Title:	**Satellite cloud properties derived using ISCCP-NG radiances and NASA Langley SatCORPS algorithms**

Author/Speaker:	Rabindra Palikonda
Company/Organisation:	Analytical Mechanics Associates, NASA Langley Research Center
Co-Authors:	William L. Smith Jr David Painemal Douglas A. Spangenberg Thad Chee Konstantin V. Klopenkov
Presenting Author:	Rabindra Palikonda

Summary:

The International Satellite Cloud Climatology Project – Next Generation (ISCCP-NG) provides geostationary satellite radiance data from full-disk scans at a gridded spatial resolution of 0.05 degrees (~5-km) for up to 19 channels. The NASA Satellite ClOud and Radiation Property retrieval System (SatCORPS) routinely applies algorithms to current geostationary satellite data to provide near real-time, cloud properties, radiative fluxes and other parameters globally between 60N and 60S. This poster will illustrate cloud properties derived from the first application of the SatCORPS algorithms to ISSCP-NG radiance data and evaluate their consistency with the standard SatCORPS cloud properties.

Title: **Hourly Global Cloud Property Composite Derived from Merged Geostationary and Sun-Synchronous Satellite data**

Author/Speaker: David Painemal
Company/Organisation: AMA/NASA LaRC
Co-Authors: David Painemal
William L. Smith Jr.
Louis Nguyen
Thad Chee
Rabindra Palikonda
Konstantin Khlopenkov
Douglas Spangenberg
Cecilia Fleeger
Presenting Author: David Painemal

Summary:

Operational satellite imager radiances are valuable for cloud detection and for deriving many different physical parameters that can be used for a variety of weather, aviation, and energy applications. By merging retrievals from geostationary (GEO) and sun-synchronous satellites, we demonstrate that it is possible to generate products with a global coverage and at a high temporal resolution that can meet the needs of multiple users and stakeholders.

This paper describes a new global high-resolution dataset of cloud properties made available for community use that is constructed from analyses of a constellation of meteorological satellite imagers. We apply common algorithms and calibration methods developed by the NASA Satellite ClOud and Radiation Property retrieval System (SatCORPS) to improve retrieval consistency across different platforms. These algorithms have been developed over many years to support NASA weather and climate programs such as the Clouds and Earth's Radiant Energy System (CERES). Data taken from Meteosat-8/9 and -11, Himawari-8/9, GOES-16, and -17/-18, Aqua, Terra, Suomi-NPP and NOAA-20 are processed and composited on a 3-km grid to provide hourly global coverage. A brief description of the methods highlighting the unique aspects of the SatCORPS Global Cloud Composite (GCC) data products will be presented along with information on their status and availability.

Title: **ACM-CAP: EarthCARE's synergistic and unified retrieval of clouds, aerosols and precipitation**

Author/Speaker: Shannon Mason
Company/Organisation: ECMWF
Co-Authors: Robin Hogan
Alessio Bozzo
Presenting Author: Shannon Mason
Summary:

When EarthCARE launches in 2024 it will recommence the record of synergistic radar, lidar, and radiometric measurements that was begun in 2006 by CloudSat, CALIPSO, MODIS and CERES within the A-Train of satellites. EarthCARE's multispectral imager (MSI), three-view broadband radiometer (BBR), Doppler-capable cloud profiling radar (CPR) and high-spectral resolution atmospheric lidar (ATLID) provide some technical advances over the A-Train; furthermore, hosting the four instruments aboard a single platform will improve the coregistration of the measurements. Ultimately, the greater novelty of the EarthCARE mission may arise from the degree of coordination between its L2 data products, from single-instrument detection, classification and retrieval products, to synergistic retrievals, radiative transfer modelling, and top-of-atmosphere radiative closure assessment. This enhanced coordination facilitates one of the overarching mission goals: to use radiative closure assessment to verify in-orbit that retrievals have adequately captured the radiative properties of clouds, and are therefore reliable for climate applications and evaluating climate models. Central to the ESA production model is the synergistic (ATLID-CPR-MSI) "best estimate" retrieval of all clouds, aerosols and precipitation in the atmosphere, called ACM-CAP.

ACM-CAP employs the CAPTIVATE optimal estimation retrieval algorithm, which includes sophisticated and efficient representations of hydrometeor fallspeeds (used to constrain ice particle density and raindrop size), ice particle scattering properties, radar and lidar multiple scattering, passive solar, thermal and microwave radiances, and the HETEAC model for aerosol properties.

In this talk we provide an overview of the ACM-CAP product, its capabilities, and its place in the ESA EarthCARE production model. We will discuss how the challenges for unified retrievals in complex and layered scenes inform the regimes of interest for validation and evaluation once EarthCARE data come online. Finally, we will explore the sensitivity of the radiative closure to retrieval quality using real A-Train data, in light of EarthCARE's sophisticated approach to 3D scene reconstruction and radiative transfer modelling across the imager swath.

Title: **Recent Cloud Algorithm Enhancements in the NASA SatCORPS**

Author/Speaker: William Smith
Company/Organisation: NASA LaRC
Co-Authors: Sarah Bedka
Gang Hong
David Painemal
Rabindra Palikonda
Ben Scarino
Bao Shan
Sunny Sun-Mack
Qing Trepte
Cecilia Wang
Chris Yost
Presenting Author: William Smith

Summary:

The NASA Satellite ClOud and Radiative Property retrieval System (SatCORPS) is a data processing and visualization system with a heavy focus on deriving historical and near real-time global cloud properties and radiative effects from geostationary satellite imagers for use in weather and climate applications. SatCORPS retrieval algorithms are like those developed for the Clouds and the Earth's Radiant Energy System (CERES) project. CERES requires global, high-resolution cloud properties even under the most difficult retrieval conditions (e.g., in the presence of thin cirrus and heavy aerosols, at night, over snow/ice) to interpret CERES broadband radiance measurements and to derive the Earth's radiation budget and cloud radiative effects. The operational CERES cloud retrieval algorithms have been frozen for more than a decade to enable production of a stable and consistent long-term record of cloud and radiation parameters for use by the climate science community. In the meantime, the CERES Clouds Working Group and SatCORPS team have been working synergistically to validate current data products and to enhance the cloud algorithms and implementation approaches for CERES next data product edition and for the SatCORPS processing system. This paper briefly summarizes and demonstrates impacts for key retrieval algorithm and ancillary dataset updates designed to improve cloud parameter accuracies, day/night and cross-platform consistency, and to reduce problematic artifacts.

Title: **A 3-channel algorithm for retrieving spatially and temporally continuous cloud properties across different geostationary satellite imagers**

Author/Speaker: Sarah Bedka
Company/Organisation: Analytical Mechanics Associates
Co-Authors: William Smith
David Painemal
Rabindra Palikonda
Qing Trepte
Christopher Yost
Gang Hong
Fu-Lung Chang
Presenting Author: Sarah Bedka
Summary:

Cloud parameter retrieval algorithms for passive satellite imagers are generally designed to take advantage of all the useful spectral information available for a particular satellite. This strategy optimizes the accuracy of the cloud property retrievals, and reduces misidentification and retrieval biases, particularly for modern satellites with many spectral channels. However, the application of dissimilar algorithms tailored for different satellite sensors can present a problem within the climate data record (CDR). Algorithm inconsistencies can introduce artificial trends in the CDR that are tied to instrument changes rather than physical changes, especially when older satellites with limited spectral information are included. The NASA CERES (Clouds and the Earth's Radiant Energy System) data record provides global cloud property retrievals across 23 years and more than 20 satellites. With the goal of producing a spatially and temporally continuous record of cloud properties, the CERES cloud working group has developed algorithms that use only 3 channels that are common to most geostationary satellite imagers: 0.65, 3.9, and 10.8 um (and their equivalents). In this presentation, we will compare cloud optical depth, particle size, and cloud fraction (mask) derived using this continuity algorithm, vs. the CERES Edition 4 cloud products. We will show that spatial continuity in cloud properties improves when we apply this 3-channel algorithm to 2 different sensors with adjacent domains (GOES-16 and Meteosat-11 data from July 2019). We will also show that temporal continuity in cloud properties improves when we apply this algorithm to different generation satellites that operated over the same domain (GOES-13 and GOES-16 data from December 2018). Finally, we will use CALIPSO cloud mask/fraction to assess the potential loss of accuracy in cloud detection when we use this 3-channel algorithm, vs. the CERES Edition 4 cloud products.

Title: **Update from the International Wind Working Group**

Author/Speaker: Steve Wanzong
Company/Organisation: UW-Madison/SSEC/CIMSS
Co-Authors: Régis Borde
Jaime Daniels
Presenting Author: Steve Wanzong

Summary:

The 16th International Winds Workshop (IWW) was held in May 2023, in Montreal, Quebec, Canada. A plenary session at the workshop discussed results from the 4th AMV Intercomparison. This is particularly relevant to the ICWG as AMV producing centers moved towards pixel-level solutions for their height assignments, which are provided by upstream cloud algorithms. Highlights from the plenary discussion will be discussed. A CGMS action describing the state of the art in wind observations will also be presented.

Title:	**Validation and Comparison of Himawari cloud products.**
Author/Speaker:	Caroline Poulsen
Company/Organisation:	Bureau of Meteorology Australia
Co-Authors:	Caroline Poulsen Vincent Villani
Presenting Author:	Caroline Poulsen
Summary:	

Satellite observations of cloud from geostationary satellites are one of the key tools used by Australian national weather forecasters situational awareness particularly as radars only cover 50% of the country.

The satellite cloud observations are the key input into deriving Atmospheric Motion Vectors (AMVs), estimating rainfall products and estimating surface solar irradiance for Australia's energy and agriculture services. Cloud masks (signifying either the presence or absence of cloud) are essential to all surface derived products, including sea surface temperature retrievals for our ocean services and numerical weather prediction (NWP), as well as in data assimilation for identifying regions where the water phase differs.

In this presentation we present results of validating the Bureau's Implementation of the NWCSAF-GEO Himawari products (for Bureau forecasting and Nowcasting), the JAXA/JMA Himawari cloud products and the Reading University Bayesian cloud mask (used for sea surface products). The products have been validated using collocated Calipso and Cloudsat data. The period of validation was every 10 minutes for 2017 allowing detailed statistical analysis of the quality of the retrievals in particular, cloud height (CTH), cloud mask and microphysics as a function of the number of cloud layers, satellite angular geometry, cloud optical depth, cloud type and location.

A key finding is the strong dependence on the decrease in CTH accuracy as the number of layers and large differences exist in cloud masks depending on the end users. The collocated and parallax corrected data set will be made available and can be used to develop bias corrections and/or train machine learning models.

Title: **Feature importance of imager cloud products, microwave radiometry, and atmospheric reanalysis variables in a deep neural network for estimating severe hail likelihood**

Author/Speaker: Benjamin Scarino
Company/Organisation: NASA
Co-Authors: Kristopher Bedka
Kyle Itterly
Sarah Bang
Daniel Cecil
Presenting Author: Benjamin Scarino

Summary:

Deep convection signatures in satellite infrared (IR) and passive-microwave imagers, together with environmental variables from atmospheric reanalysis, can provide a method of severe weather detection around the globe where ground-based observations are otherwise inconsistent or unavailable. Distinct patterns in these remote-sensing datasets, such as cold overshooting cloud tops and prominent local brightness temperature depressions, can be leveraged to analyze the occurrence of costly storms hazards like hail. When analyzed alone, these satellite measurements and model parameters suffer from key limitations, but otherwise complement one another when collocated to combine high-resolution identification of storm cores with cloud penetrating retrievals, all embedded within environments conducive to severe weather. As such, this work highlights the use of a deep neural network (DNN) for quantifying predictor importance in estimating severe hail likelihood, defined by ground-based weather radar, from geostationary and MODIS IR overshooting cloud top detections and related height/temperature products, AMSR-E passive-microwave signatures, and ERA5- and MERRA-2-derived convective parameters. Initial studies show that a DNN utilizing IR and microwave predictors identifies better than 74% of potentially severe maximum expected size of hail (MESH) signatures with false alarm occurrence under 29%. Including MERRA-2 predictors does not meaningfully impact model skill, but use of either one of these data sources alone (i.e., either IR, microwave, or reanalysis predictors in isolation) significantly increases false positive predictions. In an effort to select the most optimal and generalized features for global application, the parameter space of the various predictors is explored to diagnose ambient environmental conditions and storm properties across different regions, which serves to benefit those interested in better understanding hail frequency and severity in places with insufficient storm reporting. With this project, we seek to comprehensively define the capabilities offered by these datasets for hailstorm detection and severity quantification.

Title: **Cloud retrieval properties from SAFNWC**

Author/Speaker: Emmanuel Fontaine
Company/Organisation: Météo-FRANCE/CNRM
Co-Authors: Gaëlle Kerdraon
Tony Le Bastard
Sonia Péré
Presenting Author: Emmanuel Fontaine

Summary:

The cloud Team of the national center for research in meteorology in Météo-France (CNRS/MF) is dedicating its activities around the retrieval of cloud properties via remote sensing observations. As part of the Now Casting satellite application facility of EUMETSAT and because of the coming of first the meteosat third generation (MTG), we are improving and updating the retrieval of cloud properties. Some of the new features will be presented and discussed.

Title: **MODIS and VIIRS L1b and L2 Monitoring Capabilities Developed by the University of Wisconsin Atmosphere SIPS**

Author/Speaker: Zachary Griffith
Company/Organisation: SSEC
Co-Authors: Robert Holz
Steve Dutcher
Greg Quinn
Liam Gumley
Presenting Author: Robert Holz

Summary:

The Atmosphere SIPS, located at the Space Science and Engineering Center (SSEC) at the University of Wisconsin, is responsible for supporting the NASA aerosol and cloud algorithm teams in the development and testing, operational processing, and monitoring of the VIIRS products. For long term climate data records the stability of the L1b calibration is a significant source of uncertainty which needs to be monitored as the cloud and aerosol retrievals are non-linear and sensitive to small differences in calibration. With the launch of JPSS-1 in 2017 we now have 4 sensors (MODIS Terra, MODIS Aqua, S-NPP VIIRS, and JPSS-1 VIIRS) that need to be inter-calibrated and monitored. Despite the efforts of the instrument calibration teams we find significant differences in the relative calibration between the sensors that impact the continuity of the retrievals with differences larger than 5% for individual channels. As part of the algorithm processing, calibration coefficients are derived from the A-SIPS calibration monitoring system which are applied to the individual sensors. In addition to L1, the L2 products are monitored for stability as there are other sources of uncertainty that can change over time.

We present the methodology developed by the Atmosphere SIPS for active real-time monitoring of both the L1b and L2 products. This includes a seasonal decomposition of the inter-calibration time series, with automated alerts for outliers and trending on a per-channel basis. L2 product distributions are routinely compared against a climatological record for abnormal behavior. The results of these tests are made available via automatically updated, interactive web applications. These monitoring efforts provide science algorithm developers with ready access to quality assurance of their data products which will presented.

Title: **Development of the NASA Cloud Retrieval Continuity Algorithms for Next Generation Geostationary Imagers**

Author/Speaker: **Robert Holz**
Company/Organisation: **SSEC**
Co-Authors: **Kerry Meyer**
Steve Platnick
Presenting Author: **Robert Holz**
Summary:

A new generation of geosynchronous multispectral imagers (ABI on the GOES-R series, AHI on Himawari-8/-9) dramatically improves upon the spatial, spectral and temporal resolution capabilities of heritage GEO imagers and provides for the first time from a geo-stationary platform MODIS/VIIRS like spectral and spatial resolution. We will report on our continued efforts to port the MODIS/VIIRS continuity product (CLDPROP) to the geo-stationary observations including results of initial 10-min processing of AHI during the CAMP2Ex mission which provides a unique dataset to validate the cloud products. CLDPROP is based on the legacy MODIS cloud products suit that leverages heritage algorithms–MODIS cloud mask (MOD35), MODIS optical and microphysical properties product (MOD06), and the NOAA AWG Cloud Height Algorithm. In addition, the GEO sensors have additional capabilities expected to be useful for cloud retrievals (e.g., atmospheric absorption channels, temporal information). This presentation will focus on the challenges that need to be addressed to achieve a LEO/GEO cloud product that is consistent across all sensors leveraging CAMP2Ex to both validate the products and support the mission science objectives. These include:

1. Pixel growth and view zenith angles that are geographically fixed for the GEO imagers can be expected to induce systematic biases in cloud masking and property retrievals relative to LEO products.
2. Scattering angles that are correlated with time of day for GEO (see Figure 2) have additional sensitivities to the liquid and ice cloud radiative models used for optical property retrievals; these models can have distinct angular features (e.g., cloud bows, glories, etc.) that can cause biases relative to LEO products when concurrent LEO/GEO observations have differing view geometries.
3. Relative radiometric inconsistency across sensors that has been shown to induce large inter-sensor differences in cloud optical property retrievals between MODIS and VIIRS; such inconsistency is also possible with GEO.

