EARTHCARE SCIENCE WORKSHOP

11 – 15 June 2018

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ABSTRACT AND POSTER OVERVIEW

Contents

Monday 11 June 2018 - Process Studies

Observing the cloud evolution process by using passive and active spaceborne sensors such as EarthCARE, A-Train, and Himawari-8

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Understanding the cloud evolution process is important for studying climate change through improving the general circulation model and cloud resolving model, which are used for forecasting Earth's climate. Because cloud evolution occurs globally, we use spaceborne sensors aboard satellites for this purpose. Cloud droplets grow from aerosols that act as cloud condensation nuclei, so we need to observe both aerosols and clouds. We are in an exciting era of observations; the A-Train constellation, which has active (CPR/CloudSat, CALIOP/CALIPSO) and passive sensors (MODIS/Aqua), has been in orbit for more than 10 years, and the EarthCARE satellite, which is a post-CPR/CALIOP/MODIS satellite, will be launched in 2019. The contoured frequency by optical depth diagram (CFODD) technique to visualize the cloud evolution process was proposed by Nakajima et al. (2010) and Suzuki et al. (2010). CFODD statistically classifies the stages of cloud droplet evolution in warm water cloud as cloud condensation growth, collision-coagulation process, and rain, based on the probability density function of the radar reflectivities as a function of in-cloud optical depth. CFODD is obtained by using passive (MODIS) and active (CPR) sensor data. An interesting feature of CFODD is that we can estimate the in-cloud evolution process from the effective cloud particle radii estimated by a passive imager that represents cloud-top properties. In the EarthCARE era, more useful information will be available from the Doppler capability of CPR/EarthCARE to clarify the cloud evolution process.
In this presentation, we will describe the standard algorithm of the EarthCARE Multi Spectral Imager (MSI) in cloud evolution research. We will show an example of a time-series observation of cumulus cloud evolution over Kyushu, southern Japan, from the third-generation geostationary satellite, Himawari-8.

Interpretation of passive geostationary microphysical properties of ice clouds using synergistic lidar-radar observations

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Ice clouds play an important role for climate since they can contribute to the greenhouse effect of the Earth. The interactions between clouds and radiation are determined by both their macroscopic and microphysical properties. Microphysical properties of ice crystals in particular show a large variability and can vary strongly during the cloud lifetime, from nucleation to growth and sublimation, due to the different physical processes and the different dynamical forcings involved. Furthermore, microphysics of ice clouds is difficult to access and can either be probed at selected heights with in-situ airborne measurements or derived from satellite observations.

The Meteosat Second Generation (MSG) satellite with its multispectral imager SEVIRI is well suited for the investigation of cirrus life cycles thanks to its temporal resolution of 15 minutes over the full earth disc or 5 min in rapid scan mode over Northern Africa and Europe. Microphysical geostationary observations of ice clouds, in particular effective radii derived from solar or thermal channels, can give important insights into the physical processes connected to formation, growth, deposition and sublimation of ice crystals during their entire lifetime. However, passive retrievals only provide vertically averaged cloud properties. In contrast, synergistic lidar-radar algorithms like those developed for CALIOP-CPR on CALIPSO-CloudSat or ATLID-CPR aboard EarthCARE can provide vertical profiles of microphysical quantities along the track of the satellite(s), but miss the horizontal coverage and have a limited temporal resolution.

In this presentation the relationship between the single pixel values of effective radius, ice water path and ice cloud optical thickness retrieved by a solar and a thermal MSG/SEVIRI retrieval will be investigated using vertical profiles of cloud properties retrieved from active satellite observations of the A-Train and active airborne measurements performed by the HSRL WALES lidar and the MIRA radar aboard the German research aircraft HALO. To this end, flights performed during the NARVAL and the Techno mission will be evaluated using a synergistic lidar-radar algorithm and the profiles of microphysical properties related to collocated passive MSG/SEVIRI ice cloud products.

From this kind of studies we expect to gain a better understanding of the relationship between active and passive observations that shall improve our interpretation of the evolution of microphysical properties of cirrus clouds.

The diagnosis of mixed phase cloud and estimates of aggregation and riming rates from Doppler radar

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Remote sensing of global snowfall is critical to quantifying the hydrological cycle and evaluating its representation in numerical models, but current satellite estimates of snow rate are highly uncertain, especially where the riming of snow in mixed-phase cloud is undiagnosed. EarthCARE's Doppler cloud profiling radar will provide a measure of the fallspeed of snow, by which it should be possible to estimate the density of particles or their degree of riming, thereby improving estimates of snow rate. The presence of mixed-phase cloud layers can be diagnosed from the onset of riming, while the degree of riming is related to the liquid water content. In a retrieval of the size, number and bulk density of ice and snow particles through the vertical profile, it should be possible to estimate the rates of aggregation and riming processes.

In this study we use CAPTIVATE, the optimal estimation algorithm for EarthCARE synergy retrievals, to demonstrate the novel retrieval of the degree of riming of snow from ground-based Doppler radars deployed during the Biogenic Aerosols---Effects of Clouds and Climate (BAECC 2014) field campaign at Hyytiala, Finland. The retrieved properties of snow particles are evaluated against in situ particle imaging measurements, and the degree of riming compared against estimates of liquid water path from a microwave radiometer. Estimates of particle properties through the vertical profile show that the onset of riming is associated with increased ice water content due to the accretion of supercooled liquid, while in the absence of mixed-phase cloud layers aggregation dominates the growth of snow particles. Single and dual-frequency radars retrievals and their associated uncertainties are compared, and applications to EarthCARE discussed.

Parametrization of falling snow microphysical and scattering properties for W-band radar retrievals

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Since the launch of NASA CloudSat and preparation for the upcoming ESA EarthCARE missions. There is a renewed interest in deriving ice cloud and precipitation properties from W-band radar observations. To develop a robust retrieval method, snow microphysical properties, such as particle size distribution and mass-dimensional relations, need to be parametrized. Additionally, these properties have to be linked to radar observables. Both steps present a challenge.

To improve our knowledge of snow microphysics and to derive parametrization characteristic to high-latitude snowfall, comprehensive snow measurements at the SMEAR-II research station of University of Helsinki located in Hyytiala, Finland are being carried out since January 2014. Using observations of precipitation accumulation, PSD and particle fall velocity snowflake masses are derived using the general hydrodynamic theory. There are several ways to describe the PSD of ice particles, in this study we have adopted the normalized PSD approach and expressed the PSD as a function of the melted equivalent particle diameter, which provides an unambiguous measure of particle dimension. From the analysis of more than 40 snowfall cases, we have observed that generalized Gamma distribution provides a better fit to the data than the standard Gamma PSD used in many studies. Additionally, we have found that the observed snowflakes are typically larger and heavier than in the currently used parameterizations.

To link these findings to multi-frequency radar observations, forward modelling study is performed. To model scattering properties of snowflakes we have used both “soft-spheroid” particle approximation and complex ice particle models. Scattering properties of “soft-spheroid” models were computed using T-matrix method, while single scattering properties of complex ice particles were taken from the existing scattering databases. It was found that the difference between two methods is not as big as was previously expected. Furthermore, it is found that snowfall rate retrievals can be greatly constrained by using dual-frequency radar observations. The parameters of the normalized PSD represented in the generalized Gamma form most suitable for dual-frequency radar analysis were also derived.

Combined lidar and radar observations of the relationship between cloud-top temperature, in-cloud dynamics and rain rate

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Aerosol-cloud-rain relationships are complex and poorly understood. They are thus not represented in a physical way in numerical weather prediction and global circulation models used in climate change research. Field observations in key areas with climate relevance are required to improve our knowledge about the physical foundation of the aerosol-cloud-rain interaction process. The highly polluted Eastern Mediterranean/Middle East region is such a hot spot where a strong aerosol influence on precipitation must be expected.

The Leipzig Aerosol and Cloud Remote Observation System (LACROS) was operated for over 18 months in the framework of the CyCARE project (Cyprus Clouds, Aerosol, and Rain Experiment) at Limassol from October 2016 to March 2018, and thus covered two winter rain seasons. The state-of-the-art remote sensing facility LACROS consists of an aerosol lidar to measure height profiles of aerosols, a Doppler wind lidar mainly for profiling of updrafts and downdrafts at cloud base, a 35 GHz cloud radar mainly for mixed-phase and ice cloud profiling and ice water content measurements, a microwave radiometer to measure the cloud liquid-water path (or cloud water amount), and a disdrometer for rain amount observations at ground level.

The present study deals with the relationship between aerosol particles, cloud microphysics and the finally produced rain amount. The cloud top as measured with cloud radar is the coldest part of the cloud and thus the probability for the initiation of ice nucleation is highest. We present statistics on the relationship between cloud top temperature, in-cloud updraft characteristics and rain amount measured with disdrometer. The statistics of cloud-top-temperature and rain rate is compared to long-term measurements with Cloudsat/Calipso and GPM satellites. It will be possible to extend the study with the EarthCARE satellite because it will be the only satellite in orbit to provide combined observations of aerosols, clouds and rain.

How do temperature inversions control aerosol vertical distribution in the Arctic during polar winter?

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The most ubiquitous meteorological phenomena in the Arctic that influence the vertical distribution of aerosols during winter and early spring are the temperature inversions. In this study, we investigate how the varying magnitude of the atmospheric stability can affect the dispersal of the aerosols. Ten years of collocated aerosol retrievals from CALIOP-CALIPSO and temperature and humidity profiles from AIRS-Aqua, both sensors being part of the A-Train constellation are used for this study. It is shown that, as the degree of atmospheric stability increases, the fraction of aerosol vertical distribution trapped below inversion layer during winter also increases by up to 21%, 17% and 14% in the Atlantic, Barents/Kara Sea and Labrador Sea sectors respectively. The average aerosol optical depths also increase consistently with increased frequency. In contrast, aerosol layers are often accumulated above inversion layers during spring months additionally by up to 15% in the Eurasian and Pacific sectors as the stability increases. These contrasting sectorial differences can be explained by the nature of long-range pollution transport into the Arctic.

Tuesday 12 June 2018 - Observational Techniques

Lidar Observations as Climate Data Records

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Cloud feedbacks represent the dominant source of uncertainties in estimates of climate sensitivity and aerosols represent the largest source of uncertainty in climate forcing. Resolving current uncertainties requires highly accurate multi-decadal data records. We now have more than a decade of experience with lidar in space from CALIOP flying in the A-Train. These observations have demonstrated new capabilities of active sensors relative to passive sensors and point to the benefits of continued and more advanced lidars. This talk will discuss utility of and prospects for multi-decadal climate data records from CALIOP and ATLID.

From collocated spaceborne lidar-imager observations to the geostationary remote sensing of thin cirrus clouds and the anvil cirrus life cycle

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Cirrus clouds play an important role for the Earth's energy budget and climate as they reflect incoming solar radiation and absorb outgoing thermal radiation. Nevertheless, cirrus clouds remain one of the largest uncertainties in atmospheric research, both in remote sensing and modeling. To better understand the physical processes that govern the life cycle of cirrus clouds and to evaluate weather and climate models, accurate large-scale satellite observations are essential.

To this end, the CiPS (Cirrus Properties from SEVIRI) algorithm, targeting thin cirrus clouds, has been developed. CiPS is based on neural networks and has been trained predominantly with coincident MSG/SEVIRI infrared observations and CALIPSO/CALIOP cirrus cloud retrievals. The geostationary multispectral imager SEVIRI possesses a large spatial coverage and a high temporal resolution of up to 5 min, while the CALIOP lidar offers a high sensitivity to thin cirrus clouds with its high vertical resolution. By combining the advantages of the two sensors with a set of neural networks, CiPS has gained a high sensitivity to thin cirrus clouds and detects, on average, 70 % (95 %) of all cirrus clouds with an optical thickness of 0.1 (1.0). In addition to the cirrus cloud detection, CiPS also retrieves the corresponding ice optical thickness, ice water path and cloud top height for pixels classified as cirrus. The large spatial coverage and high temporal resolution of CiPS allows for both weather and climate model evaluation and cirrus life cycle studies. To demonstrate the latter, the life cycle of anvil cirrus clouds, forming in the upper troposphere from deep convection, has been analyzed. Despite large variabilities in lifetime, spatial extension and cloud top height, the anvil cirrus ice water path (and optical thickness) is observed to decrease rapidly as convection stops, with comparably little variability among the analyzed anvil cirrus clouds.

The synergy between the geostationary imager and the polar orbiting lidar has proven to be very successful and useful and with the upcoming launch of EarthCARE, further advances can be made in this direction using ATLID (and possibly CPR) retrievals as training reference data for similar algorithms.

Comparison of airborne configurations in a radar-lidar retrieval technique as a preparation for EarthCARE

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The upcoming ESA/JAXA EarthCare (Earth Cloud Aerosol Radiation Explorer) satellite is expected to play a major role in the future of Earth observing space missions as it will provide simultaneous profiles of clouds, aerosols and precipitation from state-of-the-art remote sensing instruments mounted on the same platform. To bridge the gap with the previous Cloudsat-CALIPSO tandem mission, from NASA's A-Train constellation, which has been successfully providing insights of cloud microphysical mechanisms for more than 10 years, airborne missions are of great interest, especially as aircraft can board instrumentation similar to the satellites' different payloads and provide observations giving some insight on what can be expected from this new observation platform.

