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- Overview of organizations
- Airborne and Satellite Instruments
- Cooperative Research Topics and Example Applications*

Satellite remote sensing of land, ocean surface, atmosphere, R20

***Hydrometeor size distribution measurement capabilities- point to global**

Synergies in cloud modeling



National Space Science
and Technology Center

NSSTC

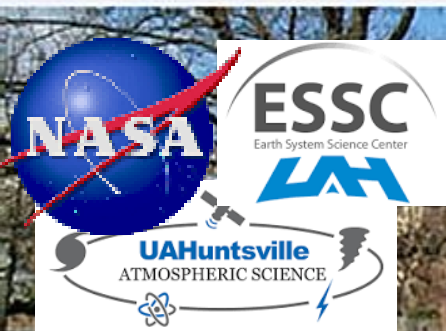
MAIN

ABOUT US

CENTERS

NEWS

EVENTS



SEARCH

www.nsstc.org

go!

320 Sparkman Drive, Huntsville, AL 35805
256.961.7000

Collaboration of multidisciplinary teams from universities, government, and private sectors in order to conduct / communicate cutting edge space research and education in support of NASA missions. For Earth / atmospheric science, brings together

- 25 NASA civil service, 20 computer scientists and support staff (misc. contractors)
- 60 research scientist (UAH, USRA, others), 10 faculty, >60 graduate students
- 20 NWS forecasters

195 personnel supporting weather /disaster related activities



Earth System Science Center and Department of Atmospheric Science at the University of Alabama in Huntsville

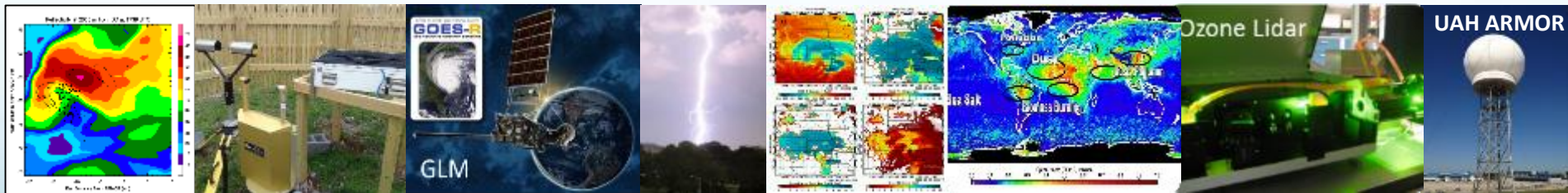


<http://www.uah.edu/essc>

<http://www.uah.edu/atmos>

Integrated earth-atmosphere research, undergraduate and graduate education
60+ Researchers, 15 Full Time Faculty Members, 1 Joint Faculty Appointment with Political Science, 1 Research Faculty Member, 1 Full Time Lecturer, 15+ Affiliate Graduate and Adjunct Faculty Members

Climatology, Land-Atmosphere-Ecosphere Systems, GIS, Satellite Remote Sensing, Severe Weather, Cloud Processes, Lightning and Atmospheric Electricity, Radar Meteorology, Meteorological Instruments, Atmospheric Modeling and Data Assimilation, Space Archaeology, Public Policy, Atmospheric Chemistry and Aerosols



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Chair, Department of Atmospheric Science (ATS)
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SWIRLL

Severe Weather Institute and Radar & Lightning Laboratory



THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE



Research Education Outreach

Tour Tuesday
3:30 PM at UAH
SWIRLL



NASA MSFC Earth Science Branch

~ 25 civil servants (management, technical, engineers), 80 Contractors (UAH, USRA, Jacobs, ENSCO, Post-Docs...)

Our Mission

Integrating unique space-borne observations, data, and models, we

- **advance understanding** of the Earth's weather and its energy and water cycles,
- **develop scientific and technical solutions** to challenging coupled Earth-atmosphere systems problems, and
- **transition research** to applications that enable decision support **for societal benefit**.

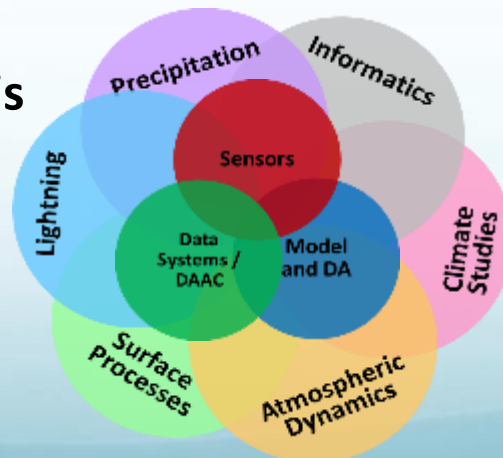
Our Vision

Expand our role as Agency **leaders and innovators** of Earth science discovery and focused technology development for capacity-building and societal benefit.

Scientific and Technical Expertise

Thematic Research Emphasis

- Lightning
- Precipitation
- Data Informatics
- Climate Studies
- Atmospheric Dynamics
- Surface Processes



Enabled Programs

- SERVIR
- SPoRT
- NOAA Support



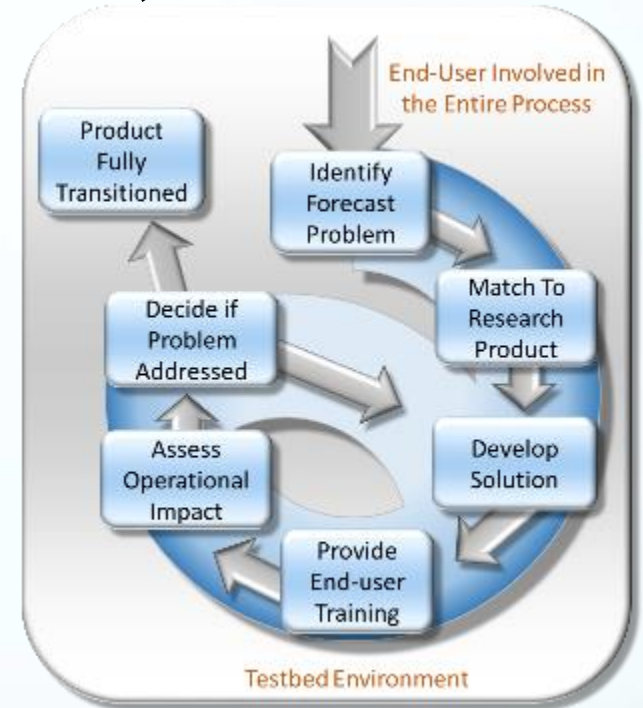
Hardware Development

- LIS, ISS LIS
- AMPR, HIRad, FECS



Short-term Prediction Research and Transition (SPoRT)

- SPoRT is focused on transitioning unique NASA and NOAA observations and research capabilities to the operational weather community to improve short-term weather forecasts on a regional and local scale
- Established research-to-operations and operations-to-research paradigm that solves specific forecast problems, develops applications-focused training, and integrates data into end-user decision support systems



Data downlinked from satellite



Data obtained by SPoRT; value-added products generated



Product disseminated to end-user formatted for their decision support system



End-user makes operational decisions using SPoRT products

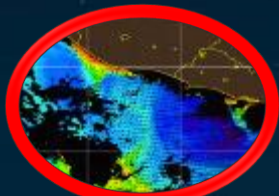
<http://weather.msfc.nasa.gov/sport/>
<https://nasasport.wordpress.com/>
 @NASA_SPoRT



ALL MATERIAL UNCLASSIFIED



SERVIR is a joint development initiative of NASA and USAID, working in partnership with leading regional organizations around the globe, to help developing countries use information provided by Earth observing satellites and geospatial technologies to address Food Security, Water and Disasters, Weather and Climate, and Land Use/Land Cover Change.



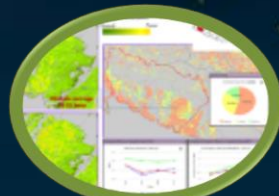
Preventing seafood poisoning by mapping harmful microalgae



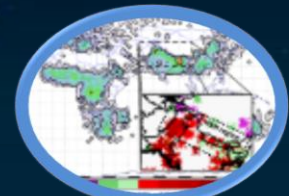
Helping herders and farmers by detecting ephemeral water bodies



Conserving forests by mapping land cover and land use change



Supporting food security by monitoring agricultural drought



Protecting lives by monitoring and forecasting intense thunderstorms

ALL MATERIAL UNCLASSIFIED



Technology Development/Application Lightning Imaging Sensor (LIS) on ISS



Mission

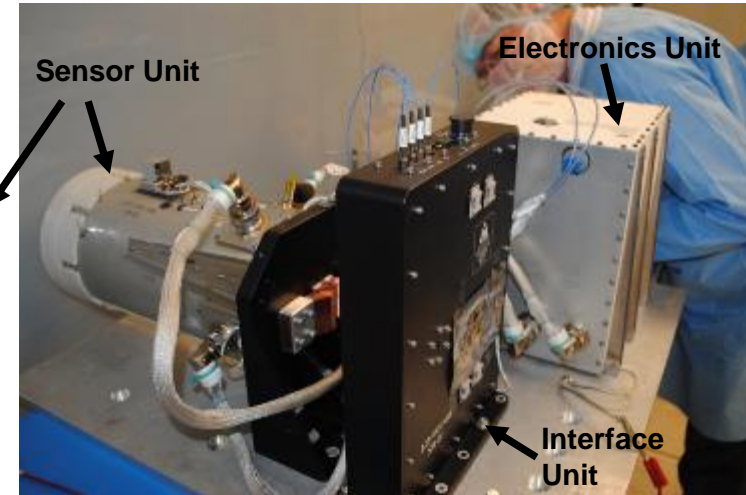
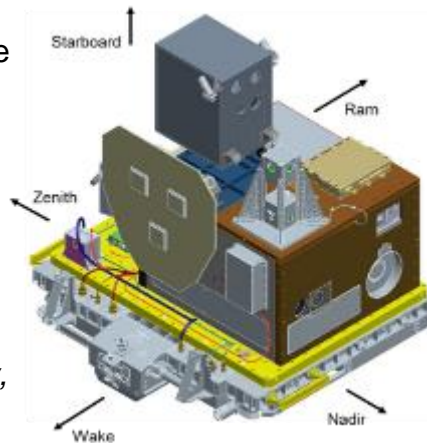
- TRMM and GOES-16 GLM development associated; fly a flight-spare LIS on ISS to take advantage of *high inclination, real time data*.

Measurement

- Global lightning (*amount, rate, radiant energy*) with high detection efficiency

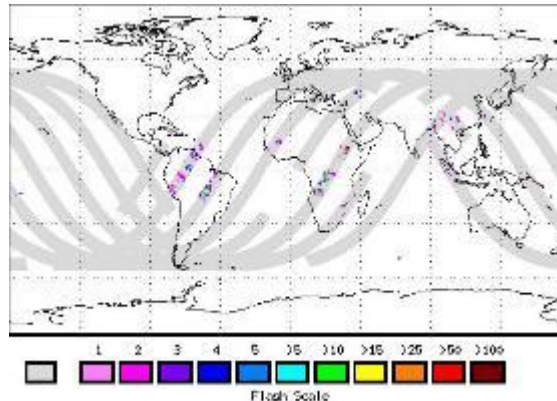
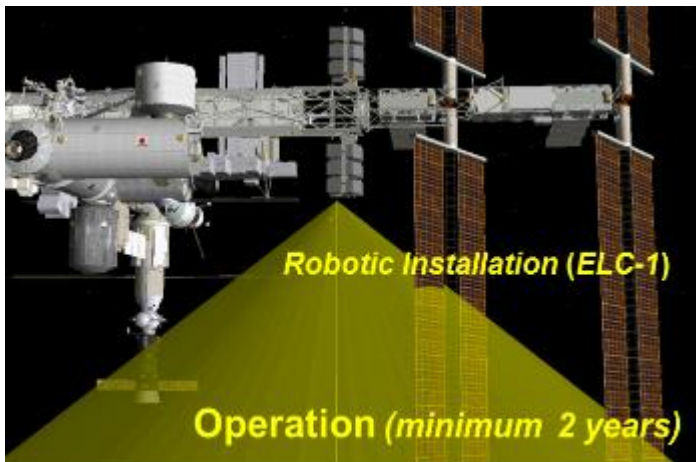
Need and Benefit

- Lightning coupled to many geophysical processes and a wide range of disciplines (e.g., *weather, climate, atmospheric chemistry, lightning physics*).
- ISS LIS extends TRMM heritage LIS, expands latitudinal coverage, provides real time data to operational users, cross-validates GOES GLM

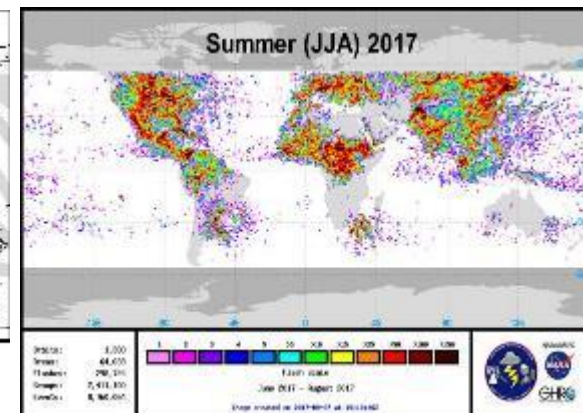


LIS is flown as a hosted payload on the Space Test Program STP-H5 mission

LIS being prepared for integration on STP-H5 payload (February 17, 2015)



