Determination of Atmospheric Aerosol Properties Using Satellite Measurements

Abstracts

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Aerosol optical depth and air mass mapping with satellite multi-angle imaging

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Among the strengths of the NASA Earth Observing System's Multi-angle Imaging SpectroRadiometer (MISR) are (1) its multi-angle sampling of atmospheric air-mass factors ranging from one to three, offering sensitivity to optically thin aerosol layers, and making it possible to retrieve aerosol optical depth even over bright land surfaces, and (2) the very large range of scattering angles captured -- between about 60˚ and 160˚ at mid latitudes -- providing constraints on particle size and shape. Using MISR hyper-stereo observations, aerosol plume height is retrieved, to a fraction of a kilometer, based solely on geometric considerations. Taken together, these capabilities make it possible to analyze the behavior of major, over-land aerosol sources, and to map aerosol air mass types and trace their evolution.

This talk will present some of the latest results of MISR aerosol amount and type mapping, for example, in the heavily populated Mexico City region during the INTEX-B /MILAGRO field campaign in spring 2006, and in the complex, mixed desert dust and pollution environment of the Arabian Gulf during the UAE2 campaign in late summer, 2004. Progress on reconstructing air mass development, based on satellite and *in situ* observations, combined with regional-scale modeling, will also be discussed.

Simultaneous retrieval of aerosol and surface optical properties using Multi-angle Imaging SpectroRadiometer (MISR) Data

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The operational aerosol product of the Multi-angle Imaging SpectroRadiometer (MISR) is available only for a grid cell size of 17.6 km. This spatial resolution is too coarse for studies in complex terrains like Switzerland. An algorithm for retrieving simultaneously aerosol and surface optical properties at a resolution of 1.1 km was developed. It uses MISR subregion radiance data of the 9 cameras and 4 spectral bands to generate characteristic functions $\rho_{\mathrm{surf}} = f_{,cam}(\sigma_{\mathrm{e}}(550\ \mathrm{nm}))$, where σ_{e} (550 nm) and ρ_{surf} are the ground level aerosol extinction coefficient at 550 nm and the surface reflectance, respectively. The analysis of the mutual intersections of those functions yield optimum values for σ_{e} (550 nm), aerosol optical depth (AOD) at 550 nm and ρ_{surf}. MODTRAN 4 v3r1 was used to create radiance look-up tables. The algorithm was tested for MISR paths covering Switzerland and northern Italy. Results of two days (low and high aerosol loads on May 14 and June 17, 2002, respectively) were analyzed and compared with sun-photometer measurements. First, ground level aerosol extinction coefficients and optical depth over water were derived. From those data it was possible to retrieve a best-fit aerosol mixture. AOD (550 nm) over water is in satisfactory agreement with both sun-photometer data and the operational aerosol product of MISR. Second, the Ross-Li approach for the bidirectional reflectance factor (BRF) supported by MODTRAN 4 was applied to simulate the radiance over vegetation surfaces. In this case the retrieved aerosol extinction coefficients and optical depths over vegetation are significantly lower than the values derived over water. We assume that the incomplete coupling of BRF and radiation in MODTRAN 4 is at least partly responsible for this discrepancy.

Aerosol remote sensing from the PARASOL mission and the A-train

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Since December 2004, the CNES Parasol (Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar) mission is flying in the A-train with Aqua and Aura (NASA), further completed in 2006 by Calipso (NASA/CNES) and CloudSat (NASA/CSA). Parasol carries a wide-field imaging radiometer/polarimeter designed to improve the knowledge of the radiative and microphysical properties of clouds and aerosols.

Simultaneous AERONET measurements and aerosol retrievals from PARASOL and MODIS/Aqua are compared. Advantages of each instrument are described. For instance, by measuring the directionality and polarization of light reflected by the Earth-atmosphere system, PARASOL can detect non-spherical particles within the coarse mode, which is not the case for MODIS. Simulations of MODIS measurements from PARASOL inverted aerosol models are also performed (cross-simulations). Directional and polarized informations from PARASOL with simultaneous MODIS spectral data can also be combined to retrieve more accurately aerosol optical properties. Results from the joint inversion scheme are compared.

These A-Train satellites for the first time ever combine a full suite of instruments for observing aerosols, from passive radiometers to active sounders. The lessons learned from these exercises allow to show the benefit from the synergy between sensors.

Retrieval of aerosol properties over land surfaces: capabilities of multiple-viewing-angle intensity and polarization measurements

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We will present an investigation of the capabilities of various instrument concepts for the retrieval of aerosol properties over land. It will be demonstrated that, if the surface reflection properties are unknown, only multiple-viewing-angle measurements of both intensity and polarization are able to provide the relevant aerosol parameters with sufficient accuracy for climate research. Furthermore, retrieval errors are only little affected when the number of viewing angles is increased at cost of the number of spectral sampling points, and vice versa. This indicates that there is a certain amount of freedom for the instrument design of dedicated aerosol instruments. The final choice on the trade-off between spectral sampling and the number of viewing angles should be made taking into account other factors, such as instrument complexity and the ability to obtain global coverage.

Improvements in AOD estimation using multi-angle CHRIS/PROBA images

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A method has been developed to estimate Aerosol Optical Depth (AOD) over land surfaces using multi-angle CHRIS/PROBA images. The CHRIS instrument is mounted aboard the PROBA satellite, and provides up to 62 bands. The PROBA satellite allows pointing to obtain imagery from five different view angles within a short time interval. The method uses inversion of a coupled surface/atmosphere radiative transfer model, and includes a general physical model of angular surface reflectance. An iterative process is used to determine the optimum value of providing the best fit of the corrected reflectance values for a number of view angles and wavelengths with those provided by the physical model. This method has previously been demonstrated on data from the Advanced Along-Track Scanning Radiometer (AATSR), and is extended here to the spectral and angular sampling of CHRIS/PROBA. The values obtained from these observations are validated using the Aerosol Robotic Network (Aeronet) and it is expected that an improved estimate of AOD will be provided not only over dark vegetation but also over desertic and maritime scenarios.

Dual-view aerosol retrievals from AATSR using the Oxford-RAL Aerosol and Cloud (ORAC) optimal estimation algorithm

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The Oxford RAL Aerosol and Cloud (ORAC) retrieval scheme is an optimal estimation retrieval scheme for deriving cloud and aerosol properties from visible/IR satellite radiometers. Thus far it has been successfully applied to ATSR-2, AATSR and SEVIRI data in the GlobAEROSOL and GRAPE projects, however, the algorithm as applied in these projects does not take advantage of the dual-view capability of the ATSR instruments. In the case of aerosol retrievals in particular, this results in the accuracy of the retrieval being limited by the accuracy of the a priori surface reflectance used in the retrieval - an especially critical factor over land.

This limitation has been reduced in three ways:

- The way in which the surface reflectance is represented in the retrieval has been improved.
- A dual (or multiple) view capability has been introduced into the algorithm.
- Thermal infrared channels have been included in the retrieval to improve the detection of dust above desert surfaces.

This talk will give an overview of how these improvements have been implemented and present example results to demonstrate the changes from the single view, visible/near-IR method.

Towards a 12-year record of global aerosol properties from ATSR-2 and AATSR

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Aerosols have a significant influence on the Earth's radiation budget, but there is considerable uncertainty in their effect on the Earth's climate. Currently, considerable effort is going into using satellite remote sensing in order to improve our understanding of the effect of atmospheric aerosols on the climate system. To this end, we are producing a global dataset of aerosol properties from the ATSR-2 (Along-track Scanning Radiometer) and AATSR (Advanced Along-track Scanning Radiometer) missions. Together this represents a dataset spanning nearly 12-years from 1995 to the present, on top of which the AATSR mission is scheduled to continue until 2010. Atmospherically-corrected surface reflectance is also generated allowing quantitative analysis of the land surface properties. We use a simple physical model of light scattering to retrieve surface bi-directional reflectance and atmospheric aerosol properties. From the dual-angle top-of-atmosphere reflectances both the spectral and angular information can be used to solve the inverse problem and enable separation of the atmospheric and surface scattering contributions to the observed signal. For computational efficiency, the software uses pre-calculated lookup tables derived from an atmospheric radiative transfer model to allow for rapid inversion. Although the software is computationally efficient, the large volume of AATSR data in the archive makes this a substantial processing requirement. Thus we rely on a high performance computing facility to enable us to perform large-scale processing with high data throughput at global-scales. The key output products will include surface reflectance and aerosol optical depth at 550 nm. Surface reflectance is retrieved for every 1km pixel corresponding to the top-of-atmosphere observations, while AOD is produced on a 10 by 10 km grid. After validation against sun-photometer measurements and other satellite instruments such as PROBA/CHRIS, ICESAT/GLAS, MODIS and MISR these datasets will be made available to ESA and to other scientists.

Aerosol retrieval over land using the dual-view AATSR algorithm

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The dual view of the Advanced Along Track Scanning Radiometer (AATSR) allows for the accurate retrieval of aerosol properties over land. Algorithms have been developed in which these two views are used to eliminate the influence of the land surface reflectance on the top of the atmosphere radiation. The algorithm uses the AATSR IR and visible wavebands for cloud detection and the visible and NIR wavebands for aerosol retrieval. The retrieval is based on minimizing the error function between modeled and measured TOA reflectances, using all available wavelengths. The TOA reflectances are modeled for a variety of aerosol mixtures. Hence, both the aerosol optical depth at various wavelengths (and thus the Ångström coefficient) and the dominant aerosol types can be determined. The results are evaluated by comparison with independent data: sun photometers and, when available, aerosol composition. The dual view algorithm has been developed as a scientific algorithm for case studies and has been transformed into a ‘quasi-operational’ algorithm to allow for the processing of large data sets. However, several problems were revealed by comparison with MODIS and AERONET data. In particular a stricter cloud screening has been implemented and spatial variations are used to detect erroneous retrieval results. This leads to enormous improvements and the 2003 data over Europe used in the past to determine correlations between satellite AOD and PM2.5 are re-processed. Furthermore, the use of the dual view algorithm for the detection of the influence of aerosol formation on the optical properties is explored. The dual view algorithm is also used to explore the synergy between AATSR and MSG-SEVIRI over land, to couple accurate aerosol retrieval to high temporal resolution.

