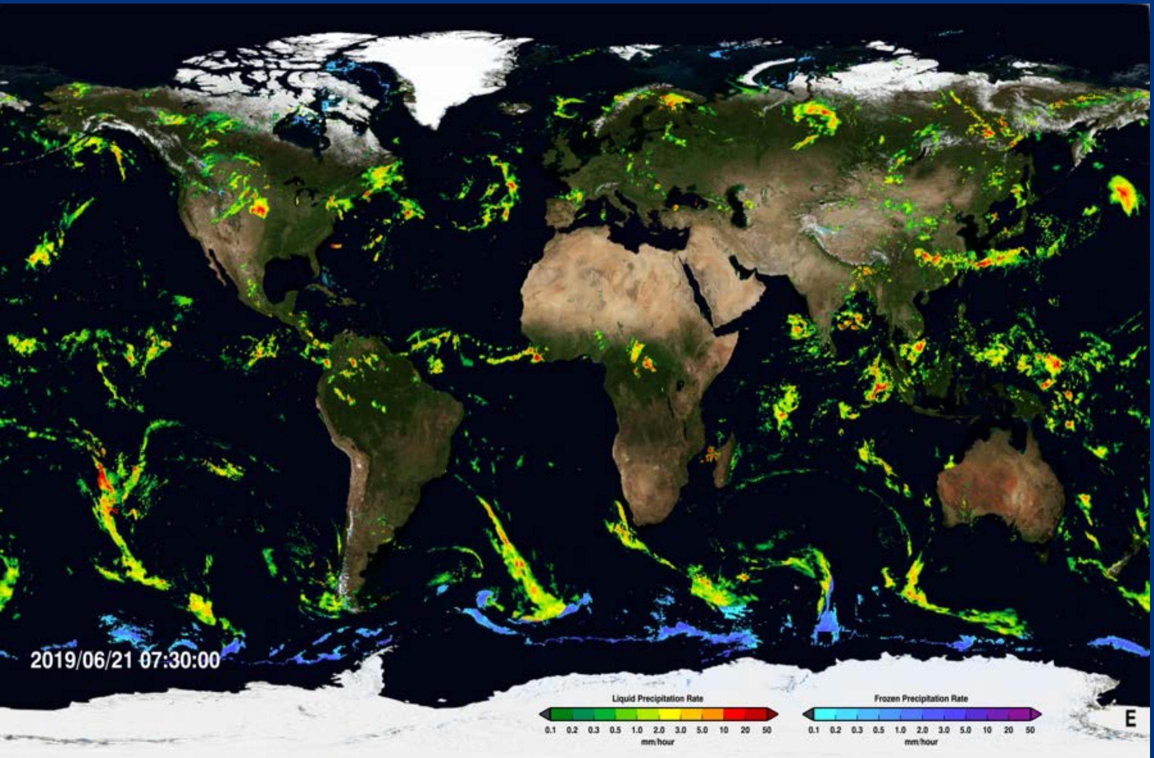
GPM Mission Status and NASA Decadal Survey Activities Related to Precipitation



IMERG analysis for 07:30 UTC
June 21, 2019

Scott Braun
GPM Project Scientist

NASA Goddard Space Flight Center

12th International Precipitation Conference
June 21, 2019

www.nasa.gov/gpm
Twitter: NASARain
Facebook: NASARain

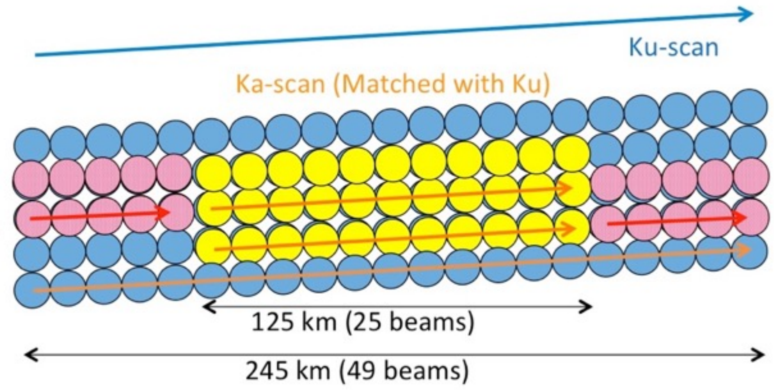
Significant Announcements

- Walt Petersen selected to be Science Research and Projects Division (SRPD) Deputy Division Chief
  - Joe Munchak (GSFC) will replace Walt as GPM Deputy for Ground Validation
- FCC auctioning off bandwidth near 24 GHz for 5G
  - Will impact all sensors flying 23.8 GHz
- IMERG V06 reprocessing of reprocessing for TRMM & GPM

Spacecraft and Instrument Status

Spacecraft and instrument status: All systems are fully functional

DPR switched to full scan on 5/21/18
Algorithms still need to be updated to process full scan for Ka



Fuel Predictions (w/controlled re-entry)

Prediction	Plus/ Early	Mean/ Nominal	Minus /Late
June-2015	05/2029	11/2039	06/2043
Nov-2015	03/2027	03/2035	08/2039
May-2016	06/2032	04/2037	10/2047
Nov-2016	08/2029	01/2035	10/2038
May-2017	12/2034	05/2036	02/2037
Nov-2017	08/2027	07/2032	08/2035
May-2018	03/2033	05/2035	03/2037
Nov-2018	**11/2026**	**09/2033**	**11/2036**

Fuel is unlikely to be the limiting factor

GPM Anomaly

Reaction wheel #2 (of 5) stopped rotating on May 30, 2019.

Flight operations team investigating cause.

No data impact.

