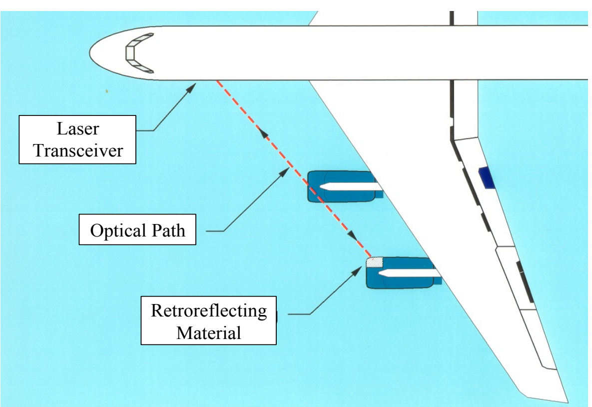
Airborne Measurements and Analysis of H_2O(v), CO, CH_4, and N_2O in support of the SEAC^{4}RS and DC3 Field Campaigns

Measurement Description: Tracer gas measurements will be provided using two techniques: an external path, near-IR diode laser hygrometer for H_2O(v) (DLH); and a folded-path, differential absorption mid-IR diode laser spectrometer for CO, CH_4, and N_2O (DACOM). Instrumentation types slated for the DC-8 aircraft, as well as their performance characteristics, are shown in Table 1 followed by brief instrument descriptions.

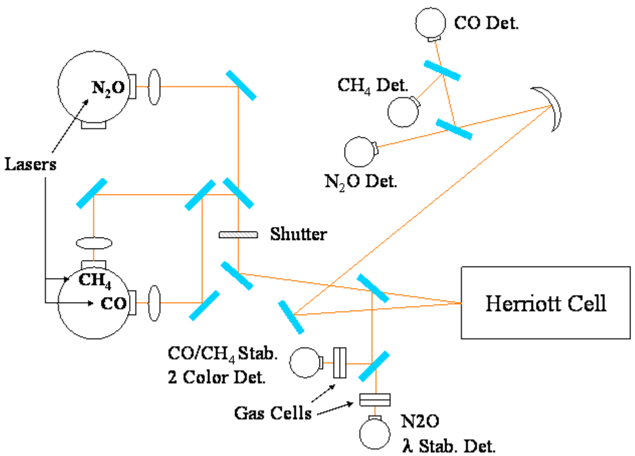
Table 1.

Instrument	Species	Time Response	Precision (1σ)	Accuracy
DLH	H_2O(v)	<50 msec	0.% or 0.05 ppmv	5% or 0.5 ppmv
DACOM	CO	1 sec	1% or 1 ppbv	2%
DACOM	CH_4	1 sec	0.1%	1%
DACOM	N_2O	1 sec	0.1%	1%



Location of DLH) on DC-8 (typical installation).

Diode Laser Hygrometer (DLH): The DLH has been successfully flown during many previous field campaigns on several aircraft, most recently ATTREX (Global Hawk), DISCOVER-AQ (P-3), MACPEX (WB-57), SPartICus (Learjet), and Operation ICE Bridge (DC-8). This sensor measures water vapor (H_2O(v)) via absorption of a strong, isolated line in the (101) combination band near 1.4 µm and is comprised of a compact laser transceiver mounted to a DC-8 window plate and a sheet of high grade retroflecting road sign material applied to an outboard DC-8 engine housing to complete the optical path. Using differential absorption detection techniques, H_2O(v) is sensed along the 28.5m external path negating any potential wall or inlet effects inherent in extractive sampling techniques. A laser power normalization scheme enables the sensor to accurately measure water vapor even when flying through clouds. An algorithm calculates H_2O(v) concentration based on the differential absorption signal magnitude, ambient pressure, and temperature, and spectroscopic parameters that are measured in the laboratory. Water vapor mixing ratio is provided in real-time to investigators aboard the DC-8, and will be transmitted to scientists on the ground during SEAC^{4}RS.



Optical layout of DACOM instrument.

