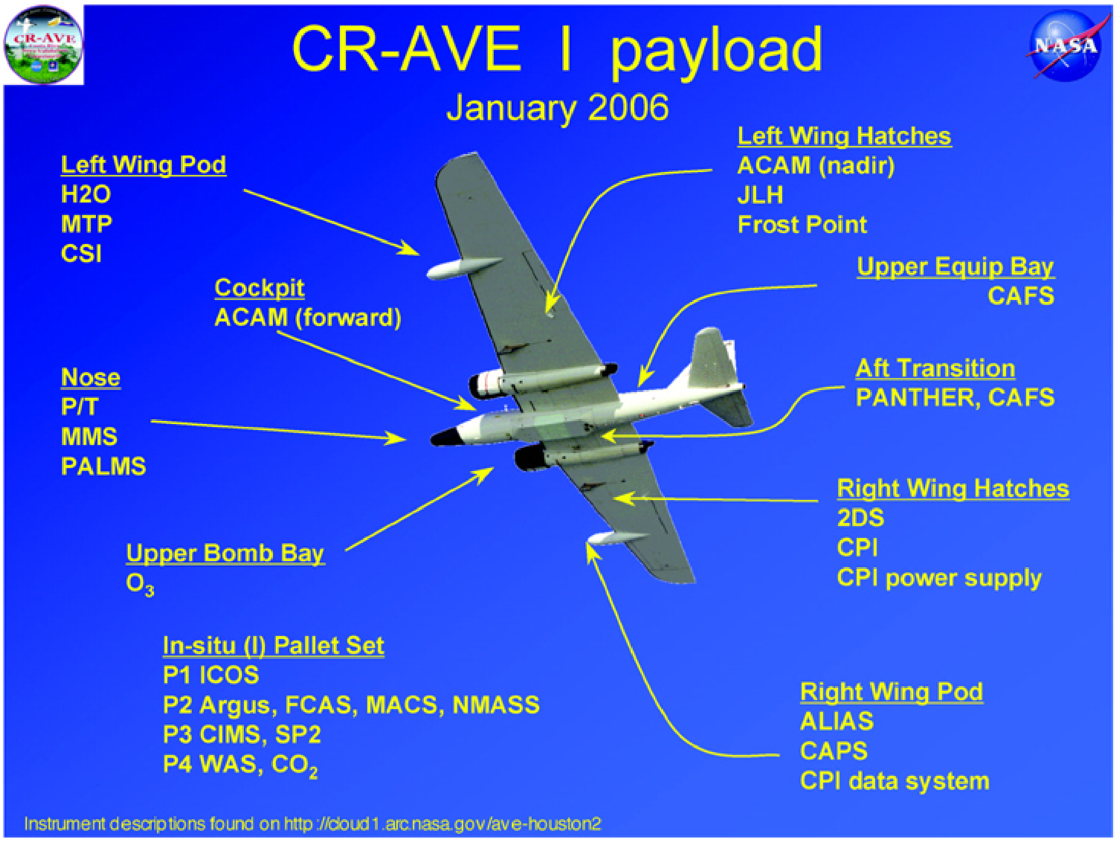
In Figure 4 we show the total nitrogen dioxide (NO2) field over the region of interest. The total NO2 column fields show little detail except near strong sources of anthropogenic activity. The image also reveals the presence of pollution outflow over the Pacific Ocean. The challenge here to measure NO2 ion such outflow events above open ocean and above land.

In Figure 5 we show the tropospheric NO2 column fields over the region of interest. The tropospheric NO2 column fields show much more detail and reveals the precise location of the Mexico City Metropolitan and several cities along the coast of Nicaragua. From such images the tracks of pollution outflow, in this case over the Pacific Ocean, can be clearly monitored as well. Most probably the elevated presence of aerosols is linked to this observation. The challenge is to quantify the tropospheric NO2 column with airborne observations and investigate the variability at the sub-pixel scale. The challenge is also to actually quantify the variability. Measurements are needed in close proximity of the sources hence along the coast line and over cities.