Global retrieval of aerosol properties over land from MODIS and SeaWiFS

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Among the many components that contribute to air pollution, airborne mineral dust plays an important role due to its biogeochemical impact on the ecosystem and its radiative-forcing effect on the climate system. Due to the relatively short lifetime (a few hours to about a week), the distributions of these airborne dust particles vary extensively in both space and time. Consequently, satellite observations are needed over both source and sink regions for continuous temporal and spatial sampling of dust properties. However, despite their importance, the high spatial resolution satellite measurements of dust near its source have been lacking.

In this paper, we will demonstrate the capability of a new satellite algorithm to retrieve aerosol optical thickness and single scattering albedo over bright-reflecting surfaces such as urban areas and deserts. Such retrievals have been difficult to perform using previously available algorithms that use wavelengths from the mid-visible to the near IR because they have trouble separating the aerosol signal from the contribution due to the bright surface reflectance. The new algorithm, called Deep Blue, utilizes blue-wavelength measurements from instruments such as SeaWiFS and MODIS to infer the properties of aerosols, since the surface reflectance over land in the blue part of the spectrum is much lower than for longer wavelength channels.

We have validated the satellite retrieved aerosol optical thickness with data from AERONET sunphotometers over desert and semi-desert regions. The comparisons show reasonable agreements between these two. These results also indicate that the coarse mode particles can be distinguished from the fine mode particles using the Deep Blue products. These new satellite products will allow scientists to determine quantitatively the aerosol properties near sources using high spatial resolution measurements from SeaWiFS and MODIS-like instruments.

Multispectral aerosol optical depth retrievals from high-resolution satellite imagery

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The advancement and proliferation of high-resolution commercial imaging satellites presents a new opportunity for overland aerosol characterization. Current aerosol optical depth retrieval methods typically fail over areas with high surface reflectance, such as urban areas and deserts, since the upwelling radiance due to scattering by aerosols is small compared to the radiance resulting from surface reflection. The method demonstrated here uses shadows cast on the surface to exploit the differences between radiance from the adjacent shaded and unshaded areas of the scene. Shaded areas of the scene are primarily illuminated by diffuse irradiance that is scattered downward from the atmosphere, while unshaded areas are illuminated by both diffuse and direct solar irradiance. Given uniform surface reflectance for the shaded and unshaded areas, the difference in reflected radiance measured by a satellite sensor is related to the direct transmission of solar radiation. Aerosol optical depth can then be determined from its contribution to the total atmospheric optical depth following correction for molecular Rayleigh scattering. Results based on QuickBird imagery of several sites of varying surface and aerosol type will be presented and compared with ground truth from nearby AERONET measurements. Analysis of particle size from the full spectral retrievals will also be discussed.

The retrieval of spectral aerosol optical thickness over land using MERIS observations with respect to the determination of particulate matter

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An estimation of quantitative information on particulate matter from space-borne observations requires more than a retrieval of one value of an aerosol optical thickness (AOT). The determination of PM10 from AOT needs: the particle size distribution, the aerosol concentration for a given size distribution, the height of the planetary boundary layer (PBL), the fraction of AOT within the PBL, the humidity status of the aerosol. Although meteorological parameters, like PBL height and relative humidity need to be contributed from prediction or analytical forecast models, the required columnar information on size and concentration need to be determined from a retrieval of spectral AOT over land.

Bremen AErosol Retrieval (BAER) separates the spectral aerosol reflectance from surface and Rayleigh path reflectance for the short wave range of the measured spectrum of top-of-atmosphere reflectance less than 0.670 µm. The advantage of MERIS is the existence of several spectral channels in the blue and visible range enabling the spectral determination of AOT in 7 channels (0.412 – 0.670 µm) and additionally channels in the NIR, which can be used to characterize the surface properties. A dynamical spectral surface reflectance model for different surface types is used to obtain the spectral surface reflectance for this separation. Normalized differential vegetation index (NDVI), taken from the satellite observations, is the model input. Spectral AOT is obtained from aerosol reflectance using look-up-tables, obtained from radiative transfer calculations with given aerosol phase functions and single scattering albedo either from aerosol models, given by OPAC or from experimental campaigns. Validations of the obtained AOT retrieval results with AERONET data over Europe gave a preference for experimental phase functions derived from almucantar measurements.

Aerosol properties from OMI using the multi-wavelength algorithm

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The Ozone Monitoring Instrument (OMI) is an imaging UV-VIS solar backscatter spectrometer. It is a Dutch-Finnish instrument onboard the NASA satellite EOS-Aura which has been launched in July 2004. The OMI mission has yielded more than 2 years of science data including global data sets of various atmospheric parameters with high spatial resolution on a daily basis. In this contribution we present the multi-wavelength retrieval algorithm used to retrieve aerosol parameters from OMI measurements. This retrieval algorithm uses up to 19 wavelength bands between 331 nm and 500 nm including a band at 477 nm comprising an absorption band of O_2-O_2. This absorption band has been included in order to increase the amount of information on the aerosol vertical distribution. A principle component analysis shows that OMI measurements have 2 to 4 degrees of freedom of signal, which for cloud free scenes can be attributed to aerosol parameters. The aerosol optical thickness is retrieved for a set of aerosol models and the best fitting aerosol model is determined, which provides information about aerosol properties such as the single-scattering albedo. The algorithm is capable to distinguish between absorbing aerosol types, such as desert dust and biomass burning, and weakly absorbing aerosols like sea-salt and sulphates. We show retrieved aerosol parameters for various scenes. Furthermore we show how the aerosol vertical distribution available from spaceborne lidar instruments (e.g. CALIPSO) can be used in the OMI retrievals.

Dust aerosol optical depth retrieval over desert surface, using the SEVIRI window channels

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Dust aerosols have a significant impact on the earth radiation budget. The aerosol direct radiative forcing is correlated with enhanced optical thickness. Therefore it is useful to retrieve the optical thickness of dust aerosols over desert for assessing the aerosol effect.

Dust aerosols have an impact in the thermal infrared wavelengths, what allows to detect aerosols over desert surfaces. To retrieve the aerosol properties over land we have to take into account the surface contribution. The surface radiation depends on the skin temperature, which is characterized by a strong diurnal variation. Therefore it is better to use the surface emissivity, which we assume constant over a time span of 24 hours.

The surface emissivity is based on clear sky observations that are corrected for atmospheric extinction and emission. The clear sky image is a composite of pixels that are characterized by the lowest brightness temperature difference between the SEVIRI channels at 8.7 and 10.8 µm. Due to the low desert surface emissivity at 8.7 µm we can assume that the selected pixel values are obtained for a clear sky day.

We use a forward model to simulate the thermal infrared radiation transfer in the dust layer. The apparent surface emissivity in the presence of aerosols is calculated as a function of the geometric angles, the surface emissivity, and the aerosol optical depth (AOD). This is stored in lookup tables (LUT) that are inverted to retrieve the AOD from the apparent surface emissivity.

The retrieval algorithm consists of firstly: processing of the clear sky image and computation of the surface emissivity, secondly: processing of the instantaneous image and computation of the apparent surface emissivity, and thirdly: selection of the corresponding LUT and retrieval of the AOD that matches to the observed apparent surface emissivity.

Benefits and limitations of synergetic aerosol retrieval

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At DLR-DFD a new synergetic aerosol retrieval method was developed (Holzer-Popp et al., JGR 2002), which exploits the complementary information of a radiometer and a spectrometer onboard one satellite platform to extract aerosol optical depth (AOD) and speciation (as choice from a representative set of 40 pre-defined mixtures of water-soluble, soot, mineral dust, and sea salt components). Whereas the radiometer (e.g. AATSR) is used to quantify the AOD and surface brightness through a dark field technique, the spectrometer (e.g. SCIAMACHY) is applied to choose the most plausible aerosol type through a least square fit of the measured spectrum with different simulations. Recently, a first larger dataset covering over 2000 ENVISAT orbits over Europe and Africa from 2003 to 2006 has been processed. With this dataset a thorough evaluation of the results against multi-spectral ground-based observations from AERONET has been started. This validation effort so far shows the potential to estimate the aerosol type from space (AOD error around 0.1 from UV to NIR, which is in perfect match with the expected noise level for the exploited pixel size), but also reveals cases of large AOD errors. Suspected reasons for these are surfaces with higher albedo and cases, where the sun-photometer observation is not representative for the satellite pixel of $60x30\,km^2$. In parallel, several parts of the retrieval methodology have been assessed in more detail to better understand these issues. This includes a stringent analysis of the information content for different surface-atmosphere conditions and illuminations as well as the investigation of airborne surface spectra to improve the dark field treatment. The overall goal is a refinement of the methodology to improve its accuracy and better characterize its limitations. Preliminary results of this refinement effort will be summarized and discussed.

The determination of aerosol optical thickness over Germany using different satellite algorithms and instruments: a case study

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An inter-comparison of the aerosol optical thickness (AOT) at 0.55 µm retrieved using different satellite instruments and algorithms based on the analysis of backscattered solar light is performed for a single scene over Germany (7-12E, 49-53N) on October 13th, 2005(10:00-13:30UTC depending on the instrument used). The scene covers a densely populated area of central Europe with Nurnberg at the southern and Bremen at the northern boarder of the scene. A large portion of the scene includes hills covered by forest (e.g., Harz). In addition, agricultural areas covered by vegetation and also bare soil are present in the scene studied. It is found that on the scale of a single pixel there can be large differences in AOT retrieved over land using different retrieval techniques and instruments. However, these differences are not as pronounced for the average AOT over land. For instance, the average AOT at 0.55µm for the area 7-12E, 49-53N was equal to 0.14 for MISR, NASA MODIS and POLDER algorithms. It is smaller by 0.01 for the ESA MERIS aerosol product and larger by 0.04 for the MERIS BAER algorithm. AOT as derived using AATSR gives on average larger values as compared to all other instruments, while SCIAMACHY retrievals underestimate the aerosol loading. These discrepancies are explained by uncertainties in a priori assumptions used in the different algorithms and differences in the sensor characteristics. MERIS retrievals gave AOTs closest to those measured by ground-based sunphotometers operating in the scene under study at the moment of satellite measurements.

