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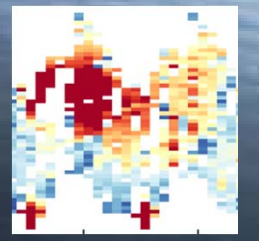
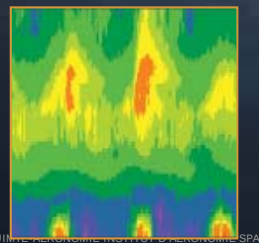
NILU

MARIE CURIE ACTIONS

Stratospheric Aerosol Data Record for the ESA Climate Change Initiative (CCI), and beyond





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

[1]Royal 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

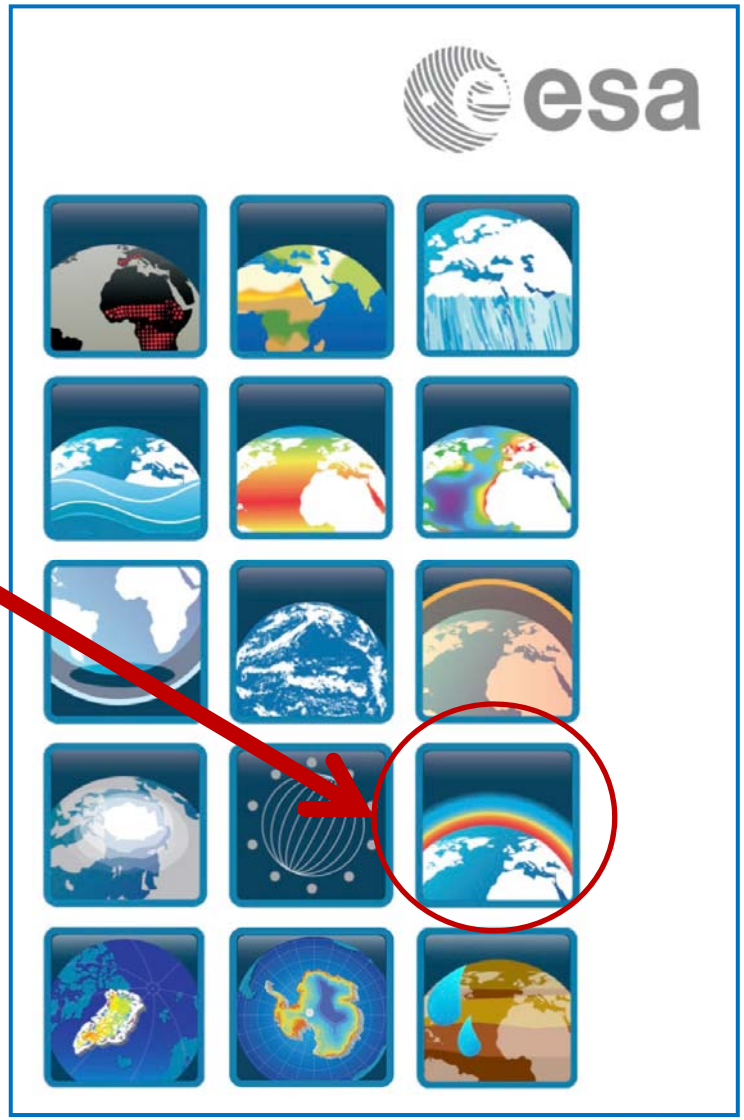
Chapman Conference • 18-23.03.2018 • Tenerife, Spain

ESA Climate Change Initiative (CCI)

- Main objective:

  Development of Climate Data Records from ESA satellite experiments for Essential Climate Variables

- 12 projects, including Aerosol_cci
- Cover troposphere+stratosphere
- 2 phases of 3 years



ESA Climate Change Initiative (CCI)

- Principle:
  - Important involvement of the climate modelling community (user requirements, validation, product assessment)
    - Stratospheric aerosols: SPARC: MPI-Chem, Mainz, Germany
  - Based on ESA satellite experiments
    - Stratospheric aerosols: GOMOS

GOMOS (Global Ozone Monitoring by Occultation of Stars)

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- Main features:
  - 2002-2012; flew on board ENVISAT
  - Spectral range: SPA: 250-675 nm;
    SPB1: 756-773 nm
    (+ SPB2: 926-952 nm)
  - Measurement principle: stellar occultation
  - Dramatic increase of the measurement rate w.r.t. solar occultation.

Envisat at ESTEC, April 2000, courtesy ESA

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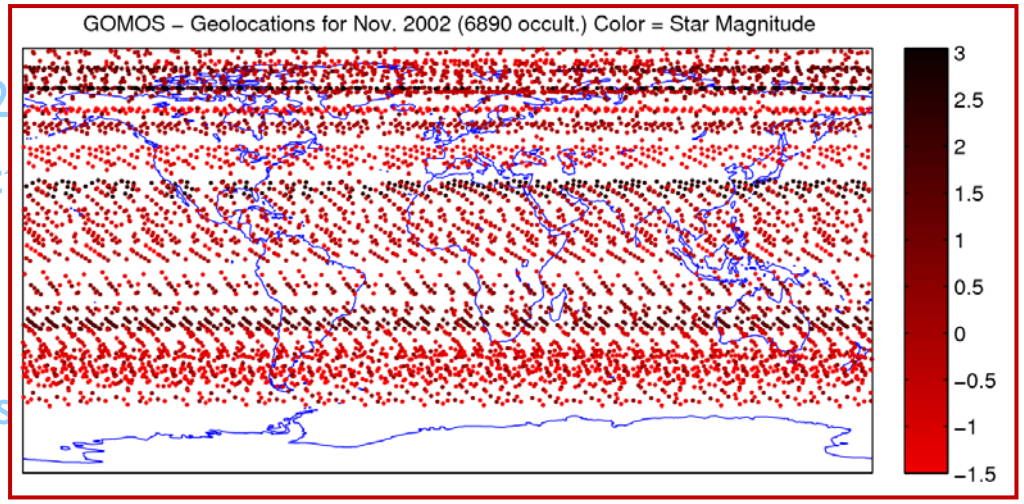
GOMOS (Global Ozone Monitoring by Occultation of Stars)

- **Main features:**
  - 2002
  - Spec
  - Meas



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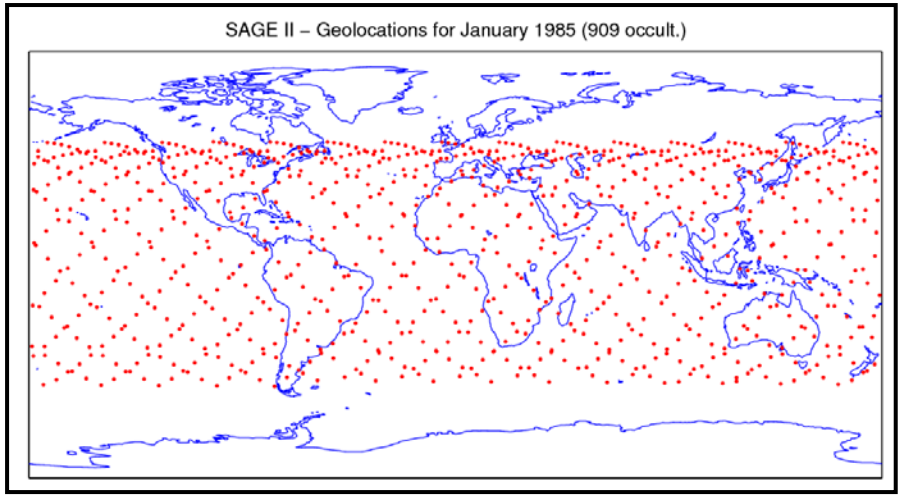

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    SPB1: 756-773 nm
  - Measurement principle: stellar occultation
  - Dramatic increase of the measurement rate w.r.t. solar occultation.

➢ *Reduced signal-to-noise ratio*

➢ *Signal altered by scintillation*

➢ *Data quality depends on the star/orbital parameters*

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GOMOS (Global Ozone Monitoring by Occultation of Stars)

BIRA·IASB

- **Dependence on the star characteristics:**
  - **Magnitude**: bright vs. dim star → impact on the signal-to-noise ratio
  - **Temperature**: Cf. Emission of a black body:

GOMOS (Global Ozone Monitoring by Occultation of Stars)

