DOE Atmospheric Science Program

Project Overview: Cumulus Humilis Aerosol Processing Study (CHAPS)

Proposed Summer 2007 ASP Field Campaign

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1. Abstract:

This white paper presents the scientific motivation and preliminary logistical plans for a proposed ASP field campaign to be carried out in the summer of 2007. The primary objective of this campaign is to use the DOE Gulfstream-1 aircraft to make measurements characterizing the chemical, physical and optical properties of aerosols below, within and above large fields of fair weather cumulus and to use the NASA Langley Research Center's High Spectral Resolution Lidar (HSRL) to make independent measurements of aerosol backscatter and extinction profiles in the vicinity of these fields. Separate from the science questions to be addressed by these observations will be information to add in the development of a parameterized cumulus scheme capable of including multiple cloud fields within a regional or global scale model. We will also be able to compare and contrast the cloud and aerosol properties within and outside the Oklahoma City plume to study aerosol processes within individual clouds. Preliminary discussions with the Cloud and Land Surface Interaction Campaign (CLASIC) science team have identified overlap between the science questions posed for the CLASIC Intensive Operation Period (IOP) and the proposed ASP campaign, suggesting collaboration would benefit both teams.

2. Rationale and Overview of the Campaign:

The primary goal of this field campaign is to characterize freshly emitted aerosols above, within and below fields of cumulus humilis (or fair-weather cumulus, FWC) in the vicinity of a mid-size, mid-latitude city, and to use these observations to aide in the development and evaluation of regional-scale and Global Climate Model (GCM) cumulus parameterizations that describes the transport and transformations of these aerosols by FWC. This final product has the potential to reduce the uncertainty associated with the treatment of aerosols by these models. Supporting the *in situ* observations by the DOE Gulfstream-1 (G-1) will be High Spectral Resolution Lidar (HSRL) measurements from the NASA Langley Research Center's King Air Be-200 that will measure aerosol backscatter and extinction profiles (with a horizontal resolution of order 50 m for backscatter) surrounding these cloud fields. We will also make measurements of the chemical composition of aerosols inside and outside of the urban plume as part of an ASP study to characterize both activated and interstitial aerosols.

We will sample within cloud fields close to Oklahoma City so as to measure 'fresh' aerosols that are still undergoing relatively rapid changes in their size, chemical properties and related hygroscopic and optical properties. Our motivation for such near field sampling is at least partially driven by observations made during the 2002 NEAQS field campaign describing rapid changes downwind of urban areas of the eastern U.S. (Kleinman et al., 2006). Our selection of Oklahoma City stems from its relatively isolated nature which will make its plume more distinguishable from regional-scale features and the observation that other mid-size metropolitan areas characterized by populations of order one-million people are known to be associated with sub-micron hygroscopic particles produced by incomplete automotive combustion, cooking and industry (Husar et al., 1997). The proposed timing for the campaign has been determined from climatological studies on the distribution of FWC, known to be associated with mid-latitude, continental summer time conditions (Warren et al., 1986). Finally, collaboration with the ARM CLASIC campaign is anticipated to yield additional benefits to both ASP and ARM investigators (see Section 5, 'Why Oklahoma City/Collaboration.')

The primary goal of the campaign is provide information with which to **evaluate changes to aerosols as they move through the large fields of fair-weather cumuli** that are found over much of mid-latitude North America during the summer months. There are a number of reasons to anticipate that the transport of aerosols from the boundary layer to the free atmosphere by fields of FWC will affect the radiation budget.

1) Aerosol mass is the single most important factor in determining the amount of particulate scattering and absorption under clear sky conditions. Clearly, if there is no aerosol mass there will be no aerosol scattering regardless of the magnitude of the aerosol mass scattering efficiency.

Conversely, for a given mass scattering efficiency the scattering will increase with aerosol mass concentration.

2) The transport by clouds of 0.1 to 1 micron aerosols from within the boundary layer to the free atmosphere results in moving optically important particles from a region of relatively low wind speeds and high net deposition rates, to a region of higher wind speeds and negligible deposition, greatly enhancing the particle lifetime and hence aerosol mass loading in areas downwind of the source region. While updrafts associated with FWC do not transport air to great heights, significant transport through the clouds does occur. Using Large Eddy Simulation (LES), Cotton et al. (1995) found that 30% of the boundary-layer air passed through a region of FWC in a one-hour period while Lu et al. (2003) found cloud processing to be associated with significant differences between aerosol size distributions measured in the free atmosphere and the marine boundary layer. In addition, lifting strongly absorbing aerosols from below clouds into and above the cloud layer will alter the energy budget by effectively reducing the insolation reaching lower levels of the atmosphere (Harshvardhan, 1993; Ghan and Penner, 1992).

