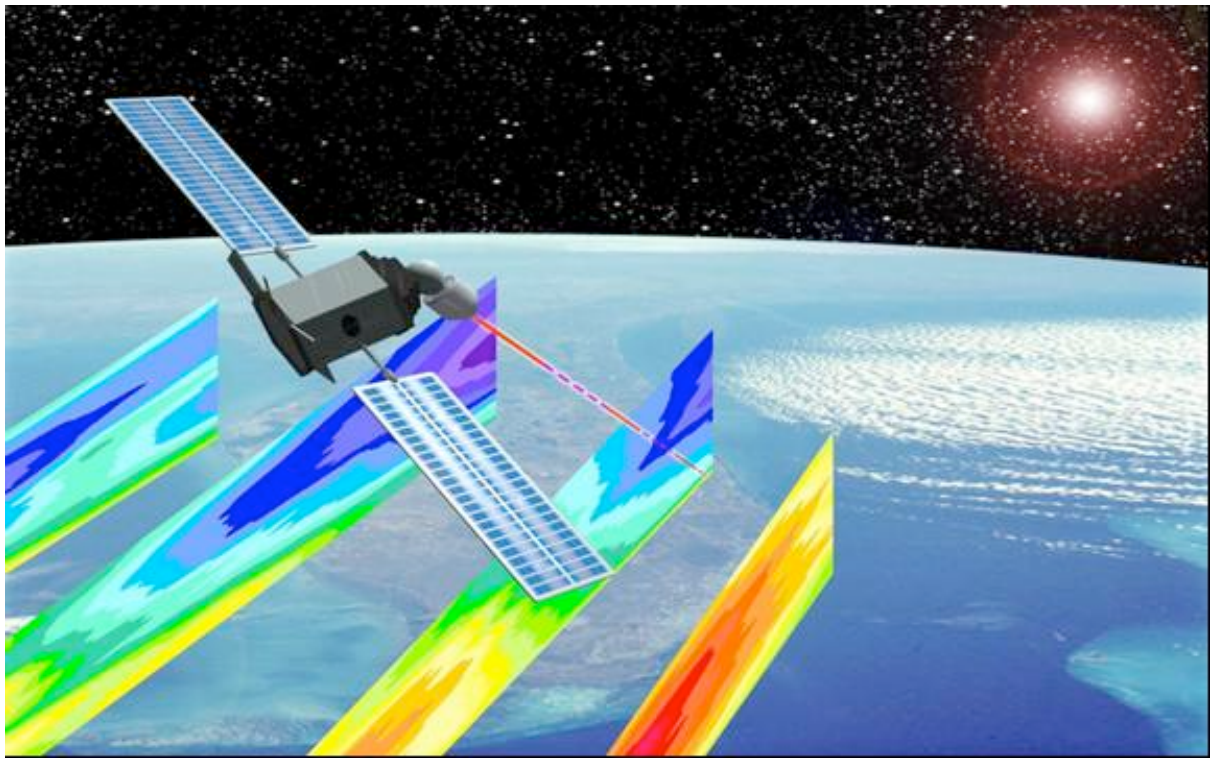
Meeting of the Working Group on Space-Based Lidar Winds
Wintergreen, Virginia
June 16 - 19, 2009

Minutes



Background. Since 1994, the Lidar Working Group (LWG) has met twice yearly to bring together Doppler Wind Lidar (DWL) technologists and potential users from government, industry, academia, and international organizations to exchange information, review technology developments, and build consensus for missions to measure the global wind field from space.

The importance of global wind profile measurement is well established. It is the number one unaccommodated Environmental Data Record (EDR) and the single most important measurement needed for the Global Observing System. The Numerical Weather Prediction (NWP) community unanimously identifies timely global wind profiles as the most important missing observations. Independent modeling studies at the National Centers for Environmental Prediction (NCEP), NOAA Earth System Research Laboratory (ESRL), NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML), NASA, and the European Centre for Medium-range Weather Forecasts

(ECMWF) all show tropospheric wind profiles to be the single most beneficial measurement missing from the Global Observing System. The National Research Council (NRC) Decadal Survey recently recommended the Hybrid Doppler Wind Lidar (HDWL) instrument as a priority to be implemented in a NASA demonstration mission followed by an operational mission.

More than 25 years of development have led to a viable conceptual design for a space-based HDWL. An HDWL design incorporates two lidar subsystems, one a direct detection ultraviolet DWL for aerosol-free regions of the atmosphere and the other a coherent detection infrared DWL for atmospheric regions with aerosol loading. HDWL has been shown to meet data requirements while optimizing mass, power, and volume in NASA design studies. Recent instrument design studies include:

- **Global Wind Observing Sounder (GWOS)** for space demonstration in a 400 km orbit. This is a NASA-sponsored conceptual design developed at the Goddard Space Flight Center (GSFC) Instrument Synthesis and Analysis Laboratory (ISAL) in 2006.

- **NPOESS Wind Observing Sounder (NWOS)** for a National Polar-Orbiting Environmental Satellite System (NPOESS) second-generation (NexGen) satellite in an 824 km orbit. The NPOESS Program Executive Office (PEO) sponsored this design activity at the GSFC Instrument Design Laboratory (IDL) in 2008.

GSFC GWOS and NWOS design teams both concluded that HDWL is viable for space missions. The instruments are designed to measure global 3-D horizontal wind vector profiles for the first time. They use bi-perspective views of atmospheric target volumes to directly measure horizontal wind vectors. Cost benefit studies show potential societal benefits on the order of $1B per year as a result of improved weather forecasting with assimilation of global winds observations.

The European Space Agency (ESA) plans to launch the first space-borne DWL (not an HDWL) instrument, Aeolus, in 2011 in the Atmospheric Dynamics Mission (ADM). ADM will provide global line-of-sight wind profiles.

A future joint mission by NASA, NOAA, and Department of Defense (DOD) offers the best opportunity for the U.S. to demonstrate an HDWL in space in the coming decade.

