Expectations from ADM-Aeolus

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1. Introduction

The Atmospheric Dynamics Mission, ADM-Aeolus, is the fourth of ESA's Earth Explorer Missions[1] (ESA 1999, 2008; Stoffelen *et al*. 2005a). ADM-Aeolus is scheduled for launch in mid-2009 and has a projected lifetime of three years. Its objective is to demonstrate the capability to measure wind profiles from space using a Doppler Wind Lidar (DWL). The need for such data, with high accuracy and good vertical resolution, has been identified as a priority for the global observing system (WMO 2004). The mission objectives and observation requirements have been designed to meet scientific goals in user communities in climate research, atmospheric modelling and numerical weather prediction (NWP).

The expectations from ADM-Aeolus are high, and stem from:

1) the mission objectives, for which Aeolus promises to address key observational needs;
2) the increasing number of studies with wind lidar data that support theoretical expectations about the benefits to NWP;
3) the advanced state of pre-launch preparations, including the development of algorithms to retrieve accurate and representative wind profiles suitable for assimilation in numerical weather prediction (Tan *et al.* 2008). These algorithms are coded as a portable software package that will be made freely available to the meteorological research community.

This remainder of this paper expands on these points. Section 2 provides an overview of the mission objectives, the observation requirements and viewing geometry, and a brief introduction to previous preparatory studies and data simulations. Section 3 surveys the preparations for launch. Conclusions and open issues are in Section 4.

2. The ADM-Aeolus mission

2.1. Mission Objectives

The primary objectives of ADM-Aeolus are (ESA 1999, ESA 2001):

- to provide global observations of wind profiles from space,
- thereby improving the quality of weather forecasts (via better initial conditions, i.e. analyses obtained through data assimilation), and
- improving understanding of atmospheric dynamics and climate processes (global atmospheric transport, global cycling of energy, water, aerosols and chemicals).

1 ESA Earth Explorers web site: www.esa.int/esaLP/LPearthexp.html

The mission is thus expected to provide data needed to address key concerns in numerical weather prediction and in the World Climate Research Programme (WCRP), i.e. quantification of climate variability, validation and improvement of climate models and process studies relevant to climate change. The newly acquired data are also expected to help realise some of the objectives of the Global Climate Observing System (GCOS). This would be achieved by:

a) contributing directly to the study of the Earth's global energy budget (by measuring wind profiles globally), and

b) providing data for the study of the global atmospheric circulation and related features such as precipitation systems, the El Niño and the Southern Oscillation phenomena and stratosphere-troposphere exchange.

Secondary mission objectives are related to model validation and short-term "wind climatologies": the mission should provide data sets suitable for the validation of climate models by providing high quality wind profiles from a global measurement system. Reliable short period wind "climatologies" are also needed to improve our understanding of atmospheric dynamics and the global atmospheric transport and cycling of energy, water, aerosols, chemicals and other airborne materials.

In keeping with the aims of the ESA Earth Explorer Programme, ADM-Aeolus is a research and demonstration mission - it aims to demonstrate the feasibility of a new observational technique, namely active remote sensing with a Doppler wind lidar from space. A further expectation of the mission is that it could lead to follow-on operational missions fulfilling more demanding requirements on data quantity and quality. The scalability of lidar remote-sensing offers many benefits in this regard. Increased accuracy and vertical resolution are in principle achievable through increasing laser transmitter power and/or adopting larger receiver telescopes. Improved horizontal coverage and different lines of sight could be achieved with multiple satellites or scanning instruments. The benefits anticipated from the mission include:

a) a major improvement in our understanding and modelling of tropical dynamics through the provision of observations of the essential component of the flow,

b) a more precise definition of the initial state for forecasting, leading to a significant increase in the accuracy of tropical forecasts,

c) improvements in forecasts of intense wind events through a proper measurement of vertical wind shear,

d) an increase in the usefulness of medium-range forecasts for the extra-tropical region through a better definition of planetary-scale waves.

Furthermore, it is worth noting more generally that remote sensing by lidar offers a much needed quality control standard for temperature and humidity retrievals, which will lead indirectly to improvements in forecasting skill, particularly in the Southern Hemisphere, where remote sensing data are the primary source of information (Gérard *et al*. 2005).

2.2. Observation Requirements and Viewing Geometry

Observation requirements specified for the ADM-Aeolus mission are listed in Table 1. Aeolus places highest priority on accuracy and vertical resolution. After accounting for errors of representativity, the quantity and quality of Aeolus data expected from these requirements is comparable to the well-established conventional network of radiosondes and wind-profilers. At the time Aeolus requirements were formulated, the radiosonde/wind-profiler network was the most important observing system for ECMWF's 4d-var data assimilation, exceeding the benefit of all available satellite data in data-rich areas (Bouttier and Kelly 2001). This situation raised expectations that Aeolus wind profile data would also be valuable in data-sparse areas, such as the Tropics and over ocean regions, especially in the Southern hemisphere where radiosondes are relatively rare and assimilation systems depend more on satellite data. In that context, setting the expectation that a demonstration mission such as Aeolus would have impact comparable to the radiosonde/wind-profiler network was very ambitious. Subsequent studies (Section 3.2) confirm that such expectations remain valid today.

