A US Effort for ADM/Aeolus Calibration and Validation


Aeolus Cal-Val Workshop
9-13 Feb 2015
Elements of the US Cal-Val Effort for Aeolus

• A broad proposal for the US cal-val effort includes multiple organizations, investigators, and instruments

• Major components of the efforts are:
  • Airborne lidar underflights
    • Direct and coherent detection lidars
    • Multi-wavelength, HSRL aerosol lidars
  • Surface observations during overpasses
    • Upward-looking Doppler and aerosol lidars
  • Atmospheric Motion Vector Studies
  • Data Assimilation Studies
NASA DC-8: DAWN Wind Profiling Lidar (Kavaya)

- NASA/Langley DAWN system is a 250 mJ/pulse, 10 Hz nadir-pointing coherent lidar
- Wedge scanner provides conical scans
- Operated previously on DC-8 for hurricane and arctic studies
- More details on DAWN capability in the next talk (Emmitt)

DAWN Lidar vs. dropsonde
1 Sept. 2010, DC-8
Lidar 33 s; dropsonde 13 min.

DAWN Lidar vs. ground radar
12 June 2013, UC-12B
Lidar 23 s; radar 30 min.
TWiLiTE is a compact, molecular direct detection scanning Doppler lidar designed to measure wind profiles in clear air from 20 km to the surface.

TWiLiTE is modular and operates autonomously on NASA research aircraft (ER-2, DC-8, WB-57, Global Hawk).

Engineering flight tests on the NASA ER-2 in 2009, 2011 and 2012 demonstrated autonomous operation of all major systems.

TWiLiTE was recently configured to fly in Zone 25 of the NASA Global Hawk (AV6) and is now being modified to install in the DC-8.

### TWiLiTE Performance Summary

<table>
<thead>
<tr>
<th>Data products</th>
<th>Vertical profiles of u,v wind field from aircraft to surface, clouds permitting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity accuracy (m/s)</td>
<td>&lt; 2.0</td>
</tr>
<tr>
<td>Range of regard (km)</td>
<td>0-18 (ER-2,WB57); 0-12 km (DC-8)</td>
</tr>
<tr>
<td>Vertical resolution (km)</td>
<td>0.250 (programmable)</td>
</tr>
<tr>
<td>Horizontal integration per LOS (s)</td>
<td>10 s (programmable)</td>
</tr>
<tr>
<td>Nadir angle (deg)</td>
<td>45</td>
</tr>
<tr>
<td>Scan pattern</td>
<td>8 position conical step-stare (programmable)</td>
</tr>
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</table>
ATHENA-OAWL Venture-Tech

- Green-OAWL (GrOAWL): wind measurements at the 532 nm wavelength
- High altitude (15-20 km) NASA WB-57 flights out of Houston: Johnson Space Center Ellington Field
  - Develop robust airborne platform/data system and demonstrate performance
  - First flights planned for April/May 2016: Aiming to have 355 nm HAWC channels online for these flights, TBD. (best comparison for Aeolus)
  - Primary focus: OAWL validation. Flight plans around ground-based radiosondes, potential for automated dropsonde system on WB-57
  - Secondary focus: Underfly Aeolus for comparison.
- Team: University of Colorado-Mike Hardesty (PI), Ball-Sara Tucker, Fibertek -Floyd Hovis.

HAWC-OAWL ("HAWC")

- HSRL (High Spectral Resolution Lidar) for Aerosols, Winds, and Clouds (HAWC) using Optical Autocovariance Wind Lidar (OAWL)
  - OAWL: Wind measurements at 532 nm & 355 nm wavelengths
  - HAWC: Adding concurrent HSRL (aerosol backscatter ($\beta$), extinction ($\alpha$), and depolarization ($\delta$)) retrievals to OAWL winds
- A NASA Earth Science Technology Office Instrument Incubator Program (IIP)
- Additional flights tentatively late 2016/Early 2017: Focus on wind + HSRL data Flight location TBD
Two Looks from the NASA WB-57 aircraft

