CloudSat/CALIPSO Science Workshop

28-31 July 2009
Monona Terrace, Madison WI

Abstracts of Poster Presentations

1. Tim Berkoff

(NASA GSFC/UMBC)
Co-Authors: T. Berkoff, T. Varnai, S. Stewart, L. Belcher, E. Welton

Multiple scattering measurements for possible implmentation in the Micro-Pulse Lidar Network (MPLNET)

MPLNET is a collection of ground-based lidar systems stationed around the globe to provide long-term observations of aerosols and clouds. Unlike space-borne CALIOP lidar backscatter signals, the narrow field of view (FOV) used and small beam geometry for MPLNET normally limits the effects of multiple scattering. More recently, a data set is being generated at NASA-GSFC using a simple dual FOV MPL configuration that is being considered for use at some MPLNET sites. The dual-FOV set-up allows in-field lidar calibrations as well as quantification of multiple scattering. The additional information is currently being evaluated for the ability to generate useful long-term statistics and determination of cloud micro-physical properties. Preliminary measurements and modeled examples of expected multiple scattering signals will be shown.

2. Diana Bou Karam

(LATMOS/CNRS)
Co-Authors: Diana Bou Karam, Earle Williams, Michael McGraw-Herdeg, Juan Cuesta, Cyrille Flamant and Jacques Pelon

Dusty gust front at synoptic scale, initiated and maintained by moist convection over the Sahara

So-called 'dry' microburst outflows are well known phenomena in desert environments when rain from moist convection aloft evaporates into deep, dry-adiabatic boundary layers. Furthermore, moist convection outflows are well recognized as an efficient mechanism for dust mobilization over arid and semi arid regions. Extreme synoptic scale versions of this convective scale phenomenon have been documented in this study, in which the collective episodes of convective downdraft feed a common cold pool that expands as a gust front density current, raising large amount of dust in the boundary layer, and initiating new moist convection over the Sahara.

Satellite observations from the Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) combined with selected West African surface station observations (thermodynamics and visibility) have been integrated to study the gust front and its associated dust activity in the period of August 3-6, 2006. The meteorological conditions accompanying this event have been described using the European Centre for Medium-range Weather Forecasts (ECMWF) analyses.

The gust front was initiated by a cluster of isolated cumulonimbus clouds over central Niger at 1400 UT on August 3 that lengthened to MCS size over Mali by the end of the day. At maximum expansion on August 5, the extending gust front exceeded 1500 km in length, with a transited area of lofted dust reaching a million square kilometers, mostly over southern Algeria and northern Mali. The aerosol optical depth (AOD) associated with the dust cloud was in the order of 1.5, as evaluated from the Moderate Resolution Imaging Spectroradiometer (MODIS) /AQUA Deep Blue Collection 005 over desertic surfaces. The northward gust front speed, estimated with SEVERI imagery, is rapid in initial stages (20 ms^{-1}) but declines with time (10 ms^{-1}) as the cold air absorbs heat from the hot desert surface and the gust front density contrast is diluted.

The synoptic character of this event (both the length and the duration) allows for four intersections with CALIPSO orbits, thereby providing information on the evolution of the characteristics of the dusty gust front during its lifetime. Young dusty gust fronts (i.e. during the first 24 hours of the event) were characterized by lidar reflectivity at 532 nm in excess of 3 x 10-3 km-1 sr-1, temperature drops exceeding 10°C, 1 km visibility and their associated dense dust cloud reached 2 km in altitude. Older dusty gust fronts (i.e. from August 5 on) were associated with

weaker lidar reflectivities (below 3 x 10-3 km-1 sr-1), similar visibility conditions (~1km), temperature drops at the surface of about 5°C and their associated dust clouds reached higher altitudes (3-4 km).
The northward transport of moisture over the Sahara desert associated with the northward excursion of the gust front was evident during this event. All gust front crossings were characterized by moisture increases at the surface; dew point decreased by 3°C in Agadez (Niger) and by 5°C farther north in Tamanrasset and InSalah (Algeria). The ECMWF analyses of Water Vapor Mixing Ratio (WVMR) at 925hPa show a pronounced meridional perturbation in the InterTropical Discontinuity by 0600 UT on August 4 in connection with the advance of the gust front to the north. As result, a large area (~400 km over longitude and 100 km over latitude) of high WVMRs (up to 16 g kg-1) covered northeastern Mali and southwestern Algeria, confirming an impact at the synoptic scale.
The pronounced northward propagation of the dusty gust front and its associated moisture may have been favored by the presence of an active African Easterly Wave. Further work with CALIPSO and SEVIRI is aimed at determining the fate of the large area of dust raised by events of this kind.

3. Katie Carbonari

(Northrop Grumman)
Co-Authors: Katie Carbonari, Randall Alliss, Heather Kiley

A Comparison between GOES derived clouds and CALIPSO optical depths

Using multi-spectral imagery from GOES, we have developed the Cloud-Mask Generator (CMG) which provides high quality information about the distribution of clouds among the lines of sight between GOES satellites and the Earth's surface. The CMG provides a cloud/no cloud decision every 15 minutes for each GOES 4km pixel but does not provide cloud altitude, thickness, or fraction. CALIPSO's 5km cloud product is used in this analysis to investigate the accuracy and the detection limit of the GOES-derived CMG cloud decisions through a direct comparison between the two satellites.
In our analysis, we compared all CMG pixels (cloud/no cloud) to each CALIPSO footprint within 15 minutes of the CALIPSO overpass for various locations in CONUS.
In order to compare CALIPSO to the CMG, CALIPSO's optical depth measurements must first be converted into a cloud/no cloud decision.
An optical depth measurement above 0.349 optical depth is classified as a cloud; this threshold of 0.349 was chosen because this value gives the highest agreement between CALIPSO and the CMG.
Overall agreement between the CMG and CALIPSO is good (above 80%), but preliminary results show that CALIPSO is finding many thin clouds that GOES is missing. For example, when the CMG pixel is clear, 60% of CALIPSO cloud optical depth are 0.7 or greater. Further investigations into disagreements between CALIPSO and CMG will be conducted and reported on.

4. Gregory Cesana

(LMD/CNRS/IPSL)
Co-Authors: G. Cesana, H. Chepfer, S. Bony, D. Winker, JL. Dufresne, P. Minnis, C. J. Stubenrauch, S. Zeng

The GCM Oriented Calipso Cloud Product

This paper presents the GCM-Oriented Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) Cloud Product (CALIPSO-GOCCP) designed to evaluate the cloudiness simulated by General Circulation Models (GCMs). For this purpose, CALIOP L1 data are processed following the same steps as in a lidar simulator used to diagnose the model cloud cover that CALIPSO would observe from space if the satellite was flying above an atmosphere similar to that predicted by the GCM. Instantaneous profiles of the lidar Scattering Ratio (SR) are first computed at the highest horizontal resolution of the data but at the vertical resolution typical of current GCMs, and then cloud diagnostics are inferred from these profiles: vertical distribution of cloud fraction, horizontal distribution of low-mid-high and total cloud fractions, instantaneous SR profiles, and SR histograms as a function of height. Results are presented for different seasons (January-February-March 2007-2008 and June-July-August 2006-2007-2008), and their sensitivity to parameters of the lidar simulator is investigated. It is shown that the choice of the vertical resolution and of the SR threshold value used for cloud detection can modify the cloud fraction by up to 0.20, particularly in the shallow cumulus regions. The tropical marine low-level cloud fraction is larger during nighttime (by up to 0.15) than during day-time. The histograms of SR characterize the cloud types encountered in different regions.

The GOCCP high-level cloud amount is similar to that from TOVS, AIRS. The low-level and mid-level cloud fractions are larger than those derived from passive measurements (ISCCP, MODIS-CERES POLDER, TOVS, AIRS).

5. Jung Hyo Chae

(JPL/JIFRESSE)
Co-Authors: Jung Hyo Chae, Dong L. Wu, and William G. Read

Tropical Deep convection and cirrus cloud from CALIPSO

CALIPSO is useful at detecting very thin cirrus cloud in the Tropical Tropopause Layer (TTL). This thin cirrus can be distinguished from tropical deep convection with height, optical thickness and genesis. Thin cirrus is mostly generated between 15 km and the cold point where the layer is heated radiatively, but deep convective clouds and detrained anvils are formed below 15 km. The frequency of each type of clouds is strong proportional to MLS relative humidity with ice at each altitude. We found that both types of clouds occur at the same time and location in the western Pacific (WP), but two cloud types in the eastern Pacific (EP) are separated temporally and spatially from each other. Thin cirrus in the EP occurs near the equator, but deep convection forms at 5N there. Therefore, we can infer that thin cirrus is formed by overshooting convection in the WP, but formed in situ in the EP due to water vapor mostly advected from the WP by the Walker circulation.

6. Thomas Charlock

(NASA Langley)
Co-Authors: Thomas P. Charlock, Fred G. Rose, David A. Rutan, Seiji Kato, Zhonghai Jin, and Patrick Minnis

Application of CALIOP, CloudSAT, CERES, and MODIS Data to Evaluation of Archived CERES Surface and Atmosphere Radiation Budget (SARB)

This poster describes an application of preliminary CCCM results (which integrates CALIOP and CloudSAT data to advance the CERES cloud retrievals with MODIS) results for the evaluation of the Surface and Atmosphere Radiation Budget (SARB) from the global, multi-year CERES Aqua CRS Edition 2B/2C archive (which computes fluxes using passive cloud retrievals from MODIS and has been validated thoroughly for 2002-2006). While OLR from the archived SARB calculations of CRS compares uncannily well with broadband observations in the global mean, significant discrepancies are found for particular cloud regimes. CALIOP from CCCMS explains this by showing that the daytime cloud top heights used by CRS are too low. A comparison of SW fluxes unveils paradoxes, however: New CCCM calculations of reflected SW at TOA agree with CERES Rev1 (second generation) observations, but those observations do not achieve planetary balance. Archived CRS calculations are closer to the higher albedos from CERES Beta15 (proto third generation) observations, they are closer to planetary balance, and they nail cloud forcing to SW insolation close to the uncertainty of extensive, independent ground-based measurements.

7. Anne (Wei-Ting) Chen

(JPL/Caltech)
Co-Authors: Anne Chen, Frank Li, Duane Waliser, Terry Kubar, Eric Fetzer, Brian Kahn, Paul von Allmen, Seungwon Lee

Developing and applying a CloudSat-centric A-Train and ECMWF analysis data set to better characterize

Representing clouds and convection and their radiative effects in global atmospheric models remains a challenge. Akin to process-study field programs, addressing these issues require multi-parameter measurements to adequately characterize the process under study. Moreover, for many problems associated with cloud processes in weather and climate, global and high-resolution sampling is required. CloudSat and the A-Train offer altogether new opportunities for making improvements to these areas. This presentation will describe a new effort - as a contribution to the WMO Year of Tropical Convection (YOTC) research activity - to develop and apply a CloudSat-centric, multi-parameter A-Train and high-resolution ECMWF analyses data set to characterize dynamic, radiative and micro-physical processes associated with clouds and convection. The data set will include parameters from CloudSat, Calipso, AIRS, AMSR, MODIS, CERES, MLS and the ECMWF analyses. With our own work, these data are being applied to better quantify for example, cloud hydrometeors, distribution and structure associated with different cloud types from low clouds, middle levels and high clouds including deep convective clouds. In addition, the physical relationships between different cloud types and their environmental context, such as boundary-layer characteristics, mid-tropospheric temperature and moisture, vertical instability, etc, are being explored. The goal is to provide a comprehensive collocated data set with an eye towards constraining and evaluating model representations of clouds. Initial results using a preliminary version of the above data set will be presented.

