The ESA ADM-Aeolus Doppler Wind Lidar Mission – Status and validation strategy

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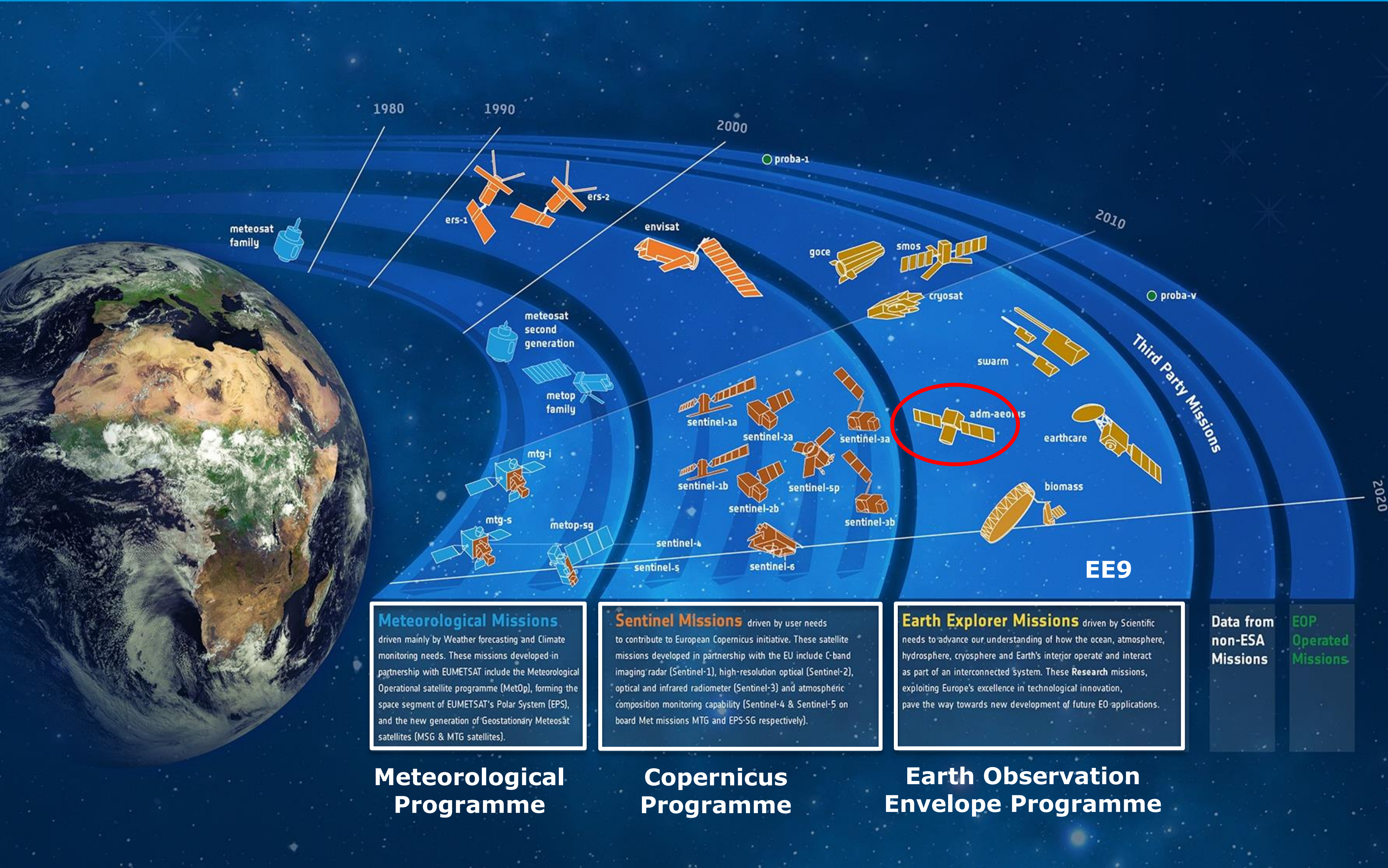
ECMWF/ESA Workshop: Tropical modelling, observations and assimilation

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

ADM-Aeolus teams

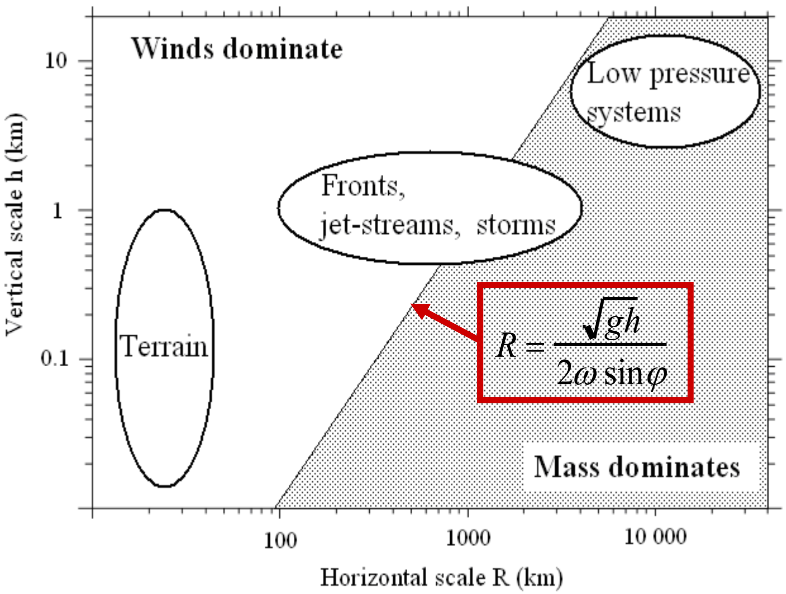
- ADM-Aeolus Project team
- Airbus Defence and Space & partners
- Mission science and campaigns team
- Ground Segment and data quality teams
- Flight Operations Team
- Aeolus Mission Advisory Group
- L1 and L2 algorithm development teams (DLR, DoRIT, ECMWF, KNMI, MeteoFrance)
- Campaign and CAL/VAL teams
- …

ESA's Earth Observation Programme



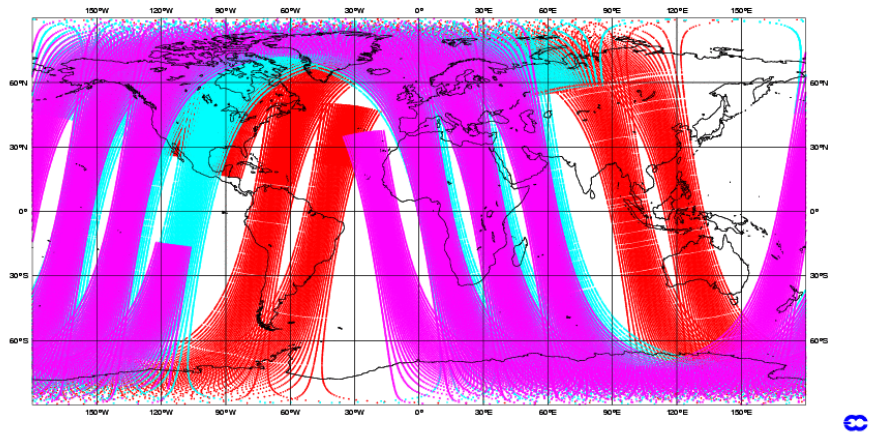
The importance of global direct wind observations

ROSSBY RADIUS OF DEFORMATION

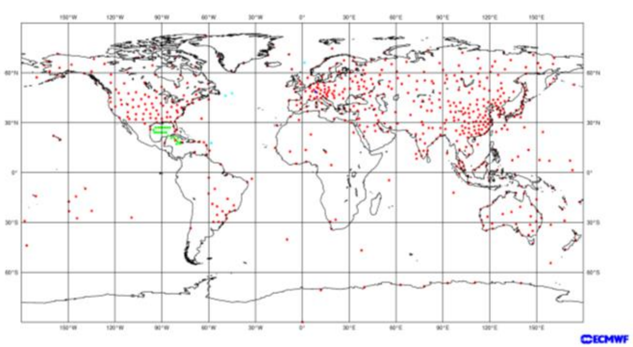


g: gravitational acceleration, h: structure depth, ω: angular velocity of Earth's rotation, φ: latitude (here 45°)

