LASER REMOTE SENSING

PART III

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São Paulo, July 2019

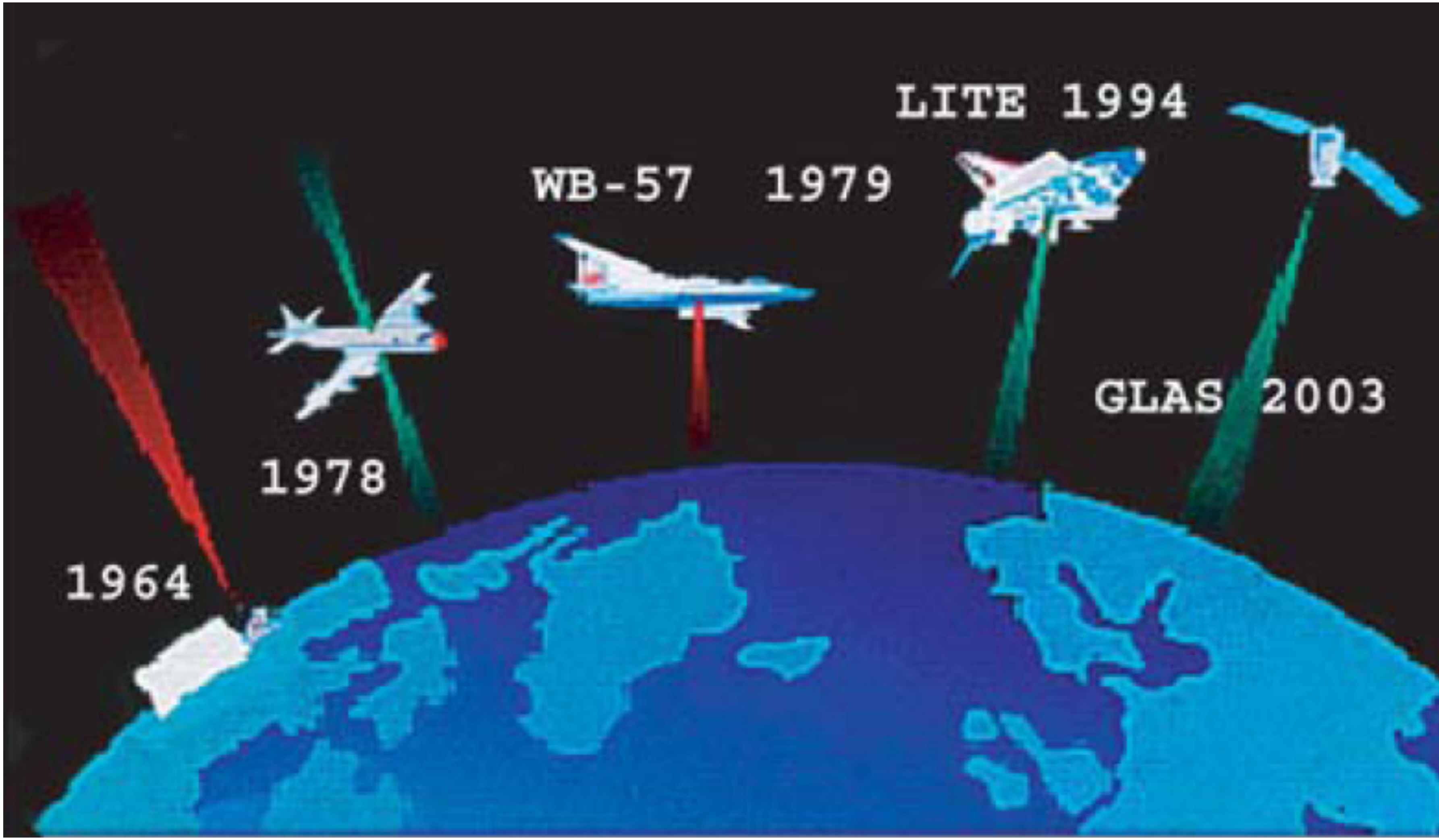
LIght Detection and Ranging

Hulburt (1937) – observation of light intensity from spotlights at 28 km of altitude

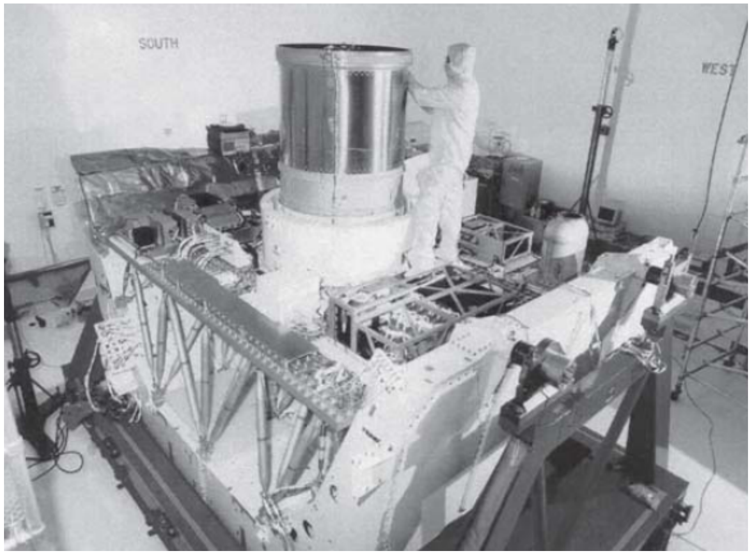
Elterman (1951) – measurement of atmospheric density distribution using spotlights

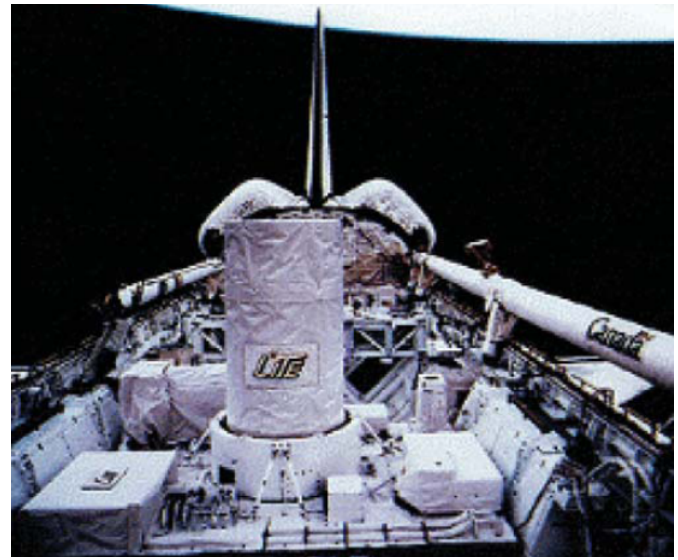
Bigg (1955) – Detection of atmospheric dust during the twilight

Where is my patience ???

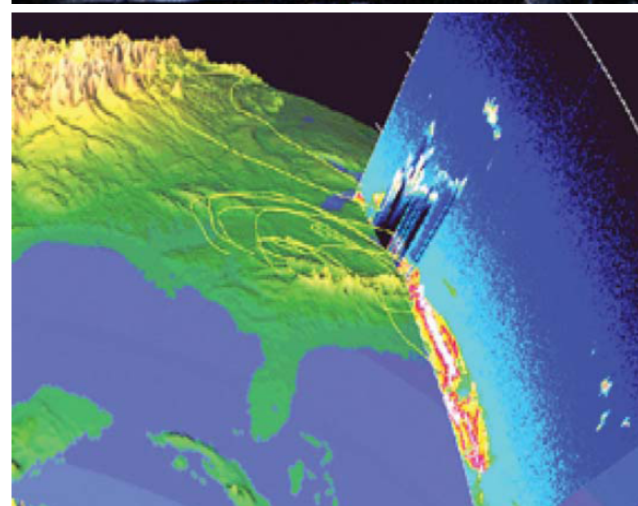

LITE 1994
WB-57 1979
1978
GLAS 2003
1964

Lidar In-space Technology Experiment (LITE) - 1994

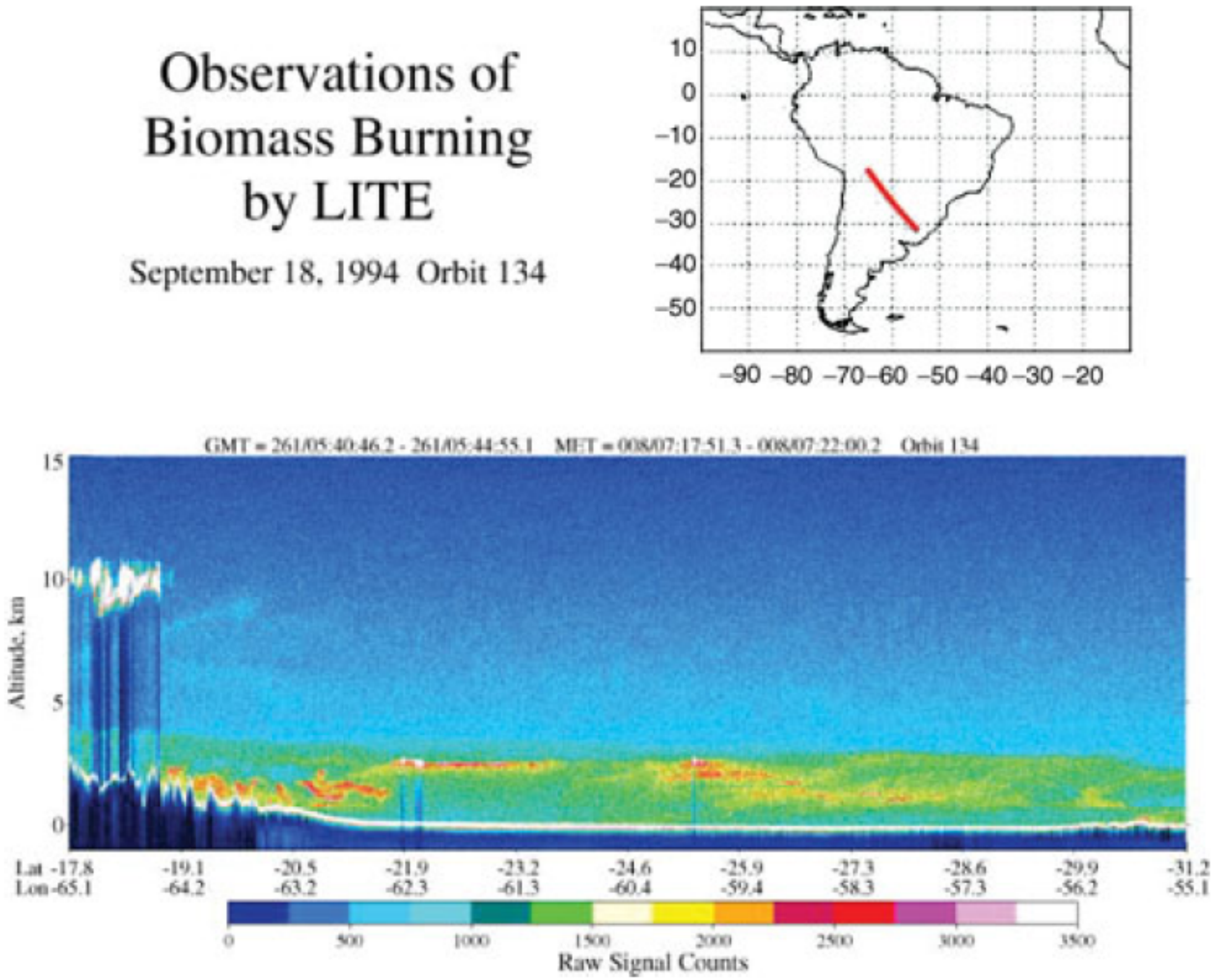




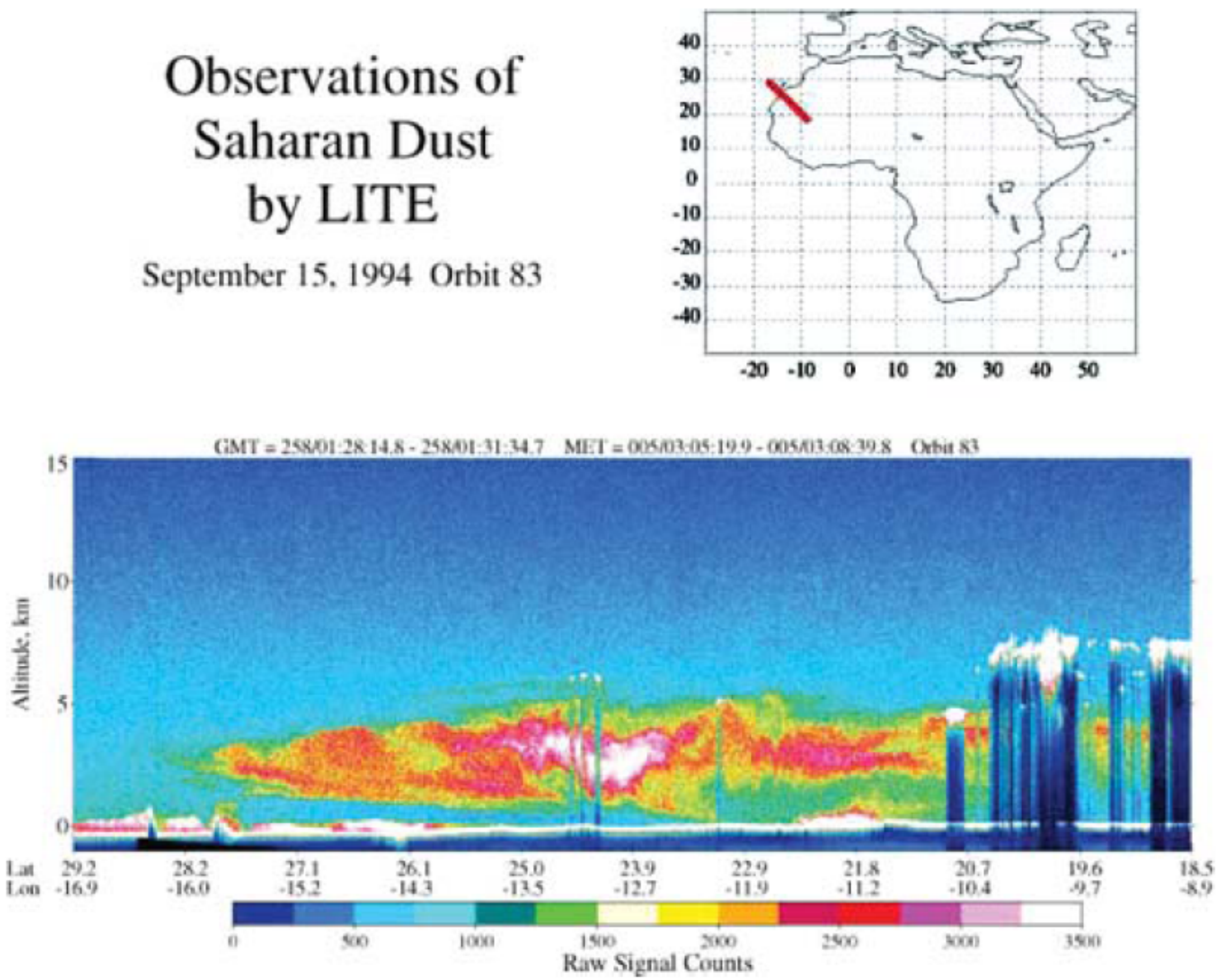
First Lidar system in space – on board of the Discovery space shuttle during 10 days of measurements



Lidar In-space Technology Experiment (LITE) - 1994



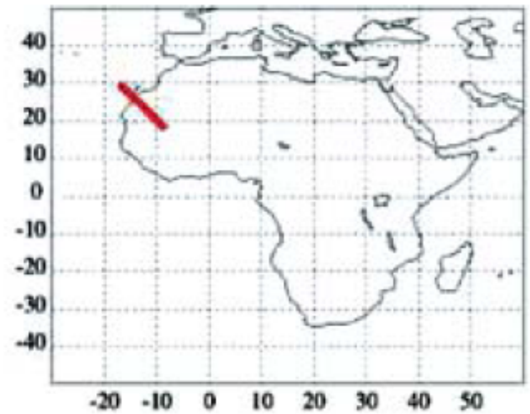
Lidar In-space Technology Experiment (LITE) - 1994

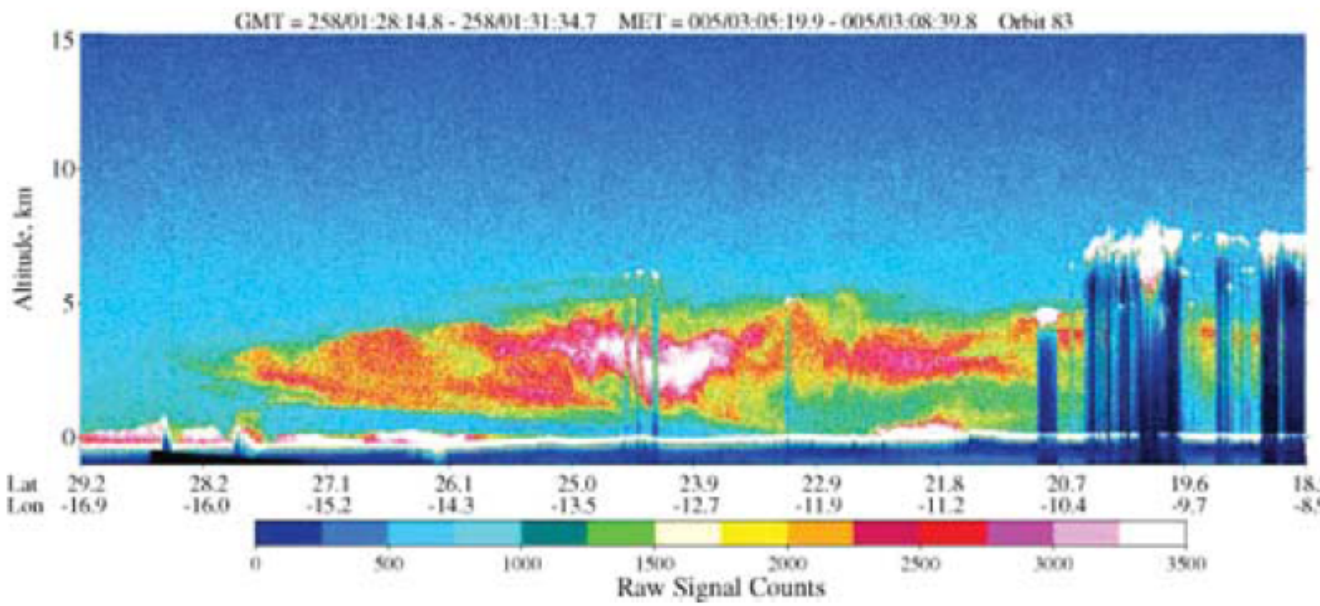


Lidar In-space Technology Experiment (LITE) - 1994

Observations of
Saharan Dust
by LITE

September 15, 1994 Orbit 83



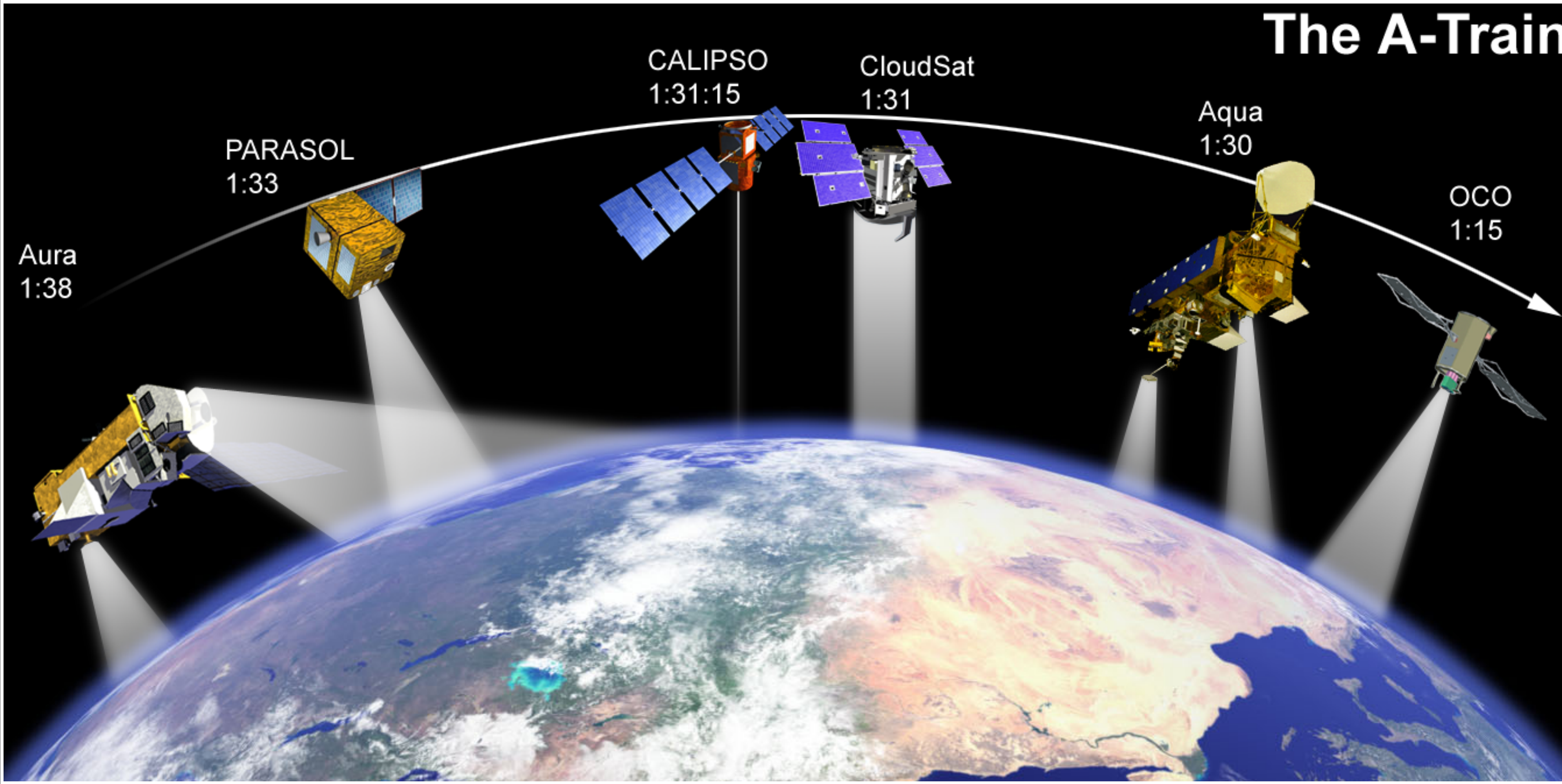


GLAS instrument (Geoscience Laser Altimeter System) on board of ICESat satellite (Cloud and land Elevation Satellite) - 2003

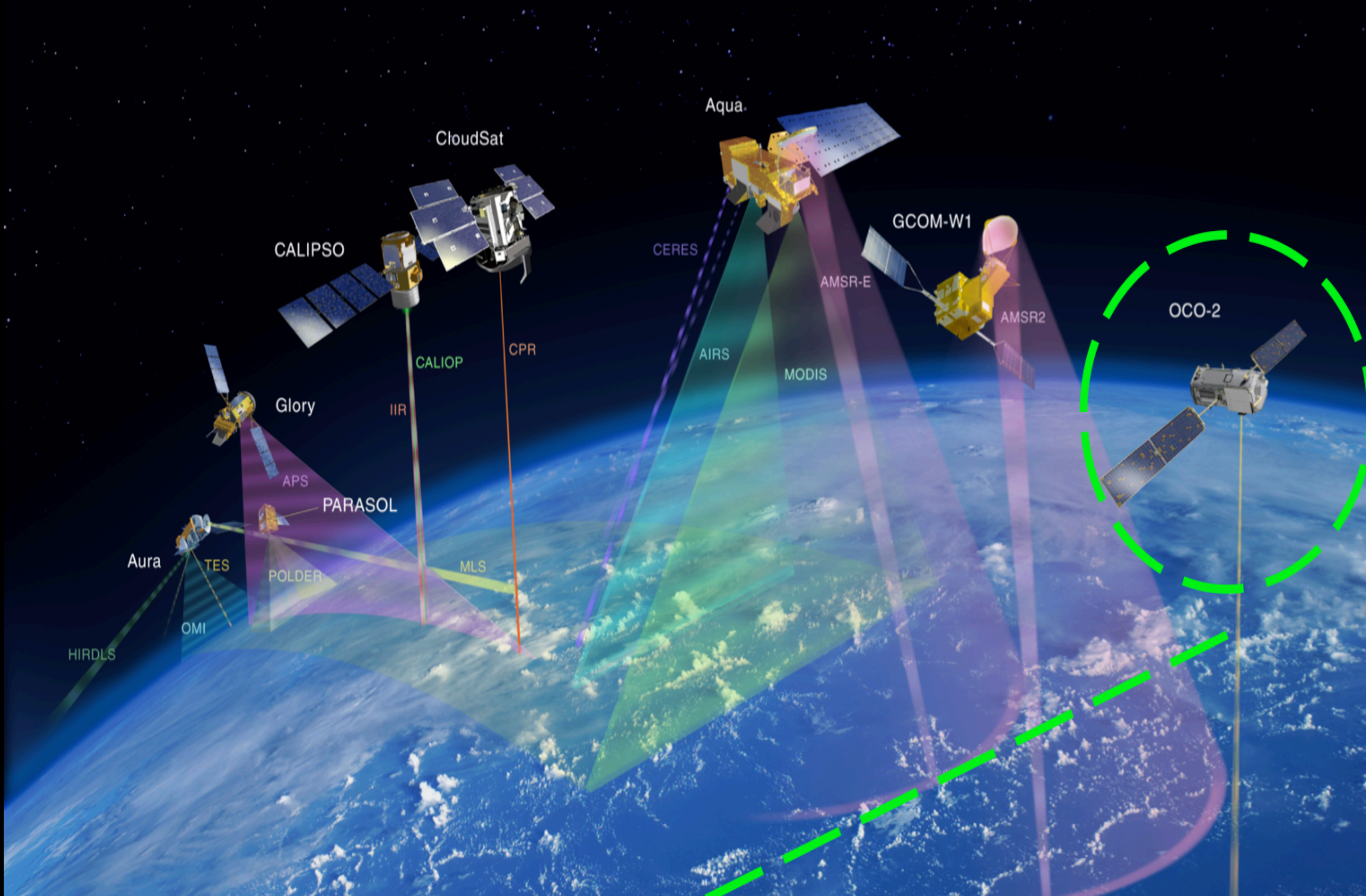
First longterm mission using Lidar in space – 664 days

