

# **SWA Environment Laser Division: Airborne Doppler Lidar Analyses and Adaptive Targeting System (ADLAATS)**

## **1.0 Introduction**

It has been well documented (e.g., Dumais et al., 2004; 2003) that a crucial current and future need for the US Army is to maintain and advance superiority on the battlefield partly through the most accurate knowledge and description of the battlefield environment and atmosphere. This knowledge not only includes the current state of the battlefield atmosphere (especially winds and aerosols) or the Weather Running Estimate (WRE), but also the rapid numerical model “nowcasting” of how conditions will change over short time periods (0 – 60 min) and small spatial scales (1 – 5 km). In addition, such knowledge and information can be critical inputs into transport and dispersion models as well as weather impact decision aids (WIDAs) or tactical decision aids (TDAs). Urban and complex terrain situations are often the most challenging to these tasks and have been the target of recent US Army related field experiments such as CASES-99 (Newsom and Banta (2003) and JOINT URBAN 2003 (Newsom et al., 2004; Wang et al., 2004; Yee et al., 2004) which included the deployment of ground-based, wind-measuring coherent Doppler lidars.

Traditionally, direct observations of winds for use in models can be obtained with tower or tethered balloon mounted anemometers, drift balloons, rawindsondes, dropsondes, SODARs, and, under special conditions, ground based radars. These methods of wind measurement suffer from one of three limitations: spatial representativeness, rapid deployment and adaptive mobility. The airborne Doppler wind lidar (DWL) can provide wind and aerosol profiles with high space and time resolution (coverage dependent on the aircraft performance), flown to specific targets of interest with dwell options and, unlike the radars, need only aerosols (or molecules in some instances)

to provide useful signals.

In the past, Simpson Weather Associated (SWA) has been funded by the Office of Naval Research and the Integrated Program Office (IPO) of NPOESS (National Polar-orbiting Operational Environmental Satellite System) to use a 2 micron coherent Doppler lidar mounted in a Navy Twin Otter aircraft to conduct a variety of atmospheric investigations. As sole operator of the TODWL (Twin Otter Doppler Wind Lidar), SWA has developed unique software, scanning strategies and data processing algorithms that have resulted in high accuracy ( $< .05$  m/s) in the wind observations and high resolution of aerosol features ( $< 5$  meters in some instances). The experience gained during two field campaigns in 2003 and 2004 (Emmitt et al., 2005a) demonstrated that the technology is ready for advanced applications associated with meso-gamma scale modeling.

While the airborne DWL has been shown to collect both timely and adaptive observations, the key to the successful implementation of any techniques/software that result is if the data can and will be used by the Army in their atmospheric models and tactical decision aids.

The airborne wind and aerosol data that is obtained by TODWL and processed, transmitted and visualized by operational software called the Airborne Doppler Lidar Analyses and Adaptive Targeting System (ADLAATS) could prove critical to the Army's need to define the current state of battlefield atmosphere (WRE) and how it will evolve in time. ADLAATS will provide high spatial and time resolution data that can potentially be utilized by US Army systems such as the current Integrated Meteorological System (IMETS) or a future integrated system such as the Army Distributed Common Ground System (DCGS-A), as well as forecast models used by the US Army such as the MM5 (Dudhia 1993) or the 3-D Wind Field Model (Wang et al., 2002, 2005). These data can also potentially be used within tactical decision aids and weather impact decision aids to assist the US Army in making command and operation decisions. The Integrated Weather Effects Decision Aid (IWEDA) (Sauter (2000), Shirkley

and Gouveia (2002)) and the Tri-Service Target Acquisition Weapons Software or TAWS (Gouveia et al., 2000) are two such aids that can make use of the observational and modeling data.

