ADM-Aeolus
ESA's Wind Lidar Mission and its spin-off aerosol profile products

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European Space Agency/ESTEC

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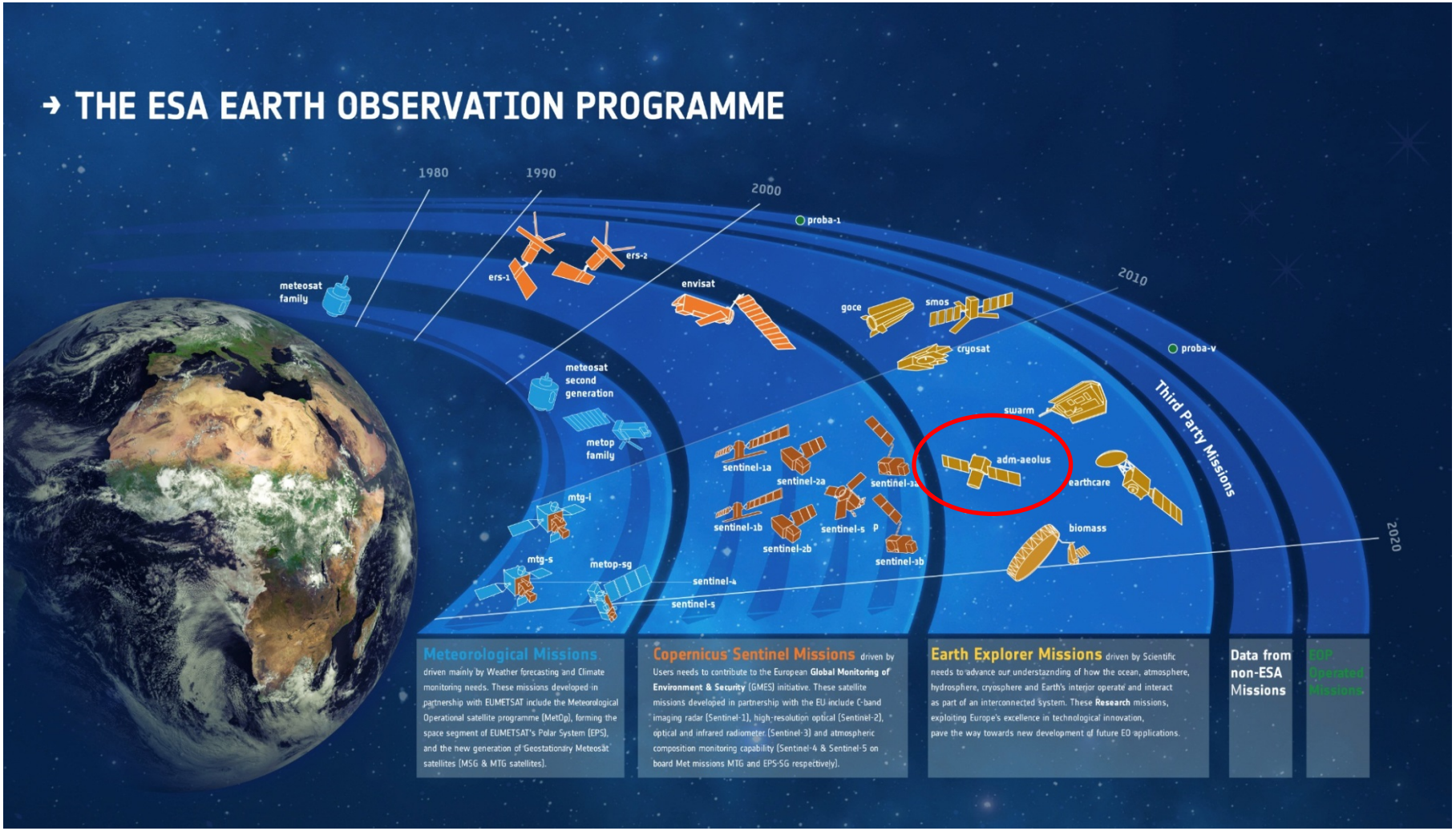
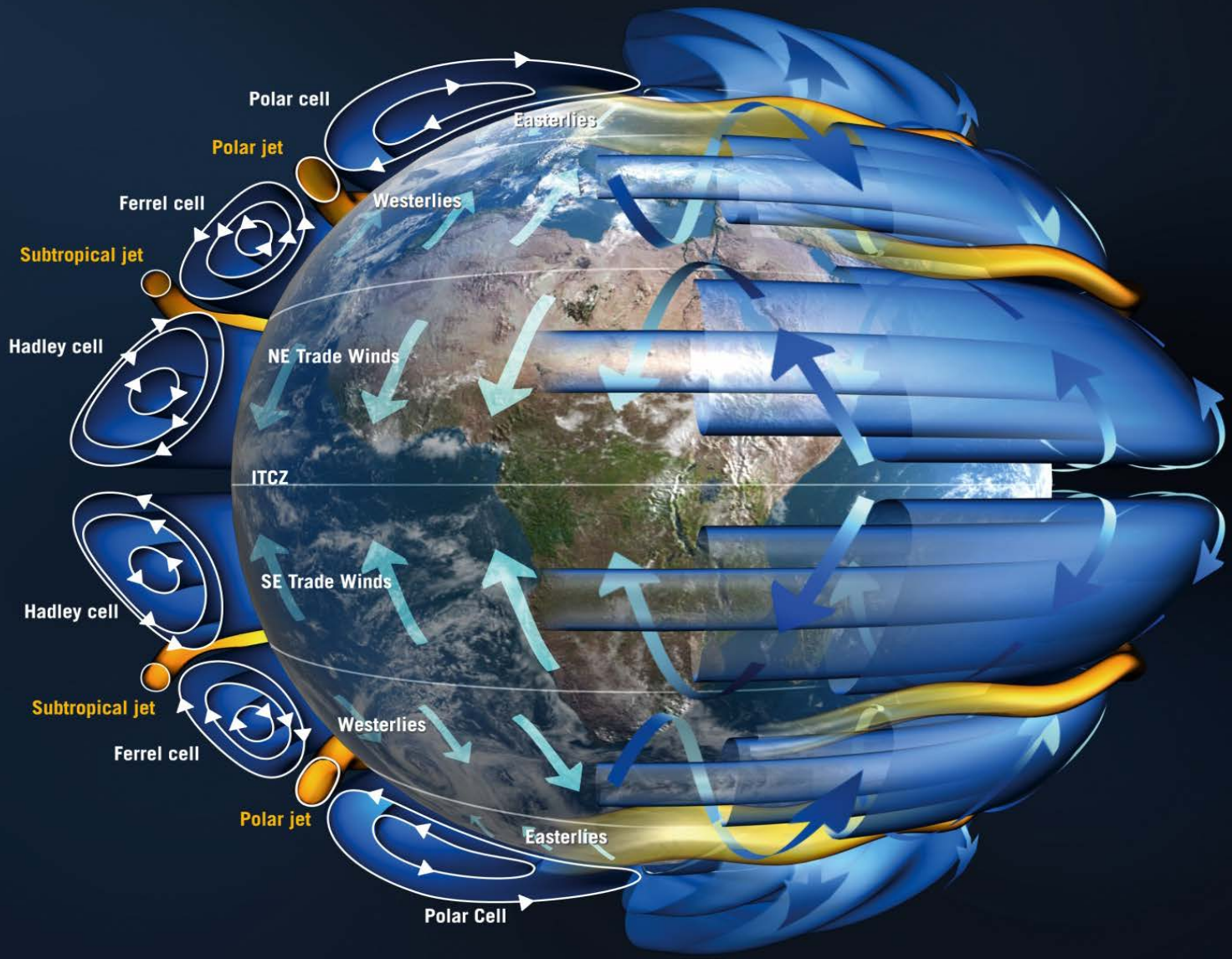
ADM-Aeolus, ESA Earth Explorer



