ACCP Aerosols and Clouds-Convection-Precipitation Study

Science and Applications Traceability Matrix

Public Release Candidate G

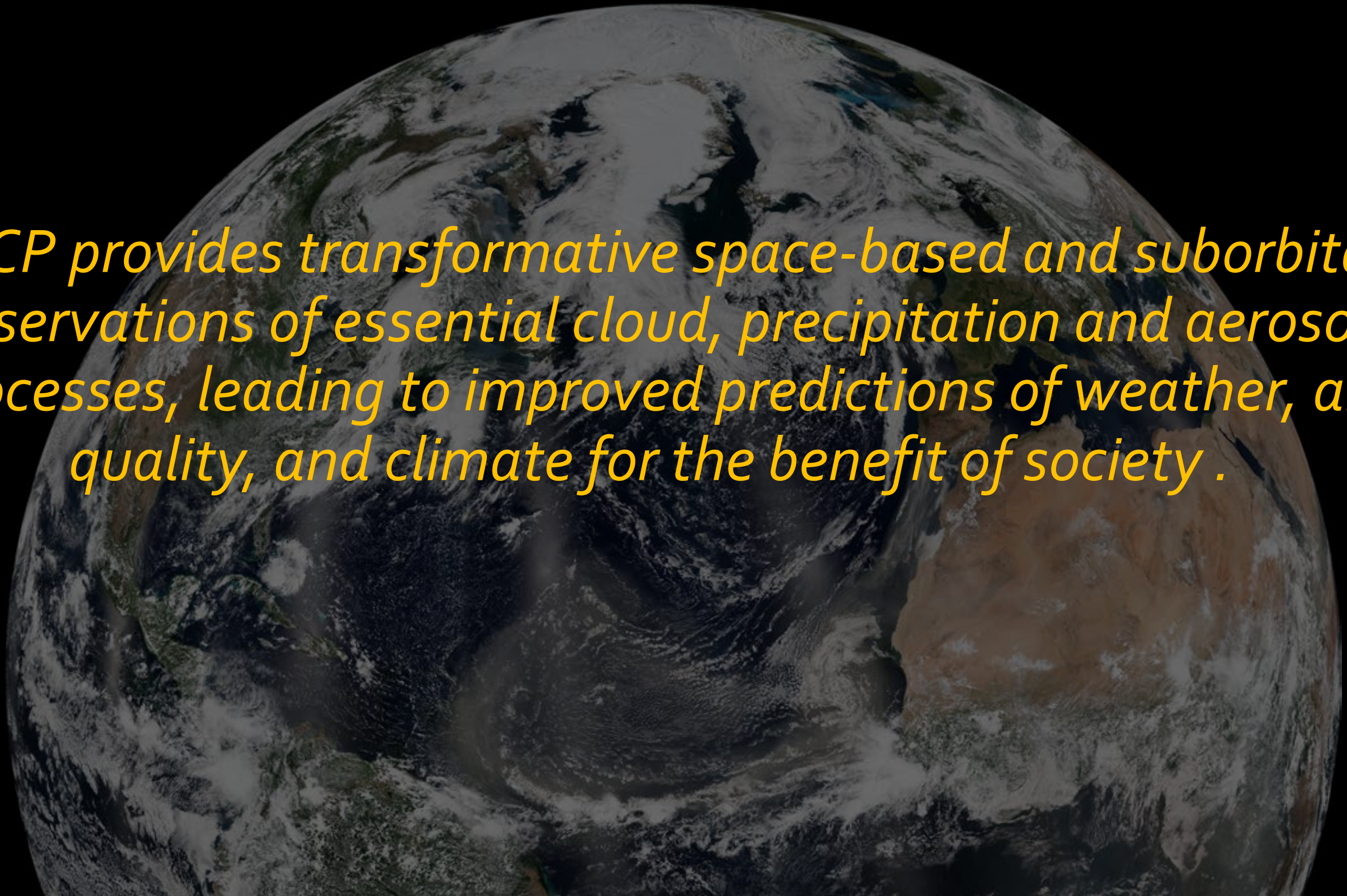
Last Release by the ACCP Study Team

May 2021

Note

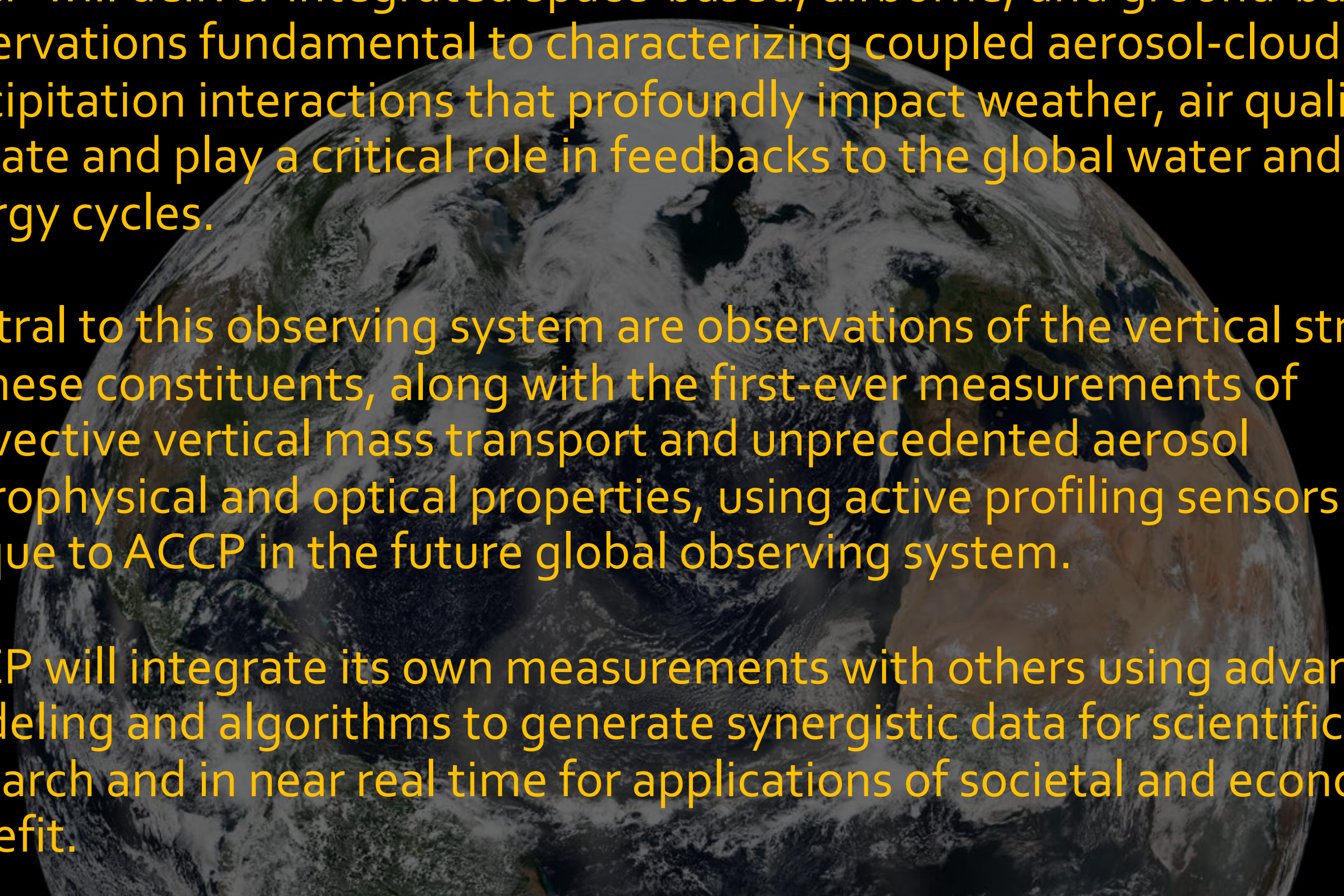
In order to follow the hyperlinks, make sure to view these slides in presentation mode.

ACCP Aerosols, Clouds, Convection and Precipitation Study



ACCP provides transformative space-based and suborbital observations of essential cloud, precipitation and aerosol processes, leading to improved predictions of weather, air quality, and climate for the benefit of society .