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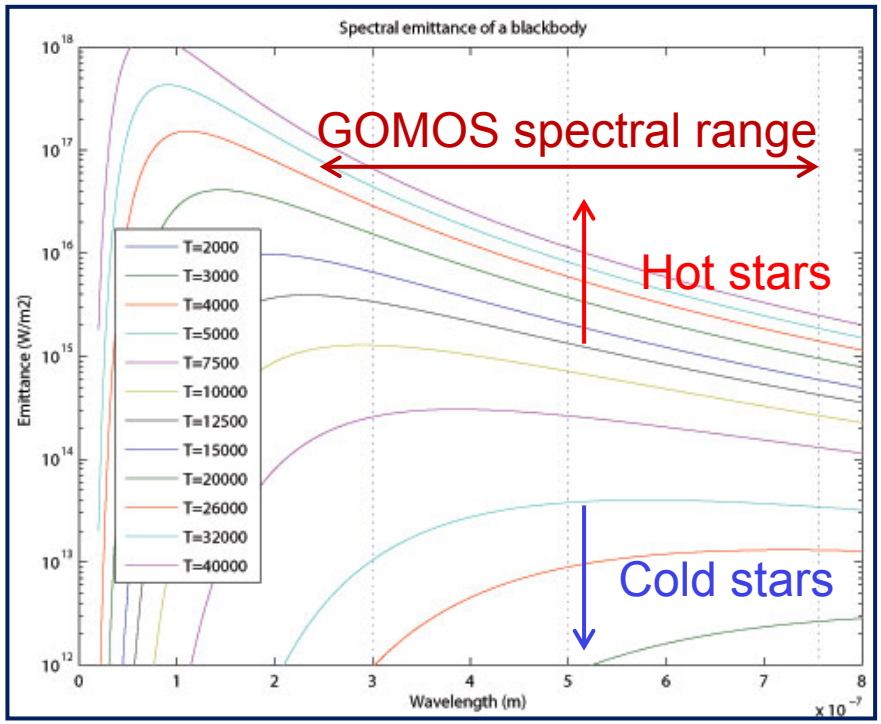
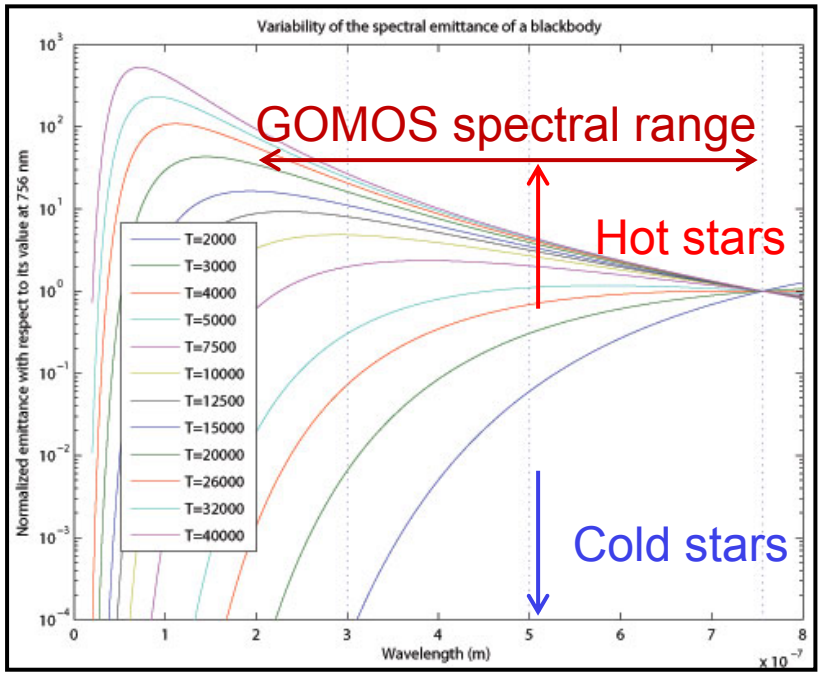


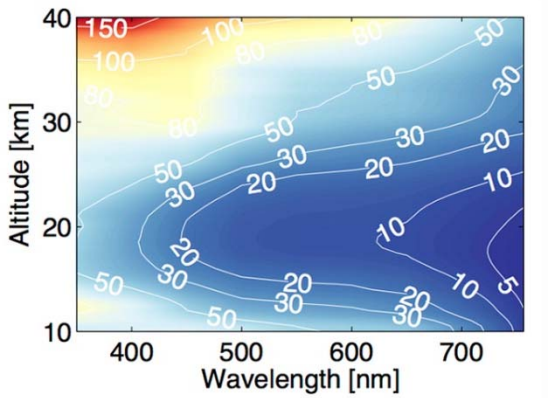
Normalized at 756 nm:



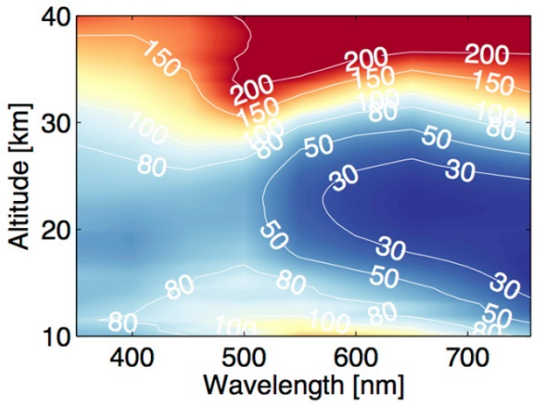
GOMOS (Global Ozone Monitoring by Occultation of Stars)

- **Dependence on the star characteristics:**
  - Impact on the uncertainty: (here on the aerosol extinction)

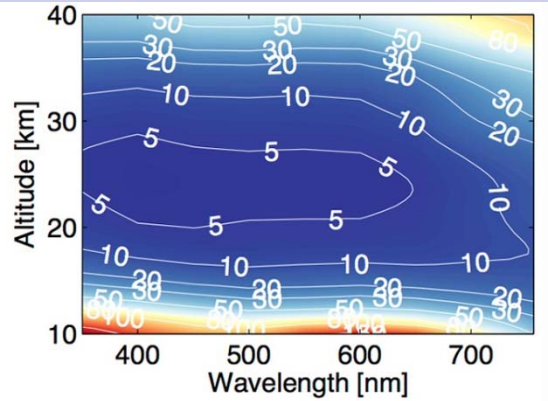
Bright & Cold stars



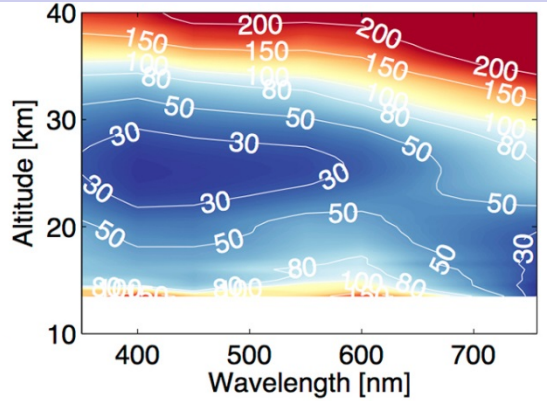
Dim & Cold stars



Bright & Hot stars



Dim & Hot stars



Aerosol retrieval algorithm

- AerGOM retrieval algorithm:
  - ✓ Optimized for aerosol retrieval
  - ✓ Retrieved simultaneously: O_3, NO_2, NO_3, aerosol extinction
  - ✓ Aerosol extinction retrieval: spectral dependence parameterized by a quadratic function in $(\text{wavelength})^{-1}$
  - ✓ Particle Size Distribution (PSD) retrieval from aerosol extinction at several wavelengths (under development)

Climate Data Records for Aerosol_cci

BIRA·IASB

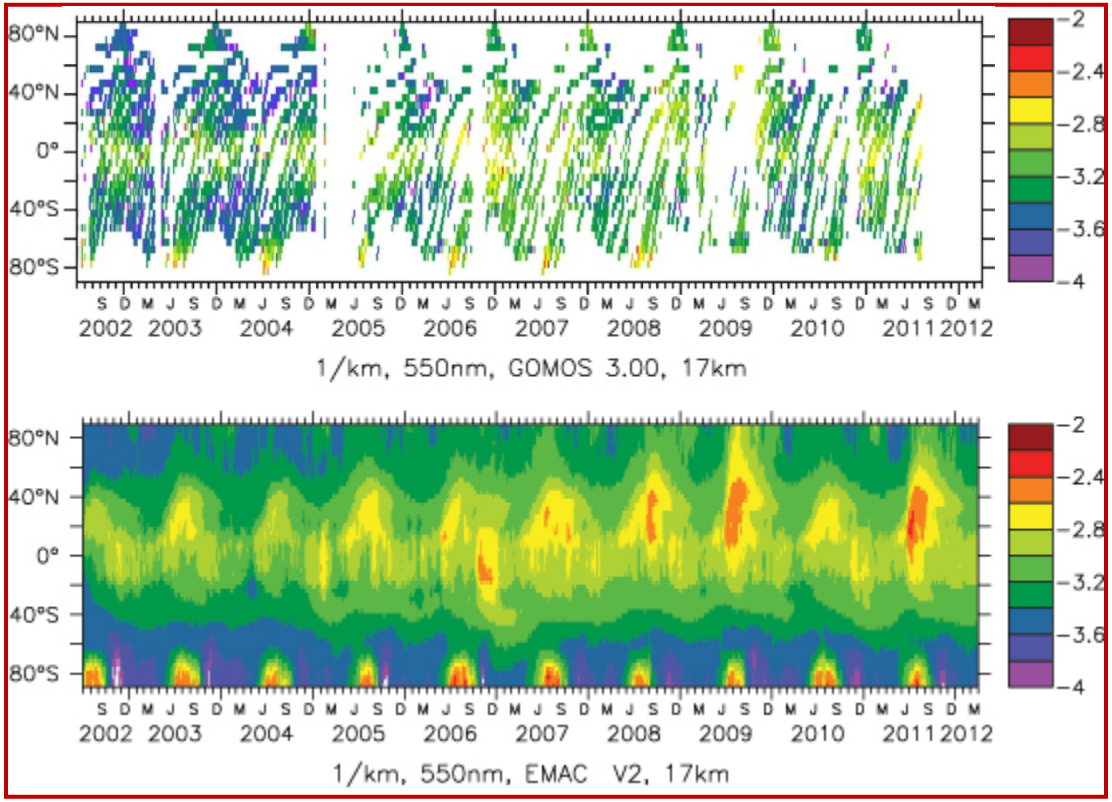
- Gridded time series for climate modelling:
  - Extinction & derived products, with uncertainties
- Optimization of
  - The choice of the grid; currently:
    - 5-day temporal grid
    - 5° latitude, 60° longitude, 1 km altitude
  - The selection criteria applied to GOMOS measurements:
    - Trade-off between best coverage and sufficient measurement quality (star parameters, solar zenith angle)