5 Payload Instruments for January 2006 Flights

5.1 In situ

2DS (ice particles), ALIAS (N2O, CH4, CO, HCl, NO2, water isotopes), Argus (CO, N2O, and CH4), CAPS (water droplets), CIMS (HCl and HNO3), CO2 (CO2), CPI (cloud particles), FCAS (aerosols), Frost point (H2O), JLH (humidity), MACS (aerosols), NMASS (aerosols), Ozone/Methane (O3, CH4), PALMS (aerosols), PANTHER (acetone, PAN, H2, CH4, CO, N2O, SF6, CFC-11, -12, halon-1211), P/T (pressure, Temperature), SP2 (soot), WAS (CFC's).



CR-AVE I payload

January 2006

Left Wing Pod
H2O
MTP
CSI

Left Wing Hatches
ACAM (nadir)
JLH
Frost Point

Cockpit
ACAM (forward)

Upper Equip Bay
CAFS

Nose
P/T
MMS
PALMS

Aft Transition
PANTHER, CAFS

Right Wing Hatches
2DS
CPI
CPI power supply

Upper Bomb Bay
O_3

In-situ (I) Pallet Set
P1 ICOS
P2 Argus, FCAS, MACS, NMASS
P3 CIMS, SP2
P4 WAS, CO_2

Right Wing Pod
ALIAS
CAPS
CPI data system

Instrument descriptions found on http://cloud1.arc.nasa.gov/ave-houston2

Figure 6: CR-AVE In-situ (I) sensing payload. Many instruments are also part of the remote sensing payload (R) high is discussed in the next section.

5.1.1 2D-S (Stereo) Probe

Two 128-photodiode linear arrays work independently as high-speed and high-resolution optical imaging probes. Captures two-dimensional images of particles passing through sample volume where laser beams overlap. The region where the beams overlap uniquely defines the depth-of-field (and thus the sample volume) for small particles. Response time is 10 times faster than the 2D-C. Particles as small as 10 microns imaged at 200 m/s.
Website: http://www.specinc.com/2DS_operation.htm

5.1.2 Aircraft Laser Infrared Absorption Spectrometer (ALIAS)

PI: Christopher R. Webster (PI), Lance Christensen, Gregory J. Flesch, Jesse Landeros, W. Steven Woodward
The Aircraft Laser Infrared Absorption Spectrometer (ALIAS) instrument is a high resolution four-channel scanning Tunable Diode Laser (TDL) and Quantum-Cascade (QC) laser spectrometer (3.4 to 8 µm) that makes direct, simultaneous measurements of (e.g. HCl, NO2, CH4, N2O, CO, water isotopes) (including vertical profiles of the tracers) in the stratosphere and troposphere at sub-parts-per-billion sensitivities. The instrument weighs 160 lbs.
Website: http://laserweb.jpl.nasa.gov/earthinstruments/alias.html

5.1.3 Argus

PI: Max Loewenstein, Co-PI: Hans Jurg Jost, James R. Podolske
Argus is a two channel, tunable diode laser instrument set up for the simultaneous, in situ measurement of CO (carbon monoxide) and CH_4 (methane) in the troposphere and lower stratosphere. The instrument measures 40 x 30 x 30 cm and weighs 21 kg. An auxiliary, in-flight calibration system has dimensions 42 x 26 x 34 cm and weighs 17 kg.
Website: http://cloud1.arc.nasa.gov/ave-houston/instruments.cgi

5.1.4 CAPS

PI: Baumgardner
The Cloud Aerosol and Precipitation Spectrometer (CAPS) measures the size and concentration of aerosol and cloud particles over a size range from 0.0003 mm to 1.6 mm. This aircraft-mounted sensor also measures the liquid water content of cloud droplets, the air temperature and pressure, and the airspeed.
Website: http://www.sba.gov/sbir/tibbetts/droplet.html

5.1.5 CIMS

PI: David W. Fahey, Co- PI: Ru-shan Gao
The Chemical Ionization Mass Spectrometers (CIMS) instrument has two independent detection channels. For CRYSTAL/FACE both channels are configured for measurements of ambient nitric acid (HNO_3). A schematic of the principal components of the CIMS instrument, including the inlets, ion sources, quadrupole mass spectrometers, vacuum chamber, pumps, and gas supply is shown in CIMSdescription.pdf. For HNO_3 detection, reagent ions SiF5- are generated and mixed into the ambient air sample.
Website: http://cloud1.arc.nasa.gov/crystalface/WB57_files/CIMSdescription.pdf
Website: http://cloud1.arc.nasa.gov/solve/payload/er2/cims2.html

