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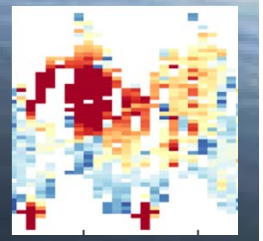
MAX-PLANCK-INSTITUT FÜR CHEMIE

NILU

MARIE CURIE ACTIONS

Current stratospheric activities in Aerosol_CCI around GOMOS



Christine Bingen[1], Charles Robert[1], Kerstin Stebel[2], Christoph Brühl[3], Jennifer Schallock[3], Filip Vanhellemont[1], Nina Mateshvili[1], Emmanuel Dekemper[1], Didier Fussen[1] and the Aerosol_CCI team

[1]Belgian Institute for Space Aeronomy (BIRA-IASB), Brussels, Belgium
[2]NILU, Norwegian Institute for Air Research, Kjeller, Norway
[3]Max-Plack Institute for Chemistry, Mainz, Germany

2nd SSiRC Workshop • 25-28.04.2016 • Potsdam, Germany

GOMOS onboard Envisat (2002-2012)

Global Monitoring of Ozone by Occultation of Stars

Main features:

- First atmospheric remote sounder based on the use of stellar occultation
- Dramatic increase of the measurement rate w.r.t. solar occultation.

➢ Reduced signal-to-noise ratio
➢ Signal altered by scintillation
➢ Data quality depends on the star/orbital parameters

- Spectral range: SPA: 250-675 nm; SPB1: 756-773 nm

Envisat at ESTEC, April 2000, courtesy ESA

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GOMOS aerosol retrieval

GOMOS operational algorithm: IPF

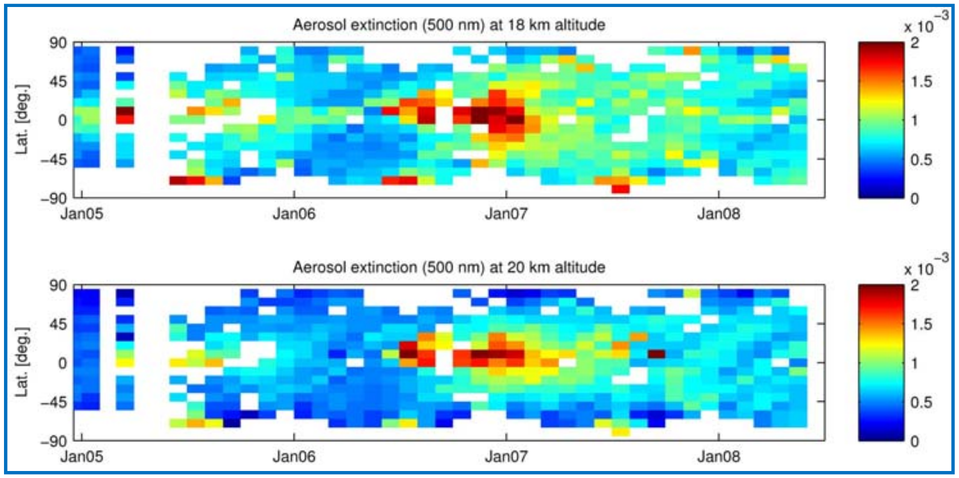
Aerosol retrieval:

- Extinction at 500 nm

But

- ➢ Very poor performances in terms of spectral dependence

Illustration:
Soufriere Hills eruption, May 2006



Vanhellemont et al., ACP, 2010

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GOMOS aerosol retrieval

Mag = 1.672; Temp = 10200K

Dashed: IPF
Solid: AerGom

400 nm, 500 nm, 600 nm

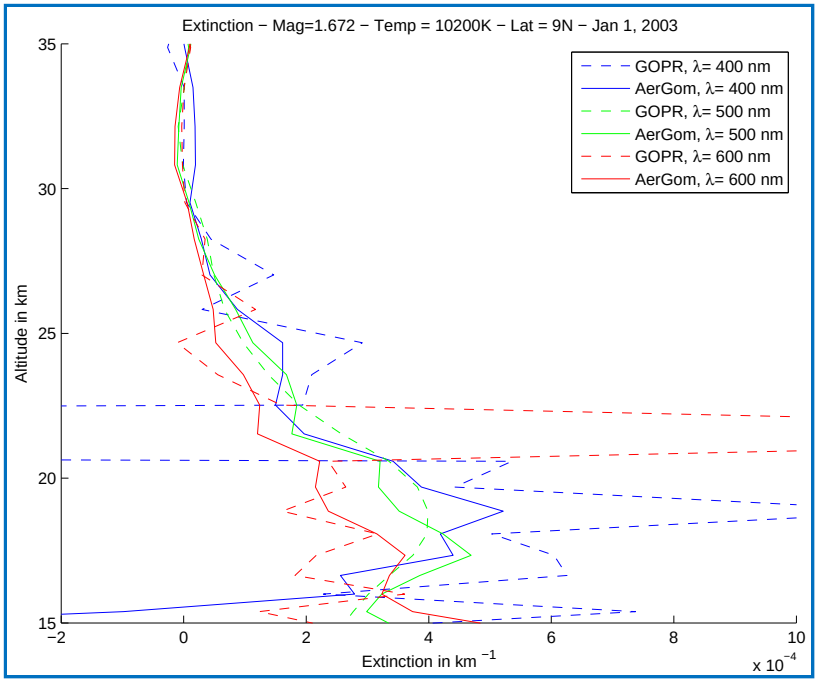
GOMOS operational algorithm: IPF

Aerosol retrieval:

- Extinction at 500 nm

But

➢ Very poor performances in terms of spectral dependence



⇒ *New algorithm: AerGom*

✓ Improved retrieval with focus on aerosol product
✓ Provides effective spectral dependence for the extinction

Algorithm description: Vanhellemont et al.: Atmos. Meas. Tech. Discuss., amt-2016-28, 2016
Validation: Robert et al.: Atmos. Meas. Tech. Discuss., amt-2016-27, 2016

GOMOS aerosol retrieval

IPF (ESA operational)	AerGOM
Spectral range:	
SPA: 250-675 nm	SPA+SPB1: 250-675 nm + 756-773 nm
Aerosol spectral dependence:	
Simple polynomial based on 1 measurement at fixed λ=500 nm	More physical parameterization based on 3 measurements at fixed λ
Retrieval methodology	
Combination of retrieval techniques: DOAS, Levenberg-Marquardt regularized for selected species	More coherent and homogeneous approach for gas + particles retrieval : Levenberg-Marquardt, all species regularized simultaneously
	Can take into account correlations between species !

Contribution to Aerosol_CCI

AerGom as GOMOS processor for Aerosol_CCI (ESA Climate Change Initiative)

CCI principle: Annual cycle of algorithm development/data processing/validation

Datasets for stratospheric aerosols:

- Development of time series covering the whole Envisat duration
- Gridded products (longitude, latitude, time)
- Radiative properties: Extinction, AOD, Angström coefficient;
- Uncertainty provided: for each quantity

New parameters (under processing):

- Microphysical properties:
  - Particle size distribution
  - Effective radius, Surface Area Density, Volume Density

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Aerosol_CCI overview: Popp et al.: Remote Sens., 2016, under revision

Contribution to Aerosol_CCI

Algorithm development

Main improvements

- Spectral inversion:
  - Bad performances found at 750 nm
  - GOMOS gas cross-section database showed outdated features
    - Lack of temperature dependence in some cases
    - Lack of data in some wavelength range

⇒ Update cross-sections using most recent data (O_3, NO_2, NO_3)
⇒ Solved the problem

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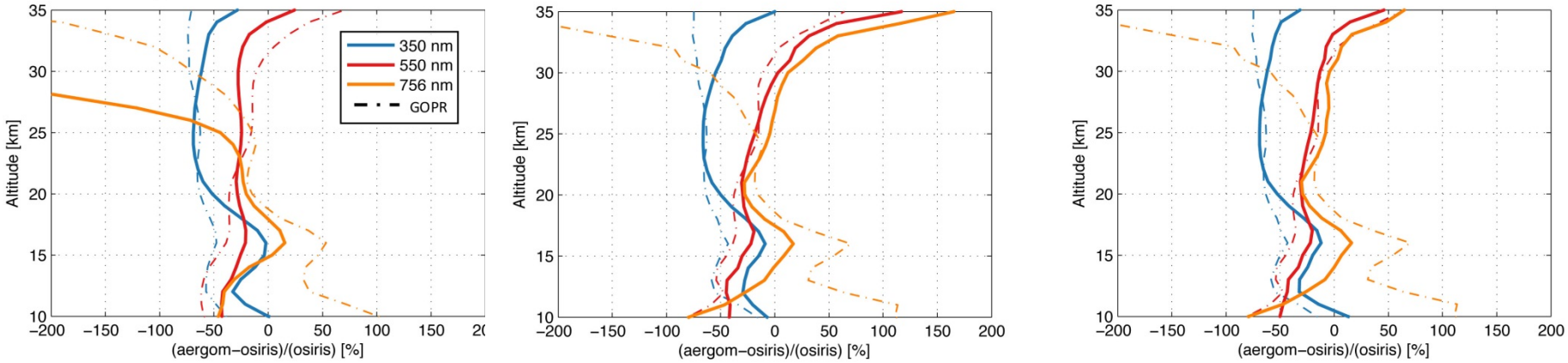
Aerosol_CCI: Algorithm development

Revision spectral inversion: Comparison with OSIRIS

Cross-sections from GOMOS database

Updated cross-sections degraded at the instrument resolution

Updated cross-sections; convolution during retrieval



Relative difference (OSIRIS, AerGOM) Extinction at 750 nm, 500 nm, 300 nm

OSIRIS extinction at 750 nm: nominal channel
at 500 nm, 300 nm: extrapolated using Angström coefficient

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Contribution to Aerosol_CCI

Production of Climate Data Records

Improvement of the climate data records: Extinction

- Improving time resolution:
  - Monthly means: widely used in the community

    … but monthly means don't reflect well the local aerosol load !
    => poor solution to constraint models !