8. Zhong Chen

(Hampton University)
Co-Authors: Omar Torres and Zhong Chen

Use of Calipso Aerosol Vertical Distribution in OMI Retrieval

9. Mian Chin

(NASA Goddard Space Flight Center)
Co-Authors: Mian Chin, Hongbin Yu, Ali Omar, David Winker

Comparisons of aerosol types and associated lidar ratios between CALIOP data and GOCART model

We will present our study comparing aerosol vertical profiles and types, as well as associated lidar ratios, from the CALIOP instrument on CALIPSO satellite with those estimated with the GOCART model. Tagging the atmospheric aerosols with their sources from pollution, smoke, dust, marine, and other natural sources, the model classifies the aerosols into 8 categories including polluted continent, smoke, polluted dust, dust, clean continent, clean marine, biogenic/volcanic, and other according to the relative abundance of aerosols from a particular sources. These categories are compared to the similar classification of “subtypes” identified by the CALIOP, based on the cluster analysis, at different geographical locations globally. The lidar ratios (extinction to backscatter) associated with each category from the GOCART model usually show significant variations, in contrast with the CALIOP which chooses one specific value for a particular subtype. The implications of using a fixed lidar ratio on the uncertainties of retrieved aerosol extinction profiles will be discussed.

10. Min Deng

(University of Wyoming)
Co-Authors: Min Deng, Gerald G. Mace, Zhien Wang and Dong Liu

Tropical cloud variations in 3D from CloudSat and CALIPSO during the 2006/08 El Nino and La Nino period

The links between the cloud field, tropical dynamics, and sea surface temperature during the 2006-2008 El Nino/La Nino event are investigated using NCEP-NCAR reanalysis data and CloudSat/CALIPOS data. During El Nino, the easterly trade winds weaken along the equatorial Pacific, and the warm SST and deep convective activities originally in the western pacific warm pool migrate eastward. While La Nino is characterized by stronger-than-normal easterly trade winds and colder tropical pacific SST. The 3D cloud variations analysis shows that there are about ±3% anomalies in deep convection, more than ±10% high cloud variation, and probably ±2% middle and low -level cloud variation during the ENSO cycle.

11. Jacques Descloitres

(ICARE)

CALIPSO/CloudSat Products and Services at ICARE

12. Andrew Dessler

(Texas A&M University)

Clouds and water vapor in the northern hemisphere summertime stratosphere

Cloud-top observations from the Calipso instrument are used to study the occurrence of clouds in the northern hemisphere (NH) summertime lower stratosphere. At low latitudes, clouds in the stratosphere tend to occur in regions of intense convection, while at high latitudes, there is little longitudinal preference for the clouds. Although there is some latitude and longitude variability, the 0.1% cloud-top occurrence contour tends to be found ~3 km or 40-50 K of potential temperature above the tropopause. Examining water vapor fields measured by the Microwave Limb Sounder, regions of enhanced cloud-top occurrence correlate well with regions of enhanced water vapor mixing ratio in the mid and high latitudes. At low latitudes, on the other hand, the correlation between cloud occurrence and water vapor is poorer. Regions of frequent cloud occurrence at low latitudes also tend to have high relative humidity, which inhibits evaporation of cloud ice there. Instead, the region of enhanced water vapor mixing ratio is offset to higher altitudes above the maximum in cloud occurrence, where the relative humidity is lower.

13. Timothy Dunkerton

(NorthWest Research Associates)

Convective and stratiform cloud distributions in tropical cyclogenesis

Tropical cyclones developing from within tropical waves in the Atlantic and eastern Pacific generally form within the critical layer of the parent wave. The critical layer represents a closed recirculation region in a frame of reference moving westward at the phase speed of the wave. This region favors storm development for dynamical and thermodynamical reasons: (i) the nearby environmental flow is cyclonic and characterized by large Okubo-Weiss parameter, indicating predominantly rotational flow rather than shearing or straining deformation, and (ii) this flow is relatively moist, with average saturation fraction of 70-95%, and contains abundant and persistent deep convective precipitation as retrieved from TRMM satellite measurements. These properties are illustrated for 55 named storms in August-September of 1998-2001. Further examination of the circulation patterns and cloud populations in developing vs non-developing environments indicates extension of the closed gyre to the surface, accompanied by surface convergence, and amplification of the convective cloud component. Evidence is presented that the closed recirculation is important to the cloud population and its associated vertical profiles of diabatic heating and mass convergence. These anomalies further enhance surface convergence and create a positive feedback for development of an intense diabatic vortex within the gyre-pouch of the parent wave's critical layer. In most cases the vortex and gyre initially move together, owing to weak relative flow in the critical layer, but after a gestation period of a few days the vortex emerges from the wave, having acquired characteristics of a tropical depression extending into the upper troposphere, with divergent anticyclonic outflow in that region.

14. Steve Durden

(JPL)
Co-Authors: S. L. Durden, S. Tanelli, and G. Dobrowalski

CLOUDSAT W-BAND RADAR MEASUREMENTS OF SURFACE BACKSCATTER

The surface backscatter measured by the W-band CloudSat Cloud Profiling Radar is of interest to multiple research communities. To those interested in scattering from land and ocean surfaces, it represents the first global measurement of surface backscatter properties at W-band. To those interested in using the surface return as an estimate of path attenuation for cloud and precipitation retrievals, the mean and stability of the surface as a reference target must be characterized. In line with these interests, the authors examine the seasonal dependence of the W-band surface backscatter cross section using CPR. They consider data over the globe and examine surface backscatter properties over the CloudSat mission. They also focus on selected regions and compile the seasonal scattering properties of these regions, as well as the backscatter variability. The scattering mechanisms that underlie the variability are also examined.

15. Jean - Francois Gayet

(CNRS / University Blaise Pascal)
Co-Authors: J-F Gayet et al.

CALIPSO validation

The poster presents a comparison of combined CALIPSO/CALIOP extinction retrievals with airborne in situ and lidar measurements in cirrus clouds. Specially oriented research flights, co-located along the satellite overpasses, were carried out in Western Europe in May 2007 with the German DLR and the French SAFIRE Falcon aircraft during the CIRCLE-2 experiment. For two selected cases the CALIOP cirrus extinction profiles are compared to the in situ extinction coefficients derived from cloud probes (mounted onboard the DLR Falcon aircraft) and to simultaneous airborne Lidar (LNG) observations onboard the SAFIRE Falcon aircraft. During a situation related to a thin frontal cirrus the results show a very good agreement: (i) between CALIOP and LNG attenuated backscatter coefficient and (ii) between CALIOP level 2.01 and in situ extinction coefficients. The Cloud Particle Imager

(CPI) shows that the ice particle population is dominated by irregular-shaped ice crystals. On the contrary in a similar cirrus situation, systematic overestimated CALIOP extinction coefficients can be explained by horizontal-oriented ice crystals with planar-plate shape as revealed by the CPI instrument. This feature is nicely confirmed by comparing with co-located Lidar (LNG) observations. While CALIOP data can be sensitive to specular effects related to pristine ice crystals due to a quasi-nadir oriented beam, LNG is not due to the tilted beam (3° ahead), thus explaining the larger CALIOP backscattering values.

16. Brian Getzewich

(Science Systems and Applications, Inc.)
Co-Authors: Brian Getzewich, Yongxiang Hu, David Winker

Overview of a New CALIPSO LIDAR Level 2 Cloud Phase Discrimination Algorithm Used in Version 3.0 Data Release

An improvement to the existing ice/water phase algorithm has been implemented for the version 3.0 release of CALIPSO data. Based on work done by Yongxiang Hu, the new algorithm primarily relies on the relationship between layer integrated volume depolarization ratio and 532nm integrated attenuated backscatter to classify the layer as being water, randomly oriented ice or horizontally oriented ice. Secondary relationships between adjoining cloud features of the same horizontal averaging or certain cloud physical properties (temperature, color ratio, etc…) are also taken into account. Aside from the benefit of now providing the orientation of defined ice layers within the layered data product, results have also shown a vast improvement when compared with the old phase algorithm. Distributions are now more physically consistent, specifically an increase (decrease) in low level water (ice) clouds in mid-latitude regions.

17. Tom Greenwald

(CIMSS)
Co-Authors: Tom Greenwald and Yong-Keun Lee

Evaluation of CloudSat Liquid Water Path Observations using CALIPSO, AMSR-E and MODIS Cloud Products

This study examines cloud liquid water path (LWP) observations derived from CloudSat's Cloud Profiling Radar using independent observations from other Aqua sensors. Comparisons are made at the spatial scale of the coarsest observations, i.e., the AMSR-E LWP products, for strictly overcast scenes over the ocean. This is done to ensure more reliable estimates of LWP from both AMSR-E and MODIS, which are both affected by cloud inhomogeneities. In addition, the comparisons are limited to nonprecipitating clouds with tops under 3 km. The recently released CloudSat column precipitation products (2C-PRECIP-COLUMN) will aid in precipitation detection. Cloud top height is determined from CALIPSO observations. Results will be presented at the workshop.

18. John Haynes

(Monash University)
Co-Authors: J.M. Haynes and C. Jakob

Southern Ocean Cloudiness: A Combined A-Train and ISCCP Perspective

Misrepresentation of the atmospheric radiation budget over the Southern Ocean is a common problem in climate models. The ACCESS model, for example, underpredicts top of the atmosphere outgoing shortwave flux by more than 40 W/m^2 in the annual mean over much of the southern high latitude oceans, and this is comparable to errors found in the IPCC AR4 GCMs as well. This bias can not be resolved without a better understanding of the clouds present in the higher latitudes and the conditions associated with their formation.

A combination of CloudSat and CALIPSO-derived cloud properties, together with three-hourly ISCCP observations, is used to examine the clouds populating the Southern Oceans. Very low cloud, with an occurrence peak near 2 km, is the most common cloud type found in these latitudes, but a mid to upper tropospheric mode is also commonly observed. To subdivide cloud occurrence into recurring regimes, K-means cluster analysis is used on cloud properties derived from both A-Train observations and ISCCP. In particular, the ISCCP-dervied regimes are further examined using vertical cloud information from CloudSat and CALIPSO, and these regimes are characterized in terms of the underlying thermodynamics and dynamics supporting cloud formation. Ongoing work extending this analysis outside the high latitudes is also presented.

19. Andrew Heidinger

(NOAA/NESDIS/STAR)

Improving Passive Cloud Retrievals with CALIPSO

CALIPSO and CLOUDSAT have provided us the ability understand the performance of our passive retrievals in the context of the cloud vertical structure. This poster will demonstrate how we have tapped into this information to develop our algorithms for future sensors (GOES-R) and to provide better uncertainty measures for our long-term cloud climatologies (PATMOS-x).

20. Andrew Heymsfield

(NCAR)
Co-Authors: Andrew Heymsfield, Aaron Bansemer, Carl Schmitt

Towards improved estimates of mass weighted fallspeeds and snowfall rates from CloudSat and CALIPSO

The goal of this study is to develop a methodology to derive mass-weighted ice particle fallspeeds and snowfall rates from CLOUDSAT radar reflectivity and CALIPSO extinction estimates. We have reanalyzed most fallspeed data sets collected in the past that cover a wide range of habits and for particle sizes beginning at 50 microns to above 1 cm. These include all of the necessary parameters: habit, diameter, mass, cross-sectional area, temperature and pressure. New, physically-based but simple parameterizations for the fallspeeds have been developed. We have applied these to the calculation of mean mass-weighted fallspeeds and snowfall rates from our extensive data base of ice particle size distributions collected in stratiform through deep convective clouds and related them to the radar reflectivity and extinction. The approach and results will be presented.

