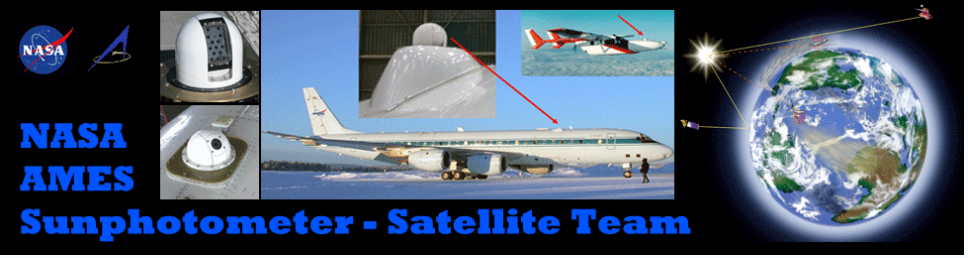
Space Borne and Ground Based Lidar

NASA ARSET- EPA Training

ARSET - AQ

Applied Remote Sensing Education and Training – Air Quality

A project of NASA Applied Sciences



CALIOP aboard CALIPSO: instrument and data

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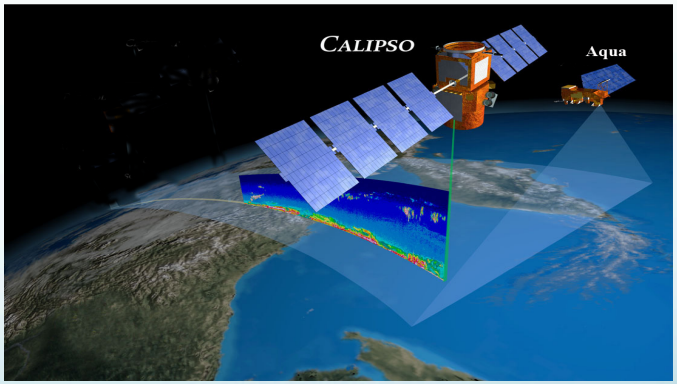
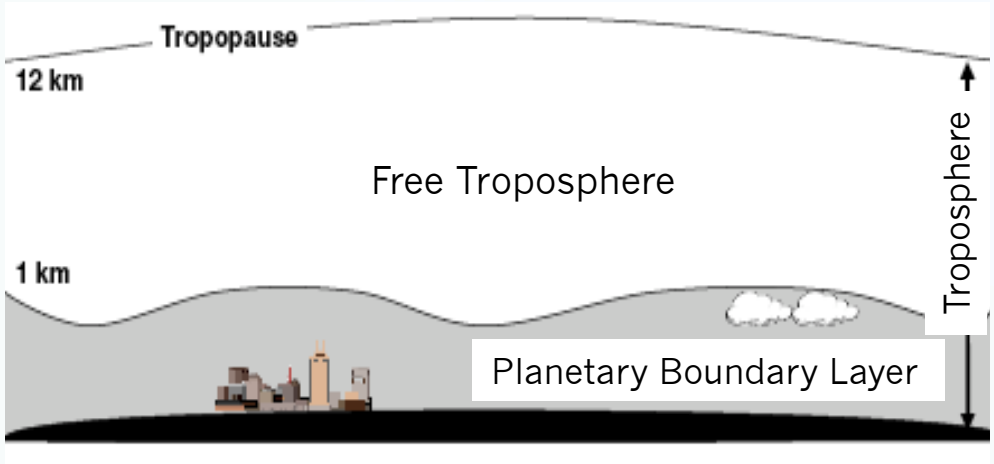
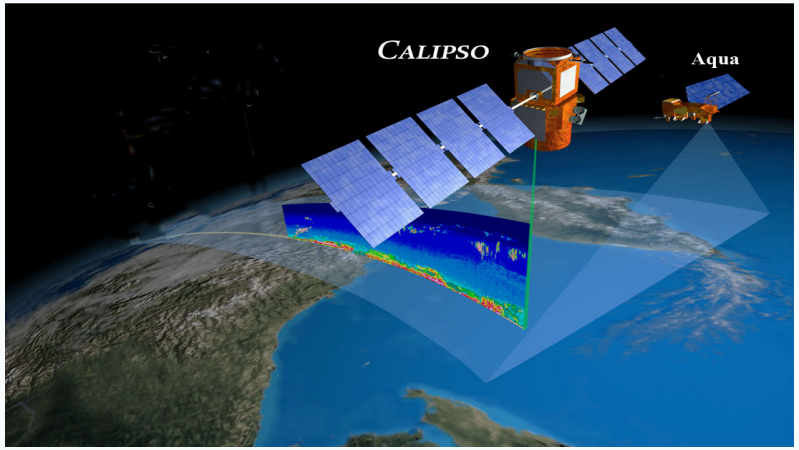
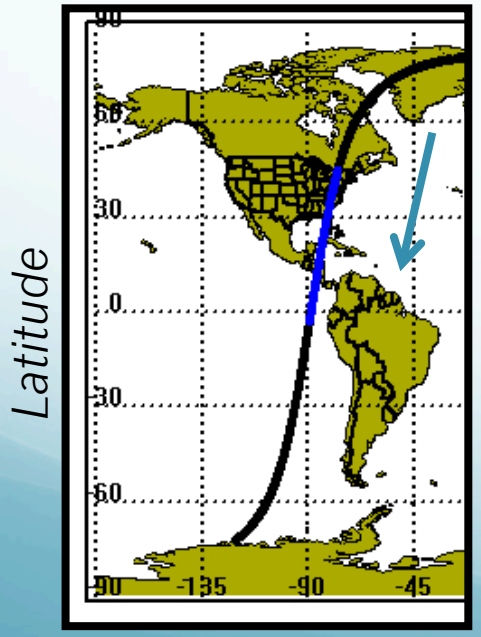
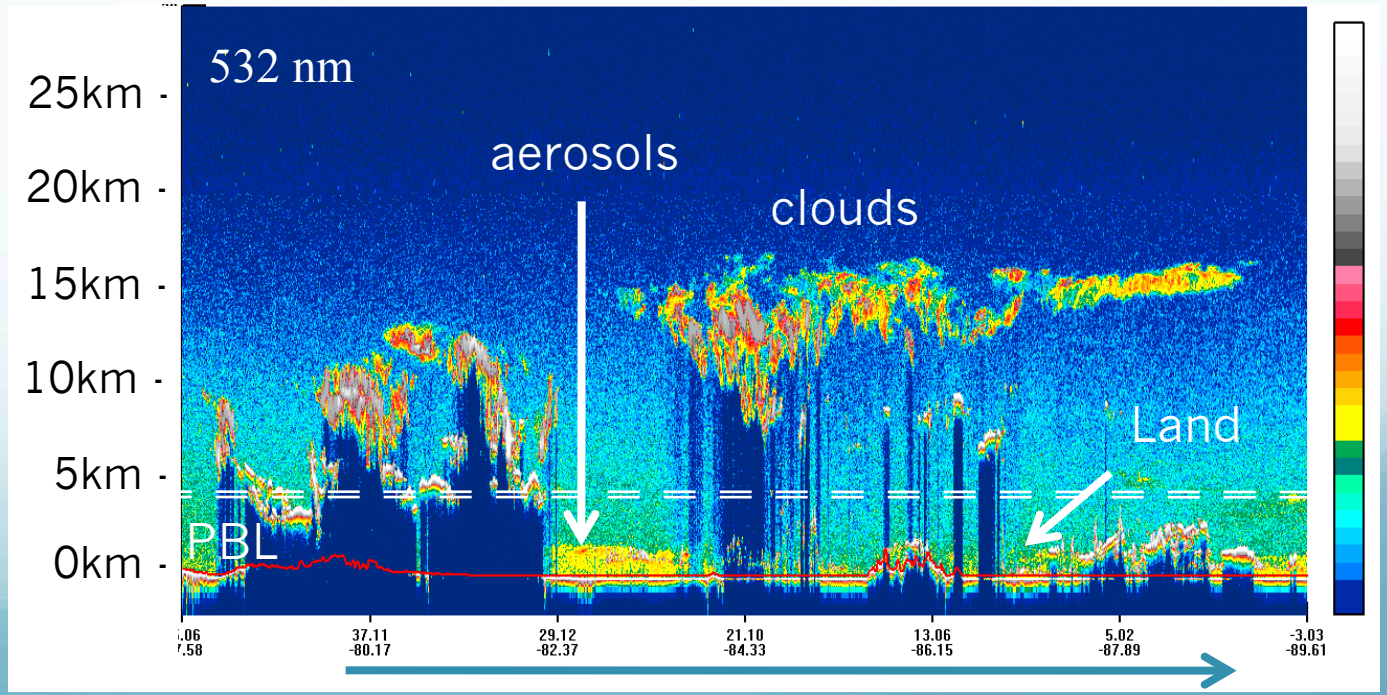


What's a CALIPSO curtain scene?

