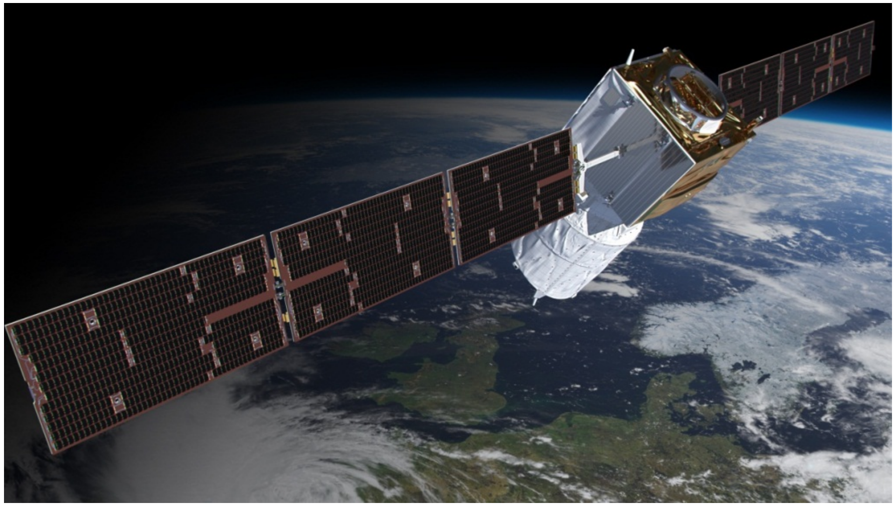
ADM-Aeolus – getting ready for launch



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http://www.esa.int/esaLP/LPadmaeolus.html

Aeolus teams

1. The Aeolus Mission Advisory Group
    - Angela Benedetti / ECMWF
    - Alain Dabas / MeteoFrance
    - Pierre Flamant / IPSL
    - Mary Forsythe / MetOffice
    - Erland Källén / ECMWF
    - Heiner Körnich / MISU
    - Harald Schyberg / met.no
    - Ad Stoffelen / KNMI
    - Oliver Reitebuch / DLR
    - Michael Vaughan / Lidar & Optics Associates
2. The Aeolus L1b, L2a and L2b algorithm development teams (DLR, ECMWF, IPSL, KNMI, MétéoFrance)
3. ESA Aeolus project and support teams (ESTEC, ESRIN, ESOC)
4. Airbus Defence and Space, and subcontractors

Outline

1. Aeolus in the ESA Living Planet programme
2. Scientific motivation for ESA’s Doppler wind lidar mission
3. Instrument and measurement principle
4. Mission products and their envisaged use
5. Programmatic status
6. Conclusions

ESA's Earth Observation Programme

aeolus because wind matters

esa

ERS1
ERS2
Envisat

Earth Explorers
Research driven

Core Missions

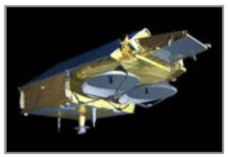
GOCE
2009

ADM-Aeolus
2015

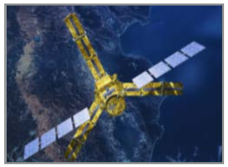
EarthCARE
2016

BIOMASS
2020

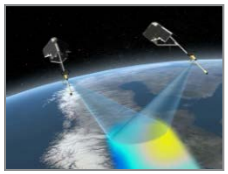
Opportunity Missions



CryoSat 2
2010



SMOS
2009



Swarm
2013

?

EE8
2022

2 Candidates
CarbonSat, FLEX

Meteosat

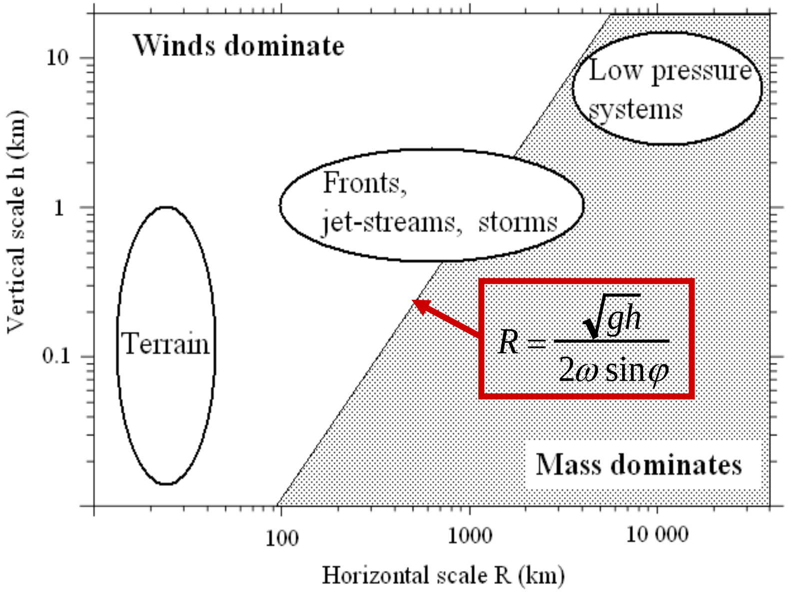
Earth Watch
Service driven

Operational Meteorology
- MSG
- MTG
- Metop
- Metop SG

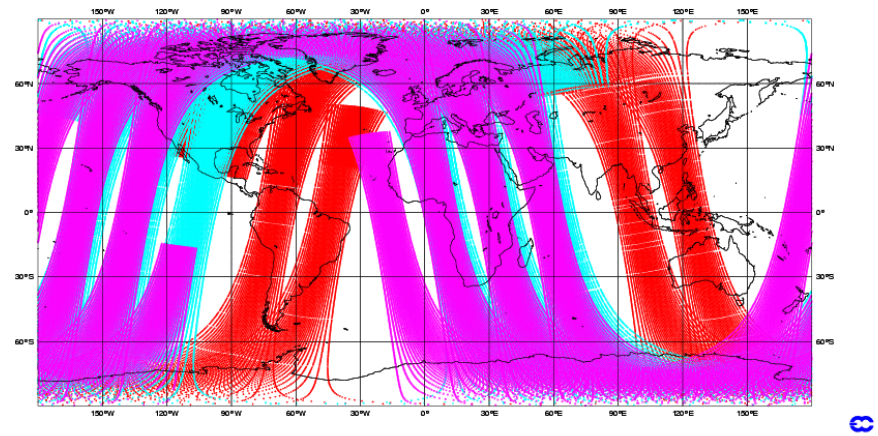
GMES
- Sentinel 1
- Sentinel 2
- Sentinel 3
- Sentinel 4
- Sentinel 5/5p

