Aerosol and cloud related products by ESA's Aeolus mission

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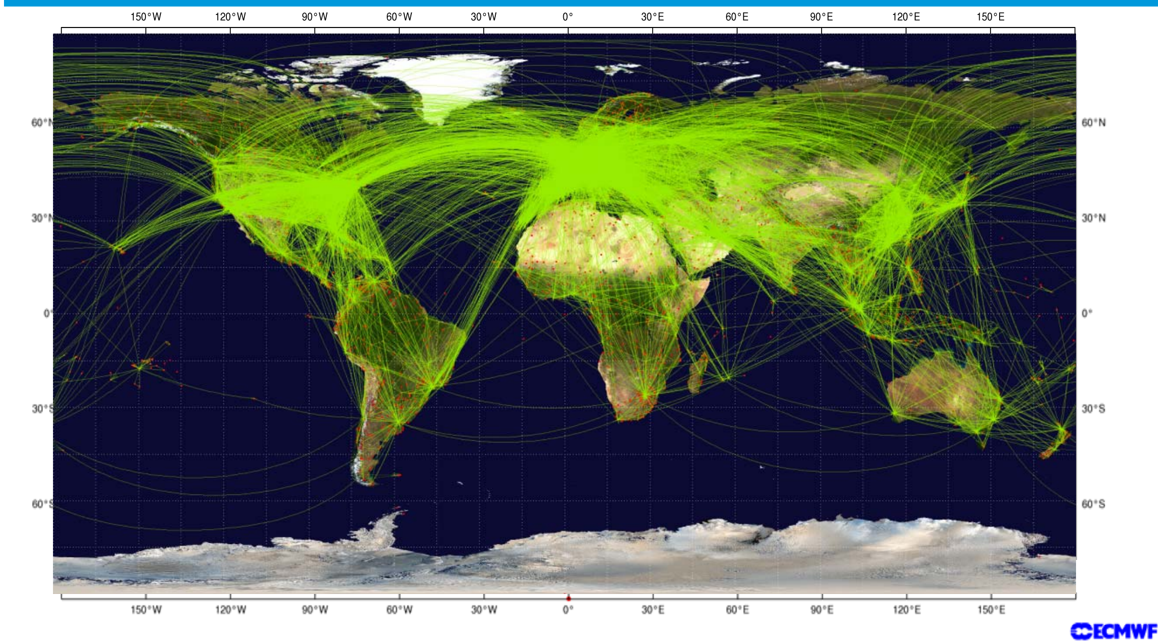
Overview

1. Motivation for ESA's wind lidar mission
2. The Aeolus Doppler Wind Lidar Mission
    a. Aeolus aerosol and cloud monitoring capabilities
    b. Aeolus vs. Calipso/ATLID
3. Cal/Val
4. Conclusions


Atmospheric Dynamics Mission - Aeolus
It’s a Doppler Lidar Wind mission ...
... providing valuable info on aerosols and clouds!
Launch date: spring 2014

Why launch a space-based DWL?

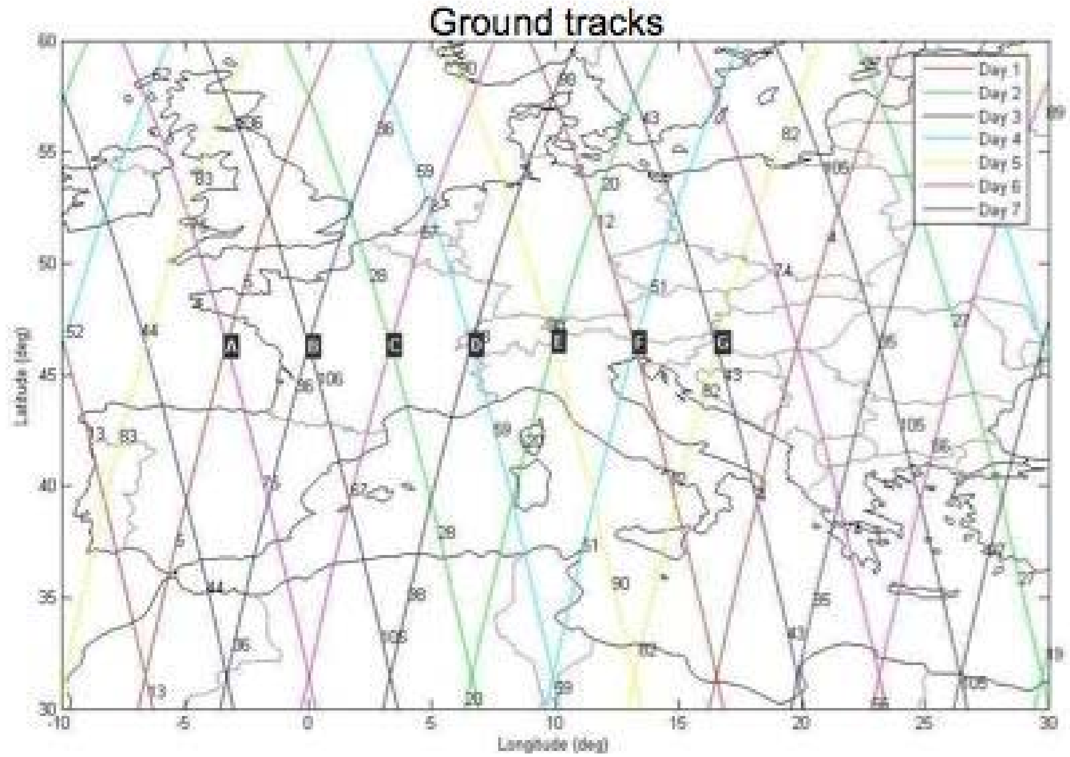


1. There is a need for **homogeneous** global direct measurements of wind profiles, in order to improve the analysis of the atmospheric state for NWP and Climate modelling
2. Aeolus shall demonstrate the capabilities of space-based HSR Doppler Wind LIDARs (DWLs) for global wind profiling and their potential for operational use

Global Observing System (GOS) wind information

- **Radiosonde and pilot** soundings – left (BUT NH continents dominate)
- **Aircraft data** (BUT NH densely populated areas dominate)
- **Satellite soundings** of temperature and humidity from Polar orbiting satellites (BUT indirect measure of large-scale phenomenon wind outside the tropics through geostrophic balance)
- **Atmospheric motion vectors** (BUT only in the presence of clouds)

