# CAMP²Ex campaign overview + Terra Data Fusion


Larry Di Girolamo

Dongwei Fu, Yulan Hong, Jesse Loveridge, Rose Miller, Arka Mitra, Steve Nesbitt, Bob Rauber, Puja Roy, John Towns, Shaowen Wang, Yizhe Zhan, Guangyu Zhao

*University of Illinois at Urbana-Champaign*

MuQun Yang — *The HDF Group*

Ping Yang — *Texas A&M*

Lusheng Liang — *NASA Langley/SSAI*



## Acknowledgements

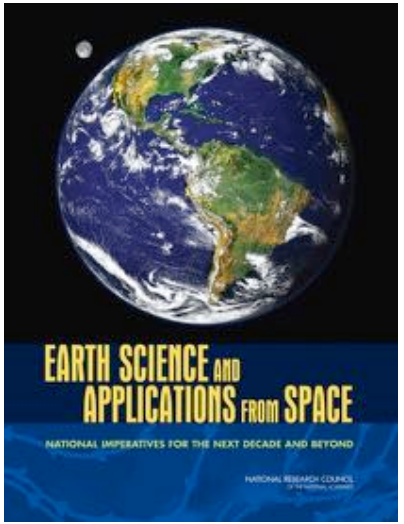
NASA Cloud and Aerosol Monsoonal Processes – Philippines Experiment (CAMP²Ex) program
NASA Advancing Collaborative Connections for Earth System Science (ACCESS) program
NASA Future Investigators in NASA Earth and Space Science and Technology (FINESST) program
NSF Blue Waters Project; NSF ROGER MRI
NASA Langley Research Center Atmospheric Sciences Data Center
NASA Atmosphere Archive & Distribution System Distributed Active Archive Center
NASA Land Processes Distributed Active Archive Center

# Terra Data Fusion

- **A key recommendation from the 2007 NRC Decadal Survey on Earth Science and Application from Space:**

***"…experts should… focus on providing comprehensive data sets that combine measurememements from multiple sensors."***

- **NASA continues to call for Terra fusion science through several ROSES program elements.**



# Terra Data Fusion

**The challenges for individual investigators for mission-scale Terra analyses are great just from a computing stand point.**

**Current Problems:**

- **Instrument data reside at different locations, in different file formats, with different granularity, and using different projections.**
- **> 1 PB and counting (~2 TB/day)**
- **There exists inadequate cyberinfrastructure to tackle whole-mission data fusion and mining problems.**
- **Distribution of fusion datasets.**
- **A range of expertise, not normally had at an investigator's institution, is required to get the job done**

***These problems greatly limits/discourages scientists to take full advantage of the Terra data.***

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

# Terra Data Fusion

## Goals

- **Develop a system to efficiently generate mission-scale Terra Level 1 fusion products that are easy to use, and make the data available on public platforms**
  - **Terra Level 1 Basic Fusion file, orbit-level granularity: TERRA_BF_L1B_OXXXX_YYYYMMDDHHMMSS_F000_V000.h5; ~2 PB; contains radiance in physical units, radiance quality indicator, geolocation for each IFOV at its native resolution, sun-view geometry, observation time, and other attributes/metadata.**
  - **Public on AWS and OSN**
- **Develop an open source advanced fusion toolkits**
  - **Basic Fusion software; the Advanced Fusion Tool (AFT) to resample/reproject radiance fields for one Terra instrument onto the grid used by another Terra instrument, a regularly spaced grid, or any other user specified grid (user-specified GDAL-supported map projections) using a highly-efficient and novel block indexing algorithm implemented in C; PYTAF is a user-friendly python interface built upon the AFT resampling core functions and can be applied to many other Earth observation datasets (Zhao et al. 2020)**
- **Develop based on scientific use cases and act as a Big Data use case for NASA ESDSWGs**

**https://digirolamo.web.illinois.edu/projects/terra-fusion/**

# Terra Data Fusion

## Recent Publications


Zhan, Y., L. Di Girolamo, R. Davies, and C. Moroney, 2018: Instantaneous top-of-atmosphere albedo comparison between CERES and MISR over the Arctic. *Remote Sens.* 10, 1882; doi:10.3390/rs10121882

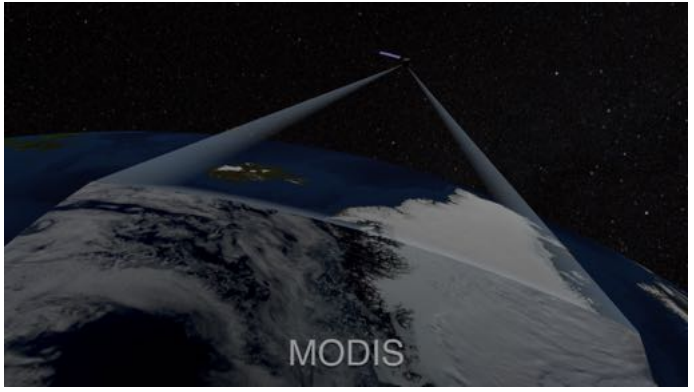
Wang, Y., S. Hioki, P. Yang,, M.D. King, L. Di Girolamo, D. Fu, B.A. Baum, 2018: Inference of an optical ice particle model through latitudinal analysis of MISR and MODIS data. *Remote Sens. 10, 1981; doi:103390/rs10121981*

Wang, Y., P. Yang, S. Hioki, M.D. King, B.A. Baum, L. Di Girolamo, D. Fu, 2019: Ice cloud optical thickness, effective radius, and ice water path inferred from fused MISR and MODIS measurements based on a pixel-level optimal ice particle roughness model. *J. Geophys. Res. Atmos., 124,* https://doi.org/10.1029/2019JD030457.

Fu, D., L. Di Girolamo, L. Liang, and G. Zhao, 2019: Regional Biases in Moderate Resolution Imaging Spectroradiometer (MODIS) marine liquid water cloud drop effective radius deduced through fusion with Multi-angle Imaging SpectroRadiometer (MISR). *J. Geophys. Res. Atmos., 124,* https://doi.org/10.1029/2019JD031063.