www.esa.int/livingplanet

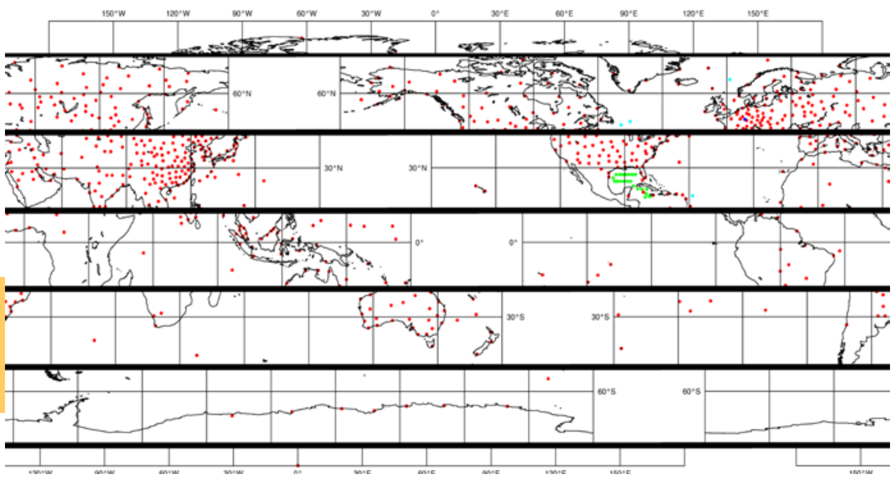
The importance of direct wind observations



Global temperature soundings



Direct wind profile soundings (radiosondes)

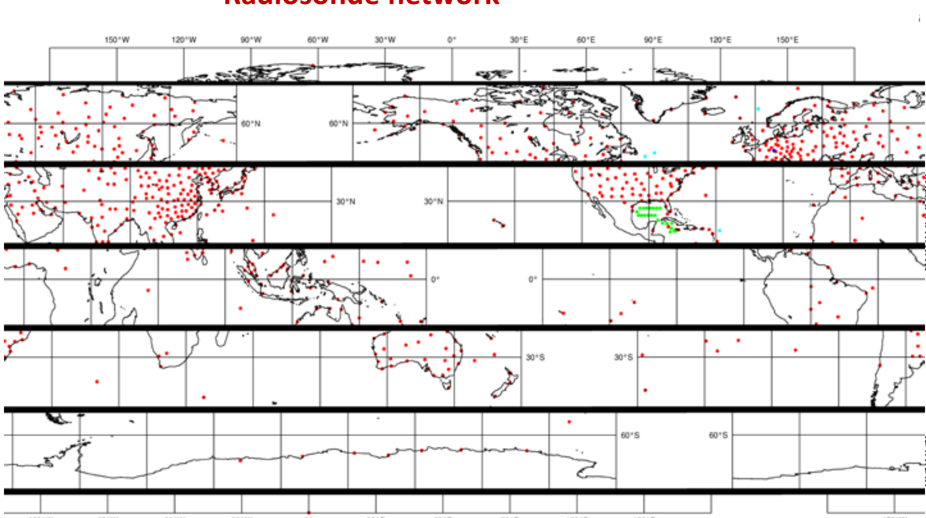


Direct wind observations are important at smaller scales

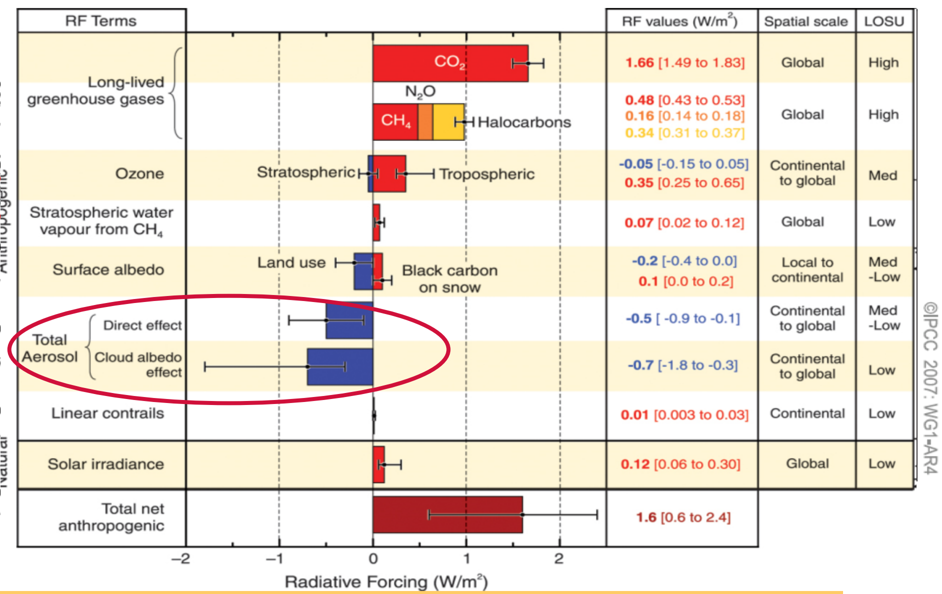
Areas of concern to weather forecasting and climate modelling

1. Lack of homogeneous global coverage of direct wind profile measurements in the current Global Observing System (GOS)
2. Large uncertainties in the estimated contribution of aerosols and clouds to the global radiative forcing

Radiosonde network



GLOBAL MEAN RADIATIVE FORCINGS



Aeolus mainly addresses the first and provides spin-off products in support of the latter

Aeolus objectives

What are the scientific requirements?

Improve our understanding and predictability of

1. Atmospheric dynamics and global atmospheric transport
2. Global cycling of energy, water, aerosols, chemicals

How are they achieved?

Improved atmospheric analysis fields, in particular:

1. Tropics: Wind fields governs dynamics
2. Mid-latitudes: Intense storm developments and mesoscale circulation

What are the benefits?