NASA and NOAA have briefed several agencies and organizations on lidar winds mission opportunities, including:

- USAir Force (March 20, 2007). In response, the USAF Director of Weather sent a letter on August 1, 2007 to NASA HQ stating support for tropospheric wind measurements, and a second letter was sent on September 22, 2009.
- USAF Space Command - May 8, 2007
- US Army - May 10, 2007

- NOAA Observing Systems Council (NOSC) – June 8, 2007; June 18, 2008
- US Navy (June 11, 2007); a supporting letter from Navy was received on August 8, 2007
- Joint Planning and Development Office (JPDO) and Federal Aviation Administration (FAA) - June 18, 2007
- FAA Director of Weather - May 16, 2008
- NOAA Research Council - May 19, 2008

Interagency support for airborne and space demonstrations continues to build. The NRC Decadal Survey, a NASA Earth-Sun System Technology Office (ESTO) study report, the US Integrated Earth Observing System Strategic Plan, and the NPOESS Integrated Program Office (IPO) assign high priority to global observations of winds at all levels. The USAF, Navy, Army, and FAA have interest in improved wind data and weather forecasts in support of their respective missions.

Technology readiness continues to advance to support GWOS and NWOS instrument reference designs for space. Both direct detection and coherent DWL systems are developing airborne demonstration equipment. Key technology components will reach Technology Readiness Level (TRL) 5 in these development and demonstration activities. HDWL reference designs were determined by GSFC design teams at ISAL and IDL to be feasible with no technological "tall poles."

Tuesday, June 16

Wayman Baker opened the 32nd meeting of the Lidar Working Group with introductory remarks and a review of Action Items from previous meetings. Action Items are available on the website at http://space.hsv.usra.edu/LWG/Index.html . Wayman introduced the new Co-Chairs of the Lidar Working Group, Michael Hardesty and Lars-Peter Riishojgaard.

Michael Hardesty and Lars-Peter Riishojgaard presented "Remarks by the New Co-Chairs of the Lidar Working Group." Mike and Lars-Peter expressed appreciation for Wayman's many years of determined and energetic leadership. They discussed the benefits of joint chairmanship, including the sharing the workload, the geographic locations of the co-chairs, and varied technology and organizational backgrounds. Both Michael and Lars-Peter are engaged in the ESA ADM program and have opportunities to work with ESA as well as US efforts.

ADM-Aeolus Session

Ad Stoffelen presented "ADM-Aeolus: Mission Status and Data Processing Chain." Ad provided an overview of ADM, including:

- Objective to improve atmospheric analysis and weather forecasts
- Mie detection for aerosol winds, Rayleigh detection for clear atmosphere
- ADM products

- Challenges
- Development status

Most new technology is complete and qualified for flight. The most demanding areas are the transmitter laser, optical coatings, harmonic crystals, and pump laser diodes. Fifty industrial partners are involved in development, led by EADS Astrium. The launch target date is November 2011. Vacuum test results showed laser-induced contamination on some UV optics, with improvements resulting from new optical coatings. Performance meets specifications over most of the altitude range. Processing is progressing, with scientific validation of the processing chain. Study activities are in progress. The space segment remains challenging but is close to completion. Calibration work is underway, including ground based campaigns. Work is beginning on the use of data. Work proposed for the Announcement of Opportunity (AO) for Calibration/Validation activities will probably begin in the autumn of 2010. The presentation was followed by an extensive discussion and question period, including discussion of correlation with other instruments near the surface. There was discussion of the status of US funding support for the calibration and validation of ADM. NOAA funding requests have been submitted for ADM data use in FY12 within the environmental modeling program. Opportunities are anticipated for NASA and NSF funding.

Ad Stoffelen presented "ADM-Aeolus: Vertical Sampling Scenarios." Ad discussed the Vertical AEOLUS Measuring and Positioning (VAMP) status and technical approach. ADM vertical sampling bins can be programmed and varied. A VAMP study is underway to optimize sampling. Issues include wind variability, representation of mean wind in heterogeneous conditions, height assignment, combined wind and optical variability, atmospheric state, and climate dependence. ADM can change its vertical sampling scenario 8 times per orbit. Parameters include 24 levels with weekly commanding set 3 weeks ahead. Ad discussed Fizeau ground calibration over land, Fabry Perot and Fizeau cross calibration at 2 to 3 km, Mie cross talk correction, and Mie contamination for Fabry Perot. Bin size limitations include multiples of 250 m with maximum of 2000 m. Other topics included atmospheric optics (including relationships to CALIPSO data), height assignment, Horizontal-Line-Of-Sight wind error, cloud resolving models, and impacts of perturbations in troposphere and stratosphere.

Mike Hardesty presented "ADM-Aeolus: Recent Instrument Modifications/Tests and Airborne and Ground-Based Field Campaigns" coauthored with O. Reitebuch, C. Lemmerz, Zhigang Li, E. Nagel, I. Nikolaus, U. Paffrath, and B. Witschas. Since the Fall 2008 ADM Mission Advisory Group (ADMAG) meeting, there have been three campaigns:

- Ground observations at DLR
- The second airborne campaign, including Falcon aircraft, ALADIN Airborne Demonstrator (A2D) and a 2 micron DWL
- Brillouin Atmospheric Investigations on Schneefemerhaus (BRAINS) with A2D

The A2D airborne simulator uses early ADM components, and supports ground and air experiments. Ground profiles, statistical comparisons of A2D to radiosonde, and radiometric performance data were discussed. In the second airborne campaign, 7 flights

(23 hours) were conducted and included intercomparison with other observations. Calibration was conducted during flights, as well as analysis of impact of aircraft motion, alignment variations, and instrument parameters. A sea surface reflectance model and comparison of model to observations were discussed. Analyses of A2D airborne observations and ground detection comparisons with the Digital Elevation Model were discussed. BRAINS 2009 was conducted from a mountain observatory with A2D. Calibration in the nearly pure Rayleigh scattering environment was described. An airborne campaign is being planned for September and October 2009.