Climate Data Records for Aerosol_cci

BIRA·IASB

Example:

Extinction at 550 nm (v. 2.19), vs. EMAC (v.2)



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

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Climate Data Records for Aerosol_cci

BIRA·IASB

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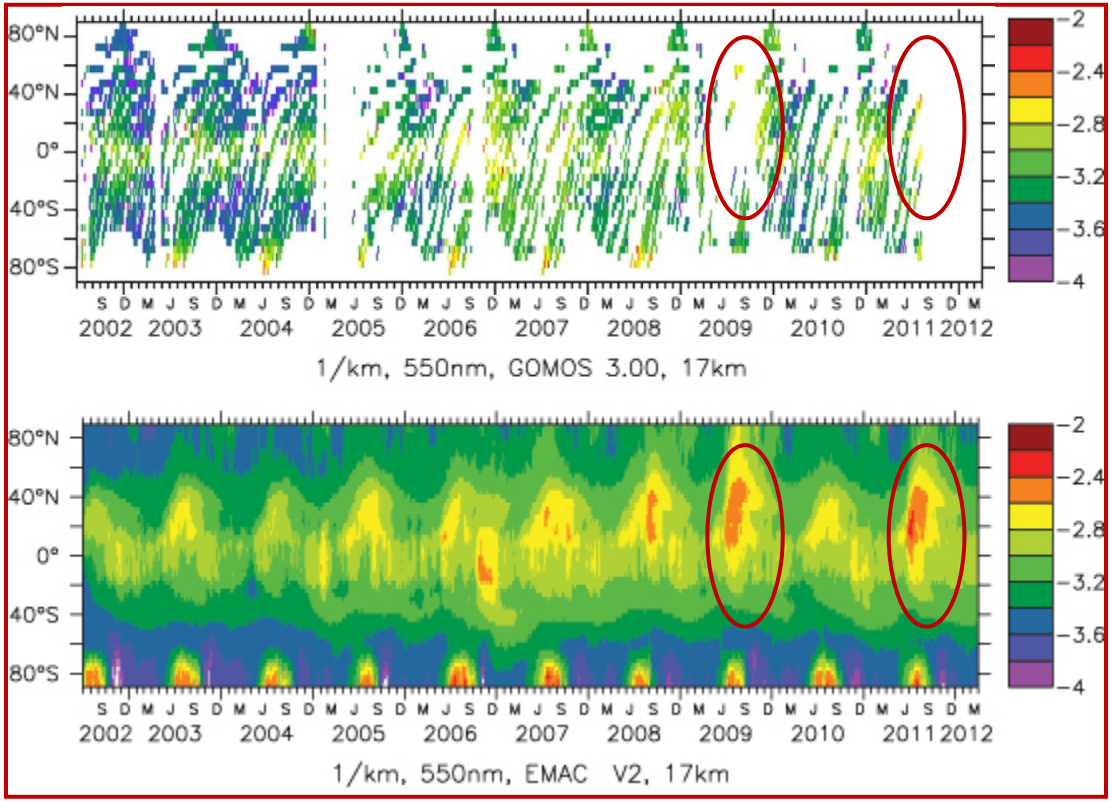

Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

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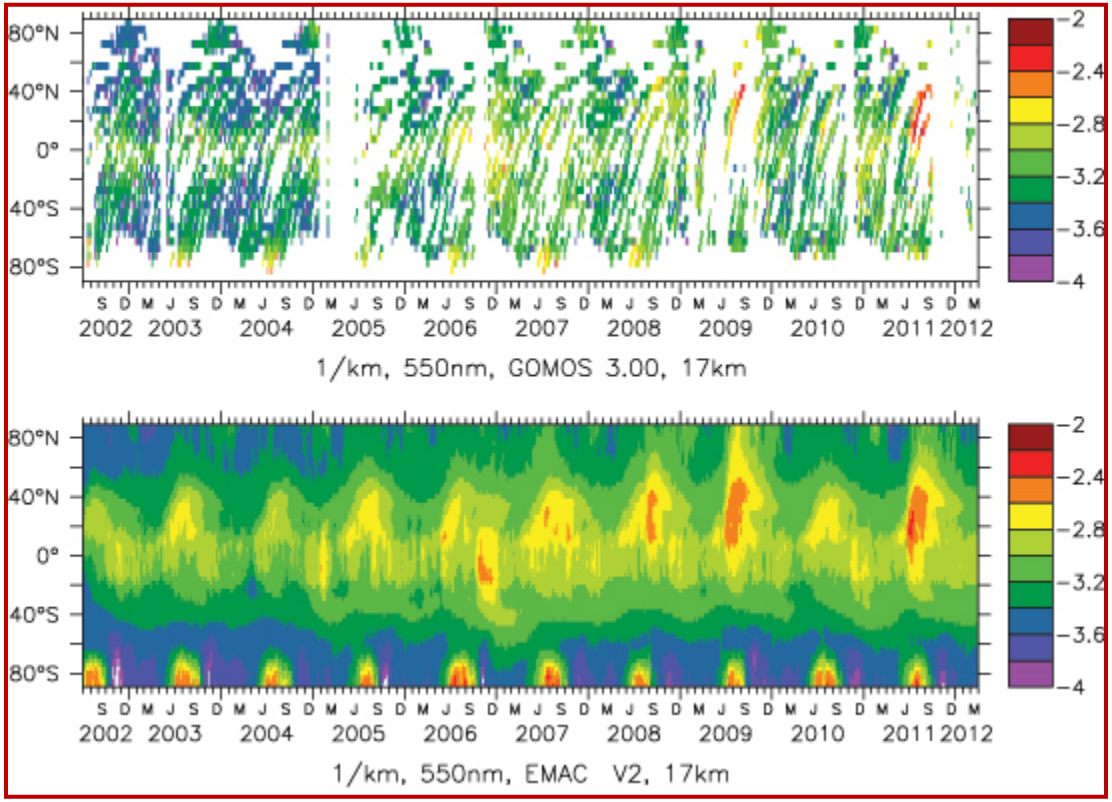
Climate Data Records for Aerosol_cci

BIRA·IASB

Example:

Extinction at 550 nm (v. 3.00), vs. EMAC (v.2)



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

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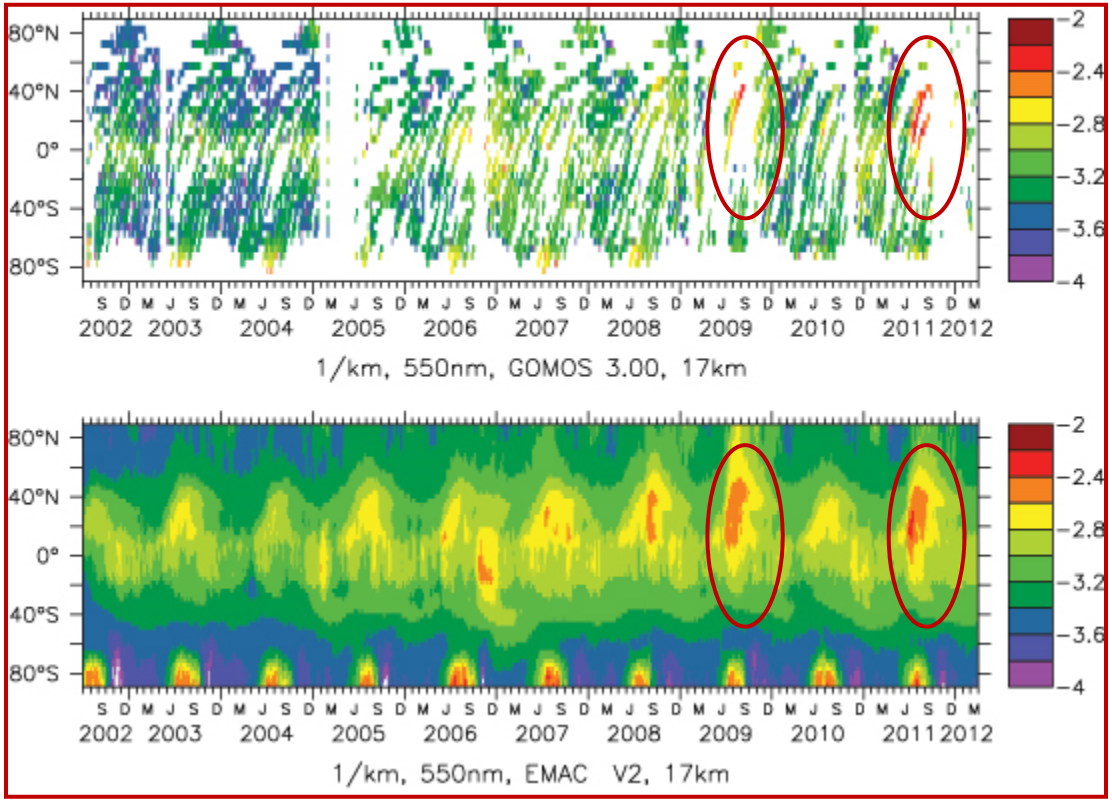
Climate Data Records for Aerosol_cci

