NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences
NNH19ZDA001N-ATDM
A.26 Weather and Atmospheric Dynamics

The study and analysis of the dynamics of the atmosphere and its interaction with the oceans and land is an important component of the Weather Focus Area. Improvement of our knowledge of weather processes and related phenomena is crucial in gaining an understanding of the Earth system. This component of the Weather Focus Area is primarily designed to apply NASA Scientific remote sensing expertise to the problem of obtaining accurate and globally distributed measurements of the atmosphere to enhance our understanding of atmospheric dynamical processes and assimilate these measurements into NASA's research, cloud and climate models, and quasi-operational weather models in order to improve and extend U.S. and global weather prediction. NASA-sponsored research continues to gain new insight into weather and extreme weather events by the utilization of data obtained from a variety of satellite platforms.

This solicitation was aimed at enabling improved predictive capability for certain weather and extreme weather events in three specific sub-element areas. The first sub-element related to difficult-to-retrieve weather conditions such as in complex environments, or with orographic influences, light precipitation cases, rain/snow transitions, etc. The second focused on the use of past NASA field campaign data from a long series of field experiments, and in conjunction with satellite data and numerical models, to better understand relationships between remotely sensed data and the physical properties of the underlying atmospheric and surface conditions for improving process knowledge, algorithm assumptions, and advancing models. The third offered an opportunity to participate in a field experiment in 2020. NASA received a total of 85 proposals in response to this NRA element and selected 20 for support. A total amount of $8 M is expected to be available to support these proposals over a period of three years.

Ali Behrangi/University of Arizona
Improving Polar Snowfall Estimation Using NASA's Complementary Remote Sensing Observations
19-ATDM19-0041

To better understand the Earth system, weather processes, changes in water and energy cycles, and to evaluate models and reanalyses, it is critical to quantify and reduce errors in observational elements of the water cycle. Here we propose to bring together complementary remote sensing observations to improve the existing estimates of precipitation in Polar Regions (including sea ice, frozen land, Antarctica and Greenland), where uncertainties in the existing satellite precipitation products are highest, availability

and reliability of the in situ data is lowest, and the need for complementary information is substantial.

Motivated by GPM's fully global focus, new sensors and retrieval capabilities, and the growing request by a broad range of users, the latest version of IMERG (V6) extended the previous 60oS-60oN coverage to fully global. IMERG is among the most popular GPM products that is (and will be) used in most weather and climate studies. Yet, IMERG does not fully utilize recent GPM Level 2 estimates over frozen land, as these regions are among the most difficult-to-retrieve conditions and in situ data are often either very sparse or unreliable. Therefore, improving precipitation estimates over these regions remains a major gap that calls for further exploration.

The objective of this proposal is not to develop new retrieval techniques. Instead, it aims to provide quantitative guidance to refine the existing estimates using complimentary remote sensing capabilities that have been underutilized. Specifically, we will:

- Construct annual, seasonal, or monthly maps of snowfall accumulation (with uncertainty) over Polar Regions (Antarctica, Greenland, and polar frozen land) using GRACE and CloudSat observations to assess and guide bias adjustment of the current precipitation products.
- Assess snow accumulation amount and pattern over sea ice and provide guidance for bias adjustment of current precipitation products, mainly by using observation of snow accumulation over sea ice from Operational IceBridge (OIB) and reconstruction.
- Develop and implement robust statistical methods to identify effective sets of variables that can be used to improve precipitation detection and mitigate false alarms, important to enhance the efficacy of bias adjustment and to help other products.
- Develop or refine strategies for bias adjustment of individual products and their integration into IMERG by working with the GPM, and in particular IMERG team.

We will also investigate other datasets, such as the new generation of reanalysis (e.g., MERRA2, ERA5) and high resolution regional models (i.e., RACMO2) for consistency checks and diagnostic assessments, given their skill in estimating precipitation in high latitudes.

The proposed effort is a new and practical way of bringing together diverse but complementary measurements (mainly invested by NASA) to refine solutions for snowfall measurement over polar regions Throughout this project we will work with IMERG and other GPM algorithm developers to explore effective ways for integrating the above analysis into existing precipitation products.

We propose under Topic 2.1: Difficult to retrieve weather by utilizing novel approaches to improve satellite retrieval algorithms. It also directly responds to NASA's interest "to advance measurement concepts and algorithms that would utilize other NASA missions,

as well as other observing systems, to enhance our understanding of the Earth System through improved accuracy and spatial resolution". The proposed work is built on the experience of the team members. The PI and collaborators have had a long-standing collaboration and participation in joint projects, improving the efficacy of the project at different stages, from development to implementation.

V. Bringi/Colorado State University
Light Rainfall Drop Size Distribution Shape and Variability: Improving the DPR-GMI Combined Algorithm
19-ATDM19-0002

This proposal falls under: A.26 Weather and Atmospheric Dynamics Topic 2.1 Difficult-to-Retrieve Weather, specifically, to improve understanding of light rainfall processes and associated drop size distribution shapes and variability, with the goal of improvement of precipitation retrievals by DPR-GMI combined algorithm at light rain rates. Under these conditions the ensemble-based optimal estimation scheme of the algorithm generally defaults to the apriori drop size distribution (DSD) state which may not be valid in the mid-to-high latitudes leading to systematic biases in rain rate (generally an underestimate) when compared with other satellite-based methods. Unbiased light precipitation estimates are important since it dominates the frequency of occurrence especially in the mid-to-high latitudes over ocean (typically the frequency of occurrence of R<0.5 mm/h ranges from 55-65% while the contribution to rain accumulation is around 4-7%). The first objective is to determine an accurate apriori DSD state which will make the Combined Algorithm estimates of rainfall more stable and consistent with climatology.
In addition to profiles of rain rate, the Combined algorithm also provides estimates of two parameters of an assumed three-parameter gamma DSD model. The parameters are the "normalized" intercept parameter and the mass-weighted-mean diameter; the third shape parameter is assumed constant. The second objective is to examine the applicability of the fixed shape gamma distribution model and to provide for more accurate constraints for the co-variability of the "normalized" intercept parameter and the mass-weighted mean diameter, as well as the distribution of the intercept parameter, and to use ground radars for validation of the Combined Algorithm precipitation retrievals.
It is now well-established that a significant fraction of light rainfall at mid-to-high latitudes over oceans is missed by the Combined Algorithm due to limited sensitivity of the Dual Precipitation Radar or due to the shallow nature of the precipitation. However, the low frequency channels of the microwave radiometers on the core satellite have been found to correlate well with the differential path integrated attenuation at the two frequencies of the dual precipitation radar which makes it possible to construct a radiometer-centric Combined Algorithm to measure light rain. The third objective is to support this development using polarimetric and dual-wavelength ground radar retrievals of liquid water path and path integrated attenuation and differential path integrated

attenuation between Ku and Ka-bands leading to simulation of brightness temperatures and to derive brightness temperature-Rain rate relationships. Moreover, Observing System Simulation Experiments making use of the ground radar retrievals will be used to get insight into the performance of radiometer estimates of PIA as well as to validate these estimates.
The proposed measurement site is the coastal oceanic Wallops Island Precipitation Research Facility. This facility is heavily instrumented with scanning polarimetric NASA S-band radar and the NASA dual-polarimetric/dual-wavelength radar. The surface measurements include a new NASA optical array probe collocated with a 2D-video disdrometer as well as a network of Parsivel, other 2D-video and rain gages. The rain types include light rain originating from stratiform with bright-band, rain without bright-band but echo top temperatures colder than 0C, pure warm rain, and marine stratocumulus drizzle (more prevalent in the oceanic sites below). The non-NASA oceanic DSD data base available is from OceanRain using an optical disdrometer designed for use on ships. Our focus is on the S. Hemisphere mid-to-high latitudes tracks SSW of Perth in 2016 and more recently south of Tasmania in 2018. During the latter cruise the RV Investigator had a C-band polarimetric radar with a number of GPM satellite overpasses.

