ABSTRACTS

of presentations during the

20th AeroCom

and the

9th AeroSAT

workshops

October 11 – 15, 2021

in alphabetical order by presenter

FULL presentation (15min)
5 SLIDE poster summary

Acharya, Asutosh

The regional northern hemispheric carbonaceous aerosols and the global monsoon

Monsoon exerts a significant social and economic impact on billions of people around the world. Through, the change in Global monsoon (GM) rainfall under global warming is known; its behaviour concerning regional aerosol emissions is limited. Using an atmospheric general circulation model (AGCM), we have attempted to quantify the response global monsoon area and precipitation by spatially removing carbonaceous aerosols over North America (AM), North Africa (AF), Europe (EU) and Asia (AS). The global average aerosol optical depths (AOD) reduce by 2.21%, -1.8%, -1.16 % and -3.8% respectively. A southward shift in the GM domain is observed when carbonaceous aerosols are removed over the regions over Northern Hemisphere. The percentage departure in the area-averaged GM precipitation is 4-fold in magnitude for the EU compared to that of AM and AF. Shrinkage in the GM area is also observed, which is maximum for EU (~ - 30 %) than AM and AF (~ -25%). GM precipitation and area response is found to be the least and opposite in nature for Asian emissions. This study provides insight into the regional nature of aerosol effects on global precipitation.

Ahsan, Hazma

An Overview of Preliminary Results from Emissions-MIP—a Climate and Chemistry Model Intercomparison Project

Anthropogenic emissions of aerosols and precursor compounds are known to significantly affect the energy balance of the Earth-atmosphere system, alter the formation of clouds and precipitation, and have substantial impact on human health and the environment. Global models are an essential tool used to examine the impacts of these emissions. The objective of Emissions-MIP is to quantify the influence of emissions characteristics on model results. Phase 1a in the project examines the impact of five emissions perturbations in ten climate and chemistry models, including chemical transport models. Participating models as of August 2021 include: CESM1, CESM2-WACCM, E3SMv1, GEOS-i33p2, GFDL-AM4.1, GISS ModelE2.1, HadGEM-UKCA, MIROC-SPRINTARS, NorESM, OsloCTM3. The reference case is based on CMIP6 historical emissions. The perturbations examined in Phase 1a are: SO2 emitted at certain heights, SO2 no seasonality, BC no seasonality, no SO4 upon emission, and higher fraction of SO4 upon emission. Each perturbation experiment uses atmosphere-only model simulations with specified sea surface temperatures and nudged winds, running for a five-year period (+ 1 year spin-up). Various data processing tools were utilized to extract, analyze, and plot model results, namely, a CMOR convertor to convert model output to the CMIP standard format, and ESMValTool to extract timeseries data for each variable. Each model simulation reported gas and aerosol concentration and deposition rate variables as well as radiative fluxes. Of the perturbations examined in this study so far, the assumed height of SO2 injection had one of the largest overall impacts, particularly on SO2 mass mixing ratio at the surface (up to 59% change), but also on total deposition rate of sulfur (up to 23% change) and net radiative flux at top-of-atmosphere (maximum absolute difference of 0.28 W m-2). Phase 1b, under development, is a second set of experiments that will focus on the spatial distribution of ocean shipping emissions. We will report on the results from Phase 1 available up to September 2021. Next steps for the project will include coupled model simulations based on a smaller set of perturbations selected from Phase 1.

Allen, Robert

Impact of near-term climate forcer mitigation on the Atlantic Meridional Overturning Circulation

The Atlantic Meridional Overturning Circulation (AMOC) is an important component of the climate system, via regulation of the global transport of heat, freshwater, and carbon. Climate model simulations suggest AMOC weakening through the 21st century in response to continued increases in greenhouse gases (GHGs). Moreover, recent studies also suggest that efforts to improve air quality via aerosol and precursor gas emission reductions will likewise weaken the AMOC. Here, we use four state-of-the-art chemistry-climate model simulations conducted as part of the Aerosol and Chemistry Model Intercomparison Project (AerChemMIP) to quantify the 21st-century impact of near-term climate forcer (NTCF) mitigation—including aerosols and chemically reactive gases such as tropospheric ozone and methane—on the AMOC, using a realistic future emission scenario with a consistent air quality policy. Non-methane NTCF (NMNTCF; aerosols, ozone and precursor gases) mitigation leads to significant AMOC weakening in all four models ranging from 5-10% by end-of-the-century, with a multi-model mean AMOC decrease of 7.0%. In contrast, NTCF (all-NTCF; aerosols, ozone and precursor gases including methane) mitigation leads to multi-model mean AMOC strengthening of 5.6% by end-of-the-century (ranging from -2 to 18%) with three of the four models yielding negligible AMOC change. This is consistent with methane mitigation alone driving a significant AMOC strengthening in all four models (5-25%) by end-of-the-century, with a multi-model mean AMOC increase of 13%. Thus, inclusion of methane mitigation offsets the projected AMOC weakening under NMNTCF mitigation. Our results suggest that efforts to improve air quality via NMTCF mitigation alone will amplify GHG-induced climate change in the North Atlantic, including a weakening of the AMOC. Concomitant reductions in other NTCFs, including methane, as well as carbon dioxide emissions, must also be adopted.

Andrews, Betsy

Systematic relationships between f(RH) and other aerosol optical properties

Particle hygroscopic growth changes aerosol optical properties and thus impacts calculations of the Earth's radiative balance. It is, however, difficult and fairly uncommon to make measurements of aerosol water uptake. Further, measurements of controlling variables (e.g., aerosol size distribution and composition) are also fairly sparse, meaning this important process is not well constrained by observations. Simulations of aerosol water exhibit a wide range that depend on model aerosol chemistry and how aerosol hygroscopicity is parameterized. Here we take a two-pronged approach to improving our understanding of water uptake by aerosol particles. We use the scattering enhancement factor f(RH) - defined as the ratio between the particle light scattering coefficient at a given RH divided by its dry value as a surrogate for aerosol hygroscopicity. First, we use the f(RH) dataset developed by Burgos et al. (2019) in conjunction with collocated observations of other, more commonly measured, in-situ aerosol optical properties to determine if single scattering albedo (SSA) or scattering Angstrom exponent (SAE) can act as a predictor for f(RH). Such a proxy would enable estimates of aerosol hygroscopicity in places where no f(RH), composition or size distribution measurements exist. This work is described in Titos et al. (2021). Second, we look at how a suite of AeroCom models simulate those same proxy relationships to evaluate if there are consistent patterns or biases. We extend the analysis to understand the role of model chemistry in defining the relationship between f(RH) and other aerosol optical properties. Specifically, we show how components such as dust, sea salt and sulfate influence the observed co-variability of model f(RH) with SSA and SAE.

Balkanski, Yves

AeroCom-AeroSat Commission on Constraining Aerosol Properties

The purpose of this commission is to set up bounds and means on useful global aerosol properties, to be revised annually. We will first establish priorities among properties that models/satellite retrievals should be able to simulate/retrieve in relation to global aerosol abundances and optical properties. These recommended targets could guide formulate future Aerocom/Aerosat experiments. The bounds and means on these properties could suggest strategies for future observations and help establish additional constraints on aerosol radiative effects. One of the goal of the commission is to create a maintenance framework, e.g. a table, that will be updated every year at AeroCom-Aerosat workshop, with revised property bounds (possibly global averages or global pdf), vertical distribution, regional averages.

Benedetti, Angela

Assimilation of MODIS reflectances in the ECMWF/CAMS 4D-Var

Satellite observations in the infrared and microwave parts of the spectrum have long been assimilated into forecasting systems to help estimate the best possible initial conditions for global weather predictions. Assimilating radiances in the visible part of the spectrum, on the other hand, continues to pose many challenges. The reason lies in the complex respective interactions of cloud and aerosol particles with radiation at those wavelengths as well as the complex characteristics of the surface as a reflector of visible light. These complications make it difficult to develop ‘observation operators’, which convert model values into satellite observation equivalents. However, progress towards assimilating visible radiances has recently been made in the context of the ARAS (Aerosol Radiance Assimilation Study) project funded by the European Space Agency (ESA). As part of ARAS, an observation operator based on the Oxford-RAL Aerosol and Cloud (ORAC) satellite retrieval scheme has been developed and incorporated into ECMWF’s Integrated Forecasting System (IFS) with the help of the RAL (Retrieval of Aerosol and Cloud) group. This operator includes look-up tables in which reflectances at the top of the atmosphere are stored as a function of aerosol optical properties such as optical depth, single scattering albedo and asymmetry parameter as well as satellite viewing geometry and the position of the sun. Observations used in the ARAS project are the level 2 aerosol visible radiances (reflectances) from the MODIS instrument on board the Aqua and Terra satellites. This is the first time that this type of observation has been assimilated in ECMWF's atmospheric 4D-Var assimilation system. While assimilating such observations is still experimental, the results show great potential for future operational implementation in the atmospheric composition forecasts produced by the EU-funded Copernicus Atmosphere Monitoring Service (CAMS) implemented by ECMWF.

Bian, Huisheng

Observationally constrained analysis of sulfur species in the marine troposphere

The NASA Earth Venture Suborbital (EVS-2) Atmospheric Tomography Mission (ATom) provided rich gas and aerosol measurements over the global oceans. In this study, we investigate the sulfur species of dimethyl sulfide (DMS), sulfur dioxide (SO2), methane sulfonic acid (MSA), and sulfate (SO4) that were measured during the ATom aircraft campaigns and simulated by AeroCom models. This study focuses on remote regions over the Pacific, Atlantic, and Southern Oceans from near the surface to ~12 km altitude and covers all four seasons. We examine the vertical and seasonal variations of these sulfur species over tropical, mid-, and high latitude regions in both hemispheres. We identify their origins from land versus ocean and from anthropogenic versus natural sources with sensitivity studies that trace source origins. Using the GEOS model, we also investigate impact of cloud simulation (i.e., bulk (1MOM) vs microphysics cloud module (2MOM)) on the sulfur cycle and identify driving mechanisms of cloud impact by performing process-level budget analyses.

Brühl, Christoph

Radiative forcing by stratospheric aerosol from 1990 to 2020 using a chemistry climate model and a volcanic emission inventory based on vertically resolved satellite observations.

We present a transient simulation with main focus on volcanic forcing using the chemistry climate model EMAC. We consider more than 500 explosive eruptions by incorporation of 3D-SO2-perturbations derived from observations by the satellite instruments SAGE II, MIPAS, GOMOS and OSIRIS. This includes the major eruption of Pinatubo in 1991 (forcing about -5W/m2) and the second largest event, the eruptions of Raikoke and Ulawun in 2019 (forcing about -0.2W/m2), but also a sensitivity study on the effects of the Australian forest fires in January 2020 which are clearly seen in OSIRIS observations.

Chen, Cheng

Sentinel-3A/OLCI aerosol and surface retrieval based on the GRASP algorithm: product development and preliminary evaluation

The Ocean and Land Color Instrument (OLCI) onboard the Sentinel-3A satellite is a medium-resolution and multi-spectral imager covering bands ranging from the visible to the near-infrared (400 to 1040 nm). These measurements are reliable information for atmospheric aerosol and surface characterization. In the framework of EUMETSAT funded study to support Copernicus Programme, we describe the retrieval of aerosol and surface from OLCI single-viewing multi-spectral TOA radiances based on the Generalized Retrieval of Atmosphere and Surface Properties (GRASP) algorithm. The high potential of OLCI/GRASP retrieval is the attempt to generate aerosol and surface products simultaneously in the fully consistence manner globally. For example, both over land and ocean OLCI/GRASP uses all 9 spectral channels and exactly the same aerosol models. Due to the lack of angular information, the angular properties of underlying surface are strongly constrained in the retrieval: over ocean Fresnel reflection is fixed using a priori wind speed, and over land BRDF retrieval is constrained using a priori values for Ross-Li volumetric and geometric terms. Meanwhile, the isotropic reflectance is retrieved both over land and ocean under mild spectral smoothness constraints. It should be noticed that OLCI/GRASP retrieval employs innovative multi-pixel concept that enhance retrieval by simultaneously inverting large group of pixels simultaneously. The concept allows for benefiting from knowledge about natural variability of the retrieved parameters.