5.1.6 CPI

PI: Dr. Bradley A. Baker
The Cloud Particle Imager (CPI) records high-resolution (2.3 micron pixel size) digital images of particles that pass through the sample volume at speeds up to 200 m/s. CCD camera flashes up to 75 frames per second (fps), potentially imaging more than 25 particles per frame.
Website: http://www.specinc.com/cpi.htm

5.1.7 CSI

PI: ?
The Cloud Spectrometer and Impactor (CSI)
Website: ?

5.1.8 FCAS

PI: Dr. J.C. Wilson
The Focused Cavity Aerosol Spectrometer (FCAS) II sizes particles in the approximate diameter range from 0.07 mm to 1 mm. Particles are sampled from the free stream with a near isokinetic sampler and are transported to the instrument. They are then passed through a laser beam and the light scattered by individual particles is

measured. Particle size is related to the scattered light. The data reduction for the FCAS II takes into account the water which is evaporated from the particle in sampling and the effects of anisokinetic sampling. The FCAS II and its predecessors have provided accurate aerosol size distribution measurements throughout the evolution of the volcanic cloud produced by the eruption of Mt. Pinatubo. Near co-incidences between FCAS II and SAGE II measurements show good agreement between optical extinctions calculated from FCAS size distributions and extinctions measured by SAGE II.
Website: http://www.engr.du.edu/aerosol/fcas.htm

5.1.9 Frost Point Hygrometer

PI: ?
Website ?.

5.1.10 H2Ov

Harvard water vapor instrument
http://www.arp.harvard.edu/sci/atmobs/h2o/vapor.html

5.1.11 JLH

PI: Robert L. Herman, Co-PI: Randy D. May
The JPL Near-IR Water Spectrometer for the ER-2, DC-8, and WB57F Aircraft is a new instrument for in-situ measurements of atmospheric water vapor from aircraft platforms such as the ER-2, the DC-8, and the WB57F aircraft. It is based upon a near-IR tunable diode laser source operating near 1.37 microns. The spectrometer features an open-path, multipass (Herriott) cell for true in situ monitoring of H_2O concentrations with precision levels exceeding those of Lyman-a and frost-point hygrometers. External sampling outside the aircraft boundary layer minimizes measurement uncertainties and enables high-speed *in situ* sampling along the aircraft flight track. Measurement precision is ± 0.05 ppmv in the stratosphere for a 2 s measurement integration period.
Website: http://laserweb.jpl.nasa.gov/earthinstruments/h2owb57.html

5.1.12 MACS

PI: Dr. J.C. Wilson
The Multiple Aerosol Collection System contains an impactor collector which permits the collection of particles on electron microscope grids for later chemical-constituent analysis. The collector consists of a two stages. In the first stage the pressure of the sample is reduced by a factor of two without loosing particles by impaction on walls. The second stage consists of a thin plate impactor which collects efficiently even at small Reynolds numbers. The system collects particles as small as 0.02 micron at WB-57F cruise altitudes. As many as 24 samples can be collected in a flight
Website: http://www.engr.du.edu/Aerosol/macs.htm

5.1.13 NMASS

PI: Dr. J.C. Wilson
The Nucleation-Mode Aerosol Size Spectrometer (N-MASS) measures the concentration of particles as a function of diameter. A sample flow is continuously extracted from the free stream using a decelerating inlet and is transported to the N-MASS. Within the instrument, the sample flow is carried to 5 parallel condensation nucleus counters (CNCs). An inversion algorithm is applied to recover a continuous size distribution
Website: http://www.engr.du.edu/aerosol/nmass.htm