Dutta, S., L. Di Girolamo, S. Dey, Y. Zhan, C.M. Moroney, and G. Zhao, 2020: The reduction in near-global cloud cover after correcting for biases caused by finite resolution measurement. *Geophys. Res. Lett. (in press).*

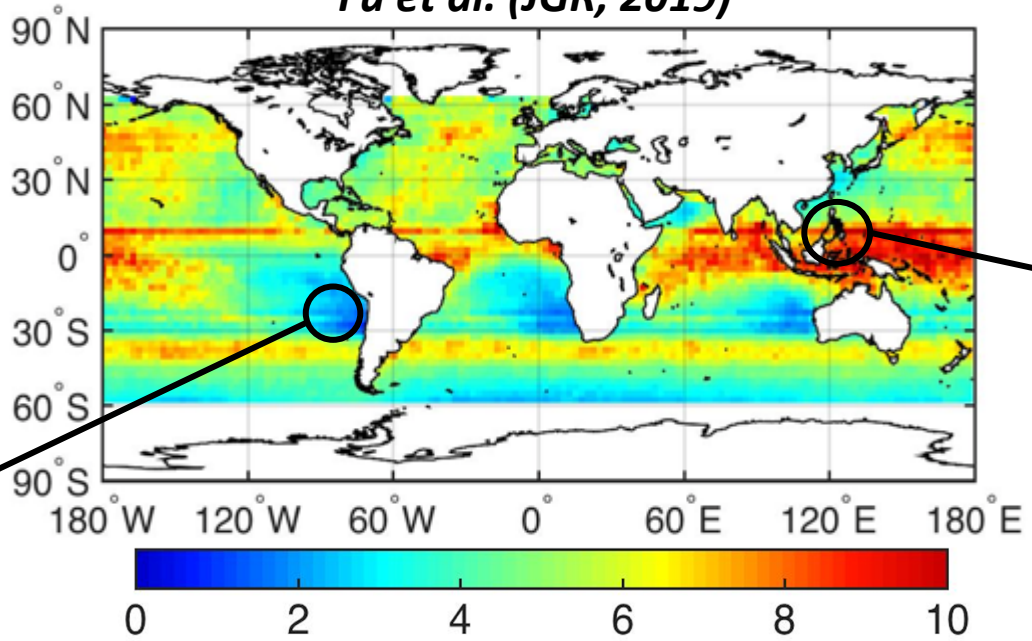
Zhao, G., M. Yang, Y. Gao, Y. Zhan, H.-K. Lee, and L. Di Girolamo, 2020: PYTAF: a python tool for spatially resampling Earth observation data. *Earth Sci. Informatics,* https://doi.org/10.1007/s12145-020-00461-w.


Terra Video opener used
TERRA_BF_L1B_O3571_20000819133750_F000_V001.h5
https://www.youtube.com/watch?v=C2uyjRGwwOs

# Terra Data Fusion

*Fu et al. (JGR, 2019)*




Large bias

Positive bias of 1 – 2 µm
Based on Aircraft
Marine stratiform cloud
High Sun
*Painemal and Zuidema (2011)*

***Re Bias (µm) for MODIS-Terra via MISR+MODIS fusion***

# CAMP²Ex Campaign Overview

## Cloud and Aerosol Monsoonal Processes – Philippines Experiment (CAMP²Ex)

**Field operations: Aug 25 to Oct 5, 2019**

**Operation Center: Clark, Philippines**

**Coordinated with ONR PISTON**

# CAMP²Ex Campaign Overview

## Goal:

***The overall scientific goal of CAMP²Ex is to characterize the role of anthropogenic and natural aerosol particles in modulating the frequency and amount of warm and mixed phase precipitation in the vicinity of the Philippines during the Southwest Monsoon.***

## Why the Philippines and southwest monsoon period?

- South East Asia's rapidly increasing population/economy/aerosols
- Need research on aerosol-cloud response (ACI) to differing environments (Stevens and Feingold 2009)
- An environment with significant challenges in investigating ACI from satellites (Reid et al. 2013)
- A period of significant biomass burning in the region, particularly from Borneo and Sumatra
- Large diversity is aerosol sources during the late SW monsoon period

# CAMP²Ex Campaign Overview

## Goal:

***The overall scientific goal of CAMP²Ex is to characterize the role of anthropogenic and natural aerosol particles in modulating the frequency and amount of warm and mixed phase precipitation in the vicinity of the Philippines during the Southwest Monsoon.***

## Objectives

***Provide a comprehensive 4-D observational view of the environment of the Philippines and its neighboring waters in terms of microphysical, hydrological, dynamical, thermodynamical, and radiative properties, targeting the environment of shallow cumulus and cumulus congestus clouds.***