Period of 20 Feb. 2003 – 11 Oct. 2009 († 30/08/2010)

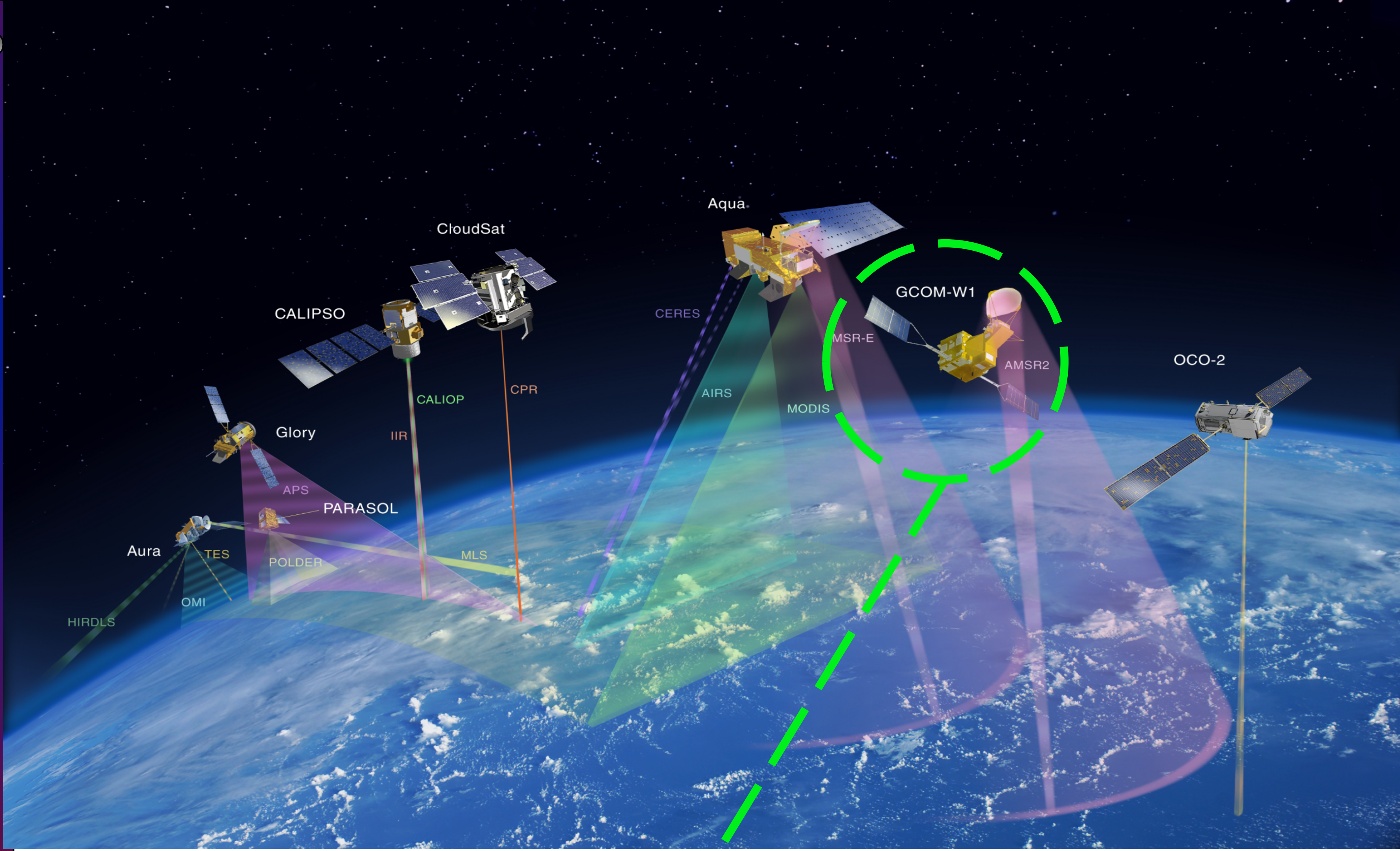
A-Train constellation – Afternoon constellation



Jazz song "Take the A-Train" composed by Billy Strayhorn and performed by Duke Ellington band

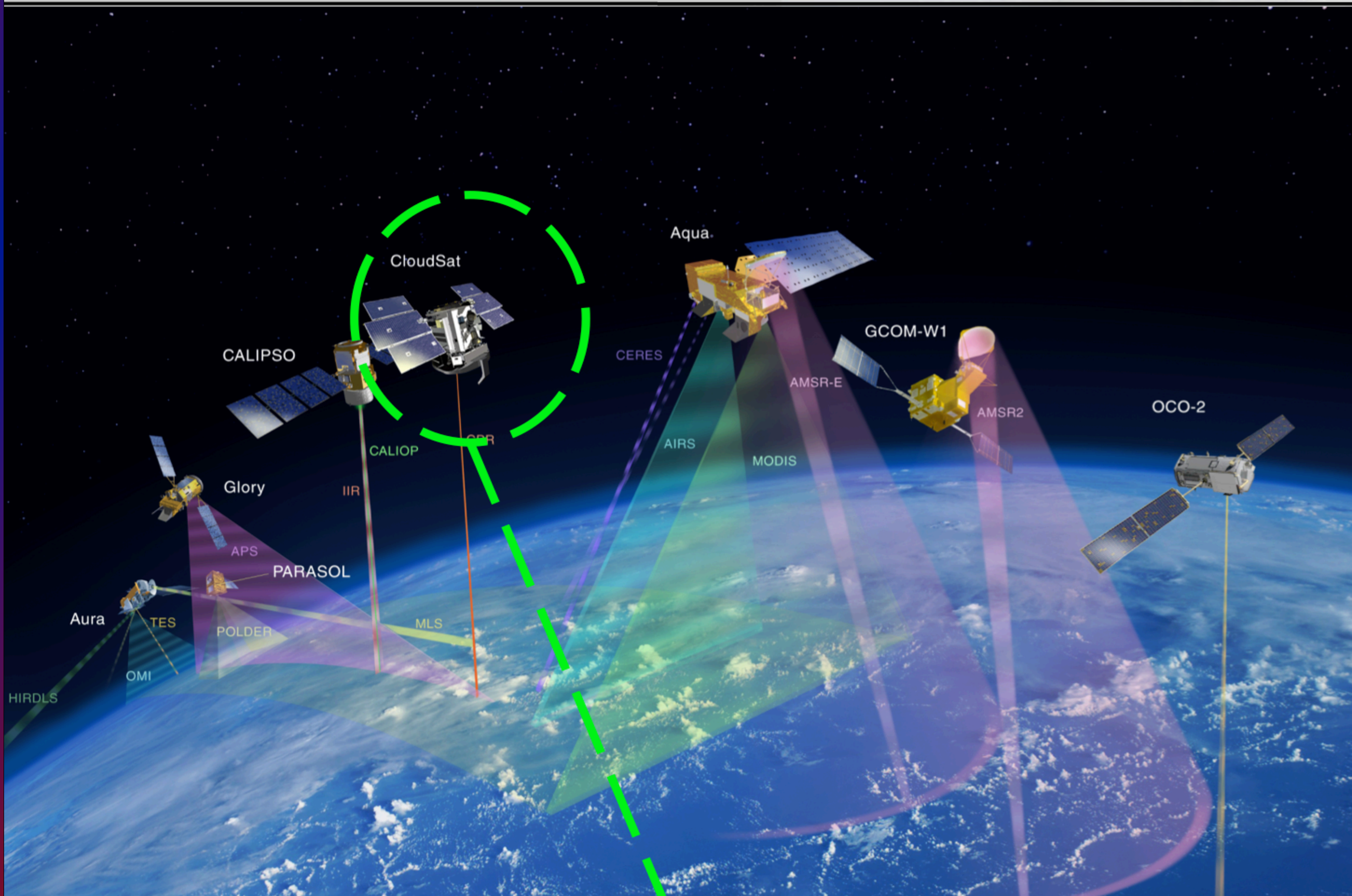


OCO-2: CO_2 detection and Carbon cycle on the atmosphere

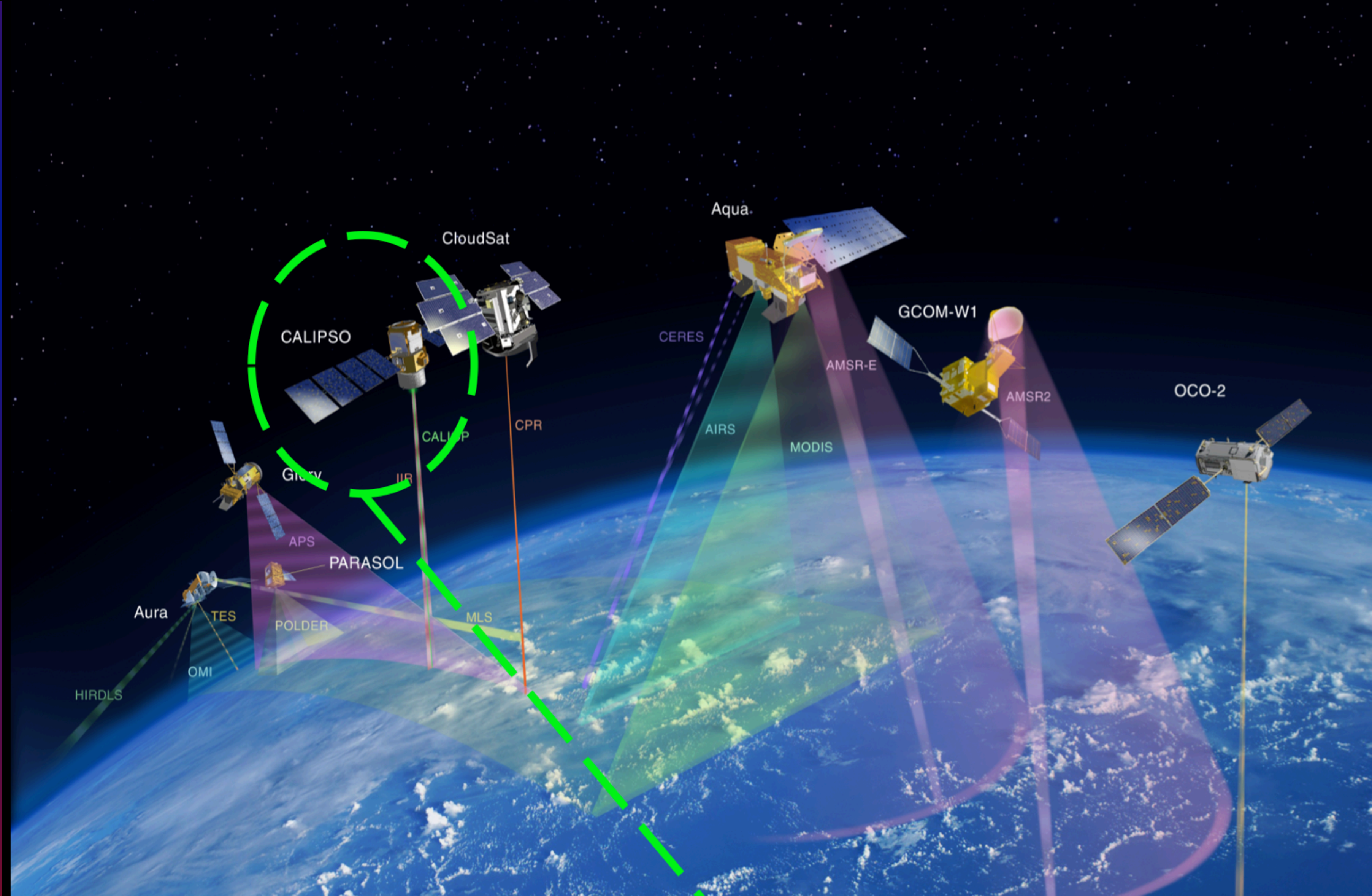


GCOM: Chemistry composition of atmosphere and water cycle

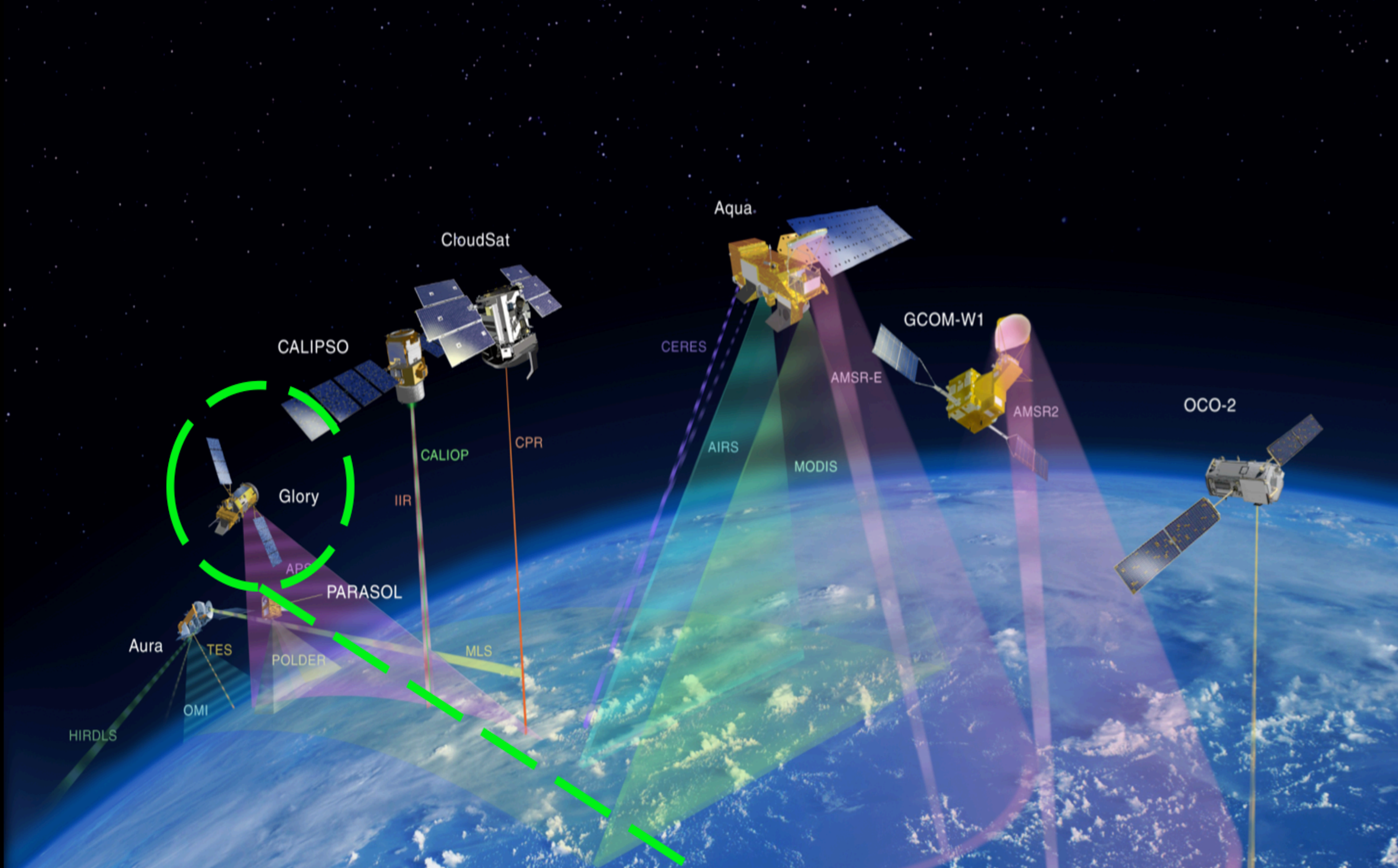
AQUA: Six instruments for atmospheric composition, carbon and water cycle and aerosol optical properties



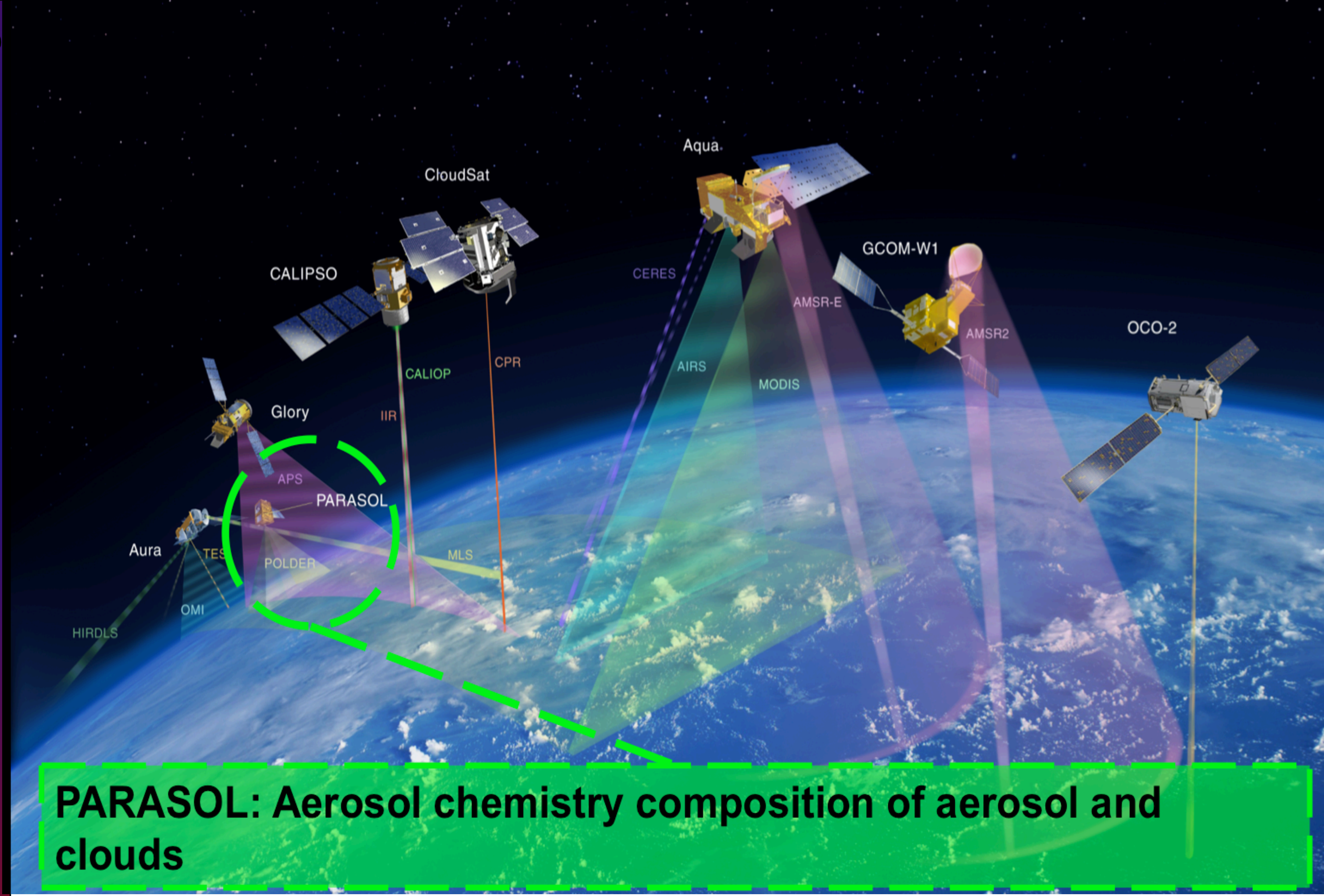
Cloudsat: Radar for clouds and rain detection



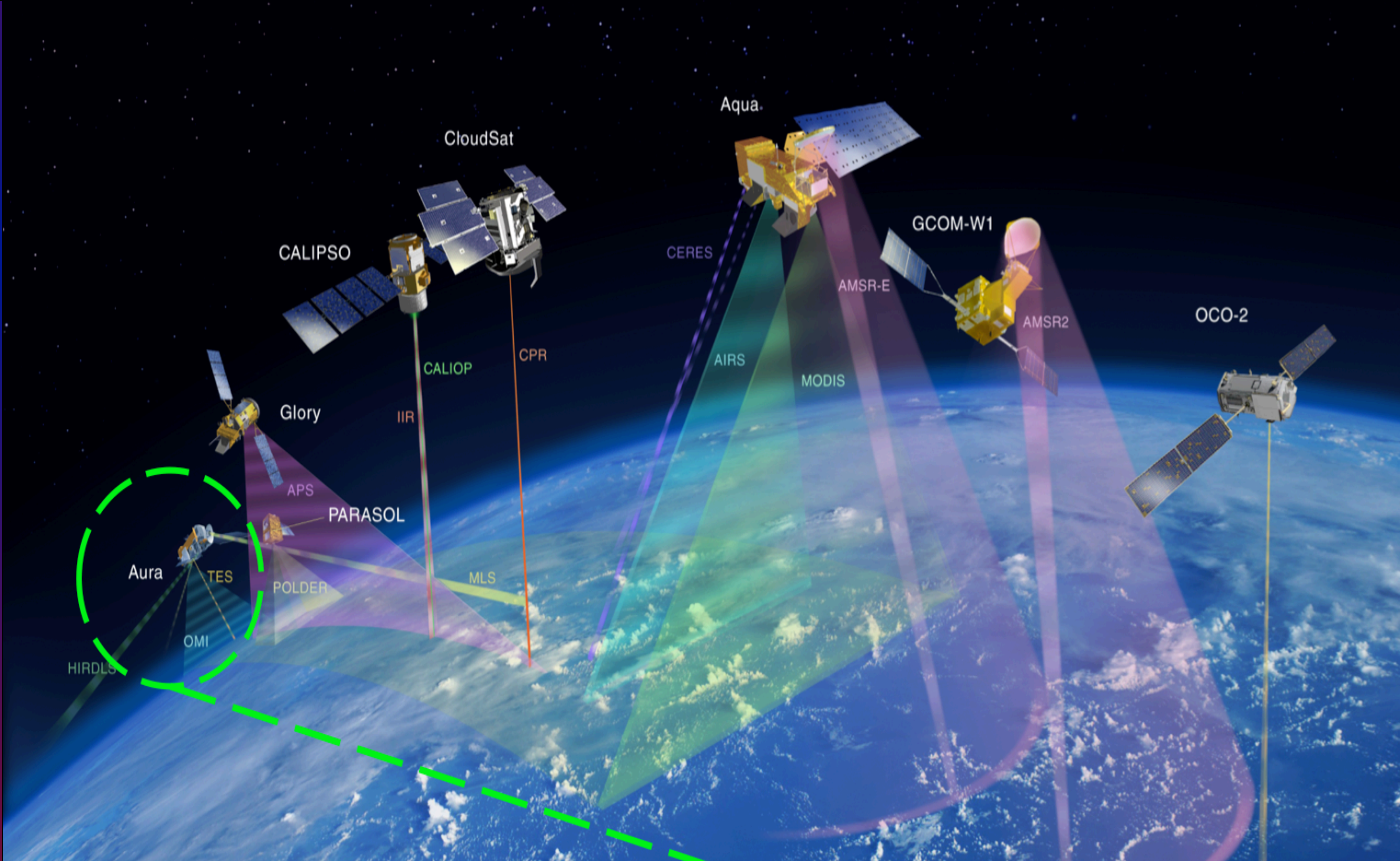
CALIPSO: Lidar system for vertical profile of aerosol and clouds