21. Michael Hiley

(University of Wisconsin-Madison Atmospheric & Oceanic Sciences)
Co-Authors: Michael J. Hiley, Mark S. Kulie, Ralf Bennartz

Global Snowfall Measurement with the CloudSat Space-borne Radar

Data from the first year of the CloudSat mission will be used to investigate global snowfall patterns by converting near-surface radar reflectivities from CloudSat's space-borne radar into snowfall rates. The sensitivity of these results to the various approximations necessary to derive snowfall rates, such as assumptions about snowflake shape, will be tested, as well as the possibility of incorporating additional quality controls steps to account for high non-precipitation reflectivities in regions of complex terrain. In addition, co-located ECMWF temperature data will be utilized to differentiate between rain, snow, and mixed precipitation, with the goal of studying regional and seasonal distributions of precipitation type. Finally, the results will be compared to ground-based data sets of snowfall observations in various regions of the globe in order to validate and improve the methodology of converting CloudSat reflectivities into snowfall rates.

22. Chris Hostetler

(NASA Langley Research Center)
Co-Authors: R. R. Rogers, C. A. Hostetler, R. A. Ferrare, J. W. Hair, M. D. Obland, A. L. Cook, D. B. Harper1, A. J. Swanson

Validation of CALIOP Aerosol Backscatter and Extinction Profile Products Using Airborne High Spectral Resolution Lidar Data

The NASA Langley airborne High Spectral Resolution Lidar (HSRL) has been deployed on over 80 coincident underflights of the CALIPSO satellite track. The flights were conducted over the Caribbean, continental US, Western Canada, and Alaska and ranged in latitude from 7 N to 76 N. The airborne HSRL acquires the same fundamental measurements made by CALIOP: total (i.e., molecular plus aerosol) attenuated backscatter at 532 and 1064 nm and total depolarization at 532 nm. In addition, at 532 nm the HSRL provides an internally calibrated and highly accurate measurement of the aerosol backscatter and independent and unambiguous measurement of aerosol extinction. In this poster we will present both statistical and profile-by-profile comparisons of HSRL and CALIOP Level 2 aerosol extinction and backscatter products. We will also present a comparison of the HSRL-measured extinction-to-backscatter ratio values with those assigned in the CALIOP retrieval of aerosol extinction and backscatter. These comparisons represent the most comprehensive validation of CALIOP Level-2 aerosol extinction and backscatter profile products acquired to date.

23. David Hudak

(Environment Canada)
Co-Authors: David Hudak Peter Rodriguez Howard Barker Hong Lin

Results from the Canadian CloudSat CALIPSO Validation Project

The Canadian CloudSat CALIPSO Validation project was conducted during the winter of 2006/07. It involved 21 flights that successfully positioned the National Research Council of Canada Convair-580 research aircraft below the A-train as it crossed over southern Ontario and south-western Quebec. In addition, an enhanced measurement site was operated north of Toronto. The remote sensing measurements included vertically pointing W-band and X-band radars and a microwave radiometer. Extensive in-situ measurements of precipitation were taken with a 2D Video Disdrometer, the Parsivel optical disdrometer, the Hydrometeor Velocity Shape Detector, the Snow Video Imager, and a Precipitation Occurrence Sensing System.

A summary of the data collected and an overview of the scientific results to date will be given. In particular, an assessment of cloud products from CloudSat, both macroscopic features and ice and liquid water profiles, will be presented for the 21 flights. The validation information includes the in-situ measurements from the Convair and from its onboard radar and lidar as well as data from CALIPSO.

24. William (Bill) Hunt

(SSAI/NASA LaRC)

CALIOP Performance Over The First Three Years

CALIPSO lidar performance trends over the first three years of on-orbit operation will be shown. New data to be presented include the results of a comprehensive study of night and day SNR trends for all three channels, and a study of the performance impact of switching to the backup laser in March 2009. It will be shown that the overall lidar performance has remained well above requirements throughout the mission, and that the performance after the switch to the backup laser is very close to what it was at the start of the mission.

25. Jonathan Jiang

(Caltech Jet Propulsion Laboratory)
Co-Authors: Jonathan Jiang, Hui Su, Steven Massie

On Studying of Aerosol Cloud interactions using CloudSat and CALIPSO datasets

26. Benjamin Johnson

(UMBC JCET and NASA GSFC)

Snowfall retrievals using CloudSat and passive microwave observations

CloudSat radar observations have been shown to be sensitive to ice-phase precipitation [L'Ecuyer, Liu, Kulie, others], which when compared to the TRMM PR, CloudSat is much more sensitive to smaller particle sizes and, therefore, lighter precipitation rates. However, CloudSat reflectivities are sensitive to attenuation and multiple scattering effects [e.g., Battaglia et al], which are often neglected in retrievals. Furthermore, traditional Z-S relationships are unable to account for these effects without pre-processing the data.

The present research uses a physically based forward model to simulate a database of Ku/Ka/W-band reflectivity profiles and coincident passive microwave brightness temperatures. These profiles include non-spherical and spherical particle shapes, and account for multiple scattering and attenuation (gaseous and hydrometeor).

Retrievals occur via a Bayesian algorithm using the database to match attenuated reflectivity profiles. The result is an \"ensemble\" of unattenuated solutions for a given observed reflectivity profile, consistent with the observed reflectivity. Additional constraints from coincident or nearly coincident AMSU / AMSR-E / TMI / SSMI/S passive microwave observations further reduce the uncertainty in the retrieved candidate profiles, leading to a more consistent solution set in the cases of high attenuation.

A snowfall case study over the CARE/C3VP site in eastern Canada will be presented as a test of the retrieval methodology.

27. Damien Josset

(NASA Postdoctoral Program)

CALIPSO-CLOUDSAT cross-calibration using the ocean surface echo

28. Seiji Kato

(NASA Langley Research Center)
Co-Authors: Seiji Kato, Sunny Sun-Mack, Fred G. Rose, and Walt F. Miller

Improvement of radiative flux computation using CALIPSO and CloudSat data

Cloud fields derived from CALISPO and CloudSat are merged. These cloud fields combined with MODIS derived cloud properties are used to compute vertical flux profiles. One month of data (July 2006) show that the difference of top-of-atmosphere shortwave irradiance compared with CERES derived irradiance is reduced from 7.8 W m^-2 to 4.5 W m^-2 using MODIS derived properties alone. Longwave difference is increased from -0.8 W m^-2 to -1.8 W m^-2. MODIS derived cloud fraction along the ground track of CALIPSO CloudSat difffers by less than 1% compared with the cloud fraction over entire CERES footprints.

29. Min Deng

(University of Wyoming)
Co-Authors: Min Deng, Gerald G. Mace, and Zhien Wang

Ice cloud profiling retrieval using CloudSat CPR and CALIPSO lidar

An algorithm to retrieve ice cloud extinction coefficient, ice water content, and effective radius is built upon a variational framework using combined spaceborne radar and lidar signal. It includes the treatments of three radar/lidar cover zones, multiple scattering, and radar attenuation. The algorithm is applied to CloudSat/CALIPSO data and lidar/radar measurement on board of ER2 during the TC4 experiment. The retrieval results are vigorously validated with in situ measurement. The first year results will be presented.

30. Mark Kulie

(University of Wisconsin-Madison)
Co-Authors: Mark S. Kulie and Ralf Bennartz

Utilizing space-borne radars to retrieve dry snowfall

A dataset consisting of one year of CloudSat Cloud Profiling Radar (CPR) near-surface radar reflectivity associated with dry snowfall is examined in this study. The CPR observations are converted to snowfall rates using derived Ze-S relationships, which were created from various ice particle models. The CPR reflectivity histograms show that the dominant mode of global near-surface dry snowfall has extremely light reflectivity values (~3 to 4 dBZe), and an estimated 94% of all CPR dry snowfall observations are less than 10 dBZe. The average conditional global snowfall rate is calculated to be about 0.28 mm h-1, but is regionally highly variable as well as strongly sensitive to the ice particle model chosen. Further, ground clutter contamination is found in regions of complex terrain even when a vertical reflectivity continuity threshold is utilized. The potential of future multi-frequency space-borne radars is evaluated using proxy 35/13.6 GHz reflectivities calculated from CPR observations and sensor specifications of the proposed Global Precipitation Measurement Dual-frequency Precipitation Radar (DPR).

31. Tristan L'Ecuyer

(Colorado State University)
Co-Authors: T. S. LEcuyer, J. M. Haynes, W. Berg, C. Mitrescu

Evaluating and Improving Global Estimates of Rainfall Incidence Using CloudSat Observations

Due to significant differences in their sensitivities to rainfall, the instruments aboard TRMM and CloudSat provide complimentary views of global precipitation that is yielding new insights into the strengths and weaknesses of each sensor. With a minimum detectable signal of -30 dBZ, Cloudsat's millimeter wavelength Cloud Profiling Radar (CPR) is uniquely suited to the problem of detecting rainfall and can be used to provide quantitative rainrate estimates in areas of light precipitation. CPR rainfall estimates, however, are much less certain in more intense precipitation events where the radar suffers from significant attenuation and multiple scattering. The Precipitation Radar (PR) aboard TRMM, on the other hand, is well suited for rainfall estimation in moderate and heavy precipitation but, with a minimum detectable signal of 17 dBZ, the PR lacks sensitivity to drizzle and very light rain. Finally, passive microwave instruments like the TRMM microwave imager (TMI) provide increased special coverage relative to the PR and especially the nadir-pointing CPR but employ empirical relationships to discriminate cloud water from rainfall and require several assumptions to quantify rainfall intensity. This presentation will compare rainfall occurrence statistics and intensity estimates over the tropical and sub-tropical oceans from two years of simultaneous operation of TRMM and CloudSat highlighting the relative strengths and weaknesses of each instrument. Differences in estimates of rainfall intensity distributions from each instrument will be quantified and the primary environmental factors that govern them will be discussed in the context of establishing the global distribution of light rainfall. The presentation will conclude with an update of the status of the joint GPM-CloudSat light precipitation validation experiment (LPVEx) planned for the Gulf of Finland, in September 2010.

32. Wing Yee Hester Leung

(University of Wisconsin - Madison)
Co-Authors: W-Y Leung, G. J. Tripoli, E. A. Smith, A. Mugnai

Potential Reduction of Uncertainty in Microwave Precipitation Retrieval by the Inclusion of Dynamic and Thermodynamic Constraints as part of the Cloud Dynamics and Radiation Database Approach

In order to achieve better understanding of the hydrological cycle and the distribution of clouds and global precipitation, various microwave satellite platforms and CloudSat have been launched in the past to allow significant advance in precipitation measurement from directly measuring microwave radiances and reflectivity from space. Physically based precipitation retrieval algorithm under study uses Bayesian approach to find microphysical profiles solution applied within a subset of Cloud Radiation Database (CRD), which consists of many realizations with sets of relationships between brightness temperatures (TBs) and rain rates. However, the relationship between the simulated microphysical profiles and the simulated multi-spectral TBs are not likely unique, as many configurations of liquid and ice hydrometeors in different directions can generate an observed set of multispectral TBs. Therefore during precipitation retrieval, given a set of observed TB's, one can often match with sets of simulated microphysical profiles with strongly different precipitation outcomes. To improve precipitation estimation, additional constraints that could describe the dynamical / thermodynamical state of the atmosphere at the time of retrieval are needed. Fortunately, constraints are typically available in the form of recent or short term projections of the synoptic situation which dramatically reduces the number of applicable profiles in the data base, when the profiles include the synoptic situation in effect when the profiles were simulated. Radar reflectivity factor that could be comparable to CloudSat radar data can also be included in the database. This information is crucial in studying the relationship in between vertical structure of various hydrometeor distributions in cloud layers and precipitation.
The Cloud Dynamics and Radiation Database (CDRD) approach is an attempt to include this additional information in the CRD to increase the available constraints in selecting applicable database entries used in the estimation procedure. In this paper, we are going to determine by thorough statistical analysis of North America CDRD, degree

to which uncertainty in precipitation estimation can be reduced through use of dynamincal / thermodynamical constraints.