Shuyi Chen/University of Washington, Seattle
Interactions of Convection, Boundary Layer, and Wind (CBWind) in the Tropics: A NASA Field Campaign
19-ATDM19-0024

One of the most challenging aspects in prediction of tropical weather systems is complex, multi-scale interaction between the convective cloud systems and environmental conditions, especially the wind in the boundary layer, air-sea fluxes, and mid-tropospheric humidity, over the tropical oceans. Convective initiation, growth, organization, and dissipation are affected by both the convective scale processes such as cold pools, cloud dynamics and microphysics, as well as their environments. Persistent convergence in the marine boundary layer (BL) of the inter-tropical convergence zone (ITCZ) largely driven by the SST and pressure gradients, African easterly waves (AEWs), and Saharah Air Layer (SAL) dry air intrusion interact with the convection to produce a large variability of convectively active and suppressed ITCZ. However, most numerical models cannot predict them accurately, which remains a grand challenge for global weather prediction. Physical parameterizations such as the BL and microphysics schemes in numerical prediction models were developed and tested largely using field observations over land, which are inadequate for prediction over tropical oceans. This proposed NASA Convection, Boundary Layer, and Wind (CBWind) field campaign, part of the joint efforts between NASA and ESA in 2020 over the tropical East Atlantic, can help address this grand challenge.

This Type2 proposal aims to 1) better understand how convective systems interact with lower tropospheric and surface winds in the ITCZ, 2) characterize vertical structure and variability of the marine BL and how they affect the convection initiation and lifecycle, 3) quantify the influence of the environmental wind and moisture on convectively suppressed and active periods of the ITCZ, and 4) improve model representation of convective and BL processes over tropical oceans using the CBWind field campaign and satellite data, and a cloud-resolving, fully coupled atmosphere-ocean model. Observations from the airborne radar APR-3, the Doppler Aerosol WiNd (DAWN) lidar, GPS dropsondes with IR SST capability, and the High Altitude Lidar Observatory (HALO) onboard of the NASA DC-8 during the field campaign will be used together with the satellite data such as Aeolus, ASCAT, CYGNSS, GPM, AIRS, and CloudSat/ CALIPSO to address the objectives and evaluate the cloud-resolving, coupled model results.

We will conduct cloud-resolving coupled model (UWIN-CM) forecast in realtime to support the daily mission planning for the field campaign, which was proved to be critical and effective for the CPEX field campaign in 2017. The high-resolution regional coupled model will be used in combination of the NASA GEOS and ECMWF model forecasts. UWIN-CM will be used for assimilating winds from the airborne measurements and Aeolus winds in support of the Aeolus Cal/Val activities, as well as the post-field campaign model physics evaluation and improvement, especially in the marine BL, using a nested LES in UWIN-CM experiments.

The PI (Chen) proposes to serve as the science team lead of the CBWind 2020, which is part of the joint NASA-ESA field campaign in support of the Aeolus Cal/Val efforts. She will work closely with collaborators from all key components of CBWind in science investigations and data assimilation (Su, Zipser, Rowe, Emmitt, Pu, Turk, Hristova-Veleva), measurements/instruments (Bedka, Durden, Tanelli) onboard of the DC-8, and data portal (Hristova-Veleva). She will take the responsibility in overall field program planning, aircraft missions, and on-site mission support on a daily base. Chen has extensive experience as a lead aircraft PI for major field campaigns including the NASA CPEX 2017, RAINEX 2005, and DYNAMO 2011. She has led the multi-aircraft missions in DYNAMO with the NOAA P3s and French Falcon aircraft. She has also participated and led field program planning and aircraft missions during TOGA COARE 1992-93, CBLAST 2003-04, and ITOP 2010.

Shu-Hua Chen/University of California, Davis
Improving Prediction and Advancing Understanding of Weather Systems over North Africa and the Tropical Atlantic Using Lidar Wind Observations

19-ATDM19-0081

The goal of this collaborative research proposal is to assimilate three-dimensional (3D) winds from an airborne lidar and a space-based lidar to improve weather forecasts and advance our understanding of dust-cloud interaction on the development and evolution of convective weather systems over the tropics.

During summer 2020, a NASA-EAS joint field campaign will take place based at the Cape Verde Islands. A coherent Doppler Aerosol WiNd lidar (DAWN) instrument will be on the NASA DC8 aircraft to observe wind information in the planetary boundary layer below 4 km. The wind data from DWAN and meteorological data from dropsondes in and around the convective storms will provide a unique dataset that will improve the storm's initial conditions and allow for an assessment of its effects on numerical weather forecasts over the tropics. The 3D lidar winds will be combined with the vertical wind profiles obtained from Aeolus, the world's first wind-mapping satellite launched in 2018.

The combination of 3D wind retrievals from DAWN and Aeolus provides the scientific community with a unique research opportunity. To take advantage of this opportunity, we propose to assimilate these 3D lidar winds together with other observations to improve the forecasts of (i) convective weather systems, and (ii) the large-scale environment over North Africa and the Eastern Atlantic Ocean, which includes the African easterly jet (AEJ), African easterly waves (AEWs), and plumes of Saharan mineral dust (SMD) aerosols. To assess to what extent the lidar winds improve the forecasts, we will diagnose the thermodynamic and dynamic structure of the storms; the structure and strength of the AEJ; the tracks and energetics of AEWs; and cloud processes. The analyses will also include examining how lidar-improved forecasts affect SMD-cloud interaction on convective weather systems. In particular, we will examine the effect of SMD as cloud condensation nuclei (CCN), giant CCN (GCCN) and ice nuclei (IN) on the modification of weather systems, including the storm's morphology, intensity, rain rate, mix-phased cloud processes, and the amount and distribution of supercooled water.

