REQUEST FOR LAOF FACILITY SUPPORT
CONTRAST
NCAR/EOL - NOVEMBER 2012 OFAP MEETING

Submitted on 30 August 2012

PART I: GENERAL INFORMATION

A. Corresponding Principal Investigator(s)

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B. Project Description

Project Title	**CONTRAST (Convective Transport of Active Species in the Tropics)**
Location of Project	**Guam**
Start and End Dates of Field Deployment Phase	**1 Jan – 28 February 2014**
NSF Facilities requested	**GV**
Funding Agency and Program Officer Name(s)	**NSF Atmospheric Chemistry; Bill Keene**
Proposal(s) affiliated with this request	**E. Atlas (UM); R. Salawitch (UMd); A. Fried (CU); R. Volkamer (CU); M. Zondlo (Princeton); G. Huey (GIT); D. Riemer (UM)**
Proposal Status	**In preparation (x),** submitted **(),** funded (); proposals being submitted to NSF simultaneously with this request
Do you expect other, non-NSF support? If yes, from whom?	**Yes, support of the ROFLEX instrument is from PI's home institution.**
Is this a resubmission of a previous request?	No
Is this a multi-year deployment or a request for a follow-on field campaign?	No

C. Abstract of Proposed Project

We propose here the CONvective TRansport of Active Species in the Tropics (CONTRAST) experiment to be conducted from the island of Guam (13.5N, 145E) during January-February, 2014. The main scientific objective of the project is to measure the chemistry and transport of reactive chemical species into the tropical Tropopause Transition Layer (TTL) over the Western Pacific warm pool region. During the boreal winter season, tropospheric air masses are preferentially transported

into the lower stratosphere in this region. Thus, the sources, chemistry, and transport of trace gases and their degradation products in the region can substantially impact the chemistry of the lower stratosphere. Considerable attention is being given to the role of tropical convection on the delivery of reactive gases to the TTL. For example, uncertainties in the abundance of reactive halogen species and the fate of short lived organic halogen compounds, particularly bromocarbons, in the tropical upper troposphere leads to significant uncertainties in the photochemistry of stratospheric ozone, especially in the lowermost stratosphere. Despite the recognized importance of this region to shaping the chemical composition of the tropical upper troposphere and lower stratosphere, relatively few chemical measurements have been made to date, partially because of the lack of suitable airborne platforms and instruments to reach the required altitudes. This limitation is no longer a factor with the deployment of the NSF GV aircraft and the development of suitable instrumentation for that platform.

Detailed in-situ measurements of a suite of gases and particles as well as meteorological parameters from the GV during CONTRAST will elucidate the roles of active convection and long-range transport on the chemical composition of the tropical atmosphere, and the altitude variation of these processes. The western Pacific region is also found, from ozonesonde measurements or remote sensing platforms, to have extremely low ozone concentrations. CONTRAST will provide detailed in-situ measurements of a suite of chemicals to characterize the region's chemical environment. The unique low-ozone environments in the upper troposphere are expected to result in very low levels of OH radicals, which can be expected to increase the lifetime of reactive gases whose main loss is through OH radical oxidation. The simultaneous occurrence of deep convection and prolonged lifetime of organic compounds in the TTL can have substantial impact on the stratospheric halogen budget. Because the chemical and radiative properties of this region are a key factor in the mechanisms that link climate forcing and atmospheric composition, the CONTRAST experiment will provide measurements necessary for diagnosing, constraining, and improving chemistry-climate models.

The proposed payload and operational range of the GV during CONTRAST will allow important progress to be made in characterizing the chemistry of the tropical upper troposphere, including the altitude region of main convective outflow (12-14 km). Moreover, the timing of the CONTRAST experiment has been designed to take advantage of collaborations with two other airborne studies planned for the same time and geographic location. These are the NASA EV1 project ATTREX (Airborne Tropical Tropopause Experiment) and the European project CAST (Coordinated Airborne Studies in the Tropics). With complementary instrument payloads, coordinated flights of the GV, the NASA Global Hawk and the UK Bae146 will provide an unprecedented examination of the full atmospheric column, from surface to >19 km, in the Tropical Western Pacific.

The CONTRAST mission will improve the fundamental understanding of convective transport processes in the tropics, and the role of convection in chemistry-climate interaction. Better understanding of the processes in this region will improve process-oriented chemistry/climate models and their validation by providing a unique suite of benchmark measurements, especially in the characterization of active halogen chemistry. The project will train students in atmospheric chemistry who are directly involved in the deployment and subsequent data analysis and modeling activities. Broader education and outreach activities will be developed using web-based tools and media.

D. Experiment Design

Please provide details about the experiment design. How will the instruments/platforms requested be used to test the hypotheses and address the objectives? What previous experiments of similar type have been performed by you or other investigators? Give references of results published and explain how the proposed experiment and the use of the requested facilities go beyond what has already been done.

(See also EDO and SPO submitted in January, 2012)

CONTRAST Objectives

CONTRAST is designed to provide a comprehensive suite of measurements needed to characterize the effect of deep convection on the chemical environment of the tropical western Pacific TTL, which is a pre-requisite for testing and ultimately improving chemical models of the tropics. Measurements of ozone, ozone precursors, and a variety of related trace gases will evaluate the oxidative chemistry in this unique environment. In addition, CONTRAST will quantify the amount of bromine injected into the TTL by deep convection, the fate of VSL bromocarbons as air is lofted through the TTL, and the reason(s) for different behavior of bromine versus iodine bearing halogens. Importantly, CONTRAST will provide, for the first time, measurement of a complete set of bromine and iodine gases (inorganic and organic) needed to address the most prominent uncertainty described above.

The main objectives of CONTRAST are to:

- **Characterize the chemical composition at the level of convective outflow over the Western Pacific during the deep convective season**
- **Evaluate the budget of organic and inorganic bromine and iodine in the TTL**
- **Investigate transport pathways from the oceanic surface to the tropopause using the GV coordinated flights with BAe-146 and Global Hawk**

These objectives and the related hypotheses are discussed next.

1) Characterize the influence of deep convection on the photochemical budget of O_3 at the level of convective outflow over the western Pacific

Deep convection associated with warm surface waters of the tropical western Pacific provides the major source of reactive chemicals and H_2O to the tropical upper troposphere. The chemical composition of air transported out of the TTL defines the chemical boundary for the lower stratosphere. The tropical TTL appears to be characterized by extremely low abundances of O_3, which should lead to a deficiency in the abundance of hydroxyl radical (OH), since OH is supplied by the reaction of H_2O with $O^1(D)$, a photolytic product of O_3. It has been hypothesized that the photochemical budget of O_3 in the tropical TTL is influenced by VSL halogens supplied by deep convection as well as NO_x supplied by lightning. CONTRAST will provide the first extensive measurements of O_3, radicals, and radical precursors in western Pacific TTL.

Data obtained during CONTRAST will provide distributions of O_3, H_2O, CH_4, H_2CO, halocarbons, NO and NO_2, BrO, IO, and a suite of short-lived hydrocarbons ***inside*** and ***outside*** regions of deep convective influence. Our first goal will be to compare and contrast profiles marked by either the presence or absence of recent, deep convective influence. Deep convective influence will be marked by meteorological analysis as well as the abundance of CH_3I, which is so short-lived (lifetime of 5 to 6 days) that the presence, or lack thereof, of CH_3I will serve as an excellent indicator of whether an air parcel was in recent convective contact with the marine boundary layer.

Hypothesis 1a. The photochemical budget of O_3 in the tropical TTL is determined by the strength of inputs of chemical precursors from convection and lightning. The simultaneous measurement of O_3, H_2O, CO, CH_4, and radiation will allow for model estimates of atomic O as well as OH and HO_2 (HO_x). Of course, volatile organic compounds (VOC) could supply HO_x to this region (*Wennberg et al*., 1998). Acetone (C_3H_6O), perhaps the most important VOC source of HO_x, will be measured both inside and outside regions of deep convective influence. Comparison of measured and modeled H_2CO will further help to evaluate the consistency of our photochemical calculations. We will calculate OH and HO_2 profiles, based on constraints for CONTRAST measurements, for air parcels ***inside*** and ***outside*** regions of deep convective influence. Measurements of NO, NO_2, BrO, and IO provide direct constraints on the abundance of radicals that participate in a series of O_3 loss steps. Although we will not have direct measurements of ClO, the abundance of total inorganic chlorine (Cl_y) will be inferred from measurement of the nighttime reservoir of Br_y species (see below). Finally, the western TTL is a region of strong lightning influence. Comparison of NO_x vs. CO will provide an empirical measure of the impact of lightning on NO_x. The CONTRAST measurements will be used to construct estimates of the photochemical loss terms of O_3 by O+O_3, HO_x, NO_x, and halogens as a function of altitude, for air parcels both ***inside*** and ***outside*** regions of deep convective influence, in order to test model representations of the photochemical loss of O_3, such as that shown in **Figure 5** [from *Saiz-Lopez et al*., 2011] and discussed in *von Glasow et al.* [2004].

Hypothesis 1b. The low O_3 environment of air undergoing recent, deep convection will increase the atmospheric lifetime of halocarbons lost by reaction with OH. As noted above, the simultaneous measurement of O_3, H_2O and radiation will allow for model estimates of OH. Of course, VOC's could supply OH to this region (*Wennberg et al.*, 1998). A likely result of the low O_3 environment associated with recent, deep convection is decreased values of calculated OH. CONTRAST measurements of a range of organic trace gases, including halocarbons such as $CHBr_3$, CH_2Br_2, and bromochloromethane (CH_2BrCl), will allow the effect of OH on the lifetime of these gases to be assessed. Table 1 contains estimates of the lifetime for removal of these gases by reaction with OH and photolysis, taken from Table 2-4 of WMO (2003).

Table 1. Lifetime at 5 km, 275 K

Chemical	τ_{OH} (days)	τ_J (days)	τ_{TOTAL} (days)
$CHBr_3$	100	36	26
CH_2Br_2	120	5000	120
CH_2BrCl	150	15000	150

The lifetimes for loss by reaction with OH shown in Table 1 are for globally averaged, background levels of [OH]. The important aspect to note is that for some species, such as CH_2Br_2 and CH_2BrCl, atmospheric loss is expected to be dominated by reaction with OH. For other gases, such as $CHBr_3$, loss is dominated by photolysis. We expect log-log scatter plots of the abundance of these gases, based on whether the air parcels were sampled ***inside*** or ***outside*** regions of deep convective influence, will reveal the signatures of loss by reaction with OH. For a given value of CH_2Br_2, for instance, the mixing ratio of $CHBr_3$ should be higher inside a convective region than outside (because loss by reaction with OH should be suppressed due to low O_3). CONTRAST will provide the first test of this hypothesis. Although our focus is atmospheric halogens, the hypothesized low [OH] environment of the tropical TTL will result in slow decomposition of any gas whose primary sink is reaction with OH, including CH_4 and CO.

2) Evaluate the budget of organic and inorganic bromine and iodine in the TTL

A suite of organic halocarbons are emitted from the tropical ocean by biological processes in near surface waters. Convection transports these gases to the upper troposphere, where they decompose. Past measurements in other parts of the tropics have provided a limited survey of the abundance of organic halocarbons, particularly bromine bearing compounds, at the top of the TTL (e.g., Figure 3, Auxiliary Material, *Salawitch et al*., 2010). These data clearly establish that the major bromine bearing organic molecules to cross the tropopause in the tropics are CH_2Br_2 and CH_2BrCl, due to their long tropospheric lifetimes (**Table 1**). All other bromocarbons are mostly lost in the TTL. Whether this distribution is also characteristic of the Western Pacific region, with significant surface emissions and potential for deeper convective penetration into the TTL, will be examined during CONTRAST. As noted above, there is tremendous uncertainty regarding the fate of the inorganic products produced upon decomposition of CBr_y and CI_y species.

Hypothesis 2a. CH_2Br_2, $CHBr_3$, and other VSL bromocarbons will be elevated in air parcels that have undergone recent deep convection. Figure 4 suggests that air influenced by recent deep convection will have higher abundances of CH_2Br_2 and $CHBr_3$ than air in nearby air parcels. Contrasting profiles will provide an important test for models such as CAM-Chem that has been used to diagnose impacts of halogens in the UT/LS (e.g., *Saiz-Lopez et al.,* 2011; also see CONTRAST EDO). The total abundance of organic bromine (CBr_y) and iodine (CI_y) contained in VSL species, for air recently influenced by deep convection, will provide an empirical upper limit for the injection of these halogens into the stratosphere. Measurements of these organic bromocarbons during CONTRAST will provide empirical determination of the total bromine budget of the assemblage of these species for the lower boundary of air sampled during ATTREX.