5.1.14 Ozone/Methane (O_3/CH_4)

Methane Near IR Tunable Diode Laser Absorption Spectrometer
The tunable diode laser (TDL) absorption instrument consists of a very high resolution scanning near-infrared diode laser spectrometer. By use of the Beer-Lambert law, the methane number density is calculated from the direct absorption measurements.
Website: http://cloud1.arc.nasa.gov/crystalface/WB57_files/CH4noaa.pdf
NOAA Dual-Beam UV Absorption Ozone Photometer
Ozone is measured *in situ* using a photometer consisting of a mercury lamp, two sample chambers that can be periodically scrubbed of ozone, and two detectors that measure the 254-nm radiation transmitted through the chamber (*Proffitt et al.* [1983]). The ozone number density is calculated using the ozone absorption cross-section at 254 nm and the Beer-Lambert Law.
Website: http://cloud1.arc.nasa.gov/crystalface/WB57_files/O3noaa.pdf

5.1.15 PALMS

PI: Dan Murphy

The PALMS instrument is a laser ionization mass spectrometer which makes in-situ measurements of the chemical composition of individual aerosol particles. Aerosols are brought into a vacuum system and individual particles are detected by light scattered as they cross the beam of a continuous laser. The scattered light signal gives a rough indication of the size of the particle and a provides a trigger for an excimer laser (193nm), which is pulsed so its beam hits the particle to desorb and ionize molecules and atoms. These ions are analyzed with a time of flight mass spectrometer to provide a complete mass spectrum from each particle. The instrument is capable of measuring particles from 0.2 to 3 microns in diameter.

Website: http://www.al.noaa.gov/palms/

5.1.16 PANTHER

PI: James Elkins, NOAA/CMDL

Target Molecules: acetone, PAN, H2, CH4, CO, N2O, SF6, CFC-11, -12, halon-1211. Method:Mass Spectrometry and Gas Chromatography, including 1 Mass Selective Detector and 4 Electron Capture Detector channel gas chromatograph

Website: http://cloud1.arc.nasa.gov/crystalface/WB57_files/PANTHERC.pdf

5.1.17 Pressure-Temperature (PT) Instrument

PI: Tom Thompson

The PT instrument measures ambient pressure and temperature of the outside air surrounding an aircraft in flight. Since there is always a velocity-heating factor that effects the temperature measurement, ram pressure must also be measured. The PT instruments consists of two accurate pressure transducers for measuring static and ram pressure, an accurate conditioning amplifier for the platinum resistor temperature probe, a means for tapping into the WB-57F pitot/static system, a platinum resistor temperature probe, and a computer for taking the probe measurements and recording the data. The temperature probe must mount outside the aircraft in the free air stream.

Website: http://cloud1.arc.nasa.gov/crystalface/WB57_files/PTnoaa.pdf

5.1.18 SP2

(Single Particle Soot Photometer)

Website

5.1.19 WAS

PI: Elliot Atlas & Stephen Donnelly (NCAR)

The Whole Air Sampler (WAS) collects samples for a range of trace gases including CFCs, HCFCs, HFCs, Methane, C2-C5 alkanes, C1 and C2 chlorinated compounds, Halons, methyl halides, Bromochloromethanes, alkyl nitrates, etc. Trace gases are collected in stainless steel canisters for analysis by GC/FID and GC/MS techniques.

