Preliminary Results from the ATHENA-OAWL Venture Tech Airborne Mission

Sunil Baidar (a, b), Sara Tucker (c), Mike Hardesty (a, b)
(a) Cooperative Institute for Research in Environmental Sciences, University of Colorado Boulder, Boulder, CO
(b) NOAA Earth System Research Laboratory, Boulder, CO
(c) Ball Aerospace & Technologies Corp., Boulder, CO

Sunil.baidar@noaa.gov

Abstract: The Atmospheric Transport, Hurricanes and Extratropical Numerical weather prediction using the Optical Autocovariance Wind Lidar (ATHENA-OAWL) is a mission concept proposed as an Earth Venture mission for space based wind profile measurements. An Airborne demonstrator for the ATHENA-OAWL system, is planned for deployment aboard the NASA WB-57 aircraft in May/June 2016. The instrument makes simultaneous measurements at two azimuthally orthogonal line-of-sight to provide u and v components of the horizontal winds. The goals of this deployment are following: (1) Validate and assess the wind measuring capability of the instrument, (2) Evaluate the instrument sensitivity and efficiency, (3) Assess the effects of different atmospheric conditions, and (4) Scale the performance to that of future space mission. Here we will present the validation efforts and preliminary results from this deployment.

Keywords: Doppler wind lidar, airborne, space, validation

1. Introduction (11 Point Ariel Font)

Three dimensional wind measurement is considered as the final frontier that needs to be crossed to significantly improve the current numerical weather prediction models [1]. Currently there are no global wind profile measurements from the space. ATHENA-OAWL is a mission concept proposed as an Earth Venture mission for space based wind profile measurement using a Doppler wind lidar.

An airborne demonstrator for the ATHENA-OAWL system has been built at Ball Aerospace & Technologies Corp. The OAWL instrument makes simultaneous measurements at two azimuthally orthogonal line-of-sight (LOS) to provide u and v components of the horizontal winds at 355 nm and 532 nm. Details about the instrument can be found in Tucker et al. [2]. It was deployed aboard the NASA WB-57 aircraft during May-June 2016 to demonstrate the wind measuring capability of the instrument. A total of 10 flights were performed over the Gulf of Mexico. Due to the new laser safety regulations, validation flights were limited to flight restricted area over the Gulf. The first 5 flights were designated as engineering test flights while the last 5 flights were considered as the validation flights. The High Definition Sounding System (HDSS) from Yankee Environmental Systems were aboard the aircraft for the validation flights and deployed dropsondes which measure wind profiles. Figure 1 shows the WB-57 flight tracks over the Gulf of Mexico during the OAWL validation campaign.

2. Validation Data

High Definition Sounding System (HDSS)

The HDSS is an automated system deploying the eXpendable Digital Dropsonde (XDD) which measures wind along with pressure temperature and humidity profiles and skin sea surface temperature (SST) [3]. The XDD measures horizontal wind velocity at 4 Hz. Horizontal wind velocity measured by the XDD deployed from various high altitude aircrafts have been extensively compared with operational radiosondes and traditional RD-94 dropsondes and showed very good agreement [3]. The HDSS was deployed aboard the NASA WB-57 along with the OAWL system for the 5 validation flights.

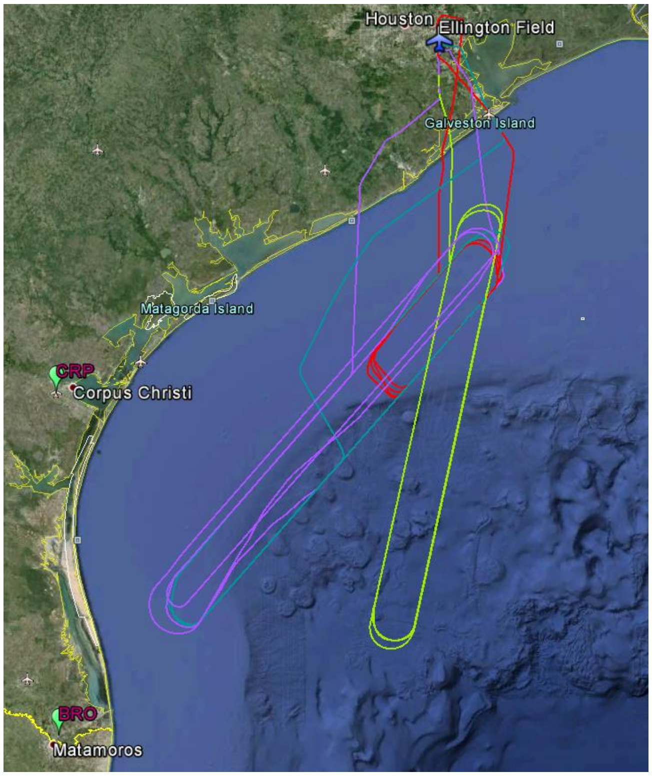

Figure 1. NASA WB-57 flight tracks during the AOVT flight campaign. NWS Corpus Christi and Brownsville office locations are marked with balloons.