Lars-Peter Riishojgaard presented "ADM-Aeolus: Ground Station Options." Lars-Peter discussed ADM/Aeolus data dissemination, data policy, baseline ground segment, and possible alternative ground stations and trades. Data availability will be in real time to operational meteorological users. The WMO Global Telecommunication System will be used. A single receiving station will be located at Svalbard, capable of full orbital dumps at 50 Mb / orbit, 110 seconds visibility is required for one orbit. There will be a Near Real Time (NRT) data stream (level 1B) with 3 hour latency targeted for NWP. This may not meet WMO's 1 hour latency requirement for global NWP. A Quasi Real Time (QRT) data stream is targeted at regional NWP and other applications, with 30 minute latency. Coverage will not include Southern Hemisphere if only the Svalbard receiving station is available. A QRT II alternative includes an additional receiving station at Troll. QRT data will be available for Europe but not for North America under the Troll/Svalbard receiving station scenario. ESA has studied implications of additional receiving stations. A QRT III scenario considers Fairbanks and Wallops receiving stations. Advantages of a Wallops/Svalbard scenario were briefed to Kathy Kelly, Director of NOAA National Environmental Satellite, Data, and Information Service and Office of Satellite Data Processing and Distribution (NESDIS/OSDPD) and this is under consideration at NOAA.

THORPEX Pacific Area Regional Campaign (T-PARC) Session

Dave Emmitt presented "Overview of P3DWL T-PARC/TCS-08 Mission and Data Analysis" coauthored with Steve Greco. Twin Otter DWL (TODWL) research is supported primarily by the NPOESS IPO and NOAA. Dave described the Tropical Cyclone Structure (TCS-08) experiment in the Western North Pacific. ONR (Dr. Ronald Ferek) funded the P3 DWL activity. Additional funds and hardware are provided by NASA and DOD. Dave Emmitt is the Principal Investigator. The DWL will co-fly with the NCAR ELDORA radar and dropsondes. DWL resolution was 50 m vertical, 1 km horizontal. The campaign saw 4 typhoons. Data will be archived on the Simpson Weather Associates (SWA) website. The mission plan included P3 and Falcon aircraft with DWLs, ferry flights, 171 flight hours, and 118 hrs of data. Investigations included dropsonde comparisons, dropsonde representativeness, typhoons, Organized Large Eddies (OLEs) in the eastern Pacific (Ralph Foster), and ocean surface winds. There were no problems getting readings from 10,000 foot flight altitude.

Zhoaxia Pu presented "The Impact of Airborne DWL Observations on Mesoscale Numerical Simulations of Tropical Cyclones: Case Studies During T-PARC/TCS-08," coauthored with Dave Emmitt, Lei Zhang. This study explored the effectiveness of different assimilation methods using airborne DWL data. Typhoon Nuri in the Western Pacific was studied, using data from the P3 DWL (see above presentation). The Weather Research and Forecasting (WRF) and three-dimensional variational (3DVAR) data assimilation system for the NCAR mesoscale MM5 model were used to make 48 hour forecasts. DWL data improved storm forecasts. The study concluded that assimilation is sensitive to background statistics in 3DVAR and that the 4DVAR extension is potentially better.

Yucheng Song presented "Winter T-PARC 2009 Field Campaign" coauthored with Zoltan Toth and others. Yucheng described the Winter T-PARC 2009 and participants. Research interests included Rossby wave analysis and International Polar Year connection, mesoscale storm structure study, moist processes study, multi-scale tropical influences, data assimilation, satellite data calibration and validation with in situ data, adaptive targeting, ensemble-based probabilistic forecasting and other topics. Field work is complete, data has been archived by NASA. Support is being sought for post-field research and evaluation. Yucheng discussed an example of improved forecasting using T-PARC data. ONR is funding hardware for T-PARC 2010. NOAA P3 flights are anticipated.

OSSE Session

Dave Emmitt presented "Plans for DWL OSSEs – Global and Regional" coauthored with Robert Atlas, Lars-Peter Riishojgaard, and Zhoaxia Pu. Observing System Simulation Experiments (OSSEs) began in the late 1980s, and have been used for DWL observation experiments following the Laser Atmospheric Wind Sounder (LAWS) program. The series of OSSEs includes

- NOAA/NCEP (Lord et al)
- NASA/GSFC (GMAO) (McCarty)
- NASA (Roses07) (Riishojgaard, Emmitt)
- NASA (SIVO) (Seablom and SWA)
- NOAA/AOML (Atlas and Emmitt)
- University of Utah (Pu)

OSSE preparation is expensive. The NWP OSSE Steering Group provides oversight, planning, funding, reviews of results, and reports to NASA and NOAA. Members of the Steering Committee include Bob Atlas, Steve Goodman, Lars-Peter Rishojgaard, Steve Koch, Fuzhong Weng, Rolf Langland (NRL), Ron Gelaro (GMAO), and Hans Huang. The NASA Research Opportunities in Space and Earth Sciences (ROSES07) OSSE effort was funded by Ramesh Kakar. It supported further development of the GWOS concept for ADM follow-on and studied impact on medium range forecast skill, hurricane track forecast, analysis quality, and requirements. Dave discussed experiments that were part of ROSES07 OSSEs. This work established a numerical test bed for trade studies, obtained multi-agency support, and defined advantages and limits of the hierarchy of OSSEs

including rapid prototyping or data assimilations. There was extensive discussion about maximizing the utility of OSSEs.

Zhaoxia Pu presented "On the Problems and Challenges in Regional OSSEs" coauthored with Robert Atlas. Regional OSSEs support studies of high impact weather systems, tracks, intensities, and structures. Global model resolution is too coarse. Zhoaxia discussed whether European Centre for Medium-Range Weather Forecasts (ECMWF) global nature runs adequately represent hurricane structure and whether they are adequate for verification. Case 00UTC October 1 2005 was represented reasonably well in the Nature Run for a model of intermediate resolution. The low resolution of a Nature Run vs. the scale of the inner storm core render the Nature Run more useful for track forecast than for intensity forecast. Regional OSSEs need regional Nature Runs. Other issues and challenges include the choice of physics parameterization options, differences among forecasts originating from different models, sensitivity to boundary conditions, and calibration.