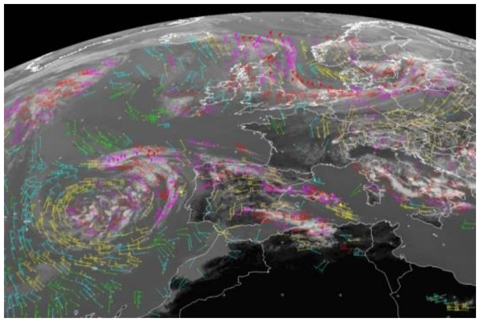
Global temperature soundings



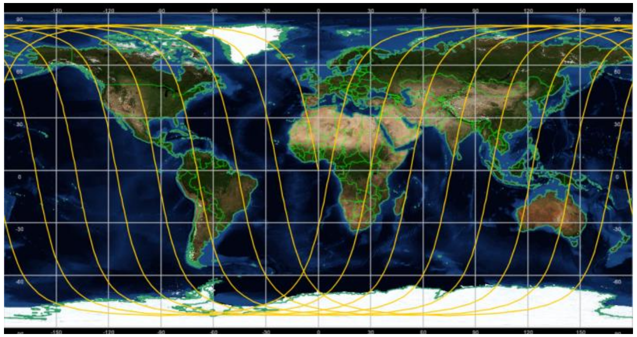
Radiosondes



AMVs



Aeolus 12 h sampling



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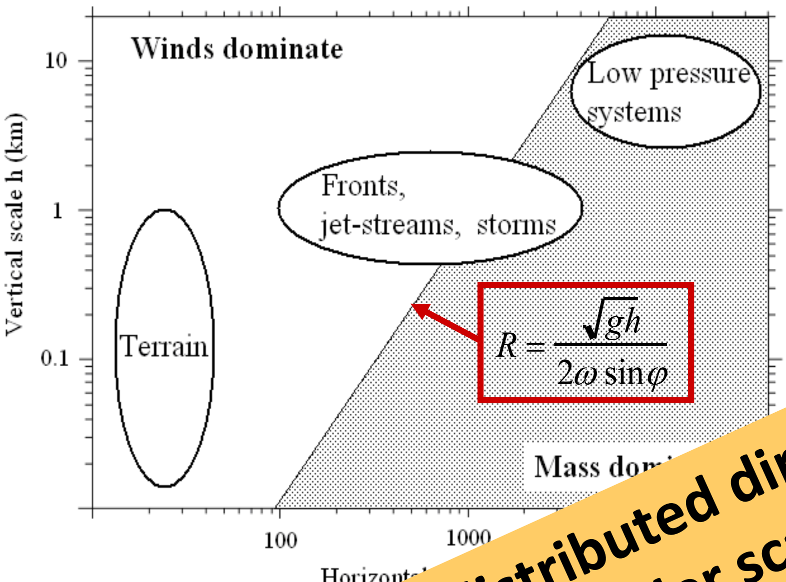
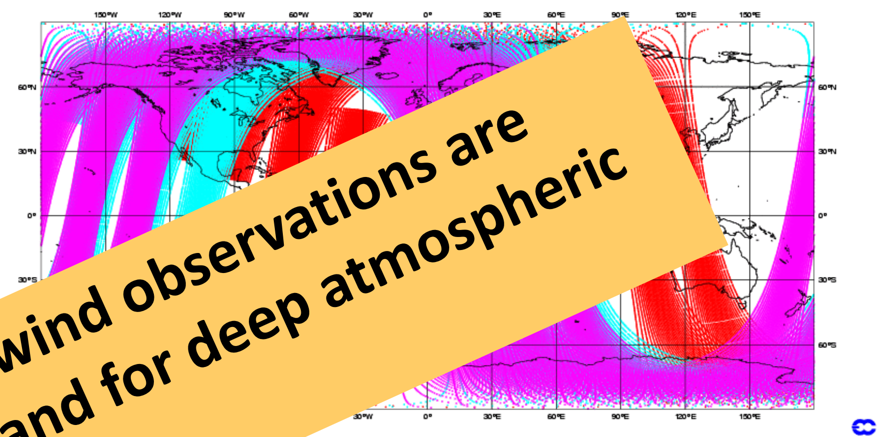
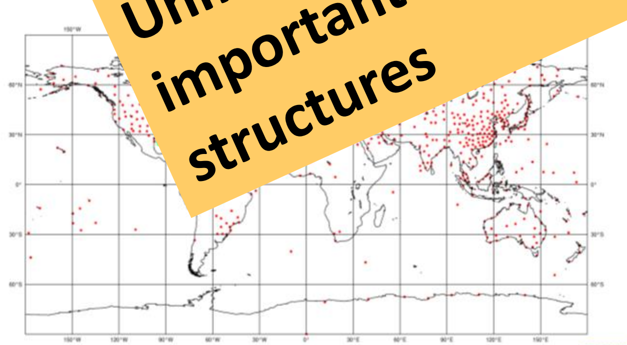


g: gravitational accelerati…
velocity of Earth’s r…

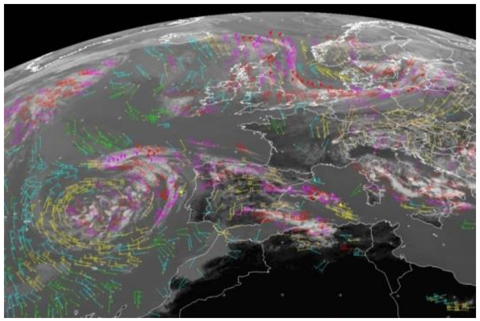
Global temperature soundings



Uniformly distributed direct wind observations are important at smaller scales and for deep atmospheric structures



AMVs



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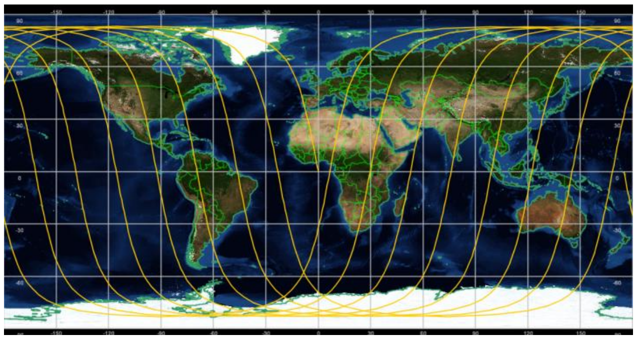


ADM-Aeolus Mission Objectives

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.

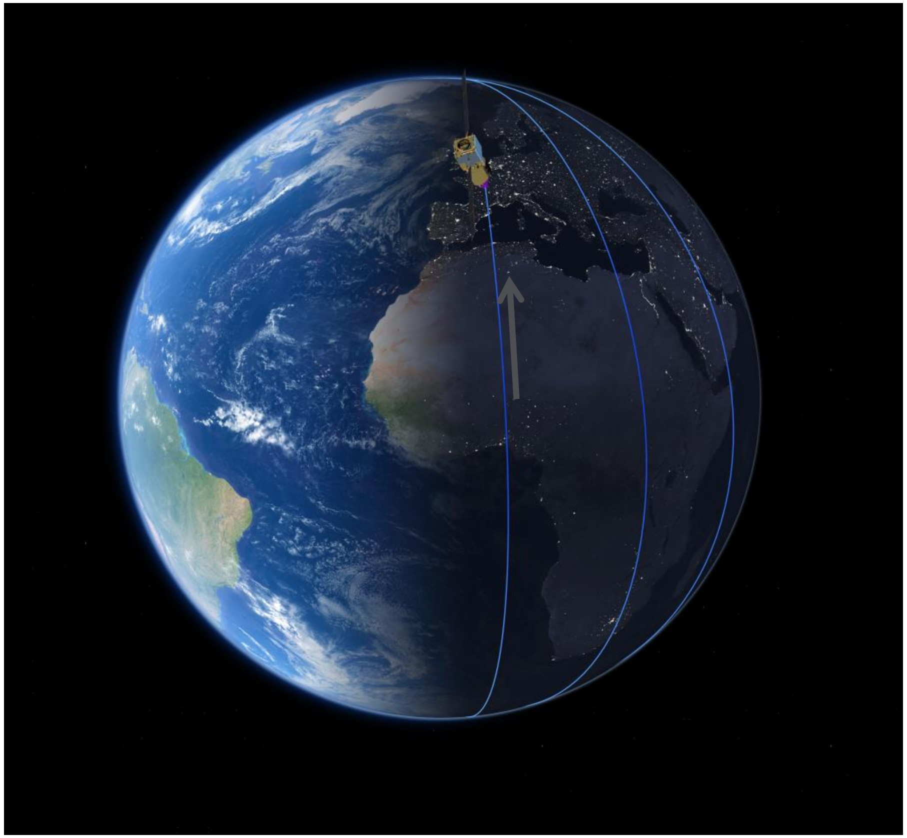
Observation means:

- Provide global measurements of horizontal wind profiles in the troposphere and lower stratosphere

Payload

- ALADIN: Atmospheric LAser Doppler INstrument

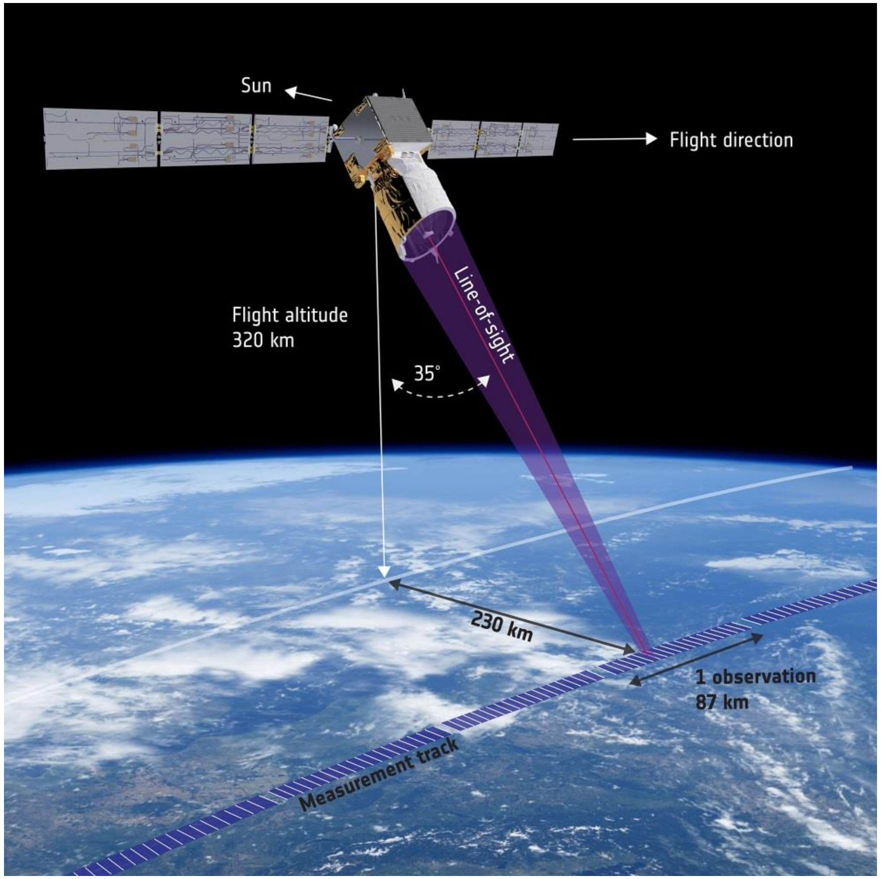
Mission characteristics



Mission Parameters

- Orbit: sun-synchronous
- Mean altitude: ~320 km
- Local time: 18:00 ascending node
- Inclination: 96.97°
- Repeat cycle: 7 days / 111 orbits
- Orbits per day: ~16