Evaluation of global aerosol properties in the MODIS Collection 5 products

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Accurate determination of global and regional aerosol effects on the radiation budget requires accurate and complete characterization of Earth's global aerosol budget. Aerosol retrievals from satellite observations provide the most comprehensive spatial picture of global aerosol. Of the many satellite–derived products, those from the MODerate resolution Imaging Spectro-radiometer (MODIS) have received the most attention in the literature. Although MODIS products (Collection 4, C004) were validated with ground-based sunphotometers, there were systematic biases to aerosol optical depth (AOD) over the land (especially in near-clean conditions) and to fine aerosol weighting (FW) over the ocean. The separate algorithms (over dark land and over non-glint ocean) were each systematically evaluated, suggesting a complete overhaul of the over land algorithm and a significant change to that over-ocean. Over-land algorithm improvements include: new assumptions and lookup tables for expected global aerosol properties, a new surface reflectance parameterization, a new technique of multi-channel inversion, and a change in philosophy for reporting near zero AOD conditions. The primary change to the over-ocean algorithm is in its assumptions of coarse mode aerosol refractive indices. As of early this year, the entire MODIS mission (from Terra since February 2000 and Aqua since June 2002) had been re-processed using the two separate algorithms (products known as Collection 5, C005). Performing spatial-temporal averaging with regards to AERONET observations, we find that over land, C005-derived AOD (at 0.55 μm) regresses to AERONET as $y = 0.024 + 0.942x$, $R^2 = 0.76$, with over ocean (generally near coastlines) regressing as $y = 0.021 + 0.968x$, $R^2 = 0.83$. While C005-derived FW over land is not yet robust, FW over ocean (compared to AERONET spectral de-convolution) regresses as $y = 0.324 + 0.61x$, $R^2 = 0.57$. In addition to better comparison with sunphotometers, the two separate algorithms provide realistic continuity of AOD from ocean to land. In terms of global averaged properties, C005 estimates (compared to C004) over-land AOD of ~0.21 (25% decrease), over-ocean AOD of ~0.135 (3% increase) and over-ocean FW of ~0.45 (20% decrease). The AOD decrease over land is extremely significant, so that MODIS-based estimates of over-land aerosol direct radiative effect would be reduced by 25%, or about 0.7 Wm^{-2}. Since the entire MODIS mission has been processed with the same algorithms, with consistent instrument calibration, it is becoming possible to evaluate the presence and significance of aerosol trends.

Towards an AOD climatology by combing the strengths of different remote sensing techniques

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An adequate global distribution of aerosol properties is essential for estimates of the aerosol impact on climate. With new aerosol dedicated space sensors many aerosol data-sets are offered during the last decade, in particular for the most important aerosol property, the aerosol optical depth (AOD). Unfortunately, differences among AOD retrievals (even for highly averaged monthly statistics) are on the order of the retrieved value. This is explained mainly by retrieval differences, as they are tied to specific sensor capabilities and to necessary a-priori assumptions (e.g. aerosol absorption, back-ground reflection). In other words satellite retrievals have different regional and seasonal strengths. Or alternatively, weaknesses often do not allow for globally (and temporarily) complete coverage. Thus, the overall goal is to combine individual strengths of different statistics into an AOD data-set which is superior to any single AOD retrieval in accuracy as well as spatial and temporal coverage. The overall concept is to combine superior retrieval choices based on statistical analysis (e.g. bias, error) compared to quality references by statistics from ground sun-photometry, into single satellite retrieval composites. Choices for retrievals are based on multi-annual monthly statistics for mid-visible AOD by MODIS (collection 5), MISR, TOMS, POLDER and for several AVHRR retrievals.

Recent aerosol trends from long-term global aerosol climatology project satellite record

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Analysis of the long-term Global Aerosol Climatology Project dataset reveals a likely decrease of the global optical thickness of tropospheric aerosols by as much as 0.03 during the period 1991–2005. This recent trend mirrors the concurrent global increase in solar radiation fluxes at Earth’s surface and may have contributed to recent changes in surface climate. The unique advantage of the AVHRR dataset over the datasets collected with more advanced recent satellite instruments is its duration, which makes possible the detection of statistically significant tendencies like the substantial decrease of the global tropospheric AOT between 1991 and 2005. This change is consistent with long-term atmospheric transmission records collected in the Former Soviet Union and recently published analysis of MODIS data.

Our analysis shows that the observed changes are not distributed uniformly. While the majority of the open ocean areas experienced a reduction in aerosol optical thickness compared to pre-Pinatubo period significant increases were observed in Indian Ocean and off the coast of China. Higher aerosol loads also were found in middle latitudes of the Southern Hemisphere.

Neither AVHRR nor other existing satellite instruments can be used to determine whether the recent AOT trend is due to long-term global changes in the natural or anthropogenic aerosols. This discrimination would only be possible with an instrument like the Aerosol Polarimetry Sensor (APS) scheduled for launch in December 2008 as part of the NASA Glory Mission.

Aerosol vertical profiles from the CALIPSO spaceborne lidar. Capabilities and first results

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The CALIPSO satellite is a collaborative effort between the US and the French space agencies, respectively NASA and Centre National d'Études Spatiales (CNES). It was launched on April 28, 2006 and carries a two-wavelength lidar at 532 and 1064 nm. The measurements permit the description of the aerosol backscatter profile at several wavelengths,. From the measurements, the vertical distribution of aerosols and clouds can be derived.

The data are rather noisy however, so that considerable averaging is necessary for a proper quantitative analysis of the data. We will present several applications of Calipso for the evaluation of aerosol transport models.

In particular, we have analyzed the Calipso data over regions of biomass burning activity. The height of the aerosol layers deduced from the lidar observations is compared to the mixing layer top diagnosed from numerical weather forecasts, to identify whether or not the aerosols are directly injected in the free troposphere. During July and August 2006, the best cases (limited cloudiness, high density of fires) are found over South Africa and Northern Australia. Over these regions, the top of the aerosol layer is close to the mixing layer height, which is a strong indication that the aerosols are injected within the mixing layer. Other tropical areas with biomass burning activity are more difficult to interpret but the valid data support the same conclusion. For higher latitudes regions with biomass burning activity, although several aerosol plumes are identified above the mixing layer, most of the load is within the mixing layer. These observations made over a limited period and set of regions indicate that cases with pyro-convection and/or direction injection to the free troposphere are not frequent.

We also analyze the vertical distribution of aerosol in transport models against that observed by the lidar in a few cases of long-range transport.

AMALi, the Airborne Mobile Aerosol Lidar, as a tool for the validation of CALIPSO in the Arctic region

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The Airborne Mobile Aerosol Lidar AMALi is used on board of the Polar 2 aircraft in the ASTAR (Arctic Study on Tropospheric Aerosol, Clouds and Radiation) campaign (Longyearbyen, Svalbard, March 26th to April 18th 2007) with the aim of validating the CALIPSO data. The satellite passes twice a day within the operation radius of the aircraft. The instrument is integrated in the aircraft in a zenith looking configuration. The flight altitude is between 100 m to 3000 m. Flight patterns are chosen along the satellite track for validation as well as perpendicular to the track to estimate the temporal and spatial variability of aerosol and cloud layers.

The AMALi system uses a Nd:YAG laser emitting both at a wavelength of 355 nm and 532 nm. It is able to detect the backscatter signal of both wavelengths, and additionally the cross-polarized signal at 532 nm with a vertical resolution of 7.5 m. The system covers the range of 250 m above the aircraft up to the tropopause level.

The AMALi specifications are well suited to compare data with the CALIOP lidar system on board of CALIPSO, which also utilizes the 532 nm wavelength in two polarization directions. First preliminary comparisons of CALIPSO quicklooks and AMALi data obtained during the ASTAR 2007 campaign are presented.

Validation of the OMI multi-wavelength aerosol product

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One of the science goals of the Ozone Monitoring Instrument (OMI) on board of EOS-Aura is to help answer the question "What is the role of aerosols in climate change?". To this end, properties such as the aerosol UV absorbing index and, for cloud-free scenes, aerosol optical thickness are derived from the near-ultraviolet and visible spectra that are measured by OMI. The application of ultraviolet spectra is especially useful since in that wavelength range, aerosol retrievals are less sensitive to surface albedo assumptions.

One of the OMI aerosol products makes use of the multi-wavelength algorithm. This algorithm extends the wavelength range employed by the proven TOMS algorithm to visible wavelengths including the 477-nm absorption band of the O2-O2 collision complex that is sensitive to aerosol altitude. This product has been provisionally released and is currently being validated. In this presentation, results of comparisons, both qualitative and quantitative, with AERONET ground-based observations, as well as with other satellite sensors will be shown.

The pixel-wise correlation between OMI and other satellite sensors, varies from good to relatively poor, depending on the region and the prevalent aerosol type. Comparisons with ground-based observations point out problematic areas and give clues for further improvement of the algorithm and its cloud-screening procedure. On the other hand, monthly regional averages generally show the same seasonal trends as similar observations from Aqua/MODIS and MISR and proves the quality of the OMI multi-wavelength aerosol algorithm.

Comparison of surface and satellite derived aerosol optical depth measurements in Finland

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When the reflectance of the ground is evaluated from satellite measurements, it is extremely important to know the contribution of the atmosphere, since satellites measure the backscattered radiance from the surface-atmosphere system. Attenuation of radiation in the atmosphere deteriorates the quality of satellite images of land surfaces, thus the effect of atmosphere has to be removed from the data. The effect of aerosols is especially challenging to estimate due to their large spatial and temporal variability. Aerosol optical depth (AOD) is a quantity which describes the amount of total aerosol attenuation (scattering and absorption). In this study AOD values calculated from the Moderate Resolution Imaging Spectroradiometer (MODIS) measurements are compared with AOD values measured with ground-based Precision Filter Radiometers (PFR) located in Sodankylä and Jokioinen. Comparisons are done over a long time-period and in a wide range of weather conditions. MODIS instruments are aboard the Terra and Aqua satellites. Terra MODIS and Aqua MODIS cover Earth's surface every 1 to 2 days. These instruments have 36 spectral bands and they measure near-nadir radiance over a 2300-km wide swath. The resolution of the measurements varies between 0.25 to 1 km. (Anderson et al., 2005). The PFR measures direct solar irradiance in four narrow spectral bands (862, 500, 412 and 368 nm). The resolution of the instrument is 5 nm.

The Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on board CALIPSO satellite, launched April 28th 2006, is a three-channel backscatter lidar. It is optimized for aerosol and cloud profiling. CALIOP transmits linearly polarized laser pulses at 532 nm and 1064 nm. The receiver at 1064 nm is insensitive for the polarization of the backscatter signal, whereas the receiver at 532 nm measures separately the components polarized perpendicular and parallel to the outgoing beam. The lidar measurement provides the vertical distribution of aerosols and clouds, cloud ice/water phase (via the ratio of signals in two orthogonal polarization channels), and a qualitative classification of aerosol size (via the wavelength dependence of the backscatter). CALIOP measures only at nadir providing a curtain of data along the orbit track. Maximum resolution is 30 m vertical and 300 m along-track(Winker and Hunt, 2004; Anderson et al., 2005) CALIOP has the advantage of not being seensitive to surface reflectance. Therefore AOD values, integrated from CALIOP-measured vertical profiles, are also included in the comparison.

Optimal estimation applied to multi-angular and multi-spectral data for the joint retrieval of aerosol load and surface reflectance: application to MSG/SEVIRI observations

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A new algorithm, based on the optimal estimation method, has been recently developed at EUMETSAT. This algorithm derives the mean daily tropospheric aerosol load and surface reflectance from observations acquired by the SEVIRI radiometer on-board the Meteosat Second Generation satellites. The aerosol load is calculated through the optical depth parameter, for various types of aerosols over land surfaces, and is inferred from the inversion of a forward radiative transfer model against daily accumulated observations in the 0.6, 0.8 and 1.6 μm SEVIRI bands. These daily time series provide the angular sampling used to discriminate the radiative effects that result from the surface anisotropy and from those caused by the aerosol scattering. The inverted forward model explicitly accounts for the surface anisotropy and the multiple scattering for the coupled surface-atmosphere system. The Optimal Estimation method provides a rigorous mathematical framework to combine satellite data, prior information on the observed system, and the modelling representation of that system. The retrieval error resulting from the measurement and forward model uncertainties can be explicitly calculated. A detailed analysis of the error covariance matrix will be shown together with some comparisons against AERONET observations.

SAMUM and satellite aerosol retrieval over Saharan regions with MERIS

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SAMUM (Saharan Mineral dUst experiMent) is a joint project of several German research institutes in cooperation with the Mohammed I. University of Oujda Morocco. Thereby DREAMS (Dust Aerosol Retrievals from Space-born Instruments) is a subproject and the contribution of the Institute of Environmental Physics of the University Bremen to the SAMUM main project. It is focused on the measurement and analysis of the effect of mineral dust from the Saharan desert on the atmospheric radiation budget. Combined satellite and ground based closures enable the determination of required aerosol characteristics for a remote sensing of aerosol optical thickness over bright surfaces. The SAMUM experiment, during May-June 2006, was conducted using two aircraft flying over two ground stations. One aircraft and one ground station was based at Ouarzazate airport (south of Morocco), the second aircraft operating from Casablanca airport, while the second ground station was located in the surroundings of Zagora at “Port au Sahara”. The following physical properties were measured during the experiment: AOT (Aerosol Optical Thickness) and phase function from sunphotometer measurements; Solar radiation (up- and downward irradiances); micro physical data of the dust particles (size distribution, shape, hygroscopicity), as well as their optical properties (scattering and absorption coefficients); standard meteorological data (temperature, humidity, air pressure). Various detectors for light and particles, meteorological radiosondes, and lidar instruments were used for this purpose. In desert regions in general the surface reflectance is very bright in the red part of visible spectrum and near infrared, however decreasing to blue range of spectrum in comparison to e.g. clouds or snow (i.e. wavelength lower 500 nm). The consideration of increased surface reflectance in lookup tables and the retrieval scheme enables a modification of the BAER approach (Bremen AErosol Retrieval) to extend its application to brighter regions. Examples of aerosol optical thickness derived using the BAER algorithm over the Sahara Desert reveal various dust sources, which are important contributors to airborne dust transported over long distances. The aerosol optical thickness and surface reflectance are determined simultaneously in the algorithm using lookup tables to match the satellite observed spectral top of atmosphere radiance. Reduced Resolution Level 1 data of the Medium Resolution Imaging Spectrometer (MERIS), which is an radiometer on the ENVISAT Satellite are used, giving top of atmosphere radiance at 15 channels in the wavelength range of 412 to 900 nm. The spatial resolution of the radiometer is 1 km reduced up to 300 m full resolved. First estimates of aerosol optical thickness over arid regions are obtained for the channel 1 (412 nm). The spectral behavior of the aerosol optical thickness depends strongly on assessed spectral surface properties and is subject of investigation.

Airborne measurement of the spectral surface albedo in Morocco

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Spectral measurements of the downwelling and the upwelling irradiance have been performed from an airborne platform during the SAMUM experiment 2006 in south-eastern Morocco. The spectral range covers the visible and most of the near-infrared portion of the solar spectrum (300 to 2200 nm). Various dust conditions have been covered, with aerosol optical thickness values ranging from 0.04 to 1.1. Different surface types to the west, east, and south-east of Ouarzazate have been overflown, and radiation has been measured at different altitudes within a dust plume. From irradiance data at relatively low aerosol optical thickness the spectral surface albedo is retrieved by an atmospheric correction algorithm. Geolocated results for the surface albedo are presented. Their possible contribution to the quality estimate of satellite retrievals of aerosol are discussed, as the surface albedo, its spectral dependence, and its spatial variability are issues that influence the top-of-atmosphere radiances. Satellite retrieval algorithms of aerosol are based either on certain assumptions about the spectral behaviour of the surface albedo or on the angular dependence of the surface reflecting properties, e.g., BRDF. In addition, irradiance measurements within dust plumes can be used for determination of the radiative forcing of Saharan dust, especially in combination with available irradiance measurements at surface stations.

Investigation of the Saharan dust events over Athens in the period 2000-2005

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This study focuses on Saharan dust (SD) events over Athens covering a 6-year (2000-2005) period on the basis of daily optical depth at 550 nm (AOD_{550}) and fine-mode (FM) fraction, derived from Terra-MODIS observations. Based on the AOD_{550}-FM relation, the cases satisfying the criterion AOD_{550}>0.3 and FM<0.6 are assumed to refer to coarse-mode aerosols, probably dust particles. Back-trajectories ending at Athens at 500, 1000 and 4000 m altitude were calculated by means of HYSPLIT model. Several criteria have been taken into account in order to identify the SD events (e.g. all the three altitude trajectories to have Saharan origin, the 4000 m trajectory to carry desert dust particles, the trajectories to interact with the mixed layer in arid areas where the surface wind is strong, or spend a large fraction of time over Sahara desert). Based on the AOD_{550}-FM criterion out of 1809 days of individual MODIS observations, 337 (18.6%) are characterized as coarse-mode particles, from which 79 (23.4%) correspond to SD events of various duration, from 1 to 5 consecutive days. The monthly distribution of coarse-mode particles shows a peak in July (74 cases, 42.6%), followed by August (72 cases, 40.4%). The majority of the SD events are depicted in April-May period and in July, while the minimum in November-December. The average number of SD events per year is about 13, with a maximum of 20 in 2000 and a minimum of 7 in 2003. The Aerosol Index (AI) derived from TOMS and OMI is found to be adequate for the characterization of dust load over Athens despite the fact that 35% of the dust cases related to back trajectory analysis do not correspond to high (above 0.5) aerosol index values. As a conclusion, this study shows that the combination of remote-sensing and back trajectories constitutes a powerful tool for the identification of SD events over Athens and in whole Mediterranean, since the results are in close agreement with relevant studies.

Integrated measurements from satellite and ground based instruments for air quality studies

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The integration of ground-based measurements and satellite observations is strongly demanded for realizing integrated air quality assessments that can allow solving environmental problems. Reliable information on air quality is usually derived in most cities by ground-based measurements of major pollutants. Such measurements provide point information on the concentration of pollutants. However, the spatial continuity of this data is on average rather poor as a consequence of rather high running costs of systems controlled by man power. The need to enlarge the spatial coverage of reliable experimental data on air quality, without significantly increasing running costs, has lead in the last years to an increasing demand for the exploitation of satellite Earth Observations. Sensors on board of satellites provide spatial measurements allowing geographically synoptic views of pollution related phenomena, and turn out to be extremely flexible tools for integration with the monitoring techniques.

Aerosol products by MODIS on board of Aqua and Terra satellites and ground-based measurements are integrated for air-quality studies over the Salento peninsula of southeast-Italy, in the central Mediterranean. Due to its geographical location, this area is significantly affected by marine, desert (from Sahara), and continental (natural and anthropogenic) aerosols. Thus, it is interesting to asses the use satellite data for regional air quality analyses.

Ground-based particulate matter (PM10 and PM2.5) data from daily measurements at rural and urban stations maintained by the regional agency for environment (ARPA Puglia) are used to investigate the correlation between MODIS aerosol optical depths (AOTs) and ground-based PM measurements. Preliminary studies have shown that satellite AOTs have a seasonal dependence, whereas ground PM concentrations do not show any systematic trend along the year. For investigating this effect, PM concentrations have been complemented by data on the vertical distribution of aerosols retrieved by Lidar measurements performed within the European Project EARLINET-ASOS, and by estimates of the Planetary Boundary Layer height from Sodar measurements. We have observed that ground PM concentrations corrected by the seasonal variation of the aerosol vertical distribution show enhanced correlation to MODIS AOTs.

To quantitatively relate AOTs to ground-PM concentrations, a model based on the Mie-Lorentz's theory is used. To this end, microphysical aerosol parameters from sun/sky radiometer measurement performed within the NASA network AERONET, are employed. Results on the seasonal dependence of the relationships between satellite AOTs and ground-PM concentrations will be presented both for the urban and rural sites.

