Science and Applications Traceability Matrix

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Note to <u>External</u> Reviewers: Please use this on-line form to provide your comments: https://goo.gl/forms/RbSbNez4lNjjEjun2

A-CCP SATM Navigation Map

Click on Blue Lines or Text

Overarching A-CCP Goal

- **Goal 1** - Cloud Feedbacks
  - **Objective 1** – Low Clouds — **O1** Geophys. Vars. — **O1 -** Observables
  - **Objective 2** – High Clouds — **O2** Geophys. Vars. — **O2 -** Observables
- **Goal 2** - Storm Dynamics
  - **Objective 3** – Convective Storms — **O3** Geophys. Vars. — **O3 -** Observables
- **Goal 3** - Falling Snow
  - **Objective 4** – Falling Snow Processes — **O4** Geophys. Vars. — **O4 -** Observables
- **Goal 4** - Aerosol Processes
  - **Objective 5** – Aerosol Redistribution — **O5** Geophys. Vars. — **O5 -** Observables
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- **Goal 5** - Aerosol Rad. Forcing
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Links to :
- Geophysical Variable Tables
- Enabled Application Tables
- Decadal Survey Tables
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Work in Progress

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 storms.
				H-1b, H-1c, W-1a, S-4a	**G3** Falling Snow To advance understanding of its role in cryospheric-climate feedbacks, quantify the rate of falling snow, particularly at middle to high latitudes.
				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-2h, C-5c	**G5** Aerosol Radiative Forcing 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

A+ CC P	A	CC P	Goal	Overarching Science Questions	Objectives
			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*	*1) To what extent can the properties of low clouds be determined by environmental factors?* *2)* *2) How do the properties and formation of high clouds relate to (i) deep convection and (ii) large-scale environmental factors?*	**O1** Low Clouds **Minimum:** Determine the sensitivity of boundary layer *bulk* cloud physical and radiative properties to large-scale and local environmental factors including thermodynamic and dynamic properties. **Enhanced:** Adds to Minimum cloud *microphysical* properties and enhanced bulk cloud properties.
					O2 High Clouds **Minimum:** 1) Relate the vertical structure, horizontal extent, ice water path, and radiative properties of *convectively generated* high clouds to convective vertical transport 2) Relate the vertical structure, horizontal extent, ice water path, and radiative properties of *large scale* high clouds to environmental factors. **Enhanced:** Adds to Minimum microphysical properties of ice clouds.

A+ CCP	A	CCP	Goal	Overarching Science Question	Objectives
			G2 Storm Dynamics *Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within storms.*	*How do different convective storm systems contribute to the vertical mixing and transports of heat, water, and other constituents within the atmosphere and how do these transports relate to the cloud and precipitation properties of storms?*	**O3** Convective Storms **Minimum:** Relate vertical motion within convective storms and its cloud- and precipitation-structures to a) storm life cycle, b) local environment thermodynamic and kinematic factors such as temperature, humidity, and vertical wind shear, c) ambient aerosols, and d) surface properties. **Enhanced**: Relate vertical motion within convective storms *and other storm types* and their cloud- and precipitation-structures to a) *latent heating profiles,* b) storm life cycle, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and vertical wind shear, d) ambient aerosols, and e) surface properties.

A +C CP	A	CC P	Goal	Overarching Science Questions	Objectives
			G3 Falling Snow *To advance understanding of its role in cryospheric-climate feedbacks, quantify the rate of falling snow, particularly at middle to high latitudes.*	1) *What large- and mesoscale factors determine the areal extent and intensity of snowfall.* 2) 2) *To what extent do clouds and precipitation influence the surface mass and energy balances at Earth's ice covered surface?*	**O4** Falling Snow Processes **Minimum:** Detect and quantify vertical profiles of falling snow rate and relate these to cloud physical properties, meteorological forcing and regime, orography, and land surface properties. **Enhanced:** Enhancement of Minimum with an additional focus on the surface energy balance particularly at higher latitudes.

A+ CC P	A	CC P	Goal	Overarching Science Questions	Objectives
			G4 Aerosol Processes *Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.*	*1)* *1) What are the major anthropogenic and natural sources of aerosol and how do they vary spatially and temporally?* *2)* *2) What are the factors that relate AOD to surface PM concentrations?* *3)* *3) To what extent does long-range transport of smoke, dust, and other particulates impact regional near-surface air quality?*	**O5** Aerosol Redistribution **Minimum:** Characterize the removal and redistribution of aerosols by clouds and light precipitation (<2 mm/hr). **Enhanced:** Characterize the removal and redistribution of aerosols by clouds and heavy precipitation (> 2 mm/hr).
					O6 Aerosol Attribution **Minimum:** Determine aerosol speciation to quantify the contributions of different aerosol types to observed aerosol properties and improve emission estimates of the different aerosol sources. **Enhanced:** Characterize changes in aerosol amounts and properties over space and time in terms of 3D transport and spatially resolved emission sources.
					O7 Air Quality **Minimum:** Enhance understanding of the processes controlling boundary layer and near surface speciated extinction as means to constrain air quality predictions and estimates of human health impacts. **Enhanced:** Determine the spatial and temporal variations in boundary layer and near surface speciated PM concentrations as means to constrain air quality predictions and estimates of human health impacts.