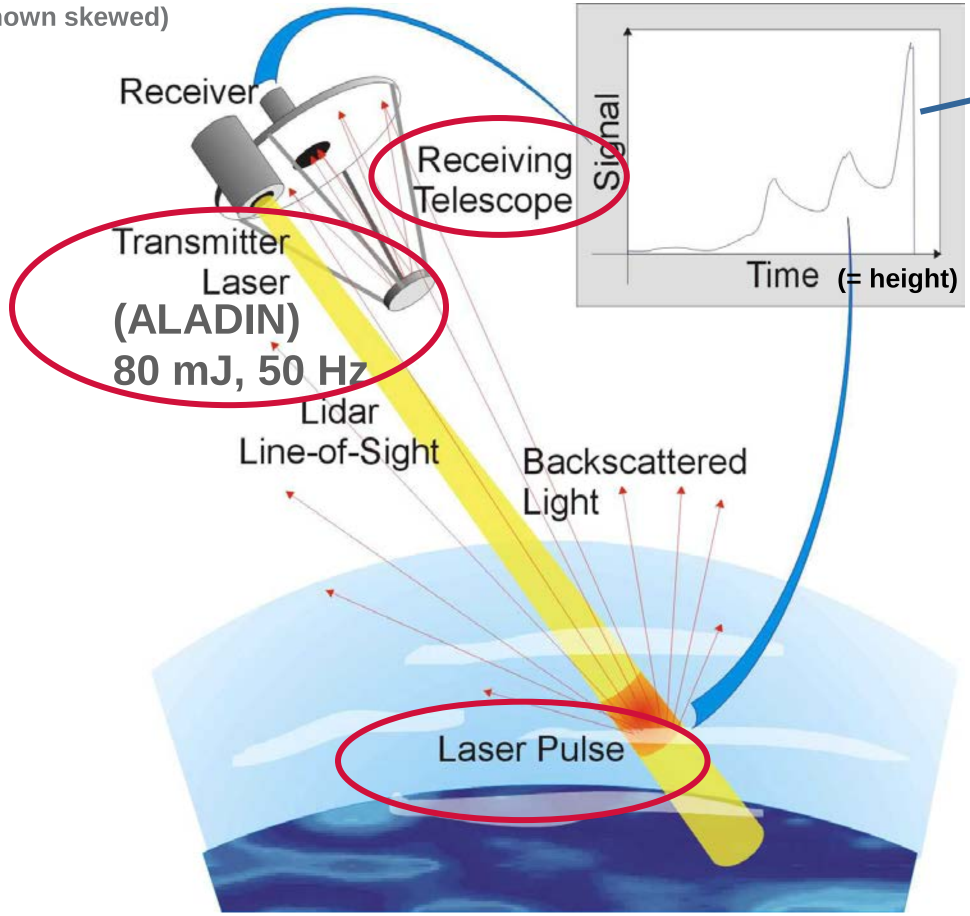
1. Better initial conditions for weather forecasting
2. Improved parameterisation and modelling of atmospheric processes in climate and forecast models

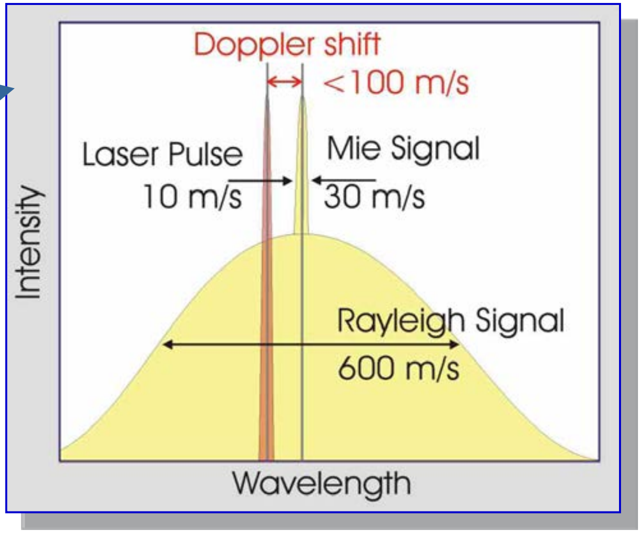
Demonstrate the capabilities of space-based Doppler Wind LIDARs (DWLs) for global wind profiling and its potential for operational use

Aeolus Mission

Aeolus measurement concept

Monostatic emit-receive path
(shown skewed)



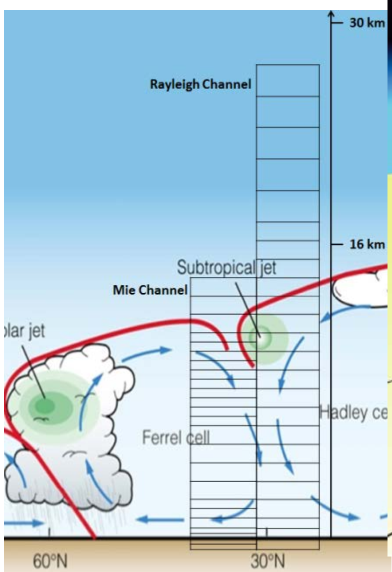


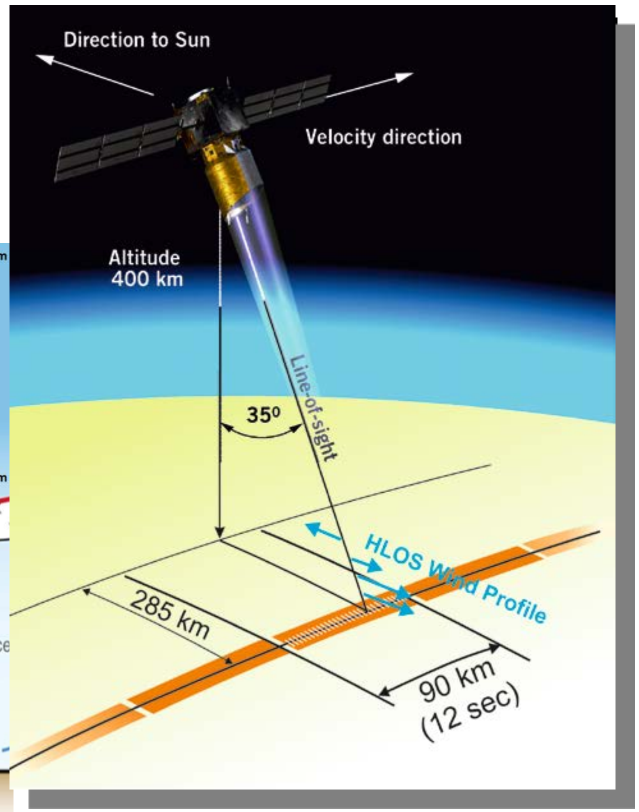
Wind and atmospheric optical properties profile measurements are derived from the Doppler shifted signals that are back-scattered along the lidar line-of-sight (LOS)