In this context, a field campaign took place in Iceland, Keflavik in October 2016, taking advantage of 2 research aircraft, French F20 and HALO (High Altitude and Long-range) being operated within the NAWDEX (North Atlantic Waveguide Downstream Experiment) campaign. Both aircraft were boarding active and passive remote sensing instrumentation perfectly in line with the A-Train and EarthCARE payloads. For instance, the RALI platform, on board the French SAFIRE Falcon 20, consists in a radar-lidar platform combining the measurement of the 95GHz multiple-beam Doppler cloud radar RASTA and the high spectral resolution (HSR) LNG lidar with two simple backscatter measurements at 532 nm and 1064 nm and HSR and depolarization channel at 355nm. This payload offers several options from the Cloudsat-CALIPSO-like configuration to one similar to the upcoming EarthCARE project (a 94GHz Doppler radar and a high spectral resolution lidar at 355nm on the same platform). Similarly, the payload on board the HALO operated by DLR, consisting in the MIRA 35GHzDoppler dual-polarization radar combined to the WALES HSRLidar with a high spectralresolution channel at 532nm, also allows for EarthCARE-like measurements and provides an independent remote sensing measurement dataset for comparisons with RALI during conjoined flights.

Both RALI and HALO measurements can be implemented in a variational scheme that retrieves ice cloud properties such as Ice Water Content and effective radius from the combination of radar and lidar observations. The presented work will focus on the comparison of the different instrumental configurations made available by both aircraft during the NAWDEX campaign: we will show what the lidar HSRL channel can provide us with as additional information and how to make the best of it in our radar-lidar variational algorithm.

How Solar Reflectance can be used to improve a Variational Radar-Lidar Retrieval for Ice Clouds

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Ice clouds play an essential role in the climate system since they have a large direct effect on Earth's radiation budget, which still represents one of the largest uncertainties in climate change predictions. These uncertainties arise from uncertainties associated with the optical and microphysical properties of ice clouds as well as from insufficient knowledge about their spatial and temporal distribution. This knowledge can be significantly improved by active remote sensing techniques to explore vertical profiles of ice cloud microphysics.

While active backscatter retrieval techniques surpass the information content of most passive, vertically integrated retrieval techniques, their accuracy is limited by essential assumptions about the ice crystal shape. Since most radar-lidar retrieval algorithms rely heavily on a mass-size relationship to parameterize the prevalent ice particle shape, biases in ice water content and ice water path are to be expected for individual cloud regimes. In many cases, these biases could be identified and corrected when a vertically integrated quantity, like the solar reflectance, is considered simultaneously. For the first time ever, the upcoming ESA/JAXA satellite mission EarthCARE will give the opportunity to implement this synergistic use of radar, lidar and solar reflectance measurements on a single platform.

In anticipation of EarthCARE, great efforts were made in the last years to acquire airborne datasets and to develop synergistic cloud retrievals. Within this context, the German research aircraft HALO was equipped with a EarthCARE-like payload consisting of a high spectral resolution lidar (HSRL) system at 532 nm with additional polarization sensitive channels at 532 and 1064 nm, a high-power cloud radar at 35 GHz and passive measurements of solar reflectance with the hyper-spectral imager specMACS.

In this particular study, we utilize airborne measurements from HALO to retrieve ice cloud properties using the variational radar-lidar retrieval VarCloud. For the retrieved ice cloud properties we simulate solar radiances, which are then compared to measured solar radiances from specMACS. The objective of this closure study is the identification of inconsistencies and their explaination. With respect to the radiative closure, modifications to the ice particle shape assumptions are devised and checked with simultaneously acquired in-situ measurements. The scientific findings of this study will advance the state of the art to integrate passive solar radiances measurements within an operational retrieval of ice cloud microphysics. With ESA's Earth Explorer Mission EarthCARE on the horizon, this study will improve the understanding of ice cloud microphysics with respect to the prevalent ice crystal shape, which better replicates radar, lidar and solar radiance measurements.

A synergistic "best estimate" retrieval of clouds, precipitation and aerosol for EarthCARE, and its planned use in evaluating the ECMWF forecast model

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The new observational capabilities and enhanced sensitivity of EarthCARE offers the possibility to evaluate the ECMWF model and other global forecast models in more detail than ever before. We have developed the algorithm "CAPTIVATE" that will provide the operational EarthCARE level-2 product "ACM-CAP" containing a best estimate of the properties of clouds aerosol and precipitation. We will first describe how CAPTIVATE combines the observations from the radar, lidar and radiometers on-board EarthCARE within a unified synergistic variational framework. The algorithm incorporates many novel features, such as explicit representation of radar and lidar multiple scattering, a new fast forward model for solar radiances, a Kalman smoother to provide robust aerosol retrievals even in the presence of noisy lidar measurements and an advanced diagnostics of retrieval confidence such as properties of the averaging kernel. We will present an evaluation of the algorithm's capability using a 6000-km swath of synthetic EarthCARE data simulated from 250-m resolution cloud-resolving model simulations, investigating the impact of the different observations on the retrieval of a variety of atmospheric profiles.

We will then discuss how EarthCARE products could be used to evaluate numerous aspects of the ECMWF model. This includes a focus on snow rates and fall speeds, which are very uncertain in the model and for which new insights can be expected via the CPR's Doppler capability. The co-location of accurate microphysical retrievals and broadband fluxes will enable the simultaneous evaluation of model cloud properties and radiative fluxes. This could allow a more precise attribution of model errors to errors in cloud forecast versus errors in cloud optical properties.

Observations of cloud- and precipitation-microphysics and vertical motion

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Doppler cloud profiling radar CPR, high spectral resolution lidar ATLID, and multi-spectral imager MSI on EarthCARE are expected to produce (1) continuous records of cloud and precipitation microphysics with better accuracy compared with those products from CloudSat and CALIPSO satellites and (2) new features of cloud motions; terminal velocity of the particles and vertical air motion inside clouds.
Following products will be distributed; CPR-only products, CPR-ATLID synergy products and CPR-ATLID-MSI synergy products. In each category, there are standard and experimental products. The former ones do not use Doppler information and the latter needs Doppler information from CPR. Cloud mask algorithms are the first task. Then cloud particle type algorithms are conducted. Cloud phase and ice particle orientation and particle type are determined. Cloud and precipitation microphysics are then retrieved after cloud particle type. In addition, fall velocity of cloud particles and vertical air motion are also determined.
These algorithms have been developed and evaluated by the next-generation-ground-based-active-sensor-systems. The systems contain multi-field-of-view multiple scattering lidar (MFMSPL), Doppler cloud radar, direct- and coherent Doppler lidars, and multi-wavelength high spectral resolution lidar. MFMSPL was designed as the first ground-based lidar that can detect similar degree of depolarization ratio as space-borne lidar. We also developed Physical Model approach (PM) to simulate space-borne lidar signals. PM is much faster compared with the Monte Carlo method and the mean relative errors are about 15%. We plan to extend the PM to analyze the above systems.

The EarthCARE CPR Doppler measurements in Deep Convection: Challenges, Post-Processing and Science Applications

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The Earth Clouds, Aerosols and Radiation Explorer (EarthCARE) satellite is a joint European Space Agency (ESA) and Japanese Aerospace Exploration Agency (JAXA) mission and is scheduled for launch in 2020. EarthCARE (EC) includes the first Dopplerized Cloud Profiling Radar (CPR). In addition to constraining microphysical retrievals in particle sedimentation regimes, the Doppler capability of the CPR is expected to provide unique global observations of convective vertical air motion and associated mass flux. Here, an extensive analysis of the performance and quality of the EC-CPR Doppler velocity measurements in convective conditions is presented. The challenges in the EC-CPR Doppler measurements in deep convection are investigated using theoretical calculations and the use of forward simulations using a state-of-the-art EC-CPR Doppler simulator and input from airborne radar datasets and high resolution numerical models. A climatology of CloudSat observations and a multiple scattering (MS) algorithm are used to determine the penetration depth (defined as the distance from the convective cloud top to the lowest level before attenuation and MS degrade the EC-CPR signal. The post-processing algorithms for mitigating the non-uniform beam filling and velocity aliasing are presented and a quantitative assessment of the Doppler performance in deep convection is presented. Using the aforementioned analysis, the potential of the EC-CPR Doppler measurements in deep convection to address scientific questions regarding the contribute of convective clouds to vertical mixing and the impact of vertical velocities on cloud microphysical processes will be discussed.

Radar Sub-Millimeter Synergy

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The ESA-funded project "Scientific Concept Study for Wide-Swath High-Resolution Cloud Profiling" (Contract 4000119850/17/NL/LvH) explores the synergy between a possible future satellite radar instrument and the millimeter/sub-millimeter instruments MWI and ICI on the Metop-SG satellite. Two different types of synergy are studied. Type 1 is joint retrieval for an along-track "curtain", which is observed by both the radar and the passive sensors. The main question here is in which way the passive observations may enhance the already rich (in vertical structure) radar observations. The other synergy, Type 2, is the retrieval of 3-D scenes from the passive observations in the vicinity of the radar observations in the middle of the swath. This synergy has already been explored for passive observations in the IR/visible spectral range, but not for millimetre/sub-millimeter passive observations. The main question here is in which way the nearby radar observations may enhance the passive observations.

The synergy in these retrievals is studied by careful simulations using high resolution atmospheric model data. A special attention is given to the representation of ice hydrometeors. Dedicated scattering data for each category (cloud ice, snow, graupel and hail) have been developed to match each model's assumption on mass-size relationships.

EarthCARE's Broadband Radiometer: Unforeseen Sampling Uncertainties Associated with Cloudy Atmospheres

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The ESA-JAXA satellite mission EarthCARE will be launched in 2020 and is designed to conduct a space-borne radiative closure assessment, comparing simulated and measurement-based top-of-atmosphere (TOA) shortwave (SW) and longwave (LW) fluxes. The broadband radiometer (BBR) will facilitate the measurement-based end of the closure, and consists of three along-track viewing (i.e. nadir, 55° forward, and 55° backward) telescopes and a rotating chopper drum. As a result, the BBR will measure alternating TOA SW and totalwave (TW) radiances over ~0.6km diameter pixels with ~0.4km along-track ground sampling distance (GSD) between subsequent SW and TW measurements. Corresponding LW radiances will be inferred from TW and SW radiances. Finally, radiance-to-flux conversions will produce TOA SW and LW fluxes. A successful closure requires a difference of less than 10 W/m² over a horizontal domain of ~100km² between BBR-based fluxes and simulation-based fluxes (derived from an active-passive retrieval of cloud and aerosol vertical profiles, and subsequent broadband radiative transfer simulations).

Radiances over domains of ~100km² will be aggregated from individual BBR pixels. By design of the pixel point spread functions, overlap with neighboring pixels will be perfect in across-track and imperfect in along-track direction. The performance of the chopper drum motor will be adjustable to allow for an increase in instrument lifetime. Given a lower performance, along-track GSD between pixel centers would only grow and their overlap decrease.

Uncertainties of SW and LW radiances, that arise from BBR sampling, will increase with higher levels of horizontal radiance variability – as offered by realistic cloudy atmospheres. By using high-resolution Landsat 8 imagery and mimicking BBR observations, we show that uncertainties of formed nadir SW and LW radiances are highly sensitive to 1) chopper drum rotation rate, 2) level of horizontal radiance variability, and 3) along-track length of domains. Our methodology allows for a recommendation of minimum chopper drum speed to achieve the mission requirement of 10 W/m², and for an in-flight prediction of BBR uncertainties based on 1km² resolved radiances with domains.

The potential of a multi-decades space-borne lidar record to constrain cloud feedbacks

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Synthetic multi-decadal space-borne lidar records are used to examine when a cloud response to anthropogenic forcing would be detectable from space-borne lidar observations. The synthetic records are generated using long-term cloud changes predicted by two CMIP5 (Coupled Model Intercomparison Program 5) models seen through the COSP/lidar (CFMIP –Cloud Feedback Model Intercomparison Project, Observation Simulators Package), and cloud inter-annual variability observed by the CALIPSO (Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations) spaceborne lidar during the past decade.
CALIPSO observations do not show any significant trend yet. Our analysis of the synthetic time series suggests, the Tropical cloud longwave feedback and the Southern ocean cloud shortwave feedback might be constrained with 70% confidence with, respectively, a 20-year and 29-year uninterrupted lidar-in-space record. A 27-year record might be needed to separate the two different models predictions in the tropical subsidence clouds.
Assuming that combining the CALIPSO and Earth-CARE (Earth Clouds, Aerosols and Radiation Explorer) missions will lead to a space-borne lidar record of at least 16 years, we examine the impact of gaps and calibration offsets between successive missions. A 2-year gap between EarthCARE and the following space-borne lidar would have no significant impact on the capability to constrain the cloud feedback if all the space lidars were perfectly inter-calibrated. Any intercalibration shift between successive lidar missions would delay the capability to constrain the cloud feedback mechanisms, larger shifts leading to longer delays.

EarthCARE-like measurements on the research aircraft HALO for preparation and validation studies

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Aerosols and clouds still introduce the largest uncertainties in estimates and interpretation of future climate changes. To gain better information of the temporal and spatial distribution of aerosols and clouds on global scale and their radiation properties is one of the objectives of the upcoming ESA/JAXA satellite mission EarthCARE. Its high spectral resolution lidar (HSRL) at 355 nm and the cloud radar at 94 GHz with Doppler capability will be the most advanced instruments in space, and combining them on one single platform next to passive imager and radiometer measurements will make EarthCARE the most complex Earth Explorer mission to study aerosols and clouds. To effectively exploit these future measurements, large effort was undertaken to prepare and develop methods for EarthCARE. Airborne platforms with similar instrumentation are a valuable tool to prepare for upcoming satellite missions as well as for future calibration and validation activities. They allow testing and further development of algorithms, and comparisons with current satellites to estimate what can be expected from future satellite missions.
With its so called NARVAL (Next-generation aircraft remote sensing for validation studies) payload the German research aircraft HALO (High Altitude and Long-range) is equipped with an EarthCARE-like payload. Active remote sensing measurements of simultaneous aerosol and cloud profiles are provided by the combined differential absorption and high spectral resolution lidar (532 nm) system WALES and a METEK cloud radar (35 GHz). Additional passive remote sensing instruments complement the active remote sensing measurements. This payload was employed during the NARVAL-I mission over the tropical and extra-tropical North Atlantic region in December 2013 and January 2014 and again during the NARVAL-II over the tropical North Atlantic in August 2016 and NAWDEX (North Atlantic Waveguide and Downstream Experiment) in the extra-tropical North Atlantic region in September/October 2016. During all these flight experiments a major focus was set on underpasses below NASA's CALIPSO (Cloud Aerosol Lidar Infrared Pathfinder Observation) and CloudSAT satellites. We use these measurements to test and further develop synergistic algorithms, as well as to study possible effects occurring from the limitation of spatial and temporal resolution of the satellite measurements.
We will give a presentation of the EarthCARE-like payload on HALO, the measurements and studies that have already been performed in the preparation of EarthCARE, and information for future studies and planned cal/val activities.