A +CCP	A	CCP	Goal	Overarching Science Questions	Objectives
			G5 Aerosol Radiative Forcing *Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.*	*1) What is the role of absorbing aerosols in the Earth's radiation budget?* *2)* *2) How do changes in anthropogenic aerosols affect Earth's radiation budget and offset the warming due to greenhouse gases?* *3)* *3) Under what conditions do aerosols impact the albedo or coverage of shallow clouds?*	**O8** Absorbing Aerosols **Minimum**: Quantify the impact of absorbing aerosol on the Earth's radiative balance at TOA and surface, and on atmospheric stability. **Enhanced:** Quantify the impact of absorbing aerosols on *vertically resolved* radiative heating rates.
					O9 Aerosol Direct Effect **Minimum**: Reduce uncertainties in estimates of global mean clear and all-sky shortwave direct radiative effects (DRE) to ±1.2 W/m^2 at TOA and ±0.6 W/m^2 at surface with commensurate improvements in regional estimates of DRE and anthropogenic aerosol radiative forcing. **Enhanced:** Quantify vertically resolved aerosol radiative forcings.
					O10 Aerosol Indirect Effect **Minimum**: Provide process level constraints on aerosol-warm cloud interactions as a means to constrain estimates of aerosol indirect radiative forcings. **Enhanced:** Provide process level constraints on aerosol-cold cloud interactions as a means to constrain estimates of aerosol indirect radiative forcing.

A+C CP	A	CCP	Objectives
			O1 [Low Clouds](#) **Minimum**: Determine the sensitivity of boundary layer *bulk* cloud physical and radiative properties to large-scale and local environmental factors including thermodynamic and dynamic properties. **Enhanced**: Adds to Minimum cloud *microphysical* properties and enhanced bulk cloud properties.

A+CCP Potential Enabled Applications	
PEA1	Weather, agriculture, energy and air quality modeling (NWP centers, USDA, IBM, AFWA, Private Companies)
PEA2	Issuing alerts of fog/vog (air quality and weather communities)
PEA7	Cloud evolution for aviation and weather prediction (FAA, DoD, DoE, NOAA)
PEA9	Icing and visibility hazards for aviation industry (FAA, AFWA, Airlines,NOAA)
PEA15	Storm warnings for lightning and severe storm development (AFWA, NWS, and NWP modeling communities)
PEA16	Forecasting snow and mixed precipitation events (NWP modeling communities, private weather companies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
	√	S	(√)	1	Cloud liquid water path	
	√	S	(√)	1,2,7,9	Cloud optical depth	
	√	S	(√)	1,2,7,9,15	Cloud droplet effective radius	
√	√	S	(√)	1,2,7,9,15, 16	Cloud top phase	
√	√		(√)	1,2,7,9,15, 16	Cloud top height	
	√	S	(√)	1,2,7,9,15	Areal cloud fraction	
	√		(√)		Precipitation phase	
	√		(√)	1,15,16	Precipitation rate profile	<2 mm/hr
√			(√)		PBL height	
			√		Synoptic scale motion	
			√		Environmental thermodynamic profiles	
	√		(√)		Cloud albedo	Derived
					Enhanced (=Minimum+)	
	√			1,2	Cloud droplet concentration	Layer
√	√			1,2,7,9,	Cloud base height	
	√		(√)	1	Total water path	
	√			1,	Volumetric cloud fraction	
			√	1,2,7	Diurnally resolved cloud cover	
		S	(√)		Surface turbulent fluxes (land and ocean)	

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+CCP	A	CCP	Objectives
			O2 High Clouds **Minimum:** 1) Relate the vertical structure, horizontal extent, ice water path, and radiative properties of *convectively generated* high clouds to convective vertical transport 2) Relate the vertical structure, horizontal extent, ice water path, and radiative properties of *large scale* high clouds to environmental factors. **Enhanced:** Adds to Threshold microphysical properties of ice clouds.

A+CCP Potential Enabled Applications
PEA9 Icing and visibility hazards for aviation industry (FAA, AFWA, Airlines, NOAA)
PEA10 Characterization of hail events and damage (NWP communities, reinsurance, and agricultural communities)
PEA15 Storm warnings for lightning and severe storm development (AFWA, NWS, and NWP modeling communities)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√	√	S	(√)		Ice water path	
√	√	S	(√)	9,10,15	Cloud optical depth	
√	√			9,10,15	Cloud base height	
√	√		(√)	9,10,15	Cloud top height	
√			(√)	9,10,15	Cloud top temperature	
			√	9,10,15	Cloud areal extent	
			√	10	Diurnally resolved cloud cover and cloud top height	
	√			10,15	Vertical air velocity	Above 5km, >2 m/s
√	√			9,10,15	Cloud vertical structure	
	√			9,10,15	Melting layer detection (base and top height)	
			√	15	Cloud lifecycle categories	
			√		Synoptic scale motion	
√					Cloud radiative effects, SW LW	
			√	10,15	Environmental thermodynamic profiles	
					Enhanced (=Minimum+)	
√	√			9,10,15	Ice crystal number concentration	Layer
√	√	S		9,10,15	Bulk crystal size, including effective radius	
	√		√	9,10,15	Convective cloud cover	
	√		(√)	9,10,15	Cloud vertical structure	In convection

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+CCP	A	CCP	Objectives
			O3 [Convective Storms](#) **Minimum**: Relate vertical motion within convective storms and its cloud- and precipitation-structures to a) storm life cycle, b) local environment thermodynamic and kinematic factors such as temperature, humidity, and vertical wind shear, c) ambient aerosols, and d) surface properties. **Enhanced**: Relate vertical motion within convective storms *and other storm types* and their cloud- and precipitation-structures to a) *latent heating profiles,* b) storm life cycle, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and vertical wind shear, d) ambient aerosols, and e) surface properties.

