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Science and Validation Workshop
13 – 17 November 2023 | ESA-ESRIN, Frascati
(Rome), Italy

Aerosol and Carbon dioxide Detection Lidar (ACDL) Overview

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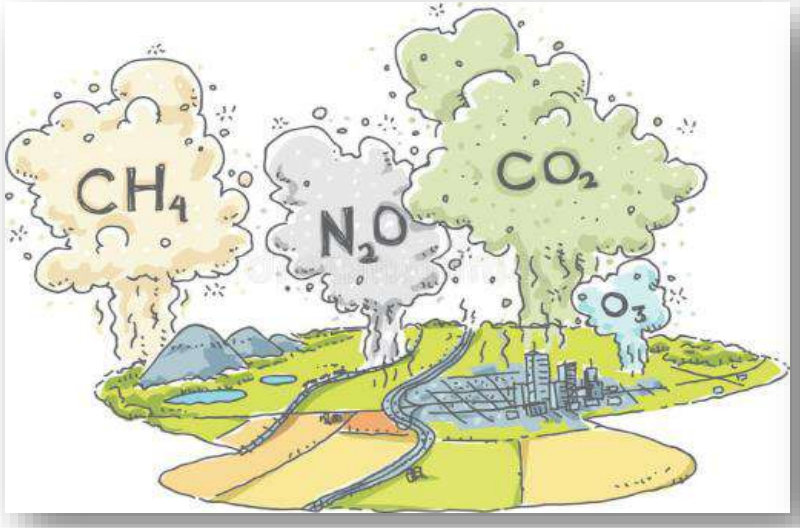
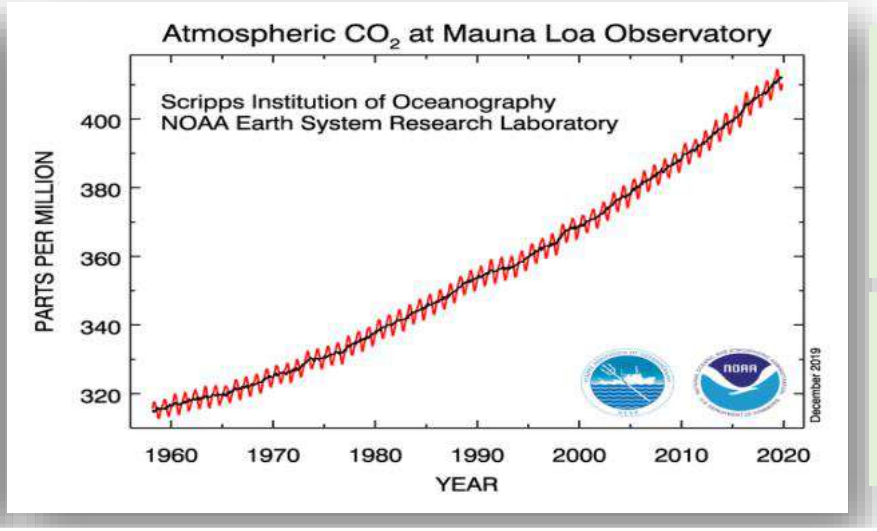
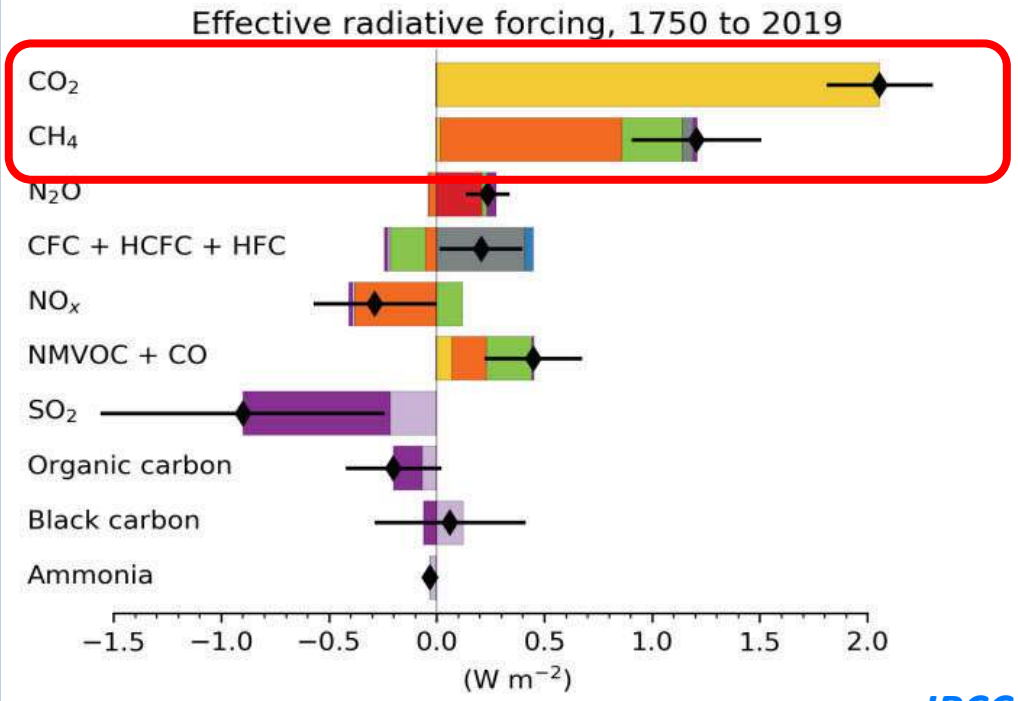
1. Motivation

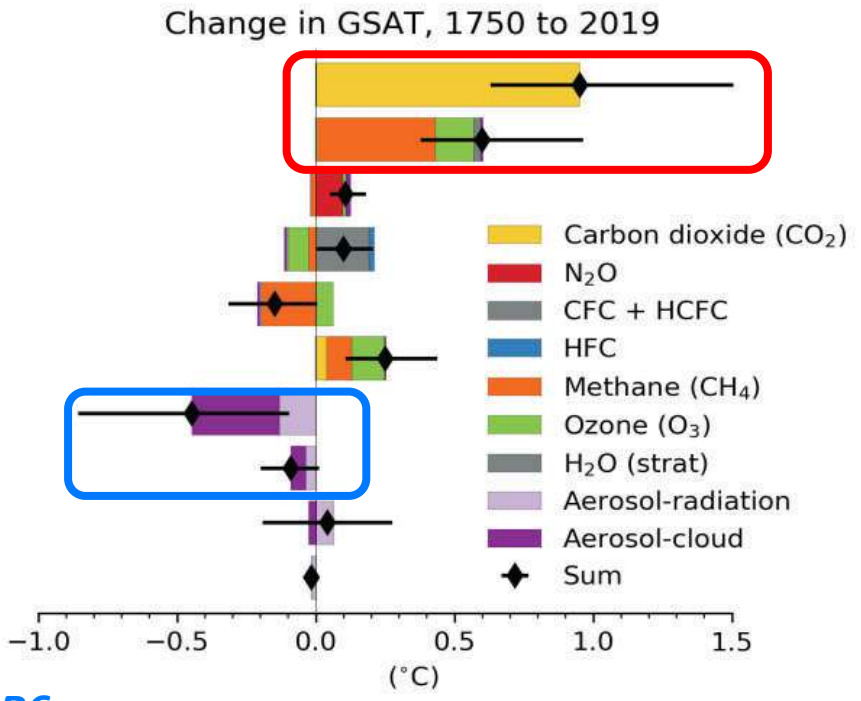




CO_2 and CH_4 are the most important greenhouse gases responsible for global warming, currently contributing about **+1.3 ℃** to global warming

Aerosol and cloud are the most important masses that cooling the atmosphere with **-0.4 ℃**.





IPCC AR6

"The Paris Agreement"

Focus on the global distributions of the CO_2 and aerosol/cloud from **Space**.

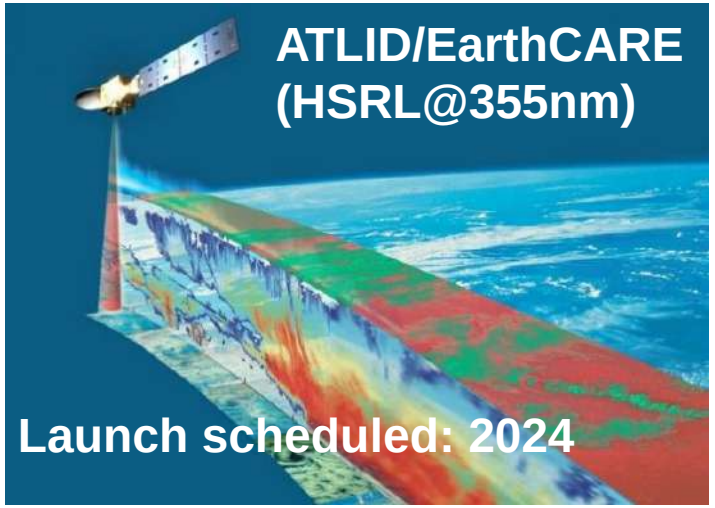
1. Motivation

2006.4-2023.7
(Switch off)

HSRL at 532 nm
IPDA at 1572 nm

Launch: 2022
In-orbit

2018-2023
(Switch off)

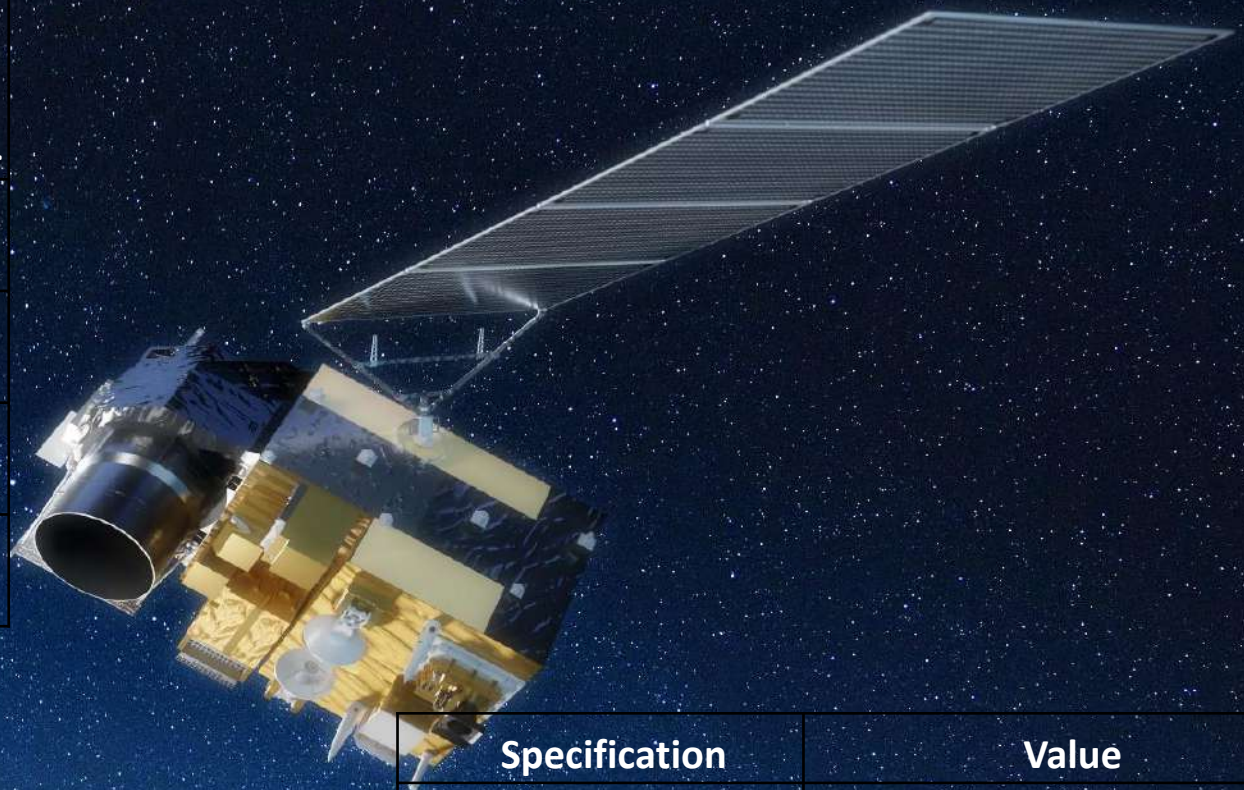


Aeolus-2
Probably 2030

HSRL at 355

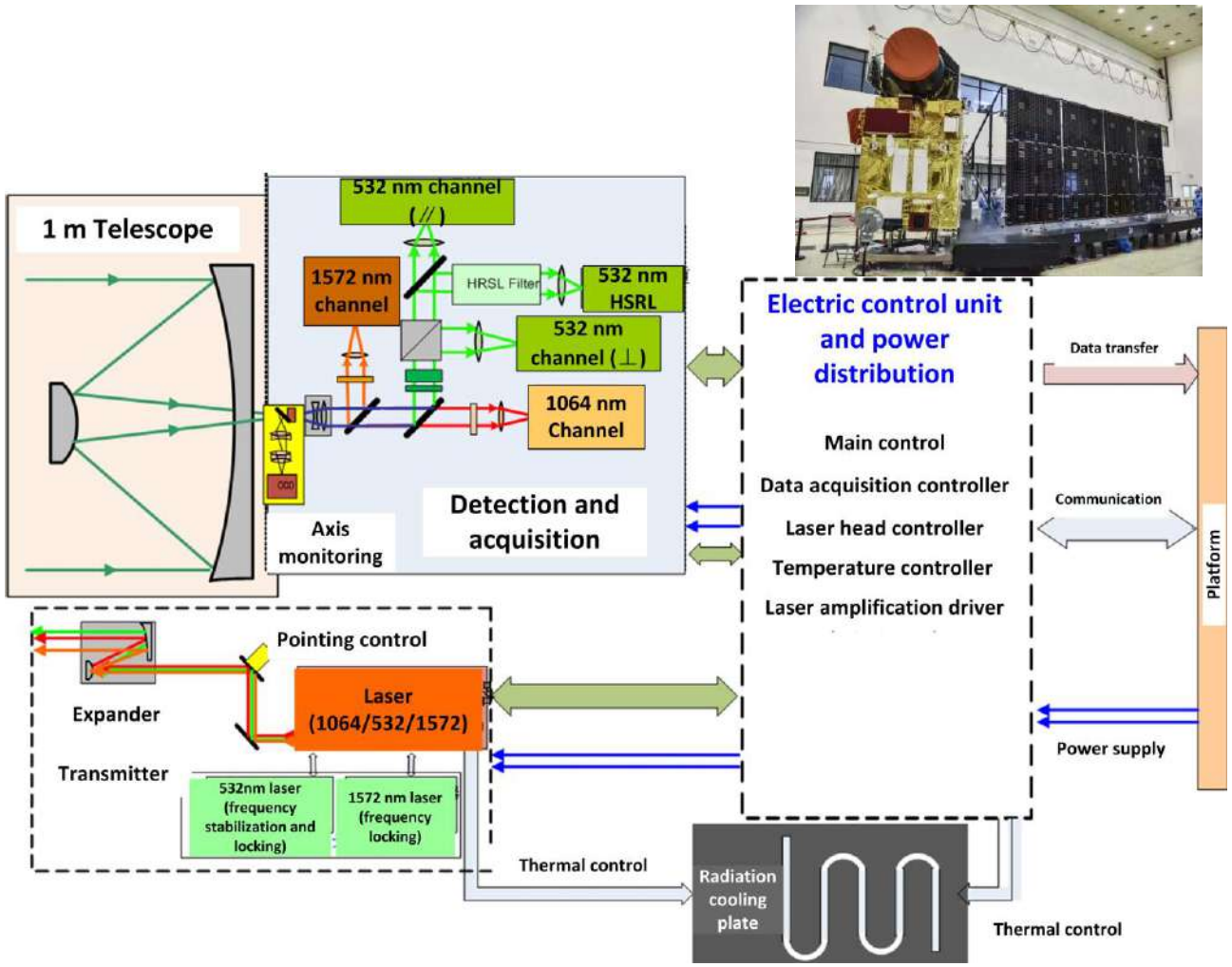
2. ACDL/DQ-1 introduction

Sensor	Observed object
[main Payload] Aerosol and Carbon Detection Lidar (ACDL)	Global column CO_2; Global aerosols and clouds profile; Global pollutant distribution PM2.5 etc.
Particulate Observing Scanning Polarimeter (POSP)	Aerosols and clouds, PM2.5
Directional Polarization Camera (DPC)	Aerosols and clouds, PM2.5
Environmental trace gas Monitoring Instrument (EMI)	NO_2, SO_2, O_3 etc.
Wide Swath Imaging system (WSI)	Temperature and humidity, aerosols and clouds