3) Those aerosols activated as cloud condensation nuclei are subject to aqueous phase chemistry in cloud drops, with an associated change to aerosol mass following the resuspension of particles when the droplets evaporate. This change in mass, resulting from, for example, the enhanced production of sulfate, in turn is expected to change the aerosol mass extinction efficiency, E_{ext}, the aerosol mass scattering efficiency, E_{scat}, and the aerosol mass absorption efficiency, E_{abs}. Each of these variables is dependent on the aerosol size (diameter), the wavelength of incident radiation and the refractive index of the aerosol. The potential importance of these changes stems from the sensitivity of radiative forcing to these quantities. Depending on the surface reflectance and the backscattering fraction, very small changes in the single scattering albedo, $\omega_0 = E_{scat}/[E_{scat} + E_{abs}]$, are believed to be associated with a change in sign (±) of the direct forcing (Haywood and Boucher, 2000; Hansen et al., 1997).

4) Scavenging is a function of aerosol composition, with the result that some types of aerosols that are more readily scavenged (e.g. sulfate) are more likely to scatter light, while others that more resistant to scavenging (e.g. soot) are more likely to absorb light. As a result we expect to detect changes in the scattering efficiency, the absorption, the number density and the chemical composition of aerosols above clouds relative to those below which in turn will have a substantial effect on the back scatter of solar radiation to space. While the net transport of aerosols from below to above cloud tops is not the only source of such aerosols, studies of trace-gas transport has shown that FWCs play an important, though not the

only, role in determining the chemical composition of air above cloud top (Taylor et al., 1997; Edy et al. 1996; Thompson et al., 1994; Vukovich and Ching, 1990; Ching and Alkezweeny, 1986; Greenhut, 1986; Ching et al., 1984).

5) The relative humidity is much lower in the free troposphere then in the boundary layer so changes would be expected in the size distribution of aerosols associated with hygroscopic swelling.

The proposed campaign is built around making measurements from the G-1 to provide statistics of aerosol properties and related quantities, including: aerosol size distributions, aerosol scattering, aerosol absorption, aerosol chemical composition, and size distributions and concentration of cloud condensation nuclei below and above fields of FWC downwind of Oklahoma City. The basic flight plan will be built around cross-wind sampling legs of ~40km length made below, within and above the cumulus fields. Additional details are provided in Section 3 ('Basic Flight Plans and Sampling Strategy'). The spatial scale of the sampling is intended to provide statistics against which to test the fidelity of parameterizations used in large-scale models describing aerosol transport over typical GCM grid cells ($\Delta x \sim 100$km).

ASP scientists from the NASA Langley Research Center also plan to evaluate how aerosol optical depth (AOD) varies in the vicinity of clouds. Satellite observations have noted increases in aerosol optical depth (AOD) near clouds (Wetzel and Stowe, 1999; Nakajima et al., 2001), but these results may simply be an effect of cloud contamination in seemingly cloud-free pixels. This uncertainty in the behavior of aerosol extinction near clouds, and the uncertainty in cloud cover fraction, leads to increased uncertainties in determining direct radiative forcing (Coakley et al., 2005). Additional measurements of the small scale spatial variability using higher resolution sensors from both space-based and airborne platforms are needed to help understand the limitations of aerosol retrieval algorithms and cloud screening procedures that are used.

Previous airborne measurements have observed small scale variability in AOD. During the Chesapeake Lighthouse and Aircraft Measurements for Satellites (CLAMS) experiment, airborne Sun photometer measurements indicated that AOD typically varied by 25-30% over distances of 50 km (Redemann et al., 2005). The lack of spectral variability of AOD indicated little variability in the aerosol size distribution, so that this study concluded that over the east coast of the U.S. during the summer, AOD variability is caused primarily by the transport and diffusion of similar aerosol types rather than the mixing of aerosol types of different size and composition. It is not clear whether these same results apply to the central U.S. or whether they are unique to the east coast.

