Science Plan

Improved Wind Profile Assimilation Procedures for ADM-Aeolus

ADM-Aeolus L2B processor

This documentation was developed within the context of the ESA ADM-Aeolus L2BC processor development project, between ESA and ECMWF, and by one or more partners. The partners in the ADM-Aeolus L2BC processor development project are ECMWF, KNMI and Météo France.

Change record

Version	Date	Author / changed by Remarks
0.1	12-Sep-2007	Ad Stoffelen Baseline version
0.2	14-Sep-2007	J. de Kloe, some small textual changes
0.3	20-May-2008	J. de Kloe, adapted to ESA comments dd. 21-Apr-2008

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1. Rationale and outline description

1.1 Objective

The ADM-Aeolus L2B processor, L2Bp, provides wind profiles over the globe taking account of both heterogeneous optical and wind characteristics [1]. However, combined optical and wind heterogeneities are not yet measured routinely in the atmosphere and representative observation sources are sparse. In the scientific development of the ADM-Aeolus L2B processor, sources of such data will be acquired by combination or simulation with the aim to provide a globally representative ~~view~~dataset suitable for testing the expected performance of the forthcoming ADM-Aeolus Doppler Wind Lidar, DWL, mission. The ADM-Aeolus simulation scenarios are stored in the KNMI Aeolus atmospheric data base [2].

Simulation scenarios of increasing complexity will be selected in order to study potential improvements of the ADM-Aeolus L2Bp. A small set of reference scenarios will be kept in order to guarantee a continuous performance increase.

1.2 Situation at the start of development

DWL winds promise to be very useful for the forecasting of dynamic weather [3]. Increased coverage, such as from tandem Aeolus measurements, would clearly further improve the situation [3,4]. Attempts to assimilate simulated DWL data were carried out with general success, and expectations of the gain and benefit of the Aeolus mission are high [5]. Recently ECMWF carried out a first observing system experiment with a limited amount of airborne DWL winds, but showing a clear beneficial impact [6], corroborating the simulation studies.

The Aeolus L2Bp exploits both the wide band molecular return readings from a Fabry-Perot interferometer, FP, and the ~~small~~narrow band particulate atmospheric return measurements from a Fizeau type interferometer, Fz [7]. The radiometric and spectral characteristics of these two measurement devices and the laser system and optical path will be characterised by ESA. The ADM-Aeolus wind performance will critically depend on the stability and in-flight control of these optical properties.

The backscattered and thermally substantially broadened laser light spectrum by molecules and the cloud and aerosol backscattered laser light at basically unchanged spectral width (compared to the laser bandwidth) both reach and affect the FP and Fz receiver channels. Prior NWP information on the atmospheric temperature and pressure is currently exploited to account for the thermal broadening and separate the molecular and particulate returns in the FP receiver. The sensitivity to the prior information and the priors are stored in the L2Bp output, such that further corrections may be applied at the data assimilation stage, although these sensitivities are verified to be very low. The broadening function is based on a Tenti model [1].

The retrieved optical properties are used in the L2Bp to classify the atmosphere [1] and to retrieve both Fz and FP wind profiles for different atmospheric classes, e.g., cloud / no cloud. These wind classes will be validated in order to determine their representation of the local mean atmospheric flow. This will determine the weight for data assimilation in Numerical Weather Prediction, NWP, analyses.

The FP and Fz measurement channels both accommodate 24 vertical measurement levels, but which may be commanded differently, depending on channel and geographical location. In the Aeolus ground segment development it is assumed that an integer number of Fz range gates fits into one FP vertical range. Some measurement levels may furthermore be used for ground surface wind calibration, such that the total atmospheric measurement ranges of both channels may differ. The L2B processor development takes ~~account of~~ this flexibility in the vertical sampling into account.

1.3 Deficiencies of the initial situation

The following problem areas exist and continue to need further investigation

- The control and stability of the instrument optical characteristics is not yet verified;
- The Tenti model for thermal and pressure broadening of the molecular backscatter spectrum needs to be validated;
- Only academic Aeolus simulation scenarios have been studied; More complex optically and dynamically heterogeneous atmospheric Aeolus sampling scenarios need to be investigated, representative of the Aeolus global sampling. In particular, due to the limited vertical sampling, signal height assignment needs careful attention;
- As more scenarios are studied, the atmospheric classification should become more sophisticated and/or better tested, by considering both optical and dynamical properties of the sampled atmosphere. Residual parameters from both the L1Bp and the L2Bp need to be further exploited in this context;
- The sole purpose of the L2Bp atmospheric classification is to distinguish wind performance classes. Analysis methods to statistically evaluate this wind performance in the different classes need to be elaborated. This will profit both the classification algorithm and the application of the L2Bp winds in NWP data assimilation;
- Guidance and/or procedures, observation operator, on the assimilation of the observed classes at the Aeolus sampled locations, i.e., Basic Repeat Cycles, BRCs.

