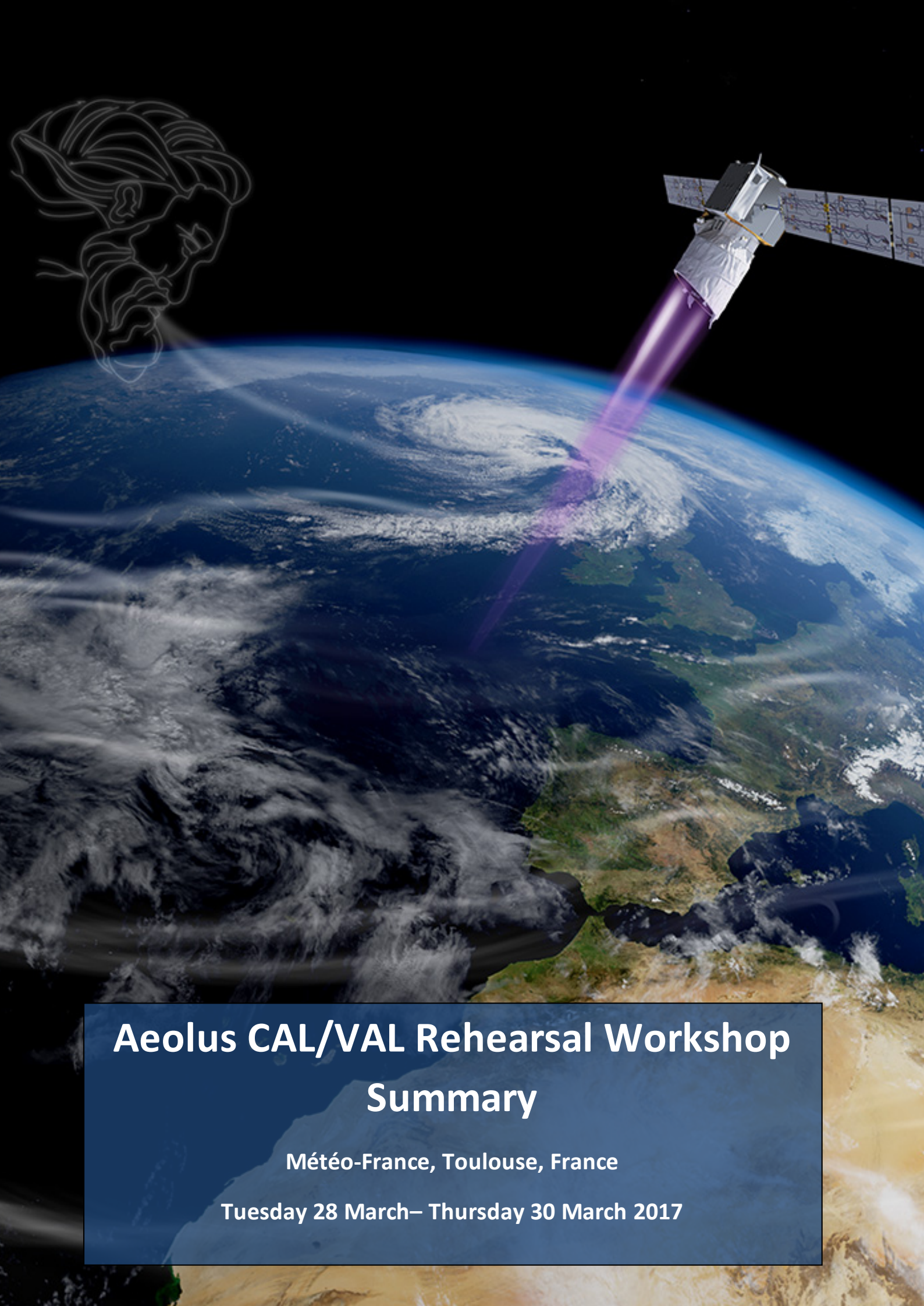

Aeolus CAL/VAL Rehearsal Workshop Summary

Météo-France, Toulouse, France

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Workshop Summary by E. Källén

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A third Aeolus CAL/VAL workshop was organised in Toulouse at the end of March 2017, anticipating a launch of the Aeolus satellite in late 2017 or early 2018. The two previous CAL/VAL workshops in 2006 and 2015 were followed up and an up-to-date plan of CAL/VAL activities was discussed.