### 1.1 The Twin Otter Doppler Wind Lidar (TODWL)

Currently, the only known USA airborne DWL on ready for research is the TODWL operated by the PI and owned by the US Navy through its Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS). The instrument is installed in a Navy Twin Otter used for general atmospheric and oceanographic research (Figure 1). The lidar is a 2 micron coherent system built by Coherent Technologies, Inc. Table 1 summarizes the technical details of the lidar. A defining capability of the TODWL is its ability to profile above, on and below the flight level. With its side door mounted, bi-axis scanner (Figure 2), the beam can be adaptively (in flight) directed in a variety of scan patterns including conical, nadir stares and flight level stares.



Figure 1.0 TODWL

Table 1. Doppler lidar

|                               |                                     |
|-------------------------------|-------------------------------------|
| Wavelength (mm)               | 2.0125                              |
| Pulse Duration (usec at FWHM) | .3                                  |
| Energy per pulse (mJ)         | 4-6                                 |
| Pulse Rep Rate (Hz)           | 80                                  |
| Telescope Diameter (cm)       | 10                                  |
| Digitization Rate (MHz)       | 100                                 |
| Scanner                       | Two axis ( $\pm 30$ and $\pm 120$ ) |



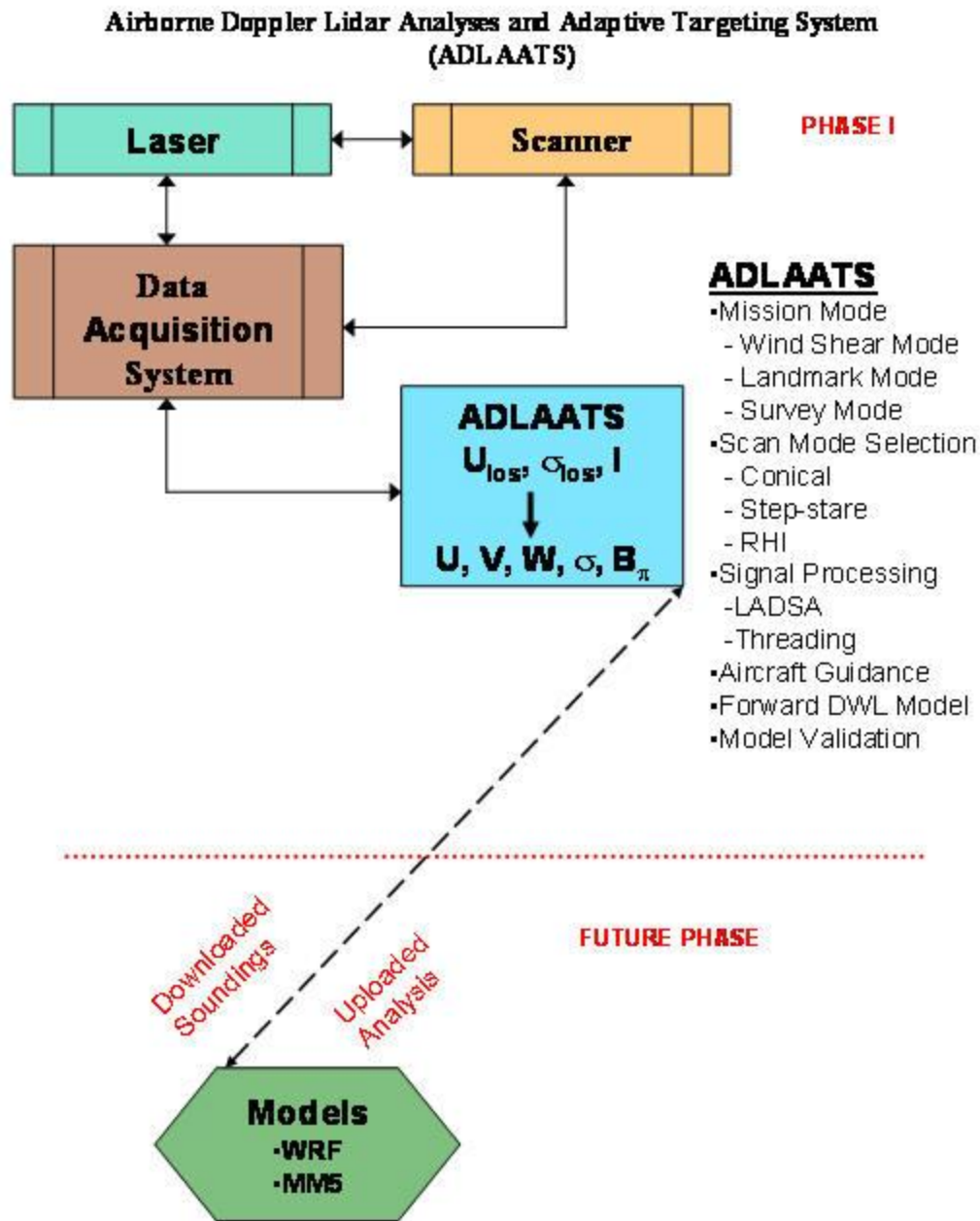
Figure 2.0 TODWL two axis scanner in Twin Otter side door.