***Provide key calibration and validation data for satellite observations***

# CAMP²Ex Campaign Overview

**To reach these objectives, numerous assets were deployed in coordination**


Learjet

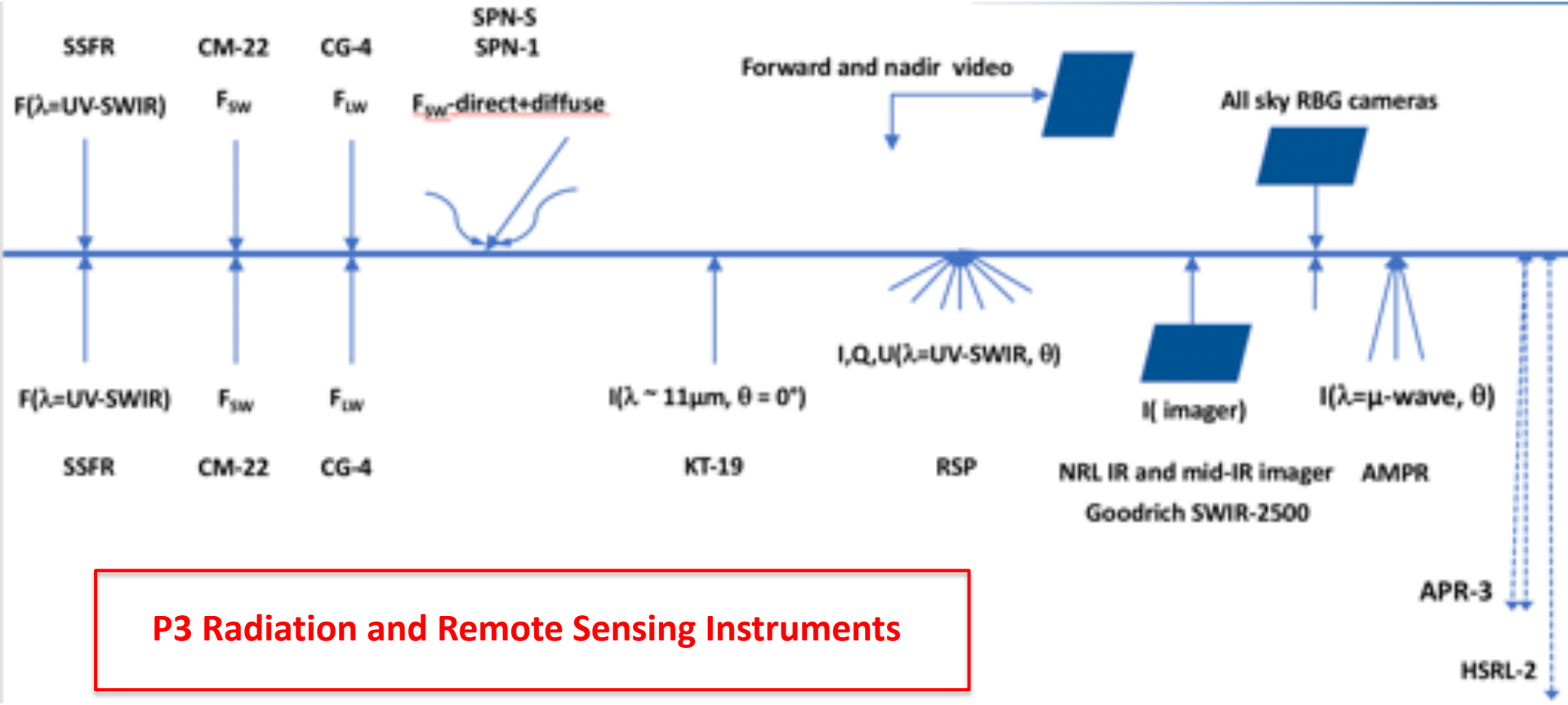

Orion-P3

The Sally Ride

Manila Observatory


Satellites

# CAMP²Ex Campaign Overview




**P3 Radiation and Remote Sensing Instruments**

# CAMP²Ex Campaign Overview

**NASA P-3 (Aug 25-Oct 5, 19 flights, 147 hrs)**

- Black carbon-SP2
- Cloud condensation nuclei
- Cloud water chemistry (307 samples)
- CN (3 nm, 10 nm, 10 nm non vol)
- Composition (POM, $SO_4$, $NO_y$, $NH_4$, Cl)
- Light scattering (TSI 3l, dry & 80%)
- Size distribution (FIMS, LAS, PCASP)
- Tracer gases ($CO_2$, CO, $SO_2$, NO, $NO_y$)
- Cloud and precip microphysics (Hawkeye FSSP, 2D-S, CPI; FCDP, HVPS)
- State Variables from in situ and AVAPS dropsondes
- WINDS turbulence

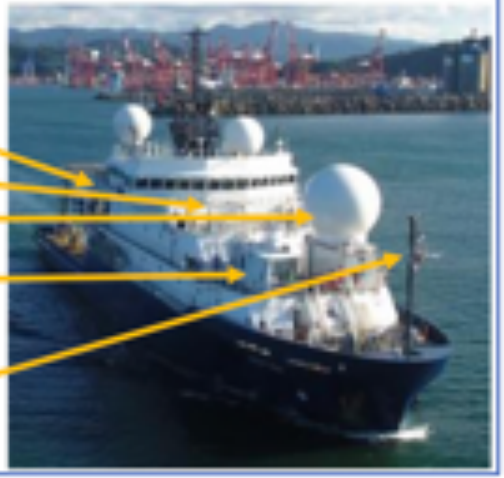
**SPEC Learjet 35 (Sep 5-29, 11 flights, 40 hrs)**

- CPC
- PCASP
- Hawkeye FCDP, 2D-S, CPI; HVPS, Nevzorov
- State Variables from in situ
- AIMMS 20

# CAMP²Ex Campaign Overview

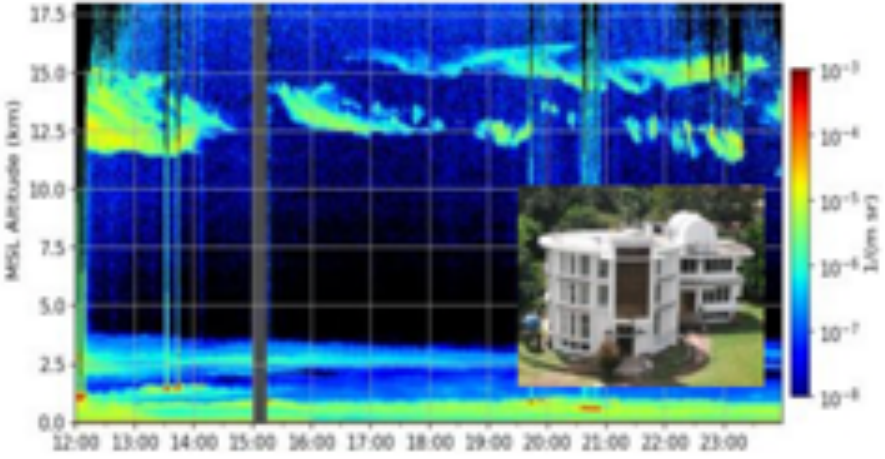
## ONR PISTON R/V Sally Ride

- CAMP²Ex-PISTON cooperation was initiated at the beginning of both missions programmatic levels.
- CAMP²Ex needs the Ride's continuous SEA-POL radar, HSRL, and flux data to constrain cloud hypotheses.
- PISTON benefits from P3 and Satellite remote sensing.
- Coordinate 3 P3 & 5 SPEC Lear 35 flights in WESTPAC.
- Ride data also being house at LaRC




## Manila Observatory

- An enhanced sampling site was established at the Manila Observatory for monitoring throughout the monsoon season.
- Central were the AERONET, UW HSRL, UA aerosol chemistry, CU radiation, and NRL aerosol and met measurements.




*Courtesy Jeff Reid*

# CAMP²Ex Campaign Overview

## How did we do?

**Weather: great for mission objectives. Lots of diversity in aerosol species, cloud types, and mesoscale phenomena. The rapidly evolving environment was a challenge, but we managed well. Monsoon transition around Sept 22-23. Two to three days with significant smoke.**

**Instrument up time: excellent; P3 cabin heat issues were a problem for PBL characterization.**

**Typical P3 flight plan: along convective lines aloft, cross-track below to characterize forcing; RSP PP constraints; SSFR box spirals; mostly early morning to mid-afternoon flights**

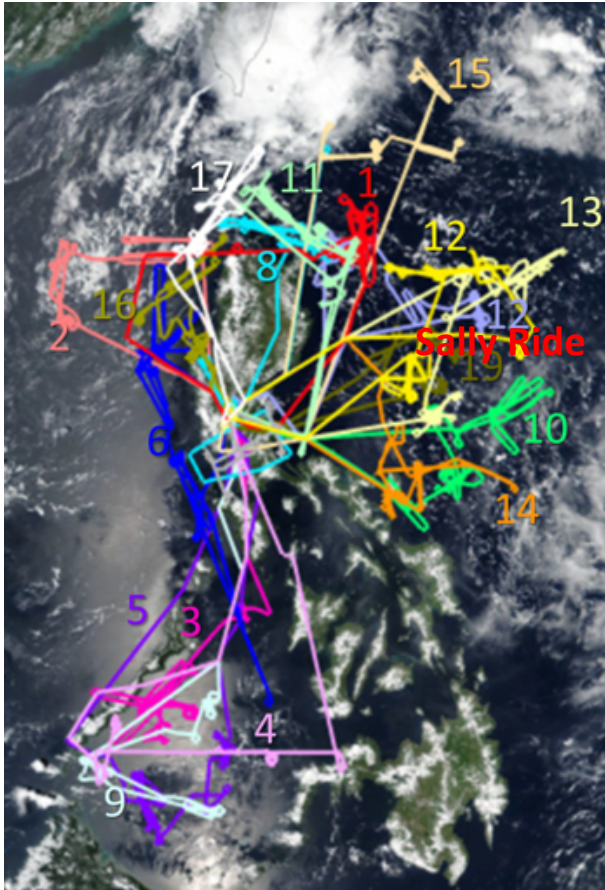
**NASA P-3 operated from Aug 25 – Oct 5, 19 flights, 147 hours**

