AEROSAT
Introduction

Thomas Popp / DLR
Ralph Kahn / NASA-GSFC

AEROSAT Goals (1)

- **Work with modelers to make satellite aerosol data as useful as possible for climate modeling (e.g., AeroCom)**
- **Achieve an open and active exchange of information**
  - Retrievals and their strengths and limitations
  - Match user requirements to measurement technical capabilities
  - Share the latest technological advances
  - Work toward inter-operability (data formats, data standards, terminology)
- **Forum for satellite aerosol retrieval experts**
  - Learn from each other, collaborate as appropriate
  - Initiate new developments, participate in ***AeroSat Experiments***
  - Work toward product harmonization

AEROSAT Goals (2)

- **Promote the use of satellite data**
  - As **complementary** to other sources of information
  - To better understand the role of aerosols in climate, climate change, air quality, and atmospheric processes
- **Forum includes satellite data users** (AEROCOM / CCMI models, ICAP forecasts) **and data providers** (AERONET reference, space agencies)
  - Listen to each others' needs, any issues, and limitations
  - Discuss what is possible; Motivate new activities
  - Contribute to integration of satellite & suborbital observations
- AEROSAT is an unfunded network (as is AEROCOM)

Challenges for Satellite Aerosol Remote Sensing

- Providing *Consistent, Global, 3-D Aerosol Amount and Type* products
- Providing *Quantitative, Credible Uncertainty Estimates on all levels, especially for aerosol type*
- Producing Consistent *Long-term* satellite data records
- Exploiting satellite information content to constrain aerosol type
- Finding *CCN proxies*
- Applying satellite datasets to *Constrain* and/or *Validate Models*
- More generally, using *Multiple Data Sources* to constrain models
- *Using Models* to supplement measured quantities
  (e.g., AOD in broken cloud; aerosol type at low AOD)
- Providing *"Deliverables"* (results) on zero budget...

The Role of Satellite Retrievals

Satellites

frequent, global *snapshots*; aerosol amount & aerosol type maps, plume & layer heights

Remote-sensing Analysis
- Retrieval Validation
- Assumption Refinement

Regional Context

Suborbital

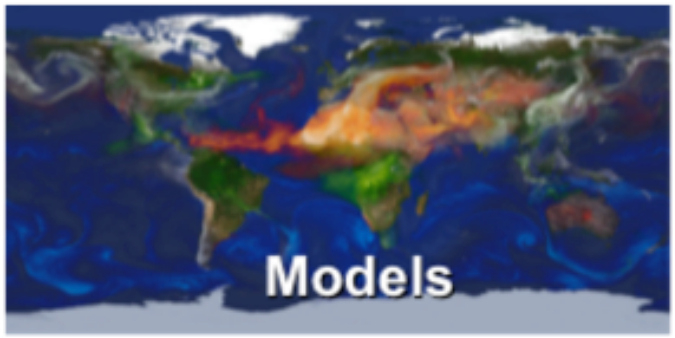
targeted chemical & microphysical detail

point-location time series

CURRENT STATE
- Initial Conditions
- Assimilation

Aerosol-type Predictions; Meteorology; Data integration

Model Validation
- Parameterizations
- Climate Sensitivity
- Underlying mechanisms



space-time interpolation,
Aerosol Direct & Indirect Effects
calculation and prediction

Must ***stratify*** the global satellite data to treat appropriately situations where **different physical mechanisms** apply

Adapted from: Kahn, Survy. Geophys. 2012

Perspectives on Collaboration with Modelers

- **Support model-satellite consistency**
  - Discuss + publish ***definition similarities & differences*** (Mod + Sat)
  - Provide ***aerosol typing information*** in a useful form
    -- Includes application of ***optical vs. compositional "types"***
  - Provide ***uncertainty characterization*** in a useful form

- **Guide the use of satellite datasets**
  - Provide a ***critical assessment*** of strengths and limitations
  - Provide harmonized ***quality statements***
  - Create ***data-record ensembles*** –> report the spread / confidence

- **Experiments**
  - Involve modelling to tie evaluations to critical variables
  - Develop smart ways to integrate complementary information content

AeroSat in the First Five Years

- **Joint Sessions with AeroCom**
  - Needs of modelers ←→ Possibilities & limitations of data producers
  - Toward a common understanding of definitions
- **Internal Retrieval Expert Discussions**
  - Principles, *consistent definitions*, strengths / limitations
  - Constraining *aerosol type* with satellite data
  - Deriving *pixel-level uncertainties*
  - Producing *long-term* satellite data records
  - Satellite capabilities / limitations for *air quality applications*
- **Summary (draft) outcomes**
  - Intensified dialogue (among retrieval experts & with modelers)
  - List of long-term datasets & inter-comparison studies
  - Inventory of aerosol-type products & definitions
  - Review of validation metrics
  - Major advances in assigning *pixel-level uncertainties*
  - Satellite constraints on *biomass burning injection (height & strength)*
  - First ***AEROSAT Experiments*** in progress
  - First AEROSAT-motivated ***Overview Papers*** submitted

First AEROSAT-motivated papers in preparation / submitted / in review

Schutgens et al.