Algorithms

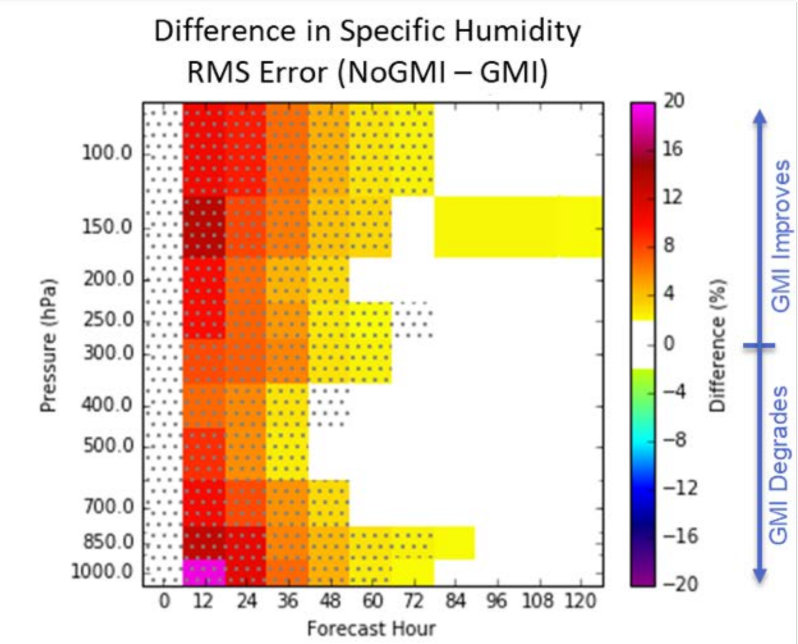
- All Level 2 GPM and TRMM products were reprocessed to V05 (passive microwave) and V06 (radar & combined) in 2018
- IMERG V06 reprocessing for TRMM & GPM
  - GPM data reprocessed, reprocessing back through TRMM
  - Corrupted input file recently discovered that requires reprocessing
  - Near real-time products to be reprocessed back through TRMM for applications users
- TRMM CSH latent heating reprocessing to begin soon.
- GPM V07 reprocessing no earlier than end of 2020. Algorithm priorities include:
  - Extending dual-frequency retrievals across the full Ku swath
  - Fixing low bias in TRMM PR and GPM Ku PR rainfall rates

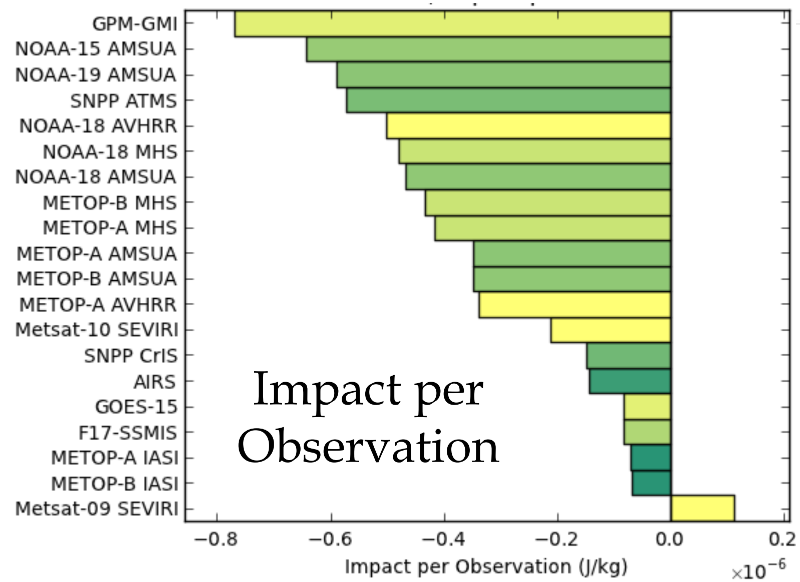
All-Sky GPM Data in GEOS Weather Forecasts

- Largest impact of GMI radiances in the Tropics
  - Specific humidity improved in short term (0-72 hour) forecasts (top, hatched indicates significance)
  - Similar improvements occur in tropical mid and lower tropospheric temperature and winds (not shown)

- Other modeling and initialization improvements included in the GEOS upgrade extend these improvements into the medium range

- **GMI is seen to have the highest impact per observation of all the radiance observation types**, and the total impact of GMI (bottom) is comparable to a single Microwave Humidity Sounder instrument (not shown)

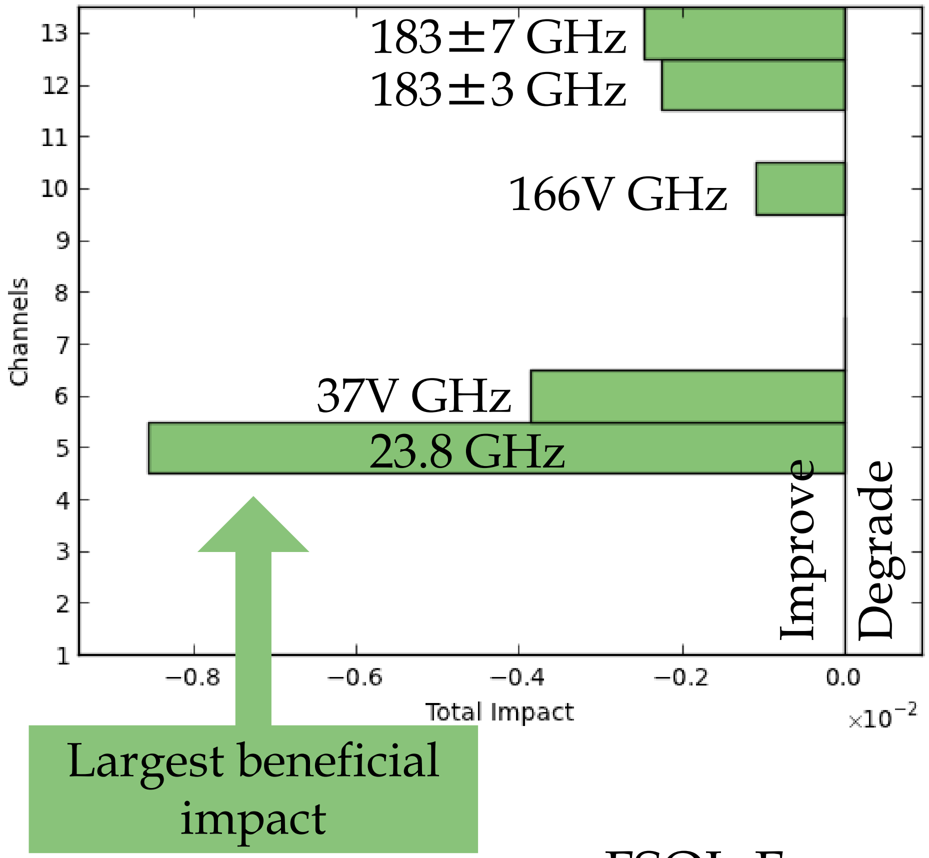




Min-Jeong Kim (GMAO/GESTAR)