Zhaoxia Pu presented "The Potential Impact of Space-Based DWL Profiles on Hurricane Forecasts: Preliminary Results from Regional OSSEs" coauthored with Lei Zhang, Bruce Gentry, and Belay Demoz. Most previous OSSEs used global models. Zhaoxia addressed ways to improve hurricane intensity forecasts. She discussed a Regional Nature Run and regional simulation with high resolution. She concluded that DWL can help improve high impact (hurricane) forecasts and that there is a need to explore instrument strategies for intensity forecasts and to develop mesoscale data assimilation systems.

Will McCarty presented "Preliminary Efforts to Simulate and Assimilate DWL Observations at the Global Modeling and Assimilation Office." The goals of this work were to prepare for ADM and LOS data using a Gridpoint Statistical Interpolation (GSI)-centric data assimilation system. The work can be expanded to future DWL measurements. Will described the current system, ADM data flow preparedness, HLOS in GSI, and limitations of the methods.

Sara Tucker presented "Diurnal Cycles in the South Pacific Marine Atmospheric Boundary Layer" coauthored with William Brewer, Scott Sandberg, and Michael Hardesty. This work used the NOAA High Resolution Doppler Lidar (HRDL) on NOAA research vessel RV Brown to make measurements on the southeast Pacific Ocean. Much of the data were taken under heavy cloud cover. Profiles extended up to clouds or to where aerosol densities ran out. Sara showed satellite images of the stratus deck over the southeast Pacific and profiles of signal to noise ratio (SNR) and horizontal and vertical velocity. Weak diurnal cycles were observed, with late afternoons having least cloud cover. Observations of cloud base height vs. latitude / longitude were described. Velocity variance has a diurnal cycle, exhibiting lowest variance (turbulence) when the sun is out and higher variance at night. Profiles of averaged wind velocity variance showed atmospheric decoupling. Observations related to decoupling included: advection of stratocumulus over warmer waters, buoyancy fluxes, cloud thinning, drizzle, latent heat flux, land circulations, sea surface temperature, stable transition layer, turbulence

beneath and near clouds, ocean eddies, ocean temperature profiles, and wind shear. Wind studies continue in conjunction with VAMOS Ocean-Atmosphere-Land Study (VOCALS) and the Texas Air Quality Study (TexAQS). VOCALS is part of an international interagency project. VAMOS is the acronym for the parent program called Variability of the American Monsoon Systems. Research will include aerosol properties. Late afternoon passes with space-based lidar have both pros and cons. Pros include fewer clouds and less turbulent mixing, while cons include decoupling from aerosol gradients and two possible cloud layers. Combining lidar observations with other satellite data such as scatterometer and imagery may be useful. A second part of the talk addressed applications to wind energy. Energy related programs that were mentioned included

- NOAA ESRL program for Sustainable Energy and Atmospheric Sciences (SEAS)
- Colorado Renewable Energy Laboratory, involving Universities, public agencies, and industry
- Corporations

Wind energy challenges include dispatch, turbine control, and blade control. Lidar wind energy applications are being addressed at NOAA/SEAS, as well as shortfalls in weather forecasting for renewable energy (see http://www.esrl.noaa.gov/research/renewable energy/). Applications of lidar to wind energy were outlined. NOAA has done a turbine site study using HRDL in Colorado and multiple studies on boundary layer dynamics around the Great Plains.

Sid Wood presented "Update on NASA's Sensor Web Experiments Using Simulated Doppler Wind Lidar Data" coauthored with Dave Emmitt and Steve Greco. NASA ESTO and NASA Headquarters are funding GWOS OSSEs. Simulations for current observations are being prepared. The NASA Software Integration and Visualization Office (SIVO) supports Sensor Web concept development. Objectives are to develop a foundation for decisions on GWOS and ADM follow-on missions. The Sensor Web is a model-driven system for earth-observing targeted observations using earth orbiting and ground based sensors. This work will strive to demonstrate the value of sensor webs, quantify cost savings, and address science goals. An integrated simulator will be built for use in "what-if" experiments. The first simulation will investigate extending mission life by using power modulation. The approach will conserve power by using aft shots only when there is significant disagreement between the model first guess LOS winds estimate and winds measured by fore shots. This strategy can save power and increase laser lifetime. The second simulation experiment will address the improvement of science products using targeted observations. This simulation will address slewing the satellite to optimize target volume selection. Anticipated benefits include reduced duty cycle (reducing power and extending laser life) and improved feature detection. The SWA Doppler Lidar Simulation Model (DLSM) will be used in constructing experiments. Assimilation model needs include a Line-of-Sight wind operator, integration of the Satellite Toolkit into a workflow tool to provide satellite location and attitude, T511 and T799 nature runs in DLSM format including aerosol, molecular and cloud optical property databases, slewing capability in the scanner model, Global/Mesoscale OSSE-like experiments, and an adaptive cloud avoidance Scheme to avoid wasting shots where the region of interest is blocked by clouds

Steve Greco presented "Visualization and Fusion of Model and Airborne Doppler Wind Lidar Data Within a Google Earth," coauthored with Dave Emmitt, Steve Shipley. Steve described work using Google Earth to illustrate real time results time in flight. Past work has demonstrated flight tracks with vector wind profile graphs projected onto Google Earth maps. Capabilities of the Airborne Doppler Lidar Analyses and Adaptive Targeting System (AADLATS) and In-flight Lidar Integrated Mission Management System (I-LIMMS) will be merged with autonomous on-board observation management and processing for airborne wind observation. Google Earth capabilities will be used to help optimize data collection and processing. Steve described programs and outputs for visualization. Airborne realtime comparisons of DWL observations with WRF forecasts have been studied. Ongoing work includes fine tuning for interpolation and comparison, extension to LOS comparisons, generalizing software, and extending to other numerical models.