Chimot, Julien

The new Collection of the Copernicus Sentinel-3 NRT Aerosol - Towards homogeneised quality over Land

EUMETSAT has the exclusive Copernicus mandate, entrusted by the European Commission, to lead the scientific expertise & procure the operational Sentinel-3 Near real Time (NRT - < 3h) Sentinel-3 (S3) aerosol product. The baseline is based on the Sea & Land Surface Temperature Radiometer (SLSTR), on-board the S3 A and B satellites. The very 1st Collection started last August 2020, disseminated directly from the EUMETSAT Sentinel-3 ground-segment located in Darmstadt, Germany. The new coming Collection, expected to be released in October-November 2021 time frame, will include a major step-forward toward homogenized quality over land and more resilient for potential changes in the future SLSTR-like sensors. The overall algorithm design of today is a joint development between EUMETSAT & Swansea university (SU). The original aerosol dual-view developments were developed for the SLSTR predecessors, i.e. the (A)ATSR series on-board ENVISAT & ERS-2. The SU ENVISAT algorithm was supported by the European Space Agency (ESA) Climate Change Initiative (CCI). However, in view of preparing for S3 SLSTR, EUMETSAT SU have further investigated & reported the information content for a joint aerosol-surface retrieval is incredibly heterogenous and strongly depends on the overall dual-view geometry (Fougnie et al., 2020). Furthermore, land cover types as well as spectral range & radiometry quality play significant roles (EUMETSAT SARP project, led by FMI https://www.eumetsat.int/SARP). Finally, needs of cloud mask need to challenge obstruction types to be filtered out before/after aerosol processing (https://www.eumetsat.int/S3-synergy-cloud-mask). Nevertheless, in spite of this, in an operational context, user needs are beforehand as much as possible global (not only restricted to some regions or latitudes) and with very low bias / precision. Consequently, EUMETSAT has designed & developed an evolved SU algorithm version to improve the aerosol - land decoupling. This notably includes: 1) an hybrid combination of surface spectral & dual-angular joint aerosol surface over land, as a function of geometry, 2) application of SLSTR radiometry correction on the flight, 3) fit of the Log(AOD) to constrain bright surface or low aerosol load cases, 4) enhanced cloud & high obstruction filtering applied internally in the processor. Quality results of the results will be summarized together with links towards the ATBD & Product validation report. In particular, a focus will be put on the developed Land Spectral method: e.g. the AFRI Red-SWIR Land Surface estimation.

Chin, Mian

Progress and results of the AeroCom UTLS+ACAM experiment

We report the progress and results of the AeroCom UTLS+ACAM experiments. Six models have finished or are about to finish all or part of the model experiments: GEOS, MIROC-SPRINTARS, GFDL-AM3, CAM5-ATRAS, ECHAM6-HMMOZ, and GISS. We will (1) show model agreement/ diversity at the UTLS region, (2) evaluate the model with multiple satellite data, (3) estimate the source attribution to the UTLS aerosols, particularly over the area affected by the Asian Summer Monsoon transport, and (4) discuss next steps.

Colarco, Peter

A Review of the Treatment of Dust Optical Properties in Earth System Modeling

Mineral dust is among the most evident aerosol species visible from space and dominates the mass loading of aerosol in Earth's atmosphere. Its abundance and myriad of interactions with the climate system and with human and natural ecosystems make it a much-studied component of the Earth system, and increasingly an essential and tightly integrated component of Earth system models. Proper treatment of dust in models requires accounting for the evolution of the dust spatial distribution, particle size, composition, and optical properties, all quantities and parameters that have considerable challenges and uncertainties associated with them that are presently not adequately constrained by observations. Here, we survey several global aerosol models that include representation of mineral dust, emphasizing especially models being used in near-realtime aerosol prediction and aerosol reanalysis activities. We focus primarily on the treatment of dust optical properties within these models, including similarities and differences in their approaches. Most of the models surveyed adopt a sectional, external mixing approach to representing the dust particle size distribution and its distinction from that of other aerosol species. The number of size sections and the range of particle size distribution considered differs widely among the models sampled, as do the choices of the effective dust refractive index used to compute optical properties. We discuss implications and limitations of the sectional approach to representing dust optical properties within the models and show diversity in the resulting optical properties caused by model structural choices, such as the number and width of size bins used.
We put our survey of models into the context of currently available remote sensing observations and look for commonalities with other modeling applications such as Mars atmospheric dust modeling.

Cuesta, Juan

Type-discrimated aerosol concentration profile derived from the ACCP spaceborne lidar multispectral measurements

Unprecedented capabilities to observe aerosols from space are potentially offered by the possible new generation spaceborne lidars onboard the ACCP mission. These active instruments will probe aerosols at several wavelengths (two or three), measuring aerosol backscatter and depolarization profiles, and for two of the three possible instruments also high spectral resolution. These lidars will not only provide high-quality vertical profiles of aerosol optical properties, but the possibility to derive additional aerosol properties that have not yet been derived from space. This is the case of the aerosol concentration vertical profile and the quantitative discrimination of the abundance of different aerosols types.
In order to assess the new capabilities to observe aerosol properties of the possible lidars onboard the ACCP mission, we implement a full nature run experiment. We use the MOCAGE chemistry-transport model as pseudo-reality describing the global 3D distributions of several aerosol species. The aerosol distributions are sampled following a typical polar orbit to obtain transects of aerosol vertical profiles. Then, we add variability to the microphysical and optical properties of each aerosol species with a magnitude similar to that observed by real AERONET ground-based sun photometer retrievals at different locations. Using these aerosols properties (spatial distributions, size and refractive indexes), a forward model simulates the vertical profiles measured by either of the three possible ACCP lidars, to which random noise is added depending on the measuring conditions (night, day, spatial resolution). Finally, the synthetic lidar measurements (from all channels of each of the lidars) are used as inputs of an innovative retrieval approach of the type-discriminated aerosol concentration profile, implemented with a so-called GRASP retrieval approach. This method derives the vertical profiles of abundance of each aerosol type along the transects measured by the spaceborne lidar, which also allows bulk estimations of the aerosol profiles of concentration, size and optical properties. The results show that the best performance is clearly obtained for the only lidar including three wavelengths with high spectral resolution for two of them (the uv and visible channels). This instrument enables the quantification of the amount of all aerosol types, even in the case of complex mixing of five different aerosol types (as could be found over India, China or other regions). It is followed by a reduced performance of the lidar operating at two wavelengths with high spectral resolution for one of them (the visible channel), only distinguishing four aerosol types (weak and medium absorbing fine particles are not properly retrieved) and not being able to quantify aerosol types in complex scenes. On the other hand, a two-wavelength lidar without high spectral resolution is unable to discriminate the abundance of each aerosol type, except for desert dust. As expected, daytime noise degrades slightly the performance of the retrievals but a similar relative performance of the lidars is obtained.

DeLessio, Meagan

Modeling atmospheric brown carbon in the GISS ModelE Earth system model

Brown carbon (BrC) is an absorbing organic aerosol primarily emitted by the combustion of biomass and biofuel. While field and laboratory studies have shown that BrC exhibits light absorption unique from black carbon (BC) and organic carbon (OC) aerosols, the climate forcing of BrC is still poorly understood as it is not well represented in most Earth system models (ESMs). BrC undergoes photochemical transformation, or aging, in the atmosphere, resulting in changing absorption. This makes it particularly difficult to incorporate into ESMs, as most are limited to tracers with invariant optical properties. BrC was introduced in the GISS ModelE One-Moment Aerosol (OMA) module by creating three BrC tracers emitted from biomass burning, each with different refractive indices and absorbance. Aging of BrC was simulated through mass exchange between lighter (less absorbing) and darker (more absorbing) BrC tracers. Through this modeling approach, we were able to successfully incorporate primary brown carbon with a hydroxyl dependent aging scheme into the GISS climate model. Sensitivity tests of BrC and OC refractive indices can be used to determine the radiative effect of including dynamic BrC tracers, rather than just attributing some absorbance to OC as previously modeled.

Eck, Thomas

Measurements of biomass burning aerosol optical and physical properties from the extreme forest fires in California/Oregon in September 2020: Comparisons of aged versus fresh smoke properties

The wildfire season in the west coast states of the US from August-October 2020 was exceptional in terms of the extent of area burned and fire severity. Extremely dry biomass fuels from multi-year drought conditions were further exacerbated with very hot and dry conditions in 2020 which coupled with strong offshore flow created the conditions for many exceptionally large and severe wildfires. Long-term monitoring at a few AERONET sites in California showed that the number of days with high AOD in 2020 was much greater than any other year going back to 2002. Additionally, the fine mode particle volume median radii of these smoke plumes were sometimes very large especially at high AOD, likely due to due to both coagulation and condensation occurring during aging at high particulate concentrations. A wide range of fine mode dominated aerosol size distributions that were retrieved from AERONET data over the course of these fires included some with exceptionally large particles coupled with relatively narrow size distributions. These combined large particle radii with narrow distributions resulted in some very rare AOD spectra showing peak AOD at 500 nm and decreasing to lower AOD at shorter wavelengths. The most extreme retrieved size distributions and associated measured AOD spectra were principally observed in long-distance transported smoke plumes from these west coast fires at sites in Colorado, Maryland and Virginia, possibly due to further aging during transport. Additionally, strong absorption was sometimes observed at short wavelengths with much lower single scattering albedo at 440 nm compared to 675 nm in some plumes thereby implying significant brown carbon (BrC) absorption in some organic carbon biomass burning particles. This strong BrC absorption signature observed at some California sites remained similarly strong at some east coast sites in Maryland and Virginia, thereby suggesting that the lifetime of these particular BrC species was greater than 5 days, thereby longer lived for BrC absorption than often cited in the literature.

Ekman, Annika

CMIP6 Overview

Espinosa, Reed

A synergistic multipixel retrieval of aerosol properties from geostationary satellite observations

Individual measurements of shortwave radiance with near-daily global coverage are currently only available from sensors that are limited to a single observation geometry. While spectral dependencies in these observations allow Aerosol Optical Depth (AOD) and some other basic parameters to be reliably extracted, single-angle measurements lack sufficient information to retrieve many other highly desired aerosol quantities. Geostationary (GEO) satellites image a given ground location many times over the course of a day, therefore acquiring data over a diverse set of solar geometries and, in some locations, overlapping fields-of-view between two sensors provides observations from multiple viewing geometries near-simultaneously. Here, we apply new multipixel retrieval techniques with temporal smoothness constraints to asynchronous GEO measurements in order to exploit the additional information contained in the solar and viewing angle dependence of the corresponding radiances. Specifically, observations from both Advanced Baseline Imagers (ABI) on GOES-16 and GOES-17 sampled over the course of a day are concurrently fed into the Generalized Retrieval of Aerosol and Surface Properties (GRASP) algorithm configured to limit temporal variation in certain aerosol properties and land surface parameterization. This technique has significantly increased information content relative to single pixel approaches, and potentially enables the retrieval of more challenging parameters like particle size and absorption. Additionally, in order to determine a set of a priori retrieval assumptions that best uses the information content of all GEO observations, we begin with synergistic retrievals that include both measurements made by collocated ground-based Aerosol Robotic Network (AERONET) sun/sky photometers and observations from both ABI instruments. The resulting GEO and AERONET jointly retrieved surface properties as well as some aspects of the aerosol size, refractive index and non-spherical fraction then drive decisions pertaining to the retrieval of exclusively geostationary-based observations. This procedure helps ensure that the retrieval assumptions map the radiances observed from space to the retrieved aerosol properties in the most consistent manner possible. The geostationary-only retrieval results are then compared with standard AERONET inversion products to assess the accuracy of the new approach.