Impact of 23.8 GHz on 24 Hour Forecasts

GPM Microwave Imager FSOI
by Band
1 Aug – 30 Nov 2018



The FSOI metric can be used to illustrate the importance of the 23.8 GHz band

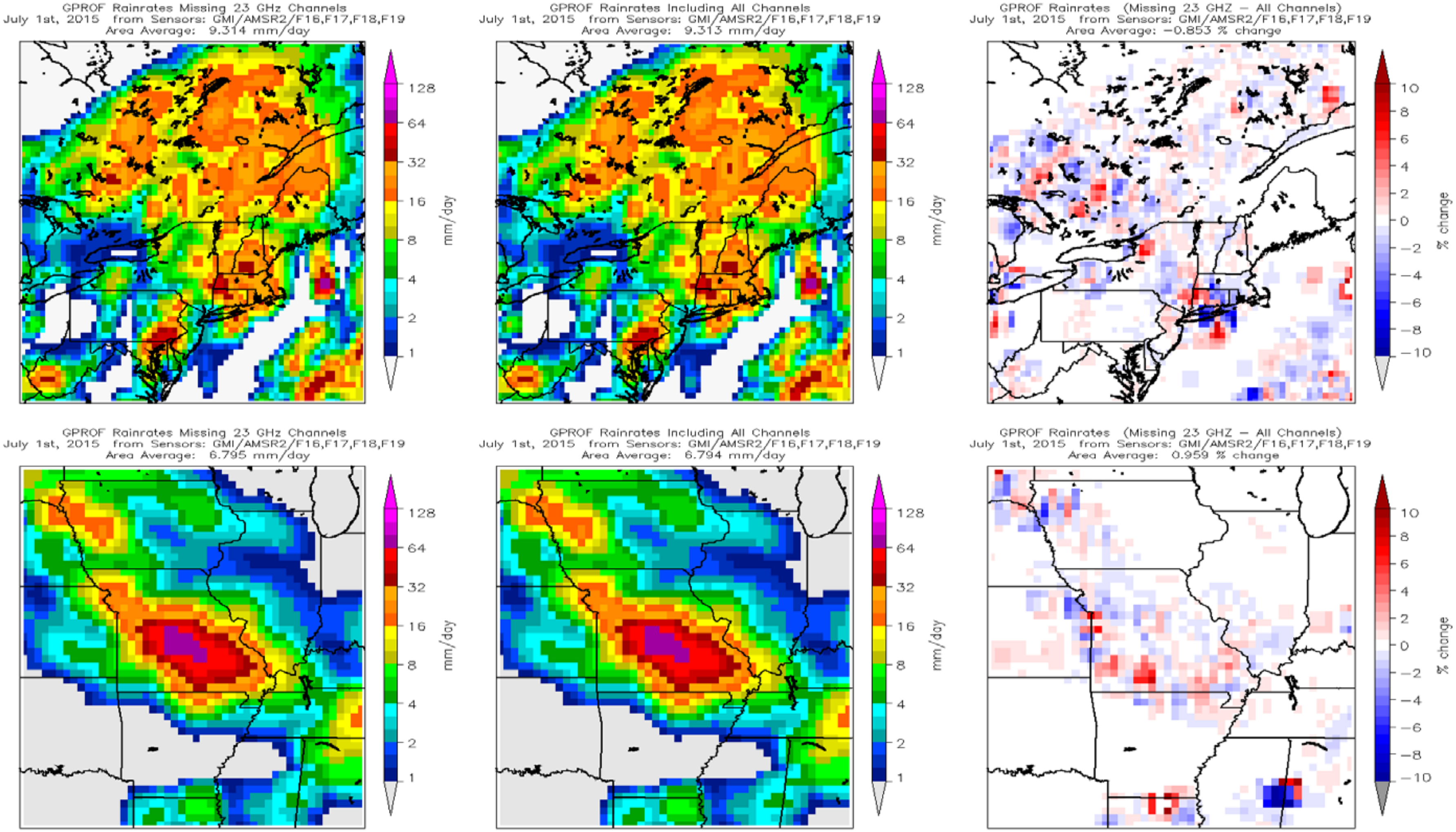
- For FSOI, negative (positive) values indicate that the observations contributed to a forecast error reduction (increase)
  - *Negative is good*
- Of the six bands used in our weather forecasting system, the 23.8 GHz band accounts for 47% of the total forecast impact from GPM/GMI

FSOI=Forecast Sensitivity-Observation Impact

Courtesy of W. McCarty

Impact on Rainfall Retrievals: Two Heavy Rain Events

Derived rain rate No 23.8 GHz data	Derived rain rate Includes 23.8 GHz data	Percentage differences between the two estimates



Courtesy of C. Kummerow

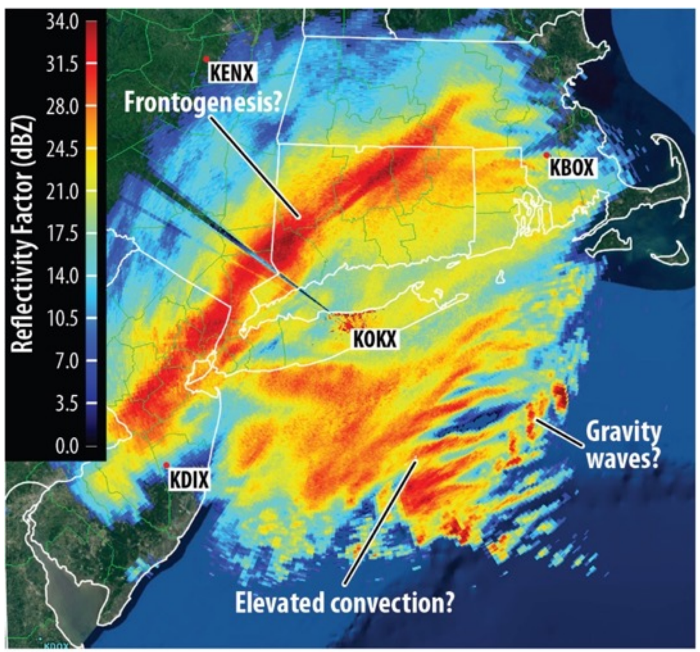
Earth Venture Suborbital-3 Selection

- Investigation of Microphysics and Precipitation or Atlantic Coast-Threatening Snowstorms (IMPACTS)
  - PI Lynn McMurdie, University of Washington, deputy PIs G. Heymsfield (GSFC), J. Yorks, and S. Braun

IMPACTS Objectives

1. **CHARACTERIZE** the spatial and temporal scales and structures of snow bands in Northeast US winter storms
2. **UNDERSTAND** the dynamical and microphysical processes that produce the observed structures
3. **APPLY** this understanding of the structures and underlying processes to improve remote sensing and modeling of snow