  - 5-day means for detection of dynamical patterns, volcanic eruption

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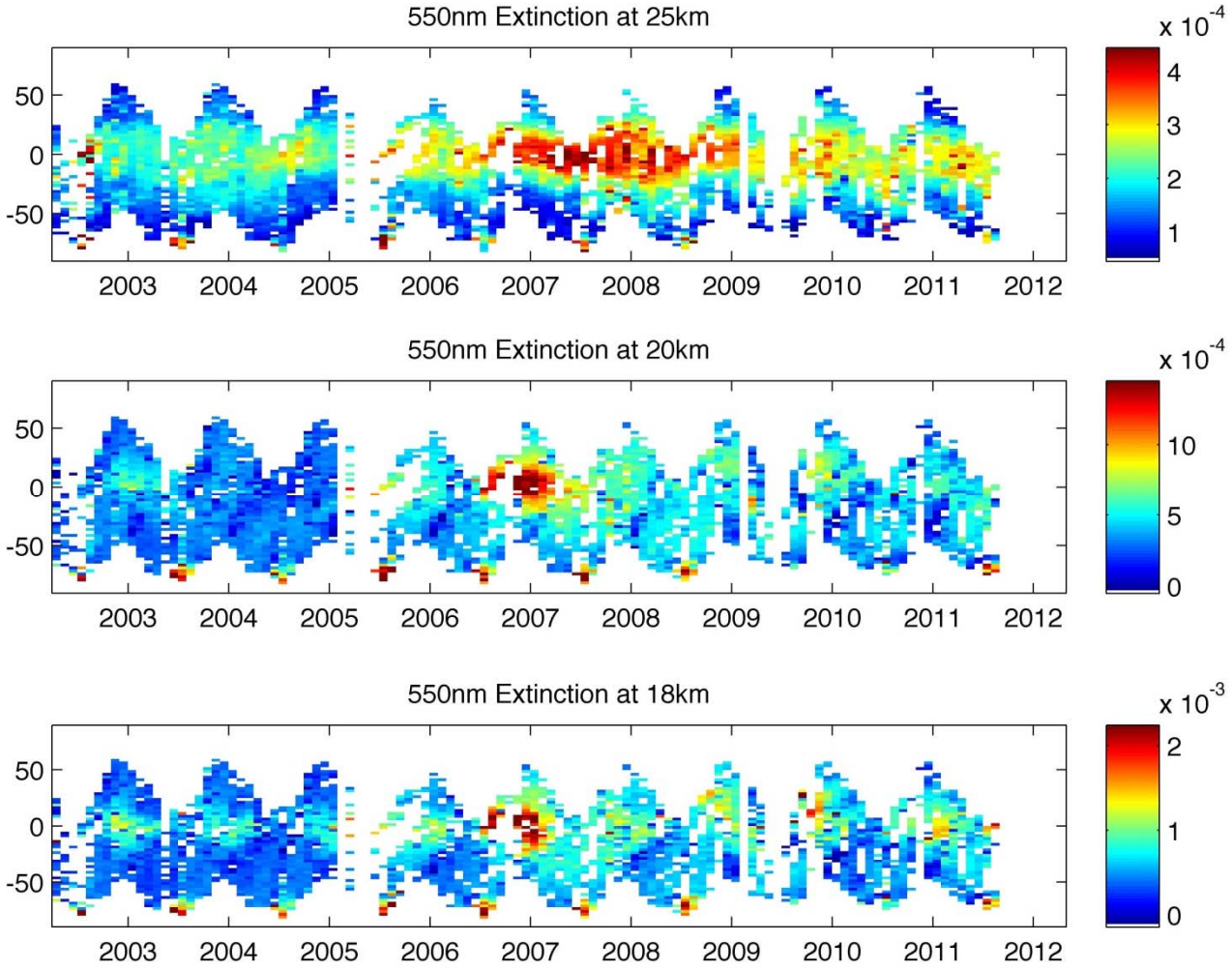
Aerosol_CCI: Datasets

Extinction as a function of time and latitude (V. 2.14)

- Monthly means
- 10° longitude bins
- 2.5° latitude bins

Selection criteria:

- Dark limb only
- Star temperature > 5000K
- Star magnitude < 2.6



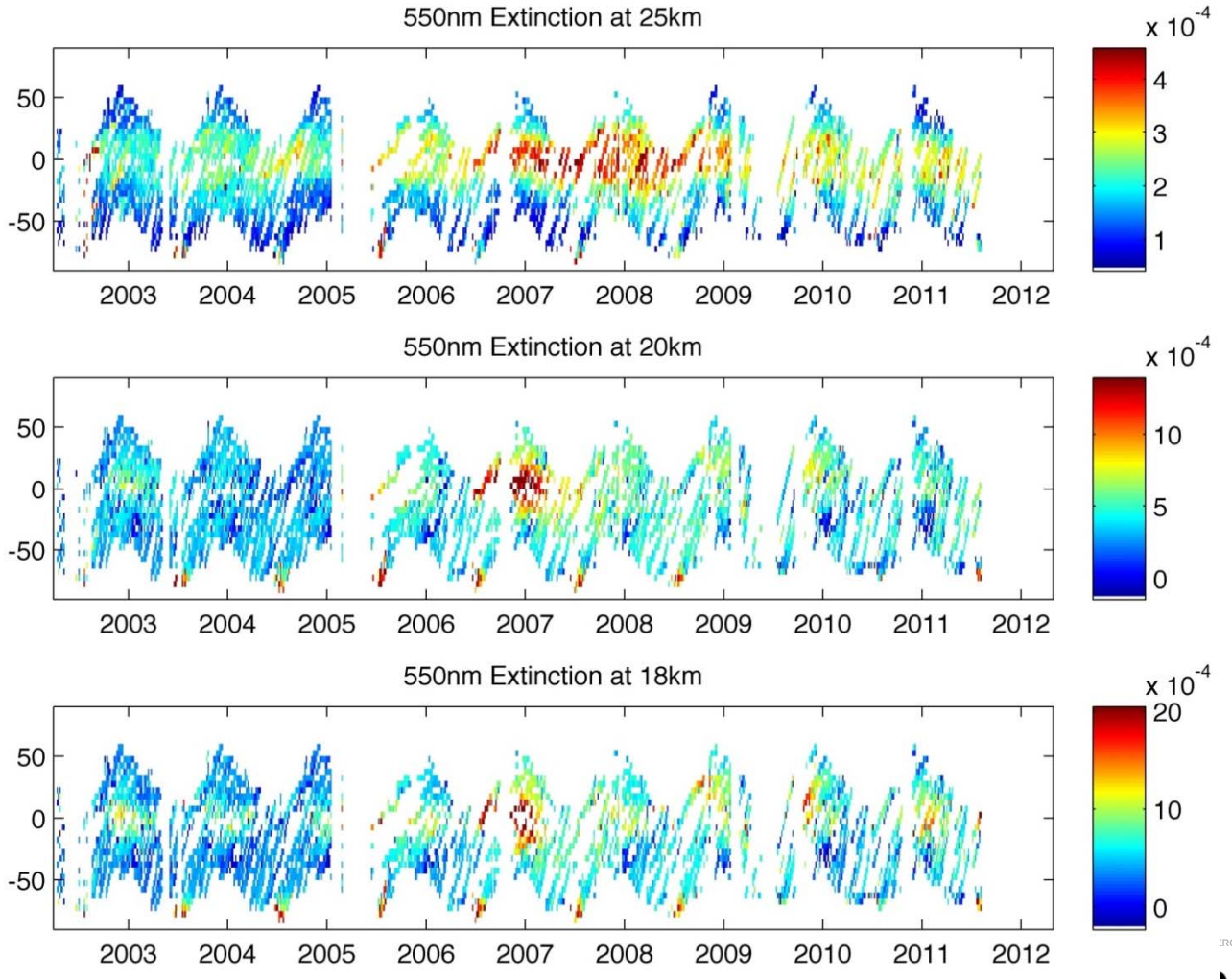
Aerosol_CCI: Datasets

Extinction as a function of time and latitude (V. 2.15)

- 5-day means
- 60° longitude bins
- 5° latitude bins

Selection criteria:

- Dark limb only
- Star temperature > 5000K
- Star magnitude < 2.6



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Aerosol_CCI: Datasets

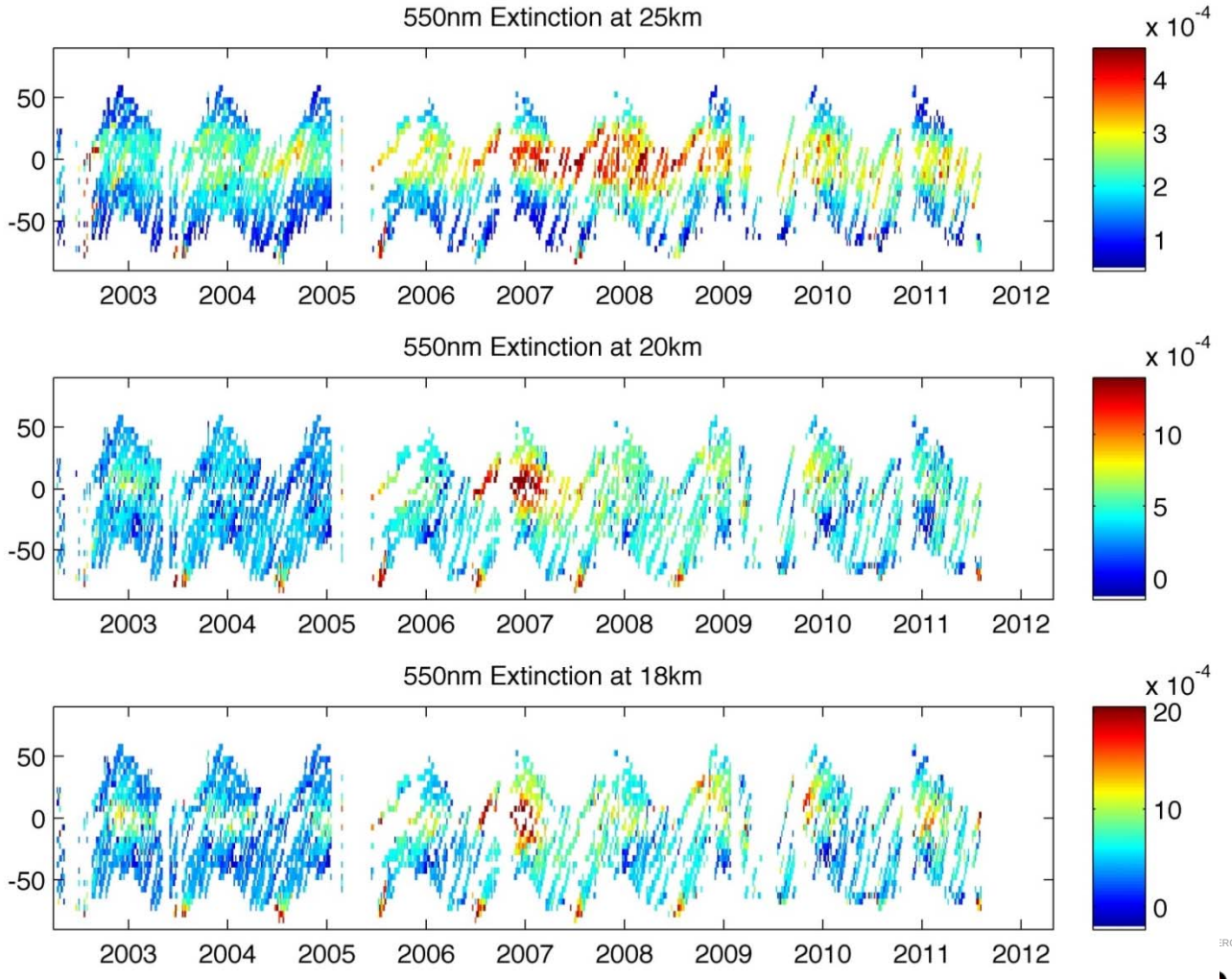
Extinction as a function of time and latitude (V. 2.15)

- 5-day means
- 60° longitude bins
- 5° latitude bins

Selection criteria:

- Dark limb only
- Star temperature > 5000K
- Star magnitude < 2.6

➢ Reduced coverage due to event selection



Contribution to Aerosol_CCI

Production of Climate Data Records

Improvement of the climate data records: Extinction

- Improving spatial coverage:
  - ➢ Issue: data quality depends on the star and occultation parameters
  - ✓ Improvement of the retrieval => possible smoothing of occultation selection criteria
  - ✓ Selection criteria on Solar Zenith Angle:

V. 2.15	→	V. 2.19
➢ Dark limb only		✓ SZA > 105°

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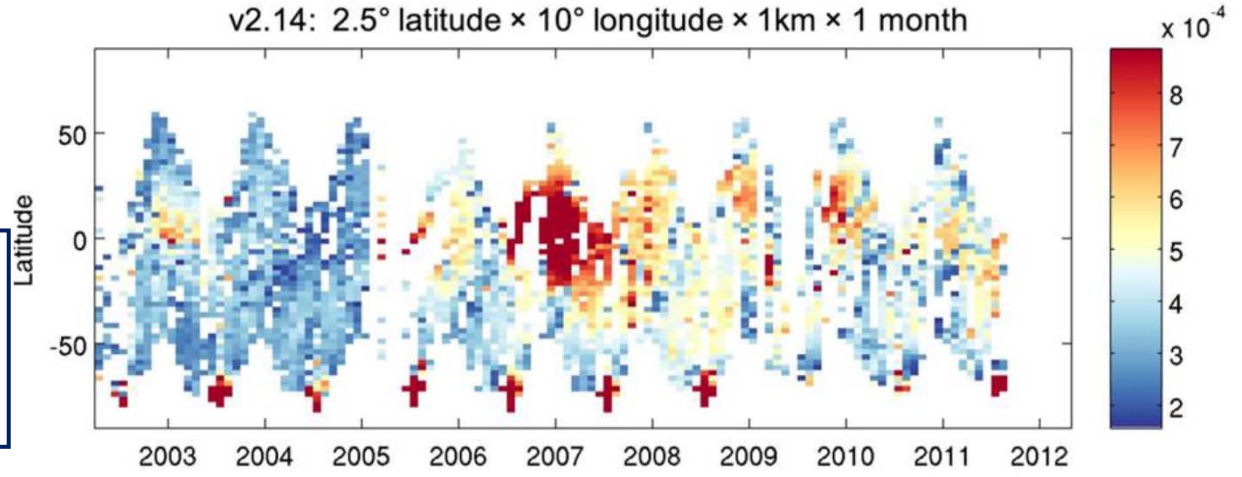
Aerosol_CCI: Datasets

Extinction as a function of time and latitude
V. 2.14 → V. 2.19

z=20 km

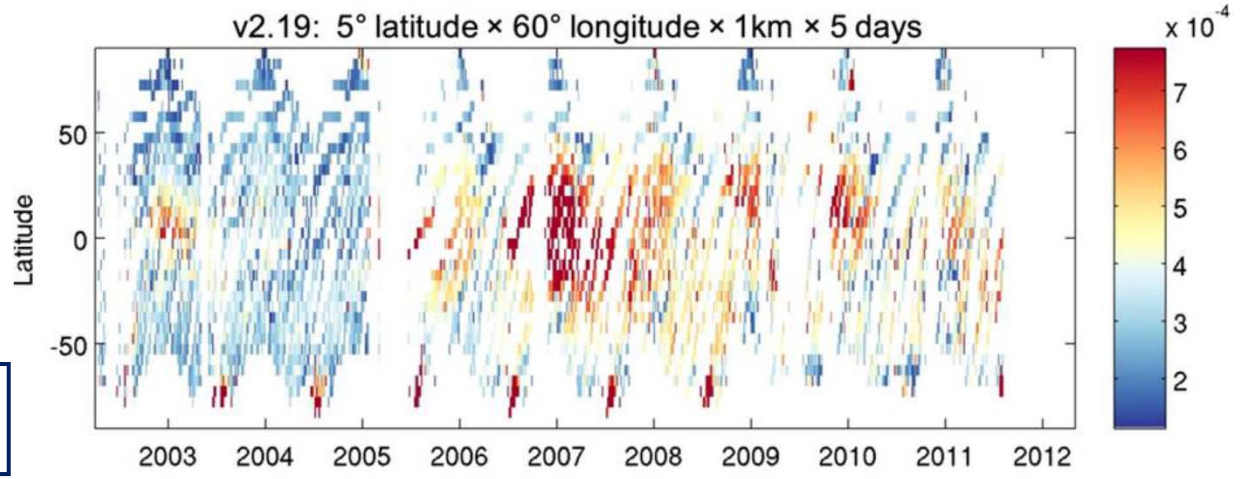
monthly

Dark limb occultations only



- ✓ Smoother star selection due to improved retrieval
- ✓ Volcanic signatures visible even for small and medium eruptions !

5-day
SZA > 105°



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Aerosol_CCI: Application to climate modeling

Volcanic eruptions inventory

Objectives :

- Better understanding of the contribution of volcanism in stratospheric aerosol burden
- Currently:
  - ➢ Estimate of aerosol load from large eruptions is not able to explain the observed radiative forcing (underestimated)

=> New inventory of small, medium and large eruptions

- ✓ Use of GOMOS time series as complementary data to MIPAS to estimate the contrbution of small/medium eruptions

Brühl et al., JGR, 2015; Solomon et al., Science, 2011

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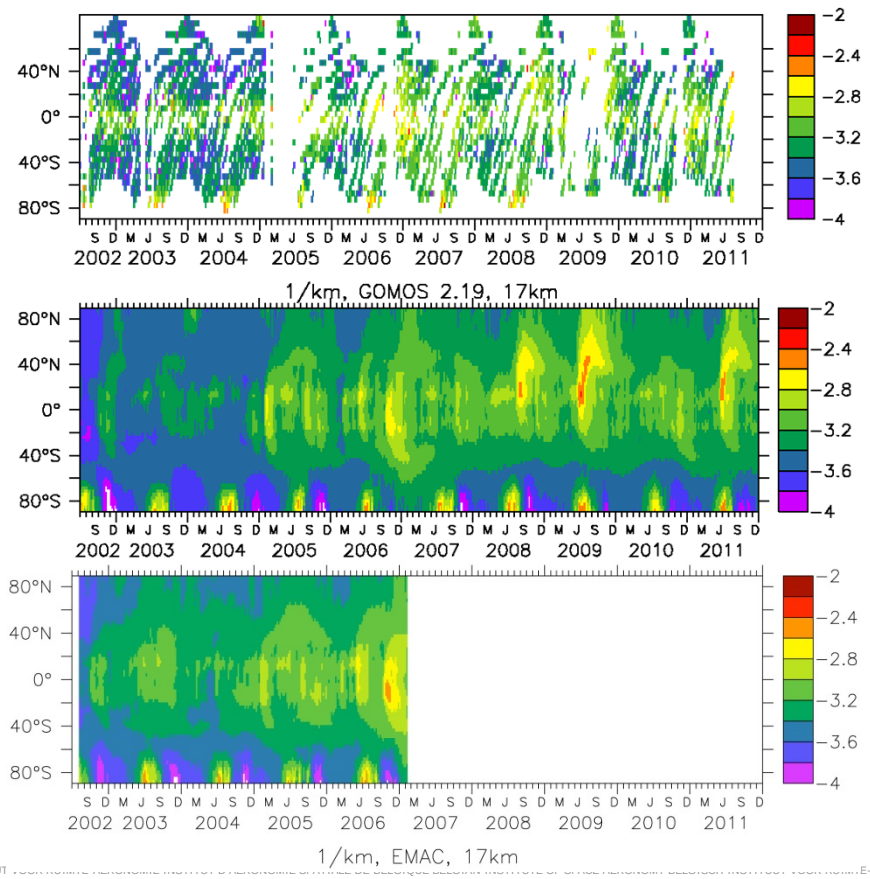
Aerosol_CCI: Application to climate modeling