Andrew Heymsfield/University Corporation For Atmospheric Research
Use of NASA Field Program Data and Satellite Observations to Explain Mixed-Phase Microphysics/Dynamics, Liquid to Ice Transition, and the Transition of Ice to Liquid Cloud in the Melting Layer
19-ATDM19-0034

Use of NASA field program data and satellite observations to explain mixed-phase cloudiness liquid to ice transition and the transition of ice to liquid cloud in the melting layer

Our proposed effort will use NASA field program data and NASA satellite-based data (GPM, CloudSat, CALIPSO) to look at the conditions leading to mixed-phase (liquid and ice) cloud and its evolution. We participated in numerous NASA airborne field programs, collecting, analyzing and archiving microphysical data from particle probes. (OLYMPEX, IPHEx, GCPEX, GRIP, MC3E, NAMMA, CAMEX-4 and CRYSTAL-FACE, among others). Currently, we are part of the NASA IMPACTS study, will measurements set to begin in winter 2019-2020. We will use the particle probe data and vertical velocity measurements from the sampling aircraft from these field programs in our analysis. We will also use coordinated/collocated multi-wavelength Doppler radar data from most of these field programs to examine the relationship of the mixed-phase regions to the cloud dynamics. Vertical motions from the aircraft will also be used in the analysis. The satellite data from CALIPSO will allow us to examine the global distribution of supercooled liquid regions (with the given limitations of CALIPSO) and the coordinated CloudSat and when possible GPM radar observations will allow us to examine the presence and amount of the ice phase present in these regions. We are currently finalizing an analysis of CloudSat/GPM precipitation rate data from an NASA-funded study and are intimately familiar with the use of these satellite-based radar data sets.

The melting layer is also a ""mixed-phase"" region. A second part of our effort will use the field campaign data to quantify the microphysical structure of the melting layer (radar bright band). The data we will use are from the airborne particle probes and relative humidity measurements from the studies noted above, along with surface observations where appropriate. This topic is becoming more important as a study we are working on is indicating that the height of the melting level (snow melting to rain) has been increasing over the past 50 years. This has obvious societal importance. Our research has indicated that the height of the melting layer has increase by 19±10 m per decade since 1979. The question at what temperature and relative humidity does snow fully melt as this question could influence policy decisions in our world of a changing climate.

Svetla Hristova-Veleva/Jet Propulsion Laboratory
An End-to-End Portal System for Support of the 2020 Nasa Airborne Field Campaign
19-ATDM19-0043

To support the 2017 NASA's Convective Processes Experiment (CPEX) airborne field campaign we developed a portal system with two main components: i) a web page which served as the official project website; ii) a data portal which integrates satellite and airborne observations with model forecasts and provides interactive visualization and online analysis tools that work with both models and observations.

The home page (https://cpex.jpl.nasa.gov) was designed with several functions in mind: 1) to introduce the mission goals and objectives; 2) to provide an overview of the participating instruments, the aircraft platform and the team; 3) to provide a quick depiction of the flight campaign, using an event calendar; 4) to serve as a repository of the daily forecast reports and the science summaries; 5) to provide a gateway to several key repositories, namely: i) the JPL Data Portal (https://cpexportal.jpl.nasa.gov) mentioned above; ii) the science data repository for all airborne, satellite and model data collected during the campaign; iii) the model forecast pages;

The CPEX portal system has been designed with two main goals: 1). to provide information to support the flight planning and operations during the field campaign; 2). to serve as a very rich source of information in the analysis stage – the post-campaign phase of the research.

The CPEX portal system has provided information to a large number of scientists and has proven to be very valuable.

Here we propose to develop a similar system in support of the 2020 NASA airborne field campaign.

Bjorn Lambrigtsen/Jet Propulsion Laboratory
Tropical Convection and Thermodynamics
19-ATDM19-0007

This is a combined Type 1 and Type 2 response to sub-element 2.3. We propose to fly the High Altitude MMIC Sounding Radiometer (HAMSR) in the 2020 field campaign to measure the small-scale structure of the thermodynamics (temperature, water vapor) and bulk convective parameters (cloud liquid and ice, precipitation) in and around pre-convective and convective cloud systems in the region accessible from the Cape Verde Islands.

We will integrate HAMSR in the rear cargo bay of the DC-8, where it was previously deployed during the CPEX campaign in 2017, and operate it during the 2020 field campaign. Geophysical data products from HAMSR will be generated in real time and be available in the aircraft, and definitive products will be delivered within 3 months of the end of the field campaign and made available to the entire science team. HAMSR has previously flown in a number of NASA field campaigns (CAMEX-4/2001, TCSP/2005, NAMMA/2006, GRIP/2010, CPEX/2017, EPOCH/2017) as well as the EV-S1 HS3 mission. It has also participated in NOAA field campaigns (WISPAR/2011, SHOUT/2015) and flew in the CalWater2/2015 atmospheric river campaign. HAMSR has become a sought after remote sensing resource, as reflected by the considerable number of past campaigns and also by requests to participate in proposals to the EV-S program. Particular value is derived from the ability to derive and deliver data products in real

time, which is useful for situational awareness during flights, for day-after planning of next flights, and for forecast assessment.

We will use data from the field campaign, relevant satellites and reanalysis to investigate the evolution and structure of convective systems organized by tropical waves and how these are modulated by the Saharan Air Layer that may be observed during the campaign. This will build on the results of studies of convective initiation we conducted in connection with the CPEX campaign. We will perform data analyses of field campaign data tied to large-scale atmospheric moisture budget. We aim at answering the following scientific questions related to evolution of convective systems organized by tropical waves:

- During the stage of convection initiation, how does moisture supply by large-scale advection and surface evaporation modify buoyancy in the boundary layer and free troposphere?
- How does precipitation and vertical wind shear co-vary with cloud top height and vertical moisture and temperature structures?
- In the wake of deep convection, how does anvil precipitation modify the buoyancy in the boundary layer and free troposphere and provide feedback to convection initiation?

Zachary Lebo/University of Wyoming

Two-Way Momentum Coupling Between Hydrometeors and Small-Scale Air Motions: Effects on Precipitation and Drop Size Distributions

19-ATDM19-0075

Turbulent motions in the atmosphere affect hydrometeor trajectories and transport. In particular, micro-scale turbulence can enhance collisions between water droplets, reducing the time needed for a cloud to precipitate. Moreover, turbulence affects the settling velocities of falling drops, which can either be preferentially swept into the downward region of turbulent eddies, enhancing the settling velocities, or become trapped in eddy vortices, reducing the settling velocities. Most, if not all, previous studies focusing on these physical problems in the atmospheric science community have relied on theoretical calculations or direct numerical simulations (DNS). Laboratory and in situ/ remote sensing observations of such effects are scarce or have not been incorporated in weather prediction platforms.

The back-reaction of droplets on small-scale atmospheric turbulence (referred to as two-way coupling) has received even less attention in the scientific literature. Fundamental studies do demonstrate that droplets in number densities and of sizes relevant for various weather systems may strongly alter air turbulence in the vicinity of hydrometeors, although specific investigations relevant to weather prediction are sparse. However, none of the existing studies have focused on conditions specifically relevant to precipitation events, nor have they leveraged the large databases of in-situ and remotely sensed aircraft

observations to better understand and ultimately implement such effects in numerical weather prediction models.

Although the ``global"" effect of two-way coupling is expected to be small in terms of altering the overall TKE owing to the small mass loading of cloud droplets under normal atmospheric conditions, it is likely to alter the local (droplet-scale) physics, i.e., the settling velocity of the droplets. Indeed, recent preliminary two-way coupled DNS show that even when the droplet loading is small enough such that the global TKE of the flow is unaffected by the droplets, the droplet settling is nevertheless strongly affected by the two-way coupling due to modification of the flow near the droplets, which in turn affects the droplet motion.