Glory: Optical, microphysical and chemistry properties of atmosphere



PARASOL: Aerosol chemistry composition of aerosol and clouds

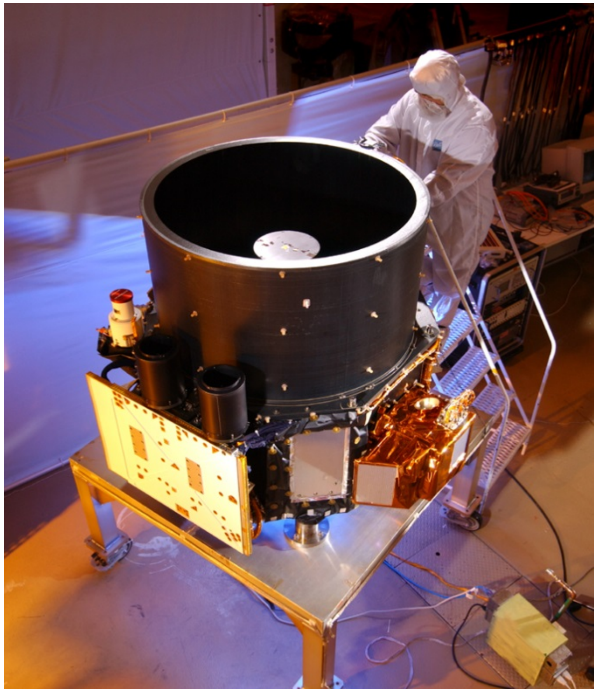


AURA: Chemistry and physical composition of atmosphere

CALIPSO – Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation

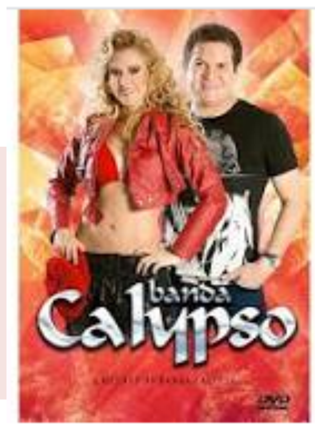
Launch in 2006 – NASA e CNES

Vertical profile of aerosol and cloud optical properties on global scale

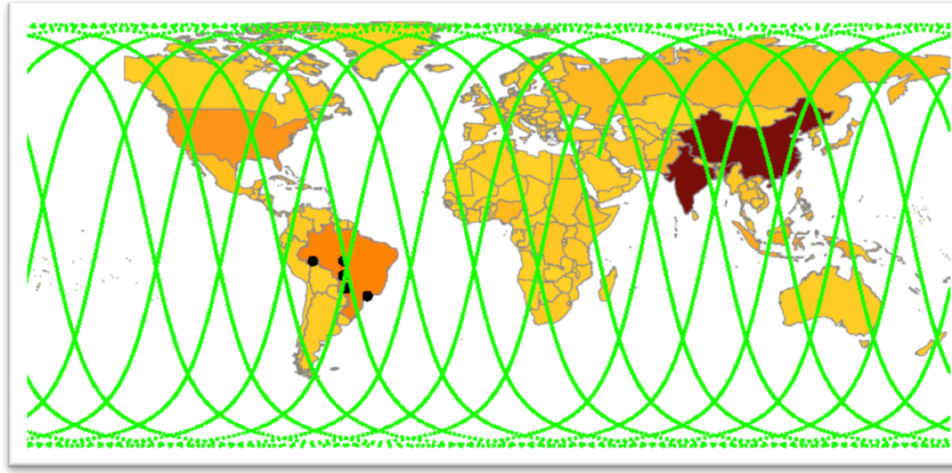


The PICASSO-CENA (Pathfinder Instruments for Cloud and Aerosol Spaceborne Observations - Climatologie Etendue des Nuages et des Aerosols) mission was selected as the primary mission of the NASA Headquarters Office of Earth Science's Earth System Science Pathfinders (ESSP) program.

CALIPSO is a joint NASA (USA) and CNES (France) environmental satellite, built in the Cannes Mandelieu Space Center, which was launched atop a Delta II rocket on April 28, 2006. Its name stands for Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations.



Launched on April 2006



Orbit altitude: 705 km

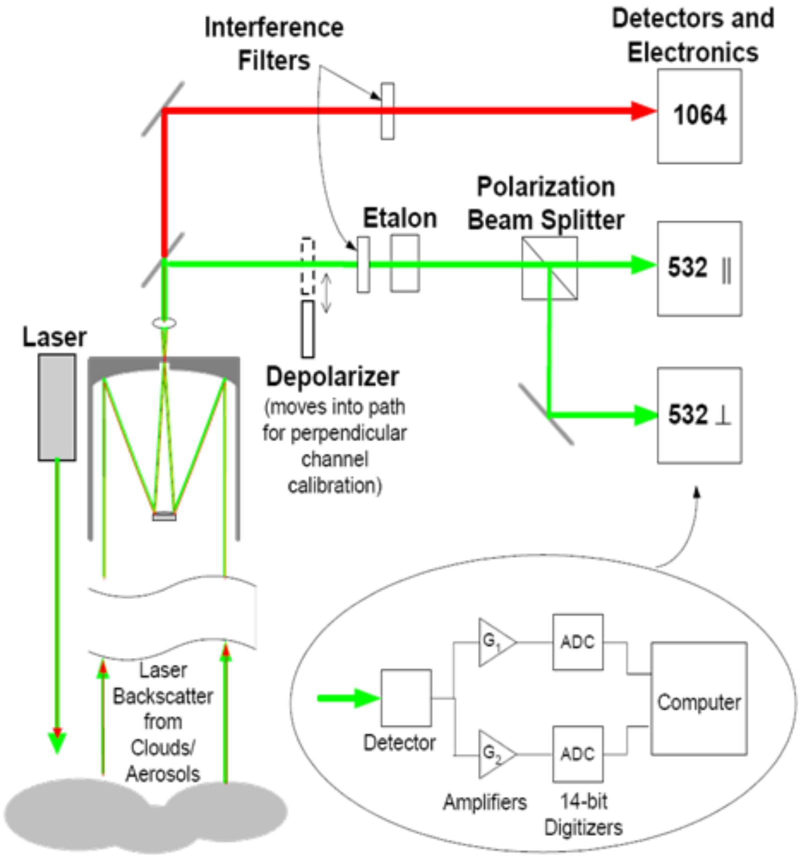
Orbit velocity: 7 km/s

Number of orbits: 14.55/day
24.7° of longitudinal separation between consecutive orbits

After one completed cycle – CALIPSO moves 10.8° forward to west

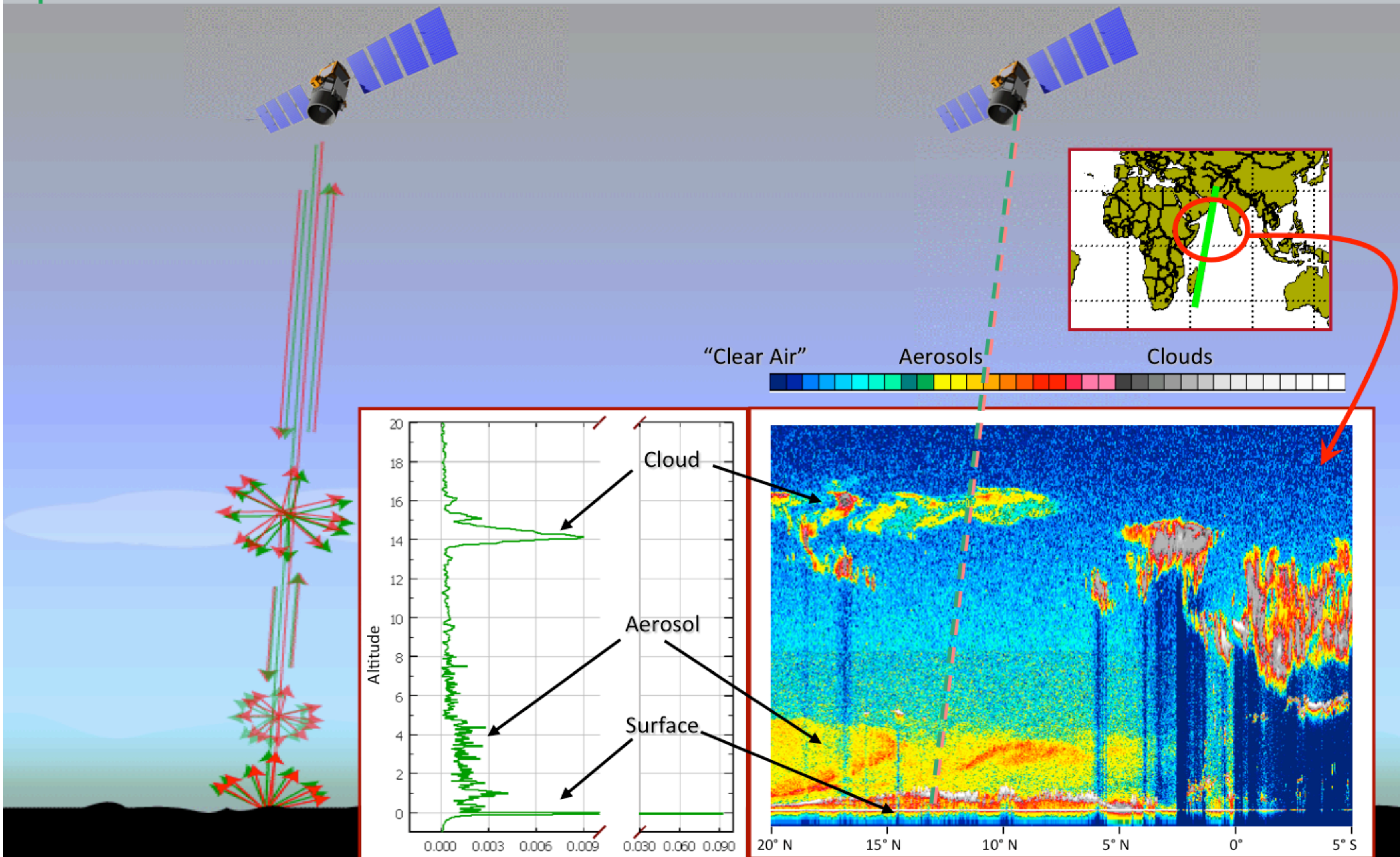
16 days period to cover all globe

CALIOP – Cloud Aerosol Lidar with Ortogonal Polarization



Laser	Nd:YAG, 2x110 mJ
Wavelenght	532 and 1064 nm
Repetition rate	20.25 Hz
Telescope	1.0 m of diameter
Polarization	532 || and ⊥
FOV	130 μrad
Vertical res.	30 – 60 m
Horizontal res.	333 m

How CALIPSO satellite retrieves aerosol and cloud at the atmosphere?



Level 1

CALIOP profiles:

- **532 nm attenuated backscatter profile**
- **$532_{\perp}$ nm attenuated backscatter profile**
- **1064 nm attenuated backscatter profile**

Level 1 resolution

Spatial resolution of downlinked data

Altitude Range (km)	Horizontal Resolution (km)	532 nm Vertical Resolution (m)	1064 nm Vertical Resolution (m)
30.1 to 40.0	5.0	300	---
20.2 to 30.1	1.67	180	180
8.2 to 20.2	1.0	60	60
-0.5 to 8.2	0.33	30	60
-2.0 to –0.5	0.33	300	300

Font: CALIOP Algorithm Theoretical Basis Document - Document No: PC-SCI-201

Level 2

- **Cloud/Aerosol layer products**
  layer base and top heights, layer-integrated optical properties

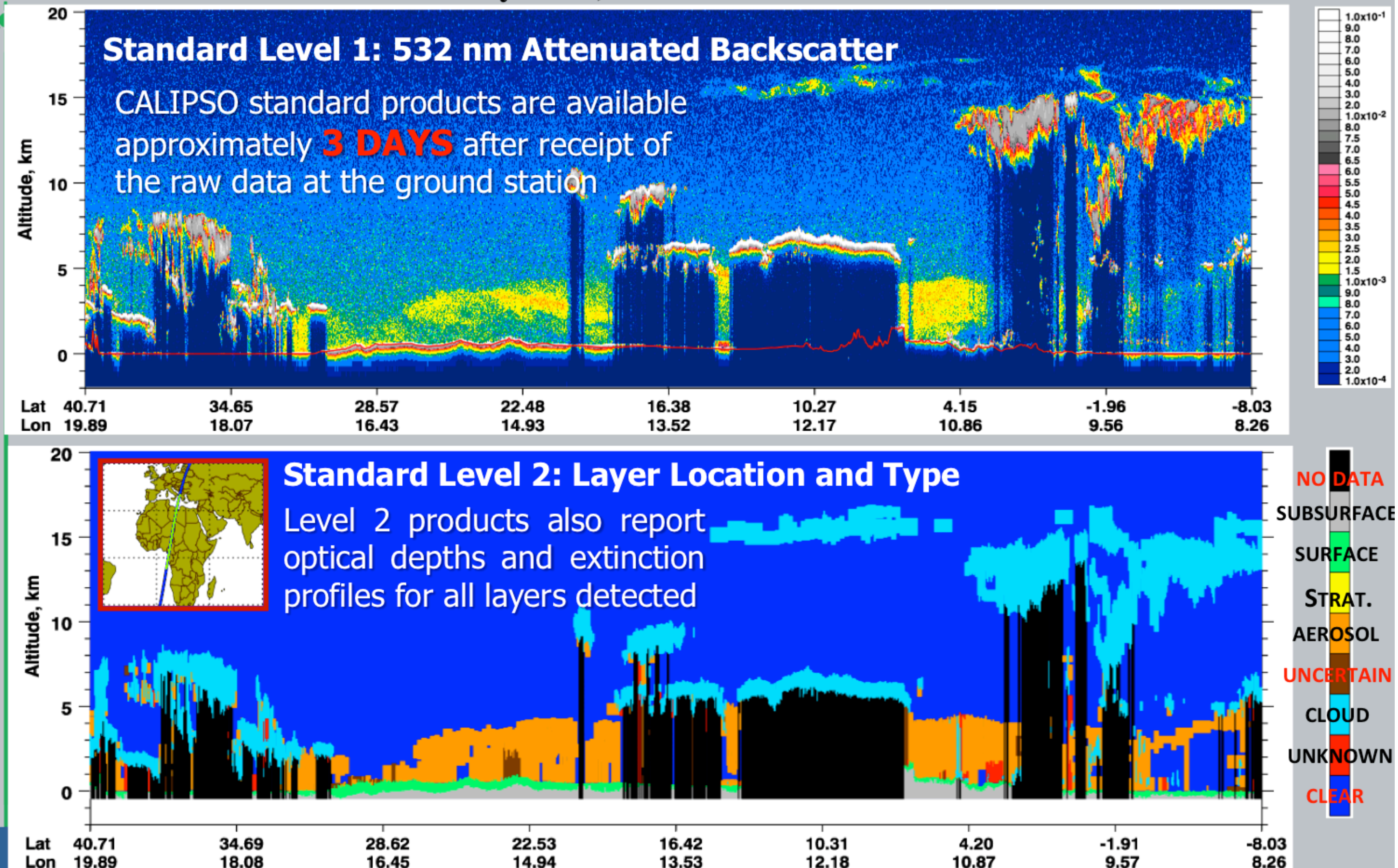
- **Aerosol profile product**
  backscatter, extinction, & depolarization profiles; aerosol type & QA flags

- **Cloud profile product**
  backscatter, extinction, depolarization, & ice water content profiles; cloud phase & QA flags

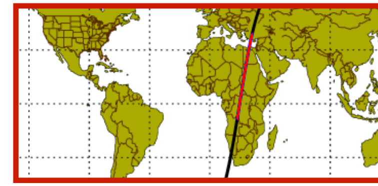
- **Vertical feature mask**
  cloud/aerosol locations, cloud phase, aerosol type & QA flags

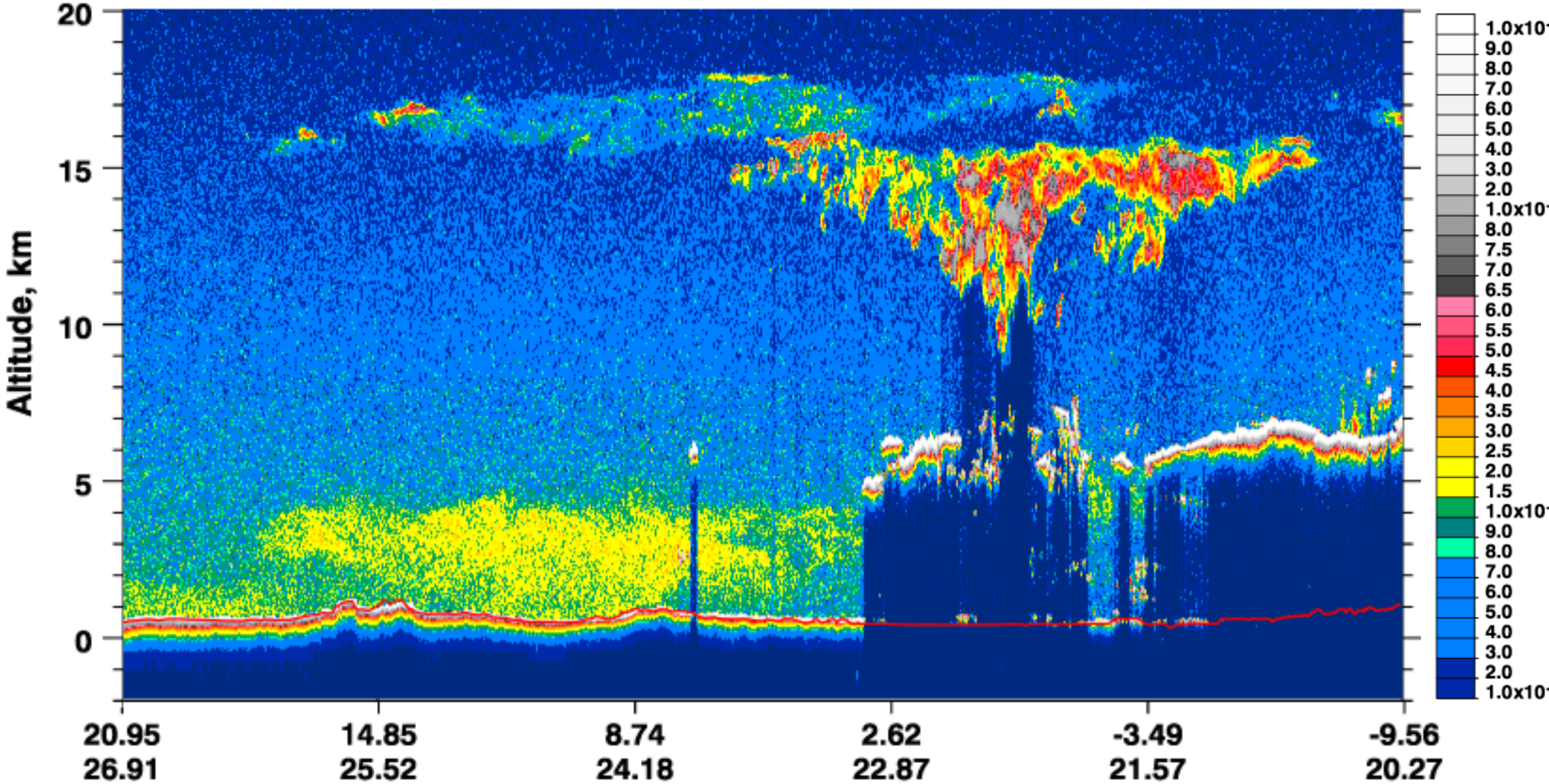
CALIPSO products

27 February 2011, UTC 00:53:30 to 01:06:59



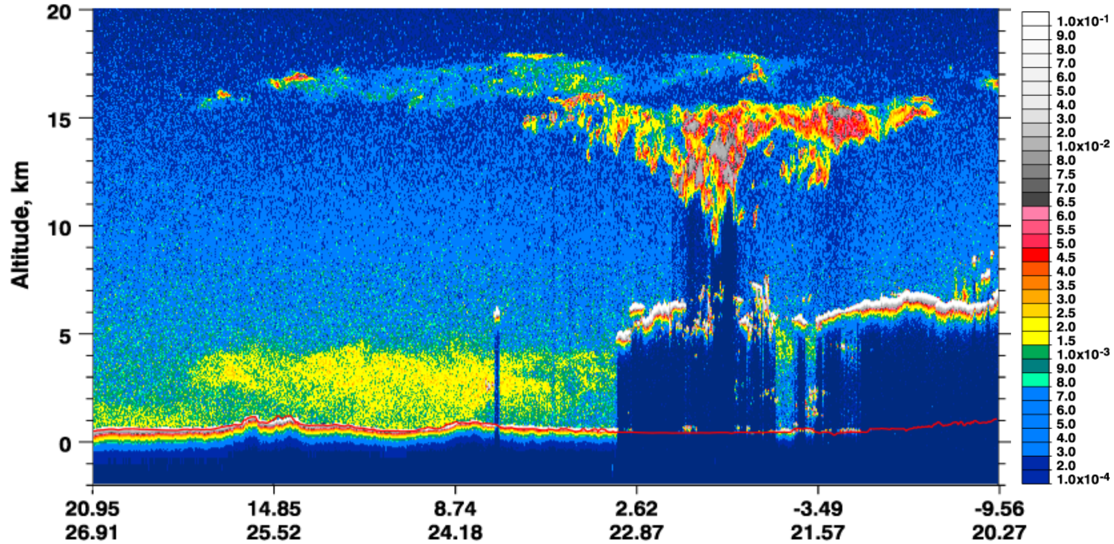
14 October 2010, ~00:13:30 UTC

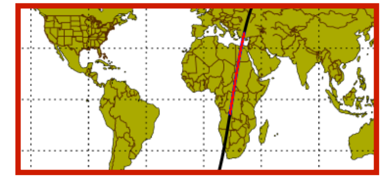


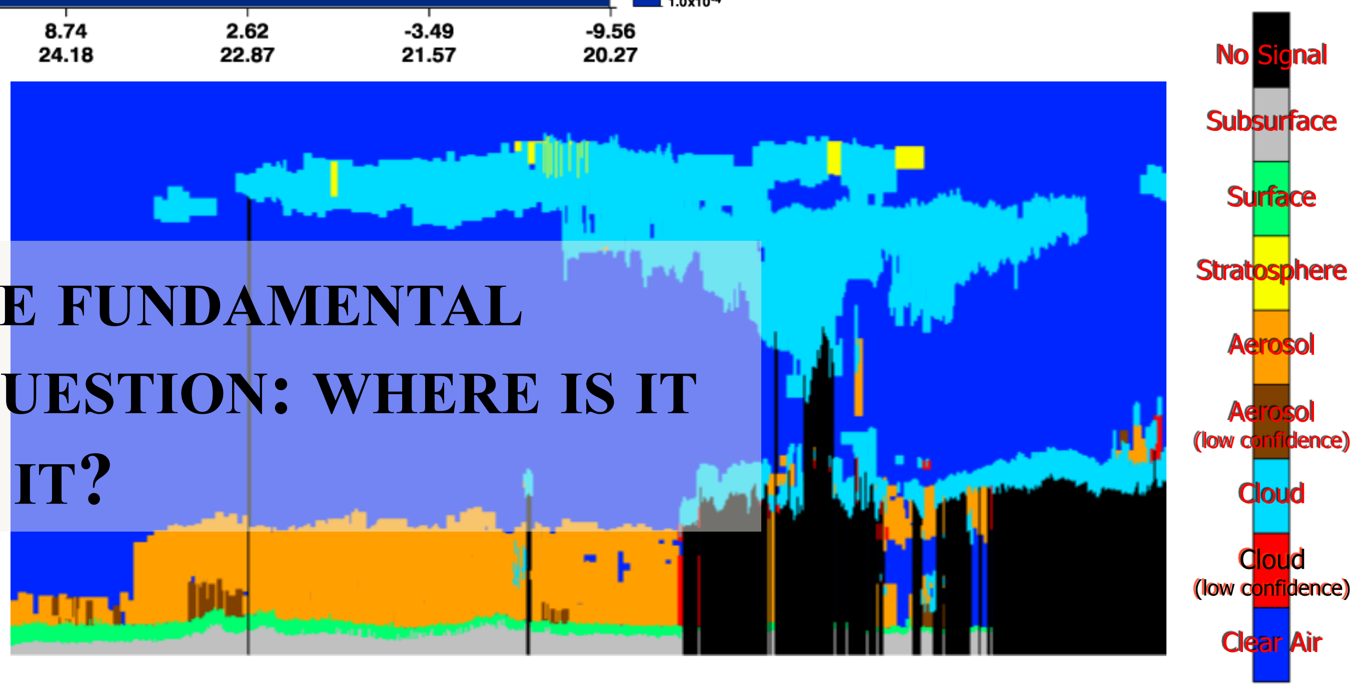


Calibrated, Geolocated, Altitude-Registered Raw Data

14 October 2010, ~00:13:30







ANSWERS THE FUNDAMENTAL RETRIEVAL QUESTION: WHERE IS IT AND WHAT IS IT?