**SPEC Learjet operated from Sept 5 – 29, 11 flights, 40 hours**

**Three good stacked flights with the Lear to verify the cloud remote sensors, plus several other days with Lear in the region of the P3.**

**Five Learjet and three P3 coordinate flights with the R/V Sally Ride**

**Excellent coordination with satellites**



# CAMP²Ex Campaign Overview

## Sampled Conditions

- Long stretch of cirrus only • • •

- Regions of shallow cumulus with no cirrus • • • • • • • •
- Regions of shallow cumulus with cirrus • • • • • •
- Regions of shallow cumulus, transects cirrus to no cirrus • • • • •

- Shallow cold pool frontal clouds, with no cirrus •
- Shallow cold pool frontal clouds, with cirrus •
- Shallow cold pool frontal clouds, transect cirrus to no cirrus • •

- Deep cold pool frontal clouds, with and without cirrus •

- Isolated congestus without cirrus • • • • • • • •
- Isolated congestus with cirrus • • • • •

- Aerosol gradients • • • • • •

Large SZA • •
Mid SZA • • • • • • • • • • • • • •
Small SZA • • • • • • • • • • • • •

Large AOD • • • •
Mid AOD • • • • • • • •
Small AOD • • • • • • • • • • • • •

Marine aerosols • • • • • • • • • • • • • • •
Manila plume • • •
Ship plume • • •
BB aerosols • • • • •
China aerosol source • • • • •

- P3 + Satellite Overpasses as proposed: ASCAT, GPM, ASTER, MISR, MODIS, VIIRS, C+C • • • • • • • • • • • • • • • • • • • • •
- P3 + Satellite Overpass opportunities: GCOM, Sentinels, etc as additional opportunities • • • • • • • • • • • • • • • • • • • • •

# CAMP²Ex Campaign Overview

## Special satellite collections at high resolution

**ASTER - Terra**

15 m resolution for VNIR channels
90 m resolution for TIR channels
60 km swath
Aug 1 to Oct 30, 2019 = 2056 60 km x 60 km tiles

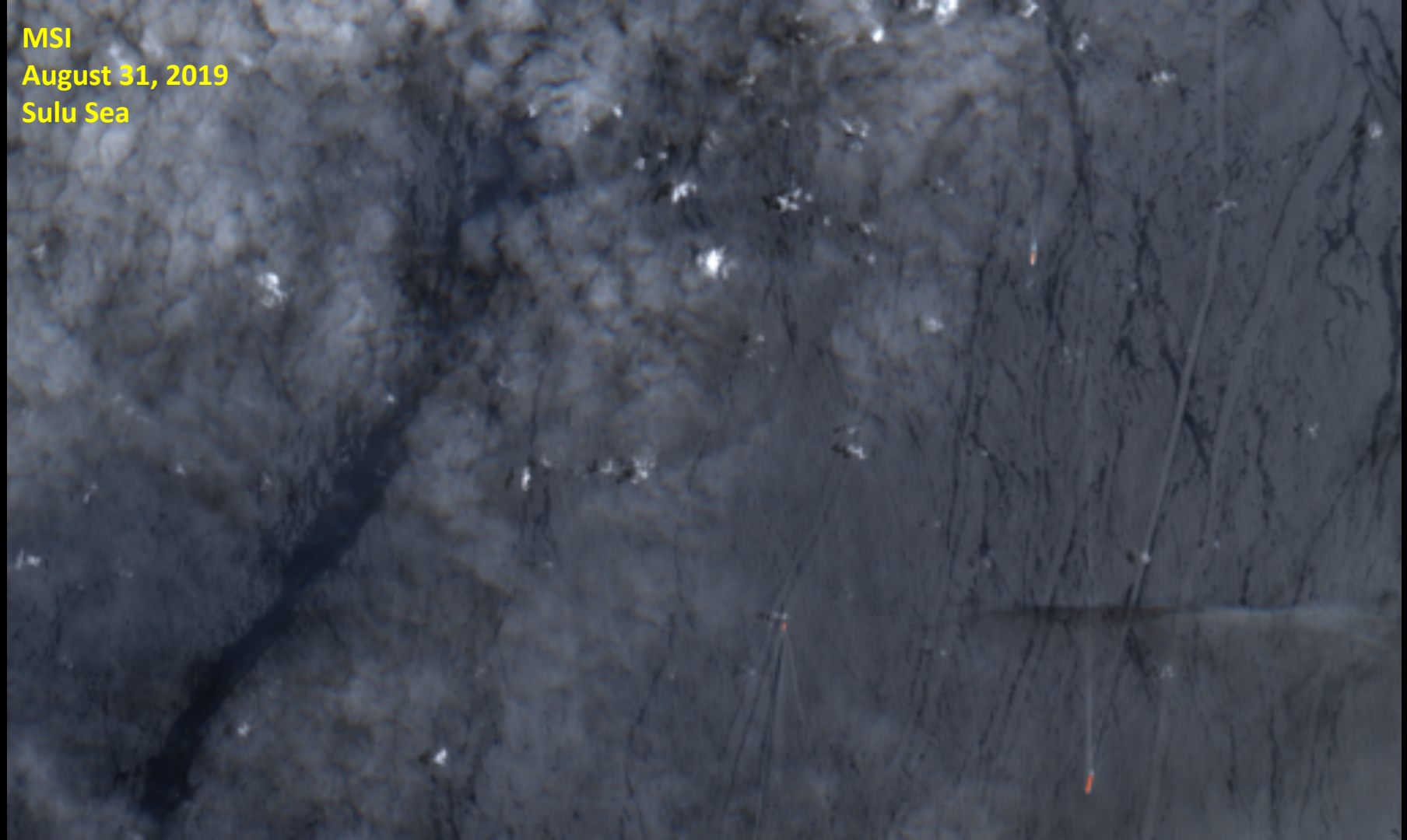
**MSI – Sentinel 2A and 2B**

10 to 60 m resolution for VNIR to SWIR channels
290 km swath
Aug 1 to Oct 30, 2019 = 24899 100 km x 100 km tiles

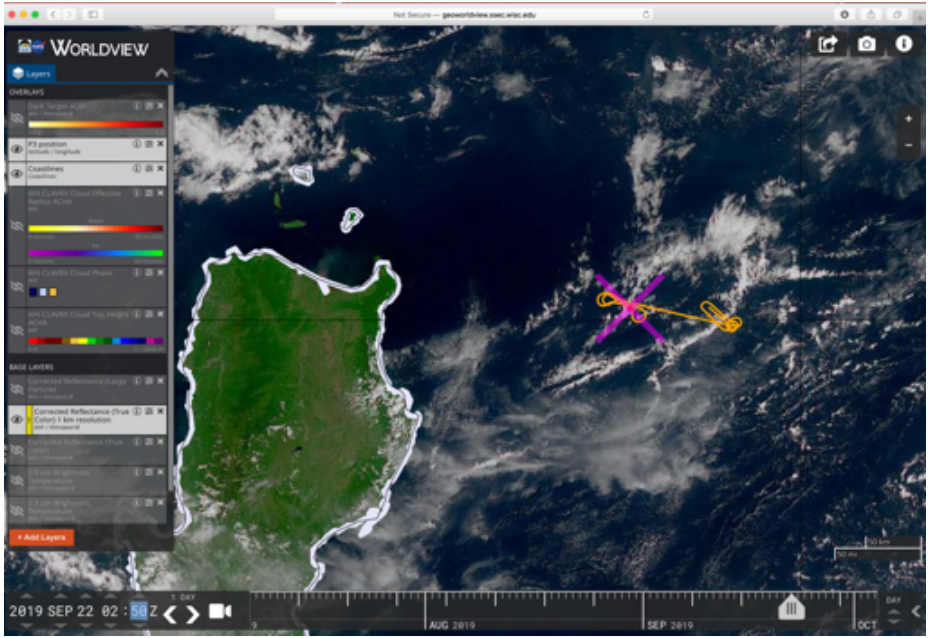

*This special CAMP²Ex collection represents the largest collection of high-resolution satellite imagery over the waters surrounding the Philippines, as well as any other oceanic region in the world.*