Requirement	Planetary Boundary Layer	Troposphere	Stratosphere
Vertical range [km]	0 – 2	2 – 16	16 – 20 (goal 30)
Vertical resolution [km]	0.5	1.0	2.0
Coverage/along-track profile separation	global/200km		
Profile frequency	120 per hour		
Random error [m/s]	1.0	2.0	5.0 (goal 3.0)
Systematic error [m/s]	0.4		
Data delivery time (L1B data products)	Global: < 3 hrs after sensing Regional: < 30 min after sensing		
Length of observational dataset	3 years		

Table 1: ADM-Aeolus Observation Requirements. Vertical range and resolution are configurable during flight.

The schematic in Figure 1shows the DWL instrument viewing from a low-altitude (~400 km) polar orbit in the direction perpendicular to the satellite track. Measurements are made in two receiver "channels": Rayleigh for molecular returns and Mie for particulates. There is information on the horizontal line-of-sight (HLOS) wind component only (line-of-sight wind velocity divided by the cosine of the local elevation angle ~53 degrees), which is close to east-west except at high latitudes. The unobserved wind component and the mass field will have to be statistically inferred within the data assimilation process (Žagar 2004, Riishøjgaard *et al*. 2004, Stoffelen *et al*. 2005b, Žagar *et al*. 2005, Tan *et al*. 2007). The instrument will provide 50 km along-track average winds, separated by 150 km data gaps (Figure 1); this is to ensure minimal error correlation between consecutive observations (Stoffelen *et al*. 2005a) and maximise the information content while conserving the energy consumption of the instrument.

The polar orbit facilitates the global data coverage that is required, providing data also over the oceans which are currently poorly observed. The DWL will provide layer-averaged wind measurements and observations[2] in 24 layers with configurable vertical distribution that can be modified in flight. The current baseline configuration will provide 1000 m vertical resolution through most of the atmosphere (from 2 to 16 km), 500 m below 2 km, and 2000 m between 16 and 26 km (Figure 1).

2 The term "measurement" is used for instrument data characterized by horizontal scales of between 1 and 10 km, whereas "observation" is used for aggregated data at horizontal scales of 50 km.

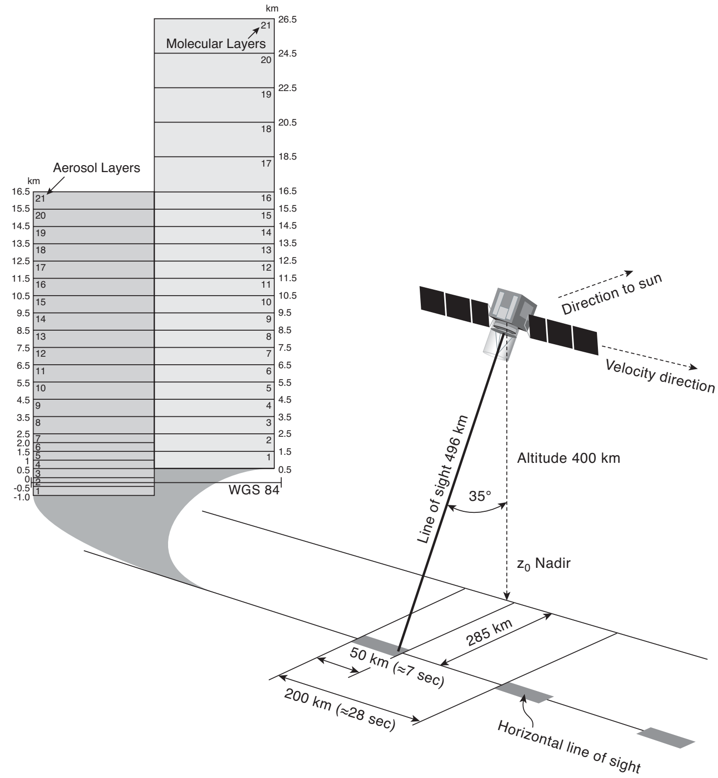

Figure 1: Line-of-sight viewing geometry and proposed vertical distribution of the range bins (layers) for the ADM-Aeolus satellite, showing the aerosol (Mie) and molecular (Rayleigh) channels separately. Courtesy of ESA.

