ACE
Aerosol/Cloud/Ecosystems Mission

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Poster Abstracts

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A COMBINED POLARIMETER AND LIDAR OPTIMAL ESTIMATION ALGORITHM TO IMPROVE AEROSOL MICROPHYSICS PROPERTY RETRIEVALS

by

X. Liu, S. Stamnes, R. Ferrare, C. Hostetler, S. Burton, E. Chemyakin, D. Mueller, Johnathan, W. Hair, and Brian Cairns

We have developed a combined lidar and polarimeter retrieval algorithm to retrieve vertically-resolved profiles of aerosol microphysics properties. The new retrieval system is modular in design. It consists of three modules, a vertically-resolved aerosol profile retrieval module for lidar data, an aerosol and cloud/ocean retrieval module for polarimeter data, and a combined retrieval module for both lidar and polarimeter measurements. In addition to performing optimal estimation retrievals on various data sources, we have designed the system so that it can be used to carry out aerosol retrieval performance trade studies by changing the input characteristics of lidar and polarimeter data. We have tested Lidar-only algorithm using both simulated data and various field campaign data (DISCOVER-AQ, CHARMS, TCAP, and ORACLES). For polarimeter-only modules, we have done the same for SABOR, TCAP, NAMES, and ORACLES data. The simulated retrieval studies show that the combined lidar+polarimeter retrieval provides much higher information content relative to their individual counterparts for retrieving effective radius, particle concentrations, and absorption properties.

ACE HIGH-SPECTRAL-RESOLUTION LIDAR (HSRL) CONCEPT, TECHNICAL MATURITY, AND COST

by

Chris Hostetler, Johnathan Hair, Rich Ferrare, Chip Trepte, Alan Little, Tory Scola, Marie Ivanco, and Beth Brumbaugh

NASA Langley developed an initial concept for the ACE lidar instrument in 2007 and has refined that concept over the last decade. These refinements have included incorporating details on technology advances made over the years, developing more detailed instrument models, and developing a detailed cost model. This poster summarizes the lidar concept, its technical maturity, and cost.

CALIPSO OCEAN SUBSURFACE DATA RECORD AND ITS APPLICATION IN OCEAN – ATMOSPHERIC INTERACTION STUDY

by

Yongxiang Hu

This poster will provide an overview of the CALIPSO ocean subsurface data record. I will also present an example of the relationship of inter-annual variations of phytoplankton and water cloud microphysics using the near 12-year CALIPSO observations of clouds and ocean.

CONSTRAINTS ON CLOUD FEEDBACKS FROM SATELLITE LIDAR

by

David Winker

The first NASA Decadal Survey Report was written around the time of the launch of CALIPSO and CloudSat. Since then, the value of cloud profiling from these two active sensors in the A-train satellite constellation has been demonstrated and our understanding of clouds and their role in the climate system has significantly advanced. Nevertheless, the response of clouds to a warming climate remains uncertain and reducing uncertainties in cloud feedbacks was identified as one of the "Most Important" Earth science objectives in the recent Decadal Survey Report. To reduce these uncertainties, it is necessary to observe long-term changes in clouds, and their controlling factors, and to also have observational constraints on the processes responsible for those changes. Verification that feedbacks simulated in models are due to the correct mixture of cloud property changes (cloud fraction, height, optical depth, phase) can best be provided by lidar observations. As the utility of lidar cloud observations is often overlooked, this poster will highlight the role of lidar in observing clouds and providing constraints on cloud feedbacks.

COUPLED AEROSOL AND LOWER BOUNDARY RETRIEVALS USING THE AIRBORNE MULTIANGLE SPECTROPOLARIMETRIC IMAGER (AIRMSPI): A REVIEW

by

Feng Xu, Gerard van Harten, David. J. Diner, Felix C. Seidel, Olga V. Kalashnikova, Anthony B. Davis, Michael J. Garay, Oleg Dubovik, Pengwang Zhai, Brian E. Rheingans, Mika G. Tosca, Brian Cairns, Mikhail D. Alexandrov, Richard A. Ferrare, Sharon P. Burton, Marta A. Fenn, Chris A. Hostetler, Robert Wood, and Jens Redemann

We give a review of aerosol retrieval algorithm development for the Airborne Multiangle SpectroPolarimetric Imager (AirMSPI [1]). AirMSPI was developed for NASA by the Jet Propulsion Laboratory (JPL) to advance our understanding of the climate and air quality impacts of aerosols, and the interactions between aerosols and clouds. It performs multi-angle observations of a target area between ±67° off nadir. Imaging is made in 8 spectral channels in the UV-NIR (355-935 nm), three of which (centered at 470, 660 and 865 nm) are polarimetric.