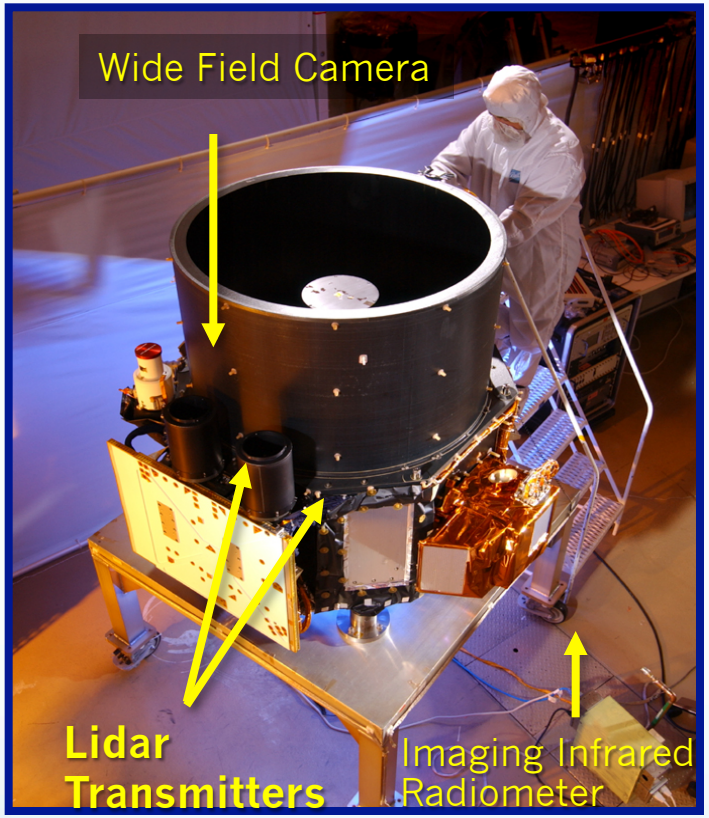








CALIOP on board CALIPSO



Two Wavelengths
3 Channels

Wavelengths	532nm		1064 nm
Channels	532 ||	532 ⊥	1064 nm

CALIOP:

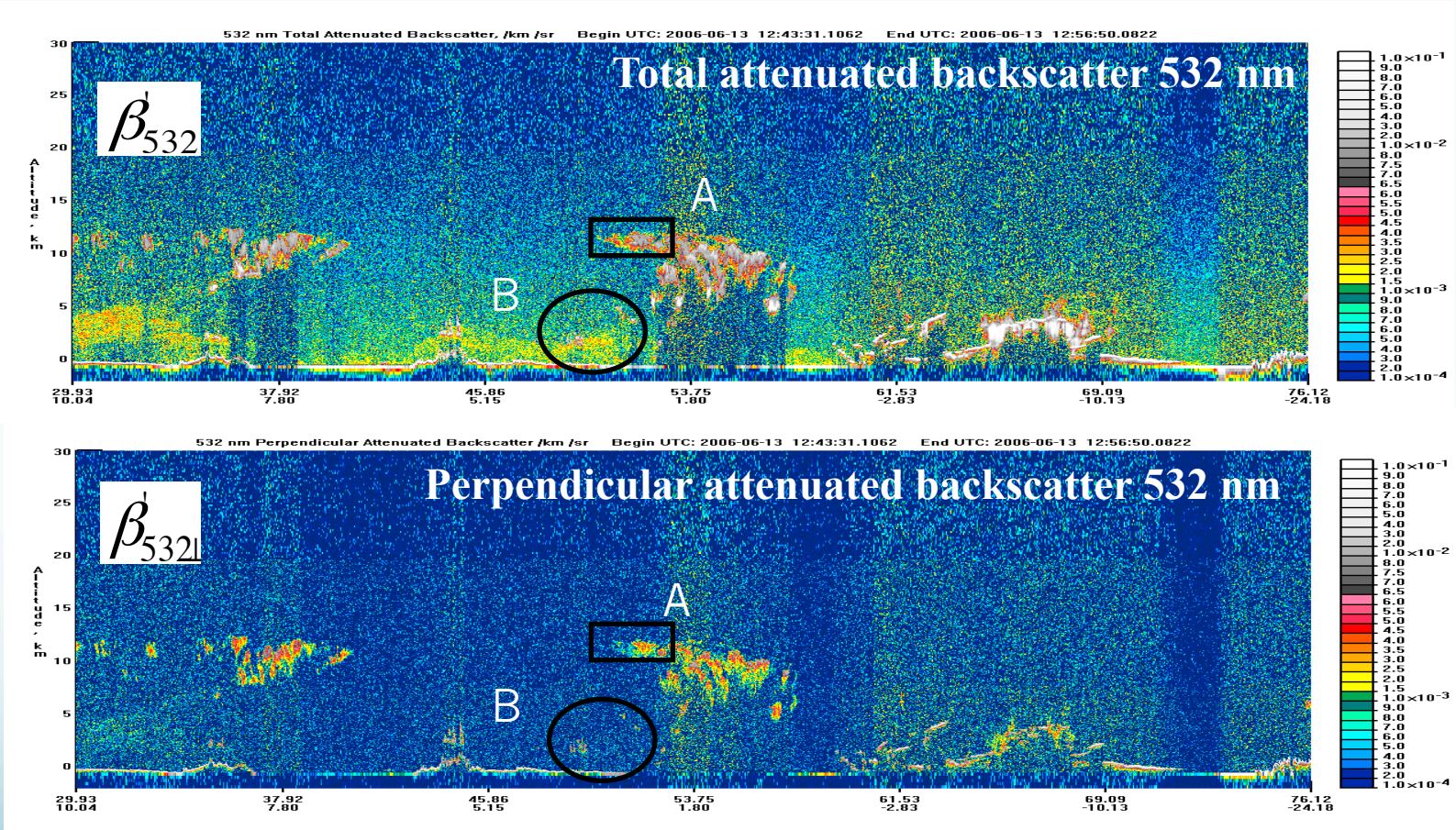
- Active downward pointing elastic backscatter LIDAR (LIght Detection And Ranging)
- 90 m diameter foot print every 333m; No daily global coverage (given region every 16 days)

CALIPSO products

Version 3 Product	Primary Parameter	Resolution due to averaging	
		Horizontal	Vertical (<8km)
Level 1 **Measured**	Total_Attenuated_Backscatter_532 Perpendicular_Attenuated_Backscatter_532 Total_Attenuated_Backscatter_1064	1/3km	30m
Level 2 **LAYER** **Retrieved**	Cloud Layer_Top/ Base_Altitude	1/3, 1, 5km	30m
	Aerosol Layer_Top/ Base_Altitude	5km	30m
Level 2 **PROFILE** **Retrieved**	Cloud and Aerosol Total_Backscatter_Coefficient_532 Extinction_Coefficient_532	5km	60m
Level 2 **Vertical Feature Mask** **Retrieved**	Feature_Classification_Flags	5km	30m