Global 3D distributions of aerosol components retrieved by synergy of CALIOP and MODIS

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For the aerosol product of the EarthCARE satellite, we are developing the method to retrieve the vertical profiles of extinction coefficients of water-soluble, light absorbing carbonaceous, dust, and sea salt particles by the synergy of the space-born lidar (ATLID) and imager (MSI). The aerosol product from the synergistic method is expected to be better than the individual products of the lidar and imager. For example, the simultaneous manipulation of two sensor-data gives us more electromagnetic spectral information. The imager retrieval is affected by the surface albedo, but the lidar retrieval is not. In this study, the developed method was applied to the CALIOP and MODIS data in 2010. The global average of aerosol optical depth was 0.07, 0.02, 0.03, 0.03 for water-soluble, light absorbing carbonaceous, dust, and sea salt particles, respectively. The retrieved global distribution was reasonable. For example, the much amount of dust particles was seen in the major desert regions in the world, and the light absorbing carbonaceous was seen in the source areas of the anthropogenic aerosols and the biomass-burning areas.

Tuesday 12 June 2018 - Modelling

Space Lidar observations constrain longwave cloud feedback

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One of the main challenging question in atmospheric science is how clouds will feed back on the climate as it warms? Over the long-term (hundred years), the clouds modifications can weaken or enhance the Earth warming triggered by greenhouse gazes emission. Here we use space lidar observations to quantify the changes in cloud altitude, cover and opacity over ocean over the last decade, and a climate model with a lidar simulator to simulate these changes in present-days climate and in a warmer climate. We found that the longwave altitude cloud feedback mechanism, relentlessly found positive in simulations since the firsts climate models and backed by physical explanations, is not the dominant long-wave feedback term in the observations, while it is in the model. These results suggest that the enhanced longwave warming due to clouds might be overestimated in climate models. These results also demonstrate the importance of developing long-term active sensor satellite record, like lidar/radar, to help reducing uncertainty on cloud feedbacks and future climate prediction.

Evaluation of microphysics in mixed-phase clouds over the Southern Ocean in NICAM using Joint simulator

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It is important to evaluate and improve the cloud properties in global non-hydrostatic models like a Nonhydrostatic ICosahedral Atmospheric Model (NICAM, Satoh et al. 2014) using observation data. One of the methods is a radiance-based evaluation using satellite data and a satellite simulator (here Joint simulator, Hashino et al. 2013), which avoids making different settings of the microphysics between retrieval algorithms and NICAM.
One of challenging issues is an evaluation of mixed-phase clouds, which consist of water vapor, ice particles, and supercooled water droplets. It is known one of the main reasons why climate models reveal large errors about the reflection of solar radiation over the Southern Ocean and Arctic.
The purpose of this study is an evaluation and improvement of mixed-phase clouds over Southern Ocean in NICAM using a Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) and a satellite simulator. We evaluate microphysics schemes for thermodynamics phase of mixed phases clouds over the Southern Ocean between 45°S to 65°S and 170°E to 170°W following Yoshida et al. (2010) method. We investigate impacts of microphysical processes on the characteristics of super-cooled water clouds. We improve super-cooled water clouds by changes of microphysical processes using a single column model. And we introduce the impact of super-cooled water clouds on the climate sensitivity tests using NICAM.

Exploring a dichotomy between process-based constraint and energy-balance requirement on aerosol-cloud interaction in climate modeling

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Global climate models have been found to share the common bias of "too-efficient" formation of warm rain. Its mitigation in reference to satellite observations, however, was found to induce overly large negative radiative forcing due to aerosol indirect effect (AIE) and deteriorate energy balance required to explain historical temperature trend. This "dichotomy" between the rain formation process and energy-balance requirement on AIE is explored in a climate model. Sensitivity experiments with alternate choices of different auto-conversion schemes are conducted to compare the results with satellite observations in the form of the statistics that probe the warm rain process and to contrast such a satellite-based constraint on precipitation process against resultant indirect radiative forcing. The "dichotomy" is found to occur, at least in part, as a result from pronounced response of cloud water to aerosol perturbations, which is amplified through interplay between precipitation formation and wet scavenging of aerosols to the extent that depends on the choice of auto-conversion schemes. These key processes are then proposed to contain critical compensation errors, underscoring the requirement of better constraint on key aerosol-cloud processes with upcoming satellite measurements including EarthCARE to mitigate the "dichotomy".

The ECMWF observation operator for direct 4D-Var assimilation of cloud radar reflectivity and lidar backscatter: developments and its use for monitoring

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In data assimilation, the observation operator simulates observing systems within the model by converting model variables such as temperature, humidity and cloud amount into measurements that are `equivalent' to those observed in reality. For conventional observations, such as those from a radiosonde or a weather buoy the observation operator is often simple and may even just be a one-to-one relationship. For remote sensing instruments, such as cloud radar, the observation operator needs to be more complex to provide realistic model equivalents. However, the complexity of the operator needs to be balanced by the computational constraints imposed in an operational context.

In this presentation we will outline developments to the ECMWF observation operator for cloud radar and lidar in preparation for the inclusion of EarthCARE observations of radar reflectivity and lidar backscatter into the ECMWF 4D-Var assimilation system. These include updates to the microphysical assumptions of clouds and precipitation, including a careful consideration of sources of error in terms of scattering properties and multiple scattering. We will also show a new `double-column' approach for parameterizing cloud overlap to increase the impact of lidar backscatter, whose signal is typically more affected by attenuation than radar. Using the new observation operators, we will then show how EarthCARE observations will be monitored to detect any problems with either the observations or model and provide rapid feedback to ESA. In a monitoring system that combines information from observations and model, a statistically significant drift in the measurements can be detected faster than monitoring observations alone. In addition to data assimilation, the work presented is also very relevant to the development of instrument simulators (e.g., COSP) used to evaluate climate models in observation space.

Experimental 4D-Var assimilation of space-borne cloud radar and lidar observations in advance of EarthCARE

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Space-borne active instruments such as cloud radar or lidar provide a wealth of information on the vertical structure of clouds and precipitation. However, most Numerical Weather Prediction (NWP) centres only assimilate cloud affected observations with limited vertical information, such as radiances. Inspired by the success of 1D+4D-Var experiments, in which CloudSat radar reflectivity and Calipso attenuated backscatter profiles were indirectly assimilated via pseudo-observations of temperature and humidity, the ECMWF 4D-Var system has been adapted to allow their direct assimilation. The feasibility to assimilate such observations has been studied as a part of extensive research activities for the future applications of the EarthCARE cloud radar and lidar observations on the global scale.

In this presentation, the methodology explored for assimilation studies will be described together with a number of certain requirements that need to be fulfilled in order to succeed. This includes the specification of sufficiently accurate observation operators, i.e. models providing equivalent model fields to observations (subject covered by other presentation). Another important aspect is observation error definition since the errors assigned to observations determine the weight to be given to them during the assimilation process. Given the rather narrow horizontal field-of-view of radar and lidar observations, the observation error definition needs to account for the spatial representativity. In addition, for the proper handling of observations in the context of an assimilation system, an appropriate quality control strategy and bias correction scheme are required and will also be discussed. Finally, results from the 4D-Var experiments will be presented.

Wednesday 13 June 2018 - Radiation

Radiative heating rate computed with clouds derived from satellite based active and passive sensors and their effects on generation of eddy available potential energy

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Close relationships between cloud radiative effects and general circulation are demonstrated by earlier studies using climate models, Suppressing radiative heating by clouds in a climate model leads to altering, for example, strength of convection in the tropics, subtropical jets, and precipitation. Despite the large sensitivity of general circulation to radiative heating rate, radiative heating rate at a global scale can only be computed with a radiative transfer model (e.g. Slingo and Slingo 1988; Randall et al. 1989; Sherwood et al. 1994; Crueger and Stevens 2015).

In this study, radiative heating rates computed with cloud properties derived from passive (Moderate Resolution Imaging Spectroradiometer and geostationary satellites) and active sensors (Cloud-Aerosol Lidar with Orthogonal Polarization and Cloud Profiling Radar) are investigated. Zonal monthly radiative heating rate anomalies computed using both active and passive sensors show that larger variability in longwave cooling exists near the tropical tropopause and near the top of boundary layer between ~50°N to ~50°S. Aerosol variability contributes to increasing shortwave heating rate variability. When cloud effects on the radiative heating rate computed with both active and passive sensors and those computed with passive sensor only are compared, the latter shows cooling and heating peaks corresponding the cloud top and base heights used for separating cloud types. The difference of these two sets of cloud radiative effect on heating rates in the middle to upper troposphere is larger than the radiative heating rate uncertainty estimate based on the difference of two radiative heating rate profile data products. In addition, the radiative heating rate contribution to generation of eddy available potential energy is also investigated. Although radiation contribution to generation of eddy available potential energy averaged over a year and the entire globe is small, radiation significantly reduces the generation of eddy potential energy in northern hemisphere during winter and increases in northern hemisphere during other three seasons. Two key ingredients for longwave radiation to contribute to the generation of eddy available potential energy are 1) land ocean temperature contrast along the longitude and 2) cooling near the cloud top of stratocumulus clouds.

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The radiative impact of double layered cloud systems in the tropical upper troposphere and lower stratosphere

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In the atmosphere, clouds can be present in two or multiple layers. Such cloud overlap is most frequent in the tropics. But quantifying the radiative effects of such overlap has so far remained elusive. Here using four years of observations from a space borne lidar (CALIOP-CALIPSO) and radar (CPR-CloudSat), we, compute radiative effects of two-layer cloud systems in detail. We show that the radiative heating from a thin cirrus clouds can be completely suppressed if there is an optically thick cloud underneath it, due to induced longwave cooling. Our findings indicate that the distance between the cloud layers needs to be less than 4 km for the net warming of the cirrus to turn into net cooling. Furthermore, we quantify the sensitivity of this radiative impact to the properties of the top and bottom layer clouds. The results have implications for studying the processes affecting the composition of the TTL.

Radiative effects of clouds from the synergy of active and passive satellite instruments: missing elements of puzzle

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Clouds play an important role in the energy budget of the planet. Radiative effects of clouds include reflection of incoming shortwave (SW) radiation, absorption of outgoing longwave (LW) radiation, and emission of LW radiation to space and back to the surface. In energy flux terms, they affect TOA (top of atmosphere) SW and LW fluxes, SRF (surface) SW and LW fluxes, and cooling/heating rates (flux divergences) in the atmospheric column, which drive the vertical transport and also impact the large-scale circulation.

Estimation of cloud radiative effects requires the following knowledge: (a) cloud cover, (b) cloud thickness and its vertical distribution, (c) cloud particle size and type distribution at different altitudes. Satellite observations provide a continuous survey of clouds over the whole globe and IR sounders have been observing our planet since 1979. Global measurements from active spaceborne instruments are available since 2006. The passive measurements can provide (a) and, partially, (b) and (c), whereas the active ones provide the information about cloud layers and cloud property distribution within the layers, but they cannot provide global cloud cover.

We present synergetic results of CALIOP/CloudSat active sounders with AIRS/IASI passive instruments. In [Feofilov et al., 2015a] we have developed a statistically based parameterization of ice water content vertical profile, IWC(z), and have shown the radiative effects of different IWC(z) types on TOA/SRF LW/SW fluxes. CALIOP/CloudSat data have also been used for a better understanding of the retrieved cloud height from IR sounders [Stubenrauch et al., 2017]. The synergy between AIRS and IASI allows to estimate the diurnal variation of high clouds and its effect on their LW emissivity and transmissivity [Feofilov et al. 2015b]. We show that the estimate of cloud-driven diurnal variation for SRF/TOA SW/LW fluxes and cooling/heating rates requires merging the data from active and passive measurements and discuss this in application to EarthCare mission.

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The McRALI Monte Carlo simulator to evaluate (HSR) lidar and (Doppler) radar observables in 3D cloudy atmospheres: Application to EarthCARE mission

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Spaceborne lidar/radar systems are favorite tools in order to infer vertical properties of clouds. At the same time, liquid, ice and Mixed Phase Clouds show complex tridimensional (3D) variabilities in their horizontal/vertical geometrical, optical and microphysical properties at different averaging scales. Therefore, 3D radiative effects of 3D cloud inhomogeneities on lidar/radar observations (the backscatter coefficient, the depolarization ratio, the reflectivity factor, the Doppler velocity, etc...) have to be considered in direct radiative transfer calculations (i.e. simulation of LIDAR/RADAR observations from mesoscale model outputs) as well as in the inverse problems (i.e. retrievals of cloud parameters from lidar/radar observations).
Generally and for practical reason, clouds are assumed to be homogenous and plane parallel in lidar/radar signal calculation algorithms (direct problem) and in cloud-property retrieval algorithms (inverse problem). Moreover, single scattering regime is often assumed.
We are going to quantify the effects of high resolution cloud inhomogeneities on the lidar/radar direct and inverse problems using numerical simulations. We will employ the classical approach of the radiative transfer community. For direct problem, the approach consists in comparison between the mean 3D radiative properties of the 3D clouds and those of the homogenous and plan parallel equivalent clouds with the same mean cloud properties. We are developing two tools for these purposes. The first one is McRALI (Alkasem et al., 2017), a polarized lidar/radar Doppler simulator taking account of multiple scattering processes and the 3D structures of cloud and wind. It is based on the 3DMCPOL model (Cornet et al., 2010). The second tool is 3DCLOUD_V3, a high-resolution synthetic 3D cloud and wind speed fields generator. It will be based on the 3DCLOUD and 3DCLOUD_V2 generators (Szczap et al., 2014; Alkasem et al, 2017) that is now in use for stratocumulus/cumulus/cirrus clouds cases.