Wednesday, June 17

Session on DWL Technology Development

Bruce Gentry presented "Status of the Tropospheric Wind Lidar Technology Experiment (TWiLiTE) Instrument Incubator Project (IIP)" coauthored with M. McGill, G. Schwemmer, M. Hardesty, A. Brewer, T. Wilkerson, R. Atlas, M. Sirota, S. Lindemann, and F. Hovis. The TWiLITE instrument is a compact, rugged, autonomous, scanning, direct detection DWL designed to measure wind profiles in clear air from 18 km to the surface. It is designed to operate on NASA research aircraft such as the ER-2, DC-8, and WB-57. Initial engineering flight tests on the ER-2 demonstrated autonomous operation. It is scheduled to fly in the DC-8 cargo bay. The Direct Detection DWL development roadmap was discussed, showing GLOW mobile lidar, TWiLiTE DC8, TWiLiTE WB57, and TWiLiTE ER2. Key technologies (solid state laser transmitter, high resolution optical filters, 355 nm photon counting receiver, and UV Holographic Optical Element telescope and scanning optics) will be advanced to TRL 5 by the TWiLiTE project. Photomultiplier Tube (PMT) quantum efficiency is up to 25% and new PMTs are coming up with higher efficiencies. Aircraft integration and test activities were completed in January 2009. The first ER-2 engineering flight took place in February 2009 at Dryden. Key functions were demonstrated. Aircraft environments are not friendly for lasers. Some parts failures were experienced, including a coolant pump and an on-board computer. The instrument was returned to GSFC to fix failed components. A second flight test was scheduled for August 2009. Adaptation to the DC-8 aircraft is funded (ROSES07- Airborne Instrument Technology Transition (AITT)) and a proposal was submitted for participation in the summer 2010 hurricane Growth and Rapid Intensification (GRIP) experiments.

Michael Kavaya presented "Development of Pulsed Coherent Doppler Wind Lidar Systems for Two Aircraft." Two aircraft projects are underway at LaRC, designated DAWN-AIR1 and DAWN-AIR2. DAWN-AIR1 is an AITT-07 project for flight on the DC-8, sponsored by the Science Mission Directorate Earth Science Division (SMD ESD). The point of contact is Ramesh Kakar. DAWN-AIR2 is an Instrument Incubator

Program (IIP-07) for the WB-57 sponsored by SMD Earth Science Technology Office (ESTO). The point of contact is George Komar. DAWN-AIR1 will require 2 operators on board and operate in a controlled temperature and pressure environment, while DAWN-AIR2 will be autonomous and operate at low temperature and pressure. AIR1 will be ready by summer 2010 and support the hurricane GRIP program. It will use a DAWN transceiver and rotating wedge scanner. The package will be upgraded for AIR2 and then co-fly with TWiLiTE on the WB-57. Michael showed photographs of the completed DAWN package and compared its specification to those of commercial lidars, showing significant advances. The telescope, scanner, data acquisition, and aircraft mounting designs were described. The first hybrid airborne demo will include DAWN and TWiLiTE.

Chris Grund presented "Optical Autocovariance Wind Lidar (OAWL) IIP Development Progress," coauthored with J. Howell, M. Ostaszewski, and B. Pierce. OAWL development and flight demonstration recently received funding through a NASA ESTO IIP. Chris discussed the single laser, single wavelength, molecular and aerosol lidar approach and identified promising qualities of the approach, including single laser, tolerance to wave front error, compatibility with a single wavelength scanner, wide field of view, and minimal laser stability requirements. The work at Ball has simplified spectral resolution control loops, stabilized interferometer thermal and mechanical properties, achieved high optical efficiency, and enabled practical tolerance requirements for collection optics. Funding has included internal Ball Aerospace internal investment and NASA IIP funding to fly on the WB-57 and exit at TRL-5. Chris discussed Internal R&D (IRAD) objectives and described the receiver design concept. The approach allows use of heritage telescope designs. Properties of the Cat's Eye Interferometer were described. Chris reviewed receiver development activities and schedule. IIP objectives include demonstration of the technique and raising TRL level through high altitude aircraft flight, among other objectives. Chris described the field experiments plan, WB-57 pallet packaging, optical system, data system, and schedule through WB-57 flight Fall 2010.

Belay Demoz presented "The Howard University Beltsville Research Campus (HUBRC): Highlights from the Recent Wind Lidar and Water Experiments" coauthored with D. Venable, T. Bacha, B. Gentry, H. Chen, K. Vermeesch, G. Koch, U. Singh, M. Boquet, and L. Sauvage. Belay reviewed HUBRC goals, facility, instrumentation, and recent experiments. The goals include enhancing the Howard University research program, providing hands-on training, and contributing to climate and environmental monitoring activities. Monitoring activities include planetary boundary layer, climate observations, satellite instrument validation, pollution studies, lidar studies (wind, aerosols and water vapor), and radiosonde sensor evaluation. The facility is located in Beltsville MD along a major pollution corridor. It is well equipped with monitoring instrumentation, and has a collaborative environment. Belay described the Network for the Detection of Atmosphere Composition Change (NDACC) WAter Vapor Variability Experiment (WAVES 2009) work (http://tropometrics.com) with water vapor profiling and climate change studies using lidar and sonde instruments. Wind lidar studies were conducted in February and March 2009 to assess DWL performance as

a function of aerosol loading, develop a seasonal wind data archive, demonstrate VALIDAR and GLOW, and compare results among sensors. Intercomparisons were made with Aircraft Communications Addressing and Reporting System (ACARS) and Aircraft Meteorological Data Relay (AMDAR) observations. Commercial aircraft deliver observations along their flight paths of winds, temperature, water vapor, and turbulence. AMDAR observations are reported to have a positive impact on weather forecasts. Substantial variability was observed between AMDAR, Sonde, and Profiler wind vector observations and these appear to represent atmospheric variations. Work was done with lidars developed by Leosphere. Leosphere has deployed a number of meteorological lidar stations internationally (www.leosphere.com). Plans for future work were reviewed.