A+CCP Potential Enabled Applications

PEA3 - Aerosols impact on precipitation and storm development (NOAA, NWP centers, IBM)
PEA4 - Improved model initialization of aerosols and severe storm development (NWP and model comm.)
PEA6 - Geospatial Analytics – Big data for planetary resource surveillance (Defense department, public and private industry, IBM)
PEA7 - Cloud evolution for aviation and weather prediction (FAA, DoD, DoE, NOAA)
PEA8 - Cloud parameterizations for model initiation (NWP and modeling communities)
PEA10 – Characterization of hail events and damage (NWP, reinsurance, and agricultural)
PEA11 - Hydrologic modeling, disease tracking, animal migration, insurance modeling and disaster applications (CDC, NOAA, Red Cross, World Bank, public/private sector)
PEA12 - Forecasting heavy rain, snow, flooding events (NOAA, DoD, FAO, reinsurance)
PEA13 - Flood and landslide monitoring and forecasting in mountains (NOAA, FEMA, USGS)
PEA14 - Streamflow, flooding, drought, energy, and agricultural monitoring and modeling (USDA, Water resource managers)
PEA15 - Warnings for lightning, severe storm development (NWP modeling communities)
PEA16 - Forecasting snow/mixed precipitation events (NWP, private weather companies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
	√			3,4,10,12-15	Vertical air velocity	Above 5km, > 2 m/s
√	√		(√)	3,4,6,7,8,10,15,16	Cloud top height	
√			(√)	3,4,6,7,8,10,15,16	Cloud top temperature	
	√		(√)	3,4	Ice water path	
	√		(√)	3,4,7,12-15	Convective classification	
			√	3,4,6,7,15	Cloud lifecycle categories	
			√		Diurnally resolved cloud cover and cloud top height	
	√		(√)	3,4,6,8,11-16	Precipitation rate profile	
	√		(√)	3,4,15	Cloud vertical structure	In convection, above melting layer
	√		(√)	3,4,10,15,16	Melting layer detection (base and top height)	
	√		(√)	4,7,10,15	Stratiform/convective precipitation discrimination	
√				3,4,6	Aerosol extinction profile	
√		S	(√)		AOD	Column, PBL
			√		Synoptic scale motion	Environmental shear
			√		Environmental thermodynamic profiles	
					Enhanced (=Minimum+)	
	√		(√)	3,4,8	Latent heating profile	
	√		(√)	3,4,6,10-16	Precipitation phase	
	√		(√)	3,4,6,10,15,16	Precipitation particle size	
	√			3,7,10,12-15	Convective core size	
√				3,4	Aerosol effective radius	Profile
√				3,4	Aerosol non-sphericity	Profile & column
√				3,4	AAOD	Profile

A+CCP	A	CCP	Objectives
			O4 Falling Snow Processes **Minimum:** Detect and quantify vertical profiles of falling snow rate and relate these to cloud physical properties, meteorological forcing and regime, orography, and land surface properties. **Enhanced:** Enhancement of Minimum with an additional focus on the surface energy balance particularly at higher latitudes.

A+CCP Potential Enabled Applications
PEA6 - Geospatial Analytics – Big data for planetary resource surveillance (Defense department, public and private industry, IBM)
PEA11 - Hydrologic modeling, disease tracking, animal migration, insurance modeling and disaster applications (CDC, NOAA, Red Cross, World Bank, public/private comp.)
PEA12 - Forecasting heavy rain, snow, flooding events (NOAA, DoD, FAO, reinsurance)
PEA13 - Flood and landslide monitoring and forecasting within mountain environments (modeling and emergency response communities, NGOs, PDC)
PEA14 - Streamflow, flooding, drought, energy, and agricultural monitoring and modeling (USDA, Water resource managers)
PEA16 - Forecasting snow/mixed precipitation events (NWP, private weather companies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√	√			6,16	Cloud top height	
√				6,16	Cloud top temperature	
	√			6,11-14,16	Ice water path	
	√	M	(√)	6,11-14,16	Surface or near surface precipitation rate	
	√			11-14,16	Vertical air velocity	> 2 m/s
	√		(√)	6,11-14,16	Precipitation rate profile	
	√			16	Cloud liquid water path	
	√		(√)	6,11-14,16	Surface or near surface precipitation phase	
			√		Synoptic scale motion	
			√		Environmental thermodynamic profiles	
					Enhanced (=Minimum+)	
	√			16	Bulk snow particle size	
	√			11-14,16	Snowfall vertical (Doppler) motion	< 1 m/s
	√			6	Volumetric cloud fraction	
	√	S		6,16	Cloud phase	
√				6,16	Blowing surface snow	
	√	S	(√)	6,16	Cloud optical depth	
			√		Water vapor advection	
√	√		√		Cloud radiative effects, LW & SW	
√	√		√		Surface radiation budget	

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+ CCP	A	CCP	Objectives
			O5 Aerosol Redistribution **Minimum:** Characterize the removal and redistribution of aerosols by clouds and light precipitation (<2 mm/hr). **Enhanced:** Characterize the removal and redistribution of aerosols by clouds and heavy precipitation (> 2 mm/hr).

A+CCP Potential Enabled Applications

- PEA1 - Weather, agriculture, energy and air quality modeling (NWP centers, USDA, IBM, AFWA, Private Companies)
- PEA3 - Modeling/forecasting impact of aerosols on precipitation and storm development (NOAA, NWP centers, IBM)
- PEA4 - Improved model initialization of aerosols and severe storm development (NWP and model comm.)
- PEA5 - Estimate radiative fluxes for air quality modeling, solar insolation, and agricultural forecasting.