Hypothesis 2b. When CBr_y and CI_y species decompose, the resulting inorganic species remain as labile, gas phase species. The test of this hypothesis will be similar to many past studies that have examined atmospheric halogen budgets, such as the study of *Zander et al*. [1996] that provided definitive proof that stratospheric inorganic chlorine species are provided by the decomposition of chlorofluorocarbons. Also, based on the studies cited above, we expect a priori that this hypothesis might be true for bromine and is not likely to be true for iodine! In other words, we expect based on a host of prior studies, summarized in Chapter 2 of *WMO* [2007] and Chapter 1 of *WMO* [2011], that aerosol uptake and washout are more important for iodine than for bromine.

A key aspect enabling this hypothesis to be tested, ***for the first time during CONTRAST***, is the capability for aircraft measurement of concentrations of atomic Br and atomic I, in addition to BrO and IO and other major inorganic halogen species. The low O_3 environment of the tropical UT drives the partitioning of Br_y species towards atomic Br, as shown in **Figure 1**. During daytime, this photochemical model calculation indicates the vast majority of inorganic bromine should be present as Br. This species converts to either HOBr or BrCl at night, depending on ambient levels of inorganic chlorine, with a brief spike of $BrNO_3$ occurring just after sunset.

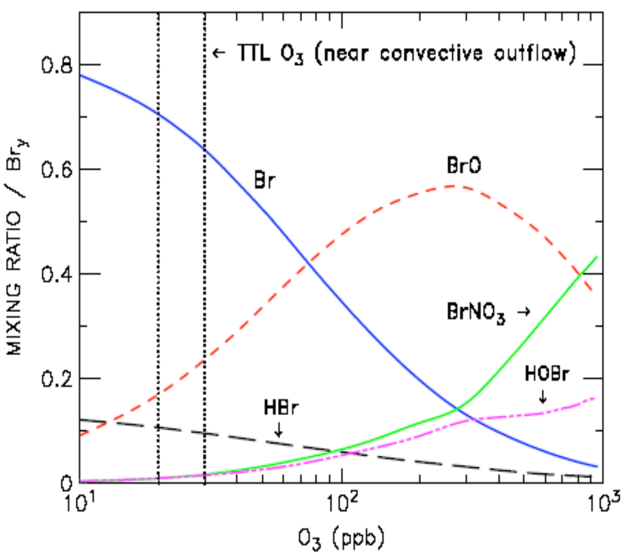

Figure 1. Calculated abundance of inorganic Br_y species, local noon, as a function of O_3. Results are normalized to the total abundance of Br_y (which was set to 4 ppt for this simulation) The photochemical box model of Salawitch et al. [2005] was run for the following inputs: Lat=10ºN, T=200 K, p=130 hPa, H_2O=12.5 ppm, CH_4=1.8 ppm, CO=60 ppb, NO_y=400 ppt for $O_3 < 100$ ppb & $NO_y = 0.00175 \times O_3$ for $O_3 >$ 230 ppb, and Cl_y=0 The low O_3 environment of the tropical western Pacific TTL is expected to strongly drive the partitioning of inorganic bromine species towards atomic Br. The capability to measure atomic Br and I during CONTRAST is thus important to properly constrain the bromine and iodine budgets.

The CONTRAST flights will include ***both daytime and nighttime flights*** that, coupled with measurement capability for HOBr and BrCl, will provide definitive quantification of the partitioning of inorganic bromine species. We will define Br_y by summing measured Br and BrO, and I_y by summing measured I and IO. CBr_y and CI_y will be based on the total organic bromine and iodine content of the suite of measured halocarbons. Our preliminary calculations suggest CONTRAST will provide, for the first time, empirical measurement of the vast majority of the total molecular mass of the bromine and iodine families.

If the inorganic products of organic halogen oxidation remain in the gas phase, then Br_y+CBr_y and I_y+CI_y (total Br and total I, respectively) should be relatively constant, with respect to altitude, for air parcels within and without regions of convection. If one family of inorganic halogens is removed by aerosol uptake, there should be a sharp departure from linearity. The CAST flights that will occur at the time of CONTRAST will provide data defining the range of expected values for total Br and total I because, near the surface, the vast majority of the molecular mass should be present as organic molecules. The ATTREX flights will provide a connection to stratospheric input: as the GH approaches the lower stratosphere, O_3 levels rise, and the titration switches back to BrO, which instruments on the GH will measure.

3) Investigate transport pathways from the oceanic surface to the tropopause using coordinated flights with CAST BAe-146 and ATTREX GH

Limited understanding of both the efficiency of deep convective transport and the rates of transport through the TTL contribute to uncertainties in our ability to predict the composition of air entering the stratosphere. Within the TTL, photochemical reactions and competing physical processes are important for chemical species whose lifetime is comparable to the ~2 months that it takes for slow ascent to traverse the TTL. Short-lived precursors of reactive halogen radicals are more likely to reach the stratosphere via rapid and extreme deep convective events that reach the upper TTL. Alternatively, transport through low-O_3 portions of the TTL where the lifetimes of VSL halocarbons lost by reaction with OH are expected to be longer, can provide an effective pathway to the stratosphere (see Section 2 above). In-mixing of air from midlatitudes will increase the age of the air in the TTL and could reduce the input of halogens to the stratosphere (VSL halocarbons are thought to be produced most efficiently in the tropical ocean [Chapter 1, *WMO, 2011*]. Such in-mixing can also reduce TTL relative humidity and cloud formation [*Fujiwara et al*., 2009].

Transport of boundary layer air into the TTL is poorly understood, both in terms of the height distribution of convective detrainment in the TTL and in terms of dilution of convective cores by entrainment throughout the free troposphere. Mid-oceanic convergent zones have convective tops that rarely exceed 13.5 km, while a significant percentage of western Pacific boreal winter convection (~3%) reaches the tropopause. These rare convective events can nonetheless be important for transport of VSL halocarbons to the stratosphere, since there is limited tropospheric decomposition and, should decomposition in the troposphere occur, there could be inefficient aerosol uptake and washout due to the arid nature of this region. Entrainment of free tropospheric air into deep convection updrafts is important, particularly for the relatively small convective cores that occur in the tropical maritime regions. Thus, the composition of air deposited in the TTL at the tops of convection will be a combination of boundary-layer composition and free tropospheric composition.

TTL transport mechanisms are also poorly understood, both in terms of mean rates and variations with longitude and season, reflecting limited observations. In the TTL, latent heat is a small term in the energy budget, and adiabatic cooling (heating) driven by adiabatic ascent (descent) is approximately balanced by radiative heating (cooling). Therefore, calculations or measurements of radiative heating can be used to diagnose large-scale TTL vertical transport. The rate of vertical transport through the TTL and lower stratosphere has been estimated from observations of the water vapor "tape recorder" [*Mote et al.,* 1996; *Niwano et al.*, 2003; *Schoeberl et al., 2008*], from observations of the CO_2 gradient in the TTL [*Park et al., 2010; Schoeberl et al. 2008*], and from radiative transfer calculations [*Rosenlof et al.,* 1997]. Since clouds contribute significantly to the TTL radiative heating, there are necessarily strong regional gradients in the radiative heating [*Corti et al*., 2006; *Yang et al*., 2010]. As a result, the time scale for vertical transport through the TTL depends sensitively on the pathways taken by air parcels. In boreal winter, the strongest ascent is over the western Pacific [*Fueglistaler et al*., 2005], with descent occurring below 14 km over much of the tropics. Thus, air parcels that linger in the western Pacific after detrainment from convection can ascend through the TTL in a relatively short time.

Science Goal 3. Quantify the relative importance of the following three pathways for trace gas transport from the surface to the stratosphere, based on observations in the tropical TTL:

1) deep convective injection directly into the stratosphere [*Danielsen, 1982; Dessler and Sherwood*, 2003];
2) convection detrainment into the TTL followed by a slow ascent into the stratosphere [*Holton and Gettelman*, 2001]; and
3) the effect of intrusion from midlatitude lower stratosphere into the tropical TTL, also known as "in-mixing" [*Waugh and Polvani*, 2000; *Konopka et al.*, 2010].

These pathways are expected to have distinct chemical signatures that can be diagnosed with tracer/tracer correlation analysis [e.g., *Marcy et al.,* 2004; *Pan et al.,* 2004, 2007*; Ridley et al.,* 2004*; Avery et al.,* 2011] that will take advantage of measurements from all three aircraft. A combination of tracers with different sources and lifetimes are expected to provide the necessary diagnostics to evaluate different transport pathways. Chemical end members for the potential mixing processes will be well characterized by the combination of CONTRAST/ATTREX/CAST measurements. Thus, marine boundary layer air will be characterized by the measurement of a variety of halocarbons and other marine emissions; air mixing in from the extratropics will be depleted in most organic trace gases, including longer lived halocarbons, and should maintain a high ozone signature; mixing with background air masses from either the N or S hemisphere can be identified from hydrocarbon, HFC, and HCFC signatures.

Mixing timescales can also be attached to the different transport processes. We have already noted the use of short-lived iodine species as a significant indicator of rapid convective transport to the UT. Mixing time scales of convective transport can be inferred from the measured distribution of methyl iodide. Other species with marine origins, such as methyl nitrate and the various bromocarbons, provide additional constraints on the transport timescales. Profiles of these species through the TTL should allow us to evaluate the relative importance of detrainment at different altitudes of convection. Similarly, measurements of CO_2 have been shown to provide a useful "clock" for diagnosing transport rates in the TTL [*Park et al.,* 2007; 2010]. These rates have also been estimated from gradients in hydrochlorofluorocarbon and hydrofluorocarbon mixing ratios. Calculated transport rates are then extremely valuable to assess loss rates and mechanisms for VSLS in the TTL region.

Because this analysis involves measurements from multiple platforms and instruments, a comprehensive effort to compare measurements between platforms will be part of the experimental design. In some cases, the same investigator has instruments on two platforms, which facilitates comparisons. For other cases, discussions are already underway to compare calibrations and techniques, for example for VSL species measured on the different platforms.

Relationship to prior experiments

The study of convection and its impacts on tropospheric chemistry, stratospheric chemistry, meteorology, and climate has been carried out in a variety of programs over many years. The focus on convective processes remains a high priority research area today, as new observational platforms and instrumental techniques open up novel approaches for improved understanding. The CONTRAST mission will advance understanding of chemistry and climate relevance of convective processes from a region long known to be a major avenue for air mass entry to the stratosphere and for contributing to important radiative impacts across the tropics. Several previous experiments have sampled this region, particularly at lower altitudes, but none have measured a comprehensive suite of chemical tracers for understanding the outflow of convection and the boundary conditions for air in the TTL, and particularly in the Western Pacific. Similarly, recent studies of convection that have contained comprehensive chemical instrument payloads have been designed to study other regions with different convective regimes and chemical emissions (e.g., DC3, TORERO). The CONTRAST project, particularly with its multiple aircraft capabilities, will add vital new information for evaluating tropical deep convective processes which can be incorporated into future climate model scenarios.

The relationship of CONTRAST to a number of previous experimental programs was outlined in the CONTRAST EDO (Jan., 2012). Selected references to these projects that are relevant to CONTRAST are listed below.

Selected references to related projects and studies.

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If this is a re-submittal of a request, please address all concerns and questions raised in the "Confidential Comments and Feedback to PI" portion that was provided with the notification letter.

N/A

If this is a second year request for continuation of a program, please provide a summary or highlights describing the results of the first field phase.