Ferrare, Richard

Airborne High Spectral Resolution Lidar-2 Measurements of Aerosol Distributions and Properties during the NASA CAMP2Ex Mission

The NASA Clouds, Aerosols and Monsoon Processes-Philippines Experiment (CAMP2Ex) occurred during August-October, 2019, primarily over the ocean near the Philippines, including the ocean west of Luzon. Critical to the successful investigation of these objectives was profiling of aerosol, cloud and meteorological properties throughout the atmospheric column. Consequently, the second generation NASA Langley airborne High Spectral Resolution Lidar (HSRL-2) was deployed on the NASA P-3 aircraft to obtain profile measurements of aerosol and thin cloud extinction and optical thickness via the HSRL technique at 355 and 532 nm, and of backscatter and depolarization at 355, 532, and 1064 nm. The HSRL technique allows for the independent measurement of extinction and backscatter without the need to assume modeled lidar ratios. Additional HSRL-2 data products include aerosol type, mixed layer depth, and range-resolved aerosol microphysical parameters. The HSRL-2 measured these backscatter, extinction, and depolarization profiles during all nineteen science flights and the transit flights to and from the aircraft operations base at Clark International Airport. The HSRL measurements reveal the temporal, spatial, and vertical variability of aerosol optical properties over these locations. Median mixed layer heights were about 560 m. About 40% of AOT was within the mixed layer with the remaining 60% above. During both missions, aerosol backscatter and extinction were systematically 20-40% higher near the top of the mixed layer. Coincident dropsonde and airborne in situ Diode Laser Hygrometer measurements show that these increases in aerosol backscatter and extinction were usually associated with pronounced (>10-20%) increases in relative humidity (RH) near the top of the mixed layer. The HSRL2 data are also being used to evaluate GEOS-5 simulations of aerosol distributions and properties and retrieve profiles of aerosol size and concentration.

Garrigues, Sebastian

Assimilation of multiple satellite aerosol optical depth (AOD) near real time (NRT) products in the Copernicus Atmospheric Monitoring Service (CAMS) data assimilation system

Global monitoring and forecasting of aerosols are required to analyse and predict the impacts of aerosols on air quality and their role in modulating the climate variability. To achieve this, the Copernicus Atmosphere Monitoring Service (CAMS, http://www.copernicus-atmosphere.eu) provides reanalysis records and operational 5-day forecasts of aerosols using the Integrated Forecasting System (IFS), which combines state-of-the-art meteorological and atmospheric composition models together with the data assimilation of satellite products. The current CAMS aerosol monitoring and forecasting system relies on the assimilation of Aerosol Optical Depth (AOD) at 550 nm NRT observations derived from MODIS (TERRA and AQUA satellites) and PMAp (synergy between GOME-2, IASI, AVHRR onboard METOP-A,B,C satellites) datasets. Implementing new observational data streams is of great importance in order to benefit from enhanced accuracy of new observations, to increase the spatial and temporal coverage of the observations, and to increase the resilience of the data assimilation system to the failure of instruments. In this paper, we present results from the implementation of two additional AOD products in CAMS, namely the SENTINEL3-A and -B/SLSTR AOD NRT product (collection 1.0, ocean only) and the VIIRS EPS AOD NRT product from S-NPP and NOAA-20 satellites. The consistency between MODIS, PMAp, VIIRS and SLSTR AOD products as well as their differences with the modelled AOD were evaluated over a 6-month experiment, from December 2019 to June 2020, at both global and regional scale. The evaluation was done at the model grid scale to understand how the differences between products may impact the assimilation. Several assimilation experiments were designed to test distinct assimilation strategies in terms of bias correction and choice of an anchor. The comparison of satellite AOD shows an overall good consistency between VIIRS and MODIS. VIIRS AOD is frequently lower over ocean and higher over biomass burning regions (e.g. central Africa) and South-America. VIIRS resolves finer spatial structures (e.g. transport of biomass burning aerosols) that are not detected by MODIS and the model. Differences between S-NPP and NOAA20 AOD are observed over the South Hemisphere, which can be due to calibration uncertainties. SLSTR AOD shows smaller values than the rest of the products which is related to both a possible underestimation of ocean background aerosols and differences in representativity due to a larger filtering of clouds applied to the SLSTR product. The largest diversity between the products is observed over the Southern Ocean where surface roughness and white foams induced by strong winds are important sources of uncertainties for aerosol retrievals.

The assimilation of VIIRS and SLSTR AOD slightly reduces the bias in the AOD forecast evaluated against AERONET. It leads to a reduction of the analysis increment over ocean which was supposed to be too high due a positive bias in the MODIS/TERRA AOD product. The assimilation of VIIRS leads to an increase of the increments over biomass burning regions and the South-America continent.
The outcomes of this work are discussed to identify shortcomings in current AOD satellite NRT products and to provide recommendations for their assimilation in global atmospheric composition models.

Gasso, Santiago

An overview of modern dust activity in South America based on satellite observations

While not a major contributor to the global dust budget, dust activity in South America is significant. Activity is highly variable from year to year and it originates from at least 5 different sectors: 1) Salar of Uyuni (Bolivia) 2) Patagonia desert (Argentina) 3) West coast along the Atacama desert (Chile/Peru) 4) Arid swath from central Bolivia to northern Argentina and 5) the central and west of Las Pampas in Argentina. Intensive agricultural practices along with multiyear droughts are expanding these regions. Most of dust deposition occurs inland but some of these sources produce major storms. Either by injection at high altitudes (Uyuni) or proximity to either ocean (Atacama , Patagonia) , long range transport of dust may be currently reaching Antartica and depositing along the Southern Ocean during transit, an area known to be sensitive to nutrients contained in dust. This presentation will provide an overview of all these sources and respective activity.

Green, Robert

Earth surface mineral dust source investigations – a NASA earth venture imaging spectrometer science mission (on ISS)

Gryspeerdt, Edward

Sampling strategies for cloud droplet number concentration in satellite data

Cloud droplet number concentration (Nd) is of central importance to observation-based estimates of aerosol indirect effects, being used to quantify both the cloud sensitivity to aerosol and the base state of the cloud. However, the derivation of Nd from satellite data depends on a number of assumptions about the cloud, making it prone to systematic biases. A number of sampling methods have been proposed to address these biases. In this work, we compare the satellite retrieved Nd to in-situ measurements using a variety of different sampling methods. We investigate the impacts of these sampling strategies on the accuracy of the retrieval, how well the satellite product represents the Nd climatology, and what this means for estimates of aerosol indirect effects.

Planning a new indirect effect experiment

A large number of analyses can be performed on a 'control-style' matched PD/PI pair of simulation, particularly one with more cloud-focused output (mostly 2D). With an aim to emulate the success of previous indirect effect experiments, the pakn is to collect potential analyses that could be performed on such a pair, along with modelling groups that are interested. A collection of initial proposed studies and results will be presented. With a similarity to the control and cloud MMPPE setups, this output could be produced as part of other experiments.

Herrera, Milagros

Rigorous dynamic error estimates provided by GRASP algorithm in diverse remote sensing applications: concept and validation.

The understanding of the uncertainties in the retrieval of the aerosol and surface properties is very important for an adequate characterization of the processes that occur in the atmosphere. However, the reliable characterization of the error budget of the retrieval products is a very challenging aspect that currently remains not fully resolved in most remote sensing approaches. For example, the retrieval uncertainties in most approaches are evaluated relying purely on validation with independent data and almost no retrievals provide trustable dynamic error estimates of retrieved parameters. In this study we describe and analyses the dynamic error estimates of all the retrieved aerosol and surface properties by GRASP (Generalized Retrieval of Atmosphere and Surface Properties) algorithm. This approach, described by Dubovik et al., (2011, 2014, 2021), consist in an inversion algorithm based on the concept of statistical optimization approach that takes into account the effect of both random and systematic uncertainties propagations to provide the dynamic error estimates. Moreover, GRASP algorithm provides full covariance matrices, i.e. not only variances of the retrieval errors and also correlations coefficients of these errors. The analysis of the correlation matrix structure can be very useful for identifying unobvious retrieval tendencies that appear to be a useful approach for optimizing observation schemes and retrieval setups. In order to evaluate the error estimates, we conduct a series of comprehensive sensitivity tests when simulated data are perturbed by random and systematic errors and inverted. Using the results of these tests we discuss and analyse the dynamic error estimates of aerosol and surface retrieved properties by GRASP algorithm from different remote sensing observations. The goal of the study is to provide a comprehensive analysis on how different error sources in the data affect the retrievals and how well the obtained error estimates reflect the real uncertainties.

Herreras. Marcos

Enhanced Aerosol Component Retrieval Using Visible and Thermal Infrared Spectrum

The high capabilities of GRASP (Generalized Retrieval of Atmosphere and Surface Properties) (Dubovik et al., 2014) to retrieve aerosol and surface properties from Space-borne and Ground-based remote sensing observations in the visible (VIS) and near infrared (NIR) ranges has been widely proven in diverse applications (Torres et al., 2016; Chen et al., 2020, Lopatin et al., 2021). This work introduces an extension of the possibilities of GRASP for utilizing also remote sensing observations in thermal infrared (TIR) spectral range. We present a synergistic retrieval strategy using combination of VIS, NIR and TIR observations in order to enhance scope and accuracy of the aerosol retrieval products.
The combined inversion of the data from different spectral ranges enables new possibilities to retrieve aerosol chemical composition. Indeed, the aerosol refractive index in TIR presents an extreme spectral variability in comparison with its behavior in the visible part of the spectrum. At the same time, the lack of angular information from the long wave radiation limits the possibilities of the retrieval restricted to TIR spectral range only. Li et al. (2019) demonstrated GRASP/components retrieval methodology that allows for distinguishing different aerosol components from observations in VIS and NIR spectra. We used this new retrieval strategy for retrieval of aerosol properties from combined observations by AERONET (Aerosol Robotic NETwork) (Holben et al., 2018) sunphotometer and CLIMAT radiometer (Legrand et al., 1999). The utilization of TIR radiation measurements enables the distinction between the clays and Quartz composition of aerosol mineral dust in addition to the rest of products retrieved by Li et al. (2019) including fractions aerosol components, particle size distribution, aerosol sphericity or refractive index.