The Aeolus mission is now getting very close to launch, the satellite is undergoing final testing and the plan is to ship Aeolus to the launching site in Kourou, French Guyana in the autumn of 2017. Reflecting on the development of the mission since it was first approved at an Earth Explorer selection meeting in Granada in 1999, it is very satisfying that we now have a launch date in sight. The instrument development, in particular the laser part, has been very challenging and we are grateful for the continued support provided by ESA Member States. The goal of the mission, to improve observations of atmospheric winds, remains a high priority for weather prediction as well as for climate monitoring. This has been emphasised several times in WMO led assessments of observational needs for weather and climate predictions.

The CAL/VAL activities are a key to the success of the Aeolus mission as well as the preparations underway to use the wind data for assimilation in global weather prediction models in Europe. ECMWF is taking a lead to produce level 2 wind data in near real time, the Met Office, DWD and Météo-France are getting prepared to assimilate the data in global models. Limited area modelling consortia such as HIRLAM, Aladin and COSMO are also underway with preparations but it appears that it may take some time until they are ready to test Aeolus wind data. It has been shown that single component Doppler wind data from radars gives a substantial forecast quality improvement for the Arome model at Meteo-France. This points to the potential of Aeolus data also for limited area weather prediction models.

The instrument oriented CAL/VAL proposals presented at the workshop cover a wide range of geographical areas as well as many different instrument platforms. Geographically there is an emphasis on Northern hemisphere regions including Europe, North Atlantic, North America, China, Iran and Japan. Tropical areas will be covered by some stations belonging to European institutes as well as a tropical balloon campaign. The instruments are surface based wind measurements as well as airborne campaigns utilising a range of sensors including the airborne Aeolus demonstrator flown on DLR aircraft. Many of the proposals are awaiting nationally funded projects to be confirmed. The CAL/VAL groups will be supported by an infrastructure supplied by ESA and EVDC in Norway. The infrastructure

includes orbit prediction tools, visualisation software and weather forecasts from ECMWF for campaign planning.

Aeolus wind data impact studies at ECMWF have clearly demonstrated the substantial positive impact that can be expected, in particular for tropical areas. In addition to the direct impact of the wind data on tropical analysis quality it has also been shown that the assimilation scheme can make much better use of temperature and humidity data from other satellites when Aeolus winds are included. Some cases of very poor forecast performance over Europe can be traced back to deficiencies in tropical analyses with a time lag of 5-6 days. It is therefore expected that Aeolus winds will reduce the number forecast failures over Europe in the medium range (3-10 days). It is also expected that Aeolus winds will improve the quality of tropical reanalyses and thus contribute to improved climate monitoring. The aerosol information from Aeolus will help to improve weather prediction and climate reanalyses.

The Aeolus mission has a limited lifetime, expected to be 3-5 years. A follow on mission has been discussed in several contexts but it is of course necessary to demonstrate the capability of the Aeolus satellite before any commitments can be made for a follow on mission. In the most recent ten year strategy document from EUMETSAT a follow on mission for Aeolus is included as a possibility and the US the Doppler wind lidar community has submitted a proposal for a spaceborne Doppler Lidar instrument. In any case it will take time for a new instrument to be developed and there is very likely to be a time gap between Aeolus and any follow on mission.

The instrument testing and in-flight commissioning of Aeolus will take place within the first few months after launch. The CAL/VAL teams will be essential for the continued validation and calibration of the Aeolus satellite. The planned activities range from NWP centres to surface based observation sites and flight campaigns. A balloon campaign focussed on the tropics is an exciting and very interesting proposal giving much needed in situ wind data in the tropics. The flight campaigns will be focussing on the North Atlantic area and the tropics, and DLR will play an important role deploying the Aeolus demonstrator payload. The continued involvement of the DLR team in flight campaigns and testing of the airborne Aeolus demonstrator has been essential for maintaining confidence and momentum in the space mission project, lessons learnt from the demonstrator will guide the exploitation of Aeolus satellite data and be very helpful in supporting the CAL/VAL teams with the experience gained using the airborne demonstrator.