33. Jui-Lin (Frank) Li

(JPL/CalTech)
Co-Authors: Jui-Lin F. Li, D. Waliser, W.-T. Chen, W.-L. Lee, J.-D. Chen, ,T. Kubar, W.-K. Tao, D. Vane

Applying CloudSat/A-Train and ECMWF analysis data sets to constrain and evaluate cloud and convection parameterizations in climate models

How to represent clouds, convections and their radiative effects in numerical weather and global climate models remains a challenge. Despite the efforts made to use theory and observations to constrain the form of various parameterizations (moist physics and radiation) used in the models, there are still many uncertainties and shortcomings regarding these parameterizations. To help resolve these issues, a CloudSat-centric, multi-parameter A-Train and high-resolution ECMWF analyses data set is being developed to characterize dynamic, radiative and micro-physical processes associated with clouds and convection. The data set will include parameters from CloudSat, Calipso, AIRS, AMSR, MODIS, CERES, MLS etc and the ECMWF analyses.

In this component of our research, we will apply the data to constrain model key physical parameters/processes associated with clouds and convection such as cloud hydrometers, cloud top, cloud fraction, precipitation, instability, structure, and cloud radiative properties etc. The target processes include model-derived concepts/parameterizations commonly used in many large-scale numerical climate models (e.g., ECMWF IFS, GEOS5/GMAO, CAM.x/NCAR and fvMMF).

The goal is to improve in climate prediction by providing collocated observation and analysis data against which model representations of clouds and convections, including PBL stratocumulus, trade-wind shallow, middle-level and deep cumulus and their radiative properties, can be more effectively developed, constrained and evaluated.

Initial results from the comparisons between cloud, convection, radiation and precipitation statistics derived from using a preliminary subset of the above data set and the ECMWF IFS, GEOS5/GMAO, and fvMMF models will be presented

34. Dong Liu

(University of Wyoming)
Co-Authors: Dong Liu and Zhien Wang

Quantify Global Mineral Dust Distribution and Properties with CALIPSO Measurements

Airborne mineral dust affects the climate by scattering and absorbing solar and thermal infrared radiation and by serving as active CCN or IN to alter cloud and precipitation formation. However, many of these dust impacts are still poorly understood. The polarization capability of CALIOP lidar on board CALIPSO satellite provides an unprecedented opportunity to study vertical mineral dust distribution globally. Based on by the first two-year CALIOP data, global height resolved mineral dust aerosol distributions in terms of occurrence, extinction coefficient, and mass loading will be provided. With these new results, issues in current model simulated mineral dust distributions, especially the cross-Atlantic transport of the Sahara dust, will be discussed. Our results show that CALIPSO measurements together with other A-train data will significantly improve our understanding of mineral dust impacts on the climate.

35. Guosheng Liu

(Florida State University)

Characteristics of snow clouds derived from CloudSat and other A-Train satellites

Snowfall is one of the important components in understanding global water cycle. CloudSat provides the opportunity not only deriving global snowfall from its radar observations, but also creating a snow cloud library that contains vertical snow water distribution, liquid water amount (from AMSR-E on Aqua), and other atmospheric variables (from ECMWF analysis). This library in conjunction with radiative transfer modeling is extremely useful for developing snowfall retrieval algorithms from passive microwave observations. We have been creating such a snow cloud library in the past two years. In this presentation, we report the characteristics of snow clouds in this library we have derived from merged CloudSat, AMSR-E, and ECMWF data. The characteristics include: (1) the horizontal and vertical distributions of snowfall/water content; their similarity and differences between over ocean and over land surfaces; (2) the relations between surface snowfall and other cloud/atmospheric variables, such as cloud liquid water path, cloud top height, surface temperature, etc., and (3) the relations between liquid water abundance and snow cloud type.

36. Yinghui Liu

(CIMSS, UW-Madison)
Co-Authors: Yinghui Liu, Steven A. Ackerman, Brent C. Maddux, Jeff R. Key and Richard A. Frey

Errors in Cloud Detection over the Arctic and its Implications for Observing Feedback Mechanisms

The negative trend in Arctic sea ice extent that has been observed for the past 30-years impacts cloud cover, this in turn affects the surface radiative fluxes and surface temperature. Understanding cloud feedback mechanism requires accurate determination of cloud amount. The dependence of cloud detection on surface type and instrument type may influence our understanding of feedback mechanisms, such as the ice-albedo feedback. To explore this dependence, we compare cloud amount product from MODIS with the cloud retrieval from CloudSat and CALIPSO. Level-3 cloud observations from the combined CloudSat and CALIPSO measurements are compared to the Level-3 MODIS(Collection 5) which is derived from the MYD35_L2, atmosphere daily cloud amount product. We will also compare the MYD35_L2 product to the MODIS successful cloud retrieval product derived from the MYD06_L2.

37. Ninoslav Majurec

(The Ohio State University)
Co-Authors: Ninoslav Majurec, Joel T. Johnson, and Simone Tanelli

Studies of Sea Surface Normalized Radar Cross Sections Observed by CloudSat

The primary science instrument of the CloudSat Mission is the Cloud Profiling Radar (CPR). The CPR is a W-band (94 GHz) nadir looking radar with the purpose of measuring backscattered power from hydrometeors (clouds and precipitation). Although the CPR contains an internal calibration system, external calibration using geophysical sources with known normalized radar cross-section (NRCS) values is also of interest. The ocean surface can potentially serve as one such geophysical source for external calibration if an accurate understanding of the sea surface NRCS versus the sea wind speed and direction and sea surface temperature is available.

Given that CloudSat operates in a near-nadiral observation geometry, it is typically assumed that a Geometrical Optics model for sea surface scattering should be applicable. In such a model, the sea surface is entirely described by its "long wave" slope variances. These slope variances are intended to describe properties of sea waves longer than a chosen "cutoff" wavelength, usually taken as some number of electromagnetic wavlengths (3 mm at W band.) Because this cutoff wavelength is a free parameter in the GO approach, it is important to develop alternative methods than avoid this ambiguity. A recently proposed "cutoff-invariant" two-scale model provides predictions that are invariant to choice of the cutoff wavenumber. This presentation will describe the implementation of such a model, and the simplification of this model into a GO prediction with an appropriate cutoff wavenumber when applicable.

Predictions of the model are compared with CloudSat observations primarily for nadiral measurements but also for periodic observations at incidence angles up to approximately 15 degrees. Required ancillary information for sea surface wind speed and sea surface temperature is obtained from the AMSR-E radiometer, and ancillary wind direction information from NCEP wind fields is utilized. Comparisons of models and CloudSat measurements are performed to assess the accuracy of existing sea spectrum models in predicting the long wave slope variances of the sea surface. Implications of the study for calibrating CloudSat measurements and for using CloudSat measurements to determine sea surface properties will be discussed.

38. Roger Marchand

(JISAO/UW)

Trade Cumulus as observed from CloudSat and Calipso

In this presentation we will examine several examples of trade cumulus cloud scenes as observed by the CloudSat radar, as well as the Calispo lidar and high-resolution wide-field-camera (WFC). The examples highlight the ability of the WFC observations to enhance detection of trade cumulus.

39. Edouard Martins

(Laboratoire de Meteorologie Dynamique (LMD))
Co-Authors: E. Martins, V. Noel, H. Chepfer

Microphysical signature of formation of cirrus clouds related to dynamical conditions of the UTLS

Cirrus are high clouds mostly composed of ice crystals. They are found at all latitudes near the Upper Troposphere / Lower Stratosphere - UT/LS (10-12km in the midlatitudes, 15-18km in the tropics) and cover ~40% of the world. The creation of these ice clouds implies the meeting of tropospheric wet air masses and cold temperatures where water vapor is transformed into ice crystals which come in a large variety of sizes and forms. A better understanding of the relationships between the microphysical properties of cirrus clouds and the dynamical conditions in the UT/LS is needed to improve our knowledge of the mechanisms driving the variation/regulation of water vapor and therefore the formation of these cirrus clouds.

On the one hand the microphysical properties of these clouds at global scale can be retrieved with the help of an active remote sensing instrument which is very sensitive to thin atmospheric features: the lidar onboard the CALIPSO (Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation) payload. We used 2.5 years of Level 1 lidar data to detect these ice clouds at global scale and access their optical properties. The methodology of detection is based on [1] a threshold on the particulate attenuated backscatter (determined after an intense sensitivity study), then [2] a choice of criteria to define accurate cloudy features (including vertical and horizontal continuity) and finally [3] a selection on cold layers (mid-layer temperature below -40°C). On the other hand we deduced the large-scale dynamical conditions of the atmosphere in the UT/LS from ECMWF (European Centre for Medium-Range Weather Forecasts) re-analyses.

We will present seasonal relationships between microphysical properties of cirrus clouds (divided into subvisible and non-subvisible) and 2 dynamical processes (convection/subsidence and jet streams) in order to find a microphysical signature of these 2 dynamical processes in the optical properties of cirrus clouds. Convection/subsidence areas will be located using monthly mean values of ѡ500, the vertical velocity at 500hPa, while jets streams will be identified using monthly mean values of the maximum of the horizontal wind speed near the tropopause level. The seasonal distributions of cirrus properties will be presented (e.g. temperature, cloud top altitude, optical and geometrical thicknesses, particulate depolarization and color ratios) and their link with these dynamical conditions will be discussed.

40. Sergey Matrosov

(University of Colorado)

CloudSat view of land falling hurricanes

CloudSat provided an unprecedented opportunity to observe vertical structure of precipitating clouds. Spaceborne radar measurements provide estimations of ice parts of such clouds where only limited attenuation of CloudSat reflectivities occurs. The novel attenuation-based approaches allow retrievals of rainfall below the freezing level. As a result, both rainfall and ice hydrometeor information can be retrieved in the same vertical column allowing studies of interactions between water phases in precipitating systems. This presentation will show results of the retrievals of ice cloud parts (e.g., ice water path – IWP) and coincident rain rates in the hurricanes Gustav and Ike, which were two major hurricanes of the 2008 season. The hurricane parameters at the landfall and during the dissipating phase are compared. These results can improve our understanding of the precipitation processes and hurricane structure especially in the areas of stratiform precipitation where ice particle melting is one of the main mechanisms of rainfall formation.

41. Shaima Nasiri

(Texas A&M University)
Co-Authors: Hyoun-Myoung Cho, Shaima L. Nasiri, Ping Yang

Comparison of cloud phases derived by MODIS and CALIOP products

The nearly simultaneous observations of clouds from CALIPSO measurements and MODIS-based cloud retrievals have potential to substantially advance our knowledge about the microphysical and optical properties of clouds and their inherent relationships for various cloud systems. The CALIOP 532-nm channel featured with polarization capability provides unique capabilities for studying hydrometeors in the atmosphere. In this study, we analyzed the relationship between the lidar backscatter and the depolarization ratio for nine types of cloud systems based on the International Satellite Cloud Climatology Project (ISCCP) cloud classification scheme (Rossow and Schiffer, 1999). We also evaluated several hypotheses of MODIS IR phase retrievals, presented by Nasiri and Kahn (2008) in their primarily radiative transfer modeling study, by comparing to the CALIPSO cloud products.