As part of the study, we will also characterize the cloud-borne aerosols within the Oklahoma City plume. The primary tool to make such measurements will be a counterflow virtual impactor, used to separate cloud drops from interstitial aerosol. Aerosol light scattering, back-scattering and absorption, hygroscopicity and size will be measured and used to derive radiatively significant parameters such as aerosol single scattering albedo and backscatter fraction for both cloud scavenged and interstitial aerosol.

We also plan to include cloud microphysical observations in the G-1 instrument suite. Observations made within wintertime stratiform clouds near Denver (CO) and Kansas City (MO) found significant differences in cloud-droplet size distributions, with clouds associated with the urban plumes of these cities having a larger number of droplets and smaller median volume diameter than clouds shown to have not been impacted by these urban plumes (Alkezweeny et al., 1993). There are climate implications to such observations. A reduction in droplet size has been postulated to result in brighter clouds with an associated cooling effect to the atmosphere (Nakajima, et al. 2001). Understanding these mesoscale downwind effects is requisite to understanding their regional and global effects (Twomey et al., 1984; Charlson et al., 1992). Smaller cloud droplets also have smaller coalescence efficiencies (Rosenfeld, 1999) resulting in reduced precipitation and longer cloud lifetimes.

The data that we propose to obtain in and around clouds inside and outside of the urban plume, may allow us to identify and evaluate the effects of the urban plume on cumuliform cloud microphysics. We recognize that most cumuliform clouds have sufficiently large optical thickness such that changes to the drop size would only have a small influence on the albedo. However, we may, for example, find evidence of the second aerosol indirect effect (which includes changes in the cloud liquid water content, cloud lifetime, and the area coverage of clouds) by comparing cloud properties inside and outside of the Oklahoma City plume.

In summary, we are proposing a campaign to let us answer a variety of questions (see Section 4) that center on the contrast expected to be found in aerosols below and above large fields of FWC and the aerosol and microphysical properties of clouds that are both within and outside the urban plume of Oklahoma City. Although the success of measurements to be made by PNNL, NOAA and NASA are independent of each other (e.g., the below/above cloud aerosol fields measured by the PNNL team, the activated/interstitial aerosol contrasts of interest to the NOAA investigators, and the large-scale aerosol distribution and AOD variation as a function of proximity to clouds of interest to the NASA team), the success of all teams will lead to a better understanding of the role of urban areas on aerosols and clouds and, through this, a better understanding of how to describe these processes in the climate models.

3. Basic Flight Plans and Sampling Strategy

By centering the campaign in the near-field downwind region of Oklahoma City, we can use the G-1 to make cross-wind transects that intersect the urban plume.

Such a strategy, used by ASP investigators on a number of past campaigns (e.g., Nashville and Houston) will let us make *in situ* samples of air that is both ‘polluted’ and relatively clean. A schematic of the general sampling strategy is shown in the figure below.