LIS near real time lightning data produced every two minutes



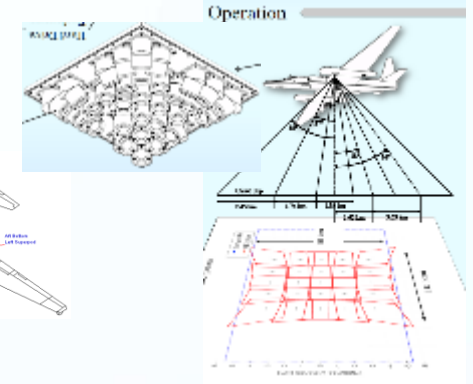
LIS global lightning detections during Summer 2017



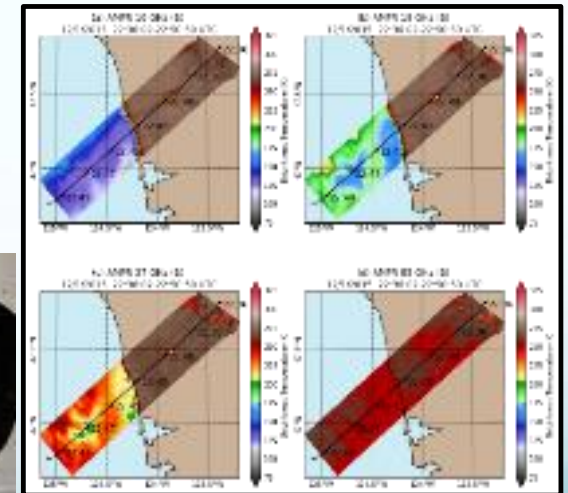
Airborne Remote Sensing Technology and Science



- Fly's Eye GLM Simulator (FEGS) Radiometer, array to map total lightning properties. Lightning Instrument Package (LIP): Electric field, conductivity, total lightning. Aircraft: ER-2- Global Hawk;



- AMPR: Advanced Microwave Precipitation Radiometer: Cross-track scanning microwave radiometer. Frequencies - 10.7, 19.35, 37.1, 85.5 GHz, dual-polarization. Surface, clouds and precipitation remote sensing. Aircraft ER-2, DC-8, P-3





HIRAD (Hurricane Imaging Radiometer)



Objectives:

- Map surface wind speed over *wide swath* (~50 km, for aircraft > FL600) in hurricanes
- Provide research data for understanding hurricane structure, intensity change
- Improve predictions, decision support

Technical Approach:

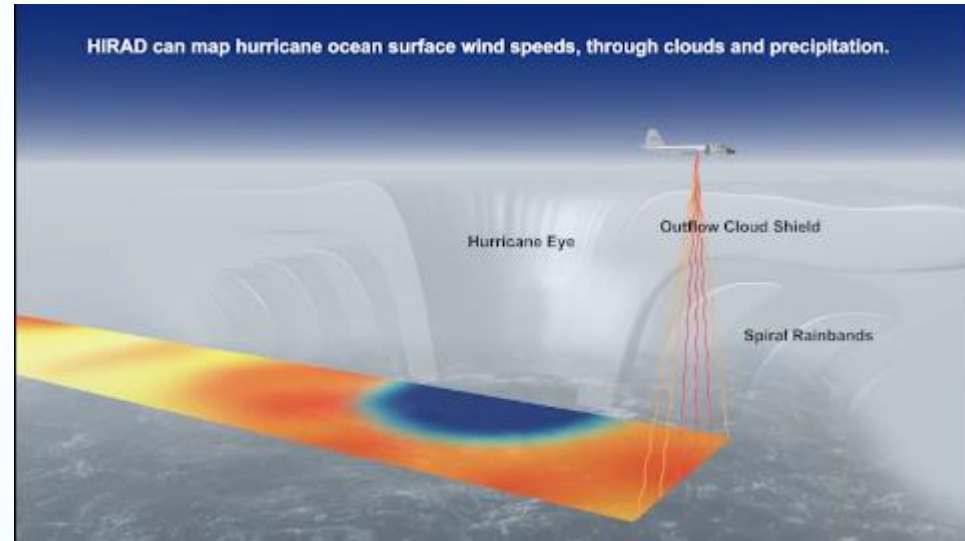
- Multi-frequency C-band radiometer
- Stronger wind -> more foam -> warmer brightness temperatures
- Minimum detectable wind speed ~ 15 m s⁻¹)

History

- Leveraged technology from UMich, LaRC
- MSFC internal and NOAA investments (2006-2010)
- Several field efforts on NASA aircraft (WB-57, Global Hawk)

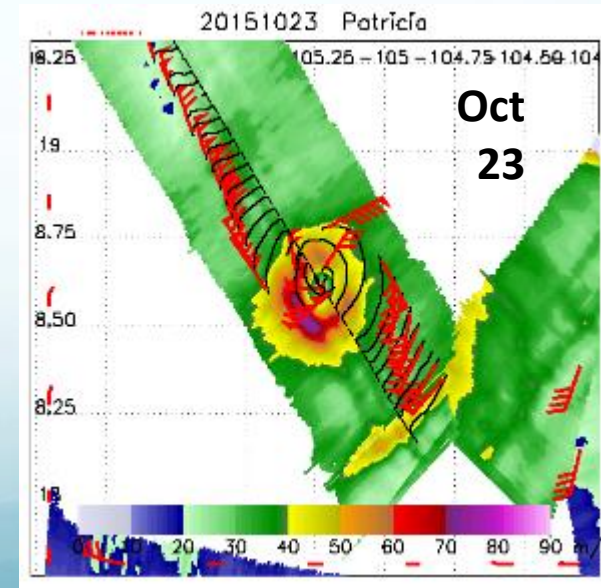
Future Goals:

- Upgrade to add wind direction
- More robust 2nd-generation instrument(s)
- Facility instrument on multiple aircraft for both research & operations



Hurricane Patricia (2015) at Cat 5 intensity, with dropsonde wind barbs overlaid.

For a small storm like Patricia, one aircraft pass maps the entire eyewall.





Research



Earth Science Missions

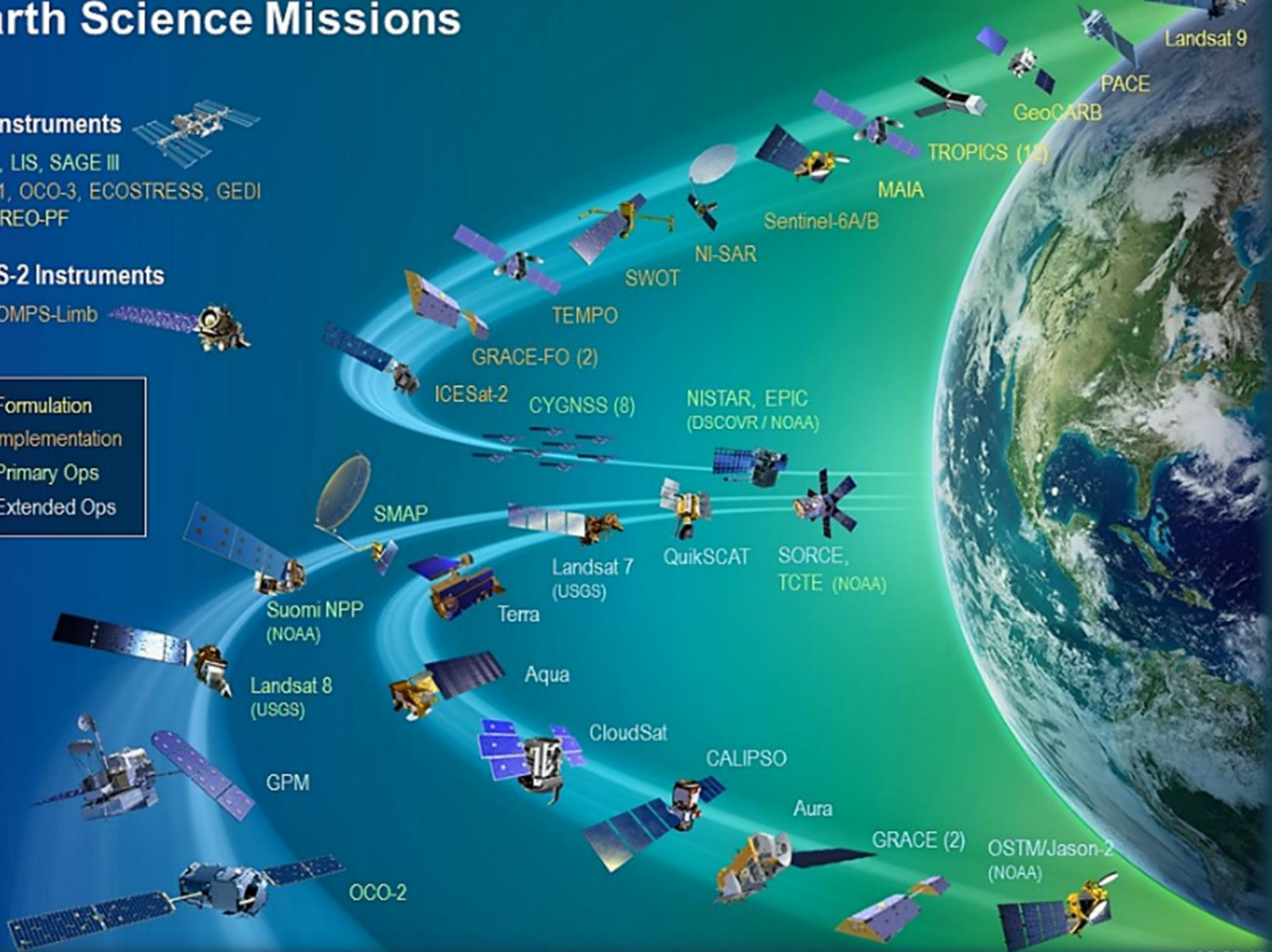
ISS Instruments

CATS, LIS, SAGE III
 TSIS-1, OCO-3, ECOSTRESS, GEDI
 CLARREO-PF

JPSS-2 Instruments

RBI, OMPS-Limb

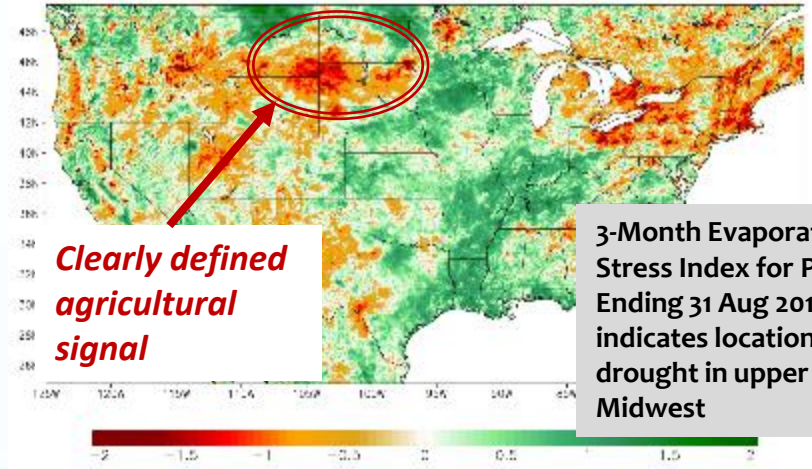
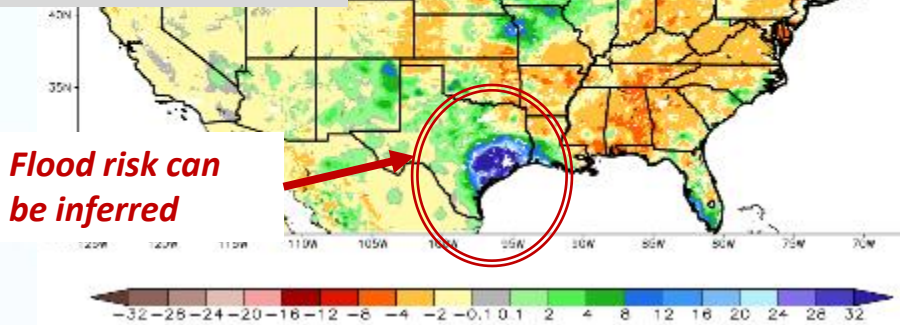
■	Formulation
■	Implementation
■	Primary Ops
■	Extended Ops



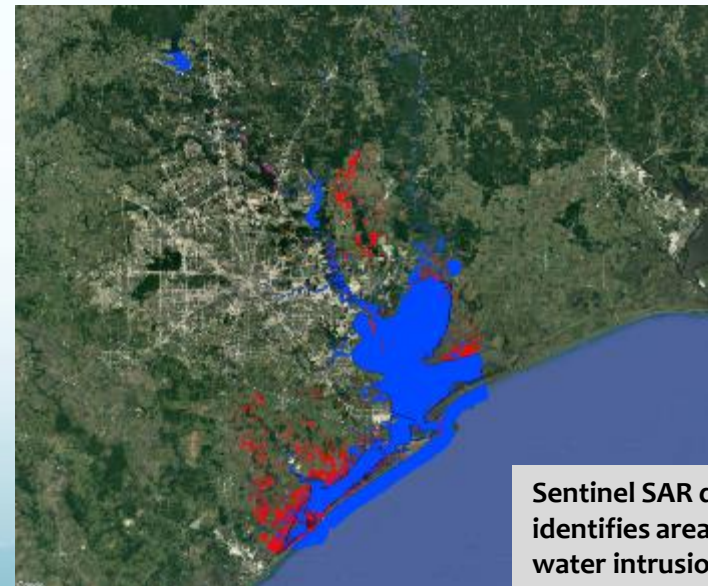


Land Surface State: Flood & Drought

1-Week Difference in Column Relative Soil Moisture (%) on 28 Aug 2017 shows impact of Hurricane Harvey