Courtesy: Mark Vaughan from LARC-NASA

Level 1 data ⇒ Calibrated, Geolocated

Calibration ⇒ based on molecular signal at 30 – 34 km altitude

Total attenuatted backscatter signal at 532 and 1064 nm

$$\beta'_{532,\,Total}(z) = \left[\beta_{\parallel}(z) + \beta_{\perp}(z)\right] T_{532}{}^{2}(z) \qquad \beta'_{1064}(z) = \beta_{1064}(z)\ T_{1064}{}^{2}(z)$$

$$T^2(z) = T_p^2(z) + T_m^2(z) + T_{O_3}^2(z)$$

532 nm perpendicular attenuatted backscatter signal

$$\beta'_{532,\perp}(z) = \beta_{\perp}(z)\, T_{532}{}^{2}(z)$$

Depolarization ratio

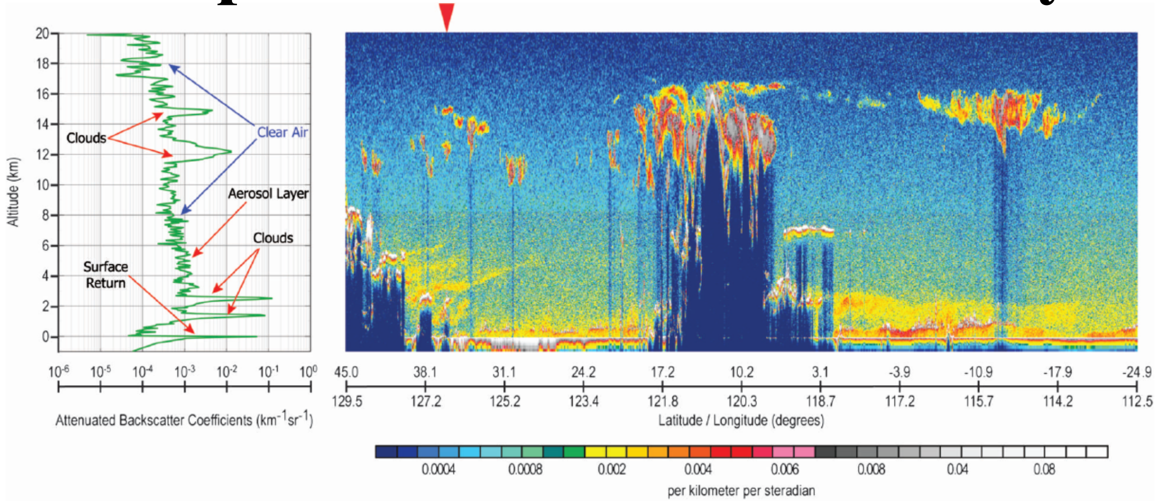
$$\delta_v(z) = \frac{\beta'_{532,\perp}(z)}{\beta'_{532,\parallel}(z)}.$$

Backscatter ratio (color ratio)

$$\chi'(z) = \frac{\mathrm{B}_{1064}(z)}{\mathrm{B}_{532}(z)}$$

Level 2 products	Parameters	Horizontal resolution
Cloud layers	Layer base and top altitude Optical depth Water/ice phase	0,33; 1 e 5 km
Aerosol layers	Layer base and top altitude Optical depth Aerosol types	5 km
Cloud profiles	Extinction and backscatter profiles	5 km
Aerosol profile	Extinction and backscatter profiles	5 km
Vertical feature mask	Clouds phase (ice/ water) Aerosol type	--

Atmospheric features detected by CALIOP



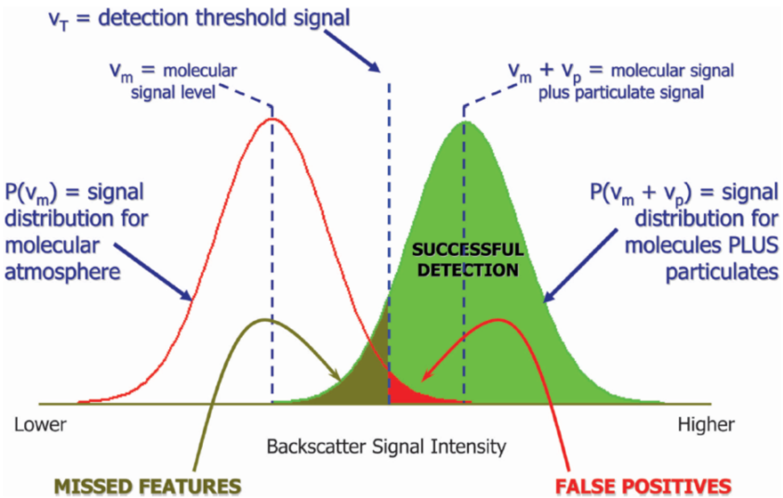
Vaughan et al, 2009 Fully Automated Detection of Cloud and Aerosol Layers in the CALIPSO Lidar Measurements, J. Atmos. Oceanic Technol. , 26, 2034-2050

Set of algorithms ⇒ Determine all the atmospheric features

<u>SIBYL</u> ⇒ Selective, Iterated BoundarY Location ⇒ Select all atmospheric layers detected

<u>SCA</u> ⇒ Scene Classification Algorithm ⇒ Classify all layers (clouds and aerosol) and classify all aerosol types

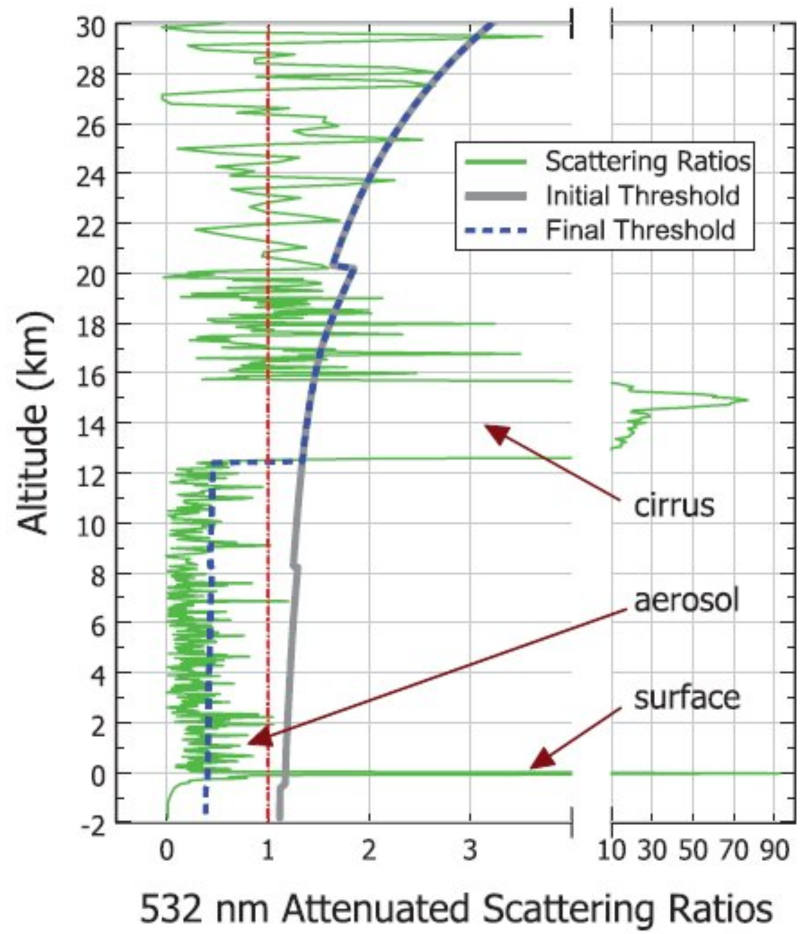
<u>HERA</u> ⇒ Hybrid Extinction Retrieval Algorithm ⇒ Retrieves the aerosol extinction profile



Backscatter signal retrieved ⇒ pure molecular signal and molecular + particle signal

$$\beta'_\lambda(r) = [\beta_{\lambda,m}(r) + \beta_{\lambda,p}(r)]\, T^2_{\lambda,m}(r)\, T^2_{\lambda,O_3}(r)\, T^2_{\lambda,p}(r)$$

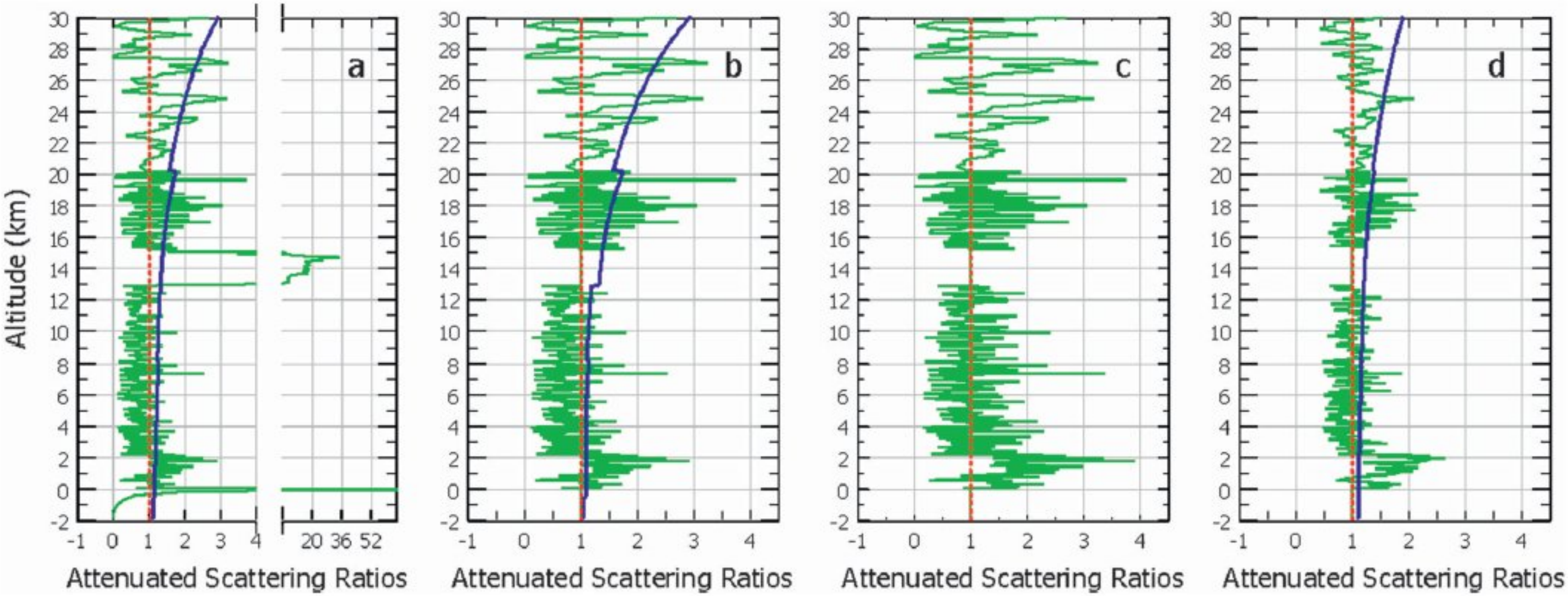
$$R'(r) = \frac{\beta'_{532}(r)}{\beta'_{\mathrm{GMAO}}(r)} = \left[1 + \frac{\beta_{532,p}(r)}{\beta_{532,m}(r)}\right] T^2_{532,p}(r)$$



Molecular density and ozone layer contribution – NASA Global Modeling and Assimilation Office (GMAO)

$$R'_{\mathrm{updated}}(r) = T^2_{\mathrm{feature}}\, R'_{\mathrm{initial}}(r)$$

Vaughan et al, 2009 Fully Automated Detection of Cloud and Aerosol Layers in the CALIPSO Lidar Measurements, J. Atmos. Oceanic Technol. , 26, 2034-2050



a) Signal profile with Cirrus clouds and initial threshold array

b) Detection and removal of Cirrus

c) Correction for Cirrus attenuation enhances the aerosol backscatter intensity

d) Average of 4 consective profiles cloud-cleared attenuation-corrected

Vaughan et al, 2009 Fully Automated Detection of Cloud and Aerosol Layers in the CALIPSO Lidar Measurements, J. Atmos. Oceanic Technol. , 26, 2034-2050

The discrimination between clouds and aerosols ⇒ performed mainly based on the differences in their optical and physical properties

The algorithm is driven by the confidence probability density function

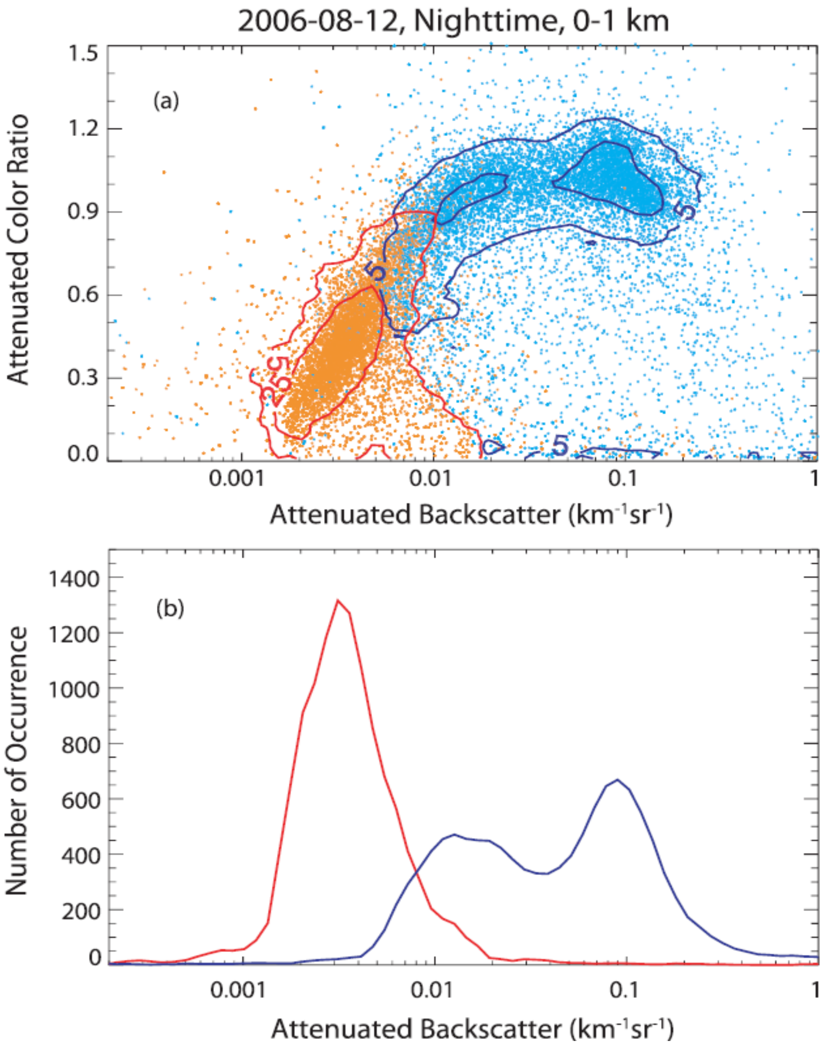
$$f(\beta'_{532}, \chi', z) = \frac{p_{\text{cloud}}(\beta'_{532}, \chi', z) - p_{\text{aerosol}}(\beta'_{532}, \chi', z)k}{p_{\text{cloud}}(\beta'_{532}, \chi', z) + p_{\text{aerosol}}(\beta'_{532}, \chi', z)k}$$

$$\beta' = \frac{1}{(i_{\text{base}} - i_{\text{top}} + 1)} \sum_{i=i_{\text{top}}}^{i_{\text{base}}} B(z_i),$$ **Layer-averaged attenuated backscatter**

$$\chi' = \frac{\beta'_{1064}}{\beta'_{532}}$$ **Attenuated total backscatter color ratio**

κ - scaling factor that is related to the ratio of the numbers of aerosol layers and cloud layers

$$f(\beta'_{532}, \chi', z) = \frac{p_{\text{cloud}}(\beta'_{532}, \chi', z) - p_{\text{aerosol}}(\beta'_{532}, \chi', z)k}{p_{\text{cloud}}(\beta'_{532}, \chi', z) + p_{\text{aerosol}}(\beta'_{532}, \chi', z)k}$$



Cloud-Aerosol Discrimination - CAD Score

0 a 100 ⇒ Clouds

-100 a 0 ⇒ Aerosols

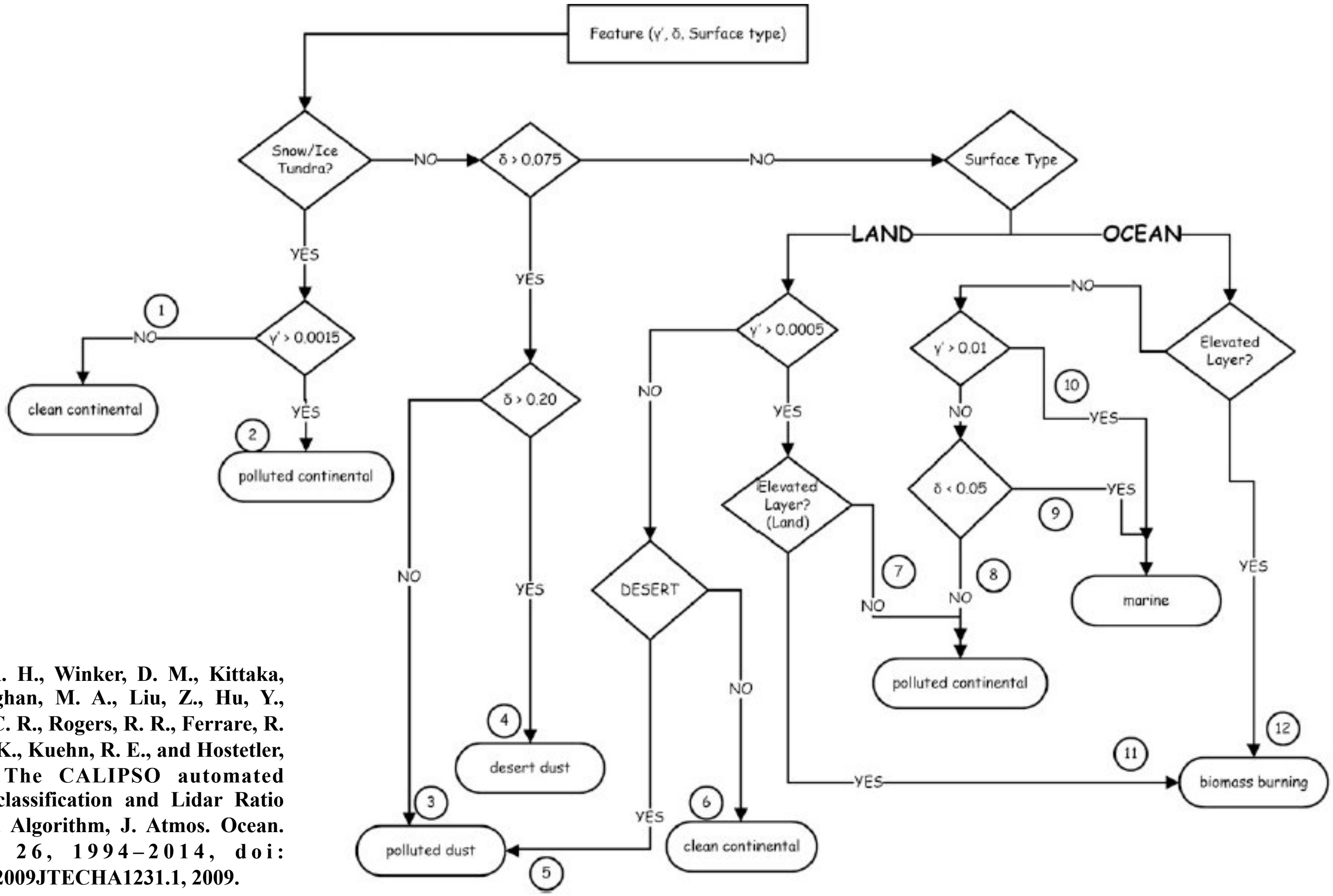
Liu, Z., Vaughan, M. A., Winker, D. M., Kittaka, C., Getzewich, B. J., Kuehn, R. E., Omar, A. H., Powell, K. A., Trepte, C. R., and Hostetler, C. A.: The CALIPSO Lidar cloud and aerosol discrimination: Version 2 algorithm and initial assessment of performance, J. Atmos. Ocean. Tech., 26, 1198–1213

Total integrated backscatter

$$\gamma' = \int_{base}^{topo} \left[\beta_p(r) + \beta_m(r)\right] T_\lambda^2(r)$$

Volume depolarization ratio

$$\delta_v(r) = \frac{\sum_{base}^{topo} \beta'_{\perp}(r)}{\sum_{base}^{topo} \beta'_{\parallel}(r)}$$



Omar, A. H., Winker, D. M., Kittaka, C., Vaughan, M. A., Liu, Z., Hu, Y., Trepte, C. R., Rogers, R. R., Ferrare, R. A., Lee, K., Kuehn, R. E., and Hostetler, C. A.: The CALIPSO automated aerosol classification and Lidar Ratio Selection Algorithm, J. Atmos. Ocean. Tech., 26, 1994–2014, doi: 10.1175/2009JTECHA1231.1, 2009.

Determination of the aerosol types representative of the aerosol mixtures most frequently observed at the AERONET[1]

AERONET dataBase – more than 10 years of measurements [2]

Aerosol type	Lidar ratio at 532 nm (sr)	Lidar ratio at 1064 nm (sr)
Dust	40	30
Smoke	70	40
Clean Continental	35	30
Polluted Continental	70	30
Clean Marine	20	45
Polluted dust	55	30

1 - A. H. Omar, D.M.Winker, C. Kittaka,M. A. Vaughan, Z. Liu, Y. Hu, C. R. Trepte, R. R. Rogers, R. A. Ferrare, K. Lee, R. E. Kuehn, and C. A. Hostetler. The CALIPSO automated aerosol classification and Lidar Ratio Selection Algorithm. *Journal of Atmospheric and Oceanic Technology, 26:1994–2014, 2009.*

2 - OMAR, A. H.; WON, J. G.; WINKER, D. M.; YOON, S. C.; DUBOVIK, O.; MCCORMICK, M. P. Development of global aerosol models using cluster analysis of Aerosol Robotic Network (AERONET) measurements. *J. Geophys. Res., v. 110, p. D10S14,* 2005.

HERA ⇒ Hybrid Extinction Retrieval Algorithm

retrieves the profile of particulate extinction coefficients from the CALIOP attenuated backscatter data

Solution of the lidar equation

$$P(\lambda, z) = P_o \frac{ct}{2} A \frac{\beta_m(\lambda,z) + \beta_{aer}(\lambda,z)}{z^2} exp\left[-2\int_o^z \alpha(\lambda, z')dz'\right]$$

$\beta(\lambda, z)$ ⇒ backscatter coefficient

$\alpha(\lambda, z)$ ⇒ extinction coefficient

Young, S. A. and Vaughan, M. A.: The retrieval of profiles of particulate extinction from Cloud-Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) Data: Algorithm Description, J. Atmos. Oceanic Technol., 26, 1105–1119, doi: 10.1175/2008JTECHA1221.1, 2009.