1.4 Description of the deliverable

Concerning the problem areas noted in the previous section, the following respective developments are foreseen

- On the one hand ground and airborne campaigns will provide improved characteristics [8] but on the other hand in-orbit monitoring and control based on prior NWP information is ~~being considered~~scheduled and will contribute to this improvement;
- Ground and airborne campaigns will provide a first validation of the Tenti model [8], but again NWP-prior validation procedures are envisaged;
- More complex optically and dynamically heterogeneous atmospheric Aeolus sampling scenarios are being investigated, representative of the Aeolus global sampling. Signal height assignment will be further elaborated;
- More scenarios will be studied to obtain improved and/or better tested atmospheric classification. To achieve this, optical and dynamical properties of the sampled atmosphere will be taken into account. Residual parameters from both the L1Bp [9] and the L2Bp are being further exploited in this context;
- Analysis methods to statistically evaluate wind performance in the different classes are being elaborated. This will profit both the classification algorithm and the application of the L2Bp winds in NWP data assimilation;
- Guidance and/or procedures for implementation of an observation operator (needed to allow the assimilation of the observed classes at the Aeolus sampled BRC's) will be provided.

1.5 Means of distribution

A complete L2Bp package for Aeolus data decoding, consistency checks, classification, wind profile determination is being developed. The project will provide user support for the maintenance and implementation of this software and for using the output data during the Aeolus life time.

2. Scientific approach, capabilities, and limitations

In order to achieve a representative Aeolus test environment for the L2Bp, close collaboration with the L1Bp scientific developments [9] and campaign study [8] is implemented. Procedures for analysis, calibration and validation are shared, as well as instrument and atmospheric data bases.

The atmospheric data base is being extended with high resolution radiosonde data. Winds, but also temperature and humidity, are used to simulate the vertical optical and wind heterogeneity. The former can be realised by using humidity as a proxy for cloud and aerosol [10]. Global optical heterogeneities may be obtained by exploiting measurements and algorithms of space-borne lidar missions, such as CAL~~Y~~IPSO [11]. Although such measurements are only sporadically collocated with high-resolution wind profiles, a first global statistical impression of the combined effect of optical and wind heterogeneities may be obtained from collocated NWP winds, e.g., ECMWF.

More sporadic, but high-resolution, scenarios are envisaged by using wind radar [12], or so-called super (measurement) sites [13], where combined systems including for example cloud radar are available to characterise wind, aerosol and cloud systems. Obviously, the Aeolus campaign results are of prominent importance and will be used to develop the L2Bp [8].

Realistic~~Aeolus~~ atmospheric scenes for optimization of the Aeolus sampling may also be simulated by using Cloud Resolving Models~~,~~ (CRMs). It is envisaged that this will be elaborated [14].

The Aeolus L2Ap [9] includes an optical atmospheric code to characterise aerosol and cloud particles. Developments herein will be exploited in the L2Bp for atmospheric classification and improved signal height assignment.

Empirical assessment of the thermal broadening by using prior NWP information is well achievable. Uncertainties and systematic effects in such procedure will be further investigated. Empirical methods to monitor the stability and performance of the L2Bp products against prior and analysis NWP data will be investigated. Such procedures are well established for most satellite and non-satellite observing systems at NWP centres. The output of such procedures provides further guidance for the characterisation of the observation operator used in NWP data assimilation.

3. Technical description of the deliverable

ESA will provide near real-time Aeolus backscatter measurements and ancillary information through L1B BUFR messages. A stand-alone and subroutine version of the L2Bp will be made available. Moreover, the Aeolus observations will be monitored at ECMWF.

Guidance and support on the L2Bp and proposed observation operator will be provided. As such the L2Bp processing package contains the modules that define the general DWL observation. The processor provides a unique observed wind field that can be assimilated.

The software package will be obtainable from ECMWF, who will support and maintain it. The package will be able to timely process the Aeolus measurements, and will be optimised for processing time when needed. Since the package use look-up tables to define the combined atmospheric and instrument responses, the processing time is limited. The RAM needed to store these look-up tables is moreover limited to a few 10ths of MB and not demanding (currently around 35 MB).

4. Development strategy

4.1 Development phases.

The following planning is used for the development of the L2Bp-related deliverables

- Specification of user requirements for data interfaces and format of L2Bp product (2006);
- Basic L2Bp software with set interfaces and basic routines (2007);
- Version of L2Bp software suitable for inclusion into an IFS like system (2008);
- Enhanced L2Bp software with more sophisticated routines (2009);
- After launch further tuning of the L2Bp is envisaged.

4.2 Validation plans

A common software coding practice has been defined within the NWP SAF leading to accessible code that eases software maintenance and support. This practise has been adopted and both general and specific performances of new code will be tested over a realistic set of geophysical data.

Developed modules are expected to be operationally implemented at several sites, and a coordinated monitoring effort will be organised at ECMWF. This will act to validate the basic satellite data, but also the satellite data processing modules. If useful reference wind products are available, such as from radiosondes, regular comparison will be performed.

For Aeolus, monitoring and control procedures will become available in 2009.

5. References

[1] ATBD

[2] KNMI database

[3] PIEW

[4] Nedjeljka

[5] Aeolus workshop

[6] Martin et al

[7] Aeolus measurement principle

[8] Campaign project

[9] L1Bp & L2A project

[10] Merci

[11] ~~Calipso~~CALIPSO

[12] Aberstywdth

[13] Cabauw

[14] SoW Vert Sampling