Extinction at 17 km :

GOMOS - Aerosol_CCI (V. 2.19) →

EMAC, Brühl, JGR, 2015 →

EMAC, Update →



❖ See Talk C. Brühl (Wednesday, 12:30)

Aerosol_CCI: Validation using NDACC LIDAR

Location	First	Last	# M	λ [nm]	Parameter	Comments
Ny-Ålesund 78.9°N, 11.9°E Spitsbergen, AWI, Germany	11-2002	03-2012	31	532	backscatter ratio temperature, pressure extinction to backscatter	**353 nm** depolarization standard deviation
Garmisch 47.5°N, 11.1°E Zugspitze, IMK, Germany	01-2003	11-2010	79	532	particle backscatter coefficient extinction to backscatter	error counting statistics
OHP 1 43.9°N,5.7°E CNRS, France	04-2002	03-2012	20	532	extinction coefficient scattering ratio	backscatter coefficient variances
OHP 2 43.9°N,5.7°E LATMOS-IPSL-, France	04-2007	04-2012	52	532	backscatter coefficient temperature, pressure	depolarization
Boulder *39.9 °N, 105.26° W* *CO, USA; NOAA*	04-2002	06-2009	83	532	backscatter ratio log10 density	error
Mauna Loa 19.5°N, 155.6°W Hawaii, USA, NASA; NOAA	02-2004	04-2012	121	532	backscatter ratio log10 of density	**353 nm**, aerosol backscatter coefficient error, range resolution pressure, density
Lauder 45.0°S, 169.7°E New Zealand, MRI, Japan	04-2002	07-2008	73	532	backscatter ratio Rayleigh backscatter	standard error + 3 M ozone DIAL data (355 nm)
Dumont d'Urville 66.7°S, 140.0°E Antarctica LATMOS-IPSL-UPMC-UVSQ, FRANCE - ISAC CNR Italy	06-2006	04-2012	44	532	backscatter ratio temperature, pressure	Depolarization, backscatter coefficient (molecular?)
McMurdo Station 77.85°S, 166.67°E	04-2002	09-2010	30	532	aerosol backscattering pressure, temperature	depolarization

Stratospheric aerosol from NDACC backscatter LIDAR @ 532 nm

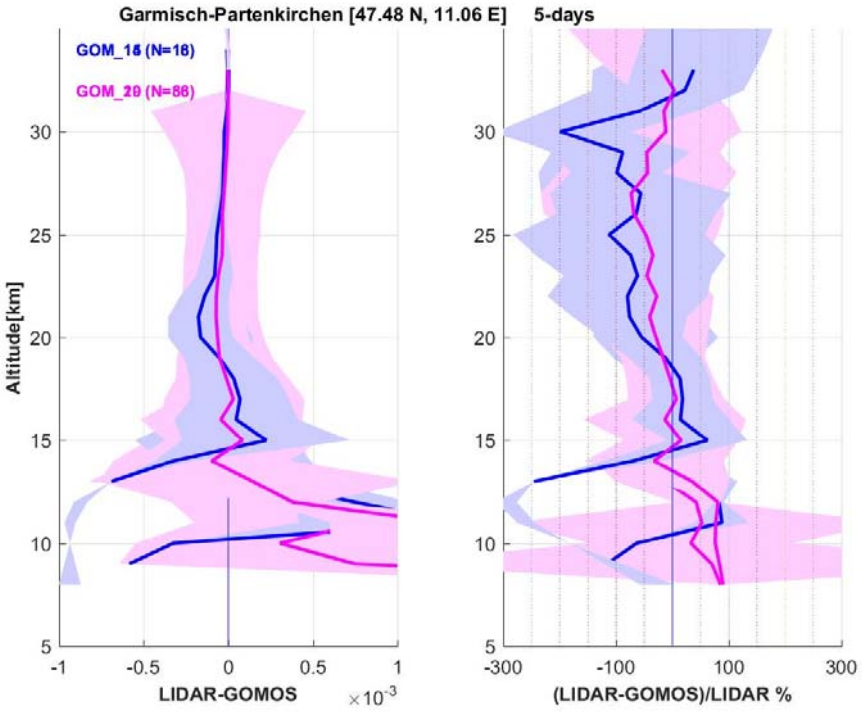
Extinction-to-backscatter ratio (LR) unknown

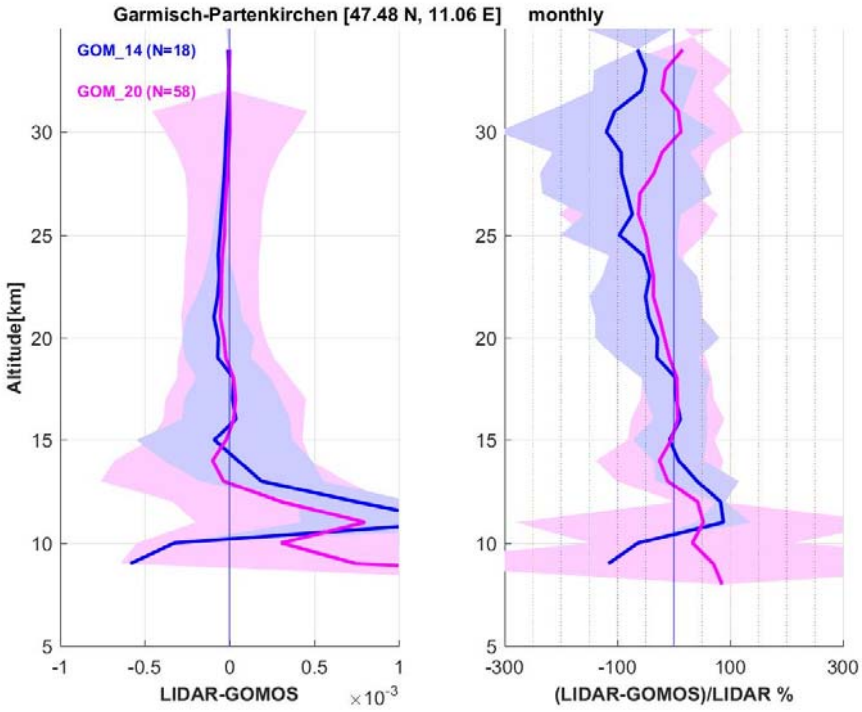
LIDAR @ Garmisch Partenkirchen, IMK-IFU, Germany (courtesy T. Trickl and colleagues)

-> Information about LR included

LIDAR @ Garmisch Partenkirchen, IMK-IFU, Germany (courtesy T. Trickl and colleagues)

Aerosol_CCI: Validation using NDACC LIDAR





Colocation criteria:

5 days, 3° latitude, 30° longitude

monthly data, 5° latitude, 20° longitude

Conclusions and perspectives

- AerGom provides effective spectral dependence to extinction in the UV-VIS range
- AerGom is the stratospheric aerosol algorithm used in Aerosol_CCI. Time series are produced, e.g. for climate modeling applications
- Algorithm development during led to several improvements of AerGOM
  - ✓ Quality of extinction at 750 nm,
  - ✓ High temporal resolution
    - ⇒ 5-day time window much better suited for climate modeling applications!
    - ⇒ Volcanic signatures are visible, even for small/medium eruptions
    - ⇒ Use for inventory of volcanic eruptions
  - ✓ Better coverage
- Validation: inherent problem with lack of LR, use climatological values, potentially use of auxiliary data (e.g. temperature for PSCs, size distribution,…)
- In preparation: Time series of particle size distribution

Vielen Dank für ihre Aufmerksamkeit…!