Jafariserajehlou, Soheila

Release of the new Polar Multi-senor Aerosol product (PMAp) vers 2.2

Polar Multi-sensor Aerosol product (PMAp) provides near real-time aerosol optical depth (AOD) and further related parameters e.g. aerosol type. The AOD retrieval algorithm uses a synergetic approach combining the data from different sensors onboard Metop that implements the EUMETSAT Polar System (EPS) programme as a series of three polar-orbiting satellites. PMAp merges the hyper-spectral and hyper-spatial information from the three instruments: Global Ozone Monitoring Experiment (GOME-2), Advanced Very-High Resolution Radiometer (AVHRR) and Infrared Atmospheric Sounding Interferometer (IASI) to retrieve aerosol properties under clear-sky, as well as partially cloudy conditions, at a global scale over both land and ocean. A new version of PMAp (v2.2) has been released in May 2021 to bring the following enhancements: i) improvement of the consistency between Metop-A, B, and C over ocean, ii) significant improvement of the retrieval over Land. The changes in PMAp mainly include: a dust detection scheme in the PMAp pre-classification step exploiting IASI measurements, a solution for the 'hotspot' issue in retrieved AOD (resulting from clouds misidentified as aerosol), updated surface reflectance database (namely Minimum LER angular database) to be compatible with the database derived from both Metop-A and Metop-B, an additional angular dependency of LER, a degradation correction procedure for GOME2 PMD Level 1b data for Metop-A, B and C to account for the aging of the sensor (in line with the latest version derived from re-processed GOME-2 L1b data), additional radiometric adjustment of GOME-2 PMD-P radiances for Metop-A, B and C (affecting bands used for land retrieval). Here we present PMAp v2.2 and a summary of its validation against AERONET. Additionally, we compare PMAp with other aerosol products e.g. MODIS and Sentinel-3 for a limited number of case studies e.g. dust outbreaks, fires, or other strongly polluting events.

Jia, Hailing

Significant underestimation of radiative forcing by aerosol–cloud interactions derived from satellite-based methods

Satellite-based estimates of radiative forcing by aerosol–cloud interactions (RFaci) are consistently smaller than those from global models, hampering accurate projections of future climate change. Here we show that the discrepancy can be substantially reduced by correcting sampling biases induced by inherent limitations of satellite measurements, which tend to artificially discard the clouds with high cloud fraction. Those missed clouds exert a stronger cooling effect, and are more sensitive to aerosol perturbations. By accounting for the sampling biases, the magnitude of RFaci (from −0.38 to −0.59 W m−2) increases by 55 % globally (133 % over land and 33 % over ocean). Notably, the RFaci further increases to −1.09 W m−2 when switching total aerosol optical depth (AOD) to fine-mode AOD that is a better proxy for CCN than AOD. In contrast to previous weak satellite-based RFaci, the improved one substantially increases (especially over land), resolving a major difference with models.

Kahn, Ralph

(aircraft) sub-orbital measurements

Khlestova, Julia

The effect of cloud condensation nuclei reduction over Moscow during spring 2020 lockdown on the cloud characteristics according to the COSMO simulations and measurements

We analyzed the impact of spring lockdown due to COVID-2019 in Moscow on the number concentration of cloud particles (Nd) and the physical characteristics of clouds. The cloud properties were evaluated according to the satellite MODIS data (version 6). In addition, we used CERES satellite data product and radiative observations at the Meteorological Observatory of Moscow State University for the evaluation of global irradiance at ground. The number concentration of cloud particles was retrieved by the methods described in (Quaas et al., 2006; McComiskey et al., 2009). Based on Nd retrievals we carried out simulations using the COSMO-Ru mesoscale model (Rivin et al., 2020) with two-moment microphysics (Seifert and Beheng, 2006) at 1 km grid step and cloud-radiation interaction scheme CLOUDRAD, which adjusts the aerosol-cloud radiative effect using the number concentration of cloud condensation nuclei (Muskatel et al., 2021). The air mass northern advection was observed during the most of the lockdown period (Chubarova et al., 2021). We showed that in similar meteorological conditions with northern advection the number concentration of cloud particles over Moscow during the spring lockdown of 2020 was lower by approximately 100 cm-3 than the Nd during the springs of 2018 and 2019. The median number concentrations of cloud particles in the cases of northern advection were 196 (221) cm-3 according to methods 1 (and 2) during the lockdown period and 269 (306) cm-3 during the springs of 2018-2019. The model simulations demonstrate that the reduction of Nd has a

noticeable effect on the liquid water path, cloud optical thickness and global irradiance at the ground. The liquid water path declines by 5 g/m² (6%) due to the Nd reduction. The clouds are getting optically thinner, and the global irradiance at the ground increases by 10 W/m² (16%) in overcast conditions.
This research has been supported by the Russian Government (grant number 075-15-2021-574).

Kim, Dongchul

Accessment of dust source attribution to the global land and ocean regions

The major source of global dust is well established as most of them are originated from a few major source regions of North Africa, Middle East, and Asia which accounting for more than 80% of global dust emssion. Although source-receptor relationship over the source regions and downwind is simple and clear, it is difficult to attribute the source contribution when they are mixed during the inter-continental long-range transport. The present study will report the source-receptor relationships over land where affected by both local and transported dust; and remote- and ocean-regions where only contributed by long-range transport, including Arctic, Antarctic, Tibetan Plattau, Mid-Pacific, Mid-Atlantic, and Upper Troposphere. A series of runs with 9 tagged regions were made to estimate the contribution of East- and West-Africa, Central- and East-Asia, North America, and the Southern Hemisphere, including 3 prominent dust hot spots of the Bodele, Middle East, and Taklimakan Deserts. In this work, we quantitively estimate (1) the contribution of dust from different source regions to various land and ocean receptor regions, (2) assess the change of simulated dust size distribution between source and receptor regions. A preliminary result shows that dust-belt is the major source of global dust distribution, however models exert large diversity in source contribution over source and remote regions and in seasonality.

Multi-model comparison of dust optical depth at 10 μm over the Northern Atlantic Ocean

In contrast to the fact that most of ground and satellite-borne remote sensing observation provide aerosol optical depth as 550 nm wavelength (DOD550), the dust aerosol optical depth at 10 μm (DOD10) products are also available from the Infrared Atmospheric Sounding Interferometer (IASI). Whereas DOD at 550 nm is most sensitive to the fine particles (<2 μm), significant amount of dust is in the coarser size and thus more sensitive to DOD10. In addition, although modeled dust optical depth at mid-visible (550 nm) is well established, that of the thermal infrared (10 μm) wavelengths in models is not well studied. It opens an opportunity to look into the behaviors of DOD10 between models and observations. We have requested DOD10 from several models as a part of the AEROCOM-III experiment. The goal of this study is to examine the current state of dust optical depth at 10 μm from the IASI observations and the AEROCOM models. Our preliminary result shows that the difference in DOD10 between satellites and models is significantly large over the Northern Atlantic Ocean in summer, when dust signal is most strong and clear.

Kinne. Stefan

Aerosol (radiative forcing) trends with MODIS data

20 years of MODIS AOD and AODf data are applied in an off-line radiative transfer model to determine semi-decadal (2001-2005, 2006-2010, 2011-2015, 2016-2020) aerosol radiative effects and from comparisons general trends. With a focus on the main industrial regions, increased forcing is deduced for India, mainly during the non-monsoon seasons (SON, DJF) and decreased forcing is indicated over Europe and N.America during summer (JJA) and over E.China mainly since 2015.

Kok, Jasper

Contribution of the world's main dust source regions to the global cycle of desert dust

Even though desert dust is the most abundant aerosol by mass in Earth's atmosphere, the relative contributions of the world's major dust source regions to the global dust cycle remain poorly constrained. This problem hinders accounting for the potentially large impact of regional differences in dust properties on clouds, the Earth's energy balance, and terrestrial and marine biogeochemical cycles. Here, we constrain the contribution of each of the world's main dust source regions to the global dust cycle. We use an analytical framework that integrates an ensemble of global model simulations with observationally informed constraints on the dust size distribution, extinction efficiency, and regional dust aerosol optical depth. We obtain a data set that constrains the relative contribution of each of nine major source regions to size-resolved dust emission, atmospheric loading, optical depth, concentration, and deposition flux. We find that the 22-29 Tg (one standard error range) global loading of dust with geometric diameter up to 20 um is partitioned as follows: North African source regions contribute ~50% (11-15 Tg), Asian source regions contribute ~40% (8-13 Tg), and North American and Southern Hemisphere regions contribute ~10% (1.8-3.2 Tg). Current models might on average be overestimating the contribution of North African sources to atmospheric dust loading at ~65%, while underestimating the contribution of Asian dust at ~30%. However, both our results and current models could be affected by unquantified biases, such as due to errors in separating dust aerosol optical depth from that produced by other aerosol species in remote sensing retrievals in poorly observed desert regions. Our results further show that each source region's dust loading peaks in local spring and summer, which is partially driven by increased dust lifetime in those seasons. We also quantify the dust deposition flux to the Amazon rainforest to be ~10 Tg/year, which is a factor of 2-3 less than inferred from satellite data by previous work that likely overestimated dust deposition by underestimating the dust mass extinction efficiency. The data obtained in this paper can be used to obtain improved constraints on dust impacts on clouds, climate, biogeochemical cycles, and other parts of the Earth system.

Levy, Rob

Comparing assumptions for dust optical properties in various Goddard-based aerosol retrieval algorithms

Over the last 20+ years, there has been incredible progress in using satellite observations for deriving aerosol optical properties including dust. Common to nearly all operational retrieval algorithms is the idea of the Lookup Table (LUT) approach, which means comparing satellite observations with forward-model simulations of 'typical' aerosol conditions. Most of these LUTs, in turn, are calculated for conditions that represent specific ‘aerosol types’, represented by ‘aerosol models’ that are combinations of assumed particle size distribution, particle shape, and spectral complex refractive index. For example, most retrieval algorithms have an aerosol model that represents ‘dust’. However, the issue is that over the same 20+ years, the different retrieval algorithms have adopted a diversity of assumed combinations that represent theoretically the same ‘dust’ aerosol type. The Dark Target, Deep Blue, and MAIAC algorithms on MODIS (operating in the visible->near-IR->IR wavelengths) all use different dust models. Different dust models are also used for the NASA -OMI (operating in UV) retrievals, as well as retrievals on MISR (visible->near IR). Each of these translates to different scattering/extinction optical properties including spectral extinction, single scattering albedos and asymmetry parameters, as well as different phase functions, depolarizations and lidar ratios. Why does this matter? As we move forward into the 2020s, our aerosol community has aspirations of merging satellite retrievals and model assumptions, as well as retrievals that fuse together observations from imagers, spectrometer, lidars and polarimeters (e.g., as envisioned for PACE, EarthCare and A-CCP). In this presentation, we intend to compare current assumptions for ‘dust’ and other aerosol models, primarily from Goddard-centric satellite retrievals. We also show some calculations that might help consolidate current models and move forward.

Update on the GEO-LEO 'Dark Target' aerosol project

The Dark Target (DT) aerosol retrieval algorithm has been used to calculate a 20-year aerosol data set from MODIS. The DT algorithm has also been ported to VIIRS, so that we may continue this dataset and create a long-term climate data record. However, this approximately once-a-day snapshot for global AOD and aerosol size parameter is insufficient for true daily sampling (too much cloud) and cannot even begin to capture the diurnal cycle. By including observations from Geostationary (and potentially beyond) orbits, we can stitch together a global dataset which is much more comprehensive. Here, we have adopted DT to Advanced Baseline Imagers (on GOES-16 and 17) and Advanced Himawari Imager (AHI) on Himawari-8, while accounting for differences in wavelength and additional computer processing needs. The resulting aerosol products are being joined with the DT products on MODIS on Terra, MODIS on Aqua, and VIIRS on Suomi-NPP to produce a merged aerosol product at 0.25°x0.25° resolution and 30-minute time intervals. Here we update the community as to the status of the GEO retrieval algorithm and products (Level 2) the GEO-LEO merging (Level 3), the data archive, and visualization. We intend to release a beta version of all products soon.