IM055

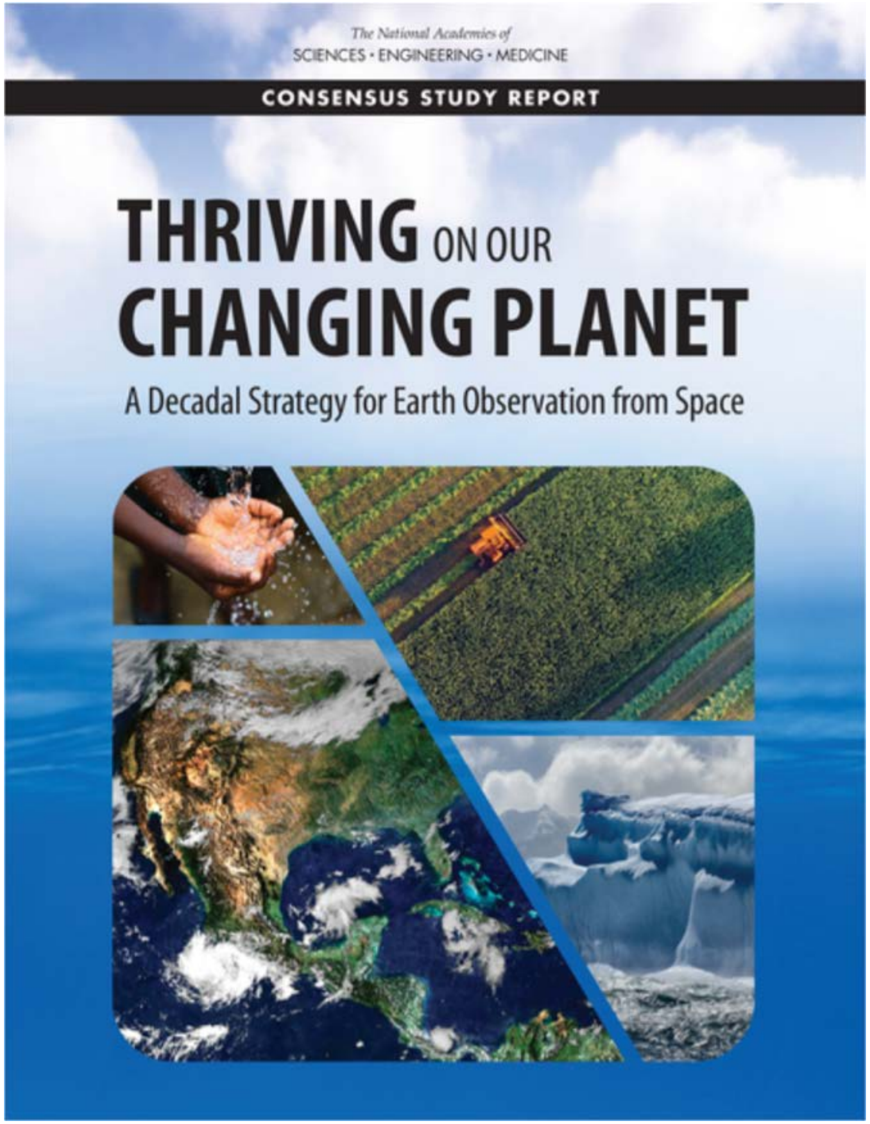


IM041

GPM expecting to add the Dual-frequency, dual-polarized, Doppler radar (D3R) at location still TBD.

See L. McMurdie talk today!

2017 NASA Earth Science Decadal Survey



- Identifies five designated foundational observations to be implemented as cost-capped medium- and large-size missions directed or competed at the discretion of NASA:
  - Aerosols.
  - Clouds, Convection and Precipitation.
  - Mass Change.
  - Surface Biology and Geology.
  - Surface Deformation and Change.

CCP Description

▶ Observable Priorities	▶ Desired Observable Capabilities
Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback.	Radar(s), with multi-frequency passive microwave and sub-mm radiometer.

Aerosols Description

Observable Priorities	Desired Observable Capabilities
Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality.	Backscatter lidar and multichannel, multi-angle/polarization imaging radiometer flown together on the same platform.

A-CCP Study Overview

- In June 2018, NASA HQ called for multi-NASA Center study plans to develop concepts/architectures for the designated observables
- NASA HQ determined that instruments will be competed rather than designed to SATM (must be TRL-6 by PDR ca. 2023-2024)
  - SATM will define appropriate *desired minimum capabilities* (not requirements)
- Challenge to envision new science beyond the Program of Record (PoR) but ensure an implementable, cost-capped observing system
- Finding an observing system that meets objectives is ultimately dependent on knowledge of available capabilities (Instrument Library)

A-CCP Science Organization and Leadership

Internal to NASA

Science/Applications Leadership Team

Da Silva, Braun (GSFC), Stephens, Waliser (JPL), Ferrare, Winker (LaRC), Petersen (MSFC), Kacenelenbogen (ARC), Kirschbaum (GSFC), Omar (LaRC)

Science Impact Team

Co-Chairs Mace (U of UT), Redemann (U of OK)

Applications Impact Team

Co-Chairs Kirschbaum (GSFC), Omar (LaRC)