Optimization based algorithms have been developed to retrieve aerosol microphysical properties from AirMSPI observations over three types of boundary, namely ocean [2], land [3], and stratocumulus cloud [4]. Some boundary properties are determined simultaneously, including water-leaving radiance, bidirectional reflectance distribution function (BRDF) for land, and cloud droplet size distribution, cloud top height and cloud optical depth for stratocumulus cloud. Column water-vapor abundance is determined from the 935 nm spectral band. Our retrieval imposes constraints on, for example, spatial variations of aerosol microphysical properties [5], relations between underwater optical properties and water-leaving radiance, or spectral variance of BRDF shape. A hybrid radiative transfer (RT) code that combines the strength of Markov chain and doubling-adding RT methods was developed to improve modeling and retrieval efficiency. Retrievals were tested using remote sensing data AirMSPI acquired in different field campaigns since 2010. Validation was performed using coincident measurements by AERONET (NASA/GSFC) [6], HSRL-2 (NASA/LaRC) [7], and RSP (NASA/GISS) [8]. AirMSPI and its retrieval algorithms are precursors of the future spaceborne Multi-Angle Imager for Aerosols (MAIA) investigation which is currently being developed by JPL.

EYESAFETEY RISK ASSESSMENT FOR SPACEBORNE LASER OPERATIONS

by

Jennifer Inman, Chris Hostetler, and Chip Trepte

NASA designs and operates spaceborne lidar systems at exposure levels that are eye-safe along Earth's surface. Past efforts attempting to estimate the degree of risk posed to binocular users and telescope operators have varied widely, both in their underlying assumptions and in the resulting degree of uncertainty in their conclusions. This continued uncertainty has threatened the viability of future satellite missions incorporating advanced remote sensing laser measurements, like those called for by the ACE mission. The science objectives of future missions must be weighed against the potential for causing injury to the public. However, there is currently no common framework for risk assessment, mitigation, and acceptance for spaceborne lidar operations. Eye safety calculations have been handled independently by each program, employing different approaches, and having different opinions on what constitutes a maximum tolerable level of risk. This has led to uncertainty and programmatic risk. To that end, the current work has attempted to quantify the potential for injury due to spaceborne lidar systems within the framework of a probabilistic risk assessment. The methodology will be proposed to NASA HQ as a potential standard by which the future space lidar missions are evaluated in terms of risk to eye safety. This poster will provide details on the methodology, assumptions, and inputs being employed as well as the expectation values of the collective risk to the general public resulting from our current analysis.

GLOBAL STATISTICS OF MICROPHYSICAL PROPERTIES OF CLOUD-TOP ICE CRYSTALS

by

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

Ice crystals in clouds are highly complex. Their sizes, macroscale shape (i.e., habit), mesoscale shape (i.e., aspect ratio of components) and microscale shape (i.e., surface roughness) determine optical properties and affect physical properties such as fall speeds, growth rates and aggregation efficiencies. Our current understanding on the formation and evolution of ice crystals under various conditions can be considered poor. Commonly, ice crystal size and shape are related to ambient temperature and humidity, but global observational statistics on the variation of ice crystal size and particularly shape have not been available. Here we show results of a project aiming to infer ice crystal size, shape and scattering properties from a combination of MODIS measurements and POLDER-PARASOL multi-angle polarimetry. The shape retrieval procedure uses pixel-level polarimetry to infer the ensemble mean aspect ratios of components of ice crystals and the ensemble mean microscale surface roughness levels, which are quantifiable parameters that mostly affect the scattering properties, in contrast to “habit”. Ice sizes are obtained from the MODIS collection 6 product, but are corrected for the bias caused by the invariable ice model used in that product. We present global statistics on the variation of ice effective radius, component aspect ratio, microscale surface roughness and scattering asymmetry parameter as a function of cloud top temperature, latitude, location, cloud type, season, etc. Generally, with increasing height, sizes decrease, roughness increases, asymmetry parameters decrease and aspect ratios increase towards unity. Some systematic differences are observed for cloud tops warmer and colder than the homogeneous freezing level. Uncertainties in the retrievals will be discussed. These statistics can be used as observational targets for modeling efforts and to better constrain other satellite remote sensing applications and their uncertainties. This study is relevant to ACE since it quantifies biases in retrieved ice cloud properties caused by unconstrained ice models used in current methods. In addition, it demonstrates that information about the shape of ice crystals, and thus about the ice optical model, can be extracted from polarimeter measurements.

HIGH SPECTRAL RESOLUTION LIDAR: PROFILING IN THE OCEAN AND WATER CLOUDS

by

Johnathan Hair

The combination of the NASA Langley High Spectral Resolution lidar (HSRL) and the NASA GISS Research Scanning Polarimeter (RSP) was deployed onboard the NASA C-130 during two field campaigns as part of the NASA's Earth Venture-Suborbital (EVS) North Atlantic Aerosol and Marine Ecosystems Study (NAAMES). The main objectives of NAAMES are to study the phases of the North Atlantic annual plankton cycle and to investigate remote marine aerosols and their impact on boundary layer clouds. This offered a unique opportunity to evaluate both ocean subsurface optical profiles and water cloud profiles, both profiles being targeted objectives for the ACE mission.

