Abstracts

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ABSTRACTS ORAL SESSION

CLIMCAPS: Use of the AIRS/AMSU and CrIS/ATMS continuity sounding product for cloud feedback studies.

Chris Barnet, Nadia Smith, Ashley Wheeler

Science and Technology Corp.

The AIRS/AMSU (Atmospheric Infrared Sounder; Advanced Microwave Sounding Unit) onboard the EOS/Aqua was launched in 2002. CrIS/ATMS (CrossTrack Infrared Sounder; Advanced Technology Microwave Sounder) onboard Suomi NPP was launched in 2011 and was also launched on the first Joint Polar Sounding System (JPSS) satellite in 2017. Demonstrating data continuity between these three platforms has become a priority especially since EOS/Aqua is well past its design lifetime. Additionally, with future JPSS satellites, this record of soundings will be extended into future decades and will enable important scientific research on atmospheric processes at large spatial and temporal scales. The AIRS/AMSU and CrIS/ATMS have many differences in instrument design, spatial sampling, spectral coverage and resolution. Instruments also degrade with time. It is only with careful and transparent error characterization that systematic effects can be accounted for, and preferably minimized, in retrieved sounding products.

We have developed the Community Long-term Infrared Microwave Coupled Product System (CLIMCAPS) to achieve a seamless record of satellite soundings. A CLIMCAPS sounding is comprised of a set of parameters that characterizes the full atmospheric state and includes profiles of temperature, moisture, cloud height and fraction, surface products, and many trace gas species. The information content of sounders, such as AIRS, CrIS, AMSU and ATMS, is a function of lapse rate, the quantity of absorbers such as clouds, moisture and trace gases, as well as the instrument's sensitivity. Information content can vary vertically, spatially, and temporally. CLIMCAPS uses the NASA Modern-Era Retrospective Analysis for Research (MERRA) as an a-priori to stabilize the temperature and moisture in low information content domains across the Aqua, S-NPP, JPSS-1 (now called NOAA-20), and future JPSS satellites. We will demonstrate the unique properties of the CLIMCAPS algorithm that enables continuity and error characterization with the Aqua and S-NPP data record. This presentation will focus on the value of the coupled microwave and infrared products for cloud feedback studies as well as the ability of this algorithm to support user-developed cloud parameter retrievals.

Towards Continuity in IR Absorption Radiances from MODIS and VIIRS

Bryan A. Baum, Elisabeth Weisz, and W. Paul Menzel

Affl. Lead author: Science and Technology Corp.

This talk will discuss the progress and issues involved with developing a continuous record of cloud properties since 1978, beginning with the High Resolution Infrared Radiation Sounder (HIRS), then MODIS (Moderate resolution Imaging Spectroradiometer) on the NASA Terra/Aqua platforms, and into the future from merged CrIS (Cross-track Infrared Sounder) and VIIRS (Visible Infrared Imaging Radiometers Suite) data. The MODIS measurements include infrared (IR) window radiances at 8.5-, 11- and 12-microns, three channels in the 4.5-micron CO2 absorption band, two channels in the broad 6.7-micron window band, and four 15-micron channels in the broad CO2 absorption band. Cloud top pressure/height and emissivity are derived using a technique in which the strength is retrievals of mid-to-high clouds but less so for low clouds where there is little thermal contrast with the surface; additionally the IR absorption bands are used to infer cloud thermodynamic phase. The goal now is to extend this record from HIRS and MODIS into the Joint Polar Satellite System era. However, VIIRS has no infrared (IR) absorption channels. Our team will demonstrate the ability to construct MODIS-like IR absorption channels for VIIRS from a fusion of VIIRS and CrIS radiometric data. The method consists of two steps: (1) performing a nearest neighbor search using a k-d tree algorithm on both high spatial and low spatial resolution split-window imager radiances, and (2) averaging the convolved sounder radiances (at the lower spatial resolution of the sounder) for the nearest neighbors selected in (1) for each imager pixel. The result of the fusion process is the construction of IR absorption channel radiances at the VIIRS pixel spatial resolution of 750 m (i.e., M-band resolution). The radiometric accuracy of this approach was tested using MODIS and AIRS (Advanced Infrared Sounder) and found to be within 1% for the CO2 channels and slightly higher for the water vapor channels. The fusion radiances are now being generated operationally in forward stream at the Atmosphere SIPS (Science-led Investigator Processing System) at the University of Wisconsin-Madison. We will show fusion results for IR radiances at 4.52 micron (CO2), 6.72 micron (H2O) and 13.94 micron (CO2) by comparing MODIS observed and constructed radiances for these bands, and further show how the MODIS radiances compare with those derived from VIIRS on the S-NPP platform.

Investigating the sensitivity of SEVIRI liquid cloud optical properties retrieval to illumination conditions using two MSG satellites

Nikos Benas, Jan Fokke Meirink, Martin Stengel, Piet Stammes

Affl. lead author: KNMI

Retrievals of cloud properties from geostationary satellite sensors offer extensive spatial and temporal coverage and resolution. The Spinning Enhanced Visible and Infrared Imager (SEVIRI), on board the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Meteosat Second Generation (MSG) satellites, provides measurements every fifteen minutes. This high temporal resolution gives unique opportunities for the detection of diurnally resolved cloud properties. However, retrievals are sensitive to diurnally varying illumination conditions, including cloud glory and cloud bow, which can lead to irregularities in the diurnal data record. In this study, these conditions and their effects on liquid cloud optical properties (cloud optical thickness and effective radius) were analyzed using the Satellite Application Facility for Climate Monitoring (CM SAF) Cloud Physical Properties (CPP) retrieval algorithm. Their quantification was based on the synergistic use of SEVIRI reflectances and products from Meteosat-8 and -10, which are located over the Indian and Atlantic Ocean, respectively, and cover an extensive common area under different viewing angles. Comparison of the retrievals over different underlying surfaces (ocean/land) and using different spectral combinations of visible and shortwave-infrared channels were also performed, to provide further insights into the relative importance of these factors in the retrieval process. The sensitivity of these irregularities to the width of the assumed droplet size distribution was analyzed by using different values of the effective variance (veff) of the size distribution. Intercomparisons of the products derived from these retrievals highlight the importance of selecting the appropriate value of veff and provide a way for improving the quality of the cloud products in future climate data record releases.

Global and regional estimates of warm cloud droplet number concentration based on 13 years of AQUA-MODIS observations

Ralf Bennartz and John Rausch

Vanderbilt University

We present a climatology of boundary layer cloud droplet number concentration (CDNC) based on 13 years of Aqua-MODIS observations. CDNC monthly mean values and uncertainties are provided for clouds over global ocean scenes. We discuss and quantify systematic error sources and retrieval artifacts that remain as a consequence of the retrieval process itself or observation geometry. Retrievals are performed at native instrument resolution (1x1 km at nadir) instead of aggregated data, which has been used in some earlier climatologies. This allows us to screen clouds that a droplet effective radius stratification consistent with that assumed in the CDNC retrieval. Through the application of this criterion, we see significant changes in the phase and magnitude of the annual CDNC cycle. After an optimal screening was established, a final CDNC climatology was generated. Resulting CDNC uncertainties are reported as monthly-mean standard deviations of CDNC over each 1deg x 1deg grid box. These uncertainties are of the order of 30% in the stratocumulus regions and 60 to 80% elsewhere.

We have developed the Community Long-term Infrared Microwave Coupled Product System (CLIMCAPS) to achieve a seamless record of satellite soundings. A CLIMCAPS sounding is comprised of a set of parameters that characterizes the full atmospheric state and includes profiles of temperature, moisture, cloud height and fraction, surface products, and many trace gas species. The information content of sounders, such as AIRS, CrIS, AMSU and ATMS, is a function of lapse rate, the quantity of absorbers such as clouds, moisture and trace gases, as well as the instrument's sensitivity. Information content can vary vertically, spatially, and temporally. CLIMCAPS uses the NASA Modern-Era Retrospective Analysis for Research (MERRA) as an a-priori to stabilize the temperature and moisture in low information content domains across the Aqua, S-NPP, JPSS-1 (now called NOAA-20), and future JPSS satellites. We will demonstrate the unique properties of the CLIMCAPS algorithm that enables continuity and error characterization with the Aqua and S-NPP data record. This presentation will focus on the value of the coupled microwave and infrared products for cloud feedback studies as well as the ability of this algorithm to support user-developed cloud parameter retrievals.

Dissecting effects of orbital drift of polar-orbiting satellites on accuracy and trends of cloud fraction climate data records

Jędrzej S. Bojanowski, Jan P. Musiał

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Polar-orbiting satellite sensors uniquely provide almost 4-decade-long global climate data records (CDR) of cloud cover. This requires combining data from consecutive satellite platforms, for instance NOAA and MetOp. One of the recently released CDRs generated in a frame of the Cloud_cci project consists of cloud physical properties derived from Advanced Very High Resolution Radiometer (1982-2014, Stengel et al., 2017). Generation of such long CDRs is challenging due to technical limitations related to: degradation of satellite sensors, different number of simultaneously operating satellites, radiometric and geometric distortions, as well as satellite orbital drift. As a result of the drift, the cycle of diurnal cloudiness is sampled at different local times, which in turn leads to ambiguous trends revealed during climatological analyses. The aim of the study is to quantify the uncertainty and ensuing spurious trends in level-3 AVHRR-based cloud climate data records caused by the satellite orbital drift.

The analysis is based on a high temporal 30-minute reference time series of cloud fractional cover (CFC) derived from the CM SAF Cloud Fractional Cover dataset from Meteosat First and Second Generation (COMET, Stöckli et al., 2018, Bojanowski et al., 2018). Initially the COMET dataset has been evaluated against synoptic observations in terms of ability to represent the CFC diurnal cycle. Further, the COMET time series has been sampled at times of NOAA and MetOp satellites overpasses. That formed the artificial CFC time series “as seen” by AVHRR sensors. Further, this time series has been aggregated to monthly means and compared with the reference COMET data. The comparison reveals the spatial and temporal variability of theoretical errors and spurious trends in AVHRR-based CFC time series related to different diurnal cloud regimes. Moreover, the study quantifies these errors separately for NOAA morning and afternoon satellites, and their ascending and descending nodes. Results of our study can serve as a background information for interpretation of global AVHRR cloud CDRs, as well as reveal a potential improvement of the level-3 CFC data accuracy after accounting for the orbital drift effect.

References:

Bojanowski, J.S., Stöckli, R., Duguay-Tetzlaff, A., Finkensieper, S., Hollmann, R., 2018, Performance Assessment of the COMET Cloud Fractional Cover Climatology across Meteosat Generations, Remote Sensing 2018 10(5) 804. doi:10.3390/rs10050804

Stengel, M., Stapelberg, S., Sus, O., Schlundt, C., Poulsen, C., Thomas, G., Christensen, M., Carbajal Henken, C., Preusker, R., Fischer, J., Devasthale, A., Willén, U., Karlsson, K.-G., McGarragh, G. R., Proud, S., Povey, A. C., Grainger, R. G., Meirink, J. F., Feofilov, A., Bennartz, R., Bojanowski, J. S., and Hollmann, R.: Cloud property datasets retrieved from AVHRR, MODIS, AATSR and MERIS in the framework of the Cloud_cci project, Earth Syst. Sci. Data, 9, 881-904, https://doi.org/10.5194/essd-9-881-2017, 2017.