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√				3,4,5	Aerosol extinction profile	
√		S	(√)	3,4,5	AOD	
	√		(√)	1,3,4	Cloud liquid water path	
√	√		(√)	1,3,4,5	Cloud top height	
	√	S	(√)	1,3,4,5	Cloud optical depth	
	√	S	(√)	1,3,4,5	Cloud droplet effective radius	
	√		(√)	1,3,4	Surface or near surface precipitation rate	< 2mm/hr
	√		(√)	1,3,4	Precipitation phase	
	√		(√)	1,3,4	Precipitation rate profile	
			√		Synoptic-scale motion	
			√		Environmental thermodynamic profiles	
√			(√)		PBL height	
					Enhanced (=Minimum+)	
√				3,4,5	Fine mode aerosol extinction profile	
√					Angstrom exponent	Column
	√		(√)	1,3,4	Surface or near surface precipitation rate	> 2mm/hr
	√			1,3,4,5	Volumetric cloud fraction	
	√			1,3,4,5	Vertical air velocity	> 2 m/s

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+ CCP	A	CCP	Objectives
			O6 [Aerosol Attribution] **Minimum**: Determine aerosol speciation to quantify the contributions of different aerosol types to observed aerosol properties and improve emission estimates of the different aerosol sources. **Enhanced**: Characterize changes in aerosol amounts and properties over space and time in terms of 3D transport and spatially resolved emission sources.

A+CCP Potential Enabled Applications
PEA1 - Weather, agriculture, energy and air quality modeling (NWP centers, USDA, IBM, AFWA, Private Companies)
PEA2 - Issuing alerts of fog/vog (air quality and weather communities)
PEA6 - Geospatial Analytics – Big data for planetary resource surveillance (Defense department, public and private industry, IBM)
PEA17 – Source attribution of pollution (EPA, NOAA, state AQ agencies)
PEA18 – Aviation industry and safety (FAA, VAACs, private industry: GE, P&W, RR, NG)
PEA19 – Wildfire management (EPA, NOAA, State AQ agencies)
PEA20 – Human health studies & health risk estimation (CDC, WHO, NIH, universities, reinsurance industry)
PEA21 – AQ rule-making (EPA, state AQ agencies)
PEA22 – Operational weather & AQ forecasting (NOAA, state AQ agencies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√				1,2,6,17-19,21,22	Aerosol extinction profile	Total and non-spherical
√				1,2,6,17-19	Aerosol layer height	
√		S	(√)	1, 6, 19-22	AOD	PBL and column
√				6, 19,20	AAOD/SSA	PBL and column
√				6, 19,20,22	Fine mode AOD	PBL and column
√			(√)	17-20	Angstrom exponent	PBL and column
√			(√)	17-20	Index of refraction	Column
√				17-20	Aerosol non-sphericity	Profile & column
√			(√)	1,2,6,19-22	PBL height	
			√		Environmental thermodynamic profiles	
					Enhanced (=Minimum+)	
√				17,19,21,22	Aerosol effective radius	Profile
√				17,19,21,22	Angstrom exponent	Profile
√				17,19	AAOD	Profile
√				17,19,21,22	Fine mode aerosol extinction	Profile
			√		Synoptic scale motion	
	√			22	Vertical air velocity	> 2 m/s

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+ CCP	A	CCP	Objectives
			O7 Air Quality **Minimum:** Enhance understanding of the processes controlling boundary layer and near surface speciated extinction as means to constrain air quality predictions and estimates of human health impacts. **Enhanced:** Determine the spatial and temporal variations in boundary layer and near surface speciated PM concentrations as means to constrain air quality predictions and estimates of human health impacts.

A+CCP Potential Enabled Applications
PEA6 – Geospatial Analytics – Big data for planetary resource surveillance (IBM, Weather Underground, etc.) PEA17 – Source attribution of pollution (EPA, NOAA, state AQ agencies) PEA19 – Wildfire management (EPA, NOAA, State AQ agencies) PEA20 – Human health studies & health risk estimation (CDC, WHO, NIH, universities, reinsurance industry) PEA21 – AQ rule-making (EPA, state AQ agencies) PEA22 – Operational weather & AQ forecasting (NOAA, state AQ agencies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√				6,19,21,22	Aerosol extinction profile	Total and non-spherical
√				6,17, 19, 21,22	Aerosol layer height	
√		S	(√)	6,21,22	AOD	PBL and column
√				6,17,21,22	AAOD/SSA	PBL and column
√				6,17,19,21,22	Fine mode AOD	PBL and column
√			(√)	6,17,19,21,22	Angstrom exponent	PBL and column
√			(√)	6,17,19,20,21,22	Index of refraction	Column
√				6,17,20,21,22	Aerosol non-sphericity	Profile & column
√			√	6,17,20,21,22	PBL height	
			√		Environmental thermodynamic profiles	
					Enhanced (=Minimum+)	
√			(√)	17,19,20,21	PM concentration	
√				17,19,20,21	Aerosol effective radius	Profile
√				17,19,20,21	Angstrom exponent	Profile
√				17,19	AAOD	Profile
√				17,19,20,21	Fine mode aerosol extinction profile	
			√		Precursor gas concentration	

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+CCP	A	CCP	Objectives
			O8 [Absorbing Aerosols] **Minimum**: Quantify the impact of absorbing aerosol on the Earth's radiative balance at TOA and surface, and on atmospheric stability. **Enhanced:** Quantify the impact of absorbing aerosols on *vertically resolved* radiative heating rates.

A+CCP Potential Enabled Applications
PEA1 - Weather, agriculture, energy and air quality modeling (NWP centers, USDA, IBM, AFWA, Private Companies) PEA3 - Aerosols impact on precipitation and storm development (NOAA, NWP centers, IBM) PEA6 – Geospatial Analytics – Big data for planetary resource surveillance (IBM, Weather Underground, etc.) PEA17 – Source attribution of pollution (EPA, NOAA, state AQ agencies) PEA20 – Human health studies & health risk estimation (CDC, WHO, NIH, universities, reinsurance industry) PEA21 – AQ rule-making (EPA, state AQ agencies) PEA22 Operational weather & AQ forecasting (NOAA, state AQ agencies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√				3,6,20-22	Aerosol extinction profile	
√				3,6,17,20-22	Aerosol layer height	
√		S	(√)	1,3,6,20-22	AOD	PBL and column
√				17,20-22	AAOD	PBL and column
			√		Environmental thermodynamic profiles	
			√		Surface albedo	
√				1,22	Cloud reflectance	
√	√		(√)	1,22	Cloud top height	
√				1,22	TOA and surface radiative fluxes (derived)	
					Enhanced (=Minimum+)	
√				3,6,20	Aerosol absorption coefficient profile	

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+CCP	A	CCP	Objectives
			O9 Aerosol Direct Effect **Minimum**: Reduce uncertainties in estimates of global mean clear and all-sky shortwave direct radiative effects (DRE) to ±1.2 W/m² at TOA and ±1.6 W/m² at surface with commensurate improvements in regional estimates of DRE and anthropogenic aerosol radiative forcing. **Enhanced:** Quantify vertically resolved aerosol radiative forcings.