Specification	Value
Orbit	705 km, sun-synchronous orbit
Revisit duration	~ 51 days
Weight	2.8 t
lifetime	> 8 years

2. ACDL/DQ-1 introduction



- **The first spaceborne lidar (IPDA) for CO2 detection in the world**
- **The first spaceborne Iodine-based HSRL working at 532nm in the world**

Specifications	Parameters
Wavelengths	532nm, 1064nm and 1572nm;
Laser energy	≥130mJ@532nm ≥190mJ@1064nm ≥40mJ@1572nm
Divergence	50μrad
Stability of the laser linewidths	1572nm: 0.6MHZ@10000s 1064nm: 5MHz@10000s
PRF	20Hz@1572nm (On/Off dual-pulse) 20Hz@532nm and 1064nm (dual-pulse)
Telescope aperture	1000mm
FOV	190μrad
HSRL	Iodine cell: OD > 25dB
Receiver channels	532nm HSRL
	532nm parallel-polarized
	532nm cross-polarized
	1064nm aerosol
	1572nm CO2

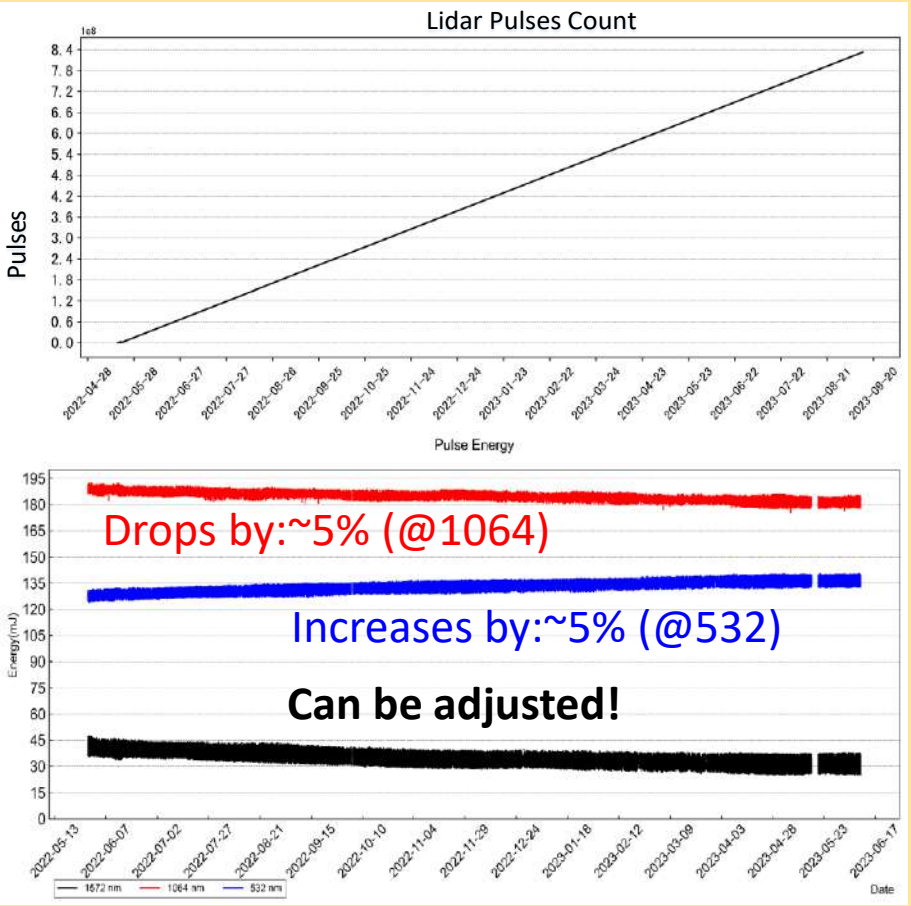
2. ACDL/DQ-1 introduction

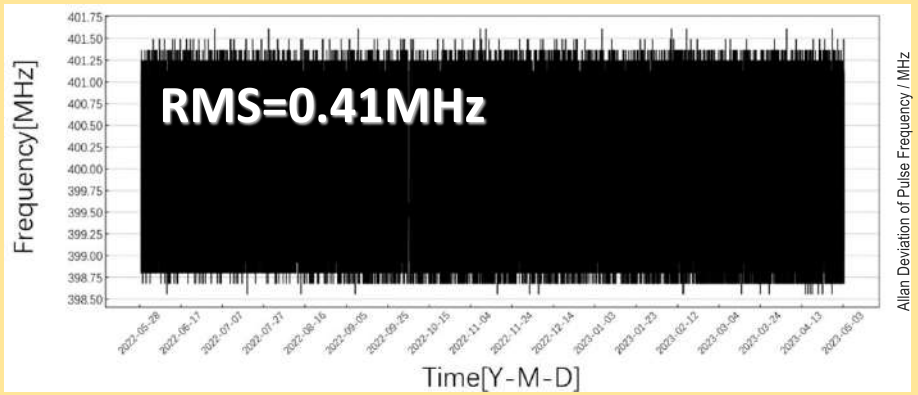
level	Data processing	Data products	Format
Level 0	The observation data obtained by downlinking multi-packet data integrity inspection and data splicing through the two channels of the satellite.	Raw data	RAW
Level 1A	Process the level 0 aerosol data, obtain the profiles of 532 nm and 1064 nm channels, with the geographic location and height corrected.	Profiles data of 532 nm and 1064 nm channels	HDF5
Level 1B	Process the level 0 CO2 data, obtain the profiles of 1572 nm channel, with the geographic location and height corrected.	Profiles data of 1572 nm channel	HDF5
Level 2A	Attenuated backscatter coefficient with systematic constant correction	Attenuated backscatter coefficient	HDF5
Level 2B	Differential Absorption Optical Depth (DAOD) products	DAOD	HDF5
Level 2C	Cloud and aerosol products including extinction coefficient, backscatter coefficient, depolarization ratio, AOD, lidar ratio and color ratio	Cloud and aerosol optical properties	HDF5
Level 2D	XCO2	XCO2	HDF5

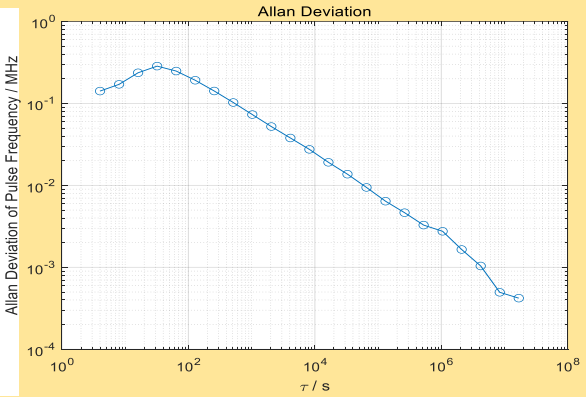
2. ACDL/DQ-1 introduction

ACDL/DQ-1 performance assessment:

- ACDL/DQ-1 have been operating in-orbit for more than **17 months**;
- Now about **1 billion** laser shots have been emitted in total from the switch-on of ACDL/DQ-1 on 17th May 2022;

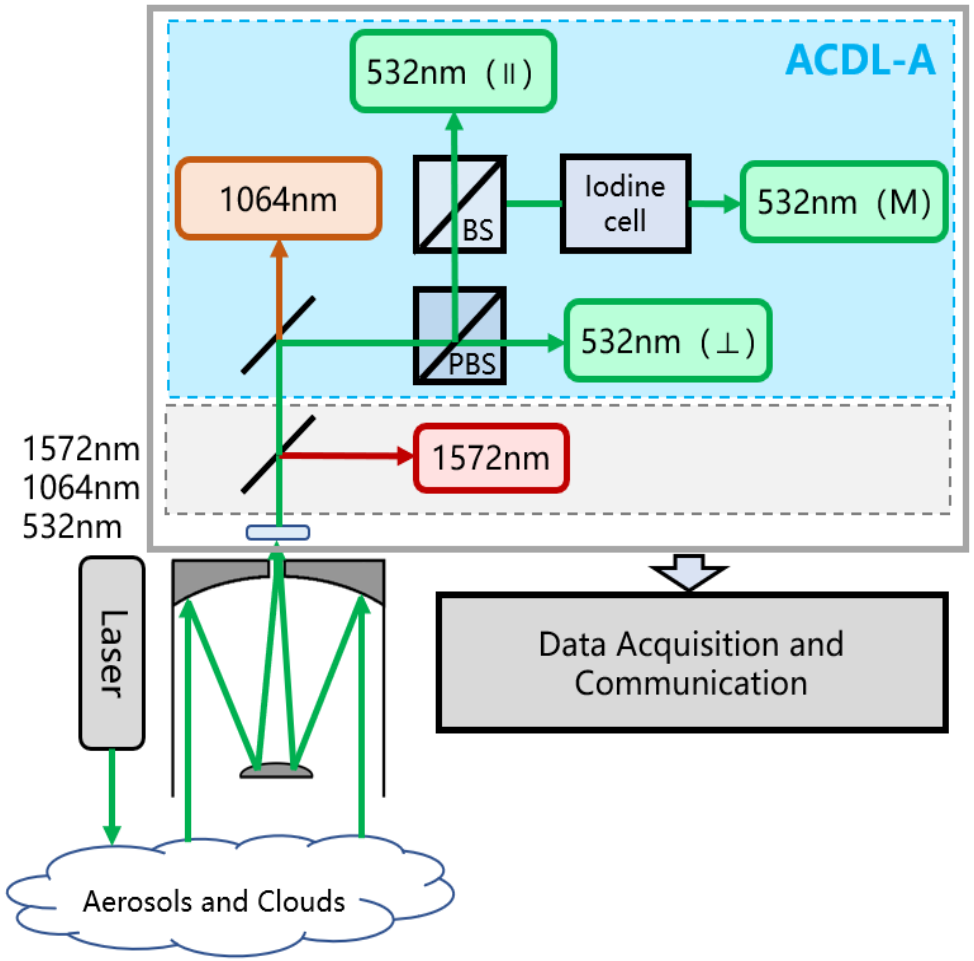






ID No.	Frequency / MHz	Maximum / MHz	Minimum / MHz	RMS / MHz	Allan deviation / MHz (@10000s)
TML0194	400.02	401.49	398.8	0.41	＜0.03

3. Aerosol and cloud optical properties

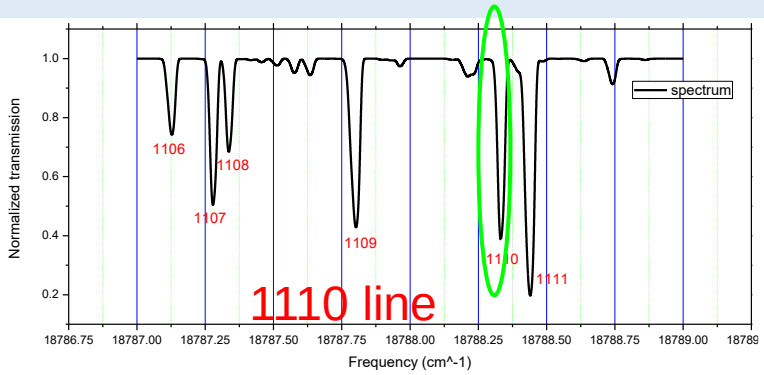


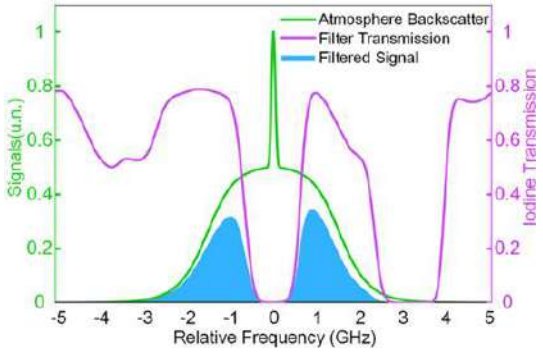
Dai G, Wu S, Long W, et al. Aerosols and Clouds data processing and optical properties retrieval algorithms for the spaceborne ACDL/DQ-1[J]. AMTD, 2023, 2023: 1-20.