Spatiotemporal Variability of Solar Irradiance at the Surface: Implications for Radiative Closrue at the Surface

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An accurate characterization of the small-scale variability of cloud inhomogeneities and the resulting modulation of the solar irradiance at the surface is important for many applications, including our understanding of cloud radiative effects and radiative closure studies. It enables us to assess the level of agreement that can be reached when comparing point measurements with area-averaged estimates, as is often done in the validation of satellite products and atmospheric models. Within the framework of the High Definition Clouds and Precipitation for advancing Climate Prediction (HD(CP)2) Observational Prototype experiment (HOPE), a high density network of 99 pyranometer stations was set up around Juelich, Germany (~ 10 × 12 km2 area) during April to July 2013 to capture the small-scale variability in cloud-induced radiation fields at the surface. A wavelet-based multi-resolution analysis is carried out on the observed time series of global flux transmittance from the pyranometer stations. We investigate (i) the wavelet-based power spectrum, and the effect of temporal averaging on the variance, (ii) the spatial correlation including its time-scale dependence, and (iii) the degree of representativeness of a point measurement for an area -averaged value. This analysis is done for different sky conditions (clear, cirrus, overcast and broken clouds). It is found that on broken cloudy days, the time series of transmittance exhibits significantly higher and distinct variability at all averaging frequencies. The variability in transmittance decreases strongly with increasing frequencies and vice versa, irrespective of the prevailing cloud cover. Both the spatial auto-correlation and the variance of irradiance are strongly scale-dependent. With an increasing area of averaging, the temporal variance at high frequencies is strongly attenuated, and only a small fraction of variance can be explained by a point measurement. For broken-cloud conditions, we conclude that a single station measurement can deviate from the spatial mean by as much as 50 W/m2 for a grid-box of 100km2. The implications of our analysis for closure between EarthCARE products and solar irradiance observations at the surface will be discussed, and recommendations for validation campaigns will be given.

Solar and thermal radiative flux estimation for the EarthCARE BBR instrument: Analysis of results

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The operational EarthCARE L2 product on top-of-atmosphere (TOA) radiative fluxes is based on a radiance-to-flux conversion algorithm fed mainly by unfiltered broad-band radiances from the BBR instrument, and auxiliary data from EarthCARE L2 cloud products and modelled geophysical databases. The conversion algorithm models the angular distribution of the back-scattered solar radiation and thermal radiation emitted by the Earth-Atmosphere system, and provides flux estimates to be used for the radiative closure assessment of the Mission.

Different methods are employed for the solar and thermal BBR angular distribution models (ADMs). Models for SW radiances are created for different scene types and constructed from Clouds and the Earth's Radiant Energy System (CERES) data using a feed-forward back-propagation artificial neural network (ANN) technique. LW ADMs are based on correlations between BBR radiance field anisotropy and the spectral information provided by the narrow-band radiances. Both retrieval algorithms exploit the multi-viewing capability of the BBR (forward, nadir and backward observations of the same target) providing flux estimates for every view and checking their integrity before being combined into the optimal TOA flux of the observed target. The reference height where the three BBR measurements are co-registered corresponds to the height where most reflection or emission takes place and depends on the spectral regime. LW observations are co-registered at the cloud top height, but the most radiatively significant height level on SW radiances is very dependent on the cloud. This reference height is instead selected by minimizing the flux differences between nadir, fore and aft fluxes.

The flux retrieval algorithms were empirically assessed by comparing results against fluxes obtained from CERES and Geostationary Earth Radiation Budge (GERB) ADMs. The utility of this exercise is limited because of the difficulties to find appropriate data to mimic EarthCARE products.

The study presented here shows a new exercise to evaluate the BBR radiance-to-flux conversion algorithms. Using the Environment Canada and Climate Change's Global Environmental Multiscale (GEM) model the EarthCARE team has simulated three EarthCARE frames (1/8 of orbit). After applying the ESA instrument models to these test scenes a set of L1 EarthCARE data have been released to the team for testing. These cases include a cold-front near Halifax, dense overcast south of Halifax, scattered shallow convection south of Bermuda, clear and cold conditions at the northern extremity, scattered cloud through the Canadian Prairies, overcast over the Rocky Mountains, clear through Utah, and cirrus in Arizona and Mexico. These ample variety of realistic samples offer a great opportunity to compute the fluxes using EarthCARE L1 and L2 and compare results against modelled radiance fields.

The BBR solar and thermal flux retrieval algorithms were successfully employed to retrieve radiative fluxes over the test scenes. The details of this comparison are shown paying special attention to the highest differences between flux estimates and "true" fields.

P9 - Recent progress of the Joint-Simulator (Joint Simulator for Satellite Sensors)

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Joint-Simulator (Joint Simulator for Satellite Sensors) can simulate EarthCARE observations from numerical weather/climate model outputs (Hashino et al. 2013, 2016). The code of the Joint-Simulator is available from the following link (http://www.eorc.jaxa.jp/theme/Joint-Simulator/userform/js_userform.html)
The basic structure of Joint-Simulator is inherited from Satellite Data Simulator Unit (SDSU) (Masunaga et al. 2010) and NASA Goddard SDSU (Matsui et al. 2013). The sensors of EarthCARE are simulated by EarthCARE Active Sensor simulator, EASE, (Okamoto et al., 2003, 2007, 2008; Nishizawa et al. 2008) for the Doppler CPR and ATLID, RSTAR 6b (Nakajima and Tanaka 1986, 1988) for MSI, and MSTRN X (Sekiguchi and Nakajima 2008) for BBR. Recently, functions of the Joint-Simulator are expanded such as in scattering database for nonspherical particles (Ishimoto 2008, Liu 2008, Yang et al. 2013) and implementations of 4 stream RTM for passive microwave sensors (Liu 1998). Furthermore, recently, application works using the Joint-Simulator are increased such as in model validations of Kotsuki et al. (2014), Matsui et al. (2016), and Roh et al. (2017) and assimilation studies of Okamoto et al. (2016). This paper will summarize recent progress of the Joint-Simulator.

P11 - Overview of the EarthCARE CPR cloud and precipitation retrieval algorithms

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The joint European Space Agency-Japanese Aerospace Exploration Agency (ESA-JAXA) Earth Clouds, Aerosol, and Radiation Explorer (EarthCARE) mission will have the first spaceborne Cloud Profiling Radar (CPR) with Doppler capability. The C-CLD is an intended operational ESA product that will provide information on cloud and precipitation retrieved using an optimal estimation method determining vertical profiles of hydrometeor water content and the mean mass-weighted diameter from reflectivity and mean Doppler velocity previously corrected for air motion. The developed algorithms are complex due to innovative procedures that have been defined and adopted and are novel in that employ an ensemble-based method to obtain the forward model relations within the OE framework and the associated uncertainty. This has been done in order to take into account a large variety of the relations found in natural ice/snow and rain and in order to quantify uncertainty in the derived average relationships caused by this variety. The retrieval algorithms for different hydrometeor categories are in the final development stage and are presented here with a sensitivity analysis of the proposed retrieval technique.

P12 - The ATLID Feature Mask processor

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The Earth Clouds Aerosol and Radiation Explorer (EarthCARE) mission is a combined ESA/JAXA mission to launch in 2020. EarthCARE will study the spatial (3D) distribution of clouds and aerosols and their impact on the Earth's radiative balance and will carry a combination of active and passive sensors designed with sensor-synergy playing a key role
The instruments are the High Spectral Resolution Lidar (HSRL) ATLID operating in the UV at 355nm, a cloud profiling radar (CPR), a cloud/aerosol imager (MSI), and a three-view long- and short-wave broadband radiometer (BBR).

To achieve the EarthCARE mission goals, retrieval algorithms are being developed for single instruments (L2a) as well as multi-instrument algorithms (L2b). The results of the algorithm chain, combining the results of ATLID, CPR and MSI retrievals will be used in an ongoing radiative closure assessment during the mission lifetime. In this closure assessment the best possible reconstructed atmospheric scene, using the derived aerosol and cloud properties, will be used as input to broad-band radiative transfer models which will, in turn, generate Top-Of-Atmosphere (TOA) flux and radiance estimates which can subsequently be compared to the actual BBR measurement.

An HSRL system, like ATLID, can separate the backscatter signals from particles (parallel and cross Mie channels) and molecular return (Rayleigh channel) . Separating the lidar molecular and particular returns enable the retrieval of extinction, backscatter and linear depolarization ratio directly. ATLID will measure atmospheric echoes with a vertical resolution of about 100 m from ground to an altitude of 20 km and 500m from 20km to 40km altitude. The design of the ATLID (L2a) retrieval chain is driven by the expected signal-to-noise ratio of the ATLID instrument and the EarthCARE requirements. Three separate (but interdependent) processors have been created in order to retrieve the atmospheric state. As a first step the feature mask algorithm (A-FM) has been developed to separate regions with particle return from molecular backscatter regions only. The feature mask identifies 'significant returns' in the lidar signal, exceeding the ATLID noise levels, indicating the presence of either aerosols or cloud particles within the beam. It does not specify the nature of the feature but is used to determine different smoothing tactics in the microphysical retrieval schemes. The other two processors are the ATLID-Profiles (A-PRO), in which profiles of extinction, depolarization and lidar ratio are determined as well as follow on products as the classification (e.g. aerosol type, cloud phase). The final ATLID processor is the ATLID-Layer (A-LAY) algorithm in which the layer products are calculated.

In order to derive reliable extinction and backscatter profiles, as well as a target classification an accurate feature mask is essential. The A-FM algorithm defines the feature mask based on the correlation of the data without relying on a number of hard coded or input dependent thresholds. As the signal strength of aerosol or very optically thin ice clouds on the single shot grid can be comparable to the instrument noise levels it was chosen to rely on image reconstruction techniques and not on signal to noise ratios and thresholds. The main reason why an image reconstruction technique can be so effective for the EarthCARE lidar data is that, in principle the Mie signals contain only particle backscatter, background noise and noise due to the Mie-Rayleigh cross-talk. It also ensures the derivation of a feature mask on the single shot resolution instead of directly going to a lower horizontal resolution of 1 or 10 km. This enables both the use of variable masks, e.g. use only those profiles which are sure to have no clouds to derive the mean aerosol signals and calculation of feature fractions which can result in a better determination of higher order products.

Additionally the processor checks and reports the existence of data gaps and determines the lidar surface, i.e. the highest pixel per profile contaminated by surface backscatter. Finally the processor calculates the mean signals of the feature free atmosphere in each of the three channels to enable the evaluation of the ATLID calibration .

In order to facilitate the algorithm development and deployment process a number of simulated data sets have been developed a KNMI. The EarthCARE scenes were formed using high-resolution cloud resolving model data from Environment and Climate Change Canada's high resolution GEM model merged with aerosol fields from the CAMS model. The constructed extinction/particle size distribution field was subsequently forward modelled in the EarthCARE simulator (ECSIM) to calculate the ATLID signals for the three channels (Co-Polar Mie, Total cross channel and Rayleigh channel). Similar signals were calculated for the other three instruments, providing consistent test scenes for the entire EarthCARE L2 retrieval chain. In this presentation the processor, its products and examples for one of the EarthCARE scenes (including ice clouds, liquid clouds and aerosols) will be presented. The work described in this poster were conducted as part of ESA/ESTEC contract No. 4000112018/14/NL/CT .

P13 - The ATLID profile processor :A-PRO

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The atmospheric Lidar (ATLID) carried by EarthCARE is a linearly polarized 355nm high-spectral resolution (HSRL) lidar. By passing the received signal through an etalon the elastic return from cloud/aerosols can be distinguished from the thermally broadened return from atmospheric molecules. This, in principle, allows the atmospheric extinction profile to be estimated independently of the backscatter profile.

The primary ATLID products related directly to the cloud and aerosol optical properties are extinction, backscatter and depolarization. Both stand-alone (L2a) products and synergistic (L2b) algorithms involving ATLID L1 and/or L2a products are being developed. The primary processor for the L2a profiles of extinction, backscatter and depolarization ratio is the so-called A-PRO processor.

Since ATLID is an HSRL design, the application of standard HSRL retrieval approaches, in principle, allow for the direct determination of the extinction profile as well as the extinction-to-backscatter ratio (also known as the lidar-ratio or S). This is in contrast to elastic backscatter lidars (e.g. CALIPSO) which must specify the S profile in order to estimate the extinction and backscatter profiles. The direct HSRL extinction retrieval using the detected molecular signal requires high signal-to-noise (SNR) data in order to be successfully implemented. For ATLID, this means that horizontal averaging on the order for 100km will be necessary for the retrieval of aerosol extinction using conventional HSRL algorithm approaches.

For situations in which clouds are present, another approach is required. Horizontal averaging on the order of 100km is defensible for aerosol fields, but not for cloud observations. This is due to the fact that clouds, compared to aerosol fields, more strongly attenuate lidar signals and are much more inhomogeneous. In addition, the SNR of elastic cloud/aerosol returns on the 1km horizontal scale are such that elastic backscatter lidar inversion methods (i.e. Klett- like) can be successfully applied. This has led to the development of a hybrid strategy which involves combining information provided by low-horizontal resolution S retrievals with high horizontal resolution Klett-like retrievals. The approach aims to find the "best" Klett-like inversion which is consistent with the observed molecular scattering attenuated backscatter profile.