Measurement baseline

New measurement baseline

Example of ADM-Aeolus vertical sampling





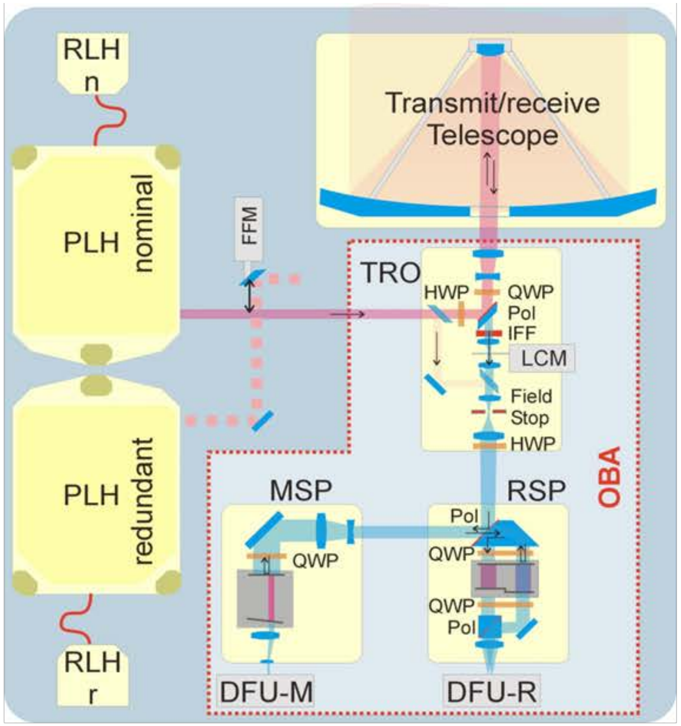
Detailed information on orbits characteristics will be presented later

1. High Spectral Resolution: Separate molecular and a particle backscatter receivers
2. UV (355 nm , circularly polarized)
3. No polarization detection
4. Ground calibration (nadir and off-nadir)
5. Adjustable vertical sampling of atmospheric layers

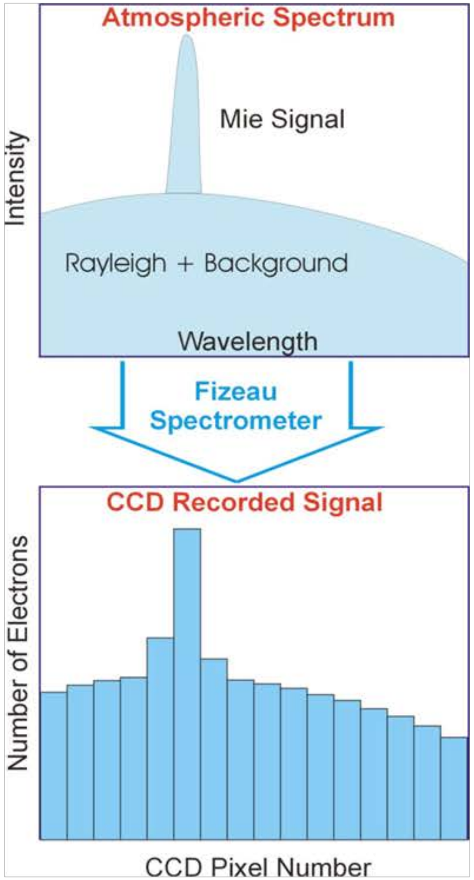
   Δz: 0.25–2 km

   z: 0-30 km

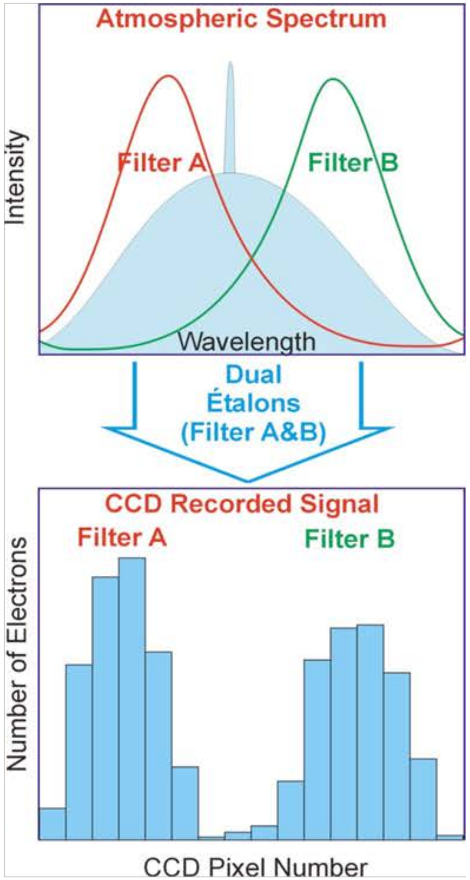
Aeolus – Aladin design



Optical architecture of ALADIN.
PLH: Power Laser Head, RLH: Reference Laser Head, FFM: Flip-Flop Mirror, LCM: Laser Chopper Mechanism, TRO: Transmit/Receive Optics, RSP: Rayleigh Spectrometer, DFU: Detection Front-end Unit, QWP: Quarter-Wave Plate, HWP: Half-Wave Plate, Pol: Polariser, IFF: Interference Filter.



Mie receiver: fringe imaging Fizeau spectrometer



Rayleigh receiver: double edge Fabry-Pérot etalon

Aeolus atmospheric products

1. **Primary (L2b) product:**
   a. Horizontally projected LOS (HLOS) wind profiles
      – Approximately zonal at dawn/dusk (6 am/pm)
      – 3 km-averaged measurements and ~85 km observation averages – 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

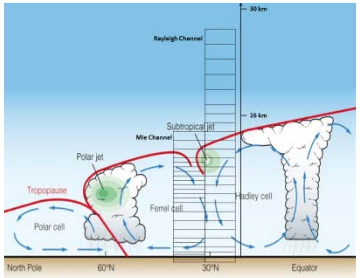
2. **Spin-off (L2a) products:**
   a. Optical properties profiles
      – β, σ, OD, scattering ratio
      – Cloud/aerosol cover/stratification

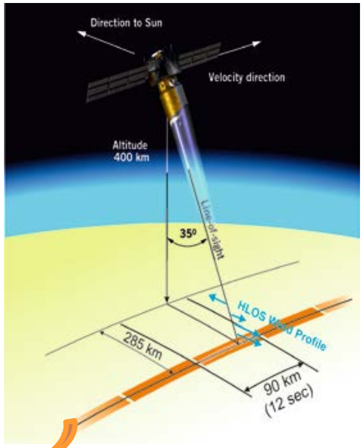
!)

