Cover Note

Subject	**ADM-Aeolus QRT and NRT Wind Profiles**
Action proposed	Decision/Consideration/Information/Recommendation
Abstract	ESA's Atmospheric Dynamics Mission (ADM), called Aeolus, is to launch the first space-borne Doppler Wind Lidar in 2011 and operate it for three years. The observed wind component profiles of radiosonde quality as to be measured by ADM-Aeolus are important to initialize Numerical Weather Prediction (NWP) models on the smaller scales and in the tropics and are particularly lacking over the ocean and in the southern hemisphere. So, for regional forecasting in Europe, the Arctic, North Atlantic, Mediteranean Sea, Africa and some eastern countries lack a dense wind profile observation network. Therefore, ESA makes an effort to organize a Quasi Real-Time (QRT) delivery of a portion of the Aeolus L1B measurement profiles (L1B) within 30 minutes. For southern hemisphere, tropical and descending Aeolus orbits Near Real-Time (NRT) delivery will be achieved. However, QRT delivery of Aeolus wind profiles (L2B) is not yet foreseen by ESA. This paper outlines the needs for a central QRT and NRT delivery, in particular for regional NWP forecasting. EUMETSAT is requested to support such service for ADM-Aeolus in preparation of future operational DWL missions. This paper has been provided by Dr. A. Stoffelen, KNMI.
Views of other EUMETSAT bodies	-/-
Decision proposed	STG SWG is invited to take note.
Majority required in Council	-/-
Cost implications	-/-
Reference documents	-/-
Annexes / Draft Resolution	-/-

ADM-Aeolus Quasi Real-Time and Near Real-Time Wind Profiles

Ad.Stoffelen@knmi.nl
Member of the ADM-Aeolus Mission Advisory Group
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SUMMARY

ESA's Atmospheric Dynamics Mission (ADM), called Aeolus, is to launch the first space-borne Doppler Wind Lidar in 2011 and operate it for three years. The observed wind component profiles of radiosonde quality as to be measured by ADM-Aeolus are important to initialize Numerical Weather Prediction (NWP) models on the smaller scales and in the tropics and are particularly lacking over the ocean and in the southern hemisphere. So, for regional forecasting in Europe, the Arctic, North Atlantic, Mediteranean Sea, Africa and some eastern countries lack a dense wind profile observation network. Therefore, ESA makes an effort to organize a Quasi Real-Time (QRT) delivery of a portion of the Aeolus L1B measurement profiles (L1B) within 30 minutes. For southern hemisphere, tropical and descending Aeolus orbits Near Real-Time (NRT) delivery will be achieved. However, QRT delivery of Aeolus wind profiles (L2B) is not yet foreseen by ESA. This paper outlines the needs for a central QRT and NRT delivery, in particular for regional NWP forecasting. EUMETSAT is requested to support such service for ADM-Aeolus in preparation of future operational DWL missions.

INTRODUCTION

ESA is currently implementing the Doppler Wind Lidar (DWL) mission 'ADM-Aeolus' in its Living Planet Programme. The mission is a demonstrator for future operational missions providing vertical profiles of the tropospheric and lower stratospheric wind field for the improvement of numerical weather prediction (NWP) and atmospheric research; see [1] for more details. The quality of the ADM-Aeolus wind component profiles is benchmarked on the quality of radiosonde winds. ADM-Aeolus data is expected to improve atmospheric analyses in the Southern Hemisphere, in the tropics, over the oceans, in Polar regions, and in other areas where conventional wind profiles and aircraft wind profiles (ascends/descends) are sparse. ADM-Aeolus would make the distribution of wind profile observations more uniform. In turn the improved analyses are expected to lead to improved NWP forecasts [2]. Simulation studies reveal that ADM-Aeolus may have an impact on forecast quality comparable to that of radiosondes. Moreover, studies in THORPEX (THe Observing system Research and Predictability EXperiment) with a very limited amount of aircraft DWL observations in the North Atlantic showed a substantial forecast impact in Europe [3]. Based on these experiences, most benefit from ADM-Aeolus for regional forecasting over Europe would be achieved when Aeolus wind profiles would be made available in quasi real time (QRT), such that most ADM-Aeolus wind profiles may be timely to be incorporated in the NWP data assimilation cycles with short time cut-off times down to 30 minutes.

In this document ADM-Aeolus is first described including its ground segment and data latency. Subsequently, the complexity of wind profile derivation is discussed and a Quasi Real-Time (QRT) and Near Real-Time (NRT) central processing is motivated.