## 1.2 ADLAATS SBIR phase 1

In Phase I of this SBIR effort, SWA demonstrated the feasibility of packaging and extending an existing set of post-flight data processing software to where it can be used as an onboard autonomous system for processing airborne DWL data and making on-board decisions. The general architecture for the onboard autonomous airborne DWL data processing, model analyses/forecast verification, adaptive targeting system as

described in the component diagram (Figure 3) was developed. During Phase I, a testbed was constructed to evaluate the performance of a complete end-to-end data processing. Using this testbed, ADLAATS has been exercised to demonstrate:

- Ingesting data from the existing TODWL DAS (data acquisition system) and signal processing in real-time for LOS winds, aerosol backscatter and wind variance
- Comparing LOS wind observations with expected LOS components obtained by applying a forward model to the up-linked IMETS analyses of the moment.



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Figure 3: Component diagram of interfaces between ADLAATS, the wind lidar and the information provide by Army models or observations (e.g., IMETS)

### 1.3 ADLAATS Phase II Technical Objectives

The overall goal of the Phase II effort is to provide an efficient operational software package that:

- Conducts continuous on-board measurement and processing of airborne DWL data
- Works with data uploaded from models (i.e., WRF) and observing systems (i.e., IMETS)
- Transmits data (u, v, w, variance, backscatter) down to the surface receiving station at least every 5 minutes
- Conducts on-board comparison between actual observations and model output with logic in place to take a variety of actions based on these comparisons.
- Can direct the aircraft to a new observation strategy, sampling pattern or sampling location based on the comparison (adaptive targeting)

With the software in place, the goal is to utilize the package to see how it benefits the Army in real time applications and operations. This will be achieved by deploying the TODWL aircraft and the ADLAATS software in a field campaign/test mission based out of Fort Irwin, CA.

Following the field missions, analysis and validation of the TODWL data will be undertaken. However, the main thrust of the post-field campaign activity will be the fine-tuning of the adaptive targeting logic and optimization of the ADLAATS software package for efficiency and computational speed. Additional commercial applications inside and outside of the military will also be investigated.

## 2.0 Basic Software Coding and Development

### 2.1 Computer System Description

- HARDWARE/OPERATING SYSTEM

ADLAATS is designed to run on a personal computer operating under the MS Windows 2000/XP operating system.

- DLSM SYSTEM ARCHITECTURE AND PROGRAMMING LANGUAGES

In the development of ADLAATS, SWA used Visual Studio in the MS Windows XP operating environment. All ADLAATS GUI inputs are coded in MS FORTRAN 90. The DWL signal processing, forward model, meso-scale atmosphere model and the product evaluation models are coded in FORTRAN 90 using Compaq Visual Fortran professional edition 6.6. Graphic routines are coded in MS Visual Basic 6.0 or FORTRAN 90. Addition graphic displays are provided using Google Earth.