HERA ⇒ Hybrid Extinction Retrieval Algorithm

$$P(r) = \frac{1}{r^2} E_0 \xi [\beta_M(r) + \beta_P(r)] T_M^2(0,r) T_{O_3}^2(0,r) T_P^2(0,r) + P_o$$

$$T_M^2(0,r) = \exp\left[-2\int_0^r \sigma_M(r')dr'\right]$$

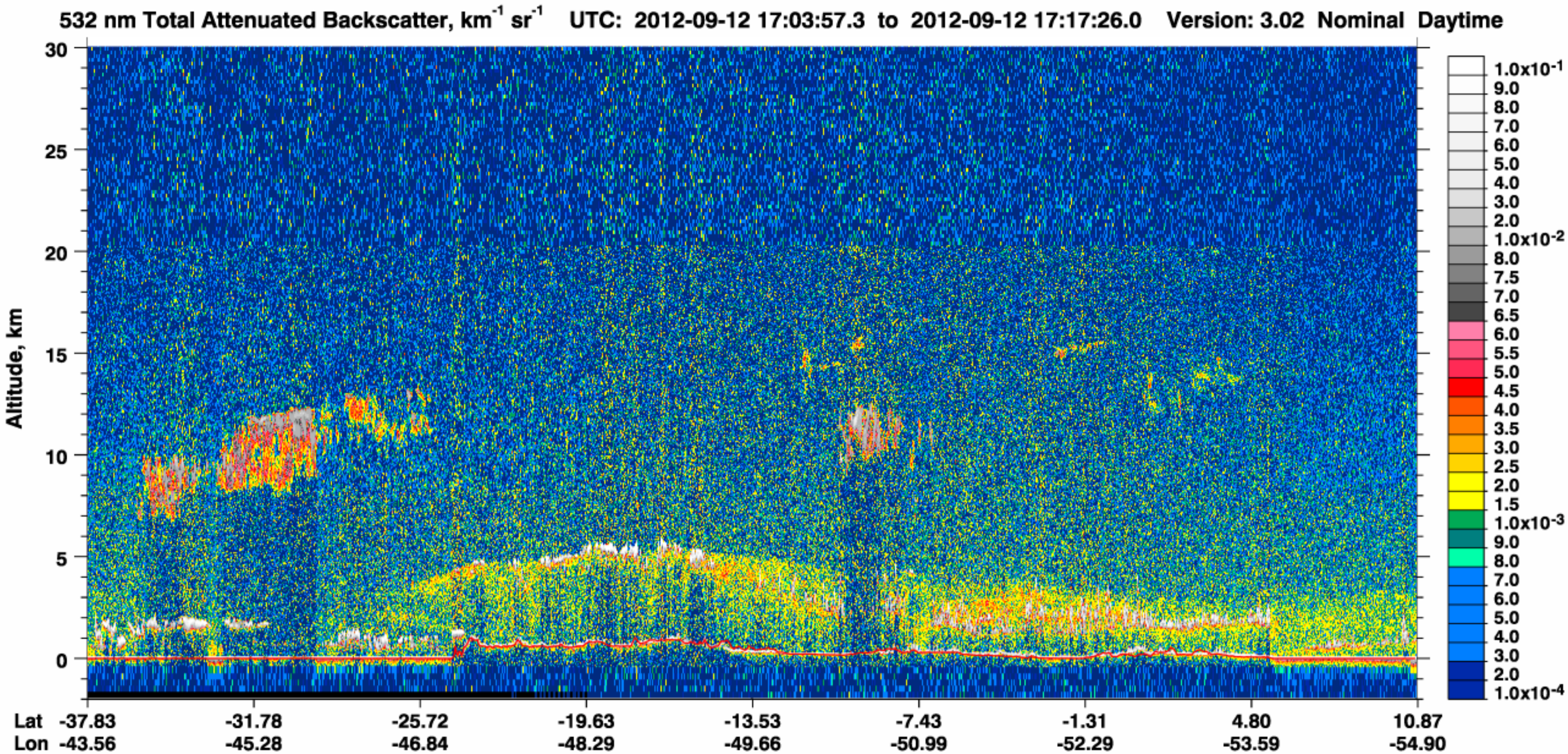
$\sigma_M(r) = S_M \beta_M(r)$ is the molecular volume extinction coefficient, and

$T_{O_3}^2(0,r) = \exp[-2\int_0^r \alpha_{O_3}(r')dr']$ is the two-way ozone transmittance

$$T_P^2(0,r) = \exp[-2\eta(r)\tau_P(0,r)]$$

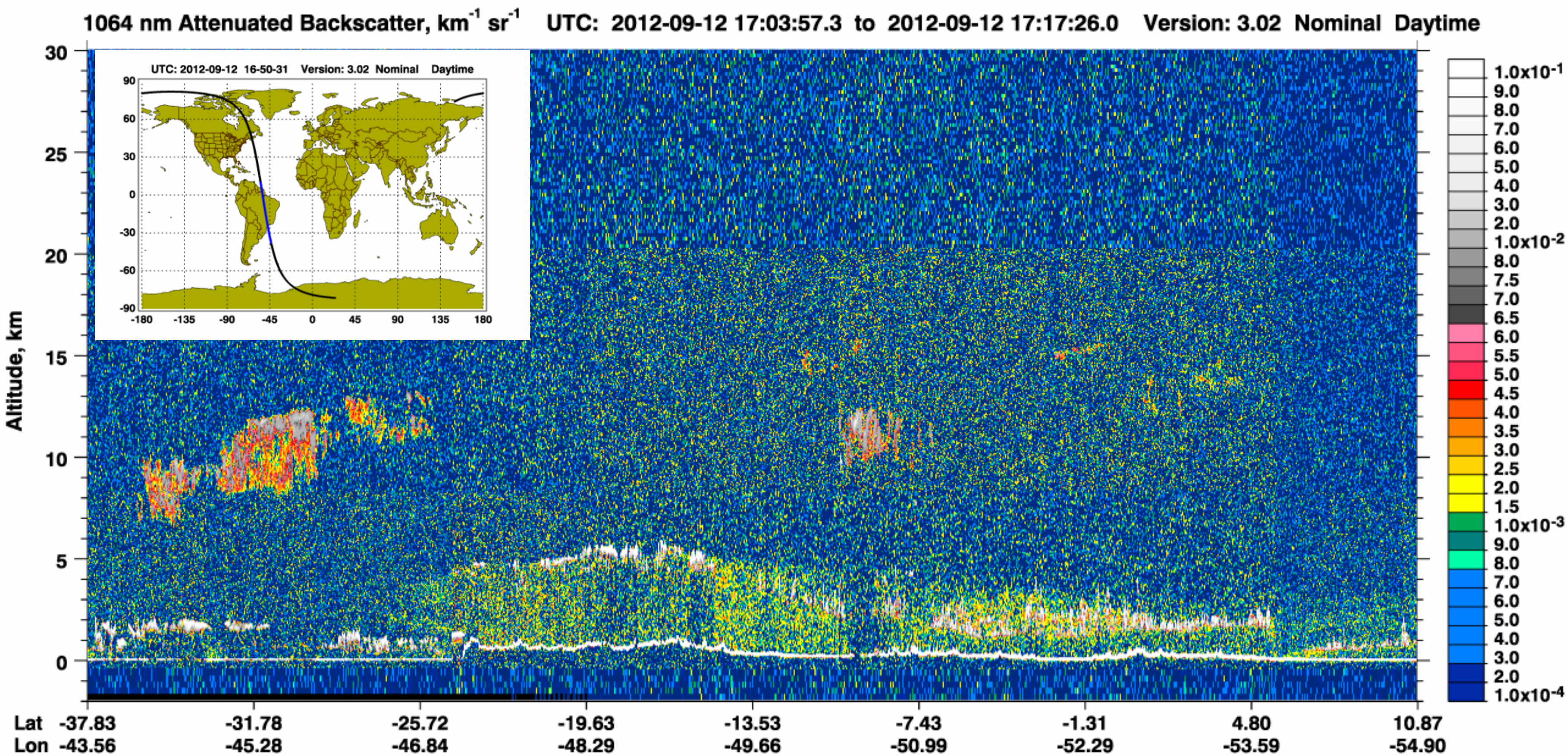
$$\tau_P(0,r) = \int_0^r \sigma_P(r')dr' = \sum_{j=0}^{n-1} S_{P_j} \int_{r_j}^{r_{j+1}} \beta_P(r')dr'$$

532 nm Total attenuated backscatter



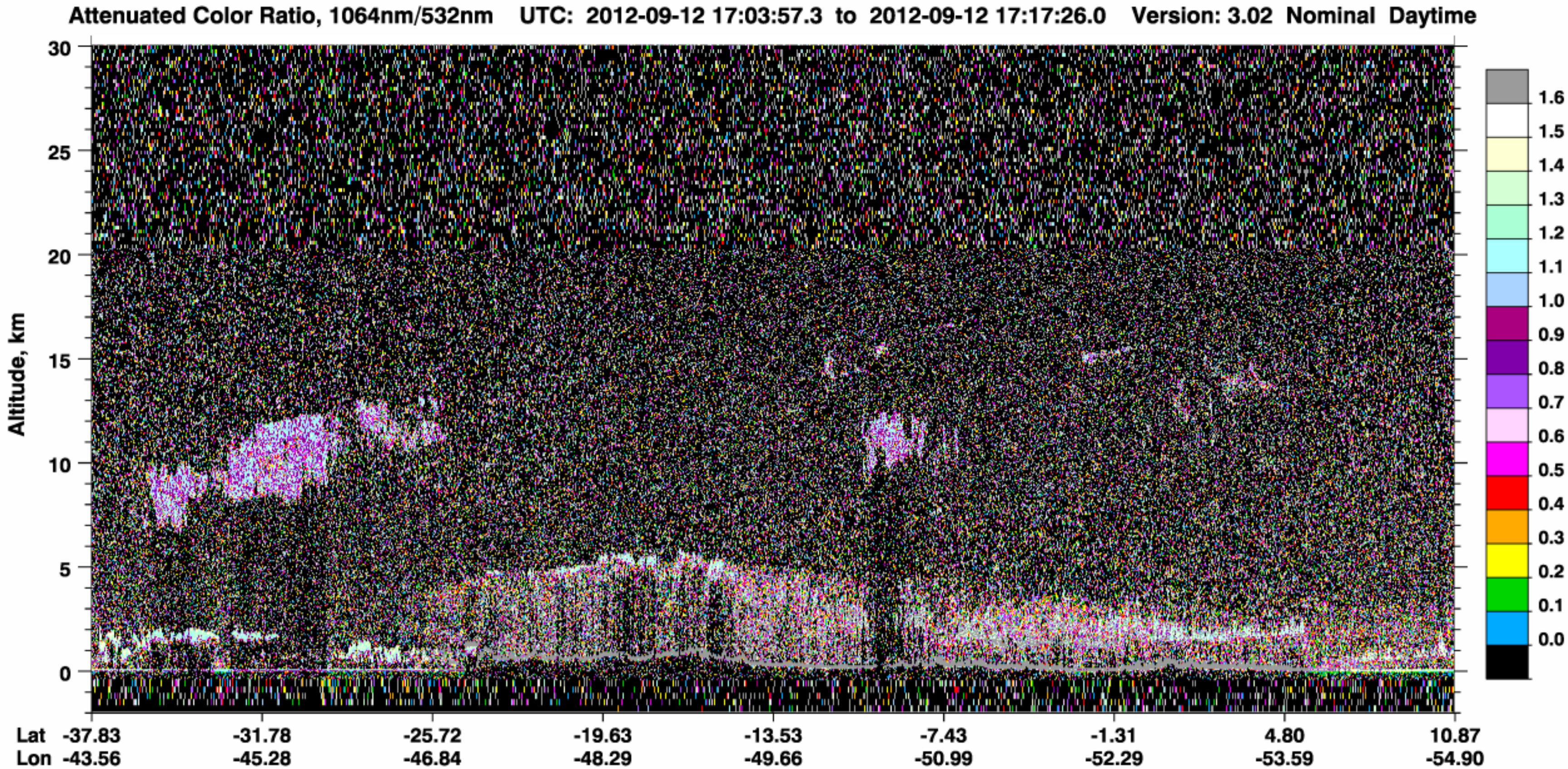
$$\beta'_{532,\,Total}(z) = \left[\beta_{\parallel}(z) + \beta_{\perp}(z)\right] T_{532}{}^{2}(z)$$

1064 nm Total attenuated backscatter



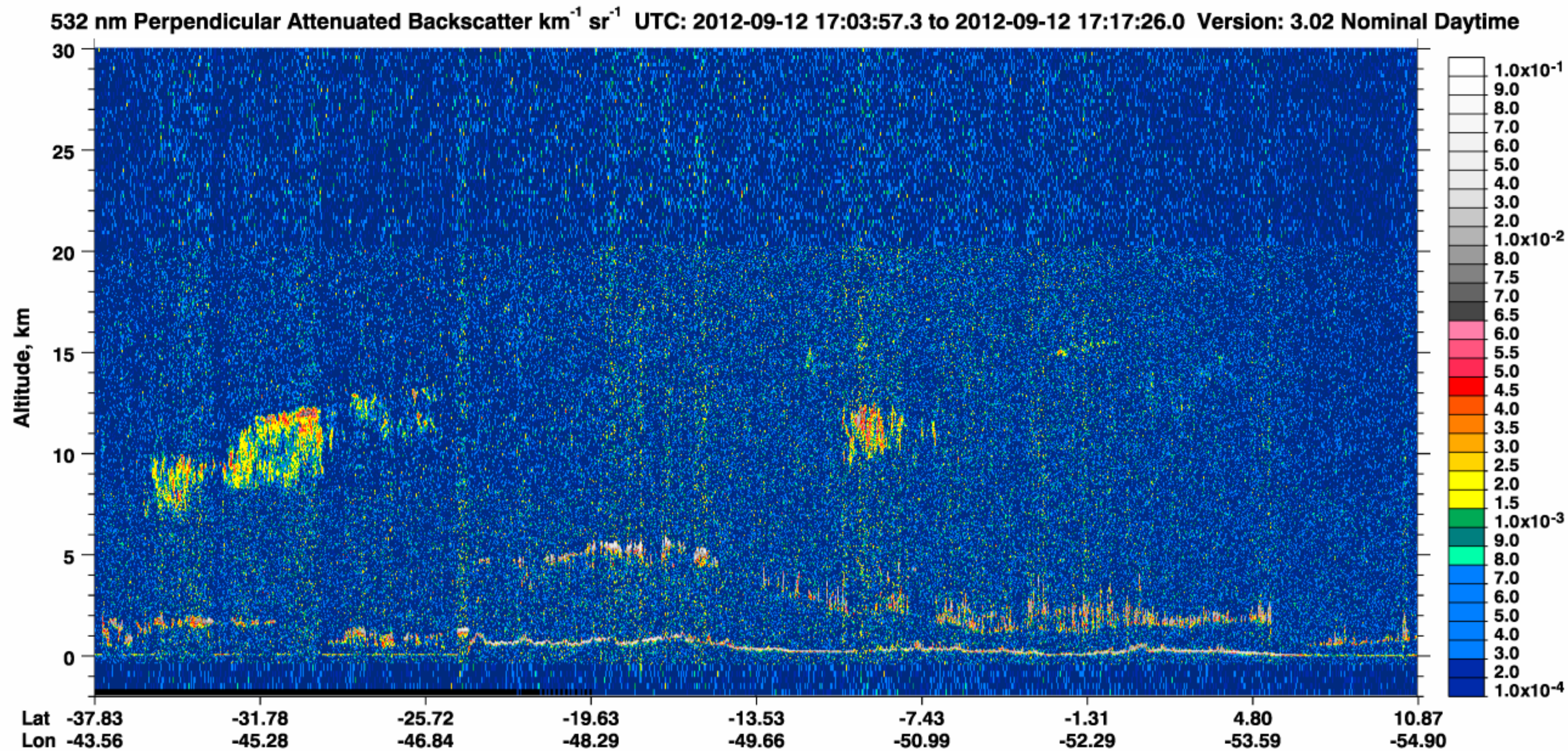
$$\beta'_{1064}(z) = \beta_{1064}(z)\ T_{1064}{}^{2}(z)$$

Color ratio 1064nm/532 nm



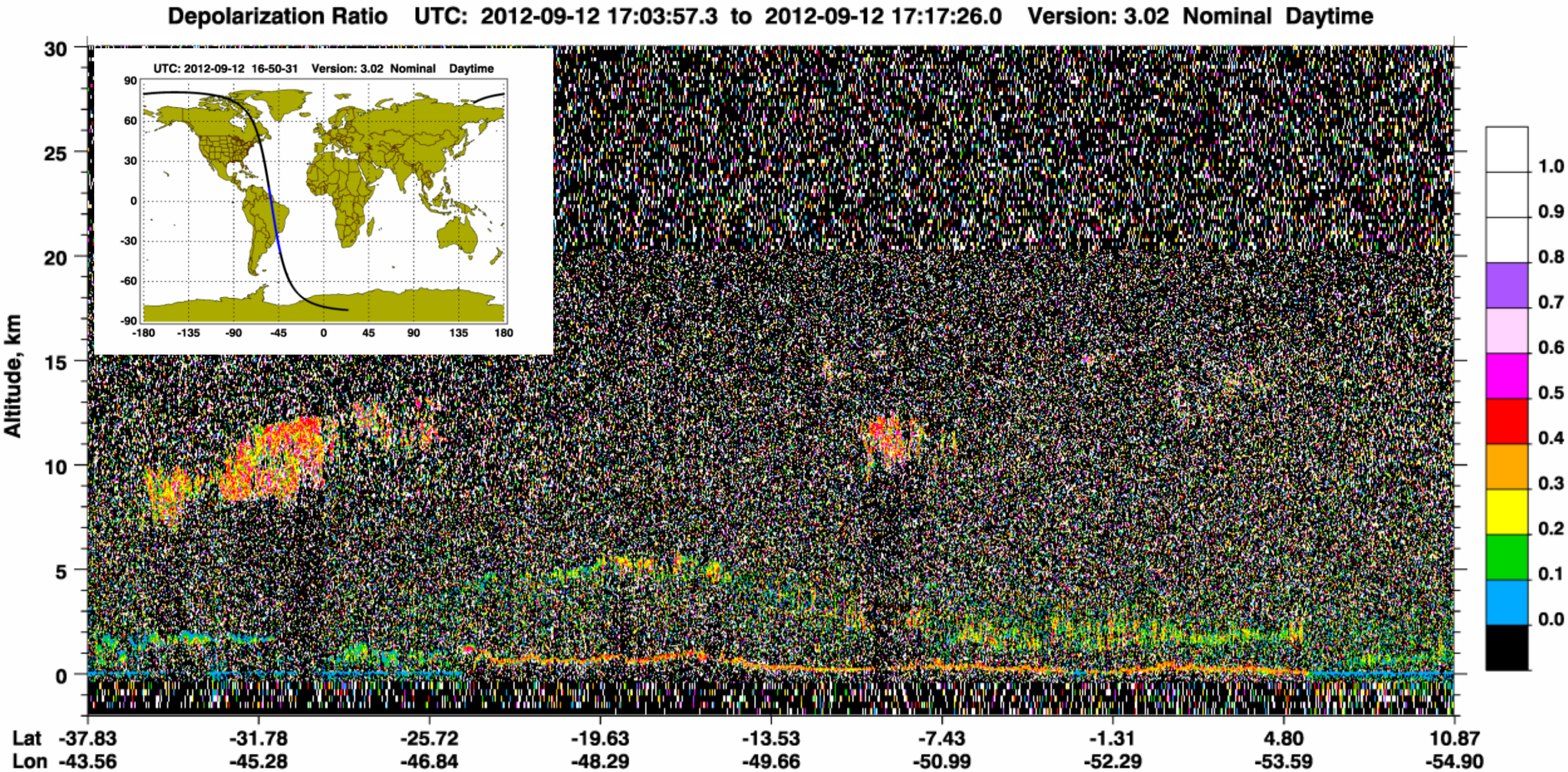
$$\chi'(z) = \frac{B_{1064}(z)}{B_{532}(z)}$$

532 nm Perpendicular attenuated backscatter



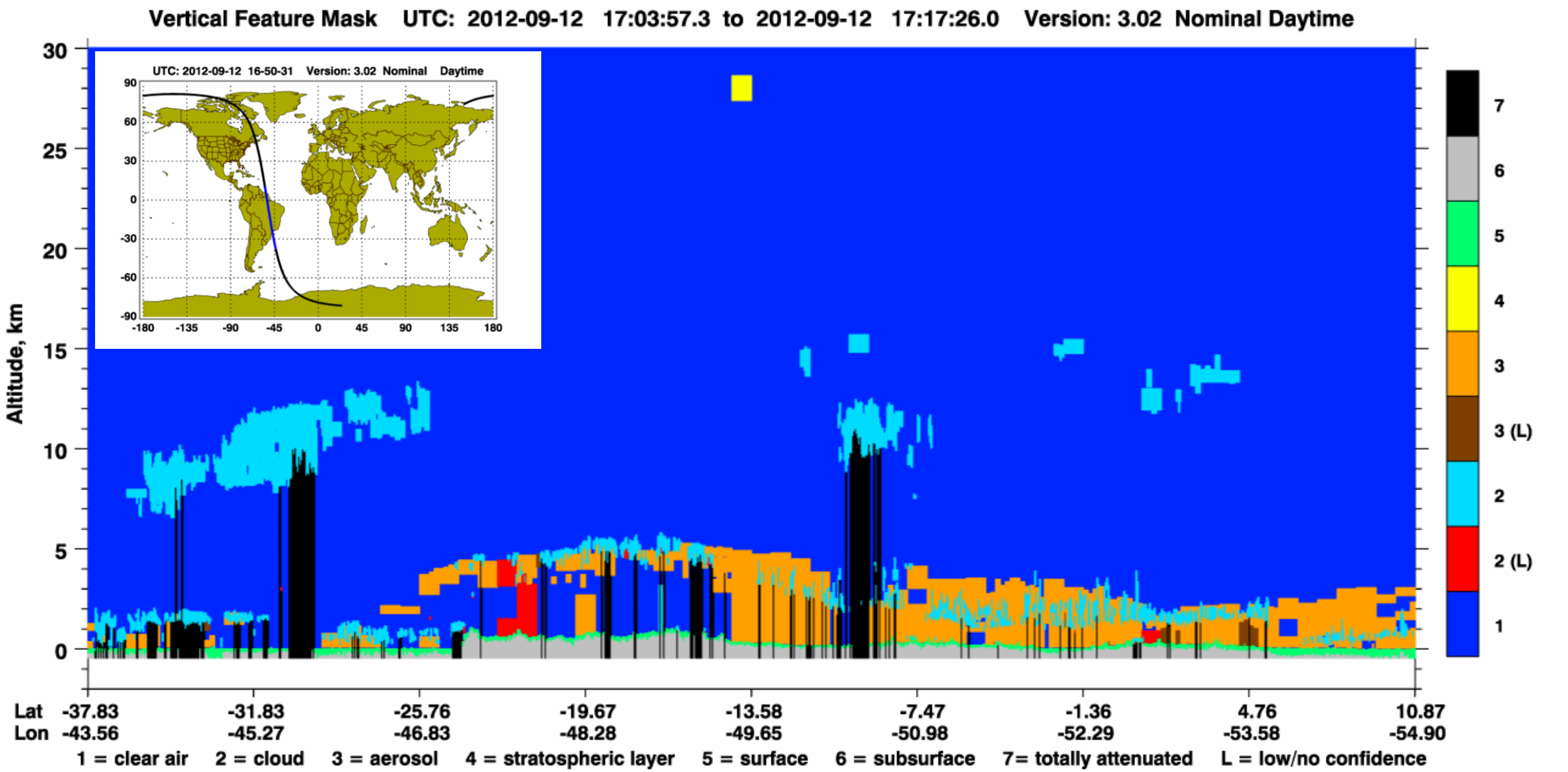
$$\beta'_{532,\perp}(z) = \beta_{\perp}(z)\, T_{532}^{\ 2}(z)$$