CALIPSO browse images online

Level 1 products



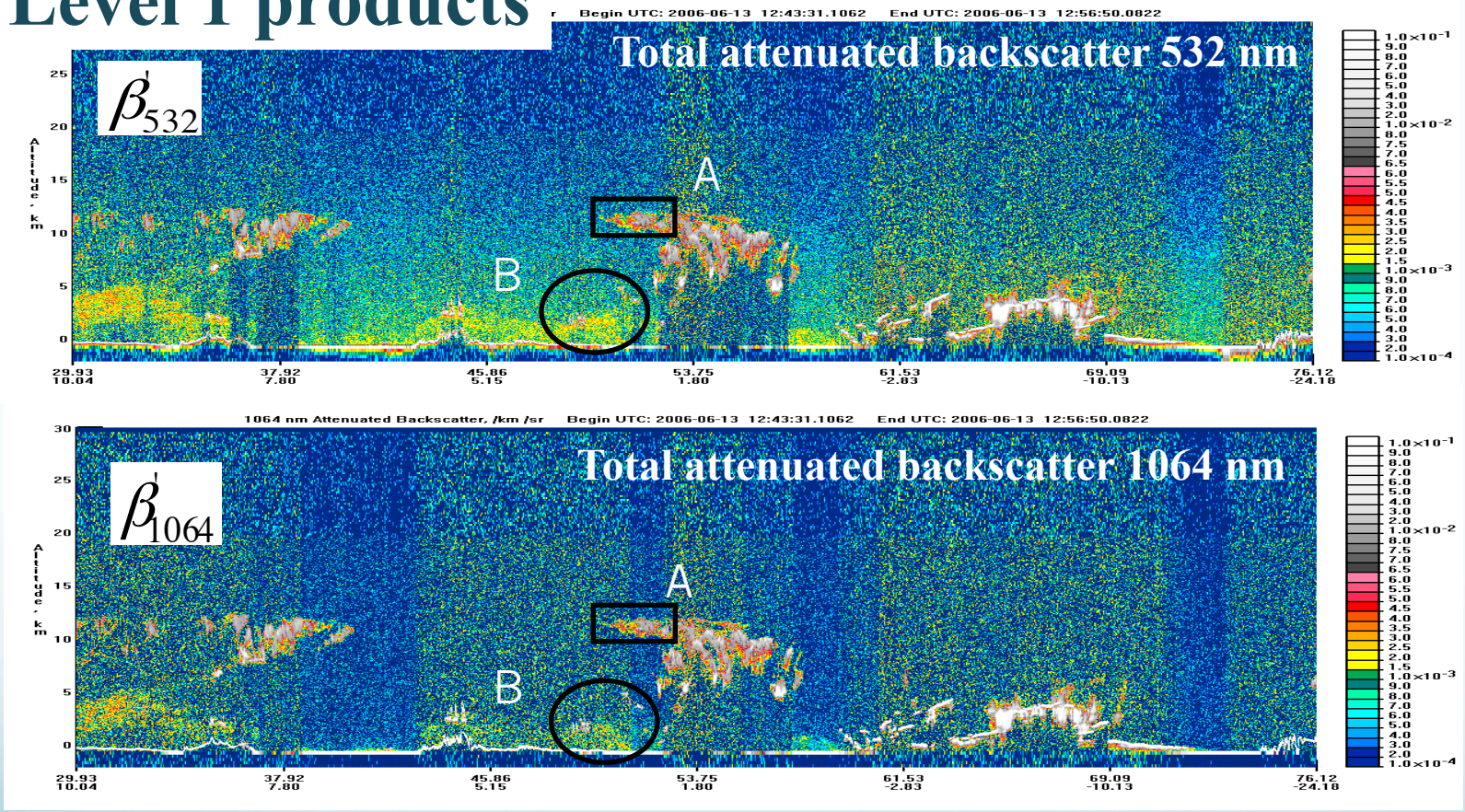
If enhanced signal in both images then non spherical particles (Region A)

If enhanced signal in total backscatter image but little or no enhancement in the perpendicular image, then spherical particles (Region B)

CALIPSO browse images online

http://www-calipso.larc.nasa.gov/products/lidar/browse_images/production/

Level 1 products



If same intensity in both channels, coarse particles

If signal more intense in β'_{532}, fine particles

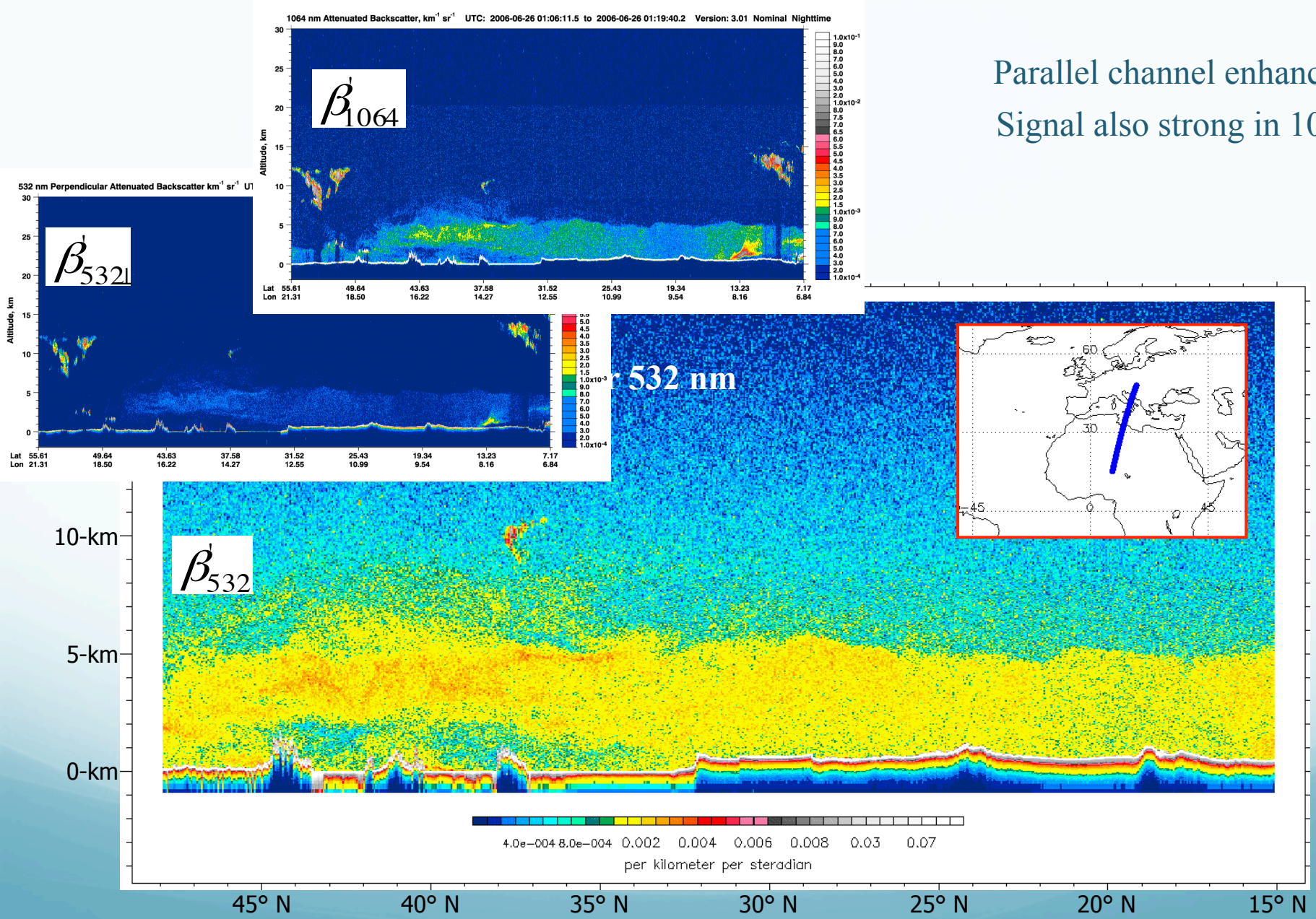
Region A: coarse non spherical = cirrus cloud?

Region B: fine spherical = urban pollution?