AEROCOM/AEROSAT: an intercomparison of 14 global satellite remote datasets for aerosol in the context of model evaluation

Nick Schutgens[1], Andrew Sayer[1], Andreas Heckel[1], Gerrit de Leeuw[1], Peter Leonard[1], Rob Levy[1], Antti Lipponen[1], Alexei Lyapustin[1], Peter North[1], Thomas Popp[1], Caroline Poulson [1], Virginia Sayer[1], Larissa Sogacheva[1], Gareth Thomas[1], Omar Torres[1], Yujie Wang[1], Stefan Kinne[1], Michael Schulz[1], and Philip Stier[1]

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Abstract. Fourteen satellite products of AOD (aerosol optical depth), obtained with 9 different retrieval algorithms using observations from 5 different sensors on 6 different platforms are evaluated and intercompared, to better understand current uncertainties in an important observational constraint. This study's primary aim is to establish the usefulness of these datasets for model evaluation and focuses on the years 2006, 2008 and 2010 (2008 and 2010 are used in AEROCOM[1] control experiments). The satellite products, super-observations consisting of $1^o \times 1^o$ aggregated L2 retrievals, are evaluated with AERONET[2] and Maritime Aerosol Network data, after careful collocation.

Results show that different products exhibit different regionally varying biases (both under- and overestimates) that may reach $\pm 50\%$, although a typical bias would be $15-25\%$ (depending on product). It appears that MODIS products give better results over land, while AATSR products perform better over ocean. In addition to these biases, the products exhibit random errors that can be 1.6 to 6 times as large. There are some very notable differences in products with some having larger biases, and others larger random errors.

The AOD spread in products, or diversity, shows very clear spatial patterns and varies from 10% (parts of the ocean) to 100% (central Asia and Australia). We provide evidence that this product diversity mostly depends on signal-to-noise ratio of the measurement and uncertainty in cloud screening. More importantly, we show that the diversity may be used as an indication of AOD uncertainty, at least in the better performing products. This allows assessment of products away from AERONET sites, provides a heuristic for new AERONET site locations, and offers suggestions for product improvements. More importantly, it provides modellers with a map of expected AOD uncertainty in satellite products.

Our analysis also suggests that these satellite products agree better in AOD than in their cloud screening.

We have attempted to account for statistical and sampling noise in our analyses. The first one is not large enough to pose problems but the second one does cause important changes in error metrics. The consequences of this noise term for product evaluation are discussed.

[1]AEROcol Comparisons between Observations and Models
[2]AErosol RObotic NETwork

Sayer et al.

A review and framework for the evaluation of pixel-level uncertainty estimates in satellite aerosol remote sensing

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Abstract. Recent years have seen the increasing inclusion of per-retrieval prognostic (predictive) uncertainty estimates within satellite aerosol optical depth (AOD) data sets, providing users with quantitative tools to assist in optimal use of these data. Prognostic estimates contrast with diagnostic (i.e. relative to some external truth) ones, which are typically obtained using sensitivity and/or validation analyses. Up to now, however, the quality of these uncertainty estimates has not been routinely assessed. This study presents a review of existing prognostic and diagnostic approaches for quantifying uncertainty in satellite AOD retrievals, and presents a general framework to evaluate them, based on the expected statistical properties of ensembles of estimated uncertainties and actual retrieval errors. It is hoped that this framework will be adopted as a complement to existing AOD validation exercises; it is not restricted to AOD and can in principle be applied to other quantities for which a reference validation data set is available. This framework is then applied to assess the uncertainties provided by several satellite data sets (seven over land, five over water), which draw on methods from the empirical to sensitivity analyses to formal error propagation, at 12 Aerosol Robotic Network (AERONET) sites. The AERONET sites are divided into those where it is expected that the techniques will perform well, and those for which some complexity about the site may provide a more severe test. Overall all techniques show some skill in that larger estimated uncertainties are generally associated with larger observed errors, although they are sometimes poorly calibrated (i.e. too small/large in magnitude). No technique uniformly performs best. For powerful formal uncertainty propagation approaches such as Optimal Estimation the results illustrate some of the difficulties in appropriate population of the covariance matrices required by the technique. When the data sets are confronted by a situation strongly counter to the retrieval forward model (e.g. potential mixed land/water surfaces, or aerosol optical properties outside of the family of assumptions), some algorithms fail to provide a retrieval, while others do but with a quantitatively unreliable uncertainty estimate. The discussion suggests paths forward for refinement of these techniques.