ADM-Aeolus orbit characteristics

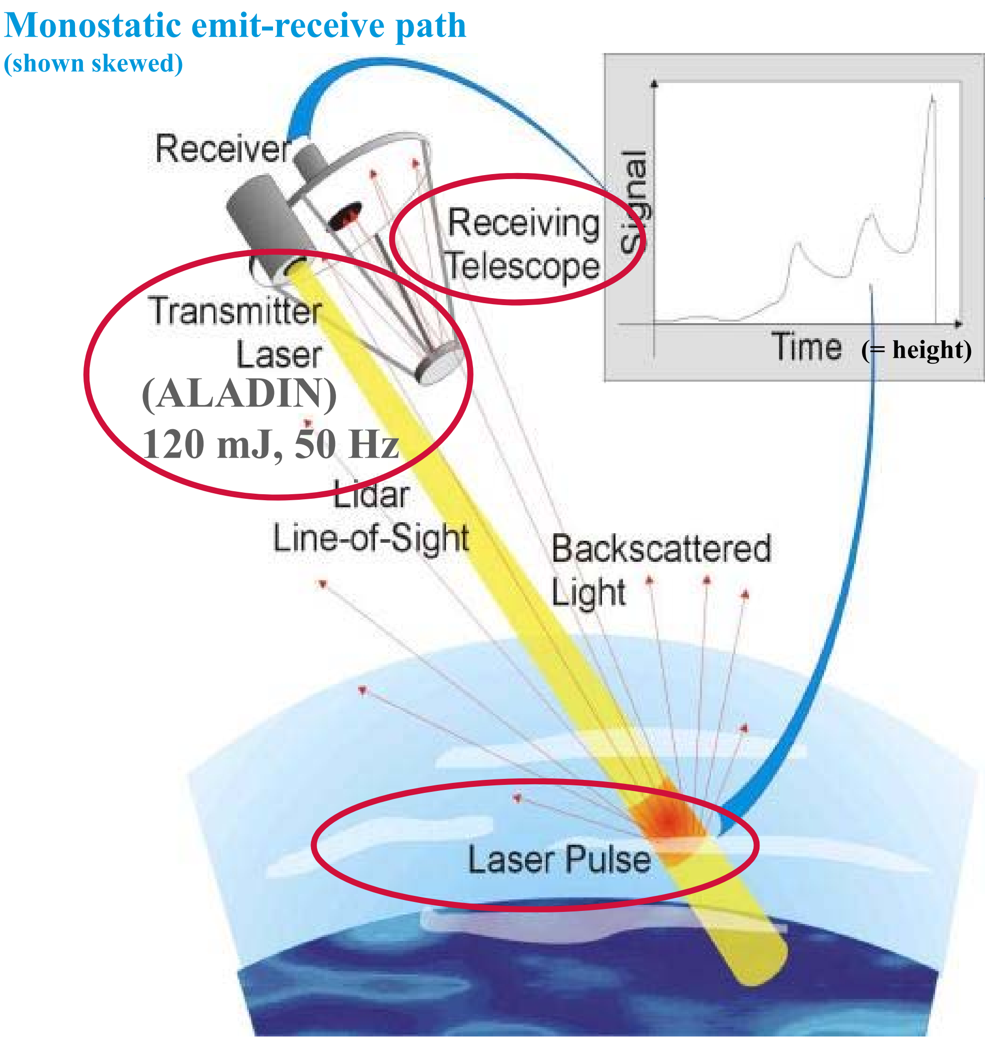


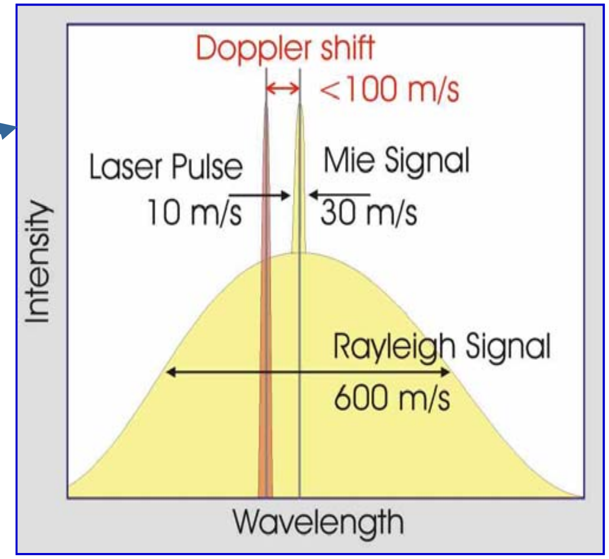
Why 6pm crossing time?

1) Solar panels almost always illuminated (power for the laser)

2) Largely reduced thermal stress (stability of environment)

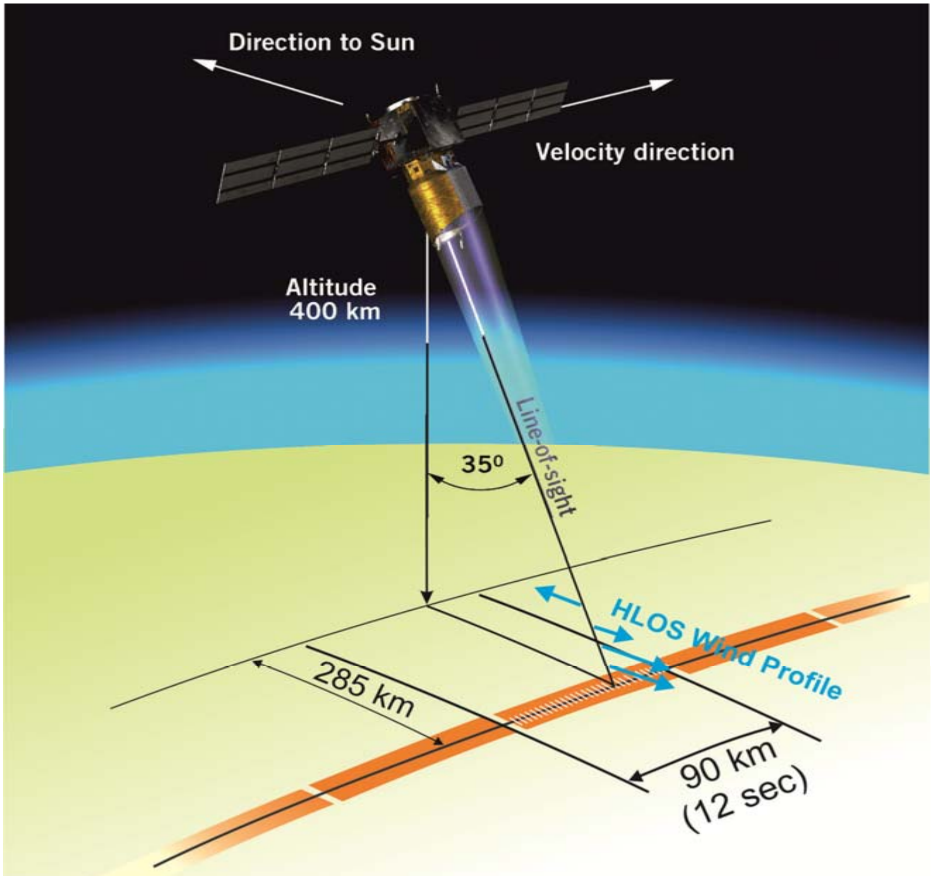
Aeolus measurement concept





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

Measurement Baseline



UV lidar (355 nm , circularly polarized)

Separate molecular and a particle backscatter receivers (High Spectral Resolution)

No polarization measurements

Adjustable vertical sampling of **24** atmospheric layers with thicknesses from 0.25 – 2 km

One <u>observation</u> is made of lidar signals accumulated over 12 sec (i.e. 90 km).

