ESA Climate Change Initiative

Aerosol_cci2

Options proposed 1 March 2016

Additional user case studies

Option proposed for Aerosol_cci2 on 1 March 2016

Option XI: additional user case studies

2. Executive Summary

In this option we propose four additional user case studies which will enhance the demonstration if usage of Aerosol_cci2 datasets, in particular of the IASI datasets and for data assimilation and climate studies.

These additional user case studies have been defined with lessons learned so far and in order to avoid overlap with baseline user case studies .

The results of each study will be described in a report at the end of the study, and will also be presented at an Aerosol_cci User Workshop. It is envisaged to also report the outcome of the experiments in a scientific publication.

3. Technical Proposal

3.1. General

Study 1: Trends in natural, in particular coarse mode aerosol (MetNo / NO)

Michael Schulz, Jan Griesfeller, MetNo

Recent analysis of trends in AOD (AERONET, MODIS, SeaWiFS) have demonstrated the continued shift in fine-mode aerosol maxima from the EU and the US to south-east Asia. These trends however also showed that the strongest trends are found for coarse mode (dust) aerosol, with strong increases east of the Sahara (e.g. Arabian Peninsula) and strong decreases west of Africa (Atlantic outflow) (Hsu et al., 2012; Zhang and Reid, 2010). Since coarse mode aerosol accounts on a global average basis for more than half of the AOD, a confirmation and further exploration as to the reasons of such trends (e.g. dynamics, precipitation using for instance ECMWF re-analysis data) are highly desirable. Global natural aerosol trends may represent a major climate feedback process, either mediated through winds or land surfaces changes, which could impact climate evolution.

Further inspection will be thus made of the coarse aerosol AOD trends with the help of ATSR and IASI retrieval as being established in cci-aerosol. While ATSR provides the Ångström coefficient, IASI indicates the presence of dust and both independently allow for an estimate of the coarse aerosol AOD trend. These are valuable new and independent data. With such data at hand we have the possibility to compare to the published trends of coarse aerosol from AERONET, MODIS and SeaWiFS mentioned above. In a second step we will seek consistency with modeled trends of coarse aerosol AOD, using the AeroCom hindcast simulations. Also - the ECMWF-MACC reanalysis (2003-2012) will be used to understand the changes in dust and winds as driving parameters of the satellite observed coarse mode AOD trends.

Study 2: Use of most Aerosol-cci data products for evaluation and improvement of aerosol in the chemistry climate model EMAC (MPI-C / D)

Christoph Bruehl Klaus Klingmüller, MPI-C

The global ECHAM/MESSy atmospheric chemistry-climate model (EMAC) includes a choice of online (i.e., depending on the meteorological conditions) emission schemes for dust (Tegen 2002, Balkanski et al. 2004, Astitha et al. 2012) and provides a comprehensive description of aerosol composition and related microphysical processes.

The online emissions schemes allow to model the relation of trends and variability of the dust AOD to land cover changes such as desertification and droughts (Klingmüller et al. 2016). The detailed aerosol model is essential to quantify chemical "aging" of mineral dust during transport in the atmosphere which has been shown to increase the particle size due to coating by soluble species and hygroscopic growth, dust deposition and scavenging efficiency (Abdelkader et al. 2015); thus having an important impact on AOD and aerosol radiative effects.

Several EMAC studies on atmospheric dust are planned, which all rely on detailed comparisons with observations to validate and, if necessary, improve the model: AOD trends and variability over the Middle East and south Asia, dust intrusions over Europe and East Asia, dust aerosol optical properties (non-spherical particles) and radiative effects, interaction of dust and anthropogenic air pollution. Here we like to use the 3 different ATSR-products for AOD for 2-4 wavelengths and the period 1995-2012 and the 4 IASI datasets at the original IR-wavelength or the dust product for 2006 to 2013. This is compared with the time series of vertically integrated extinctions from the model at the wavelengths of the satellite instruments.

Partly, these studies will be based on model data from long-term runs within the framework of the Chemistry-climate model initiative (CCMI). In most cases the transient simulations include also stratospheric aerosol allowing for comparison with GOMOS extinctions.

