Lidar to Weather Balloon Profile Comparison for Support of Orion Crew Exploration Vehicle Landings

ABSTRACT

A comparison study by the National Aeronautics and Space Administration Dryden Flight Research Center, Edwards, CA and the Naval Post Graduate School Center for Interdisciplinary Remotely-Piloted Aircraft Studies, Marina, CA was conducted to show the advantages of an airborne wind profiling lidar system in reducing drift uncertainty along a reentry vehicle descent trajectory. This effort was in support of the once planned Orion Crew Exploration Vehicle ground landing. A Twin Otter Doppler Wind Lidar was flown on multiple flights along the approximate ground track of an ascending weather balloons launched from the Marina Municipal Airport. The airborne lidar used was a 5-milli-Joules, 2-micron infrared laser with a 10-centimeter telescope and a two-axis scanner. Each lidar wind profile contains data for an altitude range between the surface and flight altitude of 2,700 meters, processed on board every 20 seconds. In comparison, a typical weather balloon would traverse that same altitude range with a similar data set available in approximately 15-20 minutes. These tests were conducted on November 15 & 16, 2007. Results comparing the balloon and a 10 minute multiple lidar profile averages show a best case absolute difference of 0.18 m/s (0.35 knots) in speed and 1 degree in direction during light and variable (<5 knots, without constant direction) wind conditions. These limited test results indicated a standard deviation wind velocity and direction differences of 0.71

m/s (1.3 knots) and 7.17 degrees for 1800Z, and 0.70 m/s (1.3 knots) and 6.79 degrees, outside of cloud layer.

National Aeronautics and Space Administration

Lidar to Weather Balloon Profile Comparison for Support of Orion Crew Exploration Vehicle Landings

Dryden Flight Research Center
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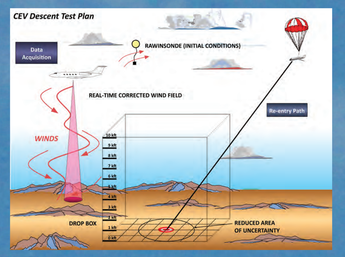
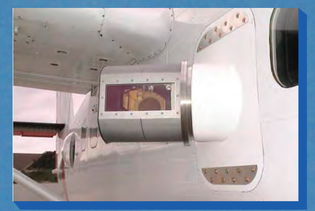


Goal of testing was to determine the integrated wind profile at the landing site in order to predict the amount of vehicle drift under chute from the desired landing location creating a reduced area of uncertainty.

CIRPAS Twin Otter is non-pressurized turbo-prop, twin-engine aircraft.



Twin Otter Doppler Wind Lidar mounted on star-board side of the aircraft.

Abstract:

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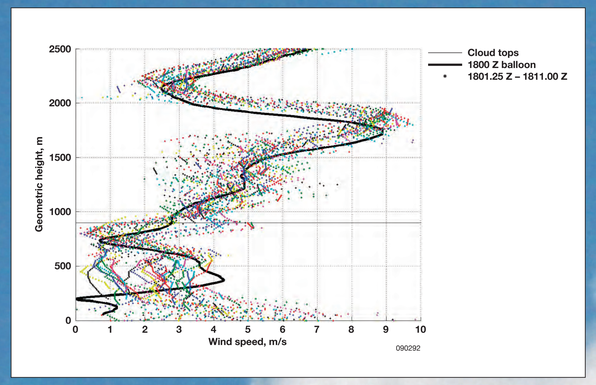
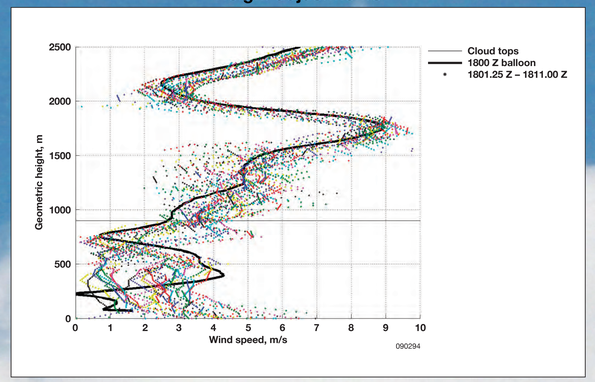
This effort was in support of the once planned Orion Crew Exploration Vehicle ground landing. A Twin Otter Doppler Wind Lidar was flown on multiple flights along the approximate ground track of an ascending weather balloon launched from the Marina Municipal Airport. The airborne lidar used was a 5-milliJoule, 2-micron infrared laser with a 10-centimeter telescope and a two-axis scanner. These tests were conducted on Nov. 15 and 16, 2007. The following figures are only for 1800 Z on Nov. 16, 2007.