Atmospheric Dynamics of the Earth



Aeolus: Mission Objectives

Scientific objectives

- To improve the quality of weather forecasts;
- To advance our understanding of atmospheric dynamics and climate processes;

Explorer objectives

- Demonstrate space-based Doppler Wind LIDARs potential for operational use.

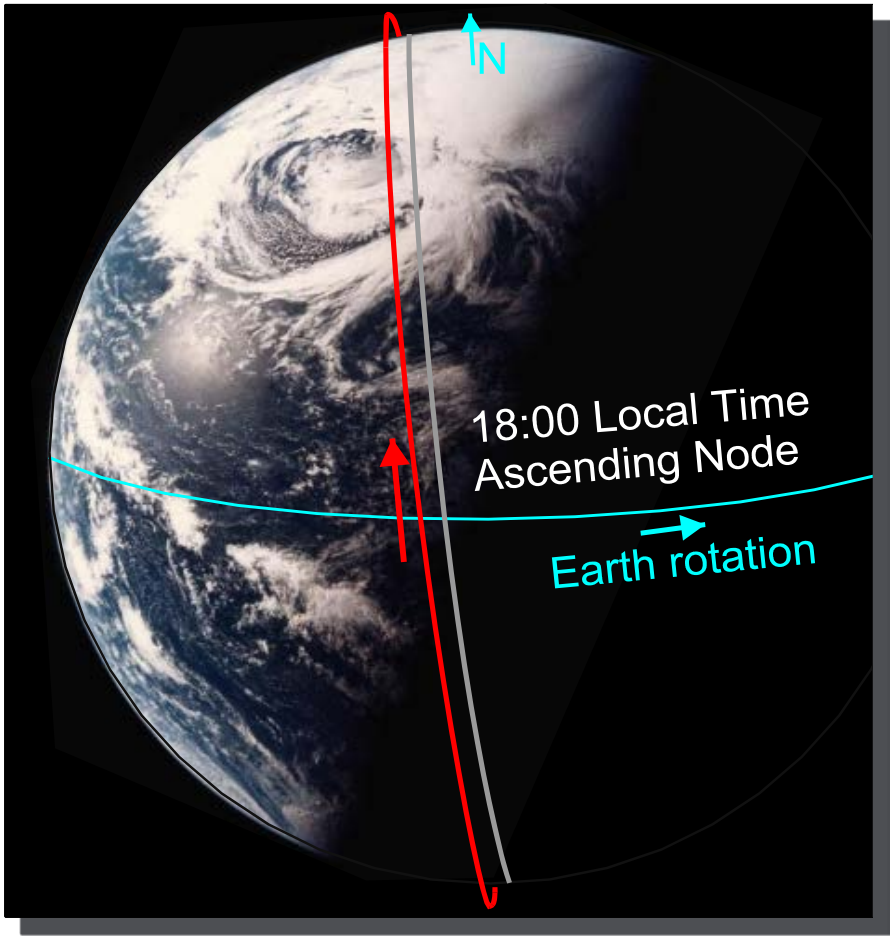
Observation means:

- Provide global measurements of horizontal wind profiles in the troposphere and lower stratosphere
- Spin-off products are atmospheric extinction and backscatter profiles