N/A

Publications resulting from EOL support (including EOL-managed data) within the last five years:

Project and Year	**Facilities Used**	**Citation**
HEFT-10, 2010; VOCALS-REx, 2008	EOL/RAF	Volkamer, R, S.Baidar, S.Coburn, B.Dix, M. Lechner, H.Oetjen, I.Ortega, R.Sinreich, R.Thalman, E.Waxman, 2010. Climate active gases other than DMS? Open ocean sources of reactive glyoxal and iodine species. SOLAS Newsletter, September 2010.
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OASIS 2009	Barrow Ground Site, Data, Logistics	*Liao, J*., L.G. Huey, D.J. Tanner, F.M. Flocke, J.J. Orlando, J.A. Neuman, J.B. Nowak, A.J. Weinheimer, S.R Hall, J.N. Smith, A. Fried, R.M. Staebler, Y. Wang, J.H. Koo, C.A. Cantrell, P. Weibring, J. Walega, D.J. Knapp, P.B. Shepson, and C.R. Stephens (2012) Observations of inorganic bromine (HOBr, BrO, and Br2) speciation at Barrow, AK in spring 2009, *J. Geophys. Res.*, DOI: 10.1029/2011JD016641
OASIS 2009	Barrow Ground Site, Data, Logistics	Stephens, C.R.,P.B. Shepson, A. Steffen, J.W. Bottenheim, J. Liao, L.G. Huey, D.J. Tanner, E. Apel, A. Weinheimer, S.R. Hall, C. Cantrell, B.C. Sive, D.J. Knapp, D.D. Montzka, and R.S. Hornbrook, The relative importance of chlorine and bromine radicals in the oxidation of atmospheric mercury at Barrow, AK, *J. Geophys. Res.*, DOI: 10.1029/2011JD016649
OASIS 2009	Barrow Ground Site, Data, Logistics	Villena, G., P. Wiesen, C.A. Cantrell, F. Flocke, A. Fried, S.R. Hall, R.L. Mauldin, J.A. McGrath, D. Montzka, D. Richter, K. Ullmann, J. Walega, P. Weibring, A. Weinheimer, R.M. Staebler, *J. Liao*, L.G. Huey, and J. Kleffman (2011) Nitrous acid (HONO) during polar spring in Barrow, Alaska: A net source of OH radicals? *J. Geophys. Res. Atm., 116*, DOI: 10.1029/2011JD016643

START05	NCAR GV	Young, L.-H., et al. (2007), Enhanced new particle formation observed in the northern midlatitude tropopause region, *J. Geophys. Res.*, 112, D10218, doi:10.1029/2006JD008109
START05	NCAR GV	Pan, L. L., et al. (2007), Chemical behavior of the tropopause observed during the Stratosphere-Troposphere Analyses of Regional Transport experiment, J. Geophys. Res., 112, D18110, doi:10.1029/2007JD008645.
START05	NCAR GV	Bowman, K. P., L. L. Pan, T. Campos, and R. Gao (2007), Observations of fine-scale transport structure in the upper troposphere from the High-performance Instrumented Airborne Platform for Environmental Research, J. Geophys. Res., 112, D18111, doi:10.1029/2007JD008685.
START08	NCAR GV	Gettelman, A., P. Hoor, L. L. Pan, W. J. Randel, M. I. Hegglin, and T. Birner (2011), The Extratropical upper troposphere and lower stratosphere, *Rev. Geophys*., 49, RG3003, doi:10.1029/2011RG000355.
START08	NCAR GV	Homeyer, C. R., K. P. Bowman, and L. L. Pan (2010), Extratropical tropopause transition layer characteristics from high-resolution sounding data, *J. Geophys. Res.*, 115, D13108, doi:10.1029/2009JD013664.
START08	NCAR GV	Homeyer, C.R., K. P. Bowman, L. L. Pan, E.L. Atlas, R.Gao, T.L. Campos, Dynamical and chemical characteristics of tropospheric intrusions observed during START08. . *J. Geophys. Res*, VOL. 116, D06111, 15 PP., 2011. doi:10.1029/2010JD015098
START08	NCAR GV	Konopka, P. and L. L. Pan (2012), On the mixing driven formation of the extratropical transition layer (ExTL), JGR-atmosphere, in final revision.
START08	NCAR GV	Kunz, A., L.L. Pan, P. Konopka, D. E. Kinnison, and S. Tilmes (2011), Chemical and dynamical discontinuity at the extratropical tropopause based on START08 and WACCM analyses, *J. Geophys. Res.*, 116, D24302, doi:10.1029/2011JD016686
START08	NCAR GV	Pan, L. L., E. L. Atlas, K. P. Bowman, The Stratosphere-Troposphere Analyses of Regional Transport 2008 (START08) Experiment, *SPARC Newsletter 34* January 2010.
START08	NCAR GV	Pan, L. L., K. P. Bowman, E. L. Atlas, S. C. Wofsy, F. Zhang, J. F. Bresch, B. A. Ridley, J. V. Pittman, C. R. Homeyer, P. Romashkin, W. A. Cooper 2010: The Stratosphere-Troposphere Analyses of Regional Transport 2008 (START08) Experiment, *Bull. Amer. Meteor. Soc.* 91, 327-342
START08	NCAR GV	Pittman, J. V., L. L. Pan, J. C. Wei, F. W. Irion, X. Liu, E. S. Maddy, C. D. Barnet, K. Chance, and R. S. Gao (2009), Evaluation of AIRS, IASI, and OMI ozone profile Retrievals in the extratropical tropopause region using in situ aircraft measurements, *J. Geophys. Res.*, 114, D24109, doi:10.1029/2009JD012493.
START08	NCAR GV	Salawitch, R. J., T. Canty, T. Kurosu, K. Chance, Q. Liang, A. da Silva, S. Pawson, J. E. Nielsen, J.M. Rodriguez, P.K. Bhartia, X. Liu, L.G. Huey, J. Liao, R. Stickel, D. J. Tanner, J.E. Dibb, W.R. Simpson, D. Donohoue, A. Weinheimer, F. Flocke, D. Knapp, D. Montzka, J.A. Neuman, J.B. Nowak, T.B. Ryerson, S. Oltmans, D.R. Blake, E. L. Atlas, D.E. Kinnison, S. Tilmes, L.L. Pan, F.

		Hendrick, M. Van Roozendael, K. Kreher, P.V. Johnston, R. S. Gao, B. Johnson, T.P. Bui, G. Chen, R. B. Pierce, J. H. Crawford, and D. J. Jacob (2010), A New Interpretation of Total Column BrO during Arctic Spring, *Geophys. Res. Lett.*, doi:10.1029/2010GL043798.
START08	NCAR GV	Tilmes, S., L. L. Pan, P. Hoor, E. Atlas, M. A. Avery, T. Campos, L. E. Christensen, G. S. Diskin, R.-S. Gao, R. L. Herman, E. J. Hintsa, M. Loewenstein, J. Lopez, M. E. Paige, J. Pittman, J. R. Podolske, M. Proffitt, G. W. Sachse, N. Spelten, C. Webster, A. Weinheimer, E. M. Weinstock, M. A. Zondlo (2010), An aircraft based upper troposphere lower stratosphere O3, CO and H2O climatology for the Northern hemisphere, *J. Geophys. Res.*,115, D14303, doi:10.1029/2009JD012731
START08	NCAR GV	Vogel, B., L. Pan , P. Konopka , G. Guenther , R.Mueller , W. Hall , T. Campos , I. Pollack, A. J. Weinheimer , J. Wei , E. Atlas , K. Bowman Transport pathways and signatures of mixing in the extratropical tropopause region derived from Lagrangian model simulations. *J. Geophys. Res.*, VOL. 116, D05306, 16 PP., 2011. doi:10.1029/2010JD014876.
START08	NCAR GV	Wei, J. C., L. L. Pan, E. Maddy, J. V. Pittman, Murty Divakarla, X. Xiong, F. Sun, C. D. Barnet, 2010: Ozone profile retrieval from advanced Infrared sounder: Experiments with tropopause based climatology and optimal estimation approach, *J. Atmos. Ocean Tech.* 27, 1123-1139, doi: 10.1175/2010JTECHA1384.1
START08	NCAR GV	Wunch, D., G. C. Toon, P. O. Wennberg, S. C. Wofsy, B. B. Stephens, M. L. Fischer, O. Uchino, J. B. Abshire, P. Bernath, S. C. Biraud, J.-F. L. Blavier, C. Boone, K. P. Bowman, E. V. Browell, T. Campos, B. J. Connor, B. C. Daube, N. M. Deutscher, M. Diao, J. W. Elkins, C. Gerbig, E. Gottlieb, D. W. T. Griffith, D. F. Hurst, R. Jiménez, G. Keppel-Aleks, E. Kort, R. Macatangay, T. Machida, H. Matsueda, F. Moore, I. Morino, S. Park, J. Robinson, C. M. Roehl, Y. Sawa, V. Sherlock, C. Sweeney, T. Tanaka, and M. A. Zondlo, Calibration of the total carbon column observing network using aircraft profile data, *Atmos. Meas. Tech. Discuss*., 3, 2603-2632, 2010.
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VOCALS-REx, 2008	EOL	Volkamer, R., S. Coburn, B. Dix, R. Sinreich, 2010. The Eastern Pacific Ocean is a source for short lived trace gases: Glyoxal and Iodine oxide; CLIVAR Exchanges, 53, 15(2), 30-33.
VOCALS-REx, 2008	EOL	Volkamer,R., S.Coburn, B.Dix, and R.Sinreich, 2009. MAX-DOAS observations from ground, ship, and research aircraft: maximizing signal-to-noise to measure 'weak' absorbers. SPIE Proceedings „Ultraviolet and Visible Ground- and Space-based Measurements, Trace Gases, Aerosols and Effects", San Diego,

		Aug 2-9, 2009, paper 7264-4. doi:10.1117/12.826792.

E. Educational and Outreach Activities

Please list anticipated number of graduate and undergraduate students who will be involved directly and in a meaningful way in field work and/or data analysis related to this project, how you plan to enhance undergraduate or graduate classes with hands-on activities and observations related to this project; and if you will conduct outreach activities for K-12 and the public.

We expect significant involvement by undergraduates, graduate students, and post-graduate scientists during the planning, execution, and subsequent analysis of the mission.

As of this writing, investigators are proposing the following:

Institution	Undergraduates	Graduate students	Post-doctoral
University of Miami	TBD	2	1 (partial)
University of Delaware	TBD	1	0
University of Colorado	TBD	3	TBD
Princeton University	1 (expected)	1	1 (partial)
Georgia Institute of Technology	2	1	0
NCAR (ACD/ASP)	0	0	1

The CONTRAST mission will be used to enhance graduate education classes in atmospheric chemistry and related fields in atmospheric and environmental science. At RSMAS, the data analysis approach and actual data provide unique opportunities for advanced graduate student classes in atmospheric chemistry (MAC503), and we anticipate inclusion of CONTRAST highlights to graduate classes being developed in Meteorology. Similarly, at Princeton, data from CONTRAST will be used in an undergraduate course, "Global Air Pollution" (CEE/CHM/GEO 311) as well as a graduate course "Aerosol Observations and Modeling" (CEE/AOS 593). CONTRAST presents a unique opportunity to quantify the chemical boundary conditions for stratospheric input, particularly by integrating data from multiple aircraft from the surface to the lower stratosphere. Such a dataset illustrates key concepts in tracer lifetime, the importance of deep tropical convection in the distribution and transport of pollutants, and the budgets and chemistry of halogens in the stratosphere. At CU, CONTRAST data will be integrated and discussed in upper level courses in atmospheric chemistry. For example, Prof. Volkamer regularly teaches undergraduate courses about Instrumental Analysis at CU Boulder. Undergraduate students that perform well in the laboratory section of the course have the opportunity to continue doing summer research. During the CONTRAST project period projects will be chosen in support of CONTRAST science objectives. Two graduate students from CU Boulder will participate in the CONTRAST field deployment, and receive training on conducting atmospheric chemistry field research from research aircraft, as well as be involved with the subsequent data analysis and modeling activities.

In addition to the assistance from EOL (see below), CONTRAST investigators plan outreach activities. Princeton investigator (Zondlo) identifies outreach activities that will include demonstrations of the VCSEL hygrometer to high school students from underrepresented groups in STEM fields through the PI's involvement in the non-profit Young Science Achievers Program

(YSAP). Specifically, air pollution, climate change, and new laser technology developments are typically explained to students through laboratory demonstrations, tours, and group activities as part of the Princeton-YSAP Science day that over 300 people attend. The PI leads this activity which includes about ~ 150 students, 100 parents, and 50 high school teachers. The PI’s group members also mentor year-long science projects with several YSAP teacher-student teams and thereby provide additional outreach efforts on a sustained and more interactive basis. GIT is also planning continuation of an outreach program to local high schools. At CU, Dr. Volkamer maintains an active community outreach program in Boulder, CO. For example in 2009, he presented the HEFT-10 and TORERO activities to High School teachers from the State of Colorado. In 2011, at the 30th Annual High School University Chemistry Teachers Conference, Dr. Volkamer delivered a lecture entitled 'TORERO Outreach (& Education): Putting High School students and CU undergraduates in charge'. The conference was attended by about 50 High School Chemistry teachers from all over Colorado, and provided an opportunity to seek the feedback from teachers over lunch and during continued email exchange as well as personal meetings after the event. In 2012, numerous other outreach activities occurred during the TORERO mission. For the CONTRAST period it is planned for a group of 32 High School students to visit Prof. Volkamer's laboratory for hands on experiments, and outreach lectures about atmospheric sciences.