In this proposal, we outline a project aimed at combining the various interactions between hydrometeors and small-scale turbulent motions using a unique combination of tools: NASA in-situ observations from select field campaigns, a novel “cloud-in-a-box” laboratory installation, DNS, and state-of-the-art large eddy simulation (LES) and cloud-resolving model (CRM) simulations. The laboratory experiments, in which high-intensity turbulence conditions are reproduced in a controlled environment, will provide millimeter-resolution information on the air-droplet two-way coupling; the conditions of these laboratory experiments (both with regard to the turbulent structure and microphysical characteristics) will be guided by the NASA in-situ field campaign observations. The results of these experiments form a basis by which to validate the DNS work, which will then be used to quantify the impact of the two-way coupling on sedimentation because the one-way effects can be separated in the DNS framework but not in the lab experiments; thus, the lab and DNS are complimentary in this work in terms of validating the latter and formulating a parameterization of the two-way coupling observed in the former. This quantification will lead to a parameterization applicable to LES and cloud resolving models (CRMs), which will be implemented in a bulk microphysics scheme. The novel parameterization will be used in hindcast simulations of the selected NASA field campaign intensive observing periods (IOPs). Comparison between the model simulations and NASA field campaign data will allow us to examine the effects of droplet-turbulence interaction on precipitation rates and cloud structure at larger scales than can be simulated with DNS.

Edward Nowottnick/Universities Space Research Association, Columbia
Untangling Interactions Between Tropical North Atlantic Dynamics and Saharan Dust Using Observations from the Joint NASA-ESA Aeolus Validation Campaign
19-ATDM19-0016

The 2020 joint NASA-ESA Aeolus Validation Field Campaign provides an unprecedented opportunity to better understand unknown dynamical controls on Saharan dust during its westward journey across the tropical North Atlantic Ocean. The Saharan

desert serves as the world's largest source of dust aerosol, depositing approximately 240 Tg of dust annually into the Atlantic and Caribbean region. During its journey, dust interacts with the atmosphere through numerous pathways, including: radiatively with the atmosphere by scattering and absorbing radiation, serving as cloud condensation and ice nuclei, thereby interacting with cloud and precipitation processes. These interactions have important implications for regional tropical dynamics and atmospheric stability and have been shown to affect the African Easterly Jet, influence African Easterly Waves, and impact tropical cyclogenesis.

The conventional theory for gravitational settling of particles suggests the largest particles should preferentially be removed from the atmosphere well before reaching receptor regions in the Caribbean. In situ observations, however, have shown giant sized (100s of microns in diameter) dust particles reaching well into the Caribbean basin, in defiance of what current transport models show. Thus, the complex interplay between dust, dynamics, and thermodynamics of the tropical environment during transport is not fully understood. These considerations have implications for meteorological, dust, and air quality forecasting efforts, as well as impacts on longer climate simulations.

Operations out of Cabo Verde during July 2020 for the joint NASA-ESA Aeolus Validation Field Campaign coincides with the timing of peak Saharan dust transport, providing simultaneous measurements of dust and meteorology to help answer the role of different dynamical mechanisms on the transport of Saharan dust. Targeting Saharan dust events serve for validation of the ALADIN wind lidar on Aeolus, which need measurements of aerosols and cloud motion to retrieve winds. Therefore, given Saharan dust transport peaks during northern hemisphere summer with events pulsing westward with a 3-5 days cadence, we should have ample opportunity to meet our goals of the proposal.

Our proposed effort entails detailed analysis of coincident dust and meteorological observations from the NASA DC-8, DLR Falcon, and French SAFIRE Falcon aircraft to determine the roles and significance of wind shear induced turbulence, entrainment zone mixing, mixing within the Saharan Air Layer, inversions layers, and convective lofting as mechanisms to transport dust particles long distances. Analysis from this effort will be subsequently used to improve dust transport process representation in the NASA Goddard Earth Observing System (GEOS) model by performing a series of high-resolution sensitivity experiments using case studies from the Aeolus Validation Field Campaign. Given that Aeolus underpasses are expected to be the focus of the field campaign efforts, the detailed analysis of field campaign data will be compared to ALADIN wind and aerosol retrievals for validation to determine retrieval limitations and challenges within the complex meteorological and aerosol environment of the tropical North Atlantic Ocean.

Completion of our proposed will help to resolve long-standing questions regarding the dynamical controls on Saharan dust during transport, improve the representation of simulated dust processes for use by the global aerosol transport community for improved dust/air quality forecasting and climate simulations, and asses the first spaceborne wind lidar to help guide design concepts for future spaceborne lidar systems. Our team leverages expertise in interpreting aerosol and wind lidar observations, in situ aerosol and meteorological data, aerosol transport modeling, and has extensive experience working with field campaign data.

Zhaoxia Pu/University of Utah, Salt Lake City
The Properties of Convective Systems in the Tropics and Their Relationships to the Tropospheric Environment and Surface Winds: A Study Using Advanced Data Assimilation with NASA Field Campaign and Satellite Observations
19-ATDM19-0046

Understanding the properties of convective systems associated with the Inter-Tropical Convergence Zone (ITCZ), African Easterly Wave (AEW), and Saharan Air Layer (SAL) is a critical area of research for improving weather and climate prediction in the Tropical Eastern Atlantic Ocean. Yet it is a challenging problem due to lack of observations and high-resolution analysis. Most of the current available global analyses are too coarse to resolve the convective systems and their associated environmental conditions. Fine-resolution analysis is necessary for progress in this area of research. In July-August 2020, NASA, in collaboration with ESA, is leading a field program of weather and atmospheric dynamics investigations based out of the Cape Verde Islands.

In light of this field campaign opportunity, this proposal aims at a highly cooperative effort to exploit data from the field campaign and NASA satellites to advance fundamental knowledge of convective initiation and life cycles over the Tropical Eastern Atlantic Ocean and their relationship with environmental conditions, especially the atmospheric boundary layer, surface winds, and low-, middle-, and upper-level convergence/divergence conditions. Specifically, we propose to employ an advanced data assimilation method (e.g., 3DEnVAR) to generate accurate mesoscale analyses at a cloud-permitting scale (~1 km horizontal resolution) for IOPs and notable convective cases during the field program, and to provide the best possible estimate of the environmental conditions in which the convective systems are initiated and evolve during their life cycles. Aircraft dropsondes, Doppler wind lidar (DAWN and Aeolus) wind profiles, APR-3 (Radar), and HALO water vapor profiles, as well as satellite data, including NASA GPM Microwave Imager radiances and SSTs, CYGNSS ocean surface winds, AIRS satellite-retrieved temperature and moisture profiles, and Atmospheric Motion Vectors, will be assimilated into the Unified Wave INterface-Coupled Model (UWIN-CM). UWIN-CM includes the Weather Research and Forecasting (WRF) model for the atmosphere, the University of Miami Wave Model for ocean surface waves, and the

HYbrid Coordinate Ocean Model for ocean circulation, allowing consistency in air-sea interaction.

With integrated data assimilation efforts, we anticipate the proposed analysis could help answer the following science questions:
1) How do convective systems interact with lower tropospheric and surface winds in the ITCZ?
2) What are the vertical structures and variability of the boundary layer, and how do they affect convection initiation and life cycles in the ITCZ?
3) What is the influence of AEWs and the SAL (dry air and dust) on convectively suppressed and active periods of the ITCZ?
4) During tropical cyclone genesis, how does convection interact with the AEW, SAL, and ITCZ? Specifically, what are the characteristics of convective systems during their interactions? What are the roles of low-level convergence and upper-level divergence in convective initiation and evolution over the Tropical Eastern Atlantic Ocean? How do low- to middle-level atmospheric conditions evolve during tropical cyclone genesis?