Payload

- ALADIN: Atmospheric LAser Doppler INstrument

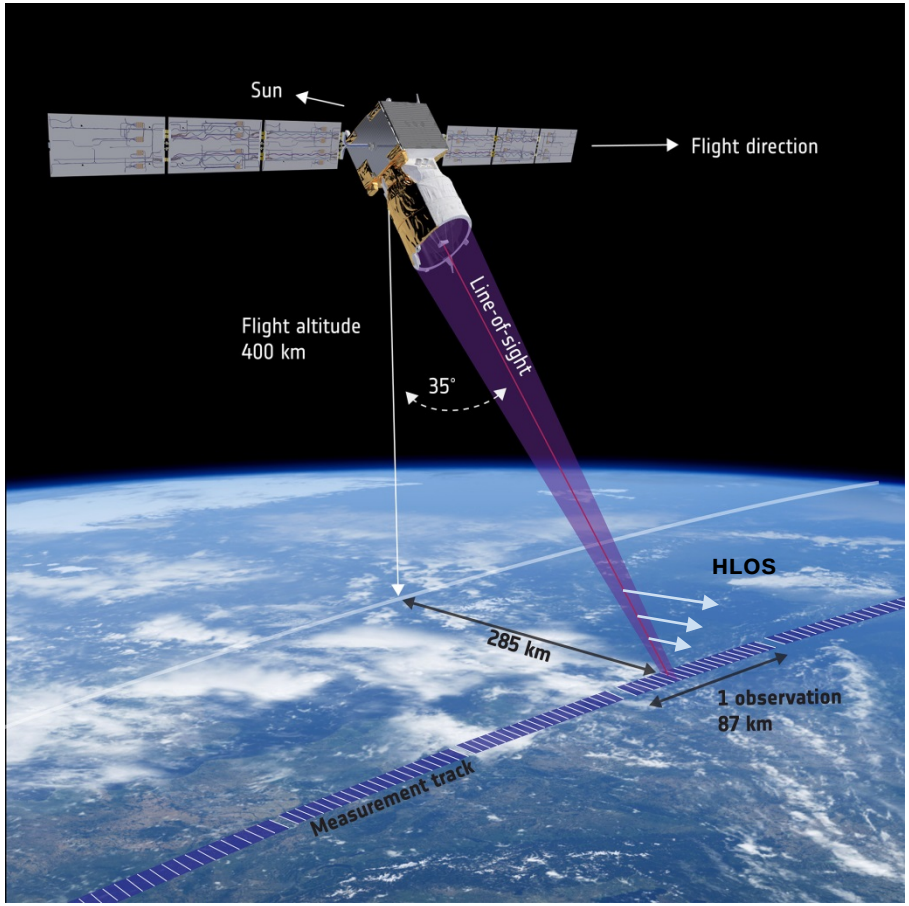
Mission Design



Mission Parameters

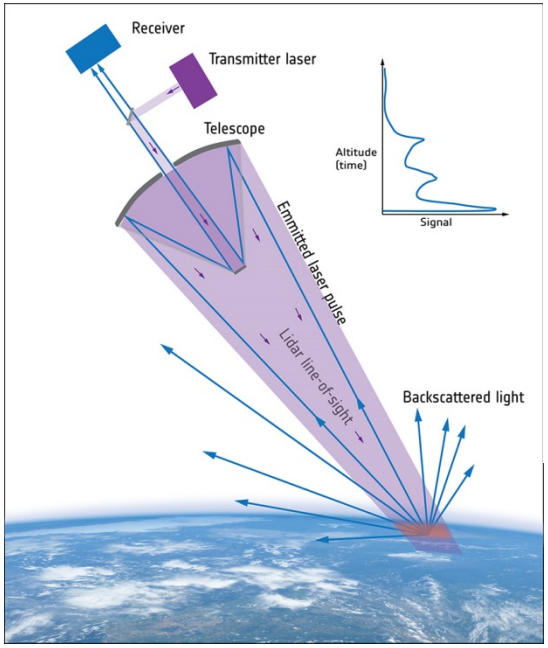
- Orbit: sun-synchronous
- Mean altitude: ~400 km
- Local time: 18:00 ascending node
- Inclination: 96.97°
- Repeat cycle: 7 days / 109 orbits
- Orbits per day: ~16
- Mission lifetime: 3 years

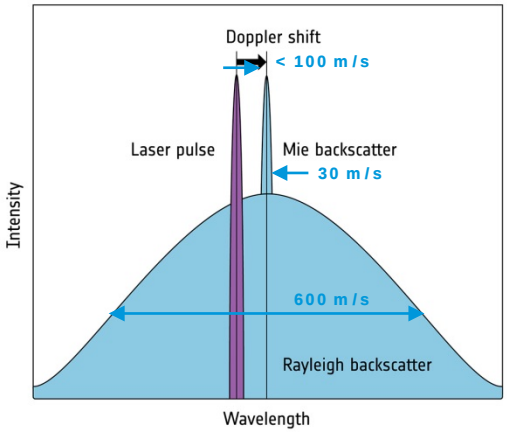
Aeolus: Measurement Principle (1/2)