ADM-Aeolus Measurement Principle



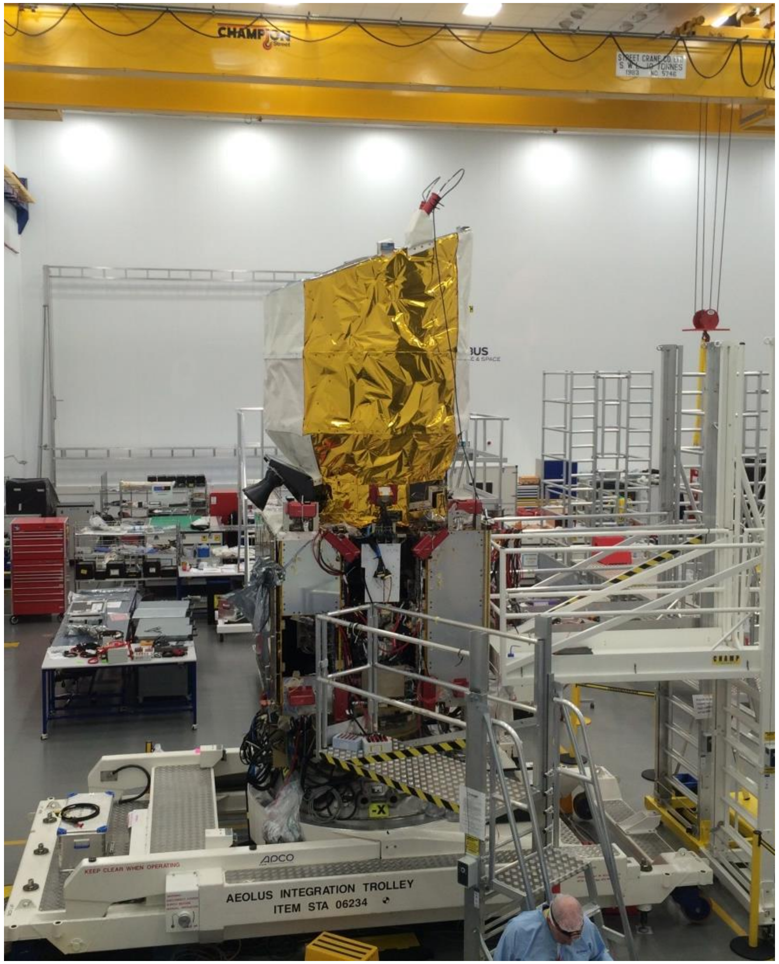
- UV Doppler wind Lidar operating at 355 nm and 50 Hz PRF in continuous mode, with 2 receiver channels (HSRL):
  - Mie receiver (aerosol & cloud backscatter)
  - Rayleigh receiver (molecular backscatter)
- The line-of-sight is pointing 35º from nadir to derive horizontal wind component
- The line-of-sight is pointing orthogonal to the ground track velocity
- Horizontal averaging (on board and on ground)
- Spacecraft regularly pointed to nadir for calibration

Instrument Status

1. Instrument Full Functional Performance Test (IFP) April 2016
    a. End-to-end testing in ambient conditions
    b. Random errors extrapolated from tests within 5% of expectations
    c. Bias requirements met
    d. Detailed correlation analysis confirm this in finalization

2. Instrument delivery: August 2016

3. Integration on platform: October 2016



Mission status

1. Instrument has been integrated on the platform
2. Testing of instrument on platform: April 2017
3. **Satellite launch readiness: October 2017**
4. Launch: at the earliest 6 weeks thereafter
5. Commissioning phase: L – L+3 months
6. **Operational Phase: L+3 months – 3 years**

Mission products

1. Primary product (L2b):

Horizontally projected LOS (HLOS) wind profiles

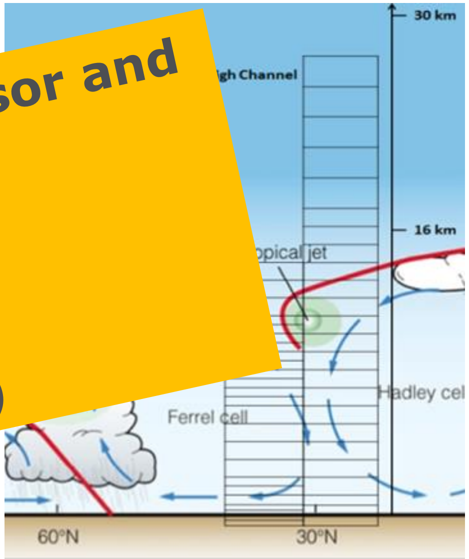
- Approximately zonal at dawn/dusk (6 am/pm)
- ~85 km horizontal integration – scene classified
- 24 vertical layers, 0-30 km altitude
- σ: 1-2(PBL), 2(Trop), 3-5 (Strat) m/s
- Bias: < 0.7 m/s
- **L2c product:**

2.

…om 3 km subsamples

…uce:

- …rosol cover/stratification
- Cloud/aerosol top heights
- Cloud/aerosol base height (optically thin)

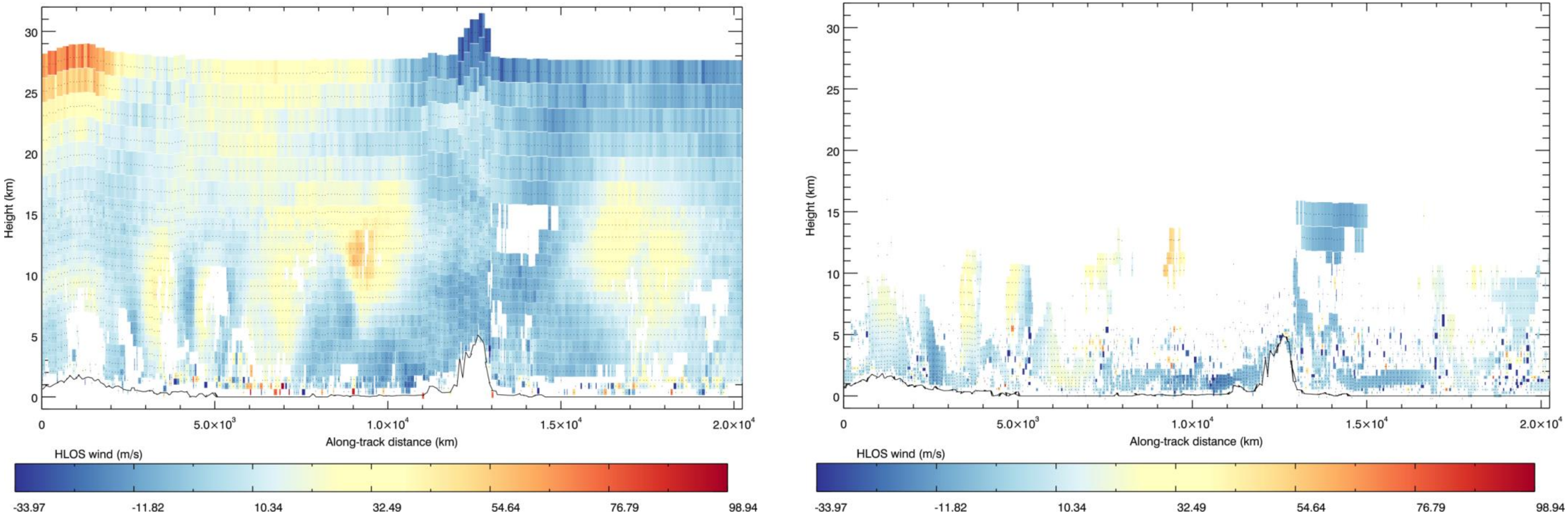


Aeolus L1b product available NRT + L2b processor and BUFR convertor from ECMWF

ESA EE binary format, L2b BUFR conversion

Aeolus L2a product available NRT (EE format)