Title: **An improved NASA MODIS/VIIRS Cloud Continuity Mask using collocated AIRS/CrIS observations**

Author/Speaker: Dongwei Fu
Company/Organisation: Space Science and Engineering Center, University of Wisconsin-Madison
Co-Authors: Robert Holz
Steven Platnick
Kerry Meyer
Ralph Kuehn
Paolo Veglio
Eva Borbas
Amanda Gumber
Greg Quinn
Presenting Author: Dongwei Fu

Summary:

The Continuity Moderate Resolution Imaging Spectroradiometer (MODIS)-Visible Infrared Radiometer Suite (VIIRS) Cloud Mask (MVCM) has been developed to provide continuity between MODIS and VIIRS products by using only channels common to both sensors, with VIIRS lacking absorption channels. MVCM is aimed to extend the ~20 years of MODIS record, and it is operational on several satellite platforms, including Terra, Aqua, Suomi-NPP, and NOAA20. Given its wide use, the absence of certain infrared bands from VIIRS, however, makes it difficult to accurately retrieve cloud properties that rely on those channels (e.g., 6.7 µm water vapor band and the 15 µm CO2 bands). Here, we introduce a new cloud mask product (MVCM-sounder) by utilizing collocated sounder observations to improve MVCM performance to better match with MODIS cloud mask (MYD35).

Taking Aqua-MODIS and the Atmospheric Infrared Sounder (AIRS, also onboard Aqua) as an example, MODIS and AIRS observations are first collocated based on geometry and temporal information. Infrared hyperspectral radiance from AIRS is then convolved with MODIS spectral response function (SRF) to match with MODIS spectral resolution. Finally, the convolved radiance value is assigned to all collocated MODIS pixels within the AIRS footprint to ensure spatial resolution consistency. Note that the same approach can be applied to VIIRS and the Cross-track Infrared Sounder (CrIS). Our results show that compared to the original MVCM, the MVCM-sounder is in closer agreement with MYD35 and collocated Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) cloud mask, particularly for night scenes over cold surface (e.g., polar region). These are cases where the cloud mask algorithm relies more heavily on the infrared channels. When applied to CrIS and VIIRS, similar performance of the MVCM-sounder is observed. This analysis demonstrates the potential of more closely replicating MYD35 cloud mask using MVCM by simply combining the infrared hyperspectral radiance from the sounder with the imager. We plan to release this new cloud mask as a NASA operational product. Future efforts will focus on investigating the use of full hyperspectral information from sounders, as well as the use of more advanced approaches (e.g., machine learning) to improve upon the current MVCM/MYD35 cloud mask.

Title: **A High Spatial Resolution Cloud Detection Algorithm based on the NASA Continuity MODIS/VIIRS Cloud Mask**

Author/Speaker: Paolo Veglio
Company/Organisation: SSEC UW-Madison
Co-Authors: Robert Holz
Presenting Author: Paolo Veglio
Summary:

A correct cloud detection is the first steppingstone for many applications from cloud property retrievals to climate analyses. On the other hand, it has been extensively shown that small scale cloud structures are often a source of large uncertainties for cloud retrievals, which propagate to radiative forcing calculations and eventually to climate studies.

Here we show how we use the Visible Infrared Imaging Radiometer Suite (VIIRS) high-spatial resolution bands (I-bands) to improve detection of fine structures with the Moderate Resolution Imaging Spectroradiometer (MODIS)-VIIRS Cloud Mask (MVCM).

The MVCM derives from the NASA MODIS Cloud Mask and uses a series of spectral tests in a fuzzy logic approach, each with assigned low and high confidence thresholds. Specific sets of tests are run on a given pixel based on surface type such as land, water, coast, desert, snow or ice, and solar illumination, i.e., day or night. Each individual test that belongs to the sets describing the current scene returns a clear sky confidence value and eventually gets combined with all the other test outcomes to create the overall clear sky confidence as reported in the final output.

For this work we modified the existing MVCM to ingest both VIIRS M-bands (750m spatial resolution) and I-bands (375m spatial resolution) and created a new set of tests, while maintaining those from the original algorithm that were still relevant for the I-bands. We then fine-tuned the old thresholds and defined additional ones to account for the new tests. As opposed to MODIS, that has only visible high-resolution bands, VIIRS I-bands extend from the visible (0.64µm) to the infrared window (11µm), allowing for multiple spectral tests for cloud detection to be performed during both daytime and nighttime.

We plan to release this high-resolution cloud mask as an additional NASA operational product alongside the existing one. This will help building an unprecedented multi-decadal record across multiple platforms from early 2012 with S-NPP and well into the 2030s and beyond with NOAA-20, NOAA-21 already flying, and the future JPSS-3 and JPSS-4 currently scheduled for 2027 and 2032, respectively.

Title: **Combination of solar and thermal retrievals of IWP from MSG and evaluation with DARDAR**

Author/Speaker: Luca Bugliaro
Company/Organisation: DLR
Co-Authors: Florian Ewald
Presenting Author: Luca Bugliaro

Summary:

Ice water content (IWC) and ice water path (IWP) are quantities that are used by models - from GCMs to LES - to represent clouds. Evaluation of clouds in models is a crucial task since clouds are complex and have been shown to represent one of the major uncertainties in climate models. For the evaluation of cloud properties spaceborne plattforms are very suitable due to their large fields of regard. In particular, geostationary satellites like Meteosat Second Generation (MSG) allow to observe clouds and their temporal evolution and can thus play an important role in model evaluation. However, the derivation of cloud properties from passive observations is challenging, especially for thin cirrus. On the contrary, active sensors - in particular the combination radar + lidar - are sensitive to both thin and thick cirrus and can provide vertical profiles of IWC. Thus, it is important to evaluate passive observations against active measurements to evaluate their potential and limitations.

In this presentation, we use the machine learning algorithm CiPS for MSG/SEVIRI in order to derive IWP for thin cirrus and combine it with the Nakajima-King-like APICS algorithm from the 0.6 and 1.6 µm MSG/SEVIRI solar channels that are rather sensitive to thicker ice clouds. We show that the combination CiPS+APICS is able to reproduce probability density functions of IWP from the VarCloud/DARDAR product from the active measurements aboard the German research aircraft HALO and the spaceborne measurements of CALIPSO and CloudSat over various orders of magnitude. To this end, we first investigate the NAWDEX campaign in mid- to high-latitudes during 2016 where the HALO aircraft was equipped with both the MIRA radar and the WALES lidar. Here, we compare IWP along the flight path of HALO derived using VarCloud with the IWP from the retrieval combination from MSG/SEVIRI. Then, we select a region over the Tropics and evaluate IWP from MSG/SEVIRI against DARDAR applied to CALIPSO/CloudSat. In both cases, the MSG/SEVIRI retrievals perform well against the active sensors and show that they can be used to evaluate models.

Title: **Current and Future Plans for the International Satellite Cloud Climatology Project (ISCCP)**

Author/Speaker: Hilawe Semunegus
Company/Organisation: NOAA NESDIS NCEI
Co-Authors: Kenneth Knapp
Presenting Author: Hilawe Semunegus

Summary:

For more than 40 years, the International Satellite Cloud Climatology Project (ISCCP) Climate Data Record (CDR) has played a critical role in enhancing our comprehension of Earth's climatic system. This project has been pivotal in shedding light on Earth's energy balance, the global water cycle, and cloud climatology. Over its lifetime, ISCCP has achieved significant advancements, transitioning through various phases such as ISCCP-C, ISCCP-D, and the latest ISCCP-H series. Future plans include reprocessing data for the entire period of record, the results of which will lead to major improvements in quality control and significant calibration refinements. The reprocessed ISCCP CDR also includes view zenith angle corrections, the inclusion of Climate Forecast System Reanalysis for temperature and humidity profiles (in addition to the currently used observation-based temperature and humidity profiles) and will extend the period of record through 2022. Furthermore, the record of low Earth-orbiting satellite observations from the AVHRR has been extended to the next-generation JPSS VIIRS sensor. We also have worked to extend previous comparisons between ISCCP and MODIS in order to better understand the ISCCP ability to observe and inform changes in clouds through time and space. In summary, this presentation will offer an extensive overview of the modifications made to the ISCCP CDR and highlight the projected trajectory of its ongoing development.

Title: **Lessons Learned from Transitioning the PATMOS-x Cloud Climatology into the VIIRS Era.**

Author/Speaker: Michael Foster
Company/Organisation: University of Wisconsin - Madison
Co-Authors: Jongjin Seo
Coda Phillips
Presenting Author: Michael Foster

Summary:

With the launch of MetOp-C in 2018 came the last of the AVHRR equipped satellites. To continue long-term AVHRR-based records a transition to the next generation of polar imagers is needed. The PATMOS-x cloud product team has begun processing and delivering VIIRS (Visible Infrared Imaging Radiometer Suite) products as a continuation of the record. This presentation will discuss the lessons learned from the process of producing climate-quality consistency between cloud records from the AVHRR and VIIRS imagers. Attention will be paid to how instrument-level differences translate downstream to level2 products and how these differences were addressed.

Title: **Polarimetric Microphysical Retrievals as a Detection of Cloud Top Entrainment**

Author/Speaker: Daniel Miller
Company/Organisation: NASA GSFC / UMBC
Co-Authors: Kerry Meyer
Nithin Allwayin
Presenting Author: Daniel Miller
Summary:

Polarimetric cloud observations offer a unique perspective on cloud top microphysics and fundamental behavior of turbulence in the atmosphere. This is because of two unique characteristics of the polarimetric cloud microphysical retrieval. The first is that it is largely insensitive to multiple scattering (due to subsequent depolarization); and second is that the retrieval largely relies on the relative angular pattern of the scattered polarized reflectance, which makes it less sensitive to variability in the magnitude of any one observation.) These features lead to a retrieval that is less sensitive to cloud inhomogeneity, 3D radiative effects, and the vertical profile of cloud properties. In fact the depolarization of the cloud top leads to sensitivity only in the first few optical depths of the cloud layer, weighted strongly toward cloud top (~10 m). This cloud top region is commonly home to numerous unique processes, such as the entrainment of dry air in the descending regions of convective cells.

In this presentation, I will show evidence from LES, Airborne, and Satellite observations that indicates that we have sensitivity to small changes in the uppermost cloud layer that can be directly related to convective cell scale and cloud top entrainment. In the case of the LES observations we use droplet size distribution similarity and cluster analysis to categorize droplet size distributions and identify their corresponding relationship to other physical variables, such as the vertical wind speed, entrainment rate, droplet size, and degree of adiabaticity of the column. This coupled with polarimetric remote sensing simulations on the same LES cloud domain provides a unique perspective on cloud top microphysical processes where remote sensing retrievals can be correlated with underlying microphysical properties only available in a model simulation. From airborne field campaigns we will show evidence from airborne simulations and CAMP2Ex observations of towering cumulus, and for satellite observations we hope to show newly developed polarimetric cloud retrievals from the HARP-2 polarimeter onboard the NASA's PACE mission.

Title: **3D Weather States Model as a tool to detect climate trends in a long-term Cloud Satellite Climatology data set**

Author/Speaker: Andi Walther
Company/Organisation: University of Wisconsin
Co-Authors:
Presenting Author: Andi Walther
Summary:

Observations of clouds from satellites span now a period of more than 40 years. The Pathfinder Atmospheres–Extended (PATMOS-x) data set derived from the Advanced Very High Resolution Radiometer (AVHRR) aims to build a consistent data archive to detect climate trends in cloud property characteristics.

The Global Energy and Water Cycle Experiment (GEWEX) Cloud Climatology Assessment evaluated the sensitivities of multiple global satellite cloud records, allowing for more meaningful inter-comparisons and use with models (Stubenrauch et al. 2013). Using average values of cloud properties, such as cloud optical thickness (COD) or cloud top pressure (CTP), often in connection with static thresholds, doesn't give robust results of long-term trends due to non-Gaussian behavior of these properties and other problems, such as saturation effects of thick clouds.

Weather states are refereed to typical weather regimes, such as low-level liquid clouds, mesoscale convection, or multi-layer situations.

Like the work by Jakob and Tselioudis (2003) for 2D COD-CTP histograms, we made a k-means cluster analysis to find typical *weather states* based on 3D cloud observations. The 3D model ("cloud cube") represents an extension of the 2D model, which also includes cloud particle size (CPS). This approach provides a more complete analysis of cloud climatology and includes all relevant cloud parameters, including cloud water content.

We will present a global survey of 35 years of weather state data with global distribution and climate trends. We will also discuss practical issues such as processing time or amount of data.

Title:	**The NOAA Enterprise Cloud Products (aka PATMOS-x) applied to ISCCP-NG L1G**

Author/Speaker:	Andrew Heidinger
Company/Organisation:	NOAA/NESDIS GeoXO
Co-Authors:	Michael Foster Coda Phillips Andi Walther
Presenting Author:	Andrew Heidinger

Summary:

The Next Generation of the International Satellite Cloud Climatology Project (ISCCP-NG) is an application of the GEORING of advanced imager data that now spans the globe. The original ISCCP (version H) continues to be generated and now spans through 2018. Given that the GOES-17 ABI achieved its GOES-West in November 2018, this allows December 2018 as the single month that allows for comparisons of ISCCP and ISCCP-NG. This presentation will demonstrate the benefits of the increased spectral resolution of ISCCP-NG to making day/night consistent cloud records of cloud amount, type and vertical extent, as well as adding information on microphysical properties. This work will also demonstrate the new applications that are possible with the improved spatial, spectral and temporal resolution of ISCCP-NG. These studies will be done using the NOAA Enterprise Cloud Algorithms which are the basis of the PATMOS-x climate data set.

Title: **Assessing the benefits of the improved spatiotemporal resolution of current geostationary imagers for surface solar irradiance retrievals based on the S2VSR campaign**

Author/Speaker: Hartwig Deneke
Company/Organisation: TROPOS
Co-Authors: Connor Flynn
Mike Foster
Andrew Heidinger
Andreas Macke
Jan Fokke Meirink
Jens Redemann
Manajit Sengupta
Andi Walther
Job Wiltink
Jonas Witthuhn
Presenting Author: Hartwig Deneke
Summary:

The current advanced geostationary imagers including the GOES-R ABI and MTG FCI instruments offer significant improvements in terms of spatio-temporal resolution compared to previous instruments, featuring pixel sizes for solar channels down to 500x500m2, and scan frequencies up to 1 per min. While these capabilities enable us to better resolve small-scale variability in clouds and radiation, our understanding of the practical benefits for monitoring cloud development and retrieving surface solar irradiance remains limited. One key reason is the limited representativity of many ground-based remote sensing observations serving as potential reference, which are point-like in nature. In contrast, satellite-derived quantities correspond to extended spatial domains.

To improve our knowledge about the small-scale structure and variability of clouds and its influence on solar radiation, the Small-Scale Variability of Solar Radiation (S2VSR) campaign was conducted at the ARM Southern Great Plains (SGP) site in summer 2023. A unique sensor network consisting of 60 autonomous pyranometer stations developed at the Leibniz Institute for Tropospheric Research was deployed at the SGP site for a 12-week period. Stations were distributed across a 6x6 km2 domain centered around the ARM SGP Central Facility. Together with operational ARM measurements including cloud profiling and a stereo-photogrammetric 4D reconstruction of clouds, this campaign offers an unprecedented dataset for studying cloud-induced small-scale variability in solar irradiance, resolving fluctuations down to the second- and decameter-scale.

