Global Wind Observations Capitalizing on Doppler Wind Lidar Synergisms with other Wind Measuring Systems

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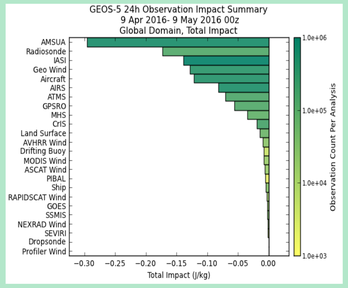
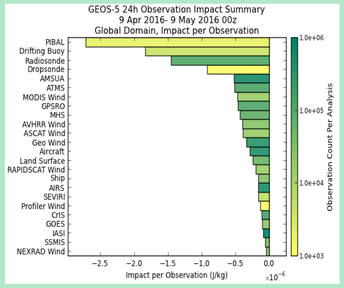
Introduction – Need for Global Winds

The general call for global 3D winds was well documented in the last Decadal survey [NRC, 2007] and the need remains just as strong today if we are to realize the "transformational" advances in NWP and climate modeling. The following recommendation was recently made in NASA's Workshop Report on Scientific Challenges and Opportunities in the NASA Weather Focus Area :

"Global measurements of the spatiotemporal (4-dimensional) evolution of large-scale horizontal wind vectors are urgently needed. It is important to avoid all or nothing strategies for the three-dimensional wind vector measurements, as important progress is possible with less than comprehensive observing strategies. ….."





Latest Advances in Coherent DWL Technology at NASA

Table 2. Coherent DWL Relevant Technology Advances in Last Decade

Year	Advance	Significance
2010	Langley completed 0.25 J, 10 Hz, 2-micron airborne coherent DWL "DAWN"	Airborne demonstration beyond space mission requirement of 0.25 J, 5 Hz
2010 – 2015	DAWN completed five airborne campaigns including NASA GRIP and NASA Polar Winds	Important aircraft experience; several lessons learned
2015	During Polar Winds Iceland, joint flights of DAWN with one other coherent and two other direct airborne Doppler wind lidar systems	Rare opportunity to compare wind profiles from four Doppler lidar systems for better performance estimation
2015	Langley demonstrated next generation 2-micron laser: 1 End pumping replaces side pumping 2 Square lasing crystal replaces cylindrical 3 Pump at 1940 nm replaces 792 nm 4 200 Hz laser pulse rate replaces 5 Hz while preserving coherent lidar laser FOM	1 Matching pump to lasing volume increases laser efficiency 2 Heat removal from 100% of flat surface much easier than from <50% of curved surface 3 Much lower quantum defect deposits less waste heat in crystal Combination of 1, 2, 3 dramatically reduces waste heat in crystal; thereby improving beam quality for coherent detection 4 For space mission, much higher probability of cloud porosity penetration, decreased representativeness error; retaining same aerosol backscatter sensitivity
2012	GSFC Instrument Design Center study showed two 70-cm diameter telescopes in ISS Japanese Experiment Module Exposed Facility (JEM EF) allowed volume	Increase from earlier 50 cm to 70 cm doubles aerosol backscatter sensitivity of mission
2015	NASA CATS lidar mission successful from ISS JEM EF	First pulsed lidar mission on ISS JEM EF

Why Coherent Detection?

Coherent detection is attractive since it provides:
1) An accurate wind estimate whenever above a threshold SNR,
2) Immunity from background light for equal day/night operation,
3) High photon efficiency from the background light immunity and the fundamental frequency estimation rather than intensity estimation,.

Coherent DWL Mission and Synergisms

We propose a road map to global winds utilizing the Coherent DWL and guided by decades of discussions within the NASA/NOAA funded WGSBLW and the following assertions:

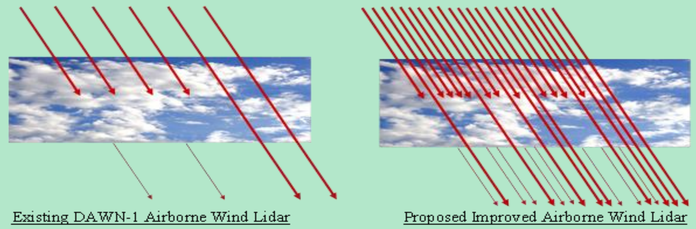
1) No single technology or mission design can deliver full troposphere/lower stratospheric wind profiles at the horizontal/vertical coverage and precision desired by the communities
2)Capitalization on synergisms between a DWL and existing or promising future wind observing systems is key to optimizing the Nation's investment in enhancing the collection of global wind data

	Height Assignment	Velocity Calibration	Associated wind profiles	Lateral spread of calibration
CMVs (GOES, MODIS, ….	+_ 10 meters depending upon backscatter gradients at cloud boundaries	+_1 m/s	Wind shear profiles within optically thin (OD< 1.0) clouds. Occasionally to cloud base.	~ 500km estimated
OVWs (ASCAT,…	N/A	Near surface winds (< 50m MSL)	Wind profiles within the pbl	~500km estimated
CYGNSS winds	N/A	Near surface wind direction to add to CYGNSS speed observations	Wind profiles within the pbl	Directional information from the DWL will have lateral weighting
Buoy winds	N/A		Wind profiles within the pbl	N/A
Ship winds	N/A		Wind profiles within the pbl	N/A
SmallSat passive WV sounder constellations	+_ 100 m height assignments	Velocity calibration and quality flagging	Wind profiles aerosols and clouds permitting	+- 500km estimated
Rawinsondes	N/A	Occasional comparisons: Line observations vs. curtain observations.	DWL provides global coverage over open oceans where rawindsondes are limited.	

Measurement within clouds

Based upon studies of LITE ,GLAS and CALIPSO, the probability of a single lidar shot intercepting clouds is > 50% globally. For 5 km segments, the probability of a cloud intercept is ~ 70 -75%.

Current Space mission simulations have revealed the large effect of clouds on mission performance. A higher pulse rate laser would increase the probability of some laser shots penetrating the porosity of the partly cloudy scenes and would lower the representativeness error of the wind measurement.



Existing DAWN-1 Airborne Wind Lidar	Laser Pulses	Proposed Improved Airborne Wind Lidar
250 mJ, 5 Hz laser	Laser Pulses	32 mJ, 300 Hz
Equal	Aerosol Sensitivity (Laser Figure of Merit)	Equal
Less	Cloud Wind Measurements	Up to 60x more
Less	Laser Shots Through Cloud Holes	Up to 60x more
Less	Wind Measurements Below Clouds	Up to 60x more
Higher	NWP Assimilation Representativeness Error	Much Lower
Good	Fractional Laser Efficiency	Higher
Good	Laser Beam Quality	Good
Low at 2 microns	Risk of Contamination Optics Damage	~8x lower

Proposed Mission

We argue that the first full horizontal vector (bi-perspective) DWL mission on the path to global coverage should not compromise precision for coverage and should be a pathfinder or survey mission which builds upon existing technology, algorithm maturity, and airborne experience.

Such a mission using coherent detection will yield equal performance in day and night and will allow for precision and vertical resolution in the PBL and through partly cloudy scenes.

It is also highly desirable to seek international and/or private sector partners in projects to achieve the most cost effective DWL space missions.