The horizontal <u>measurement</u> granularity within each observation is commendable (3 to 7 km).

Aeolus vs. Calipso / ATLID: some figures

Parameter	Aeolus/Aladin	ATLID	Calipso/Caliop
Satellite altitude	408 km	409 km	705 km
Orbital inclination	90 deg	97 deg	98 deg
Ascending node	18:00	14:00	13:30
Repeat cycle	**109** orb/7d	**389** orb/25d [nom] **140** orb/9d [cal]	**233** orb/16d
Orbits per day	16	15.6 / 11.6	15
Laser Divergence	12 µrad / ≈ **6 m**	< **30 m**	100 µrad / ≈ **70 m**
Telescope Divergence	19 µrad / ≈ **9 m**		130 µrad / ≈ **90 m**
Laser Wavelenth	355 nm	355 nm	532 nm
Laser Pulse Energy	120 mJ	34 mJ	110 mJ
Laser Pulse Length	30 ns	30 ns	20 ns
Repetition Rate	**50 Hz**	**50 Hz**	**20 Hz**
Single Shot Distance	**140 m**	**140 m**	**380 m**

ADM-Aeolus L2 products

1. Primary (L2b) product:

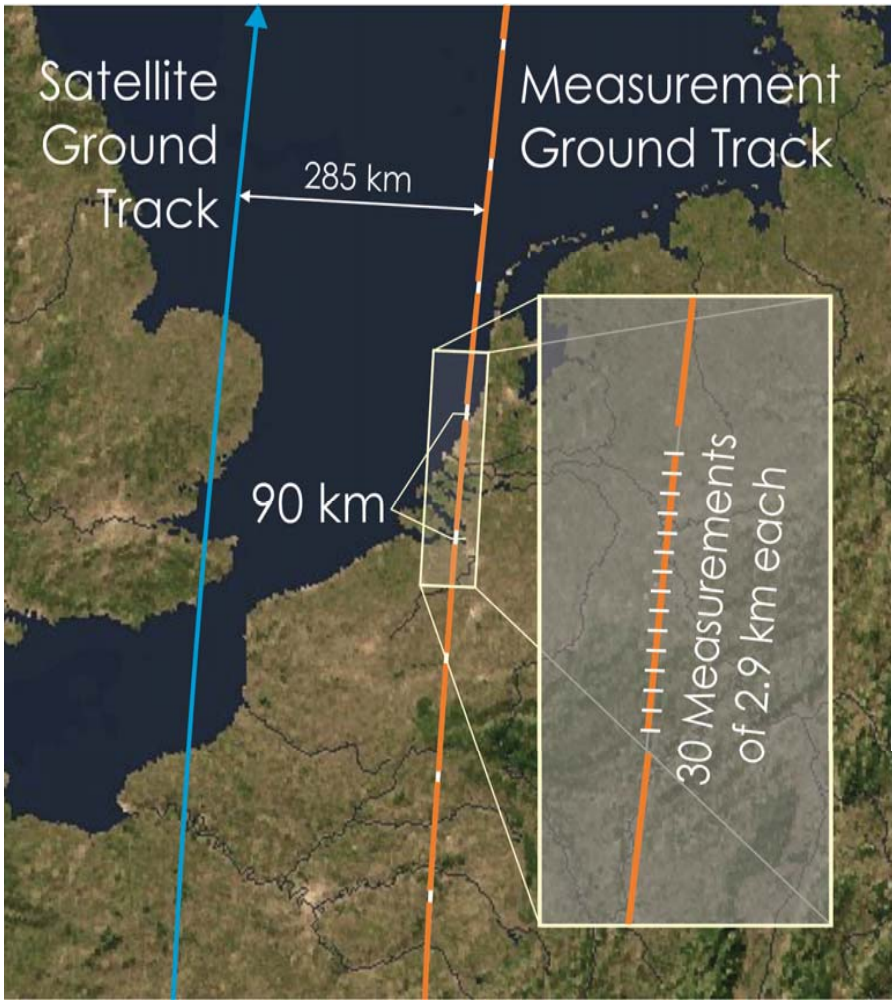
Horizontally projected LOS wind profiles

- Approximately zonal at dawn/dusk
- 3 km-averaged measurements and ~90 km averaged observations – scene classified
- Random errors (m/s): 1 (PBL), 2 (Trop), 3-5 (Strat)

1. Secondary (L2a) products:

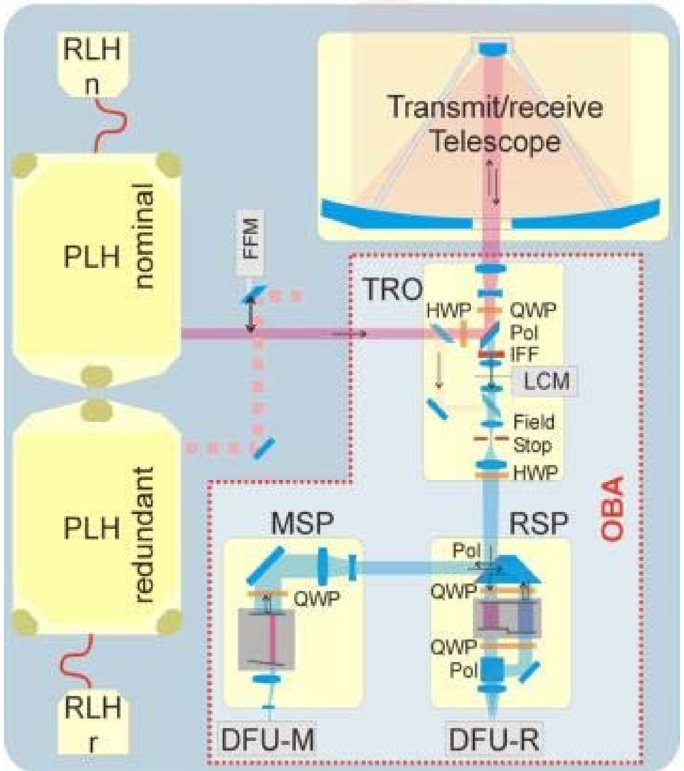
Optical properties profiles:

- **β**, **α**, **OD**, scattering ratio
- Aerosol typing (backscatter-to-extinction ratio)
- Cloud/aerosol cover/stratification
- Cloud/aerosol top heights
- Cloud/aerosol base height (optically thin)



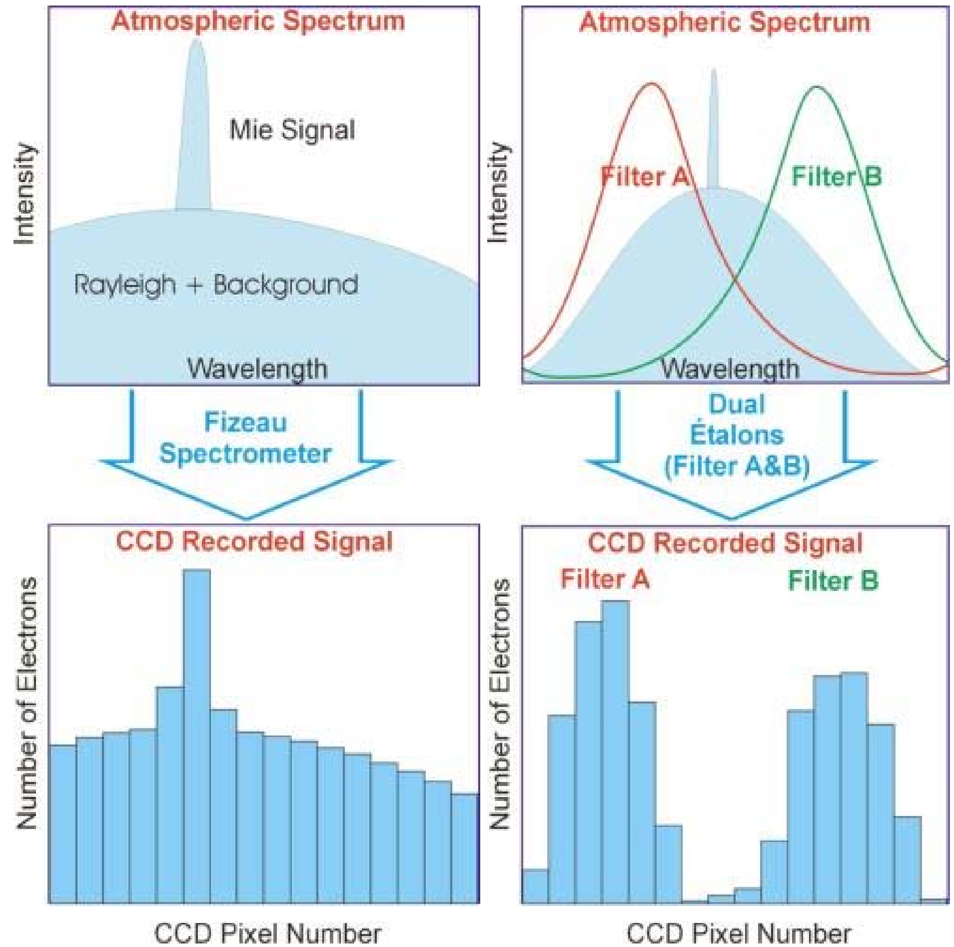
European Space Agency

DW Lidar design



Optical architecture of ALADIN.

Cross-talk (Mie ->Rayleigh and Rayleigh ->Mie)



Mie receiver: fringe imaging Fizeau spectrometer

Rayleigh receiver: double edge Fabry-Pérot etalon

Aeolus - HSRL

For each **observation**, ADM provides two signals, one Rayleigh, one Mie, related to the optical parameters of the atmosphere via the equations:

$$S_{Ray}(z) = K_{Ray}\left[C_1\beta_{mol}(z) + C_2\beta_{aer}(z)\right]\frac{\Gamma_{mol}^2(z)\Gamma_{aer}^2(z)}{R^2(z)}$$

$$S_{Mie}(z) = K_{Mie}\left[C_3\beta_{mol}(z) + C_4\beta_{aer}(z)\right]\frac{\Gamma_{mol}^2(z)\Gamma_{aer}^2(z)}{R^2(z)}$$

where C_1, C_2, C_3, C_4, K_{ray} and K_{mie} are known calibration constants ($C_1 \sim C_2$; $C_3 \ll C_4$).