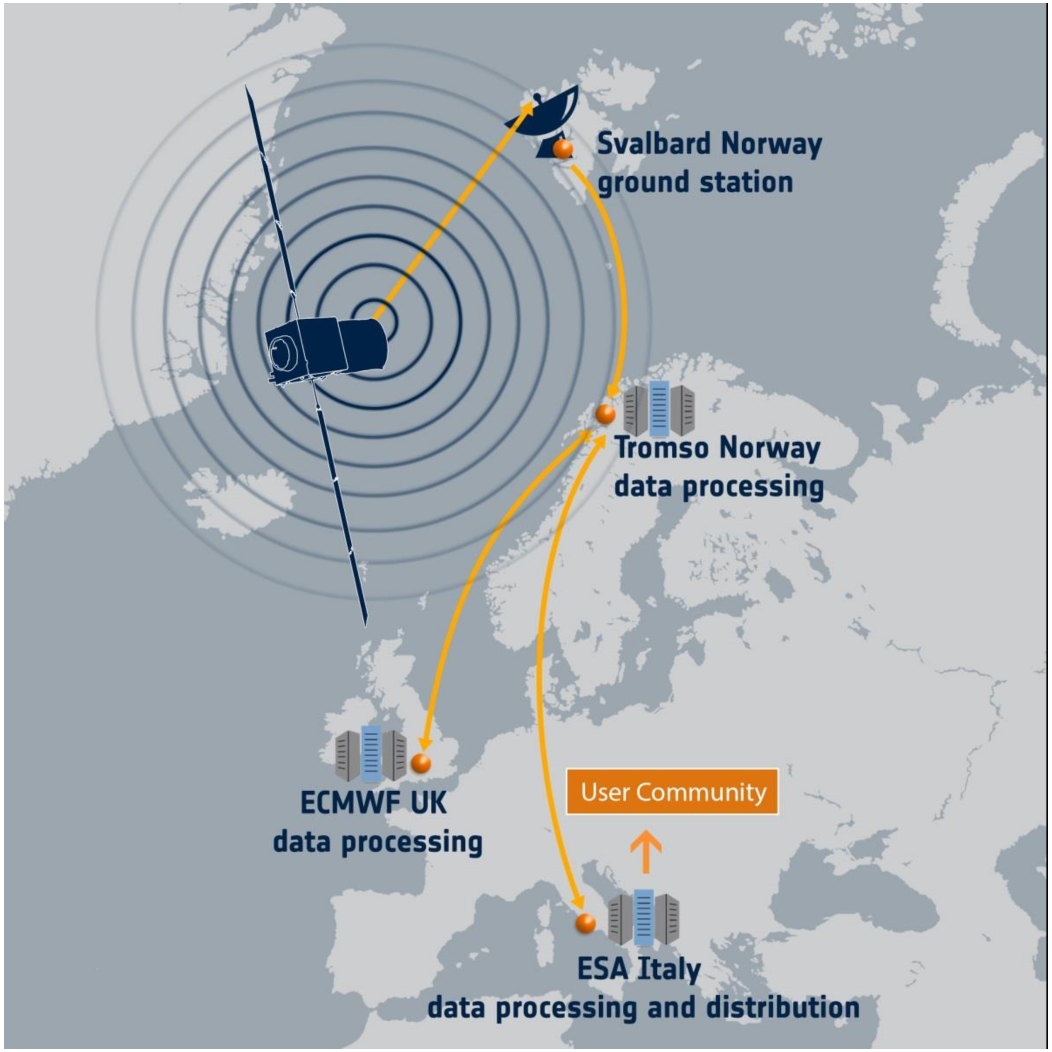
Simulated Aeolus Rayleigh (left) and Mie (right) winds



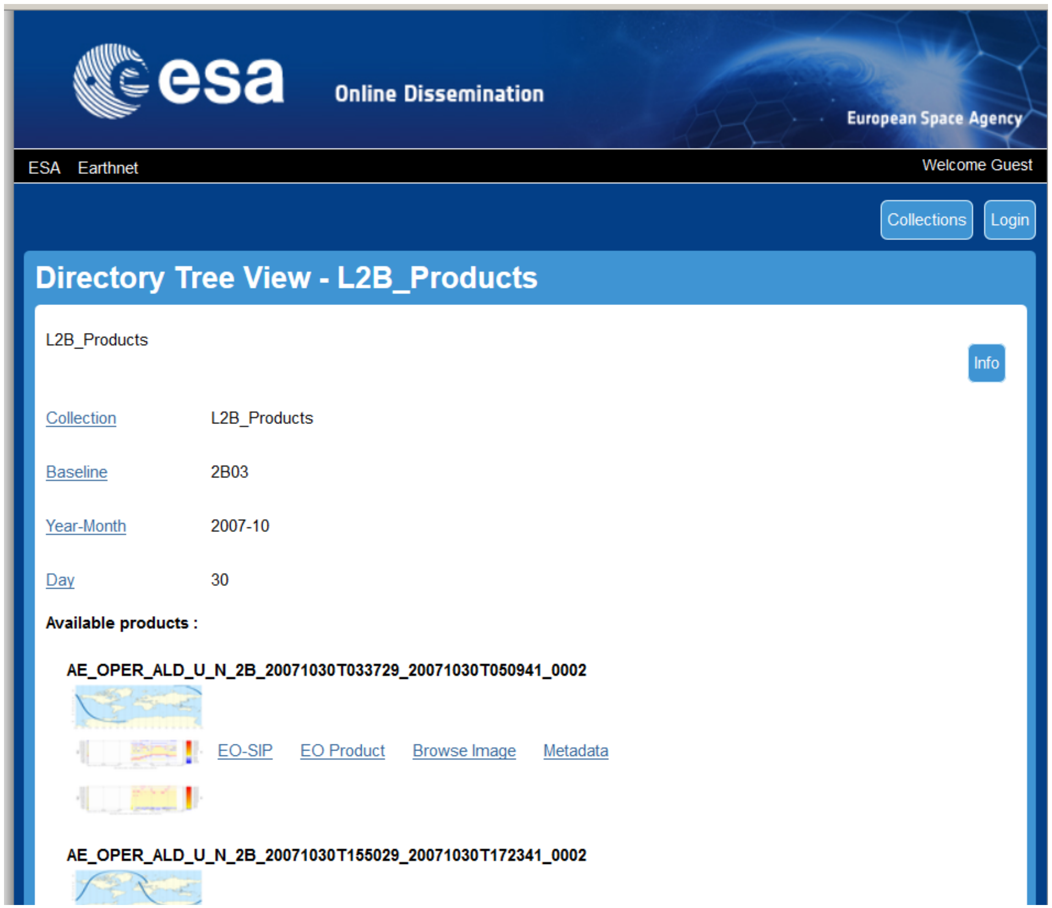
Courtesy Michael Rennie, ECMWF

(L2B processor development: KNMI & ECMWF)

Data processing and distribution



Data access portal



http://aeolus-ref-addf.eo.esa.int/addf/

In orbit instrument and product verification and validation

1. Satellite and Instrument verification by industry

2. Verification of ESA data processing and operation is done by
   a. Flight Operation teams
   b. Payload Data Ground Segment teams
   c. Algorithm core team with L1 and L2 data processing experts at DLR, MeteoFrance, KNMI and ECMWF
   d. L2 processing centre at ECMWF including NWP monitoring

3. Product verification with international science teams
   a. Collocated observations
   b. Modelling
   c. Science

ADM-Aeolus: Observational Requirements
Winds only!

		PBL	Troposphere	Stratosphere
Vertical domain	[km]	0-2	2-16	16-20 (30)*
Vertical resolution	[km]	0.5	1.0	2.0
Horizontal domain		Global		
Number of profiles	[hour^{-1}]	>100		
Horizontal track data availability		> 95%		
Temporal sampling	[hour]	12		
Horizontal resolution / integration	[km]	15 (goal) – 100 (threshold)		
Horizontal sub-sample length	[km]	3 km		
Random error (HLOS Component)	[m/s]	1	2.5	3 (3-5)**
Systematic error (HLOS component)	[m/s]	0.7	0.7	0.7
Dynamic Range, HLOS	[m/s]	±100 (150)*		
Error Correlation over 100 km		< 0.1		
Probability of Gross Error	[%]	5		
Timeliness	[hour]	3		
Length of Observation Dataset	[yr]	3		