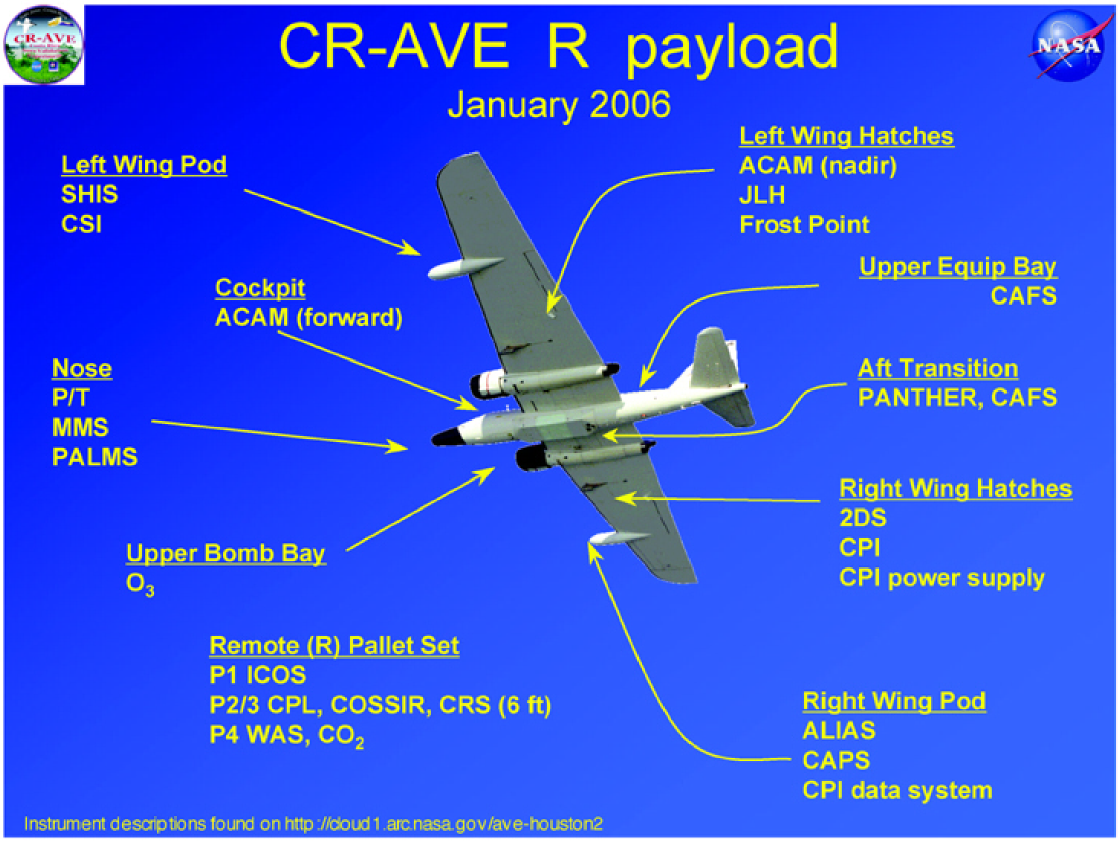
Website: http://www.atd.ucar.edu/dir_off/airborne/was.html

5.2 Remote Sensing

5.2.1 ACAM

PIs: Scott Janz and Paul Newman

The Airborne Compact Atmospheric Mapper (ACAM) consists of two spectrographs and two cameras. There are two Ocean Optics spectrographs, one optimized for the UV [covering from 290 to 380 nm at 1 nm spectral resolution], and one optimized for the visible [covering from 360 to 520 nm at 1 nm spectral resolution]. The spectrographs share a common fiber optic feed to a collimator which will image a circular FOV of ~1.5 km diameter from an altitude of 18 km. This FOV can be scanned left and right via a small mirror up to angles of +/- 40 degrees. The spectrographs cover wavelengths of interest for trace gas measurements (O3, NO2, SO2, BrO, CHCO) and aerosols. A Nikon 8700 digital camera (3,264 x 2,448 pixels) is mounted in the cockpit for forward viewing, pre-programmed to shoot 1 frame every minute. A Nikon 8800 image stabilized digital camera (3,264 x 2,448 pixels) is mounted in the wing hatch looking down, pre-programmed to shoot 1 frame every 30 seconds. Website: http://code916.gsfc.nasa.gov/Public/Ground_based/acam/acam.html



CR-AVE R payload

January 2006

Left Wing Pod
SHIS
CSI

Left Wing Hatches
ACAM (nadir)
JLH
Frost Point

Cockpit
ACAM (forward)