2.3. Preparatory Studies and Data Simulations

Preparatory studies for space-borne Doppler wind lidar have been conducted both in Europe and the USA. Baker *et al*. (1995) summarize efforts for a NASA DWL mission that was cancelled before full implementation. Preparatory work continues in the US in the form of Observing System Simulation Experiments (e.g. Masutani *et al*. 2006) which could be used to inform requirements for a mission in the 2015-2025 timeframe. ESA (1999) summarizes the European preparation that led to selection of ADM-Aeolus as a fully-funded Earth Explorer Core Mission. A condensed version has appeared (Stoffelen *et al*. 2005a), and a further update is in press (ESA 2008). These summary articles provide comprehensive references for the interested reader. They note that the space-borne wind observations being demonstrated by ADM-Aeolus offer substantial complementarity to existing wind observing systems - to radiosondes, wind profilers and aircraft data by providing global coverage especially over oceans and away from the principal flight routes, and to atmospheric motion vectors by providing profiles with good vertical resolution. Complementarity to mass/temperature observing systems, i.e. radiance and temperature data, has also been noted - this is regarded as particularly valuable for determining atmospheric motion on sub-synoptic scales and in the Tropics, i.e. for regimes in which temperature data and conventional mass/wind balance relationships are inadequate (both empirically and from theoretical/dynamical arguments).

The accuracy of the ADM-Aeolus wind measurements and observations will depend primarily on the intensity of the backscattered laser light, which in the Mie channel depends on the presence and optical thickness of clouds, and the concentration of aerosol (Marseille and Stoffelen 2003), and in the Rayleigh channel it depends mainly on the concentration of molecules (i.e. the density of air) and attenuation by overlying aerosol and cloud. The expected yield and accuracy of Aeolus winds has been studied through detailed simulation (Tan and Andersson

2005), based on model clouds (from the European Centre for Medium-Range Weather Forecasts, ECMWF) and climatological aerosol distributions (Vaughan *et al*. 1995).

Increasingly, simulated Aeolus data are being evaluated against real observations in NWP data assimilation/forecast experiments. For example, Tan *et al*. (2007) developed a technique based on the spread of an ensemble of data assimilations, to compare the expected impact of Aeolus data to that of the radiosonde and wind profiler network. They found that Aeolus can be expected to reduce analysis and short-range forecast uncertainty by an amount comparable to the radiosonde/wind profiler network, with the benefits being most apparent over oceans and in the Tropics (Figure 2). An underlying assumption of such studies is that the data processing chain, from raw instrument data up to Level-2B and including the generation of calibration/characterization data, is able to produce sufficiently accurate products (errors in HLOS wind estimates should be below 2 ms^{-1} throughout most of the atmosphere, in accordance with the observation requirements listed in Table 1). This assumption appears justified by the processors developed to date (Section 3.2, and Tan *et al*. 2008).