As we are now entering into the final stages of the Aeolus mission preparation we must acknowledge all the work that has been undertaken during a long period of time by research groups and industrial partners in close collaboration with ESA. The dedication of all the people involved as well as the support of the Aeolus mission from ESA Member States is a prominent example of the strength of European collaboration. We now have to

demonstrate that the Aeolus mission can successfully fulfil its mission objectives and reap the benefits of improved global wind profile observations from space.

Individual session summaries:

Session I: Opening Session

Charis: A. Stoffelen and A.G. Straume

The opening session provided a broad overview of the Aeolus mission components and exploitation.

H. Laure from ESA emphasized the pre-operational nature of many of the ESA Earth Explorers (SMOS use e.g. at ECMWF, Cryosat ice monitoring), but ADM-Aeolus will be a particular example with a relatively short expected life-time and the ambition to demonstrate NWP impact. With this ambition and the fact that new challenging technology will be launched, a swift and effective data quality assurance is key to Aeolus. CAL/VAL groups play an important role, for example through the quality working group. Lessons learnt: be ready for surprises, cal/val is key, exploit synergies.

M. Pontaud from MeteoFrance emphasized the large expected impact of ADM-Aeolus data given the lack of wind observations in the current Global Observing System (GOS). Wind information on smaller scales was emphasized. The importance of dynamics for air quality forecasting was underlined. Investments in radar wind assimilation show the potential for Aeolus wind impact, in particular in polar areas.

P. Tabary from CNES emphasized the French participation in CALIPSO and the importance of good international partnerships and cooperations both in realizing satellite programmes and for CAL/VAL through campaigns. CNES support to various satellite programmes and to ADM-Aeolus CAL/VAL in particular was shown. This includes balloon, aircraft and ground based wind observations.

E. Källén emphasized the importance of the GOS for initializing weather models and in support of reanalysis. Predictability of the ECMWF model has steadily increased with time, but is also weather dependent. Aeolus will not only see impact in the global trend statistics, but also extreme weather event forecasting will improve reducing the number of forecast busts. Another important issue is that the combination of Aeolus data with other observations in data-spares regions can help draw the model closer to observations. A research experiment looking at GPS Radio Occultation (GPSRO) and Aeolus was shown. Aeolus could also help improving aerosol climatologies in NWP through improvement of air quality forecast models such as CAMS (C-IFS).

A. Elfving gave an update of the Aeolus Project status including latest results from the on-going satellite mechanical testing. Many technical challenges have been overcome in this programme, and a special thanks was given to member states who have kept on supporting the mission, and to users who are still eagerly awaiting the data. The questions was brought up whether a follow-on mission should build on the current technology and lessons learnt or whether technical developments should be taken on-board increasing the risk. It was

emphasized that the time to realize a follow-on from mission conception to flight is typically 10 years and considerations and studies for a follow-on could already be collected and initiated today by interested agencies.

J. Lochard from the instrument prime (ADS-F) showed how the instrument has been tested and assembled on-ground, and what will be checked in the final instrument end-to-end testing in vacuum. Complex on-ground support equipment and labour intensive tests (24/7) have been used to demonstrate mission performance w.r.t. the requirements.

J. Brewster from the satellite prime (ADS-UK) showed the steps to be taken in-flight to demonstrate the mission performance in flight before hand-over to ESA-ESRIN. Special emphasis was given to explaining the instrument and data processing self-calibration strategy using ground returns to remove instrument-related product biases. The effectiveness of these needs to be validated by the various CAL/VAL teams.

F. de Bruin from ESA-ESTEC explained the ESA organization of the satellite commissioning phase. The coordinating role of ESA w.r.t. flight operation, support to industry activities on the instrument and mission verification, the commissioning of the ESA on-ground data processing and organization of the CAL/VAL was shown.

O. Reitebuch explained the calibration and data processing steps in the on-ground data processing up to Level 1B. The need to spend a lot of time to verify the instrument calibration was emphasized, and the role of CAL/VAL PIs in support of this.

M. Rennie showed how the L2B processing works, correcting the Level 1 Rayleigh winds from pressure and temperature effects using auxiliary meteorological data, and how the winds are classified in clear and cloudy observations. The calculation of the L2B wind errors, which is based on the photon shot-noise limited assumption (Poisson statistics), was explained. He emphasized that the averaging of measurements (too noisy) to observations (meeting the random error requirement) will be flexible and could be adjusted to user needs. However, that would call for running another instance of the freely available Level 2 processor.