Sogacheva et al.

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Preprint. Discussion started: 21 June 2019

Atmospheric Chemistry and Physics Discussions

Merging regional and global AOD records from 15 available satellite products

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Abstract. Satellite instruments provide a vantage point to study aerosol loading consistently over different regions of the world. However, the typical lifetime of a single satellite platform is on the order of 5-15 years; thus, for climate studies the usage of multiple satellite sensors should be considered. This paper assesses some options for creating merged products from an ensemble of 15 individual aerosol optical depth (AOD) data records produced from a broad range of institutions, sensors, and algorithms.

Discrepancies exist between AOD products due to differences in their information content, spatial and temporal sampling, calibration, retrieval algorithm approach, as well as cloud masking and other algorithmic assumptions. Users of satellite-based regional AOD time-series are often confronted with the challenge of choosing the appropriate dataset for the intended application. In this study AOD products from different sensors and algorithms are discussed with respect to temporal and spatial differences.

Several approaches are investigated to merge AOD records from different satellites, based on evaluation and inter-comparison results. Global and regional comparison of AOD monthly aggregates with ground-based AOD from the Aerosol Robotic Network (AERONET) indicates that different products agree qualitatively for major aerosol source regions on annual, seasonal and monthly time scales, but have regional offsets. All merged regional AOD time series show highly consistent temporal patterns illustrating the evolution of regional AOD. With few exceptions, all merging approaches lead to similar results, reassuring the usefulness and stability of the merged products.

Review AeroSat (and AeroCom) Experiment Task groups (2017)

- ***Aerosol Retrieval Comparison*** [*Kinne, Schuttgens*]

- ***Characterizing retrieval uncertainties*** [*Sayer, Povey, Govaerts, Levy, Patadia, Witek, Kahn, Dubovik, Mei, Rozanov, Thomas, Kolmonen, Stebel, Limbacher, Lyapustin, Popp*]

- ***Joint Remote-Sensing AOD and Type*** [*Kinne, others*]

- Connecting ***model – satellite aerosol type*** [*Mona, Kahn, Tsigaridis*]

- Constraining ***Aerosol Vertical Distribution*** [*Winker, Kahn, Nowotnick, Colarco*]

- ***Consistent multi-sensor trends*** [*Sogachewa, Schulz, Popp*]

- ***CCN new approach*** [*Rosenfeld, Christensen, Bauer, Shanzuka, Stier*]

AeroSat Way of Working

Focus on *discussion:*

- Only a few, brief overview presentations invited to stimulate discussion
- Presentations mostly on broader context or new concepts
- Individual work mostly presented as posters

A key role is therefore given to chairs and rapporteurs

Session chairs are invited to:

- Introduce the session (five minutes, two or three slides) to lay out the key issues
- Keep invited talks strictly to time
- Moderate the discussion, referring to the key issues at times

Rapporteurs are invited to …

- Kindly summarize main ***discussion contributions***

There is no need to report on the talks (those will be added to the website)

AeroSat website (aerosat.org or aero-sat.org)

- Currently maintained at DLR

AeroSat 2019

- **Continue *Discussion* of Strengths & Limitations**
  - Help guide users dealing with larger / multiple datasets
  - Applying uncertainties in data assimilation
  - Best practices for gridded / monthly datasets
  - Propagation of uncertainties to gridded datasets
  - Is aerosol type information best provided as fractional AOD?