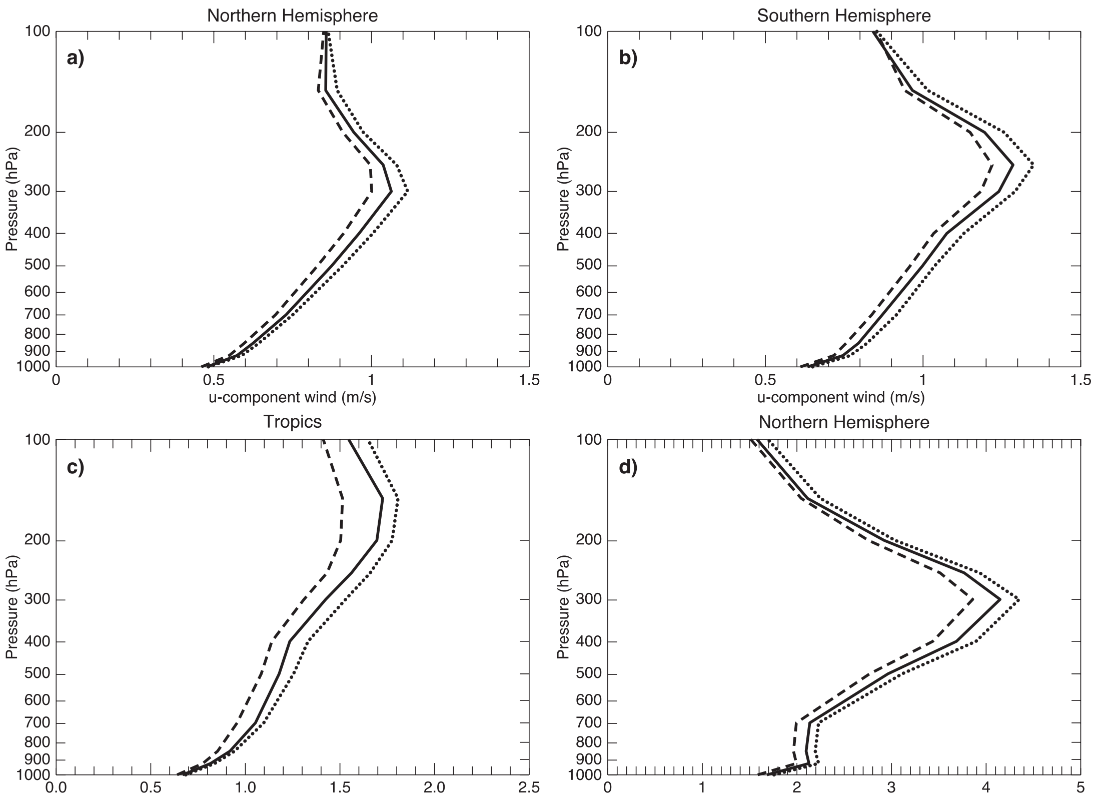

Figure 2: Root mean square east-west wind component ensemble spread, or forecast error, for (a) the extratropical Northern Hemisphere, (b) the Southern Hemisphere, and (c) the Tropics, at 12 hours, and (d) for the Northern Hemisphere at 120 hours, for each of three experiments: Control (solid line), NoSonde (dotted line) and ADM-Aeolus (dashed line). Note that the scale runs from 0. to 1.5 ms^{-1} in (a) and (b), to 2.5 ms^{-1} in (c) and to 5.0 ms^{-1} in (d). For further details see Tan et al. (2007).

As with all new satellite missions, it remains to be seen whether real Aeolus data fulfill the expectations from simulations. Nonetheless, it is worth noting that Weissmann and Cardinali (2007) showed that real DWL observations taken in the North Atlantic from an airborne platform had a significant positive impact on analyses and forecasts of the ECMWF forecast system.

3. Preparations for launch

3.1. General

3.1.1. Space segment

Industrial contracts for the ADM-Aeolus satellite and DWL instrument have been in place for several years (Nett and Endemann 2007). As might be expected, space-qualification tests have been relatively straightforward to pass for the elements with the greatest heritage. Laser diode lifetime tests have been encouraging: operation for 6 months has already been demonstrated and will continue for another two years. Laser vacuum tests planned for 2007 Quarter 4 are an important milestone.

3.1.2. Ground segment

Ground segment development is also well advanced (Nett and Endemann 2007). This covers flight operations, data acquisition at Svalbard, generation of primary data products at both Tromso (near-real-time for Level-1B data and off-line for Level-2A) and ECMWF (Level-2B and Level-2C wind products), generation of auxiliary calibration products, as well as data monitoring, archiving and distribution facilities. Algorithms for Level-2A products developed by an expert team (Flamant *et al.*, 2008) are given to ESA for incorporation in the operational Level-2A software.

It is worth noting that the near-real-time product distributed to operational weather services will be the Level-1B product, which will require further processing in order to be suitable for assimilation in a numerical weather prediction system. This is the role of the ADM-Aeolus Level-2B processor, which is explained further in Section 3.2

3.1.3. Campaign data

A demonstrator DWL has been constructed (Reitebuch *et al.* 2004, Durand *et al.* 2006) for use in ground and airborne campaigns prior to launch of ADM-Aeolus. These campaigns are intended to test key elements of performance, not only at instrument level but also within the data processing algorithms. Initially, attention is likely to focus on instrument response calibration and ground echo detection.

3.1.4. Calibration and Validation

In common with all geophysical satellite missions, it will be important for ADM-Aeolus to characterize instrument performance, determine calibration coefficients, and validate the mission products. Calibration and validation activity will be particularly intensive during the commissioning phase immediately after launch, but will of course receive regular attention throughout the entire mission lifetime. The preparations for this activity are underway with ESA in the process of releasing an Announcement of Opportunity, inviting global participation.

3.2. Wind retrieval algorithms and the ADM-Aeolus Level-2B Processor

The ADM-Aeolus is primarily a research and demonstration mission. Flexible data processing tools are being developed for use in the operational ground segment and by the meteorological community. These include algorithms to retrieve accurate and representative wind profiles, suitable for assimilation in numerical weather prediction (Tan *et al.* 2008). These algorithms have been coded as software that will be made freely available to the meteorological research community. The software has been designed to be portable, and specifically to run in four different contexts: 1) Real-time processing at NWP centres with an interest to assimilate ADM-Aeolus winds within their own forecasting systems; 2) Operational processing at the ECMWF to produce wind retrievals for delivery to ESA shortly after real time; 3) Re-processing at ESA for situations in which delays in data delivery prevent processing within the ECMWF operational schedule, and to accommodate future algorithm improvements and upgrades; and 4) as a standalone processor in a typical research environment.

The algorithms provide a flexible framework for classification and weighting of measurement-scale (1-10 km) data into aggregated, observation-scale (50 km) wind profiles for assimilation. The algorithms account for temperature and pressure effects in the molecular backscatter signal, and so the main remaining scientific challenge is to produce representative winds in inhomogeneous atmospheric conditions, such as strong wind shear, broken clouds, and aerosol layers. The Aeolus instrument provides separate measurements in Rayleigh and Mie channels, representing molecular (clear air) and particulate (aerosol and clouds) backscatter, respectively. The combining of information from the two channels offers possibilities to detect and flag difficult, inhomogeneous conditions. The functionality of a baseline version of the developed software has been demonstrated based on simulation of idealized cases.