ACCP Aerosols, Clouds, Convection and Precipitation Study

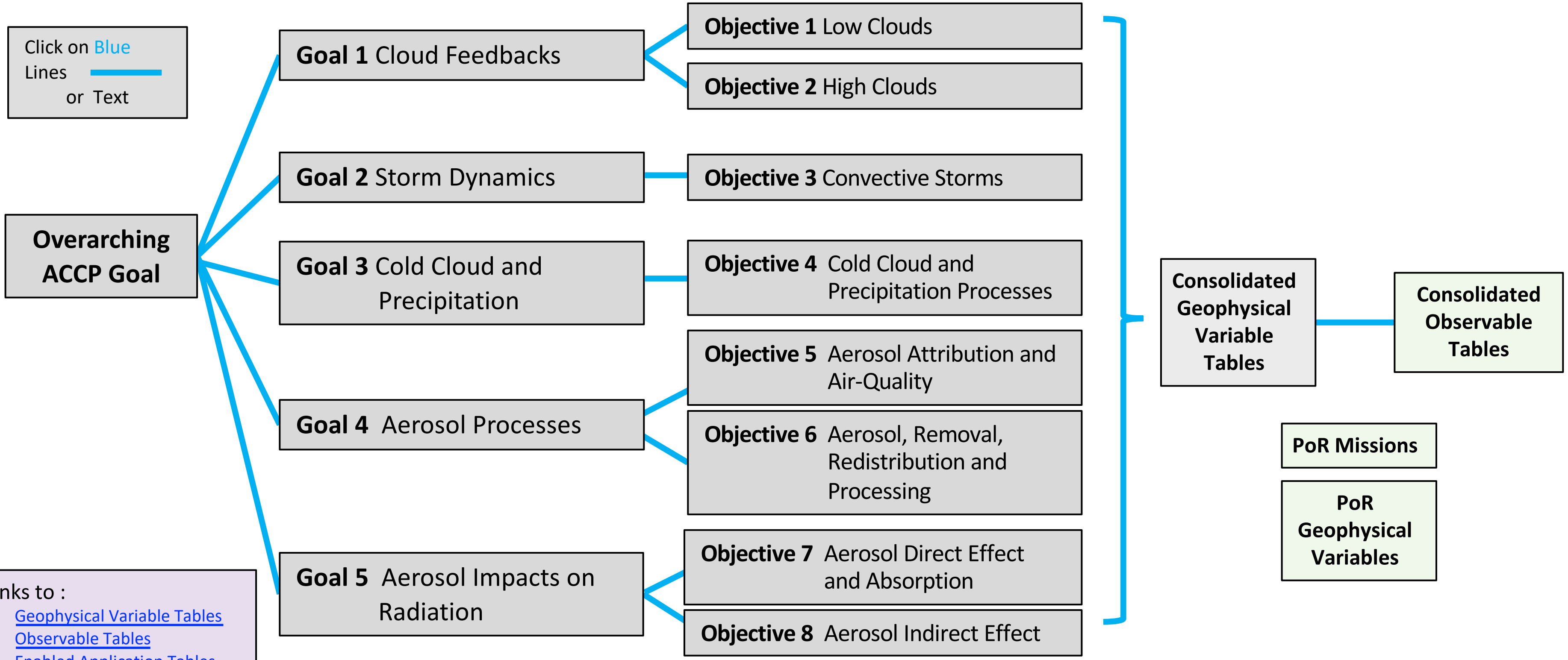


- ACCP will deliver integrated space-based, airborne, and ground-based observations fundamental to characterizing coupled aerosol-cloud-precipitation interactions that profoundly impact weather, air quality and climate and play a critical role in feedbacks to the global water and energy cycles.

- Central to this observing system are observations of the vertical structure of these constituents, along with the first-ever measurements of convective vertical mass transport and unprecedented aerosol microphysical and optical properties, using active profiling sensors unique to ACCP in the future global observing system.

- ACCP will integrate its own measurements with others using advanced modeling and algorithms to generate synergistic data for scientific research and in near real time for applications of societal and economic benefit.

ACCP SATM Navigation Map



Click on Blue Lines or Text

Overarching ACCP Goal

Goal 1 Cloud Feedbacks
- **Objective 1** Low Clouds
- **Objective 2** High Clouds

Goal 2 Storm Dynamics
- **Objective 3** Convective Storms

Goal 3 Cold Cloud and Precipitation
- **Objective 4** Cold Cloud and Precipitation Processes

Goal 4 Aerosol Processes
- **Objective 5** Aerosol Attribution and Air-Quality
- **Objective 6** Aerosol, Removal, Redistribution and Processing

Goal 5 Aerosol Impacts on Radiation
- **Objective 7** Aerosol Direct Effect and Absorption
- **Objective 8** Aerosol Indirect Effect