- Land surface (LIS; SMAP) to improve short-term weather, flood potential, and agricultural forecasts (top)
- Use Synthetic Aperture Radar (SAR) to see through clouds to observe flood extent at high spatial resolution (right)



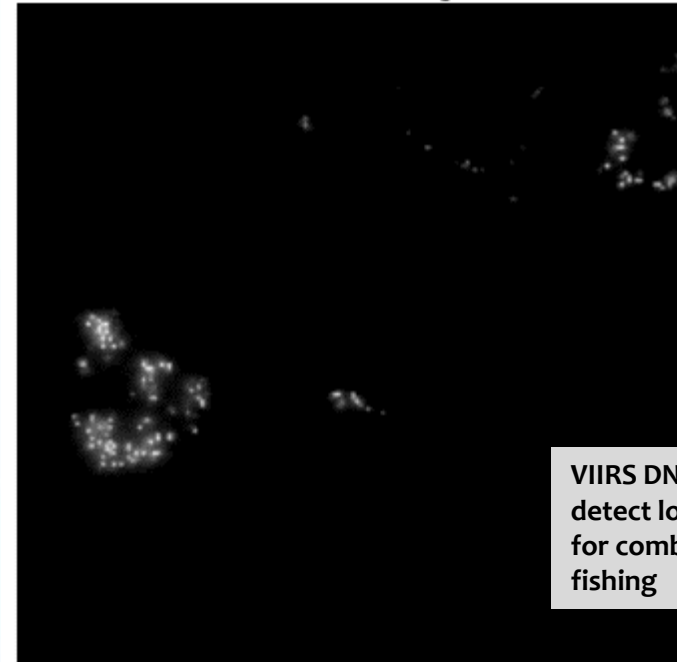
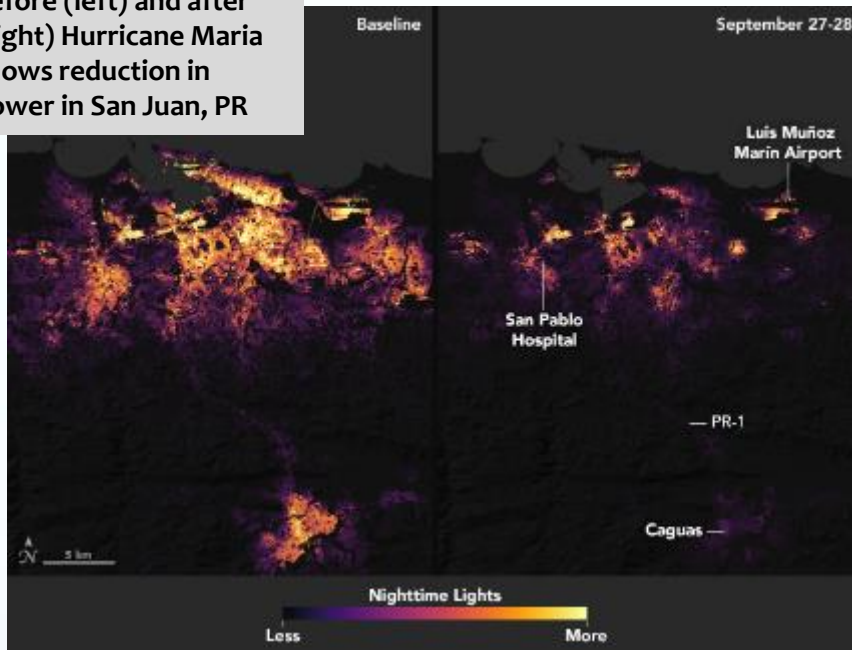
Sentinel SAR data identifies areas of flood water intrusion





VIIRS Day Night Band

VIIRS DNB comparison before (left) and after (right) Hurricane Maria shows reduction in power in San Juan, PR



- Visible Infrared Imaging Radiometer Suite (VIIRS) has a low light sensor that can detect moonlight-reflected clouds at night and lights on the ground in low-moonlight conditions
- SPoRT has developed a number of real-time products that can be used for detecting power outage related to disasters (left) or for detecting small-scale light sources (right) to track human migration

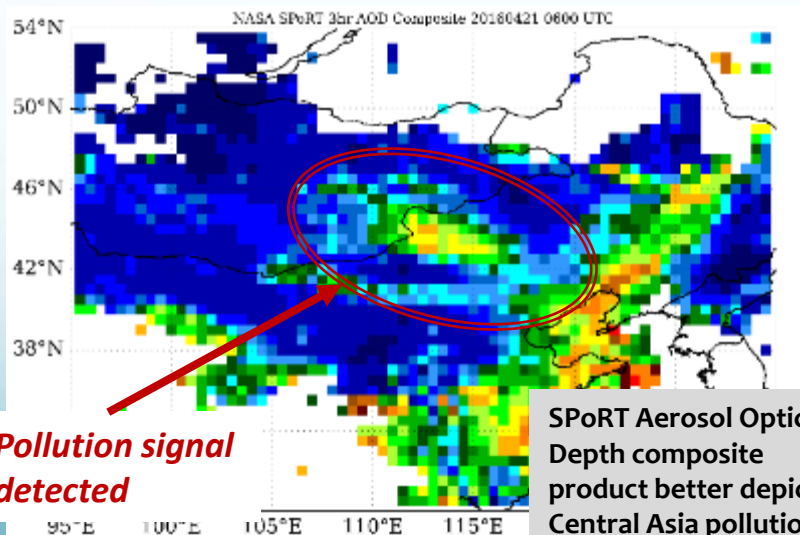




Atmosphere: Dust & Aerosols

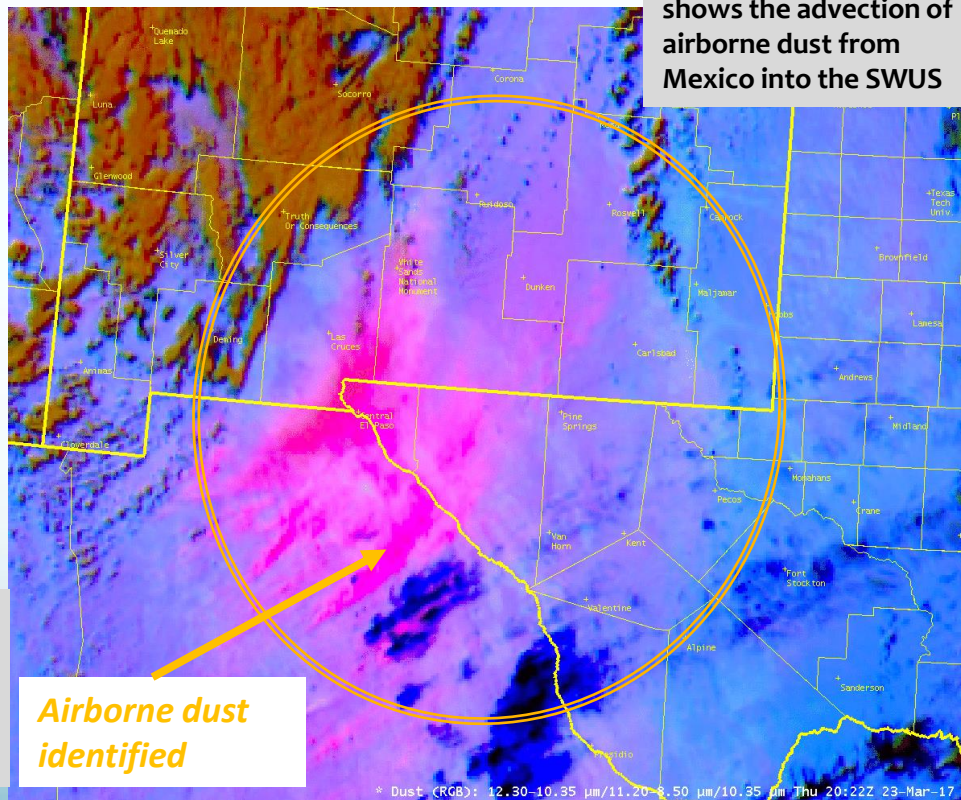


- SPoRT has developed a real-time global aerosol optical depth (AOD) composite product (left) for detecting pollution and dust for studying their impact on cloud and precipitation development
- Multispectral imagery (Dust RGB; right) identifies airborne dust (magenta) that may be difficult to identify in single-channel imagery



Pollution signal detected

SPoRT Aerosol Optical Depth composite product better depicts Central Asia pollution than model





Ocean Surface Vector Winds

Objectives:

- Integrate ground and satellite radar estimates of precipitation with satellite-based wind retrievals to resolve mesoscale low-level flow field.

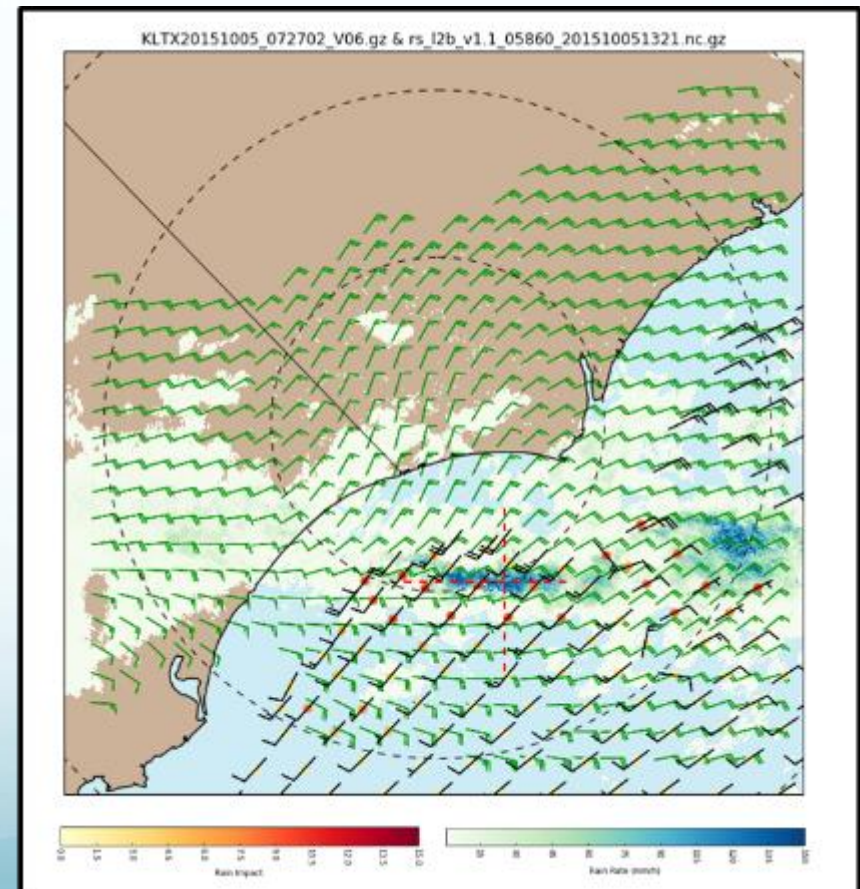
Technical Approach:

- Coastal/Island radars, GPM satellite, scatterometer, GPS-reflectometry (CYGNSS mission)

Future Goals:

- Statistical analysis of key mesoscale wind features organizing a wide spectrum of convective storms
- Model data assimilation experiments to improve prediction of convection

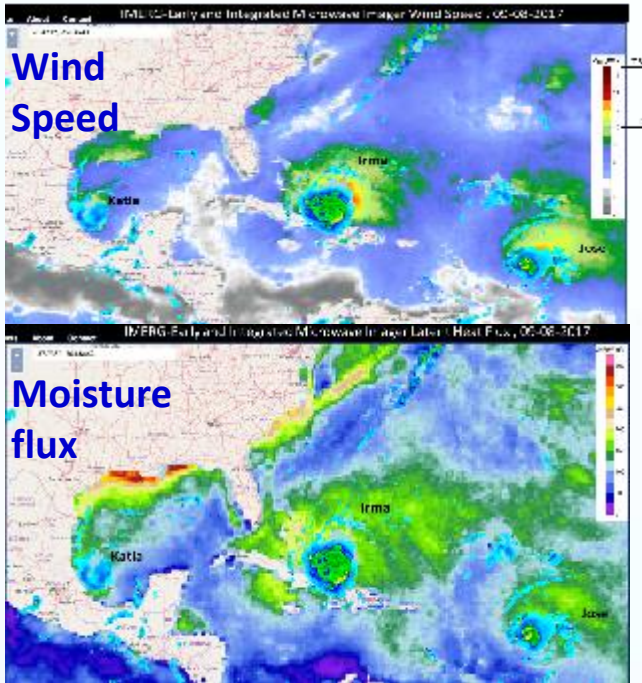
Coastal radar rainfall and single-Doppler winds (green) combined with RapidScat winds (black). The radar fills in low-level wind information where satellite is sparse (heavy rain and coastal regions). Together they show convergence line fueling heavy rain.





