AEROSAT Perspectives
On Collaboration with Modeling

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

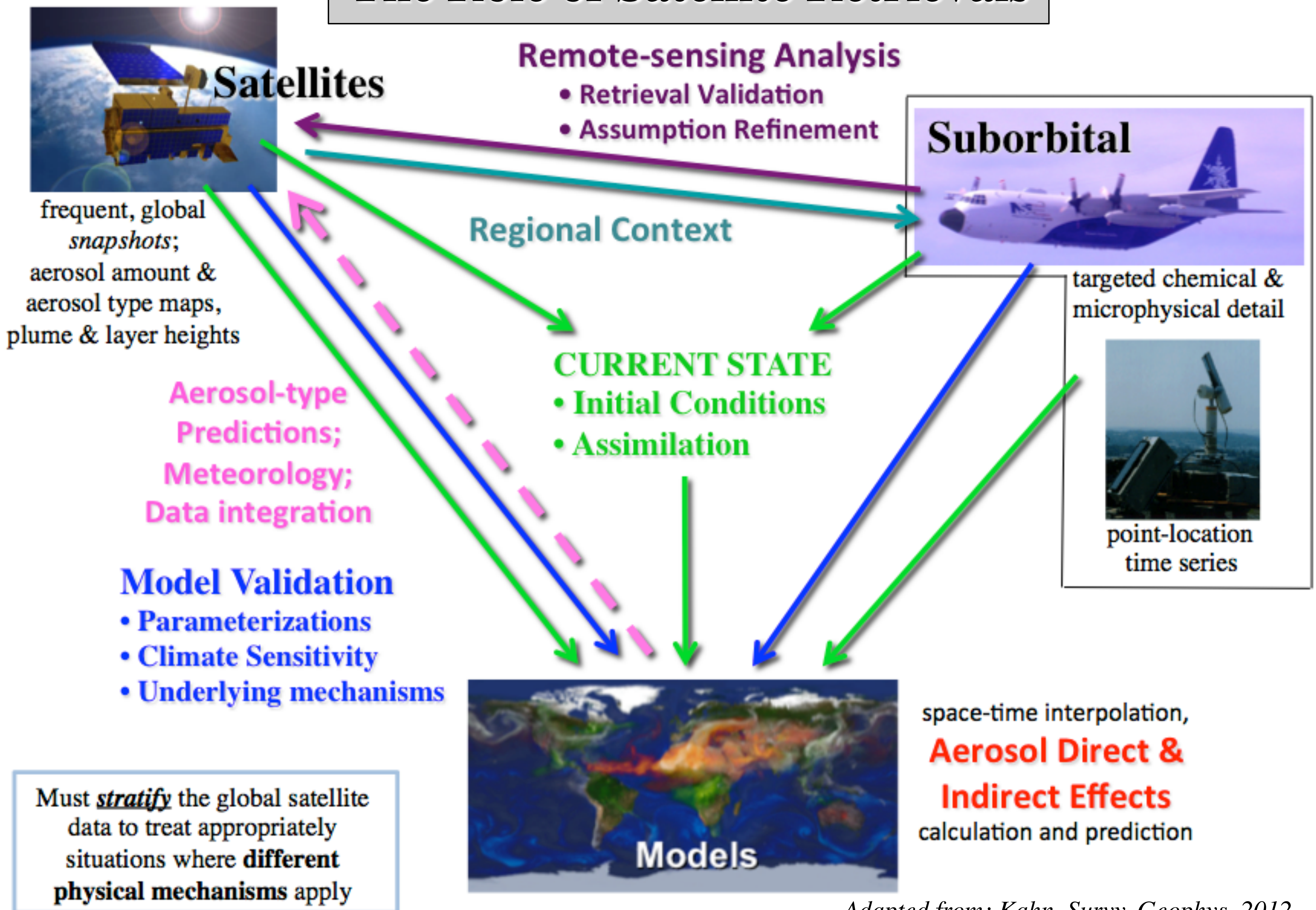
AEROSAT Goals (2)

- **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



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

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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 princple 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.

https://doi.org/10.5194/acp-2019-446
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.

AeroSat 2019

- **Continue *<u>Discussion</u>* 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**