Consolidated Geophysical Variable Tables

Consolidated Observable Tables

PoR Missions

PoR Geophysical Variables

Links to :
- ❑ Geophysical Variable Tables
- ❑ Observable Tables
- ❑ Enabled Application Tables
- ❑ Handling Observing Modes
- ❑ Decadal Survey Tables
- ❑ Acronyms

Navigation buttons on next slides: ? Help Last slide viewed Return to here

Work in Progress

Overarching ACCP 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.	🟩	▨	▨	W-1a W-2a C-2a C-2g	**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.
	🟩		▨	W-1a W-2a W-4a C-2g H-1b C-5c	**G2** Storm Dynamics Improve our physical understanding and model representations of cloud, precipitation *and dynamical* processes within convective storms.
	🟩		▨	H-1b W-1a S-4a W-3a	**G3** Cold Cloud and Precipitation Improve understanding of cold (supercooled liquid, ice, and mixed phase) cloud processes and associated precipitation and their coupling to mid-to-high latitude water and energy cycles.
	🟩	▨		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

Mapping from Top DS Questions to ACCP Goals

Key MI DS Questions

W-4 (MI): Convective Storm Formation Processes. Why do convective storms, heavy precipitation, and clouds occur exactly when and where they do? [03] DC

W-5 (MI): Air Pollution Processes and Distribution. What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems? [O5, O6] DC

C-2 (I-MI): Climate Feedback and Sensitivity. How can we reduce the uncertainty in the amount of future warming of Earth, improve our ability to predict local and regional climate response to natural and anthropogenic forcings, and reduce the uncertainty in global climate sensitivity? [O1, O2, O3,O4, O7, O8] R

Related MI DS Objectives

W-4a (MI). 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.

W-5a (MI). Improve the understanding of the processes that determine air pollution distributions and aid estimation of global air pollution impacts on human health and ecosystems by reducing uncertainty to <10% of vertically-resolved tropospheric fields (including surface concentrations) of speciated particulate matter (PM), ozone (O3), and nitrogen dioxide (NO2).

C-2a (MI). Reduce uncertainty in low and high cloud feedback by a factor of 2.
C-2h (MI). Reduce the IPCC AR5 total aerosol radiative forcing uncertainty by a factor of 2.

Linked ACCP Goals

G2 Storm Dynamics
Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within convective storms

G4 Aerosol Processes
Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.

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

G2 Storm Dynamics (see above)

G3 Cold Cloud and Precipitation
Improve understanding of cold (supercooled liquid, ice, and mixed phase) cloud processes and associated precipitation and their coupling to mid-to-high latitude water and energy cycles

G5 Aerosol Impacts on Radiation
Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.

A+CCP	A	CCP	Goal	Example 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) 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	Example Science Question	Objectives
🟩		▨	**G2** Storm Dynamics *Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within convective storms*	1) *How does convective mass flux relate to the vertical distribution and microphysical properties of clouds and precipitation in deep convection?* 2) *How do different convective storm systems contribute to vertical transports of heat, water, and other constituents within the atmosphere and how do these transports relate to storm environment and lifecycle?*	**O3** Convective Storm Systems **Minimum:** Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading. **Enhanced:** Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life cycle, ambient aerosol profiles, and surface properties.

A+CCP	A	CCP	Goal	Example Science Questions	Objectives
🟩		▨	**G3** Cold Cloud and Precipitation *Improve understanding of cold (supercooled liquid, ice, and mixed phase) cloud processes and associated precipitation and their coupling to mid-to-high latitude energy and water cycles.*	*1) What is the distribution and phase of surface precipitation (rain, mixed phase, frozen and snowfall) and how does it influence the surface water and energy balance?* *2) What are the processes that govern phase partitioning and precipitation formation in cold clouds?* *3) What are the vertical structures of microphysics of cold-cloud precipitation from cloud top to near-surface and associated microphysical processes?* *4) How do mixed-phase properties of clouds impact their radiative properties and change the resultant radiative fluxes?*	**O4** Cold Cloud and Precipitation Processes **Minimum:** Detect and quantify vertically integrated amounts of ice and liquid condensate (including precipitation) and relate these to vertical structure, cloud physical and radiative properties (including mixed-phase precipitation and snowfall), meteorological forcing and regime, orography, and surface properties. **Enhanced:** Enhancement of Minimum with an additional focus on: 1) vertical profiles of ice and liquid condensate, 2) cloud physical processes related to the density and microphysical characterization of snowfall and frozen precipitation in the column and near surface, and 2) characterization of atmospheric contributions to the surface water mass and energy balance at higher latitudes.