Here we present HSRL retrievals of the cloud top extinction and lidar ratio (extinction/backscatter ratio) enabled by the high sampling resolution (1.25m) of HSRL. The HSRL measurements of extinction and the RSP measurements of the effective radius and variance are combined to directly derive the cloud droplet number concentrations (CDNC) of boundary layer clouds, which are then compared to in situ measurements. This same combination of instruments provides key measurements needed to better understand biogeochemical processes in the global oceans and air-sea exchange processes important for climate studies. Specifically, we present lidar depth-resolved ocean optical profiles and compare them to in situ ship measurements and RSP ocean optics retrievals.

HSRL INTERFEROMETRIC RECEIVER TECHNOLOGY AND OPERATIONAL READINESS

by

Shane Seaman, Tory Scola, Sharon Burton, John Smith, and Chris Hostetler

NASA Langley has developed a high-spectral-resolution-lidar (HSRL) optical filter that meets requirements for space flight. The filter consists of a field-widened Michelson interferometer that separates particulate and molecular backscatter onto two separate detectors in the lidar receiver, and thereby enables independent retrievals of aerosol extinction and backscatter. A similar version of this interferometer has flown on four field deployments of Langley's HSRL-2 instrument. A method for the operational calibration of the interferometric HSRL measurement has been developed, and extensive work has been done to assess the precision, accuracy, and systematic errors in the retrieved aerosol products. In addition, the interferometer successfully passed preliminary environmental testing, including a three axis vibration test to GEVS workmanship levels. While the interferometer was developed as the filter for the 355 nm wavelength, a 532-nm version is currently under development and is due to be finished by September 2018. The interferometric technique will enable accurate retrievals at the highest possible precision compared to other HSRL techniques, including the iodine filter at 532 nm. Based on the comprehensive development program for this subsystem, the interferometer represents a well-tested, robust, low-risk implementation for an HSRL optical filter. The technology readiness level of this interferometric HSRL filter is currently at TRL 6.

LESSONS LEARNED FROM 33 MONTHS OF CATS DATA AND IMPLICATIONS FOR FUTURE SPACE-BASED LIDAR

by

John E. Yorks, Matthew J. McGill, and Edward Nowottnick

The Cloud-Aerosol Transport System (CATS) is an elastic backscatter lidar that operated for 33 month on-orbit from the International Space Station (ISS), firing over 200 billion laser pulses. The CATS instrument was designed to demonstrate new in-space technologies for future Earth Science missions while also providing properties of clouds and aerosols. CATS operated the first 6 weeks in a mode that provided dual wavelength backscatter and depolarization measurements (532 and 1064 nm) using 2 beams. After the first laser failed, the last 31 months of operation were limited to single wavelength backscatter and depolarization measurements using one beam.

The research community is producing high impact science with the CATS 1064 nm data products (backscatter, depolarization ratio, layer heights and type, etc.) despite the lack of a funded science team and higher-order multi-wavelength data products. CATS aerosol layer heights and 1064 nm backscatter provided in near real time, with a data latency of <6 hours, proved invaluable to predicting volcanic plume transport from aerosol models. The CATS robust 1064 nm backscatter and corresponding data products are well suited for studies of above cloud aerosol impacts on the climate system, especially the relative proximity of the full aerosol plume to the underlying cloud. Finally, CATS provides unprecedented diurnal lidar sampling from space that demonstrates the need for such measurements in the future. Given the orbit of the ISS, a three-day repeat cycle that passes over the same locations but at different local times, CATS has shown that A-Train sensors (passing over the same location at the same local time every overpass) are only capturing a “snapshot” of the cloud diurnal cycle. These results from CATS suggest an elastic backscatter lidar, possibly implemented as multiple SmallSats, is a strong potential path forward for the lidar called out in 2017 Decadal Survey aerosol mission.

LIDAR LESSONS FROM CALIPSO AND CATS: COMPARING LARGE PULSE ENERGY, LOW REP RATES TO SMALL PULSE ENERGY, HIGH REP RATES FOR ADVANCING DAYTIME AEROSOL/CLOUD SCIENCE

by

Mark Vaughan, Sharon Rodier, Matt McGill, Kathy Powell, Chip Trepte

From February 2015 through October 2017, NASA had two operational, Earth-observing lidars simultaneously in orbit. While both systems are elastic backscatter lidars, their fundamental measurement approaches are quite different. The lidar on the Cloud Aerosol Lidar Infrared Pathfinder Satellite Observations (CALIPSO) mission emits relatively high energy laser pulses (~100 mJ at both 532 nm and 1064 nm) at a relatively low frequency (20.16 Hz), and measures the backscattered energy using analog detection devices (photomultipliers at 532 nm and an avalanche photodiode at 1064 nm). In contrast, the lidars aboard the Cloud Aerosol Transport System (CATS) emitted low energy pulses (1–2 mJ) at high repetition rates (4–5 kHz), and measured the backscatter returns using photon counting technology. In this presentation we compare the demonstrated performance of these two different systems in two specific areas (signal-to-noise ratio and calibration accuracy), with the goal of determining which technique is better suited to satisfying the multi-sensor measurement requirements specified by ACE.