Specifications	Parameter
wavelength	532.024 nm; 1064.490 nm
pulse energy	~130 mJ@532 nm; ~190 mJ@1064 nm
repetition rate	20 Hz @ dual-pulse (40 Hz)
Etalon filter bandwidth	<20 pm
sampling rate	50 MHz
vertical resolution	3 m@<7.5 km ; 24 m (8 point average)@>7.5 km
horizontal resolution	~ 330 m

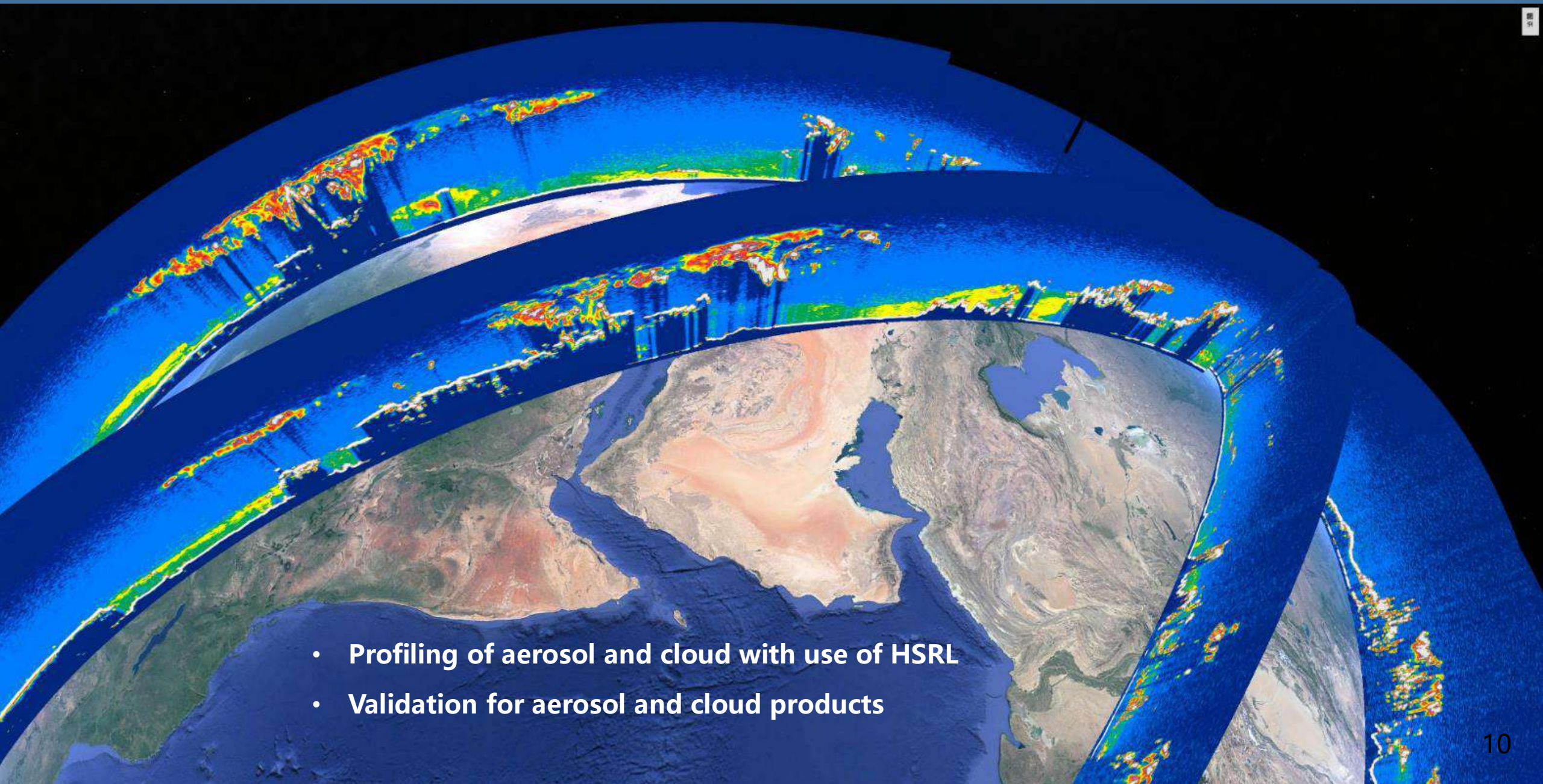
High-spectral-resolution lidar (HSRL) with an iodine vapor absorption filter (working at 1110 line, bandwidth<2GHz) and polarization detection

- 532 nm (cross- and parallel-polarized channels and molecular channel)
- 1064 nm channel





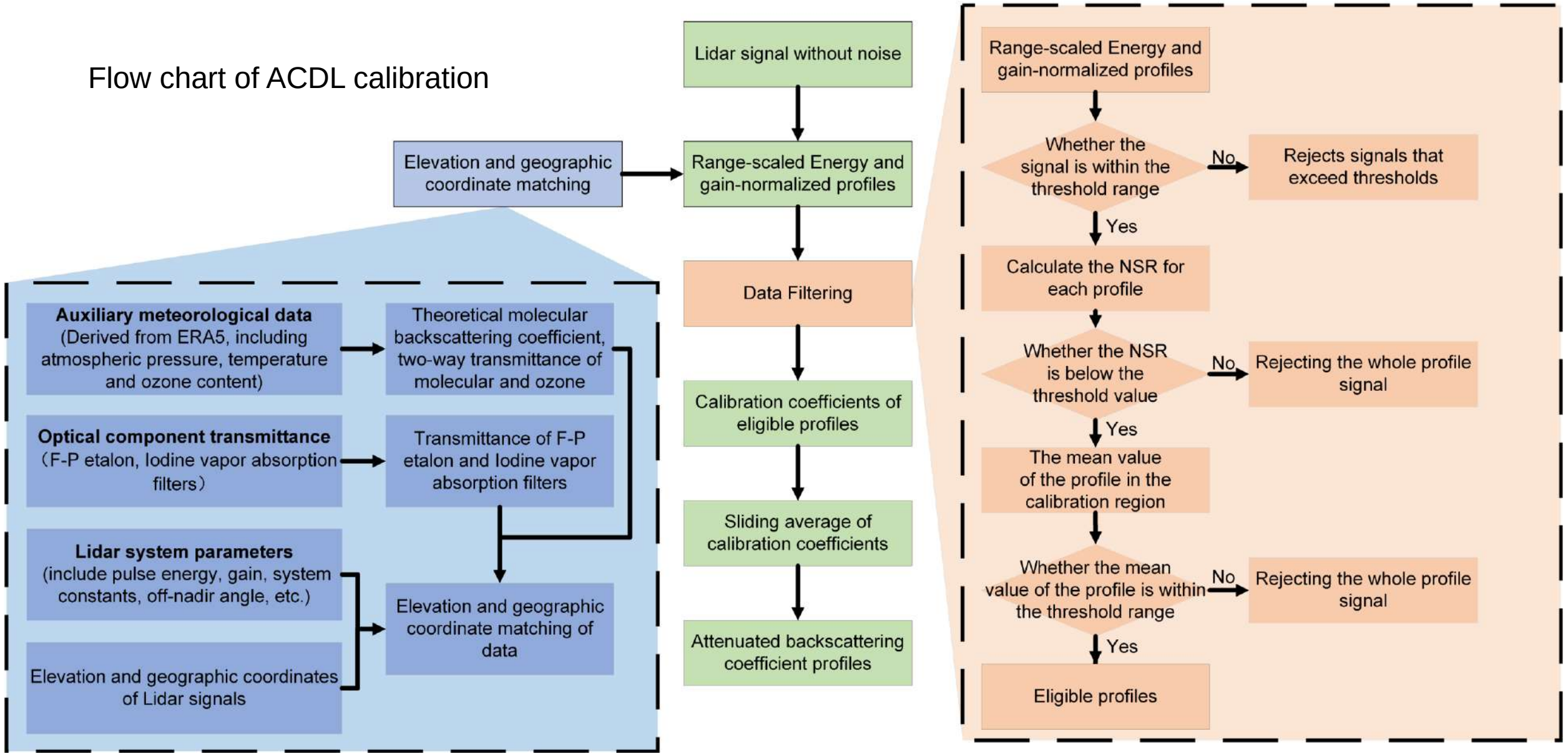
3. Aerosol and cloud optical properties



- Profiling of aerosol and cloud with use of HSRL
- Validation for aerosol and cloud products

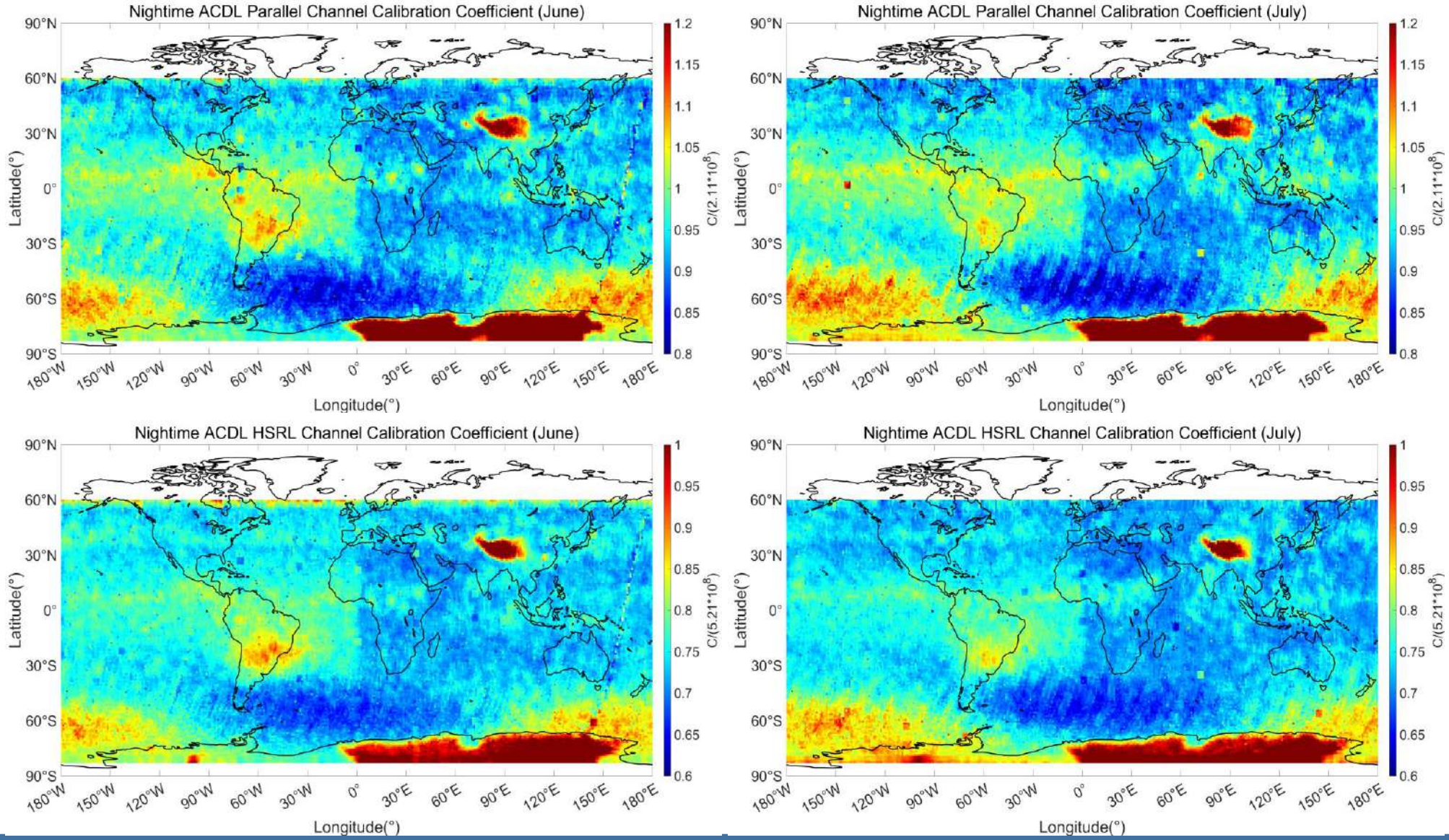
3. Aerosol and cloud optical properties: ACDL calibrations

Flow chart of ACDL calibration



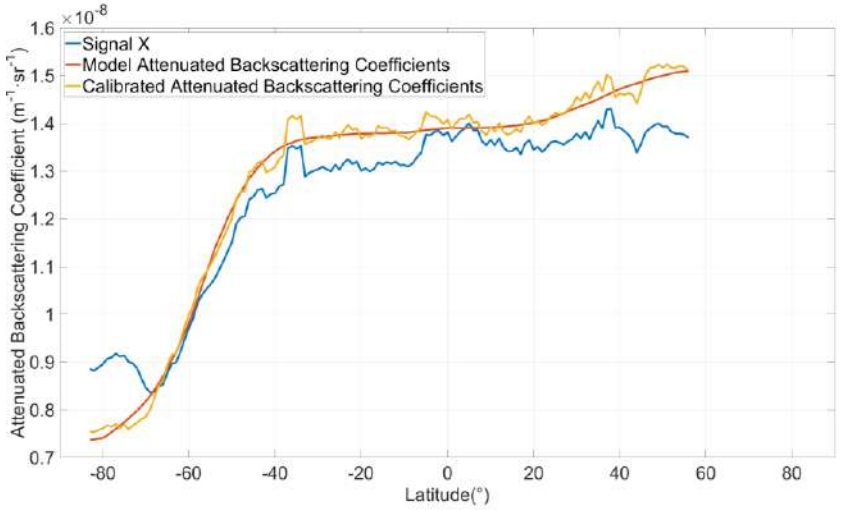
3. Aerosol and cloud optical properties: ACDL calibrations

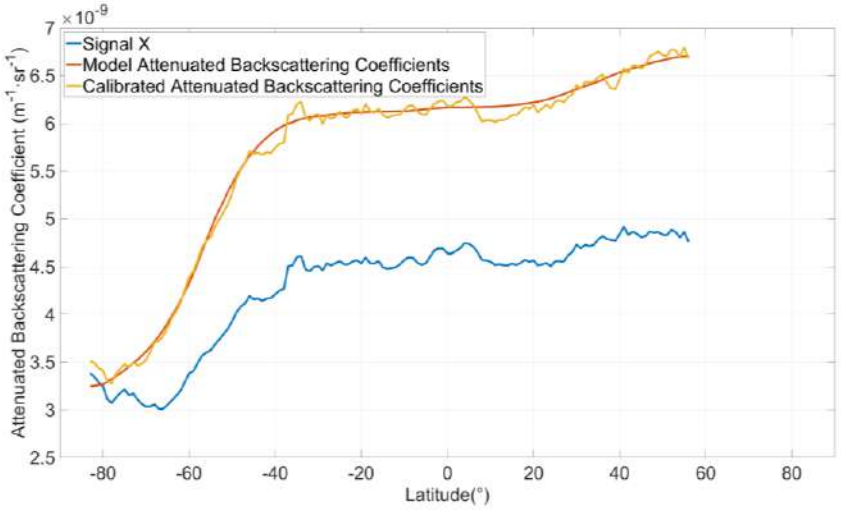
Multi-channel global calibration coefficients of ACDL (June, July 2022)