Moreover, the proposed data assimilation efforts should also help address the outstanding questions associated with Aeolus Cal/Val and climate model deficiencies related to the double ITCZ:
1) To what extent does the assimilation of DAWN and Aeolus measured wind profiles help numerical models improve the predictability of tropical
convective systems?
2) Does assimilation of field campaign and satellite observations help remove or mitigate the double ITCZ effect in numerical models?

This project is a Type 2 proposal to address component 2.3 (Field Campaign Opportunity). The PI is also interested in participating in field campaign activities and in assisting Dr. Shuyi Chen in real-time forecasting with UWIN-CM by adding atmospheric data assimilation for the WRF model.

Adriana Raudzens Bailey/University Corporation For Atmospheric Research
Shallow Convective Mixing, Precipitation Processes, and Their Influence on Low-Level Clouds
19-ATDM19-0044

Low-level clouds continue to contribute large uncertainties to predictions of future climate. One of the key processes believed to regulate low-level cloudiness and its response to global warming is shallow convective mixing—a process by which shallow cumulus clouds evaporate and export moisture from the boundary layer, near Earth's surface, into the lower free troposphere above. It has been proposed that as surface temperatures increase, so too does shallow convective mixing, moistening the free

troposphere at the expense of the boundary layer. This reduces the relative humidity of the sub-cloud layer and creates conditions unfavorable for further low-cloud development. As a result, more solar radiation reaches Earth's surface, warming the planet in response to greenhouse-gas forcing.

However, in reality, it is not clear just how sensitive low-level cloud coverage is to shallow convective mixing. On the one hand, climate simulations suggest that models that produce more vigorous shallow convective mixing tend to exhibit more vigorous boundary layer entrainment of dry free tropospheric air. Climate forecasts from these models are several degrees warmer than forecasts from models that produce less mixing. On the other hand, Large Eddy Simulations (LES) suggest that there are buffering processes that act on scales smaller than climate models resolve that should slow the loss of cloud cover as shallow convective mixing accelerates. These LES indicate that climate models exaggerate the degree to which cloud cover dissipates as shallow convective mixing increases. Understanding the sensitivity of low clouds to mixing thus remains a question of great importance and urgency.

One of the principal barriers to evaluating and quantifying the sensitivity of low clouds to mixing is the difficulty of observing shallow convective mixing across sufficiently large geographic areas and on long enough timescales to provide useful benchmarks for evaluating climate simulations. The proposed work addresses this need by developing an estimate of shallow convective mixing using more than a decade of tropical and subtropical satellite retrievals. Leveraging the fact that water vapor's isotopic composition clearly distinguishes boundary layer from free tropospheric moisture, the proposed project will use isotopic lapse rates from NASA satellite sensors to estimate the strength of shallow convective mixing. These isotopic estimates, paired with satellite retrievals of low-level cloud properties, will then reveal the dependency of low-level cloudiness on mixing under a variety of large-scale environmental and precipitation conditions.

These observed relationships will be used to evaluate whether two isotopically enabled climate models exaggerate the sensitivity of low-cloud fields to shallow convective mixing and, if so, why. Specifically, three candidate hypotheses will be tested: 1) that free tropospheric entrainment in the models is too large in response to shallow convective mixing, 2) that precipitation processes reduce the sensitivity of simulated clouds to mixing, and 3) that enhanced convective organization with warming accelerates reductions in low-level cloudiness. Ultimately, by tuning key parameters associated with these processes so that the simulated cloud response to enhanced shallow convective mixing best matches observations, the proposed work aims to deliver improved estimates of climate sensitivity and more reliable forecasts of the climate response to greenhouse-gas forcing.

Sarah Ringerud/University of Maryland, College Park
Enhancement of GPM Passive and Combined Microwave Algorithms for Drizzle and Light Snowfall Retrieval Over the Southern Ocean
19-ATDM19-0070

The objective of this proposal is enhancement of existing precipitation algorithms for the Global Precipitation Measurement (GPM) Mission constellation with retrievals of light precipitation (snow and drizzle) below the sensitivity of the active radar, using information content from the passive sensors and providing a crucial missing component in the full suite of GPM products. The Southern Ocean, with its relatively homogeneous background and known retrieval discrepancies, will serve as a testbed. Understanding the full distribution of precipitation is a vitally important component in understanding global energy and water cycles and their variability. Due to the sparsity of available measurements at the surface, satellite platforms and global models are the best current avenues for precipitation assessment on a global scale, yet these techniques along with other measurements often disagree in both location and intensity of precipitation. This presents particular difficulties over areas with historically sparse measurement availability. The Southern Ocean, home to large mid-latitude storm tracks and covering a large relative area of the globe, is one such area, where satellite retrievals from different platforms as well as models widely disagree on quantitative amounts of snow and rain, particularly on the lighter intensity end of the distribution.

We propose adding light precipitation to GPM products using an optimal estimation-type (OE) non-raining cloud and water vapor retrieval, with development and testing over the Southern Ocean. Non-convergence of the OE retrieval in areas with no detectable radar signal will be used to identify areas with high probability of light precipitation. The other component of the retrieval is characterization of the light precipitation, which will be explored using information derived from the higher sensitivity CloudSat mission along with in situ data available from a recent ship-based field campaign and model information to identify associated atmospheric state and dynamics. This is a physically-based approach that will require radiometric consistency with all available multi-spectral observations. Successful inclusion of retrieved snow and drizzle from the Combined Algorithm can then be included in the constellation databases and transfer through to the level 3 products. It is additionally anticipated that the same technique, successfully demonstrated for the Southern Ocean, could be easily adapted for light precipitation retrieval over other areas and surfaces.

This proposal addresses Research Category 2.1: Difficult-to-Retrieve Weather and makes use of multiple NASA data sets, sources, and observing systems. Passive microwave and Combined Active/Passive precipitation retrievals will be performed using the Global Precipitation Measurement (GPM) core and constellation satellite observations.

The objectives to be completed in the proposed study are:

1) Link the most current operational GPM core satellite and constellation retrievals with an OE approach for identification of light rain and snow, using the Southern Ocean as a testbed.

2) Characterize and generalize the microphysics and vertical distribution of the light precipitation using CloudSat and in situ data in correlation with the multispectral passive signal.

3) Implement and test within the framework of the Combined product.

4) Ensure sufficiently sensitive and accurate radiative transfer for application to the full GPM constellation via the retrieval database.

Implementation of this physical, process-based approach has the potential to lead to improvement in global precipitation retrievals in a much more robust way than empirically-based tuning methods, and contribute to an improved understanding of global precipitation.