A+CCP	A	CCP	Goal	Example Science Questions	Objectives
🟩	▨		**G4** Aerosol Processes *Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.*	1) *What are the major anthropogenic and natural sources of aerosol and how do they vary spatially and temporally?* 2) *What are the factors that relate aerosol microphysical and optical properties to surface PM concentrations?* 3) *To what extent does long-range transport of smoke, dust, and other particulates impact regional near-surface air quality?*	**O5** Aerosol Attribution and Air-Quality **Minimum:** Quantify optical and microphysical aerosol properties in the PBL and free troposphere to improve process understanding, estimates of aerosol emissions, speciation, and predictions of near-surface particulate matter concentrations. **Enhanced:** Characterize variations in vertical profiles of optical and microphysical properties over space and time in terms of 3D transport, spatially resolved emission sources and residual production and loss terms.
					O6 Aerosol Wet Removal, Vertical Redistribution and Processing **Minimum:** Relate the vertical structure of aerosol properties to cloud and precipitation properties to improve understanding of processes impacting aerosol vertical transport, removal, and overall lifecycle in light and moderate precipitation regimes (< 5 mm/hr). **Enhanced:** Extend minimum to include heavy precipitation regimes (> 5 mm/hr), aerosol processing (including gaseous and aqueous production) and vertical transport to UTLS region.

A+CCP	A	CCP	Goal	Example Science Questions	Objectives
🟩	▨		**G5** Aerosol Impacts on Radiation *Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.*	*1) How do changes in anthropogenic aerosols affect Earth's radiation budget and offset the warming due to greenhouse gases?* *2) What is the role of absorbing aerosols in the Earth's radiation budget and thermodynamics?* *3) Under what conditions do aerosols impact the albedo or coverage of shallow clouds and by how much?*	**O7** Aerosol Direct Effects and Absorption **Minimum**: Reduce uncertainties in estimates of: 1) global mean clear and all-sky shortwave direct radiative effects (DRE) to ±1.2 W/m^2 at TOA and the anthropogenic fraction, 2) regional TOA and surface DRE, and 3) Quantify the impacts of absorbing aerosol on atmospheric stability. **Enhanced:** Quantify the impact of absorbing aerosols on vertically resolved aerosol radiative heating rates and DRE commensurate with the uncertainties in global mean at TOA and surface.
🟩	▨				**O8** Aerosol Indirect Effect **Minimum**: Provide measurements to constrain process level understanding of *aerosol-warm cloud* interactions to improve estimates of aerosol indirect radiative forcing. **Enhanced:** Provide measurements to constrain process level understanding of interactions of aerosol with *cold and mixed-phase clouds* to improve estimates of aerosol indirect radiative forcing.

ACCP Science Objectives

1. Low Cloud Feedback
2. High Cloud Feedback
3. Convective Storm Systems
4. Cold Cloud & Precipitation
5. Aerosol Attribution and Air Quality
6. Aerosol Removal, Redistribution and Processing
7. Aerosol Direct Effect and Absorption
8. Aerosol Indirect Effect

A+CCP	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.

Approach

General Approach

a) Complement and where possible expand on existing climate data records. Examine inter-annual cloud property changes associated with cloud-controlling factors (*e.g.,* Klein et al., 2017.)

b) Quantify low cloud-controlling processes via multi-variate analysis *(e.g.,* Ming and Suzuki, 2018; etc)

c) With a) & b) combine with models to test and understand process couplings

Role of Models – primary tool to integrate observations, test understanding & examine impacts on feedbacks

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, enhance process understanding with enhanced property measurement.

New and Improved

a) Significant improvements of key cloud variables (LWP, cloud microphysics) including profiling, droplet concentrations, precipitation quantification

b) Significantly improved global analysis, model moist physics, and contextual PoR capabilities.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (1 of 2)		Qualifiers
					Minimum	Enhanced	
√	√	S	(√)	4.8	Cloud liquid water path		
√	√	S	(√)	4.7	Cloud optical depth		
√	√	S	(√)	4.7	Cloud droplet effective radius		
√	√	S	(√)	4.2	Cloud top phase		
√	√		(√)	4.7	Hydrometeor vertical feature mask		Cloud top height
√	√	S	(√)	4.0	Areal cloud fraction		
	√		(√)	3.3	Precipitation phase		Profile
	√		(√)	4.0	Precipitation rate		Profile, <2 mm/hr, near sfc
√			(√)	2.7	Planetary Boundary Layer Height		
			√	4.7	Environmental temperature		Profile
			√	4.7	Environmental humidity		Profile
			√	3.7	Environmental horizontal wind		Profile
			√	4.6	Environmental vertical wind		Profile
√				3.7	Scattering ratio		Profile, VIS
√				3.5	Full attenuation altitude		
√	√		(√)	4.3	Cloud radiative effects, SW & LW		Broadband, all sky – clear sky TOA flux diff.