<u>Do you require assistance with additional education and outreach activities?</u>

Yes. We have requested assistance from EOL for CONTRAST education and outreach activities. This includes website development, teacher outreach, etc., similar to what was done so successfully for the HIPPO campaign.

PART II – OPERATIONAL CONSIDERATIONS & LOGISTICS

Approx. how many people will be involved in the field campaign? *Please specify number of participants and location(s).*	Approximately 30-40 CONTRAST science investigators, not including EOL personnel; Locations: Broomfield and Guam
What other facilities/platforms outside the EOL suite will be deployed? Are any of them non-US facilities?	We anticipate participation/coordination of the NASA Global Hawk and the British BAe-146. Yes, the BAe-146 is a non-US facility.
Are complex inter-facility or inter-agency permissions required for flight operations and/or other facility operations that would benefit from EOL leadership and experience?	The EOL experience with multi-aircraft investigations will be a significant benefit
Is there a need for integrated diplomatic arrangements? *(e.g., customs, immigration, focal point with local hosts/governments)*	Possibly for Indonesian and Philippine airspace
If there are multiple instrumentation/operations sites, is there a need for operational coordination?	Single site for experiment
What kind of real-time data display and project coordination needs do you anticipate?	Real time data displays will be required for certain flight scenarios. Coordination between aircraft will need to be facilitated with EOL support, including field catalog and mission coordinator display.
Is forecasting support required for project operations?	Yes. We expect this to be done with expertise from the CONTRAST Science team, but EOL field catalog is requested to support the field effort.
What kind of communications capabilities do you expect on site? *(e.g., bandwidth)*	TBD. We need to determine the capabilities and capacity of communication on Guam.
Will operations center and real-time display and coordination services be required? [1]	Yes. A basic operations center will be required
Will you require work space? *(e.g., office, lab and storage space)*	Yes. Investigators will need office space for forecasting/planning meetings and instrument investigators will require laboratory space for maintenance, calibration, and analytical operations.
Will you require system administration support on site?	It is likely that the standard support will be adequate.
Is there a need for coordinated shipping, lodging or transportation? *(especially if this is an international*	Yes. We would like to coordinate advance shipment of equipment and supplies to Guam

[1] *A basic data/analysis center with LAN connections to the EOL computers and access to the Internet will be provided in the field by EOL. Support will include real-time communications links to the facility via "chat" and real-time display of selected variables via web site links. Access to forecasting tools and preparations of operational forecasts are not usually included as part of this service. These services are presently not supported by the NSF Deployment Pool. Funds to support its deployment currently must be obtained from separate sources, such as NSF Special Funds. For more information, please contact the CDS Facility Manager.*

project)	along with the RAF shipment.
Will you be shipping hazardous/radioactive material?	Potential shipment of high pressure gases. Potential shipment of radioactive 63Ni Electron Capture Detector./Polonium source for CIMS
Will you be shipping expendables? (e.g., radiosondes to local NWS offices)	None anticipated.
Do you require assistance with various planning and support activities/services? *(e.g., help with Air Traffic Control, organizing of workshops, meetings, site surveys, leases, permits)*	TBD upon discussion with RAF. We expect some assistance will be needed, e.g., with ATC, investigator work spaces, etc.

PART III: DATA MANAGEMENT

What operational data do you need? *(e.g., satellite, upper air, radar, surface, oceanographic, hydrological, land characterization, model products)*	Operational weather satellite data from the Western Pacific region are needed
Do you have any specific real-time data needs to aid in your data collection activities?	Normal satellite data, including cloud properties, should be sufficient
Is there a requirement for a local satellite receiver to acquire local or real time polar orbiter or high resolution geostationary satellite data?	TBD
Beyond the EOL dataset, will you or your Co-PIs provide additional research data to the project?	Yes. The science team will provide additional model forecast.
What data analysis products will you provide during the deployment?	We anticipate on providing meteorological and chemical forecasts for flight planning.
What other research data and products do you need?	TBD
Is an EOL Field Catalog needed to provide real-time information management, reporting, decision dissemination, data exchange and resource monitoring?	We have requested a Field Catalog for information management
Do you plan on moving a large amount of data back to your home institution during the project?	Not a significant amount.
What arrangements have been made for a comprehensive data archive, including the management and distribution of data from non-EOL platforms?	We have requested support from a data archive to be provided and managed by EOL.
Do you intend to request restricted data access? [2]	No

[2] *Please note that EOL policy will make all EOL data publicly available once the data are quality controlled. If a PI wants to have exclusive access to these data for the first year, s/he has to officially request such a restriction via email from the EOL Division Director (wakimoto@ucar.edu) eight weeks prior to the start of an experiment. The burden will fall on the requesting PI to request the restriction and also to "police" data distribution and access to the data once the restrictions are in place.*

NSF/NCAR HIAPER G-V

Contact: Dr. Jorgen Jensen
Email: jbj@ucar.edu, Phone: (303) 497-1028
http://www.eol.ucar.edu/instrumentation/aircraft/G-V

Operational Considerations

Preferred flight period	**Approx. 15 Jan – 28 February**
Total number of research flight hours requested	**138 minimum.**
Total number of flights requested	**12 research (8 hr); 2 test (10 hr total); ferry flight (32)**
Estimated duration of each flight	**8 hrs**
Total number of flights per week	**2 – 3**
Particular part(s) of day for flights	**Day and night**
Do you plan to fly night missions?	**Yes**
Preferred base of operation	**Guam**
Alternate base	**None identified**
Is JeffCo Airport (near Boulder) acceptable as your operations base?	**No**
Average flight radius from base	**1200 km**
Desired flight altitudes(s)	**Typically 39 – 45 Kft, with some profile to 1 Kft.**
Will there be operations in foreign or military airspace?	**We expect so, but need confirmation of boundaries.**
Number of scientific observers for each flight	**2 + MS + MC (note: MC seat may not be required on all flights)**
Will you require air to ground communications	**Yes**
Will you require satellite communications above base level? (see Appendix IV)	**Not anticipated**

Description of desired flight pattern(s), priorities, and estimate number of flights:
(Please include graphics and flight pattern images as needed)

LOCATION AND TIME PERIOD.

The experiment will be based in Guam (13.5N, 144.8E) and will take place during the winter of 2014. The location was specifically chosen to be out of the main convective region. Based on examination of long term meteorological conditions at Guam, we have determined that local conditions are favorable for flight operations. Importantly, the location is well within the range of the tropical warm pool convection to the south and the subtropical jet to the north (See Fig 2). Access to both of these areas is necessary to address important scientific objectives of the mission.

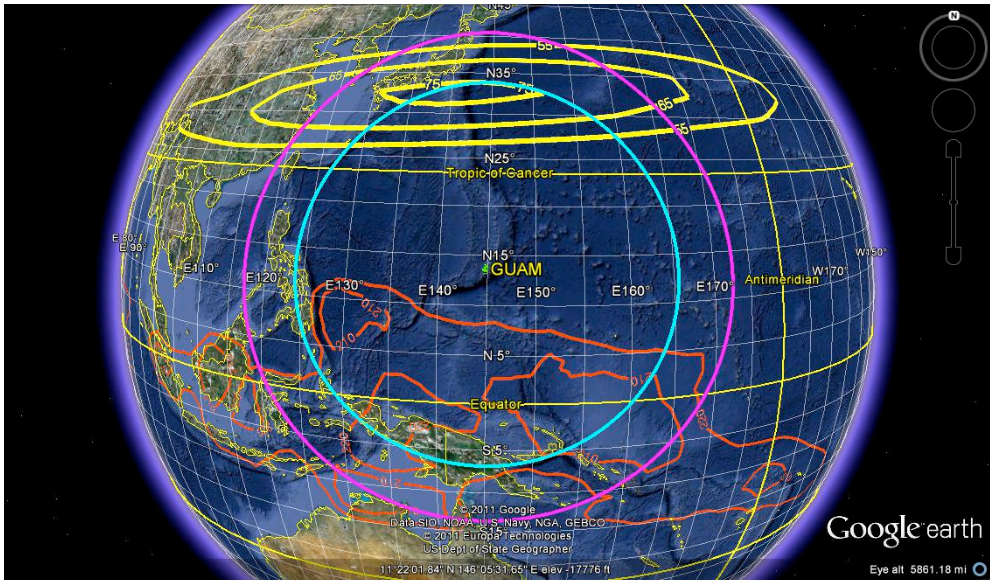


Figure 2. Range of NCAR GV in the CONTRAST study area (cyan (3hr) and purple (4hr)) from base in Guam; Also shown is contour of OLR (Red) to demonstrate good access to region of major tropical convection and windspeed (yellow) to indicate access to region of the subtropical jet and mixing gradients between tropics and extratropical air.

The timing of the mission is based on the significant convective activity that occurs over the tropical warm pool during the boreal winter. It is important to get into this region during the winter to be able to characterize the transport and chemistry associated with the deep convection that occurs in the region, and to provide a contrast to the nearby tropical upper troposphere. The other obvious important factor in the timing is the ability to coordinate flights with scientific collaborators in the ATTREX and CAST missions. The combined capabilities of the different aircraft and their complementary instrument payloads provide a remarkable synergy to characterize convective transport and chemical/radiative impacts in this region.

Meteorological factors that might affect CONTRAST during the time selected for the mission include the Madden-Julian Oscillation (MJO) and a major El Nino event. It has been determined that the MJO might only cause a shift in the ordering of specific flight scenarios, and have little impact on the overall operation. Similarly, we expect that the Guam location is appropriate for the majority of normal ENSO conditions. A severe LaNina episode could shift major convection to the most eastern reaches of the GV capability, but this contingency could be predicted well in advance of the experiment.

OBSERVATIONAL REQUIREMENTS

To meet the objectives of the CONTRAST mission requires the altitude capabilities and long-range flight operations of the GV aircraft and an instrument payload of both in-situ and remote sensing measurement capabilities. Planned measurements from the GV (**Table 1**) include a range of gases and reactive species necessary to address CONTRAST science goals. The relationship of the proposed measurements to the specific project objectives is also indicated in **Table 1**.

The main objectives cover three main scientific areas, with overlapping measurement requirements in most cases. The broad objectives can be defined as: **1)** Chemical characterization of the main convective outflow, and definition of the photochemical environment; **2**) Budget and partitioning of halogen compounds in the TTL region; and **3)** Evaluation of transport pathways to and through the TTL in the Western Pacific atmosphere during boreal winter.

Measurement of trace gases with different source emissions, lifetimes (including VSL's), and temporal trends will be used to evaluate transport time scales and mixing processes (**Objectives 1 and 3**). These measurements will be done with a combination of whole air sampling, in-situ GC/MS, and high resolution instrumentation for CO, CO_2, and CH_4. GC/MS and whole air sampling provide complementary measurements of trace gases. TOGA can measure a number of significant oxygenated VOC that are not well-behaved in whole air canisters. The AWAS can measure a full suite of NMHC, halocarbons, organic nitrates, etc. but with lower spatial resolution. A number of trace gases can be measured from both systems to provide good overlap and comparison. Measurements of radiation and relevant reactive gases will define the photochemical environment of the tropical UT to examine the impact of convective inputs of low ozone and elevated marine emissions to the UT. These measurements include actinic flux, ozone, formaldehyde, NO and NO_2, and halogen radical species (**Objectives 1 and 2**). The NO_x measurements also provide information on the input of lightning-produced nitric oxide in this area of deep convection. Potential to also measure pernitric acid (HO_2NO_2) with the CIMS instrument adds additional constraints to the HOx/NOx chemical modeling. The budget and partitioning of bromine (+ iodine) in the TTL will be evaluated with measurements of the organic bromine (+ iodine) precursors and inorganic bromine (+iodine) species (**Objective 2**). The organic bromine (+ iodine) precursors will be measured from whole air sampler and GC/MS. The inorganic halogen species will be measured by in-situ instruments (chemical ionization mass spectrometry (CIMS) and resonance enhanced fluorescence (ROFLEX)) as well as remote sensing (MAXDOAS). The MAXDOAS will provide a link to comparable measurements on the GH and BAe-146 aircraft. Contrast of daytime and nighttime partitioning of inorganic bromine species will test the proposed mechanisms of halogen partitioning that are relevant to the low ozone environment in this region. Finally, aerosol measurements will identify cloud aerosols and aerosol size distributions that may be significant for heterogeneous chemical processing. Complementary measurements from ATTREX and CAST are indicated in **Table 1** (See also Appendix 1, CONTRAST EDO, January, 2012).