Value Framework Team

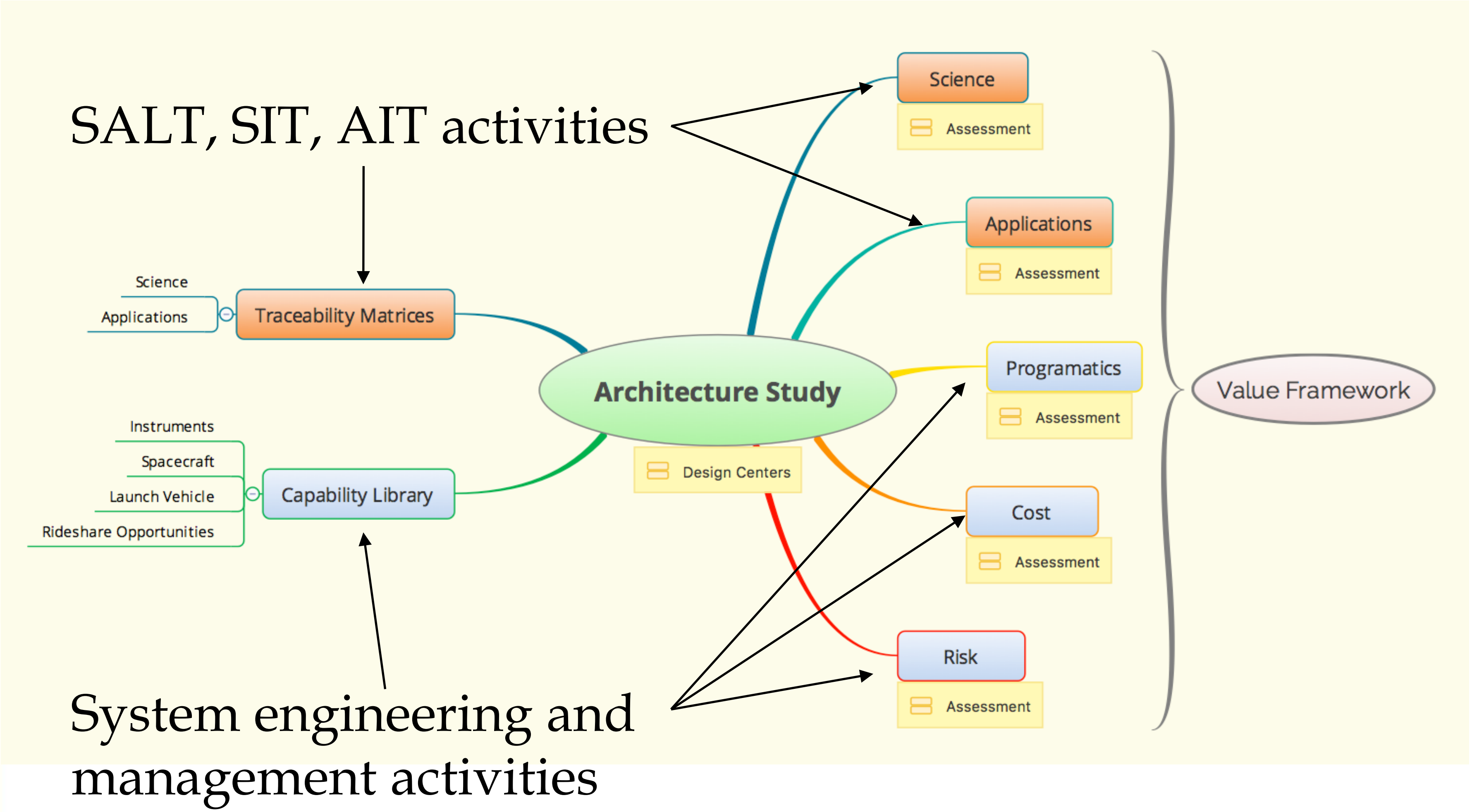
Ivanco (LaRC)

External to NASA

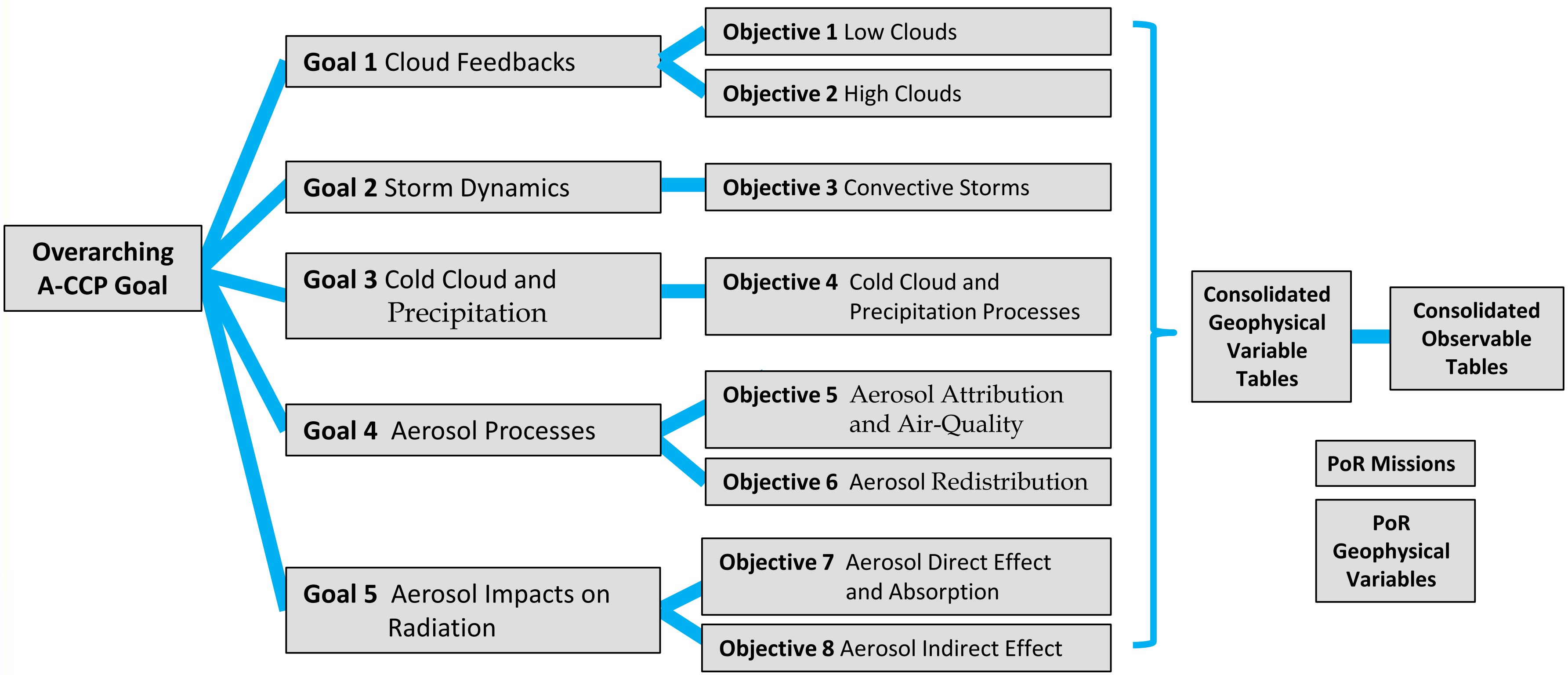
Science Community Cohort

Co-Chairs van den Heever (CSU), Carmichael (Iowa)

A-CCP Study Activities



Schematic of A-CCP SATM flow from goals to objectives to desired capabilities



Framing Assumptions for Minimum Desired Capabilities

- A-CCP is a combined Aerosols and CCP process-oriented Earth Observing System, although mapping capabilities highly desired.
- A-CCP is an Earth Observing System potentially consisting of
  a) A space-based mission (payload, spacecraft, launch vehicle)
  b) A fully integrated, sustained sub-orbital component
  c) PoR, models, data assimilation, synergistic algorithms needed to extract maximum benefits from the A-CCP measurements
- Payload may consist of:
  a) Active sensors (lidars and radars)
  b) Several passive sensors (passive MW radiometer, polarimeter, spectrometer)

A-CCP Study Current Progress

- Science and Applications Traceability Matrix (SATM) is maturing, but still under development.
- Exploring partnerships/contributions with JAXA, CNES, CSA, DLR, South Korea
- RFI responses form an instrument library
  - Contains radars, passive micro. radiometers, lidars, polarimeters, spectrometers, and others.
  - Includes a range of capabilities from cubesat to larger class instruments