Differential Absorption CO Measurement (DACOM): The in-situ diode laser spectrometer system, referred to by its historical name DACOM, includes three tunable diode lasers providing 4.7, 4.5, and 3.3 µm radiation for accessing CO, N_2O, and CH_4 absorption lines respectively. The three laser beams are combined by the use of dichroic filters and are then directed through a small volume (0.3 liter) Herriott cell enclosing a 36 meter optical path. As the three coincident laser beams exit the absorption cell, they are spectrally isolated using dichroic filters and are then directed to individual InSb detectors, one for each laser wavelength. A wavelength reference cell containing several torr each of CO, CH_4, and N_2O is used to wavelength lock the operation of the three lasers to the appropriate absorption lines. Ambient air is continuously drawn through a Rosemont inlet probe and a permeable membrane dryer which removes H_2O(v) before entering the Herriott cell and subsequently being exhausted via a vacuum pump to the aircraft cabin. To minimize potential spectral overlap from other atmospheric species, the Herriott cell is maintained at a reduced pressure of ~90 Torr. At 5 SLPM mass flow rate, the absorption cell volume is exchanged nominally twice per second. Frequent but short calibrations with well documented and stable reference gases are critical to achieving both high precision and accuracy. Calibration for all species is accomplished by periodically (~4 minutes) flowing calibration gas through this instrument. By interpolating between these calibrations, slow drifts in instrument response are effectively suppressed yielding the high precision values shown in Table 1. Measurement accuracy is closely tied to the accuracy of the reference gases obtained from NOAA/ESRL, Boulder, CO. Both CO and CH_4 mixing ratios are provided in real-time to investigators aboard the DC-8, and will be transmitted to scientists on the ground during SEAC^{4}RS.

Scientific Importance: The DACOM and DLH instruments on the DC-8 will sample the monsoon from the boundary layer (BL) to the aircraft's ~12 km altitude ceiling, which is within the outflow region of the majority of convective events in the Asian monsoon. Over this altitude range, DACOM and DLH measurements will be of great value to the success of SEAC^{4}RS. For example CO, CH_4, and H_2O(v) are necessary to understand the O_3 budget. CO is an excellent tracer of combustion-related pollution while CH_4 and N_2O are generally tracers of non-combustion-related sources (e.g. agricultural and some urban sources). Thus, the observed CO, CH_4 and N_2O distributions horizontally and vertically inside and outside of the monsoon are valuable tracers of a wide variety of BL emissions, their convective redistribution, and their evolution in the upper troposphere (UT). Fast response DACOM CO, CH_4 and N_2O measurements, along with measurements of other species (long- and short-lived) on the DC-8, will enable the calculation of emission indices (e.g. with respect to CO, CO_2 or CH_4) for many BL sources. These emission indices may enable source identification of convected air in real-time on the DC-8 (e.g. ratios $\Delta CH_4/\Delta CO$ and $\Delta CO/\Delta CO_2$ can identify biomass burning). DACOM BL tracers CO and CH_4 will be useful for investigating the life cycle of short-lived species in the UT.

During the CARIBIC flight series, grab sample measurements of CH_4 and N_2O during August/September 2008 exhibited ~100 ppbv CH_4 and ~1 ppbv N_2O enhancements within the latitude range 15° to 40° N. SEAC^{4}RS measurements will provide a more complete picture of the distribution of these and other gases since the DC-8 will have much greater range of geographical location and altitude. DACOM/DLH tracer measurements, combined with other species measurements (e.g. NMHC species), will provide orders of magnitude more data for an unprecedented airborne characterization of BL pollutant emissions, their convective transport, and their evolution in the UT for both $SEAC^4RS$ and DC3. The large, robust $SEAC^4RS$ dataset may be used to constrain models for better estimation of Asian emissions. For example, Southeast Asian rice paddy emissions may be overestimated when they compared AIRS CH_4 retrievals with global tracer model version 3 (TM3) simulations.

DACOM measurements of long-lived species CO and CH_4 may also be used to estimate the fraction of BL air convected into the UT. This calculation requires the computation of average BL and UT concentrations of a long-lived species and the average concentration of this species in fresh convective outflow. Fresh convective outflow air is identified using an age or timing indicator (e.g. the ratio NO_x/HNO_3).

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