Evaluation of satellite aerosol products for monitoring national and regional air quality in Austria

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Within the framework of the project PROMOTE, the Austrian Federal Environment Agency is evaluating the potential of satellite aerosol data for monitoring national and regional air quality. This work presents evaluations of PROMOTE aerosol services, that apply data from the ENVISAT sensors MERIS, SCIAMACHY, and AATSR. MERIS data are provided in near-real-time, which means a time delay between data acquisition by the satellite to the delivery of the aerosol product of about one day. Data are also provided temporally (monthly, seasonally, and annually) aggregated for air quality assessments and reporting. Also the SYNAER product from DLR-DFD is evaluated. The SYNAER uses simultaneous measurements from the AATSR and SCIAMACHY sensors onboard ENVISAT. SYNAER data are provided in near-real-time and in temporally aggregated form.

We present evaluations and comparisons of MERIS and SYNAER aerosol data, as well as comparisons with the national ground-based air quality monitoring network, as well as comparisons to aerosol datasets from MODIS and MISR. Advantages and limitations of satellite aerosol datasets for air quality monitoring are discussed.

Aerosol retrieval from OMI: validation results

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It is well known that aerosols affect the Earth's radiative balance, therefore it is of primary importance to monitor them. They have a direct effect by absorbing and reflecting the incoming solar radiation. They also indirectly affect the radiative balance by influencing microphysical properties and lifetimes of clouds. It is hard to make an estimation of the radiative forcing due to aerosols - because of the large variety of sources and precursors and the high variability of their concentrations and optical properties in both time and space - but necessary for a better understanding and modeling of the terrestrial climate. Satellite observations provide information on aerosol properties over a large area and can be used for monitoring on regional and global scales.

The aerosol optical depth (AOD) is one of the aerosol optical properties which can be derived from satellite data. The AOD provides information on the total concentration of particles and its spectral variation gives indications the size distribution. Current techniques allow for their retrieval over both ocean and land.

The Ozone Monitoring Instrument (OMI) was used to retrieve the AOD over Western Europe for May to July 2005. OMI is a Dutch-Finnish contribution to the Aura mission. OMI is a nadir viewing spectrometer; it measures reflected and backscattered solar light in a part of the UV-Visible domain (270-500 nm). The near-UV part of the spectrum observed by OMI enables the detection of absorbing aerosols such as minerals and carbonaceous aerosols. To derive aerosol optical properties from the reflectance at the top of the atmosphere measured by OMI, a new multi-wavelength algorithm was developed.

The main goal of this study is to validate the consistency of the OMI aerosol properties derived by means of this algorithm. The derived properties will be compared to their counterparts, measured on ground or derived from other space borne instruments like MODIS or AATSR.

Aerosol retrievals using MSG-SEVIRI measurements: preliminary results

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There is still much to learn about the way aerosols affect the Earth's climate. The relative impact of natural aerosols and those of human origin has to be accurately quantified. Aerosols scatter sunlight back to space and thus tend to cool the planet, whereas absorbing particles are warming the atmosphere. This is known as the direct effect of aerosols on climate. Aerosols play a key role in the formation of clouds, acting as "seeds" for droplet generation and growth. They can potentially modify cloud lifetime and reflective properties, which indirectly modifies earth radiative balance. The variability in particle chemical composition, physical and optical properties renders it difficult to assess the influence of aerosols on long-term global climate change.

Satellite remote sensing represents a powerful technique for the study of atmospheric processes involving aerosols on regional and global scales. The particularity of the Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument aboard the Meteosat Second Generation (MSG) satellite is its high temporal resolution. With one image every 15 minutes, one can expect to closely track the dispersion of anthropogenic pollutants.

TNO is currently developing a new algorithm for the retrieval of aerosol optical properties using two visible and one near-infrared channels from the imaging radiometer MSG-SEVIRI. With appropriate assumptions on the local aerosol type based on, e.g., climatology, the Aerosol Optical Depth (AOD) and the Ångström coefficient can be retrieved for cloud free scenes. Assuming a plane parallel homogeneous atmosphere, a radiative transfer model is used to estimate the relative contribution of different aerosol types to the top-of-atmosphere radiance. By means of a least square fitting method, aerosol optical depth and mixture are retrieved.

In the case of sea targets, which are considered dark pixels, the retrieval is done using the single-view algorithm as implemented for AATSR-ENVISAT.

Over land the correction for surface contribution requires an additional input. For this purpose, AOD from both AERONET and AATSR dual-view algorithm retrievals are used to determine the surface reflectance for the SEVIRI geometry. Assuming that the surface optical properties vary very slowly, the ground reflectance estimated at a calibration step is used to extract aerosol information at subsequent time steps, for which AOD is retrieved from SEVIRI data.

The first application of the algorithm dedicated to MSG-SEVIRI focuses on southeastern Europe, around the Mediterranean basin, during summertime 2004. These results are validated by comparisons with ground based sunphotometer measurements.

A new dust source area map derived from high spatiotemporal MSG SEVIRI IR difference images

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Mineral dust aerosol from arid and semi-arid regions plays an important role in the climate system by directly and indirectly affecting radiation fluxes and nutrient cycles. A prerequisite for estimates of the influence of dust aerosol on the climate system is the knowledge of the locations of its source areas. Satellite remote sensing has previously been used to obtain information on soil dust sources. So far, locations of dust sources are mostly implied from daily satellite retrievals from radiances measured in the UV-spectrum (Total Ozone Mapping Spectrometer (TOMS), Ozone Monitoring Instrument (OMI)) and in the IR-spectrum (IR difference dust index (IDDI) Meteosat product at daily noon-time). Determining dust source areas by such indirect methods is impeded by relatively low temporal resolution and ambiguities of the retrievals.
We present a new 1° x 1° map of monthly dust emission events for the Sahara and Sahel region derived from the Meteosat Second Generation (MSG-1) satellite IR dust index. In contrast to the previously developed IDDI we use IR brightness temperature differences between the 12.0 µm, 10.8 µm and 8.7 µm wavelength bands for every 15-minute retrieval. The MSG-1 is a geostationary satellite localised over the equator at 3.5°W. For our study we use the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) radiances which are measured at 11 different wavelength bands by a sampling rate of 15 minutes at a resolution of 3x3 km at nadir. For every measurement a dust index is computed based on the difference of the radiances for the 8.7 µm, 10.8 µm and 12.0 µm wavelength bands, converted to brightness temperatures. Due to different absorption and emission properties of dust and surfaces in different thermal spectral wavelength bands, airborne mineral dust is well identifiable in this dust index, especially over bright land surfaces. Because theses retrievals are available at very high spatiotemporal resolution, emission and subsequent transport of individual dust events can be observed and followed very well in these IR composite pictures of the 8.7 µm, 10.8 µm and 12.0 µm wavelength bands. Based on visual analysis of all Saharan and Sahelian dust events for a full year (March 2006 to February 2007) we derived new observation–based monthly 1° x 1° maps of locations of mineral dust sources together with frequencies of dust emission events over the African continent northward of 10°N. Furthermore we compare the new dust emission frequency map derived from MSG with the OMI aerosol index (AI) which indicates the atmospheric dust content. It shows downwind shifts of pattern of observed maxima in the OMI AI retrievals which can be explained by the relatively low sampling rate of AI based radiance (daily overpass over the equator at 13:45 local time).

Arctic smoke - a record air pollution event in the European Arctic – first results from MERIS using the Bremen Aerosol Retrieval (BAER)

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In early May 2006 a record high air pollution event was observed at Ny-Ålesund, Spitsbergen. An atypical weather pattern established a pathway for the rapid transport of biomass burning aerosols from agricultural fires in Eastern Europe to the Arctic. Atmospheric stability was such that the smoke was constrained to low levels, within 2 km of the surface during the transport.

The comparison of AOD values from space and from the surface in the Arctic region shows the difficulties in dealing with bright surfaces and cloud screening and demonstrates the urgent need to develop specific algorithms for high latitude regions in order to make use of the satellite data. AOD from ground-based measurements (AOD~0.6 at 442 nm) are around 33% larger as compared to satellite measurements (AOD~0.4 at 442 nm) for 2 May 2006. Thus, especially retrieval algorithms, working over snow and ice areas are urgently required. Nevertheless, the AOD from satellite showed the horizontal extension of the plume.

Comparison of MODIS and AERONET derived aerosol optical properties during an episode of long-range transported aerosols of biomass burning

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Our study compares aerosol optical properties from Moderate Resolution Imaging Spectroradiometer (MODIS) and those of AERONET during an episode of long-range transport of biomass burning aerosols from Baltic countries up to Finland in spring 2006. In addition, trajectory analysis as well as MODIS Fire product are used in order to analyze the type and origin of the air masses. During the studied two-week period AOD values ranged from near zero up to 1.2 at 0.55 micron, the linear correlation between MODIS and AERONET was very high (0.98). We also compared satellite-derived AOD values against surface PM2.5 measurements. However, this comparison did not show a good correlation, as has been also found in some earlier studies, which is likely due to the variability in vertical profiles. Temporal variability within a two-week period was also rather well explained by the trajectory analysis in conjunction with fire detections produced by the MODIS Rapid Response System. It is concluded that MODIS derived AOD data combined with the fire products, offers a great potential to monitor the smokes from biomass burning and their long-range transport.

Light scattering properties of higher order Chebyshev particles and implications for aerosols with a weak surface roughness

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Chebyshev particles of comparatively low orders *n* are used in the past to study the effects of nonspherical but concave geometries in remote sensing applications. Their shape is given by $r(\theta) = r_0 \ [1 + a\cos(n\theta)]$ where r_0 is the radius of the underlying sphere and *a* denotes the deformation parameter. We present results of light scattering computations for several Chebyshev particles characterized by higher orders *n*. Accurate results can be obtained for such particles within a T matrix approach. Moreover the scattering characteristics converge to stable results if the order is increased. Essential differences between, e.g., the phase functions of the higher order Chebyshev particles and the underlying regular scatterers can be observed. In particular an increased backscattering due to the surface roughness is obtained. This behavior is even more pronounced in the case of highly absorbing particles. The effects obtained agree with results of other approaches and correspond to expectations for particles with a weak surface roughness. This demonstrates that, on one hand, higher order Chebyshev particles can be used to estimate the influence of a weak surface roughness on the light scattering behavior of atmospheric aerosols. On the other hand, the consideration of roughness effects is important in the retrieval of aerosol properties.