Depolarization ratio

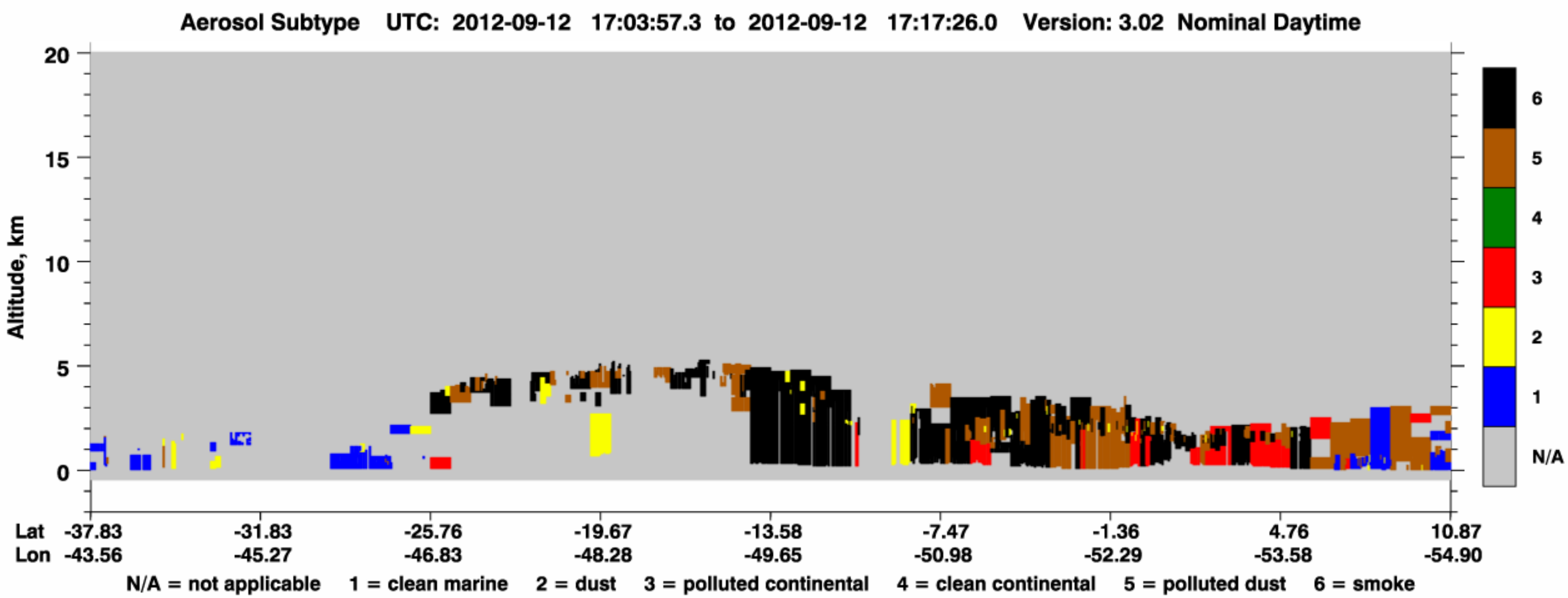


$$\delta_v(z) = \frac{\beta'_{532,\perp}(z)}{\beta'_{532,\parallel}(z)}.$$

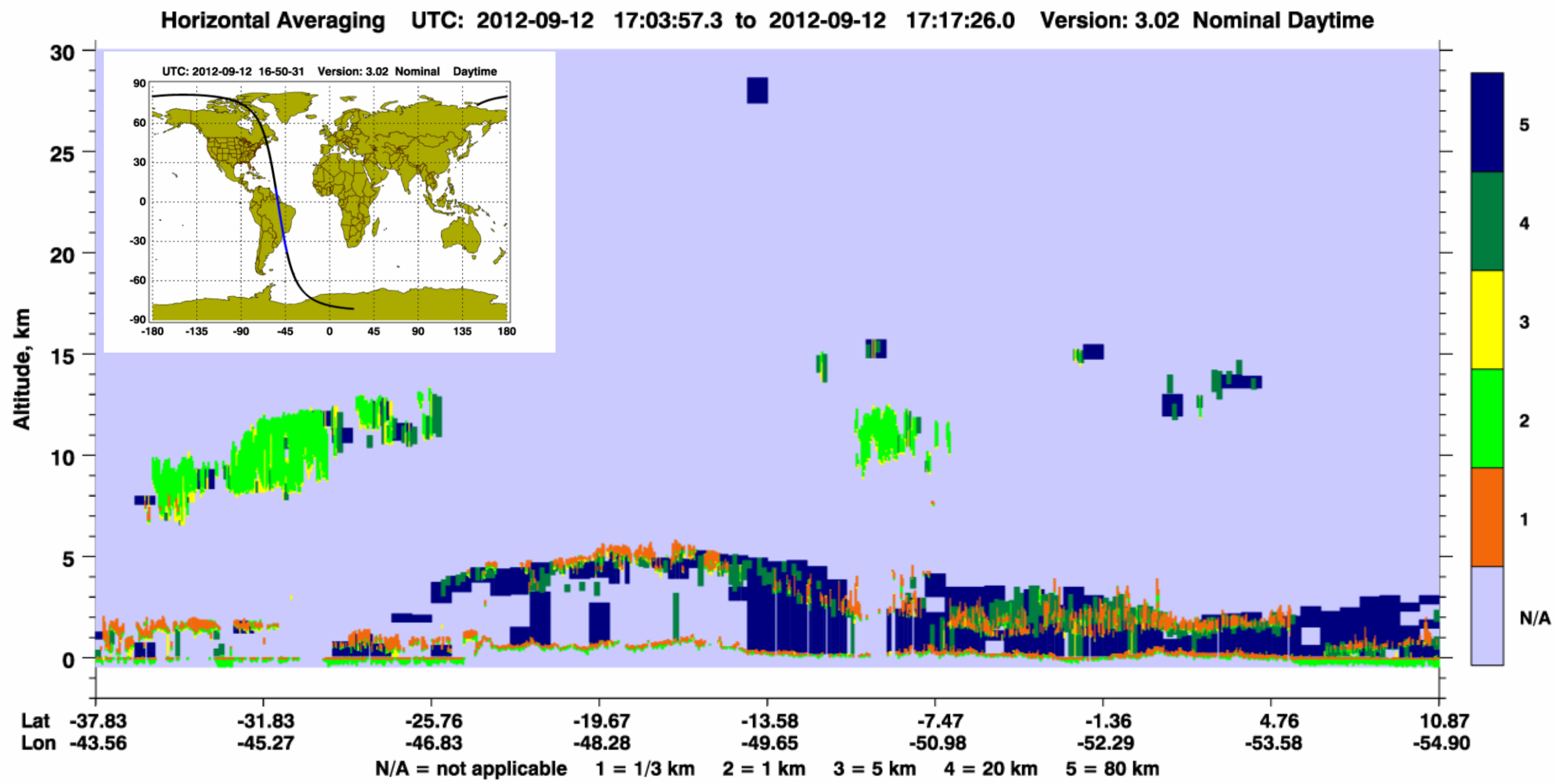
Vertical feature mask



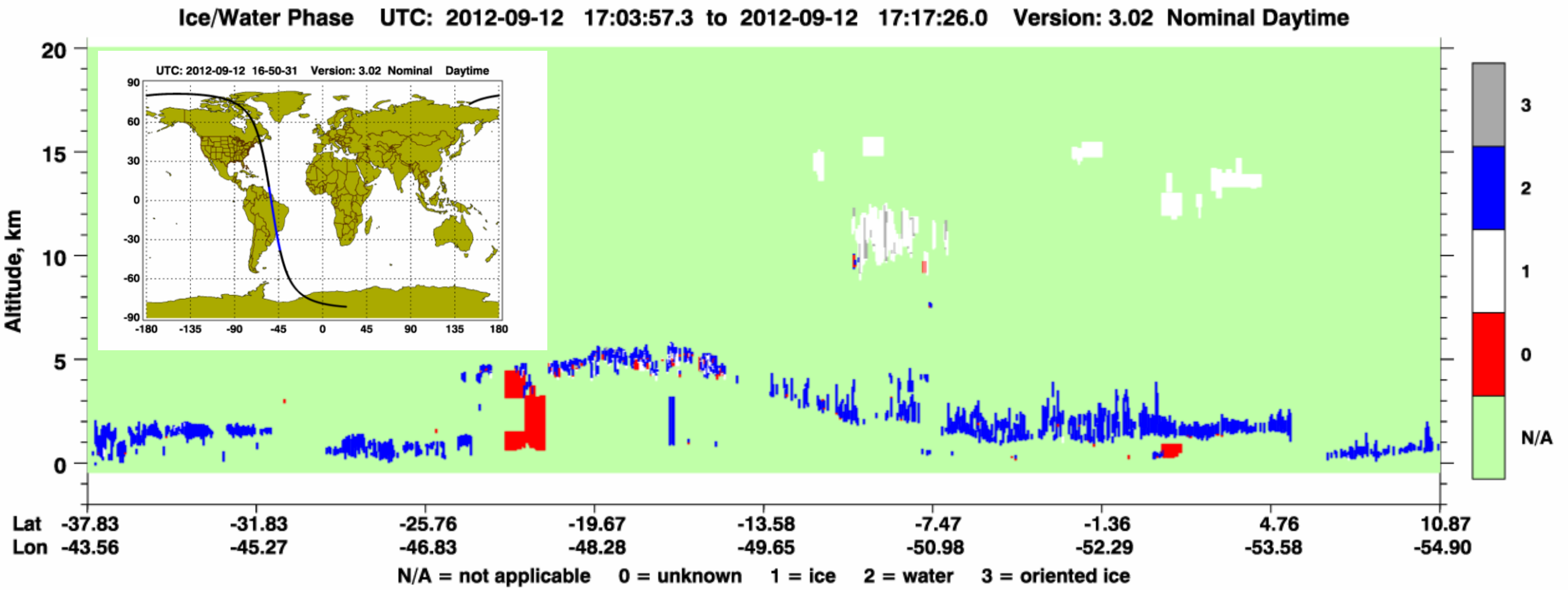
Aerosol subtype



Horizontal averaging



Ice/Water phase



http://www-calipso.larc.nasa.gov/

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

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The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)

CALIPSO, a joint mission between NASA and the French space agency, CNES, provides new insight into the role that clouds and atmospheric aerosols (airborne particles) play in regulating Earth's weather, climate, and air quality.

NEWS

15-October-2015:
CALIPSO - Lidar Level 3 Version 3.00 Data Available

Version 3.00 of the CALIOP Level 3 Aerosol Profile product contains several improvements to the initial beta release including refined sky conditions, reduced biases in single-species averages and corrected mean aerosol optical depth calculations.

The monthly products is available beginning with data from June 2006 (following CALIOP first light on June 13, 2006) through current. The Version 1.00 and 1.30 CALIOP Level 3 Aerosol Profile data products will no longer be generated beyond September 2015.

Information about these data products including data availability, user documentation and quality statements, relevant links, sample read software, and tools for working with the data, etc. can be found at the following ASDC link: https://eosweb.larc.nasa.gov/project/calipso/calipso_table. In-depth overviews of the improvements can be found in the following CALIPSO link to the data quality summaries: http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/data_summaries/l3/CALIOP_L3Products_3-00_v01.php.

INTRODUCTION

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite provides new insight into the role that clouds and atmospheric aerosols (airborne particles) play in regulating Earth's weather, climate, and air quality.

CALIPSO combines an active lidar instrument with passive infrared and visible imagers to probe the vertical structure and properties of thin clouds and aerosols over the globe. CALIPSO was launched on April 28, 2006 with the cloud profiling radar system on the CloudSat satellite.

CALIPSO and CloudSat are highly complementary and together provide new, never-before-seen 3-D perspectives of how clouds and aerosols form, evolve, and affect weather and climate. CALIPSO and CloudSat fly in formation with three other satellites in the A-train constellation to enable an even greater understanding of our climate system from the broad array of sensors on these other spacecraft.

CALIPSO is a joint U.S. (NASA) and French (Centre National d'Etudes Spatiales/CNES) satellite mission that has been in operation for four years. » Read more ...

QUICK LINKS

» CALIPSO's Data Availability Tool
» CALIPSO's Search and Subsetting Web Application

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+ Home
+ Products Home

Products

− OVERVIEW
+ UPDATES
+ USERS GUIDE
+ DATA AVAILABILITY TOOL
+ DATA SUBSETTER WEB APP
+ LIDAR BROWSE IMAGES
+ EXPEDITED BROWSE IMAGES
+ QUICKLOOK IMAGES & DATA
+ WIDE FIELD CAMERA IMAGES
+ Expedited KML/KMZ Data
+ Data Products Inventory

PRODUCTS

CALIPSO produces Level 1 and Level 2 science data products that are listed in detail in the CALIPSO Data Products Catalog (PC SCI 503). These products are archived and distributed by the Atmospheric Science Data Center (ASDC).

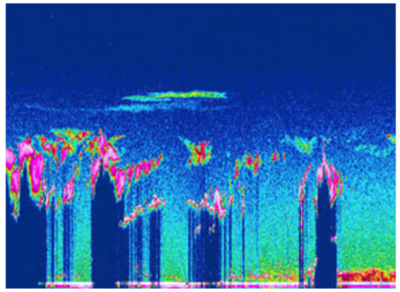

Image above: An example of data collected by CALIPSO's lidar in June 2006. The data extends from sea level to 30 km.

For more information on CALIPSO's prospective data products, visit this journal article:

Vaughan, M., Young, S., Winker, D., Powell, K., Omar, A., Liu, Z., Hu, Y., and Hostetler, C. (2004). Fully automated analysis of space-based lidar data: an overview of the CALIPSO retrieval algorithms and data products. *Proc. SPIE*, 5575, pp. 16-30. [View Paper]

Table 1 gives a summary of the CALIPSO Level 2 data products and the spatial scales at which the data products are reported. The expected accuracies given are for the maximum averaging distances for which the products will be retrieved.

Cloud products are reported at a horizontal resolution of 5 km; i.e., at the fundamental averaging resolution of the processing scheme. Cloud boundaries, which can be detected at higher resolution, are reported at that resolution. To account for weaker backscatter signals from aerosols, the Level 2 aerosol profile products are reported at a uniform horizontal resolution of 40 km at all altitudes.

Table 1. CALIPSO Level 2 Aerosol and Cloud Measurements

Data Product	Measurement Capabilities and Uncertainties	Data Product Resolution	
		Horizontal	Vertical
Aerosols			
Height, Thickness	For layers with $\beta > 2.5 \times 10^{-4}$ km^{-1} sr^{-1}	5 km	60 m
Optical depth, τ	40% *	5 km	N/A
Backscatter, $\beta_a(z)$	20 - 30%	40 km 40 km	Z < 20 km 120 m Z ≥ 20 km: 360 m
Extinction, σ_a	40% *	40 km 40 km	Z < 20 km 120 m Z ≥ 20 km: 360 m
Clouds			
Height	For layers with $\beta > 1 \times 10^{-3}$ km^{-1} sr^{-1}	1/3, 1, 5 km	30, 60 m
Thickness	For layers with $\tau < 5$	1/3, 1, 5 km	60 m
Optical depth, τ	within a factor of 2 for $\tau < 5$	5 km	N/A
Backscatter, $\beta_c(z)$	20 - 30%	5 km	60 m
Extinction, σ_c	within a factor of 2 for $\tau < 5$	5 km	60 m
Ice/water phase	Layer by layer	5 km	60 m
Ice cloud emissivity, ε	±0.03	1 km	N/A
Ice particle size	±50% for $\varepsilon > 0.2$	1 km	N/A

Note: * assumes 30% uncertainty in the aerosol extinction-to-backscatter lidar ratio, S_a.

http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/

Lidar Data

Processing Level	Data Product Name	Strategies (v4.x) / Data_Maturity (DM) Links take you to detailed quality summaries.	Example File Name* Links take you to parameter descriptions.
Level 1	1B Profile	Standard Validated Stage 1	Standard (Strategies): CAL_LID_L1-Standard-V4-00 Standard (DM): CAL_LID_L1-ValStage1-V3-30, CAL_LID_L1-ValStage1-V3-02, CAL_LID_L1-ValStage1-V3-01 Expedited (DM): CAL_LID_L1_Exp-Prov-V3-30, CAL_LID_L1_Exp-Prov-V3-02
Level 2	5 km Aerosol Layer	Provisional	Standard (DM): CAL_LID_L2_05kmALay-Prov-V3-30, CAL_LID_L2_05kmALay-Prov-V3-02, CAL_LID_L2_05kmALay-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmALay_Exp-Prov-V3-30, CAL_LID_L2_05kmALay_Exp-Prov-V3-02
	5 km Cloud Layer	Provisional	Standard (DM): CAL_LID_L2_05kmCLay-Prov-V3-30, CAL_LID_L2_05kmCLay-Prov-V3-02, CAL_LID_L2_05kmCLay-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmCLay_Exp-Prov-V3-30, CAL_LID_L2_05kmCLay_Exp-Prov-V3-02
	1 km Cloud Layer	Validated Stage 1	Standard (DM): CAL_LID_L2_01kmCLay-ValStage1-V3-30, CAL_LID_L2_01kmCLay-ValStage1-V3-02, CAL_LID_L2_01kmCLay-ValStage1-V3-01 Expedited (DM): CAL_LID_L2_01kmCLay_Exp-Prov-V3-30, CAL_LID_L2_01kmCLay_Exp-Prov-V3-02
	333 m Cloud Layer	Validated Stage 1	Standard (DM): CAL_LID_L2_333mCLay-ValStage1-V3-30, CAL_LID_L2_333mCLay-ValStage1-V3-02, CAL_LID_L2_333mCLay-ValStage1-V3-01 Expedited (DM): CAL_LID_L2_333mCLay_Exp-Prov-V3-30, CAL_LID_L2_333mCLay_Exp-Prov-V3-02
	5 km Aerosol Profile	Validated Stage 1	Standard (DM): CAL_LID_L2_05kmAPro-Prov-V3-30, CAL_LID_L2_05kmAPro-Prov-V3-02, CAL_LID_L2_05kmAPro-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmAPro_Exp-Prov-V3-30, CAL_LID_L2_05kmAPro_Exp-Prov-V3-02
	5 km Cloud Profile	Provisional	Standard (DM): CAL_LID_L2_05kmCPro-Prov-V3-30, CAL_LID_L2_05kmCPro-Prov-V3-02, CAL_LID_L2_05kmCPro-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmCPro_Exp-Prov-V3-30, CAL_LID_L2_05kmCPro_Exp-Prov-V3-02
	Vertical Feature Mask	Validated Stage 1	Standard (DM): CAL_LID_L2_VFM-ValStage1-V3-30, CAL_LID_L2_VFM-ValStage1-V3-02, CAL_LID_L2_VFM-ValStage1-V3-01 Expedited (DM): CAL_LID_L2_VFM_Exp-Prov-V3-30, CAL_LID_L2_VFM_Exp-Prov-V3-02
	Polar Stratospheric Cloud Mask	Provisional	Standard Only (DM): CAL_LID_L2_PSCMask-Prov-V1-00

http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/

Lidar Data

Processing Level	Data Product Name	Strategies (v4.x) / Data_Maturity (DM) Links take you to detailed quality summaries.	Example File Name* Links take you to parameter descriptions.
Level 1	1B Profile	Standard Validated Stage 1	Standard (Strategies): CAL_LID_L1-Standard-V4-00 Standard (DM): CAL_LID_L1-ValStage1-V3-30, CAL_LID_L1-ValStage1-V3-02, CAL_LID_L1-ValStage1-V3-01 Expedited (DM): CAL_LID_L1_Exp-Prov-V3-30, CAL_LID_L1_Exp-Prov-V3-02
Level 2	5 km Aerosol Layer	Provisional	Standard (DM): CAL_LID_L2_05kmALay-Prov-V3-30, CAL_LID_L2_05kmALay-Prov-V3-02, CAL_LID_L2_05kmALay-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmALay_Exp-Prov-V3-30, CAL_LID_L2_05kmALay_Exp-Prov-V3-02
	5 km Cloud Layer	Provisional	Standard (DM): CAL_LID_L2_05kmCLay-Prov-V3-30, CAL_LID_L2_05kmCLay-Prov-V3-02, CAL_LID_L2_05kmCLay-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmCLay_Exp-Prov-V3-30, CAL_LID_L2_05kmCLay_Exp-Prov-V3-02
	1 km Cloud Layer	Validated Stage 1	Standard (DM): CAL_LID_L2_01kmCLay-ValStage1-V3-30, CAL_LID_L2_01kmCLay-ValStage1-V3-02, CAL_LID_L2_01kmCLay-ValStage1-V3-01 Expedited (DM): CAL_LID_L2_01kmCLay_Exp-Prov-V3-30, CAL_LID_L2_01kmCLay_Exp-Prov-V3-02
	333 m Cloud Layer	Validated Stage 1	Standard (DM): CAL_LID_L2_333mCLay-ValStage1-V3-30, CAL_LID_L2_333mCLay-ValStage1-V3-02, CAL_LID_L2_333mCLay-ValStage1-V3-01 Expedited (DM): CAL_LID_L2_333mCLay_Exp-Prov-V3-30, CAL_LID_L2_333mCLay_Exp-Prov-V3-02
	5 km Aerosol Profile	Validated Stage 1	Standard (DM): CAL_LID_L2_05kmAPro-Prov-V3-30, CAL_LID_L2_05kmAPro-Prov-V3-02, CAL_LID_L2_05kmAPro-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmAPro_Exp-Prov-V3-30, CAL_LID_L2_05kmAPro_Exp-Prov-V3-02
	5 km Cloud Profile	Provisional	Standard (DM): CAL_LID_L2_05kmCPro-Prov-V3-30, CAL_LID_L2_05kmCPro-Prov-V3-02, CAL_LID_L2_05kmCPro-Prov-V3-01 Expedited (DM): CAL_LID_L2_05kmCPro_Exp-Prov-V3-30, CAL_LID_L2_05kmCPro_Exp-Prov-V3-02
	Vertical Feature Mask	Validated Stage 1	Standard (DM): CAL_LID_L2_VFM-ValStage1-V3-30, CAL_LID_L2_VFM-ValStage1-V3-02, CAL_LID_L2_VFM-ValStage1-V3-01 Expedited (DM): CAL_LID_L2_VFM_Exp-Prov-V3-30, CAL_LID_L2_VFM_Exp-Prov-V3-02
	Polar Stratospheric Cloud Mask	Provisional	Standard Only (DM): CAL_LID_L2_PSCMask-Prov-V1-00

CAL_LID_L1_SP_SD_case_2015_04_27_calbuco.nb

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```
In[5]:= filenumber = 13;

In[6]:= files⟦filenumber⟧

Out[6]= CAL_LID_L1-Standard-V4-00.2015-04-27T16-24-10ZD_Subset.hdf

In[7]:= data1 = Import[files⟦filenumber⟧]