TABLE 1. Observational Requirements and Potential Instruments for CONTRAST. Comparable instrumentation on the GH (= Global Hawk) and BAe (= BAe-146) aircraft is indicated. Relationship to scientific objectives: 1=chemical characterization, O3 budget; 2=halogen budget; 3= transport and mixing.

Observation	Requirement	Instrument Source & Status	Objective	GH	BAe
O3	1 ppbv; 10 s	Facility (Fast O3)	1,2,3	Yes	Yes
H2O Vapor	1 – 1000 ppmv; 1 s	Facility (VCSEL)	1,2	Yes	Yes
CO	5%; 10 s	CARI (VUV)	1,3	Yes	Yes
CH4	5 ppbv; 10 s	CARI (Picarro)	1,3	Yes	Yes
CO2	0.3 ppmv; 10 s	CARI (Picarro)	1,3	Yes	Yes
H2CO	25 pptv; 30 s	CU (CAMS)	1,2,3	No	No
NO, NO2	5 pptv; 10 s	ACD (Chemiluminescence)	1,2	No	Yes
BrO, HOBr, Br2 (in situ)	2 pptv; 10 s	Facility (CIMS)	1,2	No	Yes
BrO, IO, H2CO (remote)	2/1/100 pptv; 10 s	CU-AMAX (DOAS)	1,2	Yes	No
Br, I	2 pptv; <1 min	CIAC (Spain) (ROFLEX)	2	No	No
NMHC, including short lived tracers, HCFCs, halocarbons	Various	Facility (AWAS)	1,3	Yes	Yes

Oxygenated VOC, VOC	Various ; 2-4 min.	Facility (TOGA)	1,3	No	No
Aerosol (number, size, distribution)	Various	Facility (USHAS)	1,2	No	No
Cloud detection		Facility (2D-C)	1,2	Remote	No
Microwave Temperature Profiler	2 K 6 km above / below aircraft	Facility (MTP)	3	Yes	No
Radiation (Actinic Flux) *		Facility (HARP)	1,2	Yes	Yes

* Irradiance measurements are not requested due to payload limitations. However, some measure of cloud optical depth would provide useful data for retrieval of the halogen oxides from MAX-DOAS. If pyranometers were available, those could be a useful addition to the payload since they would not require cabin space.

Payload Risks and Uncertainties.

With one exception, all of the instruments identified for the CONTRAST mission have been tested and deployed on the GV in other missions prior to CONTRAST. Thus, there is an experienced and capable payload available for the mission. The single exception is the atomic-halogen resonance fluorescence instrument (ROFLEX). The instrument has been used for ground-based deployments, even in rugged and remote locations [*Mahajan et al.,* 2011; *Gomez-Martin et al*., 2011]. Plans have already begun to design the instrument for airborne operation, and initial testing of halogen atom transmission through an RAF inlet has demonstrated little loss (Saiz-Lopez, personal comm.). Given the successful use of the instrument in ground-based studies, we are confident that the transition to a research-grade airborne instrument can be accomplished prior to the deployment in 2014. We recognize the risk in this projection, but think the unique reward is worth it. Even without the ROFLEX, significant advances could be made in evaluating the halogen budget and partitioning with the other instruments available on the aircraft (MAXDOAS, CIMS, AWAS, TOGA), but the measurement of atomic halogens from ROFLEX most directly and uniquely provides the information necessary to test some of the photochemical model predictions.

FLIGHT PLANS AND RATIONALE

We anticipate approximately 12 flights of ~ 8 hours each based out of Guam over 6 weeks in the field, plus science ferry flights that will provide measurements in the central and eastern Pacific atmosphere (**Table 2** and **Figures 3 -5 and 8**). Many of the flights will be coordinated with the collaborating missions (ATTREX and CAST) to achieve individual and common scientific objectives. The flight duration and altitude ranges of the aircraft involved in the mission are highly complementary for research of tropical convection. The NCAR GV has access to the main altitude of convective outflow altitude centered around 350 K potential temperature (12 – 14 km altitude) and can define conditions in the lower altitudes of the TTL. Furthermore, the GV has the altitude range to reach the lower stratosphere at higher latitudes. The upper altitude limit of the GV (about 14.5 km) leaves off where the lower altitude level of the Global Hawk picks up (about 14 km), with an eventual altitude ceiling near 19 km. With these two aircraft, we would be able to measure a detailed profile of chemical constituents throughout the TTL and into the lower stratosphere. The UK BAe-146 aircraft has a more limited duration and lower altitude ceiling (about 9 km). This aircraft has a payload designed to characterize chemical emissions and inputs within the marine boundary layer and the lower to mid free troposphere. Current plans for CAST include multiple short flights/day as well as island hops to get the aircraft deep into the intertropical convergence zone inflow region.

TABLE 1. Nominal flight types and descriptions for CONTRAST GV. See Figures 3-5 and 8 for additional detail on flight plans.

Number of flights	Description	Flight type	Coordination with other aircraft
2 - 3	Sample across the subtropical jet to obtain composition information in the lower stratosphere; define latitudinal gradients; isentropic mixing	**1**	GH
4	Profile tropopause cold pool region, including night flights for halogen partitioning; locate and characterize chemistry of low ozone features.	**2a,b**	GH + BAe
3	Inflow/Outflow sampling from recent/older convection. Samples background condition and residual impact of past convection; evaluate longitudinal gradient and long-range transport.	**2a,b**	GH + BAe
3	Deep convection. Sample entrainment and detrainment from a convective system. Evaluate tracer relationships and effect on vertical distributions in the TTL.	**3**	GH + BAe
4	Transit flights (Broomfield-Hawaii/Hawaii-Guam)	**4**	None anticipated

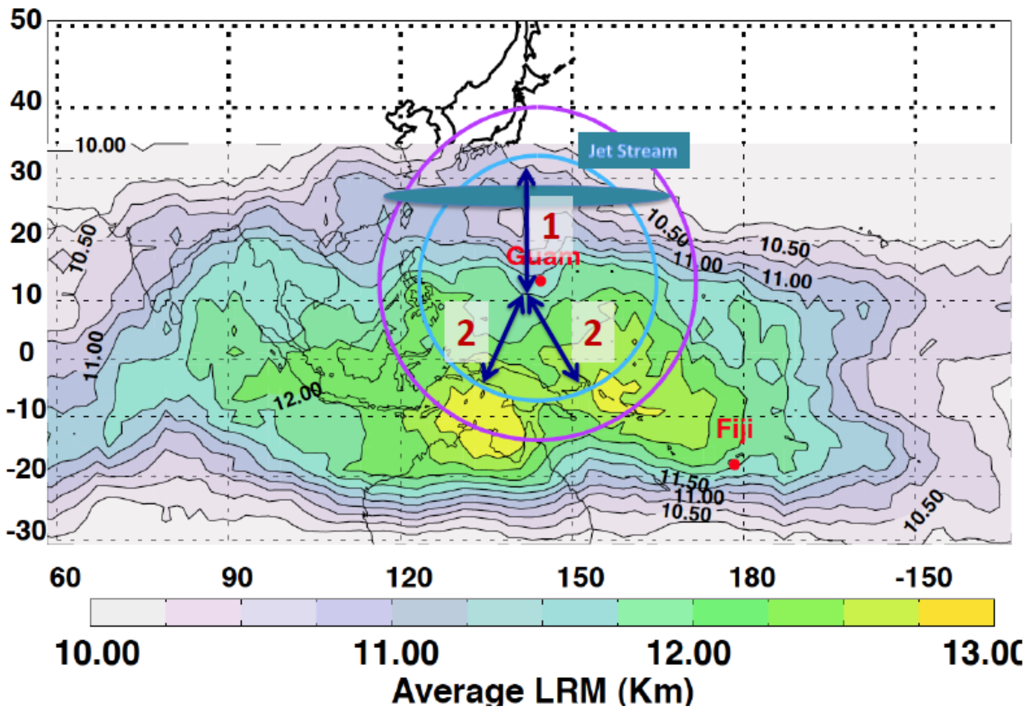


Figure 3. Expected coverage of GV flights relative to major features of 1) Jet Stream, and 2) Convective Activity (related to the LRM = Lapse Rate Minimum).

As illustrated in **Figure 3** and summarized in **Table 2**, we anticipate several basic flight plans to meet CONTRAST objectives. Of course, meteorological conditions will dictate the details of each flight plan, but we envision four basic sampling scenarios. Sampling during transit flights **(#4)** from Colorado, through Hawaii, and to Guam will allow a good characterization of the longitudinal variations in the chemistry of the background tropical and subtropical upper troposphere. Flights to the north of Guam **(#1)** to the region of the Subtropical Jet Stream will be used to examine chemical gradients and potential mixing pathways between the TTL region and the lowermost stratosphere. A typical flight pattern for this type of flight is illustrated in **Figure 4.**

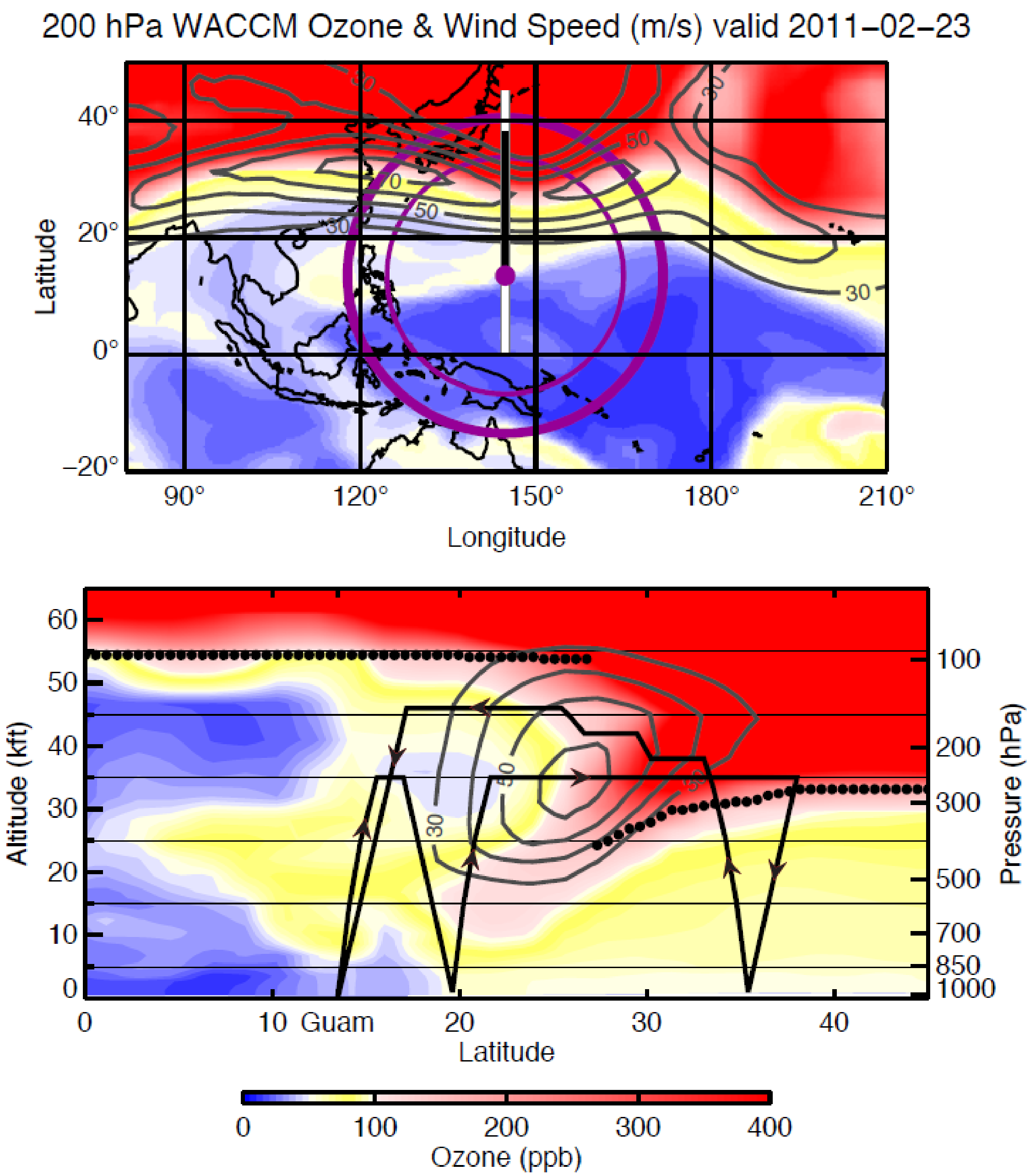


Figure 4. Nominal flight pattern for the GV to sample the region across the Subtropical Jet Stream. The panels include typical chemical and meteorological conditions estimated from the WACCM model for the CONTRAST time period. Shown are the ozone mixing ratio (color contours), wind speed (brown contours), tropopause (black dots). The thick black line is the flight track, and the thick white line indicates the region of the vertical cross-section.