The algorithm is cast in an optimal estimation framework and accounts for lidar multiple-scattering. Once estimates of S and the aerosol/cloud depolarization are available they can be used to determine cloud phase (i.e. liquid or ice) and assign classes to the detected aerosols.

In this presentation the ATLID L2a A-PRO algorithms that will determine extinction backscatter and target classification will be presented and discussed. The operation of the algorithms will be illustrated using simulated signals generated using the EarthCARE simulator corresponding to a number detailed frame-sized (6000km) scenes. The work described in this presentation was conducted as part of ESA/ESTEC contract No. 4000112018/14/NL/CT.

P14 - The EarthCARE Multi Spectral Imager cloud products

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The Multi Spectral Imager (MSI) will be one of the four instruments aboard the ESA Earth Cloud, Aerosol and Radiation Explorer satellite mission, EarthCARE. The MSI has seven channels in the visible, near-infrared, shortwave- and thermal infrared. The pixel sample distance is 0.5 km over a swath width of 150 km. The MSI observations will provide the information needed for describing the cloud and aerosol properties in the cross-track direction. The MSI cloud products combine visible to infrared channels to determine cloud microphysical and macrophysical properties, which include cloud top pressure, thermodynamic phase, optical thickness, particle size, and water path. The intent of the present study is to provide an overview of cloud products and to demonstrate the performance of the individual cloud algorithm based on synthetic MSI observations with the EarthCARE Simulator (ECSIM) and passive imager measurements. ECSIM has been developed as an end-to-end simulator for the EarthCARE mission capable to simulate the four instruments configurations. We will present results obtained with the MSI cloud processor for different scenes. Further in the scope of the the International Clouds Working Group (ICWG) the algorithm are adapted to passive imager instruments onboard polar and geostationary satellites (MODIS and SEVIRI) to test and verify the MSI cloud products with state of the art algorithms.

P15 - Aerosol optical thickness from EarthCARE's Multi-Spectral Imager

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Within ESA's EarthCARE (Cloud, Aerosol and Radiation Explorer) activity Atmospheric PRoducts from Imager and Lidar (APRIL), the MSI L2a processor M-AOT is developed to derive aerosol optical thickness (AOT) at 670nm and over ocean, additionally, at 865nm. Further, the Ångström parameter, based on the retrieved AOT at 670nm and 865nm, will be available over ocean surfaces.

The M-AOT product is based on MSI measurements from the visible (670nm) to shortwave infra-red (2200nm). The algorithm is separated in two different approaches, one for ocean and one above land surfaces, only having the correction of the measured top-of-atmosphere signal regarding gaseous absorption in common in a precursory step. The inversion relies on the optimal estimation technique. The forward model used in the algorithm relies on pre-calculated look-up tables of modelled normalized radiance for the respective MSI channels. Simulations have been carried out by using radiative transfer code MOMO [Hollstein and Fischer, 2012] applying the EarthCARE Hybrid End-To-End Aerosol Classification (HETEAC) model [Wandinger et al. 2016] to ensure consistency between aerosol products from the active and passive instruments on EarthCARE.

A brief overview of the retrieval itself that will indicate assumptions and limitations of the retrieved product and example outputs based on EarthCARE Simulator (ECSIM) test scenes and MODIS inputs will be presented.
The work described in this presentation was conducted as part of ESA/ESTEC contract No. 4000112018/14/NL/CT.

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Wandinger, U., Baars, H., Engelmann, R., Hünerbein, A., Horn, S., Kanitz, T., Donovan, D., van Zadelhoff, G.J., Daou, D., Fischer J., von Bismarck, J., Filipitsch, F., Docter, N., Eisinger, M., Lajas, D. and Wehr, T.: HETEAC: The Aerosol Classification Model for EarthCARE. EPJ Web of Conferences, 119, 2016.

P16 - EarthCARE BBR BM-RAD product and algorithm

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The Broadband Radiometer (BBR) instrument on EarthCARE will provide accurate measurements of the outgoing SW and TW radiances at the Top of the atmosphere at three viewing angles in an along track configuration. These radiances are filtered by the spectral response of the instrument and must be converted into unfiltered radiances in the Unfiltering process in order to correct for the limited and non-uniform spectral response of the instrument.

This poster describes the EarthCARE BBR BM-RAD Level 2b product. The main variables provided are the TOA solar and thermal unfiltered radiances for each of the BBR telescopes at 6 different spatial resolutions (namely: Standard, Small, Full, Assessment Domain, Joint Standard Grid, and Joint Standard Grid PSF corrected). BM-RAD also contains filtered radiances as well as the scene type characterisation, illumination and observation geometries, and geolocation.

As regards to the algorithm, two unfiltering algorithms are used: the Stand-alone (for Shortwave (SW) and Longwave (LW) channels) and the MSI based (for the SW channel). The stand-alone algorithm estimates the unfiltered radiances from the filtered ones without using information from the imager and the unfiltering is done according to the measured broadband radiances and land use classification. The MSI based algorithm makes use of the MSI cloud mask and cloud phase in the unfiltering.

BM-RAD is a key product in the EarthCARE production chain, since the unfiltered radiances produced will be used by the BMA-FLX, ACM-RT and ACM-DF processors to verify the EarthCARE radiative closure.

P17 - EarthCARE BBR BMA-FLX product and algorithm

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EarthCARE BBR radiative fluxes at the TOA are obtained by applying a radiance-to-flux conversion algorithm to the unfiltered radiances from the BM-RAD product (BBR L1 data). The algorithms for retrieval of solar and thermal fluxes are based in angular dependence models (ADMs). The ADMs model the anisotropy of the atmosphere-Earth system providing an anisotropic correction factor to the Lambertian assumption when integrating the exiting radiance field. A geophysical dataset mimicking EarthCARE data is constructed for training the algorithms and build the ADMs.

The BBR instrument observes quasi-simultaneously every target from three viewing along-track directions. The flux retrieval algorithms provide independent flux estimates for every BBR observation. To derive the most accurate flux value for the observed target a combined flux will be obtained from merging the three resulting anisotropic factors. This is only possible when the same scene is observed by the BBR telescopes. Parallax produced by clouds and/or high surface elevations makes impossible to co-register the three BBR acquisitions for the same target with the pre-defined surface geolocation of the L1 data. In order to minimize this effect, forward and backward BBR observations are co-registered at the reference level, the most radiatively significant layer height (different for LW and SW domain) in the atmospheric column defined by the nadir observation.

This poster describes the EarthCARE BBR L2b radiative product BMA-FLX. The most relevant variables in BMA-FLX product are the instantaneous TOA solar and thermal fluxes for each BBR telescope observing the scene, the combined flux computed from those flux values and the uncertainties associated to those variables. The product includes as well the PSF-weighted mean at the BBR footprint size of the input parameters employed in the flux production. The PSF-weighted standard deviation of those variables is also provided as a measure of the homogeneity in the BBR footprint. The co-registered solar and thermal radiances at the reference level are also retrieved. The BMA-FLX product is available at four different spatial resolutions. The ones obtained by the BM-RAD products, namely “Small”, “Full”, “Standard” and “Assessment Domain”. The latter is used for the radiative closure of the EarthCARE Mission.

BMA-FLX is a key product in the EarthCARE production chain since the EarthCARE radiative closure, in the ACMB-DF product, includes comparisons between radiative transfer model results and TOA co-registered radiances and ADM-derived fluxes.

P18 - Synergistic aerosol and cloud properties from EarthCARE's imager and atmospheric lidar

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ESA's mission EarthCARE will provide measurements from active sounder and passive imager from one platform. Vertical profiles of cloud and aerosol parameters will be retrieved with an active backscatter lidar (ATLID). MSI observations will provide the information to extend the spatial limited information of cloud and aerosol properties obtained from active sensors into the cross-track direction, which is required to perform a radiative closure with the broadband radiometer data.
State of the art algorithms have been developed to retrieve MSI cloud and aerosol products, e.g. cloud mask, ISCCP cloud types, cloud phase, cloud optical thickness, cloud effective radius and cloud top height, aerosol optical thickness and Ångström parameter. The synergistic use of both ATLID and MSI is providing additional information about the cloud top height, spectral aerosol optical thickness, Ångström parameter and aerosol types.
There are two different cloud top heights retrieved. The infrared effective radiating height is retrieved by the MSI and is located somewhere in the cloud while the ATLID retrieved cloud top height stands for the physical boundaries of the clouds along-track. Both the MSI and ATLID cloud top height are used to study the relationships between the effective and true cloud top height.
Further, the synergistic use of ATLID and MSI to identify aerosol types has been studied based on the information of the retrieved spectral aerosol optical thickness, which consists of measurements at 355 nm (ATLID), 670 nm (MSI) and 865 (MSI, only ocean).
We have used a combination of MODIS and Calipso observations and specific test scenes, generated with the EarthCARE Simulator (ECSIM), which have been created from model output data, as a test bed to develop a combined synergistic retrieval which uses the cloud and aerosol information from both ATLID at the track and MSI over the entire swath.

P19 - ACM-CAP: a synergistic "best estimate" retrieval of clouds, precipitation and aerosol for EarthCARE.

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The combined ATLID-CPR-MSI Clouds Aerosols and Precipitation best estimate "ACM-CAP" is the algorithm which will provide the operational EarthCARE level 2 product with realistic estimates of atmospheric vertical cross-sections for a wide range of cloud, aerosols and precipitation conditions. ACM-CAP is based on the unified synergistic variational framework CAPTIVATE and combines the observations from all three sensors onboard EarthCARE. The algorithm incorporates many novel features, such as explicit representation of radar and lidar multiple scattering, a new fast forward model for solar radiances, a Kalman smoother to provide robust aerosol retrievals even in the presence of noisy lidar measurements and an advanced diagnostics of retrieval confidence such as properties of the averaging kernel.
The poster presents a detailed description of the algorithm's capability using synthetic EarthCARE data simulated from 250-m esolution cloud-resolving model simulations and illustrates the impact of the different observations on the retrieval of a variety of atmospheric profiles.

P20 - Continuous Radiative Closure Assessment: An Official EarthCARE Process

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From its initial definition the EarthCARE mission planned to use broadband radiances, and fluxes derived from them, as measured by its BroadBand Radiometer (BBR) to provide a continuous assessment of retrieved cloud and aerosol products. As BBR data were never intended to be used for retrievals, they offer a means of performing a radiative closure assessment. In essence, broadband radiances, and fluxes, will be predicted by suitable radiative transfer models operating on retrieved data, and then compared to either BBR radiances or fluxes. Four steps are required to perform the assessments, each of which will generate distinct products. The first step (ACM-COM process) is to merge retrieved cloud and aerosol products with ancillary atmospheric and surface data as needed by any broadband radiative transfer model (e.g., temperature and moisture profiles). Since products retrieved by the active sensors only provide a narrow "curtain" of profiles, they get expanded across-track to generate 3D assessment domains (ACM-3D process). These domains get operated on by 1D and 3D broadband radiative transfer models thereby yielding domain-average radiances, which correspond to the BBR's three views, and profiles of radiative fluxes (ACM-RT process). ACM-RT's products are then compared to BBR radiances, and fluxes, resulting in an estimate of the probability that the radiometric quantities from the two sources agree to within EarthCARE's formally stated goal of ±10 W m-2 (ACMB-DF process). In this presentation sample outputs from the four steps are shown via application to synthetic test cases which span wide ranges of environments and conditions: a mid-latitude winter cold-front, a continental swath from central Nunavut to Baja California, and vigorous convection across the central Pacific.

P21 - EarthCARE CPR Doppler measurement algorithm

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One of the features of EarthCARE CPR is Doppler measurement function. A pulse-pair method is used to estimate the Doppler speed of the echoes. Doppler measurement accuracies depend on the SN ratio of echoes, the pulse repetition frequency (PRF), and the integration number of data, as well as the external error source such as satellite speed contamination with the antenna beam direction. The phase stability of the transmitter and receiver is also one of the error sources of the Doppler measurement, which CPR is designed to achieve adequate small magnitude of error. Theses days, we also found inhomogeneity of the echo intensity within the beam width of the CPR cause the Doppler velocity error.
NICT and JAXA have responsibility to develop level 1 algorithm. For developing the level 1 algorithm, we should consider various Doppler error sources and how to estimate and reduce bias and harmonics errors of Doppler velocity products. In this paper, basic concepts of Doppler estimation method and their errors are discussed. Error reduction method for horizontal inhomogeneity of the echo intensity is also discussed.

P22 - EarthCARE L2 cloud/precipitation algorithms

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Recently, development of new ground-based lidar systems is in progress to simulate the EarthCARE ATLID/CPR observations and to improve the EarthCARE L2 cloud/precipitation algorithms for cloud process studies, based on the Multiple-Field-of-view Multiple-Scattering Polarization Lidar (MFMSPL) concept. For the analysis of the observation system, a physical model that reproduces the transition of the polarized multiple scattered signals of active sensors within different scattering regimes for input vertical cloud and atmospheric profiles is developed. In this paper, further application and extension of the model for the analysis of the ground-based Doppler lidar-radar systems and satellite active sensors are studied.

