The Science Aspects of the ADM-Aeolus Mission

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Introduction

Science Activities for ADM-Aeolus

Science Benefits from ADM-Aeolus

Conclusions
Introduction

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Science Benefits from ADM-Aeolus

Conclusions
Introduction
History 1/2

• The ADM-Aeolus mission had its origins in:

• The first nine candidate Core missions originated via consultations with the user community in 1991 and 1994 (ref: ESA SP-1143; ESA SP-1186)
  – Wind mission recommended as a priority for study

• Nine Mission Working Groups established in 1995
  – Report for Assessment for ADM [See: SP 1196(4)]

• ADM recommended for study at 1st Granada User Consultation meeting in May 1996
  – Programme Board for Earth Observation (PB-EO) approval of 4 pre-Phase A studies (incl. ADM)
Introduction
History 2/2

• Established ADM Advisory Group - mid 1996
  – Consolidation of mission performance requirements
  – 1996-1998 Pre-phase A studies initiated (mission requirements document, Mission Requirements established)

• Phase A feasibility studies summer ’98 – summer ‘99
  – Change of baseline from ISS to ‘free flyer’ and from ‘coherent’ 10 \( \mu m \) to ‘incoherent’ 355 nm system
  – Drafting of Report for Mission Selection [See: SP 1233(4)]

• Presentation of Phase A results at 2\textsuperscript{nd} Granada User Consultation Meeting – Oct. 1999.
  – ESAC recommended ADM to be selected as 2\textsuperscript{nd} Core Explorer.

• PB-EO endorsement of ESAC recommendation
  – Authorised instrument pre-development
  – Re-named ADM-Aeolus
Introduction
Why measure wind independently?

- Mass information:
  - In the extra-tropics for the large horizontal scales and shallow structures

- Wind information:
  - Determines the flow in tropics
  - Elsewhere, it determines the flow on small horizontal scales and for deep vertical structures (i.e. especially important for high-resolution models like HIRLAM)

Need for independent wind profile observations
Introduction

Existing wind field information

Wind field information available to date in the Global Observation System (GOS):

- Radiosonde and pilot soundings (NH continents dominate)
- Aircraft data (NH densely populated areas dominate)
- Atmospheric motion vectors (only in the presence of clouds)
- Satellite soundings of temperature and humidity from Polar orbiting satellites (mass information, indirect measure of large-scale phenomenon wind outside the tropics)

⇒ No DIRECT, GLOBAL and UNIQUE measurements of atmospheric wind fields yet
Introduction

What is the ADM-Aeolus Mission?

• ADM objectives
  – Improve understanding of atmospheric dynamics and global atmospheric transport
  – Improve understanding of global cycling of energy, water, aerosols, chemicals

• How is this achieved?
  – Improved analysis of the atmospheric state to provide a complete three-dimensional picture of the dynamical variables

• What are the benefits?
  – Improved parameterisation of atmospheric processes in models
  – Advanced climate and atmospheric flow modelling
  – Better initial conditions for weather forecasting
## Introduction

### Observational Requirements

<table>
<thead>
<tr>
<th></th>
<th>PBL</th>
<th>Troposph.</th>
<th>Stratosph.</th>
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</thead>
<tbody>
<tr>
<td><strong>Vertical Domain</strong></td>
<td>[km]</td>
<td>0-2</td>
<td>2-16</td>
</tr>
<tr>
<td><strong>Vertical Resolution</strong></td>
<td>[km]</td>
<td>0.5</td>
<td>1.0</td>
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<tr>
<td><strong>Horizontal Domain</strong></td>
<td></td>
<td></td>
<td>global</td>
</tr>
<tr>
<td><strong>Number of Profiles</strong></td>
<td>[hour(^{-1})]</td>
<td>&gt; 100</td>
<td></td>
</tr>
<tr>
<td><strong>Profile Separation</strong></td>
<td>[km]</td>
<td>&gt; 200</td>
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</tr>
<tr>
<td><strong>Horizontal Integration Length</strong></td>
<td>[km]</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td><strong>Accuracy (HLOS Component)</strong></td>
<td>[m/s]</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Data Availability</strong></td>
<td>[hour]</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Length of Observational Data Set</strong></td>
<td>[yr]</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