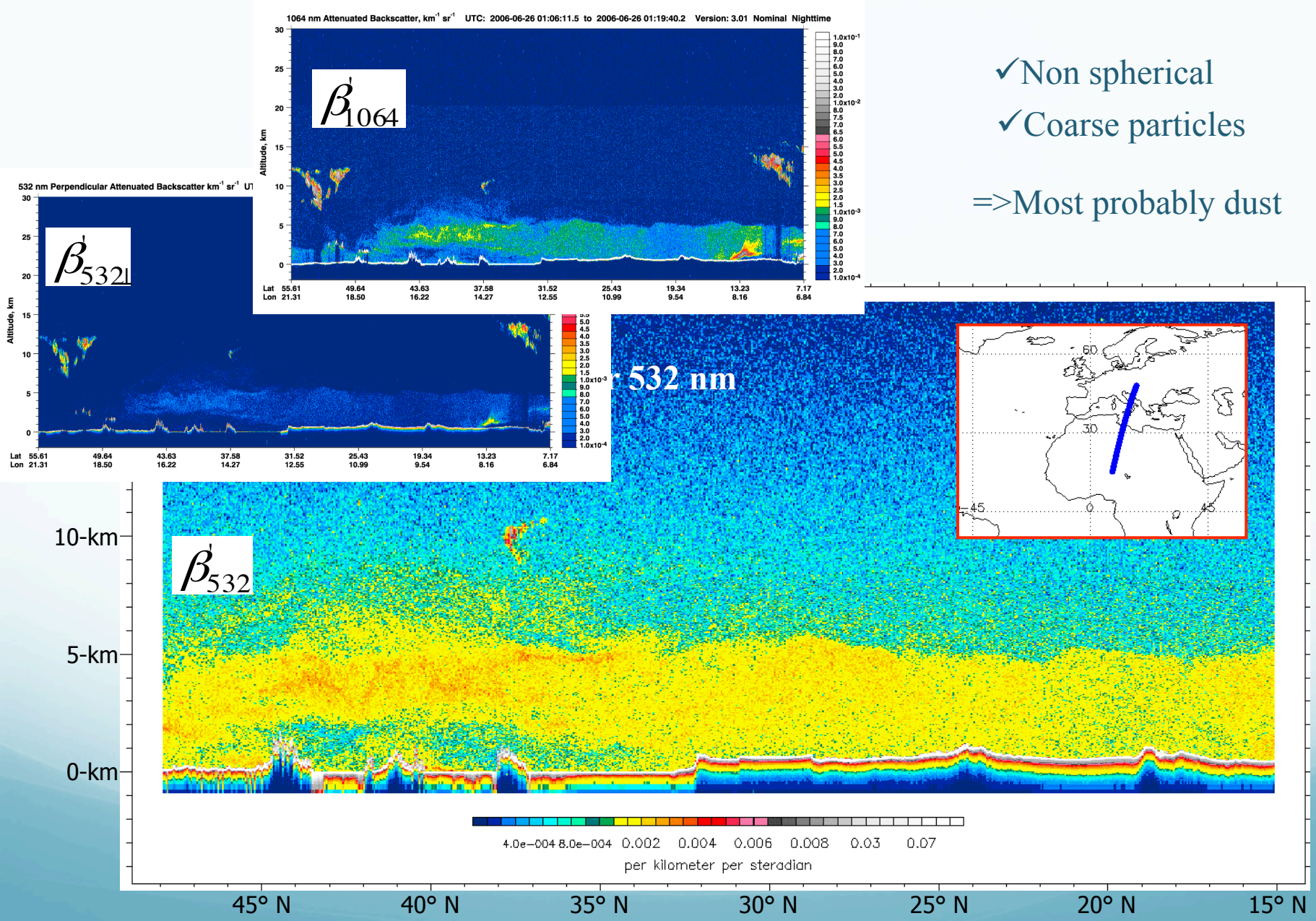
Example: June 26, 2006

Parallel channel enhanced?

Signal also strong in 1064?