Angela Rowe/University of Wisconsin, Madison
Linking Convective Cloud Processes and Air Motion Through Airborne Datasets
19-ATDM19-0020

Satellite and field-campaign observations across the globe have provided valuable insight into the occurrence, structure, and evolution of convective clouds in various environments. However, we still do not understand why convective clouds and heavy precipitation occur exactly when and where they do. To address this objective requires simultaneous observations of the physical mechanisms within precipitating clouds and of the local environment. A major limitation to this goal has been a lack of coincident measurements of in-cloud hydrometeors and vertical motion with near-cloud environmental information including winds. A joint NASA-ESA campaign is planned for summer 2020 from the Cape Verde Islands primarily as an AEOLUS validation mission by flying the Doppler Aerosol WiNd lidar (DAWN) aboard NASA's DC-8 aircraft. The DC-8 will also carry the triple-frequency Airborne Second Generation Precipitation Radar (APR-3) allowing for particle characteristics and in-cloud vertical motions to be retrieved. Rarely are air motions near and in clouds measured in such close proximity, providing a unique observational opportunity for investigating cloud processes in the context of their near-storm environment over the tropical ocean.

The 2017 NASA CPEX field campaign was one of those rare opportunities to observe the 3-D structure of convective clouds and their near-storm environment through flying both DAWN and APR-2 on the DC-8 in 16 missions over the Caribbean Sea, Gulf of Mexico

and western Atlantic. These datasets include examples of boundary layer inflow-outflow in the near-convective environment and convective outflow above the convection. Through coincident measurements of convective characteristics and near-storm environment from CPEX and the NASA-ESA 2020 field campaign, we have the opportunity to reduce our knowledge gap while showing the value in combining multi-frequency radar and Doppler wind lidar for future satellite missions. Our overarching goal for this proposal is to improve understanding of the underlying dynamical and microphysical properties of convective systems throughout their lifecycles and how these properties relate to their local and large-scale environmental conditions. Our more specific objectives are:
- SO1: Determine the range of convective types and intensities observed over these tropical oceanic regions and distinguish their large-scale environments.
- SO2: Quantify the convective inflow and relate variations in inflow characteristics to convective properties and environmental moisture variability.
- SO3: Determine the relationship between convective systems and boundary layer and free tropospheric winds throughout convective lifecycle, including quantifying the strength of convectively generated cold pools and above-storm outflow.

This proposed work addresses the ROSES 2019 A.26 Solicitation Section 2.3 Field Campaign Opportunity Type 2. There is overlap in instrument platforms between the upcoming campaign and CPEX, allowing for analyses that tie together multiple field campaign datasets for process-based studies. Our proposed study ties into the scientific focus areas in the 2018 NASA Decadal Survey, which prioritizes the need for measurements to determine how, when, and where convective storms occur. Future baseline mission requirements to meet remaining high-priority scientific goals defined in the Decadal Survey ideally will include both multi-frequency radar and Doppler wind lidar on a satellite platform. The CPEX and NASA-ESA field campaign instruments provide the opportunity to highlight the scientific value of this combined platform and determine the best practices for gleaning the most information from these coincident measurements. We will collaborate with CPEX PI Chen and JPL instrument and data product team members to ensure a successful execution of the 2020 campaign and needed product development to meet our scientific goals.

Naoko Sakaeda/University of Oklahoma, Norman
Understanding the Coastal-to-Maritime Transition of Propagating Convective Systems over the West African Coastal Region
19-ATDM19-0057

The main goal of this proposed project is to understand the evolution and processes associated with the coastal-to-maritime transition of convective systems over West Africa, which is crucial to advancing the prediction skill of extreme weather and climate events. Processes that contribute to the intensification or maintenance of West African

convective systems as they propagate offshore are particularly important for explaining maritime precipitation patterns associated with the Inter-Tropical Convergence Zone and the influence of West African convection on high-impact weather such as tropical cyclogenesis. The examination of coastal-to-maritime transition of convective systems is also necessary for achieving physical understanding of the distinct convective characteristics over land and ocean. For example, the intensity of convective precipitation is stronger over land but it is not fully understood why climatologically higher rainfall is observed offshore. Furthermore, West African weather and climate are influenced by complicated multiscale phenomena such as the monsoon, convectively coupled equatorial waves, African easterly waves, diurnal cycle, and mesoscale convective systems, whose interactions near the coast is less understood compared to inland. To fill this knowledge gap, this project proposes to address the following questions using in-situ observations collected by the summer 2020 joint NASA-ESA field campaign, satellite data (e.g., GPM and ESA Aeolus wind lidar), and idealized model experiments:

Q1) What are the roles of the diurnal cycle of circulation and heating on the evolution of coastal convective systems?
Q2) Why does the climatological rainfall maximize off the coast of West Africa while the intensity of convection weakens as they propagate offshore?
Q3) How do large-scale wind shear and moisture perturbations by synoptic waves, such as convectively coupled Kelvin waves and African Easterly waves, influence the evolution of coastal convective systems?

The proposed project will use a range of observational datasets, including the NASA-ESA field campaign data, and an idealized cloud-resolving model to answer these questions via three main tasks. The first task will apply statistical analysis techniques to GPM, MERRA-2 reanalysis, and other satellite data to understand climatological characteristics of convective systems over and off the West African coast and their relationships with the diurnal cycle and synoptic waves. The second task will utilize field campaign data to examine kinematic and thermodynamic conditions surrounding offshore propagating convective systems, relative to their decaying, maintaining, and strengthening stages. Environmental profile data, particularly winds and water vapor, from satellite and aircraft instruments will be analyzed to identify the roles of dynamic and thermodynamic conditions during the evolution of convective systems. The third task will use select observed profiles to initialize idealized experiments with the Cloud Model 1 (CM1) to quantify the sensitivity of the intensity and lifetime of offshore propagating convective systems to lower-tropospheric wind shear, moisture, and the diurnal cycle. While the first task provides a statistical perspective of the evolution of convective systems, the second and third tasks provide detailed examinations of the observed and simulated convective systems through the analysis of intensive observational data from the field campaign and unique model experiments.

This proposed activity will contribute to NASA's mission of advancing our understanding of Earth's system by resulting in 1) an improved understanding of physical processes underlying the convective evolution near the West African coastlines and its multiscale interactions with synoptic waves and 2) verification of satellite-based measurements with in-situ observations.

Mathias Schreier/Jet Propulsion Laboratory
Assimilation and Analysis of Airborne Observations of Tropical Storms
19-ATDM19-0010

Our proposal is responding to the category of "Field Campaign Data Analysis" by focusing on prior NASA field campaign datasets. We will use this data from previous NASA field campaigns to analyze intensification changes in tropical storms. Whereas the analysis of intensification changes is not a new subject, we want to propose a more modern approach:
For one, we will use a new, state-of-the-art retrieval algorithm on the old field campaign data and retrieve improved thermodynamic profiles. Secondly, we will assimilate these profiles themselves into a high-resolution model and extend the view onto the environment and dynamics of the storm. Finally, we will test proposed intensification theories on a variety of storms and get results based on a statistical sample rather than a single case study.
We think the improved retrieval and the assimilation will enable us to analyze the behavior of storms in a more rational way. We can test intensification and weakening theories and can identify indicators for storm behavior. We will not focus on a specific theory or indicator, but test a variety of ideas from the literature, e.g., observable changes in sea surface temperature, or changes in convective behavior. We also postulate that specific indicators, which we will find in airborne observations, can also be identified in satellite observations - if assimilated in a model.