42. Feng Niu

(University of Maryland - College Park)
Co-Authors: Feng Niu and Zhanqing Li

The influence of aerosols on rainfall frequency from ground-based observations and future studies using CloudSat/CALIPSO data

Aerosols have very complex effects on rainfall. On one hand, aerosols not only reduce solar radiation on the surface, stabilizing the atmosphere but also suppress rainfall by competing for water vapor, thus reducing cloud effective radius and suppress the collusion and coalescence processes. On the other hand, convective clouds with high aerosol loadings can reach higher attitudes by not raining earlier and enhance ice processes to generate more rain, which is aerosol invigoration effect. Here we show three different responses of rainfall to the changes of aerosol loadings at SGP site which is probably due to the competition of two opposing effects: the rain suppression effect (reducing cloud particle size) and the invigoration effects. Results show the rainfall frequency increases for clouds with high LWP (liquid water path) but decreases for clouds with low LWP with the increase of aerosol number concentration. For clouds with moderate LWP, the rainfall frequency shows no clear trend. The cloud thickness from ground-based observations is examined to explain the possible reasons for such different responses to aerosols. The cloud thickness increases the most significantly with CN concentration for low base clouds (cloud base <1km) but has almost no increase for high base clouds (3km<cloud base<4km). The increasing rate of cloud thickness stays in between for moderate base clouds. This implies that the different strengths of the aerosol invigoration effect determined by cloud base heights may cause such different responses of rainfall frequency to the increase of aerosol loadings. To test the competing of these two effects, future studies will make use of CloudSat/CALIPSO data to examine the relationship between rainfall frequency and aerosol loadings and also the change of cloud top heights with aerosols for clouds with different base heights.

43. Vincent Noel

(CNRS (Laboratoire de Meterologie Dynamique))
Co-Authors: V. Noel, H. Chepfer, J.-C. Dupont, M. Haeffelin, E. Martins

Ice clouds studies at IPSL/LMD

Two studies of ice clouds will be presented, each focusing on rare phenomenas and processes which were impossible to study on a statistically significant manner before the introduction of always-on spaceborne lidars: (1) a global view of oriented crystals in ice clouds, and their relationship to global-scale thermodynamical properties of the atmosphere, (2) the significant presence in ice clouds colder than 200 K near the TTL of unusual particles which share the optical properties of NAT particles in polar stratospheric clouds.

44. Yoo-Jeong Noh

(CIRA/Colorado State University)
Co-Authors: Yoo-Jeong Noh and Thomas H. Vonder Haar

Satellite and aircraft observations of wintertime mid-level mixed-phase clouds

Understanding of mixed-phase clouds with both liquid and ice phase hydrometeors is important for radar, lidar, satellite retrievals, and climate/weather numerical modeling. However, detection of mixed-phase clouds in which supercooled liquid water coexists with ice is still very challenging work and their microphysics are not well understood. Our limited knowledge of mixed-phase cloud structure and characteristics is responsible for the uncertainties in radiative transfer modeling and satellite measurements because these clouds have not been accurately represented in weather/climate models and satellite retrievals.

This work presents a study of non-precipitating mid-level mixed-phase clouds using satellite and aircraft in situ measurements. In this study, we attempt to understand and characterize the lifecycle, microphysics, dynamics and radiative properties of these clouds by analyzing the fusion of CloudSat/CALIPSO data and aircraft measurements during C3VP/CLEX-10 (the Canadian CloudSat/CALIPSO Validation Project / the tenth Cloud Layer Experiments). CLEX-10, which is part of an ongoing effort for a study of non-precipitating, mid-level, mixed-phase clouds funded by the Department of Defense's Center for Geosciences/Atmospheric Research, collaborated with C3VP that took place from 31 October 2006 to 1 March 2007 over Southern Ontario and Southwestern Quebec. The features of the clouds detected by various sensors and the vertical structure of liquid/ice hydrometeors are represented for three cases showing mixed phase signatures.

A study of the vertical structures and radiative properties of mid-level mixed-phase clouds in the middle-latitudes

Mixed-phase clouds are more common than single-phase clouds in the real atmosphere, but remote sensing studies on their physical properties have been restricted. In general, studies of cloud phase-composition for mixed-phase clouds have been significantly limited by a lack of intensive in situ measurements that can discriminate between the ice and liquid phases.

In this study, spaceborne radar/lidar data and aircraft in-situ measurements are analyzed in order to better understand the microphysical structures and radiative properties of non-precipitating mid-level mixed-phase clouds such as Altostratus and Altocumulus. CloudSat, MODIS (Moderate-Resolution Imaging Spectroradiometer) of the Aqua satellite, and the aircraft measurements during the Canadian CloudSat/CALIPSO Validation Project (C3VP) are used. The spatial distribution of hydrometeors and corresponding atmospheric sounding data are examined, and their features are compared with other aircraft observations that previously took place under different conditions in time and space such as CLEX-9 in the Great Plains of US. In addition, CloudSat retrieval products of liquid water and ice water contents (LWC and IWC) are evaluated using the C3VP aircraft data through frequency probability density function (PDF) and structure function analyses of liquid and ice phase hydrometeors to provide an important basis in the improvement of the satellite retrievals.

45. Hajime Okamoto

(Tohoku University)
Co-Authors: Okamoto, H., K. Sato, Y. Hagihara and R. Yoshida

Cloud particle type occurrences and microphysics from CloudSat and CALIPSO

We developed a combined CloudSat/CALIPSO cloud mask, type classification and microphysical retrieval algorithms. Cloud particle type, such as water, super-cooled water, randomly oriented crystals and oriented plates in horizontal plane, can be inferred by the combination of depolarization ratio and ratio of backscattering in successive layers. Zonal mean properties of water-ice ratio with respect to temperature show the strong dependence on latitude, i.e., water ratio for the same temperature is higher in subtropics region and 50% of water occurrence is found at -10ºC. The oriented crystals are found in the temperature from -20ºC to -10ºC for all latitude zones. Ice microphysics retrieved from CloudSat and CALIPSO shows that effective radius of 40 to 50µm are found at the upper part of the clouds and the particle size increases as the height decreases. Large sizes (>200µm) are found in lower altitude and the occurrences correspond to oriented crystals. Land/Ocean differences are more pronounced in ice water content than effective radius.

46. Ali Omar

(NASA)
Co-Authors: Ali H. Omar and Bruce E. Anderson

Extinction to Backscatter Ratios of Saharan Dust Layers as Observed by In-Situ Measurements during NAMMA and CALIPSO Overflights

We determine extinction to backscatter ratios (Sa) of dust using in-situ measurements of microphysical properties and CALIPSO observations during NAMMA. For nearly collocated CALIPSO measurements of the attenuated backscatter of Saharan dust lofted layers, we use the transmittance technique to estimate values of dust Sa at 532 nm and a 2-color method to determine the corresponding 1064 nm Sa. This method yielded dust Sa values of 39.8 ± 1.4 sr and 51.8 ± 3.6 sr at 532 nm and 1064 nm, respectively. Secondly, Sa at both wavelengths, is independently calculated using measurements of size distributions aboard the NASA DC-8 and estimates of Saharan dust complex refractive indices applied in a T-Matrix scheme. We found values of 39.1 ± 3.5 sr and 50.0 ± 4 sr at 532 nm and 1064 nm, respectively using the T-Matrix calculations applied to measured size spectra. Finally in situ measurements of the total scattering (550 nm) and absorption coefficients (500 nm) are summed to generate an extinction profile that used to constrain the CALIPSO 532 nm extinction profile and thus generate a stratified 532 nm Sa. This method yielded an Sa value of 35.7 sr in the dust layer and 25 sr in the marine boundary layer consistent with a predominantly seasalt aerosol. Combinatorial simulations using noisy size spectra and refractive indices were used to estimate the mean and uncertainty (one standard deviation) of these Sa values. These simulations found mean (± uncertainty) of 39.4 (± 5.9) sr and 56.5 (± 16.5) sr at 532 nm and 1064 nm, respectively, corresponding to percent uncertainties of 15% and 29%.

47. Ali Omar

(NASA)
Co-Authors: A. Omar, M. Vaughan, Z. Liu, R. Kuehn, C. Kittaka, Y. Hu, D. Winker, C. Trepte

The CALIPSO Aerosol Classification Scheme

The Cloud Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) with its 3-channel lidar affords observations that can, with minimal processing, be exploited to identify aerosol types. Several months of CALIPSO Level II data are analyzed to assess the veracity of the CALIPSO aerosol type identification algorithm and generate distributions of aerosol types and their respective optical characteristics. The distributions show that the classification algorithm has no surface type or diurnal dependencies. For this initial assessment of algorithm performance, we analyze global distributions of the CALIPSO aerosol types, along with distributions of integrated attenuated backscatter, backscatter color ratio, and volume depolarization ratio for each type. The algorithm generates the expected results in most scenes. The total attenuated color ratio distributions show significant overlap between aerosol types.

48. Min Oo

(SSEC)
Co-Authors: Min Oo and Robert Holz

Improved Aerosol Optical Depth retrieval using combined MODIS-CALIPSO sensor

Using collocated MODIS and CALIOP observations we present a combined aerosol retrieval that leverages the sensitivity of MODIS to the aerosol size distribution and CALIOP's sensitivity to the aerosol shape and vertical distribution. Preliminary result shows that the joint MODIS-CALIPSO sensor has the potential to improve the total column aerosol optical depth retrieval and reduce biases due to uncertainties in surface emissivity. We will present comparisons between the independent MODIS and CALIOP observations and our combined approach.

49. Gelsomina Pappalardo

(CNR-IMAA)
Co-Authors: Gelsomina Pappalardo, Ulla Wandinger, Lucia Mona, Anja Hiebsch, Ina Mattis, and Aldo Giunta

EARLINET correlative measurements for CALIPSO

EARLINET, the European Aerosol Research Lidar Network, offers a unique opportunity for the validation and full exploitation of the CALIPSO mission because of its geographic coverage and the deployment of advanced Raman aerosol lidars. EARLINET provides long-term, quality-assured aerosol data, which allows us to investigate a large variety of different aerosol situations with respect to layering, aerosol type, mixing state, and properties in the free troposphere and the local planetary boundary layer.

EARLINET started correlative measurements for CALIPSO since 14 June 2006, at the beginning of the operativity of CALIOP. A strategy for correlative measurements has been defined on the base of the analysis of the ground track data provided by NASA. EARLINET correlative measurements are still in progress.

After about 3 years of correlative observations, more than 6500 hours of correlative measurements have been performed and about 3100 correlative files are available for comparisons.

A number of modelling tools is used for the aerosol type and source identification in addition to the information derived from the multi-wavelength lidar observations.
The first results in terms of comparisons between EARLINET and available CALIPSO products (both level 1 and level 2 data) will be presented.

50. Michael Pavolonis

(NOAA/NESDIS/STAR)

Cloud Microphysical Properties from CALIOP and Infrared Radiances

In this study, CALIOP derived cloud boundaries are used to validate infrared-only retrievals of cloud microphysics (cloud composition and effective particle radius). These retrievals were developed for the next generation of GOES satellites, GOES-R. Further, combining cloud boundary information from CALIOP and infrared radiances allows a more robust retrieval of cloud microphysics to be performed. These combined retrieval results are particularly useful for quantifying the frequency of occurrence of small particle dominated ice clouds with a high degree of confidence.