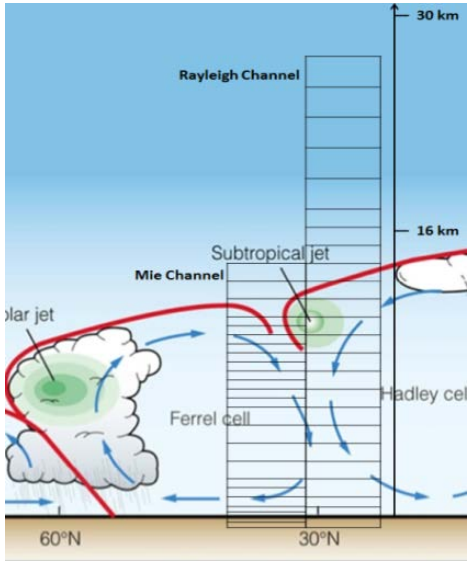


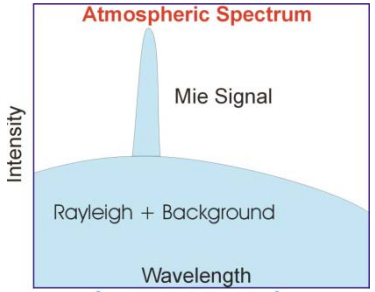
- Direct detection UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF in with 2 receiver channels
- Mie receiver to determine winds from aerosol & cloud backscatter
- Rayleigh receiver to determine winds from molecular backscatter
- The line-of-sight (LOS) is pointing 35º from Nadir to capture single component horizontal wind (LOS wind is projected to HLOS)
- The line-of-sight is pointing orthogonal to the ground track velocity vector to remove contribution from the satellite velocity

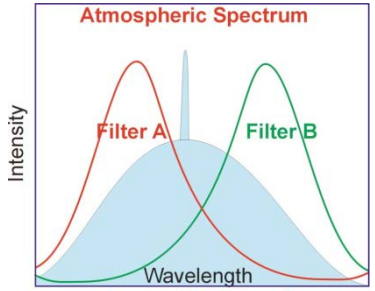
Aeolus: Measurement Principle (2/2)