()*: Desirable / Implemented
()**: corresp. to 20-30 km.a.s

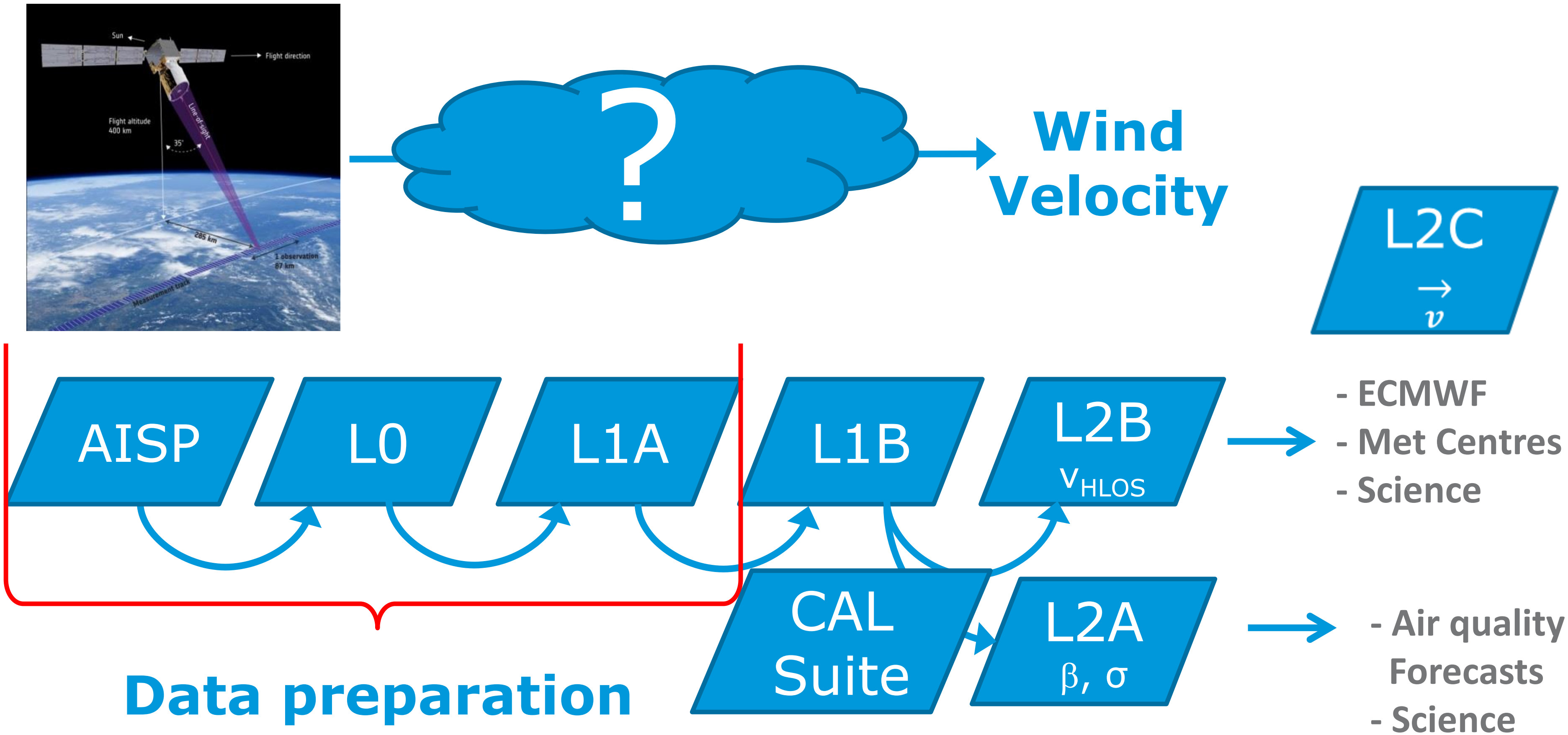
Aeolus Scientific CAL/VAL Requirements

1. Aeolus CAL/VAL Requirements to be addressed by ESA and science teams
2. **Goal: Verification of Mission Requirements (L2)**
3. Recommendations for definition of CAL/VAL techniques
4. Identification of areas covered by CAL/VAL proposals
5. Guidelines for CAL/VAL proposal review process
6. Guidelines for CAL/VAL Implementation Plan

Aeolus Scientific CAL/VAL Requirements document

1. Definitions
2. What is needed for Wind and Aerosol / Cloud product validation:
    a. Understanding product properties
    b. Product requirements
    c. Areas of special attention:
        – Sampling, error properties, product information content (instrument capability), validation activity grouping
    d. Instrumentation and modelling needs
    e. Comparing data from different instruments and spatial/temporal sampling
        – Instrument characteristics (accuracy, information content)
        – Atmospheric heterogeneities
3. Novel data products (e.g. surface reflectivity)
4. Campaign coordination

Data Processing



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Mission Requirements

		PBL	Troposphere	Stratosphere
Vertical domain	**[km]**	**0-2**	**2-16**	**16-20 (30)***
Vertical resolution	**[km]**	**0.5**	**1.0**	**2.0**
Horizontal domain		**Global**		
Number of profiles	**[$hour^{-1}$]**	**>100**		
Horizontal track data availability		**> 90%**		
Temporal sampling	**[hour]**	**12**		
Horizontal resolution / integration	**[km]**	**15 (target) – 100 (threshold)**		
Horizontal sub-sample length	**[km]**	**km scale**		
Random error (HLOS Component)	**[m/s]**	**1**	**2.5**	**3***
Systematic error (HLOS component)	**[m/s]**	**0.7**	**0.7**	**0.7**
Dynamic Range, HLOS	**[m/s]**	**±150**		
Error Correlation over 100 km		**< 0.1**		
Probability of Gross Error	**[%]**	**5**		
Timeliness	**[hour]**	**3**		
Length of Observation Dataset	**[yr]**	**3**		

** Requirements are given from 0 to 20 km altitude, but measurements up to 30 km are highly desirable. A relaxed requirement for accuracy is acceptable between 20 and 30 km*

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Areas deserving special attention by CAL/VAL

Aeolus sampling:

a. Horizontal sampling: 3 km (measurement scale) – 87 km (observation scale)

b. 250 m, 500 km (PBL), 1 km (FT), 2 km (Stratosph)

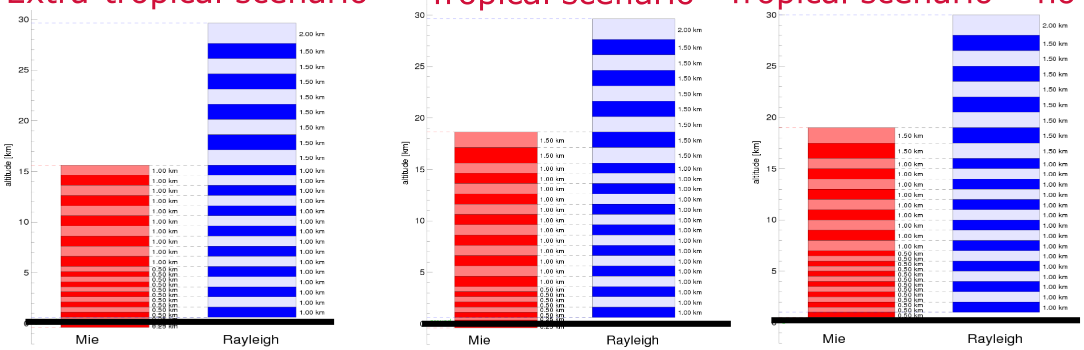
c. Terrain model

d. Optimization of Aeolus vertical sampling

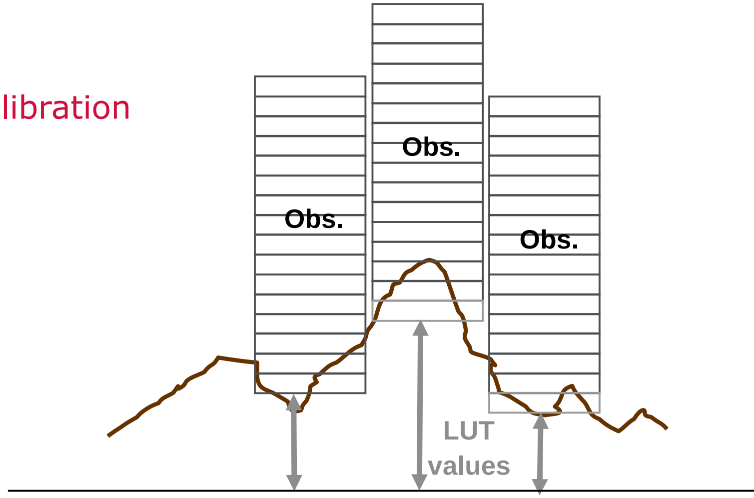
   – Change in sampling strategy up to 8 times per orbit

e. Measurement representativity and error characteristics must be taken into account

Extra-tropical scenario | Tropical scenario | Tropical scenario – no calibration



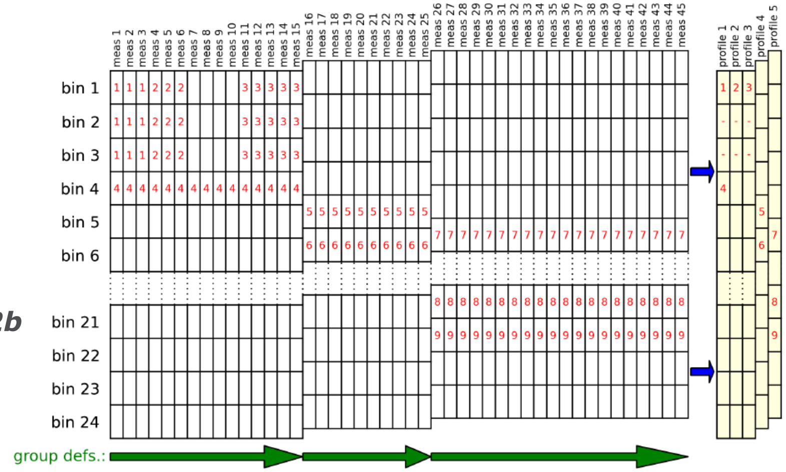
Courtesy, G.J. Marseille

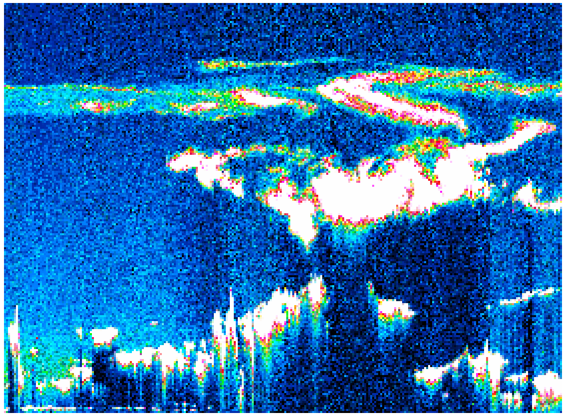


Aeolus wind/aerosol quality as function of scene

1. **Product accuracy and representativity will depend on**
   a. Scene heterogeneity (wind and particle variability)
      – Signal averaging length
      – Channel cross-talk correction (HSRL system: Mie signal contaminating Rayleigh signal)
   b. Instrument and data processing errors (next slide)