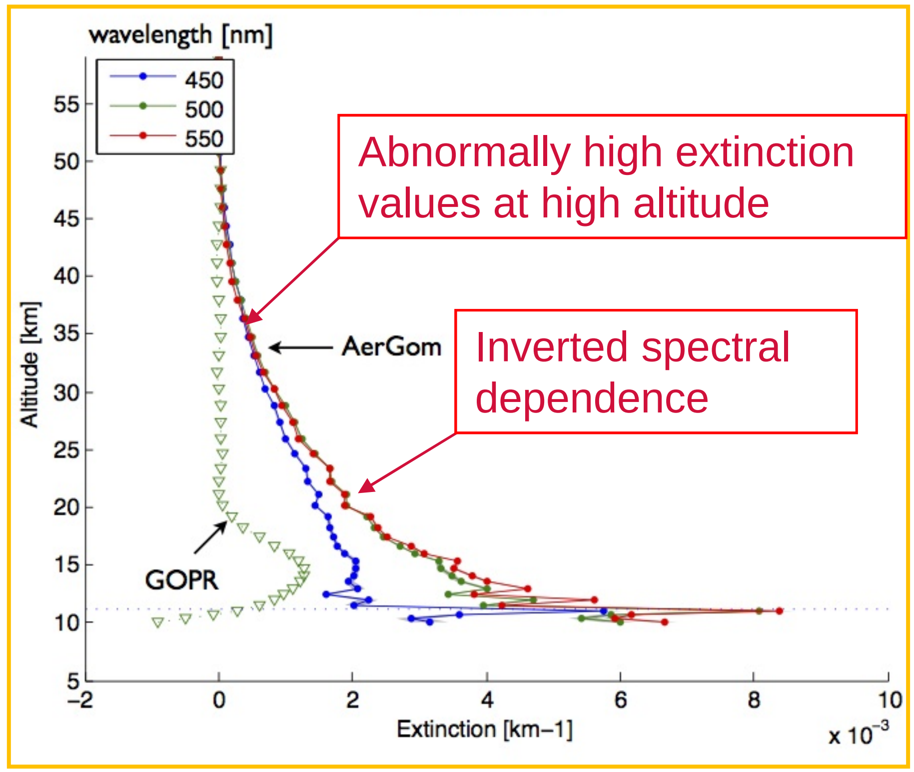
ADDITIONAL SLIDES

Contribution to Aerosol_CCI

Algorithm development

Main improvements

- A priori:
  - Problem of anomalous profile found

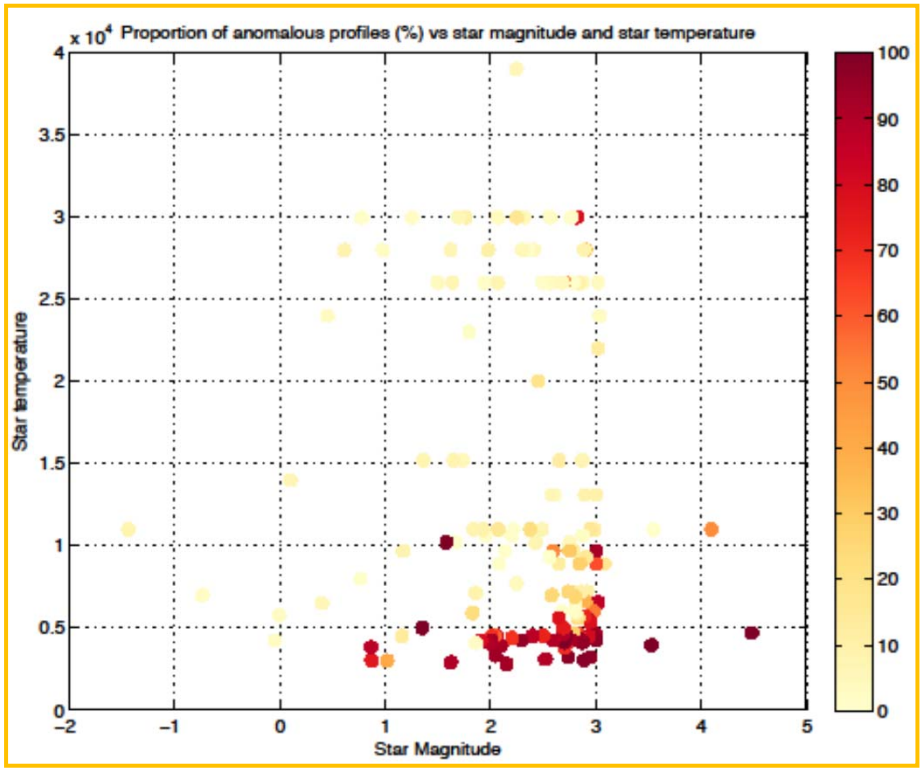


Contribution to Aerosol_CCI

Algorithm development

Main improvements

- A priori:
  - Problem of anomalous profile found
  - Mainly for dim cold stars
    (stars with poor information content)



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Contribution to Aerosol_CCI

Algorithm development

Main improvements

- A priori:
  - Problem of anomalous profile found
  - Mainly for dim cold stars
    (stars with poor information content)

  - Linked to the choice of the a priori for the spatial retrieval:
    - Solution at altitude z_i used a a priori for the solution at z_{i+1}
      Rem: retrieval from top-of-the-atmosphere (very weak signal) toward lower altitudes

⇒ Change of a priori = vertical profile close to the solution
- ✓ Ensures a realistic solution at altitudes where too limited information content
- ✓ Solves the problem

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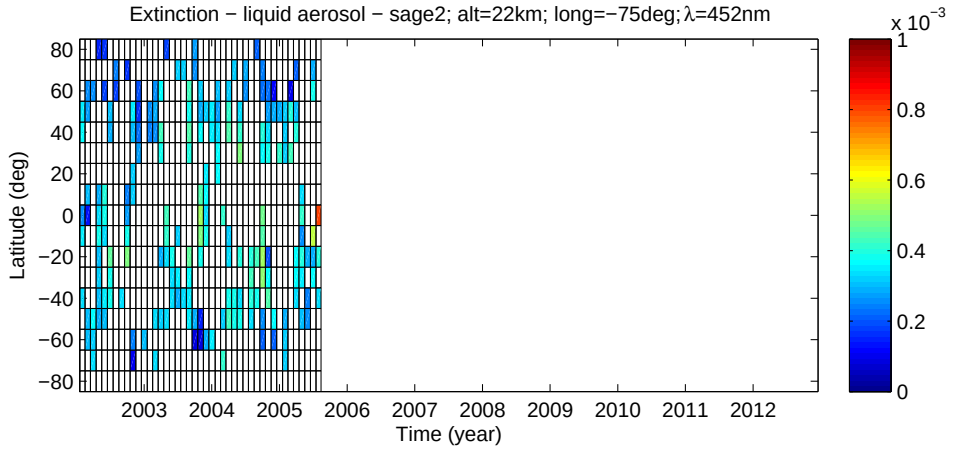
Comparison SAGE II - GOMOS

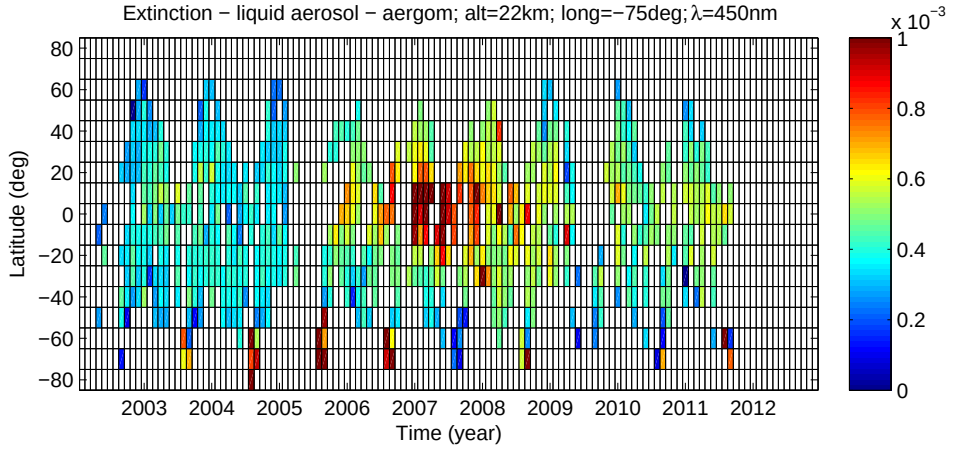
Extinction at 450 nm
V. 2.14

SAGE II

z = 22 km
Monthly means
Long = 75° W

GOMOS





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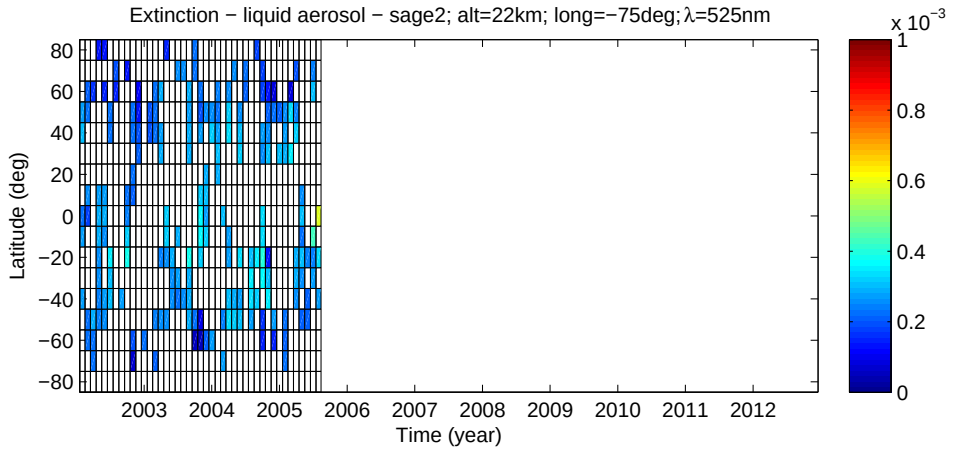
Comparison SAGE II - GOMOS