→ **Accuracy most important**

→ **NRT delivery required for use in models**
• Introduction

• Science Activities for ADM-Aeolus

• Science Benefits from ADM-Aeolus

• Conclusions
## Science Activities for ADM-Aeolus

### Basic Issues Addressed

<table>
<thead>
<tr>
<th>Issue</th>
<th>Activity</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind vector needed</td>
<td>Vector versus LOS wind analysed</td>
<td></td>
</tr>
<tr>
<td>Mission impact</td>
<td>Studied with DWL OSSE data base</td>
<td></td>
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<tr>
<td></td>
<td>OSE’s performed</td>
<td></td>
</tr>
<tr>
<td>Lidar in space</td>
<td>LITE used as a 'demonstrator'</td>
<td></td>
</tr>
<tr>
<td>Error correlation (MERCI)</td>
<td>Analysing (vertical) correlation</td>
<td></td>
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<tr>
<td>Derivation of other information</td>
<td>Analysis of wind shear and humidity fluxes</td>
<td></td>
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</tbody>
</table>
Line of sight wind need

Line of sight (LOS) wind component can be used

Forecast error

- no wind observations
- half observations, vector
- all observations, single component
- all observations, vector

(after Lorenc et al, 1992, Courtier et al., 1992)
Science Activities for ADM-Aeolus Mission impact

Improvement

Degradation

Largest impact at higher altitudes and in Southern Hemisphere
Lidar signal (355 nm) frequently penetrates cloud fields
Science Activities for ADM-Aeolus

Earth Explorer objectives

Scientific studies

NWP related
- LOS wind assimilation in the tropics
- Impact on Assimilation
- Ensemble simulations
- Mass-wind coupling
- Identification of sensitive regions
- Extreme weather
- Wind Observation
- Wind statistics

General science

Research and science
Science Activities for ADM-Aeolus
Wind Statistics

ADM-Aeolus will primarily measure the zonal component.

Reference: Håkansson, 2001
ADM sampling of the mainly zonal wind component over 6 hours (left)

Aeolus simulated data in an OSSE scenario (500 hPa) shows an improvement of the analysis in North Atlantic storm track region (right)

ADM-Aeolus samples sensitive structures in data sparse regions

Reference: Stoffelen and Marseille, 2006
Potential of Aeolus line-of-sight winds; simulation of a tropical wave

- Truth data alone
- Height and ADM data

- Isolines of the height field, thick: positive, thin: negative deviations.
- Wind vectors.
- Shading: regions of maximum wind speeds

⇒ Only mass plus (ADM-Aeolus) wind field (LOS) provide full picture

Reference: Žagar, 2004
Aeolus impact on Zonal Wind (u, m s\(^{-1}\))

- Impact (200 hPa zonal wind component (m/s)) of ADM-Aeolus wind profile data between two ensembles: Control and ADM-Aeolus.
- Green (orange): reduction (increase) in analysis error using the ADM-Aeolus data.

**Largest impact in the tropics**

Reference: Tan and Andersson, 2004
Science Activities for ADM-Aeolus Operational Data Assimilation

Impact on Zonal Wind (u, m s$^{-1}$)

For Tropics

- Northern and Southern Hemisphere similar
- Rms for 12 hr forecast (proxy for short-range forecast)
- Denial of radiosondes/profilers is detrimental, addition of simulated Aeolus data is beneficial (F-test significant at 99.99% level)
- Scaling factor ~ 2 for wind error

→ Aeolus effectively complements the 2004 observing system
The global campaign objectives are

• Check operating and calibration procedures
• Quantify instrument performance
• Check processing algorithms under realistic atmospheric conditions
• Validate and improve quality control schemes
• Assess errors of calibration schemes (zero-wind calibration) and temperature / pressure corrections
• Obtain data about atmospheric variability and ground return properties