Radiosondes

The National Weather Service's (NWS) Corpus Christi office launched additional radiosondes during the AOVT flight days. These radiosonde launches were coordinated with the AOVT flight times.

High Resolution Rapid Refresh (HRRR)

The HRRR is a real-time 3-km resolution, hourly updated, cloud-resolving, convection-allowing atmospheric forecast model developed at NOAA [4]. It is initialized by 3 km grids with 3 km radar data assimilated every 15 minutes. The 3 km spatial resolution for HRRR is comparable to the OAWL measurements at 10 s time resolution aboard the NASA WB-57 aircraft. Thus, the 0^{th} hour HRRR forecast acts as a transfer standard for regular radar/radiosonde measurements to the OAWL study area.

Goddard Earth Observing System Model, Version 5 (GEOS-5)

The GEOS-5 is an atmospheric model developed in the GMAO to support NASA's earth science research. It provides 3 hourly forecast every 6 hours at a spatial resolution of 0.25 x 0.3125 degrees. The model forecast includes aerosol extinction. We use the GEOS-5 aerosol forecast to assess the atmospheric conditions during the flights (closest forecast hour from the closest model run). It will also be used for the performance modeling of the OAWL instrument. Aerosol extinction and backscatter from CALIPSO will be used (when available) to convert GEOS-5 aerosol extinction profiles to backscatter profiles, needed for the performance modelling. Aerosol optical depth (AOD) measured by Aeronet station at Houston, TX will be used to evaluate the GEOS-5 aerosol output.

3. Preliminary Results:

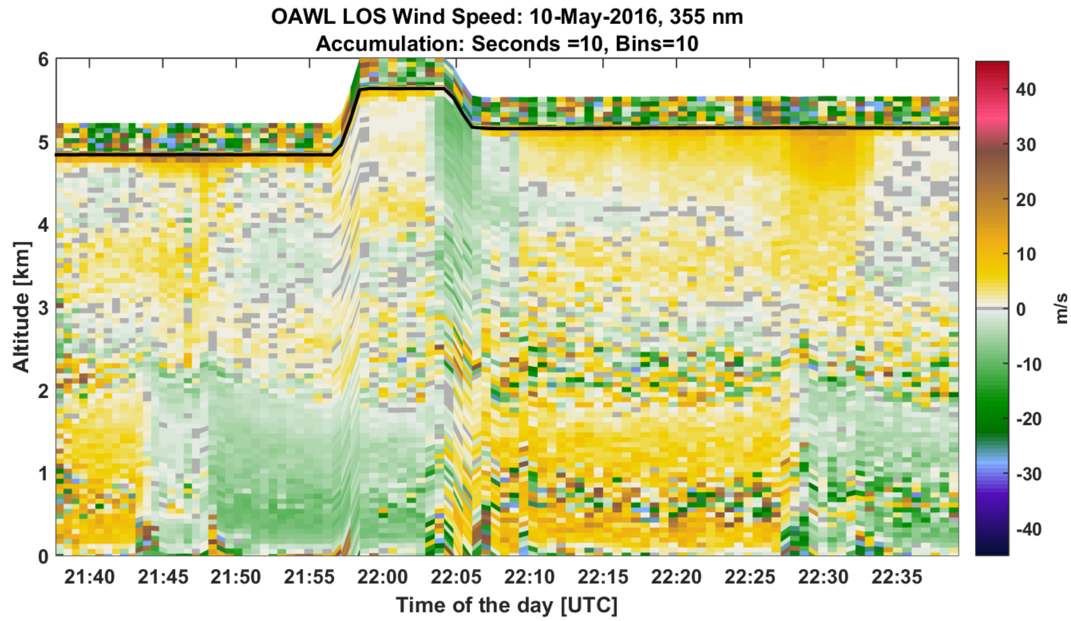

Figure 2: LOS wind speed measured by the AFT look of the OAWL instrument at 355 nm during flight #1 on May 10, 2016 (Preliminary data).