A+CCP	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.

Approach

General Approach

a) Complement and where possible expand on existing climate data records. Examine inter-annual cloud property changes associated with cloud-controlling factors (e.g. Klein et al., 2017.)

b) Quantify low cloud-controlling processes via multi-variate analysis (e.g. Ming and Suzuki, 2018; etc)

c) With a) & b) combine with models to test and understand process couplings

Role of Models – primary tool to integrate observations, test understanding & examine impacts on feedbacks

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, enhance process understanding with enhanced property measurement.

New and Improved

a) Significant improvements of key cloud variables (LWP, cloud microphysics) including profiling, droplet concentrations, precipitation quantification

b) Significantly improved global analysis, model moist physics, and contextual PoR capabilities.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (2 of 2) Minimum / Enhanced	Qualifiers
	√			4.5	Cloud droplet concentration	Layer
√	√			3.8	Hydrometeor vertical feature mask	Cloud base ht
	√		(√)	4.0	Total liquid water path	
√				2.8	Scattering ratio	Profile, UV
√	√			3.0	Volumetric cloud fraction	
	√			4.0	In-Cloud Vertical Air Velocity	|> 1 m/s|, Profile
	√			4.1	Cloud-top vertical velocity	
	√			4.3	Cloud-top horizontal winds	
			√	3.7	Diurnally resolved cloud cover	
		S	√	4.0	Surface turbulent fluxes (land and ocean)	

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 environmental factors. **Enhanced**: Adds to Threshold microphysical properties of ice clouds.

Approach (1 of 2)

General Approach

a) Complement and where possible expand on existing climate data records. Examine inter-annual cloud property changes associated with cloud-controlling factors.
b) Quantification of high cloud-controlling processes, including convective transport, radiative heating, precipitation, via multi-variate analysis
c) With a) and b) combine with models to test and understand process couplings

Role of Models – primary tool to integrate observations, test understanding & examine impacts on feedbacks (*e.g.* between convection and high clouds)

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, advance process understanding with enhanced property measurement.

New and Improved

a) First time ability to make quantitative links to convective transport (vertical motion) , convective precipitation
b) Significant improvements of key cloud variables
c) Significantly improved global analysis, model moist physics, and contextual PoR capabilities.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (1 of 2)		Qualifiers
					Minimum	Enhanced	
	√		(√)	4.9	Ice Water Path		
	√		(√)	3.9	Ice Water Content		Profile
√	√	S	(√)	4.9	Cloud optical depth		
√	√			5.0	Hydrometeor vertical feature mask		
√			(√)	4.3	Cloud geometric-top temperature		
√			√	4.5	Cloud areal extent		
			√	3.7	Diurnally resolved cloud cover		
			√	3.8	Diurnally resolved cloud top height		
	√			4.4	In-cloud vertical air velocity		Profile, above melting layer at a minimum; Velocity minimum |>2 m/s|
	√			3.4	Precipitation phase		Profile, melt.lyr also
			√	3.9	Cloud lifecycle categories		
			√	4.4	Environmental temperature		Profile
	√		√	4.3	Environmental humidity		Profile
			√	4.3	Environmental horizontal wind		Profile
√	√		(√)	4.7	Cloud radiative effects, SW & LW		Broadband, all sky – clear sky TOA flux diff.
√				4.0	Scattering ratio		Profile, VIS
√				3.8	Full attenuation altitude		