Stöckli, R., Bojanowski J.S., John, V., Duguay-Tetzlaff, A., Bourgeois, Q., Schulz, J., and Hollmann, R.: Climatological Cloud Detection with Heritage Geostationary Satellite Sensors. J. Geophys. Res. 2018. (submitted)

Indirect aerosol forcing estimates over southeast and northeast Atlantic marine stratiform clouds

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Abstract: Marine stratiform clouds significantly contribute to the earth's radiation budget by reflecting the shortwave radiation to space. The modelling of these clouds therefore plays an important role in the climate change projection. These clouds are susceptible to aerosol composition and particle number concentration, such that a perturbed environment could alter the cloud macro- and microphysical properties and therefore the cloud albedo. Additionally, covariations in the associated meteorological parameters such as inversion strength, horizontal temperature advection, sea surface temperature, surface winds, free tropospheric humidity and temperature, cloud-top entrainment rate, subsidence rate, etc. can have a significant influence on cloud properties too. Despite a relatively large number of studies focusing on better understanding the interactions between clouds and aerosols and quantifying the aerosol indirect forcing over these regimes, such forcing estimates remain one of the most substantial uncertainties in climate model simulations. For instance, the strength of dependency (regression slope) between cloud droplet number concentration (CDNC) and cloud droplet effective radius (CER) is still uncertain. In our study we focused on two stratocumulus regimes in the south-east and north-east Atlantic, which are primarily impacted by seasonal smoke plumes and desert dust transport, respectively.

We used two years of collocated satellite cloud and aerosol observations from MODIS,OMI, and AMSR-E, and the corresponding reanalysis meteorology and aerosol data from MERRA-2, to investigate aerosol-cloud-meteorology interactions and their impact on Earth's radiation budget, as well as to quantify the indirect aerosol forcing concerning both the cloud albedo and the cloud lifetime effect. Our study was performed at a 0.25-degree grid resolution unlike most previous studies, which were conducted at a coarser spatial resolution (1-degree or above). In addition, we investigated a larger pool of relevant meteorological variables than previous work. We observed a strong negative correlation and slope between CDNC and CER, and a positive correlation between CDNC and cloud albedo and fractional cloud cover, confirming the results of previous studies, while liquid water path and cloud optical thickness hinted at a slightly positive correlation with CDNC. Negative CDNC versus CER slopes were steeper in an environment with a drier free troposphere, stronger subsidence, increased cold-air advection, and stronger inversion – the favored conditions for marine stratiform clouds to form. Cloud albedo slope had the strongest dependency on inversion strength, while cloud fraction slope depended on both inversion strength and free tropospheric humidity. To disentangle the uncertainty in satellite estimates, the slope of cloud properties with respect to CDNC was estimated using ordinary least-squares and more advanced regression methods that can more accurately account for observational uncertainties. The results indicate that the cloud lifetime effect is dominant over the cloud albedo effect in our study domains.

On the influence of spatial and temporal resolution for retrieving solar surface irradiance from METEOSAT SEVIRI

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Affl. lead author: Leibniz Institute for Tropospheric Research

Over the past decades, reliable algorithms have been developed to retrieve cloud properties and solar surface irradiance from passive multispectral satellite images. The resulting products are well-tested and nowadays used in applications ranging from climate and weather research to nowcasting of solar energy production. The high variability of the solar radiation field is however known to introduce large instantaneous deviations between satellite products and ground-based observations. Thus sufficiently long periods have to be used for validation in order to separate random and systematic uncertainties, and further improvements in accuracy are highly desirable in particular for forecasting solar energy production. Several physical mechanisms contribute to such deviations: while satellite products are obtained for a spatial area given by the pixel resolution, ground-based observations are point-like measurements. Effects of 3D radiative transfer cause a decorrelation of the solar radiation fields at the top-of-atmosphere and at the surface. In addition, cloud variability depends strongly on cloud type and thus synoptic conditions. In this presentation, a novel dataset of cloud properties and solar surface irradiance as retrieved from METEOSAT SEVIRI at 5 minute repeat cycle based on its 1x1km2 high-resolution visible channel is compared to spatially resolved solar surface irradiance observations collected from a dense network of 99 autonomous pyranometers, which was operated for a 10x10km2 domain during April-July 2013 in Western Germany. A wavelet-based multi-resolution analysis is used to compare the scale-dependent variability and correlation of both datasets, and to quantify the benefits of the improved spatial and temporal resolution of the satellite dataset on product accuracy. Finally, conclusions are drawn for the increase in accuracy expected for the upcoming Meteosat Third Generation Flexible Combined Imager due to its improved spatial and temporal resolution.

A fast cloud retrieval algorithm using GOME-2 measurements of the Oxygen B-band

Marine Desmons, Ping Wang, Maarten Sneep, Piet Stammes and Olaf Tuinder

Affl. lead author: KNMI

The FRESCO (Fast Retrieval Scheme for Clouds from the Oxygen A-band) algorithm is a simple, fast and robust algorithm used to retrieve cloud information in operational satellite data processing. It has been applied to GOME-1, SCIAMACHY, GOME-2 and more recently to TROPOMI. FRESCO retrieves effective cloud fraction and cloud pressure from measurements in the oxygen A-band around 761 nm. In this study, we propose a new version of the algorithm, called FRESCO-B, which is based on measurements in the oxygen B-band around 687 nm. Such a method is interesting for vegetated surfaces where the surface albedo is much lower in the B-band than in the A-band, which limits the ground contribution to the top-of-atmosphere reflectances.

In this presentation, we first show retrieval simulations. Then, we present the results of inter-comparison between FRESCO-B and FRESCO retrievals over one month of GOME-2B data. Finally, we show validation of FRESCO-B with in-situ retrievals provided by the Cloudnet instruments network.

Global statistics of microphysical properties of cloud-top ice crystals

Bastiaan van Diedenhoven, Ann Fridlind, Brian Cairns, Andrew Ackerman, Jerome Riedi

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Ice crystals in clouds are highly complex. Their sizes, macroscale shape (i.e., habit), mesoscale shape (i.e., aspect ratio of components) and microscale shape (i.e., surface roughness/distortion) determine optical properties and affect physical properties such as fall speeds, growth rates and aggregation efficiency. Our current understanding on the formation and evolution of ice crystals under various conditions can be considered poor. Commonly, ice crystal size and shape are related to ambient temperature and humidity, but global observational statistics on the variation of ice crystal size and particularly shape have not been available. Here we show results of a project aiming to infer ice crystal size, shape and scattering properties from a combination of MODIS measurements and POLDER-PARASOL multi-angle polarimetry at the pixel-level. The shape retrieval procedure infers the mean aspect ratios of components of ice crystals and the mean crystal distortion levels, which are quantifiable parameters that mostly affect the scattering properties, in contrast to "habit". We present one year of global statistics and discuss the variation of ice effective radius, component aspect ratio, distortion and scattering asymmetry parameter as a function of cloud top temperature, latitude, location, season, etc. Mean global asymmetry parameters are 0.75, consistent with assumptions made for MODIS collection 6 retrievals, but considerable variation is observed. Generally, with decreasing cloud top temperature, sizes decrease, asymmetry parameters decrease, distortion increases, and aspect ratios increase towards unity. However, for cloud tops warmer than -20˚C, relationships with temperature are notably different and show local minima that are apparently consistent with ice crystal growth theory. Furthermore, with increasing particle size, distortion parameters are generally increasing while aspect ratios increase towards unity, which we show is consistent with in situ observations of crystal complexity and theory about crystal aggregation. This leads to asymmetry parameters that decrease with effective crystal size, which is in contrast with general assumptions. The presented statistics can be used as observational targets for modeling efforts and to better constrain other satellite remote sensing applications and their uncertainties.

PATMOS-x version 6.0: A new cloud climatology from 37 years of global AVHRR+HIRS data

Michael Foster, Andy Heidinger, Andi Walther, Elisabeth Weisz, Paul Menzel, Ray Garcia

Affl. lead author: UW-Madison

Pathfinder Atmospheres Extended (PATMOS-x) version 6.0 is described here. The global cloud record spans 1981 to present and incorporates measurements from Advanced Very High Resolution Radiometer (AVHRR) and High-resolution Infrared Radiation Sounder (HIRS). PATMOS-x is produced at the Cooperative Institute of Meteorological Satellite Studies (CIMSS) at the University of Wisconsin – Madison in collaboration with NOAA scientists. Comparisons against the previous version of PATMOS-x are made with a focus on areas where the inclusion of HIRS data supplements known constraints of the AVHRR. Two examples include the placement of semi-transparent cirrus and cloud detection over Polar inversions. Interpolation of HIRS sounder fields-of-view to the finer spatial resolution and measurements density of AVHRR is accomplished via a k-d tree method, the strengths and weaknesses of which will be discussed. This data set is scheduled for delivery to NOAA's National Centers for Environmental Information (NCEI) climate data archive and should be publicly available sometime in 2019.

Floating Snow Diurnal Cycle Inferred from Global Precipitation Measurement Microwave Imager (GPM-GMI) using CloudSat as the Baseline

Jie Gong, Dong L. Wu, Chenxi Wang

Affl. lead author: Universities Space Research Association

Ice clouds and floating snow are ubiquitous globally. They play critical roles in the Earth's energy and hydrological budgets. Understanding and accurately representing the cloud and precipitation cycle in models, especially the changes over short period of time, require intensive observations and deep knowledge of the coupled cloud-convection-precipitation (CCP) processes.

Passive infrared (IR) and microwave (MW) measurements have very different cloud diurnal cycles, because of their unique sensitivities to anvil/cirrus (IR) and deep convection/floating snow (MW). The diurnal cycle of IR clouds can be derived from geostationary (GEO) observations, but the local time variation of MW clouds needs to rely on collective samplings from low-Earth orbiting (LEO) satellites. Due to the poor polar-orbiting sampling and incompatible retrieval results from different MW sensors, the diurnal cycle of floating snow is missing in the big picture of the CCP coupling process.

In this presentation, we will present the first tropical MW floating snow diurnal cycle derived from more than 3 years of Global Precipitation Measurement Microwave Imager (GPM-GMI) measurements. An empirical forward model is developed to retrieve the floating snow ice water path (SIWP) from GMI 166 and 183 GHz channel observations using collocated CloudSat measurements as the baseline. Taking advantage of the procession orbit design of the GPM core satellite launched in early 2014, a robust floating snow/deep convection diurnal cycle is derived, which is completely different from that of the anvil/cirrus ice cloud observed by IR/VIS instruments onboard GEO satellites or by CATS lidar from the international space station (ISS). Further, the diurnal cycle of the MW and IR/VIS compliments each other in the big picture, indicating that we should use both to study the CCP coupling process.

CALIOP trained neural network cloud top pressure and height for imagers

Nina Håkansson, Claudia Adok, Anke Thoss, Ronald Scheirer, Sara Hörnquist

SMHI / Swedish Meteorological and Hydrological Institute

Further results for the NN-CTTH (Neural Network Cloud Top Temperature and Height) algorithm described in Håkansson et al. [Atmos. Meas. Tech. 11, 3177--3196 (2018)] will be presented. The neural networks used in NN-CTTH were trained with MODIS data against CALIPSO cloud top pressure. The NN-CTTH retrieval has been shown to have smaller retrieval errors compared to MODIS collection 6 and PPS version 2014 of CTTH when validated with CALIOP and CPR (CloudSat). The NN-CTTH was originally trained using MSE (mean squared error) as training loss function. Performance can however be improved further when using other loss functions such as MAE (mean absolute error). The performance of NN-CTTH for the VIIRS instrument will be presented. It will also be discussed which statistics best describe the occurring non-Gaussian error distributions.