MILLIMETER- AND SUBMILLIMETER-WAVE REMOTE SENSING OF CLOUDS AND PRECIPITATION

by

Ian S. Adams

Millimeter- and submillimeter-wave (mm/submm) remote sensing offers an attractive approach to observing clouds and precipitation. The short wavelengths, compared with microwave radars and radiometers, result in smaller sensors that can be more easily accommodated on spacecraft, especially in an era of focus on small satellites. These mm/submm sensors also offer advantages to instruments at both longer and shorter wavelengths through increased sensitivity to smaller particles and increased penetration into clouds, respectively. To support the use of current sensors and make the case for the development of future technologies, we implemented a simulation framework to determine the necessary measurement capabilities for observing clouds and precipitation. The simulations particularly focus on the utilization of multifrequency active and passive sensors for profiling layers of supercooled liquid embedded within ice clouds and snow. The simulation results, as well as data from past field campaigns, give confidence that these sensors add value to cloud and precipitation microphysical studies.

MULTI-FREQUENCY RADAR RETRIEVAL OF SNOWFALL MICROPHYSICS

by

Jussi Leinonen, M. D. Lebsock, O. O. Sy, S. Tanelli, B. dolan, r. J. chase, J. A. FINLON, D. Moisseev, A. von lerber

We have developed a method for retrieving the microphysical properties of falling snow from multi-frequency radar measurements. The method uses recent advances in simulating the radar reflectivity of snowflakes as the basis of its forward model. The microphysical properties are retrieved using a Bayesian approach that does not require the use of iterative algorithms; this enables the retrieval to be performed quickly and robustly. An exponential particle size distribution and a power-law mass-dimensional relationship are assumed. The attenuation correction scheme takes advantage of the availability of multiple frequencies, allowing stable correction of reflectivity at frequencies affected by attenuation. Plentiful test data with collocated multi-frequency radar measurements is available from recent field campaigns. We tested the algorithm using triple-frequency radar data available from the OLYMPEX/RADEX field campaign. This dataset contains collocated airborne radar measurements collected by the NASA APR-3 radar at Ku band (13.4 GHz), Ka band (35.6 GHz) and W band (94.9 GHz). We compared the results to hydrometeor identification using the NPOL radar, which was also present at the campaign, and was often overflown by the DC-8 aircraft carrying the APR-3. We also assessed the retrieval performance using the in situ data collected by the University of North Dakota Citation aircraft. Using these data, we examined the sensitivity of the algorithm to the a priori assumptions and to the number of available radar frequencies. The results show that multi-frequency radars have a substantial advantage over single-frequency radars for constraining snowfall microphysics, especially the size of snowflakes. The benefits of a third frequency are more limited, but three-frequency radars can be used to detect occurrences of graupel, which has a particularly high density. Among the three frequencies, there does not seem to be any single one that would be preferable from an information content perspective, nor is any of the dual-frequency combinations particularly better than any other. Even with the triple-frequency configuration, the retrieval results are somewhat sensitive to the prior assumptions; this emphasizes the importance of accurate climatological statistics for the microphysical parameters.

NASA LANGLEY RESEARCH CENTER AIRBORNE HSRL-2 AEROSOL MEASUREMENTS DURING RECENT FIELD MISSIONS

by

Richard Ferrare, Chris Hostetler, Johnathan Hair, Sharon Burton, Anthony Cook, David Harper, Marta Fenn, Amy Jo Scarino, Marian Clayton, Detlef Müller, Eduard Chemyakin, Patricia Sawamura, Xu Liu

We discuss aerosol measurements and retrievals derived from data acquired by the NASA Langley Research Center (LaRC) multiwavelength High Spectral Resolution Lidar-2 (HSRL-2) during recent field missions. HSRL-2, which was developed as an airborne prototype of the multiwavelength HSRL planned for the NASA ACE mission, measures profiles of aerosol and thin cloud extinction and optical thickness via the HSRL technique at 355 and 532 nm, and backscatter and depolarization at 355, 532, and 1064 nm. Additional products include profiles of extinction and backscatter Ångström exponent, extinction-to-backscatter ("lidar") ratio, mixing ratio of spherical-to-nonspherical backscatter, aerosol type, and AOD partitioned by type, and aerosol mixed-layer height. We describe our advanced, automated algorithms that use the HSRL-2 aerosol backscatter and extinction profiles to derive "curtains" of aerosol effective radius, number, surface, and volume concentrations, and fine mode fraction. We show that the retrieved profiles of aerosol concentration and effective radius compare well with coincident airborne in situ measurements.