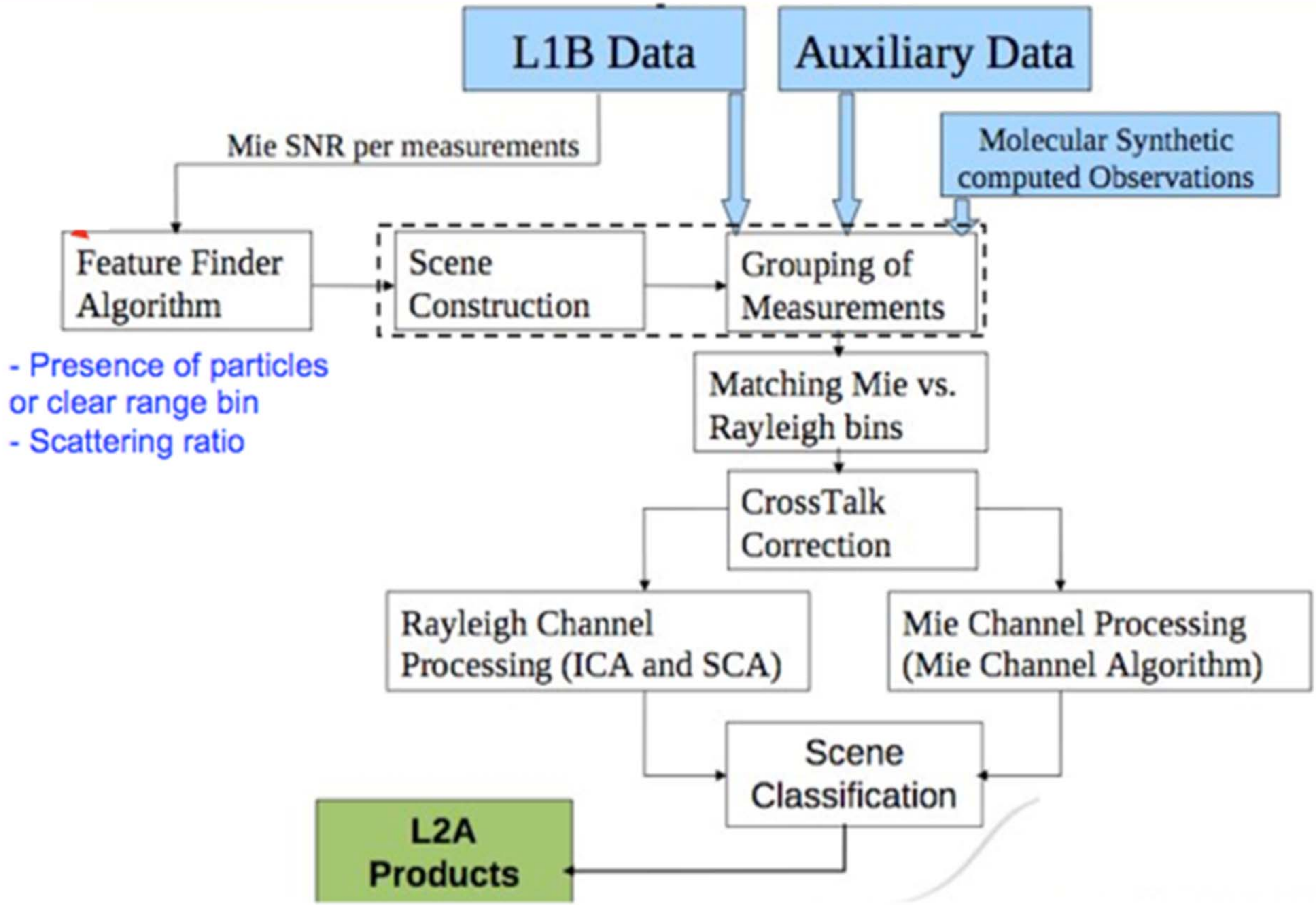
In principle, it is possible to determine $\alpha_{aer}(z)$ and $\beta_{aer}(z)$ from the equations above.

In practise, difficulties are encountered due to:

- The lidar **cannot distinguish absorption and scattering** extinction
- **Large thickness of the height bin** (vertical inhomogeneity give ambiguous results when solving the lidar equation)
- Dependence on a priori **temperature** and **pressure** information
- Only way to discriminate **aerosol** versus **cloud** particles: use **β/α**

(by A. Dabas, MeteoFrance)

ADM-Aeolus Level2A flowchart



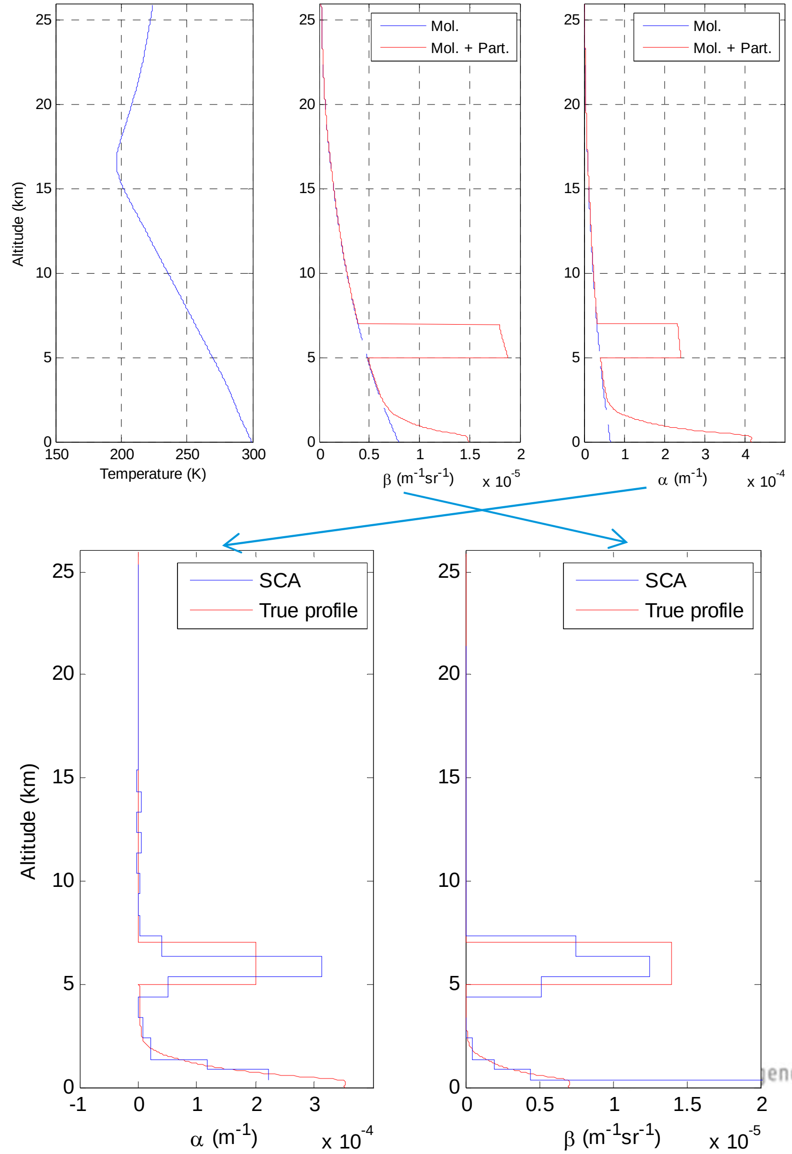
Level 2A ATBD

Retrieval algorithms for aerosols

SCA: **s**tandard **c**orrect **a**lgorithm "Normalized Integrated Two-Way Transmission (NITWT)" assuming **a uniform particle layer filling** of the entire range bin.