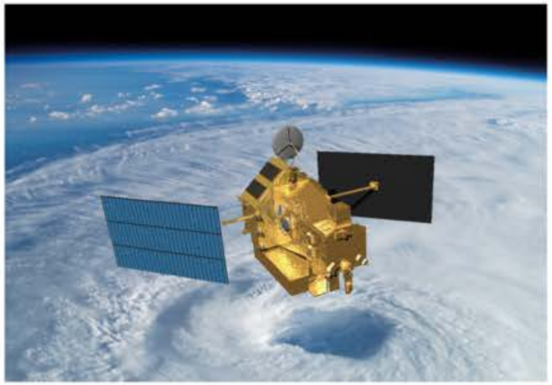
A-CCP Study Current Progress

- May Architecture Construction Workshop (ACW)
  - Explored potential polar-orbiting observing system architectures for single and two-satellite (non-smallsat) solutions
  - Explored GPM train of complementary sensors
  - Examined a range of active instrument capabilities as well as international contributions
- June ACW (the last 3 days)
  - Explored smallsat (<190 kg) solutions, including various constellations
    - Polar orbit smallsat train or hybrid smallsat/largesat
    - GPM orbit smallsat train
    - Lower-inclination orbit constellation of cubesats for diurnal sampling

A-CCP Study Upcoming Activities

- Summer 2019: Qualitative assessment of science benefit of architectures from recent workshops
- Selection of first two architecture options for more detailed collaborative design center (CDC) studies starting in October
- Value framework scoring of architectures following each CDC
- Suborbital workshop in March 2020 time frame
- Final report to NASA HQ in September 2021
- Notional launch date in 2028 time frame

Questions?



A-CCP

AGU Fall meeting session announcement

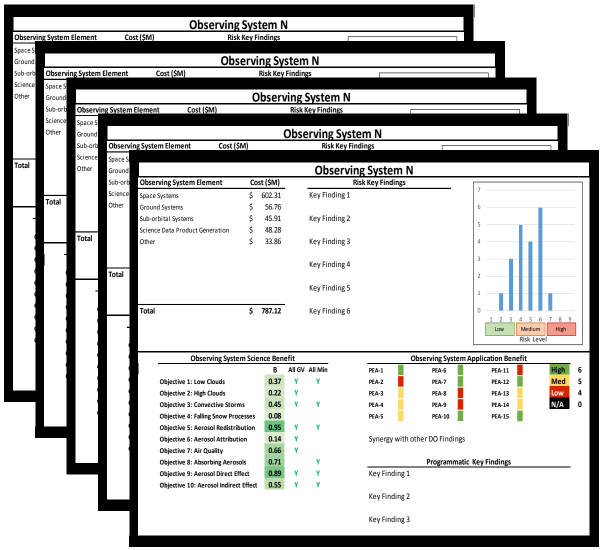
H123 “Space-based Precipitation Observations, Estimation and Applications: a Centennial Perspective”.

This session build on the traditional Global Precipitation Measurement (GPM) mission session with a broad perspective at the intersection of history and the future.

Abstract submission: https://agu.confex.com/agu/fm19/prelim.cgi/Session/80639
Deadline: July 31.

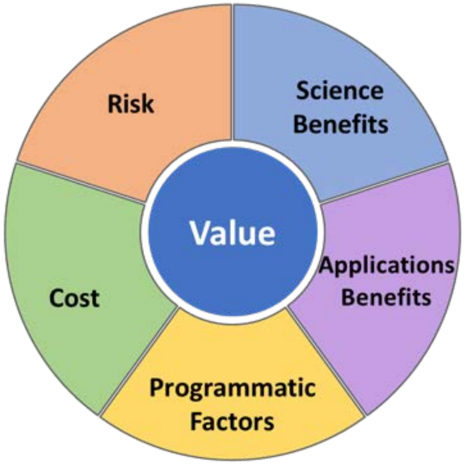
Extra slides

Science Benefits in the Value Framework



Example Baseball Cards for OS 1-5

For each **Observing System (OS)**, a **Science Benefit (B)** score is determined for each **Science Objective** and incorporated in the OS's "Baseball Card".



Science Benefit is one of five contributions to an OS's Value

	OS 1	OS 2	OS 3	OS 4	OS 5
O1: Low Clouds	0.37	0.13	0.37	0.64	0.33
O2: High Clouds	0.22	0.34	0.89	[illegible]	0.11
O3: Convective Storms	0.45	0.67	0.53	[illegible]	0.19
O4: Falling Snow Processes	0.08	0.59	[illegible]	[illegible]	0.59
O5: Aerosol Redistribution	0.95	0.67	[illegible]	0.24	0.29
O6: Aerosol Attribution	0.14	[illegible]	[illegible]	0.42	0.83
O7: Air Quality	0.66	0.44	[illegible]	0.13	0.36
O8: Absorbing Aerosols	0.71	0.86	0.34	0.75	0.40
O9: Aerosol Direct Effect	0.89	0.77	0.88	0.20	0.06
O10: Aerosol Indirect Effect	0.55	0.47	0.04	0.09	0.19