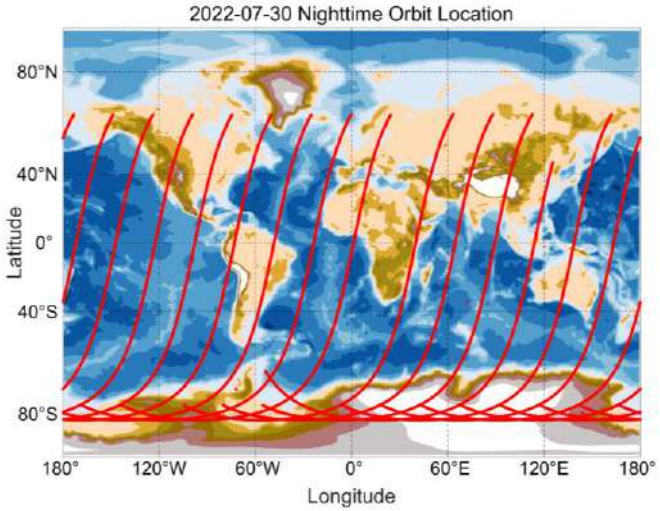


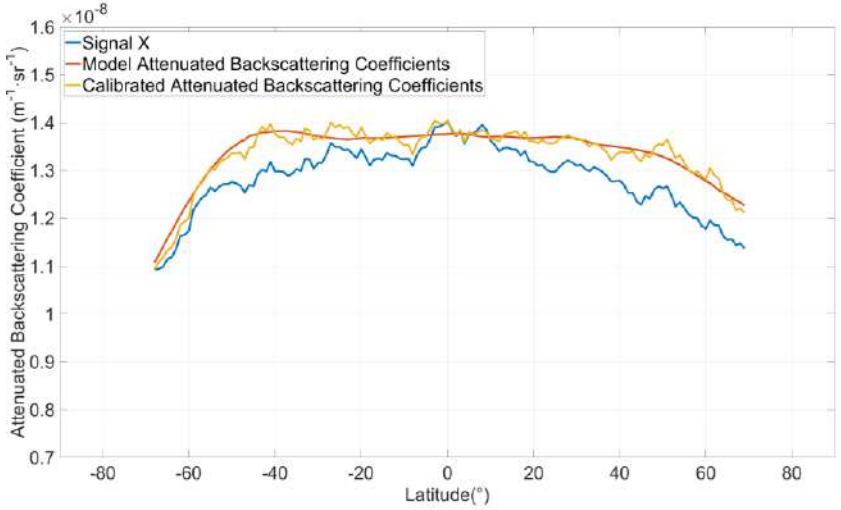
3. Aerosol and cloud optical properties: ACDL calibrations

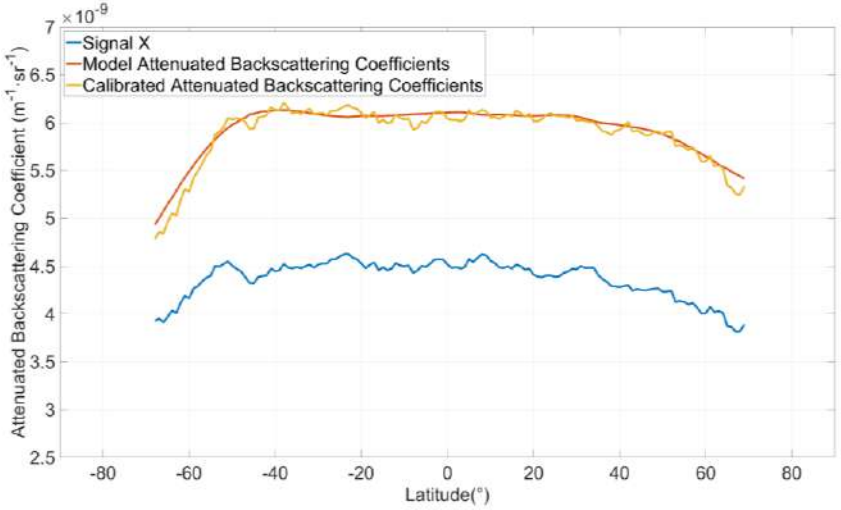
Averaged attenuated backscattering coefficients after calibration at 31-35 km altitude versus model results.
(30 July, 2022; 31 October, 2022)

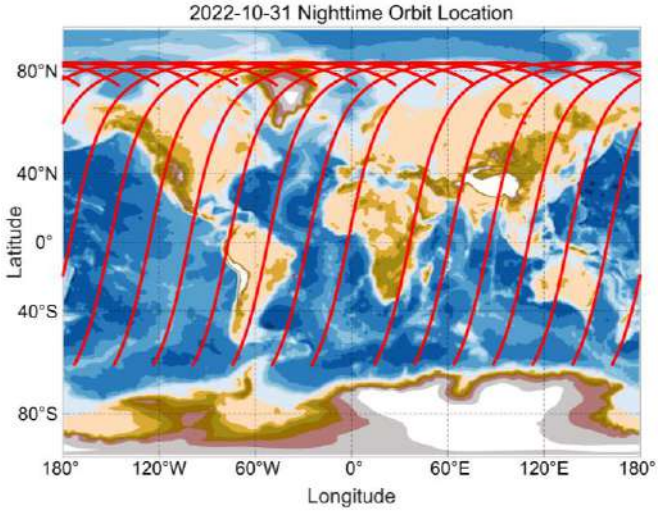






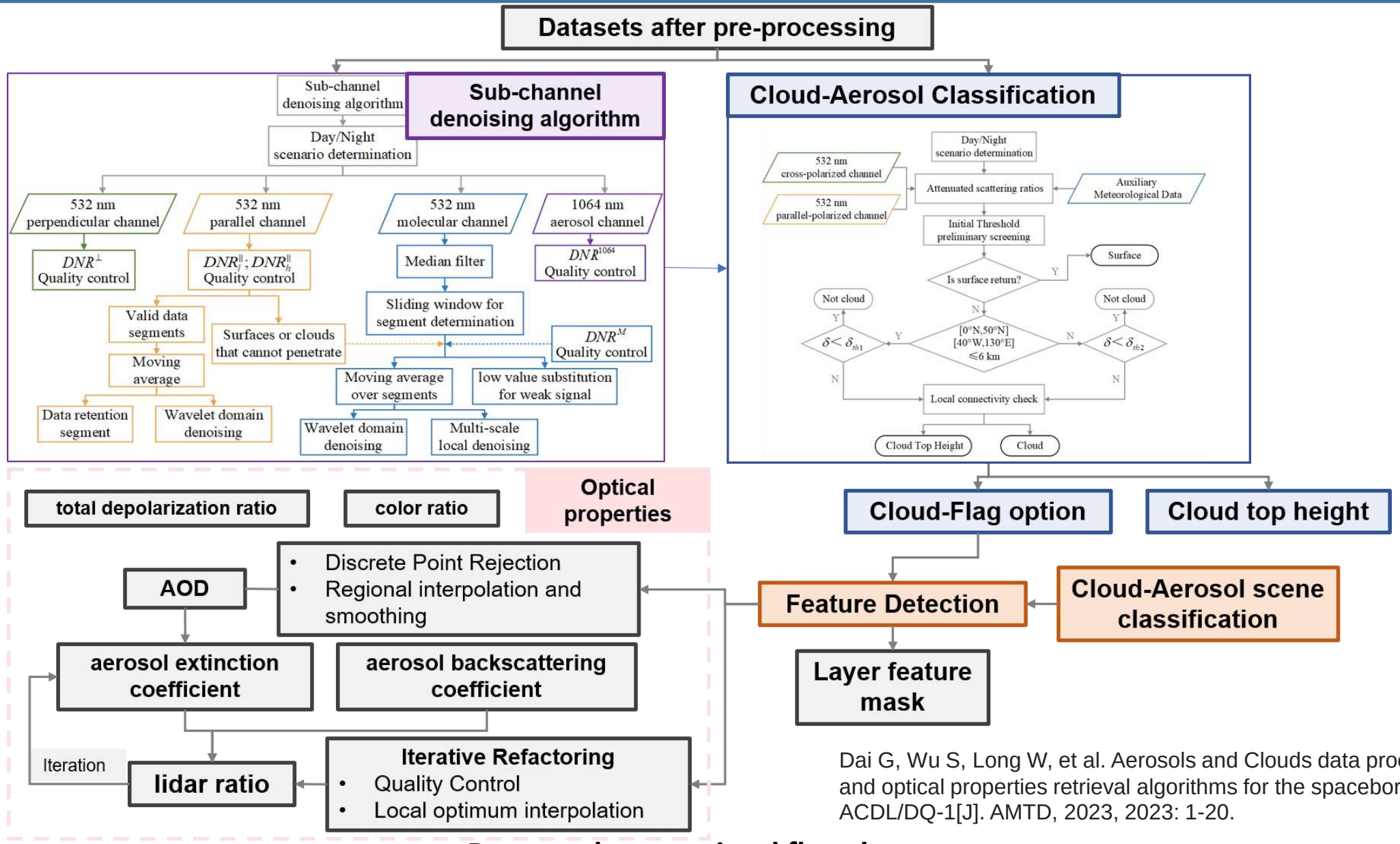






Meng F, Dai G* et al., in preparation.