Example: June 26, 2006



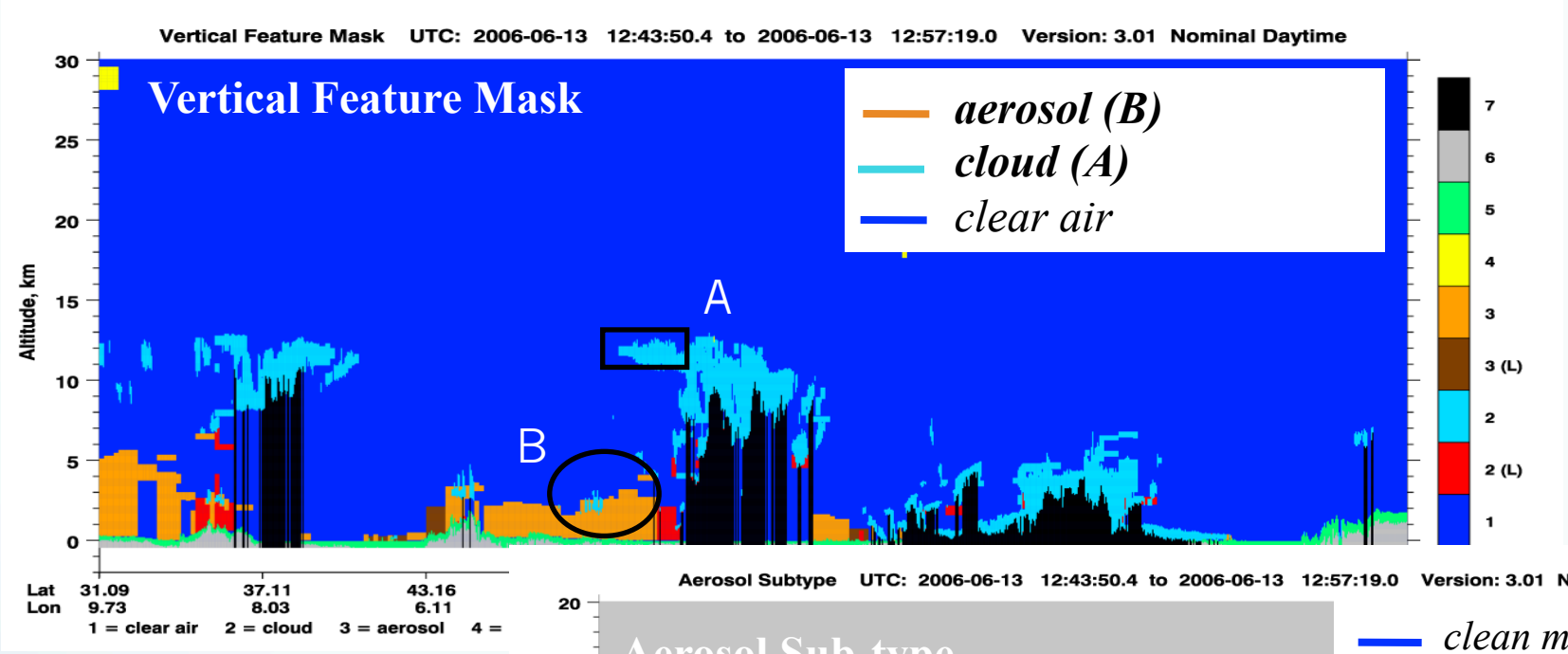
✓Non spherical

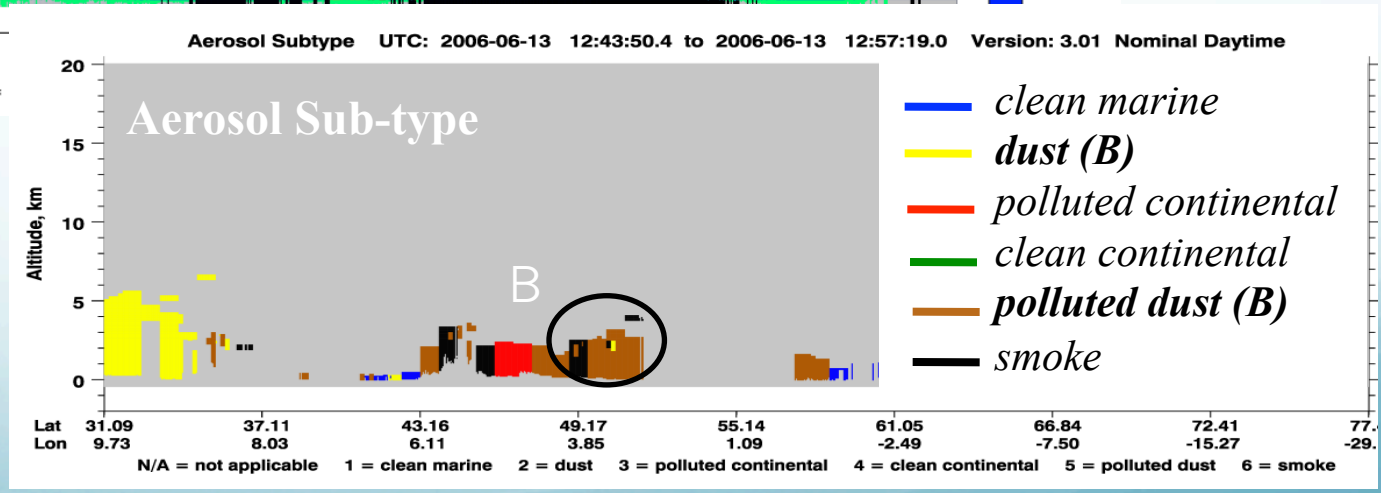
✓Coarse particles

=>Most probably dust

CALIPSO browse images online

Level 2 products

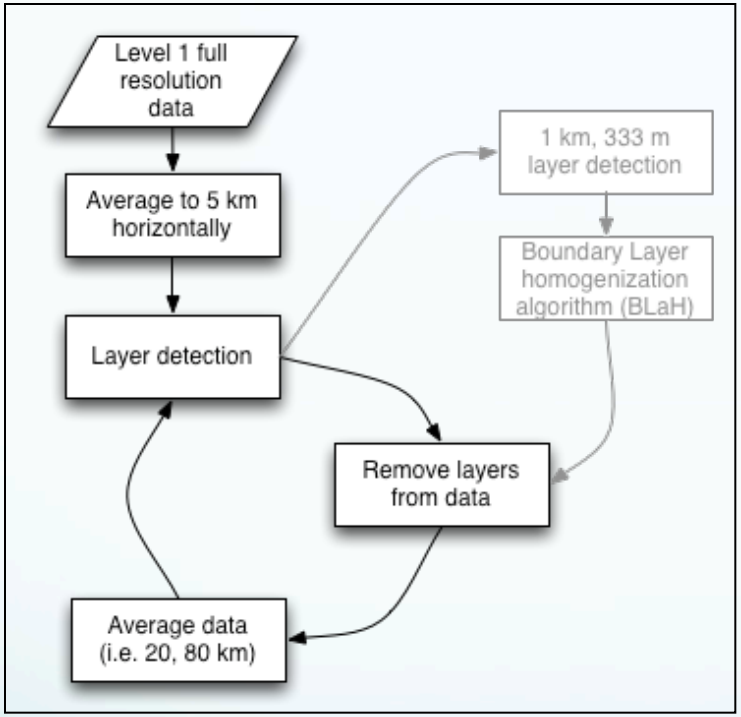




According to Level 2,
Region A: cloud
Region B: dust/ polluted dust for B

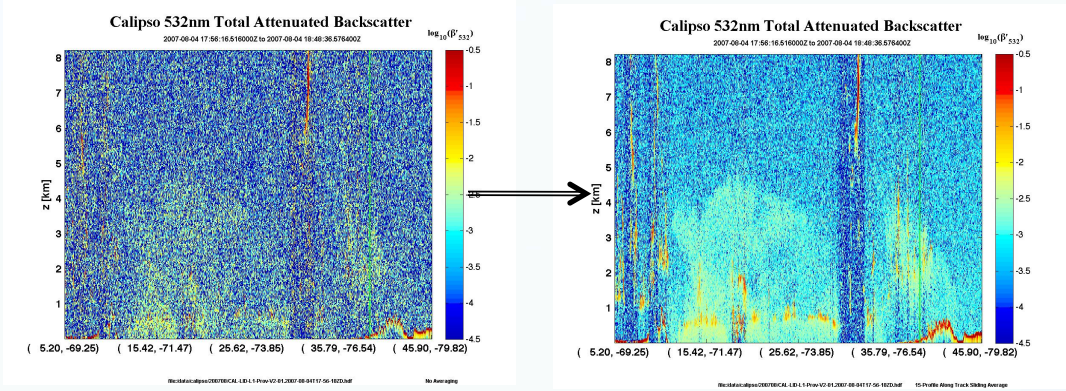
Different from Level 1 Analysis…

Layer detection



a) Input is level 1 attenuated backscatter

b) Data averaged from 333m to 5km



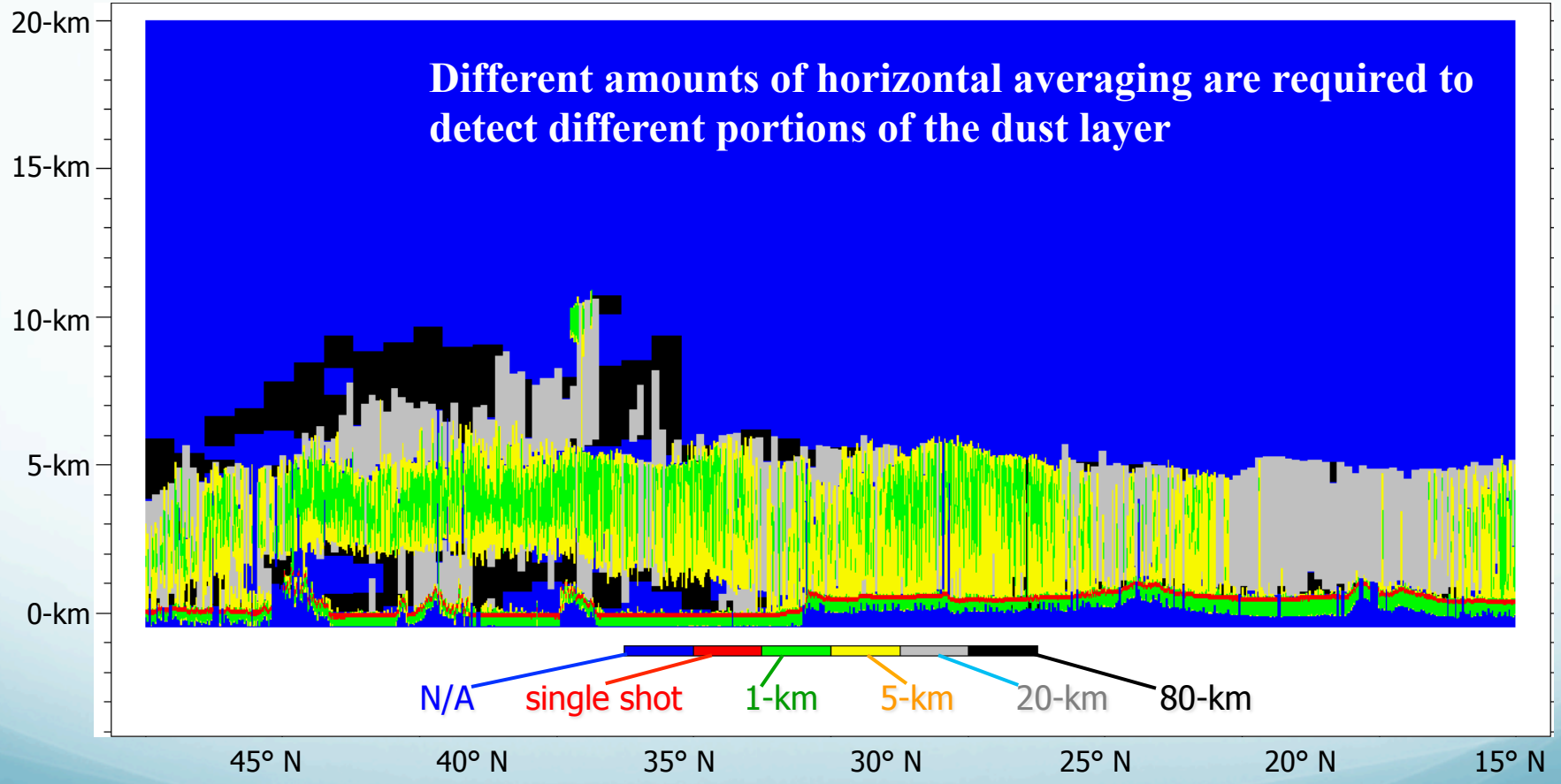
c) Layers identified as enhancements above molecular background (adaptative threshold using $\beta'_{532,\perp}$ and $\beta'_{532,//}$ and molecular model)

Here cloud detected at 333m; aerosol at 5km

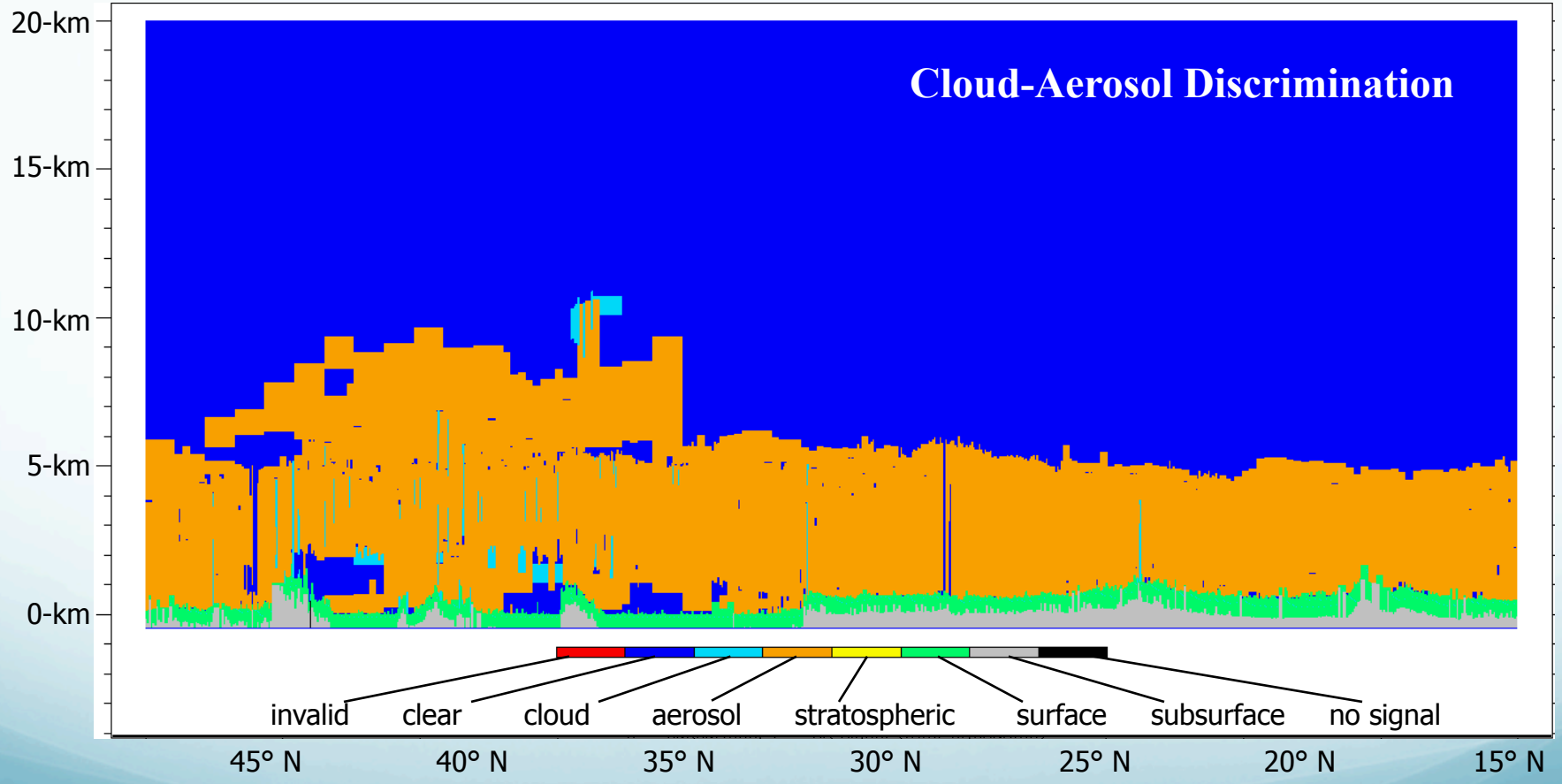
c) Detected layers removed from curtain scene