Analysis of Severe Storms and Aircraft Engine Icing Conditions using Multispectral Geostationary Imager Data

Cameron Homeyer, Elisa Murillo, Konstantin Khlopenkov, Christopher Yost, Louis Nguyen, and Douglas Spangenberg

Affl. lead author: NASA Langley Research Center

Research at NASA Langley Research Center has revealed new insights into severe storms and aircraft engine icing conditions based on analysis of multispectral geostationary satellite imager data. Intense convective storm updrafts and downstream gravity wave breaking inject cirrus clouds into the stratosphere. These above anvil cirrus plumes (AACP) can be identified in imagery via unique texture in visible channel imagery and typically anomalously warm temperatures in infrared imagery, best recognized within 1-min "super rapid scan" observations. It is found that 1) AACP storms generated 14 times the number of reports per storm compared to non-AACP storms, 2) AACPs appeared, on average, 31 mins in advance of severe weather, 3) 73% of significant severe weather reports were produced by AACP storms, 4) AACP recognition can provide comparable warning lead time to that provided by a forecaster, and 5) the presence of an AACP can increase forecaster confidence that large hail will occur. Given that AACPs occur throughout the world and most of the world is not observed by Doppler radar, AACP-based severe storm identification and warning would be extremely helpful for protecting lives and property.

Recent studies have found that ingestion of high mass concentrations of ice particles in regions of deep convective storms, with radar reflectivity considered safe for aircraft penetration, can adversely impact aircraft engine performance. Previous aviation industry studies have used the term high ice water content (HIWC) to define such conditions. Four airborne field campaigns were conducted in 2014, 2015, and 2018 to better understand how HIWC is distributed in deep convection, both as a function of altitude and proximity to convective updraft regions, and to facilitate development of new methods for detecting HIWC conditions, in addition to many other research and regulatory goals. Three satellite-derived parameters were determined to be most useful for determining HIWC probability: 1) the horizontal proximity of the aircraft to the nearest overshooting convective updraft or textured anvil cloud, 2) tropopause-relative infrared brightness temperature, and 3) cloud optical depth derived from visible channel imagery. Statistical fits between collocated TWC and GEO satellite parameters were used to determine the membership functions for the fuzzy logic derivation of HIWC probability.

This talk will summarize these recent studies, emphasizing the utility of 1-min super rapid scan imagery for severe and aviation weather research.

The EarthCARE Multi Spectral Imager cloud products

Anja Hünerbein , Jan-Fokke Meirink, Gerd-Jan van Zadelhoff and Hartwig Deneke

Affl. lead author: Leibniz Institute for Tropospheric Research

The ESA's cloud and aerosol mission EarthCARE will provide measurements from active sounder and passive imager from one platform. MSI observations will provide the information needed to extend spatial limited information of cloud and aerosol properties obtained from the active sensors into the cross-track direction, which is required to perform a radiative closure with the broad band radiometer data. MSI has seven channels in the visible, near-infrared, shortwave- and thermal infrared. The pixel sample distance is 0.5 km over a swath width of 150 km. The MSI 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. The intent of the present study is to provide an overview of cloud products and to demonstrate the performance of the individual cloud algorithm based on synthetic MSI observations with the EarthCARE Simulator (ECSIM) and passive imager measurements. ECSIM has been developed as an end-to-end simulator for the EarthCARE mission capable to simulate the four instruments configurations. We will present results obtained with the MSI cloud processor for different scenes. Further in the scope of the the International Clouds Working Group (ICWG) the algorithm are adapted to passive imager instruments onboard polar and geostationary satellites (MODIS and SEVIRI) to test and verify the MSI cloud products with state of the art algorithms.

Improvement of operational cloud products by Meteorological Satellite Center of Japan Meteorological Agency

Haruma Ishida, Kouki Mouri, Ryo Yoshida, Hiroshi Suzue, Masahiro Hayashi

Affl. lead author: Japan Meteorological Agency

Since 7 July 2015, Meteorological Satellite Center (MSC) of Japan Meteorological Agency (JMA) operationally provides cloud products, Fundamental Cloud Product (FCP), which includes cloud mask, phase (ice/water), type, and top height, derived from Advanced Himawari Imager (AHI) radiance data. The algorithm for cloud top height retrieval has been recently improved to incorporate the 2-layer cloud atmosphere model, referring to the GOES-R algorithm. This improvement reduces underestimation that appears in the previous version for optically thin clouds.

For improvement of cloud products in the future, MSC researches the utility of machine-learning methods for algorithm of cloud product. A candidate is “CLAUDIA3”, which has been introduced into cloud mask for some multi-spectral optical imagers on satellite. This applies the support-vector machine with a training data collection procedure specialized to be suitable for cloud detection. Preliminary experiments suggest that the method is practical and useful for cloud detection and cloud type discrimination by AHI, such as nighttime low cloud.

Advances Cloud Radiance Simulation using the Community Radiative Transfer Model

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Affl. lead author: Joint Center for Satellite Data Assimilation

The Joint Center for Satellite Data Assimilation (JCSDA) Community Radiative Transfer Model (CRTM) is a fast, 1-D radiative transfer model used in numerical weather prediction, calibration / validation, etc. across multiple federal agencies and universities. The key benefit of the CRTM is that it is a satellite simulator, in that it provides a highly accurate representation of satellite radiances by making appropriate use of the specific sensor response functions convolved with a line-by-line radiative transfer model (LBLRTM). CRTM covers the spectral ranges consistent with all present operational and most research satellites, from visible to microwave. The capability to simulate ultraviolet radiances are being added over the next two years.

Another unique aspect of the CRTM is that it also provides the tangent-linear, adjoint, and Jacobian outputs needed for satellite data assimilation applications. The ability to compute a Jacobian for various geophysical input parameters significantly expands the capabilities beyond tradiational forward RT models, such as those used in remote sensing retrieval algorithms and other \"Bayesian\" or \"1D-VAR\" applications.

The present talk will focus on recent advances in the ability of the CRTM to simulate satellite radiances in the presence of cloudy and precipitating scenes, with a particular emphasis on ice-phase microphysics. We'll explore the radiance sensitivity to cloud microphysical parameters through a series of experiments that will form the basis of the next generation of operational satellite data assimilation and numerical weather prediction. This represents a significant and necessary expansion of the CRTM capabilities to perform in an all-weather, all-surface, all-sensor environment.

I will also present a novel 1D-VAR retrieval algorithm that makes explicit use of the CRTM's capabilities for sensor-specific retrievals.

Cloud trends from 15 years of Atmospheric Infrared Sounder observations

Brian H Kahn

NASA/JPL

Establishing robust satellite-based benchmarks of secular cloud trends is an ongoing challenge because of imperfect radiometric calibration, sampling, and sensitivity limitations, and many additional reasons related to the satellite orbit, instrument, and retrieval algorithm. The Atmospheric Infrared Sounder (AIRS) has now provided 15+ years of radiances with very stable infrared radiometry that has enabled the detection of statistically significant trends in some cloud properties. We describe trends in effective cloud fraction (ECF), cloud top temperature (CTT), cloud thermodynamic phase (liquid and ice), and ice cloud optical thickness (COT) and cloud effective radius (CER) with AIRS observations. While the ECF does not exhibit statistically significant trends in the extratropical storm tracks, statistically significant trends emerge when liquid and ice phase clouds are partitioned, with clear decreases in ice cloud frequency and COT, and increases in liquid cloud frequency. Statistically significant increases in ice CER are observed over most of the globe. Trends in CTT strongly depend on whether the clouds are liquid or ice phase, with liquid clouds warming and ice clouds cooling. The cloud trends inferred from AIRS appear to exhibit similarity to climate GCM predictions in the Coupled Model Inter-comparison Project Phase 5 (CMIP5) model ensemble results.

Cloud Masking in Passive Imagery: Recent Advancements and Assessments Utilising CALIPSO-CALIOP Data

Karl-Göran Karlsson

SMHI / Swedish Meteorological and Hydrological Institute

Cloud masking is generally the first processing step for most cloud parameter retrievals based on passive imagery. Consequently, the quality of cloud parameter retrievals is highly dependent on the success of cloud masking since errors in cloud masking propagate downstream in processing chains, thus affecting errors of all cloud parameters.

The development of cloud masking methods took a giant step in 2006 after getting access to high-sensitive and high-quality reference observations from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) onboard the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite. CALIOP has now delivered more than a decade of invaluable global cloud observations but is now approaching the end of its lifetime. For cloud masking studies, CALIOP data is indispensable because of being the only global high-quality observation reference which provides both cloud occurrences and information about cloud optical thicknesses. Most importantly, the CALIOP optical thickness estimations cover a much larger range for the thinnest clouds than what is observable from passive imagery.

This presentation will give an overview on how CALIOP data has been used for improving and assessing cloud masks being used in various cloud climate data records (CDRs). Examples are given based on data from the Advanced Very High Resolution Radiometer (AVHRR) and the Spinning Enhanced Visible and InfraRed Imager (SEVIRI). Improvements for traditional thresholding methods (e.g., as used in the CLARAA2 CDR), Bayesian methods (e.g., as in the PATMOS-x CDR) and neural-network based methods (e.g., as in ESA Cloud CCI CDR) are described. New tools, like the investigation of cloud detection sensitivities and cloud detection uncertainties, are also described.

TUNING OF THE NWCSAF CLOUD MASK ALGORITHM FOR THE FUTURE METEOROLOGICAL GEOSTATIONARY SATELLITE MTG

Gaëlle Kerdraon, Hervé Le Gléau, Sonia Péré

Météo-France

In the frame of the EUMETSAT NWCSAF, Météo-France has developed software to retrieve the description of the cloud cover (cloud mask, cloud types, cloud top height and cloud microphysics) from a set of meteorological geostationary satellites including MSG, GOES and Himawari. These software modules are part of the SAFNWC/GEO software package which next version (v2018 to be released by end 2018) can be applied to imagery from all kind of meteorological geostationary satellites (MSG, Himawari08, GOES) provided the satellite data are input in HRIT (only for MSG) or NetCdF format. The software can be obtained from www.nwcsaf.org.

This presentation focuses on the outcome of a study performed to analyse in depth the impact of the MTG spectral response on the expected quality of the cloud mask as implemented in v2018. The software has already been applied to SEVIRI of MSG1,2,3,4, the imager of GOES (8-15), ABI of GOES-16, AHI of Himawari-8 & -9. It will be similarly applied to process FCI of MTG. The objective is to identify the geostationary satellite that could prototype the more accurately MTG/FCI in order to better tune the algorithm for MTG/FCI before launch. We will present some results from Himawari08, which channel 10.45µm is very close to the one of MTG/FCI 10.5µm.

Current status of Geo-KOMPSAT-2A Cloud Detection Algorithm in NMSC/KMA

Hee-ae Kim, Byung-il Lee, Sung-rae Chung, Seong-hoon Cheong

National Meteorological Satellite Center / Korea Meteorological Administration

KMA plans to launch the next Korean geostationary meteorological satellite Geo-KOMPSAT-2A (GK-2A) which has a new generation geostationary imager named Advanced Meteorological Imager (AMI) in November 2018. The GK-2A/AMI will provide high resolution data in time and space through 16 channels. KMA has developed fifty-two meteorological products for GK-2A/AMI since 2014 for applying to now-casting, numerical weather prediction, climate and so on.