BIRA·IASB

Example:

Extinction at 550 nm (v. 3.00), vs. EMAC (v.2)



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

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Validation

- Intercomparisons with lidar time series
  - ESA requirement
- 3 sites:
  - Garmisch-Partenkischen, Germany
    - 79 months, 236 profiles relevant for comparison
    - Extinction-to-backscatter ratio provided
  - Mauna Loa, Hawaii, USA
    - 121 months, 409 profiles relevant for comparison
  - Dumont d'Urville, Antarctica
    - 44 months, 380 profiles relevant for comparison
- Issue: Extinction-to-backscatter ratio

Validation

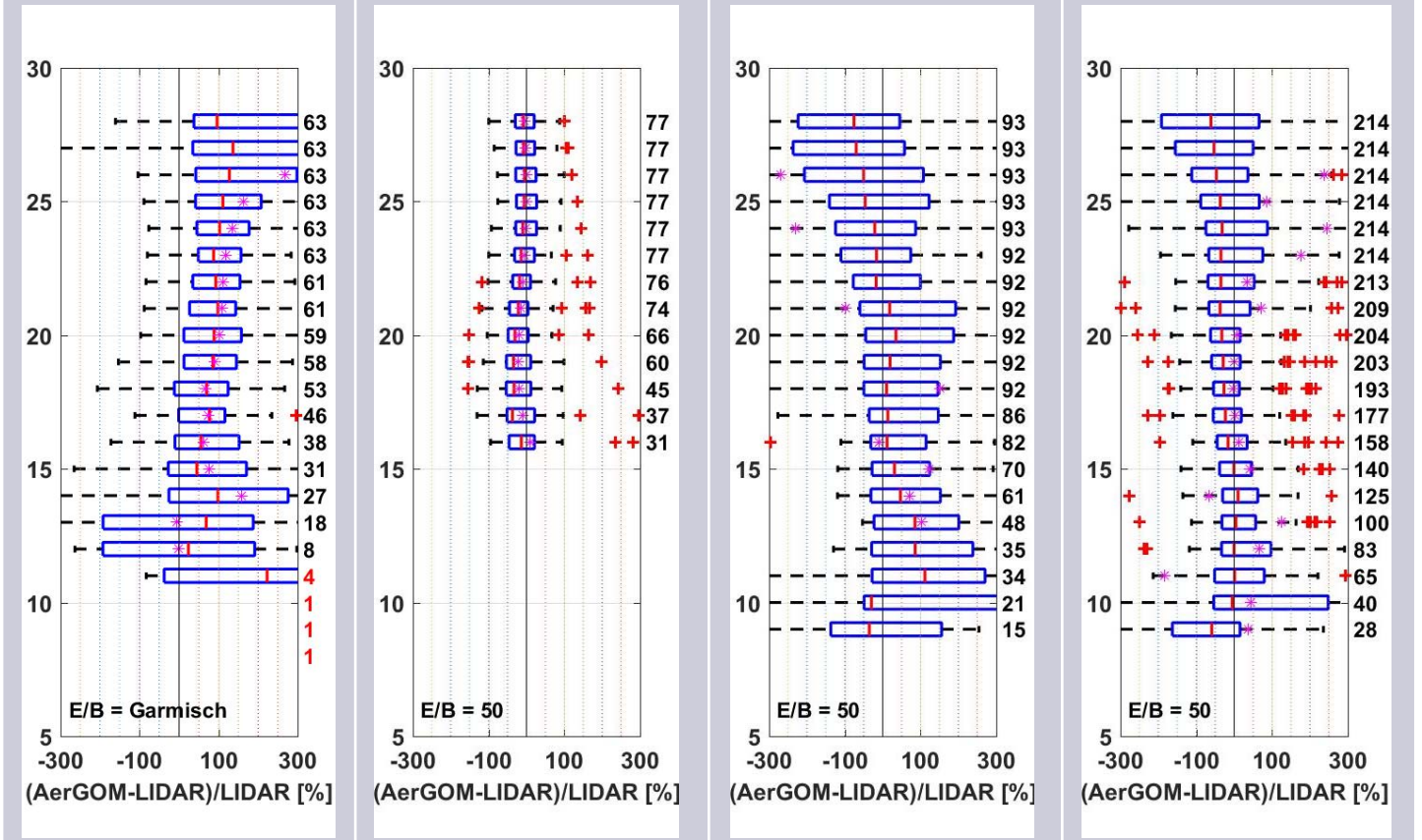
Comparison

AerGOM (Level 2)

With

Lidar

Garmisch Partenkischen	Mauna Loa	Dumont d'Urville (Background)	Dumont d'Urville (PSCs)



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

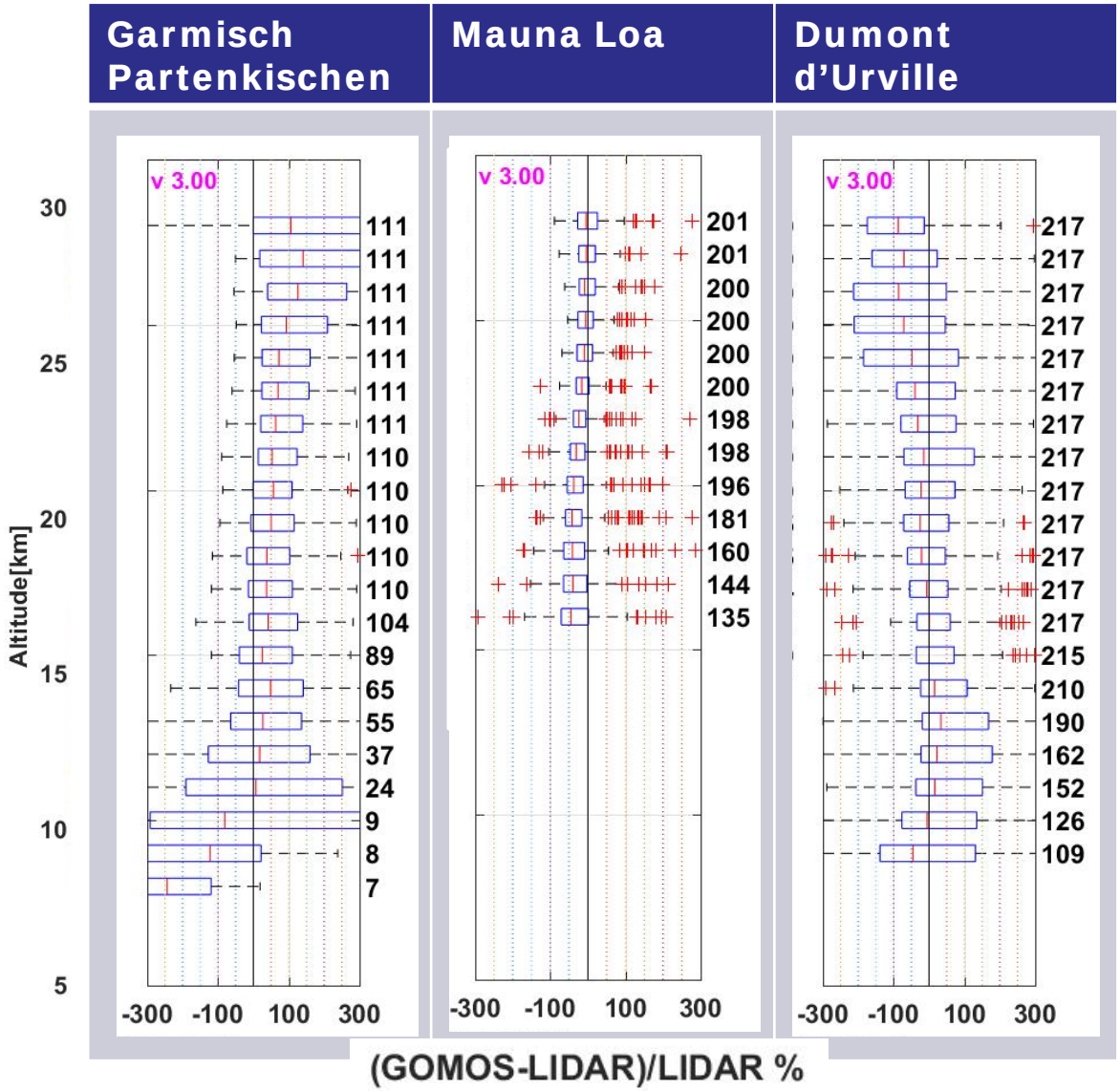
Validation

Comparison

CCI-GOMOS (Level 3)

With

Lidar



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

Particle Size Distribution (PSD) Retrieval

- Radial inversion: extinction → PSD
  - Extinction at 9 wavelenghs between 350 and 750 nm

- Use of a sectional PSD
  - 20 size bins from 20 nm to 3 µm
  - Tikhonov regularization

