Doppler Lidar Measurements from the NOAA Twin Otter using a Hemispheric Scanner

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Motivation

To capture the spatial and temporal dynamics of large scale, complex flows we installed the ARS mobile Doppler lidar on the NOAA Twin Otter to make range resolved measurements of:

- Wind speed and direction
- Aerosol backscatter intensity

Hemispheric type scanner configuration enables measurement above and below the aircraft, as well as complex scan geometries

- Motion stabilized scans
- Target tracking for fine scale atmospheric features
- Cloud base velocities

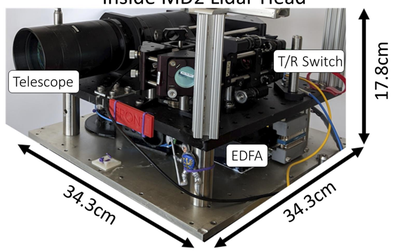
ARS Mobile Lidar System (MD2)

Lidar system consists of small robust optical head for transmitting and receiving lidar signal and separate instrument rack which houses electro-optics and FPGA-based data acquisition hardware.

- The two-module configuration facilitates motion stabilization of the optical head during field deployments
- A compact and robust design allows for the lidar head to be mounted in space-prohibitive platforms
- Real-time FPGA processing allows for Doppler signal to remain in detection band, despite significant aircraft motion in the line of sight measurement
- Narrower detection bandwidth improves measurement sensitivity in low signal regions such as very clean air

Pulse Width	25-90 m
Beam Rate	1-10 Hz
Pulse Rate	20 kHz
Wavelength	1.5 µm
Range	7.2 km

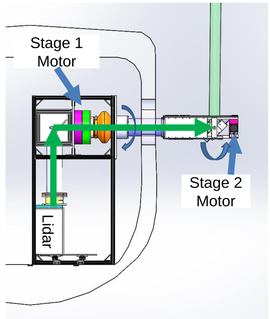
Inside MD2 Lidar Head



Side Scanner Design and Installation

ARS worked with a team of students from the CU Mechanical Engineering Senior Design Program to design and fabricate a hemispheric type scanner which extends out the side of window of the NOAA Twin Otter (Figure 2 right)

- The system was installed and flew in Summer 2021 as part of SITE (System Integration and Test Experiment) in Lakeland, FL
- Side mounting and two motor design (Figure 2a) allowed for two axis scanning above and below the aircraft
- The inertial navigation unit (INU) on a scanner frame fed back to motors to remove aircraft motion in both pitch and roll for motion stabilized stares



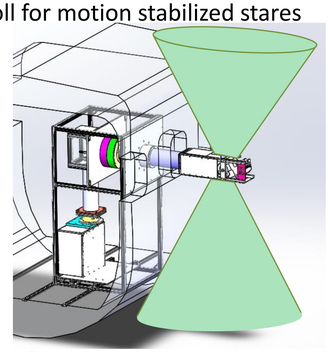


Figure 2: Left) *Cross-section of Twin Otter. Blue arrows indicate positions of stage 1 and stage 2 motors. Lidar is mounted on bottom left of figure.* ***Center)*** *CAD model of side scanner showing full range of the scanner.* ***Right)*** *Scanner installed on the NOAA Twin Otter for SITE.*

Preliminary Results

Tests flights targeted dynamics which will be investigated in upcoming field experiments to determine optimal sampling strategies

- Coastal flights were performed on the East and West coasts of Florida. This data will be used to inform scanning strategies for the upcoming Coast Urban Plume Dynamics Study in Summer 2023
- Plume characterization flights were performed to inform California Fire Dynamics Experiment in Summer 2022
- Low altitude flight paths and missed approaches were tested for future collaborations with in-situ measurements onboard the aircraft

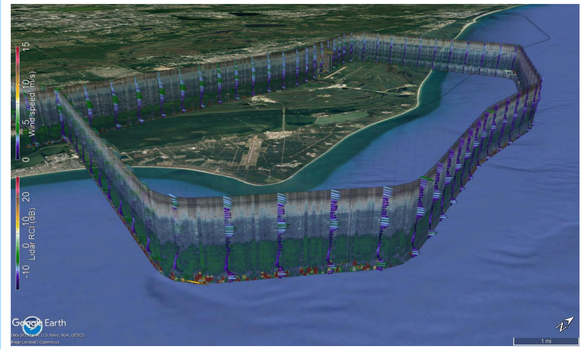


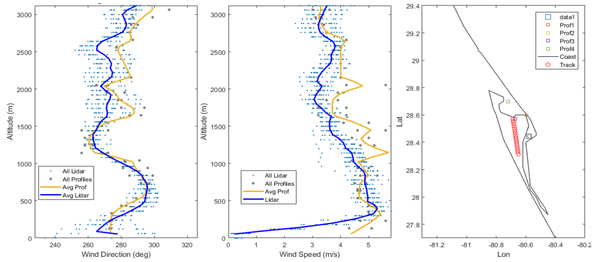
Figure 3: *Example of complex coastal dynamics around Cape Canaveral. Shows layers of aerosol from offshore flow mixed with layers of clear air from flow along coastline. The altitude of the top of curtain corresponds with 2.7km above ground.*

System Validation with Ground-Based Doppler Radar

Several flights were performed around Cape Canaveral to validate the side scanner lidar retrievals against a system of profiling Doppler radars

- Validation enables us to diagnose errors in scanning configuration or motion compensation processes
- Pulled all profiler data from ±40km of lidar location and within ±5 minutes of lidar retrieval time

Figure 4: *Example comparison against ground based Doppler radar. Blue dots are all lidar retrievals and grey dots are all radar retrievals within range of the comparison. Solid blue lines are the averaged lidar retrievals and the solid yellow lines are the averaged radar retrievals.* ***Left)*** *Wind direction comparison.* ***Center)*** *Wind speed comparison.* ***Right)*** *Map of profiler locations at Cape Canaveral (squares) and locations of lidar retrievals used for comparison (red circles).*



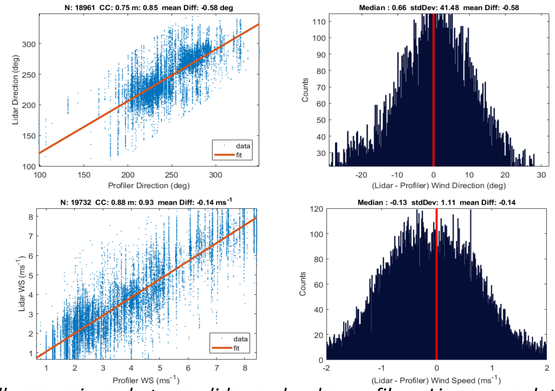


Figure 5: *All comparisons between lidar and radar profilers. Linear correlations are shown in the left plots with distribution of the differences shown in the right plots.*