A+CCP Potential Enabled Applications

PEA5 – Estimate radiative fluxes for air quality modeling, solar insolation, and agricultural forecasting. – (EPA, CMAQ, WRFChem)
PEA6 – Geospatial Analytics – Big data for planetary resource surveillance (IBM, Weather Underground, etc.)
PEA17 – Source attribution of pollution (EPA, NOAA, state AQ agencies)
PEA20 – Human health studies & health risk estimation (CDC, WHO, NIH, universities, reinsurance industry)
PEA21 – AQ rule-making (EPA, state AQ agencies)
PEA22 – Operational weather & AQ forecasting (NOAA, state AQ agencies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√				6,17,20,21,22	Aerosol extinction profile	
√				6,17,21,22	Aerosol layer height	
√					Non-spherical aerosol extinction profile	
√		S	(√)	5,6,17,21,22	AOD	Column
√			(√)	6,17,21,22	AAOD	Column
√			(√)	5,6,17,21,22	Fine mode AOD	Column
√			(√)	6,17,21,22	Angstrom exponent	Column
√			(√)	6,17,21,22	Index of refraction	Column
√				17,21	Aerosol non-sphericity	Profile & column
			√		Environmental thermodynamic profiles	
			√		Surface albedo	
	√			5,6,22	Cloud reflectance	
x	√			5,6,22	Cloud top height	
√	√		√	5,6,22	TOA and surface radiative fluxes (derived)	
					Enhanced (= Minimum+)	
√				17,20,21	Aerosol effective radius	Profile
√				17,20,21	Angstrom exponent	Profile
√				5,17,20,21	Aerosol absorption coefficient profile	

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+ CCP	A	CCP	Objectives
			O10 Aerosol Indirect Effect **Minimum**: Provide process level constraints on aerosol-warm cloud interactions as a means to constrain estimates of aerosol indirect radiative forcings. **Enhanced:** Provide process level constraints on aerosol-cold cloud interactions as a means to constrain estimates of aerosol indirect radiative forcing.

A+CCP Potential Enabled Applications

PEA2 - Issuing alerts of fog/vog (air quality and weather communities)
PEA5 – Estimate radiative fluxes for air quality modeling, solar insolation, and agricultural forecasting. – (EPA, CMAQ, WRFChem)
PEA6 – Geospatial Analytics – Big data for planetary resource surveillance (IBM, Weather Underground, etc.)
PEA17 – Source attribution of pollution (EPA, NOAA, state AQ agencies)
PEA20 – Human health studies & health risk estimation (CDC, WHO, NIH, universities, reinsurance industry)
PEA21 – AQ rule-making (EPA, state AQ agencies)
PEA22 – Operational weather & AQ forecasting (NOAA, state AQ agencies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Minimum	
√		S	(√)	6,17,21,22	AOD	PBL and column
√				6,17,21,22	Angstrom exponent	PBL and column
√				6,17,21,22	Fine mode AOD	PBL and column
√				6,17,21,22	Aerosol extinction profile	
√	√		(√)	2,5,22	Cloud LWP	
√			(√)	2,5,22	Cloud optical depth	
√			(√)	2,5,22	Cloud droplet effective radius	
√	√			2,5,22	Cloud droplet concentration	Layer
√				2,5,22	Cloud top phase	
√	x		(√)	2,5,22	Cloud top height	
√			√	5	Areal cloud fraction	
√				5	Cloud reflectance	
	√		(√)		Surface or near surface precipitation rate	<2 mm/hr
√			√	6,17,20-22	PBL height	Lidar and reanalysis
			√		Synoptic scale motion	
			√		Environmental thermodynamic profiles	

(See next slide for Enhanced)

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

A+CCP	A	CCP	Objectives
			O10 Aerosol Indirect Effect **Minimum**: Provide process level constraints on aerosol-warm cloud interactions as a means to constrain estimates of aerosol indirect radiative forcings. **Enhanced:** Provide process level constraints on aerosol-cold cloud interactions as a means to constrain estimates of aerosol indirect radiative forcing.

A+CCP Potential Enabled Applications
PEA6 – Geospatial Analytics – Big data for planetary resource surveillance (IBM, Weather Underground, etc.) PEA17 – Source attribution of pollution (EPA, NOAA, state AQ agencies) PEA20 – Human health studies & health risk estimation (CDC, WHO, NIH, universities, reinsurance industry) PEA21 – AQ rule-making (EPA, state AQ agencies) PEA22 – Operational weather & AQ forecasting (NOAA, state AQ agencies)

A	CCP	ODO	POR	PEA#	Geophysical Variables	Qualifiers
					Enhanced (= Minimum+)	
√				6,17,20-22	PBL aerosol number concentration	
√				6,17,20-22	Aerosol effective radius	PBL
√	√			2,22	Cloud droplet concentration	Layer
√				2,22	Cloud top extinction	
				2,22	Cloud top droplet size	
				2,22	Cloud top droplet concentration	
√	√			2,22	Cloud base height	
	√			17,22	Vertical air velocity	> 1 m/s
	√		(√)	22	Precipitation phase	
			√		Diurnally resolved cloud cover	
			√		Surface turbulent fluxes (land and ocean)	
√	√			6,22	Ice crystal number concentration	
√	√			6,22	Ice crystal particle size	