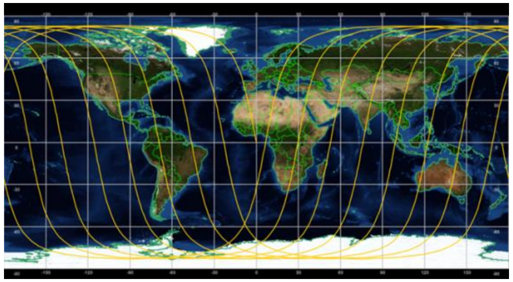
Sketch of Aeolus L2b measurement accumulation, Courtesy J. de Kloe

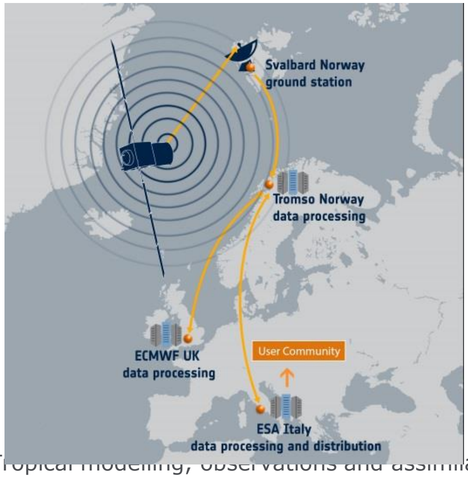




LITE image of multilayer clouds, courtesy NASA

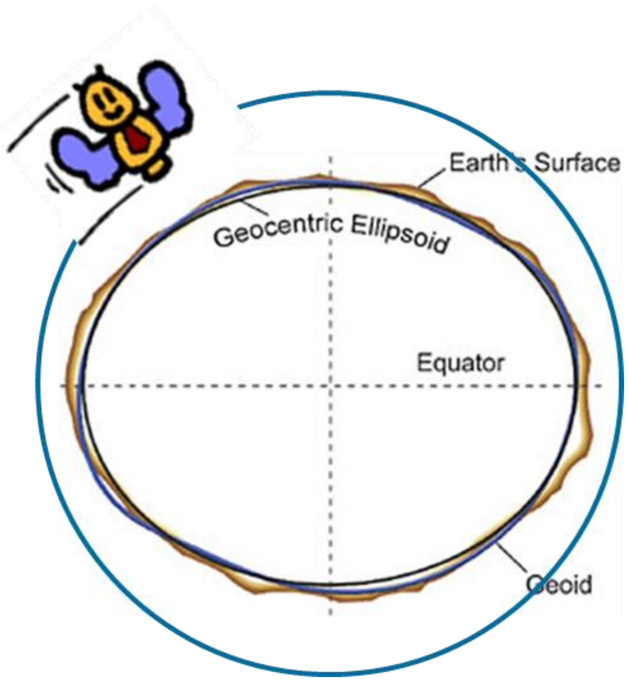
Examples of ADM-Aeolus error sources





1. **Instrument errors**
   a. Instrument alignment and transmission
   b. Spectrometer imperfections
   c. Instrument degradation and laser stability, …
2. **Satellite / orbit related errors**
   a. Harmonic biases from thermal variability
   b. Range dependent biases
   c. Pointing stability, …
3. **L1 (and lower) processing errors**
   a. Calibration
   b. Signal processing and QC
   c. EQ, …
4. **L2 processing errors**
   a. *A-priori* T and p (ECMWF)
   b. Calibration, signal processing and QC …
   c. EQ, …

Examples of spatially varying error sources



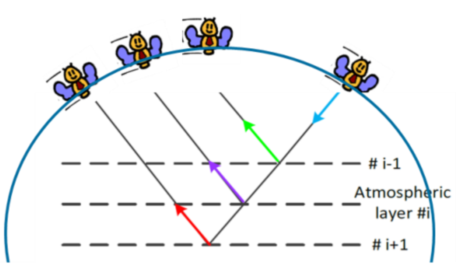
1. **Orbit phase dependent wind biases**:
   a. **Thermo-elastic** - solar aspect angle
   b. **Thermo-elastic** effects thermal fluxes
   c. **Satellite altitude** (harmonic range-dependent biases)

   Harmonic bias correction scheme implemented using ground returns and error fitting through harmonic functions

2. **Range-dependent wind bias**
   a. Variable backscatter angle on telescope as function of range (time)

   Range Dependent correction scheme being implemented

3. **Regional T and p accuracy variations**



Aeolus wind/aerosol quality as function of scene

1. **Product accuracy and representativity will depend on:**
   a. Scene heterogeneity (wind and particle variability)
      – Signal averaging length
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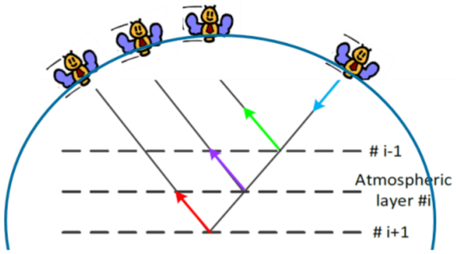
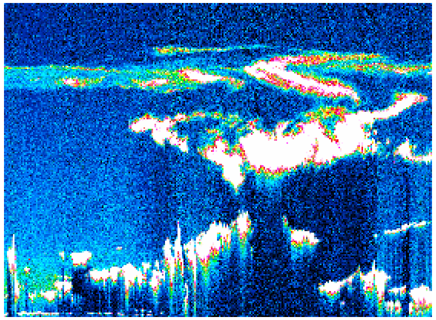
   b. Instrument and data processing errors
   c. Error correlation



Range-dependent biases



Laser frequency jitter

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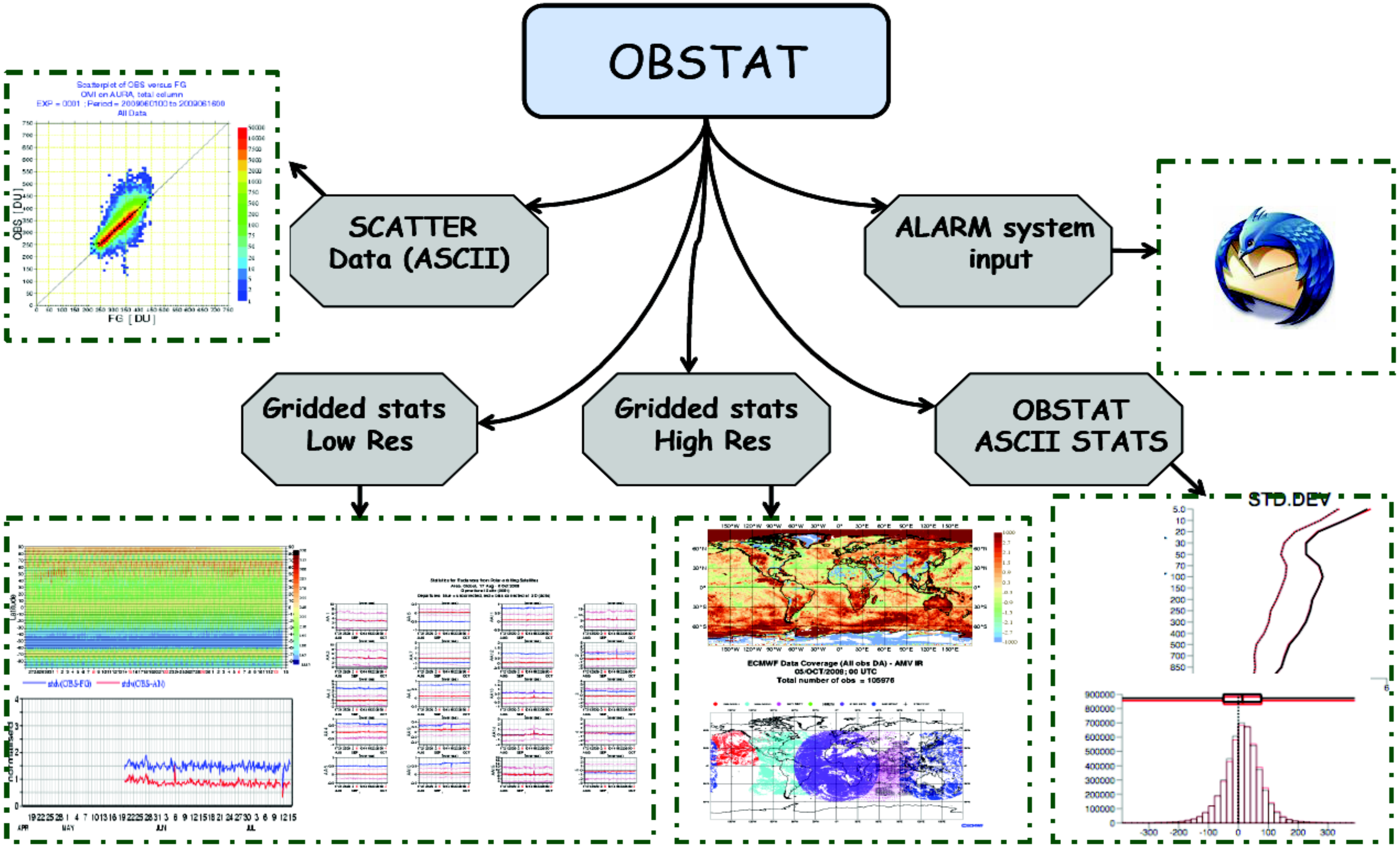
4. Campaign coordination