P23 - Algorithm development to retrieve aerosol and cloud optical properties from ATLID and MSI measurements

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We develop algorithms to derive aerosol and cloud optical properties corresponding to the ATLID level 2 parameters planned to be distributed by JAXA, using the ATLID level 1 data of Mie copol, Mie crosspol, and Rayleigh attenuated backscatter coefficients at 355nm (ATLID algorithm). The developed algorithms (1) estimate extinction coefficients (α), backscatter coefficients (β) and depolarization ratio (δ) of particles (aerosols and clouds) without assuming a particle lidar ratio (S=α/β), (2) identifies molecule-rich, aerosol-rich, or cloud-rich slab layers using the derived β by a threshold method, (3) classifies aerosol type (e.g., dust and maritime) and cloud type (e.g., water-droplet and ice-crystal) using the derived β, S, and δ by a threshold method, (4) retrieve planetary boundary layer height using the feature mask products (i.e., (2)), and (5) estimate extinction coefficients for several main aerosol components in the atmosphere (e.g., dust, sea-salt, carbonaceous, and water-soluble aerosols) using difference in depolarization and light absorption properties of the aerosol components from the retrieved α, β, and δ. With this method, we assume an external mixture of aerosol components and prescribe their size distributions, refractive indexes, and particle shapes. This method considers hygroscopic growth of water-soluble and sea salt aerosols. In the retrieval of α, β, and δ (i.e., (1)), we proceed with introduction of an optimization method using Gauss-Newton method with biconjugate gradient method instead of conventional direct method. For the aerosol typing (i.e., (3)), we proceed with construction of optical and microphysical models for each aerosol type by cluster analysis using sky scanning radiometer data (e.g., AERONET and SKYNET) and ground-based lidar data (e.g., Raman lidar and HSRL). Furthermore, we develop an aerosol retrieval algorithm using both the ATLID and MSI data (ATLID and MSI synergy algorithm). This algorithm retrieves vertically mean mode-radii for dust and water-soluble aerosols as well as the extinction coefficients for the four aerosol components similar as ATLID algorithm from radiances at 670 and 865nm of MSI level 1 data and the α, β, and δ derived from the ATLID level 1 data with the optimization technique used in the ATLID algorithm (see (1)). With this method, we use the spectral property of aerosols sensitive to particle size as well as the depolarization and light absorption properties. We assume an external mixture of aerosol components, prescribe their refractive indexes and particle shapes, and consider hygroscopic growth of water-soluble and sea salt aerosols. In the conference, we report the latest status of these algorithm developments and key performances of the algorithms. In addition, we briefly report our activities on ground-based lidar observation to evaluate and improve the algorithm performance.

P24 - Compilation of JAXA EarthCARE A-train Research Products

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Clouds and aerosols play a crucial role in Earth's radiation budget and hydrological cycle and therefore in present and future climate model simulations. Evaluation of their representation in climate models requires global and long-term observational data sets. The Japan Aerospace Exploration Agency (JAXA)/European Space Agency (ESA) are developing the EarthCARE (Earth Clouds, Aerosols, and Radiation Explorer) satellite due to launch in 2019 that will carry a Cloud Profiling Radar (CPR), a high-spectral-resolution atmospheric lidar, a broadband radiometer, and a multispectral imager. It may be considered the successor to the National Aeronautics and Space Administration (NASA) A-Train. Thus, the JAXA Earth Observation Research Center (EORC) is constructing a JAXA EarthCARE "A-train research products" derived from A-train (CloudSat radar/CALIOP lidar/MODIS imager) data using algorithms developed by the JAXA EarthCARE science team. All the observables and retrieved parameters are collocated to the horizontal and vertical resolutions of 1.1 km and 240 m, respectively. The height of the grid centers ranges from 120 to 19800 m. The retrieved products include radar and lidar cloud masks [Hagihara et al., 2010], vertically resolved lidar cloud particle type [Yoshida et al., 2010; Hirakata et al., 2014], radar and lidar cloud microphysics [Okamoto et al., 2010], lidar aerosol mask and properties [Nishizawa et al., 2007; 2008], and imager cloud mask and microphysics [Ishida and Nakajima 2009; Kawamoto et al., 2001]. The product is expected to be used in the evaluation of climate models [e.g., Hashino et al., 2013], and they are available online through the JAXA/EORC website with various visualized figures. In addition, we also will demonstrate the statistical analysis results by making use of our product.

P25 - The 4-sensor algorithm for radiative fluxes: Current status

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Cloud and aerosol play a crucial role in the Earth's radiation budget. Moreover, aerosol-cloud interactions are recognized as one of the primary sources of uncertainty in understanding and predicting global climate change. To improve our understanding of the role of aerosol-cloud interactions in Earth's radiation budget, we develop an algorithm for calculating the vertical profiles of radiative flux and heating rate based on the Earth Clouds, Aerosols, and Radiation Explorer (EarthCARE) satellite sensors. For this purpose, one-dimensional (1-D) and three-dimensional (3-D) radiative transfer (RT) simulations are applied to the cloud and aerosol properties obtained from CPR, ATLID and MSI, and are validated against radiative fluxes at the top of atmosphere (TOA) measured by Broadband Radiometer (BBR). The results from the 1-D and 3-D RT simulations will be provided as the standard and research products, respectively, from Japanese science team of EarthCARE. In our poster presentation, we will report initial results from the algorithm under development using A-Train satellite measurements (CPR, CALIOP, MODIS) as a test bed for EarthCARE. The results are also compared and verified against CERES-observed TOA radiative fluxes for assessment of the radiative closure within 10Wm-2 for instantaneous TOA fluxes.

P26 - Hydrometeor Particle Type Classification Algorithm for JAXA EarthCARE Product

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An algorithm for classifying cloud and precipitation particle phase and ice crystal shape by synergetic use of space-borne radar and lidar was developed towards JAXA EarthCARE Level 2 Product. The radar-lidar synergy estimates are defined based on the estimates by the individual schemes of radar and lidar. The lidar scheme is based on the algorithm originally developed by Yoshida et al. [2010] and modified by Hirakata et al. [2014], which mainly uses depolarization ratio to identify ice plates and backscattering ratio of two vertically consecutive layers (as a proxy of lidar attenuation) to discriminate randomly-oriented ice crystals and water particles. The radar scheme is based on the algorithm by Kikuchi et al. [2017] which uses radar reflectivity and temperature to identify hydrometeor types including water, randomly oriented crystals, ice plates, rain and snow. Taking the advantage of the radar's capability to penetrate cloud and light precipitation and lidar's capability to detect thin clouds, the synergy algorithm derived the global distribution of hydrometeor particle types from thin cirrus clouds, convective clouds to light precipitation.

In this presentation, the details of the algorithm are explained, together with the classification results using the cloud profiling radar (CPR) onboard CloudSat and Mie-scattering lidar, Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO).

P27 - Optical properties of dust spheroid particles using AERONET observations

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Aerosol distribution in the atmosphere depends on the sources, transport processes, and chemical reaction of aerosols. The vertical profiles of aerosol classification help the understanding of the life cycle of various aerosol types; therefore, we need to make the model of optical properties for main aerosol types in the atmosphere (e.g., smoke, dust, and marine) in order to classify the aerosol types from the EarthCARE/ATLID measurements.
We perform a cluster analysis of aerosol optical properties estimated from the sun/sky photometer measurements of Aerosol Robotic Network (AERONET). We adopt the clustering method, Fuzzy c-means, which is an unsupervised clustering technique that allows each data point in a dataset to belong all clusters to some degrees. We use the AERONET level 2 products and the radiative transfer code Pstar3 (Ota et al., 2010).
We can calculate aerosol lidar ratio and depolarization ratio using the radiation code and the aerosol optical properties retrieved by the AERONET observations (size distributions, complex refractive index, and sphericity). We use 12 parameters to classify aerosol characteristics in the Fuzzy c-means clustering method. The six parameters used in the clustering are fine mode fraction (FMF), which is the ratio aerosol optical thickness (AOT) of the fine mode aerosols to that of total aerosols, and the imaginary part of complex refractive index, respectively, at 3 wavelengths (440, 675, and 870 nm). In addition, we use the simulated lidar ratio and depolarization ratio at 355, 532, and 1064 nm for the clustering.
For example, two aerosol types are classified in the Saharan desert region. We assume that one type is pure dust and the other type is the mixture of dust and smoke. In comparison with the ground-based and airborne lidar measurements (Burton et al., 2012; Illingworth et al., 2015), the dust lidar ratio is overestimated and the dust depolarization ratio is underestimated in this study. It indicates the possibility that the aerosol optical properties calculated by using the shape of spheroid particles (Dubovik et al., 2006) are not consistent with the lidar observations. We will examine the dependence relationship between lidar ratio and depolarization ratio and the aspect ratio of spheroid particles.

P28 - Evaluation of CPR Doppler velocity error with NICAM/Joint-simulator

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The Earth Clouds, Aerosol and Radiation Explorer (EarthCARE) satellite is a joint mission by the Japanese Aerospace Exploration Agency and European Space Agency and scheduled launch in 2019. It will carry the Cloud Profiling Radar (CPR), which have the first Doppler measurement capability in space. Here, the performance of the CPR Doppler velocity measurements is discussed using a satellite-sensor simulator (NICAM/Joint-Simulator). The Doppler error caused from the Doppler broadening by satellite velocity contamination within the beam width is added to the Doppler velocity of the Joint-Simulator. Then, pulse-pair covariances are calculated from them. The 500 m horizontally integrated CPR Doppler velocities are processed first, then 1 km and 10 km horizontally integrated Doppler velocities are estimated from them. We calculated those Doppler errors from NICAM/Joint-Simulator and checked Doppler error reduction by the horizontal integration. We found that the standard deviations of the Doppler error for -15 dBZ cloud echo are 2.2, 1.6, 0.6 m/s for 500 m integration, 1 km integration, and 10 km integration, respectively.

P29 - The preliminary result of ground based CPR for EarthCARE/CPR validation

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We developed ground based Cloud Profiling Radars (CPR) for EarthCARE/CPR validation, using the experience airborne cloud profiling radar (which nickname is SPIDER) and EarthCARE/CPR. One is High sensitivity Ground based CPR (HG-SPIDER), which sensitivity is -40dBZ at 15km height and after 1 seconds integration. HG-SPIDER is used for validate sensitivity. The other is Electronic-Scanning CPR (ES-SPIDER), which can be scanned +/- 4.5 degree from zenith angle and its sensitivity is -26dBZ at the zenith angle and 15km height and after 1 seconds integration.
The advantages of EarthCARE/CPR are higher sensitivity (-35dBZ) than CloudSat/CPR and the Doppler measurement capability. The HG-SPIDER covers the validation of sensitivity. For the Doppler velocity measurement, it is known that non-uniformity of cloud within antenna beam footprint caused measurement error. So ES-SPIDER is designed to measure the non-uniformity of EarthCARE/CPR footprint at 5km height.
Both radars are starting operate several times, so the preliminary results taken by both radars are reported.

P30 - Observations of cloud- and precipitation-microphysics and vertical motion

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Doppler cloud profiling radar CPR, high spectral resolution lidar ATLID, and multi-spectral imager MSI on EarthCARE are expected to produce (1) continuous records of cloud and precipitation microphysics with better accuracy compared with those products from CloudSat and CALIPSO satellites and (2) new features of cloud motions; terminal velocity of the particles and vertical air motion inside clouds.
Following products will be distributed; CPR-only products, CPR-ATLID synergy products and CPR-ATLID-MSI synergy products. In each category, there are standard and experimental products. The former ones do not use Doppler information and the latter needs Doppler information from CPR. Cloud mask algorithms are the first task. Then cloud particle type algorithms are conducted. Cloud phase and ice particle orientation and particle type are determined. Cloud and precipitation microphysics are then retrieved after cloud particle type. In addition, fall velocity of cloud particles and vertical air motion are also determined.
These algorithms have been developed and evaluated by the next-generation-ground-based-active-sensor-systems. The systems contain multi-field-of-view multiple scattering lidar (MFMSPL), Doppler cloud radar, direct- and coherent Doppler lidars, and multi-wavelength high spectral resolution lidar. MFMSPL was designed as the first ground-based lidar that can detect similar degree of depolarization ratio as space-borne lidar. We also developed Physical Model approach (PM) to simulate space-borne lidar signals. PM is much faster compared with the Monte Carlo method and the mean relative errors are about 15%. We plan to extend the PM to analyze the above systems.

P31 - Observing the cloud evolution process by using passive and active spaceborne sensors such as EarthCARE, A-Train, and Himawari-8

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Understanding the cloud evolution process is important for studying climate change through improving the general circulation model and cloud resolving model, which are used for forecasting Earth's climate. Because cloud evolution occurs globally, we use spaceborne sensors aboard satellites for this purpose. Cloud droplets grow from aerosols that act as cloud condensation nuclei, so we need to observe both aerosols and clouds. We are in an exciting era of observations; the A-Train constellation, which has active (CPR/CloudSat, CALIOP/CALIPSO) and passive sensors (MODIS/Aqua), has been in orbit for more than 10 years, and the EarthCARE satellite, which is a post-CPR/CALIOP/MODIS satellite, will be launched in 2019. The contoured frequency by optical depth diagram (CFODD) technique to visualize the cloud evolution process was proposed by Nakajima et al. (2010) and Suzuki et al. (2010). CFODD statistically classifies the stages of cloud droplet evolution in warm water cloud as cloud condensation growth, collision-coagulation process, and rain, based on the probability density function of the radar reflectivities as a function of in-cloud optical depth. CFODD is obtained by using passive (MODIS) and active (CPR) sensor data. An interesting feature of CFODD is that we can estimate the in-cloud evolution process from the effective cloud particle radii estimated by a passive imager that represents cloud-top properties. In the EarthCARE era, more useful information will be available from the Doppler capability of CPR/EarthCARE to clarify the cloud evolution process.

In this presentation, we will describe the standard algorithm of the EarthCARE Multi Spectral Imager (MSI) in cloud evolution research. We will show an example of a time-series observation of cumulus cloud evolution over Kyushu, southern Japan, from the third-generation geostationary satellite, Himawari-8.

P32 - Enhancement of Attitude and Geolocation Information for the EarthCARE mission

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The European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) are co-operating to develop the EarthCARE satellite mission with the fundamental objective of improving the understanding of the processes involving clouds, aerosols and radiation in the Earth's atmosphere.