Legend: **√** Needed to meet objective, **(√)** From PoR but insufficient to meet objective, **S** Complimentary observation from SBG, **M** Complimentary observation from MC

O1 Low Clouds **Geophysical Variables**	**Desired Capability**					**Observables**	**Notes**
	Range	**Precision/ Accuracy**	**Resolution**				
			Δx	**Δz**	**Swath**		
Minimum							
Cloud LWP	20-400gm^{-2}	20 gm^{-2}			fp	VIS + SWNIR reflection ~5%, µwave radiances NEΔT~ 3K matched to radar, radar reflectivity Z<-15dBZ	Uwave and optical based methods match under carefully prescribed conditions
Cloud optical depth	0.3-100	15%			20km	VIS reflectance, ~3%	
Cloud droplet effective radius	4-100 µm	2µm		~ 3 OD	20km	VIS + SWNIR reflection ~ 3%	Re is needed as deep into cloud as we can get - (~3 OD) for purpose of deriving LWP - 2.1um Re aPEArs to most optimally match uwave based LWP
Cloud top phase	Liquid,Solid or mixed	30%		~ 1 OD	fp	Polarized backscatter , Δβ>0.05km^{-1}, SWNIR reflectance ~5%	also with DOLP
Cloud top height	0.5-15km	100m		100m	fp	VIS backscatter, Δβ>0.05km^{-1}	Expect to address this this from lidar backscatter
Areal cloud fraction	0.05-1.00	5%		N/A	20km	VIS reflection ~5%	Cloud amount matched radar/lidar footprints and will be used in diagnostic analysis
Precipitation phase	Liquid,Solid or mixed	30%	5km	N/A	fp	Z Bright band, ΔVr, polarimetric radar linear depolarization ratio (LDR; e.g., Ka > ~-15 dB), differential reflectivity ΔZ~2dBZ , dual-frequency ratio (snow index), polarimetric VIS backscatter , Δβ>??5km^{-1}	Basic separation of liquid and frozen phases in stratiform is most straight forward.
Precipitation rate profile	<2 mm/hr						
PBL height	<3 km	250 m				GPS RO might be source	

(continue…)

O1 Low Clouds Geophysical Variables	Desired Capability					Observables	Notes
	Range	PrecisionAccuracy	Resolution				
			Δx	Δz	Swath		
Minimum (continued)							
Synoptic scale motion						From met analysis	
Environmental thermodynamic profiles						From met analysis	
Cloud Albedo (derived)	0.1-0.8	5% absolute	5km	N/A	fp	A calculated quantity with threshold inputs. Can then be cross calibrated with PoR (CERES & EVC)	
Enhanced							
Cloud droplet concentration	10-1000 cm^{-3}	50%	1km			VIS + SWNIR reflection ~5%, μwave radiances NEΔT~ 3K matched to radar, radar reflectivity Z<-15dBZ	We are advocating a completely new approach using cloud and precip data jointly.
Cloud base height	250 m-15 km	250 m		250m		Radar reflectivity >35GHz	
Total water path (cloud+precipitation)	20-400 gm^{-2}	20 gm^{-2}	1km	N/A	fp	VIS + SWNIR reflection ~5%, μwave radiances NEΔT~ 3K matched to radar, radar reflectivity Z<-15dBZ	
Volumetric cloud fraction							
Diurnally resolved cloud cover	0.05-1.00	5%	5km	N/A	wide	VIS reflection/IR - Geostationary from PoR	For context only
Surface turbulent fluxes (land and ocean)						TBD - this is a link to SBG	

O2 High Clouds Geophysical Variables	Desired Capability					Observables	Notes
	Range	Precision Accuracy	Resolution				
			Δx	Δz	Swath		
Minimum							
Enhanced							

O3 Convective Storms Geophysical Variables	Desired Capability					Observables	Notes
	Range	Precision Accuracy	Resolution				
			Δx	Δz	Swath		
Minimum							
Enhanced							

Place Holder

O4 Falling Snow Processes Geophysical Variables	Desired Capability					Observables	Notes
	Range	Precision Accuracy	Resolution				
			Δx	Δz	Swath		
Minimum							
Enhanced							

Place Holder

O5 Aerosol Redistribution **Geophysical Variables**	**Desired Capability**					**Observables**	**Notes**
	Range	**Precision Accuracy**	**Resolution**				
			Δx	**Δz**	**Swath**		
Minimum							
Enhanced							

Place Holder

O6 Aerosol Attribution Geophysical Variables	Desired Capability					Observables	Notes
	Range	Precision Accuracy	Resolution				
			Δx	Δz	Swath		
Minimum							
Enhanced							

Place Holder

O7 Air Quality Geophysical Variables	Desired Capability					Observables	Notes
	Range	Precision Accuracy	Resolution				
			Δx	Δz	Swath		
Minimum							
Enhanced							

O8 Absorbing Aerosols **Geophysical Variables**	**Desired Capability**					**Observables**	**Notes**
	Range	**Precision Accuracy**	**Resolution**				
			Δx	**Δz**	**Swath**		
Minimum							
Enhanced							

Place Holder

O9 Aerosol Direct Effect Geophysical Variables	Desired Capability					Observables	Notes
	Range	Precision Accuracy	Resolution				
			Δx	Δz	Swath		
Minimum							
Enhanced							

Place Holder

O10 Aerosol Indirect Effect **Geophysical Variables**	**Desired Capability**					**Observables**	**Notes**
			Resolution				
	Range	**Precision Accuracy**	**Δx**	**Δz**	**Swath**		
Minimum							
Enhanced							