51. Kathleen Powell

(NASA LaRC)
Co-Authors: Kathy Powell and Brian Getzewich

CALIOP Laser Switch Consistency Between LOM 2 and LOM 1
CALIOP Level 1B Major Algorithm Improvements Implemented in Version 3
CALIOP 532-nm Daytime Calibration Version 3 Results

CALIOP LOM 2 operated from launch through February 2009 and LOM 1 began operations on March 13, 2009. A comparison of 532-nm Integrated Attenuated Backscatter for all 5, 20, and 80 km cloud layers within three weeks before and after the March 2009 laser switch show the excellent consistency between the LOM 2 and LOM 1 data. The CALIOP Version 3.00 Lidar Level 1B data product was released for the LOM 1 data for March 12 through mid-June, 2009. Several algorithm improvements were implemented in Version 3.00 and they include a revised 532-nm daytime calibration, improved laser energy calculations and signal normalization by laser energy, modifications to the interpolation of GMAO gridded data products to the CALIPSO orbit tracks, additions to the quality flags, corrections to the meteorological data altitude array, and additions to the data parameter list that describe the orbit and path number. Revisions were made to the 532-nm daytime calibration algorithm to produce 8-12 km, clear-air attenuated scattering ratios that are consistent with co-incident nighttime scattering ratios. Comparisons of Version 2 and 3, 532-nm daytime 8-12 km, clear-air attenuated scattering ratios with co-incident nighttime scattering ratios show the improvement achieved by the Version 3 algorithm

52. Pallav Ray

(University of Miami)
Co-Authors: Pallav Ray and Brian Soden

An Analysis of the Vertical Structure of Cloud Ice under Different Precipitation Regimes: CloudSat versus GCM Simulations

Previous research has shown that global climate models (GCMs) systematically underestimate the intensity of heavy rain events, and their sensitivity to changes in climate. Such deficiencies limit the utility of these model for projecting future changes in extreme rainfall events. To better understand the cause of this deficiency, we examine the vertical structure of liquid (LWC) and ice water content (IWC) from CloudSat and GCM simulations under different precipitation regimes. The location of peak IWC at 300 hPa in the CloudSat is well captured in the model; however the model also produces a secondary peak in IWC around 550 hPa, which is not seen in the CloudSat observations. Both the model and observations show an increase in liquid and ice water path for the heaviest precipitation events. This increase is most pronounced at the upper levels of the troposphere. However, the simulated IWC is much weaker, in particular, at heavy (60-90%) and very heavy rain rates (>90%), suggesting that model deficiencies in simulating extreme rain events may be associated with underestimating the concentrations of non-precipitation cloud water in the GCM. We also explore the correction of GCM simulated water contents to account for the presence of falling hydrometeors within the GCM column using empirically-based relationships derived from TRMM. This correction produces better agreement with CloudSat IWC, but systematic biases in the model simulations remain. Implications and limitations of these results will be discussed at the meeting.

53. Jessica Ram

(Colorado State University/CIRA)

Observing drizzling marine stratocumulus

54. John Reagan

(University of Arizona)
Co-Authors: J. A. Reagan and C. J. McPherson

Progress on Approaches for Maximizing the Aerosol Information Retrievable from CALIPSO Observations

The key to maximizing aerosol information retrieval from CALIPSO lidar (CALIOP) observations is to make full use of the data from the two CALIOP lidar channels (532 and 1064 nm), including the depolarization measurement capability of the 532 nm channel which permits discrimination of dust aerosols. While lidar measurements at just two elastic scatter channels do not permit a practical inversion to retrieve aerosol backscatter and extinction, it is possible with the inclusion of meaningful constraints to achieve these retrievals. The Constrained Ratio Aerosol Model-fit (CRAM) technique is one such method by which aerosol optical properties may be retrieved from dual-wavelength elastic scatter data by applying constraints from aerosol models developed from the analysis of more extensive aerosol observations such as those acquired by the AERONET global network. In particular, CRAM employs aerosol models which associate spectral ratios (~532/1064 ratios) of aerosol extinction, backscatter and the extinction-to-backscatter ratio (lidar ratio) of various aerosol types with a window range of the 532 nm aerosol lidar ratio, Sa, for a given type. Dual-wavelength retrievals on lidar data made assuming the Sa values for a given model yield extinction and backscatter spectral ratios that can be compared to the model ratios to confirm goodness of fit to the assumed model. Success with the CRAM approach has been demonstrated with several satellite lidar data sets. Enhanced CRAM (E-CRAM) retrievals which make use of added information (e.g., Sa at 532 nm determined by say HSRL observations) can be employed to more independently determine the properties of aerosols for a given situation where the CRAM models do not give a good fit, including determining CRAM model mixtures that yield an improved fit. Also, as each CRAM model has an associated aerosol phase function, size distribution and single scatter albedo, achieving a CRAM fit provides significantly more useful information than just the retrieved aerosol backscatter and extinction profiles for assessing aerosol radiative effects. Example CRAM and E-CRAM applications will be included in the presentation/poster.

55. Donald Reinke

(CIRA/Colorado State Univ.)

CloudSat Data Processing Update and Reprocessing Plan

This presentation will provide an update on the CloudSat Standard and Enhanced data products, to include: status, production and distribution statistics, and plans for additional products and reprocessing.

56. Lorraine Remer

(NASA/GSFC)
Co-Authors: R. Fernandez-Borda, J.V. Martins, R.A. Ferrare, L.A. Remer, C. Hostetler, S. Burton, J. Redemann, A. Clarke

Testing a joint Lidar-MODIS retrieval using airborne High Spectral Resolution Lidar, sunphotometer and in situ data.

Measured profiles of aerosol extinction and particle size are needed to better constrain aerosol radiative forcing estimates, pathways of aerosol-cloud interaction and air quality forecasts. These profiles cannot be obtained from backscattering lidar alone. Here we develop the theory to retrieve aerosol extinction and particle fine fraction profiles over water using backscattering lidar coupled with measured spectral radiances at the top of the atmosphere. The method makes use of the MODerate resolution Imaging Spectroradiometer (MODIS) aerosol-over-ocean algorithm's assumptions of a bimodal aerosol size distribution and calculated Look-Up Table. We apply the method to profiles of attenuated backscatter measured by the NASA Langley High Spectral Resolution Lidar (HSRL) and spectral radiances measured by MODIS.

The retrieved profiles of aerosol extinction and extinction to backscatter ratio are compared to profiles measured by the HSRL, providing a validation strategy unavailable with previous backscatter lidar exercises. Six opportunities of collocation are identified during two deployments in 2006. Of these six cases, four retrievals result in an excellent match between retrieved and measured extinction profiles. In two of the six cases the aerosol layers are resolved, although there is an absolute offset within the expectations of retrieval uncertainties. In the cases where comparison to independent aircraft measurements of fine mode fraction is possible, the results are encouraging. This technique opens new possibilities for future application to the measured profiles of attenuated backscatter by CALIPSO.

57. Jerome Riedi

(Laboratoire d'Optique Atmospherique)

Remote sensing of aerosols over clouds from A-Train observations

58. Kenneth Sassen

(University of Alaska Fairbanks)

59. Kaori Sato

(EORC/JAXA)
Co-Authors: Kaori Sato

Use of Cloudsat/CALIPSO data and model outputs to asses the usuage of Earthcare Doppler

Experience from Cloudsat/Calipso provides useful insight into the probable performance of forthcoming cloud radar and lidar missions. In the case of the Doppler function obtainable from EarthCARE mission, the new data is expected to measure directly the motions inside the clouds as well as cloud particle sedimentation, but the usuage of the data for such purpose needs to be assessed from existing data as much as possible.

Sensitivity study of the sensor from past cruise data suggests that the detectability of the Doppler signal is less sensitive to the minimum detectability difference of CloudSat and Earthcare. This means that CloudSat data can be used to roughly simulate the performance of Earthcare Doppler. In this paper I would like to report on where Doppler function from Earthcare may add information to the existing cloud radar measurment from space using Cloudsat data and in-cloud vertical velocity from model outputs.

60. Gregory Schuster

(NASA Langley Research Center)

CALIPSO Aerosol Optical Depth Comparison with AERONET

Highly accurate measurements of aerosol optical depth (AOD) are routinely provided by the Aerosol Robotics Network (AERONET) of surface sunphotometers. Thus, we compared the CALIPSO column aerosol optical depths (obtained by summing all CALIPSO aerosol features) to the AERONET product for overpasses that occurred within 15 minutes and 85 km of the AERONET measurements (during 6/1/2006--9/30/2007). We binned our results by CALIPSO's "closest approach" over the AERONET sites and by AERONET aerosol optical depth, and found that the average CALIPSO AOD at a given overpass distance from the AERONET sites is always lower than the average AERONET AOD.

We explore this discrepancy in terms of overpass distance from the AERONET sites, the geometrical thickness of the aerosol layers, CALIPSO QA confidence levels, CALIPSO feature subtype, and minimum aerosol layer height. We binned the data according to AERONET AOD (0.05 resolution), and obtained a slope, intercept, and correlation of CALIPSO-averaged AOD with AERONET AOD of 0.37, 0.07, and 0.86 for 425 overpasses in all-sky conditions. However, the slope and intercept are greatly improved if we subset the dataset to include only cases where the minimum aerosol feature height is less than 1 km, in which case the slope and intercept are 0.75 and 0.007 for 294 overpasses (and the correlation coefficient is 0.81). The slope in clear-sky conditions is always less than the slope in all-sky conditions, possibly because of the smaller sampling size and lower aerosol optical depths of the clear-sky datasets.

Cloudsat to improve and understand our results. We will also describe future activities.

63. Eric A. Smith

(NASA/GSFC)
Co-Authors: Eric A. Smith, Hezekiah Carty, Kwo-Sen Kuo

Improving Our Understanding of Spectral Diurnal Variability of Precipitation By Observationally Enhancing TRMM Profiles with CloudSat Profiles of Rain Rate

An improved understanding of the diurnal variability of precipitation and latent heating by way of their dependence on rain rate spectra and vertical structure can be obtained by enhancement of TRMM Precipitation Radar (PR) observations of rain rate profiles from the TRMM satellite with concomitant profiles obtained from the Cloud Profiling Radar (CPR) on the CloudSat satellite. Our hypothesis in this research is that in order for latent heating vertical structures within the tropics to exhibit similar first order behavior, i.e., similar diurnal modulation of altitudes and amplitudes of maximum heating -- their concomitant spectral diurnal vertical structures must be comparable. In pursuing this hypothesis, our initial scientific objective is to demonstrate that similar precipitation regimes in the tropics exhibit similar spectral-vertical diurnal variability. In this presentation we discuss the methodology behind and preliminary analyses of spectrally extended and vertically projected retrievals of precipitation diurnal variability using three distinct datasets of spectral rain rate profiles: (a) PR-only, (b) PR-enhanced using explicit CPR measures, and (c) PR-enhanced using explicit CPR measures and proxy CPR estimates. In our lexicon, “proxy CPR estimates” pertain to rain rate profiles determined from a CPR-PR rain profile matching scheme underpinned by a database of spatially and temporally coincident CPR and PR profiles in which the spatial coincidence is near-exact and the temporal coincidence is within 2 minutes. Rain profiles are matched instead of attenuation-corrected reflectivity profiles for various, somewhat subtle reasons. The CPR rain rate profiles are determined from a Z-R / Z-K iterative and recursive Hitchfeld-Bordan retrieval algorithm in which K represents vertical axis attenuation within a light rain rate environment. Two years of CloudSat data are used to generate the database. An elaborate, 9-dimensional graphics operator that we refer to as the

61. Alexander Sinyuk

(SSAI, NASA/GSFC)
Co-Authors: A. Sinyuk, B. Holben, J. Schafer, O. Dubovik, and AERONET team

Validation of CALIPSO aerosol retrievals by AERONET (2): joint sun-photometer/lidar inversion.