The cloud detection is to identify the presence of cloud in all observed pixels from GK-2A/AMI. Since the identified clear and cloudy information will be used as input data of most GK-2A Level 2 algorithms, the result of cloud detection should be accurate, fast and reliable. KMA has developed cloud detection algorithm with conventional multi-spectral threshold method using Himawari8/Advanced Himawari Imager (AHI) as proxy data. The algorithm consists of 5 steps, which are clear sky brightness temperature simulation, threshold tests for single and dual channel difference, spatial uniformity test, restoral test and quality control. The GK-2A cloud mask has been validated using MODIS collection 6 data products. In this paper, the status and the preliminary results of GK-2A cloud mask algorithm are presented.

Intercomparison of cloud retrievals from Himawari-8 over five issued areas

Hye-Sil Kim, Yong-Sang Choi, and Hyoji Kang

Ewha Womans University

This is the second report for current status of satellite cloud data in the International Cloud Working Group. We focus on the scene analysis over five issued areas such as sun glint, fractional clouds, clouds over deserts, cirrus, and slant view. Those targeted areas are challenges for remote sensing of cloud properties. The level-2 cloud retrievals are produced from the latest Japanese geostationary satellite, Himawari-8, on the golden day, 19 August, 2015. The analyzed cloud retrievals are cloud detection, phase, temperature (pressure/height), optical thickness and effective radius. Each cloud retrieval from nine institutions (KMA, JMA, CMA, CIMSS, NASA/LaRC, NASA/GSFC, NOAA/NESDIS, NWCSAF, UK Met office) are compared with Himawari-8 RGB imagery over the five selected areas. The scene analyses show where and how much cloud retrievals are uncertain, so that the limits of the current algorithms are identified. This study would serve to improve satellite cloud data quality for the five issues.

Impacts of clouds in the generation of Climate Data Records at EUMETSAT from Meteosat within the Copernicus Climate Change Service (C3S)

A. Lattanzio, M. Doutriaux-Boucher, M. Grant, R. Roebeling, L. Medici, H.-J. Lutz, R. Borde, M. Carranza, and R. Stoeckli

EUMETSAT

EUMETSAT has a unique patrimonial archive of Meteosat data covering more than 35 years of observations starting in 1978 originating from two generations of Meteosat satellites. For the Copernicus Climate Change Service (C3S) EUMETSAT is providing climate data records of infrared radiances that result from careful recalibration activities. These data are used by EUMETSAT to derive further climate data records of geophysical parameters such as land surface albedo, Atmospheric Motion Vectors (AMV) and All/Clear Sky Radiances (ASR, CSR), the last two being contributions to C3S exploited by the reanalysis activities at ECMWF. Key to all retrieval systems for geophysical parameters is the ability to effectively detect all clouds in the satellite's field of view. More than a state-of-the-art algorithm for the individual parameter, the choice of a robust and reliable cloud mask and for some parameters the cloud top height algorithm is key to generate a stable and homogeneous climate data record, but is constrained by the applicability of the cloud algorithms to the different imagers implemented on the two Meteosat generation satellites. For example, a failure in determining if a pixel is cloudy or not will result in an albedo dataset with its quality being highly dependent on the location and season, preventing the creation of a robust and reliable data record. AMVs are derived by tracking the movement of clouds and water vapour features in consecutive satellite images (both clear and cloudy targets are tracked). High uncertainty in the distribution of clear and cloudy scenes will result in an uncertainty in the wind products. While wind speed and direction are expected to remain mostly unaffected by the choice of cloud mask, the repartition between AMVs derived from clear and cloudy targets as well as their vertical distribution is affected. This contribution will focus on the impact of the cloud mask and the cloud top pressure on the generation of stable and homogeneous CDRs, e.g., the Meteosat AMV time series. Constraints and limitations of the exploited algorithms will also be discussed.

Validation of cloud top height and microphysics retrieved from geostationary meteorological satellites using NWCSAF/GEO SW

Hervé Le Gléau

Centre de Météorologie Spatiale / Météo-France

In the frame of the EUMETSAT NWCSAF, Météo-France has developed software to retrieve the description of the cloud cover (cloud types, cloud top height and cloud microphysics) from meteorological geostationary satellites. These software modules are part of the SAFNWC/GEO software package which next version (v2018 to be released by end 2018) can be applied to imagery from all kind of meteorological geostationary satellites (MSG, Himawari08, GOES) provided the satellite data are input in HRIT (only for MSG) or NetCdF format. The software can be obtained from www.nwcsaf.org.

This presentation focuses on the cloud top height and cloud microphysics (thermodynamical phase and droplet/ice crystal size at the top of the cloud; cloud optical thickness and liquid/ice water path). The main features of the retrieval algorithms are first summarized. Validation results for MSG (1-3), Himawari8 and GOES-16 obtained using micro-wave imagery and space-born radar and lidar measurements, are then presented and discussed.

The characterization of ice cloud properties from Himawari-8/AHI measurements

Husi Letu, Takashi Y. Nakajima, Takashi M. Nagao, Hiroshi Ishimoto, Jerome Riedi

Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences (CAS), China b Research and Information Center (TRIC), Tokai University, Japan

The Japan Meteorological Agency (JMA) successfully launched the Himawari-8 new-generation geostationary me-teorological satellite with the Advanced Himawari Imager (AHI) sensor on 7 October 2014. In September 2016, the Japan Aerospace Exploration Agency (JAXA) released the AHI cloud property products.

Fractal ice partial scattering model called "Voronoi" is applied in the "Comprehensive Program for Cloud Optical Measurement" (CAPCOM) algorithm to retrieve the ice cloud properties from AHI measurements. Single-scattering properties of the Voronoi model are calculated by combination methods of the finite- difference time-domain (FDTD) method, Geometric Optics Integral Equation (GOIE) technique, and geometric optics method (GOM) for used in the ice cloud remote sensing.

The ice cloud properties of the ice cloud optical thickness (COT) and effective particle radius (CER) retrieved from the AHI measurements are compared to the MODIS-C6 ice cloud products to characterize the AHI ice cloud products. The results show that the COT from the AHI products agrees well with its counterpart from the MODIS C6 products. There are significant differences in the ice cloud CER values derived from MODIS C6 products and the MODIS L1B data, which are likely caused by the definition of the CER, PSD and selected IPS model. The CER from the AHI products agrees well with the results from MODIS L1B data. The retrievals of the ice cloud COT are concluded to be less affected by both the satellite viewing angles and ice scattering models applied in the retrieval algorithms. The CER is easily affected by the definition of the CER, PSD and IPS model, which is less affected by the satellite viewing angle.

Using NUCAPS Cloud Products to Enhance Thin Cirrus Cloud Height Estimation in NOAA's Cloud Height Retrieval Algorithm

Yue Li, Andrew Heidinger, Steve Wanzong

SSEC

The AWG Cloud Height Algorithm (ACHA) is NOAA's operational cloud height retrieval algorithm. The ACHA is based on a 1-D VAR optimal estimation (OE) approach and its performance is highly dependent on proper a priori information. Lack of CO2 absorption channels in the VIIRS sensor onboard the SNPP and NOAA-20 platforms makes thin cirrus cloud height retrievals highly uncertain. The CrIS Sounder instrument onboard the same platforms provides spectral channels from shortwave Infrared (IR) to longwave IR which covers the CO2 bands. Cloud top pressure (CTP) and cloud fraction are included as standard products in the NOAA Unique Combined Atmospheric Processing System (NUCAPS) from CrIS/ATMS. A comparison against CALIPSO/CALIOP indicates that the NUCAPS CTP provides ideal a priori information for thin cirrus. At the time of this study, only NUCAPS for SNPP is available. We incorporate the NUCAPS CTP in the ACHA and demonstrate an improved performance for thin cirrus height estimation for the SNPP VIIRS sensor.

Performance of cloud amount of three satellite cloud climate date records over the Tibetan Plateau

Jian Liu

National Satellite Meteorological Center

The Tibetan Plateau(TP) is called the third pole of the world. The Tibetan Plateau affects not only the monsoon circulation in the region, but also the energy and water cycle in Asia.There are few ground stations to provide enough observation data for research. Satellite observations can provide a continuous synoptic survey of the state of the atmosphere so that meteorological satellite data play an important role in the Tibetan Plateau cloud properties study. Three kinds of cloud fraction of PATMOS-x/NOAA, CLARA-A2/NOAA and Aqua/MODIS are evaluated over Tibetan Plateau. Compared with ground observation, the correlation between PATMOS-x and ground observation is highest in the three kinds of data. The mean correlation coefficient of PATMOS-x is higher than 0.8. CLARA-A2 and surface observation don't agree well. Three kinds of cloud fraction data show the similar spatial and temporal distribution pattern but the value is different. The annual mean cloud fraction of MYD06, PATMOS-x and A2 is 60.4%, 61.96% and 69.58% in the daytime and is 59.34 %, 48.50 %, 50.47 % at night from 2003 to 2015 respectively. The monthly average cloud of CLARA-A2 is more than that of PATMOS-x in both daytime and nighttime. In the daytime, monthly average cloud fraction of CLARA-A2 is the highest and Aqua/MODIS is less than that of PATMOS-x except in winter. At night, the monthly average cloud fraction of Aqua/MODIS is more than that of PATMOS-x and CLARA-A2 except in summer. The linear regression and accumulate bias analysis showed that the annual mean cloud fraction of both PATMOS-x and CLARA-A2 all displayed a decrease trend from 1982 to 2015. The trend of night cloud is more obvious than that of daytime. CLARA-A2 displays obvious trend than PATMOS-x, especially at night.

Cirrus clouds in the far infrared: some highlights from the FORUM mission Phase-A study

Tiziano Maestri, William Cossich, Rolando Rizzi, Luca Palchetti, Giovanni Bianchini and the FORUM Team

Physics and Astronomy Dep. of the University of Bologna

The Far-infrared-Outgoing-Radiation Understanding and Monitoring (FORUM) mission has been recently selected by ESA as one of the two candidates for the Earth Explorer 9 mission program and is currently undergoing the industrial and scientific Phase-A study (2018-19). FORUM will measure the Earth's top-of-atmosphere emission spectrum from 100 to 1600 cm-1 (nominal resolution of 0.3 cm-1), thus filling the observational gap across the so-called far-infrared (100-667 cm-1) where the exiting radiance is highly sensible to upper tropospheric water vapor and cirrus clouds.

The present work illustrates Phase-A activities related with ice clouds studies. In particular, clouds sensitivity studies introductory to cloud identification/classification algorithms and cloud properties retrieval techniques exploiting the far infrared information content are shown.

Also, down-welling radiance spectra measured in clear and cloudy sky conditions at the ground during 2013 by a Far Infrared Fourier Transform Spectrometer at Dome C, Antarctica, named REFIR-PAD (Radiation Explorer in the Far InfraRed-Prototype for Applications and Development) are analyzed. The simulation-data residuals in the far infrared are evaluated for a selected number of 'window' channels. Results are examined in relation to crystal's habit assumption, cloud retrieved features and atmospheric water vapor content.

Evaluating the MODIS C6 multilayer cloud detection and phase algorithms through comparisons with CALIOP and CloudSat

Benjamin Marchant, Steven Platnick, Kerry Meyer, Galina Wind

Affl. Lead author: USRA

Most heritage satellite imager-based global retrievals of cloud thermodynamic phase and optical/microphysical properties make simplified assumptions, e.g., that cloudy pixels are composed of single layer, plane-parallel clouds, while in nature clouds are much more complex. Because a field of view having multiple cloud layers represents a breakdown of the cloud retrieval forward model, discriminating pixels containing multilayer from monolayer cloud scenes is an important part of assessing retrieval quality. Here we report on an evaluation of the MODIS Collection 6/6.1 multilayer cloud classification and optical property thermodynamic phase algorithms using co-located CloudSat CLDCLASS-lidar and CALIOP 5km Cloud Layer products. While similar investigations have been performed in the past, this assessment appropriately considers the intent of the MODIS multilayer cloud identification algorithm design, namely to identify those cases in which multilayer clouds have radiative consequences that adversely affect cloud microphysical retrievals. Thus, our MODIS multilayer cloud identification comparisons with CloudSat/CALIOP are assessed in terms of several parameters such as the optical thickness of the upper cloud layer, the distance between the upper and lower cloud layers, the cloud thermodynamic phase in each cloud layer, etc.