Tan *et al.* (2008) describe the ADM-Aeolus Level-2B (L2B) wind retrieval algorithms which form part of the ADM-Aeolus data processing chain. The purpose of these algorithms is to obtain representative and accurate winds suitable for use in NWP. Level-1B (L1B) wind retrievals are not suitable for use in NWP for a number of reasons, the principal one being that L1B algorithms do not account explicitly for temperature and pressure effects on the response of the molecular (Rayleigh) channel of the instrument (Dabas *et al.* 2008). The L2B algorithms use NWP information to take these effects into account. The design of the L2B algorithms takes account of the technical capabilities and constraints of the instrument, for example with respect to vertical and horizontal sampling, instrument pointing stability and zero wind calibration. Quality control and product confidence indicators are important items that will be provided with the wind retrievals – in particular, quantitative error estimates (in units of m/s) will be provided for each wind retrieval. In broken cloud scenes, it is envisaged that separate wind retrievals will be derived for clouds and clear air. This will be done through selective averaging of measurement-scale data in the layers of clear air above clouds, from cloud-top layers, from layers in and below thin clouds, and from layers with sufficient aerosol in the lower parts of the atmosphere.

The algorithms outlined in Tan *et al*. (2008) are involved in calculating the L2B HLOS wind observations at the 50 km scale based on ADM-Aeolus measurements and instrument performance data. They were derived primarily to form part of a piece of software that creates the ADM-Aeolus Level-2B (L2B) data products. Based on the calibrated measurements (L1B) as inputs, they apply the modifications, corrections and additions required to obtain accurate and representative HLOS winds suitable for assimilation by NWP systems, as well as the appropriate quality control flags and uncertainty estimates. Key features of Aeolus products are summarized in Table 2. The so-called Level-2C (L2C) product is a superset of the L2B product and will be described elsewhere. Briefly, it contains additional output from ECMWF assimilation of L2B data, i.e. ECMWF analysed winds at the Aeolus data locations. Thus, L2B products are intermediate between L1B and L2C data. Level-2A products (information on aerosol and cloud layer optical properties) are described by Flamant *et al*. (2008).

Product Level	**Description**	**Typical size (Megabytes per orbit)**	**Comments**
Level 1B	Engineering-corrected HLOS winds	21–70	Near-real-time product. Spectrometer data at measurement scale, HLOS wind profiles using algorithms that do not account explicitly for scene classification nor for Rayleigh-Brillouin (pressure/temperature) effects.
Level 2A	Aerosol and cloud layer optical properties	7–10	Off-line product. See Flamant *et al*. (2008)
Level 2B	Meteorologically-representative HLOS winds	13–18	Shortly after near-real-time for operational products (generated at ECMWF), potentially near-real-time for other meteorological centres (depending on schedule). HLOS wind profiles using algorithms that a) group measurements according to a scene-classification procedure, and b) account explicitly for Rayleigh-Brillouin effects - making use of NWP estimates of atmospheric temperature and pressure, typically from a short-range forecast. Subset of Level 2C products.
Level 2C	Aeolus-assisted wind vectors	19–24	Superset of Level 2B products. Adds ECMWF analysed winds (2 horizontal components) at the ADM-Aeolus locations, and supplementary product confidence data derived during assimilation of Level 2B data at ECMWF. The analysed winds take into account other atmospheric observations and the ECMWF forecast model through the data assimilation scheme.

Table 2: The main ADM-Aeolus data products. For further details, see Tan et al. (2008).

The operational production of L2B data will be done at ECMWF slightly behind real time, just before the assimilation (and production of L2C) is carried out. The L2B processing uses a priori information on the state of the atmosphere at the time and place of the Aeolus L1B measurements. This information is best provided by the background fields of the NWP system, that is, the fields predicted by the forecast model run from the previous analysis. Meteorological background data, interpolated in the vertical plane along the flight track will also be created and delivered to ESA to facilitate re-processing of the Aeolus L1B data at a later time, and for off-line calibration tasks. Figure 3 is a schematic diagram showing the various data sets involved in creating the L2B data. It is envisaged that for their own purposes, many meteorological centres other than ECMWF will produce L2B data with local background inputs, and according to the timeliness constraints of their own operational NWP systems.