Early results had been derived in the frame of VALID in 1999
VALID-2 Campaign (July 1999)

First verification of direct detection lidar performance
## Science Activities for ADM-Aeolus Campaigns

<table>
<thead>
<tr>
<th>Objectives</th>
<th>AGC</th>
<th>AC1</th>
<th>AC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument performance</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Atmospheric influence on performance</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Algorithm improvement and Quality-Control</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Calibration</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Optimization of L2B processing</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Deriving of L2A products</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Database of geophysical parameters</td>
<td>x</td>
<td>x</td>
<td>x</td>
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</table>

AGC: Ground-based campaign validating the Aladin Airborne Demonstrator (A2D)

AC1: First airborne campaign validating the A2D

AC2: Second airborne campaign validating the A2D
Other activities are either underway or in preparation

- Level 0 to Level 2b processing
- Potential cloud and aerosol products
- Validation of products from other satellites
- Impact on stratospheric analyses
Introduction

Science Activities for ADM-Aeolus

Science Benefits from ADM-Aeolus

Conclusions
Science Benefits from ADM-Aeolus

- Tropical winds (El Niño)
- Model deficiencies
- Tracer advection (ozone, humidity, aerosols)
- Model verification
Science Benefits from ADM-Aeolus

ECMWF - NCEP Re-analysis

Large uncertainty in tropics using different models - three months average
Science Benefits from ADM-Aeolus

ECMWF - NCEP Re-analysis

Large uncertainty in tropics on seasonal flow using different models
Wind profiles demonstrated important but impact could be higher, e.g. 2002 early Southern polar vortex break-up
Science Benefits from ADM-Aeolus
Cloud and Aerosols databases

• ADM-Aeolus data on clouds and aerosol layers could be used directly by scientists for research on **Atmospheric radiative budget** and **Water cycle** applications

• ADM-Aeolus data could be combined with contemporary data available from operational space based visible and infrared radiometers in order to derive higher level data products on clouds and aerosols

• **ADM-Aeolus** launched in late 2008 will continue to build up a long term **database on clouds and aerosols** started by Calipso and the A-Train in early 2006
Science Benefits from ADM-Aeolus

Climate Forcing

Direct forcing
- Scattering and absorption of solar and terrestrial radiation by aerosols

Indirect forcing
- Effects of aerosol optical properties of clouds

Recent work:
- Reduced uncertainty for direct aerosol effect on radiation
- Still very large uncertainty on indirect effect on clouds (albedo and lifetime) and any effect on ice clouds still unknown.
Climate model intercomparison projects (AMIP-I & -II, CMIP) reveal uncertainties in predictive skill.

Observations are used to validate individual models prior to comparison.

Re-analyses (consistently assimilated observations) provide reference datasets to indicate the most significant model deficiencies.

Underpins improvements in understanding of processes model parameterizations.

Wind field knowledge is very important for model verification.
Science Benefits from ADM-Aeolus
International Context

• GOS [Observational data requirements and redesign of the global observing system, i.e. new GOS] - WMO

• GEWEX
  – Observation requirements for 3-d tropospheric wind
  – Consistent with those of NWP/GCM communities

• SPARC
  – Need for assimilation products, esp. 3-d wind fields
  – Stratosphere-troposphere coupling & exchange

⇒ NWP “pre-processing” applies quality control and adds value – recognized by WCRP Scientific Steering Groups
⇒ Operational missions lead to long-term climate datasets
Introduction

Science Activities for ADM-Aeolus

Science Benefits from ADM-Aeolus

Conclusions
Conclusions-1

- Direct observation of winds in the tropics
- Use of observations in model verification
- Better description of transports (ozone, humidity, aerosols,...)
- Dynamics in the lower stratosphere
Conclusions-2

• Accurate wind profile observations are needed to improve Numerical Weather Prediction, climate modelling and climate analysis

• A feasible concept for a demonstrator has been developed and will be implemented as the second Earth Explorer Core Mission

• Various activities related to science, operational use and campaigns are being and will be performed in parallel to the technical activities

• Full science benefit can only be estimated at present

…and this workshop