HSRL-2 was first deployed in 2012 for the DOE TCAP mission and has subsequently been deployed on the: 1) NASA LaRC King Air for three NASA DISCOVER-AQ EV-S missions, 2) NASA ER-2 for the first ORACLES EV-S mission and the NASA ACEPOL mission, 3) NASA P-3 for the second ORACLES EV-S mission. The HSRL-2 aerosol measurements and retrievals from these missions have been used to assess regional and global model representations of aerosol backscatter and extinction profiles and mixed layer heights; evaluate aerosol extinction profiles derived from airborne in situ measurements and CALIPSO operational and research algorithms; evaluate aerosol optical thickness derived from airborne and satellite remote sensors; characterize the behavior of aerosol optical properties near clouds; accurately specify aerosol extinction for quantifying aerosol radiative transfer; provide a detailed representation of horizontal and vertical distributions of smoke relative to low clouds over the Southeastern Atlantic Ocean; reveal different spectral behaviors of aerosol depolarization for nonspherical dust and smoke particles, and retrieve curtains of PM2.5 concentration over the California central valley. We describe some of these applications in this poster.

NON-PARAMETRIC METHODOLOGY TO ESTIMATE SNOW FROM DUAL FREQUENCY (KA-W) RADAR REFLECTIVITY OBSERVATIONS

by

Mircea Grecu and Gerald M. Heymsfield

A major challenge in deriving accurate estimates of physical properties of falling snow particles from single frequency space- or airborne radar observations is that snow particles exhibit a large variety of shapes and their electromagnetic scattering characteristics are highly dependent on these shapes. Furthermore, snow Particle Size Distributions (PSDs) can not be accurately described by single parameter functions, which further hinders the derivation of reliable relationships for snow estimation from single frequency radar observations. Dual frequency (Ka-W) radar observations are expected to facilitate the derivation of more accurate snow estimates because the information in the Ka-W dual frequency ratio along with climatologic information regarding the vertical distribution of PSD parameters may be used to better quantify the size of the snow particles in the radar observing volume.

In this study, a non-parametric methodology to estimate snowfall from multiple frequency radar observations is investigated. The methodology does not require any assumption regarding the distribution of snow particle sizes and relies on a efficient search procedure to incorporate information from observed Particle Size Distributions (PSDs) in the estimation process. Over 200,000 PSDs derived from in situ observations collected during the OLYMPEX and IPHEX field campaigns are used in the development and the evaluation of the non-parametric estimation methodology. These PSDs are used to create a database of snow related variables and associated computed radar reflectivity factors at Ka- and W-band. The computed reflectivity factors are used to derive snow estimates and investigate the associated errors and uncertainties. The methodology is applied to Ka-W frequency radar observations collected during the Olympic Mountains Experiment (OLYMPEX) and the Integrated Precipitation and Hydrology Experiment (IPHEx) field campaigns. Direct comparison of estimated snow variables to estimates from in situ instruments show results consistent with the error analysis. Estimates are also compared to triple frequency (Ku-Ka-W) estimates, that, in theory, are expected to be more accurate.

RETRIEVAL OF BOUNDARY LAYER CLOUD WATER PATH AND EFFECTIVE RADIUS USING HIGH RESOLUTION IMAGERY AND 3D RADIATIVE TRANSFER

by

Roger Marchand

Differences in Boundary Layer Cloud (BLC) responses between climate models have been identified as one of the largest sources of uncertainty in climate model projections. Satellite retrievals of BLC water path and effective radius from MODIS and other Visible-and-Near-Infrared satellite imagers are being widely used in the assessment of climate and other atmospheric models. However, operational satellite imager retrievals for BLCs are based on one-dimensional radiative transfer (1D RT), which nominally limits application of retrievals to homogeneous stratocumulus. However about 25% of the ocean surface (at 1 km resolution) is only partly-filled-by-cloud or on-a-cloud-edge. Conditions that result in both significant uncertainties in BL cloud fraction and large errors in cloud microphysical retrievals based on 1D RT.

While higher resolution visible imagery (that is, significantly better than the 250 m to 1 km used by MODIS) can almost certainly reduce uncertainties in BL cloud fraction (at least over ocean), it is not clear that such high resolution imagery can be used to improve retrievals of cloud water path, effective radius, or even optical depth due to 3D scattering effects. In this presentation we report on our efforts to retrieve BL cloud water path and effective radius using a full 3D radiative transfer (RT) rather than relying on 1D RT. The analysis will include examination of an iterative 3D retrieval applied to both idealized and observed clouds.

RSP RETRIEVALS OF AEROSOL/OCEAN/CLOUD PRODUCTS USING MAPP/NASA HPC WITH COMPARISON TO HSRL-1/HSRL-2

by

Snorre Stamnes, Brian Cairns, Xu Liu, Sharon Burton, Chris Hostetler, Richard Ferrare, Bastiaan van Diedenhoven, Jacek Chowdhary, Johnathan Hair

The NASA GISS RSP (Research Scanning Polarimeter) and the NASA LaRC HSRL-1/HSRL-2 (High Spectral Resolution Lidar) are advanced, airborne ACE prototype instruments, capable of retrieving detailed and accurate aerosol/cloud/ecosystem products. We present operational and simultaneous retrievals of aerosol/cloud microphysical properties and ocean color products from RSP measurements collected during the SABOR, TCAP, NAAMES, and ORACLES field campaigns. Comparisons are made to simultaneous HSRL-1 and HSRL-2 AOD measurements and to HSRL-1 ocean products. A description is also provided of the retrieval framework, called MAPP (Microphysical Aerosol Properties from Polarimetry). MAPP was designed in collaboration with the NASA GISS RSP and NASA LaRC HSRL teams, to enable combined lidar and polarimeter measurements, and to leverage NASA's existing HPC resources so that entire campaigns of data can be processed within hours. Thus, the MAPP algorithm framework is a prototype for operational processing of spaceborne polarimeter data for an ACE-like mission.