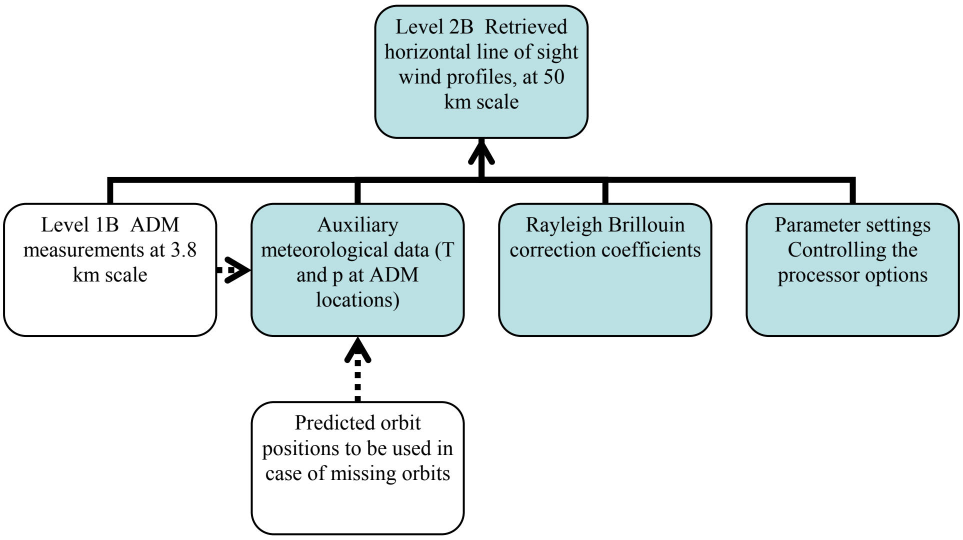

Figure 3 Schematic showing main inputs to the ADM-Aeolus wind retrieval algorithm and the output L2B data. Unshaded boxes indicate that geolocation information is used to determine the locations of auxiliary meteorological data. For further details, see Tan et al. (2008).

Work is in progress for the ECMWF operational implementation of wind retrievals from the Aeolus L2B processor. The strategy involves integration of the processor within the Screening task of the assimilation system (Figure 4). Although L2B wind retrievals could be performed as a pre-processing step prior to Screening, the chosen strategy facilitates access to the background fields of the NWP system at the highest spatial and temporal resolution, and bears some similarity to the strategy for assimilation of radiances affected by cloud and rain (Bauer *et al*. 2006ab, Geer *et al*. 2007). Off-line experimentation with the L2B processor has shown that retrieval accuracy is within the mission requirements and hence compatible with expectations of data impact (Figure 5 and Tan *et al*. 2008).

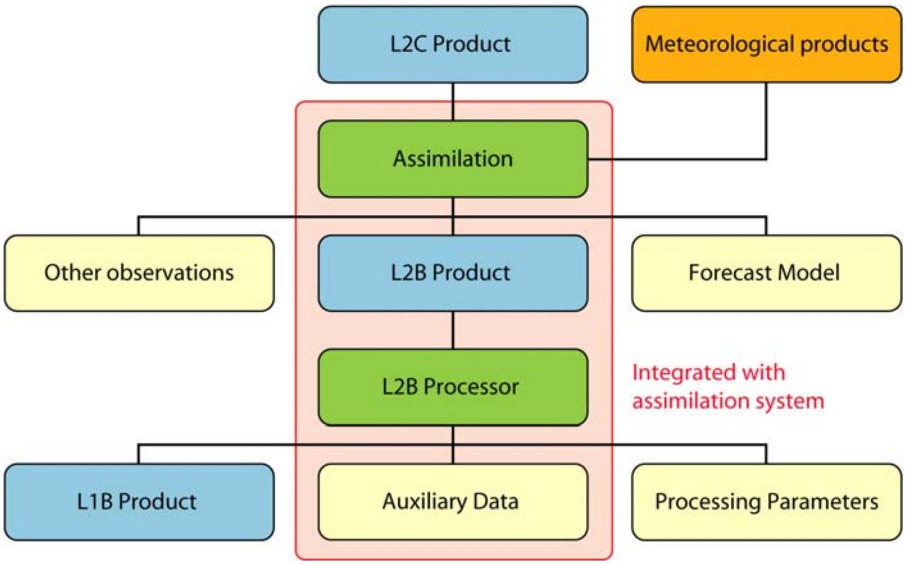

Figure 4: Integration of the Aeolus Level-2B processor in the ECMWF Integrated Forecast System. The Level-2B processor generates HLOS wind component retrievals during the Screening task of the data assimilation scheme, and these wind components are subsequently used as input to the variational assimilation (4d-Var). The Level-2C product contains "Aeolus-assisted wind vector profiles" - profiles of 2 horizontal wind components at the Aeolus observation locations, using the data assimilation scheme to take into account other observational data and prior forecast model information