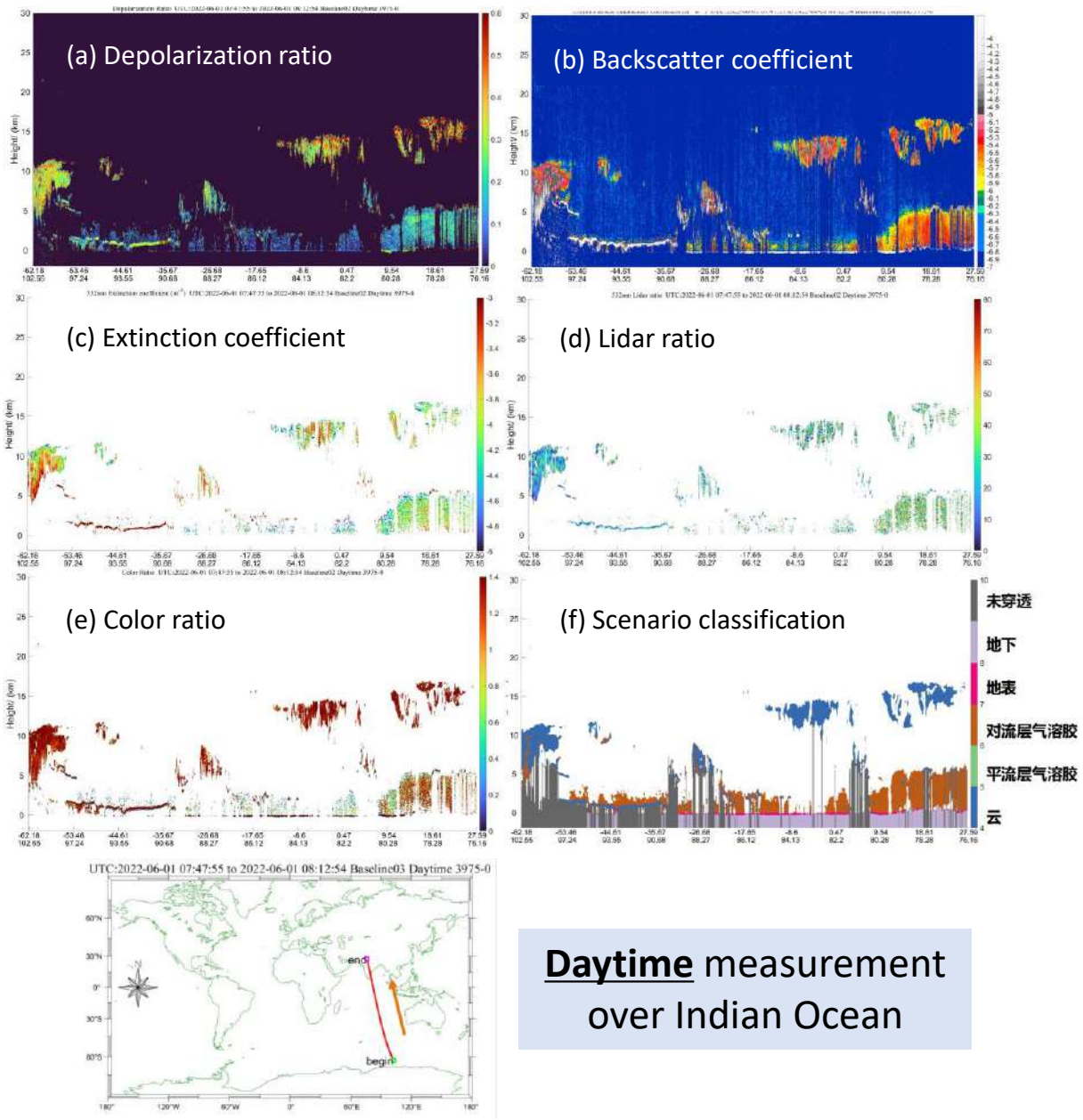
3. Aerosol and cloud optical properties



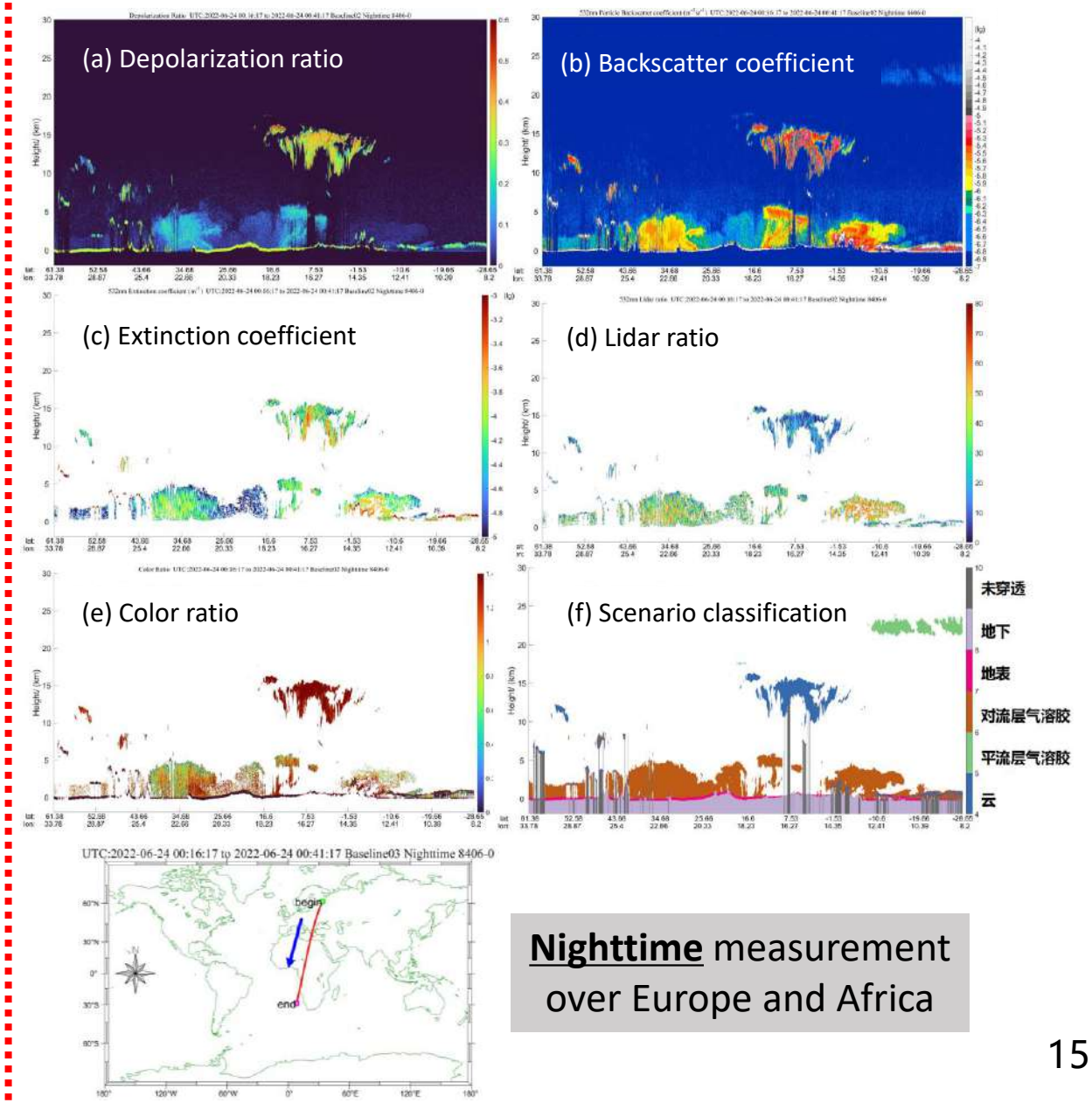
Dai G, Wu S, Long W, et al. Aerosols and Clouds data processing and optical properties retrieval algorithms for the spaceborne ACDL/DQ-1[J]. AMTD, 2023, 2023: 1-20.

Data products retrieval flowchart

3. Aerosol and cloud optical properties

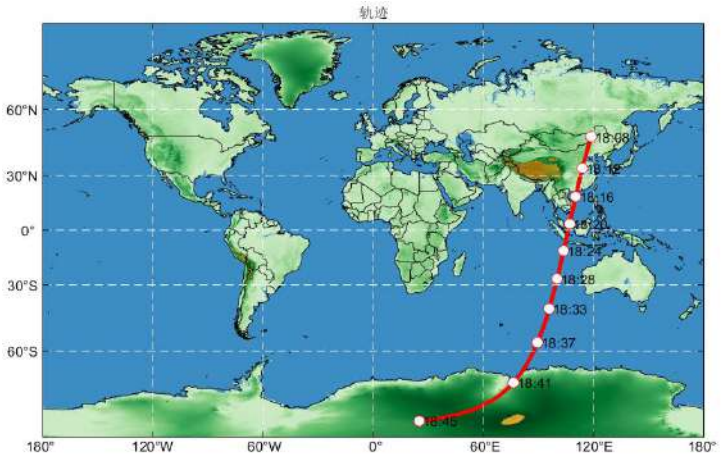


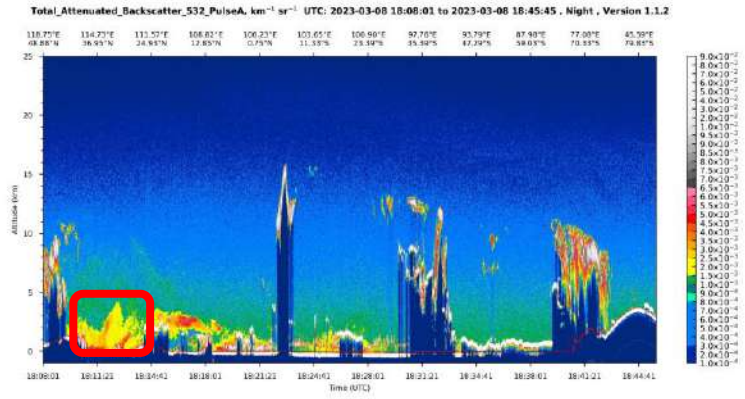
Daytime measurement over Indian Ocean

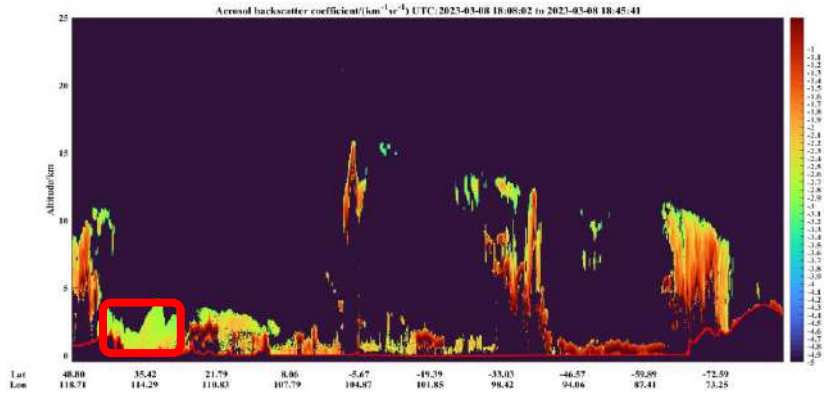


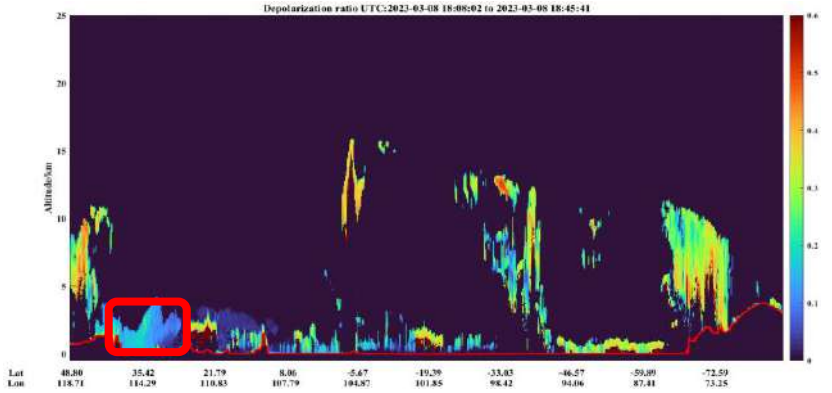
Nighttime measurement over Europe and Africa