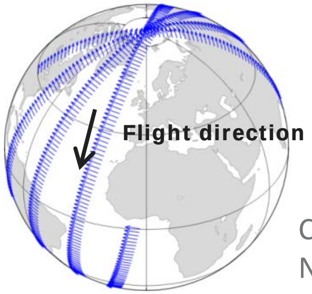
ation

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**







Dusk/dawn orbit

Courtesy N. Žagar

European Space Agency

Science related activities in support of the mission

1. ***Phase 0***
    - investigating data impact on NWP and atmospheric modelling
2. ***Phase A***
    - elaborating on system and data processing requirements (performance and end-to-end simulation tools), user requirements (impact studies), ground-based validation campaigns

   -> Lead to the scientific and technical mission concept which was evaluated and recommended at the Granada UCM in 1999
3. ***Phase B***
    - OSSE impact experiment, data assimilation, wind and cloud/aerosol statistics, signal processing, random and systematic errors and quality control

   -> Leading to the 2001 Mission Requirements Document (MRD) and SRD
4. ***Phase C/D***
    - Wind and spin-off product processing, campaigns, **product optimisation**, **further impact verification following baseline changes (SRD update)**

-> **Leading to the 2013 MRD update**

European Space Agency

Mission Baseline changes resulting from hardware qualification

1. Change from Burst Mode (BM) to Continuous Mode (CM) operation in 2010 to ensure the necessary stable laser operation

2. Relaxation of the planned laser output power operation at the start of the mission from 110 to 80 mJ in 2012

3. ADM-Aeolus MAG:
    a. Is the mission still meeting the MRD, i.e. will the mission still provide beneficial atmospheric modelling and NWP impact?

4. **Two parallel scientific Impact Study activities** were launched to provide a consolidated answer using different tools and methods:
    a. KNMI, met.no, MISU/SMHI: Theoretical and Ensemble Data Assimilation impact experiment using simulated observations
    b. ECMWF: Impact of real observations adapted to the ADM-Aeolus sampling / properties in an Observing System Experiment (OSE)

Impact Study by KNMI and partners (1/5)

Study Motivation:

1. Forced change from BM to CM operation after 2010 expert review
    a. Pulse repetition frequency: 100 Hz $\Rightarrow$ 50 Hz
2. Performance specification over 50 km were hence not met anymore
3. On the other hand
    a. Double the amount of energy is emitted into the atmosphere
    b. More flexibility for measurements accumulation to observations (no data gap)
4. Does CM allow to derive positive NWP impact?
5. How to optimally exploit CM for NWP?
6. Does 80 mJ operation allow the mission to meet the MRD random and systematic error requirements? (added during the activity)

Impact Study by KNMI and partners (2/5)

Study Objective:

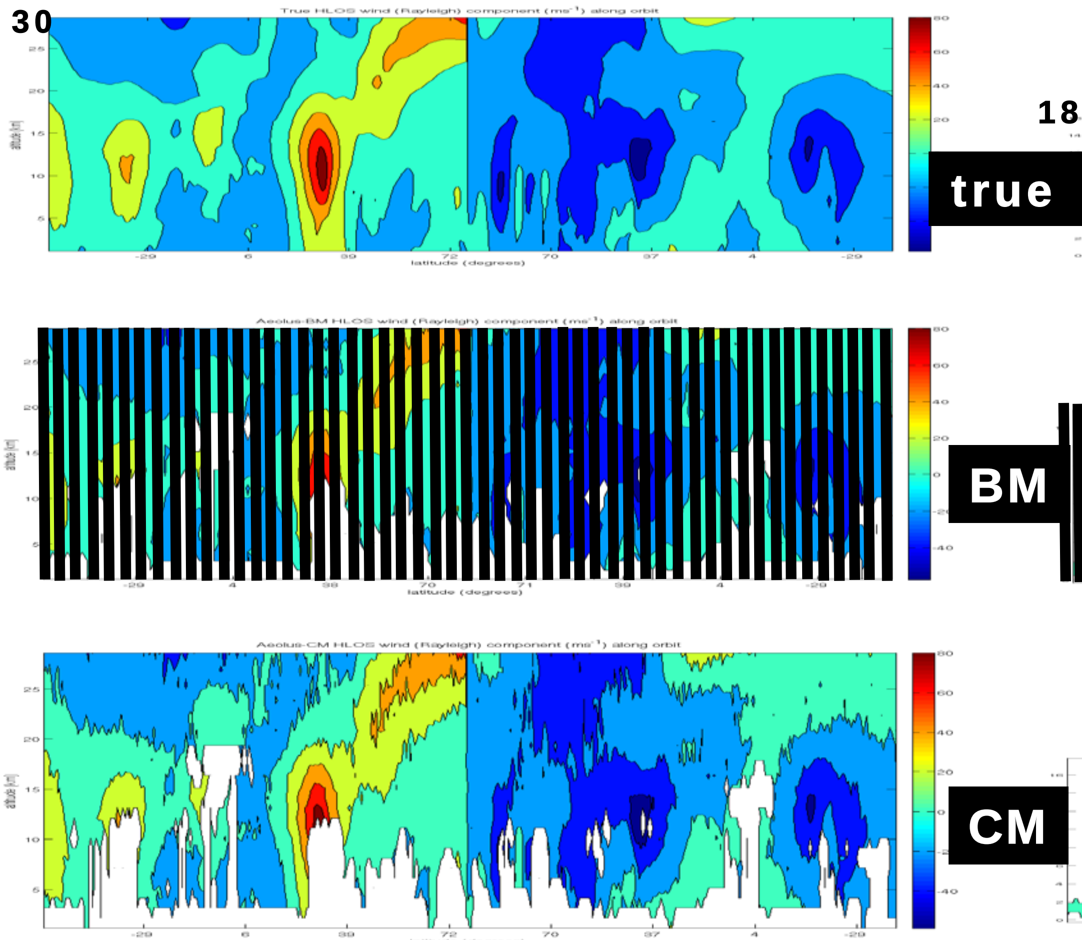
1. Recommendation on ADM-Aeolus integration and bin positioning
    a. Horizontal and vertical
    b. Input for the L2B processing
2. Assessment of Mission Impact
3. Input for revision of the MRD