Relative radiometric calibration – Addressing a key challenge for achieving continuity of NASA cloud climate data records from Aqua-MODIS to SNPP-VIIRS

Kerry Meyer, Steven Platnick, Robert Holz, Steve Dutcher, Nandana Amarasinghe

Affl. Lead author: NASA GSFC

Suomi NPP, launched in the fall of 2011, began the next generation of U.S. operational polar orbiting Earth observations and provides an opportunity to extend many of the climate data records of NASA's EOS. Similar to MODIS on the EOS Terra and Aqua platforms, SNPP's imager VIIRS provides visible through IR observations at moderate spatial resolution with a 1330 LT equatorial crossing consistent with Aqua MODIS. A significant effort has been undertaken by NASA to develop and implement a common algorithm to achieve a continuous cloud property data record across the two observing systems. This effort necessarily involves appropriately addressing known obstacles to cloud climate data record continuity, including the lack of key water vapor and CO2 absorbing channels on VIIRS that on MODIS are used for high cloud detection and cloud-top property retrievals, and a significant change in the spectral location on VIIRS of the 2.1µm shortwave-infrared channel used for cloud optical/microphysical retrievals and cloud thermodynamic phase on MODIS.

Equally as important, however, are unanticipated relative radiometric biases between MODIS and VIIRS, specifically in the shortwave channels common to both imagers that are used for cloud optical property retrievals. These biases have been shown to induce significant, non-linear inter-sensor differences in cloud optical thickness retrievals, and have also been shown to be detrimental to other NASA Atmosphere Discipline Team continuity efforts (e.g., Deep Blue aerosol retrievals). Here, we detail the cloud algorithm team's efforts towards quantifying and reconciling apparent radiometric biases between analogous channels of the two imagers via an extensive analysis of MODIS-VIIRS collocated match files. The resulting VIIRS calibration offsets, derived here for bright scenes (i.e., clouds), are consistent with those derived by the Deep Blue team for dark scenes for channels considered in both analyses, and early testing of their impacts on cloud property retrievals show improved inter-sensor continuity, particularly for cloud optical thickness. Furthermore, we discuss the challenges in monitoring and quantifying MODIS-VIIRS relative radiometric biases as the coincident imager data records continue into the future.

Application of the GOES-R Series Cloud Mask to generate Clear Sky and All Sky Radiance Products for Data Assimilation

Sharon Nebuda, James Jung, Andrew Heidinger, Andrew Collard

Affl. Lead author: UW-Madison CIMSS

Most NWP centers now assimilate radiances from geostationary imagers. The cloud detection performance plays a critical role in the quality of this application. This talk will present the generation of GOES-16 radiance productions for data assimilation at NOAA. The characteristics of cloud detection that are important to this application will be discussed. The potential for this application to serve as a test-bed for comparing the cloud detection schemes will also be discussed.

WMO SCOPE-Nowcasting: Activities of Relevance to the ICWG

Michael Pavolonis (NOAA/NESDIS) and Werner Balough (WMO)

Affl. Lead author: NOAA

The World Meteorological Organization (WMO) Sustained Coordinated Processing of Environmental Satellite Data for Nowcasting (SCOPE-Nowcasting) initiative aims to demonstrate continuous and sustained provision of consistent, well-characterized satellite products for nowcasting. The SCOPE-Nowcasting Executive Panel, which reports to the WMO CBS Inter-Programme Expert Team on Satellite Utilization and Products (IPET-SUP), was formally established in 2017. The SCOPE-Nowcasting Executive Panel oversees the execution of several pilot projects in support of the SCOPE-Nowcasting objectives. Two of the pilot projects may be of interest to the ICWG. One of the ongoing pilot projects is aimed at improving satellite-based volcanic ash cloud tracking and forecasting, as satellites are a critical tool for tracking and characterizing volcanic ash clouds. The primary component of the volcanic ash pilot project is an international effort to benchmark and inter-compare volcanic ash products derived from satellite measurements, similar to the ICWG efforts to benchmark various meteorological cloud products. Another pilot project of relevance to the ICWG is entitled \"Nowcasting in a Big Data World Multi-sensor feature-based nowcasting of convective impacts.” This pilot project is motivated by the lack of standards for products that diagnose and nowcast convective storms using satellite data in tandem with other data sources. For instance, several satellite operators generate products that utilize satellite data to help diagnose the state of convective systems and nowcast the future impacts of developing convection. However, product definitions and standards vary considerably from one data provider to another. This project aims to establish basic product standards and accelerate research on multi-sensor (satellite + non-satellite data sources) tools for nowcasting convection. Coordination between the ICWG and WMO SCOPE-Nowcasting is important. With the aim of facilitating coordination, an overview of related SCOPE-Nowcasting activities will be given.

Progress and challenges in generating multi-instrument imager cloud data records: MODIS, VIIRS and AHI

Steven Platnick, Kerry Meyer, Robert Holz, Steven A. Ackerman, Andy Heidinger, Nandana Amarasinghe, Galina Wind, Chenxi Wang, Benjamin Marchant, Richard Frey

Affl. Lead author: NASA GSFC

The Suomi NPP and JPSS-1 VIIRS imagers provide an opportunity to extend the EOS MODIS Terra (18 year) and Aqua (16 year) cloud climate data record into the next generation operational LEO era. However, building long-term cloud data records has been challenging for MODIS alone due, in part, to instrument radiometric changes that can alias into data record trend studies. Further, in transitioning to the operational imagers, VIIRS lacks key water vapor and CO2 absorbing channels used by MODIS for high cloud detection and cloud-top property retrievals. In addition, there is a significant mismatch in the spectral lo-cation of the 2 micron shortwave-infrared window channels on MODIS and VIIRS that are used for cloud optical/microphysical retrievals and cloud thermodynamic phase.

We will summarize progress towards merging the MODIS observational record with SNPP VIIRS to generate cloud masking, cloud-top, and cloud optical property climate data record continuity across the observing systems using a common algorithm approach for reducing the impact of inherently different imager spectral information content.

In addition, a new generation of geosynchronous multispectral imagers (ABI on the GOES-R series, AHI on Himawari-8/-9) dramatically improves upon the temporal, spatial, and spectral (close spectral overlap with VIIRS in addition to gas absorption channels) resolution capabilities of heritage GEO imagers. This provides a unique opportunity to extend the data records derived from LEO imagers into the time domain. A small pilot study was initiated by NASA to port the MODIS-VIIRS continuity cloud property algorithm described above to the ABI/AHI GEO imagers. We will report on initial results from AHI.

NOTES TO PROGRAM COMMITTEE. Note 1: This 'omnibus' abstract covers a wide range of inter-related algorithm development efforts from three distinct teams (cloud masking, cloud-top properties, and cloud optical properties). The committee is encouraged to consider distributing this presentation into component parts as agenda time permits. Note 2: A companion abstract on shortwave relative radiometric assessments/corrections between MODIS Aqua and SNPP VIIRS is being submitted by K. Meyer et al.

Towards integrated retrievals of aerosol, cloud and the surface

Caroline Poulsen, Gareth Thomas, Matt Christiansen, Adam Povey, Don Grainger, Simon Proud Greg Mcgarragh, Rainer Hollmann, Martin Stengel, Caroline Cox

Affl. lead author: STFC

Within the ESA CCI (Climate Change Initiative) program climate records of cloud properties and fluxes were generated for both AVHRR, ATSR-2 and AATSR cloud records and more recently cloud retrievals from the recently launched SLSTR (Sea and Land surface Temperature Radiometer) on board Sentinel-3a and b.

In this paper we will focus on the key algorithm developments within this project, progress towards a multi-layer cloud retrieval demonstrated with data from the MODIS instrument and outline the insights gained on identifying clouds through working closely with AATSR/SLSTR aerosol retrieval colleagues. We present progress towards harmonising the aerosol and cloud climatology's from AATSR and SLSTR and recent insights into the radiative effect of cloud aerosol interactions.

Finally we discuss how a joint surface and atmosphere (cloud or aerosol) retrieval can reduce biases in surface temperature retrievals in regions of heavy aerosol loading or thin cloud.

Evaluation of Satellite Imager Ice Cloud Retrievals using CALIPSO and CloudSat Data

William L. Smith Jr., Patrick Minnis, Sunny Sun-Mack, Christopher Yost, Gang Hong, Ping Yang, Rabindra Palikonda

Affl. Lead author: NASA LaRC

Knowledge of ice cloud optical, micro- and macro-physical properties is important for a wide range of weather and climate applications but challenging to accurately diagnose. Passive satellite imager data provide the most optimal horizontal and temporal resolution of clouds across the globe, but little direct information on vertical structure leading to potentially large retrieval errors in some conditions. Active sensors, on the other hand, provide high vertical resolution but limited spatial and temporal coverage. Assumptions regarding the ice crystal size distribution, including their shapes and habits are needed in both passive and active remote sensor retrieval schemes since they cannot be inferred directly. This paper compares optical depth, ice water path and cloud top height derived during daytime from GOES-16, Himawari-8 and MODIS to retrievals derived from CloudSat and CALIPSO (CC) data. The passive sensor retrievals are derived assuming two different scattering models. One is based on a single-habit model (SHM) of hexagonal ice columns with roughened surfaces which is used in the current Edition 4 MODIS cloud algorithm for the NASA Clouds and the Earth's Radiant Energy System (CERES) project. The other is based on a new two-habit model (THM, the ice cloud consists of an ensemble of hexagonal columns and 20-element aggregates with specific habit fractions at each particle size bin) being evaluated for the next edition of CERES cloud and radiation products. The asymmetry factor at 0.65 mm for the THM is 0.04 lower than that for the SHM. This will result in lower optical depths overall when retrieved using the THM, as well as higher cloud top heights for optically thin clouds, both of which are desired outcomes based on previous validation studies. In this study, we use several CC data products to assess the relative level of agreement in the passive sensor retrievals of optical depth, cloud height and ice water path when the SHM and THM are employed over a wide range of ice cloud conditions. We perform the evaluation using MODIS data, which is limited to nadir only matchups with CC data. We also evaluate the retrievals from Himawari-8 and GOES-16 to establish an initial assessment on potential view angle dependencies. It is anticipated that this study will contribute to an improved understanding of passive sensor ice cloud retrieval uncertainties and help guide future improvements.