d) Further averaging of the data (20, 80km)…

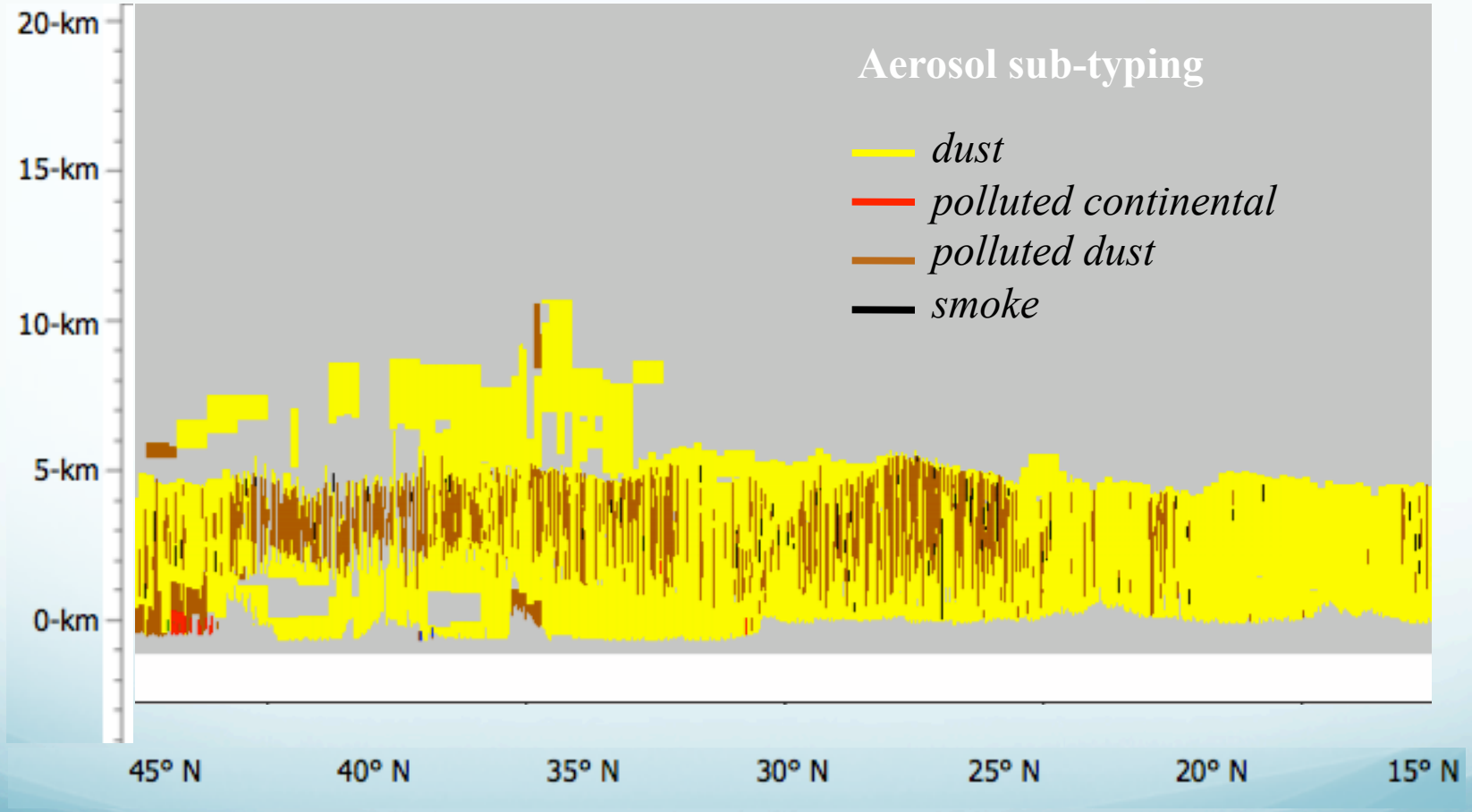
Example: June 26, 2006



Example: June 26, 2006



Example: June 26, 2006



Take home message

CALIOP/ CALIPSO provides aerosol vertical distribution and info on type of particle (size and shape)

Safest use of CALIOP data:

1. Qualitative (browse lidar images online)
2. Latest version (currently V3.01)
3. Level 1 (contains less uncertainties than level 2 data)

Concerning the use of CALIOP Level 2 data,

- recognize the unvalidated nature of the data
- keep in mind the uncertainties
- make sure to read all quality assurance information and to apply the appropriate quality flags

(see user guide, http://www-calipso.larc.nasa.gov/resources/calipso_users_guide/)

- If you have any concerns, ask the CALIPSO team

Online

- ***User Guide*:**

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

  FAQ, Essential reading, Data Product Descriptions, Data quality summaries (V3.01), Example and tools, Order Data, Publications

- ***Data download***

  http://eosweb.larc.nasa.gov/HBDOCS/langley_web_tool.html

  http://www-calipso.larc.nasa.gov/search/ **for subset files**

- ***LIDAR browse images***

Level 1 and Level 2 Vertical Feature Mask; No level 2 profile

EXPEDITED 12h-RELEASE with kmz files

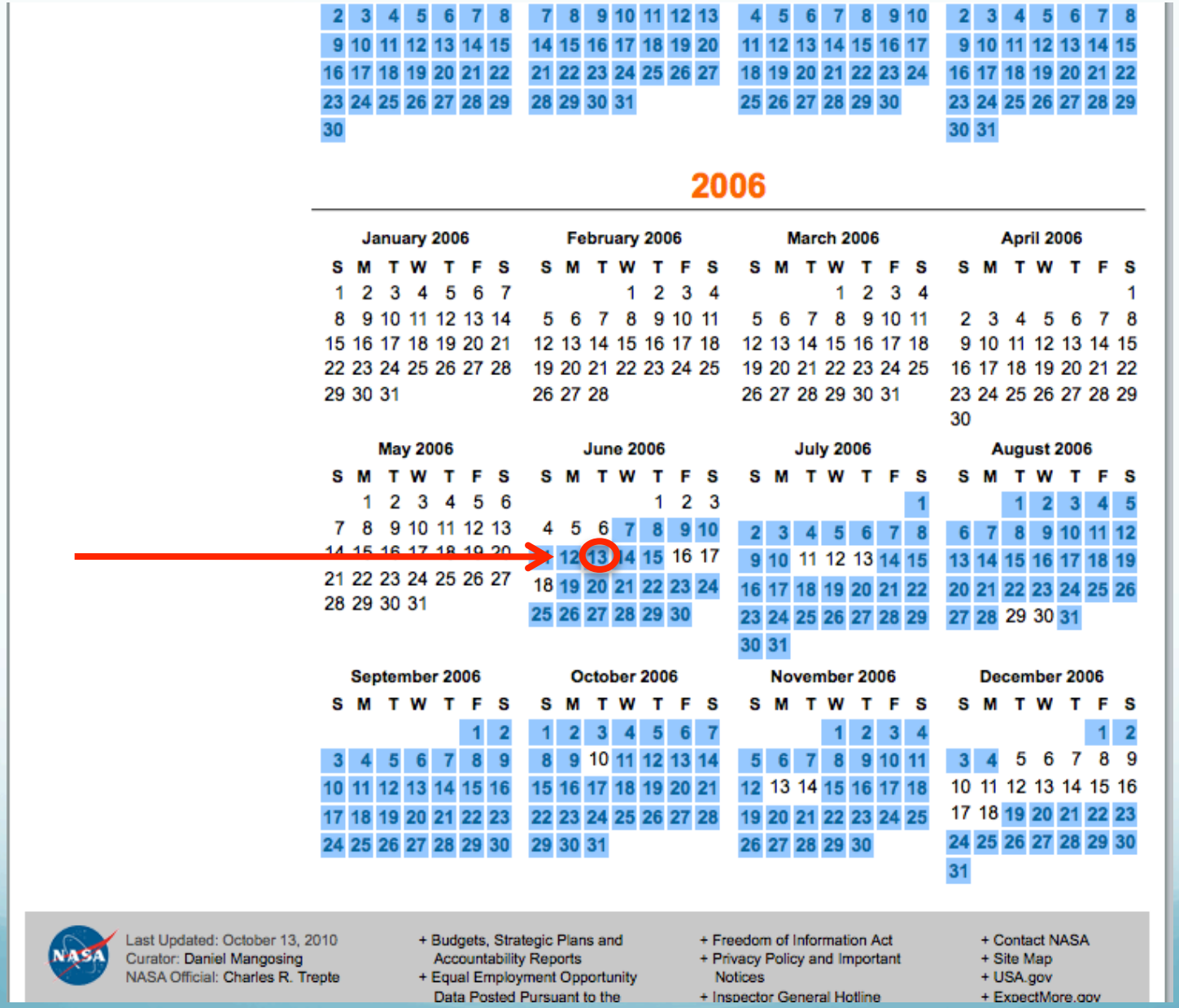
http://www-calipso.larc.nasa.gov/products/lidar/browse_images/expedited/