Scattering database for nonspherical particles

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Scattering of electromagnetic waves by nonspherical dielectric particles becomes of growing importance in remote sensing of the earth's atmosphere. Studying the influence of Saharian dust or Cirrus clouds on our climate are only two examples in this context. In the former case we have to consider nonspherical particles of the mineral origin, and in the latter case we are faced with nonspherical ice crystals like hexagonal columns or plates, for instance. The existence of nonspherical particles within a certain volume can be checked directly with modern LIDAR systems by detecting the depolarization in back scattering direction. But also indirect measurements provide several hints for the necessity to take light scattering on nonspherical particles into account.

But there are especially two aspects which makes this necessity a complex task. First, the numerical effort is much higher as compared to the case for spherical particles within the Mie theory. Time of calculations strongly depends on the morphology of particles and can be performed on-line only in very specific situations. Second, the convergence procedures of the existing approaches are much more complex as compared to spheres. To obtain reliable results, one needs a detailed knowledge of the methodology behind a certain approach. Otherwise, one can run into a lot of pitfalls. Therefore we present a scattering database for nonspherical particles of a certain accuracy that releases the users from dealing with numerical aspects of the light scattering problem.

The effect of coarse particles on estimates of aerosol optical parameters from ground based and satellite measurements

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Estimates of aerosol influence on radiative regime of the Earth climatic system in the literature are ambiguous or disagree. There is especially wide scatter in estimates of its radiative forcing during the injection into the atmosphere of a great number of particles emitted by forest fires and dust storms. Under such conditions, in many respects it is connected with the incorrect work of aerosol retrieval algorithms used in the existent ground-based and satellite systems.

The distinctive feature of the presented researches is the account of optical properties possessed by coarse particles in determination of aerosol parameters and in calculations of radiative fluxes. The coarse particles in combination with large optical thickness, typical for fire smokes and dust storms, require a change in the existing algorithms of data processing, received from ground-based measuring networks such as AERONET and USDA. This change is necessary to provide stability of retrieval of aerosol microphysical parameters, mainly Aerosol Optical Thickness (AOT) and Single Scattering Albedo (SSA). Existing methods of processing these networks' measurements do not consider the particles with radii more than 15 micrometers.

The analysis of the parallel measurements performed by CIMEL and MFRSR photometers at two sites in the U.S.: Oklahoma (at the ARM Southern Great Plain) and Greenbelt (at GSFC) has allowed to detect the influence of coarse particles on AOT and SSA estimates even under conditions of the quiet atmosphere. In this connection the special models with coarse particles to derive an aerosol turbidity from AERONET data have been developed. Using computational modeling of satellite measurements, the differences in estimates of AOT under dust storm conditions for previous and new models were obtained for MODIS (in visible spectrum) and the new IR interferometer IASI.

NLCs as observed by SCIAMACHY

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SCIAMACHY aboard ENVISAT is gathering data from the Earth's atmosphere since 2002 up to this day. Its excellent spectral range and resolution and the possibility of using a limb viewing mode is well suited for the study of noctilucent clouds (NLCs), which are optically thin phenomena occurring in both hemispheres at the summer mesopause at latitudes of 55 up to 90°.

In the northern hemisphere, the geometrical setting is such that NLC particles size can be retrieved using a Mie scattering algorithm assuming different particle size distributions (monodisperse, normal, log-normal). Using SCIAMACHY data, we built a climatology of NLC particle sizes and occurrences for years 2002 to 2006. Moreover, the satellite global coverage grants us the possibility to study inter-hemispheric differences in frequency of occurrence.

We will also present the more technical aspect of the correction scheme which must be applied in order to take into account the instrument degradation and solar spectrum variation over time. Both processes being wavelength dependent, they can affect significantly the particle size retrieval and introduce artifacts in the data set.

Geographic distribution of polar stratospheric clouds

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Polar Stratospheric Clouds (PSCs) play a key role in the depletion of ozone in the stratosphere. They contribute to the formation of the ozone hole by facilitating the conversion of chlorine from inactive compounds to active Cl_2 on the surface of the cloud particles and by the perturbation of gas phase chemical cycles through sedimentation of cloud particles.

It is possible to detect PSCs from limb scattering measurements using a color index approach. The SCIAMACHY instrument on board the European Space Agency's Envisat satellite provides limb scattering data since summer 2002, allowing the comparison of the geographic distribution of PSCs over the course of several years. The results of the PSC distributions of both hemispheres are shown in connection with ECMWF temperature data.

Over the course of the season the detected PSCs descend in altitude. This descent at the rate of 2-3 km per month corresponds to the altitude of the temperature minimum in the stratosphere. The geographic location of the PSCs shows that mountain waves have an effect on PSC occurrence especially in the northern hemisphere.

Retrieval of microphysical properties of polar stratospheric aerosol and clouds from observations of the Improved Limb Atmospheric Spectrometers (ILAS)

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The Improved Limb Atmospheric Spectrometer (ILAS) was a satellite-based solar occultation sensor onboard the Advanced Earth Observing Satellite (ADEOS). The ILAS was developed by the Environment Agency of Japan (now the Ministry of the Environment) and regularly monitored stratospheric ozone from November 1996 until June 1997. The ILAS had observed polar stratospheric clouds (PSCs) in winter over both the Arctic and Antarctic.

The solar occultation measurements in the infrared wavelengths region of 6.21 to 11.8 micrometers were processed by an inversion method that included aerosol physical modeling and permitted simultaneous retrieval of stratospheric trace gases and particle size distributions for key aerosol and polar stratospheric cloud components such as liquid ternary solution, nitric acid trihydrate, nitric acid dihydrate, and water ice.

Investigation of the effect of aerosols on satellite observations of the Ring effect and the absorptions of light by O_2 and O_2-O_2

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We present a systematic investigation of the effects of aerosols on trace gas retrievals and the Ring effect by DOAS satellite measurements using our Monte Carlo radiative transfer model TRACY-2. We performed simulations to investigate the sensitivity of air mass factors (AMF) as well as the Ring effect to various aerosol properties. Aerosol profiles were studied that differ in height, thickness, shape of the layer and optical depth. In addition, the single scattering albedo and the asymmetry parameter of the aerosol particles were varied. The simulations were performed for various solar zenith angles and elevation angles of the detector with respect to the horizon. Air mass factors for O_2 and O_4 (at various wavelengths) were calculated. The first promising result from our simulations is that absorbing and non-absorbing aerosols can be distinguished based on the AMF of O_4. Depending on the aerosol properties (e.g. the single scattering albedo) and on the extinction profiles, aerosols can either increase or decrease the sensitivity of satellite observations with respect to trace gases. The comparison of these quantities to satellite measurements allows estimating the optical properties of aerosols and their height profile. In particular, also the aerosol effect on satellite observations on various trace gases can be quantified and corrected.

Aerosol retrieval over Finland using the dual-view AATSR algorithm

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The dual view of the Advanced Along Track Scanning Radiometer (AATSR) allows for the accurate retrieval of aerosol properties over land. The TNO dual view algorithm has been implemented at the University of Helsinki and the Finnish Meteorological Institute where it will be used for scientific studies, the results of which will be implemented for operational use. One of the research applications is a study on the influence of new particle formation on the aerosol optical properties. This study is undertaken over Finland, where in general the AOD is often very low and new particle formation events occur frequently (Dal Maso et al. 2005). A statistical analysis of the occurrence of NPF events in the period 2003-2006 has been made in terms of air mass trajectories and meteorological conditions (Sogacheva et al., 2007). These results are used to look for occasions where influence on optical properties may be expected, which are subsequently coupled to the availability of AATSR data. The AATSR dual view algorithm will be tuned to include aerosol models that apply over Finland for the conditions of the study day and area, including meteorological conditions. *In situ* ground based data on aerosol optical properties will be used, as well as the sun photometer data from the FPR network in Finland and, in the future, the CIMELs that are planned to be installed at three locations in 2007. The challenge is to discriminate the optical properties resulting from new particle formation and those from the background aerosol.

Dal Maso, M., Kulmala, M., Riipinen, I., Wagner, R., Hussein, T., Aalto, P. P., and Lehtinen, K. E. J.: Formation and growth of fresh atmospheric aerosols: eight years of aerosol size distribution data from SMEAR II, Hyytiälä, Finland., *Boreal Environ. Res*., 10, 323–336, 2005.
Sogacheva , L., Saukkonen, L., de Leeuw, G. and Kulmala, M. Atmospheric fronts, cloudiness and aerosol particle formation in Hyytiälä, Southern Finland. Submitted to EAC 2007, Salzburg.
Sogacheva , L., Saukkonen, L., dal Maso, M. and Kulmala, M. Aerosol particle formation in different types of air masses in Hyytiälä, southern Finland. Submitted to ICNAA 2007, Galway.

Validation of PM_{10} mass concentration retrieved from MERIS/ENVSAT with air-quality surveillance measurements over Germany

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Particulate matter mass concentrations have been derived with the Bremen AErosol Retrieval (BAER) using MERIS/ENVISAT top-of-atmosphere spectral measurements over Germany. The results are validated with ground based air quality surveillance measurements over Germany. The retrieval considers the aerosol optical thickness at seven wavelengths over land and an effective particle radius derived from Angström α to determine the columnar aerosol volume. The estimation of surface reflectance is based on a vegetation–bare soil mixing model, using the Normalized Difference Vegetation Index (NDVI) and the topography of the actual satellite scenes. Assumptions on aerosol optical thickness fraction within the boundary layer height, humidity state and density are used to scale down the columnar aerosol volume to particulate matter concentrations for particles smaller than 10 μm in diameter. First validation results over Germany are presented. The potential impact of different meteorological parameters like the boundary layer height or humidity is shown. The validation reveals the expectations that reliable derivation of particulate matter columnar mass concentrations can be obtained using additional meteorological information.