An assessment of the impacts of cloud vertical heterogeneity on global ice cloud records from passive satellite retrievals

Chenxi Wang, Steven E. Platnick, Thomas Fauchez, Kerry Meyer, Zhibo Zhang, Hironobu Iwabuchi, Brian H. Kahn

Affl. Lead author: ESSIC/UMD GSFC

Spaceborne passive instruments are widely used to infer long term ice cloud properties due to their large temporal and spatial coverage. Although observations from active instruments (e.g., Lidar and radar) demonstrate the ice particle variability in the vertical direction of ice clouds, a prevailing assumption made in passive cloud retrieval algorithms is that the observed scene consists of a single-layered plane-parallel cloud. In this study, a theoretical exploration on how ice cloud vertical heterogeneity (ICVH) influences MODIS-like cloud optical and macrophysical properties (i.e., cloud optical thickness COT and ice water path IWP) is implemented at the pixel scale. Moreover, with an established ice cloud profile database inferred from one-year joint Lidar and radar observations (CALIPSO/CloudSat), we quantitatively estimate impacts of the ICVH on monthly averaged cloud macrophysical and radiative properties derived from biased retrievals. Results show an average underestimation (-35%) of MODIS monthly IWP product due to the ICVH for global ice clouds over ocean. The ICVH impacts are enhanced at large IWPs (e.g., > 500 g/m2) and solar zenith angles (SZA), resulting in a profound underestimation of MODIS IWP (up to -50%) in deep convective regions and middle to high-latitude regions in the winter hemisphere. The global averaged ice cloudy-sky reflected solar radiation (RSR) and outgoing longwave radiation (OLR) derived from MODIS retrievals are slightly overestimated, suggesting the ICVH has little impact on cloud radiative properties. Relatively large RSR (0.3 W/m2) and OLR (0.1 W/m2) flux differences occur at high and low IWPs, respectively. The largest RSR or total (RSR+OLR) flux difference (~ 2 W/m2) is associated with deep convection where the typical IWP is greater than 2000 g/m2.

Highlights of the 14th IWW and the CGMS-46

Steve Wanzong, Régis Borde, and Jaime Daniels

Affl. Lead author: UW-Madison/SSEC/CIMSS

The 14th International Winds Workshop (IWW) was held in April 2018, in South Korea. Approximately 40 participants from 13 countries attended the meeting. The IWW meetings cover many topics including the status of operational AMV production and the use of AMVs within NWP. One of our two plenary sessions was devoted to the 3rd AMV Intercomparison. This is particularly relevant to the ICWG as AMV producing centers moved towards 1DVAR solutions for their height assignments. Sections of each IWW address the concerns of the CGMS as they relate to the IWWG. The IWWG also works towards consensus recommendations to the CGMS. These actions and recommendations were presented at CGMS-46 in June 2018. Highlights of IWW14 and CGMS46 will be presented.

Cloud property retrieval from SEVIRI and METimage at EUMETSAT

Phil Watts, Loredana Spezzi, John Jackson

EUMETSAT

Cloud property retrievals from the EUMETSAT imagers FCI and METimage are to be based on the VIS/IR combined Optimal Cloud Analysis OCA method currently operational for SEVIRI but several developments are underway with varying degrees of maturity and these will be described.

The two cloud layer capability has been developed to include a more precise radiative transfer. The principles, problems and verification of retrievals will be described.

- The LUT RT approach of OCA permits to some extent the incorporation of more realism to the cloud models including vertical and horizontal inhomogeneities. Some initial results, plans and verification of results will be presented.
- The METimage Oxygen band channels present an additional cloud top pressure measurement technique to the IR (VIS/IR) methods. The rationale to integrate the techniques into a single scheme will be described.
- Efforts towards concise presentation of the multi-parameter cloud property retrievals to enhance their use amongst operational forecasters will be demonstrated.

A 38 year record of UV cloud albedo from UV sensing instruments: inter-satellite calibration, trends and response in cloudiness during El Nino events

Clark Weaver, Dong Wu, P.K. Bhartia, Gordon Labow

Affl. Lead author: ESSIC/NASA GSFC

UV sensors have unique sensitivity to atmospheric clouds that reveal a morphology different from IR and Vis sensors. How the UV-sensible cloud albedo changes in the past decades has an important implication for understanding climate variability and radiative forcing. To quantify global cloud variability with the new observations, we derive a long-term (1980-2018) inter-calibrated record of Hemispheric Cloud Albedo (HCA) from the suite of NOAA and NASA UV (331-380nm) sensing satellite instruments. Our derived HCA assumes a C-1 water cloud at varying cloud optical depths, a Cox-Munk surface BRDF over ocean and a lambertian surface over land.

The satellite observed radiances, prior to HCA calculation, are calibrated over the East Antarctic Plateau and Greenland during summer. Here we assume there has been NO long-term change in the ice albedo since 1980 and adjust the radiances accordingly. While the ice cap adjusted intensities show no long-term trend, there are sometimes small reductions in radiances in specific years as seen by multiple instruments. This suggests there are geophysical events such as surface melting or airborne aerosols that temporarily reduce the observed intensities. We infer an uncertainty of 0.5% in the observed intensities over both ice sheets which converts to 1.8% in global mean HCA, and cloud albedo forcing uncertainty of 0.77 Watts m-2

Over the course of the 38-year record five El Nino events occur and global mean surface temperatures warm about +0.5 C. So each successive El Nino event occurs under warmer background conditions.

During the five El Nino events (1982, 1986, 1998, 2010, 2016) there was a marked positive response in HCA over the pool of warmer ocean water in the Eastern Tropical Pacific (180oW – 100oW, 15o S-15oN) and the timing is in agreement with the Multi-variate ENSO index. However, there was an equally compensating negative HCA response in the Western Tropical Pacific. The result is that a time-series of HCA over larger areas (30o S- 30oN) shows no HCA response during El Nino conditions; instead, the only anomalies are from the Pinatubo and El Chichon volcanic eruptions. Over the tropical ocean there is also no detectable HCA trend from -30S to 30N over the 38-year record despite the warming surface temperatures.

Joint Polar Satellite System (JPSS) Aviation Initiative

Jeffrey Weinrich

NASA Goddard Space Flight Center

The Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) program facilitates initiatives to increase or improve the use and value of JPSS data products in user products, services, and application or service areas. Building on the success of the Fire and Smoke, River Ice and Flooding, Hydrology, Sounding, and Arctic Initiative, the JPSS Aviation Initiative is the latest endeavor of the JPSS PGRR program to increase of the use of JPSS Cloud Products to improve NOAA's products and services in the Aviation Community. The major participants in the Aviation Initiative to date are the JPSS program office, Alaska Aviation Weather Unit (AAWU), Federal Aviation Administration (FAA) Alaska Flight Service Stations, the National Environmental Satellite, Data, and Information Service (NESDIS) Center for Satellite Applications and Research (STAR), National Weather Service (NWS) Center Weather Service Units (CWSUs), NWS Arctic Test Bed, and The Geographic Information Network of Alaska (GINA). An evaluation of the JPSS Cloud Products is being planned for 2018. This presentation will discuss plans for the aviation initiative and the JPSS Cloud Product Demonstration.

The 183 GHz Channels for Long-Term Upper-Tropospheric Cloud Ice

Dong L. Wu and Jie Gong

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High-frequency (> 150 GHz) microwave (MW) channels are sensitive to ice particle scattering and have been widely used for cloud ice retrievals. Using the CloudSat cloud ice measurements collocated with the MW radiances, we developed a fast retrieval algorithm for ice water path (IWP) using the 183/3, 183/7 and 150-166 GHz radiances, which yields consistent products with the radar measurement. The 183/7 GHz is the key channel in this cloud ice retrieval whereas an additional window channel can help to improve the sensitivity to cloud ice. The 183 GHz channels, used in UARS/MLS, SSMT-2, AMSU-B, and MHS, has a data record since 1991.

Validation of Cloud Fraction Estimates from Passive Imagers Using CALIOP Observations with Attention to the Effects of Spatial Resolution

Christopher R. Yost, William L. Smith, Jr., Qing Trepte, Rabindra Palikonda

Affl. Lead author: Science Systems & Applications, Inc.

Cloud fraction estimates are routinely derived from passive imagers on polar-orbiting and geostationary platforms and are a fundamental parameter in cloud remote sensing. A variety of conditions can present challenges for cloud detection by passive imagers. For example, it is known that coarse sensor spatial resolution can cause overestimation of cloud fraction for cumulus and stratocumulus cloud fields. In the absence of solar illumination, lack of thermal contrast between clouds and the underlying surface makes cloud detection difficult. Given these and other uncertainties, active sensors such as Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) have been used to validate cloud fraction estimates from passive imagers. Being an active sensor, CALIOP is not subject to the same challenges as passive imagers, but its spatial and temporal coverage is much more limited. The CALIOP algorithms detect weakly-scattering features by averaging measurements from consecutive laser shots. The distance scale used for this averaging must be considered when comparing cloud fraction estimates to other sensors which have different spatial resolutions. Cloud fraction computed from CALIOP detections can vary significantly depending on the spatial scales chosen to include in the computations. This study uses CALIOP data to derive cloud fraction estimates which can be reliably used to assess estimates from passive imagers and identify situations in which improvements can be made. Particular attention is given to the spatial resolution and detection limits of the sensors.

A practical way to detect and quantify the 3-D radiative effects in passive cloud property retrievals: theoretical basis and feasibility study

Zhibo Zhang and Chamara Raja

UMBC

Most operational remote sensing algorithms are based on the computationally efficient 1D radiative transfer (RT) theory while in reality the RT process is intrinsically 3D. The 1D RT is based on two fundamental assumptions--the \"plane parallel approximation\" (PPA) and \"independent pixel approximation\" (IPA). When actual cloud fields deviate from these assumptions, the cloud radiative properties derived from the 1D RT simulations will be different from the observed values, which is known as the “3D effects” in radiative transfer and cloud remote sensing. As a result, the retrieved cloud properties will be biased depending on the magnitude of the 3D effects and also on the retrieval technique. Take the bi-spectral cloud optical thickness (COT) and cloud effective radius (CER) retrieval for example. The so-called “illuminating effect” can lead to an overestimation of COT and underestimation of CER, while the opposite shadowing effect leads to an underestimation of COT and overestimation of CER. Despite substantial efforts made in the past, there is still a lack of practical way to detect and quantify the 3D effects at the pixel level.

Recently, we have developed a theoretical framework that uses the combination of polarimetric and radiometric measurements to detect the pixels of a radiometric image of clouds that are affected by the 3D radiative transfer effects. Moreover, with the aid of synthetic cloud fields from the large-eddy simulation model and 3D radiative transfer simulations, we have successfully demonstrated how the corrected radiances can significantly improve the statistics of cloud property retrievals.

ABSTRACTS POSTER SESSION

New Methods for Improving the Characterization of Cloud Properties and Vertical Structure from Satellite Imager Data

Sarah Bedka, W. L. Smith Jr., P. Minnis, S. Sun-Mack, R. Palikonda

Science Systems and Applications Inc.

The SATellite ClOud and Radiative Property retrieval System (SatCORPS) employs a set of algorithms designed at NASA Langley Research Center to retrieve daytime and nighttime cloud properties from passive satellite observations. The methods are similar to those developed for application to MODIS and VIIRS data for the CERES (Clouds and the Earth's Radiant Energy System) program. They have been adapted for application to current and historical Geostationary satellite data including GOES, Himawari-8 and MSG, and are widely used in weather and climate applications and studies. While the retrieval methods are well suited to identify the geographic location of clouds and cloud top information at high spatial and temporal resolution, obtaining accurate estimates of cloud layering, geometric thickness and cloud ceiling have proven difficult. During the daytime, satellite solar reflectance measurements provide some information about vertical dimension, since they can be related to a wide range of cloud optical thicknesses. Assessment of cloud vertical structure at night is problematic since only infrared data are available, and optical thickness sensitivity is limited to thinner clouds. The challenge is in developing methods that best exploit the information contained in the satellite radiances to improve cloud vertical structure characterizations over the entire diurnal cycle. This paper describes progress in developing and applying new techniques that employ artificial neural network approaches to estimate cloud geometric thickness, multilayer cloud occurrence and properties, and nighttime optically thick cloud properties from satellite imager data. The training datasets in the initial methods employ CloudSat/CALIPSO data matched with nadir observations and retrievals from MODIS. Here, we test the methods for off-nadir use based on co-located Geostationary satellite data with CloudSat and CALIPSO, and report progress in refining the methods for more general use.