In the present contribution, a preliminary analysis of the benefits of 500m-resolution retrievals based on the GOES-R ABI imager using the S2VSR data will be given. Specifically, the deviation of satellite retrievals of surface solar irradiance from single-site measurements caused by the limited representativity will be quantified. An estimate of the instantaneous retrieval uncertainty will be given for different cloud situations. Also, the effects of navigation accuracy of the satellite images and the impact of two different parallax correction strategies will be quantified.

Title: **Enhancing cloud top phase and height estimates from geostationary imagers in multilayer conditions using a deep neural network**

Author/Speaker: Benjamin Scarino
Company/Organisation: NASA
Co-Authors: William Smith
Christopher Yost
Presenting Author: Christopher Yost

Summary:

Cloud systems are commonly comprised of multiple layers of ice and liquid water cloud formations, accurate characterization of which is important to meet the needs of a wide range of weather and climate applications. Under multilayer cloud conditions, satellite imager cloud property retrieval techniques can yield large errors in both the vertical placement of clouds and in the derived optical/microphysical properties because the methods are based on a single-layer assumption. For example, thin cirrus over a stratus cloud is often identified as a mid-level liquid water cloud, and therefore, compared to the actual condition, cloud tops are placed too low and cloud bases are placed too high, which adversely affects estimates of atmospheric heating and surface radiative fluxes. Furthermore, the stratus cloud often dominates the signal in the satellite radiances, which can lead to failed recognition of the upper-level cirrus cloud, resulting in errors in effective radius estimates and other derived products. To mitigate satellite imager cloud top phase misclassification and height errors in these multilayer environments, a deep neural network (DNN) is employed to identify and estimate layer top and base heights of non-opaque cirrus over liquid water clouds based on geostationary (GEO) satellite imager channel radiances and atmospheric reanalysis profiles. The DNN classifications and height estimates, based on CALIPSO ground truth, offer some potential to improve the utility of satellite derived cloud properties by providing more accurate characterizations of cloud vertical structure.

Title: **Validating solar irradiance retrievals from Meteosat SEVIRI at improved spatial resolution against a dense network of ground-based observations**

Author/Speaker: Job Wiltink
Company/Organisation: Royal Netherlands Meteorological Institute (KNMI)
Co-Authors: Job Wiltink
Hartwig Deneke
Chiel van Heerwaarden
Yves-Marie Saint-Drenan
Jan Fokke Meirink
Presenting Author: Job Wiltink

Summary:

Accurate and detailed retrieval of surface solar irradiance (SSI) has great societal benefits, for instance to support the energy transition towards an energy supply with a high share of renewable energy sources, but also in the validation of high-resolution weather and climate models. In this study, we apply a downscaling algorithm that combines the High-Resolution Visible and standard-resolution channels onboard MSG-SEVIRI. This enables us to obtain cloud physical properties and SSI at an improved nadir spatial resolution of 1x1 km^2 instead of 3x3 km^2. We validate the accuracy of the high-resolution retrievals with respect to the standard-resolution against ground observations from a network of pyranometers employed during the HOPE field campaign in Jülich, Germany from 18 April to 22 July 2013. Over the entire length of the field campaign, a statistically significant reduction in RMSE of 2.4 Wm^{-2} is observed when we apply the downscaling algorithm. The added value of the downscaling algorithm is the largest for days where SSI fluctuates strongly. When we use the high resolution instead of the standard resolution retrieval, the 10 most variable days give a significant reduction in RMSE of on average 7.6 Wm^{-2}. For clear sky and fully overcast days, we did not find significant differences between both resolutions.

With an increase in resolution, it also becomes increasingly important to ensure that the geolocation of the satellite grid remains accurate. Therefore, we need to account for parallax displacements and shadow effects occurring in cloudy pixels. We investigate the impact of different geolocation correction approaches on the RMSE between SEVIRI retrievals and the pyranometer network.

Title:	**Ship emission effects on clouds from the SEVIRI-based CLAAS-3 data record**

Author/Speaker:	Nikos Benas
Company/Organisation:	Royal Netherlands Meteorological Institute (KNMI)
Co-Authors:	Jan Fokke Meirink Rob Roebeling
Presenting Author:	Nikos Benas

Summary:

The effect of ship emissions on clouds has been detected and studied in the past as a typical manifestation of an aerosol-cloud interaction mechanism: particles emitted from ships act as cloud condensation nuclei that can increase the Cloud Droplet Number Concentration (CDNC) and decrease the Effective Radius (CRE) of cloud droplets. These microphysical adjustments lead to an increased shortwave radiative effect of the clouds, which can be further modulated by macrophysical adjustments. The study of these effects is even more timely after the implementation of stricter rules on sulfur emissions from ships, imposed by the International Maritime Organization (IMO) in 2020.

In this study we analyze cloud properties over part of the Southeastern Atlantic stratocumulus region, where the effect of a busy shipping corridor on clouds is pronounced. We use cloud data retrieved from the geostationary Spinning Enhanced Visible and InfraRed Imager (SEVIRI) for the EUMETSAT Climate Monitoring Satellite Application Facility (CM SAF) CLAAS-3 (Cloud property dAtAset using SEVIRI – Edition 3) data record, which was recently released. CLAAS-3 contains cloud coverage, top height, phase and microphysical properties, including CDNC and CRE. Along with the quantification of the ship emissions effect on an annual and seasonal basis, the high temporal resolution of CLAAS-3 allows also for an analysis of its diurnal variation. Additionally, a trend analysis is performed for the 20-year period of CLAAS-3 (2004-2023). This period includes the transition to lower emissions, imposed by IMO in 2020, and the effect of these new rules on clouds is also analyzed.

Title: **GeoRing data and services for the cloud and aerosol community at AERIS/ICARE**

Author/Speaker: Maximilien Patou

Company/Organisation: AERIS/ICARE Data and Services Center, Université de Lille, CNRS, CNES, UAR 2877

Co-Authors: Djamal Loualia
Nicolas Pascal
Jérôme Riedi
Nicolas Ferlay
Xavier Ceamanos
Timothy J Garrett
Sebastien Payan

Presenting Author: Maximilien Patou

Summary:

The potential of combining geostationary observations from several operational satellites to create the so-called GEORING is attracting increasing interest from the cloud and aerosol remote sensing community. Thanks to their enhanced spatial and spectral capabilities, the new geostationary imagers allow the development of cloud and aerosol products with a quality comparable to those previously available only from polar orbiting satellite. Combined with their unique temporal sampling, GeoRing based products open perspectives for cloud and aerosol process studies at global scale (Ceamanos et al, 2021, 2023). By providing an almost instantaneous global view of cloud cover, the GEORING also provided an unprecedented view of the cloud cover alleviating temporal or spatial discontinuities found in all other previous database (Garrett et al, 2023, Dewitt T., 2023).

AERIS/ICARE is committed to provide the atmospheric research communities with access to data, processing capabilities and tools to face the multiple challenges induced by increasingly massive and diverse satellite observations, especially those generated by modern operational meteorological satellites. We will present here the status of current geostationary data archives available at AERIS/ICARE and illustrate through selected use cases the different services offered by AERIS/ICARE for the discovery, processing and analysis of the GeoRing data.

References:

T. Garrett, K. Rees, T. DeWitt, C. Bois, J. Riedi and S. Krueger, "Simplified power law relationships relating cloud amount from millimeter to planetary scales.”. Communication at CFMIP/Pan-GASS July, 2023

Thomas DeWitt’s M.S. 2023 thesis: Revisiting and expanding the extent of scale invariance in cloud horizontal sizes.

Ceamanos, X., Six, B., & Riedi, J. (2021). Quasi-global maps of daily aerosol optical depth from a ring of five geostationary meteorological satellites using AERUS-GEO. Journal of Geophysical Research: Atmospheres, 126, e2021JD034906. https://doi.org/10.1029/2021JD034906

Ceamanos, X., Coopman, Q., George, M. et al. Remote sensing and model analysis of biomass burning smoke transported across the Atlantic during the 2020 Western US wildfire season. Sci Rep 13, 16014 (2023). https://doi.org/10.1038/s41598-023-39312-1

Title:	**A probabilistic approach to determine the thermodynamic cloud phase using passive satellites**

Author/Speaker: Johanna Mayer
Company/Organisation: DLR
Co-Authors: Johanna Mayer
Presenting Author: Johanna Mayer

Summary:

The cloud thermodynamic phase (ice / mixed-phase / liquid) is a crucial parameter to understand the earth radiation budget, hydrological cycle and atmospheric thermodynamic processes. The phase partitioning of clouds and their parameterization in global climate models have therefore become of particular interest.

To improve our understanding of the frequency of occurrence and temporal evolution of cloud phase, geostationary passive sensors can be very useful due to their wide field of regard and high temporal resolution. However, the retrieval of cloud phase using passive instruments is challenging since the spectral signature of the phase is weak compared to other parameters of the clouds and atmosphere. Especially the distinction between ice and mixed-phase clouds is difficult and previous efforts to retrieve cloud phase often only distinguished between ice and liquid phase.

We present a new method to detect clouds and retrieve their phase using the passive instrument SEVIRI aboard the geostationary satellite Meteosat Second Generation. The method uses probabilities derived from active observations (the Lidar-Radar product DARDAR) of cloud top phase. Combining these probabilities for different SEVIRI channels gives probabilities for the presence of a cloud and for its cloud top phase. Our probabilistic approach includes a measure of uncertainty and allows us to distinguish between ice, mixed-phase, supercooled liquid, and warm liquid clouds. The method is tested against active satellite measurements and shows good agreement.

In the future we plan to use our new method to study phase transitions and the microphysical (such as optical thickness and effective radii) and macrophysical (such as temporal evolution and extent) properties of mixed-phase clouds.

Title: **EarthCARE mission - an overview with regards to the cloud products from the multi-spectral imager and the sensor-synergy between imager and atmospheric lidar**

Author/Speaker: Anja Hünerbein
Company/Organisation: Leibniz Institute for Tropospheric Research
Co-Authors: Sebastian Bley
Jan Fokke Meirink
Moritz Haarig
Ulla Wandinger
Athena Floutsi
Presenting Author: Anja Hünerbein

Summary:

The ESA cloud, aerosol and radiation mission EarthCARE will provide active profiling and passive imaging measurements from a single satellite platform. This will make it possible to extend the products obtained from the combined active/passive observations along the ground track into the swath by means of active/passive sensor synergy, to estimate the 3D fields of clouds and to assess radiative closure. The backscatter lidar (ATLID) and cloud profiling radar (CPR) will provide vertical profiles of cloud and aerosol parameters with high spatial resolution. Complementing these active measurements, the passive multi-spectral imager (MSI) delivers visible and infrared images for a swath width of 150 km and a pixel size of 500 m. The MSI cloud products combine visible to infrared channels to determine cloud microphysical and macrophysical properties, which include cloud mask, ISCCP cloud types, cloud phase, cloud optical thickness, cloud effective radius and cloud top height. ATLID L2 algorithms provide the vertical structure of aerosol optical properties as well as the cloud top height. The cloud top height retrieved from MSI is an infrared effective radiating height, which is located somewhere within the cloud. The ATLID cloud top height gives the physical boundaries of the clouds along track, which will be used to study the relationships between the effective and true cloud top height.
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 and ALTID observations with the EarthCARE Simulator (ECSIM). 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. Specific ECSIM test scenes have been created from weather forecast model output data. The 6000 km long frames include clouds over the Greenland ice sheet, followed by high optical thick clouds, a high ice cloud regime as well as low-level cumulus cloud embedded in a marine aerosol layer below. These synthetic scenes make it possible to evaluate and intercompare the different cloud properties from active and passive sensors such as cloud liquid water path or cloud effective radius. Further the input of the synthetic scenes offer the opportunity to extract the extinction profiles for each MSI pixel, and to contrast them to the retrieved cloud properties and types. This approach can be used to better understand and quantify the differences between the retrieved cloud properties based on the different measurement principles (passive and active).

Title: **Validation and Visualisation Tools for the EUMETSAT Central Facility Cloud Products**

Author/Speaker: John Jackson
Company/Organisation: EUMETSAT/Innoflair UG
Co-Authors: Andre Belo Do Couto
Loredana Spezzi
Alessio Bozzo
Phil Watts
Presenting Author: John Jackson

Summary:

The validation of EUMETSAT cloud imaging products from the current MSG/SEVIRI strongly relies on the use of lidar/radar measurements from space (e.g., CloudSat/CALIPSO), which have established themselves as a trustworthy source for the validation of cloud detection, height and microphysics. However, active space-based instruments may not be available in the FCI and METimage timeframe (except for the expected ~3yr lifetime of EarthCARE) and, hence, EUMETSAT is exploring alternative ground-based sources of reference data.

This contribution focuses on the validation of EUMETSAT cloud products via cross-comparison with a network of ground-based cloud radar and lidar measurements made by ACTRIS (the European Research Infrastructure for the observation of Aerosol, Cloud and Trace Gases), using cloud products generated by the Cloudnet processing facility maintained by the Finnish Meteorological Institute (FMI). In the context of its Cal/Val infrastructure, EUMETSAT developed a validation tool specifically dedicated to this cross-comparison, taking into account the basic requirement of continuous monitoring of the product quality during the full missions and overall possible global scenarios. Thus, the tool is automated in terms of data download, handling, and creation of statistical analysis plots and reporting. The strategy is herewith demonstrated via validation exercises performed using MSG/SEVIRI cloud products.

This validation tool will be incorporated into the FCI-Star and VII-Star validation chains, used for daily monitoring of the new FCI cloud products and of the future METimage cloud products, respectively. The analysis plots automatically generated for the daily reports will in the future be available to the users via the METIS, a public web interface maintained by EUMETSAT.

Title: **Cloud Detection and Characterization Based on Spectro-polarimetry – Operational Implementation for EPS-SG/3MI**

Author/Speaker: Bertrand Fougnie
Company/Organisation: EUMETSAT
Co-Authors: Margarita Vazquez Navarro
Loredana Spezzi
Alessio Bozzo
Jerome Riedi
Souichiro Hioki
Nicolas Ferlay
Laurent Labonnote
Nicolas Henriot
François Thieullieux
Mathieu Compiègne
Presenting Author: Bertrand Fougnie

Summary:

The 3MI instrument is one of the missions of the EUMETSAT Polar System Second Generation (EPS-SG) program to be launched in 2025. This polarimetric mission has a direct heritage from the POLDER mission, with improved capabilities and is implemented within a fully operational long-term framework. The spectral range was extended from the visible-near-infrared (410–910 nm) to the shortwave-infrared domain (up to 2200 nm). The spatial resolution (4 km at nadir) and the instantaneous swath (2200×2200 km²) were also improved compared to previous POLDER instruments. The spectro-polarimetric capabilities of 3MI allows very specific observations of the atmosphere and the particles scattering the solar light. Consequently, 3MI provides new information content, in addition to the usual spectral information, which is beneficial for aerosol and cloud characterization, and also requires more specific retrieval approaches. The cloud detection and characterization is based on a combination of various tests using the polarized, directional, as well as spectral information.

For cloud detection, the following parameters are compared to threshold values or expected range using the most favourable viewing directions for each test (14 different views are available). A target can be identified as cloudy if it is observed a deficit of apparent pressure deducted from oxygen absorption band, a deficit of polarization at 865nm out of the backscattering, an excess of polarization at 865nm in the cloud-bow geometry, a deficit of Rayleigh pressure deducted from polarization in the blue, an excess of reflectance at 443nm over land and 865nm over ocean, an excess of reflectance in the cirrus band at 1370nm. At the opposite, a target can be identified as cloud-free if the following parameters are close to the expected values for clear sky: the reflectance at 865nm and 1650nm, the apparent pressure deducted from oxygen absorption band, or several ratios of reflectance (over ocean : 865 to 443nm, and 2130 to 865nm; over land: 670 to 865nm and 2130 to 670nm). A combination of the different results is elaborated through a decision tree, allowing an evaluation of the associated confidence.