## 2.2 ADLAATS system

2.2.1 Re-coding existing research code and SBIR phase 1 code to operational code within the Visual Studio environment.

The menu driven architecture of ADLAATS for the SBIR 2 is based upon the designed and tested architecture of ADLAATS from the SBIR1. Figure 4 is a component diagram that depicts the model's functionality and data flow.



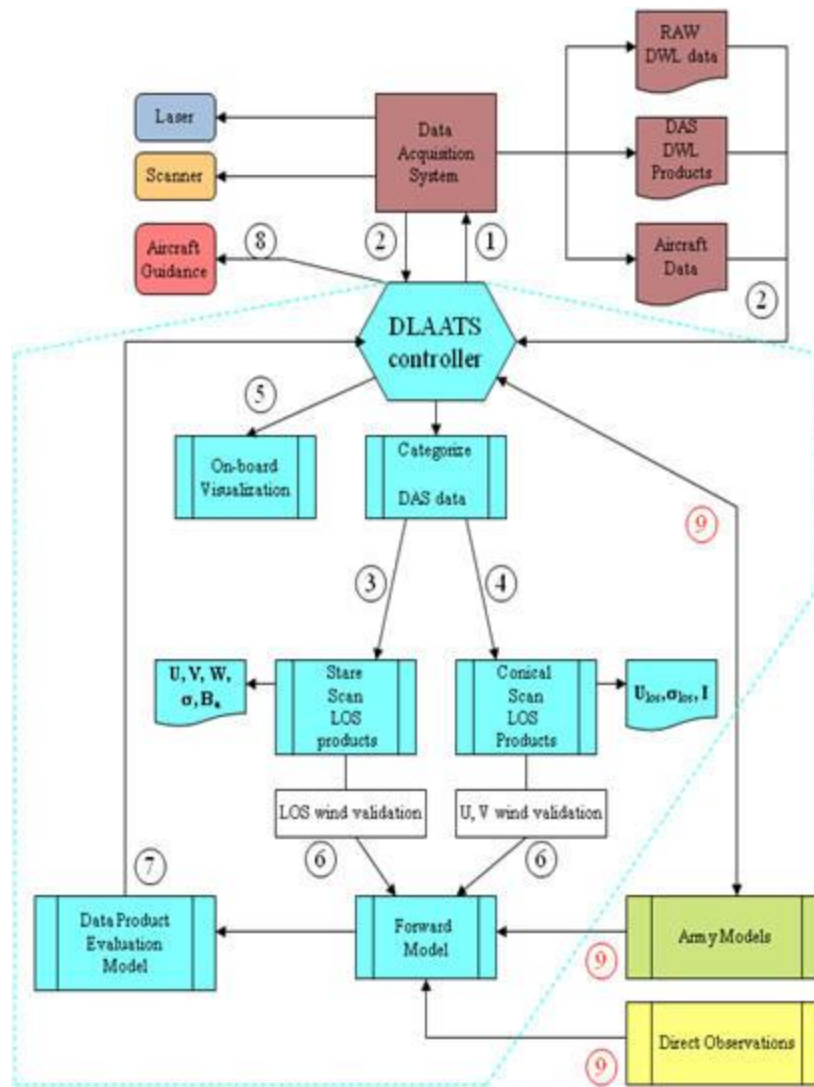
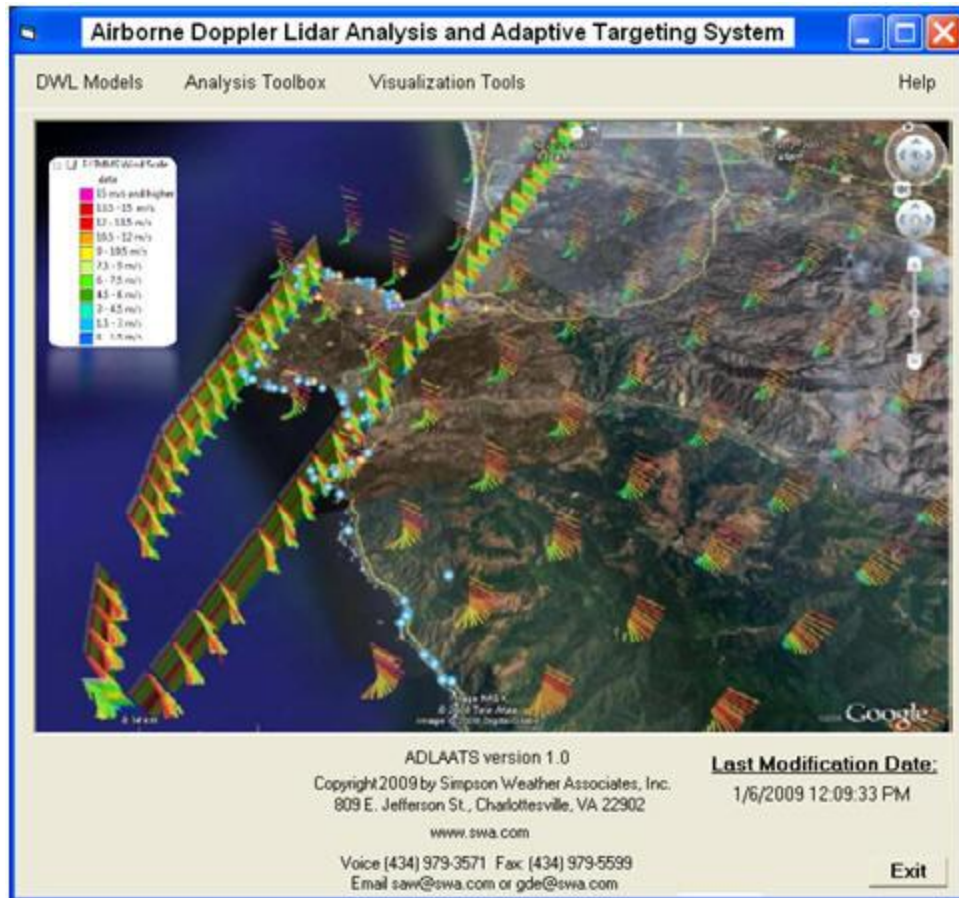