Lipponen, Antti

Deep Learning Based Post-Process Correction of the Aerosol Parameters in the High-Resolution Sentinel-3 Level-2 Synergy Product

Satellite-based aerosol retrievals provide global spatially distributed estimates of atmospheric aerosol parameters that are commonly needed in applications such as estimation of atmospherically corrected satellite data products, climate modeling and air quality monitoring. However, a common feature of the conventional satellite aerosol retrievals is that they have reasonably low spatial resolution and poor accuracy caused by uncertainty in auxiliary model parameters, such as fixed aerosol model parameters, and the approximate forward radiative transfer models utilized to keep the computational complexity feasible. As a result, the improvement and re-processing of the operational satellite data retrieval algorithms would become a tedious and computationally excessive problem. To overcome these problems, we have developed a machine learning-based post-process correction approach to correct the existing operational satellite aerosol data products. Our approach combines the existing satellite retrieval data and a post-processing step where a machine learning algorithm is utilized to predict the approximation error in the conventional retrieval. With approximation error we refer to the discrepancy between the true aerosol parameters and the ones retrieved using the satellite data. Our hypothesis is that the prediction of the approximation error with a finite training data set is a less complex and easier task than the direct fully learned machine learning based prediction in which the aerosol parameters are directly predicted given the satellite observations and measurement geometry. With our approach, there is no need to re-run the existing retrieval algorithms and only a computationally feasible post-processing step is needed. Our approach is based on neural networks trained based on collocated satellite data and accurate ground based AERONET aerosol data. Based on our post-processing approach, we propose a post-process corrected high resolution Sentinel-3 Synergy aerosol product, which gives a spectral estimate of the aerosol optical depth at five different wavelengths with a high spatial resolution equivalent to the native resolution of the Sentinel-3 level-1 data (300 meters at nadir). With aerosol data from Sentinel-3A and 3B satellites, we demonstrate that our approach produces high-resolution aerosol data with better accuracy than the operational Sentinel-3 level-2 Synergy aerosol product or a conventional fully learned machine learning approach.

Litvinov, Pavel

Surface and aerosol characterisation from S5P/TROPOMI using GRASP algorithm: new possibilities, validation and expected performance

In the framework of the ESA S5p+Innovation AOD/BRDF project GRASP algorithm was adapted to the S5p/TROPOMI instrument to retrieve aerosol and surface properties. The Copernicus Sentinel-5p/TROPOMI instrument provides hyperspectral measurements in the ultraviolet (UV), visible (VIS) and shortwave infrared (SWIR) spectral range. Though the main purpose of this satellite mission is characterization of trace gases at high spectral resolution, it is also capable of aerosol and surface characterization. In particular, S5p/TROPOMI measurements in the UV have unique information about absorption and elevation properties of aerosols. Moreover, measurements in the wide spectral range are very sensitive to aerosol size and surface type. Together with basic aerosol and surface characteristics like AOD and different surface albedos, GRASP algorithm for S5p/TROPOMI instrument provides extended aerosol characterisation from UV to SWIR spectral range including the Angstrom exponent, spectral aerosol single scattering albedo and surface BRDF. Here we present the results of validation of GRASP/S5p aerosol and surface products. New advanced possibilities of aerosol and surface characterization from S5p/TROPOMI instrument with GRASP algorithm will be discussed.

Luffarelli, Marta

Combined Aerosol and Cloud optical thickness from SLSTR observations

Several studies have shown that aerosol retrieval from satellites is strongly affected by cloud contamination errors and cloud enhancement. In the transition zone between clouds and cloud-free air, cloud enhancement leads to an increase of aerosol optical thickness and to changes in the aerosol particle size. The choice of the cloud mask to be used in aerosol retrieval (AOT) applications is thus critical.

Mei, Linlu

Above cloud aerosol properties retrieved from the XBAER algorithm

In this talk, the eXtensible Bremen Aerosol/cloud and surfacE Retrieval algorithm (XBAER) has been developed to retrieve aerosol and cloud properties for aerosol above cloud conditions. A comprehensive sensitivity study with respect to impact of aerosol vertical profile, aerosol layer position, aerosol type has been performed for typical cloud and aerosol conditions. The XBAER algorithm is then tested on the MODIS instrument, for a direct comparison with the two NASA algorithms (OMI/OMACA and M-S algorithms). The both NASA algorithms have been applied on the MODIS instrument. The comparison between three satellite derived products show good agreement for aerosol optical thickness (AOT), cloud optical thickness (COT) and cloud effective radius (CER). The correlation coefficients are higher as 0.9 for AOT, ~0.8 for CER and ~0.7 for COT. XBAER derived cloud properties is then compared with ground-based MicroWave Radiometer (MWR) measurements, and a significant improvement of cloud properties under high AOT is found.

Mielonen, Tero

Comparing aerosol type time series in a climate model and a satellite retrieval

Identification of aerosol types (in terms of their source origin and main composition) is important because of the effects that different aerosols have on health, visibility and Earth's climate. However, typing of the atmospheric aerosols using satellite retrieved aerosol properties is a challenging endeavor due to uncertainties associated with the retrieval process and top-of-atmosphere measurements. Furthermore, the comparison of simulated and retrieved aerosol types is difficult as models tend to categorize aerosols based on their chemical composition whereas the types used in satellite retrievals are more tightly linked to their sources. To overcome this hurdle between models and observations we have used satellite-based aerosol typing also for model data. In practice, the categorization of the aerosol types were based on Ångström exponents and single scattering albedos (SSA). Aerosol optical depth (AOD) was used as an auxiliary parameter supporting the other parameter thresholds to separate background aerosol conditions (low AOD), and high aerosol concentration conditions (anthropogenic pollution, dust outbreaks). Then we calculated the frequency of different aerosol types globally and in several subregions for the period of 2003-2010. The analysis was based on The Advanced Along-Track Scanning Radiometer (AATSR) observations and ECHAM6-SALSA aerosol-climate model simulations. By comparing the regional time series of the distributions of these aerosol types we can see where and for which aerosol types the simulations and retrievals are in agreement and where they disagree the most. This information is essential for bridging the gap between observed and simulated aerosol types and, hopefully, it will help the satellite and model communities find a common language regarding this topic. However, our preliminary results show that there are significant differences between the retrieved and simulated trends of aerosol types regionally and globally.

Miinalainen, Tuuli

Correcting ECHAM-HAMMOZ derived PM2.5 concentrations with statistical downscaling

In this study, we study the potential of correcting ECHAM-HAMMOZ-derived surface PM2.5 values with random forest regression algorithm. We chose New Delhi area as our target region, and used data from multiple measurement stations to downscale the simulated fine particle concentrations. Furthermore, we apply the correction algorithm for future simulations with two different emission projections.

Moseid, Kine

Lifetime of BC affected by intermodel differences in particle ageing

Lifetime of an aerosol is calculated from Earth System Models as the global atmospheric load divided by the sum of global wet and dry deposition. But both deposition and load differs in region, and between models. We define lifetime* as the regional ratio between atmospheric load and total deposition, and find large intermodel differences between 11 CMIP6 models regarding black carbon lifetime* in the northern hemisphere. Some models have large reduction in BC lifetime* throughout the historical experiment - which we believe is connected to the models ability of coating and ageing BC particles, making them more hydrophilic.

Mott, Andrea

Community Emissions Data Systems (CEDS): Emissions to 2020

Data on historical trends and spatial distribution of greenhouse gas emissions and air pollutants is central to our understanding of their past and current impacts on health and the global environment. The Community Emissions Data Systems (CEDS) produces historical anthropogenic emissions by country, sector, and fuel, recently updated to v_2021_04_21 extending to 2019. Recent improvements include updated default and country inventory data, updated energy data, improved assumptions for BC/OC from coke production in China, improved trends for emissions from petroleum production over time, and lower assumed biomass consumption in Nigeria and Ethiopia. We will discuss plans to update historical trends out to 2020, which will reflect the global impact of changes in energy consumption during the first part of the COVID-19 pandemic. In addition to general improvements, we are breaking out sectors into more detail and adding satellite-driven point source emissions to the inventory. Providing more detailed sectors (such as refining) and pinpointing pollutants from specific sources (power plants, refineries, metal smelters) can provide more accurate emissions data for models. The breakdown to finer resolution allows us to use more precise data from satellites and other sector specific driver data, which increases spatial and temporal accuracy.

Narayan, Kanishka

Evaluation of SO2 emissions from the OMI point source catalog

Pollutant emission measurements from the Ozone Monitoring Instrument (OMI) satellite are a valuable source of data on emissions given their spatial and temporal coverage especially for regions where no inventory data are available. These measurements are updated annually and include sources that may be missed by bottom-up inventories. Satellite measurements are combined with a meteorological re-analysis to derive a catalog of roughly 500 point sources. However, to understand and validate this point source catalog, they need to be compared to definitive bottom-up inventory data. In this project we compared the Sulfur Dioxide (SO2) emissions from the OMI point source catalog for the contiguous US with SO2 emissions inventory data. Specifically, we compared the satellite emissions with 3 different datasets namely, the Energy Information Administration (EIA) power plants dataset (which includes SO2 emissions largely from Continuous Emission Monitoring Systems (CEMS) for power plants), the National Emissions Inventory (NEI) maintained by the Environmental Protection Agency (EPA) (which includes all point sources, power plant and non-power plant) and the Emissions and Grid Resource Integrated Database (EGRID) also maintained by the EPA (which covers point sources for power plants). Through comparisons with such diverse datasets, we intend to validate the emissions from the point source catalog both in terms of the source of emissions (power plants vs other sources) and temporal coverage (including multiple datasets allows us to examine trends over time in more detail). To make the emissions from the point source catalog and the inventories more comparable, we aggregated emissions from the inventories within a radius of 40 kms. This approach allowed us to categorize emissions from individual sources in inventories as either “detected” by the satellite or “not detected” thus also allowing us to quantify the error structure (satellite measurement – inventory value) from detected sources. We find, as expected, that emission sources not detected by the satellite are the largest aggregate source of error between the satellite estimates and the inventories, especially in more recent years. For sources that are detected, we find that errors in aggregate (total of all detected sources) are relatively low. However, when exploring errors for individual sources over time, we find that the errors are not necessarily random i.e., there are consistent positive biases (over-estimates) or consistent negative biases (under-estimates) for many sources. Moreover, the errors for individual sources in any given year can be significant with large over or under-estimates ranging from -90% to +500% (roughly 10 - 90th percentile) in an asymmetric distribution with a long tail.

Neubauer, David

Climate impacts of aviation aerosol emissions

Aircraft emissions increased in the last decades, and are expected to rise even further in the coming decades. Natural cirrus are known to have a positive radiative forcing, i.e. a warming effect on our climate. Here we show through a series of sensitivity tests how aircraft emissions impact the competition of different ice nucleation processes, and how this further impacts ice cloud properties. We find including aircraft emissions, in particular soot, leads to higher positive radiative forcing, highlighting the potential warming impact of aviation on climate. Enabling soot to act as an ice nucleating particle increases heterogeneous nucleation, while reducing homogeneous nucleation confirming our knowledge of the competition between different ice nucleation modes in cirrus clouds. The impact of aviation is only weakly notable in slight changes of cloud properties.

Olivie, Dirk

Comparing the climate impact of CMIP5 versus CMIP6 aerosol (precursor) emissions in NorESM2

We present results of simulations with the NorESM2 Earth System Model and analyse the impact of using CMIP5 versus CMIP6 aerosol (precursor) emissions in the same model. Traditionally, when going towards a new phase of CMIP, both model improvements and updates in the external forcings such as GHG concentrations, aerosol and aerosol precursor emissions, and stratospheric AOD, are often applied simultaneously. To estimate the impact of updating the emissions from CMIP5 towards CMIP6, we have rerun the historical simulation (1850-2014) using the CMIP5 aerosol emissions and keeping all other external forcings as in CMIP6. NorESM2 showed a reasonably strong aerosol forcing when using CMIP6 emissions, and the new simulations indicate that this is also the case when using CMIP5 emissions.