Relationship between aerosol optical thickness and surface wind speed over the ocean

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Retrieved aerosol optical thickness (AOT) based on data obtained by the Sea viewing Wide Field Sensor (SeaWiFS) is combined with surface wind speed, obtained at the European Centre for Medium-Range Weather Forecasts (ECMWFs), over the North Pacific for September 2001. In this study a novel cloud screening approach is introduced in an attempt to exclude pixels partly or fully covered by clouds. The relatively broad swath width for which the nadir looking SeaWiFS instrument scanned over the North Pacific means that the AOT can be estimated according to relatively large range of wind speeds for each of the scenes analyzed. The sensitivity of AOT to the sea salt and hygroscopic growth of the marine aerosols has also been investigated. The validation approach is based on previous parameterization in combination with the environmental quantities such as wind speed, RH and boundary layer height, estimated at the ECMWF. In this study a factor of 2 higher mean AOT is obtained for a wind speed up to about $12\,m/s$ for September 2001 over remote ocean areas. Furthermore, a factor of 2 higher AOT is more or less supported by the validation of the results. Approximately, 40% of the enhancement seems to be due to hygroscopic growth of the marine aerosols and the remaining part due to increase in the sea salt particle mass concentrations, caused by a wind driven water vapor and sea salt flux, respectively. Reasonable agreement occurs also between satellites retrieved aerosol optical thickness and AOT observed at several AERONET (Aerosol Robotic NETwork) ground-based remote sensing stations.

Lidar measurements in Ny Ålesund, Spitsbergen, for CALIPSO validation and the 2-stream approach

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The Koldewey Aerosol Raman Lidar (KARL) is located in the joint French-German AWIPEV station in Ny Ålesund, Spitsbergen. It is a Nd:Yag based "3+2" lidar, with additional Raman H_2O channels and volume depolarisation at 532nm. The lidar is mainly designed for aerosol and water vapour measurements in the troposphere, but can detect aerosol layers and PSC with the elastic channels in the low and middle stratosphere as well.

In the recent months different lidar measurements, partially isochronic to CALIPSO overpasses have been performed. Extinction profiles, thereby, could be retrieved up to the tropopause. These data sets, which shall be well suited for CALIPSO validation in the troposphere and low stratosphere, will be presented.

As well during this year's ASTAR (Arctic Study on Tropospheric Aerosol, Cloud and Radiation), as in prior campaigns the 2-stream method, where 2 lidars probe the same air from opposite directions, has been applied successfully. We propose this method for an evaluation of CALIPSO data. Care must be taken to find the optimal matching lidar profiles, however. A way of adequate correlation of the 2 lidar data sets is described for the case where the AMALi lidar on board of the Polar 2 aircraft overflew the ground station.

Exploring NASA and ESA aerosol data using Giovanni, the online visualization and analysis tool

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Giovanni, the NASA Goddard online visualization and analysis tool (http://giovanni.gsfc.nasa.gov), allows exploration of various atmospheric phenomena without learning remote sensing data formats and downloading voluminous data. Using NASA MODIS (Terra and Aqua) and ESA MERIS (ENVISAT) aerosol data as an example, we demonstrate Giovanni usage for online multi-sensor remote sensing data comparison and analysis. As proof of concept, the publicly available MERIS Aerosol Optical Thickness at 550 nm monthly Level 3 products (http://envisat.esa.int/level3/meris/) are integrated into Giovanni for intercomparison with MODIS data. Because MERIS was designed mainly to measure ocean properties, MERIS atmospheric products over oceans are biased toward clear skies, i.e., high optical thickness pixels are most likely rejected. We compute time-series of AOT for the area to the west of Sahara and Sahel. Usually, in early spring there are dust storms in that area that can be easily seen in Giovanni maps and time-series of MODIS AOT. MERIS does not report high AOT values while being quite consistent with MODIS sensors at other times over the same area. To quantify the MERIS – MODIS differences, for the March 2004 (high aerosol month) west of Sahara and Sahel, the Giovanni scatter plot is used. The linear fit of regression gives a slope of 0.24 for MERIS vs. Aqua MODIS (Col. 5) AOT. A similar regression for the area but for November 2004 low aerosol loading period gives a slope close to 0.93. This is another indication of some kind of effective threshold on optical thickness imposed by MERIS algorithms.

Studies of spectral and angular light reflectance from random media using computer modelling (ray-optics approach)

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In this work we are going to present the results of our computer modeling of light scattering in particulate random media. The results consist of two parts: 1) the research of backscattering enhancement effect, which appears due to different mechanisms like coherent effects and shadowing in the medium of large opaque spherical particles, and 2) light scattering in random medium of transparent spherical and non-spherical particles.

We use a computer model of a medium, the main characteristics of which are the particle size, packing density (the part of volume occupied by particles), the optical constants of the particles, and the shape of particles, which can be spherical or nonspherical. The second type of particles was generated by random overlapping of several tens of different-sized spheres. A parallel beam of random light rays illuminates such a medium at a given angle. We associate a Jones matrix with each ray. The matrix is rotated at each surface to bring its coordinate system to the local reflection/refraction plane, then multiplied by the reflection or refraction matrix. To include coherent effect we calculate the trajectory of the time-reverse ray that meets the same particles as the direct ray, but in the reverse order. Then we sum the Jones matrices of the direct and also such a reciprocal trajectory and convert this sum to the Mueller matrix. These matrices are additive and we accumulate them in the 3-D histogram for each coordinate angle and each scattering order. We can make several conclusions. For opaque particles the main contributions to the coherent opposition spike are the second and third orders of reflection. High reflection orders give a minor contribution to the total intensity even for highly reflective materials. The main electromagnetic phase shift between the direct and reciprocal trajectories is the outer phase shift that depends only on the path length in the medium and the phase angle. Third-order scattering results is a superposition of wide and narrow opposition spikes that correspond to two different types of scattering trajectories, closed and opened ones. For media consisting of equal-size spheres with size parameter X = 125 and packing density $\rho = 0.3$, but for different particle materials, we detect weak negative polarization branches at small phase angles. Their depth and width are about 0.5% and 7°, respectively. This detail is related to the second and third orders of reflection. The iron shows a deeper polarization opposition effect and aluminium (bright metal) demonstrates almost no polarization opposition effect; dark silicate takes an intermediate position. We find that for the second scattering order, the phase dependence of M22/M11(sum) varies noticeably with density. The deep minimum of the negative polarization branch for the density $\rho = 0.5$ becomes shallow at ? = 0.1. The parameters characterizing 45-linear and circular depolarization, show the same effect with opposite sign. All normalized elements on the main diagonal of the scattering matrix are sensitive to the angle of incident radiation: whereas, those on the secondary diagonals are mainly sensitive to the phase angle. The developed code can be used to study the angular and spectral light reflectance from natural surfaces such as various soils.

AMSSP (Airborne Multi-Spectral Sunphoto- & Polarimeter), a proposed new spectrometer system for the High Altitude and Long Range Research Aircraft (HALO) and the development of adequate algorithms and methods for optimal retrieval of atmospheric aerosol optical properties

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We propose a new spectrometer system to measure simultaneously the degree and angle of the linear polarization or the direct solar and the aureole radiation. The system is based on diffraction grating spectrometers with multiple channels from the visible to the near infrared. The multi-angle viewing capability enables a number of possible future applications. The polarization unit expands the dimension of the information derived from an aureole sun photometer unit with the possibility to derive the Stokes parameters I, Q and U for the radiation field of scattered light coming from the atmosphere. With this new instrument setup it is possible to enhance the information which can be derived from measurements of the electromagnetic radiation in the atmosphere by applying new algorithms for the retrieval of the scattering and absorption coefficients of aerosols, the atmospheric correction for different air- and spaceborne instruments. The new procedures enable the validation of future satellite instruments (e.g. EnMAP, Sentinel 2 and 3, APS) and the validation of existing satellite instruments (e.g. MERIS, POLDER).

ART algorithm to determine aerosol optical thickness and land reflectance from satellite data

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We will present a new algorithm ART to retrieve aerosol optical thickness (AOT) and land reflectance from satellite data. This algorithm adopts some procedures from MODIS (particularly, the clear pixel selection technique) and BAER (for instance, a priori land reflectance model). The most important difference of the ART code from MODIS, BAER and some other codes is that the ART does not use the LUT technique but instead deploys our earlier developed extremely fast code *RAY* for radiative transfer (RT) computations. The ART is supposed to provide not only AOT but parameters of aerosol composition. The absence of the appropriate aerosol model for ART input enforced the more modest statement as the first step. The scattering phase function is taken as in BAER code, and the AOT, Angstrom parameter, and land reflectance are the retrieved parameters.

Using the RT computations in the course of the AOT retrieval allows us

- to include any available local models of molecular atmosphere and of aerosol in upper and middle atmosphere layers for the treated area. Practically, the AOT and Angstrom parameter of a lower troposphere aerosol are retrieved;
- to use the method of least squares in the retrieval of optical parameters of aerosol because the *RAY* code provides the derivatives of the radiation characteristics with respect to the searching for system parameters. This technique allows the optimal use on multispectral information if it is available.

We consider these features as definite merits in comparison with the LUT technique. But the main question in the case is a time of calculations because of need to process a large amount of pixels. At present, the retrieval of the AOT, Angstrom parameter, and land reflectance for a pixel takes about 0.02s; the area with $2\cdot 10^5$ pixels is processed for about 1 hour at usual PC. We have been developing even faster semi-analytical technique that uses the combination of analytical solutions and numerical computation.

The data of the retrieval with this algorithm were compared with results of the retrieved AOT at $0.55\mu m$ with some other retrieval algorithms from data of different satellite instruments performed for a single scene over Germany (7-12E, 49-53N) on October 13th, 2005. The first results show a reasonable agreement our data with other algorithms retrieval. It is shown that the accuracy of the AOT retrieval depends substantially on the used aerosol model, particularly on the chosen aerosol phase function. The possible indefinites of the phase function in the range of the scattering angles $\sim 90 \div 150\,\text{deg}$ can cause 2 times difference in the retrieved AOT values. Meanwhile, retrieved spectra of the surface albedo are comparatively stable.