Methodology:

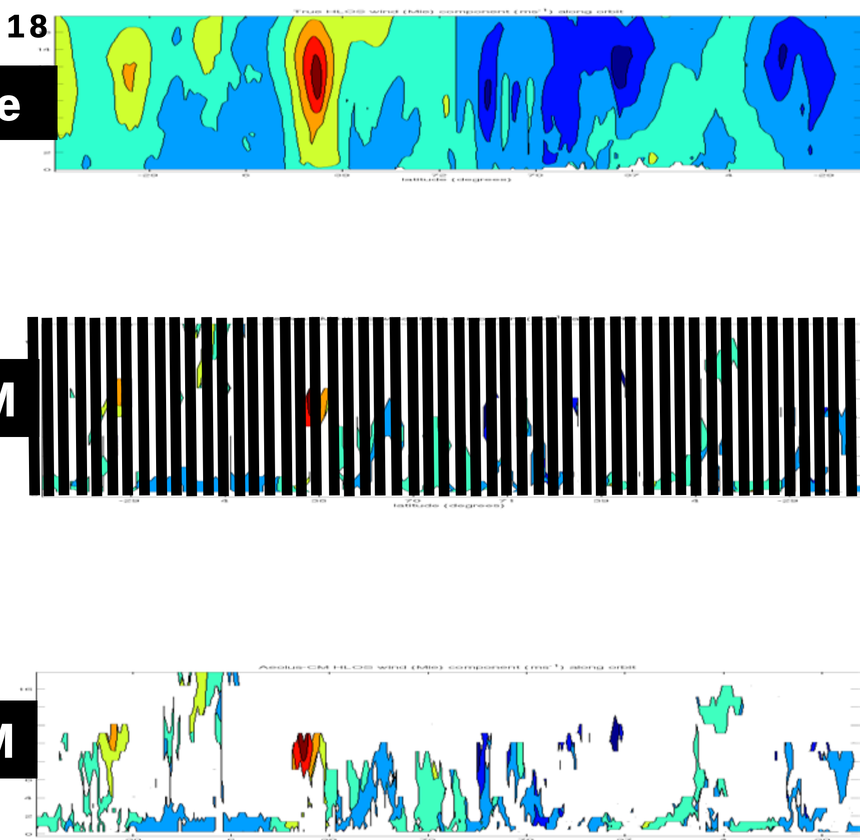
1. Establish the weather models ability to exploit wind observations
2. Establish optimal ADM-Aeolus observation size and their quality to maximize mission impact
3. Simulate such ADM-Aeolus observations and investigate impact using
    a. Simple theoretical tool
    b. Ensemble Data Assimilation System
4. Review of MRD in light of ADM-Aeolus operation concept changes

Simulated ADM-Aeolus BM/CM HLOS winds at 110 mJ (3/5)

HLOS wind (Rayleigh)



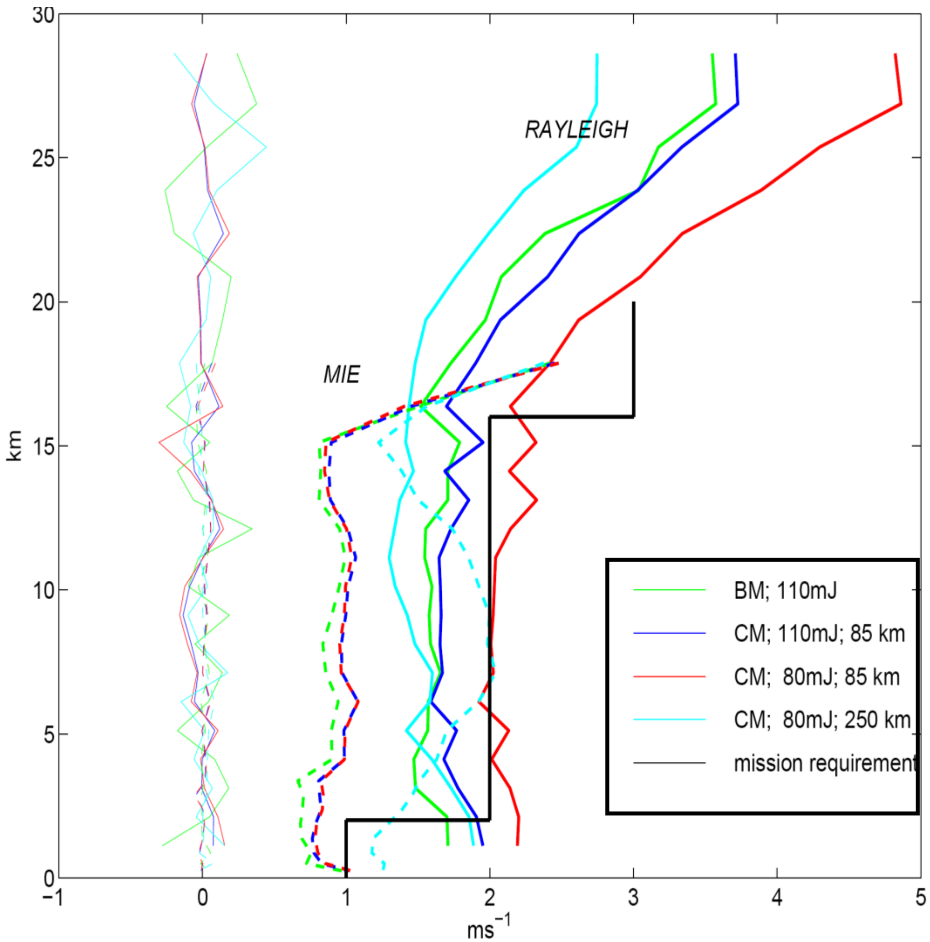
HLOS wind (Mie)



Courtesy: G.J. Marseille, KNMI

CM more noisy but larger coverage

Simulated ADM-Aeolus HLOS wind statistics over 1 month (4/5)



Courtesy: G.J. Marseille, KNMI

ADM-Aeolus HLOS bias (left thin lines) and random errors (right thick lines)