Upper Equip Bay
CAFS

Nose
P/T
MMS
PALMS

Aft Transition
PANTHER, CAFS

Right Wing Hatches
2DS
CPI
CPI power supply

Upper Bomb Bay
O_3

Remote (R) Pallet Set
P1 ICOS
P2/3 CPL, COSSIR, CRS (6 ft)
P4 WAS, CO_2

Right Wing Pod
ALIAS
CAPS
CPI data system

Instrument descriptions found on http://cloud1.arc.nasa.gov/ave-houston2

Figure 7: CR-AVE Remote (R) sensing payload

5.2.2 CAFS

PI: Rick Shetter, Co-PI: Ned Reidel

The CCD Actinic Flux Spectroradiometry (CAFS) measurements we will be making on the WB-57 are wavelength dependent down and up welling actinic flux. The actinic flux optical collectors are a series of concentric quartz hemispheres that provide photons to the transfer fiber optic bundle. These optics collect photons independent of angle over the upper or lower hemisphere. The Zeiss solid state monochromators used have cooled back thinned UV enhanced CCD detectors and a wavelength range of 280-680 nm with a FWHM of ~1.9 nm. We will probably limit the wavelength range to the UV with an optical filter to improve the stray light rejection of the spectrometer for improved UV measurements. The angular acceptance of the up-looking instrument will be limited to approximately +/-80 degrees to enhance the sensitivity to total column ozone.

The WB-57 instruments are small (~40 lbs each) and low power (~8 amps of 28 volt DC power). These instruments have previously flown on the WB-57 and showed a stable performance. We have a lot of experience determining wavelength dependent actinic flux from aircraft. We have been making measurements on the NASA DC-8 and P-3B, the NCAR C-130, and the NOAA P-3 Orion for ~8 years. These missions concentrated on atmospheric photochemistry so we derived atmospheric photolysis frequencies for ~20 photo-chemically important molecules from the UV and visible. We are jointly developing and algorithm to determine the total ozone above the aircraft from the WB-57 measurements. The algorithm will use the UV irradiance in a Dobson like approach. This should allow for some ozone profiles. In addition, we hope to develop techniques to determine some aerosol parameters. We do not believe that we will be able to retrieve NO_2, CH_2O, or SO_2 from our spectra due to the instrument resolution and line shape.

Website: http://www.atd.ucar.edu/dir_off/airborne/safs.html
Website: http://arim.acd.ucar.edu/people/shetter.html

5.2.3 COSSIR

PI: Frank Evans

CoSSIR is a new airborne total-power microwave radiometer that is designed to measure cirrus cloud parameters (IWP, the ice water path, and Dme, the median mass diameter of ice crystals) and water vapor profiles (between 0-12 km altitudes). The CoSSIR's widely separated groups of frequencies at 183.3, 220, 380, 487, and 640 GHz (see table above) are well suited for the retrievals of Dme and IWP of cirrus clouds. The dual polarization capability at 487 GHz has the potential of inferring the shape of ice particles. Based on the results of recent MIR observations (89-340 GHz), CoSSIR will undoubtedly extend the cirrus measurement capability to the regime where a direct comparison with visible/IR technique becomes possible.

Website: http://cloud1.arc.nasa.gov/crystalface/instruments_files/cossir_desc.pdf

5.2.4 CPL

PI: Matthew McGill

The Cloud Physics Lidar (CPL) is a cloud lidar developed by NASA Goddard and flies on the ER2 high altitude aircraft (McGill, M. et al., 2002). The CPL is an active remote sensing system, capable of very high vertical resolution cloud height determinations (30 meters), cloud visible optical depth, and backscatter depolarization. The depolarization measurement allows for the discrimination between ice and water clouds. Photons backscattered on the surface of spherical water droplets have very little depolarization in contrast to ice crystals where the backscatter results in large depolarization. For CPL measurements, depolarization of greater then 25% are ice while polarizations less then 10% are generally water clouds. The CPL laser transmits at 355, 532, and 1064 nm and fires 5000 shots/sec. For this paper, the 532 nm one second averaged data is used. The high sample rate of the CPL results in a surface footprint that can be approximated as a continuous line with a diameter of 2 meters. A robust collocation algorithm is used to collocate the CPL measurements with the SHIS. On average, ten CPL are measurements are found in each 2-km SHIS field of view. The collocated CPL measurements of cloud height, depolarization, and optical thickness are used in this paper to analyze the sensitivity of SHIS cloud top retrievals.