Notional scores for example only

Example comparison of Science Benefit (B) across OSs 1-5

For a given OS and Science Objective

$$B = \sum Utility * Quality$$

Utility and Quality : A Cooking Analogy

$$B = \sum UQ$$

B = Family/Customer Satisfaction

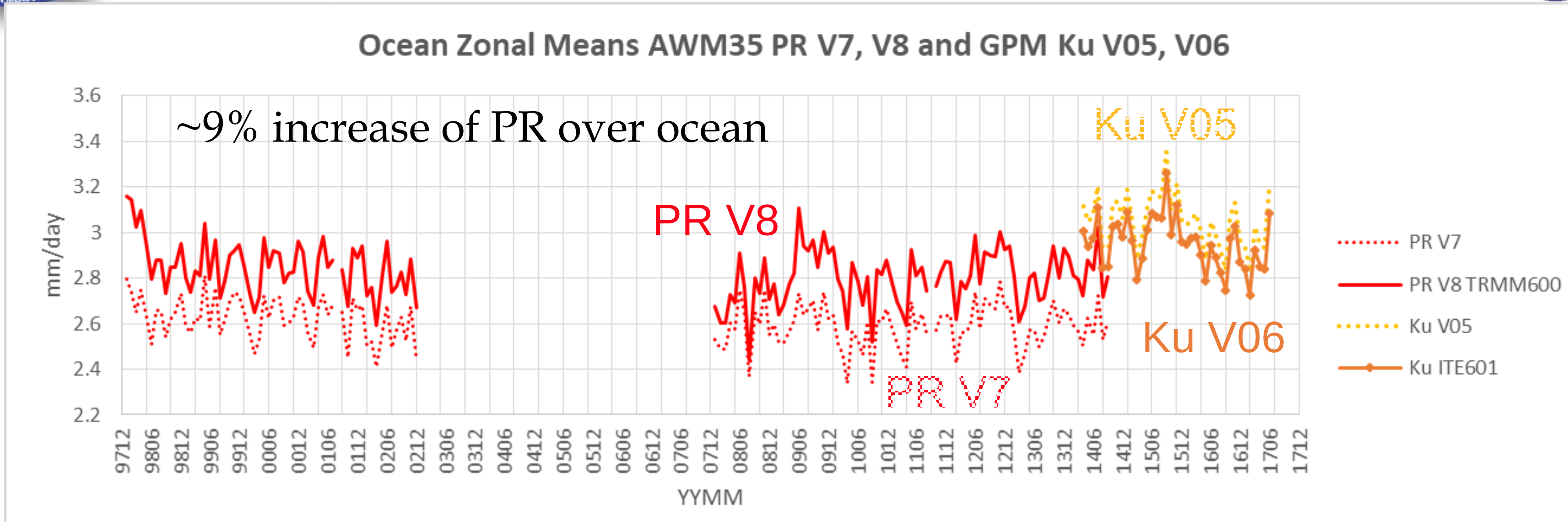
TRADITIONAL HAMBURGER RECIPE

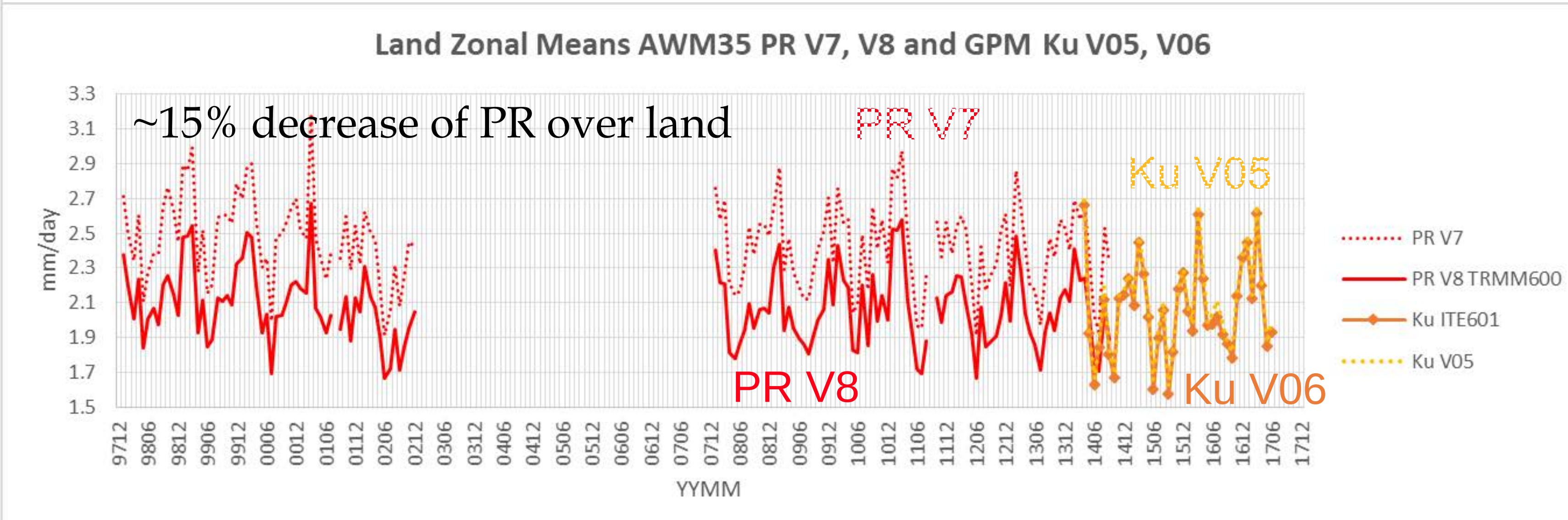
Ingredients	Utility	Quality
Patty	0.60	1.0 = ½ lbs, 100% Angus Beef, Charbroiled 0.4 = vegan "Impossible" burger
Bun	0.20	0.8 = sesame seed topped whole wheat bun 0.4 = small, white bread bun
Cheese	0.10	0.9 = Cheddar 0.6 = American 0.3 = Mozzarella
Tomato	0.04	etc
Lettuce	0.04	etc
Onions	0.01	etc
Ketchup	0.01	etc

Utility is the importance of the Ingredient to the Recipe
Quality is the quality of the given ingredient relative to a best possible
(NOTE: Utility is probably more subjective than Quality)
OS is the approach to acquiring the ingredients, e.g. 1-N trips to store, which store, who goes, rely on what's in fridge (POR)…

From Duane Waliser (JPL)