Instrument and modelling needs

1. Pre-launch campaigns for
    a. Instrument characterization, algorithm preparation, calibration

2. Post-launch CAL/VAL:
    a. Airborne (wind, aerosol, temperature, …)
    b. Ground-based (radiosondes, lidars, profilers, …)
    c. Satellite-to-satellite (CALIPSO, scatterometers, AMVs, …)
    d. NWP monitoring
    e. Aerosol transport models / air quality models
    f. Back trajectories
    g. Algorithm intercomparison

Example of planned NWP monitoring of Aeolus at ECMWF



Some examples of OBSTAT output
Courtesy Mohamed Dahoui (ECMWF)

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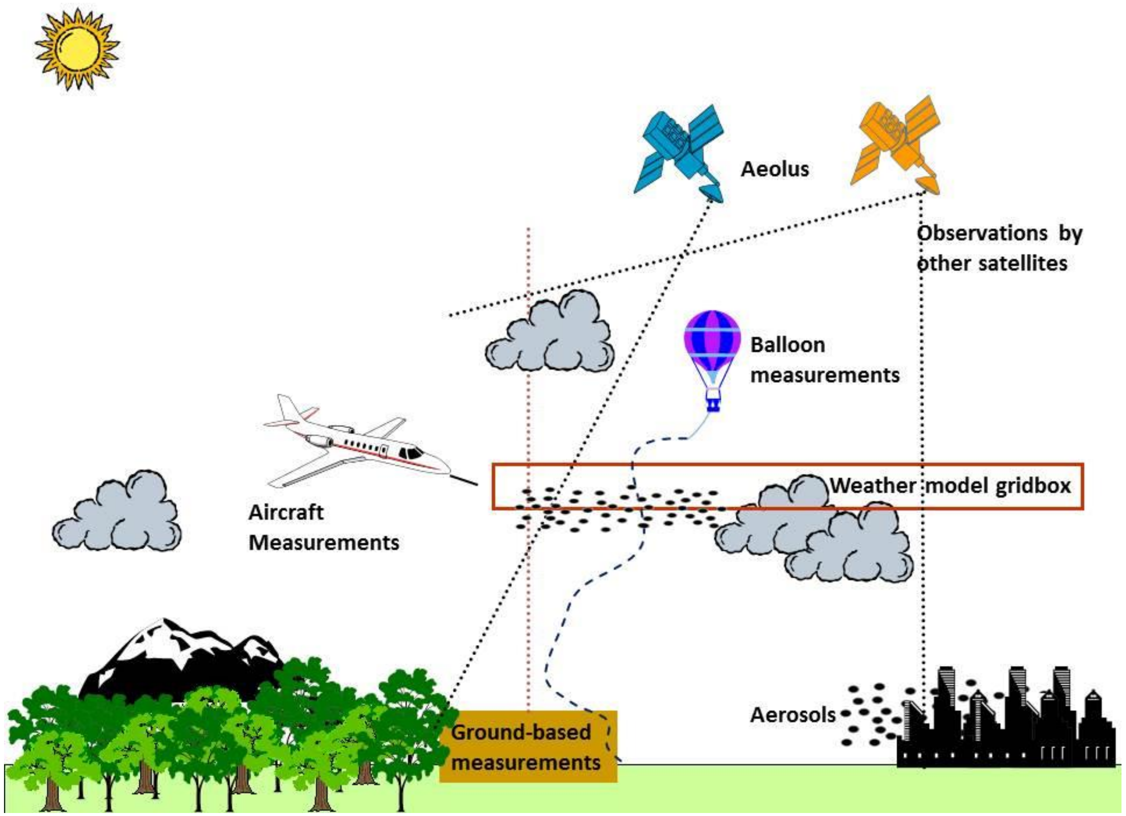
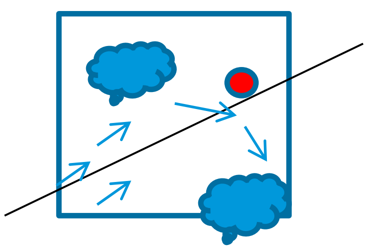
Comparisons with collocated instrumentation

1. Sampling of different atmospheric volumes
2. Temporal variability
3. Spatial variability
   a. Vertical
   b. Horizontal
4. Different instrument accuracy and product information content
   a. e.g. CALIPSO and Aeolus extinction profile information content differ!





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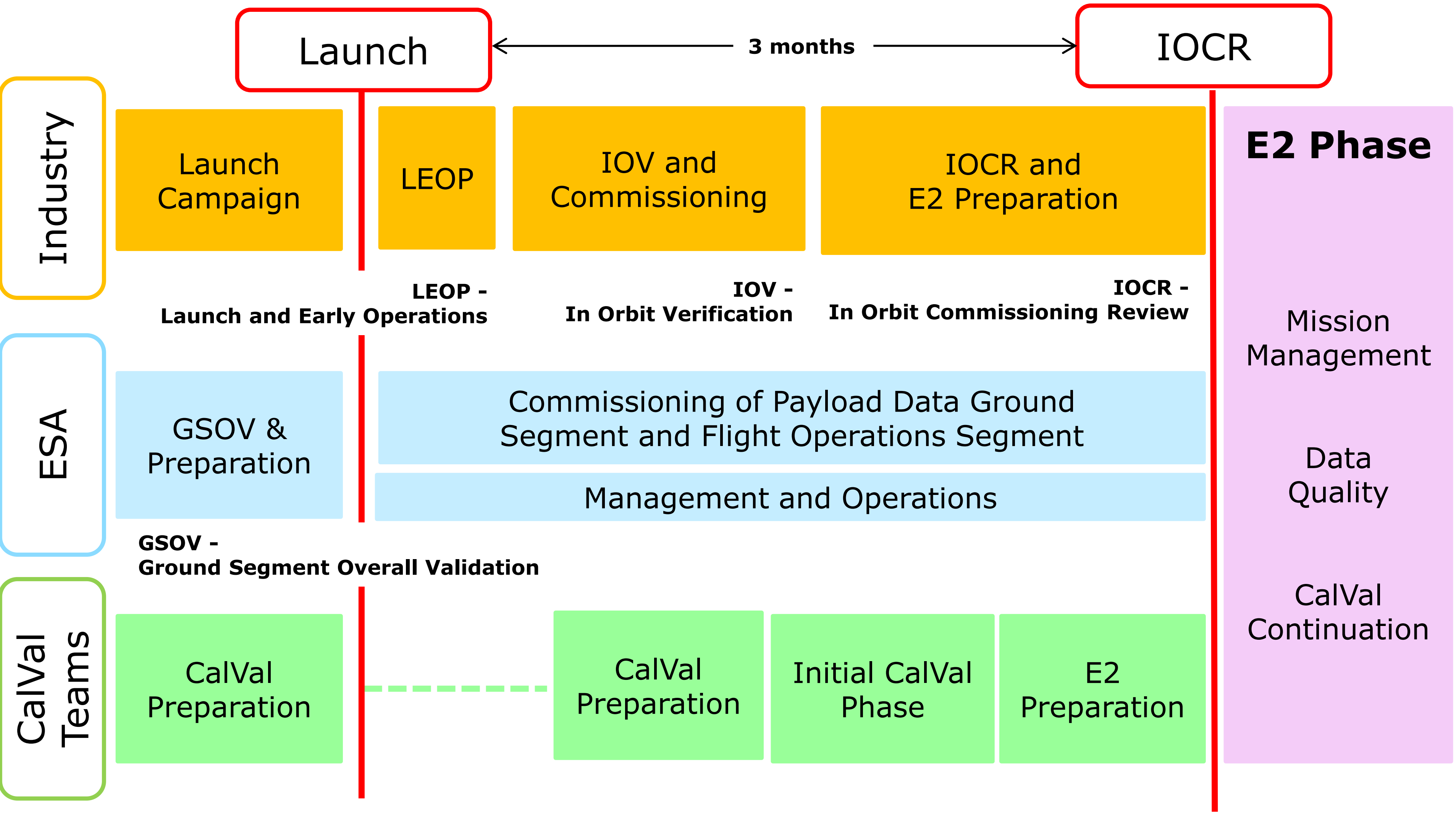
Aeolus Commissioning and Operational activities