Ocean Real-Time Surface Meteorology and Energy Fluxes from Space

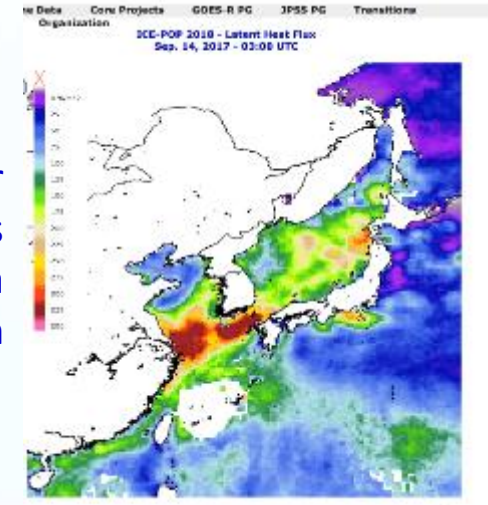
Near-real-time *global ocean surface meteorology* and heat flux estimates (25 km, hourly resolution) from GPM satellite constellation *passive microwave imagers*



Applications

Topical cyclone and other synoptic disturbances

Coastal storm systems: E.g., over Korean Peninsula ocean provides moisture flux to air transiting Sea of Japan; subsequent mountain interaction produces heavy snow.



Atmosphere

- Short-term weather forecasts can potentially be improved through use of near-real-time estimates of surface meteorology and atmosphere-ocean exchanges of heat and moisture
 - Hurricane Forecasting, Winter-weather forecasting / Air-mass modification via surface fluxes

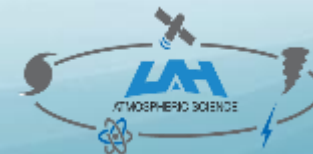
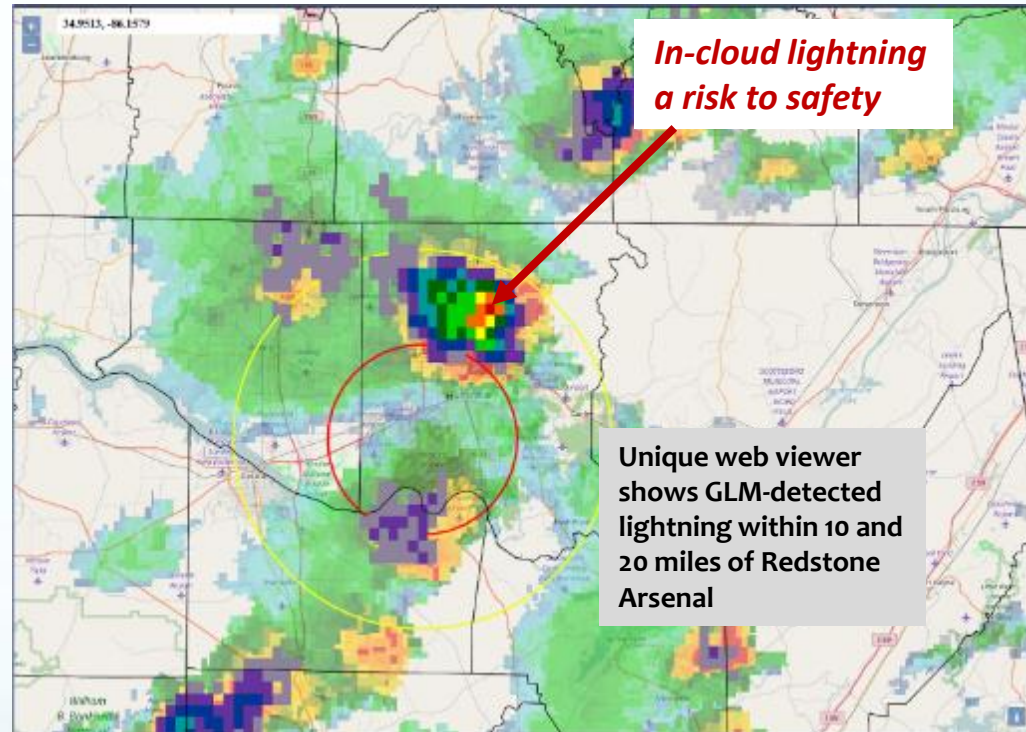
Ocean (discussion with NRL-Stennis- potential applications with NFLUX product)

- Ocean models are forced by near-surface temperature, humidity, and wind fields
- Can be used to improve model forecasts and/or develop bias-corrected forcing



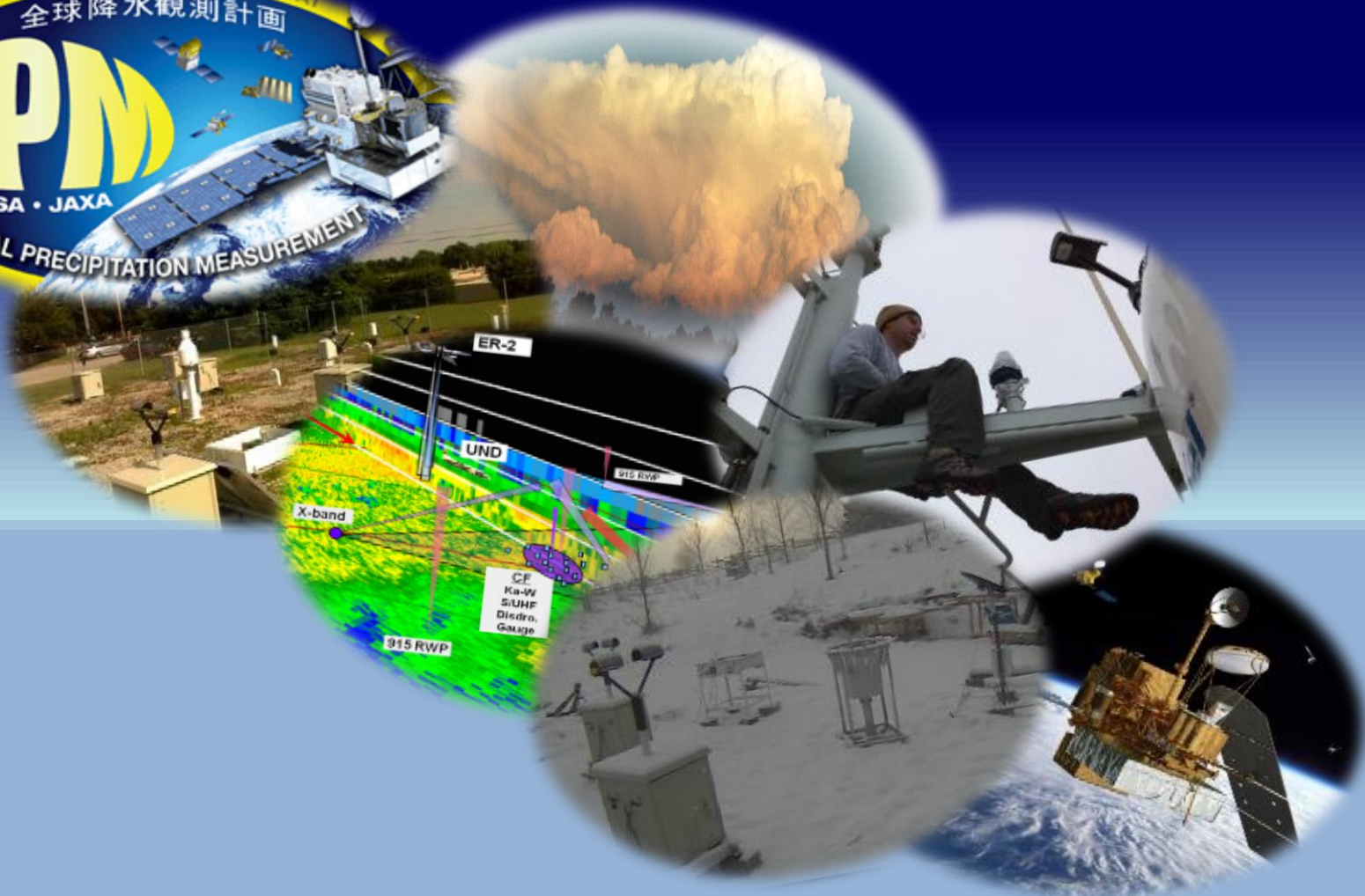
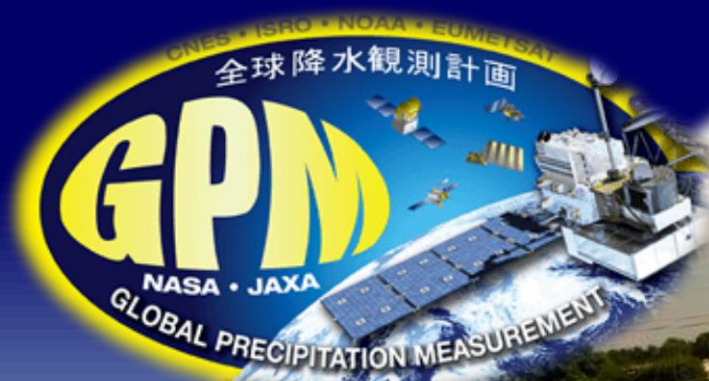
Atmosphere: Thunderstorms and Lightning

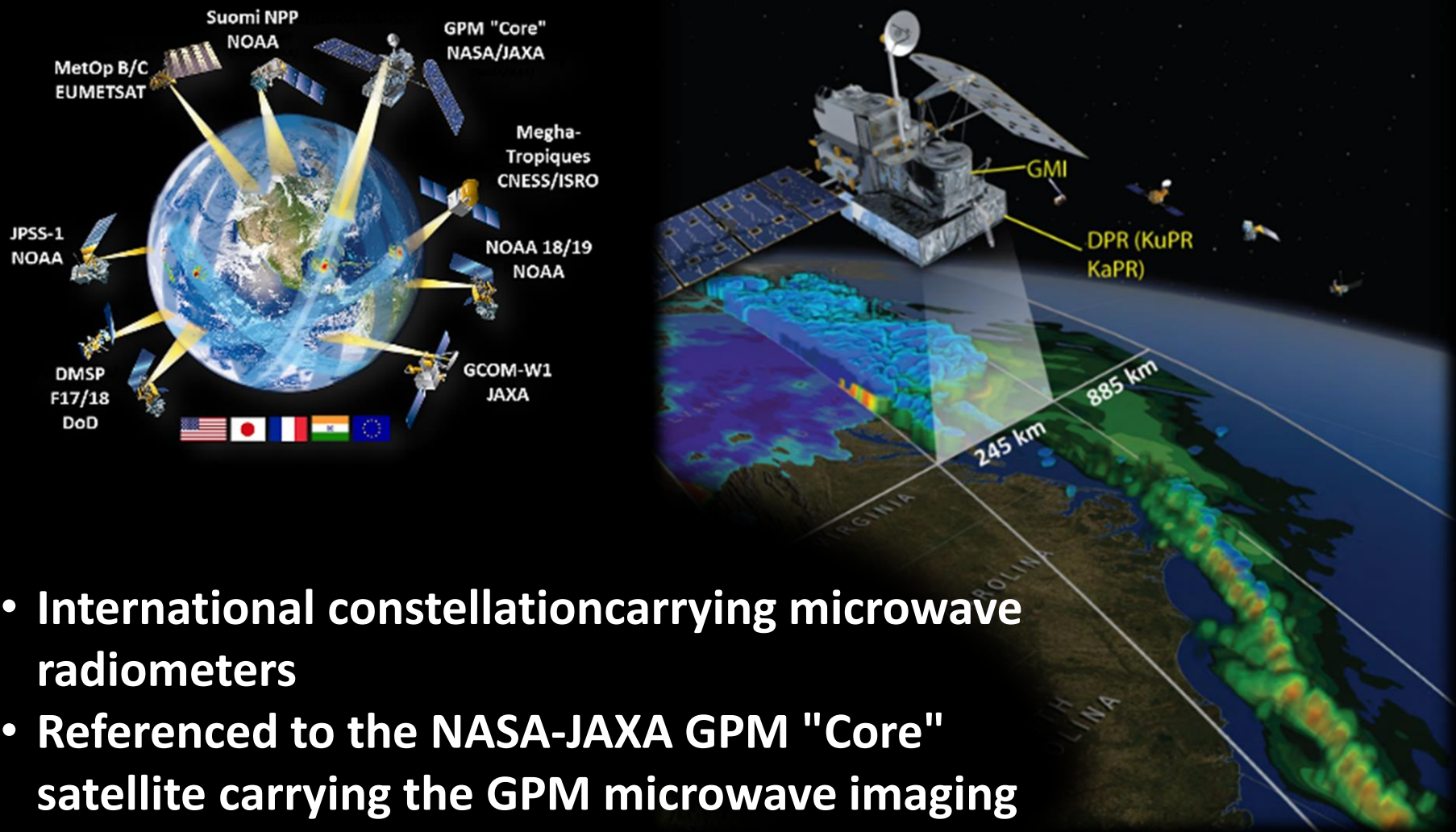
- Transition unique total lightning data from VHF ground-based Lightning Mapping Array (LMA) and space-based GOES-16/S Geostationary Lightning Mapper (GLM) for severe weather and lightning safety applications
- Europeans and Japanese planning similar GLM-like lightning sensors in early 2020s with coverage in areas of international interest
- SPoRT expertise develops value-added products





Precipitation Science





- International constellation carrying microwave radiometers
- Referenced to the NASA-JAXA GPM "Core" satellite carrying the GPM microwave imaging radiometer (GMI) and the **Dual-frequency Precipitation Radar (DPR)**

The Drop Size Distribution (DSD): Fundamental to remote sensing of precipitation physics



Your brain on "DSD"