The cloud phase is estimated based on the angular polarization signature, completed by the additional information from SWIR. For the specific geometry of the cloud-bow around 140° scattering angle, a low polarization signal is characteristic of non-spherical ice particles, while a significant polarized peak unambiguously identifies liquid spherical particles. In backscattering geometries, the dispersion of the polarization reflectance due to supernumerary bows indicates liquid particles. For all other geometries, the slope of the polarized reflectance with scattering angle will suggest ice particle when negative, and liquid particle when positive. Some undetermined situations can be reclassified based on apparent and Rayleigh pressures. Finally, the ratio of reflectance at 2130 to 670nm over land and 865 over ocean is added to the evaluation. At the end, a score, the associated particle type, as well as the level of uncertainty, can be attributed to the observed target.

Once the surface type as well as particle type are identified, the radiative properties of the cloud are derived by selecting the pair cloud spherical albedo and effective radius that minimises the difference between observed reflectances at 2130nm and 670/865nm (for land/ocean, respectively) and look-up-tables. An averaged value is then derived through a weighted angular mean. Knowing surface and particle types, albedo and particle size are used to derive the spectral cloud albedo and the associated cloud optical thickness.

The vertical structure of the cloud can mostly be assessed through the oxygen pressure derived from bands 763 and 765nm, and its dispersion among the different views; it is then possible to derive the cloud top pressure, and the cloud middle pressure. Based on these pressures, an estimation of the geometrical extend of the cloud can be estimated. By a combination of the available information from oxygen, Rayleigh pressures, and their respective differences, it is also possible to derive a multi-layer index informing about the vertical structure of the cloud.

Finally, an evaluation of the errors associated to every parameter will also be provided. This information will be completed by the sub-pixel cloud fraction within a 3MI pixel based on the METimage cloud mask. The proposed cloud algorithm is currently being implemented on the ground segment and will be available as Day-1 product after the commissioning. A second generation of added-value products, using synergistic opportunity with METimage on-board the same platform, are under consideration for Day-2.

Title:	**Improvement of optimal retrievals of cloud through the vicarious estimation of uncertainties**
Author/Speaker:	Adam Povey
Company/Organisation:	NCEO, University of Leicester
Co-Authors:	Roy Grainger
Presenting Author:	Adam Povey
Preferred Presentation Method:	poster
Summary:	

Optimal estimation is a method of statistical minimisation widely used in the atmospheric sciences and underpins the CC4CL/ORAC retrieval used by the cloud projects of the Copernicus Climate Change Service and Climate Change Initiative. Optimal estimation requires a robust understanding of the uncertainties on both measurement and the radiative transfer model in order to produce unbiased results. The characterisation of geostationary sensors often does not meet the necessary standards. This presentation will outline a vicarious technique to estimate the measurement uncertainty from the spatial variability of a large collection of satellite images. The technique is demonstrated for MODIS and SLSTR, where the uncertainty behaviour is reasonably well understood, before application to SEVIRI. The improved uncertainty information is then used within a CC4CL-like cloud retrieval, demonstrating improved performance, and aims to inspire dialogue with Level 1 data producers about the requirements on uncertainty for Level 2 processing.

Title: **Retrieval of cloud bottom altitude from TROPOMI on Sentinel-5P**

Author/Speaker: Luca Lelli
Company/Organisation: Remote Sensing Technology Institute, German Aerospace Centre (DLR), Wessling, Germany
Co-Authors: Andrew Sayer
Rene Preusker
Klaus Bramstedt
Marco Vountas
Athina Argyrouli
Presenting Author: Luca Lelli
Summary:

Retrieval of cloud properties from satellite measurements has applications in a variety of fields such as light path correction for atmospheric composition, assessment of earth's radiation budget, study of aerosol-cloud interactions, and meteorology. One parameter of particular interest, to which little attention has been paid to date, is the height of the bottom layer of clouds. This is due to the attenuation of light available for passive remote sensing in the case of substantial opacity of tropospheric clouds. In this work it is illustrated a solution to the radiative transfer problem in the molecular oxygen absorption band (the O_2 A-band), measured by TROPOMI aboard Sentinel-5P, leading to the inference of cloud bottom altitude. The concurrent analysis of cloud properties derived with independent algorithmic approaches sheds light on the complementarity of the respective techniques and shows how the retrieval of cloud bottom altitude, together with the characterization of the thermodynamic cloud-top phase, is functional to a more accurate description of clouds. Prospectively, the validation of the derived cloud parameters (top and bottom altitude, cloud-top phase and optical thickness) will provide the constraints for the production of a long-term cloud data record for climate applications.

Title:	**Evaluating CMSAF's CLAAS-3 cloud products on global ISCCP-NG data**

Author/Speaker:	Salomon Eliasson
Company/Organisation:	SMHI
Co-Authors:	Karl-Göran Karlsson Nina Håkansson Martin Stengel
Presenting Author:	Salomon Eliasson

Summary:

Cloud Climate Data Records (CDRs) are pivotal in assessing climate dynamics, and the radiance dataset based on geostationary satellite data, ISCCP-NG, provides an excellent opportunity to create high-resolution and global CDRs.

We assess the suitability of CMSAF's CLAAS-3 cloud product algorithm, initially tailored for Meteosat SEVIRI, on the ISCCP-NG dataset. Our methodology involved spectral adjustments aligning all ISCCP-NG satellite radiances from visible to IR with Meteosat-11 SEVIRI before applying the CLAAS-3 algorithm. We used this harmonized ISCCP-NG dataset to produce 30-minute, 5km resolution cloud products for 2021.

Despite certain cloud artifacts in the output, a comparison of this test cloud dataset based on ISCCP-NG against CALIOP measurements showcased alignment between the CMSAF CLAAS-3 and the CLARA-A3 CDRs, the latter derived from the AVHRR instrument onboard polar-orbiting satellites.

This investigation emphasizes the feasibility of utilizing the CLAAS-3 cloud algorithms on ISCCP-NG radiances and the potential to create a high-resolution cloud CDR aligning with other established CDRs. Such coherence offers opportunities for detailed cloud process explorations, strengthening climate monitoring initiatives.

Title: **METIS – Clouds**

Author/Speaker: Andre Couto
Company/Organisation: CS Group - Germany GmbH
Co-Authors: Alessio Bozzo
Helmut Bauch
John Jackson
Hans J. Lutz
Loredana Spezzi
Presenting Author: Andre Couto

Summary:

METIS (Monitoring and Evaluation of Thematic Information from Space) is a web application tool developed by EUMETSAT to routinely monitor stability, quality and performance of the EUMETSAT operational cloud products, both globally and in specific regions of interest. The tool, publicly accessible, has twofold purpose: a) to allow EUMETSAT developers to identify possible anomalies in the product processors and validate the retrieved cloud parameters; b) to provide the users with an overview of the scientific accuracy of the products, in order to establish the suitability for specific user applications.

METIS-Clouds currently provides clear analysis of clouds and cloud related products derived from EPS/AVHRR, MSG/SEVIRI and MTG/FCI. The tool will be extended to the future cloud products from EPS-SG/METimage, EPS-SG/3MI, Sentinel 3 OLCI & SLSTR, and CO2M/CLIM observations. Amongst all the cloud (and cloud related) parameters monitored within METIS-Clouds, in this contribution we focus on those parameters that are most requested by the users: the cloud mask, the cloud top Pressure and microphysical properties, and the total precipitable water.

Title: **How ERA5 vertical resolutions and top-of-atmosphere cut-off impact simulated MTG/IRS infrared spectra**

Author/Speaker: Xuemei Chen
Company/Organisation: CNRM, Université de Toulouse, Météo-France, CNRS
Co-Authors: Romain Joseph
Gaëlle Kerdraon
Sonia Péré
Benoît Tournadre
Jérôme Vidot
Emmanuel Fontaine
Presenting Author: Xuemei Chen

Summary:

The MTG-S (Meteosat Third Generation sounding satellite)will carry a hyperspectral interferometer, namely IRS (InfraRed Sounder), on a geostationary orbit. For satellite sounders, cloud information is useful for the subsequent retrievals of atmospheric and surface products or for data assimilation in NWP (numerical weather prediction) models.Our project aims at studying how to retrieve cloud properties from MTG/IRS.

The first stage of our project is the fast radiative transfer modeling by RTTOV to simulate the top-of-atmosphere radiance as observed by IRS. This requires explicit information on atmospheric conditions, for example, the profiles of temperature and humidity, and the cloud vertical descriptions of water liquid and ice contents. We carried out RTTOV simulations using ERA5 reanalysis as meteorological inputs. ERA5 is originally computed on 137 model levels in the vertical, and resides in the ECMWF's MARS (European Centre for Medium-Range Weather Forecasts' Meteorological Archival and Retrieval System) tape archive. ERA5 is also available as interpolated to a reduced vertical resolution on 37 pressure levels, and stored on the Climate Data Store disks with a faster access. This study discusses the differences between simulated brightness temperatures depending on the ERA5 inputs on 137 models levels or 37 pressure levels. In addition, we also discuss the influences on simulated brightness temperatures if we cut off the atmospheric levels above 25 hPa and only keep the lower part.

Title: **L1g-based cloud products from the Geosatclim cloud algorithms (COMET) compared with CM SAF, CALIPSO and MODIS cloud datasets**

Author/Speaker: Karl-Göran Karlsson
Company/Organisation: SMHI
Co-Authors: Salomon Eliasson
Nina Håkansson
Nicolas Christen
Anke Duguay-Tetzlaff
Presenting Author: Karl-Göran Karlsson

Summary:

The Level 1g (L1g) format for Georing satellite data was originally developed for being used in the ISCCP-NG project with the purpose of collecting data from advanced imagers with 10+ common spectral bands. However, the format is also now planned to be used for historical datasets from imagers with less channels and with coarser temporal and spatial resolution. This opens up for comprehensive studies of climate datasets based on both historical and modern satellite data. An important study topic will be to characterize what is gained by starting to use the modern sensors in comparison to what has already been achieved based on historical data. Attached to this is to see if ways of mitigating differences in results can be found for allowing climate trend analyses based on the entire L1g dataset. A secondary object is to evaluate if a common basic cloud mask can be added to the L1g datasets for supporting other applications than cloud studies.

This study focusses on the bi-spectral (VIS/IR, i.e., using one visible and one infrared channel,) cloud retrieval method COMET (Stöckli et al., 2019), originally developed on historic Meteosat MVIRI data but now applied on L1g data from all satellite sensors available in 2021. COMET results for four months (January, February, June and July) in 2021 are compared with corresponding results based on multispectral data derived by the CM SAF cloud algorithms. Reference data from CALIPSO-CALIOP and MODIS is also used for validation purposes.

Stöckli, R.; Bojanowski, J.S.; John, V.O.; Duguay-Tetzlaff, A.; Bourgeois, Q.; Schulz, J.; Hollmann, R. Cloud Detection with Historical Geostationary Satellite Sensors for Climate Applications. Remote Sens. 2019, 11, 1052. https://doi.org/10.3390/rs11091052

Title:	**First impressions of MTG-I1 FCI in the context of continuing the CM SAF CLAAS cloud property record**

Author/Speaker:	Jan Fokke Meirink
Company/Organisation:	KNMI
Co-Authors:	Nikos Benas Martin Stengel
Presenting Author:	Jan Fokke Meirink

Summary:

In December 2022 the first imaging satellite of Meteosat Third Generation (MTG-I1) was launched. Onboard is the Flexible Combined Imager (FCI), providing increased spatial resolution and measurement frequency as well as improved spectral capability compared to the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) instrument, which has been operational in the past two decades.

Targeting the application for cloud processes and regional climate studies the EUMETSAT Climate Monitoring Satellite Application Facility (CM SAF) generates the CLoud property dAtAset using SEVIRI (CLAAS). In the next edition (CLAAS-4), FCI observations will be included. The goal is to have a seamless transition in cloud properties between the two instruments.

In this contribution, we will provide a preliminary analysis of FCI measurements and retrieved cloud properties. The focus will be on the SEVIRI heritage channels and the consistency between FCI and SEVIRI retrievals will be assessed. Strategies for a seamless inclusion of FCI in CLAAS-4 will be discussed.

Title: **Retrieval of Mixed-Phase Clouds over the Arctic from satellite: method and first results**

Author/Speaker: Marco Vountas
Company/Organisation: Universität Bremen
Co-Authors: K.s. Vinjamuri
L. Lelli
M.d. Shupe
J.p. Burrows
H. Bösch
Presenting Author: Marco Vountas

Summary:

Mixed-phase clouds (MPC) in the Arctic are relatively persistent and have an important impact on radiative fluxes in the Arctic. Effects on the radiative balance have been studied for several years with campaign data by many groups. In the absence of suitable satellite retrievals, large-scale distributions in the Arctic have not yet been studied on an observational basis.

In this study we introduce an AI-approach to train liquid and total water paths obtained from the MOSAiC expedition to measurements of the Sea and Land Surface Temperature Radiometer (SLSTR) onboard the Copernicus Sentinel-3 satellites. The quantity to be retrieved is the ice fraction (IF) defined as IF=IWP/(IWP+LWP). Cross-validation results and first application to SLSTR will be presented. The algorithm’s performance within the Arctic cryospheric regime is encouraging. First retrievals show realistic values and good coverage. Furthermore, an outlook for the validation planned will be given.

This work was supported by the DFG funded Transregio-project TR 172 ”Arctic Amplification $(AC)^3$”.

Title: **Low-level cloud life cycle assessment**

Author/Speaker: Jan Cermak
Company/Organisation: Karlsruhe Institute of Technology (KIT)
Co-Authors:
Presenting Author: Jan Cermak

Summary:

This contribution presents recent progress in understanding temporal and spatial patterns of coastal and continental fog and low-level clouds based on satellite observations. Progress is presented on the continual and consistent monitoring of fog and low-level clouds across the day/night transition with a machine-learning technique applied to Meteosat SEVIRI infrared data. An evaluation against existing algorithms and ground-based observations shows good usability. Based on this product, life cycle stages of fog and low-level clouds are identified and linked to meteorological and environmental conditions in an explainable-artificial-intelligence approach, revealing quantitative constraints on the determinants of formation and dissipation processes, as well as a basis for nowcasting.

Title: **NWCSAF-PPS recent improvements of cloud top temperature retrieval**

Author/Speaker: Nina Håkansson
Company/Organisation: SMHI
Co-Authors: Sara Hörnquist
Bengt Rydberg
Karl-Göran Karlsson
Salomon Eliasson
Presenting Author: Nina Håkansson

Summary:

The cloud top temperature algorithm in the NWCSAF-PPS sofware is used both for nowcasting and production of climate data records (CLARA-A3 and CLAAS3). The retrieval algorithm is a neural network mainly using the 11µm and 12µm channels. It is now retrained to prepare for EPSSG-SG-A1 and CLAAS4. The algorithm is updated to predict pressure, temperature and error estimates at the same time. Training data is tweaked to improve performance for very low clouds. Also for SEVIRI the training dataset now also include cloud top pressure for single shot data missing from the CLAY 5km CALIOP product. Validation results is shown for cloud top pressure and temperature. Networks including also the 13.3µm channel that will be available with METimage are evaluated.

Title:	**Leveraging spatial textures, through machine learning, to identify aerosols and distinct cloud types from multispectral observations**

Author/Speaker: Willem Marais
Company/Organisation: Space Science Engineering Center
Co-Authors: Robert Holz
Presenting Author: Willem Marais

Summary:

Clouds and aerosols are integral parts of the climate system that are indicative and influence atmospheric dynamics through modulating in- and out-bound radiate fluxes. Multi decadal imager records provide a treasure trove of data for identifying aerosols and a broad range of cloud types indicative of various meteorological conditions. Such an venture would add value to efforts in understanding and modeling the climate system since aerosols and cloud types correlate with atmospheric dynamics and the climate radiative budget.

Although operational imager cloud and aerosol identification methods confidently detect cloud phase (i.e. ice vs water) and most aerosols, it is non-trivial to identify a broader class of cloud types and identifying severe aerosols. Specifically, pixel based spectral tests are not sufficient to discriminate between open- (i.e. transitional) and closed-stratiform clouds. Furthermore, the spectral signatures of opaque elevated smoke and clouds are very similar which induce uncertainty in aerosol identification. For these challenges both spatial and spectral information are required as it is evident when we visually inspect imager data.