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  Lidar_Submode, Calibration_Constant_532, Calibration_Constant_Uncertainty_532, Depolarization_Gain_Ratio_532,
  Depolarization_Gain_Ratio_Uncertainty_532, Laser_Energy_532, Molecular_Number_Density, Noise_Scale_Factor_532_Parallel,
  Noise_Scale_Factor_532_Perpendicular, Ozone_Number_Density, Parallel_Amplifier_Gain_532, Parallel_Background_Monitor_532,
  Perpendicular_Amplifier_Gain_532, Perpendicular_Background_Monitor_532, Amplifier_Gain_1064, Calibration_Constant_1064,
  Calibration_Constant_Uncertainty_1064, Laser_Energy_1064, Noise_Scale_Factor_1064, Parallel_RMS_Baseline_532,
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  Spacecraft_Altitude, Spacecraft_Attitude, Spacecraft_Attitude_Rate, Spacecraft_Position, Spacecraft_Velocity, Subsatellite_Latitude,
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In[9]:= back1064 = Import[files⟦filenumber⟧, {"Datasets", "Attenuated_Backscatter_1064"}];
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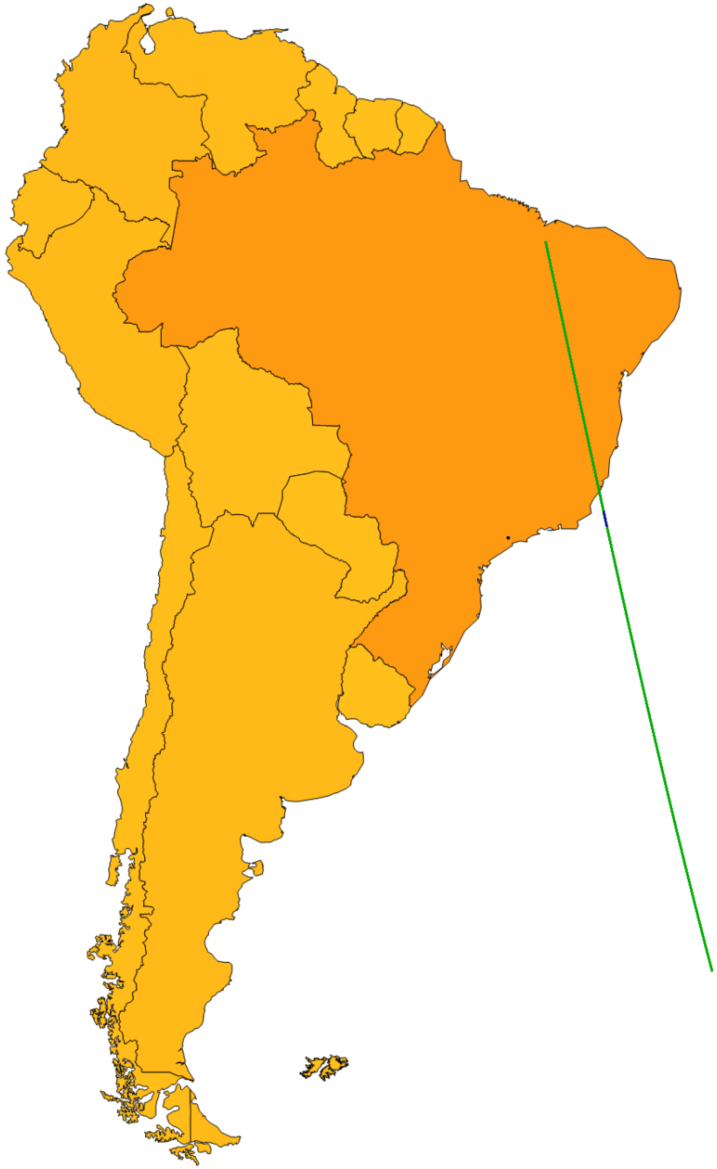
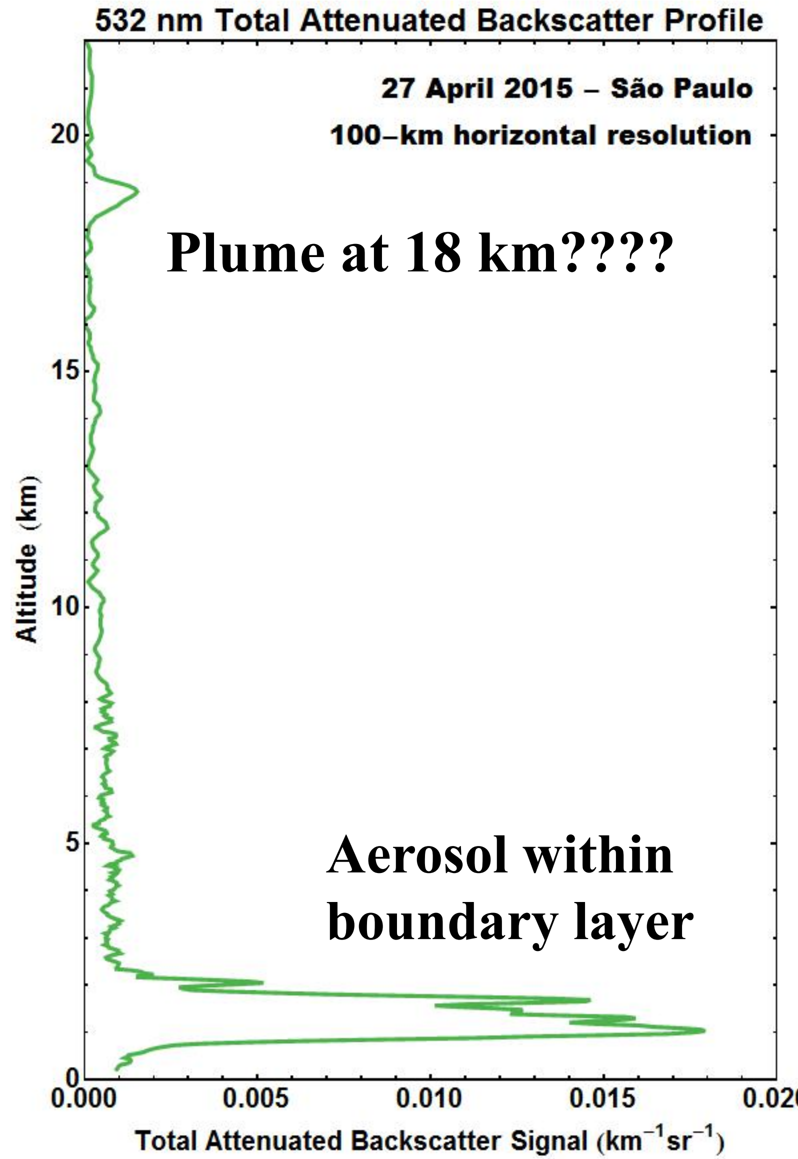
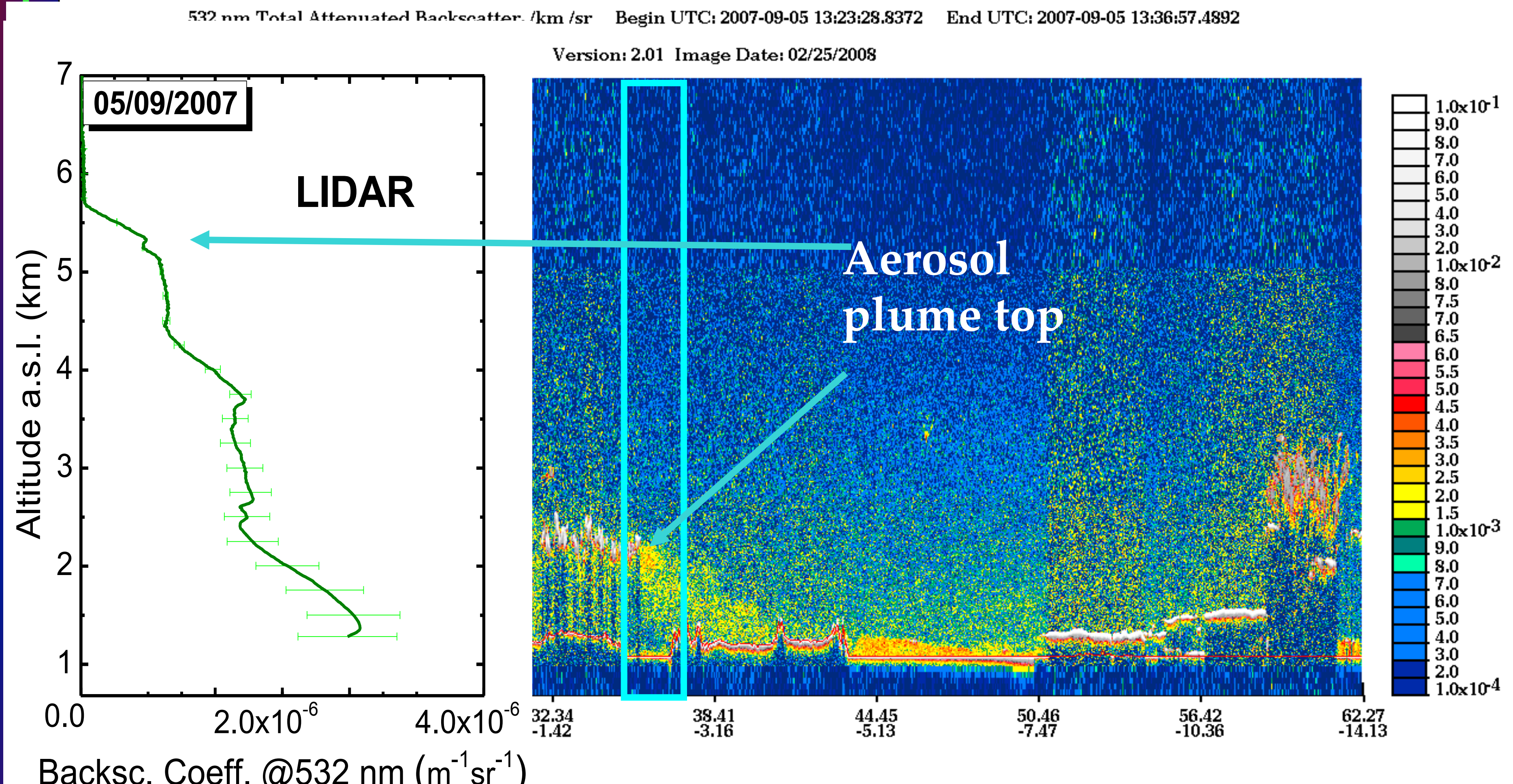
532 nm total attenuated backscatter profile from CALIPSO



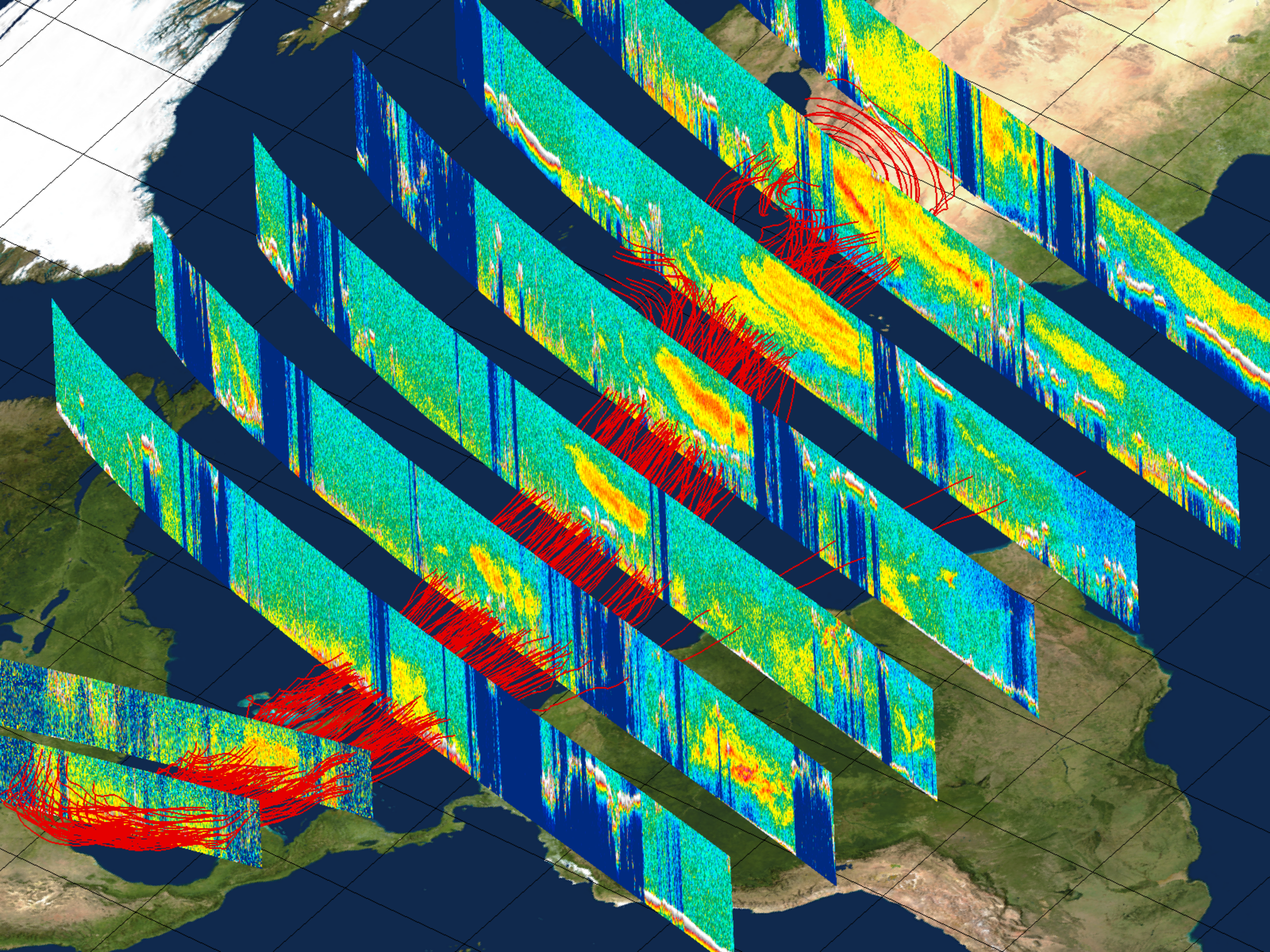


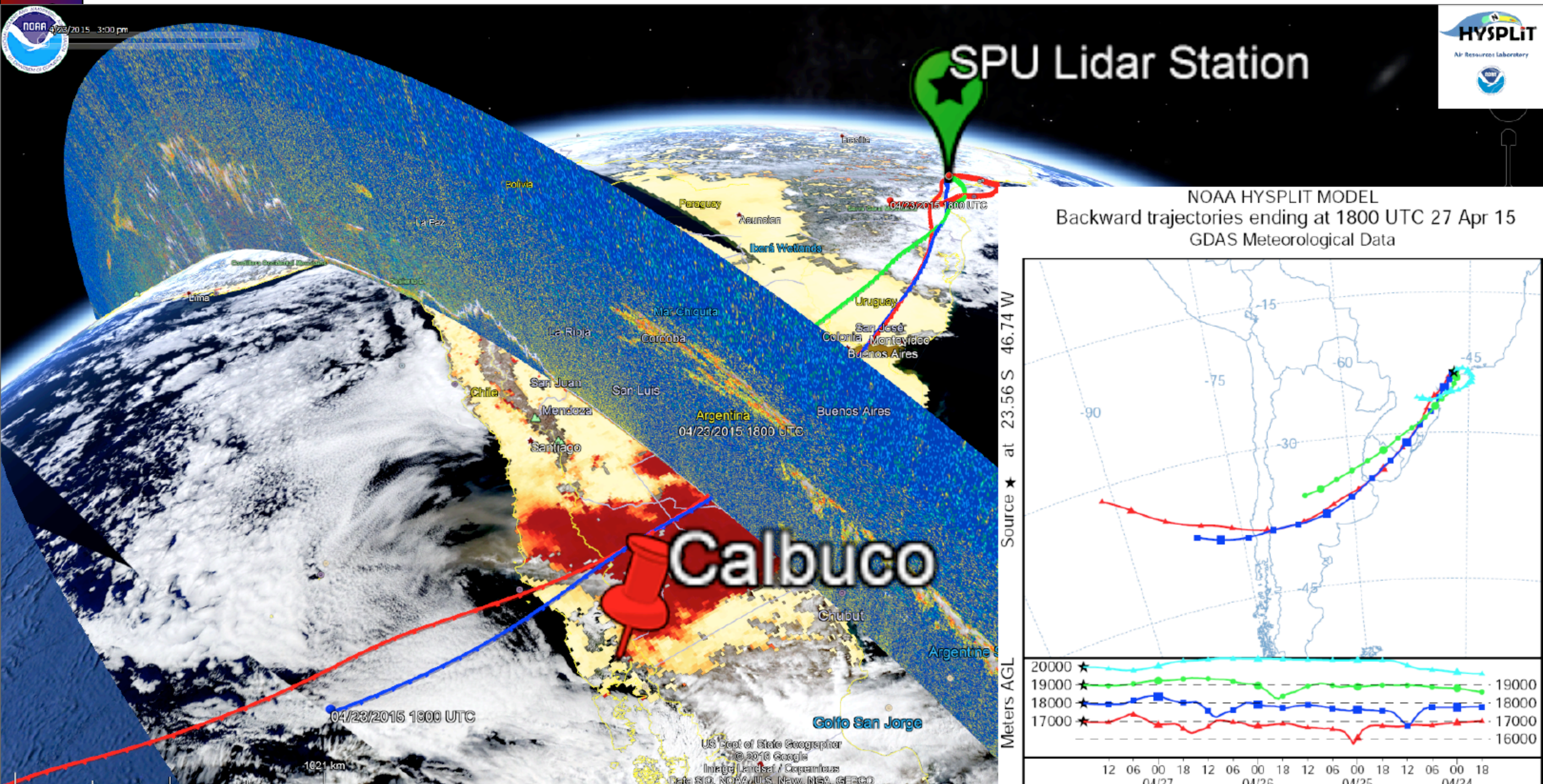
Plume at 18 km????

Aerosol within boundary layer



Cortesy: Juan Luis Guerrero-Rascado - University of Granada



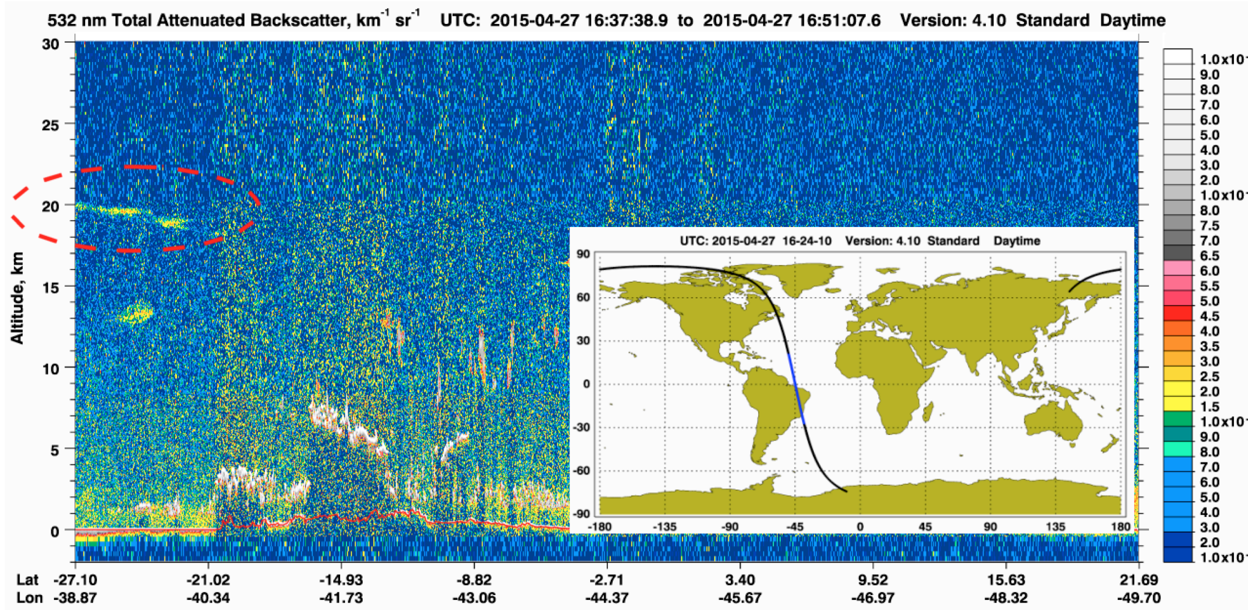


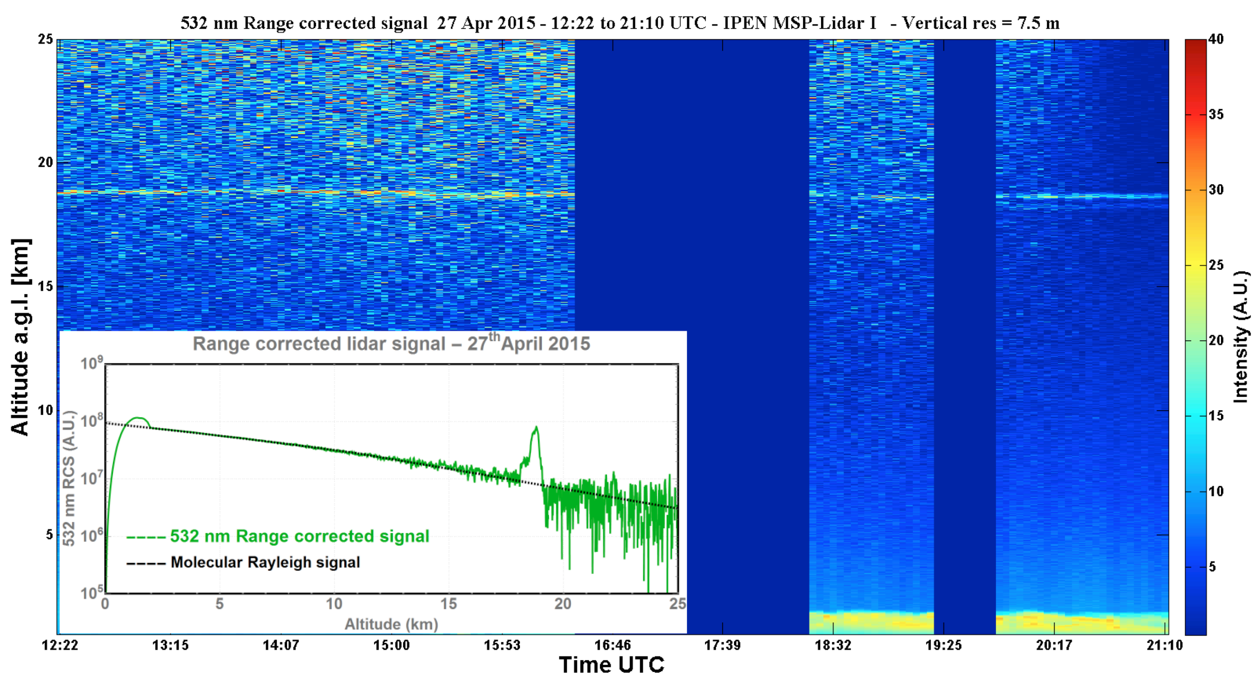
Synergetic Aerosol Layer Observation After the 2015 Calbuco Volcanic Eruption Event

Fábio J. S. Lopes [1,*], Jonatan João Silva [1,2], Juan Carlos Antuña Marrero [3], Ghassan Taha [4] and Eduardo Landulfo [1]

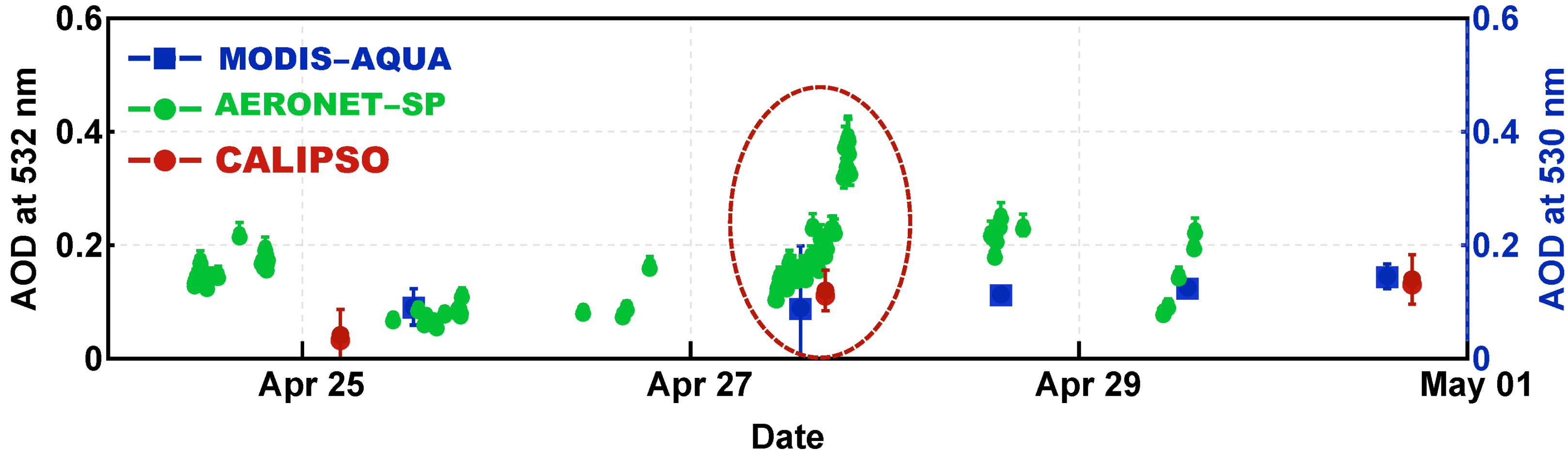
SPSAS on Atmospheric Aerosols

São Paulo, July 2019


532 nm Total Attenuated Backscatter, km-1 sr-1 UTC: 2015-04-27 16:37:38.9 to 2015-04-27 16:51:07.6 Version: 4.10 Standard Daytime
Altitude, km
UTC: 2015-04-27 16-24-10 Version: 4.10 Standard Daytime
Lat -27.10 -21.02 -14.93 -8.82 -2.71 3.40 9.52 15.63 21.69
Lon -38.87 -40.34 -41.73 -43.06 -44.37 -45.67 -46.97 -48.32 -49.70

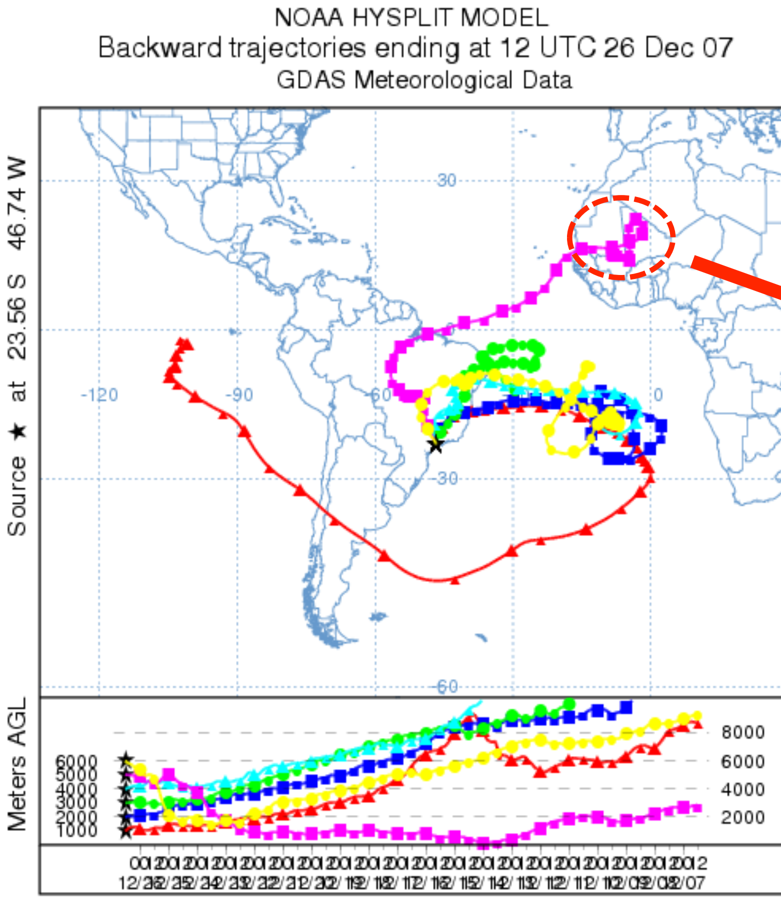

532 nm Range corrected signal 27 Apr 2015 - 12:22 to 21:10 UTC - IPEN MSP-Lidar I - Vertical res = 7.5 m
Altitude a.g.l. [km]
Intensity (A.U.)
Range corrected lidar signal – 27th April 2015
532 nm RCS (A.U.)
532 nm Range corrected signal
Molecular Rayleigh signal
Altitude (km)
Time UTC