Common representation (Normalized Gamma Distribution)

$$N(D) = N_w f(\mu, D_m) \exp[-(\mu+4)D/D_m]$$

μ (shape parameter; *fixed at 3* for GPM algorithms)

D_m = mass-weighted mean diameter

N_w = normalized intercept (measure of drop concentration)

Level 1 Science Requirement

- GPM Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, D_m to within +/- 0.5 mm. [note- no N_w requirement]



Measuring DSD Properties: Disdrometer Capabilities



We collect and process high resolution liquid/frozen hydrometeor size distribution measurements/datasets to support a variety of precipitation science applications

Instruments



Autonomous Parsivel² Units (APU)



Two-dimensional Video Disdrometers (2DVD)



Meteorological Particle Spectrometer (MPS)



Precipitation Imaging Package (PIP)



Micro-Rain Radars (MRR)

Global Field Deployments

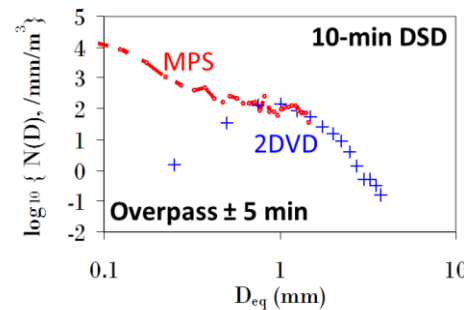


Applications:

- Satellite and multi-parameter radar-based precipitation retrievals (e.g. NASA-GPM)
- Flight environments and sensors requirements/research (e.g., AMRDEC)
- Severe storm dynamics (e.g., UAH-SWIRL, VORTEX-SE)
- Cloud-modeling (model microphysical parameterizations; multi agency/institution)

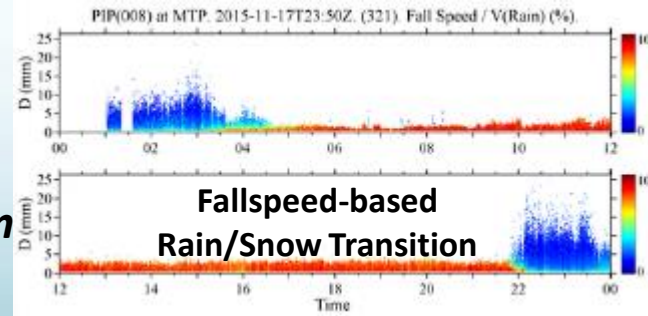
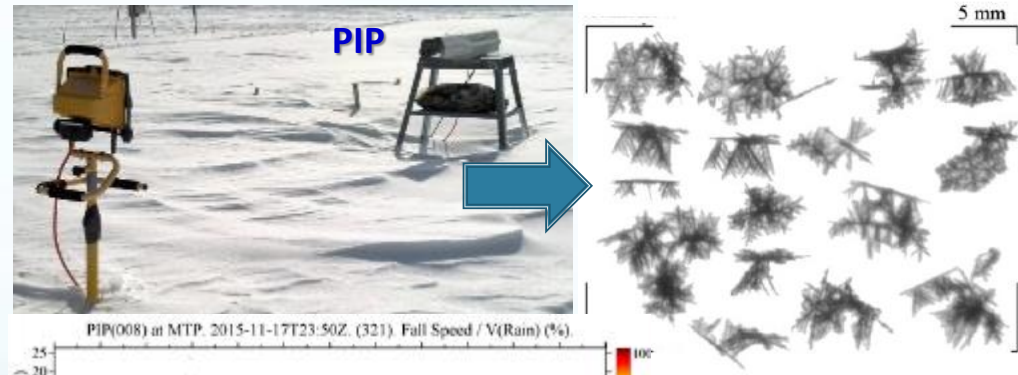
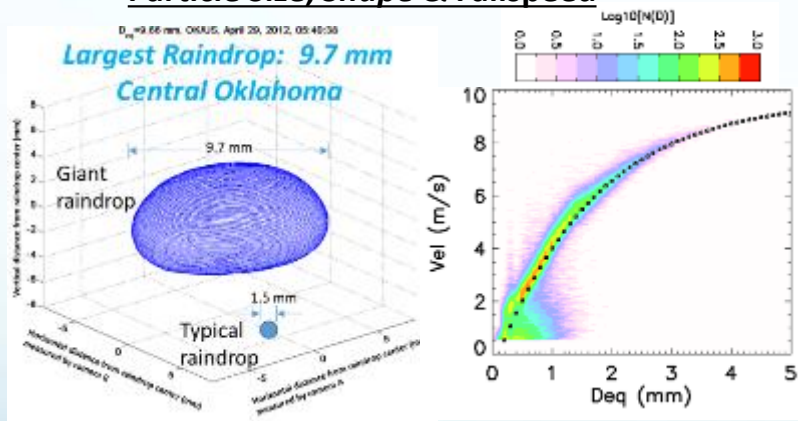


A More Complete Depiction of the Raindrop Size Distribution



- Disdrometer limitations can mask the “truth”
- Small drops more prevalent than often specified in drop size distribution models

Particle Size, Shape & Fallspeed



Complex Snowflakes
Scattering computation and water equivalent sensitivities

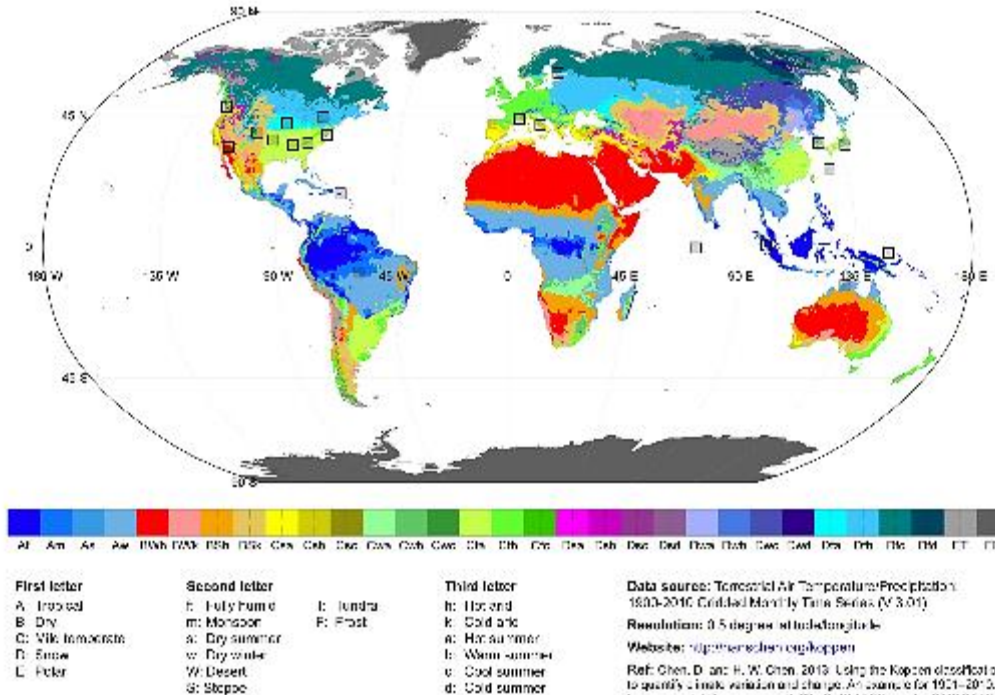
→ Implications for accurate remote-sensing involving a precipitation medium
Liquid, freezing, frozen!



2DVD DSD Datasets Collected Around the Globe



World map of Köppen climate classification for 1901–2010



- 20 different locations (more if APU collections included)
- 8+ of 31 climates
- ~9,500 hours of rain observations
- Primarily via NASA's GPM precipitation science satellite validation activities
- Highly accurate measurements of raindrop (also snow) size, shape and fallspeed

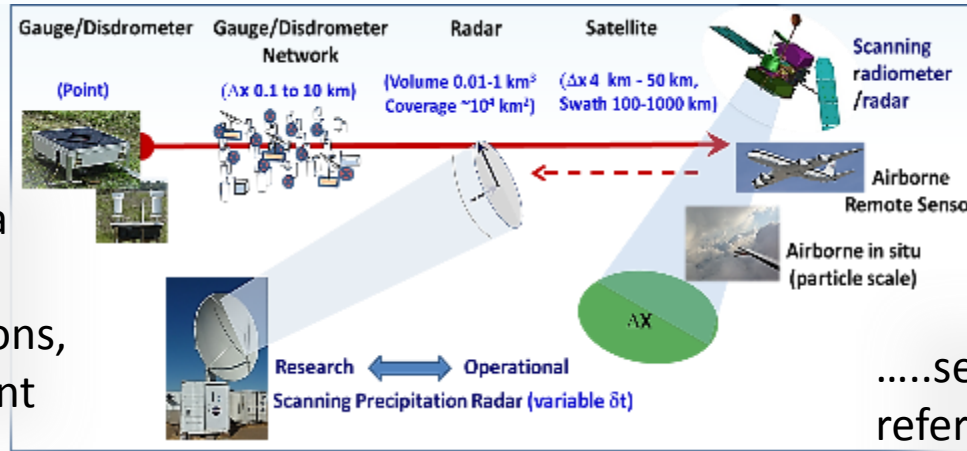
A treasure trove of highly detailed information about naturally occurring precipitation that can be used to constrain theoretical models.



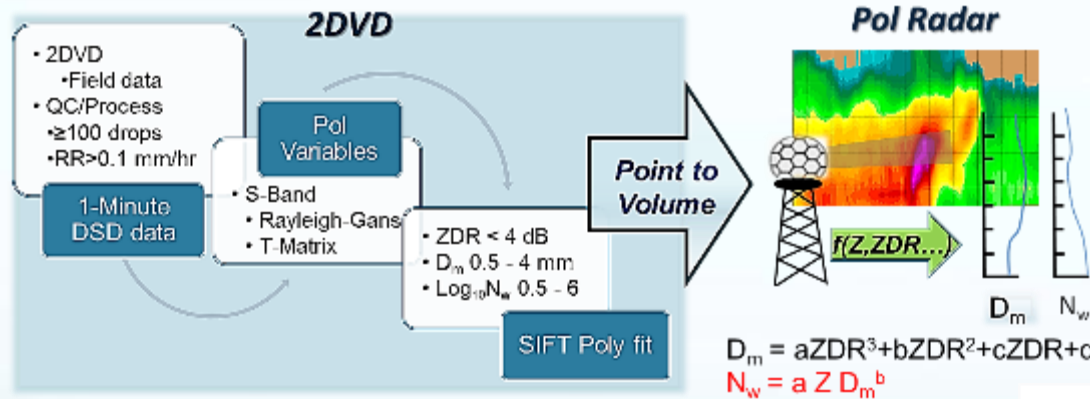
Translating the DSD: Upscaling from Point to Global



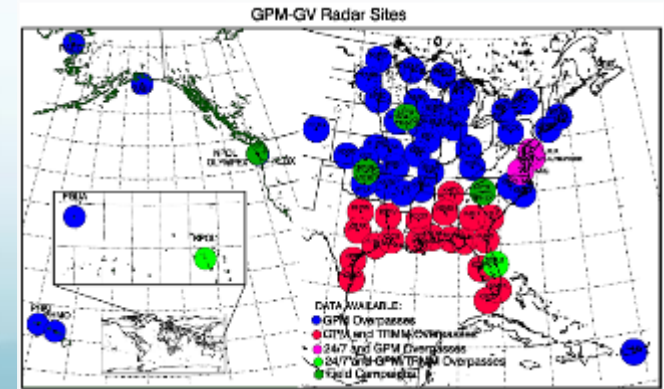
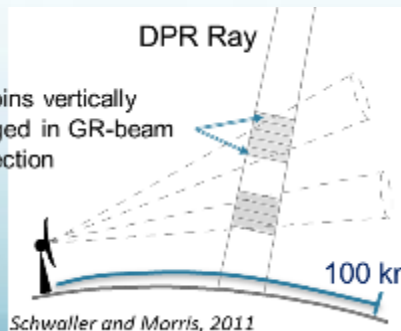
2D Video disdrometer data collected at numerous locations, regimes, and point scales.....



.....serves to reference volume scanning multi-parameter radar retrievals from pulse-volumes to regional domains.....