SUMMARY OF HSRL-2 AEROSOL MEASUREMENTS FROM ACEPOL CAMPAIGN

by

Marta Fenn, Chris Hostetler, Richard Ferrare, Johnathan Hair, Sharon Burton, Anthony Cook, David Harper

The NASA Langley Research Center (LaRC) multiwavelength High Spectral Resolution Lidar-2 (HSRL-2) participated in the Aerosol Characterization from Polarimeter and Lidar (ACEPOL) campaign from Oct-Nov, 2017 aboard the NASA ER-2. Remotely measurement profiles of aerosol and cloud backscatter were collected from 500 m below the ER-2 flight altitude (~ 20 km) to just 30 m above the surface.

We will show vertically range resolved “curtains” of aerosol backscatter, extinction, and depolarization measurements at three wavelengths (355, 532, and 1064 nm) from the ACEPOL campaign with special focus on the aerosol loading near the surface. For contrast, we will also show high aerosol loaded measurements made by the same instrument during the ORACLES campaign. These and additional products such as extinction and backscatter Ångström exponent, extinction-to-backscatter (“lidar”) ratio, mixing ratio of spherical-to-nonspherical backscatter, aerosol type, and aerosol optical depth, are archived at the NASA following address: https://www-air.larc.nasa.gov/cgi-bin/ArcView/acepol

THE IMPACT OF LIDAR DETECTION SENSITIVITY ON ASSESSING AEROSOL DIRECT RADIATIVE EFFECTS

by

Tyler Thorsen, Richard Ferrare, Chris Hostetler, Sharon Burton, John Hair, Kathleen Powell

One of the thematic goals of the ACE mission is to further our understanding of the direct aerosol radiative forcing. This sentiment was echoed by the 2017 Decadal Survey that identified as ``most important'' the objective of reducing the IPCC AR5 total aerosol radiative forcing uncertainty by a factor of 2. The 2017 Decadal Survey further suggested the combination of a backscatter lidar and polarimeter to address this and various other aerosol-related Earth science application objectives.

In this work, we focus on the simplest of aerosol-radiation interactions: the aerosol direct radiative effect (DRE), i.e. the radiative effect of all aerosols both natural and anthropogenic. Several recent estimates of the
aerosol DRE have been made using observations the CALIPSO lidar, which has the potential to provide better global all-sky estimates than passive sensor-derived estimates. However, comparisons to more advanced ground-based and airborne lidars show that CALIPSO does not detect all radiatively-significant aerosol, i.e. aerosol that directly modifies the Earth's radiation budget. We estimated that CALIPSO's lack of sensitivity results in an underestimate of the magnitude of the global mean aerosol DRE by up to 54%. Additionally, the CATS lidar on-board the ISS is shown to have a poorer sensitivity than CALIPSO.

To achieve the goal of reducing aerosol radiative forcing, the most basic requirement is a more sensitive lidar. To this end, high-accuracy ground-based and airborne lidar datasets have been used to compute the detection sensitivity required to accurately resolve the aerosol DRE. Preliminary simulations of the LaRC ACE high spectral resolution lidar (HSRL) concept shows a detection sensitivity that could nearly eliminate the current aerosol DRE bias. Also discussed is the inherent detection advantages of a HSRL. Additionally, an HSRL would provide several other benefits for aerosol-radiation studies.

UNCERTAINTY CHARACTERISTICS OF TOTAL WATER PATH RETRIEVALS IN SHALLOW CUMULUS DERIVED FROM SPACEBORNE RADAR/RADIOMETER INTEGRAL CONSTRAINTS

by

Matthew Lebsock, Kentaroh Suzuki

A precipitating marine cumulus cloud simulation is coupled to radiation propagation models to simulate active and passive microwave observations at 94 GHz. The simulations are used to examine the error characteristics of the total water path retrieved from the integral constraints of the passive microwave brightness temperature or the path-integrated attenuation (PIA) using a spatial interpolation technique. Three sources of bias are considered: 1) the misdetection of cloudy pixels as clear, 2) the systematic differences in the column water vapor between cloudy and clear skies, and 3) the nonuniform beamfilling effects on the observables. The first two sources result in biases on the order of 5–10 gm2 of opposite signs that tend to cancel. The third source results in a bias that increases monotonically with the water path that approaches 50%. Nonuniform beamfilling is sensitive to footprint size. Random error results from both instrument measurement precision and the natural variability in the relationship between the water path and the observables. Random errors for the retrievals using the CloudSat PIA are estimated to be the larger of either 20 gm22 or 30%. A radar/ radiometer system with a measurement precision of 0.3K or 0.05 dB could reduce this error to the larger of either 10 gm2 or 30%. All error mechanisms reported here result from variability in either the spatial structure of the atmosphere or the hydrometeor drop size distribution. The results presented here are specific to the cloud simulation and in general the magnitude will vary globally.