Particle Size Distribution (PSD) Retrieval

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- Inference of the aerosol composition
  - From temperature, altitude, latitude, etc.
  - Separate products for « sulfate », « PSC » , « meteoretic dust », « uncertain »

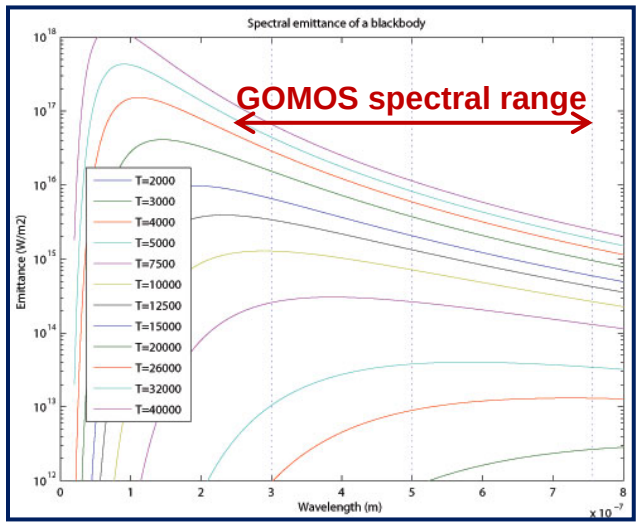
- Expected derived products (under development)
  - Effective radius
  - Surface area density, volume density
  - Total particle number density, mode parameters
  - Radiative parameters derivable from Mie scattering

Particle Size Distribution (PSD) Retrieval

- First step:
  1. Retrieval applied on each GOMOS L2 profile
  2. Processing CCI-GOMOS time series (L3)

☹Results are unsatisfactory:

- ➢Retrieval increases the noise
- ➢Very bad results for events with unfavourable star parameters



Particle Size Distribution (PSD) Retrieval

- First step:
  1. Retrieval applied on each GOMOS L2 profile
  2. Processing CCI-GOMOS time series (L3)

  ☹Results are unsatisfactory:
  - ➢Retrieval increases the noise
  - ➢Very bad results for events with unfavourable star parameters

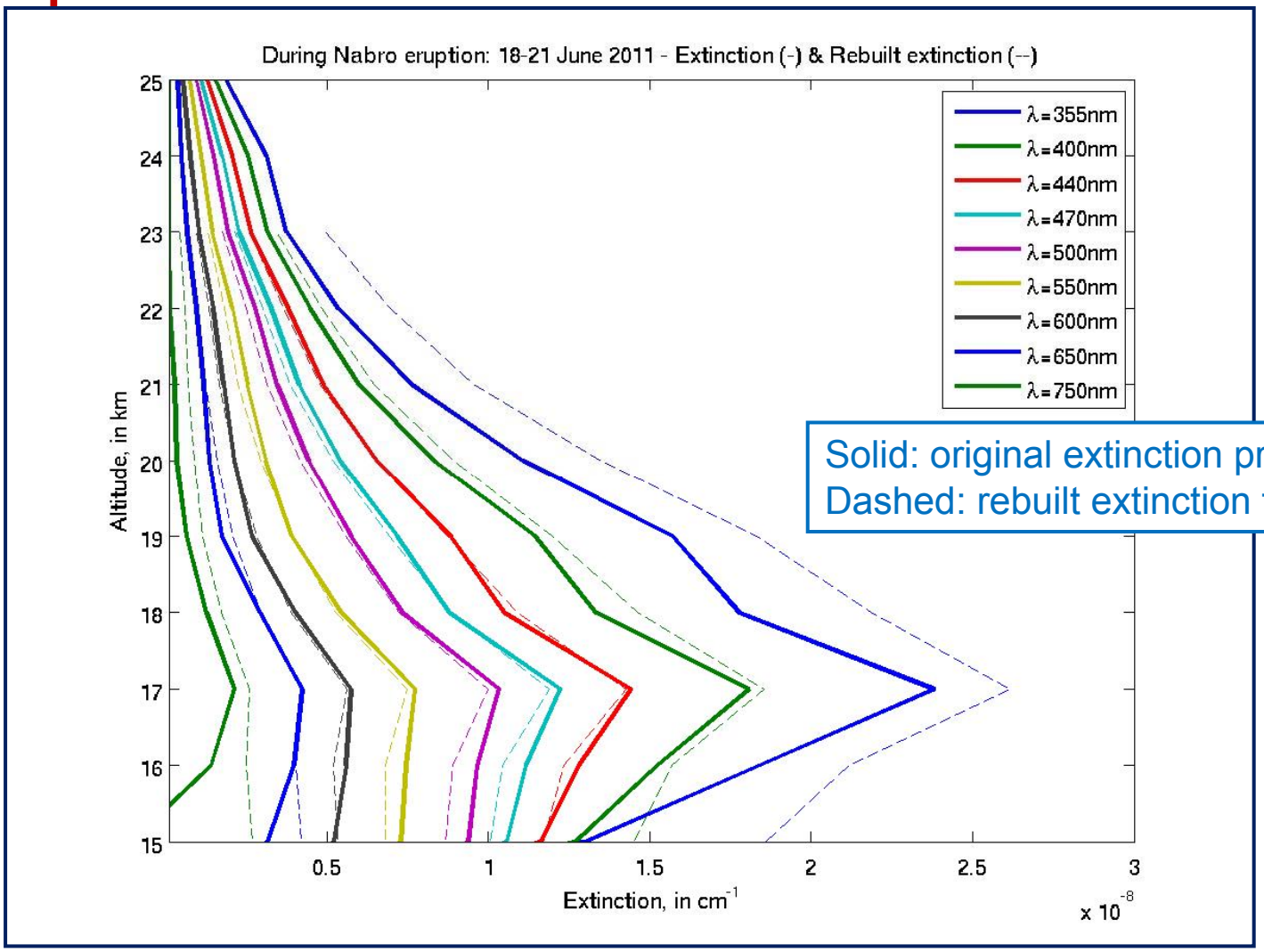
- Second step:
  1. Processing CCI-GOMOS extinction time series (L3)
  2. Retrieval applied on each CCI-GOMOS L3 profile

  ☺Better quality of the extinction spectral dependence

  ☺Improved quality of the retrieved PSD

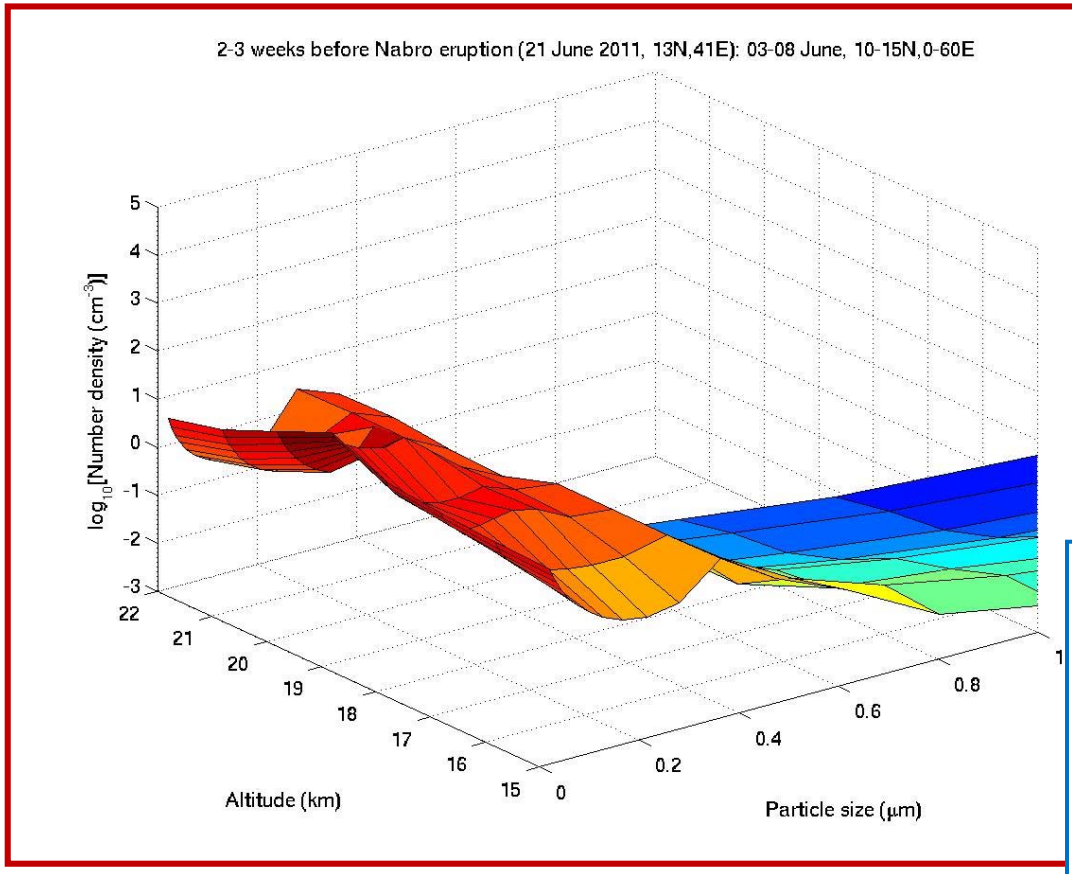
Test: rebuilt of the extinction from PSD