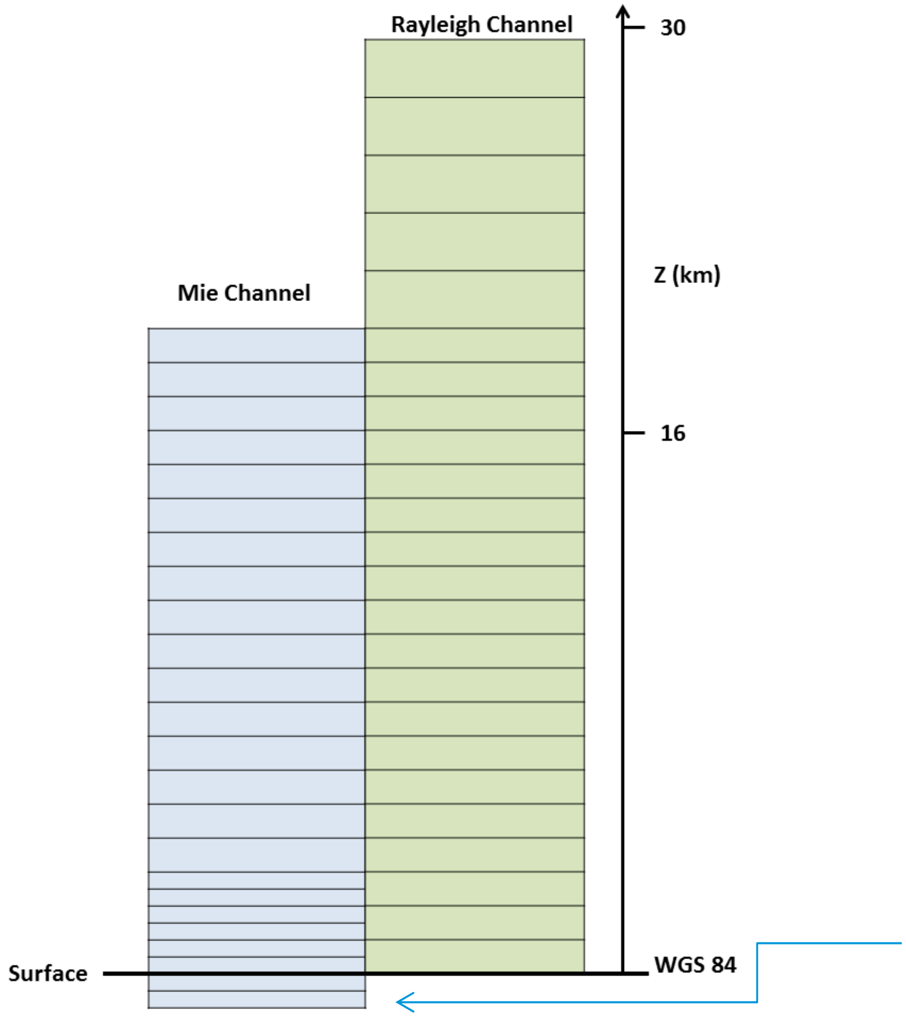
ICA: **i**terative **c**orrect **a**lgorithm is intended to retrieve both, the location of the layer in the range gate and the local optical depth when accounting for **partial layer filling** of the range bin.

MCA: **M**ie **c**hannel **a**lgorithm, uses Mie channel data and climatology when **no valid Rayleigh data are available**



Level 2A ATBD

Aeolus vs. Calipso / ATLID: vertical resolution



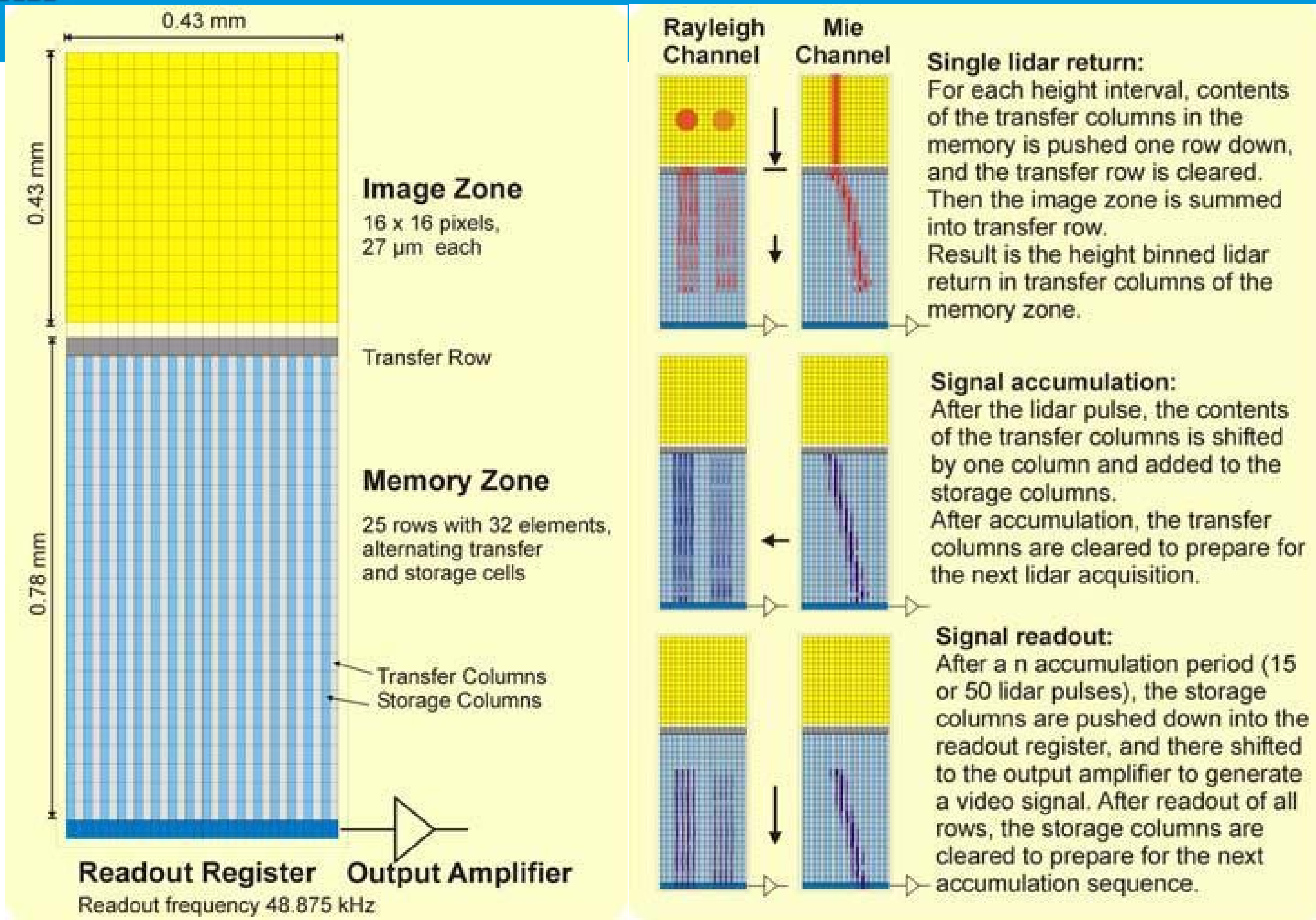
Finer grid (0.5 km) for Mie channel below 3 km

Calipso

Layer (km)	Resolution in km
30 – 40	0.30
20 – 30	0.18
8 – 20	0.06
0 – 8	0.03
-2 – 0	0.30

ATLID: 0.1 km

Aeolus: Why only 24 range bins?