The remaining bulk of the flights will be to the south of Guam to probe different convective regions and vertical structures within the TTL. Flights that will profile the TTL will be targeted for conditions that include recent convection with outflow near 350K **(#2a,b; 3)**, areas outside of recent convective activity **(#2a,b)**, and regions of the TTL impacted by deep convection (>350K) **(#3)**. Though we do not expect to probe active convective cells, we are interested in penetrating the anvil downstream of convection to compare with adjacent clear air chemical conditions. Though details of the flights will depend on specific meteorological conditions, a basic profile is envisioned as shown in **Figure 5**, below.

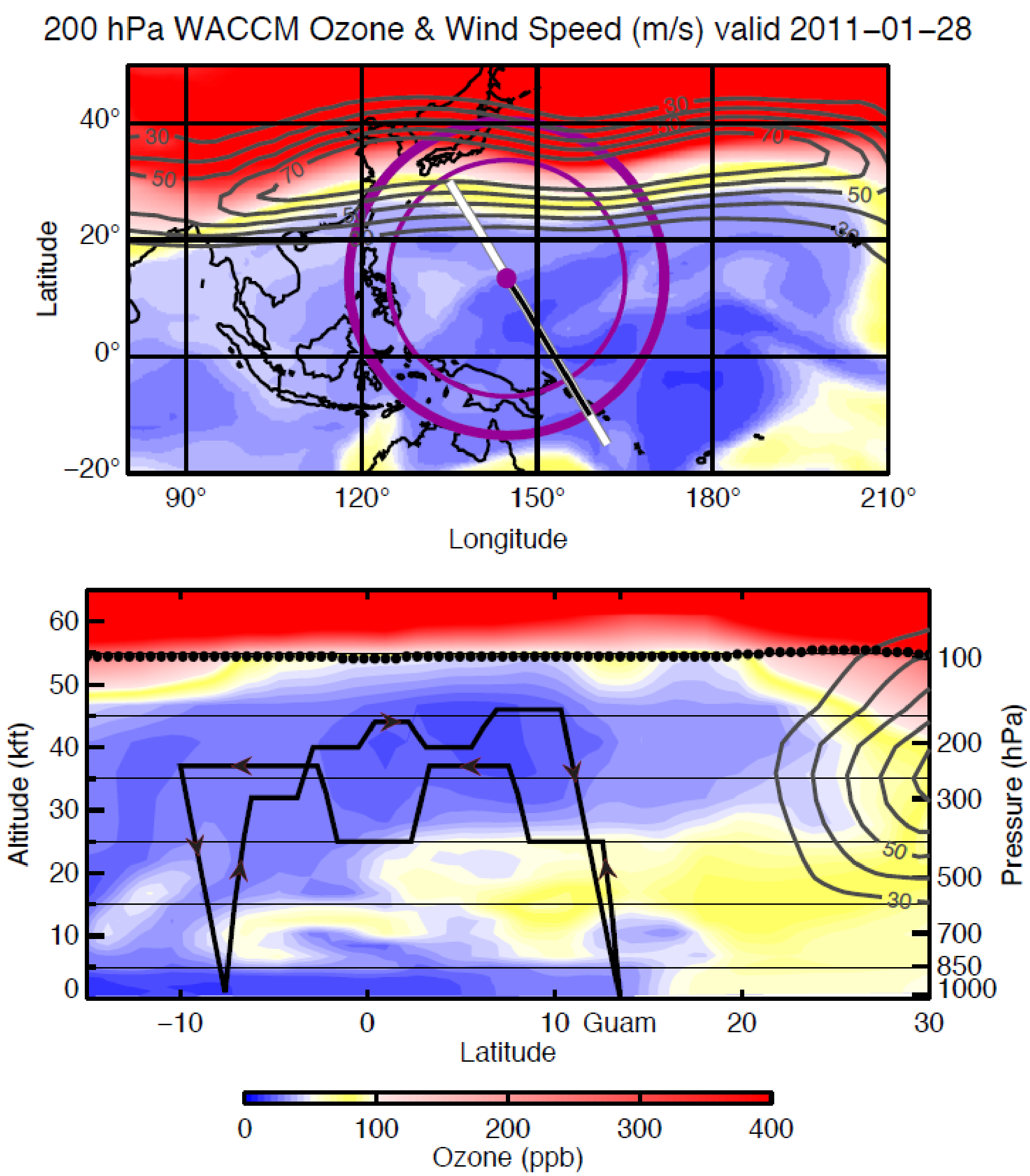


Figure 5. Typical flight patterns for the GV during CONTRAST Type 2 and 3 flights to probe convective outflow, tropical cold pool regions, and aged convection and long range transport. Colors and definitions as in Figure 4.

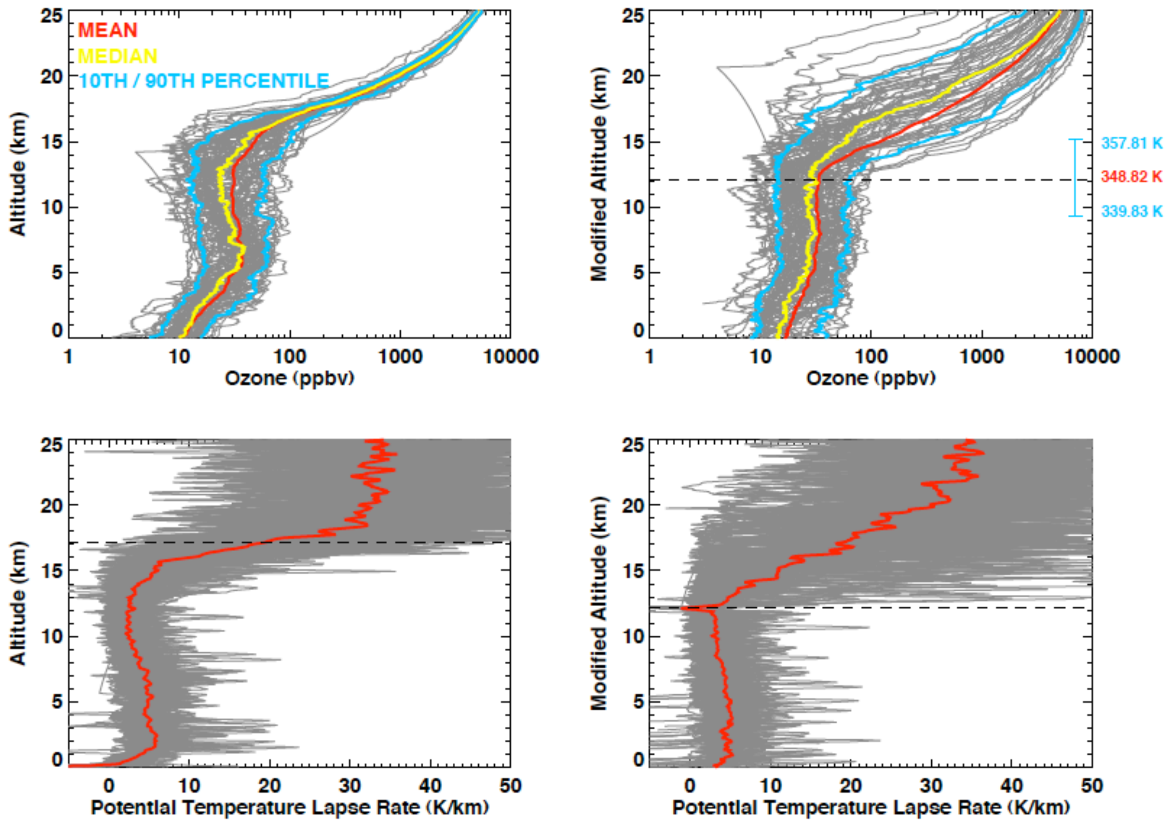


Figure 6. Multi-year record of ozonesonde profiles from Fiji vs altitude (Top-left) and in modified altitude, i.e., altitude relative to the level of minimum static stability (also referred to as the lapse rate minimum (LRM)) calculated from temperature profiles and adjusted to the mean level of minimum stability (dashed line) (top-right). Red=mean; Yellow= median; Blue =- 10th and 90th percentile. The range of variability in level of LRM is marked by the blue vertical bar on the dashed line (top-right). The potential temperature lapse rate profiles associated with the ozonesondes are shown in the bottom panels in the same vertical coordinates.

Flights will be designed to study the vertical structure and relationships of chemical tracers and dynamical background in the TTL. For example, it is known that the tropical ozone profile has a characteristic "S" shape. Low ozone at ~14 km is an indication of convective outflow [*Folkins et al*., 1999] that contains surface layer air depleted in ozone. Using a multi-year record of ozonesonde data from Fiji, we can see this behavior for the DJF time period (**Figure 6**). Also shown in Figure 6 are the ozone profiles and associated lapse rate profiles in altitude relative to the level of lapse rate minimum (LRM), which is also referred to as the level of minimum static stability. The sharp increase of both ozone and stability at the level of LRM shows that LRM is a critical level of convective influence and serves as the lower boundary of the TTL [*Gettelman and Foster*, 2002. Based on calculations using 4 years of COSMIC GPS temperature profile data (See EDO), we find the average LRM height shows the contrast in the level of convective influence between the southern and northern part of the CONTRAST domain. The LRM is above 12 km in the southern domain, with a higher frequency of occurrence above the average. We plan to investigate the behavior of chemical tracers of different lifetimes in relation to the TTL boundary and contrast the behavior between the southern and the northern domain. In both sides of the domain, the typical LMR is within the GV altitude capability. This relationship will provide a good diagnostic for the signature of convective influence in the chemical species of interest. Utilizing this relationship, a sampling strategy will be designed to obtain complete vertical profiles through the troposphere using coordinated flights of the GV, Global Hawk and BAe-146 aircraft. The level of convective influence will be characterized using both temperature and ozone profiles, and additional detailed chemical measurements at this level will provide totally new information for the transport into TTL.

Flight Coordination with Global Hawk and BAe-146

As noted, the complementary objectives, capabilities, and instrument payloads of CONTRAST, CAST, and ATTREX present a unique opportunity for understanding the convective atmosphere of the Western Tropical Pacific during a period of active and deep convection. Conceptual flight plans of the GH for ATTREX are shown in **Figure 7**, with an overlay of the GV operational range. The overlap region presents excellent opportunities for meeting common scientific objectives (compare **Figure 3**).

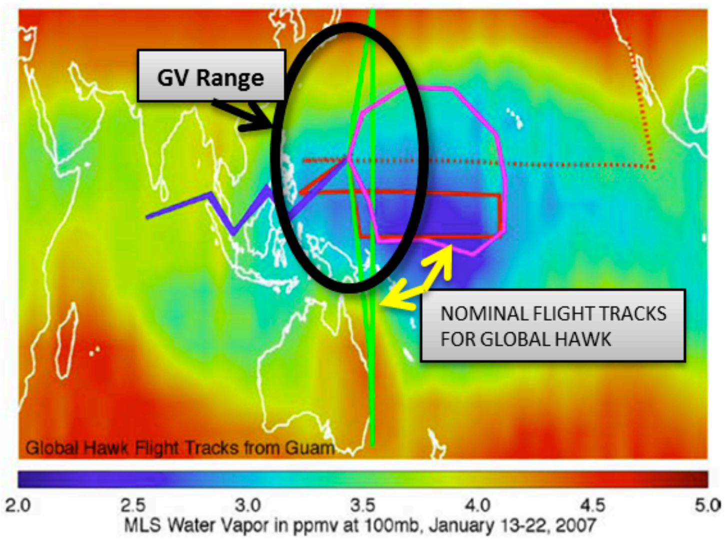


Figure7. Nominal flight tracks of the ATTREX Global Hawk aircraft for missions from Guam. The flights are designed to get long transects and detailed information in and over the TTL region over the Tropical Warm Pool. The blue color represents the low water vapor conditions characteristic of cold tropopause in the region. The operational range of the GV indicates excellent opportunities for coordinated flights (see also **Figure 3**).