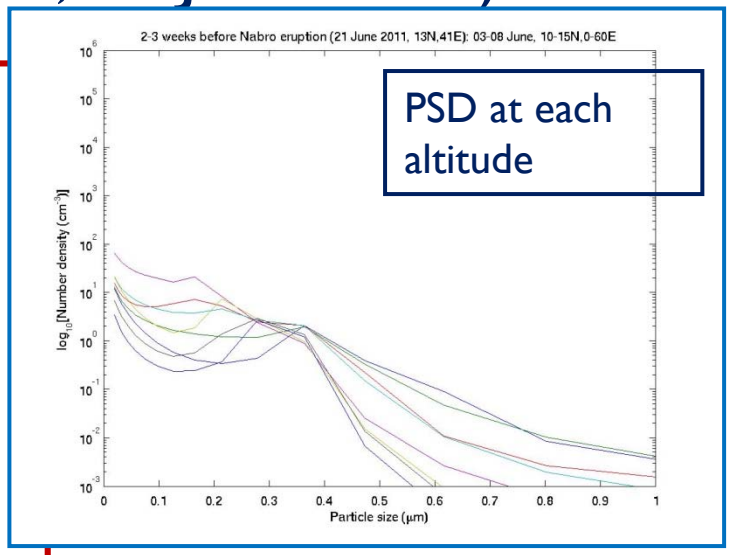
- Example:

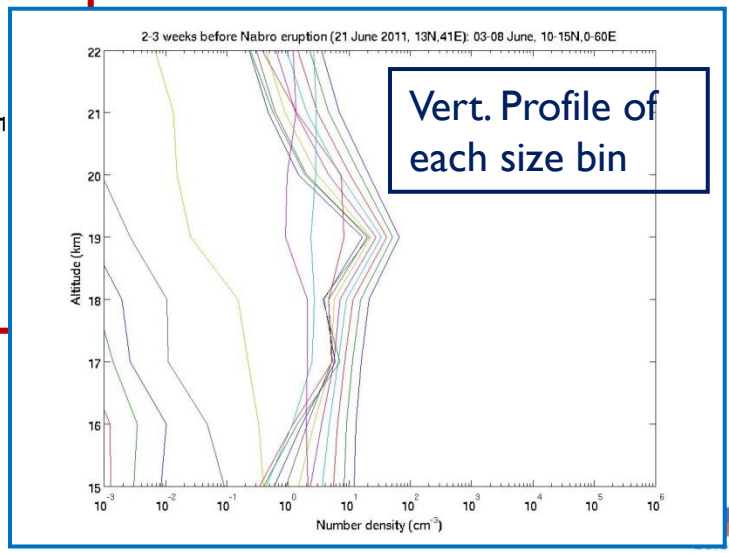


Example of PSD retrieval:

The Nabro eruption (13°N, 40°E, 21 June 2011)



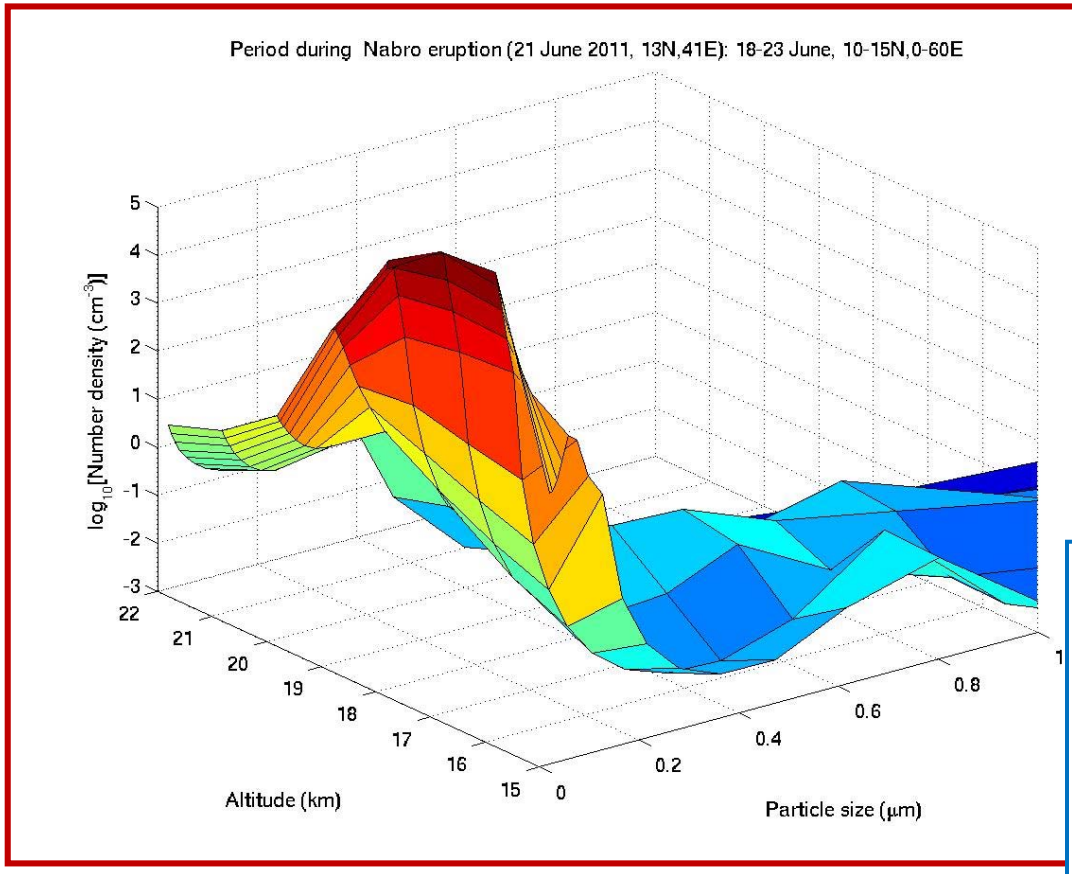


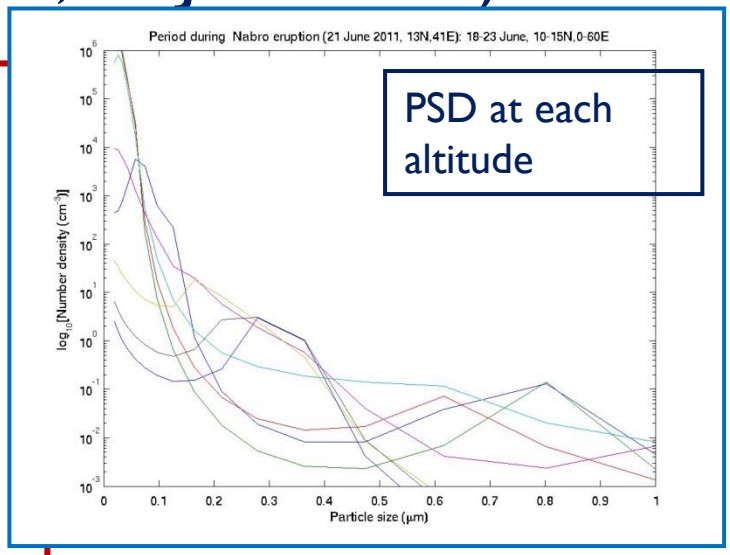


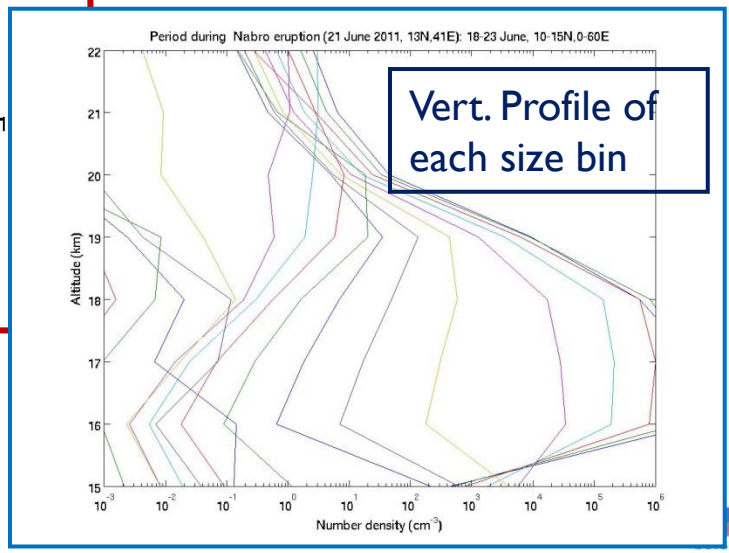
2-3 weeks before the eruption

Particle Size Distribution (PSD) Retrieval:

The Nabro eruption (13°N, 40°E, 21 June 2011)