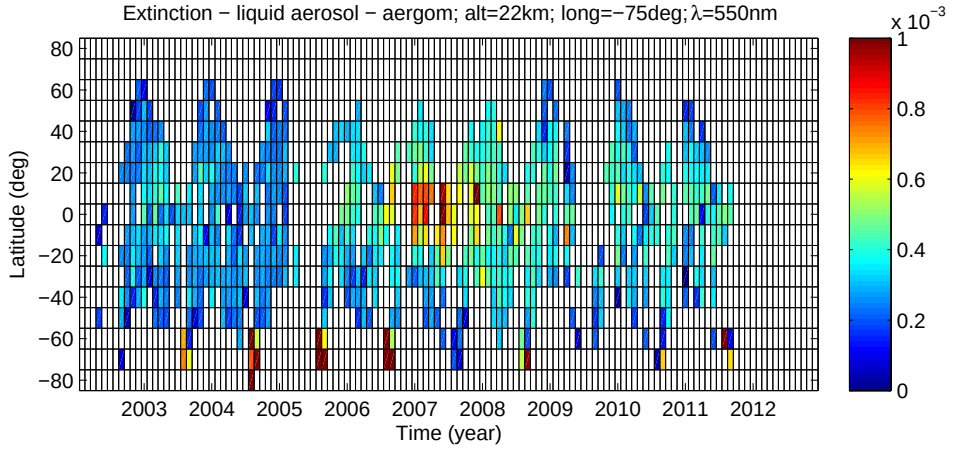
Extinction at 525 nm
V. 2.14

SAGE II

z = 22 km
Monthly means
Long = 75° W

GOMOS





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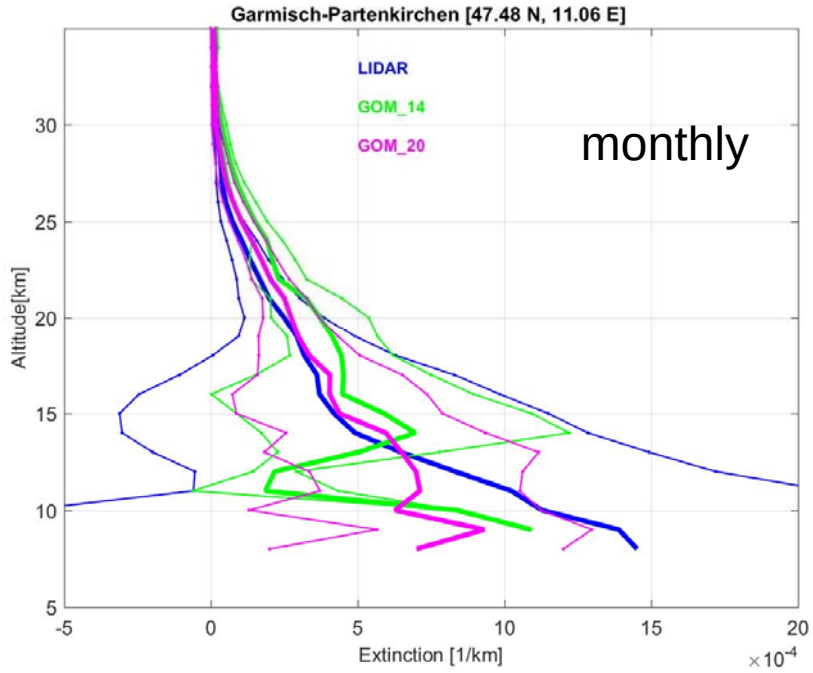
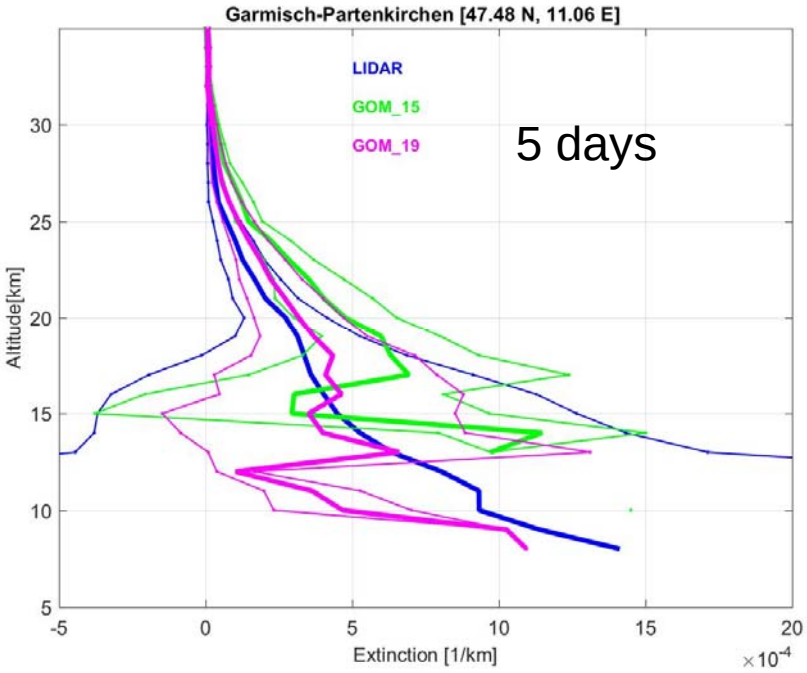
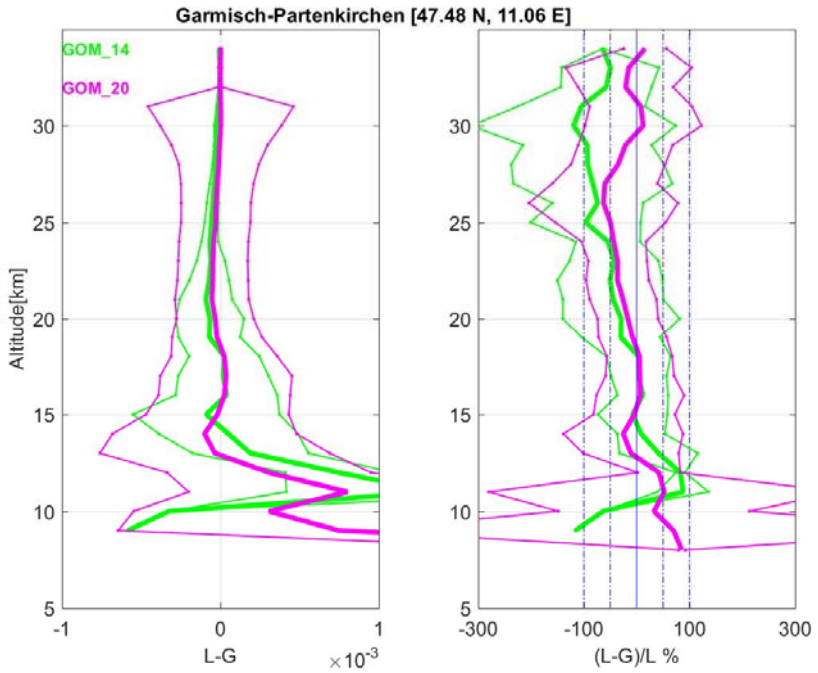
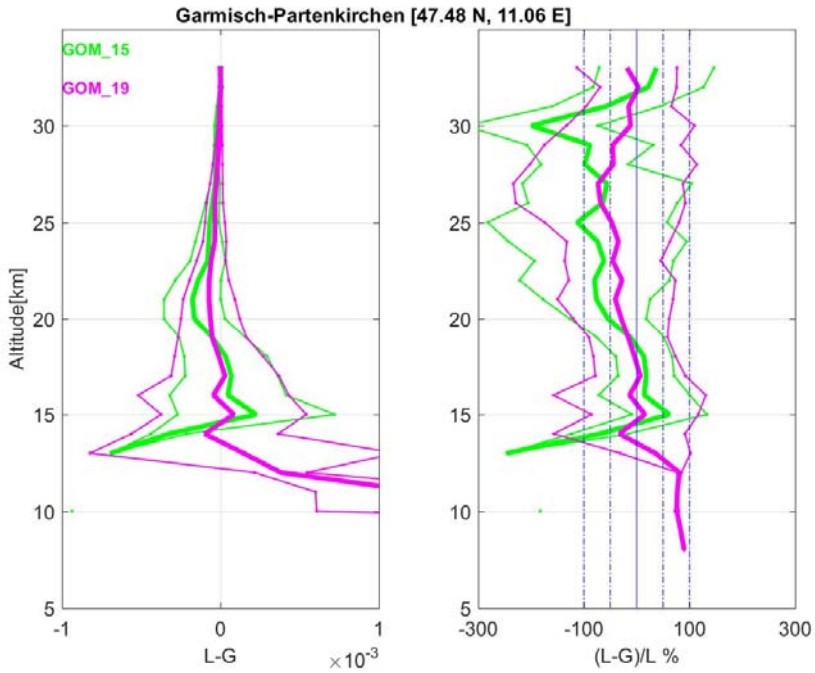
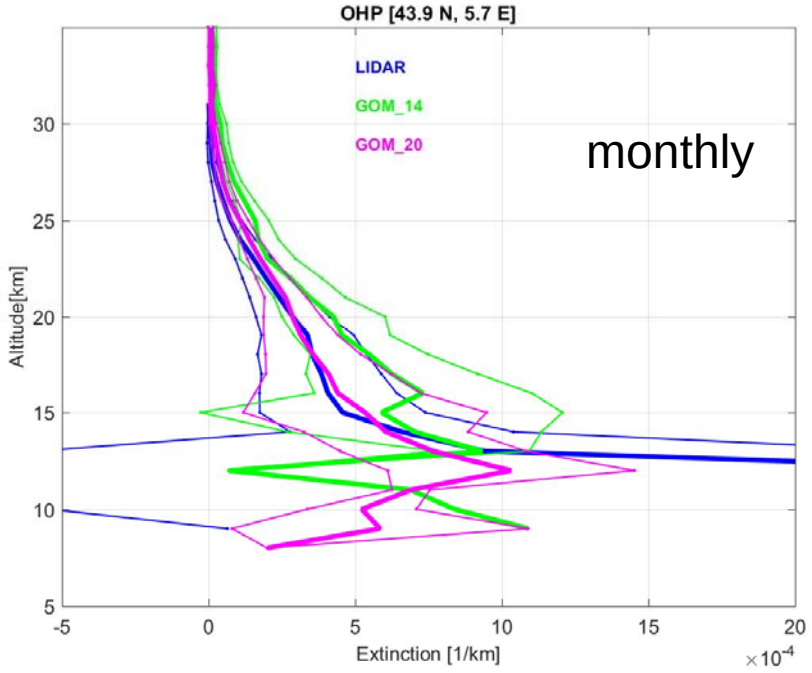
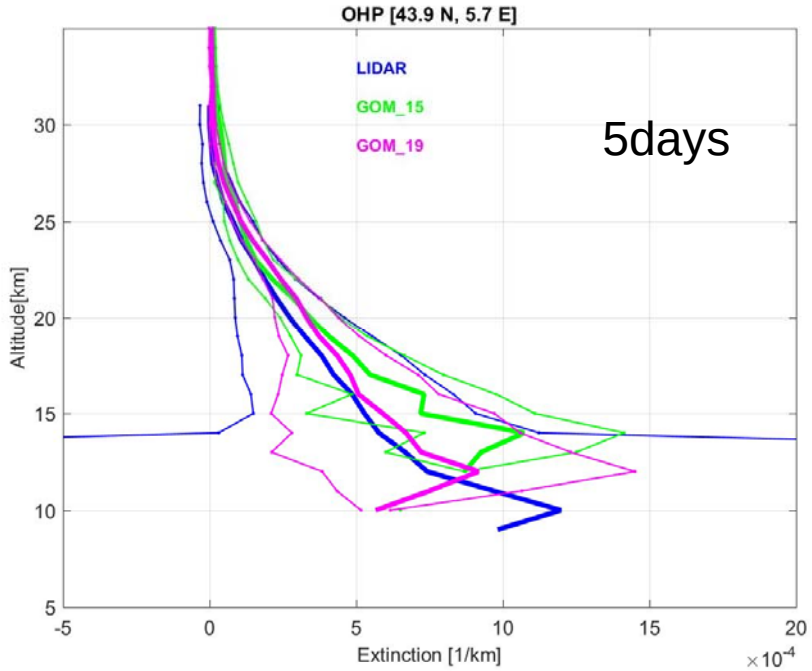