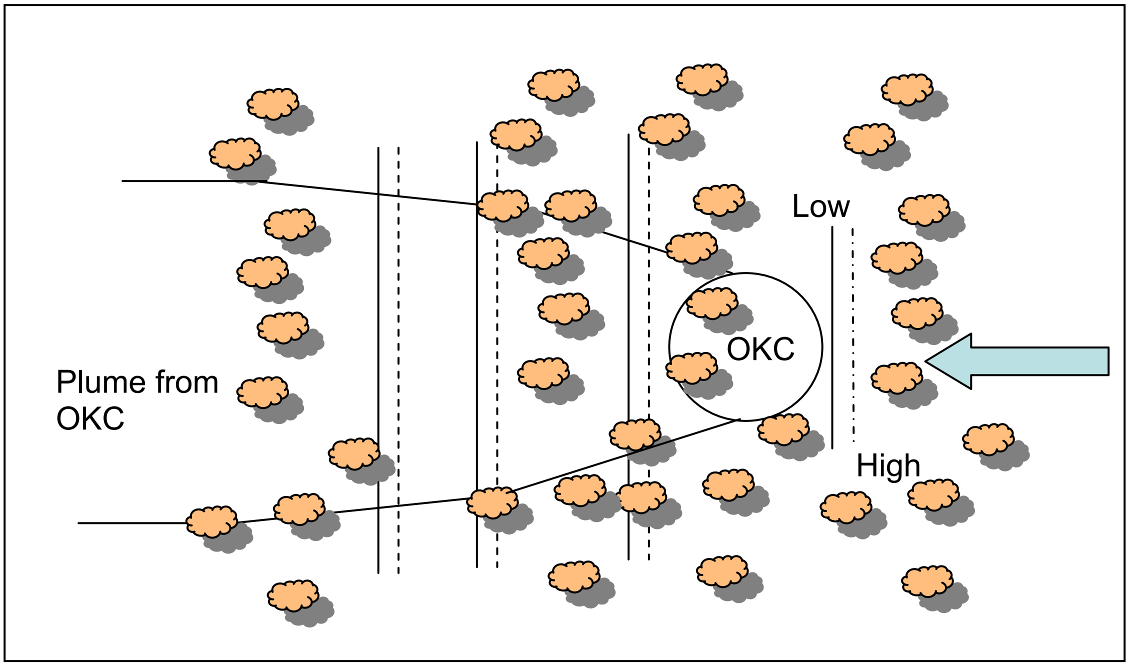

Figure 1: Schematic showing generic flight plan for sampling fields of cumulus within the plume emanating from Oklahoma City. Wind flow is from right to left.

In this figure, the predominant wind direction is shown by the large arrow on the right, with fields of cumulus humilis extending over the region. Solid vertical lines represent cross-wind transects to be made below cloud base while dashed vertical lines represent similar transects flown above cloud top (these two sets of lines have been displaced slightly for purposes of clarity). Characterization of background fields would be made via short cross-wind transects flown upwind of the prevailing wind pattern, these to be followed by a series of longer below- , within and above-cloud cross-wind transects made downwind but relatively close (<50 km) to the edge of Oklahoma City. Identification of air that had passed over the city would be made via onboard measurements of compounds associated with urban emissions, e.g., CO.

The exact number of transects will be determined by the availability of G-1 flight hours (both total and per mission), with a balance struck between the number of in-cloud transects and the total number of sets of downwind transects. We anticipate this basic sampling strategy to be modified in two respects as details of the field program evolve. First, spirals will likely be added over ground-sites that may be deployed in conjunction with the CLASIC IOP (see Section 5). And second, we will likely link the G-1 flights with those to be made by the NASA King Air Be-200. While the details of how this linkage will be done are still under discussion, we anticipate that, in addition to surveys upwind and downwind of Oklahoma City, the Be-200 would often be flown directly above the G-1 transects, acquiring lidar profile data to provide vertical context on aerosol and cloud structure above and below G-1.

4. Scientific Questions

The proposed study will addresses the following scientific questions:

Question 1: How do below-cloud and above-cloud aerosol optical properties differ downwind of a typical mid-latitude North American city? What are the differences in the:

a. radiative properties (e.g., single scattering albedo, mass scattering efficiencies)
b. the chemical composition,,
c. hygroscopic properties (including capability to serve as CCN) and
d. size distribution

To address questions relating below- and above-cloud aerosol properties, we must identify aerosols that have passed through the cloud system. Of course aerosols above cloud top need not have passed through the cloud immediately below. To identify those air parcels that have passed through clouds over which the G-1 has sampled, we plan to make use of conserved thermodynamic tracers to identify air that has been lifted from the convective boundary layer through the FWC. By definition, the value of a conserved variable does not change during adiabatic ascent and descent of an air parcel. Because we are focusing on non-precipitating clouds, we can make use of a number of variables that are conserved for both dry and moist adiabatic processes, including total water mixing ratio, equivalent potential temperature and liquid-water potential temperature. As an alternative method, a number of authors (Lu et al., 2003; Perry and Hobbs, 1996; Radke and Hobbs, 1991) have used regions of high relative humidity around clouds to identify parcels that have been processed by clouds.

Conservative variables can be combined in a tool known as a conserved variable diagram to identify the source region of air parcels. Conserved variable diagrams have been used study a number of boundary-layer processes, including mixing within individual clouds. One application of the conserved variable diagram that has been applied to cloudy boundary layers makes use of observations of equivalent potential temperature or liquid water potential temperature plotted as a function of total liquid water mixing ratio. Air that consists of a mixture containing boundary-layer air, which we would expect for parcels that emerge from FWC, will lie on a line connecting the boundary-layer thermodynamic properties and the mean cloud-layer properties. The relative location of an observation on the mixing line indicates the proportion of air from each source region for that parcel. Air that does not lie on or near the mixing line did not originate in the boundary layer and is assumed not to have been processed by clouds. We recognize that total liquid water is difficult to measure in the cloud, but we only need accurate measurements below and outside of the clouds to determine if air has been processed by clouds. In addition to thermodynamic variables, measurements of atmospheric non-soluble gas concentrations can be used to indicate the source region of air parcels.