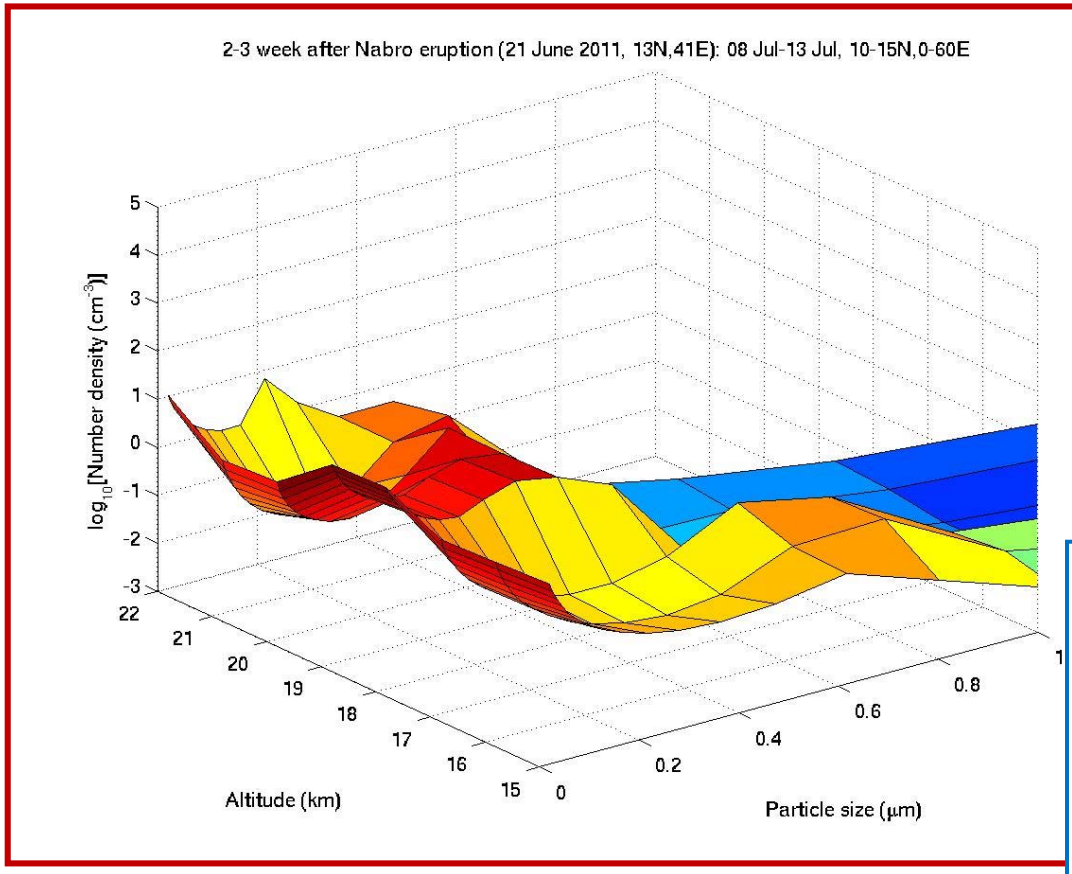


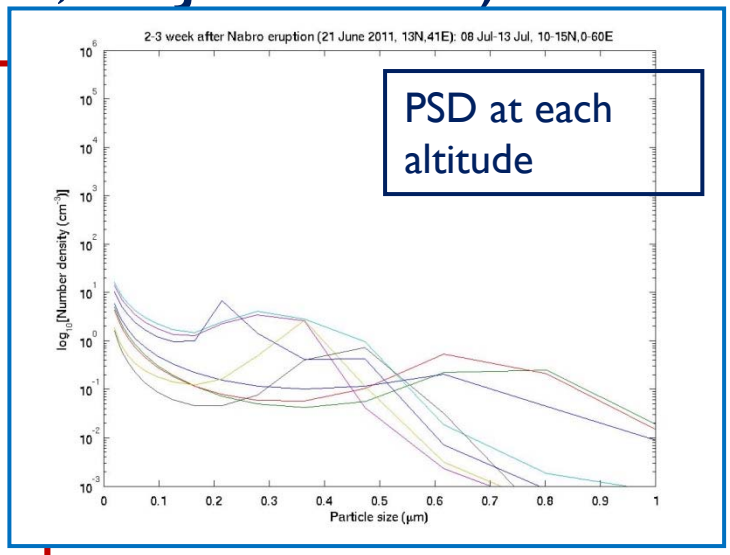


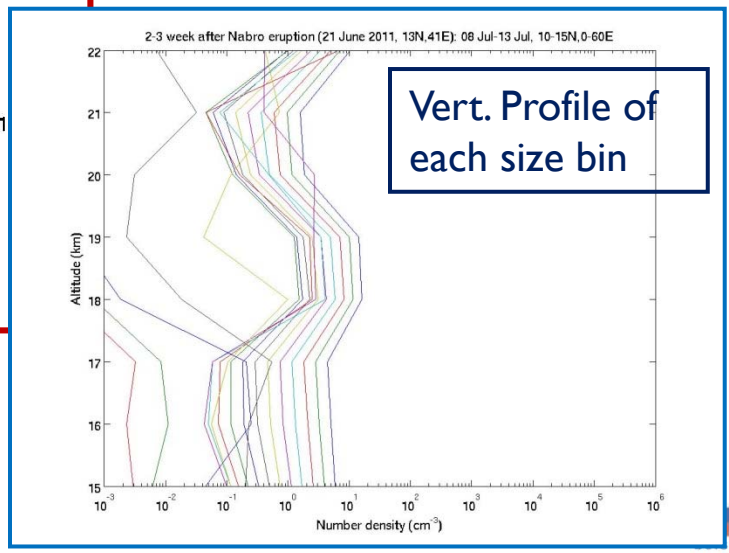
During the week of the eruption

Particle Size Distribution (PSD) Retrieval:

The Nabro eruption (13°N, 40°E, 21 June 2011)







2-3 weeks after the eruption

Conclusion

CCI-GOMOS climate data records from AerGOM (2002-2012)

- CCI-GOMOS aerosol records using 5-day, 60° longitude, 5° latitude, 1 km altitude grid
  → Customized for modelling application

- Comparisons with lidar measurements from 3 stations (low, mid-, high latitude)
  → Issue: unknown extinction-to backscatter ratio

- Retrieval of the particle size distribution
  → Challenging
  → Quality of the retrieved PSD improved by using binned extinction values
  → Time series expected in the coming months

- Use of CCI-GOMOS records in climate modelling applications
  → See presentations by Jennifer Schallock and Christoph Brühl

- Perspectives for the future
  → Improvement of the PSD
  → Possible continuation of CCI
  → Preparation of the ALTIUS mission

Main references

Contact: Christine.Bingen@aeronomie.be

Aerosol_CCI

- C. Bingen, et al., Stratospheric aerosol data records for the Climate Change Initiative: development, validation and application to Chemistry-Climate Modelling, accepted for publication in *Remote Sensing Environment, Special issue on Earth Observation of Essential Climate Variables*, **2017**

- T. Popp, et al., Development, Production and Evaluation of Aerosol Climate Data Records from European Satellite Observations (Aerosol_cci), *Remote Sens.*, *8*, 421-454; doi:10.3390/rs8050421, **2016**

AerGOM algorithm:

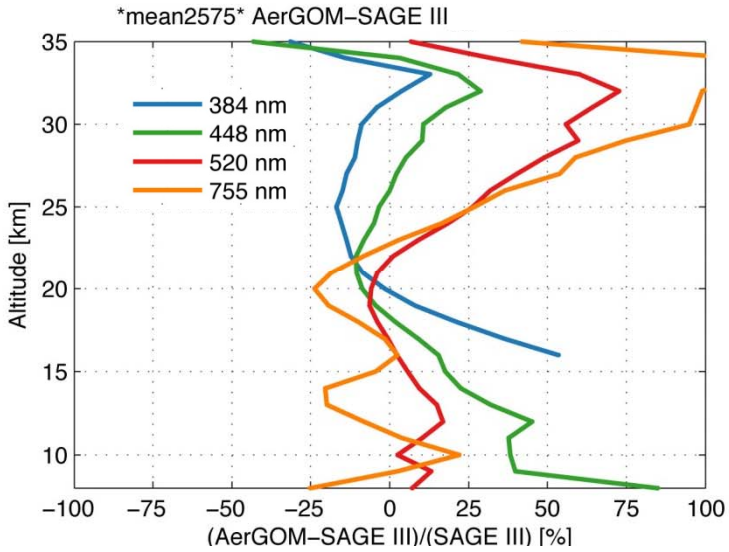
- F. Vanhellemont, et al., AerGOM, an improved algorithm for stratospheric aerosol extinction retrieval from GOMOS observations – Part 1: Algorithm description, *Atmos. Meas. Tech., 9,* 4687–4700, **2016**

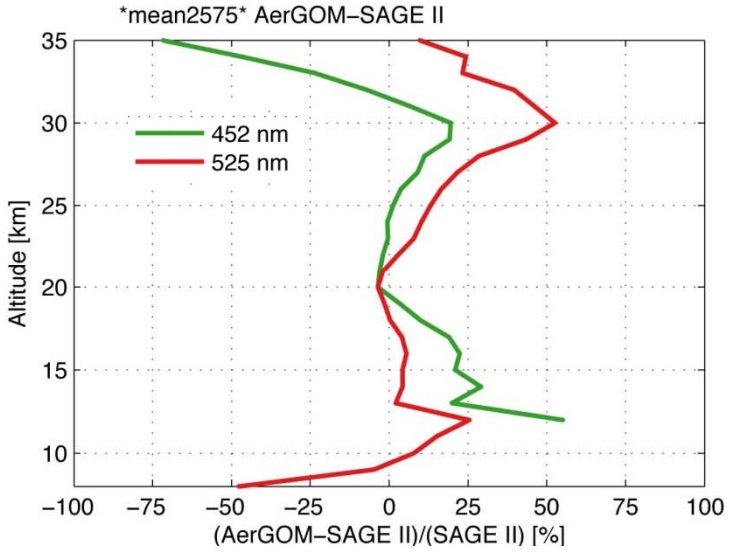
- C. Robert, et al., AerGOM, an improved algorithm for stratospheric aerosol extinction retrieval from GOMOS observations – Part 2: Intercomparisons, *Atmos. Meas. Tech., 9*, 4701–4718, **2016**