T. Flament and A. Benedetti explained the processing of Aeolus data to backscatter and extinction coefficient profile information and how these can be assimilated in air quality forecast models. Despite of Aeolus being a wind mission, it's spin-off aerosol products are very interesting to air quality forecast models due to the information of the vertical distribution of aerosols and clouds.

Session II: ESA Data distribution, Data quality, Tools and CAL/VAL Rehearsal

Chairs: A. Benedetti and T. Kanitz, F. Buscaglione and I. di Lodovico

The CAL/VAL relevant infrastructure has been introduced in this session. The data dissemination facility design and logic have been presented including the product baseline information. The product baseline is used to trace the actual processor setup (e.g., input parameter settings) and is updated at every change. Upgrades are communicated via the EARTHNET webpage.

The Sensor Performance, Products, and Algorithms (SPPA) section, in charge of the data quality management in phase E2, and its tasks were presented. Their central role in processor and product improvement, Cal/Val as well as routine and off-line performance monitoring and the Data Innovation and Science Cluster (DISC) concept as an effective approach for the quick establishment of the necessary data quality in phase E2 was highlighted. It is the clear aim to maximize the efficiency and interaction between the groups and entities involved in CAL/VAL via meetings, workshops, the Aeolus DISC etc. (supported by several modes of communication, as for example a forum, which were further discussed in the panel discussions of the workshop).

The ESA's atmospheric Validation Data Centre (EVDC) and its user web interface was introduced (evcd.esa.int). This has been updated in terms of improved performance and new features. The EVDC serves as a central, long-term repository in Europe for archiving and exchange of correlative data for validation of atmospheric products from satellite platforms. It includes amongst others an orbit prediction tool, which allows to overlay different satellites, and a campaign planning tool with a direct link to meteorological information from ECMWF. The EVDC platform provides the advantages of a comprehensive data storage space with harmonized data, citable DOIs, and offering tools for interactive cooperation and possibility to investigate new Aeolus products by other communities, which have not been involved in Aeolus yet.

The current status of ESA supported measurement campaigns were presented. For Aeolus previous campaigns with A2D were briefly shown. For the future, campaigns in Iceland and the Tropics are planned in the framework of the CAL/VAL of Aeolus.

For the support of the CAL/VAL activities a number of tools are available including the EVDC tools and further tools developed under contract by the ESA Earth Observation Science and Projects directorates. The software package BEAT (http://www.stcorp.nl/beat/) was presented, which consists of CODA (open and read Aeolus products), HARP (harmonize products, regroup and smooth data, automate CODA routines), and VISAN (a product viewer and plotting tool). A web-based data visualization tool called VIRES was shortly presented with real data from SWARM. VIRES allows fast data visualization of the full data archive without downloading any data. The data can be filtered based on selected time periods, parameters or data quality control parameters and can be downloaded with Vires, which can be useful for algorithm developers and scientists. ESA CFI tools (http://eop-cfi.esa.int/) for the determination of overpass tables (based on GUI and command line) were introduced

as well as SAMI, which allows to simulate Aeolus orbit position with accurate Sun illumination.

Participants at the workshop have been encouraged to test the tools to get familiar with the infrastructure, the Aeolus products, and the available tools. A summary of the outcome of the CAL/VAL Rehearsal was given (see http://www.aeolus-calval-2017.org/, Presentations, Assessment of Aeolus CAL/VAL Rehearsal - Testing downloading and reading Aeolus test datasets). Questions from the audience concerned amongst others the purpose of the L2B product BUFR convertor tool (non-NWP users are not familiar with BUFR format and purpose of the tool), and the usefulness of an ASCII convertor tool. It was mentioned that asci convertors are available from ESA and that the CODA software can also be used for this purpose. DWD mentioned that they would prefer to be able to pick up the L2B data in BUFR format directly as opposed to run the BUFR convertor tool locally. The distribution of Aeolus L2B data in BUFR format over EUMETCast has already been agreed in the EUMETSAT Operations Working Group.