References

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Study 3: Linking satellite aerosol retrievals with retrievals for clouds (MPI-M / D)

Stefan Kinne, MPI-M

One of the larger uncertainties in climate modeling is related to aerosol induced changes to cloud properties. Since climate modeling is based on rather coarse spatial scales and local phenomena (such as brighter clouds above ship-tracks due to additional aerosol from fossil fuel burning) may not apply, or at least not to the degree as they are observed at smaller scales. To reduce the diversity associated with interactions between aerosol and clouds in modeling, statistical relationships between relevant aerosol and cloud properties are needed. And satellite remote sensing can provide such statistical relationships. Although already qualitative associations can be good indicators, it certainly is desirable to work with data of assured quality and close associations in space and time (since simultaneous retrievals of aerosol and clouds from the same sensor are not possible). Even if there is no proven causal relationship, any well-established 'observed' relationship will constrain global modeling. Possible links to be explored are relationships between fine-mode aerosol (representing CCN) and low altitude clouds (involving sensors like MODIS, MISR, MERIS, ATSR and CALIPSO) and between dust aerosol optical depth (representing IN as function of temperature) and high altitude clouds (involving sensors like IASI, AIRS or CALIPSO).

For a demonstration reliable cloud droplet number concentration (CDNC) estimates (e.g. overcast, over oceans) were spatially (within a 1x1deg lat/lon grid box) associated with fine-mode aerosol optical depths (AODf) estimates using the same sensor.

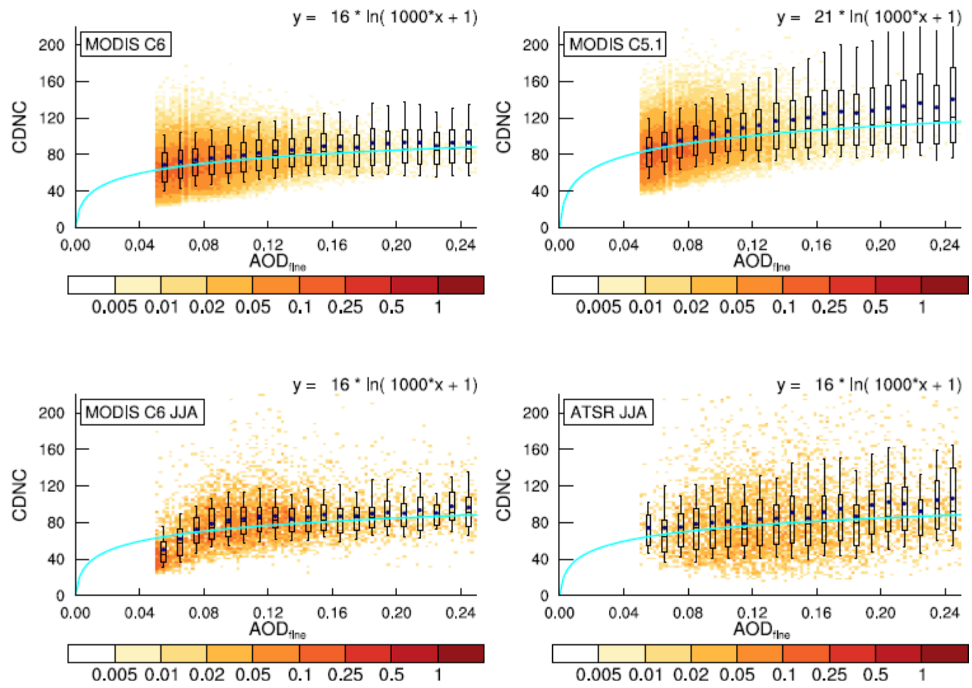

Figure 1. Relationships between fine-mode AOD and CDNC with MODIS c6 data (by John Rausch) with MODIS c5.1 data (by Dan Grosvenor) and with AATSR data (Matt Christensen). Relationships within 1x1 deg lon/lat grid-points are considered only If it involved CDNC retrievals over oceanic and overcast regions at higher zenith observations and if AODf data (at 550nm) exceeded values of 0.05.

Statistical relationships yielded the expected logarithmic relationship (reduced CDNC increases with increased fine-mode AOD due to CCN saturation). The AODf vs CDNC relationship was quite similar using data from different satellite retrievals and sensors (using MODIS and ATSR data). Yet this relationship was much weaker than the same relationship diagnosed in many climate models. To illustrate the usefulness of such a relationship, it was applied to anthropogenic changes in tropospheric (fine-mode) aerosol in an off-line radiative transfer code to offer spatial and temporal patterns for the associated indirect aerosol forcing. Hereby the needed local pre-industrial fine-mode AOD was adopted from the MACv2 aerosol climatology, so that (anthropogenic) additions to the fine-mode AOD could be locally converted into CDNC changes. In an off-line radiative transfer model with ISCCP clouds the local CDNC were translated into water cloud droplet reduction (without changes to the cloud water content).

The simulated (climate relevant) aerosol indirect radiative forcings (reductions to the solar radiative netfluxes at the top of the atmosphere … thus a climate cooling) are presented in Figure 2.