EarthCARE is designed as a multi-instrument mission with a strong focus on synergistic products. The accuracy of the available attitude and geolocation information has a significant impact on the achievable performance of the higher level data. Airbus Defence and Space has developed two algorithms which improve the attitude and geolocation knowledge beyond the levels achievable by single sensor measurements. In the proposed poster presentation we will give an overview of the algorithms developed by Airbus DS and a summary of the expected performance in flight.

Firstly, a fixed-interval smoothing algorithm will be applied to the attitude information provided by the onboard Star Tracker sensors. The tuning parameters of the Extended Kalman filter based forward and backward estimators are optimized to the simulated dynamic behavior of the EarthCARE satellite and the attitude measurement statistics. After tuning, the filtering process improves the accuracy for the short-term attitude knowledge roughly by a factor of four. This leads to significantly improved CPR Doppler measurement performances, as the knowledge of the relative S/C to ground velocity parallel to the instruments Line of Sight without filtering was a notable contributor to the overall Doppler measurement accuracy budget.

Secondly, an attitude calibration campaign is proposed for the commissioning phase, in which the a-priori geo-located samples of all four instruments will be compared to reference data with accurate location information, such as the Sentinel-2 Global Reference Image for MSI & BBR and Digital Elevation Models for ATLID & CPR. Recently developed Airbus methods for geolocation enhancement provide unprecedented quality in terms of accuracy and robustness, i.e. the algorithms can extract many precise landmark matches in a short period. After calibration, most Geolocation and Co-Registration performances are expected to be better than 100 m, compared to the mission requirements of 350 m to 1000 m. The improved knowledge is very useful to the generation of synergistic products, where the measurements of all instruments will be resampled to a common grid. With the improved geolocation information, the quasi-noise due to inaccurate localization of high spatial contrasts is significantly reduced. The same calibration tools can be used to monitor geolocation accuracy of the four instruments and for co-registration between them during the mission.

P33 - Ice processes over Antarctica

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Because polar regions act as global energy sinks, changes of cloud cover and radiative properties of polar clouds can have ripple effects for the general circulation of the atmosphere. Clouds are also at the center of several not thoroughly understood feedbacks to the climate system. For instance, low-level liquid clouds can play a key role in enhancing melting events by increasing near-surface temperatures. Under a warming scenario at the global scale, extratropical cloud phase appears to play a key role in equilibrium climate sensitivity and active cloud feedback processes. Recent years have seen multiple field campaigns in the Arctic where permanent observatories like the ARM sites in Alaska and the Summit station in Greenland have now been established. Such long-term observations have highlighted the ubiquitous presence of supercooled liquid water clouds (SLWC) rooted in the boundary layer and their disproportionately large impact on surface melting. Ice particles grow fast in these mixed-phase clouds, produce solid precipitation and may scavenge the supercooled droplets. Global climate models commonly fail to accurately simulate enough SLWC compared to observations, and thus do not succeed in representing the surface energy balance correctly. Are Northern latitude conditions generally representative also of the Southern latitudes which are characterized by colder and more pristine environment than their Arctic counterparts?

The deployment at the McMurdo site on the southern tip of Antarctica's Ross Ice Shelf during the ARM AWARE field campaign of an unprecedented number of multi-wavelength active and passive systems simultaneously observing the vertical column -with the first ever triple-frequency radar observation in Antarctica- offers the opportunity of overcoming the scarcity of cloud information at southern high latitudes and of unravelling processes related to cloud&precipitation physics at high temporal and spatial resolution. Co-located Doppler Ka and W-band and HSRL observations of different case studies during January-February 2016 will be presented to showcase the potential of such observations in microphysical fingerprinting processes like depositional growth, sublimation, aggregation, riming, or secondary ice generation and to investigate which role these processes play in Antarctic clouds.

P34 - Expected ambiguities in the discrimination between insects and boundary-layer clouds from EearthCARE CPR observations

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Atmospheric plankton, i.e., non-meteorological particles observed at radar wavelengths, is ubiquitous in the planetary boundary over the continental air masses. It either consists of coarse particles dispersed into the atmosphere under strongly turbulent conditions or of birds or insects that fill the lower troposphere during the biologically active seasons. Observing and understanding the characteristics of atmospheric plankton is fundamental for several reasons: Atmospheric plankton produces radar reflectivity factors that are comparable to the ones of cloud droplets. A reflectivity-based discrimination between co-existing clouds and insects is thus subject to misclassifications. On the other hand - with respect to the currently ongoing discussion of a decrease in the global insect populations - a global dataset of insects is of high relevance for understanding the reasons, extent, and the impact of a potential drop in insect populations.
Within this study we present the expected impact of atmospheric plankton on the observations of the EarthCARE cloud profiling radar (CPR). First analyses show that CPR will be able to detect approximately 30% of all atmospheric plankton. The remaining 70% produce reflectivities that are below the detection threshold of CPR. An evaluation of ground-based observations of a 35-GHz cloud radar from Leipzig, Germany (51.3°N, 12.4°E) of TROPOS with co-located observations of the spaceborne 94-GHz cloud radar CloudSat is shown to present the ambiguities that are to be expected in the discrimination between plankton and cloud particles.

P35 - Observed drop size distributions for improved EarthCARE rain retrieval constraints

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Satellite estimates and global models disagree on the frequency and magnitude of light precipitation, especially in stratocumulus regions and high latitudes, and this is partially due to uncertainties about the size and distribution of raindrops. Despite the technical advances represented by CPR, raindrop population distributions constitute an ongoing uncertainty for EarthCARE retrievals and the satellite precipitation community more broadly. Moreover, Doppler vertical velocity measurements are strongly tied to particle size, making its characterisation critical to maximise the scientific return from CPR. Using the recently released OceanRAIN dataset of in-situ measurements from ship-borne disdrometers, this study analyses data on raindrop distributions that are global in scope. These data are synthesised to provide a priori information on location- and regime-dependent means and variances of the modified gamma distribution parameters, including their covariances. Results are separated by binned values of the shape parameter (μ), as this is both a proxy for stratiform/convective partitioning and acts as a point of comparison with current single-pol radar retrievals that assume a constant μ. The intention is to provide CPR with better a priori constraints for raindrop populations to aid future retrieval development.

P36 - EarthCARE-relevant aerosol classification applied on CyCARE ground-based lidar measurements

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Aerosol typing from EarthCARE's UV-lidar ATLID is a substantial feature to ensure consistency of the different aerosol products from the multi-instrument platform as well as facilitate the conform specification of broad-band optical properties necessary for the EarthCARE radiative closure efforts. Therefore, the Hybrid End-To-End Aerosol Classification (HETEAC, Wandinger 2015) model was developed for the upcoming EarthCARE mission. The hybrid approach of HEATEC ensures the theoretical description of aerosol microphysics consistent with the optical properties measured by EarthCARE which are known for various aerosol types from ground-based observations. The end-to-end model permits the uniform representation of aerosol types in terms of microphysical, optical and radiative properties.

We will use ground-based multiwavelength lidar (Engelmann, 2016) data from the CyCARE campaign at which the multi-instrument suite LACROS (Bühl, 2013) was deployed for more than 1.5 years in Limassol, Cyprus in 2017/2018.
Cyprus is a unique place for aerosol studies offering a wide-range of aerosol conditions from clean marine, to mineral dust intrusions and pollution scenarios.
We apply HEATEC on the UV profiles from the lidar measurements for specific scenarios for which also in-situ measurements of the DLR Falcon are available (A-Life campaign). The obtained microphysical properties of the aerosol and the radiative properties as calculated with HEATEC for the VIS and near-IR spectral range will then be compared to the direct measurements from the ground-based lidar at this wavelength range (e.g., Baars, 2016) and, if available, to the microphysical aerosol properties measured on the aircraft.
This will give first indications how good the aerosol characteristics need to be known to perform 3d-cloud radiative transfer and finally obtain radiation closure.

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P37 - A miniature 94-GHz radar network in Europe for the Calibration/Validation of the EarthCARE Cloud Profiling Radar L2 data products

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The joined ESA-JAXA EarthCARE features the first Doppler capable 94-GHz Cloud Profiling Radar (CPR), with enhanced sensitivity compared to the CloudSat CPR and improved resolution. These features, especially the availabilityof Doller velocity measurements, are expected to improve the CPR-based detection of clouds, microphysical retrievals in clouds and precipitation and for the first time provide information about convective motion in clouds. As important as the new features of the new CPR are, the development of comprehensive strategies for the evaluation/validation of the L2 CPR products are just as important.
Here, we describe one of these strategies, an ESA funded activity called FMR4RADAR for the development of a 94 GHz miniature Network for EarthCARE Reference Measurement. Within the FMR4RADAR a small ground based 94 GHz radar network is going to be instilled within Europa (FMR4RADAR project – INOE, Bucharest, Romania; SMHI, Narrköping, Sweeden; University of Cologne, Cologne, Germany). Using the ground-based, 94-GHz radar observations and supplemental information from other sensors available at the various sites, ground-based, equivalent versions of the L2 CPR products will be developed. The Cal/Val of the primary observations will be based on procedures similar to those established for the CloudSat CPR.
To validate the EarthCARE retrieval products, a 94-GHz adapted version of the CloudNet algorithm is going to be used. The novelty of this project is that it will give the possibility to monitor the performance of the EarthCARE radar over its entire live time. Therefore, the stability and drifts of the cloud radar can be monitored and calibration/validation standards for future satellite missions developed and installed.

P38 - The ARTS infrastructure

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ARTS - the Atmospheric Radiative Transfer System - is a publicly available, open source software. It is designed to be flexible and modular. General features include that simulations can be done for 1D, 2D or 3D atmospheres, a flat or spheroidal planet can be assumed and that one to four Stokes elements can be considered. Its present main strength is simulations of passive microwave observations. For such measurements, an extensive support regarding calculation of absorption and representation of sensor properties is provided, and several scattering solvers can be activated. Also radar measurements can be treated, most broadly by a module restricted to single scattering. For both passive microwaves and radar, (multiple) scattering effects can be studied in detail by fully polarised 3D Monte Carlo code. ARTS comes also with a general OEM (1DVAR) implementation, and both separate and joint passive/radar retrievals are possible. The infrastructure now also includes a broad database of scattering properties, between 1 and 876 GHz. The database focuses so far on totally randomly oriented ice hydrometeors, but will be extended to also cover oriented and melting particles. Planned extensions of ARTS itself include to allow making use of radar Doppler information, as well as testing and adopting the scattering solvers for the infrared region.

The capabilities of ARTS are here presented with focus on possible applications around EarthCARE. The software and the associated scattering database should be of special interest when exploring synergies between the EarthCARE radar and passive microwave observations. This synergy should be especially high with the Ice Cloud Imager (ICI), to be launched 2022 onboard Metop-SG. This instrument will perform measurements between 183 and 664 GHz, and thus add the sub-millimetre region to the set of operational measurements. The main objective of ICI is to provide ice hydrometeor information. ICI will not match EarthCARE in vertical resolution, but provides a broad swath (>1000 km) and the use of sub-millimetre is expected to give unique information on mass-weighted mean particle size. Further, for any EarthCARE retrieval, the scattering database should be relevant for testing the impact of assumed ice particle habit, that is demonstrated using CloudSat.

P39 - EarthCARE's Broadband Radiometer: Unforeseen Sampling Uncertainties Associated with Cloudy Atmospheres

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The ESA-JAXA satellite mission EarthCARE will be launched in 2020 and is designed to conduct a space-borne radiative closure assessment, comparing simulated and measurement-based top-of-atmosphere (TOA) shortwave (SW) and longwave (LW) fluxes. The broadband radiometer (BBR) will facilitate the measurement-based end of the closure, and consists of three along-track viewing (i.e. nadir, 55° forward, and 55° backward) telescopes and a rotating chopper drum. As a result, the BBR will measure alternating TOA SW and totalwave (TW) radiances over ~0.6km diameter pixels with ~0.4km along-track ground sampling distance (GSD) between subsequent SW and TW measurements. Corresponding LW radiances will be inferred from TW and SW radiances. Finally, radiance-to-flux conversions will produce TOA SW and LW fluxes. A successful closure requires a difference of less than 10 W/m² over a horizontal domain of ~100km² between BBR-based fluxes and simulation-based fluxes (derived from an active-passive retrieval of cloud and aerosol vertical profiles, and subsequent broadband radiative transfer simulations).

Radiances over domains of ~100km² will be aggregated from individual BBR pixels. By design of the pixel point spread functions, overlap with neighboring pixels will be perfect in across-track and imperfect in along-track direction. The performance of the chopper drum motor will be adjustable to allow for an increase in instrument lifetime. Given a lower performance, along-track GSD between pixel centers would only grow and their overlap decrease.

Uncertainties of SW and LW radiances, that arise from BBR sampling, will increase with higher levels of horizontal radiance variability – as offered by realistic cloudy atmospheres. By using high-resolution Landsat 8 imagery and mimicking BBR observations, we show that uncertainties of formed nadir SW and LW radiances are highly sensitive to 1) chopper drum rotation rate, 2) level of horizontal radiance variability, and 3) along-track length of domains. Our methodology allows for a recommendation of minimum chopper drum speed to achieve the mission requirement of 10 W/m², and for an in-flight prediction of BBR uncertainties based on 1km² resolved radiances with domains.

P40 - Doppler measurement from space: EarthCare to prepare for future missions DYCECT/WIVERN

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EarthCare will be the first space-borne radar to perform Doppler measurement at nadir. The next breakthrough in terms of Doppler measurement from space will be to scan along a swath of a few hundred km in order to try to provide a 3-dimensionnal wind field. This wind field would allow us to get the dynamical structure of the clouds and build a global statistic that would take process studies one step further.
Two projects are being studied, one was submitted at the EE10 call under the name WIVERN, the other one is a series of studies under CNES funding. These two projects share a number of design aspects, noticeably, a conical scanning 94 GHz system. DYCECT is also looking at electronic scanning design at 35 GHz.
This measurement remains extremely challenging because of the platform motion that combines with the radar beam motion to degrade even further the quality of the measured Doppler when compared to EarthCare. In order to assess the performances of the system an end-to-end simulator of both WIVERN and DYCECT is currently being developed.
The poster will present the various effects that can impact the quality of the Doppler measurement and quantify these impacts. These effects are also relevant for EarthCare measurements and will serve to develop wind retrieval methods and explore ways to perform processes studies using the dynamic information.