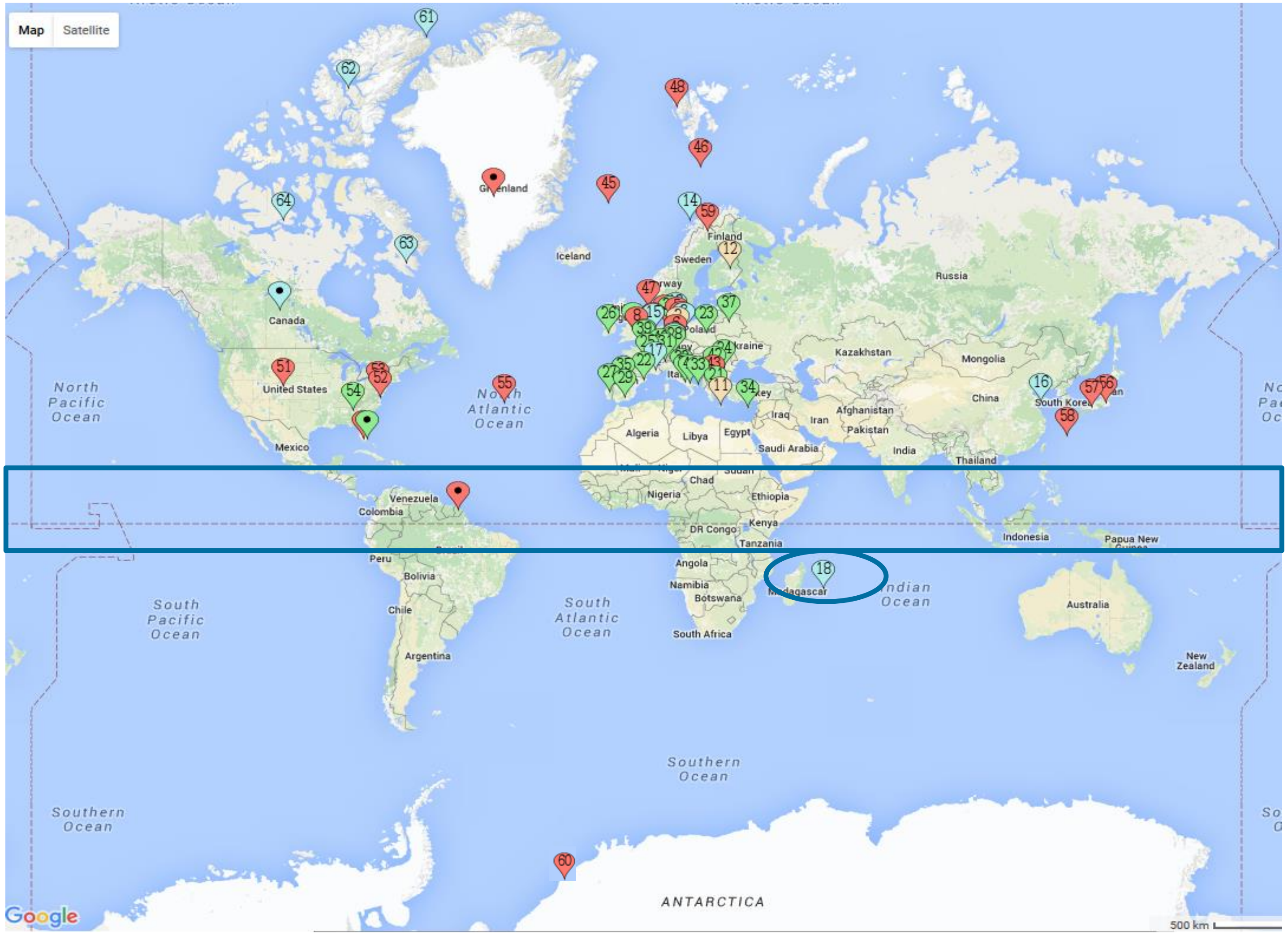
CAL/VAL Team organization (non-ESA)

Team / Role	Function	Name	Organization
Phase C/D Industrial Team	spacecraft and payload development and expert team	...	ADS-Astrium
Algorithm Core teams	L1B/2A/2B algorithm development, validation expert team	...	DLR, ECMWF, KNMI, MétéoFrance
ECMWF Operations Team	L2bP MetPF team	...	ECMWF
CAL/VAL Core Team	CalVal expert team, in charge of specific calibration, characterization and optimization tasks	...	DLR A2D Team, ...
AO Team 1	CAL/VAL Teams - modelling	...	...
AO Team 2	CAL/VAL Team ...		
AO Team X	...	...	...

CAL/VAL Implementation Plan

1. Objective
2. Mission
3. Products, requirements, information content,
4. CAL/VAL requirements, lessons learnt pre-launch
5. CAL/VAL Proposals
    a. Summary, expected innovation and results, data
    b. Mission phase
    c. Mapping to Commissioning and CAL/VAL Plan (Gaps)
    d. Status assessment
6. CAL/VAL coordination
7. Links to other missions/campaigns
8. Exchange of results, tools, etc.

Geographical coverage CAL/VAL proposals



Conclusions

1. ADM-Aeolus selected in response to identified deficiency in the Global Observing System on global coverage of direct wind profile observations

2. ADM-Aeolus will serve Numerical Weather Prediction and Air Quality Forecasting and support Climate Modelling (verification, parameterizations)

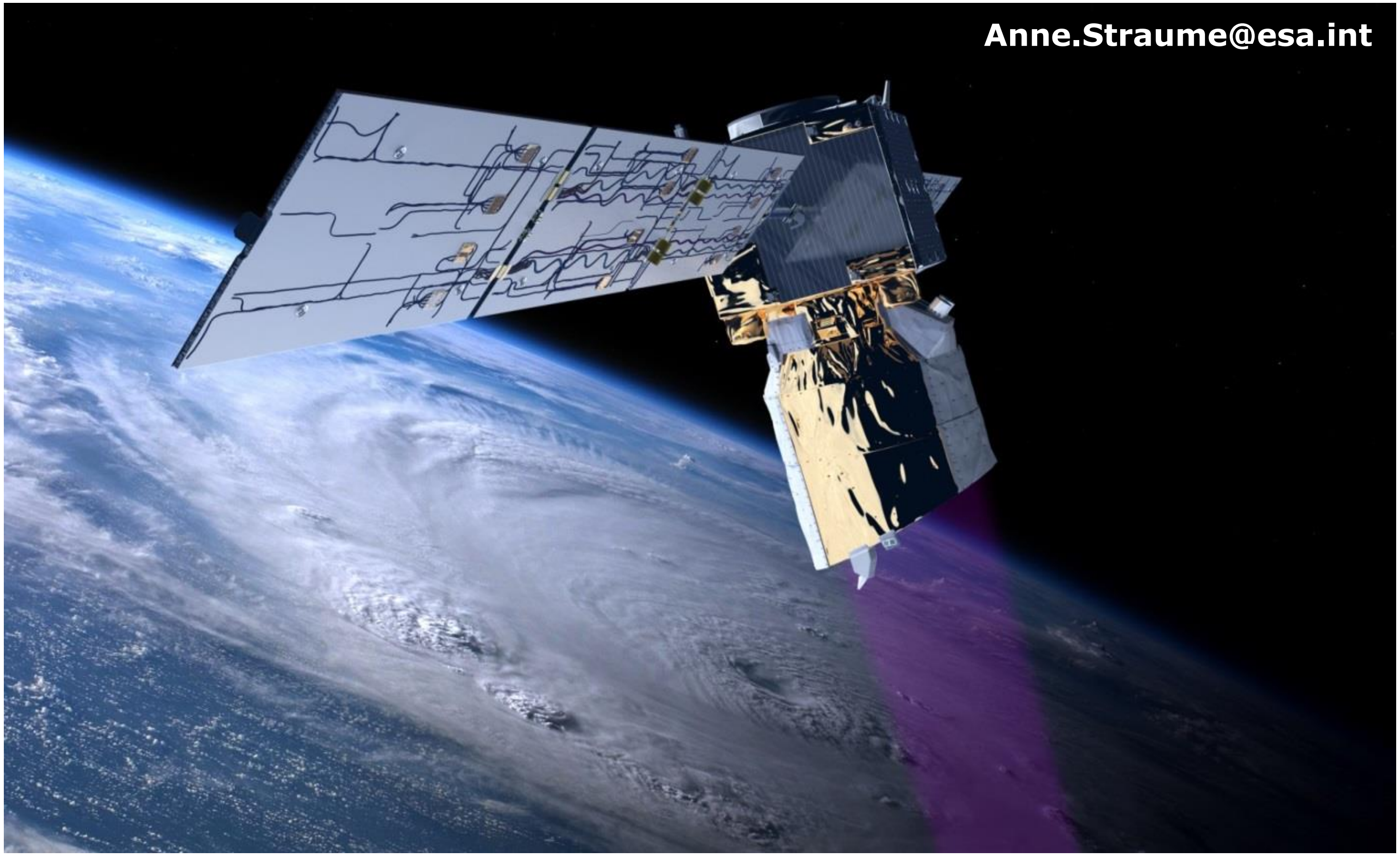
3. ECMWF Product Monitoring

4. 17 (inter-) national CAL/VAL teams are getting ready to validate and exploit ADM-Aeolus data

5. Aeolus CAL/VAL Rehearsal Workshop March 28-30 2017, Toulouse

6. ADM-Aeolus launch readiness: 4th quarter 2017

7. ADM-Aeolus L1 and L2 data availability to science community expected 3-5 months after launch



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