Question 2: How does the distribution of aerosol extinction vary in relation to proximity to individual clouds and fields of clouds?

As noted earlier, the behavior and variability of AOD near clouds is uncertain. The measurements required to address this uncertainty can be acquired using the NASA High Spectral Resolution Lidar (HSRL), independent of the G-1's *in situ* observations. The HSRL profiles of aerosol backscattering and extinction, retrievals of layer aerosol optical thickness, and aerosol intensive parameters (backscatter color ratio, extinction/backscatter ratio, and depolarization) can be used to investigate the spatial variability of aerosol optical properties over the southern Great Plains within and beyond the geographical domain to be sampled via *in situ* measurements from the G-1. Furthermore, the aerosol extensive (extinction, backscatter) and intensive (backscatter color ratio, depolarization, aerosol extinction/backscatter ratio) parameters derived from the HSRL measurements can be used to infer whether AOD variability is due to changes in aerosol type (e.g. composition, size) or amount.

Question 3: What is the horizontal variability of the boundary layer depth upwind and downwind of a major U.S. city and what effects does this have on transport and mixing? How high does urban plume reach? How does relative amount of AOT within and above PBL vary around major city**?**

The HSRL aerosol backscatter and extinction profiles can be used to characterize the Planetary Boundary Layer (PBL) height and the entrainment zone depth. Lidar systems have been widely used to examine the structure and variability of the PBL top and to derive the entrainment zone depth (e.g. *Cohn and Angevine,* 2000; *Brooks,* 2003). The Haar wavelet covariance transform technique with multiple dilations (*Brooks,* 2003) can be used as a robust and objective method to derive PBL heights and transition zone thicknesses using the HSRL data. This method has been used to derive these parameters from water vapor and aerosol backscatter and extinction profiles measured by the DOE ARM Southern Great Plains (SGP) Raman lidar (*Ferrare et al.,* 2003). The HSRL measurements of aerosol backscatter can be used in a similar fashion to determine the horizontal and vertical variability of the PBL height and transition zone; the backscatter, extinction, and depolarization measurements can also be used to investigate the variability of aerosol optical properties within and above the PBL.

Question 4: How do the properties of activated and interstitial aerosol change between clouds that are within the urban plume and those that are outside the urban plume of Oklahoma City?

The proposed observations to address this question will follow from the basic flight plan illustrated in Figure 1 (albeit with in-cloud transects in addition to the below-cloud and above-cloud skeleton strategy).

Question 5. Can large-scale models with state of the art cloud parameterizations capture the bulk features of the below-above cloud aerosol fields?

One of the ASP program's deliverables is the addition of parameterized aerosol physics and chemistry to an existing cumulus parameterization suitable for inclusion in regional-scale models or GCMs. The role of FWC in determining the size and spatial distribution of aerosols is difficult, if not impossible, to assess using current global and regional-scale models. Regional scale models are often used to explicitly treat deep convection, but ignore FWC. New approaches in climate modeling, like the Multi-Scale Modeling Framework, in which two dimensional cloud-resolving models are each run inside GCM grid box still do not explicitly resolve FWC. In most other applications the vertical transport associated with the clouds is represented using parameterizations that were designed for deep convection. Some global models, like the NCAR Community Atmosphere Model (CAM2) do include a parameterization for shallow cumuli although the parameterization is independent of the cloud cover and ignores the sub-grid variability of temperature and moisture in the model grid cell. The observations of this campaign are tailored to evaluating this product.

Estimations of various aerosol effects on climate, air quality, and chemistry have been obtained from aerosol models. Yet, the vertical distribution of aerosols remains the largest source of disagreement among the models, as shown in several global model intercomparison activities from the Comparison of Large Scale Sulphate Aerosol Models (COSAM; Barrie et al., 2001; Lohmann et al., 2001), Intergovernmental Panel on Climate Change (IPCC, 2001), to the most recent Global Aerosol Model Intercomparison (AEROCOM) in 2004 (Textor et al., 2005; Kinne et al., 2005). Moreover, although models have shown reasonably good agreement among themselves and with measurements in terms of aerosol optical thickness (AOT), AEROCOM model intercomparisons have shown that there are large differences in how the various models partition aerosol mass and optical depth among these various components (Kinne et al., 2005).