- **AOVT & HAWC**: Airborne Systems
  - Two telescopes
  - Two looks

- **AOVT**: Two lasers for an ATHENA-like configuration - one per direction.
  - Existing OAWL laser
    - Runs at both 355 nm & 532 nm wavelengths – use 532 nm only
  - Second (new) Fibertek laser
    - 532 nm wavelength only
    - 355 nm compatible with future upgrades
  - Lasers with alternate pulses (looks)
    - 2x200 Hz PRF = 400 Hz PRF for the data system
    - 2x150 Hz planned for space version

- **HAWC**: adds 355 nm wavelength channels
  - Existing OAWL laser still used
  - Add 355 nm data channels and processors
  - Data acquisition is 50% higher rate (two processor boards)
355 & 532 nm Winds using OAWL

- Horizontal views out to > 11km (analog)
- 75m, 6s accumulation
- Strong extinction (~0.3 km\(^{-1}\))
HSRL-1 Aerosol Data Products:
- Backscatter coefficient (532, 1064 nm)
- Depolarization (532, 1064 nm)
- Extinction Coefficient (532 nm)
- Optical Depth (AOD) (532 nm)
- Mixed Layer (ML) Height
- Aerosol Classification

HSRL Technique:
- Independently measures aerosol backscatter, extinction, and optical thickness

Typically deployed on NASA/LaRC King Air
- Also flown on NASA P-3
- Flight altitude ~ 9 km
- Nadir pointing lidar

NASA Langley Airborne HSRL-1 (Hostetler, Hair, Ferrare)
The NASA Langley HSRL-1 instrument has flown extensively in diverse regions and different seasons.

- NASA LaRC Airborne HSRL-1 has flown on 26 field missions since 2006.
- During this time, it has acquired >1000 hours of data on >350 flights.

Airborne HSRL-1 data have been used to:
- Validate satellite measurements (CALIPSO, MODIS, MISR)
- Provide detailed aerosol measurements for air quality studies
- Evaluate regional (WRF-Chem) and global (GEOS-5, ECMWF) aerosol models
- Evaluate aerosol measurements from airborne in situ instruments
- Classify aerosol types for evaluating models and satellite retrievals
Second Generation HSRL-2: $3\beta+2\alpha+3\delta$ Lidar

- **Measurements**
  - Backscatter: 355, 532, 1064 nm ($3\beta$)
  - Extinction 355 and 532 nm ($2\alpha$)
  - Depolarization at 3 wavelengths ($3\delta$)

- Deploys on ER-2 and other aircraft
- Flown on 4 field missions to-date
- Fully operational data processing code
Aeolus Cal/Val: Saharan Aerosol Layer (Dunion)

Objectives:

• Obtain aircraft measurements of wind speed and aerosol structure/backscatter/extinction under the Aeolus flight track using GPS dropsondes and the NOAA P-3 Doppler Wind Lidar;

• Analyze aircraft measurements to assess precision, bias, errors, sources of error, and representativeness of Aeolus measurements >> improve Aeolus methods & algorithms;

• Compare Aeolus retrieved radial winds with collocated GPS dropsonde observations made by the NOAA G-IV high altitude jet and P-3 Orions flying in the environments of the SAL and TCs, and examine the capability of Aeolus to measure important dynamical features in these regions;

NASA Global Hawk Mission: 24 August 2013

GPS Dropsonde Profile: 1833 UTC
The Cloud Physics Lidar (McGill)

CPL is a self-contained, autonomous backscatter lidar

- optical depth
- extinction
- depolarization

CPL 532 nm attenuated backscatter profiles

- subvisual cirrus
- low-level cumulus
- cirrus convective clouds
- Saharan dust boundary layer aerosol
Airborne Cloud-Aerosol Transport System (ACATS) instrument

From single wavelength (532 nm) profiling at 45 degrees:

1) Direct measurements:
   a) Line-of-sight wind profile
   b) Corrected backscatter ratio profile
   c) Layer and surface locations