Correlating aerosol parameters estimated by two independent retrieval techniques constitutes a way of indirect validation of these parameters estimates. A new retrieval technique inverting joint AERONET/CALIPSO observations collocated in space and time has been developed. This technique allows retrieval of vertical profile of aerosol concentration in addition to parameters estimated by AERONET aerosol operational algorithm. Thereafter vertical profiles of backscattering and extinction can be calculated. The technique was tested by inverting joint AERONET/CALIPSO data sets collected during two field campaigns organized by AERONET project: CATZ (2007, USA) and TIGERZ (2008, India). Estimated vertical profiles of backscattering and extinction are compared to CALIPSO retrievals.

62. Gail Skofronick-Jackson

(NASA Goddard Space Flight Cent)
Co-Authors: Gail Skofronick Jackson, Benjamin T. Johnson, James R. Wang, Anne W. Kramer

Retrievals of Precipitating Snow Using CloudSat Reflectivities and High Frequency Brightness Temperatures

The Canadian CloudSat/CALIPSO Validation Program (C3VP) was a field campaign held during the winter of 2006-2007. The C3VP provided an opportunity for CloudSat and Global Precipitation Measurement (GPM) scientists to participate in cold-season northern latitude data collection activities. This poster will describe the field campaign, present some observations, describe a falling snow detection algorithm, and provide early analysis from a Bayesian falling snow retrieval analysis. Snow retrieval is subject to errors due to land surface emission uncertainties and to ambiguities in the vertical profiles. These challenges will be discussed on the poster. Furthermore, while these retrievals are currently focused toward high frequency brightness temperature imagery, we link knowledge gained from

"Stained Glass" gridding scheme is used to prepare maps of spectral vertical diurnal precipitation behavior in a latitude-longitude framework. These maps are used to help illustrate our findings vis-à-vis our initial scientific objective.

64. William Smith Jr.

(NASA LaRC)
Co-Authors: W. L. Smith Jr., P. Minnis, D. Spangenburg, R. Palikonda, J. K. Ayers, F. Chang, S. Benjamin and S. Weygandt

Evaluation of GOES and RUC cloud parameters over CONUS with CloudSat and CALIPSO data

Hourly cloud top height information derived from Geostationary Operational Environmental Satellite (GOES) data are being assimilated into the Rapid Update Cycle (RUC) to improve the representation of clouds and their effects in an operational weather prediction system over North America. In the current system, the satellite data provide no information on cloud vertical extent or the density of cloud water. However, this information is currently being derived routinely from passive satellite measurements during the daytime and offers the potential to improve the representation of the horizontal and vertical distribution of cloud hydrometeors in numerical weather analysis and forecast systems provided that the conditions for which the passive retrievals are sufficiently accurate are well understood. In this study, we present a comparison of cloud parameters derived from GOES data over the continental United States (CONUS) with cloud parameters generated by the RUC analysis and forecast system and similar parameters derived from CloudSat and CALIPSO data. The comparisons help identify the relative strengths and weaknesses of the observed and modeled cloud fields under various conditions and should be useful in guiding the development of improved assimilation techniques that utilize additional information content available from passive satellite cloud retrievals during the daytime.

65. William Smith Sr.

(University of Wisconsin and Hampton University)
Co-Authors: William L. Smith, Elisabeth Weisz, and Melissa Yesalusky

Validation of Climate Sounding Algorithm Cloud Heights

A fast, but accurate, atmospheric sounding retrieval algorithm has been developed to produce global climate products from satellite hyperspectral radiance data (e.g., AIRS, IASI, and CrIS). The retrieval algorithm has been applied to six years (2003-2008) of AIRS observations. The accuracy of the soundings below cloud level is highly sensitive to the accuracy of the cloud-top altitude and effective cloud optical depth/emissivity specified by the sounding retrieval process. This poster presents statistics produced from comparisons of AIRS derived cloud heights with the cloud heights obtained from Calipso Lidar and the CloudSat Radar observations, which have been co-located with Aqua AIRS observations. Data from the Calipso multi-spectral Infrared Imaging Radiometer (IIR) are used to detect conditions where the cloud heights within the AIRS field of view differ from those observed by Calipso and CloudSat.

66. Jeremy Solbrig

(Naval Research Laboratory / Texas A&M University)
Co-Authors: Jeremy Solbrig, Shaima Nasiri, Andrew Dessler

Thin Cloud Length Scales Using CALIPSO and CloudSat Data

Thin clouds are the most difficult cloud type to observe. As a consequence, despite their radiative importance and the biases they may cause in passive cloud measurements, very little is known about thin clouds. The recent availability of joint cloud products from the active remote sensing instruments aboard CloudSat and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite (CALIPSO) facilitates the study of these clouds. A post-processing algorithm is applied to one of these joint cloud products, 2B-GEOPROF-Lidar. The algorithm is designed to find horizontally continuous thin clouds within the cloud product and determine their locations, length scales, and vertical distributions by length. It is found that thin clouds may vary in length from a few km to over 2900 km and tend to be longest in the tropical upper troposphere with shorter clouds at higher latitudes and lower altitudes. In the upper troposphere between 0º and 40ºN, over 20% of all thin cloud measurements in the 2B-GEOPROF-Lidar product are contributed by thin clouds that are longer than 500 km. In fact, in this latitude range, over 65% of all thin cloud measurements are contributed by clouds longer than 100 km.

67. Olaf Stiller

(ECMWF)

Tackling the Representativity Problem

Great efforts are made at ECMWF to exploit CloudSat and CALIPSO data for model validation (improvements) and data assimilation. These applications require some knowledge of the error involved with these measurements. Of great importance is the representativity error which results from the different horizontal support of these satellite measurements [whose projection on a horizontal plane is basically a one dimensional (1D) line] and the 2D horizontal surface of a model grid box. Representativity issues become very important when dealing with cloud related variables which exhibit strong spatial variations, and, particularly, if one is interested in the subgrid properties of such a field.

To tackle the representativity problem, stochastic modeling methods are being employed at ECMWF which produce synthetic data that share some statistical properties (marginal probability density function and spatial covariances) with the observations of interest. The method is particularly suited to assign and validate a flow dependent measure for the local size of the representativity error. The validity of this approach is demonstrated for some cases where the 2D truth is known (from a scanning satellite instrument).

68. Kentaroh Suzuki

(Colorado State University)
Co-Authors: Kentaroh Suzuki, Graeme L. Stephens, Takashi Y. Nakajima and Susan C. Van den Heever

A study of warm cloud microphysics using multi-sensor satellite observations and cloud-resolving models

Warm cloud microphysics is an important process that determines how the cloud water falls from the atmosphere and controls optical properties of liquid clouds, providing a pathway through which aerosols influence the clouds. The CloudSat and the A-Train provides a unique opportunity to obtain an entirely new insight into the warm cloud microphysical processes. Some recent attempts to combine these sensors of the A-Train are highlighted in this presentation for investigating several key aspects of the warm rain formation processes. This includes a joint CloudSat, MODIS and AMSR-E analysis to diagnose the particle growth processes, to infer the time-scale of warm rain formation and to examine the drop collection processes. The vertical cloud structure revealed from CloudSat is also combined with MODIS multi-wavelength analysis to obtain more detailed understandings of how the particle growth processes relate to rain formation. These analysis methods can also be applied to the results from cloud-resolving models and compared with the observations. I would also like to discuss how these comparisons can be used for evaluating the cloud parameterizations in the models and for better understanding the observed characteristics of warm rain processes.

69. Didier Tanré

(L.O.A., Bat. P5)
Co-Authors: S. Peyridieu, A. Chedin, V. Capelle, C. Pierangelo, N. Lamquin and R. Armante

Dust infrared optical depth and altitude retrieved from 6 years of AIRS observations: a focus on Saharan dust using A-Train synergy (MODIS, CALIOP)

Remote sensing of aerosol properties in the visible domain has been widely used for a better characterization of these particles and of their effect on solar radiation. On the opposite, remote sensing of aerosols in the thermal infrared domain still remains marginal. However, knowledge of the effect of aerosols on terrestrial radiation is needed for the evaluation of their total radiative forcing. A key point of infrared remote sensing is its ability to retrieve aerosol optical depth as well as mean dust layer altitude, a variable required for measuring their impact on climate. Moreover, observations are possible night and day, over ocean and over land. In this context, six years (2003-2008) of the 2nd generation vertical sounder AIRS observations have been processed over the tropical belt (30°N-30°S). Our algorithm is specifically designed to retrieve coarse mode dust aerosol 10 µm optical depth (AOD) and mean layer altitude from infrared brightness temperatures. Benefiting from the unprecedented synergy between passive and active instruments brought by the Aqua-Train, results are compared to aerosol products from the active sounder CALIOP/CALIPSO.

First, our retrievals of the dust optical depth at 10 µm show a very good agreement with the 0.55 µm MODIS/Aqua optical depth product, particularly for tropical Atlantic regions downwind of the Sahara during the dust season, even far from the sources. Second, time series of the mean aerosol layer altitude, retrieved simultaneously with AODs, are compared to the CALIOP Level-2 products starting June 2006. This comparison, for regions located downwind of the Sahara, again shows a good agreement with a mean standard deviation between the two products of about 400 m over the period processed, demonstrating that our algorithm effectively allows retrieving accurate mean dust layer altitude.

An interesting feature of these results is the fact that if the AOD decreases from Africa to the Caribbean as a result of transport and dilution, altitude decreases less rapidly. This is in agreement with in situ measurements made during the Puerto Rico Dust Experiment (PRIDE) campaign and modelled forward trajectories. A global climatology of the dust optical depth at 10 µm and of the aerosol layer mean altitude has also been established, emphasizing the natural cycles of Saharan dust. This algorithm has been designed for processing high spectral resolution infrared sounders in general. Here applied to AIRS/Aqua, it is currently being extended to the processing of IASI/Metop observations, and should allow an even more accurate determination of aerosol properties.

70. Omar Torres

(Hampton University)
Co-Authors: Omar Totrres, Zhong Chen

Use of CALIPSO aerosol vertical distribution in OMI retrievals

We will discuss the combined use of CALIOP's observed aerosol vertical distribution and OMI radiance measurements in the near UV to retrieve aerosol single scattering albedo. The CALIPSO and OMI sensors observe the atmospheric aerosol load eight minutes apart. The quasi-simultaneity of OMI and CALIPSO measurements allows the implementation of an algorithm scheme that uses actual aerosol profiles. Preliminary results will be presented.

71. Mark Vaughan

(NASA)
Co-Authors: Mark Vaughan, Zhaoyan Liu, Matt McGill, Yong Hu, and Mike Obland

An assessment of CALIOP's 1064 nm Calibration Algorithm

72. Mark Vaughan

(NASA)
Co-Authors: Mark Vaughan, Ralph Kuehn, Ali Omar, Zhaoyan Liu, Yong Hu, and Brian Getzewich

CALIOP Version 3 Algorithm and Data Product Updates

7
3. Mark Vaughan

(NASA)
Co-Authors: Mark Vaughan, Ralph Kuehn, Dave Winker, Jim Lambeth, and Joe Howell

The CALIOP Version 3 Profile Products

74. Jean-Paul Vernier

(CNRS/LATMOS)
Co-Authors: J.P. Vernier, J.P Pommereau A. Garnier, J. Pelon, A. Hauchecorne, J.C Lebrun and L. Blanot

CALIOP calibration adjustment with GOMOS stellar occulation extinction

Aerosols have been observed in the tropics in the CALIOP calibration zone (30-34km) confirmed by past SAGE II observations. A first method has been proposed to adjust the lidar calibration in a cleaner altitude region at higher level (36-39km), where corrections coefficient are typically of 5 to 12% in the tropics. Another approach using ESA GOMOS/ENVISAT current aerosol extinction has also been explored. Both methods are compared with aerosol measurements from balloon flights and ground-based lidar.