Session III: Aeolus Operational Phase and CAL/VAL AO Proposal overview

Charis: S. Melo and J. von Bismarck, M. Hardesty and D. Schuettemeyer

W. Lengert presented the Aeolus Mission Exploitation phase, starting at launch + 3 months and lasting until the end of the mission and beyond. A key element of the Aeolus mission is to demonstrate its impact and potential for becoming an operational mission, which shall pave the way for a mission follow-on, most probably within the EUMETSAT programs. To achieve this, key mission-related activities are to establish good data quality early in the mission, to stimulate the mission exploitation both by national and commercial partners, and to make sure that the mission is well assessed at the upcoming WIGOS NWP Impact Assessment Workshop in 2020.

It was commented from the audience that Aeolus also addresses air quality analysis and monitoring. It was discussed how the community can best assess the potential of an Aeolus follow-on and agreed that both dynamic and radiation aspects should be analyzed, also in synergy. The potential of the mission to also address cloud microphysics was raised by Canada, and France mentioned the planned campaigns for Aeolus where both wind, aerosol and cloud properties are assessed with a combination of lidar and radar instrumentation, also in preparation of EarthCARE.

The Aeolus CAL/VAL proposal PIs presented their project and their status in 10-minutes presentations. The main topics outlined were the proposal objectives, a description of the CAL/VAL techniques applied, the proposal contribution to the Aeolus CAL/VAL Requirements, status of manpower, tools and funding and an outlook on the next steps.

Most of the CAL/VAL proposal activities are planned to run for a number of months up to years. The duration depends on amongst others manpower needs and the CAL/VAL

technique used. Whereas ground-based stations need to perform data collection over longer time period to achieve statistical significant results and trend information, airborne campaigns with satellite under flights are more compact in time but also much more costly. The following was in particular mentioned; efforts to include more stations in the Aeolus CAL/VAL efforts (e.g. the inclusion of the KNMI tropical Paramaribo station, inclusion of stations in Iran, …), the importance of combining satellite, independent observations and model data to arrive at a complete data quality picture, a number of campaigns will have to be performed in a scientific and/or multi-mission context, the importance of hiring (PhD) students within the CAL/VAL projects to perform the data quality and scientific assessments, the importance of training new researchers still to be hired on the projects, the importance of studying satellite, model and collocated observation representativity before comparisons are made, most projects still do not have secured funding for their projects (applications have to be submitted or resubmitted in summer 2017), synergetic use of Aeolus winds with other observations such as sea-ice properties, the scientific aspects of the CAL/VAL work. These issues are/shall be addressed in the CAL/VAL Implementation Plan.

Session IV: Panel Discussions

Chairs: O. Reitebuch, A. Dabas, U. Wandinger and H. Körnich
Secretaries: A.G. Straume, D. Schuettemeyer, T. Kanitz and J. von Bismarck

Four panels were formed to discuss in detail the Aeolus CAL/VAL requirements and implementation plan. Panel A focused on the completeness of the requirements and gap analysis, panel B on protocols for the validation of the wind products, panel C for protocols for validation of the aerosol products and Panel D on the grouping and coordination of different CAL/VAL activities. The summaries from these sessions are presented in the power point slides on the CAL/VAL web site: http://www.aeolus-calval-2017.org/ , Presentations.

Session V: Posters

Most of the Aeolus CAL/VAL projects were also presented as posters, which were displayed throughout the workshop and presented in dedicated sessions during coffee breaks and the Icebreaker. This allowed for further in-depth discussions between the CAL/VAL teams on the projects, CAL/VAL techniques and their coordination. Posters on future Aeolus CAL/VAL projects (which are planned for submission when the Aeolus CAL/VAL AO call reopens before the launch) were also presented together with posters on the Aeolus calibration and monitoring facility, the Aeolus L2A data processing and on the simulated impact of Aeolus in a limited area model.

Workshop wrap-up

Chairs: P. Ingmann, P. Tabary, P. Ingmann

A historical overview of the mission was given by P. Ingmann, and is available as powerpoint slides on: http://www.aeolus-calval-2017.org/ , Presentations.

P. Tabary provided concluding words from the CNES side, thanking ESA for holding the Aeolus CAL/VAL Workshop in Toulouse, providing a view to the upcoming French CAL/VAL participation and mission exploitation, assessing mission impact and potential of the Aeolus technology demonstrator.

E. Källén provided a workshop summary (chapter 1 of this document) and concluded the Workshop.