2) Semi-direct measurements assuming atmospheric density profile (from radiosonde or similar):
   a) Corrected particulate backscatter profile
   b) Particulate extinction profile
   c) Cumulative particulate optical depth profile
   d) Particulate extinction-to-backscatter ratio (S) profile
   e) Aerosol/cloud discrimination
NOAA surface wind measurements (Brewer)

- NOAA operates four coherent Doppler lidars for ground-based, boundary layer studies.
- These lidars operate unattended for extended periods of time, generating several profiles per hour.
- During Spring 2016 the instruments will be deployed in Washington, Colorado, and Indiana.
Goddard Lidar Observatory for Winds (GLOW) (Gentry)

Data Products:
• Radial wind speed profiles
• Wind speed and direction profiles derived from multiple LOS
• Useful altitude range: 0.1 to 30 km
• Minimum range res: 45 m
• Azimuth/Elevation range: 0-360 deg/0-90 deg
• Velocity Accuracy (typ): 0.3 to 5 m/s (signal dependent)

Ground-based aerosol studies: GTRI H₂O Raman lidar (Gimmestad)

- Transportable, in modified 20-foot shipping container.
- On two-axis mount, with elevation angles from horizontal to vertical.
- Based on NASA GSFC designs:

  - Pulse Energy: 300 mJ
  - Wavelengths: 0.3547 μm transmitted
                 0.3547 μm received (elastic)
                 0.3867 μm received (N2)
                 0.4075 μm received (H₂O)
  - PRF: 50 Hz
  - Receiver aperture diameter: 50.8 cm
  - Detectors: Hamamatsu R9880 PMTs
  - Data acquisition: Licel hybrid analog/photon counting system
JCSDA Data Assimilation (Boukabara, Yoe)

Via Joint Center for Satellite Data Assimilation
- NASA’s Global Modeling and Assimilation Office
  - GEOS-5 Model and GSI analysis
- NOAA’s NESDIS/STAR and NWS/NCEP
  - GFS Model and GSI, 4D Hybrid DAS

JCSDA will investigate ADM/Aeolus DWL wind assimilation as well as that for AMVs

- Compile Innovation Statistics
  - L2b products from ECMWF, KNMI processors

- Perform Data Impact Experiments LOS winds
  - Use multiple standard forecast diagnostics
  - Data selection criteria, observations error statistics based on innovations initially
Comparing ADM-Aeolus winds to conventional Atmospheric Motion Vectors (AMVs) (Velden and Genkova)

• Compare ADM Aeolus global-coverage line-of-sight wind profiles with current state of the art feature-tracked AMVs.
  • By comparing the ADM wind profiles with this global AMV data set, ADM vector coverage, quality and differences with AMVs will be documented, thus assessing the complementary value of the ADM winds to the existing upper-air winds observing system.

• Investigate how ADM-Aeolus wind profiles can be used to assess the uncertainty introduced by the assumption that cloud and water features are ideal tracers, and additionally interpret how the ADM cloud top heights and cloud-independent wind vector altitudes correlate.
  • Such study would be most valuable over ocean where limited RAOBs are available for similar type studies. Further analysis will improve utilization of the U and V winds components separately in NWP models.
Aeolus data for optimizing AMV’s (Hoffman)

• Optimize use of AMVs by comparing to AEOLUS winds and cloud tops

• Co-location of AEOLUS and AMVs to develop joint statistics
  – Identify and possible correct cloud top assignment errors.
  – Determine best vertical averaging of analysis system first guess (background) by testing versus DWL profiles.

• Test these ideas in data impact studies with the Research to Operations DA system at JCSDA.

Use Aeolus data to improve the AMVs in an analogous way that the Global Precipitation Measurement Mission Precipitation Radar is used as the standard to improve precipitation retrieved from IR/MW.
Summary and Future Plans

• A variety of assets from the US can potentially be brought to bear for Aeolus calibration and validation: airborne, surface-based, AMV studies, assimilation and modeling

• After this workshop we will move forward to develop the implementation plan for the efforts

• Key aspect: prioritize the efforts and secure funding