New machine learning (ML) methods have been developed to better represent spatial information of images to improve the discrimination between different image types. A new methodology has been developed to employ these ML methods to improve the discriminate between aerosols and different cloud types indicative of different meteorological conditions. Specifically, 1) the NASA Worldview platform was adapted to create labeled datasets of aerosol and distinct cloud types, 2) and a pre-trained convolutional neural network (CNN) was adopted to exploit both spatial and spectral information from multi-spectral images. By harnessing CNNs with a unique labeled dataset, an improvement is demonstrated of the discrimination between aerosols and distinct cloud types from ABI, MODIS and VIIRS images. In the presentation we will share the progress that we have made in developing the cloud type and aerosol ML methods.

Title:	**Evaluation of the MODIS/VIIRS Cloud Team's Pixel-Level Cloudy-Sky Radiative Flux Datasets using Ground- and Space-based Radiation Measurements**

Author/Speaker:	Colten Peterson
Company/Organisation:	NASA Goddard Space Flight Center and UMBC
Co-Authors:	Kerry Meyer Steven Platnick Gala Wind Nandana Amarasinghe
Presenting Author:	Colten Peterson

Summary:

Clouds are a critical component of the global radiation budget, and cloud radiative effects at the top-of atmosphere (TOA) and surface can significantly depend on the optical properties of the cloud. Passive spaceborne imagers, such as MODIS and VIIRS, can be used to retrieve cloud optical properties at spatial scales of 1-km or less. Since these imagers lack broadband channels necessary to estimate top-of-atmosphere (TOA) broadband radiative fluxes, the fluxes must be computed. This allows for estimates of cloud radiative effects at the surface and TOA for the cloud imager spatial scales. Given the global and multi-decadal data record from MODIS, such pixel-level cloud radiative effects produced using MODIS cloud observations as inputs can provide a useful long-term and global cloud and radiation dataset. This dataset can also be extended to VIIRS when MODIS is no longer operational.

Newly developed pixel-level shortwave (SW) and longwave (LW) surface and TOA radiative flux datasets calculated directly from two NASA MODIS/VIIRS Science Team cloud products, the MOD06 and MYD06 standard cloud products for Terra and Aqua, respectively (collectively referred to as MOD06) and the MODIS/VIIRS CLDPROP product for cloud climate data record continuity, are intercompared and evaluated globally against collocated ground- and satellite-based (i.e., NASA CERES) radiation measurements. Example pixel-level flux imagery is presented, as well as evaluations for different regions (e.g., polar vs. tropics) and cloud types (e.g., liquid vs. ice clouds). Level-3 globally gridded all-sky and cloudy-sky surface and TOA flux aggregations are also discussed, as well as ongoing efforts and updates on the development status of the MODIS/VIIRS flux datasets.

Title: **Lessons learned from the updated GEWEX Cloud Assessment database**

Author/Speaker: Claudia Stubenrauch
Company/Organisation: CNRS LMD
Co-Authors: Stefan Kinne
Giulio Mandorli
William Rossow
David Winker
Steven Ackerman
Helene Chepfer
Larry Di Girolamo
Anne Garnier
Andrew Heidinger
Karl-Göran Karlsson
Presenting Author: Claudia Stubenrauch

Summary:

Since the first Global Energy and Water Exchanges (GEWEX) cloud assessment a decade ago, existing cloud property retrievals have been revised and new retrievals have been developed. The new global long-term cloud datasets show, in general, similar results to those of the previous assessment. A notable exception is the reduced cloud amount provided by the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) Science Team, resulting from an improved aerosol-cloud distinction. Height, opacity and thermodynamic phase determine the radiative effect of clouds. Their distributions as well as relative occurrences of cloud types distinguished by height and optical depth are discussed. The similar results of the two assessments indicate that further improvement, in particular on vertical cloud layering, can only be achieved by combining complementary information. We suggest such combination methods to estimate the amount of all clouds within the atmospheric column, including those hidden by clouds aloft. The results compare well with those from CloudSat-CALIPSO radar-lidar geometrical profiles as well as with results from the International Satellite Cloud Climatology Project (ISCCP) corrected by the cloud vertical layer model which is used for the computation of the ISCCP derived radiative fluxes. Furthermore, we highlight studies on cloud monitoring using the information from the histograms of the database and give guidelines for: 1) the use of satellite retrieved cloud properties in climate studies and climate model evaluation and 2) improved retrieval strategies.

complete list of authors:

Stubenrauch C.J., Kinne S., Mandorli G., Rossow W.B., Winker D.M., Ackerman S.A., Chepfer H., Di Girolamo L., Garnier A., Heidinger A., Karlsson K.-G., Meyer K., Minnis P., Platnick S., Stengel M., Sun-Mack S., Veglio P., Walther A., Cain X., Young A.H., Zhao G.

Title: **Cloud products from the new NASA PACE mission**

Author/Speaker: Andrew Sayer

Company/Organisation: UMBC at NASA GSFC

Co-Authors: Brian Cairns
Bastiaan van Diedenhoven
Sean Foley
Kirk Knobelspiesse
Luca Lelli
Kerry Meyer
Chamara Rajapakshe
Jeremy Werdell

Presenting Author: Andrew Sayer

Summary:

NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission is scheduled to launch in early 2024 and will continue and improve data records in its eponymous domains. PACE is a global mission (not only oceans!) in a Sun-synchronous (~1 pm) polar orbit. The mission's main sensor, the Ocean Color Instrument (OCI), will provide a cloud mask; heritage-type optical depth, effective radius, and water path from the CHIMAERA (MODIS/VIIRS) algorithms; and cloud top pressure from a new algorithm (CHROMA) based on O2 A-band measurements. OCI will provide daily global coverage with an approximately 1.2 km horizontal pixel size at the sub-satellite point. PACE will also carry two multi-angle polarimeters – HARP2 and SPEXone – which will be able to provide more detailed cloud characterization, such as cloud-top phase indices and drop size distributions with an approximately 5 km footprint. The instruments will also be used synergistically to provide droplet number concentrations, liquid water path, and complementary cloud top pressure and optical thickness estimates. Multi-angle data from HARP2 will be analyzed with computer vision algorithms in order to estimate the full 3D cloud field. In this presentation we introduce the PACE mission and data/performance expectations.

Title: **Evaluating imager spectral cloud effective radius retrievals against multi-angle polarimetry and in situ cloud probes**

Author/Speaker: Kerry Meyer
Company/Organisation: NASA Goddard Space Flight Center
Co-Authors: Steven Platnick
Nandana Amarasinghe
G. Thomas Arnold
Daniel Miller
Presenting Author: Kerry Meyer
Summary:

Cloud droplet effective radius (CER), defined as the ratio of the 3rd moment of the droplet size distribution (DSD) to the 2nd moment, is a radiative quantity widely used for studies of aerosol/cloud interactions and their impacts on Earth’s radiation budget and hydrological cycle. CER commonly is retrieved simultaneously with cloud optical thickness from passive imagers using a bi-spectral technique pairing a non-absorbing visible/near-infrared spectral channel with an absorbing shortwave/mid-wave infrared spectral channel. Multi-angle polarimetry also can be used to retrieve CER, and DSD width, from polarized reflectance observations across the cloud-bow. Spaceborne imagers providing global CER retrievals include MODIS (Terra, Aqua) and VIIRS (SNPP, NOAA-20/21+). Spaceborne polarized cloud-bow retrievals have been limited primarily to POLDER, though several upcoming missions will include multi-angle polarimeters (e.g., ESA's EarthCARE, NASA's PACE and AOS).

Evaluating CER retrievals typically is done via comparisons against CER derived from DSDs measured in situ by cloud probes. However, these comparisons involve numerous confounding factors that influence the interpretation of comparison results, including instrument calibration, retrieval forward model assumptions, information content/sensitivity differences, etc. Here, we show an extensive comparison of airborne imager CER retrievals from the Enhanced MODIS Airborne Simulator (eMAS) against co-located multi-angle polarimetric retrievals from the Research Scanning Polarimeter and in situ cloud probes obtained for marine stratocumulus during the NASA ORACLES field campaign. eMAS is spectrally similar to MODIS and VIIRS and includes channels in the CER-sensitive 1.6µm (2 channels), 2µm (4 channels), and 3.7µm (1 channel) bands that enable a variety of bi-spectral retrieval channel pairings beyond those of any single spaceborne imager. We also show CER and DSD effective variance inferred from eMAS observations of the backscatter glory using peak-matching similar to the polarized cloud-bow. The impacts of numerous confounding factors are explored, and the broader implications of retrieval differences due to differing fundamental sensitivities of multi-spectral imagery and multi-angle polarimetry are discussed.

Title:	**The NASA MODIS/VIIRS CLDPROP continuity cloud products: Status and updates for Version 2**

Author/Speaker: Kerry Meyer

Company/Organisation: NASA Goddard Space Flight Center

Co-Authors: Steven Platnick
Robert Holz
Gala Wind
Nandana Amarasinghe
Colten Peterson
Steve Dutcher
Andrew Heidinger

Presenting Author: Kerry Meyer

Summary:

The NASA CLDPROP cloud-top and optical properties products were designed to bridge the early afternoon data records of MODIS on NASA's Aqua satellite and VIIRS on the new generation of advanced NOAA operational weather satellites, with the goal of creating a multi-sensor, multi-decadal continuous climate data record for clouds. The CLDPROP algorithms follow a "continuity of approach" paradigm – applying a common algorithm to a subset of channels available on both MODIS and VIIRS, thus mitigating to the extent possible the impacts of differing spectral information content, science algorithm approaches, and ancillary input dataset usage. As the decommissioning of NASA's venerable Earth Observing System (EOS) missions, including Aqua and its morning afternoon sibling Terra, draws near, sustaining continuity algorithm efforts into the VIIRS era is an essential enabling activity for climate studies and trend monitoring.

Here, we provide details on current CLDPROP product status and evaluation efforts. Currently, Version 1.1 (V1.1) of CLDPROP is available for Aqua MODIS, SNPP VIIRS, and NOAA-20 VIIRS, with the full data records of each publicly archived and distributed by the LAADS DAAC at NASA Goddard Space Flight Center. Efforts to extend CLDPROP to NOAA-21 VIIRS, including assessing the relative radiometric calibration of the key shortwave channels used for cloud optical property retrievals, is ongoing. We also present planned major science updates for the next iteration of CLDPROP, Version 2 (V2), including pixel-level SW and LW broadband TOA and surface flux calculations enabling radiative studies consistent with the cloud-top/optical property retrievals; a new IR cloud-top properties algorithm that also provides day/night retrievals of ice cloud optical properties; ingesting co-located IR sounder observations (VIIRS+CrIS, MODIS+AIRS) to mitigate the lack of IR absorbing channels on VIIRS that have enhanced information content for high, thin clouds; and a new cloud thermodynamic phase classification algorithm leveraging machine learning.

Title: **Multi-instrument Cloud and Aerosol Retrieval Simulator and Its Applications**

Author/Speaker: Gala Wind
Company/Organisation: NASA GSFC / SSAI, Inc
Co-Authors: Arlindo da Silva
Peter Norris
Kerry Meyer
Steve Platnick
Robert Levy
Shana Mattoo
Presenting Author: Gala Wind
Summary:

Multi-instrument Cloud and Aerosol Retrieval Simulator and Its Applications

G. Wind[1,2], A. M. da Silva[2], P. Norris[2,3], K. Meyer[2], S. Platnick[2], R. Levy[2], S. Mattoo[1,2]

1. SSAI, Inc, Lanham, MD, USA
2. NASA Goddard Space Flight Center, Greenbelt, MD, USA
3. USRA, Columbia, MD, USA

Multi-instrument Cloud and Aerosol Retrieval Simulator (MCARS) is a radiance-based observation system simulation experiment (OSSE) with unique capabilities. MCARS combines model output with a radiative transfer code in order to simulate radiances that may be measured by a remote sensing instrument if it were passing over the model fields. (Wind et al, 2013, 2016, 2022).

MCARS allows a user to set up a wide variety of cloud and aerosol experiments. It has been used to examine accuracy of cloud representations in models. It has been used in experiments to develop data assimilation constraints for cloud and aerosol remote sensing data. It has been used to examine algorithm sensitivities and retrieval uncertainties. MCARS also has the capability of modeling sensors that do not yet exist. MCARS gives user full control over every constituent present in the atmospheric column that would result in an observed MODIS pixel. Aerosols, atmosphere, clouds, surface, can all be included, excluded or modified as per study design in a simple fashion.

In this presentation we will give a brief overview of MCARS studies that have been successfully completed. We will also show some early results of MCARS studies that examine performance of atmospheric correction used during retrieval of cloud optical and microphysical properties within the Cross-platform HIgh resolution Multi-instrument AtmosphEric Retrieval Algorithms (CHIMAERA) system.

Wind, G., da Silva, A.M., Norris, P.M., and Platnick, S.: Multi-sensor cloud retrieval simulator and remote sensing from model parameters – Part 1: Synthetic sensor radiance formulation, Geosci. Model Dev., 6, 2049-2062, doi:10.5194/gmd-6-2049-2013, 2013.

Wind, G., da Silva, A.M., Norris, P.M., Platnick, S., Mattoo, S., and Levy, R. C.: Multi-sensor cloud retrieval simulator and remote sensing from model parameters – Part 2: Aerosols, Geosci. Model Dev., 9, 2377-2389, doi:10.5194/gmd-9-2377-2016, 2016.

Wind, G., da Silva, A.M., Meyer, K.G., Platnick, S. and Norris, P.M.: Analysis of the MODIS above-cloud aerosol retrieval algorithm using MCARS Geoscientific Model Development 15 (1):1-14. doi:10.5194/gmd-15-1-2022, 2022.

Wind, G. (., S. Platnick, K. Meyer, et al. T. Arnold, N. Amarasinghe, B. Marchant, and C. Wang. 2019. The CHIMAERA system for retrievals of cloud top, optical and microphysical properties from imaging sensors Computers & Geosciences 134 104345 [10.1016/j.cageo.2019.104345]

Title:	**First results of the MTG-FCI cloud mask and cloud analysis product at EUMETSAT and plans for future developments**
Author/Speaker:	Hans-Joachim Lutz
Company/Organisation:	EUMETSAT
Co-Authors:	Alessio Bozzo Loredana Spezzi John Jackson
Presenting Author:	Hans-Joachim Lutz
Summary:	

First results of the MTG-FCI cloud mask and cloud analysis product at EUMETSAT and plans for future developments

<u>Hans Joachim Lutz[1,2]</u>, Alessio Bozzo[1], Loredana Spezzi[1], John Jackson[1,3]

[1]EUMETSAT, Eumetsat-Allee 1, 64295 Darmstadt, Germany

[2]Telespazio Germany GmbH, Europahaus, Europaplatz 5, 64293 Darmstadt, Germany

[3]Innoflair UG, Richard-Wagner-Weg 35, 64287 Darmstadt, Germany

The EUMETSAT Cloud Mask (CLM) and Analysis (CLA) products are operated on MSG-SEVIRI data since 2004. As basis for the initial operator for MTG-FCI the CLM and CLA algorithms were expanded to include features of the NWCSAF cloud processor.

The CLM product provides the cloud detection and is derived from a threshold based algorithm. We will discuss the initial CLM results obtained during the FCI commissioning phase, which includes the threshold tuning to adapt the differences to the SEVIRI-like channels. The CLM algorithm also includes a dust detection module.

The cloud analysis (CLA) product is derived from an algorithm consisting of a cloud type (CTy) and a cloud top height (CTTH) module. The CTy algorithm is also threshold based and retrieves the different cloud types together with the cloud phase. The CTTH retrieves the cloud top height and pressure with different methods, i.e. IR opaque cloud retrieval, IR/WV-intercept retrieval, and the rationing method.

The preliminary validation of CLM and CLA products is performed against SEVIRI based retrievals as well as other cloud retrieval algorithms available. In addition, a dedicated threshold tuning tool is used to improve the algorithm.

We also discuss the future improvements of these algorithms, which will be based on the inclusion of the additional FCI channels and a volcanic ash detection module.