Website: http://cpl.gsfc.nasa.gov/

5.2.5 CRS

PI: Gerry Heymsfield

The Cloud Radar System (CRS) is a 94 GHz (W-band; 3 mm wavelength) Doppler radar developed for autonomous operation in the NASA ER-2 high-altitude aircraft and for ground-based operation. It will provide high-resolution profiles of reflectivity and Doppler velocity in clouds and it has important applications to atmospheric remote sensing studies. The CRS was designed to fly with the Cloud Lidar System (CLS), in the tail cone of an ER-2 superpod. There are two basic modes of operation of the CRS: 1) ER-2 with reflectivity, Doppler, and linear-depolarization measurements, and 2) ground-based with full polarimetric capability. The overall radar system parameters are listed in the attached table.

Website: http://rsd.gsfc.nasa.gov/912/crs/crs_id_description.htm

5.2.6 ICOS

PI:

The Harvard CRDS/ICOS instrument is a new absorption spectrometer, flight-tested in May 2001, that uses the relatively new and highly sensitive techniques of integrated cavity output spectroscopy (ICOS) and cavity ringdown spectroscopy (CRDS) with a high-finesse optical cavity and a cw quantum cascade laser (QCL) source.

Website: http://www.arp.harvard.edu/atmobs/sciobj/instrument/cr.html

5.2.7 MTP

PI: M.J. Mahoney

When the MTP is scanned in frequency and elevation about the flight altitude, it measures the total emission from oxygen molecules along the viewing direction. The temperature profile is not measured directly however. The 20 or 30 measurements that the MTP makes in scanning from near-zenith to near-nadir, are converted into a temperature profile by performing a "retrieval" which takes into account where the aircraft is flying and the time of year. You might imagine that many different combinations of atmospheric conditions in the viewing direction might produce the same measurement, and you would be correct! The retrieval process, however, uses all of the measurements during a scan from zenith to nadir to figure out which is the most likely set of temperatures to

produce the measurements, and this becomes the retrieved altitude temperature profile. In a nutshell, that is what an MTP does.
Website: http://mtp.jpl.nasa.gov

5.2.8 SHIS

PI: Fred. A. Best, Co-PI: Joe K. Taylor
The Scanning High-resolution Interferometer Sounder (SHIS) is an aircraft based scanning Fourier transform interferometer designed to measure atmospheric infrared radiances at high spectral and spatial resolutions (Revercomb, H. E. et al., 1998). The SHIS measures the infrared emission between 3.0 – 16 microns with a spectral resolution of approximately 0.5 wavenumbers. The SHIS has a 100 mrad field of view and is capable of cross scanning. The measured emitted radiance is used to obtain temperature and water vapor profiles of the Earth's atmosphere. SHIS produces sounding data with 2-kilometer resolution (at nadir) across a 40-kilometer ground swath from a nominal altitude of 20 kilometers onboard a NASA ER-2 aircraft or 20 kilometer ground swath from a nominal altitude of 10 kilometers aboard the NASA DC-8 aircraft. With a flight altitude of 20 km the nadir SHIS fields of view have a 2 km diameter surface footprint. The footprint is slightly oval along the flight track due to the 1- second dwell time and 200 m/s along track velocity.
Website: http://deluge.ssec.wisc.edu/~shis/
Website: http://www.kgs.ukans.edu/Hydro/Hutch/NASA/

5.3 Navigation

The MMS instrumentation consists of three major systems:

- Air motion sensing system measuring the velocity of the air with respect to the aircraft (true air speed)
- Inertial navigation system measuring the velocity of the aircraft with respect to the earth (ground speed)
- Data acquisition system to sample, process and record the measured quantities.

The air motion sensing system consists of sensors, which measure temperature, pressures, and airflow angles (angle of attack and yaw angle). The Litton LN-100G Embedded GPS Inertial Navigation System (INS) provides the aircraft attitude, position, velocity, and acceleration data. On the DC-8, the Trimble TANS Vector provides secondary attitude and navigation data. The TANS Vector utilizes the GPS carrier phase shift between multiple antennas to derive independent aircraft attitude. The Data Acquisition System samples the independent variables simultaneously and provides control over all system hardware.
Website: http://geo.arc.nasa.gov/sgg/mms/instrument.htm

6 References

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