Pan, Xiaohua

Update on AeroCom Biomass Burning Emission Injection Height experiment (BBEIH)

The environmental impacts of smoke aerosols depend not only on the emitted mass, but also on the injection height, which affects the longevity, chemical conversion, and fate of the plume's chemical constituents. This is especially true for large boreal forest fires that often inject smoke above planetary boundary layer (PBL) into the free troposphere and even the lower stratosphere. However, most atmospheric chemistry transport models (CTMs) assume that fire emissions are dispersed only within PBL, or use simple vertical profiles or simple plume-rise parameterizations. In order to test the sensitivity of model results to smoke injection height, we proposed the biomass burning emission injection height experiment (BBEIH) in the AeroCom 2019 workshop. The description of implementation methods and input data for BBEIH can be found in https://wiki.met.no/aerocom/phase3-experiments #biomass_burning_emission_injection_height_experiment_bbeih. In BBEIH, we introduced the biomass burning injection heights based on MISR stereo-derived plume-height retrievals (Val Martin et al., 2010; 2018) in four participating CTMs. Specifically, we proposed 4 simulations for the year 2008: 1) BASE:

using the biomass burning emissions from Global Fire Emissions Database version 4 with small fires (GFED4s) and the model default fire emission injection height; 2) BBIH: Same as BASE, but using the injection height derived from the seasonally and regionally varying MISR-retrieved plume heights; 3) NOBB: no fire emission; 4) Same as BASE, but using Fire Energetics and Emissions Research version 1.0 (FEER 1.0). We will address the following scientific questions: 1) To what extent are the model simulations sensitive to the assumed biomass burning injection height? 2) In which regions/ seasons/ surface-types are the aforementioned sensitivities most important? We will update the multi-model inter-comparison with a focus on the vertical aerosol distribution in near-source characteristics and downwind plume evolution.

Popp, Thomas

Uncertainty-weighted ensemble products for (Dust) AOD

In ESA Aerosol_cci, an ensemble algorithm had been developed for AATSR, which uses the pixel-level uncertainties in the aerosol products to combine results of several algorithms for the same sensor. This algorithm was now applied within the Copernicus Climate Change Service (C3S) to several sensors: AATSR (and ATSR-2), SLSTR, OLCI (and MERIS) and IASI. Before calculating the ensemble results, the pixel-level uncertainties of all algorithms / instruments were evaluated against true errors versus AERONET. This evaluation included comparison of histograms of true errors with integrated error distributions calculated by summing up error Gaussian distributions with the width of the pixel-level uncertainties in the products. Secondly, percentiles in pixel-level uncertainties were assessed as function of binned true errors to judge, how well the pixel-level uncertainties can discriminate "good" and "bad" pixels. Those evaluations proved the high performance of part of the pixel-level uncertainties, while they also revealed some weaknesses of others. Based on these evaluations, piece-wise linear corrections of those pixel-level uncertainties were manually developed and applied, before the ensemble values were calculated. Validation of the gridded daily ensemble products with the AEROCOM tools showed clearest beneficial effects for the IASI ensemble (improved coverage, 4 algorithms contribute), slight effects for (A)ATSR(-2) and SLSTR (smallest bias, best consistency of the two ATSR sensors; 3 algorithms contribute) and no benefit for OLCI (only two algorithms involved).

Povey, Adam

Updating quality control in the Optimal Retrieval of Aerosol and Cloud (ORAC)

Quality control is one of the most important aspects of an aerosol retrieval: identifying circumstances where the environment is poorly suited to satellite retrieval, flagging failed calculations, and removing cloud contamination. This poster outlines recent work to revise the QC methods applied in the ORAC aerosol retrieval to account for the shift from processing 10 km to 1 km pixels. The methods are demonstrated, as is traditional, by validation against AERONET and, I hope, MAN.

Quaas, Johannes

Aerosol trends since 2000 and aerosol ERF

Aerosol emissions declined over many regions since 2000, and satellite data of various quantities, but also surface observations, show declines in aerosol concentrations, cloud droplets, and (clear-sky) radiation. Ocean heat uptake, in turn, does not point to a very strong increase in the overall positive anthropogenic forcing. The talk will present these trends and aim at conclusions about model constraints and ERF constraints.

AtmoDat model data standard

Together with partner institutes, we have worked on a data standard that - as we propose - may be useful for our intercomparison studies. It is intended to be versatile and light-weight but still allows for standardisation of output. The poster will explain how it works and what may be advantages of applying it.

Regayre, Leighton

Constraining aerosol forcing uncertainty using satellite data

We constrain aerosol-cloud interaction forcing uncertainty in a single Earth system model, using satellite microphysical observation data. We densely sample model uncertainty by perturbing multiple process parameters related to clouds, aerosols, radiation and precipitation. Our ensemble of model variants samples regional uncertainty in anthropogenic aerosol emissions and includes high time resolution data for optimal model-measurement comparison. We rule out observationally implausible model variants (parameter combinations) using satellite-derived values of cloud properties such as cloud droplet concentrations, albedo and cloud fraction. The remaining model variants have a narrower range of aerosol-cloud interaction forcing values. Additionally, we use statistical methods to identify the relative importance of processes as causes of aerosol-cloud interaction forcing uncertainty and quantify the effect of constraint on the associated parameter values. Processes that cause the remaining uncertainty indicate which specific measurement types will be of most value in reducing the uncertainty further.

Robbins, Daniel

Improving Differentiation of Cloud and Extreme Smoke Plumes in Himawari-8 Scenes

As the climate changes, it is expected that bushfires will become more frequent and intense in Australia. High-intensity bushfires produce large amounts of smoke that interact with the atmosphere and can cause poor air quality. The recent 2019-2020 Australian bushfires serve as a useful case-study for these future scenarios, with smoke plumes achieving optical depths of 7 and several significant pyrocumulus events. Existing satellite algorithms often struggle to identify thick aerosol. However it is important to be able to distinguish thick smoke plumes from clouds within remote sensing data, to understand the impact of both radiative forcing and air quality. To deal with these conditions, we developed a cloud mask based on several neural networks (NNs) which were trained on data collocated between AHI, CALIOP and ERA5 to improve cloud and aerosol detection when observing high aerosol amounts. We compared the resulting NN cloud mask to products offered by the JMA and BoM both statistically and in case-studies. We then used the NN cloud mask in an aerosol retrieval algorithm to measure the properties of the aerosol during the Australian 2019/2020 fires.

Sand, Maria

Aerosol absorption in global models from AeroCom Phase III

Aerosol induced absorption of shortwave radiation can modify the climate through local atmospheric heating, which affects lapse rates, precipitation, and cloud formation. Presently, the total amount of aerosol absorption is poorly constrained, and the main absorbing aerosol species (black carbon (BC), organic aerosols (OA) and mineral dust) are diversely quantified in global climate models. As part of the third phase of the AeroCom model intercomparison initiative (AeroCom Phase III) we here document the distribution and magnitude of aerosol absorption in current global aerosols models and quantify the sources of intermodel spread, highlighting the difficulties of attributing absorption to different species. 15 models have provided total present-day absorption at 550 nm (using year 2010 emissions), 11 of which have provided absorption per absorbing species. The multi-model global annual mean total absorption aerosol optical depth (AAOD) is 0.0054 [0.0020 to 0.0098] (550 nm) with range given as the minimum and maximum model values. This is 28% higher compared to the 0.0042 [0.0021 to 0.0076] multi-model mean in AeroCom Phase II (using year 2000 emissions), but the difference is within one standard deviation which in this study is 0.0023 (0.0019 in Phase II). Of the summed component AAOD, 60 % (range 36-84%) is estimated to be due to BC, 31 % (12-49%) is due to dust and 11% (0-24%) is due to OA, however the components are not independent in terms of their absorbing efficiency, and in models with internal mixtures of absorbing aerosols, a major challenge is the lack of a common and simple method to attribute absorption to the different absorbing species. Therefore, when possible, the models with internally mixed aerosols in the present study have performed simulations using the same method for estimating absorption due to BC, OA and dust, namely by removing it and comparing runs with and without the absorbing species. We discuss challenges of attributing absorption to different species, we compare burden, refractive indices, and density, and we contrast models with internal mixing to models with external mixing. The model mean BC mass absorption coefficient (MAC) value is 10.1 [3.1 to 17.7] $m^2\ g^{-1}$ (550 nm) and the model mean BC AAOD is 0.0030 [0.0007 to 0.0077]. The difference in lifetime (and burden) in the models explain as much of the BC AAOD spread as the difference in BC MAC values. The difference in spectral dependency between the models is striking. Several models have an absorption Ångstrøm exponent (AAE) close to 1, which likely is too low given current knowledge of spectral aerosol optical properties. Most models do not account for brown carbon and underestimate the spectral dependency for OA.

Sayer, Andrew

All-sky vs. clear-sky AOD and the problem of partial cloudiness when comparing model and satellite aerosol fields

Most satellite retrievals can provide AOD only for cloud-free pixels. Dozens to thousands of pixels fit into a model grid cell, and many model grid cells are partially cloudy. Models carry speciated aerosol mass and, because many aerosols are hygroscopic, need to make some assumptions about the aerosol and humidity partition between clear and cloudy portions of the grid cell when calculating AOD. Consequently, the clear-sky (CS) AOD observed by satellites can be quite different from the all-sky (AS) AOD provided by models. This is one of several reasons why comparing satellite-derived and model-simulated AOD can be an apples-to-oranges comparison. We took GISS ModelE simulated AS and CS AOD at fine (30 min) temporal resolution and matched with coincident MODIS and POLDER aerosol retrievals (on the model grid) for the year 2010. We looked at the difference between satellite AOD and the AS or CS model estimates in several regions, as a function of estimated cloud cover. We also examined the consistency between model-diagnosed and satellite observed cloud cover. We would like to foster a discussion about how best to make meaningful AOD comparisons in partially cloudy grid cells, and how to improve model representation of AS vs. CS AOD. We welcome other modelers to provide data: year 2010, sub-daily (ideally 30-60 min) output, your regular model spatial grid, clear-sky and all-sky AOD.

Schmeisser, Lauren

Updates on the AeroCom INSITU Project: Using In-situ Surface Measurements of Aerosol Optical Properties to Evaluate Model Simulations

Aerosols absorb and scatter incoming sunlight and are thus an important part of the climate system. Despite their key role, aerosols are still the largest uncertainty in estimates of Earth's energy budget. Global climate models provide a way to evaluate the effects of aerosols on climate; however, these model simulations make assumptions about aerosol characteristics and processes that need to be continuously evaluated against observational datasets in order to confidently interpret model output. Using long-term in-situ surface measurements provides unique advantages over comparisons using satellite and remote sensing products. In-situ measurements can be related to physical standards, can be made more reliably at low aerosol loadings, and can be made at night and during cloudy conditions. Here we use high-quality in-situ aerosol optical property measurements from over 350 surface monitoring stations worldwide to evaluate the suite of models from the AeroCom INSITU experiment. We explore model/measurement comparisons of aerosol scattering coefficient, aerosol absorption coefficient, scattering and absorption Ångström coefficients, as well as single scattering albedo, and find large inter-model variability in representation of aerosol amount, seasonality, and characteristics. The biases outlined here provide a path forward to improve the predictive capability of global climate models.