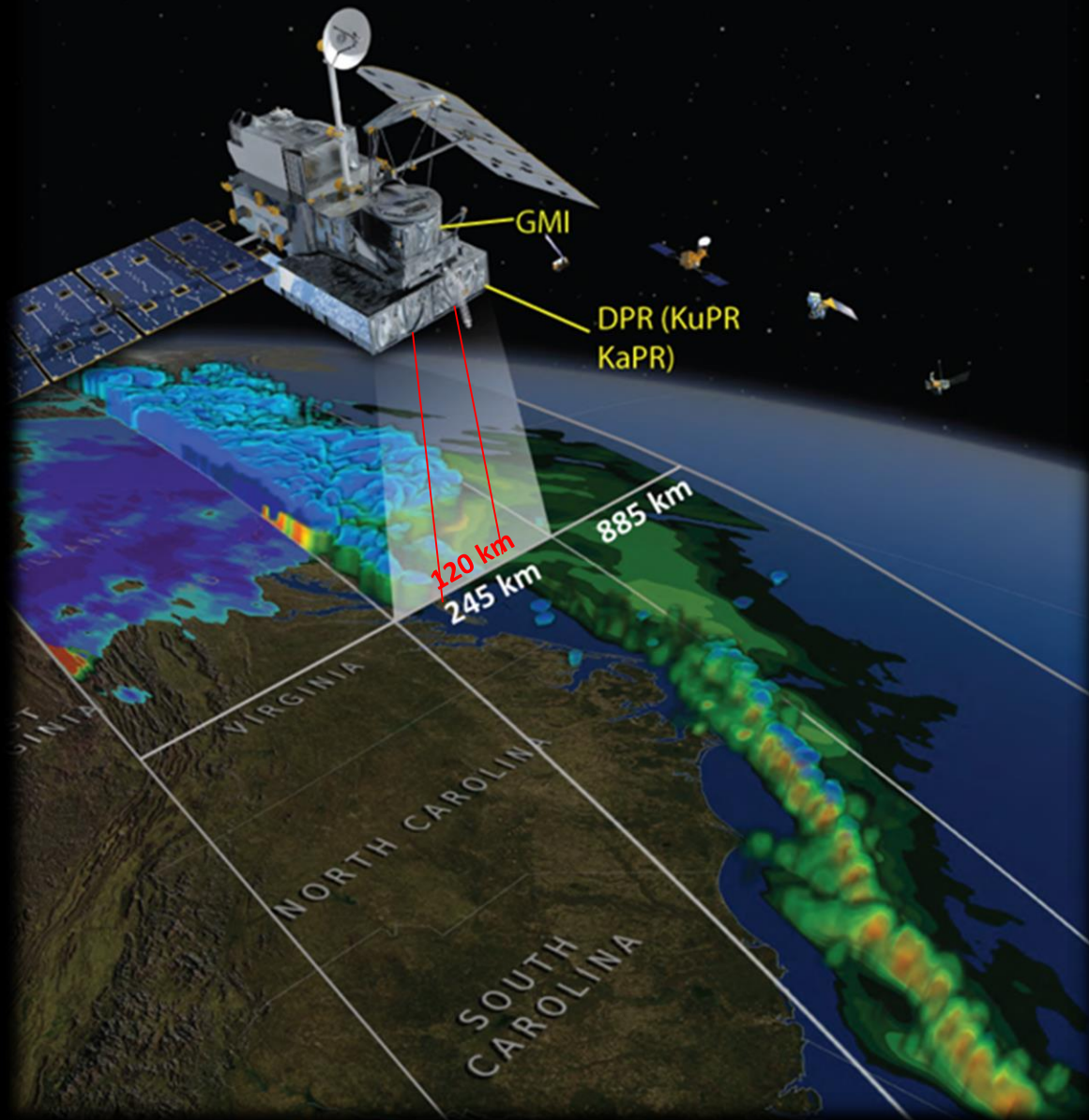


.....subsequently matched to GPM satellite footprint and continental scales





Application: Verifying GPM Radar-Retrieved Rain and DSD Data Inner Dual-Frequency (MS) and Outer Single Frequency (NS) Swaths



The rain rate estimate is **driven by estimate of the Drop Size Distribution (DSD)**

Dual-frequency DSD and rain rate retrieval in MS swath should be more accurate in light/moderate rain rates

Single-frequency retrievals in the NS swath

DPR data files combine dual and single frequency retrievals in the NS files.....

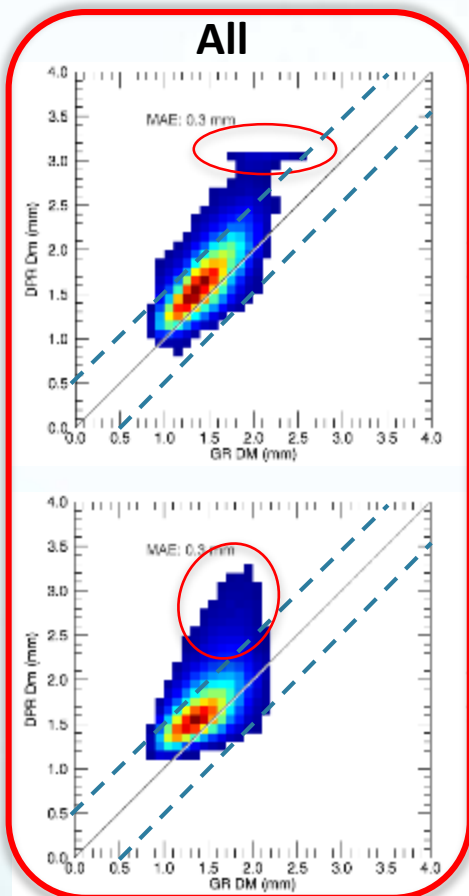


View from Ground-Validation (GV)



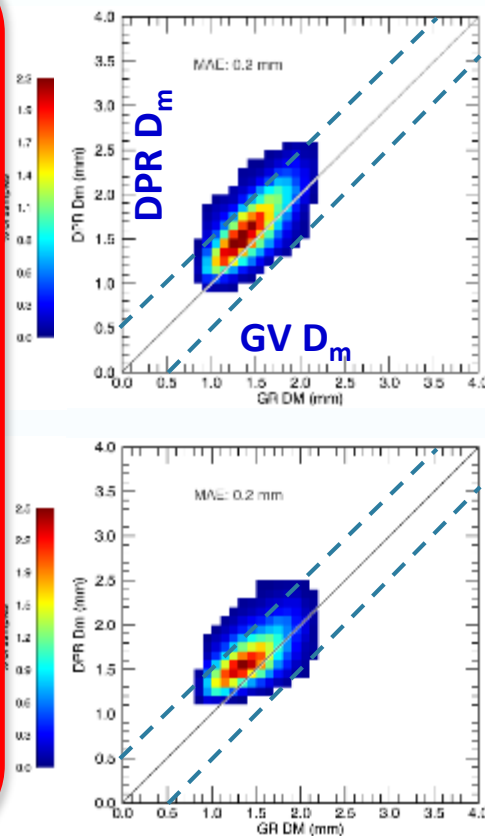
GPM DPR Mid (MS) and Outer (NS) Swath D_m vs. GV Radar D_m

DPR MS

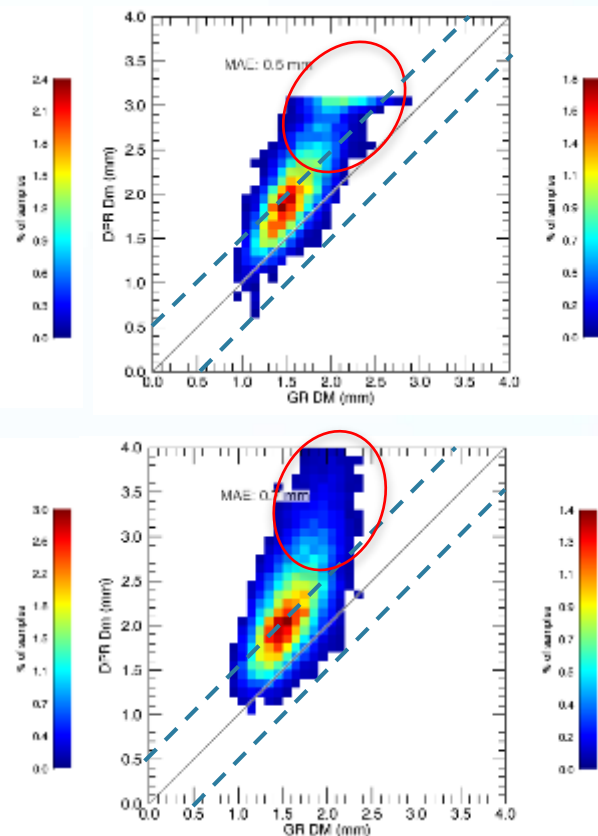


DPR NS

Stratiform



Convective



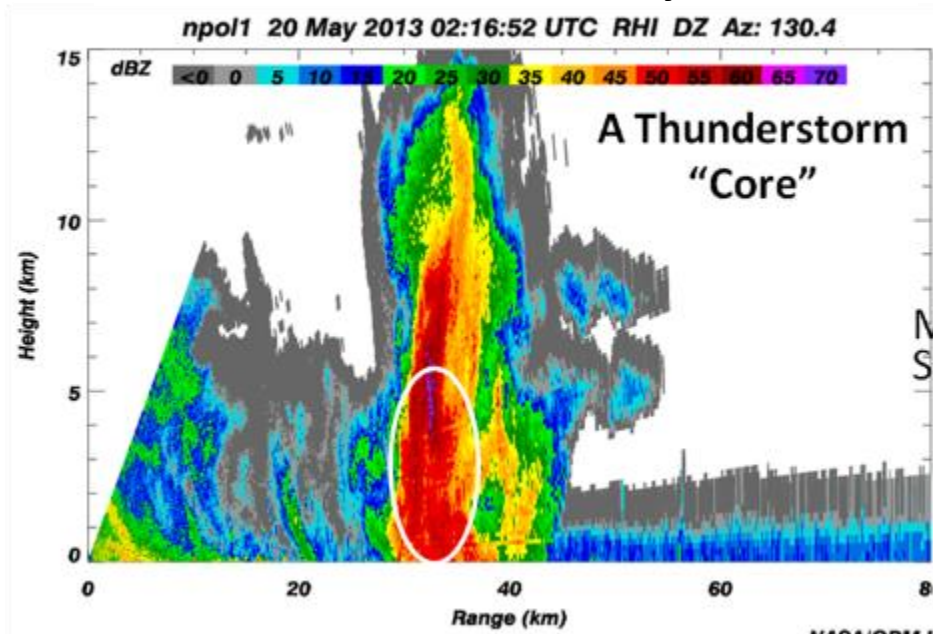
- **GPM Requirement: Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, D_m to within ± 0.5 mm**

- In stratiform precipitation, V5 DPR is about ~ 0.2 mm higher than GV
- **2ADPR Convective D_m bias is a problem** (D_m ceiling at 3 mm in MS is an artifact), large positive deviation in NS creates an underestimation of rain rate.....

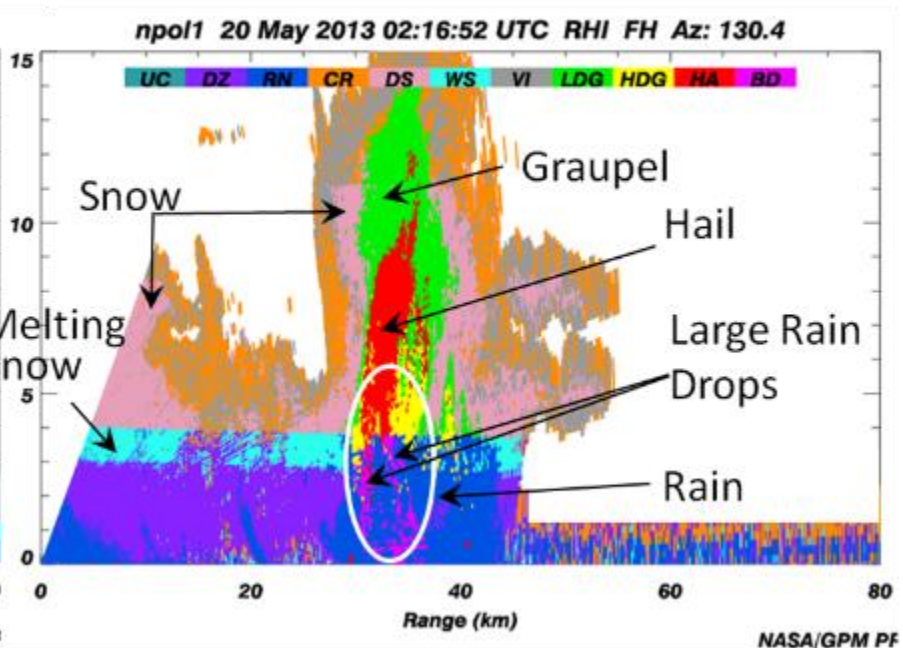
Polarimetric Radar and Role of Ice Physics in Rain DSD