USING HIGH-SPECTRAL RESOLUTION LIDAR TO INFER CCN SPECTRA: RESULTS FROM NASA DISCOVER-AQ AND NAAMES FIELD CAMPAIGNS

by

Richard H. Moore, Patricia Sawamura, Kyle Dawson, Sharon P. Burton, Eduard Chemyakin, Detlef Müller, Alexei Kolgotin, Richard A. Ferrare, Chris A. Hostetler, Luke D. Ziemba, Andreas J. Beyersdorf, Ewan Crosbie, Edward Winstead, Yohei Shinozuka, Lee Thornhill, and Bruce Anderson

There has been intense interest in recent years in developing correlations between CCN number concentrations and satellite observables such as column-integrated aerosol optical depth (AOD) or ambient aerosol extinction in order to place constraints on the global CCN budget and geographical distribution. These parameters are chosen because of the existing NASA Earth Observing System Sensors, particularly MODIS, but also CALIPSO. Airborne and ground-based field campaigns provide the comprehensive observational datasets upon which to develop and test these correlations with a number of relationships being previously reported in the literature (e.g., Andreae, 2009; Liu et al., 2014; Shinozuka et al., 2015). Generally, these correlations are monotonic, but are ill-constrained (variability of 10-100-fold). Lessons from HSRL and CALIPSO lidar remote sensing aerosol classification efforts tell us that aerosol intensive optical parameters encode information about the aerosol size and composition regardless of number or mass concentration that can be used to differentiate aerosol types. Since aerosol size and composition are the primary drivers of CCN activity, this information holds promise for placing constraints on the shape of the CCN spectrum.
Here, we present comparisons of in situ aerosol and CCN properties with remotely-sensed aerosol microphysical properties (number, volume, effective radius, and refractive index) as well as newly-developed inferences of CCN spectra. Measurements were carried out during the NASA DISCOVER-AQ and NAAMES campaigns in urban and remote marine environments, respectively. Large differences in both aerosol loading and composition were observed during these campaigns, which makes them ideal for exploring much of the range in aerosol microphysical and optical properties. We discuss relationships between HSRL aerosol typing, extinction, and intensive parameter measurements to predict CCN.

WHY HSRL?

by

S. P. Burton, C. A. Hostetler, J. W. Hair, R. A. Ferrare, K. A. Powell, X. Liu, S. Stamnes, T. Thorsen, M. A. Vaughan

The ACE science working group satellite concept calls for a combination of high spectral resolution aerosol lidar and a polarimeter able to determine vertical profiles of aerosol extinction and clouds. Here we discuss why an HSRL lidar is required to achieve these requirements. The primary advantage of an HSRL over an elastic backscatter lidar is that the HSRL channel allows for the independent retrieval of vertically resolved aerosol extinction without constraint. Not requiring a constraint means greater availability of retrievals in polar regions, on the night side, and in broken cloud situations, plus greater accuracy particularly in the lowest part of the atmosphere and in scenes with aerosol heterogeneity. Advantages go beyond the extinction products. Unlike attenuated backscatter, which is an integrated quantity, the aerosol backscatter coefficient depends only on the aerosol at a specific level in the atmosphere, making it preferable for use in quantitative applications. The aerosol backscatter coefficient is more accurate from an HSRL system compared to the retrieval from a single-channel system. This is because errors in both extinction and backscatter from a single-channel system increase with decreasing altitude, due to the need to accurately characterize the overlying attenuation. This means that an HSRL will also have more valid data in and near the boundary layer where aerosol is of primary interest for air quality and weather applications and for many climate objectives including aerosol-cloud interaction studies. Even cloud properties that do not directly use the HSRL capability (cloud phase and thin cirrus retrievals) benefit from the more accurate calibration of an HSRL system. The improved accuracy of backscatter and extinction also lead to better capabilities for aerosol typing, improved retrievals of aerosol radiative effect, and increased information content for combined lidar + polarimeter retrievals of profiles of microphysical properties such as vertically resolved effective radius.