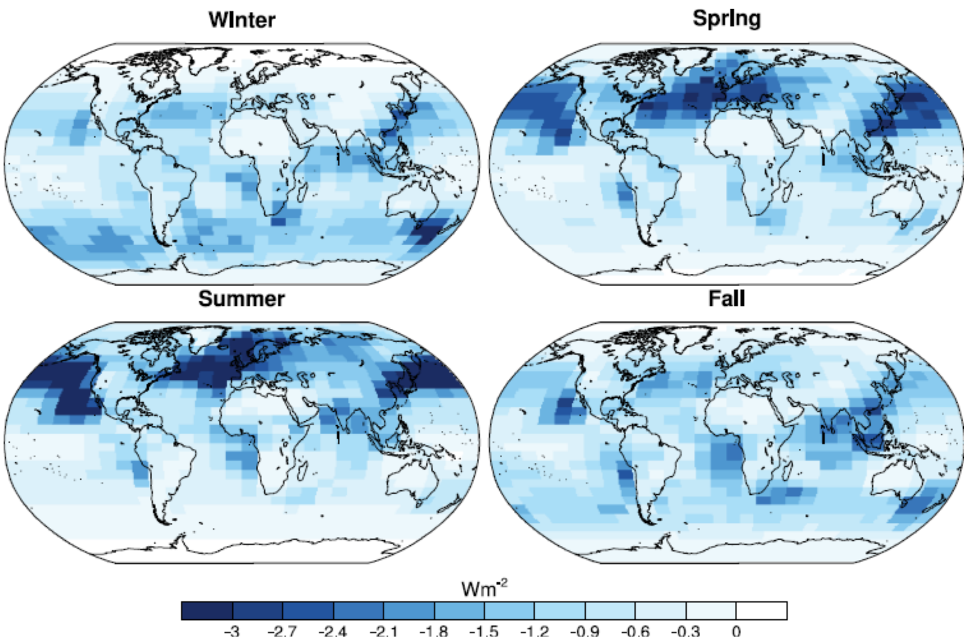

Figure 2. Calculated seasonal indirect effects (via water cloud modifications) by anthropogenic aerosol

The cooling is stronger during the summer (longer sunshine hours) and usually located, where low altitude clouds are not obscured by higher altitude clouds. Also note, that the indirect cooling at about -0.9 W/m2 is globally much stronger than the global average direct cooling at about -0.3W/m2.

To make such studies work, we first need to establish important and needed relationships. This involves use of data from CCI aerosol and cloud retrieval groups in efforts to match these data.

- ATSR (potential collaborations/sources are RAL (Matt C., Caroline P.) and FMI (Larissa S.))
- IASI data (potential collaborations/sources are LMD (Virgine C,. Claudis S.)
- SEVIRI data – using the unique high temporal resolution (Y.Goevaerts, DWD?)

Considered relationships are:

- cloud rad. impact (CERES) vs fine-mode AOD (or AOD*Ang): overall aerosol impact on clouds
- CDNC (or drop radius) changes vs fine-AOD: 1st indirect effect, delayed precip (init >15um)
- (effective) cloud cover vs fine AOD: 2nd indirect (cloud lifetime) effect
- ice cloud cover / microphysics vs dust AOD (and T): indirect effect for high altitude clouds

MPI-M will collect those data and establish useful relationships and subsequently interpret these relationships with their off-line radiative transfer code.

Study 4: Assimilation of Aerosol_cci IASI Dust AOD into the NMMB/BSC-Dust model (BSC / ES)

Sara Basart, Enza Di Tomaso, BSC

Summary. The proposed study will showcase the potential of assimilating dust AOD observations from IASI into a dust forecast model. It will evaluate the usefulness of Aerosol_cci products for mineral dust simulations, and the benefit of dedicated dust observation products from satellite in the range of Aerosol_cci products. The study will furthermore assess the

potential benefit of using aggregated dust information from the full range of Aerosol_cci IASI dust products compared to the use of single products. The usage of observations through data assimilation has improved significantly in the recent decade the characterisation and prediction of atmospheric constituents. However, in the case of aerosols, data assimilation often influences only total aerosol fields as the system is not always able to constrain correctly the concentrations of the individual components. The lack of information on aerosol speciation can, in some cases, produce wrong AOD attributions in the analysis field. The Aerosol_cci IASI dust AOD has the potential to provide a valuable constrain, at a global scale, to mineral dust, a prominent type of aerosol. This will be relevant for the forecast of atmospheric concentrations and surface depositions, but also for the monitoring of past and current state of mineral dust, one of key players of the Earth system. In this study Aerosol_cci IASI dust AOD observations will be tested for assimilation into the Barcelona Supercomputing Center's NMMB/BSC-Dust model with an ensemble-based data assimilation technique that has shown to be particularly suitable for the assimilation of aerosol information.