Garmisch-Partenkirchen [47.48 N, 11.06 E]
LIDAR
GOM_14
GOM_20
monthly
Altitude[km]
Extinction [1/km]
×10^-4

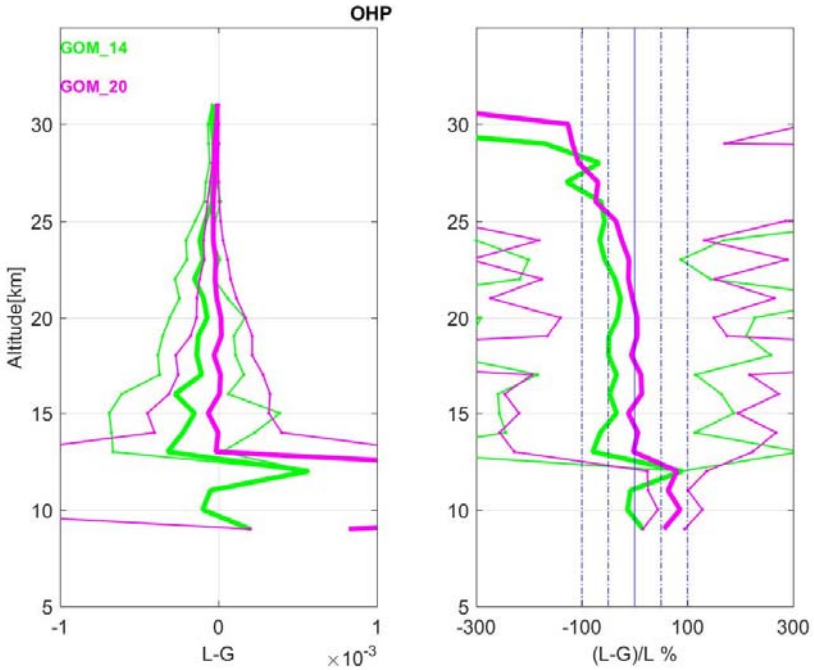

Garmisch-Partenkirchen [47.48 N, 11.06 E]
LIDAR
GOM_15
GOM_19
5 days
Altitude[km]
Extinction [1/km]
×10^-4

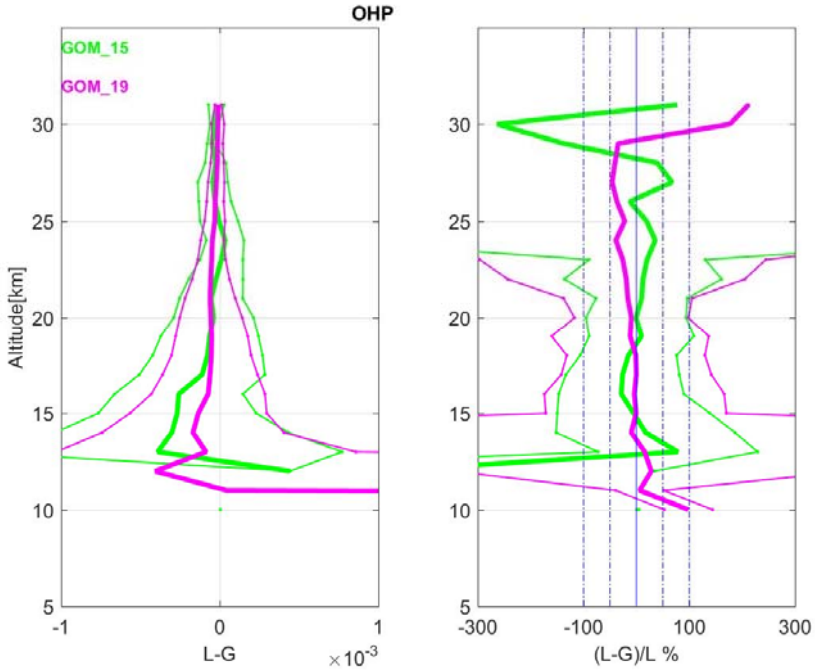

Garmisch-Partenkirchen [47.48 N, 11.06 E]
GOM_14
GOM_20
Altitude[km]
L-G
×10^-3
(L-G)/L %

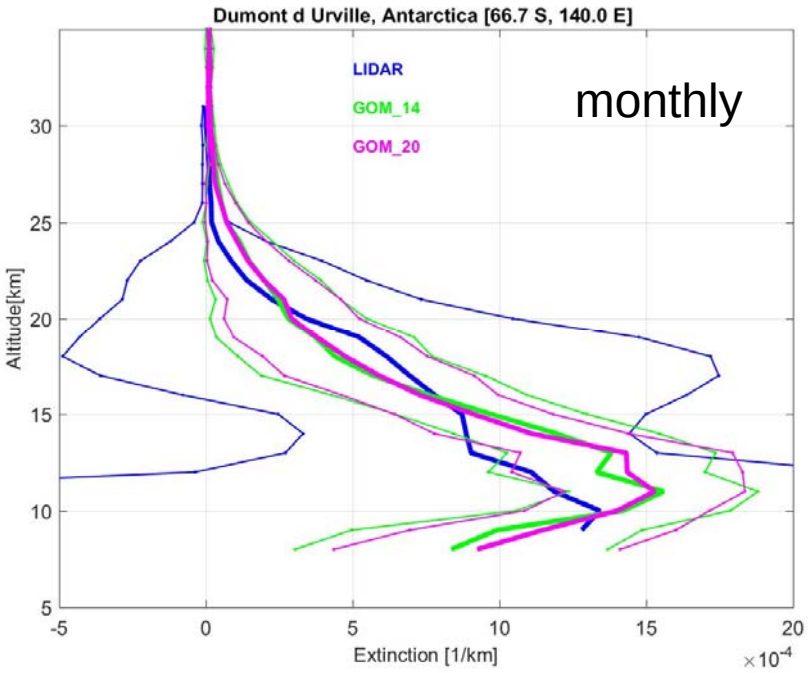

Garmisch-Partenkirchen [47.48 N, 11.06 E]
GOM_15
GOM_19
Altitude[km]
L-G
×10^-3
(L-G)/L %

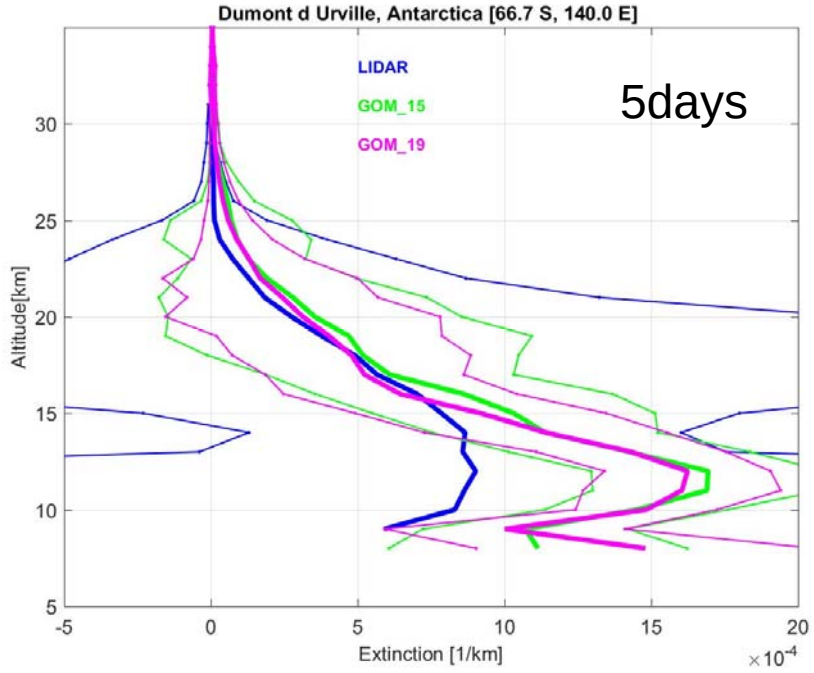

OHP [43.9 N, 5.7 E]
LIDAR
GOM_14
GOM_20
monthly
Altitude[km]
Extinction [1/km]
×10^-4