CHARACTERIZING THE TRADE SPACE BETWEEN CAPABILITY AND COMPLEXITY IN NEXT GENERATION CLOUD AND PRECIPITATION OBSERVING SYSTEMS: SHALLOW CUMULUS CONVECTION

by

Jay Mace, Zhuocan Xu, Derek Posselt

The 2017 U. S. National Academy of Sciences Decadal Survey for Earth Sciences identifies cloud and precipitation processes as a key target for observational constraint in the next decade. Observationally constraining the processes that cause cloud water to become precipitation is important because these processes control critical cloud lifetime and cloud coverage quantities and they are susceptible to modulation by variations in aerosol. Furthermore, such processes present unique challenges to measurement strategies and demand a level of complexity that may exceed what is reasonably possible for the measurement systems of the next decade. We are, therefore, exploring the trade space between complexity and capability in characterizing the precipitation processes in liquid-phase cumulus convection using techniques such as Markov Chain Monte Carlo (MCMC) that allow us to specify the characteristics of a notional measurement system and then explore the ability of that measurement system to characterize the processes that govern precipitation production. Because MCMC allows us to efficiently and fully characterize the posterior retrieval solution space, we can accurately quantify the information content that an observing system contributes under realistic conditions. This approach is being applied to observations collected during the recent campaigns and results from those campaigns will be discussed.

NEW RETRIEVAL TECHNIQUES USING A BACKSCATTER LIDAR: APPLICATIONS FOR EXTINCTION AND PM2.5

by

E. Nowottnick, A. da Silva, J. Yorks, M. McGill

Recent developments in aerosol data assimilation techniques incorporate optical thickness (AOT) in global aerosol transport models, a 2-dimensional column integrated quantity reflective of the aerosol loading. This capability has greatly improved simulated AOT forecasts, however, the vertical position, a key control on aerosol transport and surface air quality measurements, is often not impacted when 2-D AOT is assimilated.

Using the near-real time data downlinking and processing capability of the NASA Cloud-Aerosol Transport System (CATS) onboard the ISS, we have developed a 1-D ensemble-based (1-D EnsVar) retrieval technique that incorporates vertical profiles of total attenuated backscatter to produce vertically resolved estimates of speciated aerosol extinction, concentration and surface PM 2.5, among other parameters. Ensemble perturbations and prior information are derived from NASA Goddard Earth Observing System (GEOS) atmospheric general circulation model and assimilation system which currently assimilates AOT from a number of passive sensors. The applications of this methodology are multiple, providing a path forward to inform air quality forecasting models, and an effective way to improve estimates of surface PM2.5 concentrations from passive sensors. Another key application of this technique is the capability to retrieve a dynamic lidar ratio that is a reflective of aerosol mixtures simulated by the GEOS system, a new opportunity to improve extinction products from backscatter lidars.

RECONSTRUCTING HIGH SPATIAL AND TEMPORAL RESOLUTION EXTINCTION AND BACKSCATTER IMAGES FROM VERY PHOTON LIMITED LIDAR OBSERVATIONS

by

Robert Holz

This poster proposes a new method to infer the backscatter and extinction coefficients from very photon limited photon-counting lidar observations such as spaced lidar observations. The new method uses the photon detector noise model with the lidar forward model to infer the coefficients while constraining the coefficients to be piecewise smooth in a coarse-to-fine image resolution framework. Specifically, the inferred coefficients at a coarse image resolution is used to improve the inference of the next finer resolution, resulting in state-of-the-art backscatter and extinction inference results. In this abstract we demonstrate that the new method infer accurate high spatial and temporal resolution backscatter and extinction coefficients from very photon limited photon-counting High Spectral Resolution Lidar (HSRL) observations, whereas the standard approach that is used by lidar experts is unable to achieve the same accuracy.

The HARP Family of Polarimeters for the Retrieval of Aerosol, Cloud and Surface Properties

by

J. Vanderlei Martins, Brent McBride, Roberto Fernandez-Borda, Henrique Barbosa, and Lorraine Remer

The Hyper-Angular Rainbow Polarimeter (HARP) is an imaging polarimeter concept with components in the UV, VNIR and SWIR wavelength ranges that has been developed for ACE applications. The VNIR concept of this sensor has been funded as technology demonstration by the NASA Invest Program in the form of a CubeSat satellite aimed to launch in 2018. A second copy of the HARP VNIR concept has been adapted for airborne applications as the AirHARP VNIR sensor, and a third copy (HARP-2 VNIR) is under development for deployment in the NASA PACE mission.

Details and differences between the different HARP concepts will be presented and discussed in this poster. Laboratory characterization and field data will be presented for HARP and AirHARP. In particular, the AirHARP imaging polarimeter has flown in two recent airborne campaigns (Lake Michigan Ozone Study – LMOS and the Aerosol Characterization from Polarimeter and Lidar campaign – ACEPOL) to demonstrate its applications on the measurements of aerosols, clouds, and surface properties. During ACEPOL, AirHARP has flown together with other 3 airborne polarimeters (AirMSPI, AirSPEX, and RSP) for intercalibration, intercomparison and for the study of potential joint retrievals.
Preliminary results from these campaigns will be presented here exploring the particularities and unique features of the HARP design. The wide cross track FOV (94 deg) and AirHARP's hyper-angular capabilities will be explored for the retrieval of aerosol and cloud microphysical properties. First intercomparison results with other polarimeters will also be explored and presented here.