Schulz, Michael

AeroCom status

Schuster, Greg

Tables of Aerosol Optics (TAO)

TAO is a new set of optical tables that we are computing. The new tables will provide mass extinction coefficients, mass absorption coefficients, lidar ratios, etc. at the OPAC wavelengths (0.25-40 um) for all pertinent species (sulfate, nitrate, sea salt, BC, OC, BrC, dust, etc.). Additional tables will be built corresponding to remote sensing wavelengths (AERONET, MISR, MODIS, POLDER, etc.). Multiple tables for each species will be created to account for the multiple valid size distributions and complex refractive indices that we find in the literature. All tables will be stored in a public repository when complete. In this talk, we will discuss how the TAO tables are built. Classic papers by Tang et al will be used to characterize the hydration of the water-soluble salts, and kappa theory will be used for organic aerosols. Dust optics will be computed using non-spherical shapes (spheroids and hexahedrals) and mineral mixtures that are consistent with AERONET and SAMUM refractive index retrievals at vis-nir wavelengths. Black carbon optical properties will be computed using recent SP2 size distribution measurements and recommendations by Bond and Bergstrom (2006); internal mixtures of black carbon and organic carbon will also be addressed.

Schutgens, Nick

Model evaluation with satellite data of AAOD and SSA

AAOD and SSA from satellite are potentially very important observables to constrain the role of absorbing aerosol in our climate system. We recently published a detailed evaluation of 4 such datasets and will use them in this talk to evaluate AEROOM models. First, we present a new method for dealing with the limited spatio-temporal sampling of satellite datasets (especially AAOD and SSA datasets). In brief, model data are used to provide a link between the limited sampling of a satellite and the full field. Second, we show how models' AAOD & SSA perform against the satellite data. Underestimation of AAOD is still fairly typical in models, although over biomass regions some models actually overestimate. Third, we analyse why model AAOD varies across models. For instance, we find that over source regions fairly linear relationships exist between model AAOD and black carbon or dust emissions. This is used to present new estimates of emissions from the Amazonian and Savanna fires as well as Saharan dust outbreaks.

Skeie, Ragnhild

Changes in aerosol atmospheric composition and radiative forcing in OsloCTM3 over the past decade – the effect of the updated CEDS emission inventory

Over the last decade, the total global anthropogenic emissions of aerosol precursors have declined according to the most recent Community Emissions Data System (CEDS) emission inventory. The CEDS emission inventory used in CMIP6 has recently been updated and extended from 2014 until 2019 (version v_2021_02_05). The role of the updated emissions and the trend beyond 2014 on the modeled atmospheric composition and radiative forcing using an atmospheric chemistry transport model (OsloCTM3) will be presented. In addition, we present consistent modeling results for 2020, using the most recent CEDS emission inventory for 2019 combined with the 2020 CovidMIP-emission perturbation for 2020, as aerosol precursor emissions declined further due to containment policies to combat the COVID-19 pandemic.

Song, Qianqian

Deriving Size-Resolved Dust Direct Radiative Effect Efficiency from a Satellite-based Decadal Dust Optical Thickness Climatology

The role of dust aerosol in global radiative energy budget is often quantified by the dust direct radiative effect (DRE). Spatial and temporal variation of dust optical depth (DAOD) is vital for estimating dust DRE and evaluating dust simulations in models. In our recent study (Song et al. 2021), we derived two observation-based global monthly mean DAOD climatological datasets from 2007 to 2019 with a 2° (latitude) ×5° (longitude) spatial resolution, one based on CALIOP and the other on MODIS observations. The two datasets compare reasonably well with the results reported in previous studies and the collocated AERONET coarse mode AOD. Based on these two datasets, we carried out a comprehensive comparative study of the spatial and temporal climatology of dust. On multi-year average basis, the global (60°S-60°N) annual mean DAOD is 0.032 and 0.067 according to CALIOP and MODIS retrievals, respectively. CALIOP and MODIS show similar seasonal and interannual variations in regional DAOD. For dust aerosol over Northwest Pacific (NWP), both CALIOP and MODIS show a declining trend of DAOD at a rate of about 2%/yr. This decreasing trend is consistent with the observed declining trend of DAOD in the southern Gobi Desert at a rate of 3% /yr and 5% /yr according to CALIOP and MODIS, respectively. CALIOP derived DAOD spatial and vertical distribution makes it possible to estimate observation-based global dust DRE. However different combinations of DAOD and dust properties (e.g., size) can often lead to the same DRE. Therefore, the DRE efficiency (DREE=DRE/DAOD) is proposed in many studies as a stronger constraint on model simulation. Nevertheless, DREE is still influenced by the uncertainties associated with dust particle size distribution (PSD). To alleviate this problem, several previous studies have used model simulations to derive the size-resolved DREE(r). It is shown that the combination of model simulated DREE(r) and observation-constrained dust PSD and DAOD can avoid the dust size simulation bias and provide a more realistic estimation of global dust DRE. However, DREE(r) depends on numerous factors such as dust refractive index, dust shape, dust vertical distribution (especially for DREE-LW), dust spatial and temporal distribution, atmospheric and surface properties. Many of these factors (e.g., dust vertical height) are poorly simulated in the model, leading to large uncertainty in DREE(r). As an ongoing research, we derive a global size resolved DREE(r) in both SW and LW based on satellite observations. Dust spatial and vertical distribution are based on CALIOP retrievals. Atmospheric profile and surface properties are from MERRA2. Dust geometric diameter from 0.1µm to 100 µm is divided into 10 bins and the corresponding DREE(r) (with respect to DAOD at 550nm) for each size bin is derived by using Rapid Radiative Transfer Model (RRTM). Two sets of DREE(r) are derived based on two widely used dust refractive indices to investigate the sensitivity of dust DREE(r) to dust absorption. We also investigated the sensitivity of DREE(r) to dust shape (sphere vs. non-sphere). Then, for each dust RI and dust shape combination, we develop a database in which globally distributed monthly mean DREE are calculated for each of 10 size bins with 5^∘ longitude× 2^∘ latitude resolution. Finally, we show that the combination of the observation based DREE(r) and measured dust PSD and DAOD retrievals can be used to derive and understand the spatial (e.g., regional differences) and temporal (e.g., seasonal and interannual) variations of dust DREE and DRE.

Sorooshian, Armin

The Aerosol Cloud Meteorology Interactions over the Western Atlantic Experiment (ACTIVATE): Strategy and First Results

The Aerosol Cloud meTeorology Interactions oVer the western ATlantic Experiment (ACTIVATE) is a NASA Earth Venture Suborbital-3 (EVS-3) campaign aiming to reduce uncertainty in modeling aerosol-cloud interactions. The ACTIVATE concept relies on using two closely coordinated aircraft (HU-25 Falcon and King Air) with similar airspeeds for acquiring simultaneous, collocated in situ and remote sensing measurements that reduce sampling differences. The western North Atlantic Ocean (WNAO) was chosen as the study region as it affords a wide range of conditions associated with meteorology and aerosol types across different seasons. With 150 planned joint flights based out of NASA Langley Research Center (Hampton, Virginia) over multiple seasons between 2020 and 2022, an extensive dataset will be available to the research community to advance knowledge of aerosol-cloud interactions that circumvent limitations from past campaigns associated with statistics, measurement ob¬stacles, and regional characteristics. In ACTIVATE's first year (2020) of aircraft operations, 22 and 18 research flights were successfully executed in February-March and August-September, respectively. There are three objectives associated with data analysis as part of ACTIVATE: (i) characterizing relationships between aerosol particles, cloud condensation nuclei, and cloud droplet number concentrations; (ii) understanding factors governing the formation and evolution of the region's boundary layer clouds spanning the continuum from stratiform to cumulus clouds; and (iii) assessing advanced remote sensing capabilities for retrieving aerosol and cloud properties related to aerosol-cloud interactions. This presentation will summarize ACTIVATE's overall strategy and provide initial results for the WNAO region based on flight data and supplementary datasets.

Su, Wenying

Understanding top-of-atmosphere flux bias in the AeroCom Phase III models: a clear-sky perspective

We compare top-of-atmosphere (TOA) clear-sky reflected shortwave (SW) fluxes observed by the Clouds and the Earth's Radiant Energy System (CERES) and simulated by nine AeroCom models participating in the phase III control experiment. We also compare aerosol optical depths (AOD) and land surface albedos from these models with satellite products to understand the causes for the SW flux bias. Radiative kernels of AOD and land surface albedo are used to quantify their corresponding contributions to the SW flux bias. Over ocean, AOD contributes about 25% to the 60S-60N mean SW flux bias for the multi-model mean (MMM) result. Over land, AOD and land surface albedo contribute about 40% and 30%, respectively, to the 60S-60N mean SW flux bias for the MMM result. Furthermore, the spatial patterns of the SW flux biases derived from the radiative kernels are very similar to those between models and CERES, with the correlation coefficient of 0.6 over ocean and 0.76 over land for MMM using data of 2010. High correlations also exist for all models considered in this study, and the agreements with CERES TOA SW flux improve for most models after accounting for the contributions of AOD and land surface albedo to TOA SW flux biases. TOA SW fluxes from CERES are derived independently from AOD and land surface albedo used in this study, consistencies in their bias patterns when compared with model simulations suggest that these patterns are robust (as the uncertainty of SW fluxes is independent of that of AOD/surface albedo). This highlights the importance of evaluating related variables in a synergistic manner to provide an unambiguous assessment of the models, as results from single parameter assessments are often confounded by measurement uncertainty. We conclude that correcting the land surface albedo and constraining AODs in the models using satellite derived products will lead to better agreements in TOA clear-sky SW fluxes between models and CERES on both global and regional scales. Model biases in land surface albedos can and must be corrected to accurately calculate TOA flux. We also compare the AOD trend from three models with the observation-based counterpart. These models reproduce all notable trends in AOD (i.e. decreasing trend over eastern United States and increasing trend over India) except the decreasing trend over eastern China and the adjacent oceanic regions due to limitations in the emission dataset.

Thomas, Gareth

Bridging the gap between models and aerosol retrievals in the ARAS project

The ESA Aerosol Radiance Assimilation Study (ARAS) demonstrated the assimilation of satellite radiances for constraining aerosol properties in ECMWF's Integrated Forecast System (IFS) model, by utilising the fast-forward model from the Optimal Retrieval of Aerosol and Cloud (ORAC) retrieval scheme. One of the conceptual and technical challenges of this work was bridging the gap between how aerosols are typically represented in global models and satellite retrieval schemes, and the solution raises an interesting alternative for how such retrieval schemes parameterise aerosol.

Torres, Omar

Satellite-based evidence of secondary aerosol formation in the stratosphere following pyroCb events

Since the beginning of the satellite remote sensing era in the late 1970’s, unprecedented amounts of carbonaceous aerosols reached the stratosphere on two occasions over the last four years. Both events were associated with combustion-triggered pyro-cumulonimbi (pyroCb’s) clouds resulting from wildfires in British Columbia on mid-August 2017, and in Southeastern Australia between December 30, 2019, and February 4, 2020. Satellite measurements by the Ozone Mapper and Profiler Suit Limb Profiler (OMPSLP) sensor on the Suomi-NPP platform were used for monitoring the long-term evolution of these stratospheric carbonaceous aerosol layers. Results indicate that during the 2017 event, peak stratospheric aerosol mass amounts was 0.3-0.6 Tg, whereas a significantly larger maximal aerosol mass, 0.8-1.8 Tg, was observed for the Australia 2020 event. The resulting peak stratospheric aerosol mass estimates are larger than previously reported estimates of 0.2-0.4 Tg for the 2017 case and 0.3-0.8 Tg for the 2020 event based on direct injection calculations. The large resulting differences between the two estimates suggest the formation of large amounts of stratospheric secondary aerosols.