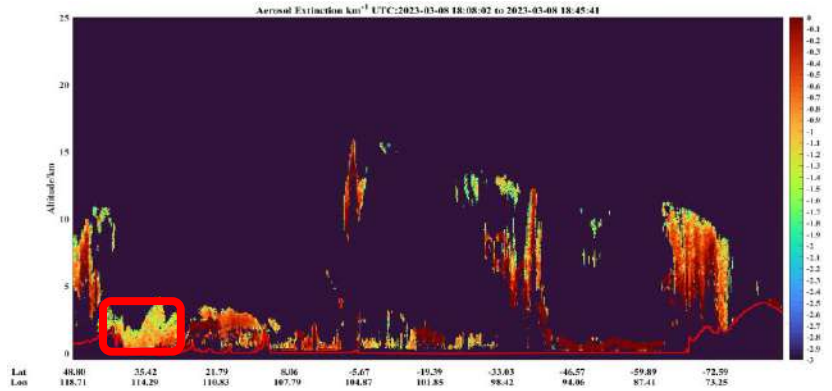
3. Aerosol and cloud optical properties

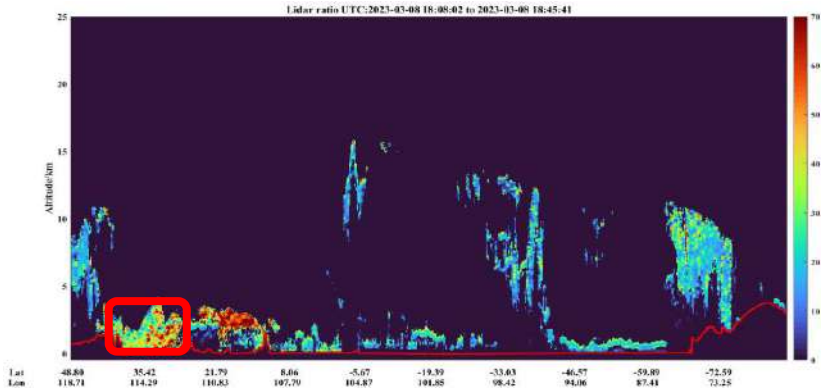


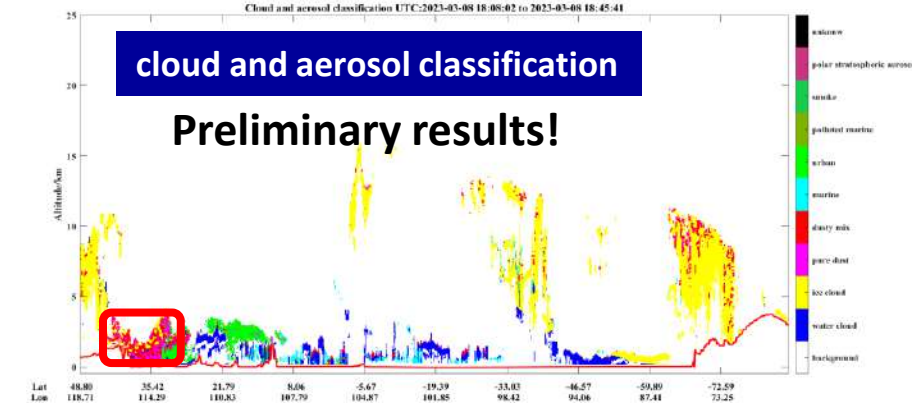






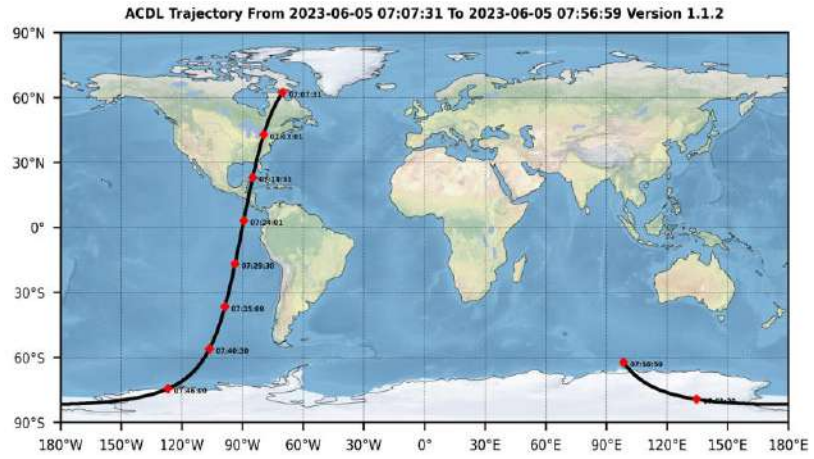


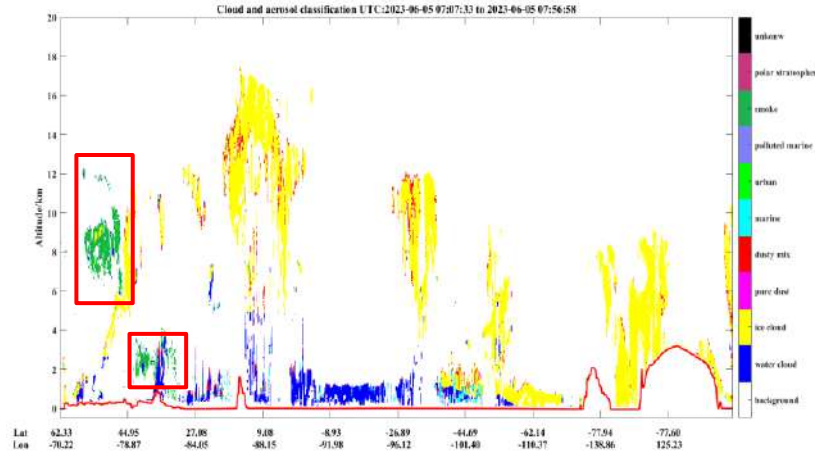


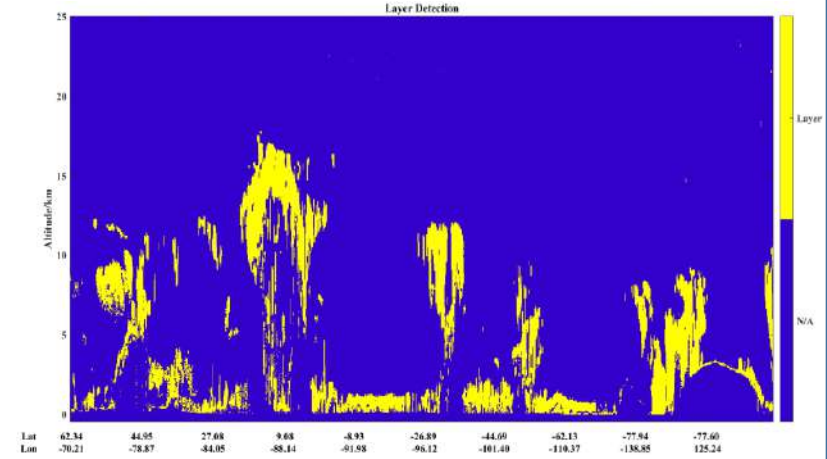


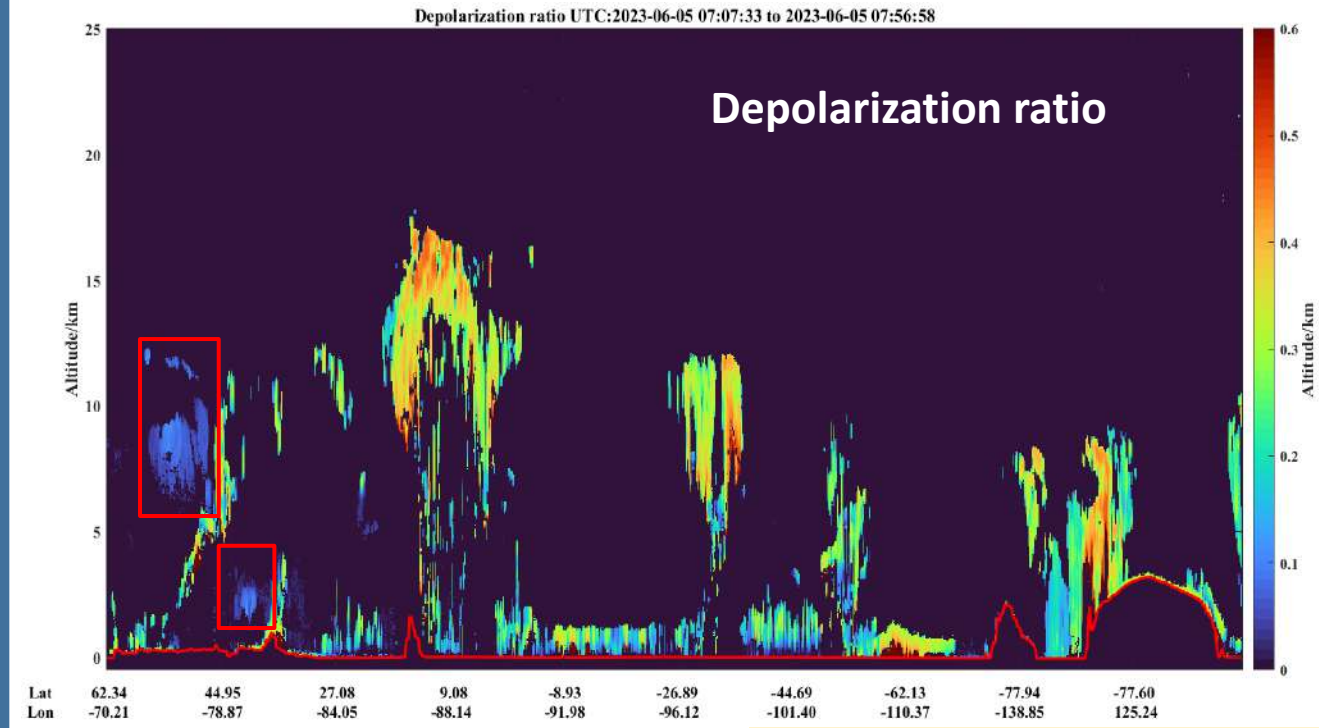
Dust event measurement case in Beijing on 8th March, 2023

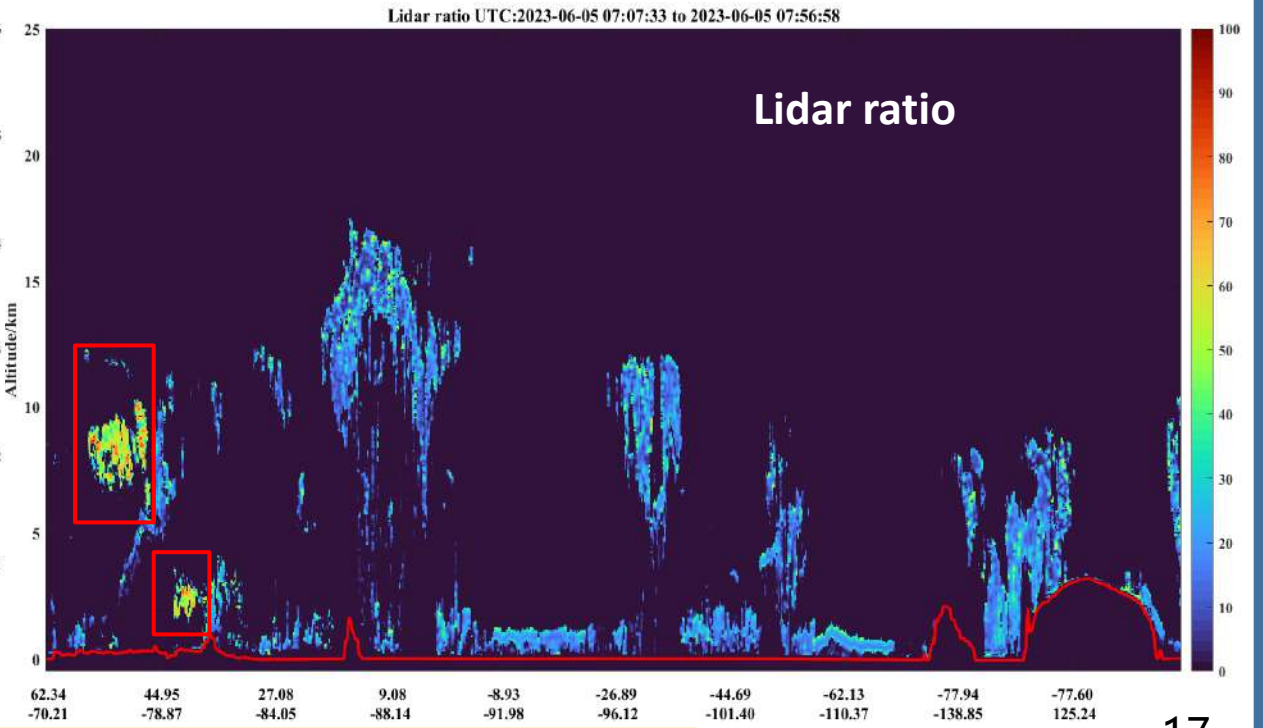
3. Aerosol and cloud optical properties





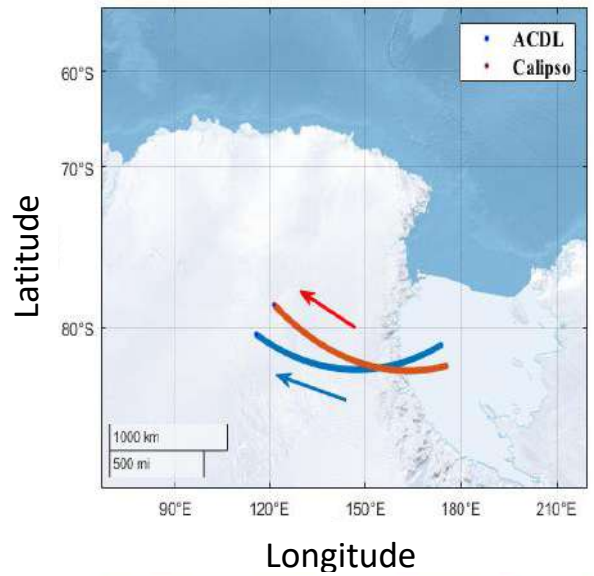


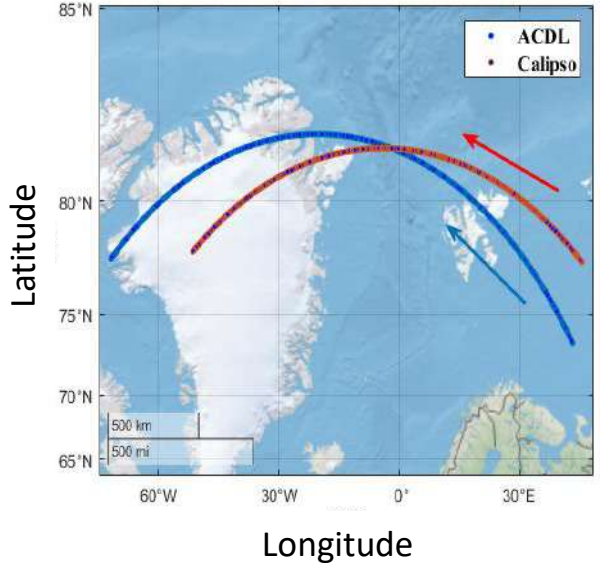


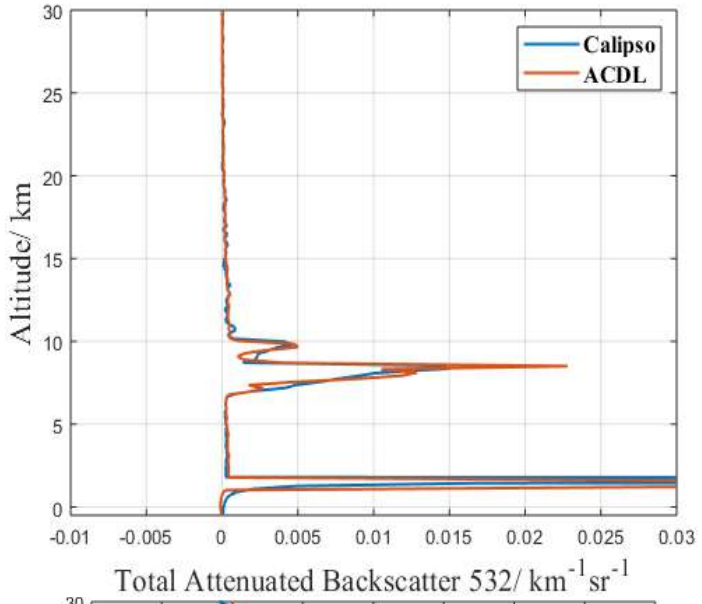


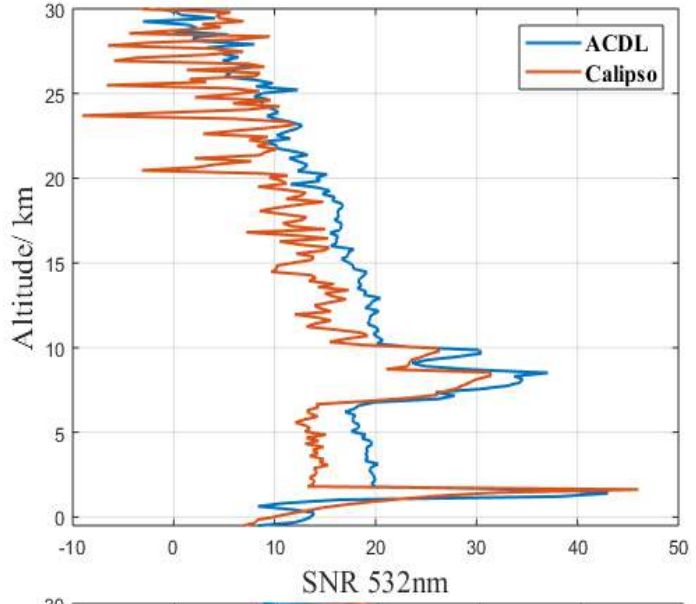
Canada wildfire on 5 June, 2023

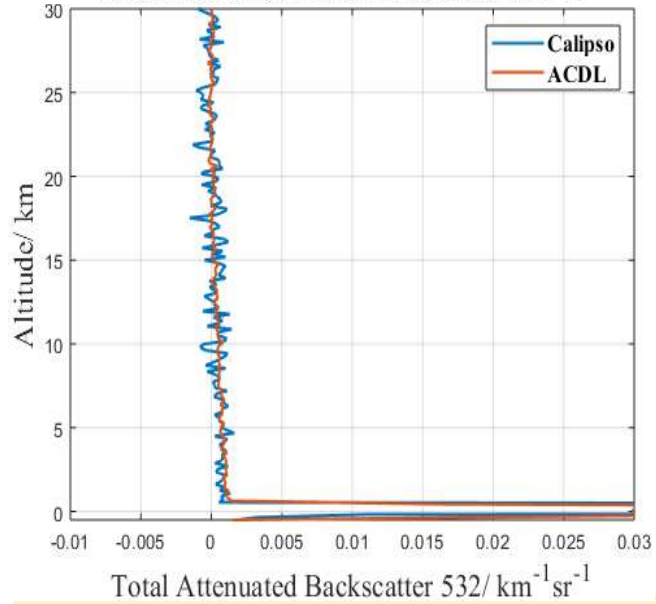
3. Aerosol and cloud optical properties: validation with CALIOP

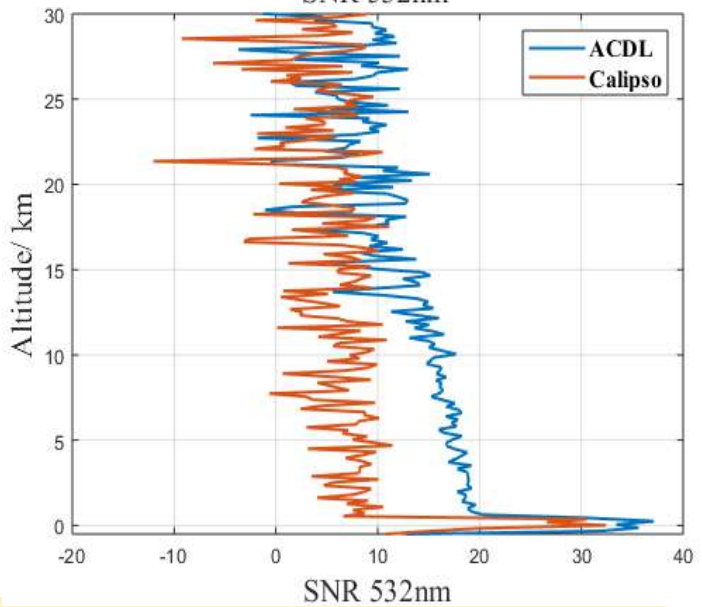








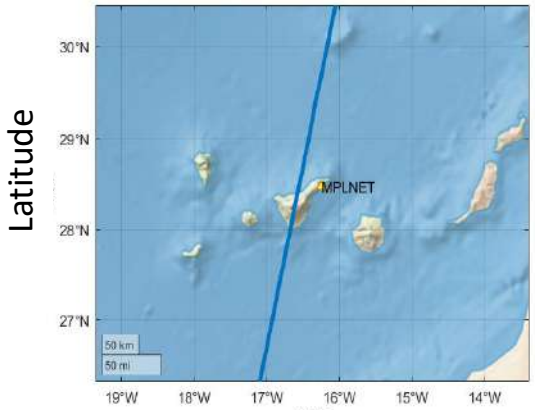




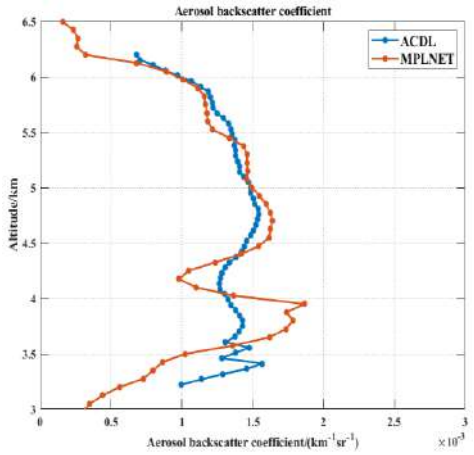
ACDL and CALIOP simultaneous measurement: 2-3 times higher