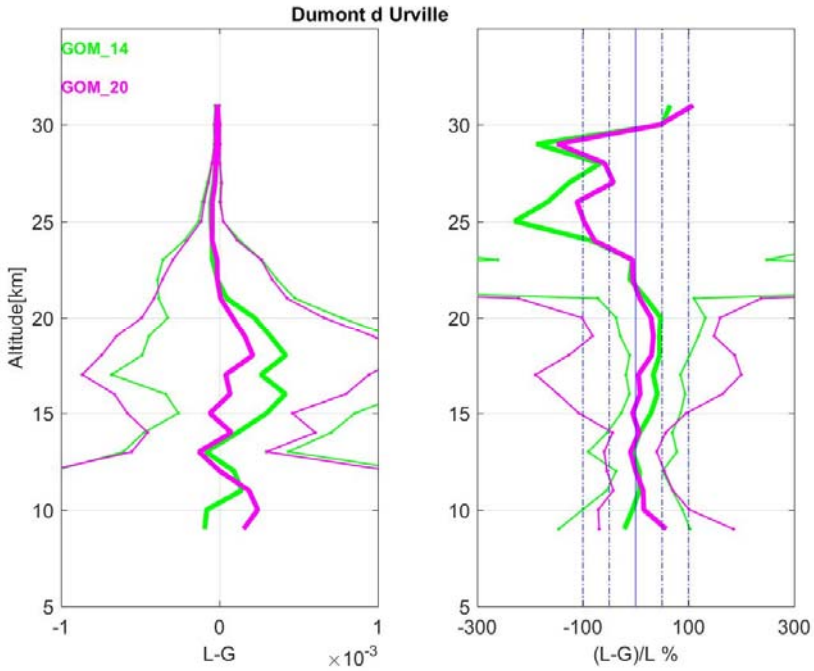

OHP [43.9 N, 5.7 E]
LIDAR
GOM_15
GOM_19
5days
Altitude[km]
Extinction [1/km]
×10^-4

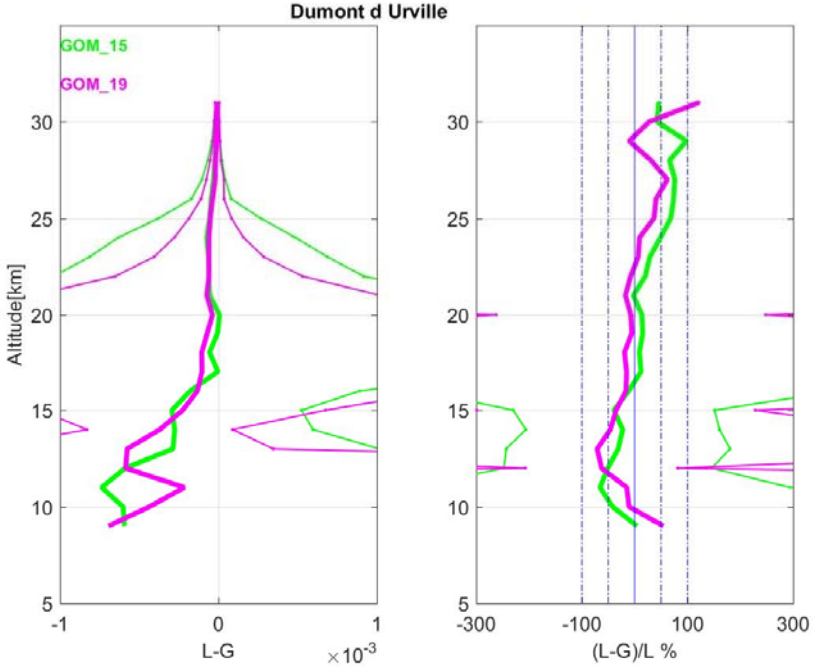

OHP
GOM_14
GOM_20
Altitude[km]
L-G
×10^-3
(L-G)/L %


OHP
GOM_15
GOM_19
Altitude[km]
L-G
×10^-3
(L-G)/L %


Dumont d Urville, Antarctica [66.7 S, 140.0 E]
LIDAR
GOM_14
GOM_20
monthly
Altitude[km]
Extinction [1/km]
×10^-4


Dumont d Urville, Antarctica [66.7 S, 140.0 E]
LIDAR
GOM_15
GOM_19
5days
Altitude[km]
Extinction [1/km]
×10^-4

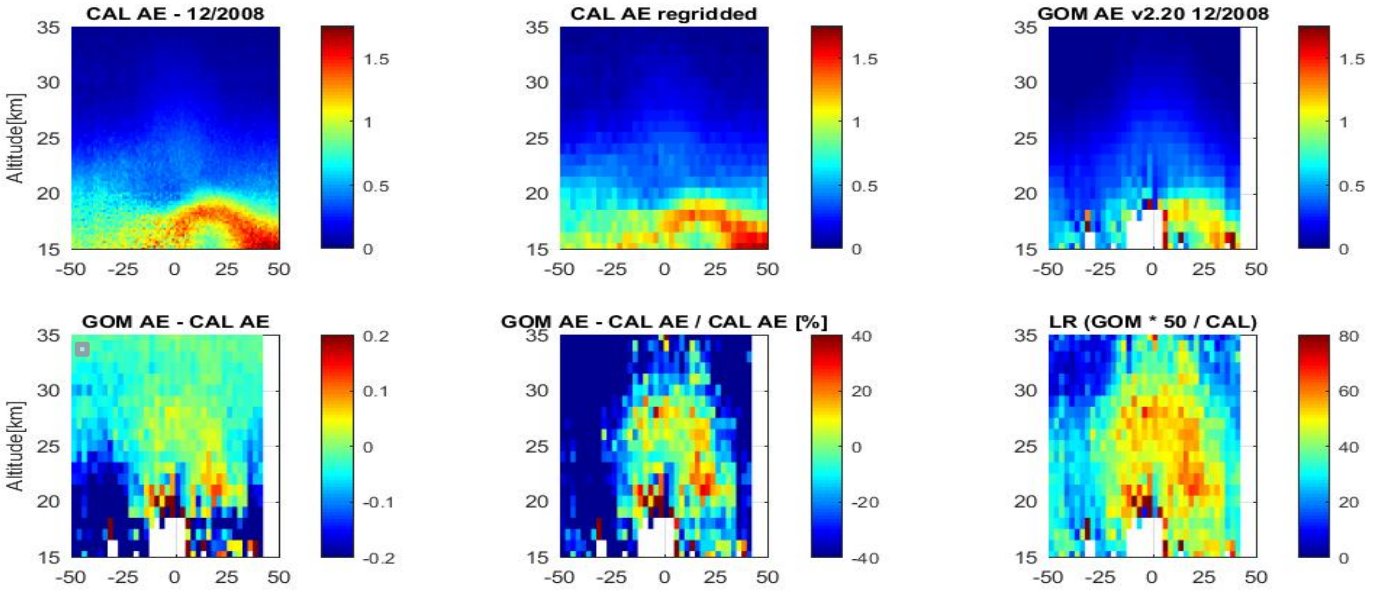

Dumont d Urville
GOM_14
GOM_20
Altitude[km]
L-G
×10^-3
(L-G)/L %


Dumont d Urville
GOM_15
GOM_19
Altitude[km]
L-G
×10^-3
(L-G)/L %

Initial test against CALIOP using a constant LR = 50 sr

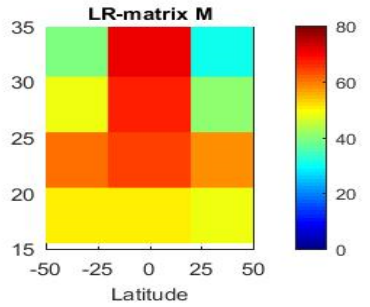
Need for independent information on extinction-to-backscatter

Aerosol_CCI: Validation using CALIOP



CALIOP data courtesy to J-P. Vernier

CALIOP zonal extinction in full resolution provided by J.-P. Vernier	CALIOP zonal extinction reduced resolution to GOMOS resolution	GOMOS zonal extinction v2.20
Absolute difference between GOMOS and CALIOP zonal extinction	Relative difference between GOMOS and CALIOP zonal extinction [%]	Ratio between GOMOS zonal extinction and CALIOP zonal backscatter ratio
	k_a (sr) / 50°S - 20°S / 20°S -20°N / 20°N -50°N 15-20 km: 51 / 50 / 48 20-25 km: 61 / 64 / 58 25-30 km: 48 / 67 / 41 30-35 km: 39 / 70 / 30	LR based on operational GOMOS data and CALIOP (*Vernier et al., 2011*).



Size distribution retrieval

Main features

- Sectional size distribution
- Separate retrieval for ice particles, PSC and liquid particles
  - Ice particles:
    - In latitude [30S, 30N]
    - Temperature < 200K
    - Complex refractive index: Warren, Appl. Opt., 1984
  - Liquid aerosols, PSC:
    - Composition (binary, ternary solution H_2O, H_2SO_4, HNO_3) depends on temperature; following Carslaw et al., Rev. Geophys., 1997
    - Refractive index: Krieger et al., Appl. Opt., 2000
- Calculation of the moments of the size distribution
- Derivation of bulk properties: Effective radius, Surface Area Density, Volume density

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