*Landsat and Worldview-1-2-3 collections, but not yet accessed*


ASTER
September 5, 2019
South China Sea

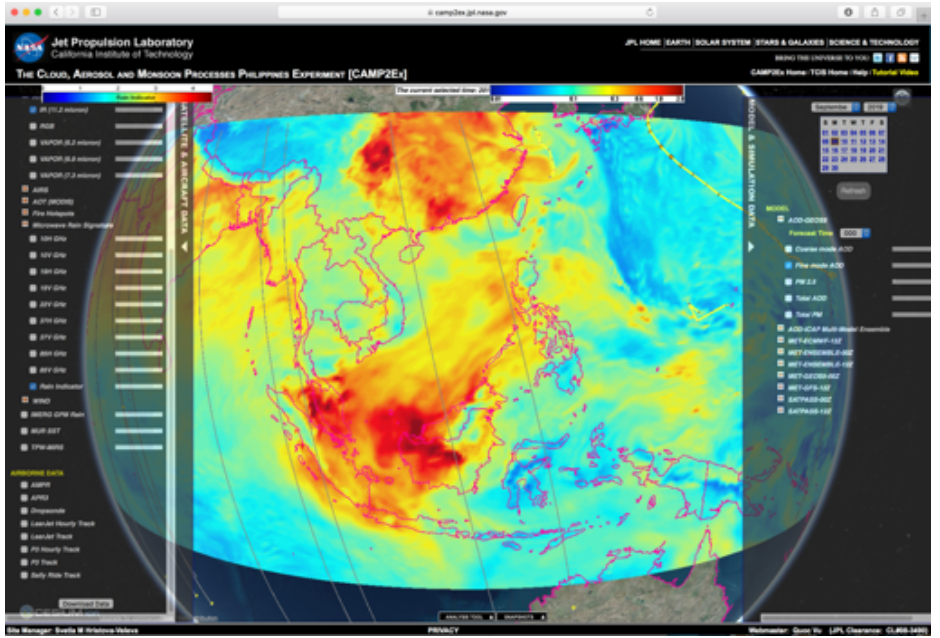

MSI
August 31, 2019
Sulu Sea

# CAMP²Ex Campaign Overview




http://geoworldview.ssec.wisc.edu

**Geostationary+polar and flight+ship track**




https://camp2ex.jpl.nasa.gov

**Remote sensing and model data portal**

# CAMP²Ex Campaign Overview

- **CAMP²Ex Virtual Science Team Meeting: Nov 4 – 6, 2020**

- **Loads of preliminary analyses presented on composition, cloud, radiation, cold pools**

**Data**

https://www-air.larc.nasa.gov/missions/camp2ex/index.html

**Other useful links**

https://espo.nasa.gov/camp2ex

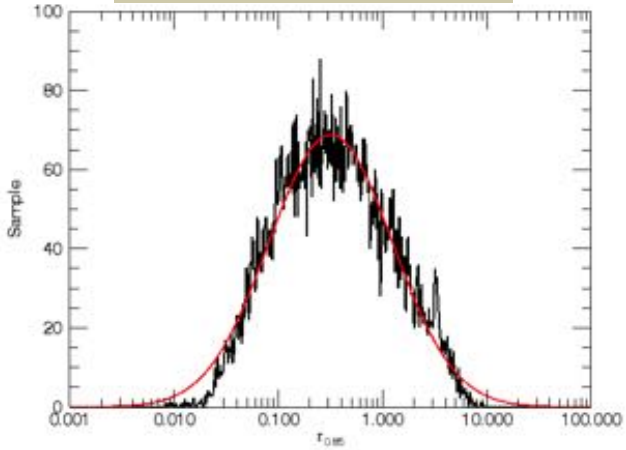
https://publish.illinois.edu/camp2ex-forecast/

# CAMP²Ex Campaign Overview

## Cirrus characterization

| Flight | Cirrus | No cirrus | Incloud |
|---|---|---|---|
| | P3 | P3 | P3 |
| RF01_20190824 | 0.75 | 0 | 0.25 |
| RF02_20190827 | 0.61 | 0.24 | 0.15 |
| RF03_20190829 | 0.64 | 0.07 | 0.29 |
| RF04_20190830 | 0.71 | 0.18 | 0.11 |
| RF05_20190904 | 0.87 | 0.03 | 0.10 |
| RF06_20190906 | 0.83 | 0.03 | 0.14 |
| RF07_20190908 | 0.56 | 0.22 | 0.22 |
| RF08_20190913 | 0.81 | 0.13 | 0.05 |
| RF09_20190915 | 0.77 | 0.10 | 0.13 |
| RF10_20190916 | 0.59 | 0.24 | 0.17 |
| RF11_20190919 | 0.79 | 0.12 | 0.09 |
| RF12_20190921 | 0.70 | 0.26 | 0.04 |
| RF13_20190923 | 0.34 | 0.61 | 0.05 |
| RF14_20190925 | 0.24 | 0.74 | 0.02 |
| RF15_20190927 | 0.32 | 0.66 | 0.01 |
| RF16_20190929 | 0.92 | 0.04 | 0.05 |
| RF17_20191001 | 0.57 | 0.35 | 0.08 |
| RF18_20191003 | 0.42 | 0.57 | 0.01 |
| RF19_20191005 | 0.23 | 0.87 | 0.05 |
| All Flights | 0.61 | 0.28 | 0.11 |