75. Jean-Paul Vernier

(LATMOS/CNRS)
Co-Authors: J.P. Vernier, J.P. Pommereau, A. Garnier and J. Pelon

The tropical stratospheric aerosol layer from CALIOP observations

The occurrence of aerosols in the tropical upper troposphere and lower stratosphere(UTLS) has been investigated using CALIOP observations available since 2006. This analysis reveals significant changes in the aerosol concentration associated with different transport processes. In the tropical CALIOP calibration zone (30-34km), aerosols have been observed where past SAGE II had also evidenced their presence. After recalibrating the lidar data in a cleaner altitude region at higher level (36-39km), the stratospheric aerosol picture displays the slow ascent of several volcanic plumes with the Brewer-Dobson circulation, with modulation of horizontal and vertical transport by the Quasi-Biennial Oscillation (QBO). A minimum vertical velocity is found at 20km, almost null during the northern hemisphere summer, consistent with radiative heating calculations. In the lowermost stratosphere, the data show the presence of fast uplift of clean air from the tropopause to 19km in February-March. Another feature is the observation of aerosols at the tropopause over Africa in April-May and South Asia in July-August during the monsoon season, whose origin in still unclear.

76. Tom Vonder Haar

(Colorado State University/CIRA)
Co-Authors: Quantz, Heather M. and Thomas H. Vonder Haar

Observations of the Double Intertropical Convergence Zone Using CloudSat

The IPCC AR4 asserts that the tropical mean climate, particularly the behavior of the Intertropical Convergence Zone (ITCZ), is poorly simulated coupled global climate models. As shown in observational studies, the ITCZ in the Eastern Pacific splits and forms two distinct bands situated quasi-symmetrically about the equator for a short period of time during the boreal spring. However, most of the IPCC models examined produce an overly-persistent double ITCZ (DITCZ) during the simulation, resulting in a misrepresentation of the tropical precipitation, sea surface temperature (SST), winds, latent heating, and shortwave flux.
The Cloud Profiling Radar (CPR) aboard CloudSat allows for vertical profiling of the clouds in the DITCZ, offering a novel look at the vertical distributions of various cloud properties. This new data can be added to previous observations to provide a more complete picture of the poorly understood DITCZ phenomenon. In addition, the vertical data will contribute to an improved understanding of the discrepancy between DITCZ observations and the model simulations.
This study investigates a few of these vertical properties within the ITCZ and DITCZ domain including cloud type, deep convective cloud frequency, and radiative heating during February 15-May 15 of 2007 and 2008. Additionally, we compare deep convection to the underlying SST and SST anomalies.

77. Ulla Wandinger

(Leibniz Institute for Tropospheric Research)
Co-Authors: Ulla Wandinger, Gelsomina Pappalardo, Anja Hiebsch, Ina Mattis, Lucia Mona, and Fabio Madonna

Long-term aerosol and cloud database from correlative CALIPSO and EARLINET observations

The European Aerosol Research Lidar Network EARLINET performs correlative observations during CALIPSO overpasses based on a sophisticated measurement strategy since June 2006 (see Pappalardo et al., this workshop). Currently, with support from the European Space Agency, we establish a long-term aerosol and cloud database from EARLINET-CALIPSO observations. This database shall provide a tool for homogenizing long-term space-borne observations conducted with different lidar instruments, operating at different wavelengths, on various platforms. The database is also used to study the representativeness of the limited number of satellite lidar cross sections along an orbit against long-term lidar network observations on a continental scale.

The ideas and contents of the database are illustrated based on the example of a major Saharan dust outbreak over Europe in May 2008 during which about 80 EARLINET measurements were performed in correlation with several CALIPSO overpasses. Based on this extensive dataset, aspects of cloud/aerosol discrimination and aerosol typing are discussed and a statistical analysis of dust properties in terms of intensive optical properties (lidar ratios, Ångström exponents, color ratios) derived from EARLINET measurements is presented. The event is also used to demonstrate the methodology for the investigation of spatial and temporal representativeness of measurements with polar-orbiting satellites.

78. David Winker

(NASA Langley Research Center)
Co-Authors: Chieko Kittaka and David Winker

Global Aerosol Observations from CALIPSO

The CALIPSO dataset provides three-dimensional view of global aerosol distributions over a three year period, beginning in June 2006. The CALIPSO lidar observes aerosol during both night and day and over all surfaces, including above clouds. Elevated aerosol layers are primarily either dust or smoke, which can be discriminated through the use of lidar depolarization signatures. This poster highlights some of the capabilities of CALIPSO to observe and characterize aerosols. Initial comparisons of AOD from CALIPSO, MODIS, and Aeronet are presented. AOD values over southern Africa, where biomass burning is the major source of aerosols, are in a good agreement between CALIPSO and AERONET, but CALIPSO AOD tends to be low relative to MODIS and Aeronet. Work is underway to further validate and improve CALIPSO aerosol products.

79. Norman Wood

(Colorado State University, Department of Atmospheric Science)
Co-Authors: Norman B. Wood, Tristan S. L'Ecuyer, Andrew J. Heymsfield, Graeme L. Stephens

Progress toward a CloudSat Level 2 Snowfall product

Current efforts in the development of a CloudSat Level 2 snowfall profile retrieval algorithm and product are presented. The main areas of work include 1) analysing snow observations from a number of field experiments in order to develop constraints on snow microphical properties, 2) evaluating the application of these constraints to the modeling of snow particle microwave scattering properties, and 3) developing the components required for the retrieval algorithm, including forward models with uncertainty analyses and a priori relationships between elements of the retrieved state. A prototype product derived from C3VP cloud resolving model simulation data is also presented.

80. Hongbin Yu

(GEST, UMBC and NASA GSFC)
Co-Authors: Hongbin Yu, Mian Chin, Dave WInker, Ali Omar, Zhaoyan Liu, Chieko Kittaka, Thomas Diehl

Global view of aerosol vertical distributions from CALIPSO lidar measurements and GOCART simulations: Regional and seasonal variations

We examine seasonal variations of the vertical distribution of dust and non-dust aerosols using a statistical analysis of the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) lidar observations. The analysis uses nighttime observations under cloud-free conditions from June 2006 to November 2007. The CALIPSO aerosol observations are compared with collocated aerosol simulations from the Goddard Chemistry Aerosol Radiation Transport (GOCART) model and aerosol optical depth measurements from the MODerate resolution Imaging Spectroradiometer

(MODIS). The CALIPSO observations of geographical patterns and seasonal variations of aerosol optical depth are consistent with GOCART simulations and MODIS retrievals especially near source regions. Both the CALIPSO observation and GOCART model show that the aerosol extinction scale heights in dust and smoke source regions are higher than that in industrial pollution source regions. The CALIPSO aerosol lidar ratio generally agrees with GOCART model within 30% on regional scales. Major differences between satellite observations and GOCART model are identified, including (1) an underestimate of aerosol extinction by GOCART over the Indian sub-continent, (2) much larger aerosol extinction calculated by GOCART than observed by CALIPSO in dust source regions, (3) much weaker in magnitude and more concentrated in the lower atmosphere in CALIPSO observation than GOCART model and MODIS observation over transported areas in mid-latitudes, and (4) consistently lower aerosol scale height by CALIPSO observation than GOCART model. Possible factors contributing to these differences will be discussed.

81. Pengwang Zhai

(NASA Postdoctoral Program Fellow)
Co-Authors: Peng-Wang Zhai, Yongxiang Hu, Charles R Trepte, Patricia L Lucker, and Damien B. Josset

A Vector Radiative Transfer Model for Coupled Atmosphere and Ocean Systems

A vector radiative transfer (RT) model has been developed for coupled atmosphere and ocean systems. The new model is based on the Successive Order of Scattering (SOS) Method. The light reflection and transmission through a random rough ocean surface have been implemented. Shadowing function has been used to avoid divergence for light incident at large zenith angles. This RT model will be used for the study of clouds and aerosols combining lidar/radar (Calipso/Cloudsat) and passive polarimetry (Glory) measurements.

82. Qiuqing Zhang

(University of Utah,Department of Atmospheric Sciences)
Co-Authors: Qiuqing Zhang and Jay Mace

Improvements to the 2B-Geoprof-Lidar Product

The new version 2B-Geoprof-Lidar products provide CloudSat/Calipso merged data sets of 1064 nm attenuated backscatter, 532 nm total and perpendicular attenuated backscatter, and 532 nm extinction coefficient. The Calipso lidar data are averaged within Cloudsat footprints using a Gaussian weight distribution that is function of the Cloudsat point spread function and the location of the CALIPSO resolution volumes. This merged data set provides a useful tool for retrieving cloud properties and using the CloudSat data. We compare and validate the data sets with measurements from TC4. Several case studies from TC4 flights are examined.

83. Yuying Zhang

(Lawrence Livermore National Lab)
Co-Authors: Y. Zhang, S.A. Klein, J. Boyle, and G.G. Mace

Evaluation of cloud systems of CAM3 using the combined CloudSat and CALIPSO observations

The representation of clouds in climate models is one of the major uncertainties for the variation in projections of climate change, and it is first required to thoroughly evaluate the simulated cloud systems. The combined CloudSat and CALIPSO observations provide 3-dimensional description on hydrometeor distribution, and are used to evaluate the cloud and precipitation statistics simulated by CAM3. To facilitate a meaningful comparison of the model with observational data by accounting for the limitations of the instruments, the COSP developed through a multi-institutional collaboration produces the model output in identical form to that of the observations. The histograms derived from the model simulations are compared with the observations for different cloud regimes in tropical and polar regions. Other data sources are also used to characterize cloud regimes, and the preliminary results from the precipitation retrievals and CERES data are shown.

84. Leonhard Pfister and Eric Jensen

Use of CLOUDSAT and CALIPSO data in evaluating the effect of convection and clouds on water in the Tropical Tropopause Laye

The Tropical Tropopause Layer (dubbed the TTL), roughly between 13 and 18 km altitude in the tropics, is one of the coldest parts of the earth's atmosphere. In contrast to the rest of the global tropopause region, radiative heating rates are positive and mean vertical motion is upward. It is thus the pathway for constituents into the stratosphere, and the cold temperatures lead to the well-known very dry stratospheric conditions. This simple picture is made more complicated by the interaction of convective injection, horizontal advection through cold regions (and consequent dehydration), radiative heating in balance with slow ascent, constraints on the nucleation of ice crystals, and complex wave motions. In this paper, we report on TTL water simulations using a trajectory-based microphysical model that includes all of these physical effects.

CLOUDSAT and CALIPSO data are very valuable in directly constraining two of these physical effects, namely convective injection and radiative heating. As shown by NASA's CRYSTAL-FACE experiment, convective cloud top altitudes derived from lidar and cloud radar measurements are significantly higher than those based on the infra-red techniques (the only source of global measurements prior to CLOUDSAT and CALIPSO). We have developed a technique to produce high horizontal and time resolution convective altitude information based on TRMM and GOES information constrained by CLOUDSAT and CALIPSO global convective cloud altitude information. For radiative heating, we have implemented recent calculations performed by other CALIPSO investigators into our model. We find that convection has a limited impact on TTL water in the boreal winter season (about .2 ppmv or less), though the results at upper levels depend strongly on the penetration of the very deepest convective systems, something that is still uncertain due to the early afternoon crossing time of CLOUDSAT and CALIPSO. Radiative heating and the related distribution of vertical velocity has important effects on the water vapor distribution.