DESCRIPTION OF AEOLUS

ADM-Aeolus exploits a 'Doppler wind lidar' (DWL), which in turn utilises light scattering and the Doppler effect to acquire much-needed wind profile observations. A lidar is similar to the more familiar radar, but transmits and receives light instead of radio waves. A lidar works by emitting a short, but powerful, light pulse from a laser through the atmosphere. As the light pulse travels through the air it interacts with air molecules, particles of dust or ice and water droplets. This causes a small amount of the light to be scattered in all directions. Some of this light is scattered back towards the lidar. The lidar's telescope collects the backscattered light, and directs it towards a receiver system. The time between sending the light pulse and receiving a signal determines the distance to the 'scatterers' (air molecules, cloud droplets, etc.), and thus their altitude above the surface of the Earth. The DWL measures the change of wavelength to determine the velocity of the scattering particles in the direction of the light pulse by exploiting the Doppler effect and precise information on the movement of the satellite platform. Aeolus will orbit the Earth at an altitude of about 400 km. Measurements will be taken orthogonal to the flight direction at an angle of 35° off-nadir. For every 700 laser-pulses, over which time the satellite moves forward 50 km, one wind component profile will be obtained. For more details on ADM-Aeolus, see [1].

Based on breakthrough technology, the Aeolus DWL instrument, called ALADIN, consists of a powerful laser system to emit short laser pulses down to the atmosphere, a large telescope to collect the backscattered light signal, and a very sensitive receiver to analyse the Doppler shift of the signal from layers at different heights in the atmosphere. The laser system generates a series of short light pulses in the ultraviolet spectral region at 355 nm. The ultraviolet region was chosen because the backscatter from air molecules at this short wavelength is particularly strong, and also because this wavelength can be generated with solid-state lasers, which are amongst the most advanced available. ALADIN is dominated by a large telescope, which measures 1.5 meter in diameter. The telescope is used to collect the backscattered light from the atmosphere and then directs it to the receiver. The receiver analyses the Doppler shift of the backscattered signal with respect to the frequency of the transmitted laser pulse. Two optical analysers are used to measure, respectively, the Doppler shift of the (Rayleigh) scattering off molecules and (Mie) scattering from aerosol and cloud particles. Highly sensitive photo-detectors then transform the light signals into electronic signals, which are amplified and stored on board until they are transmitted to the ground for processing.

The measurement profiles, each corresponding to about 3.5 km sampling length, 50 laser pulses, or 0.5 seconds, are processed over a distance of 50 km to obtain the wind profile observations. The wind observations are spaced 200 km apart complying with NWP requirements.

AEOLUS GROUND SEGMENT

The measurement data will be transmitted to a ground station once per orbit, i.e., every 90 minutes. A reduction of data latency is an important issue for operational NWP applications. All near real-time users of the ADM-Aeolus Level 1b data will receive the data in BUFR format well within 3 hours after sensing, called NRT. However, the spacecraft and ground segment will allow for a data delivery time of 30 minutes after sensing over segments of most Northern Hemisphere orbits by exploiting a US and European X band ground station and corresponding on-ground data link capabilities, called QRT here; see figure 2. This makes it possible in principle to use ADM-Aeolus wind profile observations for short-range NWP forecasting. However, although L1B measurement data is timely, ESA does not plan timely delivery of L2B wind profiles.

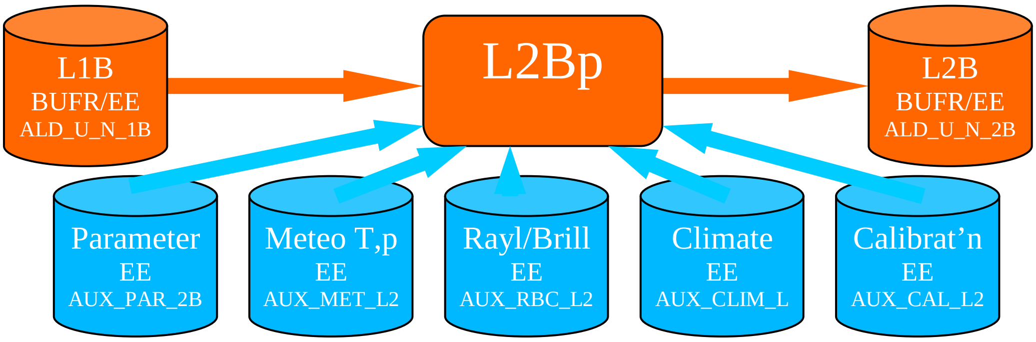

Figure 1: Schematic view of the Aeolus wind profile processor (L2Bp). The top row depicts the variable measurement information (orange) and the bottom row the static or variable auxiliary information needed to process Aeolus wind profiles. Of each 3 rows in the data boxes the top row indicates the name, the second row the format and the bottom row the file type identifier (which will be part of the file name).