- ADM-Aeolus 110 mJ BM and 110 mJ CM random errors are very similar
- ADM-Aeolus 80 mJ CM random errors are slightly non-compliant
  - Can the MRD be relaxed?
- ADM-Aeolus 80 mJ CM observations averaged over 250 km are compliant

* **Observation size BM, one basic repeat cycle (BRC): 50 km**

** **Observation size CM, one BRC: 85 km**

*** **Observation size for additional test scenario EDA: 250 km**

Solid lines: Rayleigh (molecular) channel

Dashed lines: Mie (particle) channel

Conclusions from the theoretical study (5/5)

1. All scenarios (BM, CM 110 mJ and CM 80 mJ) gave positive analysis impact
2. 110 mJ BM operation provides fewer but less redundant observations
   - Therefore, CM at 110 mJ gives only slightly more impact than BM
3. CM operation at 80 mJ reduces analysis quality, but not dramatically
4. The results assume no observation biases (perfect calibration and no miss-pointing)
5. An unknown bias of 1 m/s clearly reduces observation impact, 0.5 m/s bias requirement is recommended
6. For uncorrelated errors, an observation averaging of 85 km seems sufficient, despite of the slightly increased random errors
7. In case of correlated representativeness errors (forecast model dependent) 130 km seems better

ECMWF Impact Study (1/3)

Objectives

1. Assessment of the expected NWP impact of CM ADM-Aeolus data compared to BM data
2. Input to ADM-Aeolus Mission Requirements Document (MRD) update on observation averaging strategy and observation accuracy
3. Perform Observing System Experiments to quantify the impact of HLOS wind data in the ECMWF Assimilation system

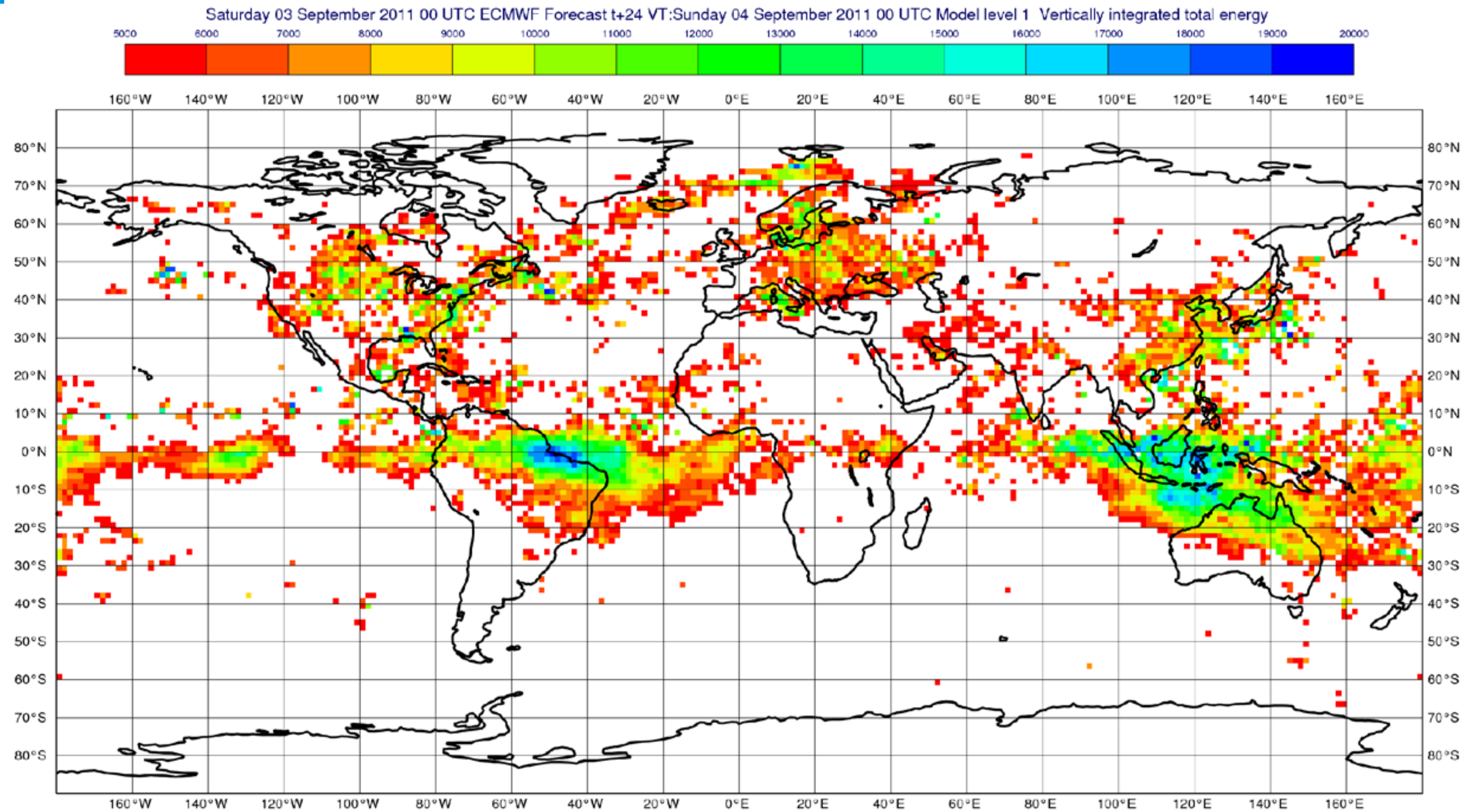
Methodology:

1. Establish the weather models ability to exploit wind observations
2. Establish optimal ADM-Aeolus observation size and their quality to maximise mission impact
3. Investigate impact of ADM-Aeolus observations using existing observations (radiosondes, aircraft, PILOTs and wind profilers)
    a. Single Observation experiment
    b. Observation Simulation Experiment
4. Review of MRD in light of proposed ADM-Aeolus operation concept changes

ECMWF Impact Study results (2/3)

1. It is not advisable to average ADM-Aeolus observations beyond 85 km
   - small-scale wind observations add more useful information despite of the higher measurement noise
2. HLOS data is most beneficial in the tropics and at high altitudes
3. CM configuration provide similar information content as the original BM configuration in terms of global NWP impact
4. Direct wind measurements are more important than temperature-derived winds, especially in the tropics and at high altitude
5. HLOS winds (one-dimensional information) provide ~75% of the value of full vector winds (two-dimensional information)
6. A slight (25%) increase in random error (corresponding to 80 mJ operation) only results in small loss of impact
7. Even small biases can be detrimental, biases should be kept below 0.5 m/s