Place Holder

A+ CCP	A	CCP	PEA#	Enabled Applications	Partners	Geophysical Variables	Relevant Objective(s)
			1	Cloud and precipitation properties enable the weather prediction and modeling communities to improve parameterizations of clouds to improve weather forecasting, energy planning, air quality modeling, and agriculture forecasting.	NWP Centers (NOAA, NRL, ECMWF, JMA, NCAR), USDA, AFWA, IBM, Private Companies	Cloud height, depth, radius, amount, phase, precipitation rate and phase	O1, O5, O6, O8
			2	Observations of aerosol and cloud properties used by the weather and air quality communities to understand and issue alerts about the development of fog/vog.	NOAA, NCAR, NASA, EPA and State Agencies	Aerosol and cloud properties	O1, O6, O10
			3	Observations of aerosols and clouds enable the weather forecasting and modeling communities to improve modeling/forecasting the impact of aerosols on precipitation and storm development, including cyclones and hurricanes.	NOAA, NASA, NCAR, NWP modeling community, IBM	Aerosols, precipitation, and cloud properties	O3, O5, O8
			4	Observations of aerosol, precipitation and cloud properties, and vertical velocities are used to improved modeling of vertical transport, scavenging, wet deposition, and links to ice particles and severe storm development .	NWS, NOAA, CTM, EPA, state AQ agencies, other modeling communities	Vertical velocity, aerosol, cloud, and precipitation properties	O3, O5
			5	Cloud and aerosol optical depths are used to estimate radiative fluxes for applications such as estimating available photosynthetically active radiation (PAR) for air quality modeling, attenuated solar insolation for solar power companies, and agricultural forecasting. Solar power companies use estimates of size resolved aerosol concentrations and precipitation to model dry and wet deposition on the panels, respectively.	Air quality modelers (EPA, NOAA, state agencies), solar energy companies, agricultural communities	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation, cloud properties	O5, O9, O10
			6	Data fusion techniques through geospatial analytics and “big data” management rely on aerosol, cloud and precipitation properties to provide continuous, detailed, multidimensional, and global monitoring as an invaluable tool for planetary resource surveillance.	Private industry (e.g., IBM, Weather Underground), Defense Department, public companies (e.g. Mars corporation)	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation, brightness temperatures, surface precipitation	O3, O4, O6, O7, O8, O9, O10
			7	Observations of cloud height and droplets enable the aviation industry and weather prediction community to improve situational awareness of cloud evolution.	NOAA, FAA, DoD, DoE	Cloud phase, height, depth, radius, and amount	O1, O3
			8	Brightness temperature and precipitation rates enable the weather forecasting and modeling communities to improve storm track and intensity forecasts of hurricanes and severe storms.	NOAA, NASA, NCAR, ECMWF, NRL, JTWC, and other NWP centers, IBM	Brightness temperature (Cloud top temperature) and precipitation rates	O3

A + C C P	A	C C P	PE A#	Enabled Applications	Partners	Geophysical Variables	Relevant Objective(s)
			9	Estimates of ice content, optical depth and cloud height are used by the aviation industry to inform rime icing, threats to engine performance, and visibility hazards.	NOAA, FAA, AFWA, Airlines	Ice content, optical depth and cloud height	O1, O2
			10	Information on microphysical properties can inform the development of hail events and are used by the weather forecasting, reinsurance and agricultural communities to forecast and asses hail events and damage.	NOAA, reinsurance, and agricultural communities	Microphysical properties (cloud phase, vertical motion, radius)	O2, O3
			11	Surface precipitation observations are used by a range of public and private communities, international and domestic governmental organizations and NGOs as inputs into hydrologic models, vector and water borne disease modeling, animal migration tracking, insurance models, and disasters applications.	CDC, NOAA, Red Cross, NASA, reinsurance, World Bank and agricultural communities, public and private companies (e.g., Johnson & Johnson, Agvesto, MiCRO)	Surface precipitation	O3, O4
			12	Observations of surface precipitation rate are used by the weather forecast community to anticipate heavy rain, snow, or flooding in areas with gaps in the in situ observational network .	NOAA, Red Cross, NASA, FAO, US Army, reinsurance community	Surface precipitation	O3, O4
			13	Estimates of extreme and orographically enhanced precipitation within mountainous regions are used by the hydrologic modeling and emergency response communities for modeling/estimating flooding and landslide hazards.	NOAA, Red Cross, NASA, reinsurance community, hydrologic modeling communities, Red Cross, NGOs, PDC	Surface precipitation	O3, O4
			14	Estimates of total water volume and long-term surface precipitation observations are critical for water resource managers, agricultural communities, and energy companies for estimating streamflow, flooding and inundation impacts, assessing drought conditions, and modeling/forecasting crop yields.	USDA, Water Resource Management community	Surface precipitation	O3, O4
			15	Estimates of ice content, and vertical motion are used by the weather forecast and NWP modeling communities as a proxy for lightning initiation to anticipate severe storm development.	NOAA, AFWA, NWP modeling communities	ice content and vertical motion	O1, O2, O3