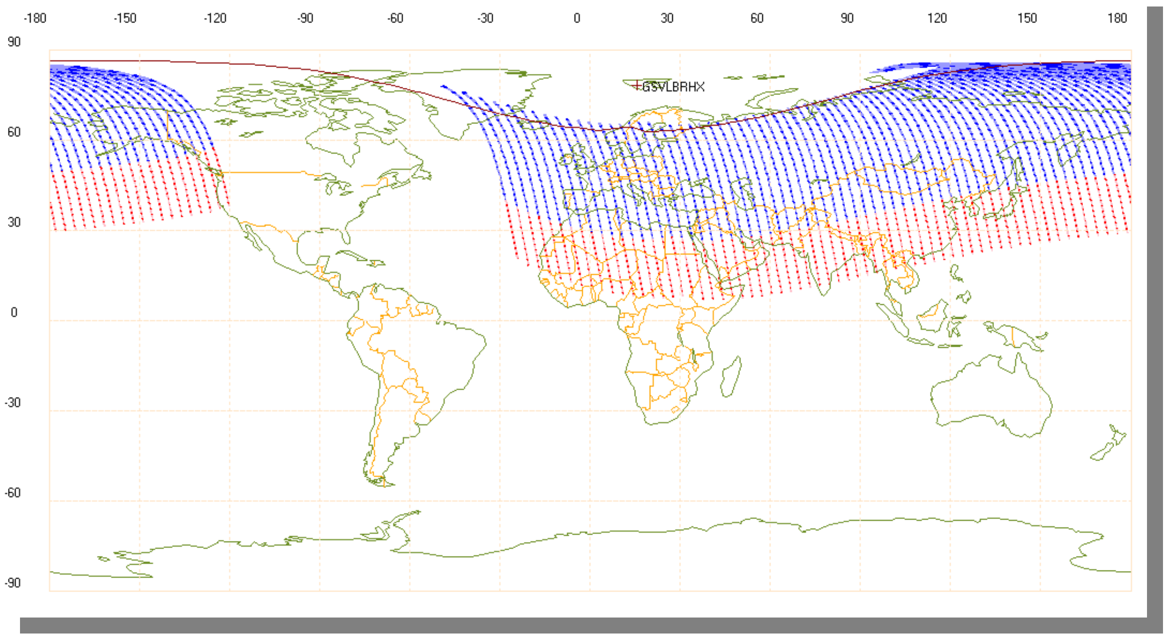

Figure 2: ADM-Aeolus Quasi Real-Time (QRT) user delivery of measurement data within 30 minutes of measurement from Svalbard. A central US QRT station is under consideration. ESA courtesy.

AEOLUS WIND PROFILES

ESA supports the complete Aeolus wind profiles (L2B product) to be made available off-line by ECMWF, through processing in their cycled Integrated Forecasting System (IFS). The inputs and outputs of the L2B processor (L2Bp) are schematically shown in figure 1. These inputs are briefly discussed below. The portable L2Bp is freely available from ESA or ECMWF [5].

Aeolus measurement data

The Aeolus measurement data is stored in the L1B product. This product contains all variable measurement information necessary to process the Aeolus wind profiles in either the BUFR or ESA's Earth Explorer (EE) formats. Besides atmospheric data, the product also contains ground calibration information that is used as a zero wind reference (from bright land targets). Exploitation of this zero wind calibration is still under development. The zero wind calibration is expectedly a function of the known orbit phase and rather stable (over several days). In the absence of an instrumental zero wind calibration, NWP-assisted calibration may be well possible or (absolute) wind shear may be assimilated.

Auxiliary Parameter file

These are static input parameters in EE format. They allow for switching on alternative algorithms and for changing numerical algorithm and threshold settings for testing purposes. In an operational setting they should not be touched.