P41 - Validation of the SLSTR cloud mask using observations from spaceborne lidars

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SLSTR on board Sentinel-3 is a well calibrated radiometer built to provide high quality observations mainly of sea surface temperature (SST), land surface temperature (LST), aerosols optical depth (AOD) and fire radiative power (FRP). In order to achieve so, a prerequisite is the determination of cloud-free pixels before the application of the respective retrieval algorithms. Especially for the case of SST and LST cloud contamination is one of the important issues (if not the most critical) affecting the quality of the products. Lidars are very efficient instruments in the detection of cloud and aerosol layers. Indeed, the spaceborne lidars CATS/ISS and CALIOP/CALIPSO are capable of detecting layers with optical depth lower than 0.01, while their signal becomes totally attenuated for layers with an optical depth of around 3.The spatial resolution of the lidars is 350 m (CATS) and 333 m (CALIOP), which is slightly finer than SLSTR and comparable to OLCI (also an imager on Sentinel-3), a fact that permits their intercomparison. Here, based on close collocations in space and time between the spaceborne lidars and SLSTR the cloud masks will be compared.

P42 - RAMOS – A newly developed Romanian Earth Observation mobile system

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Under the framework of ESA funded project – RAMOS , three Romanian top research institutions joined their expertise and capabilities to develop and implement an integrated atmospheric observation system that combines ground-based and airborne facilities, able to retrieve high interest atmospheric species such as aerosols, trace gases – NO2, SO2, CH4, HCHO, etc. In the context of future Cal/Val Earth Observation (EO) missions, this newly developed mobile EO system will serve as strategic support for ESA's programmes in Southern Europe, with emphasis in providing confidence in uncertainty estimation of the different satellites products.
The ground-based platform, including INOE's van and additional mobile platforms, provides in situ (point) and profiles of aerosol optical properties, in situ (point) volume mixing ratios and column densities of some trace gases. Its functionality has been already tested during summer of 2017, very promising result being obtained. The airborne platform, including a multi-copter UAV and a research aircraft (BN-2A 27) provides in situ (point) aerosol optical properties, in situ (point) aerosol size distribution and concentration and in situ (point) volume mixing ratios and column densities of some trace gases. The BN-2A 27 platform is currently under final modifications (integration of air inlet and racks, new electrical installation etc.), prior to receive final EASA STC certification. Moreover, this platform will be open for transnational access.
In terms of up-coming campaigns, the potential of this new EO system will be highlighted in the extended measurement campaign focused on two highly polluted areas of Romania: Bucharest and Jiului Valley, scheduled for Autumn of 2018. The alignment to ESA's standards for EO thru this new system, the capacity of Romanian research institutions to participate on future international projects, Cal/Val missions will be extend and strengthened.

P43 - Using synergetic active and passive remote sensing for evaluating simulated cirrus properties

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Cirrus clouds have a large impact on the energy budget of the atmosphere. Whereas optically thick cirrus cool the earth, optically thin cirrus mainly impact the emission of longwave radiation. Besides the cirrus coverage and optical properties, cloud top height or temperature determine the emission of longwave radiation. In a warming atmosphere the tropopause is expected to rise which is likely connected with a change in cirrus cloudiness. In particular, changes in the convective activity are thought to be connected with a change in cirrus properties, e.g. increasing cloud top heights. This would have a significant impact on the cloud feedback, enhancing global warming.
Clouds are a major uncertainty in climate model simulations with cirrus contributing significantly to this uncertainty. Ice cloud physics are represented in many models in an unsatisfactory way. On the one hand, the uncertainty in nucleation efficiencies of aerosols, the competition between heterogeneous and homogeneous nucleation and the hysteresis of cirrus coverage and, on the other hand, the sparsity of observations in the upper troposphere pose problems when representing or evaluating ice clouds in model simulations. Despite many model improvements the simulation of ice cloud properties has hardly improved in the last few years.
The synergistic use of lidar and radar satellite measurements allows the detailed characterization of cirrus clouds even if the cirrus clouds are optically very thin. Active measurements provide vertical profiles of cirrus cloud properties and give a very good indication for cirrus cloud top height. Operating aircraft based lidar and radar measurements in satellite underpasses enables an evaluation of the satellite products and can lead to improvements in the satellite based retrievals. Using the information from polar orbiting active sensors, passive geostationary remote sensing techniques can be refined, leading to accurate remote sensing products with a significantly increased temporal resolution. Those data sets lend themselves more readily than the temporally sparse active remote sensing products to the evaluation of model simulations since the temporal evolution of cirrus fields and the spatial distribution of cirrus properties can be evaluated.
We present work that brings together the use of active remote sensing techniques for retrieving ice cloud properties, the improvement of passive remote sensing techniques of ice clouds using lidar retrievals and the evaluation of model simulations regarding ice cloud properties. We intercompare aircraft and satellite based active remote sensing products regarding ice cloud properties for specific satellite underpasses looking at the effects that the resolution of the satellite based measurements or, in view of the upcoming EarthCARE/ATLID, the use of different wavelengths may have on the derived ice cloud properties. Furthermore, we infer ice cloud properties from the geostationary Meteosat Second Generation (MSG) satellite imager SEVIRI applying an artificial neural network trained with collocated lidar remote sensing products from CALIOP that can be evaluated with airborne measurements. This retrieval achieves a very high detection efficiency even for optically thin clouds (70% for optical thickness of 0.1) and is able to reproduce lidar cloud top heights accurately. Using this temporally and spatially well resolved data set of ice cloud properties from MSG/SEVIRI, we evaluate the simulation of cirrus cloud properties within the ICON model regarding cirrus coverage and cloud top height.

P44 - Aerosol dispersion analysis by ensemble-based four-dimensional assimilation approaches applying IR and Lidar data for the prototype example of volcanic ash

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In readiness for EarthCARE as part of a complementary space-borne observation system with strongly differing horizontal and vertical coverage and resolution, we developed and investigated new methodologies to assess the impact of observations on the analysis. As observational data two entirely different satellite-borne remote sensing principles are exploited: firstly, vertically integrated SEVIRI (Spinning Enhanced Visible and Infrared Imager) volcanic ash column mass loadings and secondly, vertically resolved CALIOP (Cloud-Aerosol Lidar with Orthogonal Polarization) particle extinction coefficient profiles. To compare the three dimensional volcanic ash distributions of the model state and the observations, appropriate observation operators and their adjoint realisations are constructed. If not occluded by clouds, the ash height is directly observable by lidars or ceilometers, albeit only at a few locations. Passive satellite sensors like SEVIRI only give evidence of horizontal ash cloud extension. For the latter observational data use, the Kolmogorov-Sinai entropy concept is invoked, which explains wind shear induced height analyses of the volcanic ash despite vertically not resolved observations.
The emphasis is placed on assimilation-based analyses applying both, initial value optimization within the EURAD-IM (European Air pollution Dispersion-Inverse Model) 4D-var assimilation system and emission factor optimization using the ESIAS-chem (chemical part of the Ensemble for Stochastic Integration of Atmospheric Simulations) particle smoother. The assimilation of satellite data allows for an interpolation in space and time, such that the analysis is directly comparable with independent observational data from ground based networks. The approaches presented in this study can be directly transferred to the validation of satellite data obtained by the EarthCARE mission. Combining the research fields of observability and predictability enables to identify regions of high and low uncertainty in the dispersion simulation results and provides information on the concentration patterns, which are controlled by the appended knowledge of observations.

P45 - A GIS-based Air Pollution Modeling in Tehran

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The population growth and development of the mega cities and the impacts on urban traffic is one of the most important problems of the mega cities. Increased traffic volume and air pollution lead to population health problem. In this research a prediction model has been proposed for air pollution prediction in 2004 using the data of 2002 and 2003 comparing the prediction results with the actual results of 2004. In addition, by using the method of local contribution to concentration in canyon streets, the concentration of both CO and NO at each month for six highways of Tehran and for each vehicle is calculated. The prediction model is a combination of CORINIER and Gualtieri-Tartaglia models. The proposal GIS-based model employs street geometry and vehicle numbers. Operation of CO and NO models Shows accuracy of 90% and 60%, accordingly. The evaluation done in this article demonstrates that Gualtieri-Tartaglia model. The results are appropriate for a one year prediction of CO, whereas for NO it is not appropriate and the innovation in this paper is that the results of the previous modeling (Gualtieri-Tartaglia) results are valid for about one day, however, in this paper by improving the model of Gualtieri-Tartaglia integrated with the CORINIER method, the model can be applied to estimate the air pollution within one year. The implemented data in this paper include the average monthly values of NO and CO in the second half-year of 2002 and whole years of 2003 and 2004.CO data used during 2005-2010 provided the similar results.

P46 - Measurement of the Earth Radiation Budget - A review and future perspectives

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The Earth Radiation Budget (ERB) at the top of the atmosphere quantifies how the earth gains energy from the sun and looses energy to space. It is of fundamental importance for climate and climate change. In this paper the current state of the art of the satellite measurements of the Earth Radiation Budget is reviewed. Combining all available measurements, the most likely value of the Total Solar Irradiance at solar minimum is 1362 W/m², the most likely earth albedo is 29.8 % and the most likely annual mean Outgoing Longwave Radiation is 238 W/m².

We highlight the link between decadal changes of the Outgoing Longwave Radiation, the strengthening of El Nino in the period 1985-1997 and the strengthening of La Nina in the period 2000-2009. These decadal changes appear to be caused by an aerosol cooling of the Northern hemisphere causing a southward shift of the ITCZ.

The current ERB measurements have sufficient stability to track the temporal variability of the Earth Energy Imbalance (EEI) driving climate change, but they can not measure its absolute value with sufficient accuracy. We introduce the Low Earth Orbit Novel Advanced Radiation Diurnal Observation (LEONARDO) concept which aims at making the first ever significant measurement of the EEI from space, and which has been submitted to the ESA call for ideas for a new Earth Explorer mission.

P47 - Exploiting the 3 views of the EarthCARE BBR for instantaneous TOA longwave fluxes estimation

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Within the EarthCARE payload, the BroadBand Radiometer (BBR) has for main objective to provide accurate solar and thermal radiative fluxes for closure assessment at the Top Of the Atmosphere (TOA). The accuracy requirement on those fluxes, 10 W/m², is quite challenging and significantly better to what was obtained with previous Earth radiation budget instruments. This has driven the innovative design of the BBR instrument, in particular its 3-views capability that provides an improved sampling of the radiance field at the TOA.

During the development of the BBR level-2 processing, several interesting scientific questions have arisen, such as the optimal weighting to be attributed to the 3 views of the instrument. In a plane-parallel world, the oblique views are expected to be more representative of the hemispheric flux than the nadir observation, especially for the longwave radiation. However, real cloud systems are often far from being stratiform, and 3D effects may significantly affect the fluxes.

In this contribution, data from CERES, acquired in the True Along Track scanning mode, and MODIS are used to address the question of the optimal weighting of the 3 views. It is shown that 3D effects are far from being negligible in the real world. The data also allow to verify that, at least for the longwave radiation, the BBR instantaneous flux fulfills the accuracy requirement.

P48 - The EarthCARE BM-RAD product: Methods and new science opportunities offered by the high resolution broadband observations

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The BBR instrument on EarthCARE will measure SW (0.2 - 4µm) and TW (0.2 - >50µm) radiances at three fixed viewing zenith angles in an along track configuration.
The signal provided by the BBR radiometer is a radiance filtered by the spectral response of the instrument, which is corrected in the unfiltering process in order to reduce the effect of a limited and non-uniform spectral response. In practice, the SW and TW measurements of the BBR must be converted into solar and thermal unfiltered radiances. First, the LW radiance is estimated from the SW and TW measurements. Secondly, the inter-channel contaminations, i.e, the parts of the LW signal due to reflected solar radiation and of the SW signal due to planetary radiation, are accounted for. Finally, multiplicative factors are computed in order to estimate the unfiltered solar and thermal radiances from the SW and LW channels, respectively. The computed unfiltered radiances will be provided at 6 different spatial resolutions, namely: Small, Full, Standard, Assessment Domain, Joint Standard Grid and Joint Standard Grid resolution enhanced (for the nadir view only).
The main inputs for the unfiltering processor are: B-NOM (nominal BBR filtered radiances) and B-SNG (single pixel filtered radiances), M-CM (cloud mask and cloud phase products), X-JSG (Joint Standard Grid), snow cover from the X-MET product and MSI imager radiances from M-NOM.
Particular attention is dedicated to the high resolution unfiltered radiances that are obtained at the JSG resolution from the single pixel radiances mapped to the X-JSG. It is worth to mention that this would be first broadband observations available at such a fine spatial resolution. This innovative product will help the comparison to other Earth Radiation Budget instruments retrieved radiances. It would also allow to validate narrowband to broadband conversion methodologies that have been used for a long time to estimate the Earth Radiation Budget at fine spatial scale, for instance, from AVHRR or geostationary imagers.
The study is supported by the BM-RAD radiances at different resolutions obtained from the EarthCARE Halifax simulated scene.

P86 – Long-term observation of aerosol optical properties by using ground-based and ship-borne sky radiometer

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Aerosol optical properties are studied using data from ground-based and ship-borne sky radiometers. We are seeking in this data information on the aerosol optical properties with respect to their temporal
and spatial variability and validation of satellite and numerical models. We provide the information, in this presentation, on the optical properties of aerosol with respect to their long-term variability.