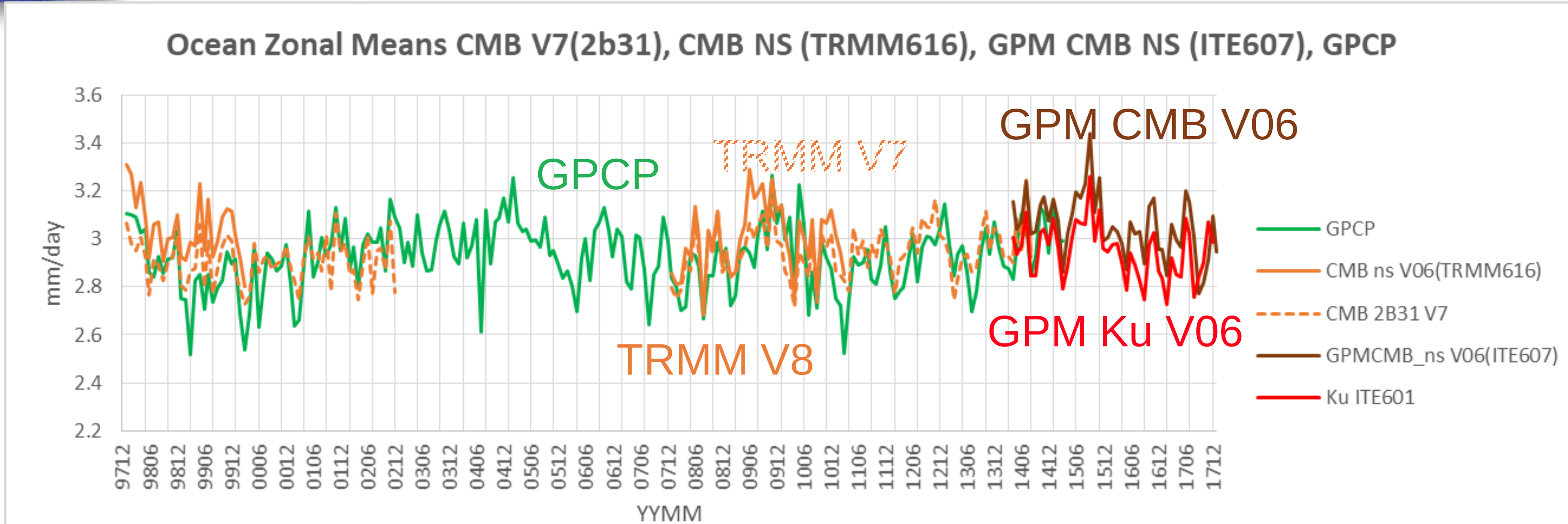
PR Time Series Of Global Mean

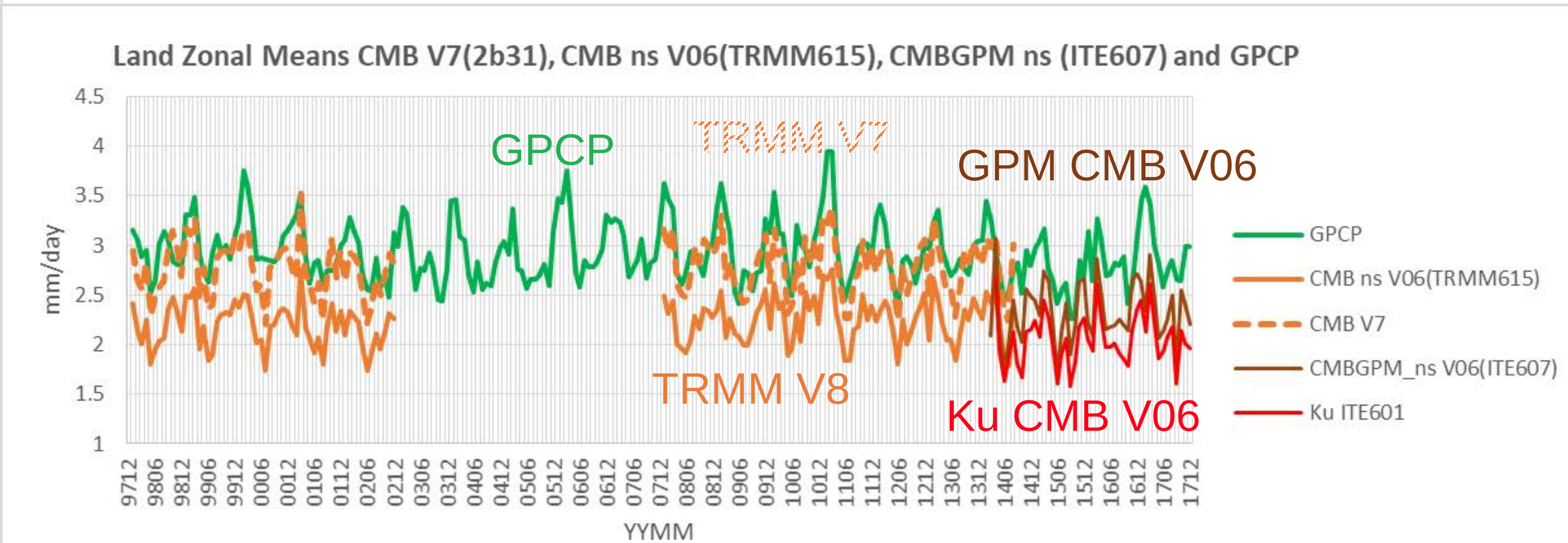




Images courtesy of John Kwiatkowski

Combined Algorithm Ocean and Land Time Series





Images courtesy of John Kwiatkowski

A-CCP Science Community Cohort Members

Proposed Names (US)				Science Expertise				Application Expertise	
First	**Last**	**Institution**	**Science Interests**	**A**	**Cl**	**Cv**	**Pr**	**A**	**CCP**
Greg	Carmichael	Iowa	Data Assimilation, GAW perspective	√				√	
Sue	van den Heever	CSU	CCP, aerosols	√	√	√	√		
Tristan	L'Ecuyer	U Wisc	clouds		√	√	√		
Ana	Barros	Duke	CCP/Hydrology			√	√		√
Andy	Dessler	Texas A&M							
Graham	Feingold	NOAA	Clouds, aerosols	√	√				
Andrew	Gettleman	NCAR	Climate Modeling	√	√	√	√		
Colette	Heald	MIT	aerosol modeling	√					
Steve	Klein	LLNL	cloud feedbacks	√					
Mark	Kulie	Mich.Tech	CCP(snow, microwave)		√	√	√		
Ruby	Leung	PNNL	precip, convection		√	√	√		
Yang	Liu	Emory	Air Quality	√				√	
Johnny	Luo	CCNY	UTLS						
Allison	McComiskey	DOE/BNL	aerosols, radiation	√					
Steve	Nesbitt	Illinois	CCP			√	√		
Jeff	Reid	NRL	Aerosols, modeling	√				√	
Lynn	Russell	Scripps	aerosol chemistry	√					
Courtney	Schumacher	Texas A&M	radar, convection			√	√		
Armin	Sorooshian	U Arizona	aerosols, clouds	√					
Rob	Wood	U Wash	Clouda-erosol interactions	√	√				

A=Aerosol, Cl=Clouds, Cv=Convection, Pr=Precipitation

A-CCP Goals

Overarching A-CCP Goal	A+CCP	A	CCP	2017 DS Most Important Very Important	Goals
Understand the processing of water and aerosol through the atmosphere and develop the societal applications enabled from this understanding.				C-2a, C-2g, W-1a, W-2a	G1 Cloud Feedbacks Reduce the uncertainty in low- and high-cloud climate feedbacks by advancing our ability to predict the properties of low and high clouds.
				C-2g, C-5c, H-1b, W-1a, W-2a, W-4a	G2 Storm Dynamics Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within deep convective storms.
				H-1b, W-1a, W-3a, S-4a	G3 Cold Cloud and Precipitation Improve understanding of cold (supercooled liquid, ice, and mixed phase) cloud processes and associated precipitation and their coupling to the surface at mid to high latitudes and to the cryosphere.
				W-1a, W-5a, C-5a	G4 Aerosol Processes Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.
		D I		C-2a, C-2h, C-5c	G5 Aerosol Impacts on Radiation Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.

Goal only fully realizable via combined mission.	A or CCP makes meaningful contribution to goal