A + CCP	A	CCP	PEA#	Enabled Applications	Partners	Geophysical Variables	Relevant Objective(s)
			17	Observations of aerosols are used for source attribution of pollution, including interhemispheric transport.	Federal weather and AQ agencies (EPA, NOAA), state AQ agencies, other modeling communities	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation	O6, O9, O10
			18	Observations of aerosols are used to estimate concentrations and location of volcanic ash and issue aviation safety alerts, which are vital to the aviation community. Aircraft engine manufacturers use ambient aerosol concentration data to assess impact of PM on engine performance.	Aviation Industry: FAA, VAACs, private industry (e.g., General Electric, Pratt and Whitney, Rolls Royce, Northrop Grumman)	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation	O6
			19	Observations of aerosols are used to estimate wildfire smoke injection heights, which enable more accurate initialization of smoke transport models for improving air quality forecasts and estimating exposure to wildfire PM and co-emitted trace gas pollutants.	Wildfire management: Federal AQ agencies (EPA, NOAA, Forest Service), state AQ agencies, other modeling communities	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation	O6, O7
			20	Observations of aerosol are used to infer spatio-temporal variations & trends of speciated surface-level PM (PM_1, $PM_{2.5}$, PM_{10}), which are used for health studies, such as to associate the effects of exposure to PM with specific health outcomes, and to calculate health risks and longevity.	Health: CDC, WHO, NIH, health researchers at universities (e.g., Global Burden of Disease), reinsurance industry	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation	O6, O7, O9
			21	Observations of aerosol are used to infer spatio-temporal variations & trends of speciated surface-level PM (PM_1, $PM_{2.5}$, PM_{10}), which used to support AQ rule-making and define exceptional events.	AQ Rule-making: EPA, state AQ agencies	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation	O6, O7, O9, O10
			22	Aerosol observations are used to infer vertically-resolved, speciated PM for operational weather and AQ forecasting (e.g., forecast initialization), tracking dust plumes, and issuing AQ alerts.	Operational AQ Forecasts: Federal (NOAA) and state AQ agencies	Aerosol Optical Depth, Aerosol Concentration Profiles, Aerosol Speciation	O6, O7, O8, O9, O10

DS Traceability Goals 1-2

2017 Decadal Survey Objectives (from Appendix B)	A-CCP Goals
C-2a Reduce uncertainty in low and high cloud feedback. **W-1a** Determine the effects of key boundary layer processes on weather, hydrological, and air quality forecasts at minutes to subseasonal time scales. **W-2a** Improve the observed and modeled representation of natural, low-frequency modes of weather/climate variability. **C-2g** Quantify the contribution of the UTS to climate feedbacks and change.	**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-5c Quantify the effect that aerosol has on cloud. **C-2g** Quantify the contribution of the UTS to climate feedbacks and change. **H-1b** Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and orographic scales suitable to capture flash floods and beyond. **W-1a** Determine the effects of key boundary layer processes on weather, hydrological, and air quality. **W-2a** Improve the observed and modeled representation of natural, low-frequency modes of weather/climate variability. **W-4a** Measure the vertical motion within deep convection to within 1 m/s and heavy precipitation rates to within 1 mm/hour to improve model representation of extreme precipitation and to determine convective transport and redistribution of mass, moisture, momentum, and chemical species.	**G2** Storm Dynamics *Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within storms.*

Most Important Very Important

DS Traceability Goals 3-5

2017 Decadal Survey Objectives (from Appendix B)	A-CCP Goals
H-1b Quantify rates of precipitation and its phase (rain and snow/ice) worldwide at convective and orographic scales suitable to capture flash floods and beyond. **H-1c** Quantify rates of snow accumulation, snowmelt, ice melt, and sublimation from snow and ice worldwide at scales driven by topographic variability. **W-1a** Determine the effects of key boundary layer processes on weather, hydrological, and air quality. **S-4a** Quantify global, decadal landscape change produced by abrupt events and by continuous reshaping of Earth's surface due to surface processes, tectonics, and societal activity. (Recommended measurement of rainfall and snowfall rates).	**G3** Falling Snow *To advance understanding of its role in cryospheric-climate feedbacks, quantify the rate of falling snow, particularly at middle to high latitudes.*
W-1a (boundary layer processes) **W-5a** (air pollution and health) **C-5a** Improve estimates of the emissions of natural and anthropogenic aerosols	**G4** Aerosol Processes *Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.*
C-2a Reduce uncertainty in low and high cloud feedback. **C-2h** Reduce aerosol radiative forcing uncertainty **C-5c** Quantify the effect that aerosol has on cloud	**G5** Aerosol Radiative Forcing *Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.*

Most Important Very Important

Acronyms (1/3)

A	Aerosols
AFWA	Air Force Weather Agency
AAOD	Absorbing Aerosol Optical Depth
AOD	Aerosol Optical Depth
AQ	Air Quality
CCP	Clouds, Convection, and Precipitation
CDC	Centers for Disease Control
CMAQ	The Community Multiscale Air Quality Modeling System
CTM	Chemical Transport Model
D	Direct
DOD	Department of Defense
DOE	Department of Energy
DRE	Direct Radiative Effect
ECMWF	European Centre for Medium-Range Weather Forecasts
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FP	Footprint
G	Goal
GE	General Electric
GPS	Global Positioning System

Acronyms (2/3)

I	**Indirect**
IR	Infrared
JMA	Japan Meteorological Agency
JTWC	Joint Typhoon Warning Center
LW	Longwave
LWP	Liquid Water Path
NCAR	National Center for Atmospheric Research
NIH	National Institutes of Health
NG	Northrop Grumman
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NWP	Numerical Weather Prediction
O	Objective
OD	Optical Depth
PBL	Planetary Boundary Layer
PDC	Pacific Disaster Center
PEA	Potential Enabled Application
PM	Particulate Matter
PoR	Program of Record
P&W	Pratt & Whitney
RO	Radio Occultation
RR	Rolls Royce

Acronyms (3/3)

S	**SBG (Surface Biology and Geology)**
SW	Shortwave
SWNIR	Shortwave-Near Infrared
TBD	To Be Determined
TOA	Top Of Atmosphere
USDA	United States Department of Agriculture
VAAC	Volcanic Ash Advisory Center
VIS	Visible
WHO	World Health Organizations
WRF	Weather Research and Weather (Forecasting Model)