Title: **Investigation of the cloud top thermodynamic phase from the synergistic use of polarimetric, multi-directional, and high temporal resolution observations.**

Author/Speaker: Jérôme Riedi
Company/Organisation: Laboratoire d'Optique Atmosphérique - Dpt de Physique
Co-Authors: Souichiro Hioki
Quentin Coopman
Presenting Author: Jérôme Riedi
Summary:

Understanding cloud evolution (formation and dissipation) and cloud processes requires accurate determination of cloud microphysical properties at both high spatial and temporal resolution. The correct determination of cloud thermodynamic phase is of primary importance for subsequent retrieval of cloud microphysical properties (particles size and shape) [Stubenrauch et al, 2013; Platnick et al, 2017] and is also key in understanding cloud processes such as glaciation [Coopman et al, 2020a] or precipitation onset [Patou et al, 2018]. Our ability to observe precisely at which temperature cloud glaciation occurs for different meteorological regimes may also be crucial to understand aerosol indirect effect on clouds [Coopman et al, 2018].

Polarimetric multiangle observations have proved very useful for cloud thermodynamic phase detection, especially when used in combination with short-wave infrared and thermal infrared channels observations [Riedi et al, 2010]. The SGLI sensor provides a unique set of polarimetric and multispectral measurements to observe cloud thermodynamic phase at an unprecedented spatial resolution, most suitable to characterize the glaciation of convective cloud tops. It is also noticeably the only polarimetric radiometer currently in space dedicated to atmospheric and surface monitoring At the same time, the increasingly high temporal and spatial resolution of geostationary sensors make those instruments very attractive to follow the evolution of cloud properties in conjunction with precipitation measurements. When combined with rainfall information, the temporal evolution of cloud microphysics, and especially the evolution of cloud phase at cloud top can inform about the cloud processes occurring within the clouds [Patou et al, 2018].

We are currently developing and evaluating algorithms for cloud thermodynamic phase determination from the SGLI/GCOM-C and AHI/Himawari in order to study how the synergistic use of these two sensors could help improve the understanding of cloud glaciation processes. In this presentation we will report on our current progresses towards establishing the necessary joint dataset that will in a second stage be used to study glaciation processes of convective cloud cells.

Coopman, Q., Riedi, J., Finch, D. P. & Garrett, T. J. (2018). Evidence for Changes in Arctic Cloud Phase Due to Long-Range Pollution Transport. Geophysical Research Letters, 45, 1-10.

Coopman, Q., Riedi, J., Zeng, S. & Garrett, T. J. (2020a). Space-Based Analysis of the Cloud Thermodynamic Phase Transition for Varying Microphysical and Meteorological Regimes. Geophysical Research Letters, 47(6).

Coopman, Q., Hoose, C., & Stengel, M. (2020b). Analysis of the thermodynamic phase transition of tracked convective clouds based on geostationary satellite observations. Journal of Geophysical Research: Atmospheres, 125
Patou, M., Vidot, J., Riedi, J., Penide, G. & Garrett, T.J. (2018). Prediction of the onset of heavy rain using SEVIRI cloud observations. J. Appl. Meteor. Climatol.,,
Platnick, S., Meyer, K. G., King, M. D., Wind, G., Amarasinghe, N., Marchant, B., Thomas Arnold, G., Zhang, Z., Hubanks, P. A., Holz, R. E., Yang, P., Ridgway, W. L. & Riedi, J. (2017). The MODIS Cloud Optical and Microphysical Products: Collection 6 Updates and Examples From Terra and Aqua. IEEE Transactions on Geoscience and Remote Sensing, 55(1), 502-525.
Riedi, J., Marchant, B., Platnick, S., Baum, B., Thieuleux, F., Oudard, C., Parol, F., Nicolas, J. M. & Dubuisson, P. (2010). Cloud thermodynamic phase inferred from merged POLDER and MODIS data. Atmos. Chem. Phys., 10(23), 11851-11865
Stubenrauch, C. J., Rossow, W. B., Kinne, S., Ackerman, S., Cesana, G., Chepfer, H., Di Girolamo, L., Getzewich, B., Guignard, A., Heidinger, A., Maddux, B. C., Menzel, W. P., Minnis, P., Pearl, C., Platnick, S., Poulsen, C., Riedi, J., Sun-Mack, S., Walther, A., Winker, D., Zeng, S. & Zhao, G. (2013). Assessment of Global Cloud Datasets from Satellites: Project and Database Initiated by the GEWEX Radiation Panel. Bull. Amer. Meteor. Soc., 94(7), 1031-1049.

Title:	**Improving Atmospheric Motion Vector quality using cloud properties and cost information from EUMETSAT's Optimal Cloud Analysis**

Author/Speaker:	Francis Warrick
Company/Organisation:	ECMWF
Co-Authors:	Alessio Bozzo Marie Doutriaux Boucher Alessio Lattanzio
Presenting Author:	Alessio Bozzo

Summary:

Atmospheric Motion Vectors (AMVs) are derived by tracking cloud features through a sequence of satellite images and are an important observation type for initialising NWP forecasts. Their main weakness comes from trying to assign a height to the AMV, with some cloud situations such as multilayer clouds or thin cirrus known to be particularly problematic.

Estimates of cloud top pressure error and the cost of finding a cloud height solution are available from EUMETSAT's Optimal Cloud Analysis (OCA) product. The idea of filtering out pixels with high cost or pressure error from the AMV derivation was examined with the aim of improving the quality of the AMV retrieval. This was assessed by considering the change in background departures versus the ECMWF model from applying the filtering, and by the impact on NWP forecasts of assimilating the filtered AMV data.

Two versions of test data were produced. The initial test data showed a reduction in background departures from applying the filtering, though the impact on NWP forecasts was neutral, likely to due to the short length of the test data. We aim to show results from the new, longer dataset derived with an improved version of OCA.

Title: **Time Series Analysis of the NASA MODIS and VIIRS Cloud Products**

Author/Speaker: Steven Platnick
Company/Organisation: NASA GSFC
Co-Authors: Kerry Meyer
Nandana Amarasinghe
Galina Wind
Robert Holz
Andrew Heidinger
Steven Ackerman
Presenting Author: Steven Platnick

Summary:

We will present an overview of recent time series analyses for the MODIS standard and VIIRS/MODIS continuity products. The analyses will include time series trends for a variety of cloud datasets as well as dataset correlations associated with ENSO phases.

With a more than two-decade data record from the MODIS sensors, cloud datasets are just beginning to be useful for climate analysis. However, the utility of the data records for this purpose fundamentally depends on instrument stability as well as the capability to distinguish interannual variability from longer term secular trends. An additional, longer-term challenge is in trying to bridge cloud data records across the EOS MODIS and Suomi NPP/JPSS VIIRS era given the substantial spectral channel differences between the sensors.

To address the latter issue, a common algorithm was developed to generate a separate MODIS/VIIRS continuity data record. The basis for the continuity algorithm was the MODIS standard cloud mask product (Earth Science Data Set filename MOD35 and MYD35 for MODIS Terra and Aqua, respectively) and the joint cloud top/optical property product (MOD06/MYD06). Both product algorithms were modified to work only on the subset of spectral channels common to MODIS and VIIRS. These continuity cloud mask and cloud property products, referred to as CLDMSK and CLDPROP, respectively, have been processed for the full MODIS Aqua and VIIRS (currently flying on Suomi-NPP and NOAA-20) time series.

Title: **Current and Future Cloud Products of the Japan Meteorological Agency**

Author/Speaker: Yuuki Saeki
Company/Organisation: Japan Meteorological Agency
Co-Authors: Yurika Yamada
Taro Handa
Masaya Takahashi
Presenting Author: Yuuki Saeki

Summary:

In December 2022, Japan Meteorological Agency (JMA) switched the operational geostationary meteorological satellite from Himawari-8 to Himawari-9. For the switchover, we conducted parallel observations of Himawari-8 and 9 from September 2022, and confirmed that there was no significant difference in the observation performance of the two instruments. This presentation presents the results of the quality evaluation of L1 and L2 data from September 2022 to December 2023, including the period of parallel observation of Himawari-8 and 9.

In addition, an overview of the Fundamental Cloud Product (FCP) operated by the JMA's Meteorological Satellite Center (MSC) and a new FCP currently under development will be presented. FCP includes Cloud Mask, Cloud Phase, and Cloud Top Height as input data for other satellite products, which are required by many other satellite products, helping to conserve computing resources and save on quality control. In the current FCP, cloud mask algorithm is created at MSC by combining the NWCSAF and GOES-R algorithms, and cloud top height and cloud phase algorithms are created with reference to the GOES-R algorithm, which was extended from one to two layers of cloud radiation model at MSC. Since the cloud mask uses Numerical Weather Prediction (NWP) to calculate threshold value for clear/cloud distinction, the accuracy of such distinction may deteriorate as the accuracy of NWP declines. In addition to this, we have received requests from FCP users to provide the optical thickness of clouds, but the current algorithm cannot handle this. To solve these issues, improve the accuracy of cloud masks, and meet user needs, MSC aims to introduce a machine learning cloud mask algorithm using SVM called CLAUDIA3 and OCA developed by EUMETSAT.

Title: **Cloud remote sensing coping with multiple natural hazards in tropical developing countries**

Author/Speaker: Yong-Sang Choi
Company/Organisation: Ewha Womans University
Co-Authors: Hyoji Kang
Gyuyeon Kim
Presenting Author: Yong-Sang Choi

Summary:

Many case studies have shown that early warning is an important precaution to disaster management that can significantly reduce human casualties. However, many countries still do not have or have poor early warning systems. In 2022, the United Nations (UN) launched the "Early Warning for All" initiative with a goal of providing early warning of climate and weather information to everyone on Earth by 2027. As a result, many international projects are being planned for developing countries in Southeast Asia and Africa, where early warning systems are weak. While the situation varies from country to country, these countries share the common characteristic that national forecast data are not trusted by residents as emergency crisis information. This is not only due to the problem of weather forecasting infrastructure, but also due to the fundamental difficulty of forecasting in the tropical atmosphere. Satellites are very important in overcoming these weaknesses. In particular, geostationary satellites that can continuously observe clouds every few minutes in near real-time are excellent sources of emergency information for early warning, rather than polar-orbiting satellites that observe less than 1-2 times a day. Therefore, we propose a method for nowcasting of thunderstorms based on observed clouds and their microphysical properties from geostationary satellites. Also, remote sensing technology for real-time and short-term forecasting of hazards such as heavy rain, wildfires, floods, landslides, and air pollution index from geostationary satellites is being further developed. The Korea Meteorological Administration's Geostationary Meteorological Satellite, GK2A, which is currently in operation, observes Southeast Asia and Pacific island countries. This GK2A field-of-view includes a population of 4 billion people, so it can play a very important role in achieving the UN's goal. This paper introduces the experience of building an early warning system based on cloud remote sensing that started in the Pacific island countries and the Bandung region of Indonesia using the GK2A satellite.

Title: **MARIO: a tool for the visualization and analysis of EUMETSAT cloud and related products**

Author/Speaker: Loredana Spezzi
Company/Organisation: EUMETSAT
Co-Authors: Alessio Bozzo
Phil Watts
John Jackson
Presenting Author: Loredana Spezzi

Summary:

The EUMETSAT central facility generates and disseminates several cloud and related products from both geostationary and low-Earth orbit satellites, which serve a variety of applications, spanning from nowcasting, to numerical weather prediction to climate monitoring. The retrieved cloud parameters include cloud/dust/ash detection, cloud top height and microphysics (particle effective radius and optical thickness), and total water vapour content. MARIO (Meteorological Analysis of atmospheric Retrievals In Orbit) is a tool developed at EUMETSAT with a twofold scope: i) perform the in-house product monitoring; ii) facilitate the users' familiarization with the products and, hence, their assessment of the product quality/suitability for specific user applications and showcase the capability of the OCA multi-layer retrievals.

In this contribution, we present the status of MARIO and the plans for its further development and release to the users. The original MARIO prototype allows the interactive inspection of the Optimal Cloud Analysis (OCA) products from MSG/SEVIRI (i.e., the most comprehensive cloud product currently disseminated by EUMETSAT) via simultaneous visualization of all retrieved cloud parameters, related imagery (RGBs), plotting of cross-sections and histograms, focus on specific points of interest on the GEO disk, etc. MARIO is now undergoing a major development including its Python implementation, extension to cloud products from new GEO and LEO satellites (MTG/FCI, EPS-SG/METimage, etc.) and additional functionalities (possibility to plot time series, display additional RGBs and parameters such as total column water vapour, etc.).

Title: **Thunderstorm Nowcasting in Tropics Based on GK2A Geostationary Satellite**

Author/Speaker: Gyuyeon Kim
Company/Organisation: Ewha Womans University
Co-Authors: Yong-Sang Choi
Presenting Author: Gyuyeon Kim

Summary:

Tropical regions experience vigorous convection patterns due to solar heating, leading to extreme weather events such as storms. Thunderstorms occurring in these areas exhibit a diurnal cycle, emphasizing the importance of considering this cycle in the detection of thunderstorms. This study suggests a novel method to detect thunderstorms considering the diurnal cycle of tropical convection using the geostationary satellite GEO-KOMPSAT 2A (GK2A). We utilize 10-minute GK2A infrared (IR) brightness temperature (BT) and cloud microphysical parameters (e.g. cloud optical thickness, cloud effective radius) to detect thunderstorms effectively. The storm detection results were validated with Global Precipitation Measurement (GPM) Integrated Multi-Satellite Retrievals (IMERG) IR precipitation variables over a May-September in 2021. As result, the thunderstorm detection was further improved when cloud microphysical parameters were applied with BT. This study proposes an optimized threshold of cloud microphysical parameters to minimize the False Alarm Ratio (FAR) value also maximize the Probability of Detection (POD) and Critical Success Index (CSI) value. This study will contribute to reducing damage due to thunderstorms in the Tropics.

Title: **A first look at FCI L2 cloud retrieval products at EUMETSAT and plans for future developments**

Author/Speaker: Alessio Bozzo

Company/Organisation: EUMETSAT

Co-Authors: Loredana Spezzi
Philip Watts
John Jackson
Andre Belo do Couto
Bojan Bojkov

Presenting Author: Alessio Bozzo

Summary:

The EUMETSAT cloud top pressure and microphysics algorithm OCA (Optimal Cloud Analysis) operated on MSG-SEVIRI data since 2013, is the basis for initial operations with MTG-FCI. We will discuss the initial OCA results obtained during the instrument commissioning phase comparing against SEVIRI-based retrievals and against ground-based retrievals from the lidar, radar and microwave radiometers of the ACTRIS/Cloudnet network.

In recent years, several improvements to the baseline algorithm have been identified and tested, leading to a new OCA version (V2). This version will be incorporated into the FCI operational processor at the earliest opportunity after launch and commissioning. The main changes include:

- an improved initialisation of cloud phase and multi-layer flag based on the *effective absorption optical depth ratios* (Pavolonis, 2010);
- a new fast forward model enabling full use of the solar channels in two layer situations, improving both the retrieved effective radii and lower cloud optical thickness compared to the original method based on thermal channels only.

The OCA-V2 prototype was tested on both SEVIRI and FCI data, and we will discuss the impact of the modifications on the retrieval quality.

Title: **Improved ice cloud phase function for passive remote sensing**

Author/Speaker: Romain Joseph
Company/Organisation: CNRM
Co-Authors: Jérôme Vidot
Emmanuel Fontaine
Presenting Author: Romain Joseph
Summary:

As part of the NWCSAF (Nowcasting Satellite Application Facility), the CNRM participates in the retrieval of cloud properties from geostationary satellite observations. These retrievals include the Cloud Mask and Cloud Types classification, thermodynamics properties at the macroscopic scales (Cloud Top Temperature and Height) as well as microphysical cloud properties (effective radius, optical thickness, liquid and ice water path). The cloud optical properties (including scattering, absorptions and emissions) are derived from cloud microphysical model in order to perform radiative transfer simulations. In this study, I combine cloud microphysical properties retrieved from DARDAR and in-situ observations with ERA-5 reanalysis to perform radiative transfer simulations with RTTOV. Hence, these simulation are compared with Meteosat Second Generation observations. Our goal is to identify the cloud properties that can affect the difference between observations and simulations in order to propose a new parameterization of the ice cloud scattering phase function in the radiative transfer model RTTOV (Radiative Transfer for TOVS).