ASP scientists at NASA have begun investigating the extent to which the intensive aerosol parameters (backscatter and extinction color ratios, depolarization) derived from lidar measurements can be used to infer the vertical distribution of these primary aerosol components and thereby help evaluate the models (Ferrare et al., 2006). As part of the 2007 ASP campaign, we propose to extend these investigations by using the vertical profiles of aerosol extinction and aerosol intensive parameters from the HSRL to help evaluate the ability of models to reproduce aerosol extinction and optical thickness profiles as well as to help determine how well models can represent horizontal and vertical variations in aerosol types.

Question 6: How well do models simulate the vertical transport and scavenging of soluble and insoluble gases such as SO_2 and CO?

Although the prime focus of ASP is about the radiative effects of aerosols, it has been argued that if we are to understand cloud processing of aerosol we also need to understand cloud processing of tracers and aerosol precursor gases. Addressing question 6 will require measurements of a few key trace gases (e.g., CO) that will allow ASP modelers to evaluate how well the vertical transport of such gases are presently simulated in their models. In many ways, success in simulating these observations, especially a relatively non-reactive compound such as CO, will be a prerequisite to modeling aerosol transport since the chemical processing of these species is much simpler than the processing thought to be associated with aerosol transport through cloud systems.

5. Why Oklahoma City? Logistics, science and collaboration

5a. Logistics and Science: Oklahoma City is relatively isolated from other urban areas which will simplify distinguishing between ‘new’ aerosols within the Oklahoma City plume and ‘old’ aerosols outside the plume, where the plume boundaries can be defined from ancillary observations of CO. By being able to sample close to Oklahoma City we will avoid sampling ‘aged’ aerosols that have already had many encounters with cloud systems. In addition, the terrain in this region is relatively uniform which minimizes the likelihood that local dynamic forcing by terrain will cause a systematic bias in the formation of clouds. Finally, the aircraft will be within heavily controlled radar air space which is an added safety feature for any airborne campaign.

5b. Collaboration: Another advantage of a summer 2007 campaign in Oklahoma is the potential collaboration between the ARM CLASIC IOP and the campaign described in this white paper. Although the ASP team is focused on the transport and transformation of aerosols through FWC, and the CLASIC team is focused on fluxes and the coupling of the clouds with surface processes, both ASP and ARM scientists feel there is clear overlap in the measurements regarding the role of FWC on vertical exchange processes.

- Both ASP and CLASIC scientists are interested in cloud microphysical measurements. The ASP team’s interest in microphysics stems from wanting to better understand in-cloud transformations of aerosols. The

CLASIC team's interest in microphysics stems from wanting to better understand changes to the cloud properties associated with varying land use and boundary layer properties.

- The ASP team is proposing a campaign in the area in and around Oklahoma City because this area provides a location to sample within (and outside) of an urban plume coming from a relatively isolated medium size city in the presence of FWC. The CLASIC team has proposed a campaign in Oklahoma as a result of their interest in abrupt change in surface characteristics (e.g., change in land use associated with the harvest of winter wheat) on fluxes and cloud microphysics.

There appear to be at least three collaborative efforts that would benefit both the ASP and CLASIC campaigns. First, both programs will benefit by deploying aircraft on the same days. Having both the G-1 and the Center for Inter-Disciplinary Remotely Piloted Aircraft Studies (CIRPAS) Twin Otter make early morning observations in the same area to the north of Oklahoma City, followed by having the G-1 continue to make observations in this area throughout the late morning/early afternoon as the Twin Otter extends its observations to the north and south will provide information on local change (from the combined early morning observations from both aircraft) and regional-scale changes (as the Twin Otter samples to the north and south). We have also discussed having the two aircraft fly in a stacked pattern, providing simultaneous observations below and above a field of clouds.

Second, as resources allow, we will deploy ground based aerosol instrumentation at the ARM CLASIC super site within the Little Washita Watershed and add a third ground site with both aerosol and meteorological measurements (in addition to the stations at the Little Washita Watershed and the ARM SGP Central Facility) closer to Oklahoma City. If we can do this then a natural addition to the 'basic aircraft strategy' described earlier would be to add profiles over the surface sites or to have concurrent flyovers by the aircraft above the ground sites. Such coordinated efforts would serve the scientific interests of both programs as it would provide additional information on the vertical structure of aerosol within columns of air extending from the surface to the highest altitude sampled by an aircraft.