Significant difference between balloon and lidar profiles due to calibration for the lidar and effective wind for the balloon profile. (for further description, see Data Analysis in paper)



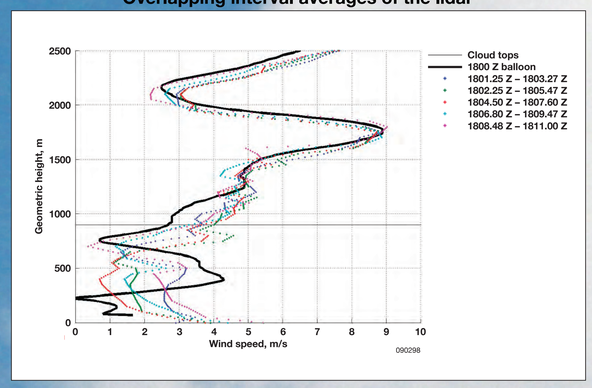
Height adjustments



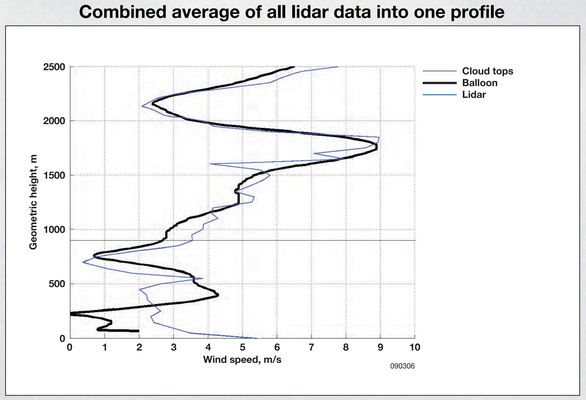
Speed, m/s of absolute differences for overlapping average and combined average at specific height intervals

Altitude	Time (Z)					
	1801.25-1803.27	1802.25-1805.47	1804.50-1807.06	1806.08-1809.47	1808.48-1811.00	Combined average
500 m	0.49	1.95	2.39	1.07	0.47	1.09
1000 m	0.76	1.34	1.71	1.57	1.11	0.91
1500 m	0.92	0.49	0.35	0.03	0.06	0.44
2000 m	0.67	0.19	0.24	0.76	0.78	0.18
2500 m	1.13	1.09	1.11	0.91	0.98	1.30

Overlapping interval averages of the lidar



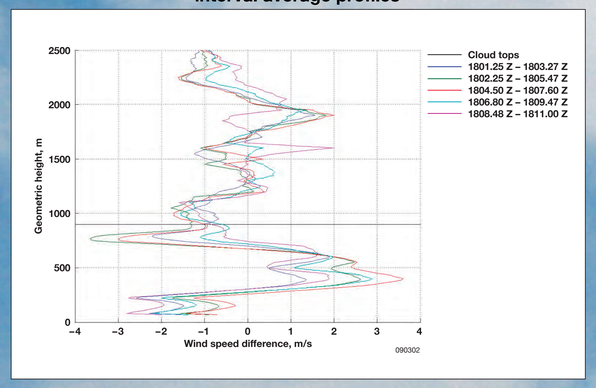
Combined average of all lidar data into one profile



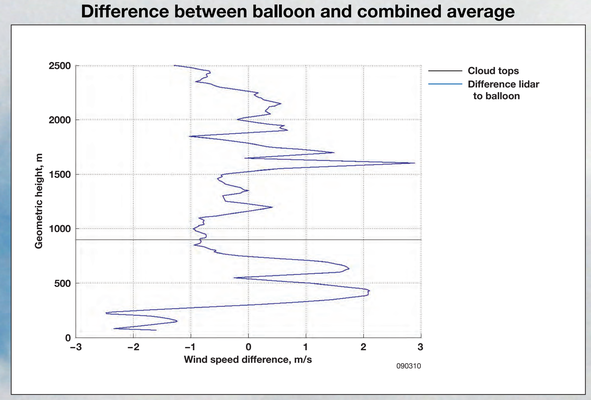
Average difference and standard deviation for combined profile

	Average direction (deg)	Average speed (m/s)	Standard deviation direction (deg)	Standard deviation speed (m/s)
Entire profile	7.89	0.02	54.00	1.00
Excluding cloud layer	5.22	0.08	7.17	0.71

Difference between balloon and overlapping interval average profiles



Difference between balloon and combined average



Conclusion:

- **Averaging all lidar data into one single profile gives best results**
- **Lidar benefits**
  - **Rapid profiles (5 min. versus 15 min. with balloon to test altitude)**
  - **Reduction in time to obtain profiles**
  - **Data always taken over site (no balloon drift)**
- **Best case results**
  - **Mean difference of 0.08 m/s and 5.22 deg**
  - **Standard deviation of 0.71 m/s and 7.17 deg**