The MODIS-VIIRS Cloud Mask (MVCM)

Richard Frey, Steve Ackerman, Robert Holz, Steve Dutcher

Affl. Lead author: UW-Madison/SSEC/CIMSS

As MODIS instruments on the Terra and Aqua platforms near the end of their useful lifetimes, concerns about continuing the time series of derived atmospheric science data products into the future has surfaced. A NASA effort to extend MODIS "climate data records" into the future using VIIRS instrumentation has begun. Included in that effort are cloud products, beginning with cloud detection. A cloud mask has been developed that continues the use of a "fuzzy logic" approach, named the MODIS-VIIRS Cloud Mask (MVCM). It is designed to bring continuity in cloud detection for MODIS, SNPP and NOAA-20 (J1) VIIRS, and the several planned VIIRS instruments beyond these. The algorithm uses only those spectral bands that are common to both MODIS and VIIRS instruments. The poster will detail similarities and differences from the current MODIS cloud mask (MOD35) and show comparisons of MVCM results to both MOD35 (Aqua) and CALIOP lidar. These comparisons illustrate that overall, the MVCM is very close to the quality of MOD35; however, it also points out regions on the globe where more work is needed. In particular, clear vs. cloudy discrimination in certain nighttime and polar scenes are impacted by the absence of atmospheric absorbing channels on the VIIRS.

Use of Sounder Cloud Products to Improve Imager Cloud Products and Derived Motion Vectors.

Andrew Heidinger, Steven Wanzong, Yue Li

Affl. Lead author: NOAA

The NOAA JPSS Risk Reduction (RR) Program has funded a study to use the NOAA Unique Combined Atmospheric Processing System (NUCAPS) cloud products to improve the NOAA Enterprise Cloud Products from VIIRS. This presentation will show how the NUCAPS data feed into the Optimal Estimation Approach used to derive the VIIRS cloud products. A demonstration of the impact on the derived motion vectors in high latitudes will be shown.

High-Resolution Radar–GOES Satellite–Lightning Field Importance Analysis for Diagnosing and Nowcasting Severe Storms

John R. Mecikalski, Thae N. Sandmael, Elisa M. Murillo, Cameron R. Homeyer, Kris M. Bedka, Jason M. Apke, Chris P.

Affl. Lead author: Jewett University of Alabama in Huntsville

The presentation overviews the development and use of a statistical model, and variable importance analysis, of 1-5 min time resolution geostationary satellite fields, radar derived parameters and lightning data, to diagnose and nowcast severe weather produced by convective storms. This research is a component of an ongoing satellite-based severe weather correlation and nowcasting study done by the authors.

The main methodology of the research begins with a "cell track" database that contains 51 meaningful predictor fields as related to convective storms that did/did not produce severe weather (hail ≥0.25" in diameter, strong winds ≥25 ms–1, tornadoes). A total of 7,288 individual storm cells were tracked at 5-min intervals on 16 separate days in 2013, 2014, 2015 and 2017. Each cell lasted from 15 min to over 2 hours. A machine learning (random forest–RF) approach was used to assess predictor importance for the occurrence of severe weather. Within the RF classification, each 5-min time is considered an "event" in the variable importance portion of the analysis, and therefore 298,095 separate events were considered. The radar data used within the cell track dataset is WSR-88D processed through the GridRad algorithm (GridRad.org), and included a wide variety of reflectivity and polarimetric fields that describe storm-scale processes including updraft strength, hail signatures, and kinematics. GOES-14/-16 data at 1-min resolution were used to develop several metrics including overshooting cloud-top (Bedka and Khlopenkov 2016) and cloud-top divergence and vorticity (Apke et al. 2016, 2018) fields for the tracked convective cells, while lightning were from Earth Networks Total Lightning Network (ENTLN) data. The RF classification algorithm used is the TreeBagger in Matlab.

First in the presentation, several approaches will be discussion regarding the down-selection of predictor fields that showed higher correlation and relationships to observed severe weather, including: (a) evaluating all 51 predictor fields, and (b) evaluating predictors per data type (e.g., radar fields alone, satellite & lightning alone). Second, a statistically-based feature down-selection process was done toward developing a predictive RF model using a small subset of 51 fields. Lastly, an evaluation of the RF model skill was done when a 50/50 testing-training split of the database was used. Results to date show that several fields consistently show high importance when identifying and nowcasting severe weather, including: ZDR median where Z>45 dBZ, volume hail ZDR >20 dB, GOES IR TBmin–NARR tropopause temperature, GOES mAMV cloud top vorticity, GOES mAMV wind speed magnitude, and GOES-derived above anvil cirrus plume (Bedka et al. 2018), all of which can be correlated to the presence of wide, persistent convective updrafts, that may be rotating and be capable of producing hail. The presentation will detail skill score statistics when a subset of ~3-8 robust and consistent predictors are used in the RF predictive model, which was determined through the predictor importance analysis component.

Upper Tropospheric Cloud Properties and Their Variability with the El Nino Southern Oscillation

Ethan Nelson, Paul Menzel, Richard Frey

Jet Propulsion Laboratory, California Institute of Technology/CIMSS

The El Nino Southern Oscillation (ENSO) is a large source of climate variability worldwide, both locally in the Pacific Ocean region and globally through teleconnections. Here we explore these features using High Resolution Infrared Radiation Sounder (HIRS) data that has been reprocessed to provide multi-decadal observations from the same polar-orbiting satellite sensor family. Spatial regressions are performed between the ENSO 3.4 index based on sea surface temperature and monthly mean afternoon high cloud information from HIRS on seven different satellites over a nearly continuous 32-year time period. Strong, negative regression slopes are found between the 3.4 index and high cloud top pressure through portions of the Eastern Pacific ITCZ and the Eastern Asian continent regions, while positive slopes are found over the Maritime Continent, Central South America, and Southern end of Africa. Regression slopes between the 3.4 index and high cloud frequency are opposite in sign and spatially more uniform. These results demonstrate the usefulness of and motivate further climate system analysis by long-term, inter-calibrated instrument climate records from space.

Global GEOsat Cloud and Surface Temperature Datasets for Climate Monitoring and Nowcasting Applications from the NASA LaRC SatCORPS

R. Palikonda, William L. Smith Jr., P. Minnis, Sarah Bedka, Gang Hong, Kris Bedka, Ben Scarino, Chris Yost, Qing Z. Trepte, Douglas A. Spangenberg

Affl. Lead author: SSAI

Geostationary satellite (GEOSat) imager radiances are valuable for remote sensing of many different physical parameters that can be used for a variety of weather, aviation, and energy applications. At NASA Langley, the Satellite ClOud and Radiation Property retrieval System (SatCORPS) has been developed for application to meteorological satellite data to provide cloud and surface parameters for the Clouds and the Earth's Radiant Energy System (CERES) program. The system is currently processing a constellation of GEOsat data in two modes. The first mode applies frozen algorithm versions to all 2nd and 3rd generation GEOsat's coinciding with the CERES data record (March 2000 - current) for trend detection and other climate applications. These retrieved properties form a GEOsat climate data record (CDR) complementary to the CERES polar orbiting cloud data set. The second mode is processing current data for nowcasting and other near-real time (NRT) applications. The algorithms in this mode are continuously evolving and updated routinely with the goal of achieving improved accuracies rather than time continuity. All data are processed hourly at 4-km resolution (8-km in CDR mode) between 60°N and 60°S. In the NRT mode, the bounds are extended for selected areas, such as Alaska where data is analyzed, at higher temporal resolution, for viewing angles up to 82.5° or latitude 75°N at a maximum. A rigorous calibration protocol has been developed to ensure accuracy and satellite inter-consistency as much as possible. A cloud masking procedure is applied to identify clear and cloudy pixels. For cloudy pixels, the cloud phase, optical depth, top height, base height, particle effective size, and in some cases, cloud layering is provided. The NRT dataset also contains an overshooting top product that provides the locations of severe convective weather, and two aircraft icing products; one, that identify the airframe icing potential and altitude range due to super-cooled liquid water encounters, and another that identifies the location of dangerous levels of high ice water content (HIWC). New methods are available for estimating the cloud ice and liquid water path simultaneously for a given pixel. Surface skin temperature, clear-sky reflectance, and, over marine areas, aerosol optical depth are estimated for clear pixels. Top-of-atmosphere and surface shortwave and longwave radiative fluxes are also currently available. The cloud data are used for climate monitoring and are being assimilated into numerical weather prediction models. The overshooting top and icing products are being evaluated for operational use in a number of weather forecast offices. This paper describes the dataset, current applications, and availability.

Retrieval of Cloud Amount from Himawari-8 observation using Machine Learning

Ki-Hong Park, Hwan-Woo Lee, Geun-Hyeok Ryu, Eun-Ha Sohn, and Jae-Dong Jang

National Meteorological Satellite Center (NMSC)
Korea Meteorological Administration (KMA)

Korea Meteorological Administration (KMA) has established a plan to automate synoptic observation of Cloud Amount (CA), instead of the naked-eye observation. Thus, National Meteorological Satellite Center (NMSC) of KMA developed CA retrieval model using Himawari-8 observation. To retrieve CA that is determined from 0 to 10 (0~100%), we used Random Forest (RF) which is one of the machine learning. For training the RF model, Target value is calibrated CA of ground at the 22 points in the South Korea during daytime for 2016. As a predictors and input for this model, 48 variables exploiting the brightness temperature difference (BTD) of IR channels from Himawari-8 were used and considered for the 9×9 pixels (18×18 km2) area to reflect ground observation characteristics. In addition, the accuracy of estimating the CA range from 1 to 9 was improved through sequential system of individual RF models generated by classification learning because of the high frequency of 0% or 100% CA. Details will be given at the conference. As a result of validation from September to December 2015, averaged bias, RMSE and correlation is –0.05, 1.58 and 91%, respectively. Proportion correct ±0 (PC±0) that means the percentile of no difference between observer and model CA is 43.9% and PC±2 is 89.3%. Also, model`s PC±2 in the range of 1 to 9 has increased 20.1% (29.9% → 50.0%) compared to COMS CA for January 2017 in the test. Finally, this product will be used to operationally enter CA code for meteorological message from 1st August 2018. In the future, we will try to apply the GeoKompSat-2A data that will release from 2019.

Analyses of Quantitative Precipitation Estimation（QPE）Based on Merging FY-2E and Raingaug

QI Dan,WANG KAICUN

China Meteorological Administration (CMA)

Satellite precipitation estimates are widely used to measure global rainfall on monthly, daily, and hourly timescales for studies. Near real-time satellite precipitation estimates are becoming increasingly available to the community. These precipitation estimates are potentially useful for applications such as numerical weather prediction (NWP) data assimilation, now-casting and flash flood warning, etc. As with any observational data, it is important to understand their accuracy and limitations. This is done by verifying the satellite precipitation estimates against independent data from rain gauges.

High resolution rainfall distribution map can be derived from satellite observation, and rain gauges data can give us accurate rainfall measurements at a fixed location .Combined them together, the merging of satellite precipitation estimates and rain gauge measurement is to "calibrate" satellite precipitation estimation with ground observation, so that a more accurate rainfall field can be drawn. In this paper, we use a intellective objective analysis scheme to accomplish the merging or called "fusing".