Auxiliary Meteorological data

Aerosol and cloud particles move generally with the air flow and the Doppler shifted frequency will be directly estimated from the imaged atmospheric spectral return. On the other hand, the Brownian motion of air molecules is generally larger than the wind speed and a double edge band pass filter technique is used to determine the Doppler shift of the broad Rayleigh-Brillouin motion spectrum. Prior knowledge on the width of this motion spectrum is required which will be based on prior NWP temperature and pressure information [4].L2B Aeolus wind profiles are thus computed using a reference temperature and pressure profile, typically a short-range NWP profile. The first order derivative of the inverted Rayleigh Line-Of-Sight (LOS) wind with respect to the temperature T for a horizontal LOS wind component of 40 m/s is in the order of 0.1 ms^{-1} per K (or 0.25% of the true wind). The wind component derivative with respect to pressure is for the same speed typically 0.003 $ms^{-1}(hPa)^{-1}$. Typical NWP temperature and pressure errors thus have a very small impact indeed on the derived winds. Anyway, the first order derivatives of the LOS with respect to temperature and pressure will be provided in the L2B product, such that corrections from the L2Bp reference values may be implemented through the data assimilation system observation operator when deemed appropriate. The corresponding AUX_MET files are in EE format.

Rayleigh Brillouin Calibration table

A Rayleigh Brillouin Calibration (RBC) look-up table is generated after an instrument calibration loop. Such loops are expected to be rather infrequent, since the instrument has been designed for optical stability. In case of optical degradation of the ALADIN system, the calibration loop may be employed more regularly, e.g., monthly.

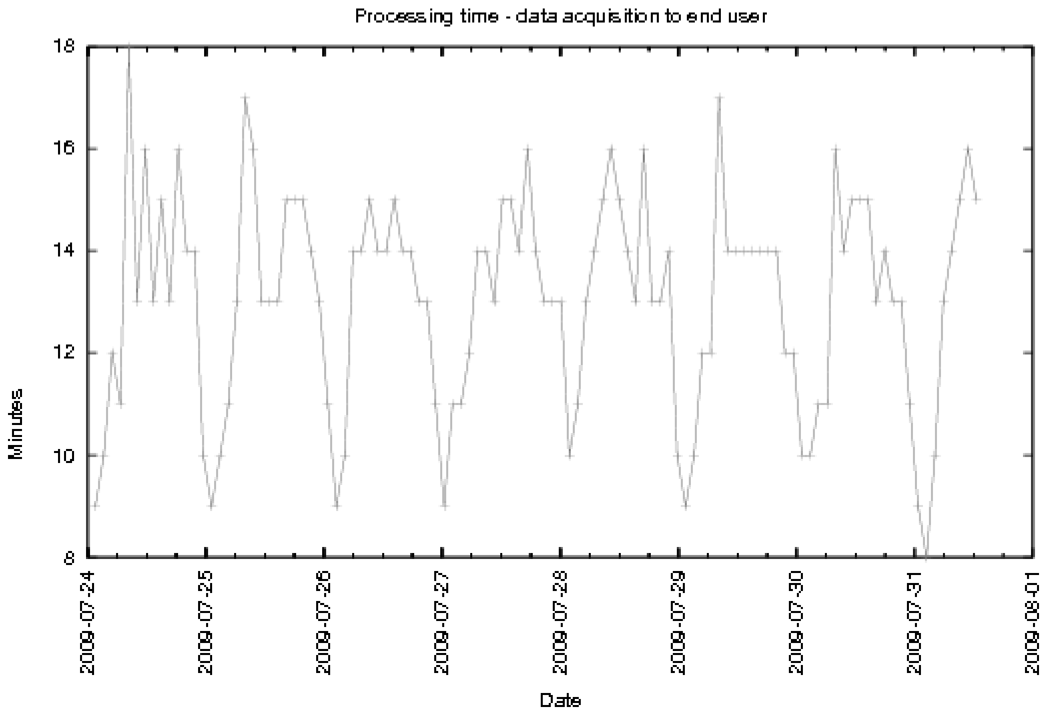

Figure 3: Timeliness of the EARS ASCAT products for the last week of July 2009 as monitored at KNMI [6].

Climate reference

To achieve an optical calibration of the L2Bp, auxiliary optical climate data is needed. It is provided in EE format and may be used to estimate the aerosol and cloud backscatter-to-extinction ratio in the stratosphere. Not considered to be critical for the L2Bp.

Auxiliary Calibration file

To achieve an absolute optical calibration of the L2Bp, auxiliary optical instrument data is needed. Expected to be very stable. Optical calibration processing increases the control on the instrument's performance monitoring.

WIND PROFILE PRODUCTION

The production of all Auxiliary files and the L1B products has been planned by ESA. However, a global NRT or regional QRT product is not yet in place. On the other hand, a portable L2B processor is being developed [5]. This processor may be installed in a central place for global NRT and regional QRT processing. Since the L2B output files are relatively small and the L2Bp processing time relatively fast, a central processing appears attractive. Even though the L2Bp is portable, its stable installation for NRT/QRT operational implementation is rather complex due to the variable auxiliary data needed in the processing.