A third area of common interest is the planetary boundary layer (PBL) depth. The PBL contains the roots of the FWC of interest to the ASP investigators, and is the area of active mixing of interest to the CLASIC scientists. We propose to provide measurements of PBL height using the aerosol backscatter and extinction profiles measured by the HSRL. Lidar systems have been widely used to examine the structure and variability of the PBL top and to derive the entrainment zone depth (e.g. Cohn and Angevine, 2000; Brooks, 2003). The long duration (~3.5 hour, 1200 km flight leg) of the NASA Langley King Air is well suited for extensive mapping of the PBL using the lidar technique. Also, since this aircraft will be flying at high (~8.5 km) altitude exclusively, with little or no changes in altitude, the lidar measurements can provide long, uninterrupted measurements of the PBL and entrainment zone, and so will not be interrupted due to changes in altitude required for in situ sampling of aerosols.

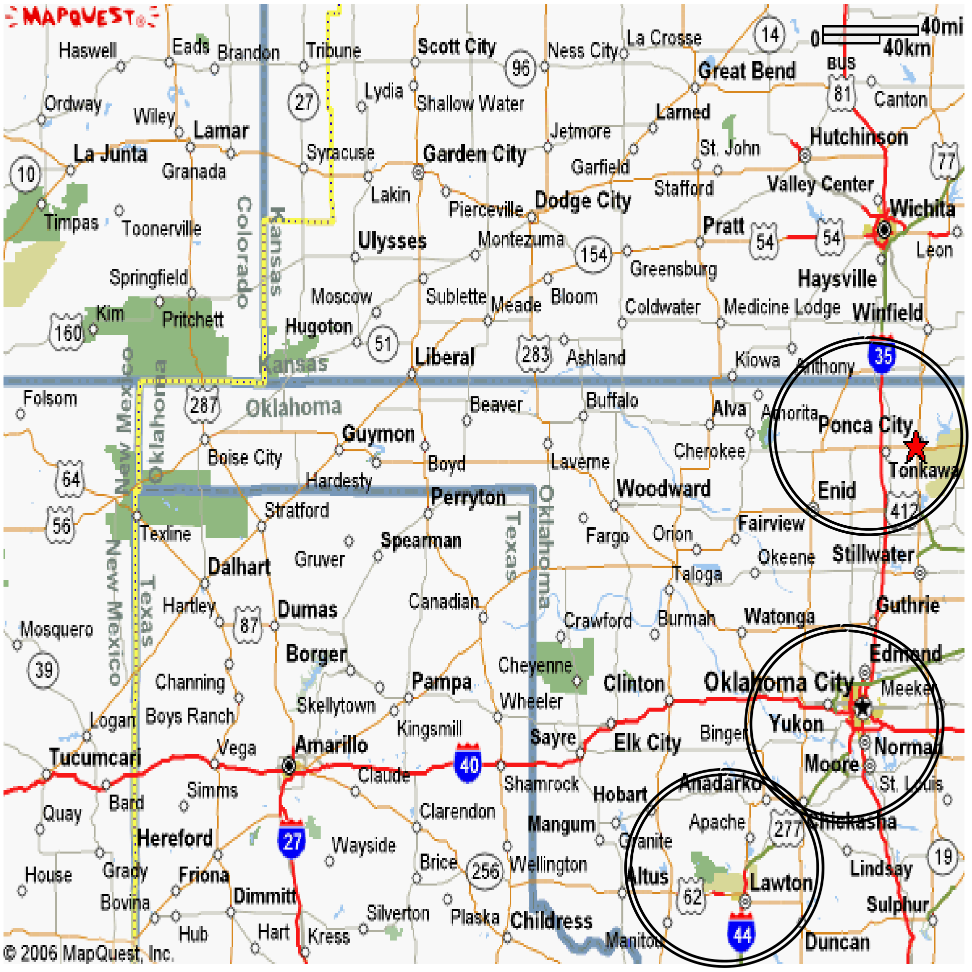

Figure 2: Map illustrating the geographic relation of key areas for the 2007 ASP campaign and the ARM CLASIC IOP. The CLASIC IOP plan calls for aircraft transects between the Little Washita Watershed (near Lawton, OK) and the SGP/Central Facility (~ 5 miles west of Ponca City). The ASP plan calls for repeated flights in the vicinity of Oklahoma City.