The satellite precipitation estimation data we used to fuse is from the National Satellite Meteorological Center (NSMC) which resolution is 0.1 degree. The rain gauge data is from the National Meteorological Information Center (NMIC). Based on the hourly and daily rain gauge precipitation observations of over 50000 rain gauges and the satellite precipitation estimation products, a real-time merging system to get the QPE product is established. Then we have done a series of evaluate and verify works to assess the accuracy. Evaluation was made with the threat score (TS), false alarm rate and missing alarm rate between the observations and the QPE products, and with the brier score to evaluate the performance. The precipitation was divided into four categories with the consistency of operational forecasts at the National Meteorological Center (NMC) of CMA as no rain, little rain, moderate rain and heavy rain with thresholds of 0.1mm (including), 9.9mm (including), 24.9mm (including) and 49.9mm (including), respectively. The test results show that the optimal result was given with an adjusting radius of 0.6-0.8 based on the "fusing" technique. The evaluation results show that the performance of QPE product based on the "fusing" technique is well improved by the satellite precipitation estimates product fusing while the case study results explained it also.

JPSS Enterprise Algorithms Migration to CSPP

Bonnie Reed

NOAA

The term, "Enterprise Algorithm" is used to describe an algorithm that uses the same scientific methodology and software base to create the same classification of product from differing input data (satellite, in-situ or ancillary). The Joint Polar Satellite System (JPSS) program has been transitioning to an enterprise approach using enterprise algorithms for the production of their level-2 data products - which include cloud, aerosol, land, ocean, and atmospheric parameters. Currently, the next generation of both polar (S-NPP and NOAA-20) and geostationary (GOES-16 and GOES-17) satellites are in orbit and as data from these satellites are processed on the ground, the enterprise methodology allows for one product algorithm to be used for both satellite streams. In addition to implementing the enterprise algorithms within the ground system, the JPSS program is working with the Cooperative Institute for Meteorological Satellite Studies (CIMSS) at the University of Wisconsin (UW) to migrate the enterprise algorithms to the Community Satellite Processing Package (CSPP) which supports the Direct Broadcast (DB) meteorological and environmental satellite community through the packaging and distribution of free open source science software. It is expected that by the end of December 2018, CIMSS will have the capability to provide these enterprise algorithms via CSPP. This talk will describe the algorithms that are currently available within CSPP and provide the migration plan for the remaining algorithms included in the CSPP software suite.

Cloud Fraction in the Dark Target product for MODIS and VIIRS

Virginia Sawyer, Robert Levy, Shana Mattoo, Geoff Cureton, Yingxi Shi

Affl. Lead author: SSAI/NASA-GSFC

The Dark Target algorithm for MODIS relies on cloud masking for its retrieval of aerosol optical depth (AOD), so its data product includes datasets of cloud distance and cloud fraction alongside datasets dealing more directly with aerosol. Because the VIIRS Dark Target retrieval (VNPAERDT) currently in development is intended to extend the MODIS data record beyond the end of the Terra and Aqua missions, making it possible to construct a multidecadal climate data record, its algorithm follows MODIS as closely as possible while still following a consistent convention with other VIIRS products. One important difference stems from the fact that the MODIS Dark Target product has a spatial resolution of 10km at nadir, while VNPAERDT is at 6km. The resolution of the cloud mask affects sampling for the level-2 AOD retrieval, which in turn causes a discrepancy in cloud fraction and AOD in the level-3 gridded averages. Comparing both retrievals to the MODIS 3km Dark Target product, which uses the same algorithm at an even finer spatial resolution, distinguishes this sampling effect from other potential sources of disagreement.

Performance of the Optimal Cloud Analysis (OCA) algorithm on MODIS measurements

Loredana Spezzi, Philip Watts, John Jackson

EUMETSAT

The Optimal Cloud Analysis (OCA) algorithm derives two-layer cloud properties from concurrent visible, near-IR, and IR observations [Watts et al. 2011]. OCA is currently used at EUMETSAT to derive operational cloud products (cloud top pressure and microphysical properties) from MSG/SEVIRI observations, and is the baseline cloud retrieval algorithm for the next generation of EUMETSAT imagers: MTG/FCI and EPS-SG/METimage.

The EPS-SG/METimage case represents the first application of OCA to low-Earth orbit imaging measurements and, as such, requires additional testing and refinements. It also offers the opportunity to test the impact of new channels not available on SEVIRI. In this context, this poster presents the first results of the application of OCA to MODIS data, chosen as proxy for METimage.

Future Development of the Scattering Properties of the Community Radiative Transfer Model

Dr. Patrick Stegmann; Dr. Benjamin Johnson

Joint Center for Satellite Data Assimilation

This presentation is giving an overview of the ongoing work to improve the scattering properties used in the Community Radiative Transfer Model (CRTM) maintained by the Joint Center for Satellite Data Assimilation, including hydrometeors and aerosols. For the assimilation of satellite data under all-sky conditions, the CRTM includes the Advanced Doubling-Adding Method (ADA) and Successive Order of Interaction (SOI) radiative transfer solvers. These solvers allow to consider cloud and aerosol layers in the setup of an atmospheric column for which measured radiometric quantities are to be determined. Light scattering properties of cloud layers are pre-computed off-line and loaded by the solvers as binary file Look-Up Tables (LUTs) during a solver run to maximize computational speed of the CRTM. However, the ongoing development of the CRTM itself and problems with the existing LUTs require a several changes in the existing database. Existing LUTs contain scalar scattering properties that have been produced early in the development of the CRTM. As such, the lack of existing documentation on how these scattering properties have been produced also provides a strong motivation to look deeper into the existing LUTs. Recent efforts have been made by Yi et al. (2016) and Stegmann et al. (2018) to include MODIS Collection 6 ice scattering properties in the CRTM LUTs and assess the possibility of a variable-density bicontinuous random medium model for the snow and graupel properties. Recent developments in considering polarimetric observations in the CRTM require the provision not only of the phase function, but the full phase matrix in the LUTs. For aerosol scatterers, recent advances in modeling aerosol optical properties are to be included in the CRTM. These include novel refractive index spectra for mineral dust by Stegmann and Yang (2017), that are physically consistent and enable both a distinction of the source region and the particle size, as well as fractal models for soot and biomass burning aerosols.

Evaluation of Cloud Detection Biases in Geostationary Satellites using CALIPSO Data

Qing Trepte, Patrick Minnis, Christopher R. Yost, William Smith Jr., Rabi Palikonda, Sarah Bedka

Affl. Lead author: SSAI

With the launch of a new generation of Geostationary satellites (GEO) such as Himawari and GOES-16, cloud detection using satellite imager data has been greatly enhanced with increased spectral bands, and higher temporal and spatial resolutions. A concern for all geostationary sensors, however, are changes in instrument sensitivity and algorithm performance at different viewing and solar zenith angles. CALIPSO lidar observations provide a valuable reference for assessing these impacts as the satellite flies in the A-Train sun-synchronous orbit and crosses a wide range of GEO viewing angles each day.

This paper will present the cloud mask results using the imager data from Himawari (AHI) and GOES-16 (ABI). The detection algorithms have been adapted from the Cloud and Earth's Radiant Energy System (CERES) MODIS Edition 4 cloud mask, and adjusted and tuned to geo-satellites. They are used operationally for the CERES Time and Space Averaging (TISA) gridded cloud products and for near-real-time retrievals for weather and nowcasting applications. Examples of Himawari nighttime cloud mask over ocean and GOES-16 daytime cloud detection over CONUS will be shown.

Cloud fraction biases compared to CALIPSO Version 4 data products will be described for different viewing angles, cloud types (ice/water), cloud optical depth, and surface backgrounds. Regional and zonal cloud amount comparisons among GEO cloud mask, CERES MODIS Ed4 and CALIPSO Vertical Feature Mask will also be presented.

Leveraging a dataset of collocated aircraft observations from SEAC4RS to find closure between visible and infrared optical properties

Paolo Veglio, Robert E. Holz

Affl. Lead author: SSEC UW-Madison

For this work we created a dataset of collocated measurements and cloud products from the Research Scanning Polarimeter (RSP), the enhanced MODIS Airborne Simulator (eMAS) and the Cloud Physics Lidar (CPL), collected during the NASA's Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) campaign in 2013, plus the Global Data Assimilation System (GDAS) profiles. We also developed an independent infrared optimal estimation retrieval (FEANOR) that can derive optical thickness and effective radius, along with their uncertainties, from eMAS measurements. The use of FEANOR provides radiative closure with the solar or near infrared retrievals that are used to derive the cloud properties in our collocated dataset.

A new machine learning based cloud phase discrimination algorithm designed for passive infrared satellite sensors

Chenxi Wang, Steven E. Platnick, Kerry Meyer

Affl. Lead author: ESSIC/UMD GSFC

Clouds play critical roles in the Earth's energy budget due to their large coverage and strong radiative effect. Among various important cloud properties, cloud thermodynamic phase is a critical one to link cloud microphysical properties with cloud optical and radiative properties. In this study, we developed a novel cloud thermodynamic phase algorithm based on a Random Forest (RF) classifier. The training (75%) and validation (25%) datasets are generated using a 3-year coincidental MODIS (onboard both Aqua and Terra) and CATS (onboard the ISS) observations. The "true" cloud thermodynamic phases are provided by a lidar on CATS and inputs are solely from MODIS thermal infrared (IR) observations and surface temperature from reanalysis. An independent 1-year cloud phase dataset from CALIPSO/CloudSat is also used for validation purpose. Our preliminary results show that the RF-based phase algorithm performs much better than current MODIS MOD06 IR Phase 1km product. In the near future, we intend to apply a similar RF-based phase algorithm to daytime clouds with a more complete spectral information (e.g., using IR and shortwave observations).

Validation of the new cloud optical and microphysical properties retrieval algorithm for the South Korea stationary satellite (GK-2A).

Yiseok Isaac Yang, Seong Soo Yum, and Junshik Um.

Yonsei university

Recent extreme weather event, such as a heat dome in northern hemisphere that might be attribute to climate changes is a serious social issue. Many studies showed that better understanding of interactions between cloud and aerosol can improve our knowledge on how climate may change. It has been proven that remote sensing of clouds and aerosols using satellite platforms is an effective method to quantify the impacts of clouds and aerosols on the earth energy budget. The Geo-KOMPSAT-2A (Geostationary Korea Multi-Purpose Satellite-2A, GK-2A) will be launched in the end of 2018. The development of GK-2A cloud properties retrieval algorithms will be completed before the launch. In this study, the GK-2A cloud optical and microphysical properties algorithm that retrieves daytime cloud optical thickness (COT), cloud effective radius (CER), cloud liquid water path (LWP), and ice water path (IWP) is explained and the algorithm's structure is also introduced. An optimal estimation (OE) approach is employed that requires appropriate a-priori values and measurement error information to retrieve COT and CER. LWP and IWP are then calculated using the empirical relationships between COT/CER and cloud water path that were determined previously. To validate the retrieved cloud properties, GK-2A cloud products are compared with those of other operational satellites. To compare the results with other algorithms that use cloud reflectance at visible and near-IR channels as input data, MODIS MYD06 cloud products are selected as reference value. For the validation with cloud products that are based on microwave measurements, COT(2B-TAU)/CER(2C-ICE) data retrieved from CloudSat cloud profiling radar (W-band, 94 GHz) are used, whereas the AMSR-2 Level-3 cloud liquid water data are selected for the cloud water path validation. Details on the development, status, and results of validation tests will be presented at the meeting.