Methodology. NMMB/BSC-Dust simulates dust mobilisation with a sophisticated physical-based emission scheme, and models dust transport using a 8 bin sectional approach. A further highly valuable characteristic of this model is its ability to switch dynamically from the hydrostatic to the non-hydrostatic mode according to the horizontal grid resolution, hence to bridge the gap among the multiple scales involved in the dust cycle. We will use a version of this model coupled with an ensemble-based technique known as Local Ensemble Transform Kalman Filter (LETKF) in order to estimate optimal initial conditions for the dust model. A very attractive feature of an ensemble-based technique is the usage of a flow-dependent background error covariance, which is derived from the ensemble of model states at the assimilation time, and evolves during forecast. LETKF has the further advantageous feature that it performs the analysis locally, allowing the global analysis to explore a much higher-dimensional space than the subspace spanned by the ensemble. This scheme has shown to be particularly suitable for the assimilation of aerosol information since it has been observed that aerosol fields have limited spatial correlations.

Description of work. A series of global dust simulations will be used for assimilating global Level-3 IASI dust AOD from Aerosol_cci at 1° resolution. The proposed experiment time would be a summertime period when the majority of dust sources are more active. The background model ensemble perturbations will be based on known uncertainties in the physical parametrisations of the emission scheme, as uncertainty in the emission term is particularly high for mineral dust modelling. A spin-up period for the ensemble will ensure that perturbations applied at the sources propagate towards outflow regions. Model simulated observations will be calculated with an observation operator based on assumed bulk optical properties of dust particles. At each model grid point only observations within a certain distance will be assimilated, and a suitable value of the localisation factor should be determined. As four retrieval groups contribute to the set of IASI dust products within Aerosol_cci, the assimilation experiments will be run for each of the IASI products alone as well as for an Aerosol_cci aggregated IASI dust AOD product to be provided by the Aerosol_cci consortium. Furthermore, the control simulations will be a standard forecast and a free-run ensemble with no data assimilation to check that the ensemble perturbations are not altering the model mean state as defined by a standard run. The IASI dust information from Aerosol_cci will include the following parameters: latitude, longitude, time, dust AOD at 550nm, and uncertainty of dust AOD at 550nm. Assumptions on AOD uncertainty will be particular critical as the performance of data assimilation is very sensitive to the error statistics specifications. The Aerosol_cci consortium agreed to support the data provision and data handling of IASI dust observations and to interact with the data assimilation team in this use case study. Data assimilation experiments will be evaluated in terms of statistics of the departures of the analysis and first-guess from the assimilated IASI retrievals, and through a comparison with independent, not assimilated observations from ground based stations. Additionally, the dust forecast up to 5 days ahead will also be validated in order to assess the impact in the short-term of initializing the model with the Aerosol_cci IASI dust analysis.

Expected results of the study will comprise

- the description of the usability of Aerosol_cci products for data assimilation purposes,
- the feedback from the assimilation team into the group of product developers by close interaction,
- the description of the impact of the different dust AOD products on simulation results,
- guidelines for the future development of dedicated dust observation products tailored for data assimilation.

3.2. Problem Areas and Technical Constraints (Section 2.8 of the Statement of Work)

Since Aerosol_cci2 datasets are already available, these user case studies carry no risk of unavailability of input data.

3.3. Improving on the results of phase 1 (Section 2.7 of Statement of Work)

The main goal of those additional user case studies is to strengthen the demonstration of the usefulness of Aerosol_cci2 datasets.

3.4. Links to the International Climate Research Community (Section 2.6 of Statement of Work)

All involved users have an important role in international communities working with aerosol modelling. The new partner Barcelona Supercomputing Center is responsible for the WMO Sand and Dust Storm Warning and Alert System of Europe / Africa.

3.5. Scientific Impact

The user case studies will analyse the added value and strengths and weaknesses of Aerosol_cci datasets for their application purposes.

3.6. Validation and User Assessment

The user case studies deal with different applications of Aerosol_cci datasets (data assimilation, model validation, trend analysis, aerosol cloud effects).

3.7. Data Procurement Plan for all Data (EO and In-Situ)

None for those studies.

3.8. Coordination with on-going and Complementary Activities

As in the baseline project.

4. Management & Administration proposal

4.1. Involvement of Climate Research Community

The partners conducting the user case studies are core users of the baseline project (MPI-C, MPI-M, MetNo) or new users (BSC) all with strong links to specific user communities.