Tsikerdekis, Athanasios

Aerosol data assimilation as a tool to detect model errors

An ensemble Kalman-filter smoother (LETKS) is used to estimate aerosol emission in the global climate/aerosol model ECHAM-HAM by assimilating retrievals from the multi-angle polarimeter POLDER. The assimilated observations (aerosol optical depth, angstrom exponent and single scattering albedo) provide a wealth of information in order to correct the aerosol amount, size and composition simultaneously. The emissions are estimated per species (dust, sea salt, organic carbon, black carbon, sulfates and sulfate precursor gases), per sector (biomass burning and fossil fuel) and by size (Aitken, Accumulation and Coarse). An evaluation of the data assimilation experiment reveals that the model errors are reduced for all the assimilated observables in most areas over the globe. Surprisingly, in the biomass burning outflow area of South Atlantic the aerosol optical depth error increases. This increase cannot be attributed to emission errors, since the model error (for all observables) over the biomass burning African sources is very low after the assimilation. Hence, we use the new corrected emissions and tune various model processes (e.g. emitted particle size, wet growth, emission height, removal processes) in order to improve the aerosol optical depth in the outflow and not affect it negatively in the sources. Further we use the sea salt analysis emissions and try to correct the default sea salt emission scheme in the model. These applications shows how data assimilation results can be used to highlight “hidden” model errors and promote future model development.

van Diedenhoven, Bastiaan

Improved CCN estimation through the retrieval of aerosol water fraction, hygroscopicity and dry size distribution using multi-angle polarimetry

The fraction of aerosol acting as Cloud Condensation Nuclei (CCN) at a given supersaturation depends on the aerosol’s hygroscopicity and dry size distribution. When relating variation in aerosol loading to variation in cloud droplet number concentrations to constrain aerosol-cloud interactions, possible variations in hygroscopicity and dry size distribution also need to be considered. However, remote sensing products generally do not contain information on hygroscopicity and retrieved quantities such as aerosol optical depth, refractive index and size distributions generally pertain to humidified aerosol under ambient conditions. Inspired by previously proposed methods, here we infer the aerosol volume water fraction from the refractive index retrieved using multi-angle polarimetry. Using data from the airborne Research Scanning Polarimeter (RSP) collected during the recent CAMP2Ex and ACTIVATE campaigns, we show that the inferred volume water fraction agrees well with data from co-located advanced in situ probes. Furthermore, we show that, for selected time periods, the fine mode effective radii increase with volume water fraction as expected. In turn, this allows us to infer dry effective radius, which compares reasonably well to in situ values. Moreover, it is generally seen that also the effective variance of the ambient size distribution increases with volume water fraction. We show that this can be well explained by assuming a fraction of the aerosol distribution is hydrophobic. Using this simple assumption, the slope of inferred effective radius with respect to the variance may be used to infer the aerosol's hydrophobic fraction. Both remote sensing and in situ observations suggest hydrophobic aerosols dominated the observed aerosol population, especially during the ACTIVATE campaign off the US east coast. We discuss how this information may be used to improve estimates of CCN concentrations from remote sensing. This study suggests that inferring information on aerosol volume water fraction, hygroscopicity and dry size distribution will soon be possible from orbit with the upcoming launch of NASA's PACE mission with the SPEXone polarimeter on board. Especially combined with polarimetric retrievals of droplet number concentration from PACE's HARP2 instrument, PACE is expected to greatly advance quantitative information on aerosol-cloud interactions.

Vogel, Annika

Assessment of present-day estimates of AOD from recent AeroCom and CMIP phases against multiple satellite products and global reanalyses

Despite the implication of aerosols for radiative forcing, there are persistent differences in aerosol estimates from both, observations and models. This study quantifies differences between current estimates of aerosol optical depth (AOD) by addressing two questions: (1) How well do we know the large-scale spatio-temporal pattern of present-day AOD across state-of-the-art data? (2) Has the representation of AOD improved across phases of aerosol-climate model intercomparison projects? To answer these questions, spatio-temporal patterns of present-day AOD from 84 different global datasets are analyzed. The multi-model aerosol ensembles from recent CMIP phases (CMIP5 and CMIP6) and AeroCom experiments (AeroCom-I and AeroCom-III) are compared to eight satellite products, two global reanalyses and one established climatology covering 1998 to 2019. The comprehensive data assessment allows to evaluate the performance of individual products concerning different spatial and temporal aspects. Our results highlight spatio-temporal differences in AOD estimates across satellite products and model simulations. Global mean AOD ranges from 0.124 to 0.164 between individual satellites, with a satellite mean of 0.14. The ensemble means from the intercomparison projects fall within the satellite range, but individual models differ considerably. Compared to the satellite and reanalysis data, all multi-model ensemble means tend to underestimate AOD in regions of high aerosol load in South America, South Africa, India, and Southeast Asia. No systematic improvement from earlier to later phases of CMIP and AeroCom is found, although some regional biases have been reduced. The identified spatio-temporal differences may be used to guide further efforts to improve satellite retrievals and model simulations for aerosols. At the same time, the spread in observed AOD implies that studies based on a single satellite product might lead to biased conclusions, even for regional and global means.

Watson-Parris, Duncan

Ongoing AeroCom experiment update

Winker, Dave

Upcoming CALIOP Data Product Release

CALIOP Version 4 data products were released in late 2016. The first major data product update since then, Version 4.5, is being readied for release later this year. Several small changes have been made to improve the quality of Level 1 profile data. Updates to Level 2 products include algorithm changes to improve the detection of smoke layers and the transitioning of two research aerosol retrievals to production algorithms. This talk will describe aspects of Version 4.5 data products of interest to the Aerocom community.

Yu, Hongbin

Updates on the Trans-Atlantic Dust Deposition (TADD) analysis of AeroCom III models

Massive dust emitted from North Africa can transport long distances across the tropical Atlantic Ocean, reaching the Americas. Dust deposition along the transit adds microorganisms and essential nutrients to marine ecosystem, which has important implications for biogeochemical cycle and climate. However, assessing the dust-ecosystem–climate interactions has been hindered in part by the paucity of dust deposition measurements and large uncertainties associated with oversimplified representations of dust processes in current models. We have recently produced a unique dataset of dust optical depth, dust deposition flux, and dust loss frequency over the tropical Atlantic Ocean by using the decade-long record of aerosol three-dimensional distribution from satellite sensors. In the last year's AeroCom meeting, we reported some preliminary results based on inter-comparisons of 16 global models submitted to the AeroCom III CTRL experiment and a suite of remote sensing and in situ observations of dust transport and deposition over the tropical Atlantic Ocean. In this presentation, we will provide an update on the analysis.

Yu, Pengfei

Persistent stratospheric warming due to 2019-20 Australian wildfire smoke

Australian wildfires burning from December 2019 to January 2020 injected approximately 0.9 Tg of smoke into the stratosphere; this is the largest amount observed in the satellite era. A comparison of numerical simulations to satellite observations of the plume rise suggests that the smoke mass contained 2.5% black carbon. Model calculations project a 1 K warming in the stratosphere of the

Southern Hemisphere mid-latitudes for more than 6 months following the injection of black-carbon containing smoke. The 2020 average global mean clear sky effective radiative forcing at top of atmosphere is estimated to be -0.03 W m-2 with a surface value of -0.32 W m-2. Assuming that smoke particles coat with sulfuric acid in the stratosphere and have similar heterogeneous reaction rates as sulfate aerosol, we estimate a smoke-induced chemical decrease in total column ozone of 10-20 Dobson units from August to December in mid-high southern latitudes.

Zhang, Kai

The representation of natural aerosols and its impact on effective aerosol forcing

Many global aerosol-climate models, even though with complex aerosol-cloud interactions, often simulate larger effective aerosol forcing (ERFaer) compared to models using simplified aerosol treatment, where the aerosol impacts on the cloud lifecycle and precipitation are not considered. Previous studies show that imposing a lower bound for simulated cloud droplet number concentrations or increasing the aerosol concentrations in the pristine condition helps to reduce the anthropogenic aerosol forcing. Here we show a further investigation using the E3SM atmosphere model. Imposing a minimum cloud droplet number concentration (CDNC) of 10-30 cm-3 in E3SM has a large impact on the net ERFaer (less negative by 0.4-0.8 Wm-2). Changing the representation of natural aerosols also has a large impact on ERFaer. Large difference is found in regions/seasons (e.g., high latitudes in boreal summer) where the CDNC is very small in the pre-industrial era but much larger in present-day condition. This suggests the cloud and aerosol parameterizations in E3SM (and perhaps other global aerosol-climate models) still need to be improved to better represent the pre-industrial condition. An AeroCom inter-comparison study on this topic would be desirable.

Zhang, Zhibo

A preliminary study of the impacts of mixing state on the scattering properties and direct radiative effects of dust particles

Once aloft, dust particles are carried by winds for long-range transport at an intercontinental or even hemispherical scale. During the long-range transport, the dust particles can become mixed with other aerosol species such as ammonium sulphate, ammonium nitrate, hydrochloric acid, sea salt, and biomass burning particles, not only externally but also internally through coagulation, cloud processing, and heterogeneous reactions. The mixing state (i.e., external vs. internal mixing) of dust with other aerosols has several critical implications. First, the mixing state influences the size, morphology, and composition of dust particles and thereby the scattering properties and the radiative forcing of dust particles. Second, the mixing state can also influence dust’s potential as CCN and IN. In particular, the internal mixing of dust with hydrophilic aerosols such as ammonium nitrate can make dust a less effective IN and a better CCN. Third, the mixing state can also have photochemical impacts on tropospheric chemistry. Finally, the differences in the scattering properties (e.g., lidar depolarization ratio) of different dust mixtures can pose great challenges, but at the same time provide valuable opportunities, for the remote sensing observations of dust. In the past, the scattering properties of the internally mixed aerosols are often modeled using simple effective medium theory (e.g., effective refractive index based on volume mixing). Recently, we carried out a preliminary study of the impacts of mixing state on the scattering properties and direct radiative effects (DRE) of dust particles. For simplicity and computational efficiency, we approximate the pure dust as spherical or elliptical particles and the internally mixed dust particles are modeled as pure particles coated with a spherical layer of other types of aerosols (e.g., sulphate and nitrate). The Mie and ADDA models are used to simulate the scattering properties of pure and mixed dust particles. This study leads to several important findings that have potentially far-reaching implications. First, we found that the scattering properties of internally mixed dust particles simulated by ADDA based on explicit coating morphology are significantly different from those based on effective medium theory. Second, we found that the internal mixing increases the size of dust particles which enhances the longwave DRE of dust more efficiently than the shortwave DRE, leading to a shift of more positive net DRE. Finally, we found that lidar depolarization ratio based on the explicit coating morphology is also significantly different from those based on simple external mixing of nonspherical pure dust and other types of spherical aerosols.

Zhong, Qirui

Aerosol models underestimate emitted particle sizes and misrepresent wet deposition for biomass burning

Biomass burning (BB) contributes significantly to the global aerosol budget. However, current BB aerosol (BBA) modeling is largely underestimated, which was usually addressed by inflating BB emissions in previous studies. Here, by combining 17 models and multi-aspect observations, we developed a new method to account for the modeled aerosol optical depth (AOD) errors in terms of emission, lifetime, and mass extinction coefficient (MEC). We show that, apart from the emission bias (38%), the underestimated MEC (28%) caused by too small particle size and misrepresent removal (21%) due to biased precipitation also contribute substantially to the overall AOD bias in current global models. Compensations among errors from the three aspects exist in all the models with different patterns. By either constraining all the three factors or only correcting emissions that have been widely presented to correct modeled BBA, we found that the previous methods overestimate the AOD by 85% over the southeast Atlantic due to the outflow of BB smoke from Africa. A detailed ECHAM-HAM simulation suggested that such overestimated AOD would double the warming effects of BBA over the southeast Atlantic.