São Paulo AERONET Station – 15th April – 08th May 2015



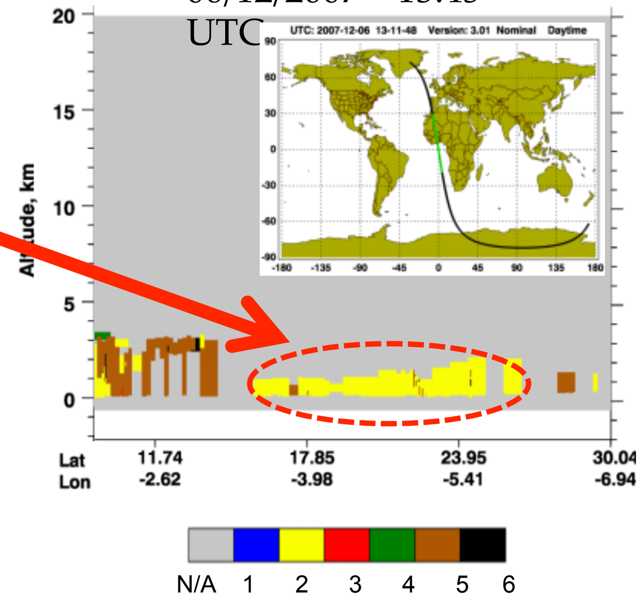
SPSAS on Atmospheric Aerosols

São Paulo, July 2019



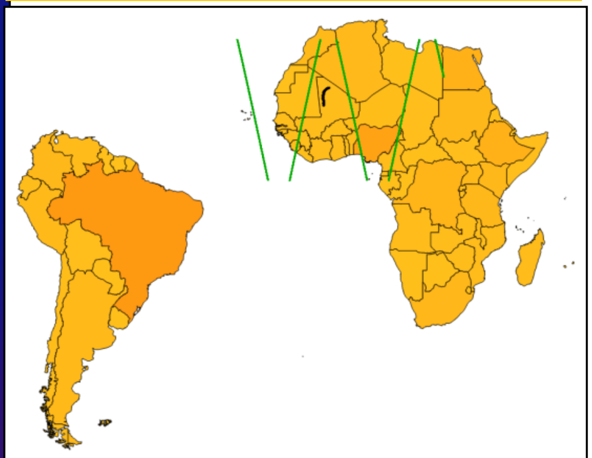
Cortesy: Juan Luis Guerrero-Rascado - University of Granada

06/12/2007 ~13:45 UTC

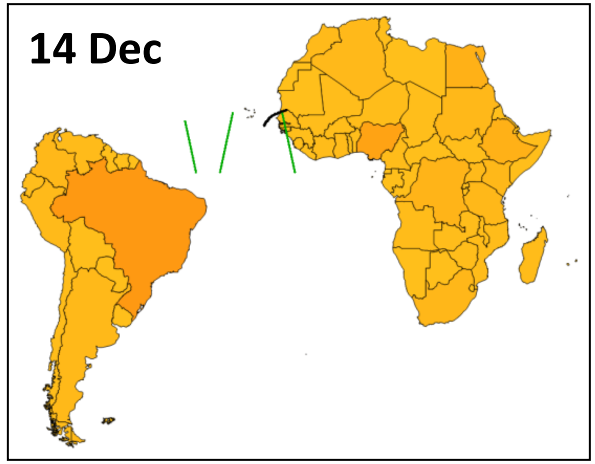


N/A = not applicable
1 = clean marine
2 = dust
3 = polluted continental
4 = clean continental
5 = polluted dust
6 = smoke

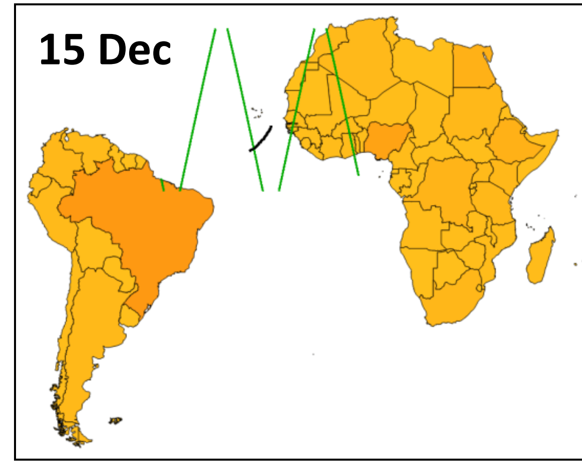
African Region



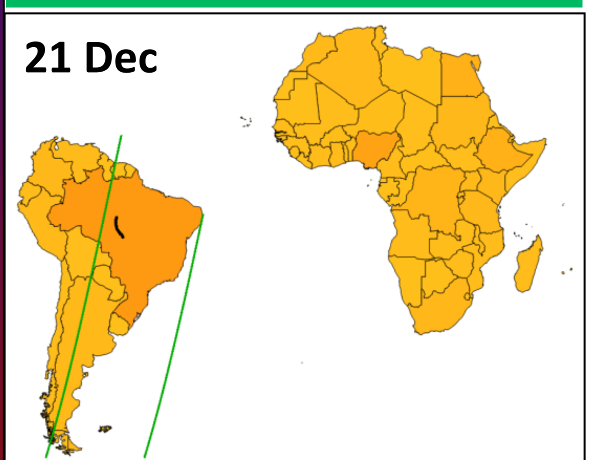
African Region



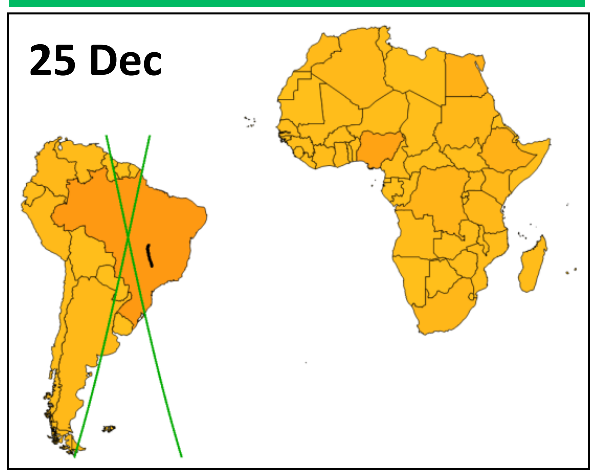
Atlantic Region



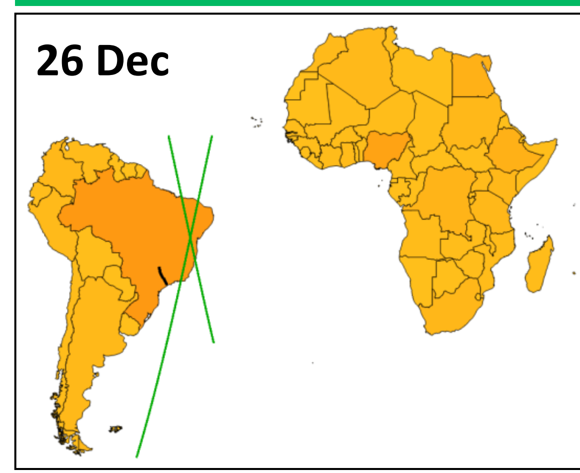
South Am. Region



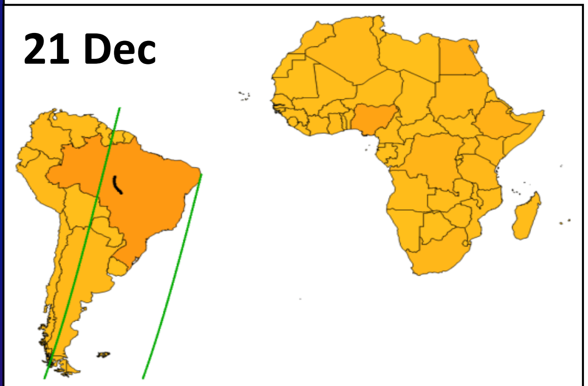
South Am. Region



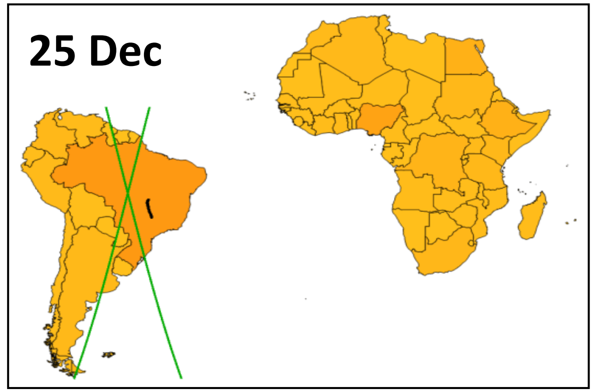
South Am. Region



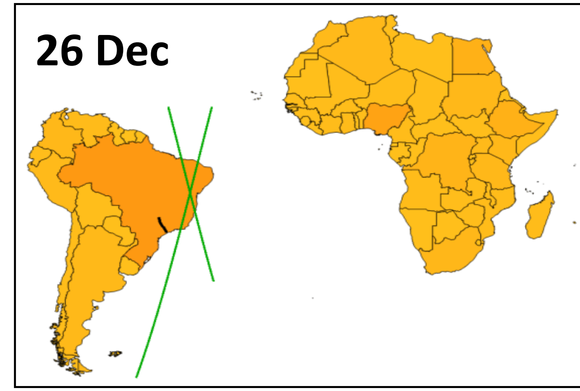
South Am. Region

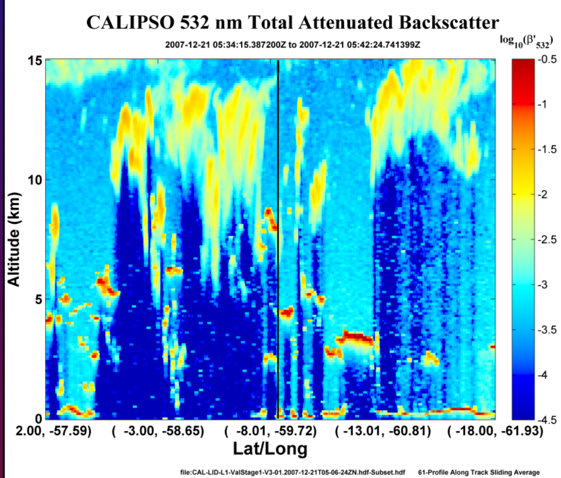


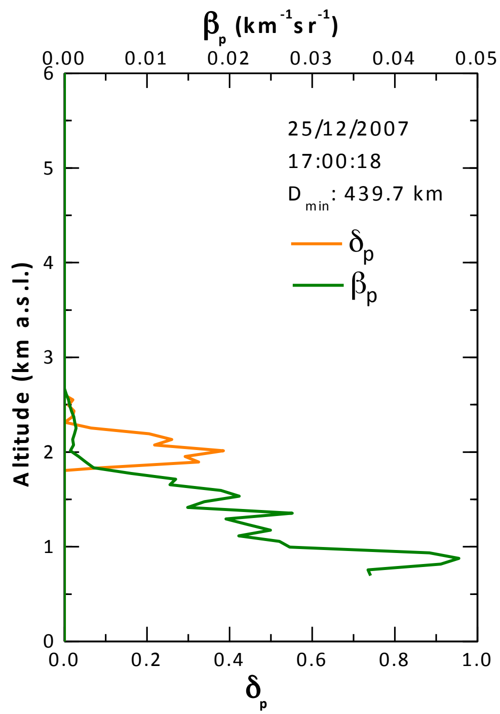
South Am. Region

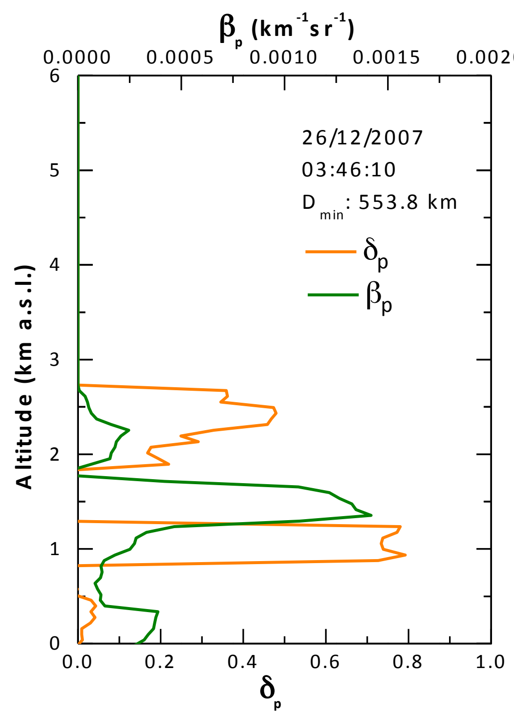


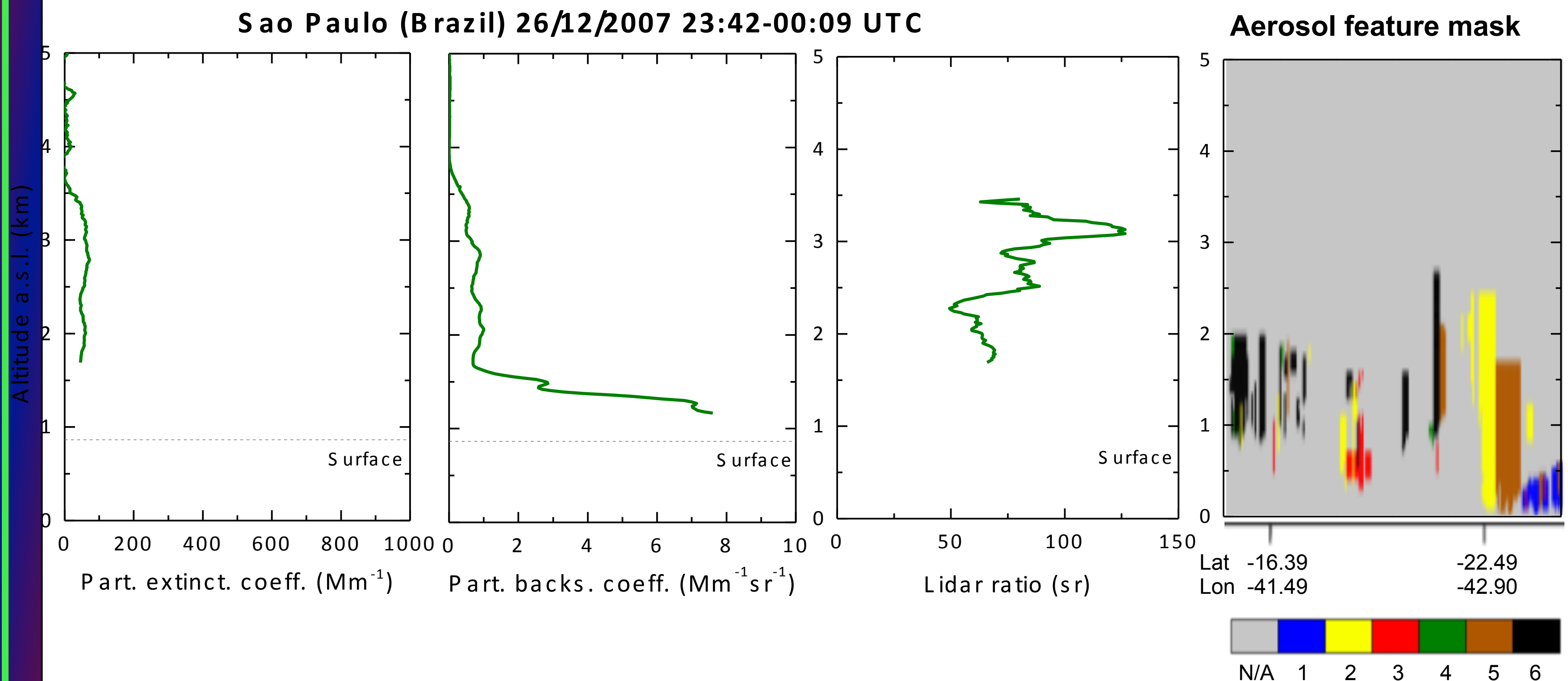
South Am. Region











CALIPSO data near to São Paulo LALINET station – mixture of dust and pollution (polluted dust flag) detection

N/A = not applicable
1 = clean marine
2 = dust
3 = polluted continental
4 = clean continental
5 = polluted dust
6 = smoke

Lidar system installed at Natal – RN
Collaboration: IPEN, UFRN and Granada University

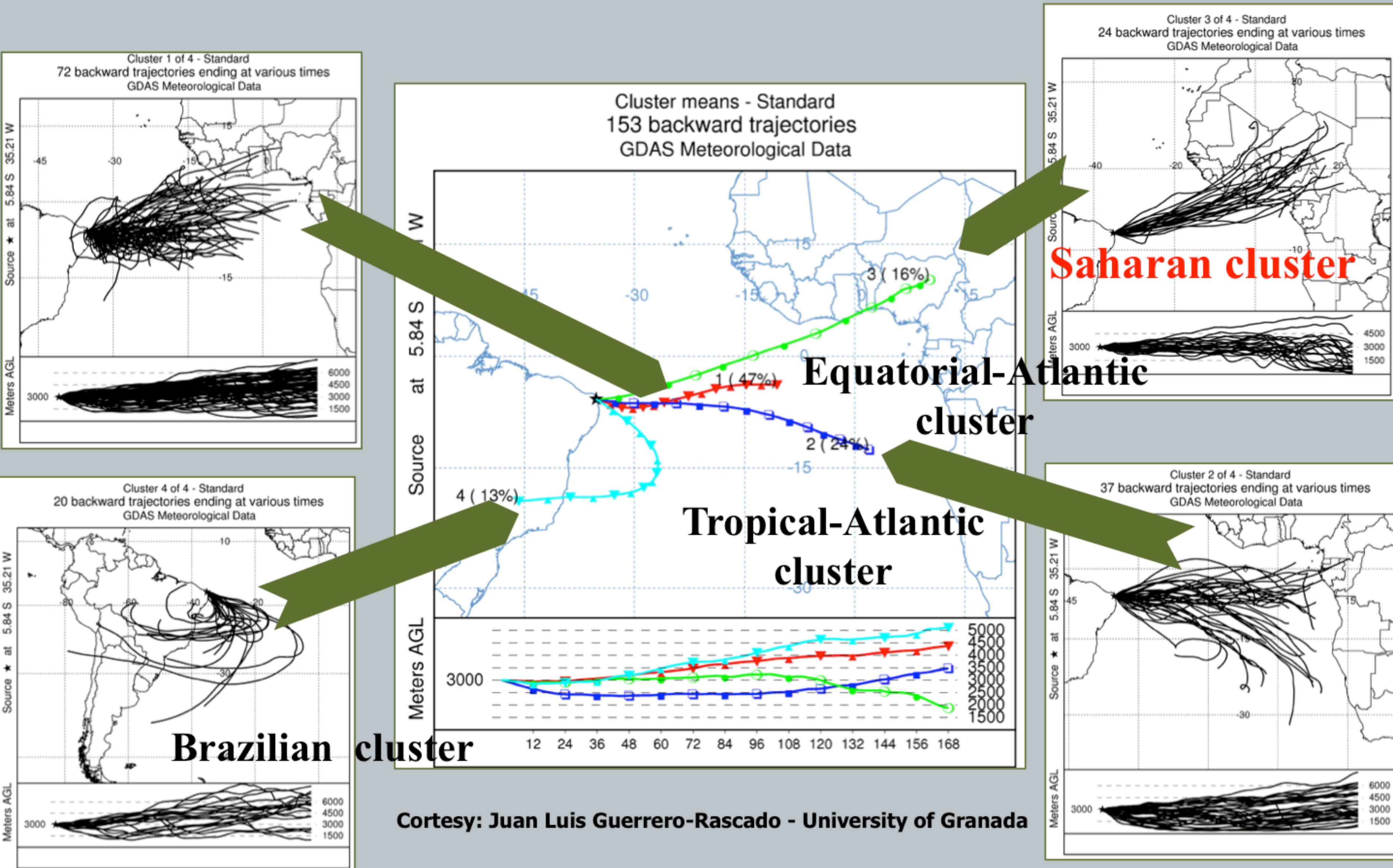
Elastic lidar with 3 wavelenghts: 1064, 532 e 355 nm

4 detection channels: 1064, 532//, 532 ⊥ e 355 nm

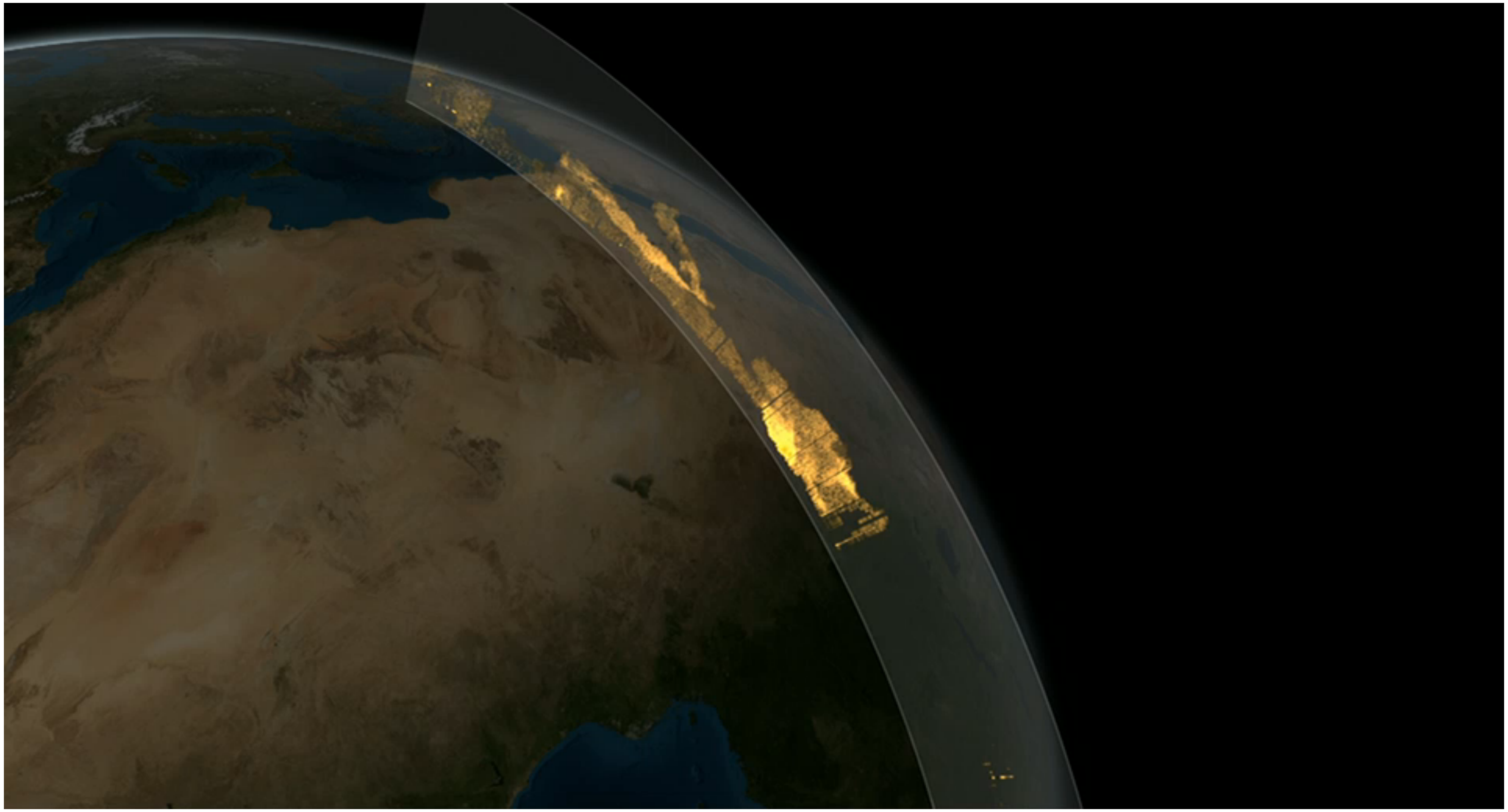
Lidar system installed at Natal – RN

Collaboration: IPEN, UFRN and Granada University

HYSPLIT – Air masses trajectory



Cortesy: Juan Luis Guerrero-Rascado - University of Granada



https://www.youtube.com/watch?v=ygulQJoIe2Y