Figure 4: Component diagram of interfaces between ADLAATS, the wind lidar and the information provide by Army models or observations (e.g., IMETS)

### 2.2.2 ADLAATS Execution

Execution of ADLAATS invokes the ADLAATS Main Screen: the model's control screen.



The ADLAATS Main Screen has four options: DWL Models, Analysis Toolbox, Visualization Tools and Help. For a first time user, the user should click on DWL Models top menu option where the user will customize model inputs, retrieve DWL data from the DAS, perform signal processing, interact with meso-scale models and communicate with the DAS. From the ADLAATS's Analysis Toolbox menu, the user can run post processor data operations such as statistics on the DWL wind results. Visualization tools allow the user to graph DWL products for LOS stares and horizontal winds. Also included is a tool to convert the DWL products into Google Earth format for display.

### 2.2.3 DWL Models top menu option for DWL processing

The DWL Models menu has six options:

- Das Intercommunication provides contact with CTI's data acquisition system

- Categorize Model obtains meta-data on DWL data sets pre-signal processing
- Compute DWL LOS products performs signal processing on DWL data produces LOS winds, backscatter and horizontal wind components
- Retrieve Army Model data obtains meso-scale atmospheric variables along the flight via data uplink or an on-board running meso-scale model
- Compute Forward Model Wind Products uses the geometry of the DWL and the meso-scale atmospheric variables to compute meso-scale LOS winds
- Run DPEM evaluates the DWL LOS winds against the Forward model LOS winds given user defined thresholds and recommends adjustment to the on-going mission if necessary.