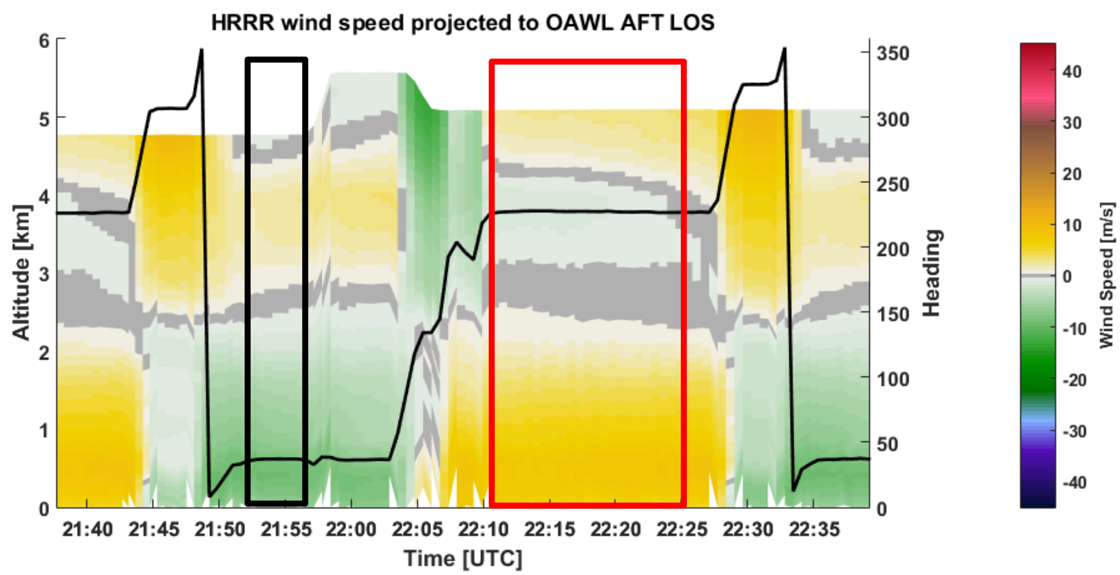

Figure 3. Projected LOS wind speed for OAWL AFT LOS using HRRR 0 hour forecast for 22 Z on May 10, 2016. The black line indicates the aircraft heading at the time of the OAWL data acquisition. The black and red boxes in the bottom panel indicate flight segment 1 and 2 respectively that is used for further analysis.

Figure 2 shows line of sight (LOS) velocity measured by the OAWL AFT look at 355 nm during flight #1 (preliminary data). The OAWL LOS velocity estimate from 532 nm agrees with the 355 nm signal but is more noisy for this flight. The HRRR wind forecast for 0 hour (22Z model run) projected to the OAWL LOS (attitude corrected) for the same time period is shown in Figure 3. The good agreement between the measurement and model indicate that the OAWL measurement generally captured the overall wind conditions over the study area. Note that while the HRRR captures the spatial variability over the study area, temporal variability in the OAWL data might not be well captured by the model and we do not temporally interpolate the model data.

The mean wind speed profile from OAWL measurements computed from the AFT look at 355 nm and projected to the horizontal and HRRR forecast for two flight segments at constant altitude and heading (see Figure 3 for details) are shown in Fig. 4. Figure 4 also shows the difference between the measurement and model. The agreement between the two is very good with differences below 2-3 m/s for most of the profile. There is also no evidence for bias in the OAWL measurements. While the model does not represent the ground truth at the time of the OAWL measurements, the good agreement does provide some validity to the measurements. Note that due to SNR, OAWL data between 500 and 900 m for segment 2 is not included in the comparison.