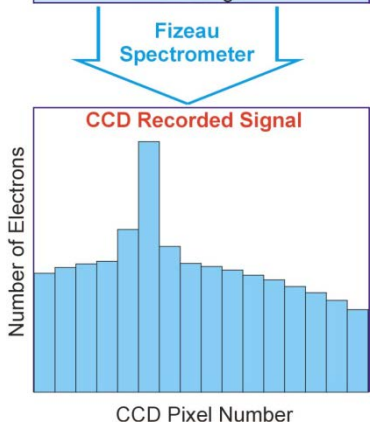


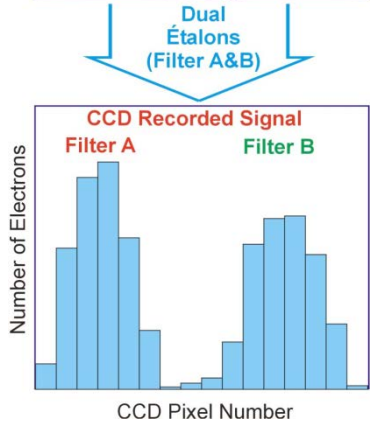








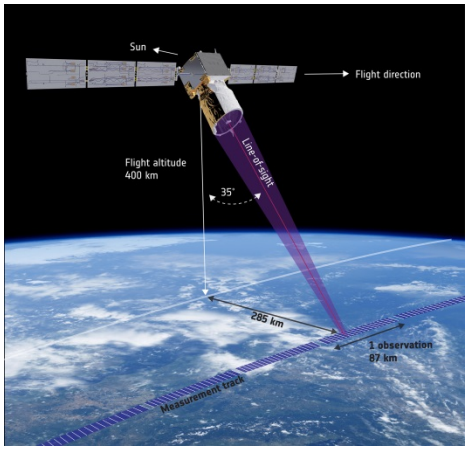


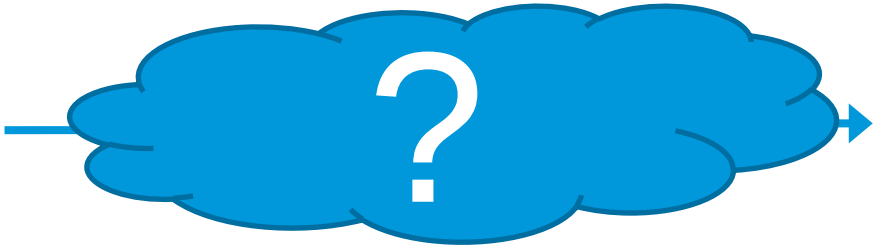


Mie channel:
- Aerosol/cloud backscatter
- Imaging technique

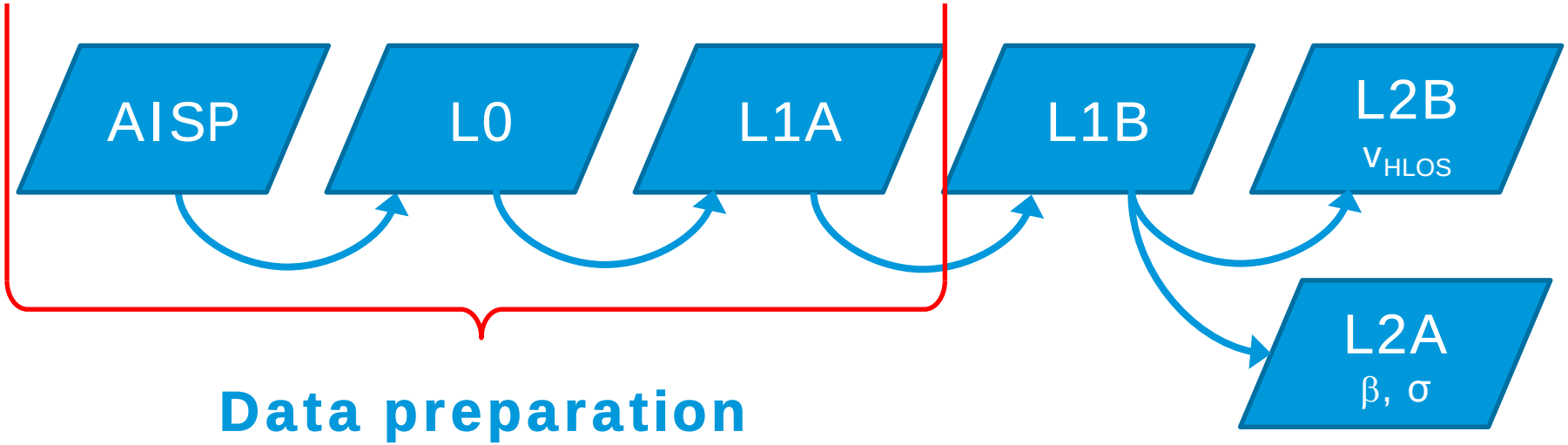
Rayleigh channel:
- Molecular backscatter
- Double-edge technique

Aeolus: Instrument Data Processing





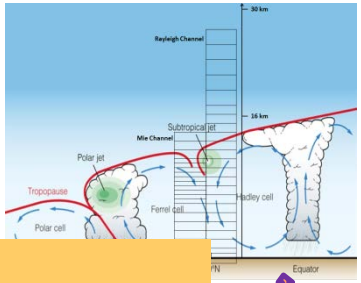
Wind Velocity

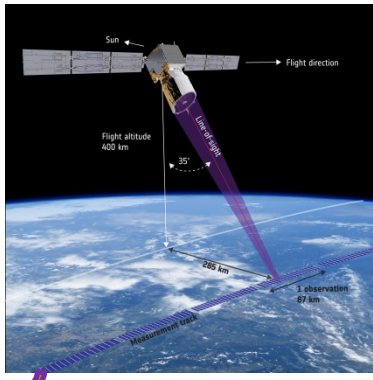


Data preparation

Aeolus atmospheric products

1. **Primary (L2b) product:**
   a. Horizontally projected LOS (HLOS) wind profiles
      - Approximately zonal at dawn/dusk (6 am/pm)
      - ~85 km observation from 3 km subsamples – scene classified
      - From surface to ~30 km in 24 vertical layers
      - Random errors: 1-2(PBL), 2(Trop), 3-5 (Strat) m/s
      - Bias requirements: 0.5 m/s

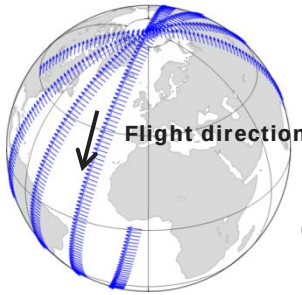




2. **Spin-off (L2a) products:**
   a. Optical properties profiles

Powerful space-borne lidar with separate molecular and particle backscatter detection

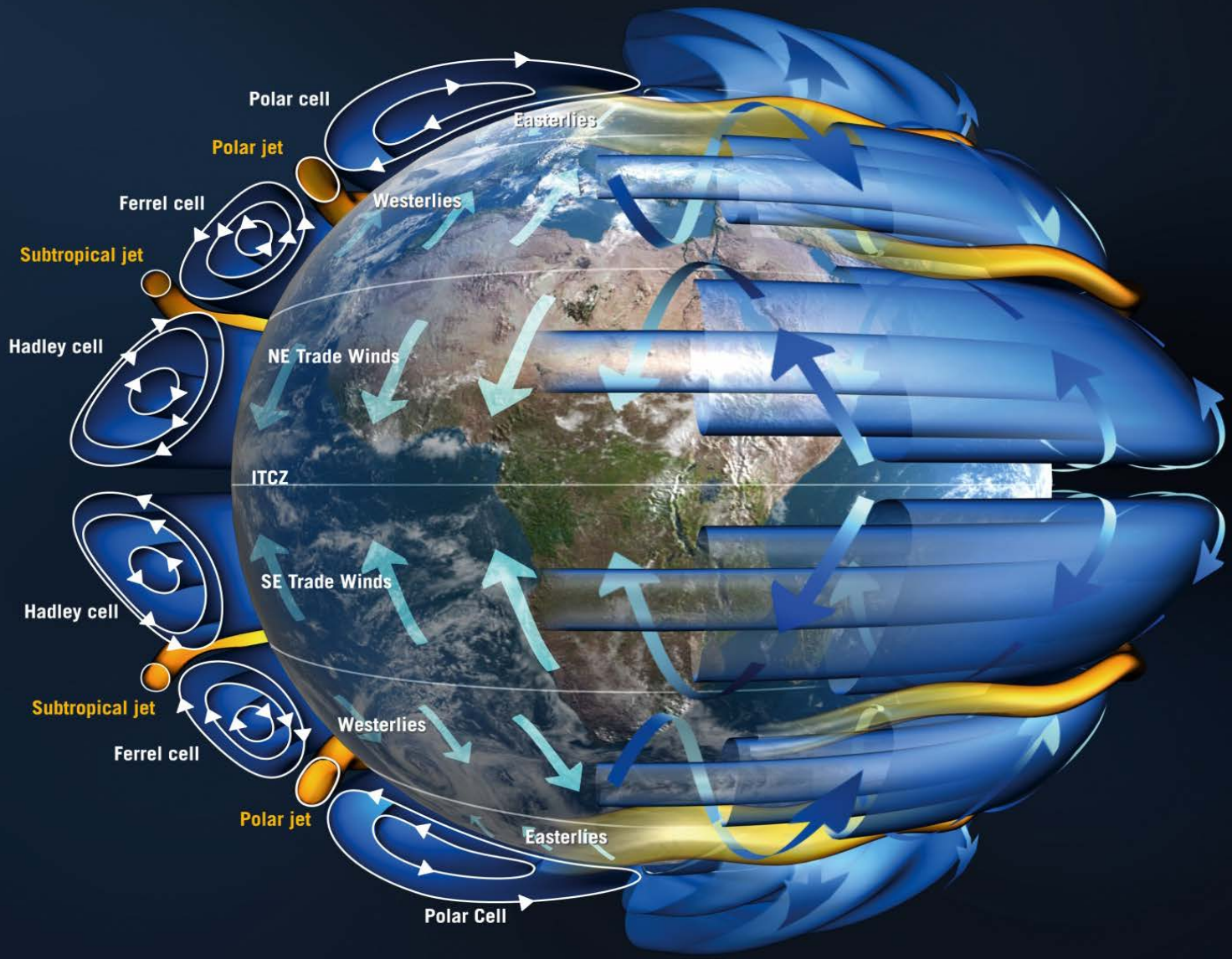
Near Real Time delivery of L1b data + L2b processor serves
*** numerical weather prediction (NWP)**
*** potential for aerosol assimilation in forecast and climate models**