Robert Trapp/University of Illinois, Urbana-Champaign
Deep Convective Updraft Populations in Organized and Unorganized Systems Across the Globe
19-ATDM19-0058

Idealized, cloud-resolving modeling (CRM) studies have recently emphasized the importance of updraft-core width in the dynamics of deep convective storms and their attendant hazards. In particular, wide updraft cores appear more likely to: promote the formation of strong, deep cold pools; support the generation of large hail; and host wide, intense tornadoes. The CRM studies have also demonstrated that the area of the overshooting top (OT) of a deep convective storm correlates strongly with the area of the associated convective updraft, and by extension its convective mass flux (CMF). Thus,

the implication is that a quantification–and perhaps prediction–of overshooting-top area (OTA) may be sufficient to determine the core width and convective mass flux (CMF) of deep convective updrafts.

Drawing on established methodologies to identify and quantify OTs in longwave infrared satellite imagery, our primary objective is to quantify the OTA associated with deep convective updrafts around the globe using NASA and NOAA satellites, alongside NASA field campaign data and a large set of CRM simulations. The quantifications will then be used to determine regional and sub regional distributions of updraft-size and corresponding CMF.

This new dataset, in turn, will be used to address the following main science questions: As estimated by OTs, how do the size (i.e., width) distributions of deep, intense updraft cores, and by extension, CMF, vary regionally across the globe? (SQ1) What are the controls of such size? (SQ2) We hypothesize that the distributions of updraft-size in the tropical oceanic regions tend to be narrow relative to those in midlatitude continental regions. (H1) This owes primarily to the possibility of strong vertical wind shear in the midlatitudes, which significantly modulates draft size; CAPE also modulates size (as does the parcel buoyancy distribution), and is more variable in the midlatitudes than in the tropics. (H2)

The proposed research will play a direct role in supporting NASA's mission of observing and understanding the Earth's weather and climate. In particular, it directly addresses Objective O3 (Convective Storms) within Goal G2 (Storm Dynamics) of the Science and Applications Traceability Matrix (SATM) of the Aerosols and Clouds-Convection-Precipitation (A-CCP) Study. It also addresses several of the enabled applications. The proposed work has implications for understanding and forecasting societally important high-impact weather events as well as for improving understanding of climate and climate change.

Indeed, the dataset delivered by this project can be used to help improve convective parameterization schemes in weather and climate models, which depend fundamentally on the distribution of updraft sizes and mass flux. More generally, the dataset can be used to better estimate the troposphere-stratosphere exchange of trace constituents by deep convective updrafts across the globe, and gain a better understanding of the global role of deep convective updrafts in the atmospheric water and energy cycle.

Melinda Webster/University of Alaska, Fairbanks
Improving Our Understanding of Precipitation Events in the Arctic
19-ATDM19-0048

Arctic weather systems serve as the dominant pathways of heat and moisture transport into the Arctic from lower latitudes. These systems have substantial effects on the Arctic energy budget. Weather systems associated with precipitation modify shortwave and longwave fluxes, result in mass and momentum exchanges between the atmosphere-ice-

ocean, and alter the physical properties of the atmospheric vertical profile. The amount, rate, and phase of precipitation impact the freshwater budget, surface albedo, and sea-ice mass balance in the Arctic, which are undergoing profound changes with a warming climate. Thus, comprehensively identifying and characterizing Arctic precipitation events is crucial for advancing our understanding of processes and consequences of high-latitude precipitation and improving future projections of their mechanisms and feedbacks.

In recent work, the role of cyclones in Arctic precipitation and the seasonal buildup of snow on sea ice was quantified using satellite, model, and in situ data for 1979-2016 (Webster et al., in revision). The results show that cyclone events account for ~83% of the total snowfall in the Atlantic sector. However, other precipitation mechanisms such as fronts (not associated with cyclones), polar lows, and trace precipitation are equally, if not, more important, for precipitating snowfall in the Arctic Pacific. These findings highlight the stark heterogeneity in atmosphere-ice-ocean interactions across the Arctic, and strongly motivate the need to identify, scrutinize, and better understand the mechanisms governing the development and intensification of precipitation events at high latitudes. However, an acute knowledge gap exists on Arctic precipitation events due to weather systems being episodic, fast-evolving, and difficult to measure in such an extreme, high-latitude environment. Here, we propose to overcome this challenge by combining a rich array of satellite observations and model simulations in a unique, data-layer framework to improve our understanding of precipitation events in the Arctic. Specifically, we will characterize the frequency, life-cycle, physical and environmental properties, and sensitivities of precipitation events using NASA assets and modeling.

We propose to merge satellite observations with model simulations to improve knowledge of the physical drivers of the formation, intensification, and decay of Arctic precipitation events. This will be accomplished by: (1) identifying and characterizing Arctic precipitation events associated with different types of weather systems from reanalysis and satellite data, (2) diagnosing mechanisms driving the life-cycle of precipitation events by unifying satellite observations of environmental conditions with numerical model simulations, and (3) developing a data-layer diagnostics package to assess the performance of global circulation models in simulating precipitation events to improve interpretation of their projected change.

The expected outcome of the proposed work directly supports the 2017 Decadal Survey's Most Important & Very Important science priorities by addressing:

- (H-1; C-4) How is the water cycle changing? How will the Earth system respond to changes in air-sea interactions? Arctic precipitation events will be characterized and examined via an Earth system approach, incorporating a suite of satellite observations and numerical simulations of atmospheric, oceanic, and sea-ice conditions to gain a deeper understanding of the precipitation mechanisms at high latitudes.
- (C-8) What are the consequences of amplified climate change in the Arctic on extreme weather events? A data-layer diagnostics package will be used to assess simulated cyclone events in the present-day climate state from Earth system models to identify model deficiencies and better interpret projected changes in precipitation events under anthropogenic warming.

Yalei You/University of Maryland, College Park
Improving GPROF Snowfall Retrieval with Brightness Temperature Temporal Variation
19-ATDM19-0064

Proposal Summary
Objective: The objective of this proposal is to augment the GPROF snowfall retrieval algorithm, by connecting observations from 10+ passive microwave radiometers (including GMI, SSMIS, MHS, and ATMS). Using observations from these sensors, a 3-hour microwave observation time series is constructed over CONUS (You et. al., 2017a). We showed that TB temporal variation (ΔTB) derived from this time series can significantly improve snowfall retrievals in the cold season and over snow-covered regions, by capitalizing the "quick-refresh" observations from multiple satellites. The ΔTB approach is particularly suitable for the snowfall estimate over the Arctic/Antarctic region, since these sensors provide an hourly microwave observation.

This proposal is aimed to improve the GPROF level-2 swatch precipitation products (e.g., 2AGPROFGMI and 2AGPROFSSMIS), which form the basis for the widely used level-3 merged precipitation product (e.g., IMERG).

Relevance: This proposal primarily addresses Research Category 2.1, which focuses on the Difficult-to-Retrieve Weather. Specifically, this proposal addresses the element "how can light snow and Arctic/Antarctic precipitation be better estimated". Built on our previously published work (You et al., 2017a, 2017b, 2018), we will extend the ΔTB approach globally by further including observations from active sensors (GPM DPR and CloudSat CPR), with the goal to augment the GPROF snowfall retrieval algorithm over cold regions (e.g., Arctic/Antarctic region).