STANDARD PRODUCT for detailed science analysis

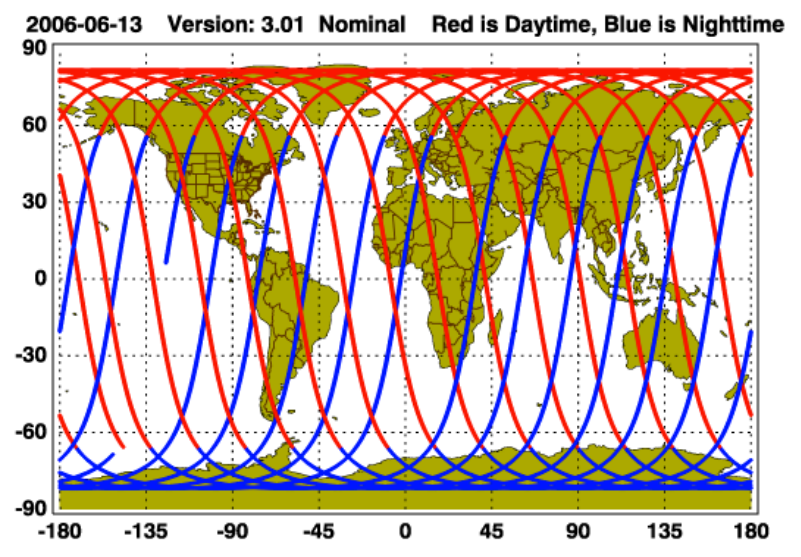
http://www-calipso.larc.nasa.gov/products/lidar/browse_images/show_calendar.php/

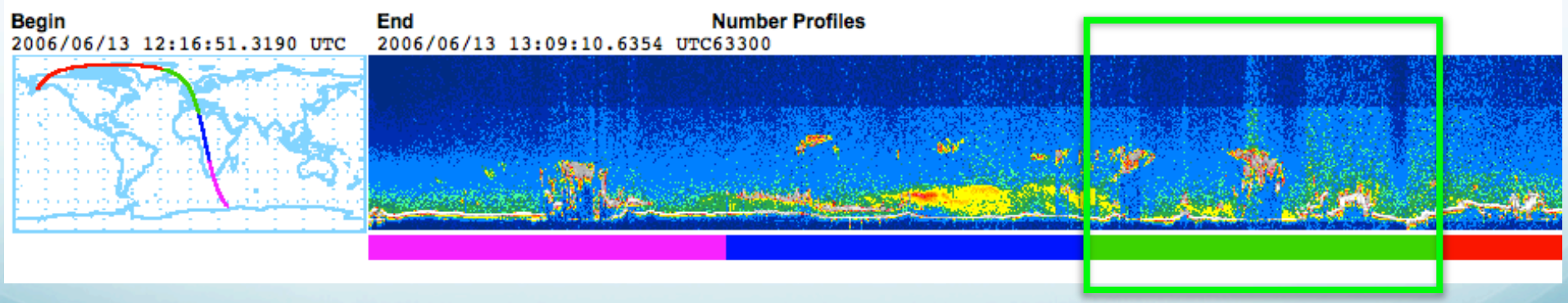
Also provides horizontal averaging, Ice/ Water phase and aerosol subtype

CALIPSO browse images online



CALIPSO browse images online





CALIPSO validation

Level 2 CALIOP layer boundaries, backscatter and extinction

✓Very little validation of CALIOP level 2 data: few case studies
✓Significant uncertainties associated with level 2 data

1. Ground-based validation with EARLINET

Example: CALIPSO **underestimate**s Sa (40 instead of ~50 sr, hence underestimates AOD) during 26–31 May 2008 Saharan Dust outbreak [*Pappalardo et al.*, 2010]

2. Airborne validation with HSRL

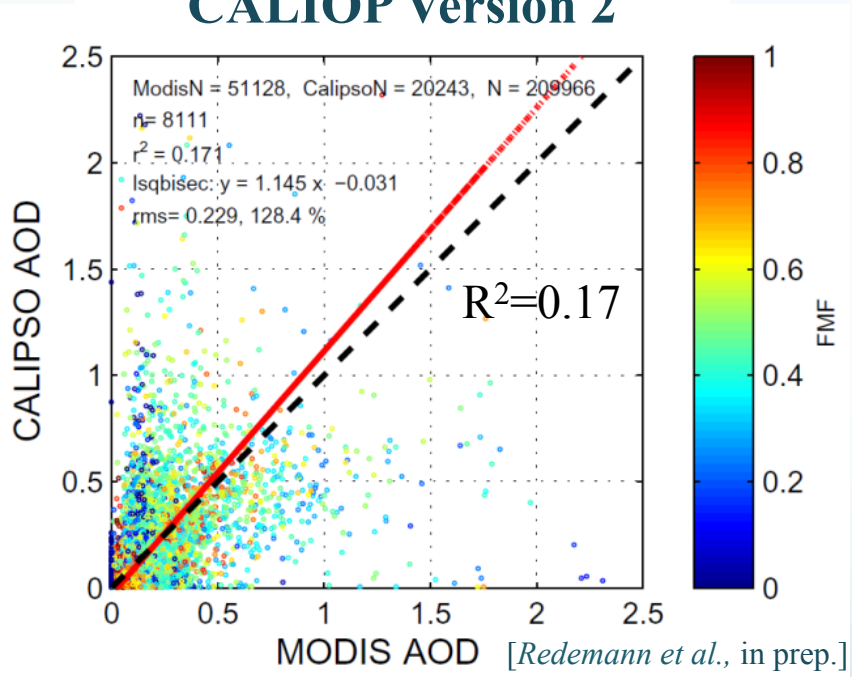
CALIOP **overestimates** HSRL extinction with an average extinction bias of ~ 24% during CATZ (CALIPSO and Twilight Zone campaign) and ~59% during GoMACCS (Gulf of Mexico Atmospheric Composition and Climate Study) [*Omar et al,* 2009]

CALIPSO validation

3. CALIOP versus other A-Train satellite AOD

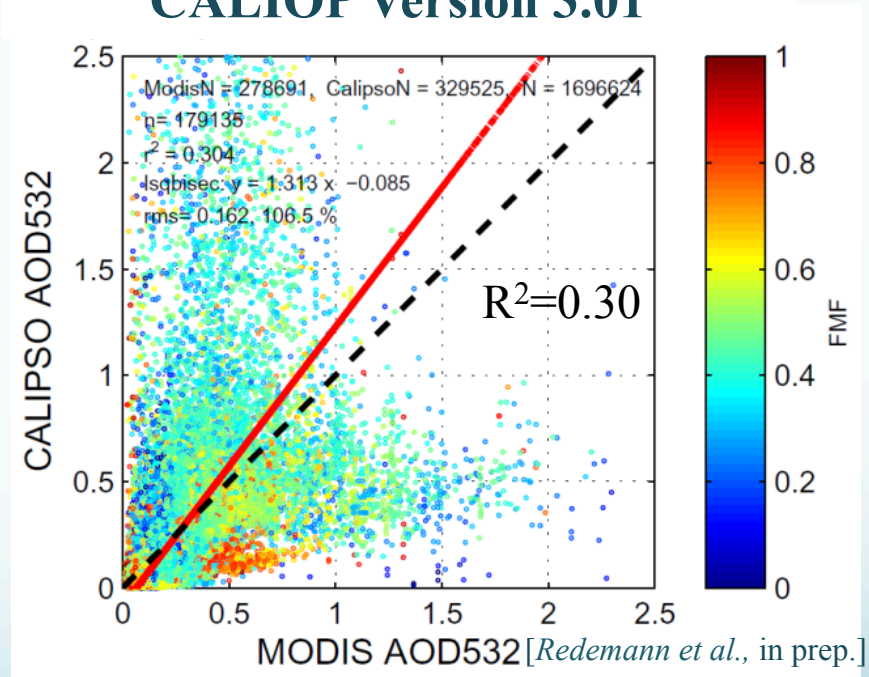
- CALIOP (V2) **underestimates** both POLDER and MODIS AOD (also AERONET and HSRL) on August 04 2007 by 0.1-0.2 during CATZ [*Kacenelenbogen et al.*, 2010]

CALIOP Version 2



[*Redemann et al.*, in prep.]