The day-to-day details of flight coordination will need to be worked out during the mission. Clearly one factor that will need to be considered is how to optimize the flight coordination of the long duration Global Hawk flights (typically 24 – 28 hours), with the normal flight durations of the GV (about 8 – 10 hours) and the BAe-146 (about 5 - 6 hours). However, the long Global Hawk flights typically include multiple scientific objectives, and we envision that one or more sections of the Global Hawk would be coordinated with the GV (for example, targeting TTL profiles). With these constraints, we expect several periods of back-to-back flights of the GV to be able to interact with the GH on outbound and return legs. Similarly, the CAST plan calls for occasional days with multiple flights per day, and for island hopping ("suitcase") flights to extend the regional coverage. The basic overlay of flight profiles of the different aircraft are illustrated in **Figure 8**, below.

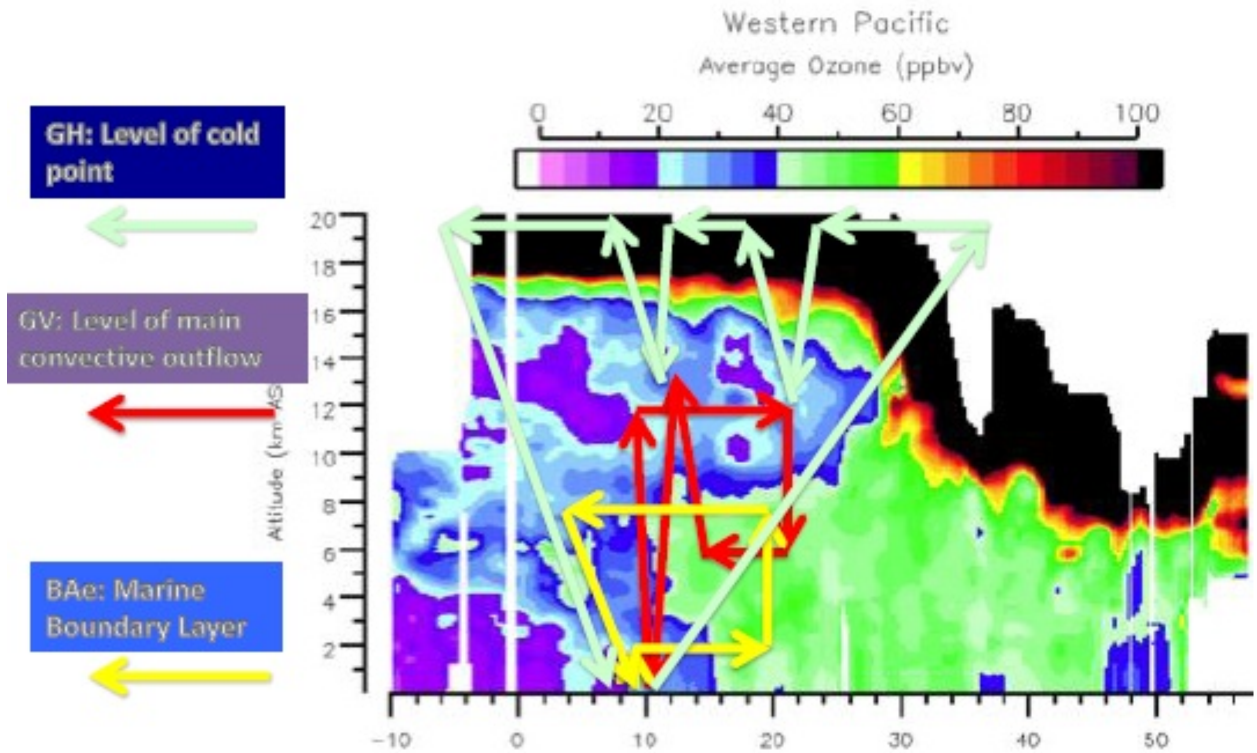


Figure 8. Relationship of coordinated aircraft flight profiles during combined CONTRAST/ATTREX/CAST flights. The nominal flight profiles are overlaid on observed ozone distribution obtained by Browell et al., during the NASA TRACE-P mission.

The other flight scenarios that are important for the CONTRAST and its collaborative partners relate to instrument comparison. As the data will need to be merged between the aircraft platforms, a concerted effort is required to evaluate instrument performance and comparability of measurements from the different platforms. Each of the aircraft has different performance characteristics, so relatively straightforward wingtip-to-wingtip comparisons are not possible. We anticipate scenarios where aircraft alternately profile the same (nominal) air mass within the shortest interval possible to examine vertical structures and correlations in the sampled air mass. In addition to the in-flight comparisons, plans are underway for those instruments calibrated from tanks or cylinders to directly compare calibration scales with tests in the laboratory or during maintenance periods.

The details of flight coordination will be determined in consultation with our mission partners in ATTREX and CAST. Potential scenarios for flight coordination are shown below for a series of daytime flights and for one period where the GV is involved in night flights. The night flight period is best accomplished over a specific period to allow adequate adjustment to night schedules, and then back to daytime. Though not all flights will be coordinated among the different aircraft, we anticipate that most flights will involve at least 2 of the aircraft, and many will include all three. This should also allow ample opportunity to include comparison activity as part of the flight plans.

Table 2. Nominal flight schedules for coordinated flights. Upper panel: daytime; Lower panel: night time.

	1		**2**		**3**		**4**		**5**		**6**		**7**	
	day	night	day	night	day	night	day	night	day	night	day	night	day	night
GV	Northern Flight				Convective Outflow						TTL Survey			
GH	Latitudinal Survey								TTL flight					
Bae-146	BL survey				Convective Inflow				Suitcase flight		Suitcase Flight			

	1		**2**		**3**		**4**		**5**		**6**		**7**	
	day	night	day	night	day	night	day	night	day	night	day	night	day	night
GV		TTL Night				TTL Night				TTL Night				TTL Night
GH	TTL flight								TTL flight					
Bae-146	BL survey				BL survey				FT survey				FT survey	

Airborne Scientific Instrumentation

Each research payload is unique and will typically consist of some combination of EOL and User-supplied instrumentation. Review the following tables for available sensors and indicate the priority of each measurement in addressing your research goals. Basic information on possible wing store configurations, rack space requirements and operator status is included. Detailed information on specific systems and platform infrastructure related to mounting User equipment can be found in the GV Handbook, available on the RAF web site (www.eol.ucar.edu/about/our-organization/raf).

Different instruments require differing levels of support. Many of the specialized chemistry measurements on the following lists require significant levels of support and are made available by special arrangement with the CARI group – a joint EOL/ACD collaboration. When considering requesting any systems marked with the CARI label, please contact Frank Flocke (ffl@ucar.edu) for performance capabilities and system limitations.

Inclusion of any "Special Request" systems will be coordinated via discussions with RAF management and the EOL science support teams assigned to those systems. Inclusion of any "Instrumentation under Development" will depend upon the timing of your deployment and the projected status of the system in question. It is recommended that contact be made with RAF prior to submitting the final request form.

a) GV Standard Instrumentation

		Data		**Sensor**
Description		**Rate(s)**	**Location**	**Quantity**
Aircraft Attitude (IRU)		1 / 25 sps	electronics bay	2
Aircraft Position & Ground Speed (IRU)		1 sps	electronics bay	2
Aircraft Position & Ground Speed (GPS)		1 sps	ads rack	2
3 - Dimensional Wind Fields		1 / 25 sps	radome	1 set
Ambient Temperature		1 sps	fuselage	2 - 4
Static Pressure		1 / 25 sps	fuselage	2
Dynamic Pressure		1 / 25 sps	radome	2
Cabin Temperature		1 sps	electronics bay	1
Cabin Pressure		1 sps	electronics bay	1
Dew Point Temperature		1 sps	radome	2
GPS Altitude (MSL)		1 sps	ads rack	2
Gas Dump Manifold Pressures		1 sps	wall tubes	2
Fwd Digital Video		1 sps	wing pylon	1
SATCOM		N/A	ads rack	
XCHAT		N/A	N/A	
Real Time Data Transfer to Ground		variable	N/A	

b) GV Instrumentation by Request

Can be added to the research payload without added expense or extra deployment staffing.
Standard data processing with output included in primary data set.

Description	Data Rate(s)	Location	Rack Space	Priority 0 - 1 - 2
Fast Ambient temperature	1 / 25 sps	radome	0	0
CDP Cloud Droplet Probe #1	1 / 10 sps	wing pod canister	0	2
CDP Cloud Droplet Probe #2	1 / 10 sps	wing pod canister	0	0
OAP 2D Precipitation Probe (25 um)	Auto	wing pod canister	0	0
OAP 2D Precipitation Probe (10 um)	Auto	wing pod canister	0	0
OAP 2D Precipitation Probe (200 um)	Auto	wing pod canister	0	0
UHSAS Aerosol Probe	Auto	wing pod canister	2-U	2
CN Concentration - water	1 / 25 sps	cabin rack	1/4	2
Differential GPS w/ ground station	1 / 10 sps	cabin rack	0	0
Digital Video - alternate views*	1 sps	partial aperture	0	2
HIMIL Chemistry Inlet (std)	N / A	std aperture	0	1
HIMIL Chemistry Inlet (heated)	N / A	std aperture	2-U	1
VCSEL TDL Hygrometer	1 sps	std aperture	0	1
King Probe Liquid Water Content	1 / 25 sps	wing hard point	0	0
Icing Rate	1 sps	wing hard point	0	0
*side views requested (as done in TORERO)				
One unit of rack space is equivalent to one standard GV rack				
There are three basic wing store configuration options:				
configuration 1: 6 pylons (12 cannisters)				
configuration 2: 2 pylons (4 cannisters)				
configuration 3: 6 pylons (8 cannisters + 2 large pods)				
Priority code: (0 = un-necessary; 1 = required; 2 = desired but optional)				

c) GV Instrumentation by Special Request

Adding these systems will require an added expense for expendables
Adding these systems will require additional support crew for a field deployment
Special data processing required by Science staff or outside participant

Description	**Inlet**	**Location**	**Rack Space**	**Num Oper**	**Priority 0 – 1 - 2**
Counterflow Virtual Impactor (CVI)	special	cabin w/ aperture	2	1	0
Airborne Whole Air Sampler	simple	cabin w/ aperture	1	0 / 1	2
Fast Ozone (CARI)	simple	cabin w/ aperture	1	0*	1
Carbon Monoxide (CARI)	simple	cabin w/ aperture	1	0	1
QCLS	HIMIL	cabin w/ aperture	1	0 / 1	0
NO-NOY (CARI)	special	cabin w/ aperture	1	0*	1
Small Ice Detector - II (SID-2)	N/A	wing pod canister	1/4	0	0
Microwave Temperature Profiler	N/A	wing pod canister	1/4	0	2
TDL Hygrometer (CARI)	N/A	std aperture	0	0	0
RDMA	simple	cabin w/ aperture	1	1	0
Wet/Dry Nephelometers	simple	cabin w/ aperture	1/4	0	0
VCSEL TDL Hygrometer	N/A	std aperture	0	0	1
HARP Radiometer Package	N/A	tail & special aper	1	0*	1**
Airborne Oxygen Analyzer (AO2)	HIMIL	cabin w/ aperture	1	1	0
Medusa Flask Sampler	HIMIL	cabin w/ aperture	1	1	0
Mission Coordinator Station	N/A	cabin	1	0 / 1	1
HSRL Lidar	N/A	cabin / Optic Win	4	1	0
GISMOS	N/A	cabin w/ windows	1	0 / 1	0
0* operators: indicates the information from CARI regarding required operators					
1** includes only actinic flux requested, though pyranometers would be a useful addition to the payload.					
One unit of rack space is equivalent to one standard GV rack					
There are three basic wing store configuration options:					
configuration 1: 6 pylons (12 cannisters)					
configuration 2: 2 pylons (4 cannisters)					
configuration 3: 6 pylons (8 cannisters + 2 large pods)					
Priority code: (0 = un-necessary; 1 = required; 2 = desired but optional)					

d) GV Instrumentation Under Development

Adding these systems will require an added expense for expendables
Adding these systems will require additional support crew for a field deployment
Special data processing required by Science staff or outside participant