**Radiation Focus Area Group teasing out cirrus from SPN-S**

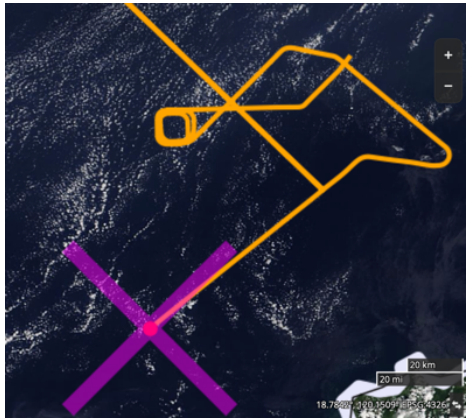


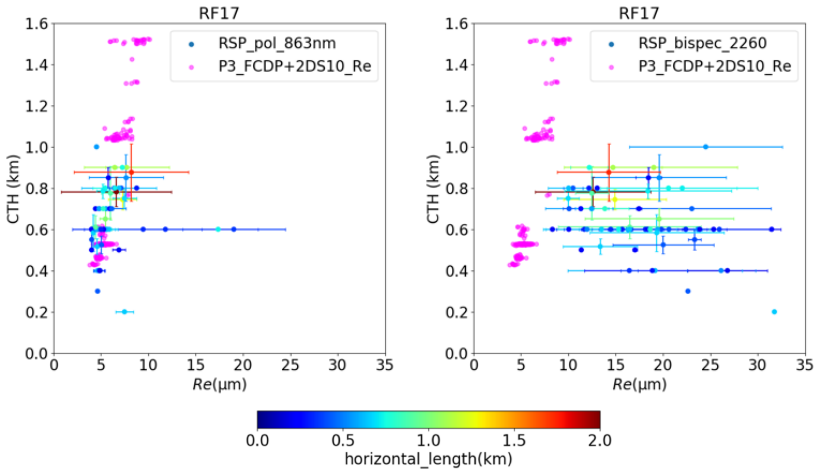

**Cirrus optical depth**

# CAMP²Ex Campaign Overview

## RSP_polarimetric vs RSP_bispectral

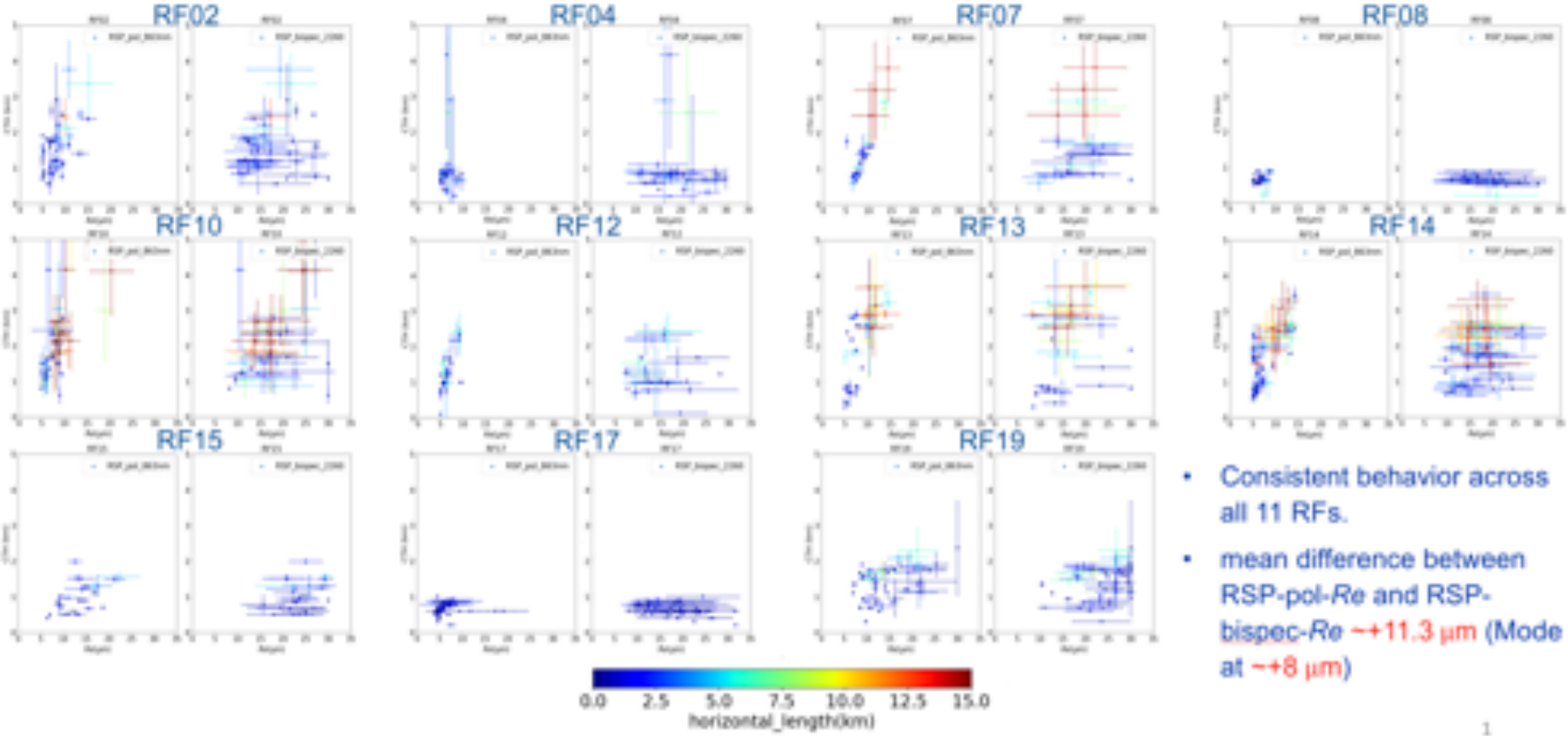
Terra-MODIS overpass at 02:40UTC






**(Analysis as a function of cloud macrophysics)**

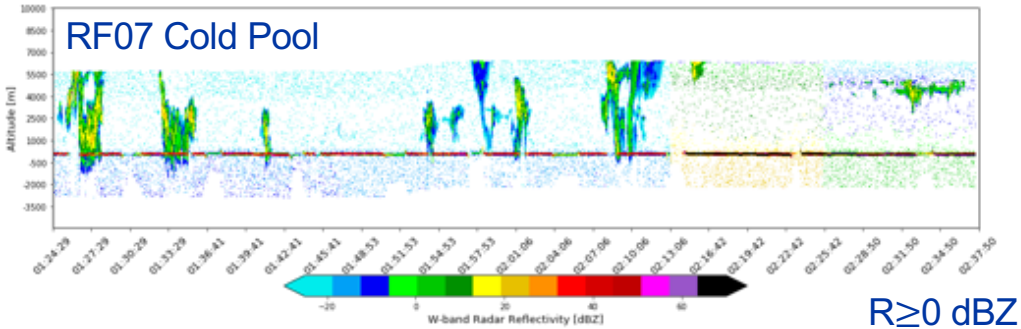
# CAMP²Ex Campaign Overview



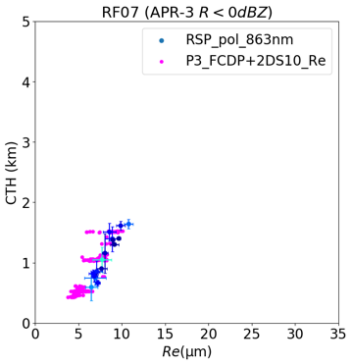

- Consistent behavior across all 11 RFs.
- mean difference between RSP-pol-*Re* and RSP-bispec-*Re* ~+11.3 μm (Mode at ~+8 μm)