CALIOP Version 3.01

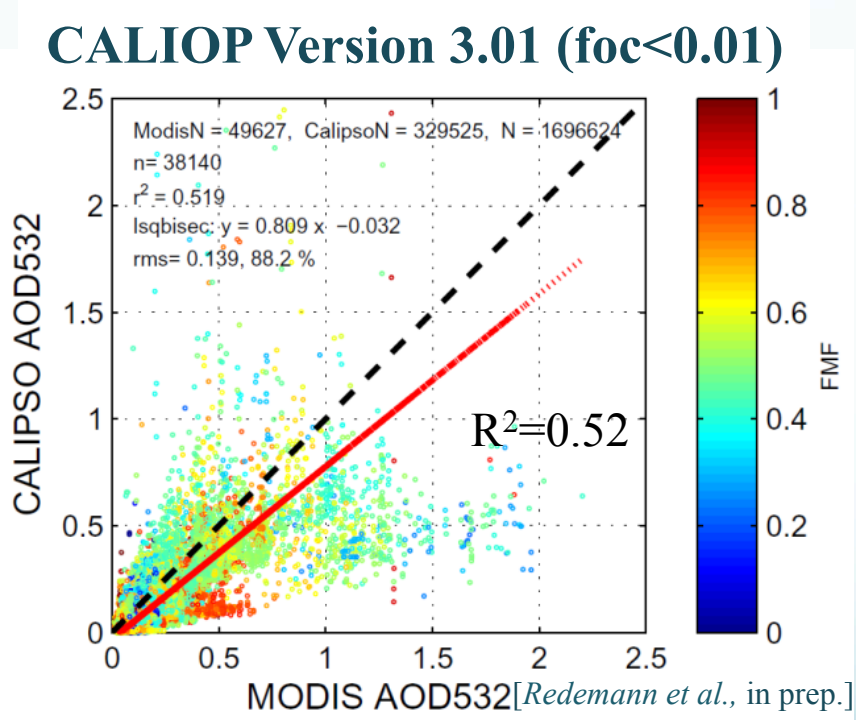


[*Redemann et al.*, in prep.]

- CALIOP **(V3.01) better** than CALIOP (V2)-MODIS AOD but still not satisfactory
- **CALIOP (V3.01) globally overestimates** MODIS AOD over ocean with R^2=0.30 in January 2007 [*Redemann et al.*, in prep.]

CALIPSO validation

Additional cloud-screening on both datasets with MODIS cloud fraction



[*Redemann et al.*, in prep.]

Reduces discrepancies between two data sets due to cloud contamination

Higher correlation coefficient (0.52 instead of 0.30)

CALIPSO slightly **underestimates** MODIS AOD

Level 2 data uncertainties

i) Low Signal to noise ratio
CALIOP will fail to detect layers with aerosol backscatter < 2~4 10^{-4} km^{-1} sr^{-1} in troposphere [*Winker et al.,* 2009] (S_a of 50sr, α of 0.01-0.02 km^{-1}, AOD of 0.02-0.04 in 2km)
=> CALIOP not measuring tenuous aerosol layers
=> Lack of photons returned from underneath highly attenuating layers (dense aerosol or cloud) leading to erroneous or total lack of aerosol identification in the lower part of a given atmospheric profile

ii) Miss-classification of layer type (aerosol or cloud) and aerosol sub-type (biomass, dust, etc…)
=> leading to incorrect assumption about lidar ratio Sa

iii) Improved calibration technique for the lidar Level 1 532 nm daytime calibration in Version 3.01 [*Powell et al.*, 2010]

iv) Multiple scattering is assumed negligible in current algorithm
=> Impact on cases with dense dust plumes recording high AOD where effects of multiple scattering applies

CALIPSO: example of application

The detection of aerosols over clouds

Aerosols and their radiative effects are a major uncertainty in predictions of future climate change

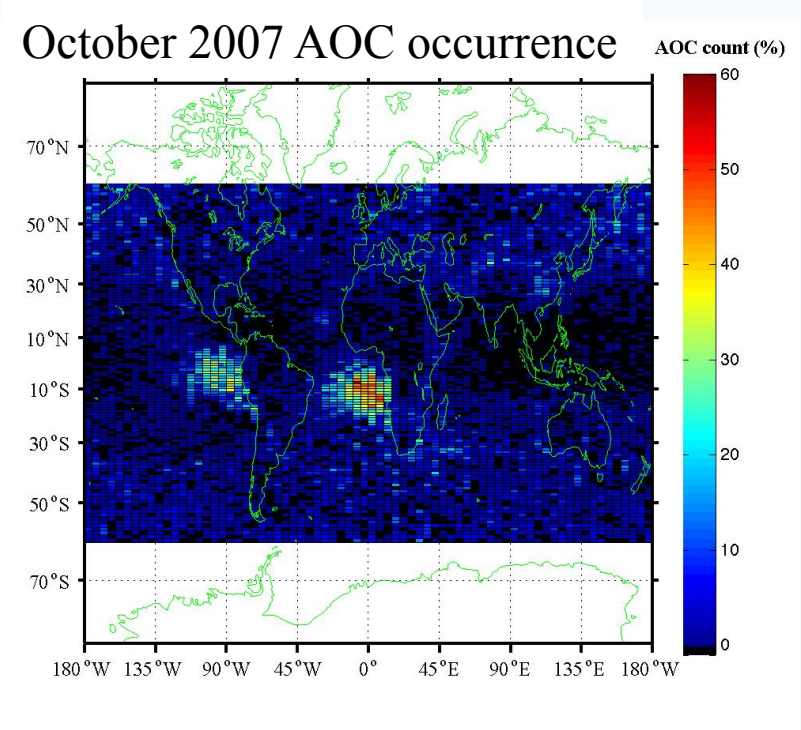
Biomass burning aerosols usually strongly absorbing, may cause local positive radiative forcing when over clouds

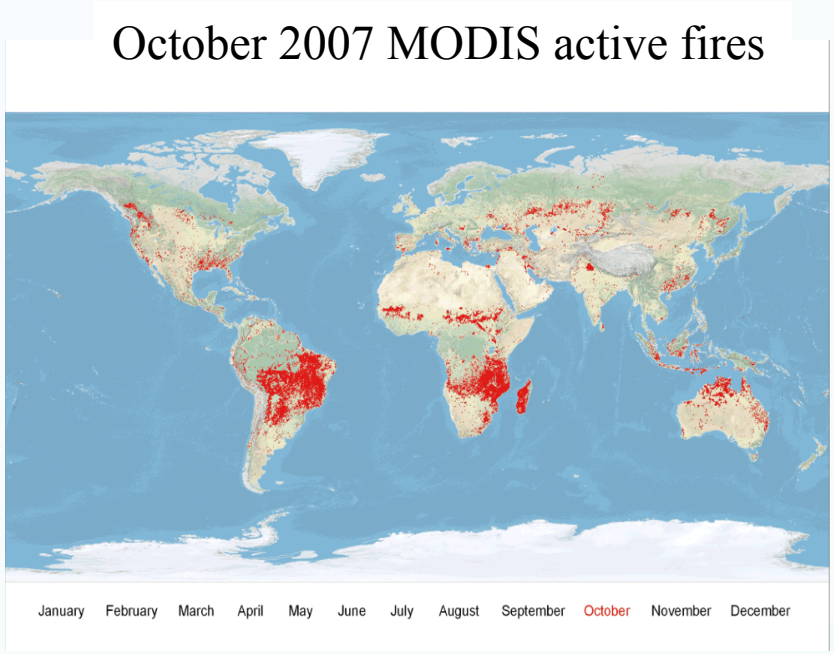
CALIOP is the only satellite sensor capable of observing aerosol over clouds without any auxiliary data (OMI or POLDER need to combine with MODIS and/ or CALIOP)

Before studying aerosol radiative effects over clouds, we need to know where and when aerosol over clouds occur as well as their intensity

We use the CALIPSO level 2 aerosol layer product…

Aerosol Over Cloud (AOC)





Over 50 % AOC (/CALIOP data) offshore from South America and South Africa

Probably mostly biomass burning smoke

"…huge increase in fire activity in 2007… largest over the last ten years" and "largest 6-month (May–October) precipitation deficit of the last ten years in South America occurred during 2007 [Torres et al., 2009]