Each input file to the L2Bp needs to be controlled, which is to some extent done by the L2Bp software, i.e., input screening. Moreover, monitoring of the wind profiles and optical signals against NWP reference data (AUX_MET) will be implemented, based on L1B and L2B outputs. When the monitoring is combined with a central processing an automatic warning flag may be included in the L2B product, on which basis automatic use of the product may be interrupted until further notice (anomaly correction by an expert). Besides the L1B input control and monitoring, control on the auxiliary files will be necessary as well.

The auxiliary meteorological data needs to be produced in each L2Bp centre. The AUX_MET file is variable and will be screened in the L2Bp. However, some of the Aeolus auxiliary calibration data may change as much as weekly (in the worst case) and, ideally, new files in an operational environment need to be tested before implementation. Automatic tests may be best conducted on a parallel experimental Aeolus data stream, started in case a new auxiliary file arrives. If L2B product differences are negligible between the operational and experimental suites, e,g., over a day, then the experimental suite may be (automatically) promoted to operational status. If the L2B product differences are not negligible, then expert judgment will be necessary to diagnose the anomaly and accept and announce a motivated change in case of product improvement. The introduction of frequent operational configuration changes will require a flexible operational environment. Therefore, NRT or QRT processing should ideally be done at or in association with an Aeolus expert centre. The resources necessary for running and integrating the L2Bp in an operational NWP data assimilation environment are substantial. On the other hand, accomodating L2B wind profile data at a NWP centre, centrally processed in QRT/NRT, appears less complex and thus less resource consuming. For this reason, the HiRLAM consortium has put up a requirement for central NRT/QRT processing.

CENTRAL GLOBAL L2B PRODUCTION IN QRT/NRT

Several centres are involved in Aeolus L2Bp development and some would be capable of combining expert knowledge on the L2Bp with flexible routine facilities for QRT/NRT processing. A precedent for QRT and NRT L2 wind processing and monitoring for an ESA research satellite instrument (ERS scatterometer) on behalf of the EUMETSAT user community can be found at [6], similar to what is needed for Aeolus. Another QRT example is in the EUMETSAT Early Advanced Retransmission Service, EARS, , see, e.g., figure 3 for ASCAT. Based on KNMI experience on the processing of scatterometer data in the EUMETSAT OSI SAF and EARS projects, some resource estimates for (central) processing are given below. We presume that Aeolus L2Bp expert knowledge will be provided by ESA and that the central processing facility has daily access to this expertise. Moreover, we assume that ESA will continue to support the development, maintenance and control of the L2Bp over the Aeolus life time. The support for the central L2B QRT/NRT processing would then be limited to the L2Bp implementation and to the implementation of monitoring and control procedures for all variable inputs as described above. The implementation would be global, since data volume is not a limiting factor, but rather the configuration management which is easier to control for global data. Under the above assumptions and assuming a worst case scenario where configuration changes leading to L2B product improvement and change on a weekly basis would occur, the effort for central processing should still be limited, i.e., to about one salary over the Aeolus life time of three years. Of course, this is just a rough estimate as in case of granted support further evaluation of suitable centres and more detailed proposals will be necessary.

CONCLUSION

ESA’s ADM-Aeolus mission is to launch the first space-borne Doppler Wind Lidar in 2011. The observed wind component profiles of radiosonde quality as measured by ADM-Aeolus are important to initialize NWP models on the smaller scales and in the tropics and are particularly lacking over the ocean and in the southern hemisphere. In line with this, for regional forecasting in Europe, the Arctic, North Atlantic, Mediteranean Sea, Africa and some eastern countries lack a dense wind profile observation network. Therefore, ESA makes an effort to organize a QRT delivery of a portion of the Aeolus L1B measurement profiles within 30 minutes. For southern hemisphere, tropical and descending Aeolus orbits a complementary NRT delivery will be achieved. However, QRT and NRT delivery of Aeolus L2B wind profiles is not yet foreseen by ESA. The ADM-Aeolus Mission Advisory Group at its 17th meeting recommended that its members be encouraged to explore alternatives for making L2B wind profiles available to the users in NRT, potentially using existing infrastructure at e.g. KNMI, EUMETSAT and/or ECMWF [7]. Following such recommendation, this paper stresses the needs for a central QRT delivery for regional NWP forecasting and for a global NRT service of Aeolus L2B wind profiles and suggests EUMETSAT to support this modest effort for ADM-Aeolus in preparation of future operational DWL missions.

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