There are differences in the tentative logistical plans for both campaigns (Figure 2). The G-1 flights will be centered directly over Oklahoma City, with most of the flights being made less than 50km downwind of the city (where 'downwind' would be determined by that days' synoptic pattern). In contrast, the Twin Otter deployments for the CLASIC IOP will focus on a north-south transect between the SGP Central Facility and the Little Washita Watershed, which is located about 100 km south of Oklahoma City. There is not perfect overlap in the sampling domains of the two campaigns, but the overlap is significant enough that observations from one aircraft should be able compliment those from the other.

6. Proposed Measurements from the Gulfstream-1, the NASA King Air and surface site(s)

6a. Proposed measurements from the Gulfstream-I Aircraft:

Our proposed suite of in situ measurements from onboard the G-1 will consist primarily (but not entirely) of two identical sets of instruments. One set of measurements would be made from the CVI inlet, thus characterizing aerosols associated with cloud droplets. As of this date, we anticipate having the following instruments on both the CVI and interstitial inlets:

3-wavelength nephelometer
3-wavelength PSAP
Two CCN (i.e., two supersaturations)
TSI-3010 CPC (D > 10 nm)
Scanning DMA (50-700 nm diameter)
TRAC sampler (electron microscopy)

The counter-flow virtual impactor (CVI) system will allow us to separate cloud droplets from interstitial aerosols in the sampling line. This separator takes advantage of the higher inertia of cloud drops to draw them through a slight counter-flow into the measurement system while smaller particles are unable to overcome the counter-flow. Downstream of the CVI the cloud drops will be evaporated and the resulting cloud droplet nuclei (CDN) fed to aerosol instrumentation to characterize their optical, chemical, physical (size, number and shape) and cloud activation properties.

The interstitial inlet will also feed an airstream to an Aerodyne Aerosol Mass Spectrometer which will let us characterize the composition of these aerosols. While the CVI airstream will be weak on chemistry, we do not, at the present time, see how to separate the airstreams so we can alternate between CVI and interstitial air as the G-1 passes into and out of the relatively small individual clouds at speeds of 100 m s^{-1} while sampling the larger cloud fields. We also hope to have air from the interstitial inlet fed into both the BNL fast tandem DMA system, and to obtain additional information on aerosol composition from a PILS system.

We propose to make cloud microphysics observations using the BNL DMT CAPS probe (cloud droplet size between .3 and 50 microns, precipitation droplet sizing between 25 – 1550 microns). The G-1 PCASP system would also be employed (for .1 to 3 micron aerosol particles). State parameters (temperature, pressure, moisture) are part of the standard suite of G-1 measurements. A 5-port gust probe built into the G-1 would provide vertical wind speeds and turbulence measurements. Gas phase measurements would consist of CO (Vacuum UV), O_3 (the NOAA B2B system) and SO_2.

6b. Proposed measurements from the NASA King Air;

Measurements to be made from the Langley Research Center King Air Be-200 are shown in Table 2, below:

Parameter	Horizontal Resolution	Vertical Resolution
532 nm backscatter	50 m	30 m
532 nm aerosol depolarization	50 m	30 m
532 nm extinction	1500 m	300 m
1064 nm backscatter	50 m	30 m
1064 nm aerosol depolarization	50 m	30 m

Table 2: Measurements to be made from the NASA King Air Be-200.

6c. Proposed measurements from the surface sites:

In our discussions with the CLASIC science team, the possibility of adding an aerosol measurement station to their super site in the Little Washita Watershed was considered. We are also looking into establishing a second surface site in the vicinity of Oklahoma City. The purpose of both sites would be to provide continuous aerosol and meteorological observations within the boundary layer in which the roots of the FWC are located. Being able to obtain some measure of the vertical heterogeneity in aerosol properties will be yet an additional set of observations with which to compare the model parameterizations discussed in Section 4 (Question 3).

At a minimum, we hope to deploy similar instruments to those put in the field at surface stations deployed during past campaigns (e.g., at Pt. Reyes during the 2005 MASE campaign). These have included aerosol microphysics and optics (nephelometer, PSAP, humidograph, CCN, CN), aerosol size distribution (Scanning Mobility Particle sizer), and particle sampling for off-line electron microscope analysis, Specific measurements to be made at the surface site(s) will be determined by the available resources for the addition of these surface sites.

7. A note on sharing data and public availability of data

All participants in this campaign will be expected to share their observations with other contributing participants, and to confirm with these other participants that suitable credit is given in any public presentation using such data. All observations will be expected to be available for archive at the central ASP site.

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