NPOL Cross-sections of Precip Microphysics

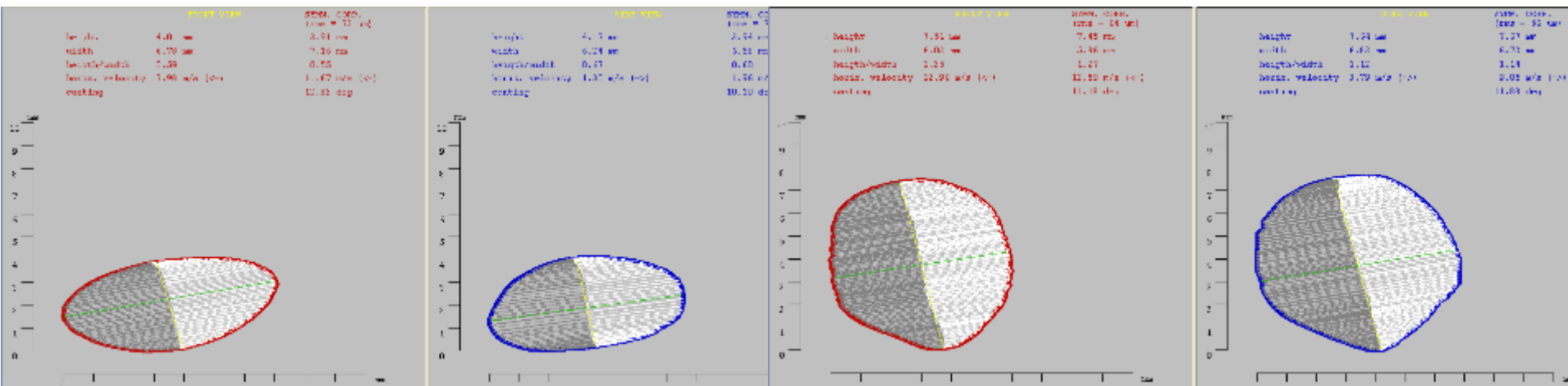
Radar Reflectivity



Diagnosed Precipitation Types



2D Video Disdrometer observes rain (large drops) and small hail mixture

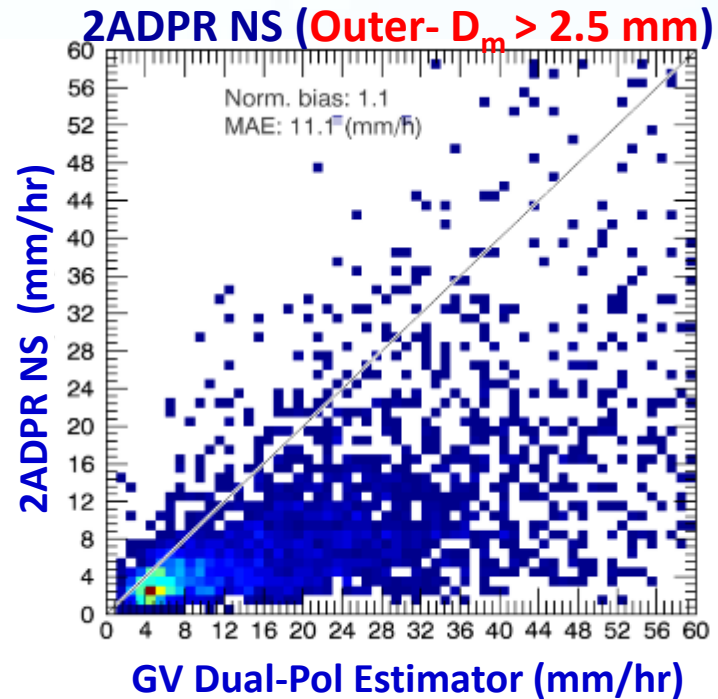
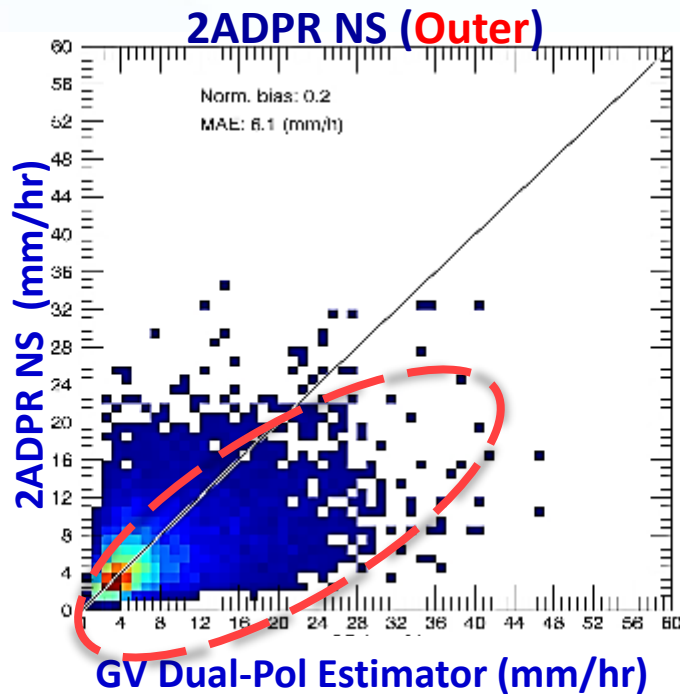




Why do we care?



DSDs impact rain rates and hence data products!
Marked low bias against GV rain rates due to DPR large drop estimates
Look for algorithm fixes in Version 6 (2018/19'ish)



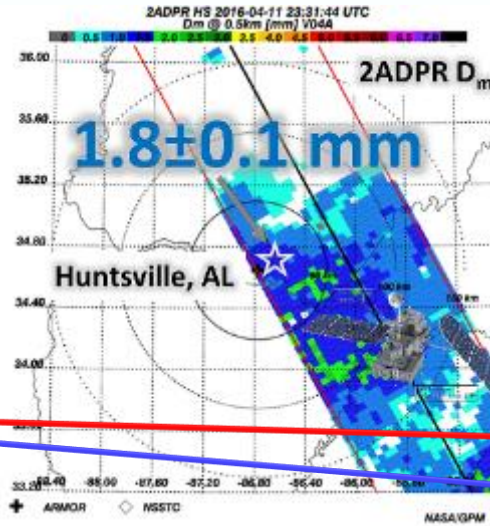


What About Light Rain and Small Drops?



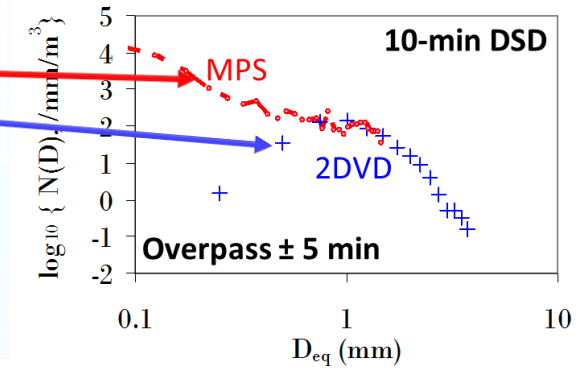
Do current DSD assumptions for GPM adequately represent the small rain drop sizes?

GPM dual-frequency precipitation radar (DPR) swath as it samples rain over Huntsville disdrometers



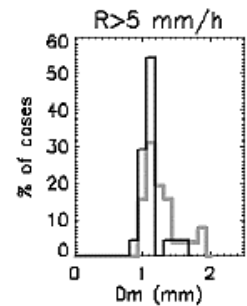
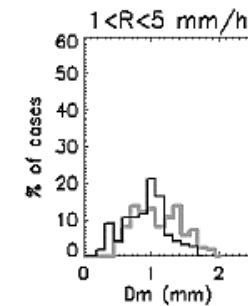
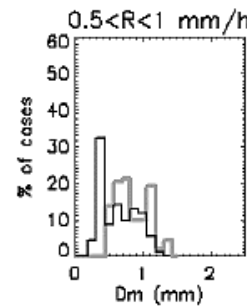
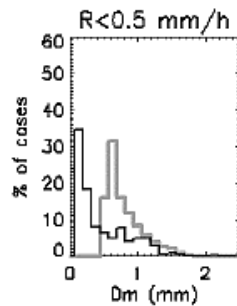
Right answer ...right reason?

DSD measured by GV
MPS+2DVD (2DVD) $D_m = 1.61$ (1.73) mm



We do not properly represent the small-drop end (< 0.7 mm) of the drop size distribution-

Likely important for light rain estimation.



Reference: Thurai et al. 2017, JAMC



DoD Application(s): Sensor Development and Testing for Degraded Visual Environments (DVE)

DVE-Mitigation sensor development/testing require *realistic* environmental characterization



- *Scenario #1:* DVE-M needs a sensor capable of “seeing” through 95% of moderate rain.
Question: What is moderate rain from a sensor perspective?
- *Scenario #2:* A vendor has a sensor that can “see” through rainfall intensities up to 10 mm/hour (0.5 inches/hour).
Question: What needs to be produced in a test environment?
- **Problem:** To define requirements for DVE-M sensor development/testing we need to know the distribution of raindrops found in nature



Solution: Utilize global disdrometer database to categorize rainfall based on relevant metrics and define associated drop size distributions for each category



Defining rain from a sensor perspective: An Application of Precipitation Science to DVE-M



A taxonomy that defines naturally occurring rainfall characteristics was constructed from the raindrop size measurements contained in NASA's global 2DVD database

Rain Taxonomy Overview

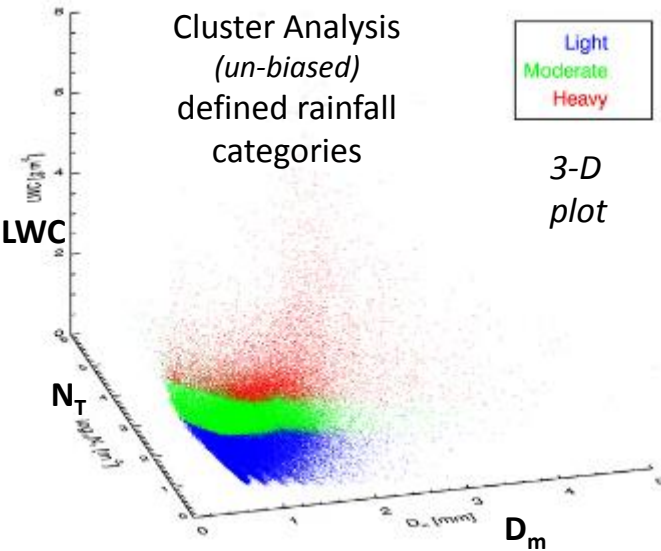
Descriptive Rainfall Category	Defining Metric: Liquid Water Content [g m^{-3}]	Rainfall Intensity* [mm/hr]	Visibility [km]	Raindrop Diameter $\langle D_m \rangle \pm \sigma_{D_m}$ [mm]
Light	$\text{LWC} < 0.09$	$R < 2.54$	$\text{VIS} > 9.6$	0.9 ± 0.3
Moderate	$0.09 \leq \text{LWC} < 0.4$	$2.54 \leq R < 7.62$	$9.6 \leq \text{VIS} < 2.6$	1.1 ± 0.4
Heavy	$\text{LWC} \geq 0.4$	$R \geq 7.62$	$\text{VIS} \leq 2.6$	1.6 ± 0.5

*Rain Intensity definitions are based on that given by the Federal Meteorological Handbook

Cluster Analysis
(un-biased)
defined rainfall
categories



3-D
plot



▶ These categories can be used for specifying sensor requirements

▶ Enables systems engineering process while providing familiar terminology for the *operational* end-users

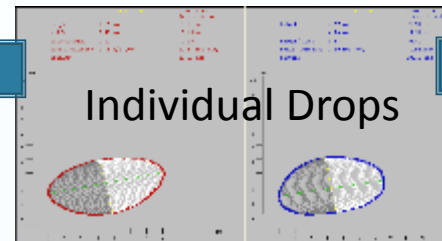
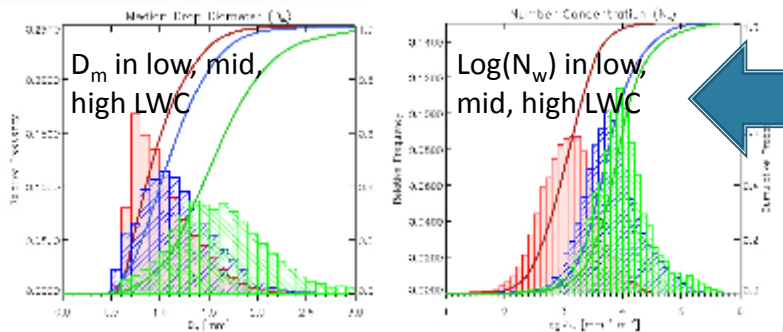


High Velocity Flight/Materials Interaction with Hydrometeors

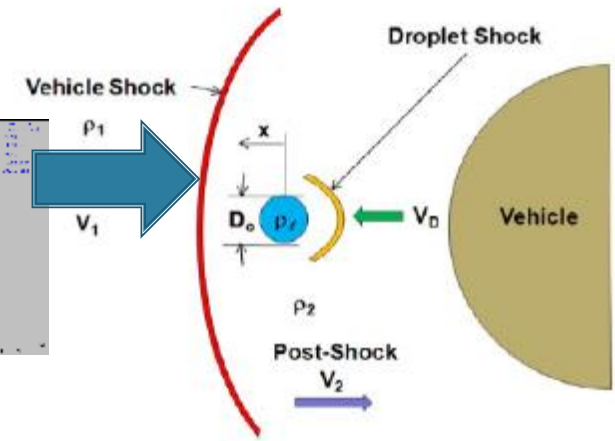


".....withstand flight through natural adverse environments such as rain, **accurate ground test protocols are required**.....work remains in order to develop material damage models of sufficient accuracy to estimate the true real-world performance of flight vehicles in adverse natural environments." (Moylan et al., 2013!)

Bulk distribution behavior



Simulate Rain environment

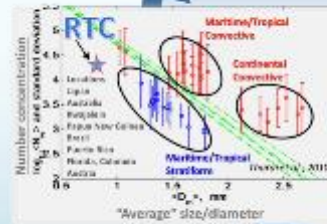


Rain simulation and direct testing....