4.2. Consortium composition

MPI-C, MPI-M, MetNo, BSC: user case studies.

DLR: management and coordination with the main project.

The other partner descriptions have been provided with the baseline proposal except for BSC.

The **Barcelona Supercomputing Center (BSC)** is the Spanish national supercomputing facility and a hosting member of the PRACE distributed supercomputing infrastructure. The Center houses MareNostrum, one of the most powerful supercomputers in Europe. The mission of BSC is to research, develop and manage information technologies in order to facilitate scientific and societal progress. BSC also hosts other high-performance computing systems such as MinoTauro, one of the most energy efficient supercomputers in the world.
The Earth Sciences Department is one of the four BSC departments and has the goal to apply the latest advances of high performance computing and big data to Earth system modelling. The Department is organized around four closely interacting groups: Atmospheric Composition, Climate Prediction, Computational Earth Sciences, and Earth Sciences Services. The Atmospheric Composition group aims at better understanding the chemical composition of the atmosphere and its effects upon air quality, weather and climate, while improving predictions from local to global scales. This goal is addressed through the development and use of the NMMB/BSC Chemical Transport Model (NMMB/BSC-CTM; http://www.bsc.es/earth-sciences/nmmbbsc-project), an online multi-scale non-hydrostatic chemical weather prediction system that can be run either globally or regionally.
A core activity of the group is mineral dust modelling and forecasting from regional to global scales. As a result of this expertise, BSC hosts, in collaboration with the Spanish meteorological agency (AEMET), both the Regional Center for North Africa, Middle East and Europe of the WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS; http://sds-was.aemet.es/), and the WMO first Regional Specialized Meteorological Center with activity specialisation on Atmospheric Sand and Dust Forecast, known as the Barcelona Dust Forecast Center (http://dust.aemet.es/).

4.3. Facilities

See baseline proposal for the other partners.

BSC hosts MareNostrum, the most powerful supercomputer in Spain and one of the most powerful supercomputers in Europe, which will be used as the main computing facility for the executions required by the project. MareNostrum is part of the PRACE Research Infrastructure as one of the 6 Tier-0 Systems currently available for European scientists. It is based on Intel SandyBridge processors, iDataPlex Compute Racks, a Linux Operating System and an Infiniband interconnection. It has a peak performance of 1,1 Petaflops, with 48,896 processors in 3,056 nodes, and 84 Xeon Phi 5110P processors in 42 heterogeneous compute nodes, with more than 115 TB of main memory. Following an ongoing upgrade, the GPFS disk storage and the Active Archive will reach respectively 3 and 7 Petabytes of capacity.

4.4. Key Personal

Table 1: Key personnel

Name	institute	country	option	% involvement
M. Schulz	MetNo	NO	11	10
S. Kinne	MPI-M	D	11	10
K. Klingmüller	MPI-C	D	11	10
S. Basart	BSC	ES	11	5
E. di Tomaso	BSC	ES	11	5

5. Implementation proposal (for all options)

5.1. List of Option Deliverable Items

List of Deliverable Items

Deliverables				
No.	**deliverable**	**option**	**editor**	**schedule (Mo is option start)**
O11.1	User case study interim presentation: study 1	11	M. Schulz	M8
O11.2	User case study interim presentation: study 2	11	K. Klingmüller	M8
O11.3	User case study interim presentation: study 3	11	S. Kinne	M8
O11.4	User case study interim presentation: study 4	11	S. Basart	M8
O11.5	User case study report + presentation: study 1	11	M. Schulz	M14
O11.6	User case study report + presentation: study 2	11	K. Klingmüller	M14
O11.7	User case study report + presentation: study 3	11	S. Kinne	M14
O11.8	User case study report + presentation: study 4	11	S. Basart	M14

Work package forms

WORK PACKAGE DESCRIPTION

PROJECT: Aerosol_cci Phase 2	PHASE: Year 3	WP: Option 11
WP Title: Additional user case studies Company: DLR WP Manager: M. Kosmale Start Event: option start End Event: project end	 Planned Date: 01/05/2016 Planned Date: 30/06/2017	Sheet 1 of 1 Issue Ref Proposal v4.0 Issue Date 1/3/2016
Inputs: Aerosol_cci2 datasets at end of year 2 **Tasks**: All: conduct user case studies as described in the technical proposal MetNo: Trends in natural aerosol from ATSR and IASI MPI-C: Use of Aerosol_cci datasets for model development MPI-M: Linking satellite retrievals of aerosols and clouds BSC: Data assimilation of IASI dust AOD **Outputs**: User case study report Presentations at progress meeting and user workshop Scientific publication		