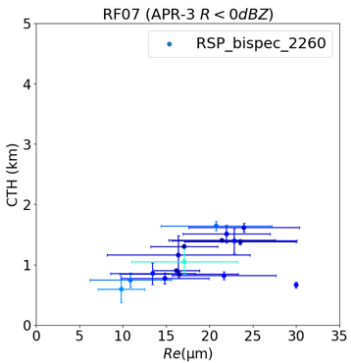
# CAMP²Ex Campaign Overview

## Impact of drizzle

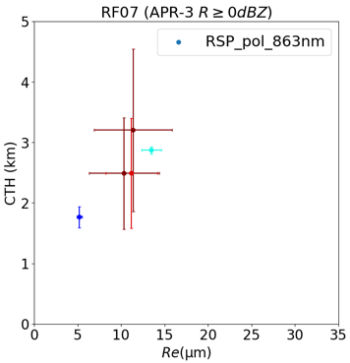


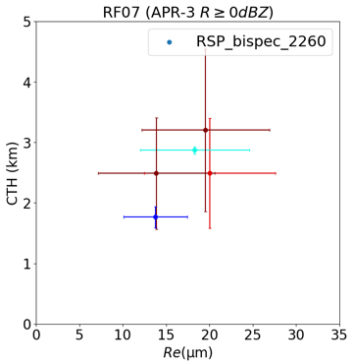

R<0 dBZ

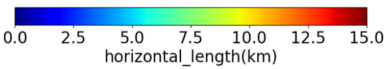



R≥0 dBZ

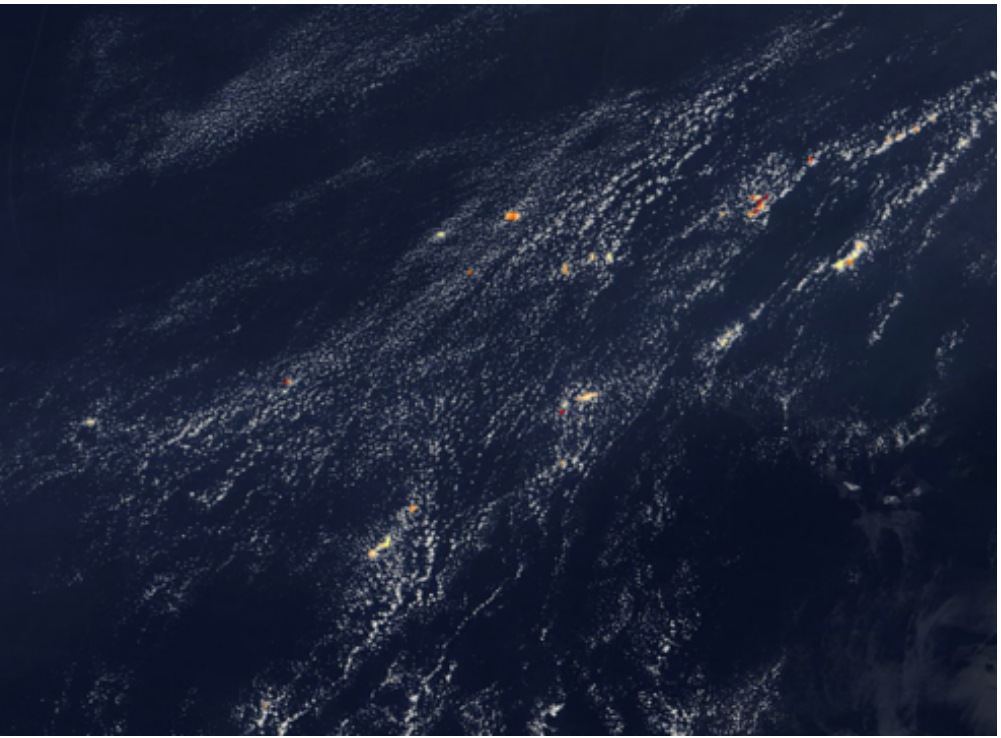


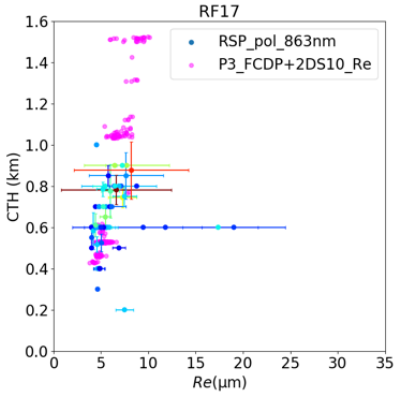



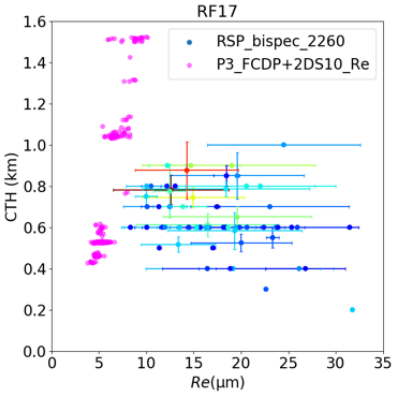

- For cold pool case in RF07, clouds with CTH ~2km and above are drizzling.
- For low clouds the *Re* bias cannot be attributed to the impact of drizzle (i.e., the single mode assumption)
- Impacts of 3-D RT remains the likely source of the bias.