ADDITIONNAL SLIDES

Validation vs. SAGE 2 / SAGE 3 (not in Aerosol_cci)

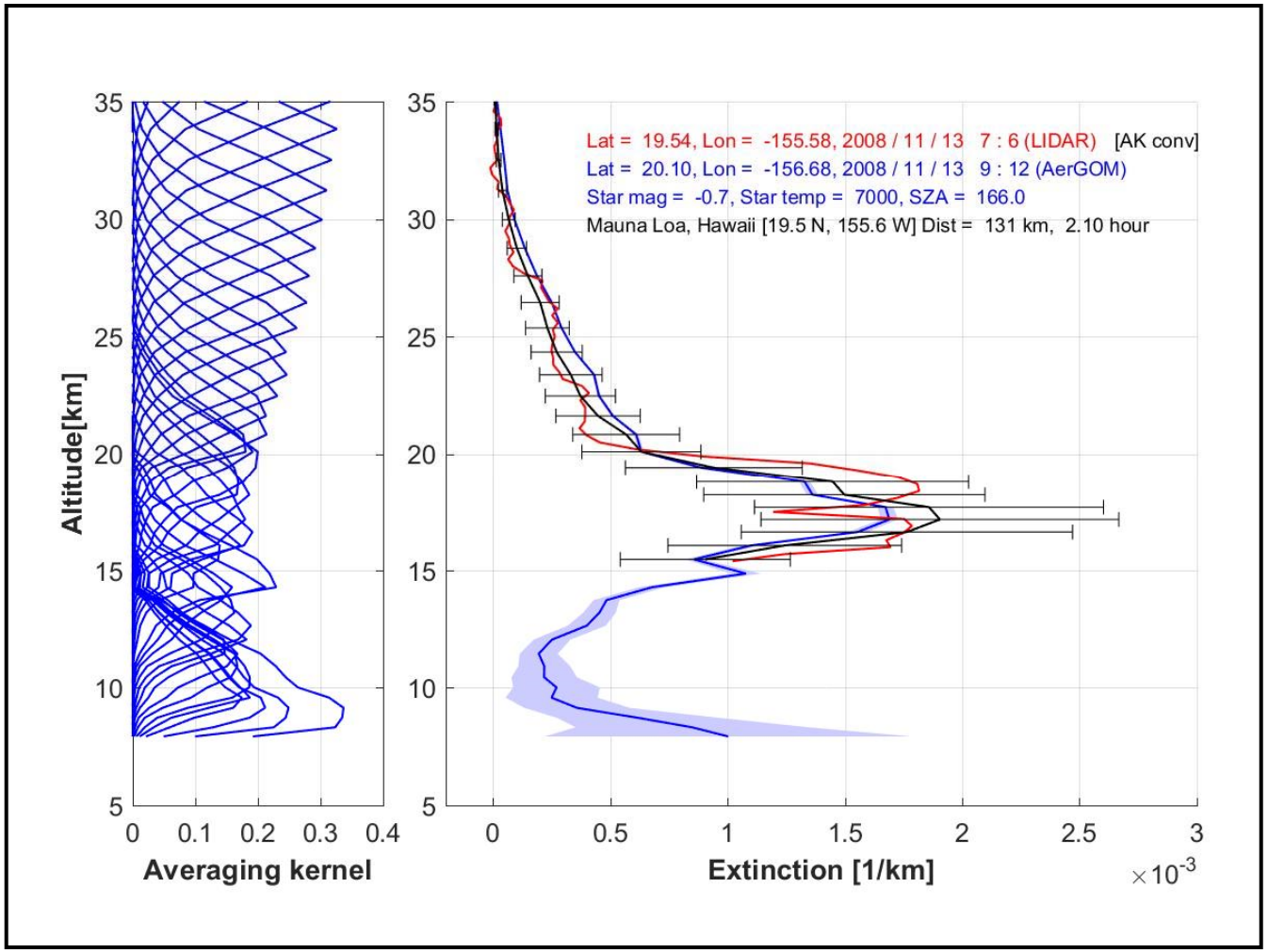
- Based of 3000 random profiles:





Validation

- Examples of comparison:



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017

AerGOM retrieval algorithm

AerGOM, an improved algorithm for stratospheric aerosol extinction retrieval from GOMOS observations – Part 1: Algorithm description

Filip Vanhellemont[1], Nina Mateshvili[1], Laurent Blanot[3], Charles Étienne Robert[1], Christine Bingen[1], Viktoria Sofieva[2], Francis Dalaudier[4], Cédric Tétard[1], Didier Fussen[1], Emmanuel Dekemper[1], Erkki Kyrölä[2], Marko Laine[2], Johanna Tamminen[2], and Claus Zehner[5]

Atmos. Meas. Tech., 9, 4687-4700, 2016

AerGOM, an improved algorithm for stratospheric aerosol extinction retrieval from GOMOS observations – Part 2: Intercomparisons

Charles Étienne Robert[1], Christine Bingen[1], Filip Vanhellemont[1], Nina Mateshvili[1], Emmanuel Dekemper[1], Cédric Tétard[1], Didier Fussen[1], Adam Bourassa[2], and Claus Zehner[3]

Atmos. Meas. Tech., 9, 4687-4700, 2016

Climate Data Records for Aerosol_cci

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Article

Stratospheric aerosol data records for the Climate Change Initiative: development, validation and application to Chemistry-Climate Modelling

Christine Bingen[1], Charles E. Robert[1], Kerstin Stebel[2], Christoph Brühl[3], Jennifer Schallock[3], Filip Vanhellemont[1], Nina Mateshvili[1], Michael Höpfner[4], Thomas Trickl[5], John E. Barnes[6], Julien Jumelet[7], Jean-Paul Vernier[8, 9], Thomas Popp[10], Gerrit de Leeuw[11, 12], and Simon Pinnock[13]

Published in Remote Sensing Environment (2017),

Special issue on Earth Observation of Essential Climate Variables

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Application: volcanoes inventory

- Sources: MIPAS, GOMOS, other sources
- About 230 explosive eruptions
  - Illustration: Simulated global radiative forcing of stratospheric aerosol at ~100hPa (Solomon et al., 2011)

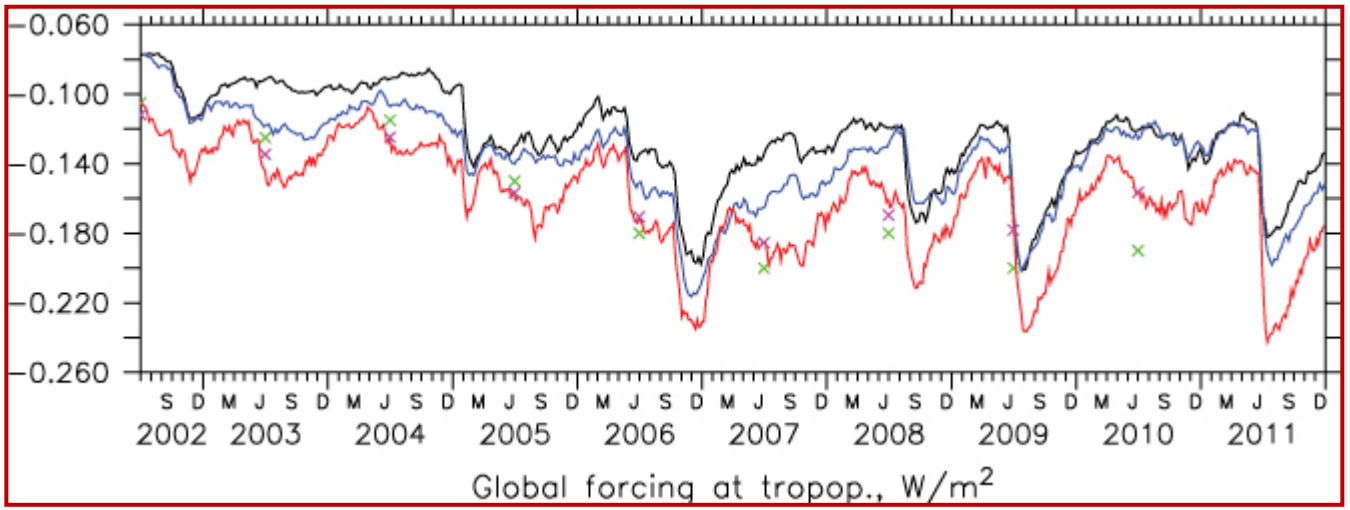
Solomon, simulated

EMAC, Brühl et al, 2015

EMAC current version

X: Solomon, annual average from meas.

X: annual average, from EMAC current version



Bingen et al., *Remote Sensing Environment*, accepted for publication, 2017