Aeolus (“measurement”) vs. Calipso / ATLID: horizontal resolution

Layer (km)	Aeolus (km)	Calipso (km)	ATLID (km)
30 – 40	-	5.00	0.28
20 – 30	3 to 7	1.67	0.28
8 – 20	3 to 7	1.00	0.28
0 – 8	3 to 7	0.33	0.28
-2 – 0	3 to 7	0.33	0.28

Retrieval Capabilities for Particles ADM vs. Calipso

Mission	Spatial sampling	Particle layer detection	Optical properties	Scene classification
ADM-Aeolus	**Limited** vertical resolution in range bins equal to .25, .50, 1 and 2 km.	**Good**. The Mie channel performs well at moderate SNR (> 10)	**Good** based on HSRL capability to derive particle local optical depth per range bin LOD_p and extinction-to-backscatter ratio *EBR* using the Rayleigh and Mie channels	**Limited**. Only two pieces of information provided by the Lidar (LOD_p and *EBR*). No complementary instruments.
CALIPSO	**Good**. Vertical sampling at high resolution provides flexibility. Accumulation to improve SNR.	**Good** SNR > 10	**Limited**. Colour ratio using 2 wavelengths and depolarization ratio are provided. But *a priori* knowledge of *EBR* is required to compute LOD_p.or backscatter or extinction coefficient	**Good**. Several pieces of information are provided by CALIOP, IIR and WAC, and other components of the A-Train

LOD = local optical density; EBR = extinction-to-backscatter ratio (1/ BER)
WAC = wide angle camera; IIR = infrared imager

Some of the ADM Cal / Val tasks

1. *Assessment, characterization of radiometric performance and stability*
2. *Validation of geo-location information*
3. *Recommendations for enhancements of algorithm and observational settings*
4. *Systematic validation of algorithms from L1A to L1B and L2A and L1B to L2B*
5. *Validation of stability of instrument calibration*

ADM-Aeolus Cal / Val plan

Wind:

Ground based DWL, HSRL, Radars, Sondes (troposphere-stratosphere), Airborne DWL, NWP models

Aerosols/Clouds

Airborne-backscatter Lidars, ground-based Lidars (including Raman), sondes

ADM-Aeolus validation campaigns

Campaigns:

a. 2 ground-based (2006, 2007) and 3 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. Phase E1 (commissioning, ESTEC) and phase E2 (operation, ESRIN) campaigns will be defined soon

Status of the Aeolus program

1. The platform was completed in 2009 and in storage; modifications for In-situ Cleaning System required
2. The Aeolus ALADIN Lidar subsystems have all been delivered and qualified on subsystem level, but some modifications are required for an In-situ Cleaning System (flow of O_2 at very low pressure)
3. The transmitter laser is the most challenging for the qualification
    a. *Laser development & qualification status reviewed by external expert team. Recommendations being implemented:*
        – Continuous mode operation
        – Harmonic section to be optimized
    b. *Continuous Mode operation:*
        – Delta Critical Design Review concluded in March '11

Conclusions

1. Aeolus wind lidar mission will deliver atmospheric optical properties measurements as secondary products (L2a)

2. The Aeolus L2a products will be made available to users off-line (now every 12 hours) but could in the future become available every 4 hours or more often

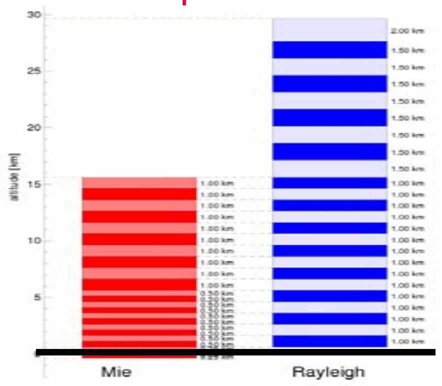
3. Aeolus L1b products will be available to users NRT and could be further processed locally

4. Launch scheduled for **spring 2014**

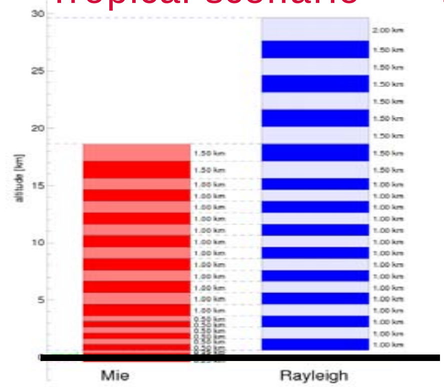
Thank you for your attention!