Example of decrease in 24 hours forecast errors due to HLOS winds (3/3)



Courtesy: A. Horanyi, ECMWF

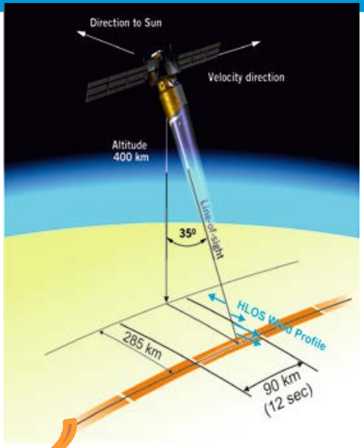
The most consistent improvements were seen in the Tropics and northern hemisphere

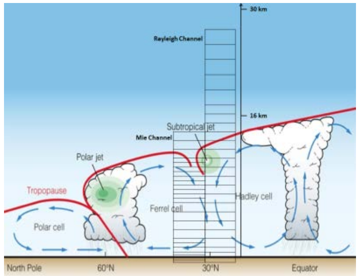
Aeolus Project status

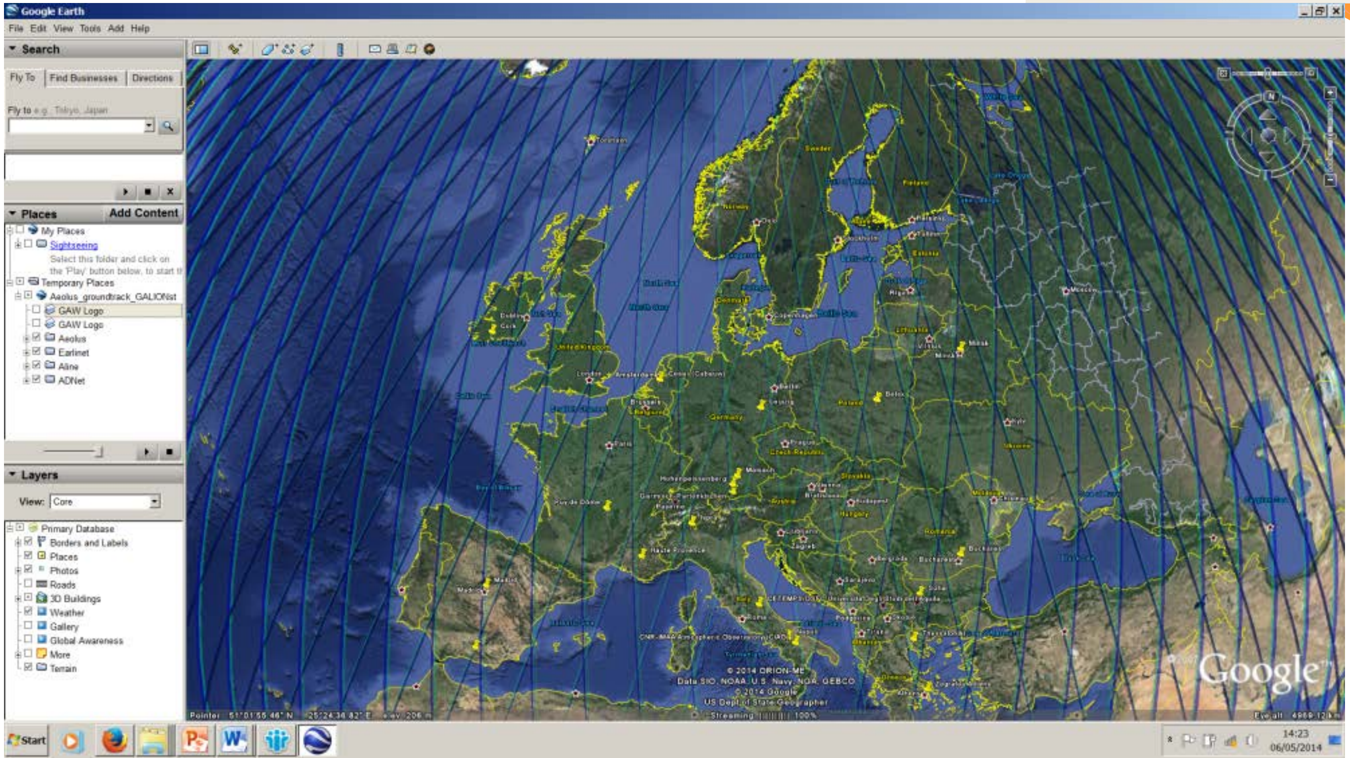
1. The platform was completed in 2009, has been regularly health checked and delta-tested, and is being prepared for satellite integration early 2015
   - In-situ Cleaning System is being implemented as a dedicated platform panel
   - Satellite tests with VEGA to determine shock levels showed compliance
   - Satellite characterization w.r.t. microvibrations by the reaction wheels: very low disturbance accelerations were measured at the laser position thanks to wheel dampers;
2. The transmitter laser is the most challenging for the qualification
   - The 1st flight laser transmitter operated for 5 weeks (August->September 2013) in vacuum: 150Mshots at 100-110 mJ output energy with ~7MHz frequency stability!
   - Transmitter successfully passed full environmental qualification in autumn 2013
   - Transmitter delivered to Airbus Defence & Space (Toulouse) for Aladin instrument integration and performance tests
   - 2nd flight laser transmitter is undergoing acceptance testing
3. Aladin instrument delivery early 2015
4. Flight Acceptance Review: November 2015

Aeolus sampling

1. Reference orbit: Equat. cros. time ascend node: 18:00 LT
2. Repeat cycle: 7 days
3. Track spacing: 285 km, no ref. ground track
4. Example orbital coverage - one repeat cycle:







European Space Agency

Prepared by
T. Kanitz

An artist's view of Aeolus in-flight

Conclusions

- The Aeolus wind lidar mission will deliver wind (suitable for data assimilation) and atmospheric optical properties products (could become suitable for NWP assimilation after R&D).
- Aeolus L1b wind profiles (not corrected for temperature and pressure effects and no scene classification) will be delivered NRT together with a stand-alone processor.
- Impact studies has shown that recent measurement baseline updates will still allow for significant mission impact.

Thank you so far