Revisit simulator design



Measure simulated Rain properties



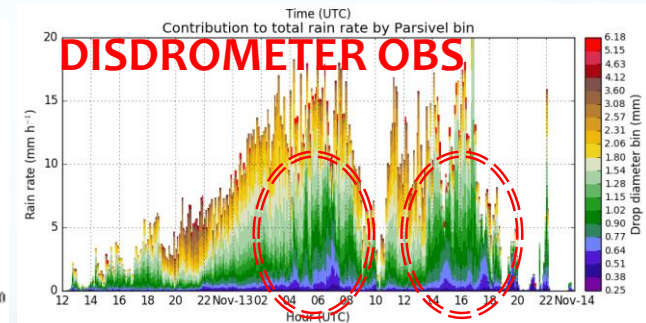
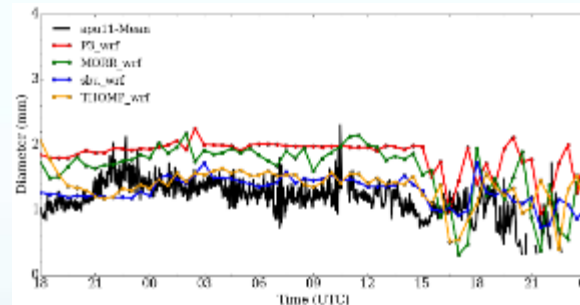
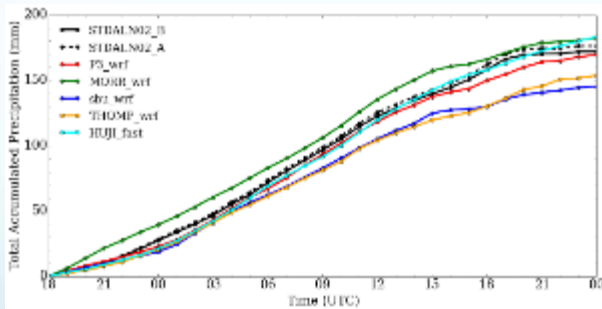
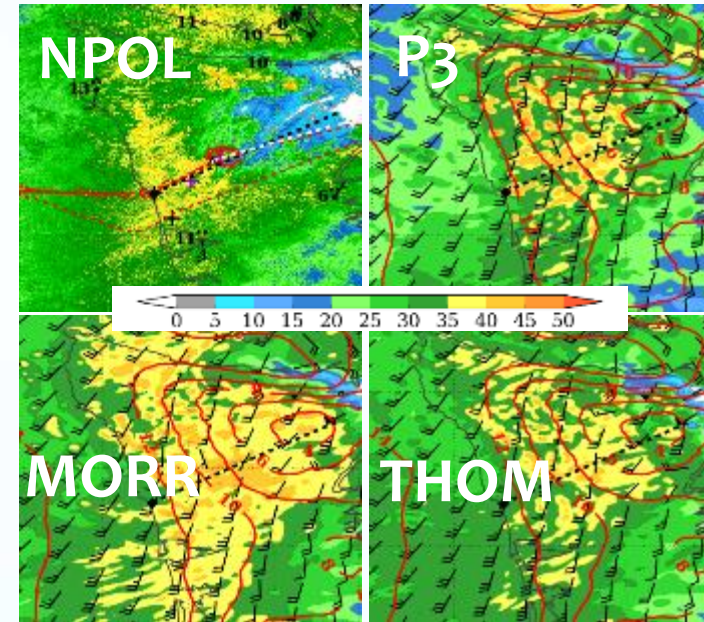
Did it look like nature?

Modeling vehicle interaction...

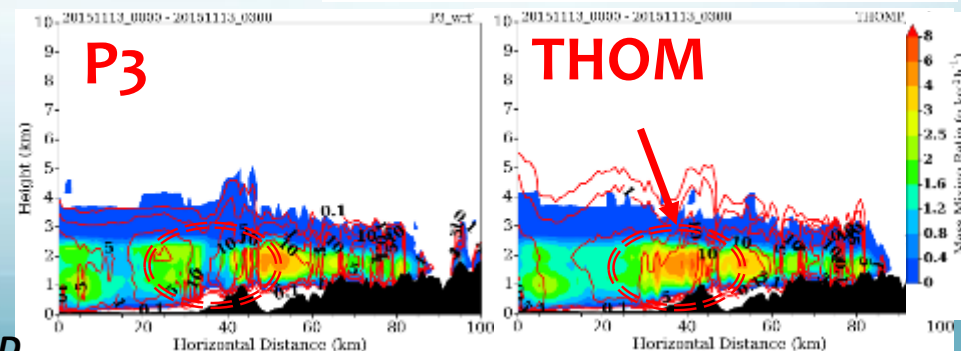
More extensive NASA DSD measurement data in multiple environments- ground, airborne and space-based provide new information to characterize "natural" hydrometeor behavior

Hydrometeor Observations for Validating Cloud Models

- Field radar and disdrometer data validates & refines cloud microphysical schemes in numerical models.
- Simulations show reasonable comparison to radar.
- Predicted Particle Properties (P3) scheme in closer agreement with obs, but raindrops too large.
- Rain drop sizes in Thompson scheme are similar to obs but the scheme under predicts precipitation.

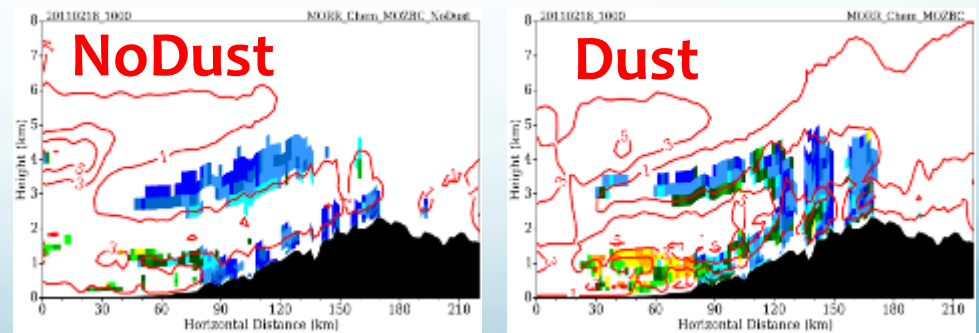
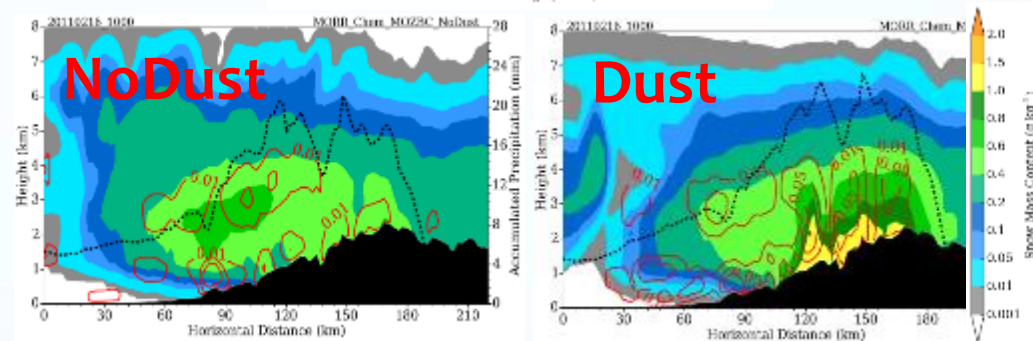
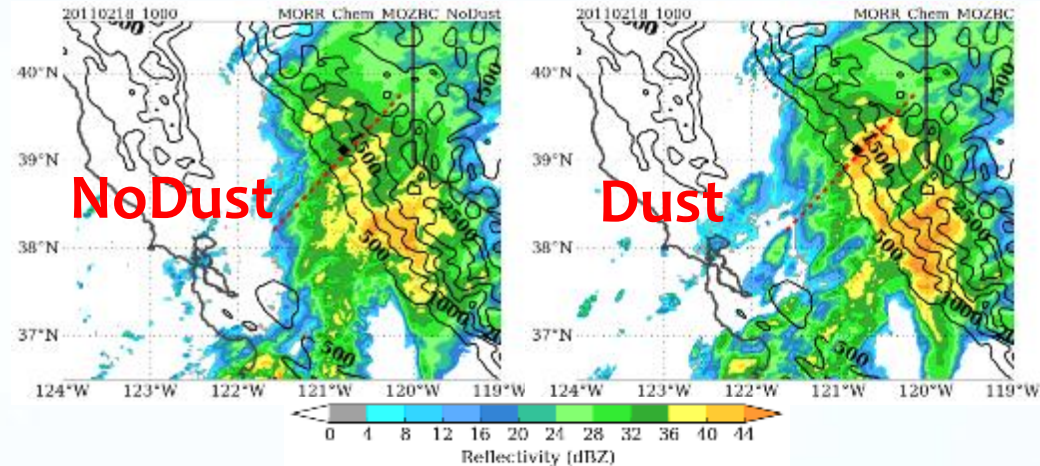


- Warm rain processes along windward slopes in Thompson scheme leads to smaller rain drops
- Cold rain processes in P3 leads to larger rain droplets.



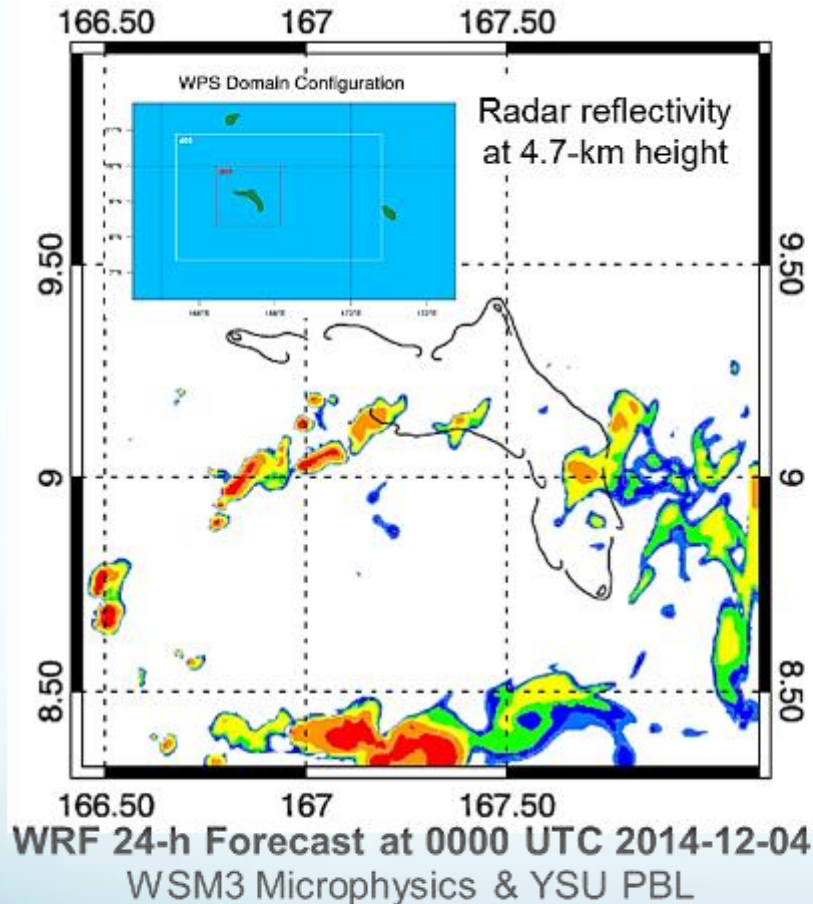
Modeling Aerosol-Cloud-Precipitation Effects

- WRF-Chem for long-range (cross-Pacific) transported dust aerosols
- Control (CTL) and experimental (EXP) runs were identical, except dust included in EXP run.
- Snow mass and precipitation significantly larger across the higher terrain of the Sierra in the EXP run
- Efficient CCN activation of dust in the EXP run leads to an increase in cloud water, and consequently, precipitation in higher terrain.
- Future work needs to treat dust as IN instead of CCN



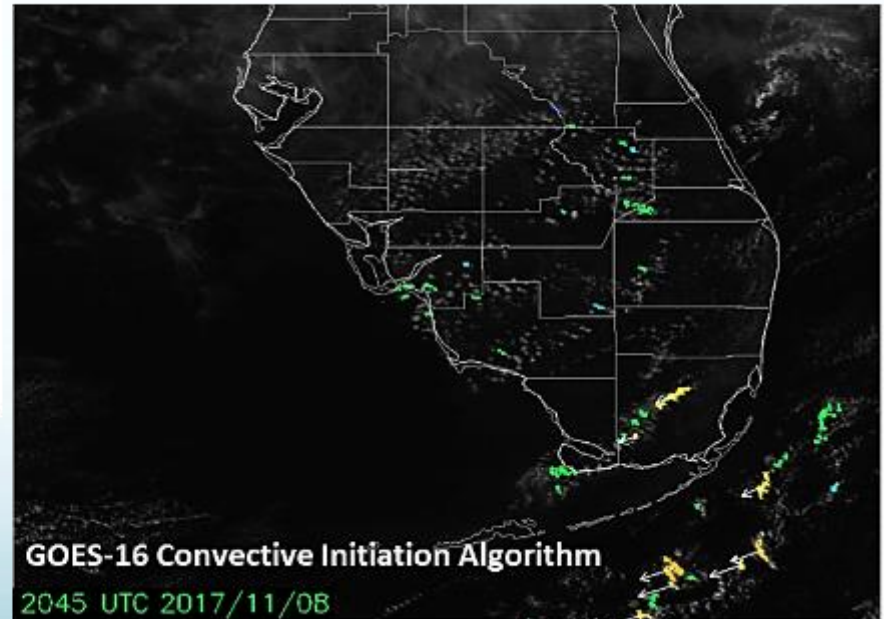
Weather Research and Forecasting Modelling over Kwajalein Atoll

Convective Storm Prediction & Nowcasting



In 2014-2015, developed a WRF modeling and 3DVAR radar data assimilation capability for CFDRG in support of defense operations over the Kwajalein Atoll.

Assisted CFDRG on development of radar and geostationary satellite based methods to estimate convective storm coverage and predict new convective storm development.



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University of Alabama in Huntsville



Thanks!



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