Title: **Is the high droplet number density of late spring Arctic water clouds an indication of algal bloom - cloud -Arctic melting feedback?**

Author/Speaker: Yongxiang Hu
Company/Organisation: NASA Langley Research Center
Co-Authors:
Presenting Author: Yongxiang Hu

Summary:

Water cloud droplet number density, Nd, together with other cloud microphysical properties such as liquid water content, extinction coefficient and effective droplet size, can be accurately estimated from CALIPSO measurements (Hu et al., 2021, https://www.frontiersin.org/articles/10.3389/frsen.2021.724615/full).

One interesting findings from the new droplet number density statistics is the huge Nd values of boundary layer clouds in the springtime Arctic. Comparing Nd with chlorophyll biomass of snow/ice algae calculated from high resolution Arctic models, we also found excellent spatial/temporal correlations between the algal biomass and water cloud droplet number density. With the 16-year global water cloud microphysics record derived from CALIPSO data, we also found good correlation between the inter-annual variability of the late spring Arctic water cloud droplet number density and that of the sea-ice retreat in the fall.

In this presentation, I will introduce

(1) the lidar measurements of water cloud microphysical properties; and,

(2) a hypothesis of a positive feedback mechanism of springtime Arctic snow/ice algae, biological aerosols, Arctic clouds and sea-ice melting.

I will also introduce the ongoing ICESAT-2 data analysis of snow properties (Hu et al., 2022, https://www.frontiersin.org/articles/10.3389/frsen.2022.855159/abstract) and the sea-ice cover that may help evaluate the feedback mechanisms.

Title: **The Polarized Submillimeter Ice-Cloud Radiometer (PolSIR): Observing the diurnal cycle of ice clouds in the tropics and sub-tropics**

Author/Speaker: Ralf Bennartz
Company/Organisation: Vanderbilt University
Co-Authors: Dong Wu
Presenting Author: Ralf Bennartz
Summary:

The Polarized Submillimeter Ice-Cloud Radiometer (PolSIR): Observing the diurnal cycle of ice clouds in the tropics and sub-tropics

Ralf Bennartz[1], Dong Wu[2], Ian Adams[2], Donifan Barahona[2], Emily Berndt[3], Helene Brogniez[4], Negar Ehsan[2], Greg Elsaesser[5,6], Jie Gong[2], Ben Johnson[7], Bryan Karpowicz[8], Rachael Kroodsma[2,9], Daniel Loveless[10], Aronne Merrelli[11], Claire Pettersen[11], Paul Racette[2], Anita D. Rapp[12], Chris Vanags[1]

1: Vanderbilt University
2: NASA GSFC
3: NASA MSFC
4: Paris Saclay University
5: Columbia University
6: NASA GISS
7: UCAR
8: GMAO
9: University of Maryland, College Park
10: Indiana University
11: University of Michigan
12: Texas A&M University

Abstract

In May 2023 NASA has selected PolSIR as the latest addition to its Earth Venture Instrument class missions. PolSIR addresses key research priorities related to uncertainties in our current understanding in high clouds and cloud feedbacks as formulated in NASA's latest Decadal Survey and in the latest Intergovernmental Panel on Climate Change (IPCC) Assessment. In this context, PolSIR will address the following objectives:

- Constrain the seasonally influenced diurnal cycle amplitude, form, and timing of the ice water path (IWP) and particle diameter in tropical and sub-tropical ice clouds
- Determine the diurnal variability of ice clouds in the convective outflow areas and understand relation to deep convection
- Determine the relationship between shortwave and longwave radiative fluxes and the diurnal variability of ice clouds

- Enable improvement of climate models by providing novel observations of the diurnal cycle of ice clouds, ultimately leading to improved climate modeling skills and increased fidelity of climate forecasts in support of critical decision-making.

The PolSIR mission consists of two 12U CubeSats, each equipped with a cross-track scanning polarized submillimeter radiometer in the spectral range of 325–680 GHz. The two PolSIR satellites fly in separate, 52-degree inclination, non-sun-synchronous orbits, taking science measurements between ±35 degrees latitude enabling monthly sampling of the diurnal cycle of ice clouds and their microphysical properties in the tropics and sub-tropics. PolSIR's observation concept provides significant benefits over the Program of Record (PoR) as well as synergies with future missions which will either be in sun-synchronous orbits, thus not sampling the diurnal cycle, or lack the observation frequencies needed to fully observe ice water path (IWP).

The mission is led by Ralf Bennartz, principal investigator at Vanderbilt University in Nashville, Tennessee, and by Dong Wu, deputy principal investigator at NASA's Goddard Space Flight Center in Greenbelt, Maryland. NASA Goddard will provide the project management team that builds the two instruments, while science operations will be conducted by the Space Science and Engineering Center at the University of Wisconsin - Madison. The two spacecraft will be built by Blue Canyon Technologies in Lafayette, Colorado. Launch of the two satellites is currently anticipated for late 2027.

Title: **Artificial intelligence technology to retrieve all-day cloud properties based on geostationary satellite measurements**

Author/Speaker: Feng Zhang
Company/Organisation: Department of Atmospheric and Oceanic Sciences and Institutes of Atmospheric Sciences, Fudan University
Co-Authors: Zhijun Zhao
Jingwei Li
Qiong Wu
Wenwen Li
Wei Han
Presenting Author: Feng Zhang

Summary:

Clouds have a profound influence on the radiation budget and climate change dynamics in the Earth-atmosphere system, the accurate acquisition of cloud physical parameters is essential for estimating shortwave radiation and advancing climate change research. With the development of remote sensing technology, satellite remote sensing has become a primary means to acquire cloud physical properties. The used satellite remote sensing cloud products are mainly derived from polar-orbiting and geostationary satellite sensors. However, existing cloud products and retrieval algorithms suffer from limitations in spatiotemporal coverage and computational efficiency.

In this study, an image-based transfer learning model (TLM) applied to advanced imager onboard the geostationary satellite was developed to realize the retrieval of all-day cloud physical properties through combining the observation advantages of geostationary and polar-orbiting satellites. This model was trained using thermal infrared measurements from geostationary imagers and auxiliary data as the input, and established a preliminary relationship with official cloud products from advanced Himawari imager (AHI) via pre-training. Then, it extended this relationship to official cloud products from Moderate Resolution Imaging Spectroradiometer (MODIS) via transfer training (Fig. 1).

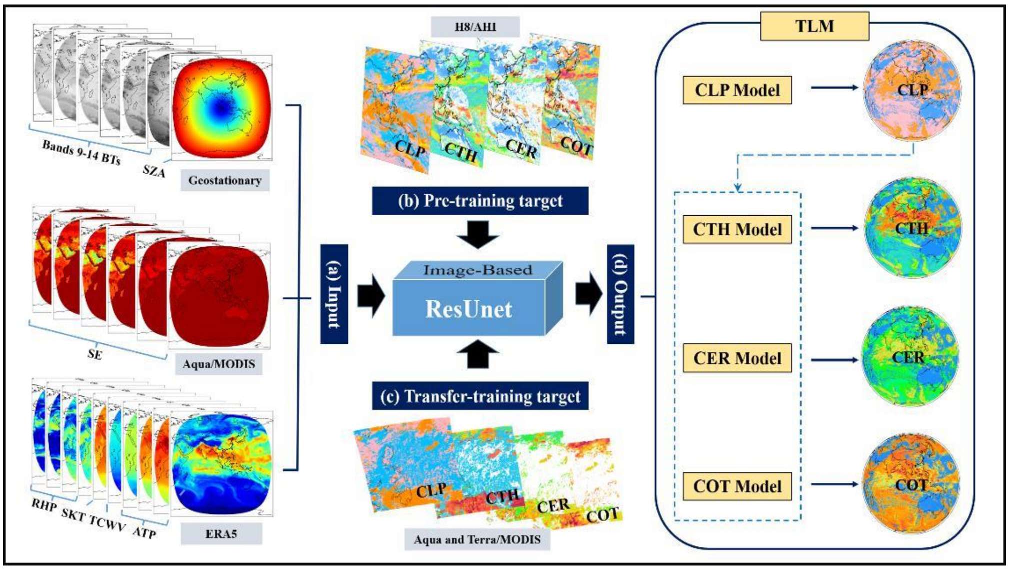

Figure 1. The framework and flowchart of image-based transfer learning model.

At first, we applied this image-based TLM to the advanced geostationary radiation imager (AGRI) equipped on the Fengyun-4A geostationary satellite. Compared to the pixel-based random forest model (RFM), TLM utilizes the spatial information of clouds to significantly improve the retrieval performance, and the retrieval speed of a single full-disk by more than 6 times. Taking MODIS official products as the benchmarks, AGRI TLM products have an overall accuracy of 79.93% for cloud phase (CLP) identification, and the root mean squared errors (RMSE) of 1.85 km, 6.72 μm, and 12.79 for cloud top height (CTH), cloud effective radius (CER), and cloud optical thickness (COT) estimations, outperforming AGRI official and AHI official products (Fig. 2). Against the active remote sensing dataset of Cloud-Aerosol Lidar with Orthogonal Polarization, CLP and CTH obtained from AGRI TLM products demonstrate stable performance at night and in seasonal cycles.

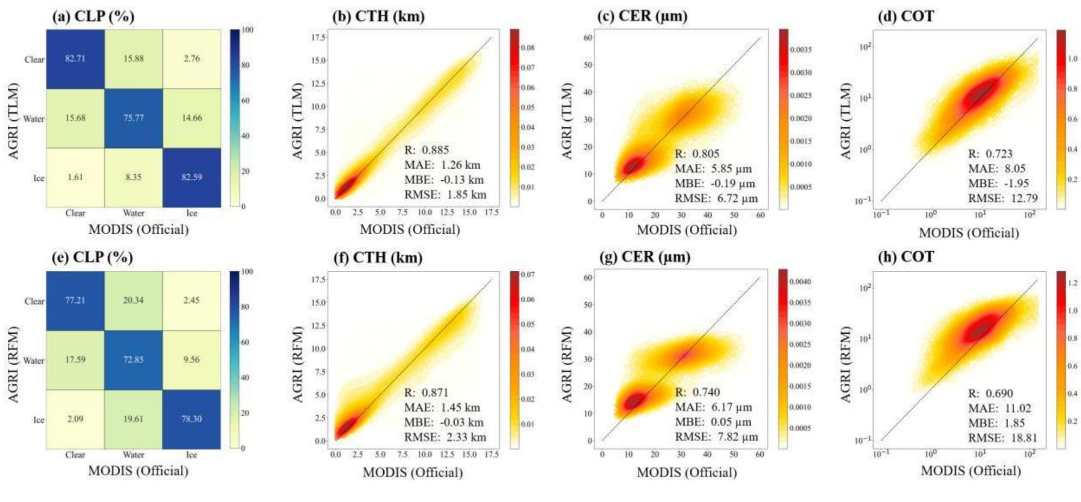

Figure 2. Confusion matrix of CLP (a, e) and joint probability density distribution of CTH (b, f), CER (c, g), and COT (d, h) between MODIS official and AGRI TLM (a-d) or AGRI RFM (r-h) products.

We also applied this image-based TLM to the AHI equipped on the Himawari-8 geostationary satellite. To evaluate the accuracy of the model in the daytime, we selected the MODIS official products to validate precision of cloud products during four different months. The results show that the AHI TLM products have higher precision of CTH (RMSE: 1.874 km), CER (RMSE: 4.575 µm) and COT (11.166) than that of the AHI official products (CTH RMSE: 2.826 km, CER RMSE: 11.299 µm, COT RMSE: 14.753), as shown in Fig. 3.

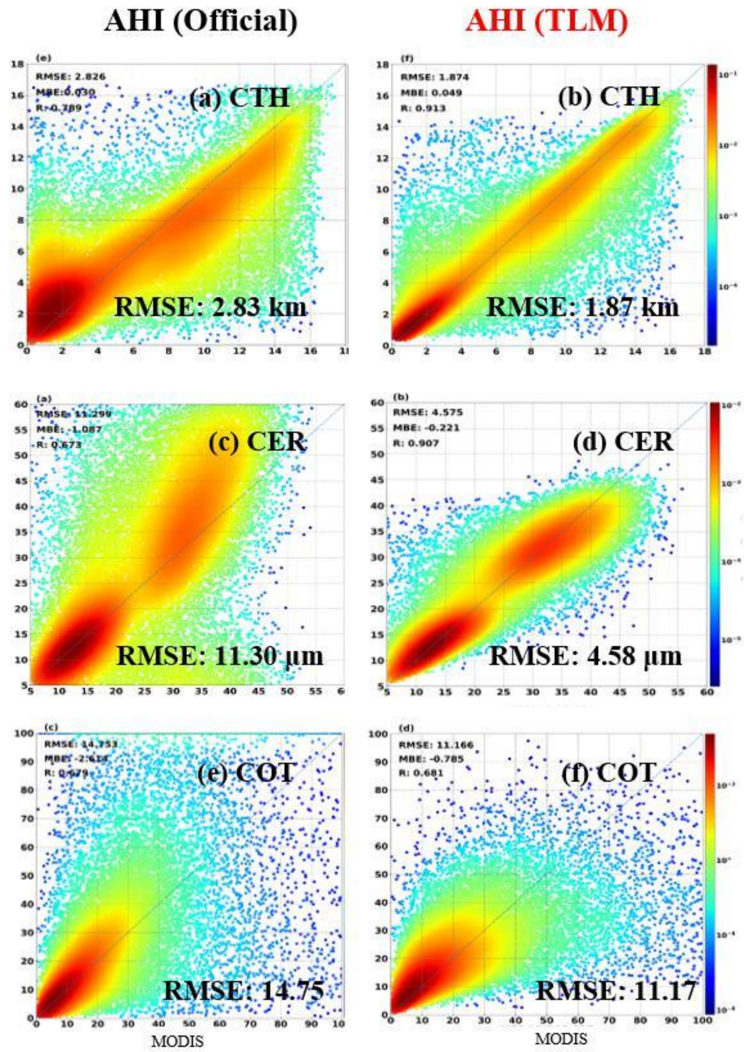

Figure 3. Joint probability density distribution of CTH (b, f), CER (c, g) and COT (d, h) obtained from AHI official (a, c, e) and AHI TLM (b, d, f) products against MODIS official product.

To validate the precision of the model during the nighttime, we used active remote sensing cloud products to validate the precision of AHI TLM and AHI official products at both day and night. The results show that AHI TLM products have slightly higher precision during the daytime than that during the night, the precision of AHI TLM products is higher than that of AHI official products during both daytime and nighttime (Fig. 4).

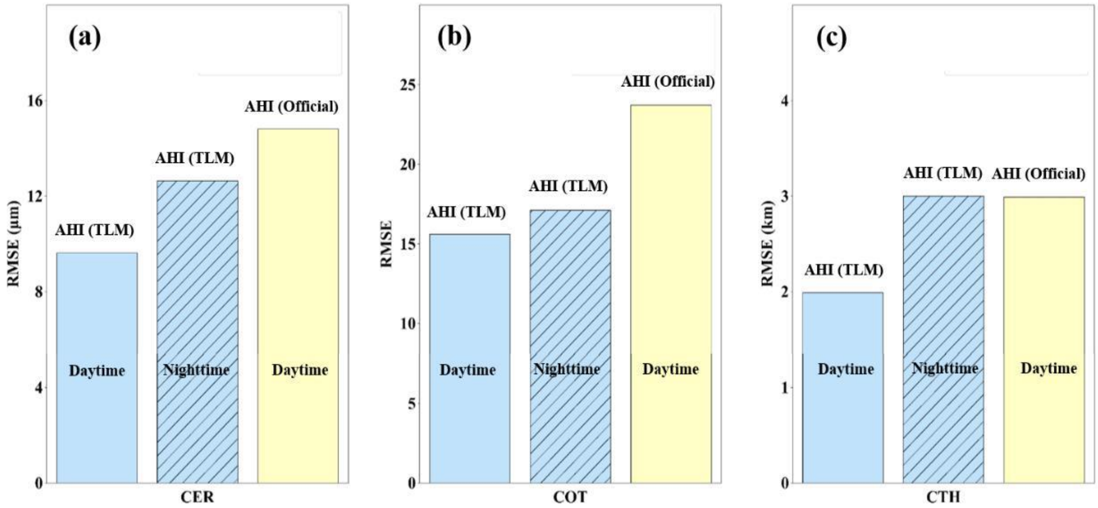

Figure 4. RMSE of CER (a), COT (b) and CTH (c) obtained from AHI official and AHI TLM products against the active remote sensing cloud products.