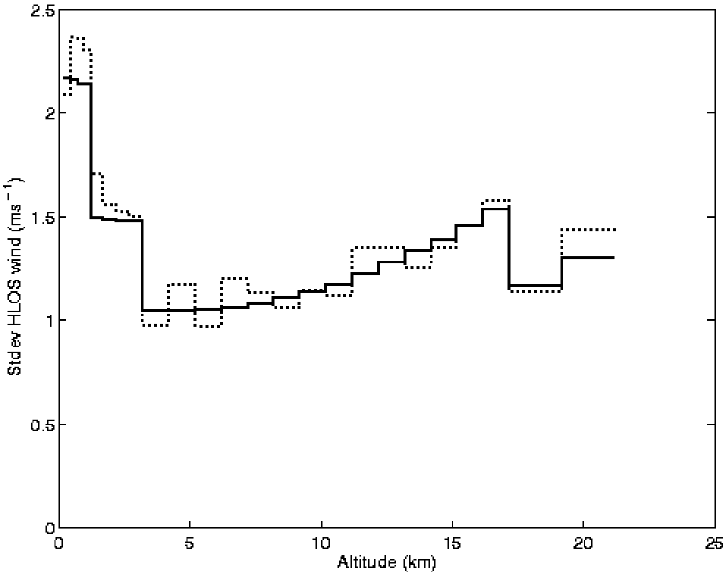

Figure 5: Error standard deviation of L2B wind retrievals (dotted line) and errors estimated from the Rayleigh useful signals in the A and B channels and sensitivity coefficients computed by the Rayleigh-Brillouin correction scheme(solid line). Further details in Tan et al. (2008).

3.3. Assimilation of HLOS wind observations from Level-2B Products

The quantities reported for the Rayleigh channel wind retrievals in Level-2B products include

1) the reference temperature T_{ref} and reference pressure p_{ref} used in the Rayleigh-Brillouin correction scheme,

2) the Rayleigh channel horizontal-line-of-sight wind component estimate $hlos(T_{ref}, p_{ref})$ where the dependence on the assumed reference temperature and pressure is made explicit, and

3) first-order sensitivity coefficients $\frac{dhlos}{dT}(T_{ref}, p_{ref})$ and $\frac{dhlos}{dp}(T_{ref}, p_{ref})$.

These quantities were selected to permit an expansion of the form

$$hlos(T,p) = hlos(T_{ref}, p_{ref}) + (T - T_{ref})\frac{dhlos}{dT}(T_{ref}, p_{ref})$$
$$+(p - p_{ref})\frac{dhlos}{dp}(T_{ref}, p_{ref}) + \text{higher order terms.}$$

Accordingly, the assimilation of Level-2B Rayleigh channel wind retrievals at ECMWF will be based on an observation operator of the form

$$
\begin{aligned}
H_{hlos} &= hlos(T,p) - (T - T_{ref})\frac{dhlos}{dT}(T_{ref}, p_{ref}) - (p - p_{ref})\frac{dhlos}{dp}(T_{ref}, p_{ref}) \\
&= \left(-u\sin\psi - v\cos\psi\right) - (T - T_{ref})\frac{dhlos}{dT}(T_{ref}, p_{ref}) - (p - p_{ref})\frac{dhlos}{dp}(T_{ref}, p_{ref}),
\end{aligned}
$$

for which the corresponding tangent linear and adjoint operators are

$$
\begin{aligned}
dH_{hlos} &= dhlos - dT\frac{dhlos}{dT}(T_{ref}, p_{ref}) - dp\frac{dhlos}{dp}(T_{ref}, p_{ref}) \\
&= \left(-du\sin\psi - dv\cos\psi\right) - dT\frac{dhlos}{dT}(T_{ref}, p_{ref}) - dp\frac{dhlos}{dp}(T_{ref}, p_{ref}),
\end{aligned}
$$

$$
dH^*_{hlos} = \begin{bmatrix} du^* \\ dv^* \\ dT^* \\ dp^* \end{bmatrix} = \begin{bmatrix} -\sin\psi \\ -\cos\psi \\ -\dfrac{dhlos}{dT}(T_{ref}, p_{ref}) \\ -\dfrac{dhlos}{dp}(T_{ref}, p_{ref}) \end{bmatrix} dy^*.
$$

The convention in the above expressions is that the line-of-sight azimuth angle ψ is measured clockwise from South (Figure 6). Further generalizations for a suitable layer-averaged observation operator are also envisaged. Observation operators for the Mie channel HLOS wind retrievals are analogous but do not include the first-order sensitivities.

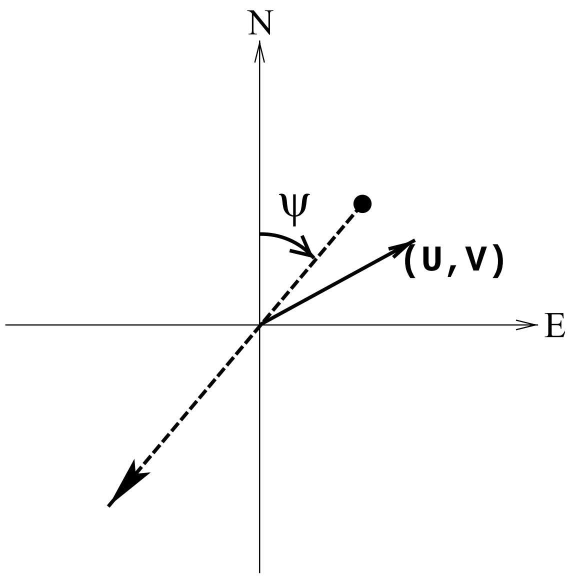

Figure 6: Geometry for horizontal line-of-sight wind observation. The Doppler wind lidar direction (dashed line) makes an azimuth angle ψ with geographical north. For the wind vector components (u,v) drawn in this illustration, the HLOS wind component is a negative value (filled circle). For actual ADM-Aeolus data, ψ in the Tropics is approximately 263^o (ascending nodes) or 97^o (descending nodes) with larger deviations from the E-W direction at higher latitudes.