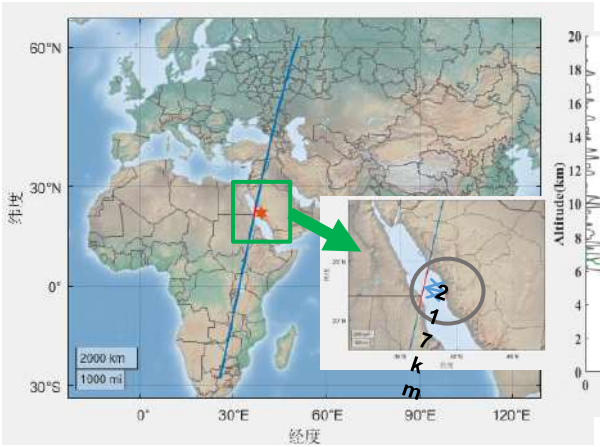
3. Aerosol and cloud optical properties: validation with GB lidars

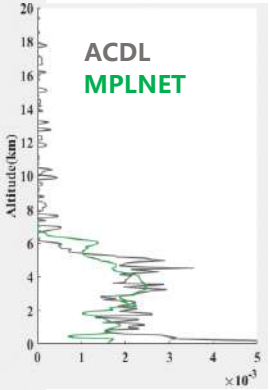
With MPLNET at 02:56 on 9th June 2023

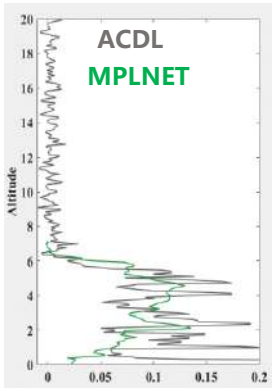


Santa-Cruz
(28.472°N, 16.247°W)





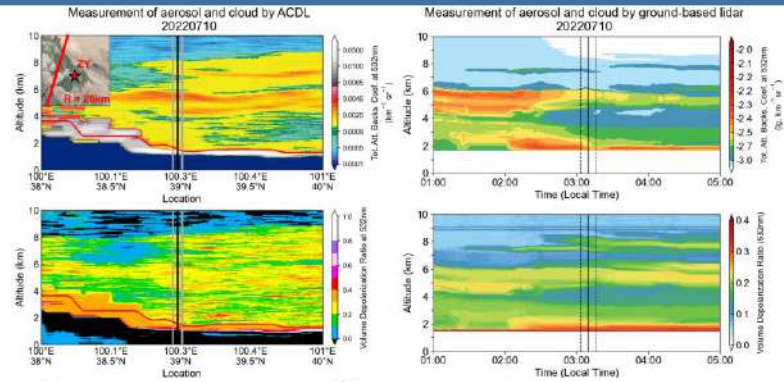


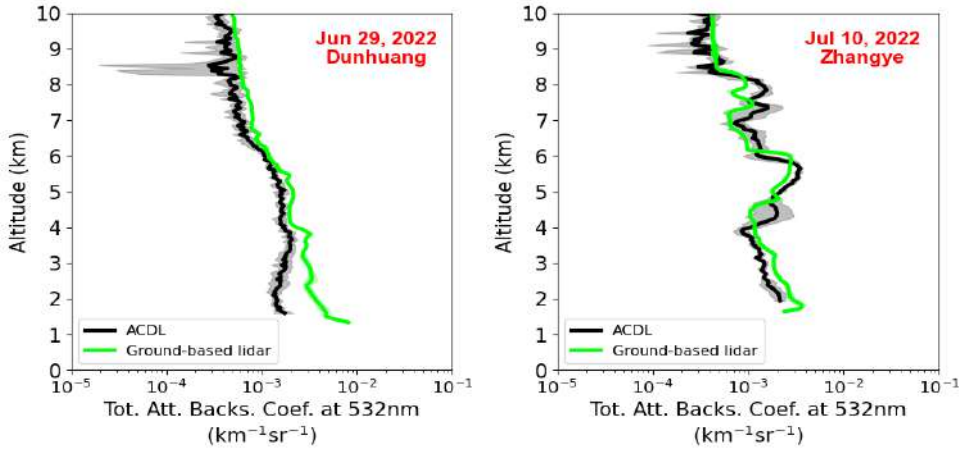


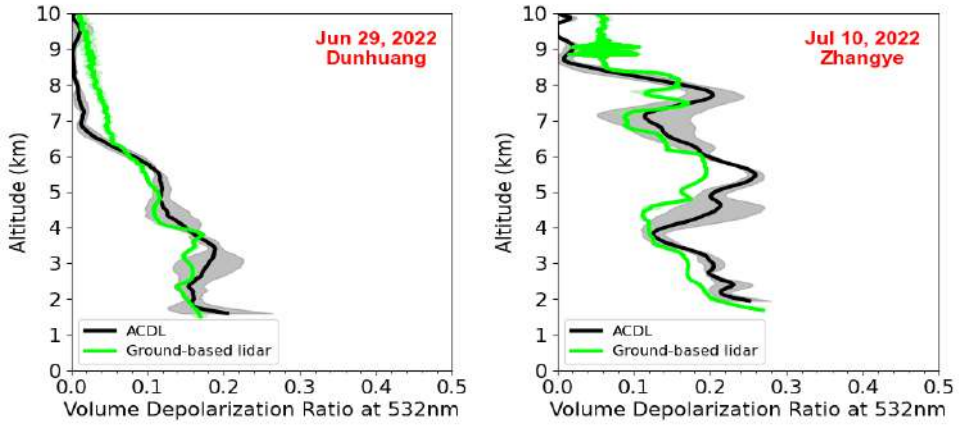
KAUST_Campus
(39.103° E, 22.305° N)