- **Sub-orbital / lab measurements to link satellite and model data**

- **AeroSat Experiments**
  - First papers from experiments drafted
  - Critical review of what is possible (unfunded)

- **Possibilities for contributing to aerosol-cloud-interaction studies**

- **Possibilities for contributing to air quality studies**

- **GCOS list of aerosol ECVs and requirements revision**

Friday, September 27, 2019 *AeroCom / AeroSAT*

	SESSION 14 AeroCom tasks / AeroSAT goals
9:00 – 9:45	*M. Schulz* **AeroCom 2019 wrap-up and outlook / link to AeroSAT**
9:45 – 10:00	*R.Kahn/T.Popp* **AEROSAT 2019 introduction / AeroSAT experiments**
10:00 – 10:30	**poster introductions (part 2)** **max 1 ppt slides / 1 minute poster introduction**
	in alphabetical order *(of those not present on Monday)*
10:30 – 11:00 coffee-break	
	chair: Pete Colarco, rapporteur: Jacques Descloitres
	SESSION 15 Data and modelling
11:00 – 11:05	*chair* **introduction, seed questions**
11:05 – 11:20	**Seed presentation:** *Matthew Christensen* **reflections on barriers to using satellite data as model constraints**
11:20 – 11:30	*Nick Schutgens* **short summary of relevant outcome for satellite community from AEROCOM/AEROSAT remote sensing experiment**
11:30 – 12:30	*joint discussion*
12:30 – 14:00 lunch	
	chair: Ralph Kahn, rapporteur: Matthew Christensen
	SESSION 16 Satellite and suborbital data
14:00 – 14:05	*chair* **introduction, seed questions**
14:05 – 14:25	**Seed presentation:** *Claudia Di Biagio / Lucia Mona* **Contribution of the laboratory experimental simulation activity within EUROCHAMP-2020/ACTRIS to the aerosol retrieval from satellite observations, Introducing ACTRIS ground and aircraft measurements**
14:25 – 15:30	*joint discussion* - *New ways to integrate suborbital, lab and satellite / model data*
15:30 – 16:00 coffee-break	
	chair: Gerrit de Leeuw, rapporteur: Marta Luffarelli
	SESSION 17 Aerosol typing
16:00 – 16:05	*chair* **introduction, seed questions**
16:05 – 16:20	**Seed presentation:** *Lucia Mona* **aerosol typing database**
16:20 – 16:30	*Antti Lipponen* **Information content analysis: Combination of satellite and groundbased observations enables more accurate aerosol SSA retrievals at low aerosol loadings**
16:30 – 17:30	*joint discussion* - *Common definitions* - *Interpretive particle composition* - *AEROSAT 2018 suggestion: Convert all variables to AOD : absorbingAOD, FineMode-AOD, Dust-AOD, medium-size AOD, non-spherical-AOD, FineMode absorbing AOD, CoarseMode absorbing AOD, spectral AOD, how define size modes?, ...*
17:30 – 18:30	**Poster viewing**

Saturday, September 28, 2019 *AeroSAT*

	SESSION 18 Climate Data records
	chair: Kostas Tsigaridis , rapporteur: Linlu Mei
09:00 – 09:05	*chair* **introduction, seed questions**
09:05 – 09:20	**Seed presentation:** *Adam Povey* **A new perspective on satellite data**
09:20 – 09:30	*Larisa. Sogacheva* **Can the merged AOD L3 monthly product (1996-2017) be extended back to 1979 with TOMS AOD?** (AEROSAT-induced paper / experiment)
09:30 – 10:30	*joint discussion* - accuracy, usefulness for modelling, how to improve them - best practices for gridding (daily, monthly)
10:30 – 11:00 coffee-break	
	chair: Thomas Popp, rapporteur: Marcin Witek
	SESSION 19 Pixel uncertainties
11:00 – 11:05	*chair* **introduction, seed questions**
11:05 – 11:20	**Seed presentation:** *Jeronimo Escribano, Enza Di Tomaso and Angela Benedetti* **Aerosol data assimilation and uncertainties**
11:20 – 11:30	*Andy Sayer (presented by Thomas Popp)* **A review and framework for the evaluation of pixel-level uncertainty estimates in satellite aerosol remote sensing**
11:30 – 12:30	*joint discussion*
12:30 – 14:00 lunch	
	chair: Yves Govaerts , rapporteur: Antti Lipponen
	SESSION 20 New remote sensing techniques
14:00 – 14:10	*Jaehwa Lee* **Aerosol plume height climatology derived from synergistic use of UVVIS sensors**
14:10 – 14:20	*Linlu Mei* **A new aerosol optical thickness research product over Cryosphere**
14:20 – 14:30	*Christina Hsu* **New "Deep Blue" aerosol products from LEO and GEO satellites**
14:30 – 15:30	*joint discussion* - What are major needs for new techniques? - Where can AEROSAT experiments help to characterize or improve algorithms?
15:30 – 16:00 coffee-break	
	SESSION 21 Wrap-up and closing
16:00 – 16:30	**Thomas Popp / Ralph Kahn** *AEROSAT wrap-up and outlook* *Any new AEROSAT (or joint AEROCOM/AEROSAT) experiments?*