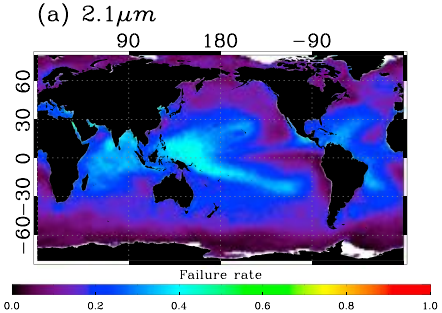
# CAMP²Ex Campaign Overview



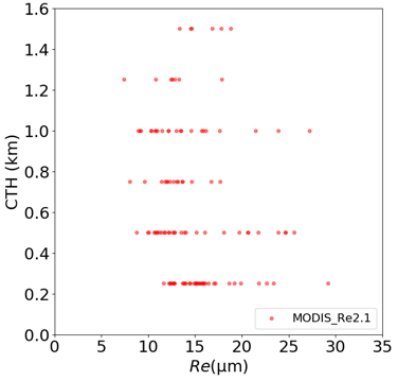
*Geoworldview is awesome!*



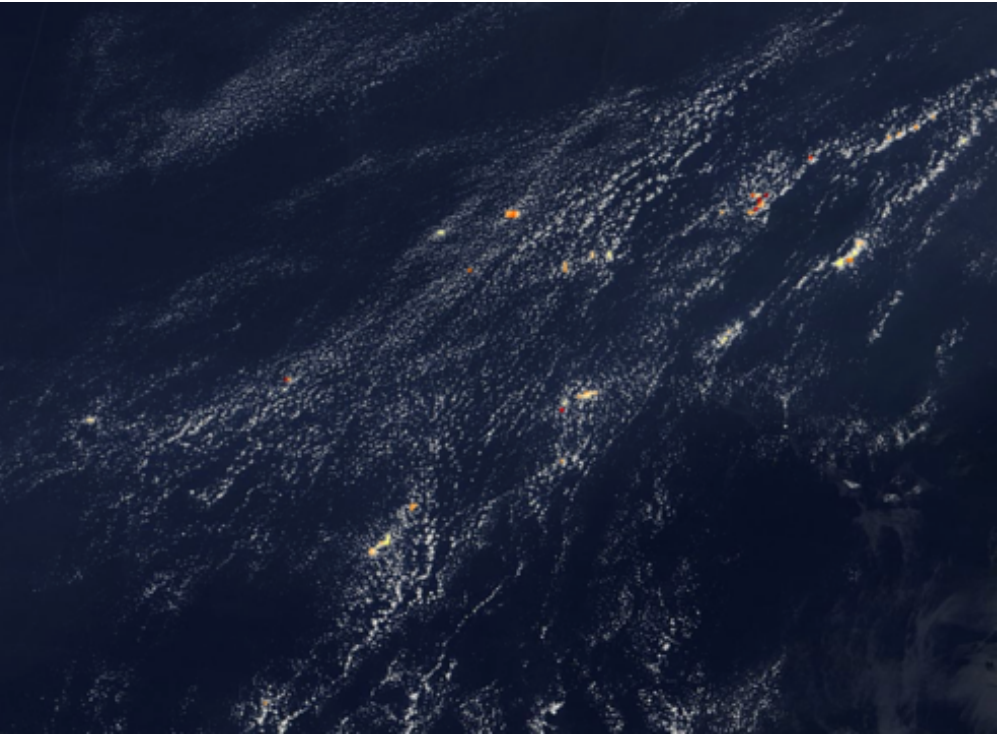



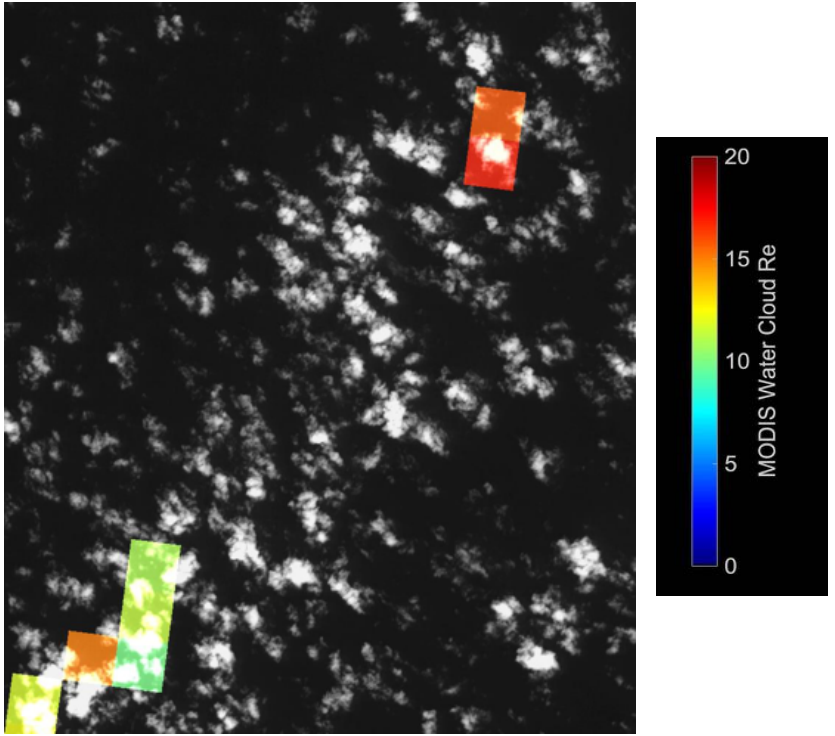

Cho et al. (2015)



# CAMP²Ex Campaign Overview



*Geoworldview is awesome!*

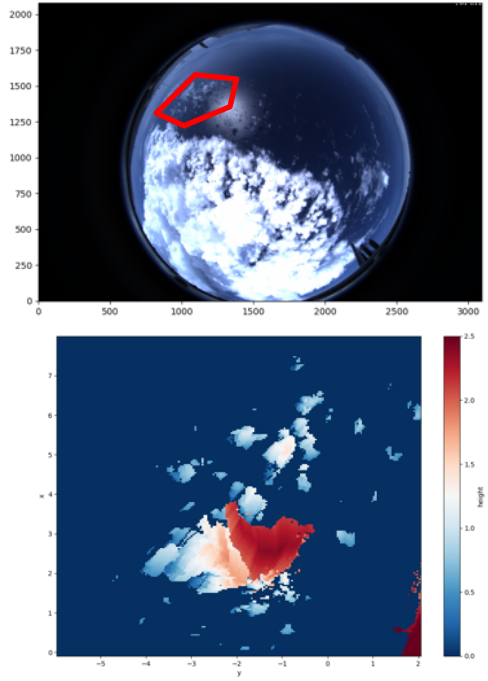



*ASTER is awesome!*

# CAMP²Ex Campaign Overview

**Illinois, Colorado and GISS CAMP²Ex teams looking into methods to account for 3D radiative effects on retrievals or to retrieve the 2D/3D distribution of cloud microphysics from RSP/All-Sky-Camera (with a view to the future)**

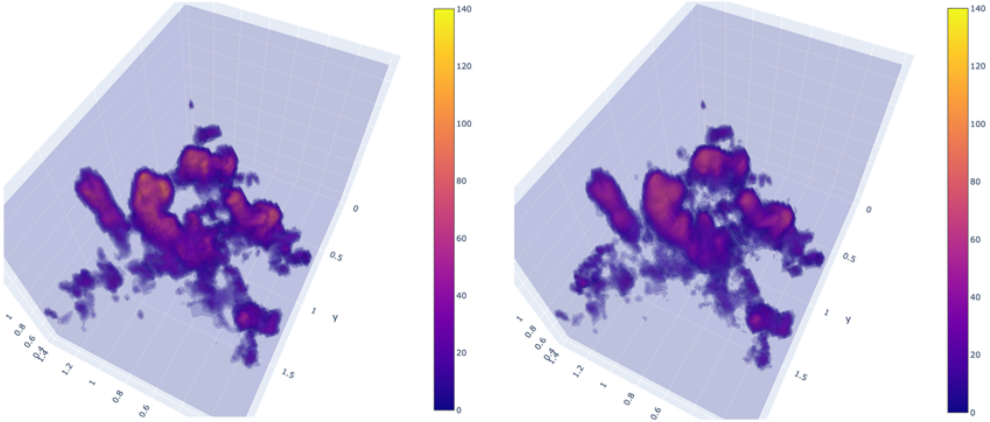
## Space carving with all-sky camera (RF 7)



## 3D distribution of volume extinction coefficient

### Original (LES)

### Retrieved



**Multi-view 3-D approach of Levis et al. (2020) by Illinois team**

# Thanks!


https://digirolamo.web.illinois.edu/projects/camp2ex/