Kevin Vermeesch presented "Comparisons of Ground-Based, Radiosonde, and Aircraft Wind Measurements at the Howard University Beltsville Research Site", coauthored with Grady Koch, B. Gentry, T. Bacha, H. Chen, and B. Demoz. These intercomparisons used the following instruments and observations:

- 915 MHz wind profiler
- ACARS
- GLOW
- LEOSPHERE WLS70 wind lidar
- Radiosonde
- VALIDAR

ACARS data was used from within 50 km from Beltsville and within 30 minutes of a profile captured by ground instruments or sondes. Kevin showed experimental data and results including parameters for different instruments, wind speed and direction plots. He concluded that generally good agreement is observed among sensors although ACARS has a lot of variance relative to other sensors.

Grady Koch presented "Ground-Based Testing of the DAWN 2-Micron Doppler Lidar and Comparison with Other Sensors." Grady discussed wind observations made with the GLOW lidar and intercomparisons with sondes. He provided results of the comparisons in terms of rms velocity differences and rms direction differences. Hybrid lidar velocity time series used 2 micron lidar up to 6 km altitude and used 355 nm lidar above 6 km.

Bruce Gentry presented "Goddard Lidar Observatory for Winds (GLOW) Wind Profiling from the Howard University Beltsville Research Facility" coauthored with H. Chen, T. Bacha, B. Demoz, and D. Venable. Goals include gaining experience with GLOW and VALIDAR working together, including intercomparisons employing a variety of sensors, developing a seasonal database archive, sampling strategy and post processing studies. Bruce described the GLOW mobile lidar. Good agreement was found between GLOW data and sonde data if observations are matched with observations from the same time and same altitude. Sampling strategy, post processing, dynamic range, and field data samples were described. The laboratory test-bed for the Edge Technique Lidar was described. Future plans include wind data collection, representativeness studies of data sampling and averaging schemes, intercomparisons, and bringing up the double edge aerosol receiver for PBL studies.

George Komar, Associate Director/Program Manager of the NASA Earth Science Technology Office, presented "Innovative Technologies Contributing to Future Earth Science Capabilities." George provided an overview of the Earth Science Division goals and six major activities. The major goal is to advance Earth System science, including climate studies, through spaceborne data acquisition, research and analysis, and predictive modeling. Wind lidar activities fall within the activity of developing technologies to improve Earth observation capabilities. Technology enables previously unforeseen or infeasible science investigations, enhances measurement or operational capabilities, and reduces cost and risk and development times. The approach to technology is science driven, competed, actively managed and dynamically communicated. Risks are retired before major investment is made. He reviewed the Earth Science Decadal Survey missions, gave examples of ESTO investments in lasers, and reviewed the roadmap to a 3-D Winds space mission. New mission classes include Foundational, National Needs, Decadal Survey, and Climate/Operational. A list of examples was shown for each class. Technology challenges exist in active remote sensing, large deployables to enable future weather/climate/natural hazard measurements, intelligent distributed systems, and information knowledge capture. This work is providing state-of-the-art instruments and systems. New awards are constantly being selected by NASA. Active remote sensing systems are key to future Earth Science success. The briefing was followed by a discussion of NASA perspectives. George indicated that we are making good progress with wind lidar technology. Demonstrating airborne and science progress can help advance the mission, as can partnering. There was discussion of possibly putting technology aboard the Space Station and the need for low cost instruments for Space Station. Wayman Baker pointed out that the Air Force has expressed interest in a DWL experiment on the Space Station. This will be followed up with the Air Force.

Jan Paegle presented "Dependence of Regional Atmospheric Circulations and Moisture Fluxes upon Ambient Wind Fields," coauthored with L. Byerle. Jan reported on a study of North and South American low level jets and discussed summer and winter climatology. The study addressed deflection of ambient winds by mountain ranges. Jan showed summer and winter wind field plots. Graphs of tornado counts and nocturnal wind speed show strong correlation between the two phenomena. Correlation is also observed between heavy rainfall and nocturnal wind speed. Examples of differences in wind profiles in periods of high tornado count vs. low tornado count were reviewed. More thunderstorm activity correlates with more low level jets. Low level jets and precipitation are responses to ambient zonal flow and orography deviations from climatology in North and South America. Jan concludes that low level jets modulate severe weather and precipitation. Detailed vertical, horizontal, and temporal evolution of low level jets might be difficult to detect from space. Strong correlation of low level jets and related phenomena with upper level cross-mountain winds could mitigate direct observational difficulties. Implications for climate impacts include weakening of zonal circulations associated with some global warming scenarios and resulting changes of low level jets, moisture fluxes, and regional hydrological cycles

Tom Wilkerson presented "Wind Profile Measurements with VISIBLE WIND: Further Developments," coauthored with Alan Marchant, Bill Bradford, Tom Apedaile, Cordell Wright, Eve Day. Tom began with photographs of micro-retro reflectors and their mounting on balloons, a Nikon rangefinder, and a Total Station Surveyor instrument used in experiments conducted by the Utah State University Space Dynamics Laboratory to measure local wind profiles with simple and readily available equipment. The experiments tracked the 3 dimensional paths of balloons released in the wind. Goals include getting useful wind profiles as a step toward more complex capabilities, and assessing the value of the approach. Tests were conducted in a winter inversion in Cache Valley UT. Intercomparisons were made with other instruments. Graphic track displays were presented as well as examples of direction, velocity, and shear profiles. Sodar data in the comparison plots were highly averaged in time and altitude. Balloon profiles provided better representation of short term wind variations; although Tom feels their resolution needs to be higher in time and along trajectory. Examples of direction, horizontal velocity, and shear profiles were shown. A photograph of the VisibleWind II Lidar range finder was shown. VisibleWind II measurements were made in complex terrain at Richmond UT, and plots of trajectories and winds at Richmond were discussed. The project succeeded in making low altitude wind profiles and demonstrated the new Laser Range Finder keyed to Elevation/Azimuth/Time records. Tom suggests that these techniques can be useful in atmospheric transport studies such as the USDA aerosol lidar project, calibrating wind sensors, and wind prospecting (related to turbine life vs. wind variability and shear). Trajectories were measured to 2200 m range, 1500 m altitude. Night tracking was demonstrated. The method was determined to be useful for wind probing at altitudes of wind turbines. Continuing work will address improved resolution, stronger winds, day/night studies, and wind/terrain studies. Field trials are planned with lidar and sodar sensors.