Courtesy N. Žagar

Dusk/dawn orbit

Aeolus: Mission Impact

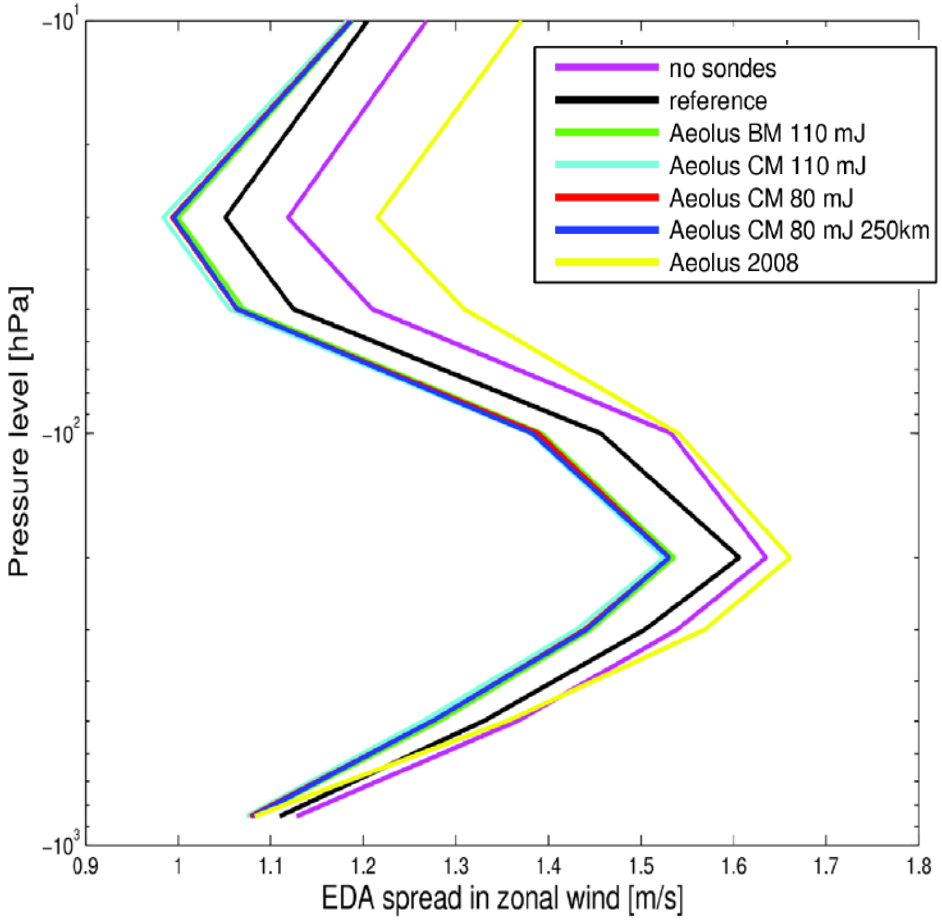


Aeolus: Mission Impact for Weather Forecast

Summary conclusions by two impact studies led by ECMWF and KNMI

- ✓ Especially beneficial in the tropics and upper troposphere
- ✓ HLOS winds provides approximately 75% of the full wind vector information
- ✓ Impact on forecast quality is of the same order as the currently available radiosonde observation network (WMO benchmark)
- ✓ Impact rather insensitive to random wind error variation
- ✓ Even small wind biases can be detrimental, so try to reduce biases!
  - ➢ **Wind bias calibration efforts will be essential!**