With ground-based lidars in China

Results from Lanzhou Univ.
Qiantao Liu, AMTD, 2023

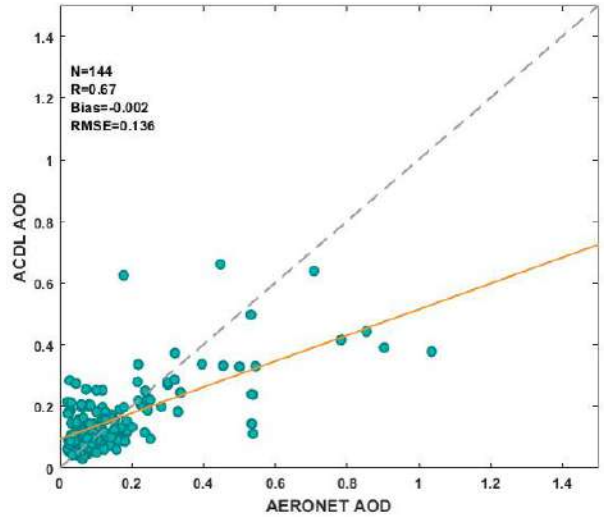




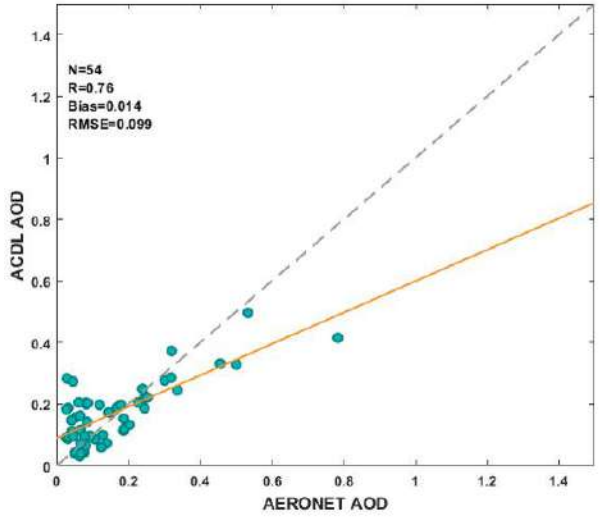


3. Aerosol and cloud optical properties: validation with AERONET/MODIS

With AERONET

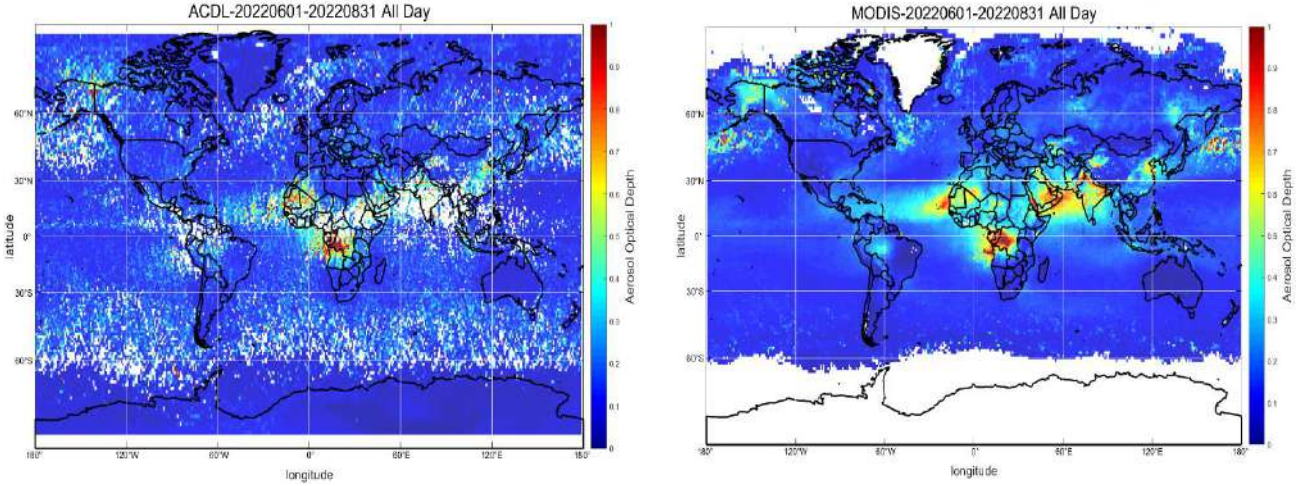


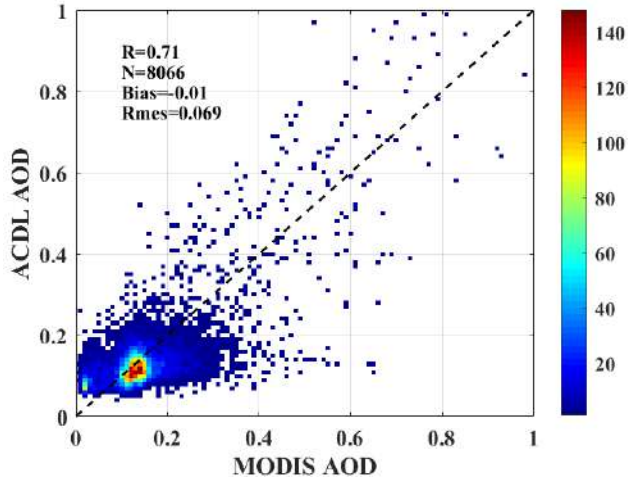
All-time measurements



Night-time measurements

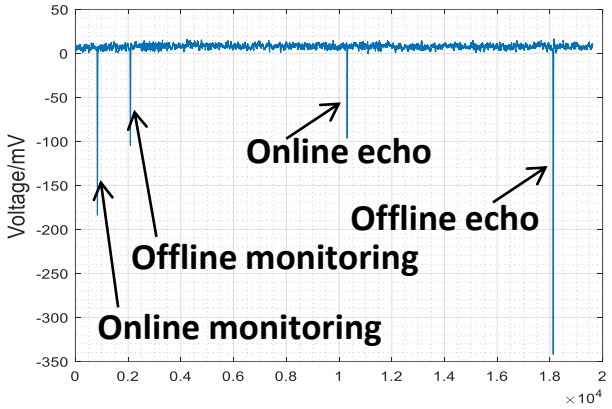
With MODIS



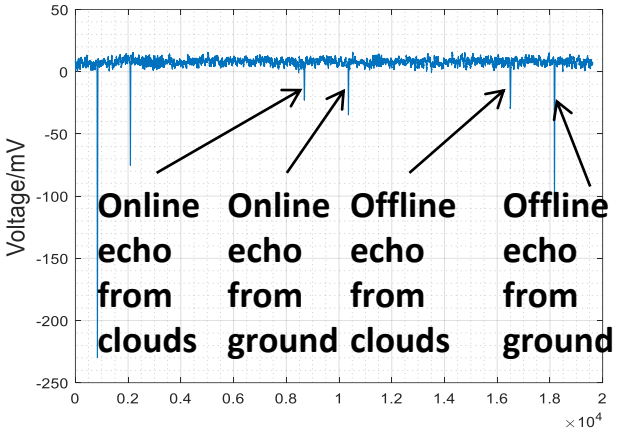


4. Carbon dioxide column measurements

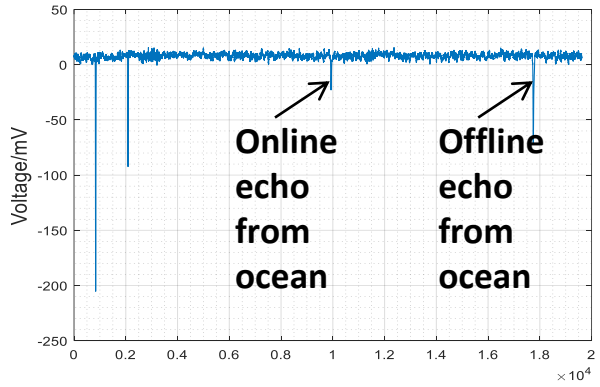
Echo from ground

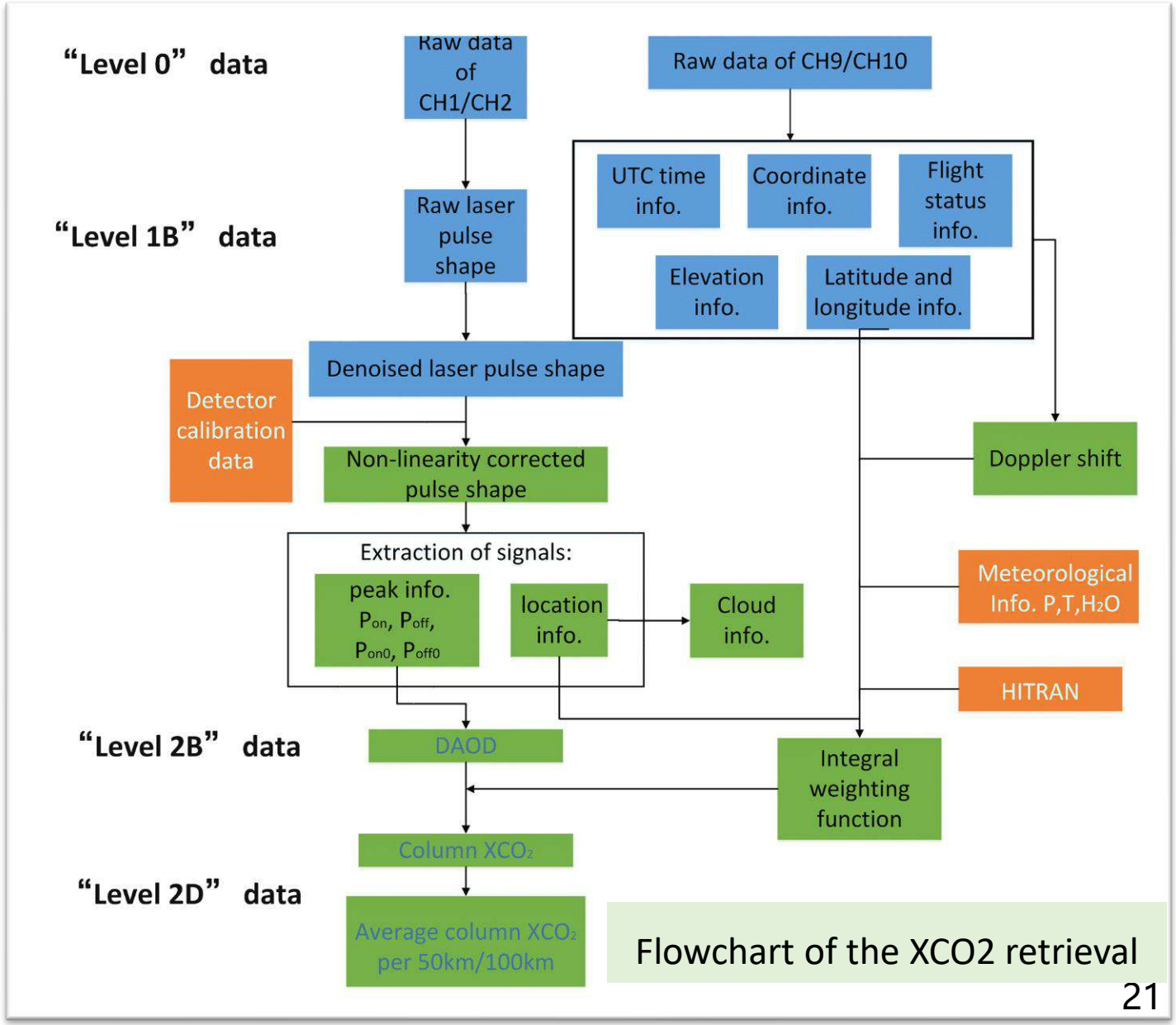


Echo from clouds



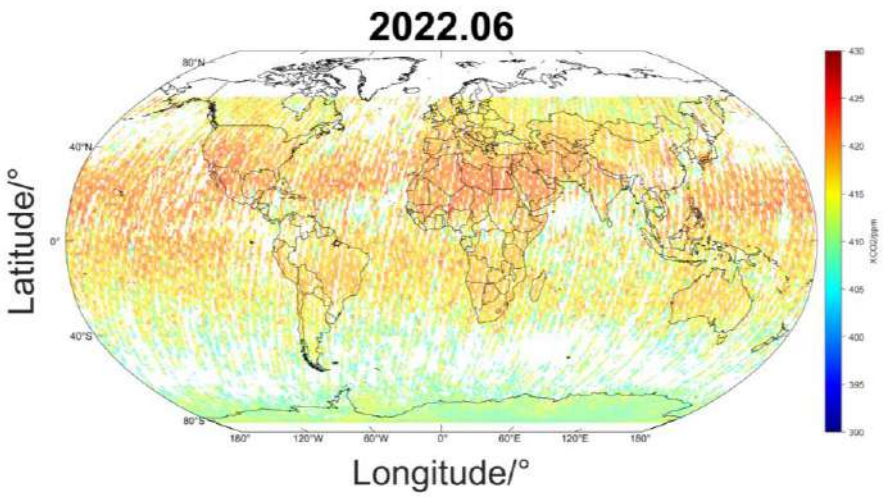
Echo from ocean



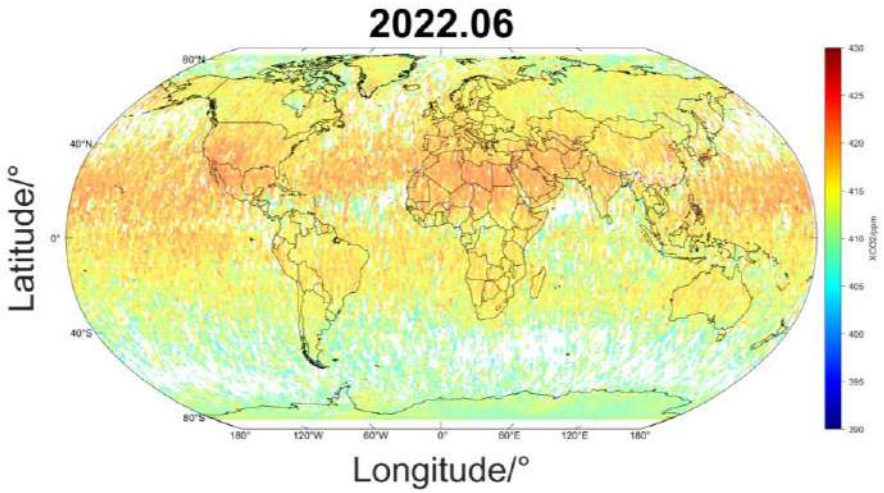


Flowchart of the XCO2 retrieval

4. Carbon dioxide column measurements



Night-time CO2 measurement in June

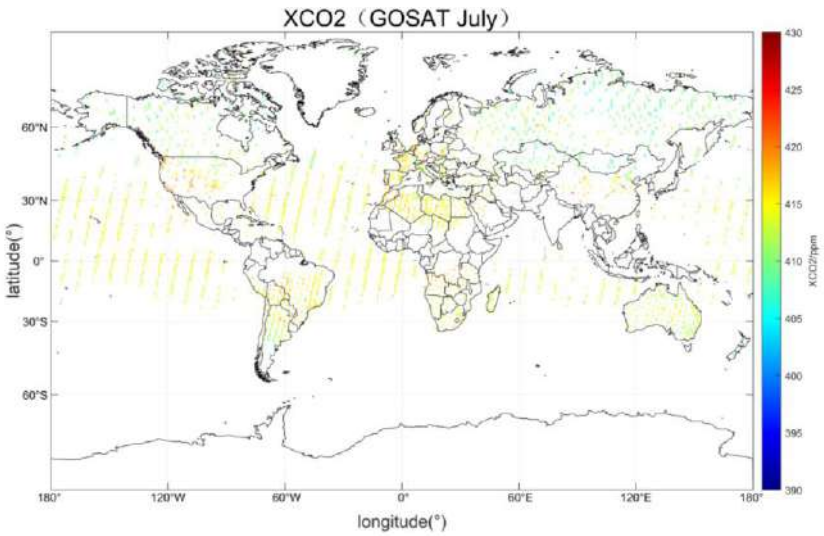


All-time CO2 measurement in June

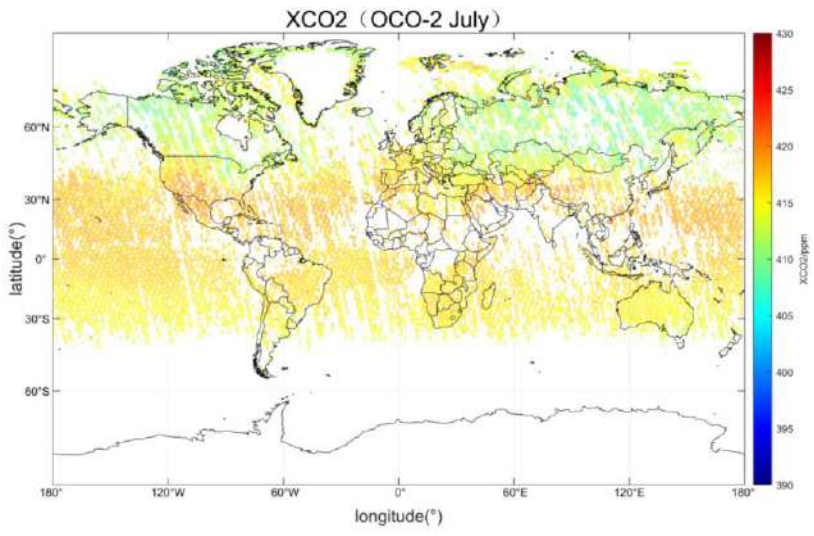
ACDL/DQ-1 CO2 performance assessment:

- Comparing with passive instruments, the ACDL/DQ-1 is capable of providing CO2 measurements both daytime and nighttime;
- ACDL/DQ-1 covers the CO2 measurements at high latitudes (from 82° N to 82° S);

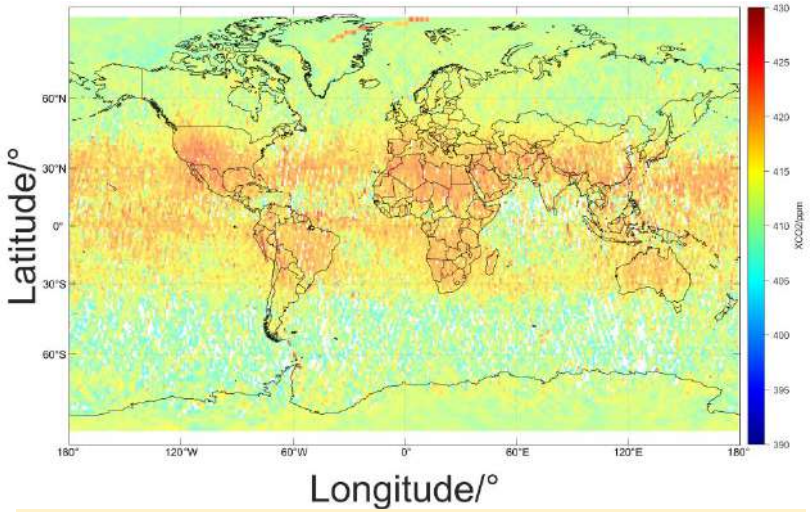
4. Carbon dioxide column measurements



GOSAT monthly coverage rate: 3-5%



OCO-2 monthly coverage rate: 7-12%



ACDL monthly coverage rate: >80%

ACDL/DQ-1 CO2 measurements:

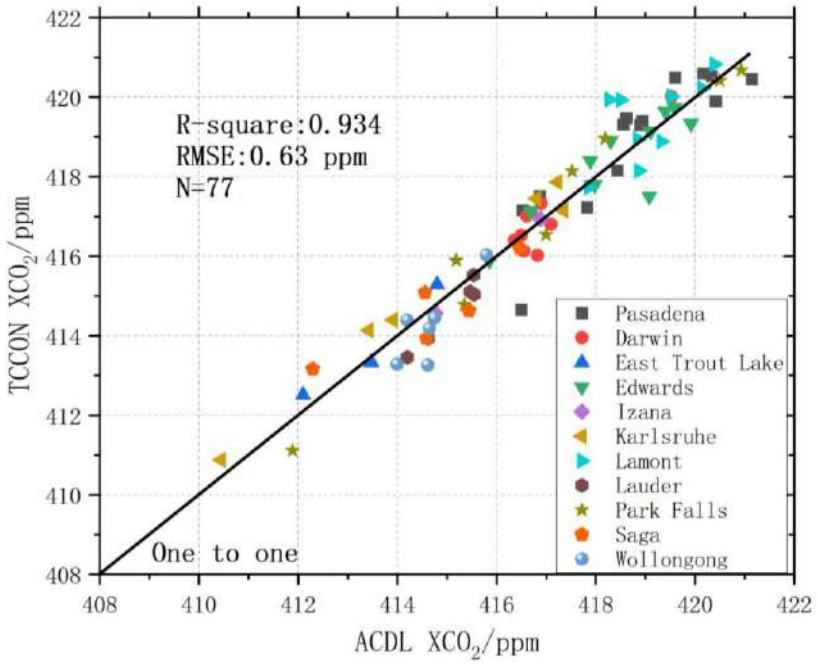
- Monthly coverage rate is 8-10 times higher than passive satellites

4. Carbon dioxide column measurements： validation

Sites	Lat/Lon	Instruments
Xianghe, Hebei	39.75N 116.96E	Bruker 125HRs
Hefei, Anhui	31.91N 117.17E	Bruker 125HRs
Shanghai	31.18N 121.59E	Bruker 125HRs
Tsukuba, Japan	36.051 N 140.121E	Bruker 125HRs

Additional sites:

Edwards, Park Falls, East Trout Lake, Karlsruhe etc.



ACDL/DQ-1 CO2 measurements:

- R square: 0.934;
- RMS: 0.63ppm.

5. Summary

1. **The first spaceborne lidar for simultaneously observation of CO2 and aerosol based on IPDA and HSRL techniques are introduced. The first in-orbit demonstration for IPDA and HSRL in space.**
2. **The procedures for the multi-channel calibration, data pre-processing, and retrieval algorithms are described. The following properties are calculated based on the data from ACDL/DQ-1:** Backscatter coefficient; Depolarization ratio; Extinction coefficient and Lidar ratio etc.
3. **Globally CO2 column concentrations are measured with active instruments (lidars) for the first time, to our knowledge.**
4. **Several measurement cases with different scenes (e.g., dust layers, pollutions, smoke, Hunga Tonga sulfate…) are presented with high temporal and spatial resolution. The observation capability of ACDL/DQ-1 is hence demonstrated.**
5. **For the further research, the calibrations and validations for the ACDL data products with collocated ground-based lidars and satellite active/passive instruments (EarthCARE…) are planned. Thus the international contributions to ACDL/DQ-1 are highly recommended and warmly welcome.**

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daiguangyao@ouc.edu.cn


Nirringrazzjak
Salamat Спасибо
Kiitos Welalin
Chokrane ありがとう Juspaxar
Obrigado
Kiitos Thank 고맙습니다
Raibh Maith Agat
Dankon You ありがとう
Mochchakkeram
Spasibo 谢谢 Kiitos
Merci Matondo
Obrigado
Kiitos Thank You Asante
Dank Je Raibh Maith Agat
고맙습니다 Kia Ora
Grazie Multumesc
Raibh Maith Agat

Thanks