Dave Emmitt presented "Plans for VORTEX 2 Using a Radar/Lidar Facility." The goals of the Verification of Rotation in Tornadoes Experiment (VORTEX) 2 include improving severe weather warnings, studies of tornado genesis and their sensitivity to microphysical and thermodynamic factors, and the role of vorticity maxima along gust fronts in tornado genesis. The experiment is funded primarily by NSF and NOAA. The plan is to package the TODWL instrument for a Radar/Lidar Van, using an Army scanner. System tests are planned in Boulder and Dugway. The lidar experiment will take place in 2010. Dave described the CIRPAS truck and phased array radar.

Michael Kavaya presented "NPOESS Orbit: Mean Local Time of Ascending Node vs. Spacecraft Time in Shadow." Background**:**

- Wind mission customers are NASA, IPO/NPOESS, and DOD
- NPOESS orbit height is 824 km with mean local time of ascending node 1330 or 1730 and 97.727 degree inclination angle
- Average sunlight vs. orbit is an important trade in mission planning
- A sun-synchronous orbit provides power for the active remote sensor instruments

Michael addressed the question of whether DWL can work with any node time, using an Excel program approach to estimate time in shadow. The Excel tool allows quick examination of time in shadow for different orbit parameters.

Dave Winker presented "CALIPSO Status and Plans". The CALIPSO 3 year baseline mission was completed in June 2009, and the mission is extended. CALIPSO has been a very successful mission, with more than 120 CALIPSO papers in print or submitted and registered data users in many countries. The largest users are the USA, China, and Japan. The instrument switched to its backup laser in March 2009. The first laser was turned off in February 2009 because of a slow pressure leak in the canister and the backup laser is operating with good performance. Dave discussed the primary laser's pulse energy trend. It produced 1.61 billion shots on orbit, with energy decreasing by 6.5%. 10 out of 192 bar drops occurred over its life and no adjustments were required. Energy and canister pressures were compared for the primary and backup lasers. CALIOP Version 2.02 data products are available. Version 3 data products will include improvements and will be released in July 2009 for all data from the beginning of the mission. Additions and improvements were discussed. Penetration statistics for LITE and CALIPSO and cloud statistics for CALIPSO and LMD GCM were compared. Aerosol statistics for CALIPSO, GMAO, and RAQMS were compared. Major differences are found between data vs. cloud models. Anticipated programs toward a long-term lidar data record were described, including CALIPSO, ADM, EARTHCARE, and ACE. CALIPSO has potential for service through 2012 or 2013. A long term record of ground-based lidar observations is needed for future studies, including WMO-GALION. There was extended discussion of the mission and data following Dave's talk.

Steve Greco presented "Comparison of CALIPSO, GLAS, and LITE CFLOS Statistics for Use in DWL Mission Design and OSSEs" coauthored with Dave Emmitt. This study, funded by NASA ROSES07 is looking at LITE and CALIPSO data to address Cloud Free Line Of Sight (CFLOS) statistics, global aerosol backscatter distributions and correlation with cloud and atmospheric dynamics, conversion of observations at CALIPSO wavelengths to those pertinent to GWOS, and instrument trade studies relevant to GWOS. LITE data is being revisited because LITE was the most powerful backscatter lidar ever flown in space. LITE is most useful for investigating weak aerosol distributions. Motivation and methodology for the study is influenced by a Simpson Weather Associates study of ICESat Geosciences Laser Altimeter (GLAS) statistics. CALIPSO level 2 products from August 2007 are used for cloud top, cloud base, number of layers, and surface elevation. Data were obtained from the NASA LaRC Atmospheric Science Data Center. Laser, data features, and previous results were compared for LITE, CALIPSO and GLAS. Key findings from CALIPSO data were presented. Work is continuing to extend statistics for cloud products, examine coincident observations with the TPARC/TCS08 P3DWL, study phenomenology, and study backscatter.

Gary Wick presented "NOAA Unmanned Aircraft Systems (UAS) Program" coauthored with Robbie Hood. The program is evaluating feasibility of UAS platforms to meet NOAA mission goals in such areas as hazardous conditions, remote locations, long endurance missions, and stealthy performance missions e.g. monitoring fisheries. Limitations include airspace authorization, cost, and ability to see and avoid problems. Demonstrations are underway in military and foreign airspace. Phase 1 (FY08 to 10) will

evaluate platforms, analyze alternatives, and submit a go/no go recommendation. If "GO", then Phase II Acquire and Operate, and Phase III Expand to Global Coverage will follow. Team members come from OAR, OMAO, NOS, and NMFS. Aircraft alternatives include

- Global Hawk 1000 to 2000 pound payload, 30 hrs, 65,000 ft (2 a/c acquired by NASA Dryden Research Center)
- Small hand-launched aircraft
- Mid size aircraft

Arctic science activities are Greenland ice mapping and ice seal observations. Hurricane monitoring activities are conducted in the Gulf/Atlantic. Air-sea fluxes, atmospheric rivers, and fishery surveillance are performed in the Pacific. A list seven mission concepts was reviewed. Capabilities of two NASA Global Hawks, located at Dryden Flight Research Center, were reviewed. A dropsonde is being developed for the Global Hawk. Missions of interest include NASA GRIP in the fall of 2010 and Atmospheric Rivers in 2011-2012 in the Eastern Pacific. Atmospheric rivers are narrow plumes of enhanced water vapor flux, responsible for 95% of meridional flux in less than 10% of the circumference. They are involved in the storms of greatest concern along the west coast and responsible for a large part of the water supply in the Sierra Nevada. Contacts and references are Gary.A.Wick@noaa.gov , Robbie.Hood@noaa.gov , http://UAS.noaa.gov

Open Discussion

Future Meetings- The next meeting will be in Destin FL, Feb 2 – 4, 2010. There was a discussion of places we have met. The 2010 summer meeting will probably be held in the Columbia River Basin or Bar Harbor. There was discussion of the duration and format of future meetings.