			Rack	Num	Priority
Description	**Inlet**	**Location**	**Space**	**Oper**	**0 - 1 - 2**
Photometric Ozone Analyzer	HIMIL	cabin w/ aperture	1/4	0	0
3V-Cloud Particle Imager	N/A	wing pod pylon	1	1	0
HOLODEC-II Cloud Particle Imager	N/A	wing pod canister	1/4	1	0
Carbon Dioxide, CH4 (CARI)	HIMIL	cabin w/ aperture	1/2	0	1
T of F Aerosol Mass Spectrometer	HIMIL	cabin w/ aperture	1	1	0
CIMS	special	cabin w/ aperture	1	0*	1
TOGA	HIMIL	cabin w/ aperture	1	0	1
Laser airspeed sensor (1D)	N/A	wing pod canister	1/4	0	0
Wind Gust Pod	N/A	wing pod canister	0	0	0
HIAPER Cloud Radar	N/A	lrg wing pod	1	1	0
0* operators: indicates the information from TOGA (Apel) and CIMS (Huey) regarding required operators					
One unit of rack space is equivalent to one standard GV rack					
Priority code: (0 = un-necessary; 1 = required; 2 = desired but optional)					
These Instruments are under development and will be made available in the future					
Check with an RAF point of contact for more information on current instrument status					

PAYLOAD SUMMARY TABLE:

Below we summarize the payload desired for the CONTRAST mission:

		CONTRAST payload specification			
Instrument		**Rack req.**	**Operator**	Payload	**Contact**
				PRIORITY	
VCSEL	HAIS		0	1	Beaton/Zondlo
Fast O3	CARI	1	0	1	Campos
NO-NO2	CARI	0.6	0	2	Weinheimer
VUV CO	CARI	0.2	0	2	Campos
Picarro CO2, CH4	CARI	0.2	0	2	Campos
CAMS CH2O^	CU	1	0	2	Fried
CIMS	HAIS/GIT	1	0	1	Huey
AMAX-DOAS^	CU	1	1	2	Volkamer
ROFLEX^	CIAC	1	0	1	Saiz-Lopez
AWAS	HAIS/UM	1	0^^	2	Atlas
TOGA	HAIS/UM	1	1	1	Apel/Riemer
UHSAS	RAF	0.2	0	2	RAF
2D-C	RAF		0	2	RAF
CDP	RAF		0	2	RAF
MTP	RAF	0.2	0	optional	Haggerty
Actinic Flux (HARP)	RAF	0.3		2	Hall
Mission coord.		0.3	1*		RAF
Mission sci.			1		Pan/Atlas/Salawitch
* not required on all flights; opens seat for instrument investigator/other.					
^^ requires operator intervention for targeted sampling					
^ Instrument specifications included below					
Priority	1=essential; 2= desired ; 3= desired but optional				

e) User-supplied Scientific Payload

Please provide the following information for each user-supplied scientific instrument:

Instrument Name:	**CU AMAX-DOAS**
Primary Contact Name:	Rainer Volkamer
Primary Contact Institution:	University of Colorado Boulder
Primary Contact Phone:	Off: (303) 4921843; cell: (720) 2159410
Primary Contact Email:	Rainer.volkamer@colorado.edu
Individual weight of all components:	6U Rack mount (inside): 55 Lb 6U Rack mount (inside): 27 Lb 4U Optical switch box (inside): 5 Lb 3U Fan tray (inside): 6 Lb 2x 1U laptop trays /w laptops: 10 Lb Telescope (below wing pod): 20 Lb
Complete size dimensions of all components:	36.7" x 19" x 23" (high x width x depth)
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	21U (36.7")
Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	NO
Hazardous material required:	N/A
Radioactive sources or materials:	N/A
Power required (watts, volts, amps):	380W @ 120V, 3.2A (cabin) 720Wmax @ 120V, 6A (pylon)
Type of power (DC, 60 Hz, 400 Hz):	120V, 60Hz
External sensor location (if any):	Telescopes mounted in pod below wing (pod location: left, inboard, inboard)
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	yes
If yes: Signal format (digital, analog, serial):	Fire wire camera image, Serial data / UDP stream to backup instrument data/status/and send a subset to ground
Full-scale Voltage:	
Range:	
Resolution:	0.3Mb (camera), ASCII stream TBD
Sample Rate (1, 5, 250 sps):	1Hz (camera/UDP on board storage); 4 images per 2 min (4 cameras to ground)
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	2 GPS antenna signal cables (coax); desirable option: Ethernet/ARINC link to avionics data in wing
Need IRIG time-code feed?	NO
Special sensor calibration service required?	NO
Need full-time operator during flight?	YES, 1
Number of lap-top computers for on-board use:	2
Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than	NO (instrument has flown on GV during HEFT-10, TORERO)

inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*	
Will you be using your own recording system?	YES, and backup to RAF system
What additional recording capability is needed? Please give us details on the number of signals, their characteristics, format, synchronous, fire-wire, ethernet, etc. (We may not be able to accommodate any and all signals.)	N/A
If nonstandard output formats and/or data rates are required, how often are the measurements needed? Note: The standard format for processed, RAF output data is net CDF. The standard output media are CD/DVD and ftp transfer. (Nonstandard rates and/or formats will be considered as special processing requests.)	N/A
On-site data access requirement:	none

Supporting Services

	Preflight needs	Postflight needs	Routine Maintenance
	On flight days	On flight days	On non-flight days
Access (hrs)	2	1	5hrs (every 3-5 flights)
Power (hrs)	1.5	0.5	4hrs
Special Support Needs	NA	NA	TBD

Instrument Name	**Compact Atmospheric Multispecies Spectrometer (CAMS)**
Primary Contact Name	Dr. Alan Fried
Primary Contact Institution	University of Colorado, Institute of Arctic & Alpine Research (INSTAAR)
Primary Contact Phone	303-492-7559
Primary Contact Email	alan.fried@colorado.edu
Total Instrument Weight including Rack	Present weight with rack and without wheels is 366 lbs, **which we are attempting to reduce.**
Complete size dimensions of all components	1 standard HIAPER rack (34” deep, 21.5” wide x 50” ht) plus an additional 10” hanging off the back of the rack (facing towards rear of airplane)
Hazardous materials	1 2000 psig fiber/Al cylinder filled with ~ 2 ppm CH_2O/air mixture plus an additional one filled with ~ 2 ppm ethylene /air mixture. Mixing ratios can be adjusted to avoid a regulator containment housing in case of inadvertent venting.
Radioactive materials	None
Power Required	2 circuits with one at 9.5 A with other at 15.2 A at 110 VAC 60Hz

Type of power	60 Hz
External Sensor	HIMIL inlet at RAF's specified location
Signals to be Recorded by RAF	None
Real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	None
Need IRIG time-code feed?	No, but need NTP
Special Sensor Calibration	None
Full Time Operator on board	**No**
Number of lap tops for onboard use	None
EOL support in preparing instrument	Yes, Mark Lord will need to do an engineering analysis on modifications to spectrometer
Own Recording System	Yes
Additional Recorded Signals	None

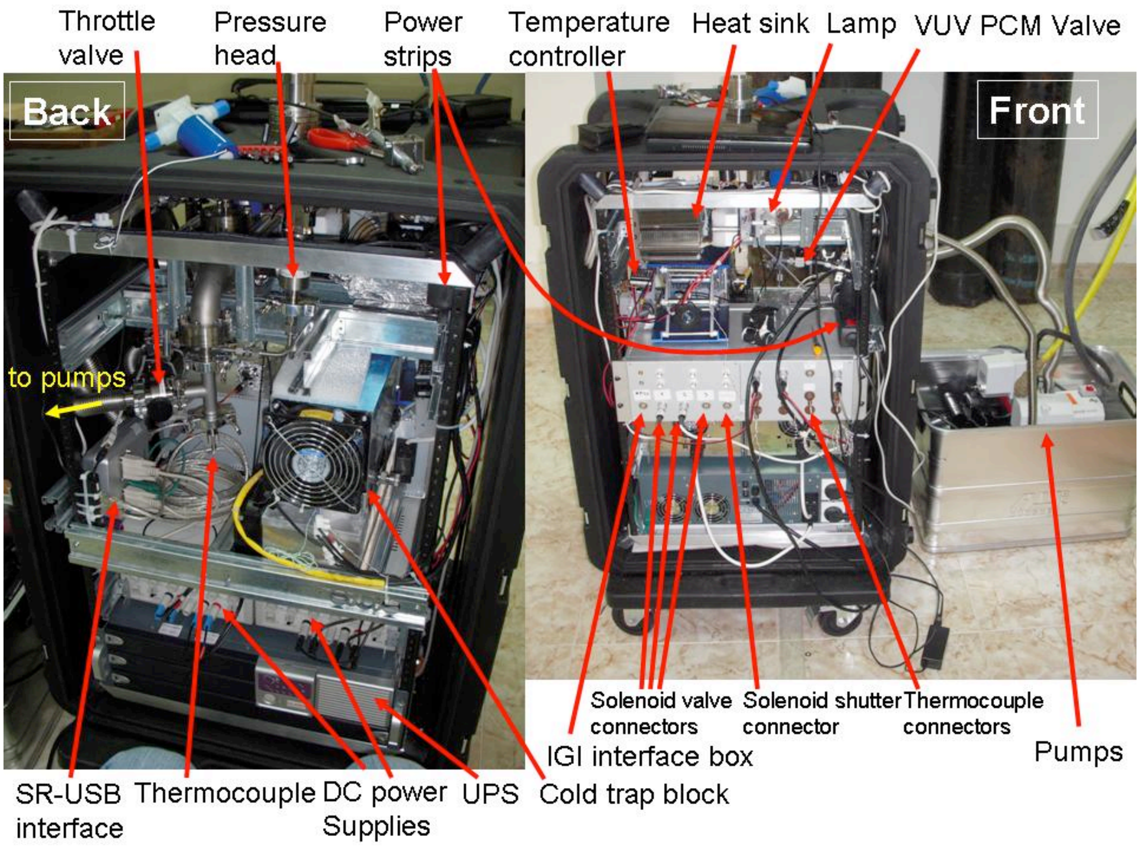
Supporting Services

	Preflight Needs	Postflight Needs	Routine Maintenance
	On Flight Days	On Flight Days	On non-flight Days
Access (hrs)	2 hours	0.5 hour	0 hours
Power (hrs)	2 hours	0.5 hour	0 hours
Special Support Needs	0 hours	0 hours	0 hours

Instrument Name:	**Resonance and Off-Resonance Fluorescence by Lamp Excitation (ROFLEX)**
Primary Contact Name:	Alfonso Saiz-Lopez
Primary Contact Institution:	Laboratory for Atmospheric and Climate Science (CIAC)
Primary Contact Phone:	+34 925245364
Primary Contact Email:	a.saiz-lopez@ciac.jccm-csic.es
Individual weight of all components:	90 Kg (Analyzer); 30 kg (Pump)
Complete size dimensions of all components:	Analyzer: 920 x 700 x 730 mm (exterior rack) Inner Rack: 16U x 19" x 508 mm); Pump Rack: 400 x 400 x 600 mm
Rack-mountable 19" panel space required (Note: depth beyond 25" will overhang in back):	TBD

Supplying your own 19" rack (yes/no): (Note: racks must survive 9G crash load.)	No
Hazardous material required:	No
Radioactive sources or materials:	No
Power required (watts, volts, amps):	Analyzer: currently 220-240V, 3A. Pump : 220 – 240 V, 2.5 A (alternate: 115V, 5 A)
Type of power (DC, 60 Hz, 400 Hz):	50/60 Hz
External sensor location (if any):	
Are signal(s) to be recorded on RAF's Aircraft Data System (yes/no)?	TBD
If yes: Signal format (digital, analog, serial):	
Full-scale Voltage:	
Range:	
Resolution:	
Sample Rate (1, 5, 250 sps):	
Need real-time, in-flight, RAF-measurement, serial data feed (RS-232, RS422)?	TBD
Need IRIG time-code feed?	
Special sensor calibration service required?	No
Need full-time operator during flight?	No
Number of lap-top computers for on-board use:	0
Will NCAR support be required in preparing the instrument(s) for use on the aircraft (other than inspection, installation and power hook-up)? EOL/RAF can provide design and fabrication support for hardware and electronic interfaces. *(If so, specify type and lead time).*	Yes, will require some support for engineering analysis of ROFLEX design and potentially power conversion.
Will you be using your own recording system?	Yes
What additional recording capability is needed? Please give us details on the number of signals, their characteristics, format, synchronous, fire-wire, ethernet, etc. (We may not be able to accommodate any and all signals.)	TBD
If nonstandard output formats and/or data rates are required, how often are the measurements needed? Note: The standard format for processed, RAF output data is net CDF. The standard output media are CD/DVD and ftp transfer. (Nonstandard rates and/or formats will be considered as special processing requests.)	N/A
On-site data access requirement:	None

Currrent instrument configuration:



Supporting Services

	Preflight needs	Postflight needs	Routine Maintenance
	On flight days	On flight days	On non-flight days
Access (hrs)	TBD	TBD	TBD
Power (hrs)			
Special Support Needs			