4. Conclusions and Open Issues

The ADM-Aeolus is primarily a research and demonstration mission that will provide many opportunities for assessing the benefits of space-based wind profile information, and for defining the steps towards future operational DWL missions. The vertically-resolved wind information is expected to be particularly valuable for determining atmospheric motion on sub-synoptic scales and in the Tropics, i.e. the regimes for which temperature data and conventional mass/wind balance relationships are inadequate for determining the atmospheric state.

Given the experimental nature of the mission, it has been recognized that data processing needs to have sufficient flexibility to explore the full potential of the mission data. The L2B wind retrieval algorithms discussed by Tan *et al.* (2008) are likely to evolve during the mission. The evolution is expected to be relatively minor, but of course any changes will be thoroughly documented. The L2B processor software has been designed to be portable, and specifically to run in four different contexts: 1) Real-time processing at NWP centres with an interest to assimilate ADM-Aeolus winds within their own forecasting systems; 2) Operational processing at the ECMWF to produce wind retrievals for delivery to ESA shortly after real time; 3) Re-processing at ESA for situations in which delays in data delivery prevent processing within the ECMWF operational schedule, and to accommodate future algorithm improvements and upgrades; and 4) as a standalone processor in a typical research environment.

The L2B processor provides a flexible framework for classification and weighting of measurement-scale (1-10 km) data into aggregated, observation-scale (50 km) wind profiles for assimilation. The main remaining scientific challenge is to produce representative winds in inhomogeneous atmospheric conditions, such as strong wind shear, broken clouds, and aerosol layers. The Aeolus instrument provides separate measurements in Rayleigh and Mie channels, representing molecular (clear air) and particulate (aerosol and clouds) backscatter, respectively. The combining of information in the two channels offers possibilities to detect and flag difficult, inhomogeneous conditions.

The functionality of a baseline version of the L2B processor has been demonstrated in terms of classification and wind retrieval (Tan *et al.* 2008). The corresponding computed error estimates of the retrieved winds have been validated. The next step is to apply the algorithms to real data obtained from an airborne Aeolus instrument demonstrator (Durand *et al*. 2006). Further refinement of the processor will continue even after launch of the satellite, in particular as based on results from the commissioning phase immediately after launch.

The L2B software is portable to a range of computers. It will be made freely available to the meteorological research community. Operational Aeolus products will be available from ESA/ESRIN.

The research into data assimilation stimulated by preparations for Aeolus data is expected to continue throughout the mission lifetime and beyond. Improved specification of background error covariances remains a key issue (Žagar 2004, Riishojgaard *et al*. 2004, Stoffelen *et al*. 2005b, Žagar *et al*. 2005), particularly in Tropics.

It is easy to envisage other applications of Aeolus data, in particular to improve interpretation and use of other satellite data. This could include, but is not limited to, more accurate height assignment of atmospheric motion vectors (e.g. Velden *et al.* 2005) and better detection of cloud-affected radiances (English *et al.* 1999). Aeolus cloud and aerosol information (the so-called Level-2A products) is expected to contribute to long-term databases complementing data from the Calipso and EarthCARE missions (Winker *et al.* 2003, ESA 2004). Other expectations from Aeolus extend beyond the mission lifetime to potential operational missions. The participation of others is encouraged in order to realize the full potential of the mission.

Acknowledgements

The author acknowledges fruitful interactions with colleagues from ECMWF, ESA's Aeolus project teams, and researchers associated with the Aeolus Mission Advisory Group.

List of acronyms and terms

(A)CCD	(Accumulation) charge coupled device
ADM-Aeolus	Atmospheric Dynamics Mission (subsequently named "Aeolus")
Aeolus	Atmospheric Explorer for Observations with Lidar in the Ultraviolet from Space
BRC	Basic repeat cycle
DWL	Doppler wind lidar
E2S	Aeolus End-to-End Simulator
EGM96	Earth geoid model, available from http://cddisa.gsfc.nasa.gov
ECMWF	European Centre for Medium-Range Weather Forecasts
ESA	European Space Agency
ESRIN	ESA Centre for Earth Observation
(H)LOS	(Horizontal) line of sight
ILIAD	Impact of LIne shape on Aeolus Doppler estimates
L1A/B	Level-1A/B
L2A/B/C	Level-2A/B/C
NWP	Numerical weather prediction
PRF	Pulse repetition frequency
WGS84	World Geodetic System 1984, available from http://earth-info.nga.mil/GandG/wgs84/
WMO	World Meteorological Organization

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