Venture Class Mission and Other Possibilities – There was discussion of what could be done with $150 M regarding a possible wind lidar demonstration mission. One topic was tradeoff between cost and reduced requirements, e.g. single wind component, single DWL type, single observation track, etc. A mission on this scale will require thinking outside the box.

The Air Force is interested in an ISS demonstration. A possible scenario would be an Air Force funded launch and 1st year of operations, with the instrument to be provided by another partner.

The Space Test Program (STP), administered by the Air Force, was discussed as a possible partnering scenario. STP funding would not cover instrument costs. Windsat launch, spacecraft, and 1st year operations were funded by the STP. The instrument was a partnership in which NPOESS paid half.

Thursday, June 18

Subcommittee Discussions

George Komar met with the Mission Definition Team to discuss future steps for wind lidar.

NASA is not spending money on third tier Decadal Survey missions at this time.

Venture class missions are science driven. Selected missions can be funded up to $150 M total. The monetary limitation suggests airborne activities, up to 5 years and up to $30M per year, with small payloads. They typically involve 2 years of development and 3 years of data. The purpose is instrument demonstration and data products, and startup is about March 2010. There may be a lot of competition and more proposals than can be funded. Venture class funds will not support technology development, but airborne DWLs shouldn't need technology development after current airborne projects.

Some areas of work to prepare for a mission are science application, platform integration, and data acquisition, processing and distribution to the science team.

There is sensitivity to supporting a mission proposal if it is too much like the Decadal Survey mission, given the Decadal Survey prioritization. An airborne mission proposal is not space-borne, so it would appear to be a viable candidate.

Some technology observations:

- Scaling from aircraft to space is by a factor of r^2 or about 400 in the product of energy times telescope aperture. This impacts mass, power and volume.
- In going from GWOS to NWOS designs, the Instrument Design Lab advanced their telescope design with "inverted telescopes", reducing volume.
- Spare lasers are a significant factor in mass and volume. CALIOP experience may reduce the spare laser requirement. Spare lasers may not be required for an ISS mission, since it can be resupplied.
- Efficiency continues to improve, and is a significant factor in future packages

The GSFC Instrument Design Lab (IDL) has been responsible for significant progress in DWL instrument concepts. IDL funding will require funding support from partners, e.g. NOAA. IDL studies cost $100K / design. The next IDL design step is not yet defined.

Advancement of partnership requires partners to provide funding, not just interest. An Air Force partnership could provide significant support for advancing a winds mission.

The Space Station could possibly provide station platform space. The 175 MHz downlink and link priorities may be constraints. The Space Station is not necessarily an ideal

platform because of vibration, but this has not been analyzed. It could be possible to get an ISS demo mission much earlier than the Decadal Survey dates.

Steve Mango discussed past partnership arrangements. International partners require committing money if they win proposals; the conditional situation with wind lidar makes it hard to arrange a partnership. International partnerships also involve bureaucratic complexity.

There was discussion of how requirements relaxation might help with getting a mission. Concepts for a Venture Class mission need to be developed, in contrast to the GWOS mission requirements.

IIP work will get key technology to TRL 5, but a big step will remain to get to space-ready from TRL 5. Where are funds to take that step? The 'Instrument First' concept was discussed along with what it would take to get from airborne instruments to space.

It was stated that a Wind Science Committee is needed to advance the mission, e.g. based on needs from atmospheric chemistry, hydrology, etc. The wind scientists are not being heard from. The general response was that ESA has the ADM community and the US has the Lidar Working Group. There is interest among the hydrology community. Need for winds observations are on many lists, but there is no single winds group such as climate, weather, etc. It was observed that we lose touch with those communities. The community behind winds is across the Decadal Survey group, creating a chicken and egg situation because we don't have the measurements now that we are advocating.

Application advocates are needed from people that will use winds observations. This can build from processing and publishing data acquired from ground and airborne work.

There was discussion of asking the IDL to iterate an instrument design-to-cost instead of to requirements, based on a list of options. This could produce a shopping list with varying requirements and costs. It was suggested we provide options that put the onus on the decision maker, e.g.

- Hybrid vs. coherent vs. direct detection
- Reduced lifetime requirement
- Number of observation tracks
- etc.

Friday, June 19

Presentation of Short Subjects – This session included several discussions, with no formal presentations.

The upcoming article for BAMS was discussed, the article is needed to encourage constituency. Wayman Baker volunteered to lead the activity.

The LWG White Paper prepared for the Decadal Survey needs to be updated with the technology advances since its release.

In regard to encouraging young participants in the winds mission, Milt Huffaker has provided a travel grant for students to attend LWG meetings.

Subcommittee Reports and Recommendations – This session included several discussions with no formal reports.

Discussions:

- Space Station Demo Mission workup, including instrument, onboard processing to reduce downlink bandwidth, location, power, heat, window, data quality and utility
- How to work with FAA on mutual interests related to improved flight weather and wind forecasts
- Venture class airborne mission workup
- Global Hawk studies

Review of Action Items – New action items were reviewed and updated. See website.

Next Meeting – The next meeting will begin Tuesday February 2, 2010 in Destin FL.

Adjourn – The meeting was adjourned.

These Minutes were prepared by Kenneth Miller, Noblis, Member of the Working Group for Space-Based Lidar Winds.