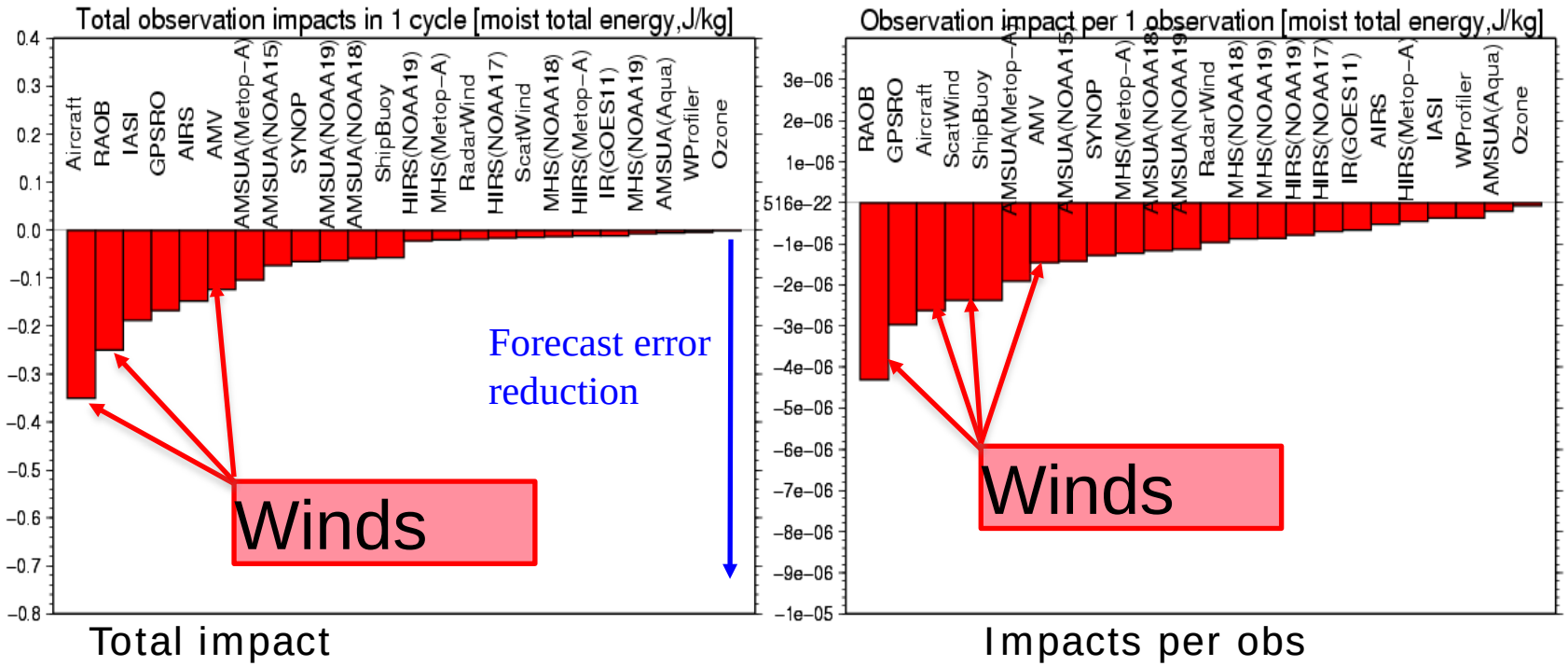
KNMI impact study, Ensemble Data Assimilation experiment



1. Ensemble Data Assimilation: Forecast spread is a measure of forecast quality (low spread means good forecast)
2. The impact of Aeolus observation is on the same order of magnitude as radiosonde data

- Reference: All current global observing observations used for ensemble forecast
- No sondes: Radiosondes removed from the observations
- Aeolus: Different types of Aeolus operation modes. CM 80 mJ now mission baseline.
- Aeolus 2008: to be ignored (“climatology” data used to simulate Aeolus winds)

WMO Workshop Sedona, May 2012
Assessment of current observation types



Total impact

Impacts per obs

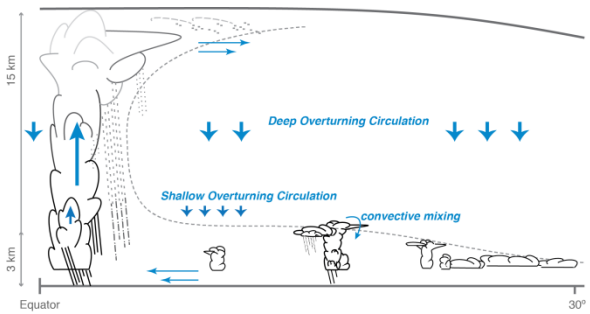
Courtesy: L.P. Riishojgaard

All observation types have positive **forecast impact** on average.

For the total impact, 1: aircraft, 2: AMSU-A, 3: radiosonde, 4: IASI, 5: GPSRO
For impact per 1 obs., 1: radiosonde, 2: GPSRO, 3: aircraft, 4: Scatterometer wind, 5: marine surface observation

Importance of winds for climate applications

1. Wind information essential for climate predictions
    a. Grand Challenges of WCRP underline role of cloud circulation interactions for climate sensitivity