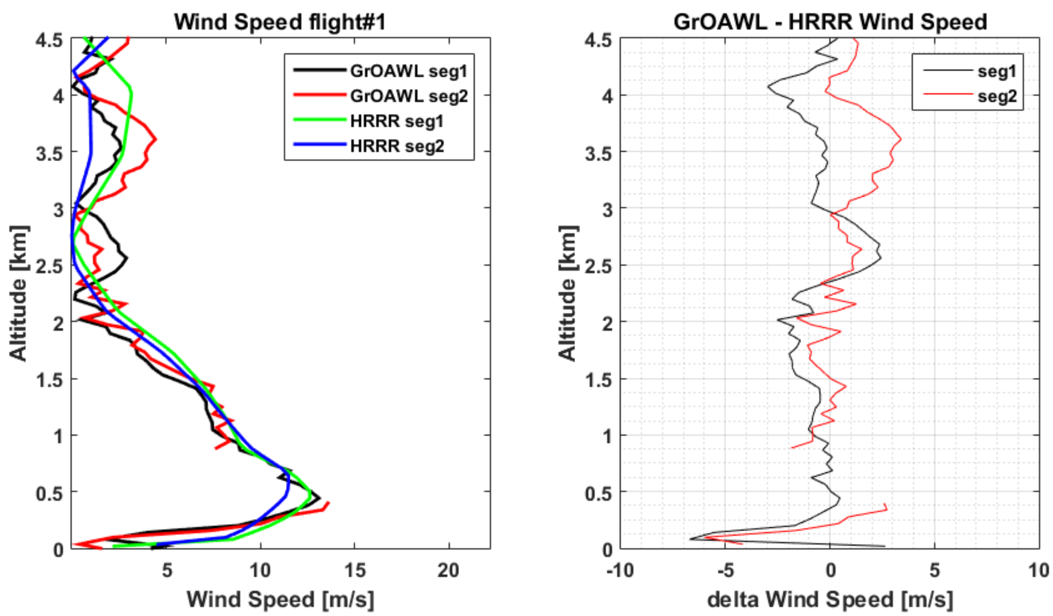

Figure 4: Mean horizontal projection of wind speed profile for OAWL (black and red) computed from AFT look at 355 nm only and HRRR (green and blue) for two flight segments at constant altitude and heading. The flight segments are marked by boxes in Figure 3. The right panel shows difference in wind speed between OAWL and HRRR for the two segments (Preliminary data).

Prior to comparison with the OAWL measurements, the performance of the model is evaluated using available radiosonde data from Corpus Christi and Brownsville, TX. Figure 5 shows comparison between the Corpus Christi 0Z radiosonde (launched at 23Z) and HRRR 0 hour forecast at the time and location of the radiosonde launch, indicating good agreement and providing confidence in the model estimates of winds along the OAWL flight path. We have arranged for additional radiosonde launches from Corpus Christi for times when the aircraft is scheduled to be offshore of Corpus Christi. These radiosondes, along with HDSS dropsondes from the aircraft will provide additional data for evaluating the suitability of the HRRR winds as validation data for periods when radiosondes and dropsondes data are not available.

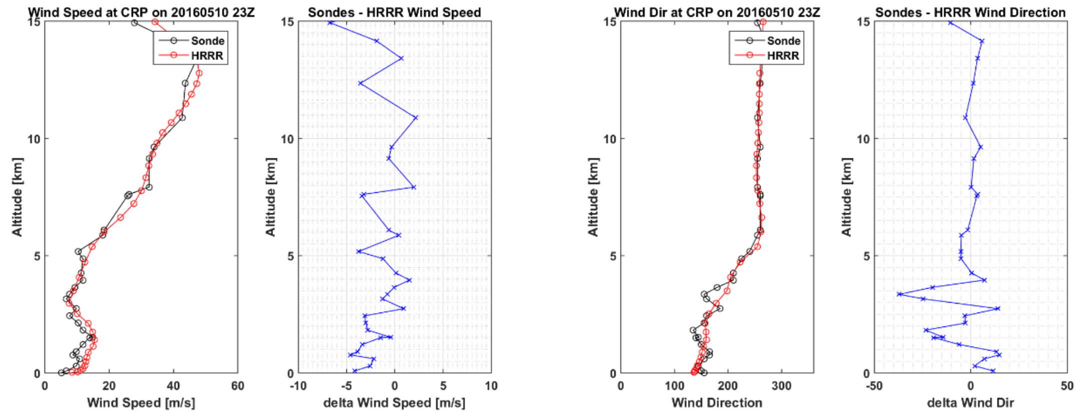

Figure 5: Comparison of wind speed (top) and direction (bottom) between Corpus Christi, TX 0Z radiosonde (launched at 23 Z) and HRRR 0 hour forecast for 23 Z at the radiosonde launch site on May 10, 2016. HRRR data were interpolated to the radiosonde altitude. The right panels show difference between the radiosonde and model data.

4. Summary:

Preliminary comparisons of OAWL radial velocity estimates at both 355 nm and 532 nm with winds estimated by the NOAA HRRR model along the aircraft track show good qualitative agreement. The OAWL signal at 355 nm is less noisy due to a stronger signal, but both estimates agree well with each other and with the model estimate. The model wind estimate from the area around Corpus Christi also agrees well with the Corpus Christi radiosonde, providing some measure of confidence in the HRRR output. We are encouraged by this result and anticipate improved comparisons for later flights as instrument issues are addressed and sensitivity is improved. In addition, OAWL data will be compared with HDSS dropsondes launched from the aircraft during the validation flights.

5. References

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