Spare I: range bins adapted to surface elevation variations

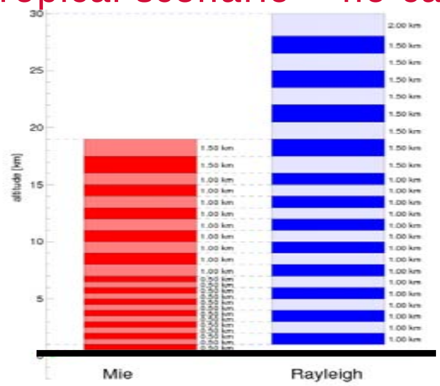
Extra-tropical scenario

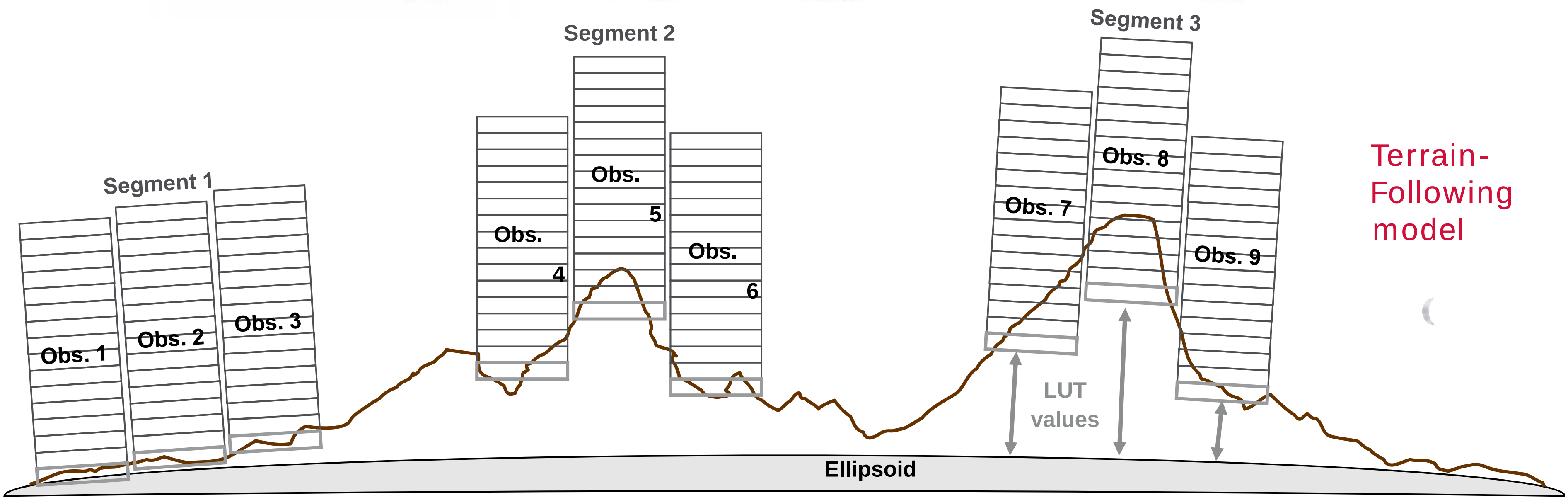


Tropical scenario



Tropical scenario – no calibration





Terrain-Following model

Co-location of Mie and Rayleigh channel sampling within an observation is essential

Spare II: scene classification

The **Scene Classification Algorithm** shall classify the types of aerosol and cloud scenes occurring within each **observation**.

The classification shall be used to distinguish backscatter from **aerosols**, **water clouds** and **ice clouds**. in each range bin.

	Water droplets, Water clouds *Aerosol layers*	
0°C		273.15 K
	Ice crystals or water droplets Mixed phase clouds *Aerosol layers*	
- 36°C		237.15 K
	Ice crystals, Cirrus clouds *Aerosol layers*	

$$Classification\big|_i = Class_{BER}\big|_i + 2 \times Class_{Rsca}\big|_i + 4 \times Class_{Temperature}\big|_i$$

$Class_{BER}$ = **0** if BER < 0.1; = **1** otherwise

$Class_{Rsca}$ = **0** if Rsca < 1.5; = **1** otherwise

$Class_{Temperature}$ = **0** if T < 237.15K; = **2** if T > 273.15K; = **1** otherwise

Spare III: scene classification

	BER classification		Scattering ratio classification		Temperature classification		Index of Classification
#1	0	Small particles	0	No features in this layer, or very few.	0	Ice crystals, Cirrus Clouds Aerosol layers	0
#2	1	Big particles	0		0		1
#3	0	Small particles	1	Features in this layer	0		2
#4	1	Big particles	1		0		3
#5	0	Small particles	0	No features in this layer, or very few.	1	Ice crystals or Water Droplets Mixed phase clouds Aerosols layers	4
#6	1	Big particles	0		1		5
#7	0	Small particles	1	Features in this layer	1		6
#8	1	Big particles	1		1		7
#9	0	Small particles	0	No features in this layer, or very few.	2	Water droplets, Water clouds Aerosol layers	8
#10	1	Big particles	0		2		9
#11	0	Small particles	1	Features in this layer	2		10
#12	1	Big particles	1		2		11

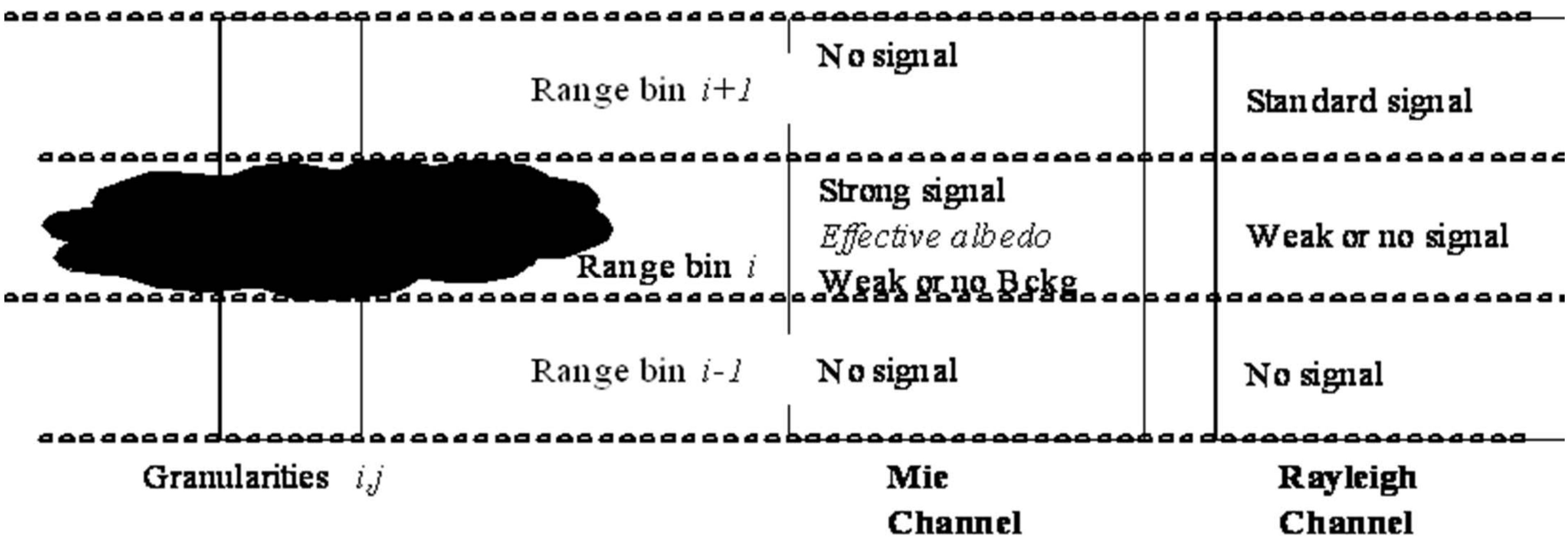
Spare IV: spectral resolution

•The two FP band-passes FP-A and FP-B have a FWHM = **0.7 pm** (or 1.67 GHz) and are separated by **2.3 pm** (or 5.47 GHz).

•The free spectral range (FSR) of the Fizeau interferometer is equal to **0.92 pm** but only a fraction of it is imaged onto the detector so the useful spectral range is USR = **0.63 pm** or 1500 MHz.

•The FWHM of the Fizeau interferometer transfer function is **0.06 pm** or about 143 MHz. Each channel has an equivalent spectral width of 93.75 MHz or 17 m/s.

Spare V: Mie and Rayleigh signals



Level 2A ATBD