Approach: We take GMI as the reference sensor and convert TBs at similar frequencies from other sensors (SSMIS, ATMS, and MHS) to GMI frequencies. We mainly rely on three statistical methods, including Simultaneous Conical Overpass (SCO), Principal Component Analysis (PCA), and a linear regression model. We will extend our previous work to compute ΔTB globally. We will further improve the ΔTB accuracy, by considering the previous overpass surface emissivity under non-precipitating conditions (provided by Co-I Joe Munchak). Then, we will incorporate ΔTB into the GPROF retrieval framework, with support from the Co-I Sarah Ringerud. Finally, we will evaluate the snowfall retrieval results with ΔTB information over cold surfaces, against the operational GPROF on PPS.

Jonathan Zawislak/University of Miami, Key Biscayne

Using Aircraft and Satellite Observations to Characterize African Easterly Wave Variability and Environmental Factors Associated with Downstream Tropical Cyclogenesis
19-ATDM19-0066

The overarching goals of the proposed work are to use both aircraft and satellite-borne data to better understand the dynamics of African easterly waves (AEWs) and their variability, AEW interactions with environmental factors that could lead to subsequent downstream hurricane formation, and to assess the ability of satellites to observe these interactions. AEWs are interconnected with other large-scale, environmental phenomena that affect the eastern North Atlantic and West African region, such as the Saharan Air Layer (SAL), African easterly jet (AEJ), and West African monsoon (WAM). AEWs notably serve as important potential seedling disturbances that develop into tropical cyclones (TCs) downstream over the Central and West Atlantic, sometimes as far east as the Cape Verde Islands.

The objectives of the proposed work fit under three primary expected outcomes: "process understanding," "validation," and "inform for better prediction." Within "process understanding," our goal is to use airborne (from the NASA DC-8) and satellite observations to characterize the dynamic, thermodynamic, and precipitation links between AEWs, the AEJ, WAM, and SAL, and the 3-dimensional structural characteristics of those phenomena that may influence TC formation downstream. Equally important, the "validation" goal will include efforts to validate, with aircraft observations, not only the NASA/European Space Agency ADM-Aeolus retrieved winds, but also retrievals of surface winds from the NASA's Cyclone Global Navigation Satellite System (CYGNSS), as well as moisture and temperature profiles from microwave and infrared sounders on the Joint Polar Satellite System (NOAA-20) and NASA-NOAA Suomi National Polar-orbiting Partnership (Suomi-NPP) satellites. Our validation work will focus on the horizontal and vertical gradients in moisture, temperature, wind, and dust that greatly impact influence AEW-AEJ-WAM-SAL interactions; gradients that we also suspect is where the retrievals are most challenged. The final goal ("inform for better prediction") of the proposed work will place the validation in the context of satellite analysis products used to assess environmental factors that affect TC formation potential, and to use the knowledge gained from the satellite validation efforts to identify the present instrument limitations and inform on the requirements of future space-borne wind lidars and remote sensors for producing improved forecasts of TC genesis and intensity change.

The assembled proposal team is experienced in studying both the dynamics of AEWs, the AEJ, SAL, and TC formation, and also in satellite validation, specifically for ADM-Aeolus, CYGNSS, and Suomi-NPP/NOAA-20. The proposed work directly addresses scientific questions posed in the "Weather and Atmospheric Dynamics" solicitation of topic 2.3, and is consistent with the objectives of the Weather Focus Area of the Earth

Science Research program to improve the prediction of extreme events, specifically through the use of remote sensing measurements to examine atmospheric dynamical processes. The investigator team is experienced in NASA field program activities and are also uniquely positioned to extend the NASA-ESA field program effort downstream into the Central and West Atlantic by incorporating similar validation and science goals into the 2020 NOAA hurricane research operations with the NOAA P-3 and G-IV aircraft.

Edward Zipser/University of Utah, Salt Lake City
The Upscale Growth of Mesoscale Convective Systems: A NASA Field Campaign in the Eastern Tropical Atlantic
19-ATDM19-0026

This proposal is in response to the 2019 NASA-ROSES solicitation A.26 (Weather and Atmospheric Dynamics) Section 2.3 (Field Campaign Opportunity) and will fall under the Type-2 category (proposals for using this field campaign data and participating in related research). Tropical Mesoscale Convective Systems (MCSs) account for significant proportions of rainfall and produce spatially broad, top-heavy latent heating profiles, which have critical impacts upon global weather and climate, and their future projections. They can also evolve into tropical cyclones which are significant high-impact weather events. The upscale growth of MCSs, especially over tropical oceans, a vast and relatively data-sparse region, is not well understood. Questions remain with regard to the conducive environmental conditions and in turn, how synoptic-scale systems promote upscale growth of MCSs. The joint-NASA-ESA 2020 field campaign, proposed to be based in the Cape Verde Islands, provides an opportunity to build on the work of the first Convective Processes Experiment (CPEX) to help answer these questions.

In response to these unresolved questions, we have the following principal hypothesis, which can be tested using IMERG as the principal tool for defining upscale growth, before, during, and after the field campaign: Upscale growth is favored predominantly within regions of substantial moisture convergence within synoptic scale waves such as Easterly and Kelvin Waves. We also have the following subsidiary hypotheses. 1) When the moisture convergence leads to a sufficiently high mid-tropospheric relative humidity, upscale growth is triggered. This may lead to the proliferation of convective cores which produce interacting cold pools and the resulting chain reaction enhances mesoscale convergence. 2) In regions of substantial low-mid-level wind shear, common near the latitude of the Cape Verde Islands where the African easterly jet exists, upscale growth of squall line type MCSs often occurs. 3) Upscale growth of MCSs, common in the ITCZ south of the Cape Verde Islands, occurs typically in weaker shear.

The IMERG precipitation product along with a tracking algorithm will be used to characterize the temporal evolution of MCSs with their volumetric rain rate used to quantify upscale growth. As an important first step in preparation for the field campaign,

we have already begun to assemble a large database of MCSs in the vicinity of the Cape Verde islands and the adjacent ITCZ. Thus, we should have a large sample size of MCSs to examine the hypotheses proposed here which will serve as background when working with the science team in planning the 2020 field campaign. During the field campaign itself, we will use the APR-3 radar on board the DC-8 to learn if, when, and why IMERG may show precipitation when none exists. To characterize the larger-scale environments associated with the MCS, we will use dropsondes, DAWN LIDAR, and other data available from the aircraft, plus data from Aeolus, and reanalyses such as MERRA-2. Following the field campaign, we will use similar techniques, as refined by experience during the field campaign, to test our principal hypothesis over all tropical oceans. The final product will be a comprehensive set of statistics on the upscale growth of tropical MCSs and the associated environments over different oceans.

Our group has extensive experience using such data for analysis of CPEX cases and in larger-scale studies using IMERG. The PI brings a wealth of experience in planning such airborne field campaigns, and proposes to be a full participant in the planning process for 2020. During the field campaign itself, the PI will be available daily either remotely or on site, while two postdoctoral scientists (James Russell and Peter Veals) and doctoral student Manikandan Rajagopal are prepared to be on site and as space is available on board the DC-8, for 2-3 weeks each.