Do aerosols influence convective clouds over India?

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The knowledge of aerosol-cloud interactions is very crucial in better understanding the Earth's radiation budget. Aerosols influence clouds in variety of ways that range from changing cloud albedo, modulating cloud microphysics, lifetime and cloud formation till even affecting cloud dynamics. These effects take place on different spatial and temporal scales. The aerosol type, composition and concentration govern the way cloud characteristics are influenced and also its magnitude. However limited knowledge on aerosol characteristics and aerosol-cloud interactions has caused biggest uncertainty in the radiation budget. Recent developments in the space-borne and ground based remote sensing are very promising in this context, especially to study these interactions at the regional scales.

The Indian subcontinent is one of the ideal places to study aerosol-cloud interactions. The aerosols (especially dust) are carried to the Ganges Basin before the southwest monsoon. The pollution from the local sources adds to it (sulphates, black carbon and particulate matter) building reservoir of pollution over this region. During the monsoon months of June, July, August and September, the southwest winds bring moist air over this region and due to solar heating, this region further experiences strong convective cloud activities. These convective clouds are responsible for much of the rainfall over India and thus indirectly govern economy of the region. The strong economic growth and increasing population have lead to considerable pollution over India during the last two decades. In this context it is important to study whether convective clouds have undergone any changes in the last two decades due to aerosols.

AVHRRs onboard NOAA satellites offer opportunity to study long-term changes in the convective clouds. Here in this study, 20 years of daytime AVHRR data from NOAA-7, -9, -11, and –14 satellites are used for this purpose. All channels of the AVHRRs are carefully calibrated and inter-calibrated. CLAVR-1 algorithm (Stowe et al, 1999) is used to detect clouds and cloud-typing algorithm suggested by Pavolonis et al (2005) is used to classify clouds. Firstly, the data are gridded at 0.1x0.1 degrees to look at the spatial distribution of convective clouds. Then seven regions over the Indian subcontinent are selected in order to study trends in the convective cloud amount. No significant trend in convective cloud amount is found for any of the selected regions. The natural variability, cloud dynamics and effect of orbital drift of satellites dominate the observed trends. Further in-depth comparisons of the observed trends with other cloud climatologies are planned.

Programme

June 21

8:30-9:00 Registration

Chair: S. Kinne

9:00-9:15 G. de Leeuw, J. P. Burrows Introduction

Session 1. Multiple views and polarization

9:15-9:45 R. Kahn Aerosol optical depth and air mass mapping with satellite multi-angle imaging

9:45-10:00 J. Keller Simultaneous retrieval of aerosol and surface optical properties using Multi-angle Imaging SpectroRadiometer (MISR) data

10:00-10:30 F.-M. Breon Aerosol remote sensing from the PARASOL mission and the A-train

10:30-10:45 O. Hasekamp Retrieval of aerosol properties over land surfaces: capabilities of multiple-viewing-angle intensity and polarization measurements

10:45-11:00 W. Davies Improvements in AOD estimation using multi-angle CHRIS/PROBA images

11:00-11:30 Break

Session 2. Dual – view techniques

11:30-12:00 G. E. Thomas Dual-view aerosol retrievals from (A)ATSR using the Oxford-RAL Aerosol and Clouds (ORAC) optimal estimation algorithm

12:00-12:15 W. Grey Towards a 12-year record of global aerosol properties from ATSR-2 and AATSR

12:15-12:45 G. de Leeuw Aerosol retrieval over land using the dual-view AATSR algorithm

12:45-14:00 Lunch and poster session

Chair: R. Kahn

Session 3. Single views

14:00-14.30 C. Hsu Retrieving aerosol properties over land from MODIS and SeaWiFS

14:30-14:45 P. A. Durkee Multispectral aerosol optical depth retrievals from high-resolution satellite imagery

14:45-15:15 W. von Hoyningen-Huene The retrieval of spectral aerosol optical thickness over land using MERIS observations with respect to the determination of particulate matter

15:15-15:45 Break

15:45-16:00 B. Veihelmann Aerosol properties from OMI using the multi-wavelength algorithm

16:00-16:15 B. de Paepe Dust aerosol optical depth retrieval over desert surface, using the SEVIRI window channels

16:15-16:30 T. Holzer-Popp Benefits and limitations of synergetic aerosol retrieval
16:30-16:45 A. Kokhanovsky The determination of aerosol optical thickness over Germany using different satellite algorithms and instruments: a case study
16:45-17:00 Discussion
17:00-18:00 posters

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Chair: G. de Leeuw

Session 4. Global aerosol properties
9:15-9:45 R. Levy Evaluation of global aerosol properties in the MODIS Collection 5 products
9:45-10:15 S. Kinne Towards an AOD climatology by combing the strengths of different remote sensing techniques
10:15-10:30 I.Georgdzhayev Recent aerosol trends from long-term global aerosol climatology project satellite record

10:30-11:00 Break

Session 5. Lidars, validation of satellite retrievals, and applications
11:00-11:30 F. M. Breon Aerosol vertical profiles from the CALIPSO spaceborne lidar: capabilities and first results
11:30-11:45 A. Richter AMALi, the Airborne Mobile Aerosol Lidar, as a tool for the validation of CALIPSO in the Arctic region
11:45-12:00 R. Braak Validation of the OMI multi-wavelength aerosol product
12:00-12:15 T. Mielonen Comparison of surface and satellite derived aerosol optical depth measurements in Finland
12:15-12:30 S. Wagner Optimal estimation applied to multi-angular and multi-spectral data for the joint retrieval of aerosol load and surface reflectance: application to MSG/SEVIRI observations

12:30-14:00 Lunch

Chair: W. von Hoyningen-Huene

14:00-14:15 T. Dinter The SAMUM experiment and its results
14:15-14:30 E.Bierwirth The surface reflectance of a desert as measured during the SAMUM experiment
14:30-14:45 D. Kaskaoutis Investigation of the Saharan dust events over Athens in the period 2000-2005
14:45-15:00 G. Mannarini Integrated measurements from satellite and ground based instruments for air quality studies
15:00-15:15 R. Holler Evaluation of satellite aerosol products for monitoring national and regional air quality in Austria
15:15-15:45 Discussion
15:45-17:00 Poster session and departure

Posters

1. Aerosol retrievals using MSG-SEVIRI measurements: preliminary results by Y. S. Bennouna and G. de Leeuw
2. A new dust source area map derived from high spatiotemporal MSG SEVIRI IR difference images by K. Schepanski, I. Tegen, A. Macke
3. Aerosol retrieval from OMI: validation results by R. L. Curier, J. P. Veelkind, R. Braak, B. Veilhmann, O. Torres, G. de Leeuw
4. Comparison of MODIS and AERONET derived aerosol optical properties during an episode of long-range transported aerosols of biomass burning by A. Natunen, A. Arola , K. Lehtinen
5. Relationship between aerosol optical thickness and surface wind speed over the ocean by P. Glantz, D. Nilsson, W. von Hoyningen-Huene
6. Arctic smoke - a record air pollution event in the European Arctic – first results from MERIS using the Bremen Aerosol Retrieval (BAER) by R. Treffeisen, P. Turnved, J. Ström, A. Herber, J. Bareiss, A. Helbig, R. S. Stone, W. Hoyningen-Huene, R. Krejci, A. Stohl, R. Neuber
7. The effect of coarse particles on estimates of aerosol optical parameters from ground based and satellite measurements by A.N.Rublev, A.N.Trosenko, T.A.Udalova, E.A.Zhitnitsky
8. Light scattering properties of higher order Chebyshev particles and implications for aerosols with a weak surface roughness by K. Schmidt, T. Rother, J. Wauer
9. Scattering database for nonspherical particles by J. Wauer
10. NLCs as observed by SCIAMACHY by Charles Robert, Christian von Savigny and John P. Burrows
11. Geographic distribution of polar stratospheric clouds by P. Reichl, C. von Savigny, H. Bovensmann, J. P. Burrows
12. Retrieval of microphysical properties of polar stratospheric aerosol and clouds from observations of the Improved Limb Atmospheric Spectrometers (ILAS) by S. Oshchepkov, Y Tatsuya , Y. Sasano, H. Nakajima
13. Investigation of the effect of aerosols on satellite observations of the Ring effect and the atmospheric absorption in O_2 and O_4 absorption bands by C. Liu, S. Sanghavi, T. Deutschmann, M. Grzegorski, U. Platt , T. Wagner
14. Lidar measurements in Ny Ålesund, Spitsbergen, for CALIPSO validation and the 2-stream approach by C. Ritter, A. Richter, R. Neuber, A. Hoffmann, I. Stachlewska
15. Do aerosols influence convective clouds over India? by A. Devasthale and H. Grassl
16. Validation of PM10 mass concentration retrieved from MERIS/ENVISAT with observations from national air quality measurements in Germany by G. J. Rohen, W. von Hoyningen-Huene, A. A. Kokhanovsky, T. Dinter, H. Bovensmann, J. P. Burrows
17. Aerosol retrieval over Finland using the dual-view AATSR algorithm by L. Sogacheva, V. Aaltonen, G. de Leeuw, A.-M. Sundström, P. Kolmonen, L. Curier, Y. Bennouna, R. Schoemaker, M. Kulmala

18. Studies of spectral and angular light reflectance from random media using computer modelling (ray-optics approach) by L.G. Istomina, D.G. Stankevich, Yu.G. Shkuratov
19. Exploring NASA and ESA aerosol data using Giovanni, the online visualization and analysis tool by G. Leptoukh, S. Cox, J. Farley, A. Gopalan, J. Mao, S. Berrick
20. AMSSP (Airborne Multi-Spectral Sunphoto- & Polarimeter), a proposed new spectrometer system for the High Altitude and Long Range Research Aircraft (HALO) and the development of adequate algorithms and methods for optimal retrieval of atmospheric aerosol optical properties by R. Preusker and T. Ruhtz
21. ART algorithm to determine aerosol optical thickness and land reflectance from satellite data by I. L. Katsev, A. S. Prikhach, E. P. Zege, A. A. Kokhanovsky

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