Key words: cloud physical properties; image-based transfer learning model; Fengyun-4A geostationary satellite; Himawari-8 geostationary satellite;

Title: **Cloud and Precipitation Retrieval for EarthCARE's Doppler Cloud Profiling Radar**

Author/Speaker: Kamil Mroz
Company/Organisation: University Of Leicester
Co-Authors: Bernat Puidgomenech Treserras
Alessandro Battaglia
Pavlos Kollias
Frederic Tridon
Aleksandra Tatarevic
Presenting Author: Kamil Mroz

Summary:

This presentation is dedicated to the development of the Cloud and Precipitation Microphysics (C-CLD) algorithm. This algorithm leverages data obtained from the EarthCARE 94-GHz Doppler Cloud Profiling Radar (CPR) to extract microphysical details from cloud and precipitation systems. The approach involves optimal estimation, combining CPR data with a-priori knowledge of cloud and precipitation climatology. The algorithm focuses on stratiform precipitation and retrieves profiles of two moments of the particle size distribution (PSD): mass content and mean mass-weighted diameter.

To reduce the number of the retrieval unknowns and establish reliable forward model relations, a large dataset of surface-based observations is employed. Additionally, a one-dimensional parameterization is introduced to represent a spectrum of ice particle densities. The retrieval framework was tested using simulated EarthCARE CPR observations across various climatological regimes, demonstrating accurate estimation of rain parameters aided by Doppler measurements. However, challenges persist in the retrieval of ice particle information.

The presentation also addresses challenges associated with generating a-priori properties for precipitation and ice scattering ambiguities. It recognizes the unique capabilities of EarthCARE's CPR, including its fine horizontal resolution that mitigates issues related to multiple scattering and non-uniform beam filling. The talk underscores the ongoing need for algorithm refinement, calibration/validation activities, and cross-validation with other precipitation products to enhance accuracy and broaden the algorithm's applicability.

Future improvements are outlined, encompassing the incorporation of two-dimensional radar information, inclusion of brightness temperature data, refining a-priori assumptions and potential application in convective precipitation. The overarching goal remains the continual enhancement of accuracy and the broadening of the algorithm's utility.

Title: **Arctic low-level clouds – an intercomparison of satellite data and reanalyses**

Author/Speaker: Irina Holtermann
Company/Organisation: Deutscher Wetterdienst
Co-Authors: Martin Stengel
Presenting Author: Irina Holtermann
Summary:

Clouds are an essential part in the processes contributing to the excessive Arctic warming, known as Arctic amplification. Satellite-derived climate data records (CDRs) and reanalysis products are used for climate studies because they provide long-term series and arctic-wide coverage of cloud parameters. However, retrieving and modelling arctic clouds are often associated with large uncertainties. Acknowledging these difficulties, it seems obvious that well-established and often used cloud datasets should be assessed over the Arctic by characterizing their discrepancies and commonalities.

This study presents the inter-comparison of satellite-derived cloud CDRs: ISCCP-HGM, Cloud_cci AVHRR-PMv3 as well as the recently released CLARA-A3 and Patmos-x v6 covering the period 1984-2020. The satellite-derived data is also compared to the reanalysis data: ERA-Interim, ERA-5 and MERRA-2. Additionally, CALIPSO and MODIS cloud products were chosen as independent satellite-based observation references.

The investigated parameter is monthly mean of low-level cloud fraction cover (CFC). The study area is defined northward of 60°N. Seasonal cycles, interannual variability and maps of monthly mean low-level CFC and its decadal trends are used for the temporal and spatial inter-comparison of the data records.

All analysed satellite-derived CDRs show in general good agreement on spatial patterns of the multi-annual mean low-level CFC. The seasonal cycles are similar for all the satellite-derived products. The largest deviation between the analysed data records for the period 1984-2018 is observed in winter months, where the monthly means of low-level CFC are spread over 22% (between 13% and 35%), the lowest deviation is seen in July where all the values lay within 11% (between 24% and 35%). The interannual variability of the low-level monthly mean CFC over 35 years is the highest between October and February, potentially reflecting an increase of the autumnal low-level CFC over the period, as found in other studies.

There is a notable difference between satellite-derived CDRs and reanalyses, especially over sea and in winter months. Reanalysis products, ERA-5 and ERA-Interim, show the same seasonal cycle as the satellite-derived products and tend to overestimate the mean low-level CFC in winter. MERRA-2 CFC shows a different annual cycle with a maximum in winter, whereas the other CDRs have the maximum in autumn.

All investigated data records show an increase of low-level cloud fractional cover in autumn and winter. Over the mean sea ice area, the upward trend achieves 4% per decade in the

late autumn. In summer a negative trend is observed in all satellite-derived CDRs, whereas the reanalyses are found to indicate a positive trend, though with a lower magnitude. The trends shown in all satellite-derived data records are in very good agreement, the reanalyses differ in the magnitude and quantity of the low-level CFC trends. Despite these discrepancies between satellite-derived CDRs and reanalyses, all data records show good agreement in the low-level CFC trend with an increasing cloud amount in winter.

Title: **Research on summer Arctic cloud detection model based on FY-3D/MERSI-II infrared data**

Author/Speaker: Xi Wang
Company/Organisation: National Satellite Meteorological Center,CMA
Co-Authors: Jian Liu
Bingyun Yang
Presenting Author: Xi Wang
Summary:

Combined with the spaceborne lidar active observations, an Arctic summer cloud detection model is studied here based on the data from the FY-3D/MERSI-II（FengYun-3D/Medium Resolution Spectral Imager-II). By using probability density function analysis method and introducing loss rate to optimize the correlating thresholds， an infrared cloud detection model for the Arctic summer is developed based on the confidence levels. The validation results reveal that the cloud detection results are highly consistent with the matched spaceborne lidar observations. The high confidence levels basically represent the cloudy pixels， while the low values correspond to the clear ones. The case study shows that the cloudy pixels is 100% consistent with the pixels of the confidence level higher than 0. 8. When the confidence level is lower than 0. 2， 10. 15% of the cloudy pixels are still misjudged as clear pixels， which are primarily single-layer clouds with the cloud top heights between 4 and 6km. This may be caused probably by the cirrus clouds, which needs further study.

Title:	**Lightning Imager Level-1b and Level-2 commissioning status**

Author/Speaker:	Bartolomeo Viticchie
Company/Organisation:	EUMETSAT
Co-Authors:	Sven-Erik Enno Fabian Mueller Steven Hadesty Janja Avbelj Johannes Mueller
Presenting Author:	Bartolomeo Viticchie

Summary:

The Meteosat Third Generation Lightning Imager (MTG LI) has been successfully launched on December 13, 2022 aboard the Ariane 5 rocket from Kourou (French Guiana). This brand new European instrument is devoted to the diagnostic of lightning activity over Europe, Africa, and a large portion of the Atlantic Ocean. In detail, LI will detect continuously from space light pulses at could-tops that are generated by lighting within a 1.9 nm wide band centred on 777.4 nm (i.e., the standard wavelength for lightning imaging), with 4.5 km resolution at sub-satellite point, and 1 kHz acquisition frequency. Since the first LI Level 0 acquisitions in April 2023, several LI Commissioning milestones have been reached. In this contribution, we present an overview of such milestones together with the key results so far derived, i.e., first assessment of LI lightning detection efficiency and lightning location accuracy at Level 1b and Level 2.

Title:	**Monitoring of LI Level-1b and Level-2 product performance during routine operations and commissioning**

Author/Speaker: Sven-Erik Enno
Company/Organisation: EUMETSAT
Co-Authors: Bartolomeo Viticchiè
Alessio Bozzo
Loredana Spezzi
David Navia
Corvin-Petrut Cobarzan
Presenting Author: Sven-Erik Enno

Summary:

The Meteosat Third Generation Lightning Imager (MTG LI) has been launched on December 13, 2022 aboard the Ariane 5 launcher from Kourou (French Guiana). This brand new European instrument is devoted to the diagnostic of lightning activity over Europe, Africa, and a large portion of the Atlantic Ocean. In detail, it will detect continuously pulses of light generated by lighting from space within a 1.9 nm wide band centred on 777.4 nm, with a 4.5 km resolution at sub-satellite point, and 1 kHz frequency. Starting from the first acquisitions, LI products (at Level 0, 1b and 2) have been undergoing rigorous performance assessment using dedicated software tools developed at EUMETSAT.

In this contribution, we outline the main functionalities of such tools and present the results so far derived on LI lightning detection performances and lightning location accuracy. In addition, we present preliminary results of an analysis aimed at interpreting LI lightning detection performances through the synergic use of LI data and Level 2 cloud products.

Title: **Arctic cloud properties and its correlation with extreme sea ice anomalies**

Author/Speaker: Jian Liu
Company/Organisation: National Satellite Meteorological Center, CMA
Co-Authors: Xi Wang
Presenting Author: Jian Liu
Summary:

The Arctic region is a sensitive and critical area for global climate and environmental changes. Arctic sea ice anomaly is an indicator of climate change. Clouds, especially low clouds, are one of the most important variables that affect sea ice variability. Given the scarcity and uneven distribution of in-site observation in the Arctic, satellites are an important means of observation.

The study data are obtained from NOAA/AVHRR and AIRS cloud products. A long-term dataset of 38 years (1982–2019) from AVHRR is applied to investigate the spatio-temporal seasonal trends in cloud fraction over the Arctic seas by the non-parametric methods. The results suggest that the cloud fraction shows a positive trend for all seasons since 2008. We further obtained a significant negative correlation between cloud fraction and sea-ice concentration during autumn, which is largest in magnitude for regions with substantial sea ice retreat. It was found that the negative correlation between cloud fraction and sea-ice concentration is not as strong as that for the surface downwelling longwave flux. It indicates the increase in cloudiness may result in positive anomalies in surface downwelling longwave flux which is highly correlated with the sea-ice retreat in autumn.

The results of the data evaluation of passive optical satellite cloud cover using active observation data show that AIRS effective cloud fraction (ECF) has the similiar spatial distribution pattern compared with active observation. The deviation is mainly distributed at the lower layers, with better agreement between the two kinds of data at the middle and upper layers. This study attempts to analyze the seasonal variations of mid-level clouds in the Arctic region and explore the possible relationships with sea ice changes using AIRS ECF over the past two decades. For the mid-level clouds of the three layers (648, 548 and 447hPa) involved in AIRS data, the high values of ECF occur in summer and the low values primarily occur in early spring, while the seasonal variations are obviously different. The ECF anomalies are notably larger at 648hPa than those at 548 and 447hPa. Meanwhile, the ECF at 648hPa show a clear reduced seasonal variability for the regions north of 80 °N, which has its minimum coefficient of variation (CV) during 2019 to 2020. The seasonal CV is relatively lower in the regions of 60-0°W and 0-60°E, where the regions are dominated by Greenland and the sea areas with less sea ice covered. The analysis indicates that the decline in mid-level ECF's seasonal mean CV is closely correlated to the retreat of Arctic sea ice during September. In the areas with lower CV of mid-level ECF, the frequency of leads increases significantly during sea ice anomaly years. However, the situation differs in the central Arctic sea region (north of 85°N), where the CV and leads frequency do not demonstrate a significant association. This probably attributed to the fact that the sea ice in this area mainly consists of multi-year sea ice with infrequent leads.

Title: **Lessons from using and comparing ISCCP, MODIS, VIIRS joint histograms and associated cloud regimes**

Author/Speaker: Lazaros Oreopoulos
Company/Organisation: NASA-GSFC
Co-Authors: Jackson Tan
Dongmin Lee
Nayeong Cho
George Tselioudis
Presenting Author: Lazaros Oreopoulos

Summary:

One of the most prominent Level-3 daytime satellite cloud products of the last two decades is the joint histogram describing the subgrid distribution of cloud fraction in different cloud optical thickness (TAU) - cloud top pressure (CTP) combinations, aka the CTP-TAU joint histogram (JH). This JH, first conceived by ISCCP, encapsulates the shortwave (primarily TAU-dependent) and longwave (primarily CTP-dependent) radiative impact of clouds. It has been used to classify clouds into types, regimes, and recently regimes of regimes. These cloud classifications can be used for cloud and radiation evaluation of appropriately equipped models (i.e. running a cloud simulator) and for studying the contribution of changes in cloud amount, height, and opacity to cloud feedback via cloud radiative kernels.

In our presentation we will summarize the different flavors of cloud regimes (CRs), derived via clustering from CTP-TAU JHs, from ISCCP, MODIS (several versions, some obtained from our own processing of Level-2 data into Level-3), and VIIRS, and techniques that can be used to understand the high-level differences between the relevant daytime cloud properties of these datasets. These techniques include matrices that summarize probability of CR agreement when assigning coincident JHs from different datasets and efforts to reconcile CRs across datasets via machine learning and regimes of regimes, the latter conveying consistency in CR mixture between two datasets over a chosen temporal scale. We also use coincident active observations from CloudSat and CALIPSO to understand possible sources of discrepancies.

Title: **Climate variability and response to sea surface temperatures in global cloud climate data records**

Author/Speaker: Abhay Devasthale
Company/Organisation: SMHI
Co-Authors: Karl-Göran Karlsson
Presenting Author: Abhay Devasthale

Summary:

Using four global cloud climate data records (CDRs), namely CLARA-A3, ESA Cloud CCI V3, ISCCP-HGM and PATMOS-x V6, spanning nearly forty years, we discuss two important aspects of cloud variability from the climate perspective. Do the cloud CDRs show similar dominant modes of variability when tested against MODIS-Aqua as a reference? And do these CDRs also show similar response to sea surface temperatures over the tropical oceans? To answer the first question, we carry out a rotated empirical orthogonal functions (REOF) analysis of the CDRs for two variables, namely total cloud fraction and cloud top temperature. We discuss the spatial patterns of REOFs and the pattern correlations against MODIS-Aqua and among the different combinations of CDRs. To answer the second question, we investigate change in cloud property per degree change in SST over the tropical oceans. We discuss potential drivers behind the observed cloud response to SSTs in the four chosen CDRs.

Title: **Global analysis of super-cooled liquid clouds from the current geo-ring of advanced VIS/IR imagers**

Author/Speaker: Martin Stengel
Company/Organisation: DWD
Co-Authors: Jan Fokke Meirink, Karl-Göran Karlsson, Salomon Eliasson, Irina Solodovnik
Presenting Author: Martin Stengel

Summary:

Within the ISCCP-NG project a geo-ring L1g product has been developed that contains the measurements of the passive VIS/IR imagers on-board the current geo-ring satellites on a common grid. This L1g product facilitates amongst others the (near-) global analysis of clouds and their properties with a 30-min resolution. First cloud property data based L1g data have been prototyped in the recent past, e.g. by CM SAF.

The CM SAF cloud algorithms are currently under revision to better suit the current and future geo-ring constellations. One important and new component is the inclusion of a new cloud thermodynamic phase retrieval based on artificial neural networks that has the potential to boost the quality of the retrieval of this very important cloud property.

Observing the thermodynamic phase of clouds, i.e. for clouds with temperature between -40°C and 0°C, can help to better understand glaciation processes in clouds and can serve as observational reference for atmospheric models. While satellite observations are restricted to spatial structures of approx. 1 km and above; they can provide regional to global and short-term to long-term representations of cloud thermodynamic phase and can thus build a sound basis for model evaluation.

In this presentation, we will introduce the new cloud phase developments and corresponding application to the geo-ring imagers ABI, AHI and SEVIRI. This also includes the homogenization of all geo-ring measurements through spectral band adjustment. We will further demonstrate the potential of (near-) global cloud products with 30-minutes for detecting the frequency of super-cooled clouds and thus for a better understanding of cloud processes such us glaciation.