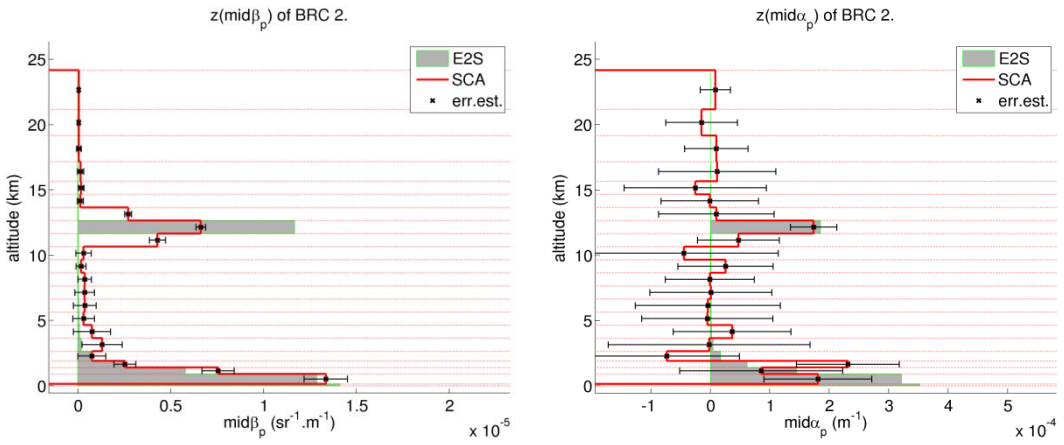
Courtesy: S. Bony, CNRS

2. Reanalysis need more wind observations

3. Tropical ozone strongly impacted by UTLS dynamics

Contribution to aerosol assimilation

1. Assimilation studies have shown the great potential of lidars to improve on current observation of total OD
2. Aeolus L2a algorithm developed and being tested
    a. Co-polar β, σ, lidar ratio, potentially also NRT

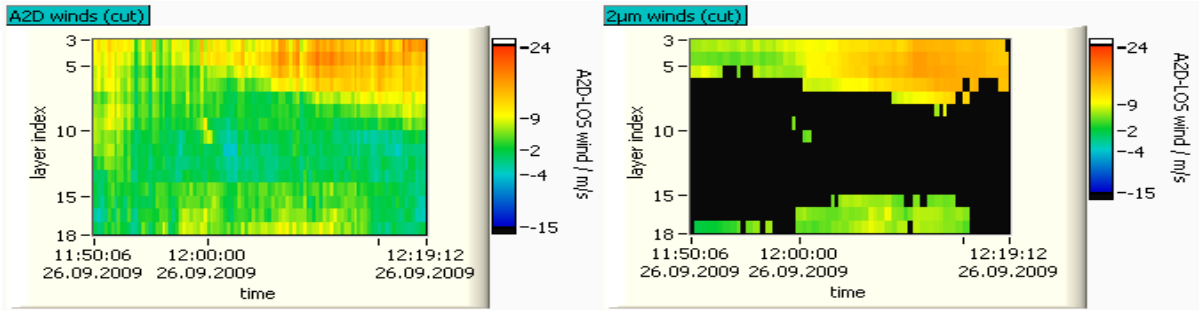


3. Lack of polarization information in the Aeolus measurements introduce uncertainties in polarizing scenes
    a. Methods to handle and/or correct for this is being developed
4. Study on the potential of Aeolus for aerosol assimilation being initiated

Aeolus campaigns

1. **Objective:**
    a. Validation of predicted instrument radiometric and wind measurement performance using the Aladin Airborne Demonstrator (A2D)
    b. Establishing dataset of atmospheric measurements with an Aeolus type Lidar to improve algorithm development
2. **2006 – 2009 A2D Campaigns:**
    a. Two ground-based (2006, 2007) and three airborne (2007, 2008 and 2009)
    b. So far, on the order of 100 recommendations for the Aeolus mission (instrument and algorithm development and testing)
    c. First atmospheric measurements worldwide with a Fizeau and Double Fabry-Perot UV lidar system
3. **Further pre-launch campaign in May 2015 successful:**
    a. extend observations in highly heterogeneous conditions (vert./hor.)
    b. extend dataset on nadir response calibrations
    c. rehearsal and preparation for CAL/VAL activities (DLR, NASA, Summit Station)

Preliminary comparisons of A2D and DLR 2µm wind lidar measurements on-board the Falcon, near Greenland, 2009. Courtesy: U. Marksteiner, DLR



Aeolus CAL/VAL AO delta-call 2014

Aeolus CAL/VAL AO call, 2007:

1. Draft Phase E1 (and E) CAL/VAL plan and requirements established
2. Call open to experts/scientists worldwide
3. 16 (joint) proposals received and reviewed
4. 15 proposals were selected but now uncertain/no longer valid due to launch delays

⇒ **DELTA AO CAL/VAL CALL NEEDED**

Aeolus AO delta-call 2014, objectives:

1. Allow for confirmation/update of current proposals
2. Attract new proposals

Aeolus delta-call outcome:

1. Open from 1 May – 15 June ‘14
2. 17 proposals received, 4 were large joint national efforts
3. Review was completed in ’14
4. Cal/Val projects were presented and discussed at the Aeolus Science & Cal/Val workshop Feb. ‘15
5. Outcome -> Aeolus CAL/VAL Implementation Plan

Aeolus CAL/VAL preparations

1. **Aeolus Science and CAL/VAL Workshop** 10-13 February 2015:
    a. **http://www.aeolus-science-calval-2015.org/**
    b. Presentation of mission and scientific / NWP application
    c. Refinement of CAL/VAL plan and compile implementation plan
    d. Campaigns planning and coordination amongst AO proposals and external campaigns

2. Launch readiness (late 2016)
3. Phase E1 CAL/VAL Workshop/meeting (L+5)
4. Phase E CAL/VAL monitoring and Workshops (coordinated by Mission Manager)

Conclusions

- ✓ More than 10 years of development challenges
- ✓ Invaluable experience has been gained
- ✓ Laser and LIDAR modifications are very time consuming
- ✓ The mission remains worldwide unique
- ✓ Enthusiastic user communities anticipating break-through in weather forecast and climate research
- ✓ The Project and the Industrial team committed to complete Aladin by end 2015 and be ready for launch in 2016.

Important link:

- Aeolus Living Planet web site: www.esa.int/The_Living_Planet_Programme/ADM-Aeolus