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 environmental factors. **Enhanced**: Adds to Threshold microphysical properties of ice clouds.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (2 of 2)		Qualifiers
					Minimum	Enhanced	
	√		(√)	4.0	Precipitation rate		Profile
√	√			3.7	Ice crystal number concentration		Layer
√	√	S		3.8	Ice crystal particle size		
√				4.1	Particle asymmetry factor		
	√		√	4.2	Convective cloud cover		
√	√			4	Radiative heating rate, SW & LW		Profile, in-cloud
	√			4.2	In-cloud vertical air velocity		Full Profile,
√	√			3.4	Scattering ratio		Profile, UV
	√			3.6	Vertically integrated ice mass flux		ΔT GV
	√			3.4	Average vertical air velocity		ΔT GV
	√			4.4	Rate of change of ice water path		ΔT GV
	√			3.7	Height of maximum vertical motion		ΔT GV
	√			3.8	Magnitude of maximum vertical motion		ΔT GV

A+CCP	A	CCP	Objectives
🟩		▨	**O3** Convective Storm Systems **Minimum:** Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading. **Enhanced:** Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life cycle, ambient aerosol profiles, and surface properties.

Approach

General Approach - Establish global convective structure climatologies that statistically characterize deep convective processes through measurement of convective scale vertical motion, cloud, precipitation, and surrounding column aerosol properties. Leverage temporal/spatial coverage of GEO and LEO PoR with ground-based observations and global/regional analysis systems.

Role of models - testing and evaluation of ACCP observational impacts on improved model physical representation of convective cloud processes.

Role of Sub-orbital - In situ and improved space-time sampling of coupled convective precipitation processes over a full range of intensities, coupled evolution of convective detrainment and impacts on in situ anvil properties and lifecycle, and sensitivity to perturbations in the ambient cloud environment. Cal/val for satellite measurements and retrieval algorithms.

New and Improved - a) global convective scale vertical motion profiles and correlated process metrics, and b) measurements of hydrometeor structure and environment aerosol properties, PoR measurements and capabilities, and global model analysis resolution/physics.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (1 of 4)		Qualifiers
					Minimum	Enhanced	
	√			5.0	In-cloud vertical air velocity		Profile, above melting layer at a minimum; Velocity minimum |>2 m/s|
√	√		(√)	5.0	Hydrometeor vertical feature mask		E.g, reflectivity profile
√	√		(√)	4.5	Cloud geometric-top temperature		
√	√		(√)	3.5	Cloud top phase		
			√	3.7	Diurnally resolved cloud cover		PoR Primary; Context
			√	4.2	Diurnally resolved cloud top height		PoR Primary; Context
	√		(√)	5.0	Precipitation rate		Profile
	√		(√)	4.0	Precipitation phase		Profile, liquid/ mixed/frozen
	√		(√)	4.3	Ice water path		
	√		√	4.2	Convective classification		Org./intensity/depth; PoR for org. context
	√		(√)	4.5	Precipitation Discrimination (stratiform/convective)		
√				2.6	Scattering ratio		Profile, VIS
√				2.4	Full attenuation altitude		

A+CCP	A	CCP	Objectives
🟩		▨	**O3** Convective Storm Systems **Minimum:** Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading. **Enhanced:** Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life cycle, ambient aerosol profiles, and surface properties.

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New and Improved - a) global convective scale vertical motion profiles and correlated process metrics, and b) measurements of hydrometeor structure and environment aerosol properties, PoR measurements and capabilities, and global model analysis resolution/physics.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (2 of 4) Minimum Enhanced	Qualifiers
			√	5.0	Environmental temperature	Profile, used for stability parameters as well
			√	5.0	Environmental humidity	Profile, used for stability parameters as well
			√	4.5	Environmental horizontal wind	Profile, used for shear calculation
			√	4.0	Environmental vertical wind	Profile
√		S	(√)	4.0	Aerosol Optical Depth	Column and PBL UV, VIS, NIR
√				3.7	Aerosol Fine Mode Optical Depth	Column, PBL
√				3.7	Aerosol Non-spherical AOD Fraction	Column, PBL
			√	3.7	Lightning	PoR

A+CCP	A	CCP	Objectives
🟩		▨	**O3** Convective Storm Systems **Minimum:** Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading. **Enhanced:** Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life cycle, ambient aerosol profiles, and surface properties.

Approach

General Approach - Establish global convective structure climatologies that statistically characterize deep convective processes through measurement of convective scale vertical motion, cloud, precipitation, and surrounding column aerosol properties. Leverage temporal/spatial coverage of GEO and LEO PoR with ground-based observations and global/regional analysis systems.

Role of models - testing and evaluation of ACCP observational impacts on improved model physical representation of convective cloud processes.

Role of Sub-orbital - In situ and improved space-time sampling of coupled convective precipitation processes over a full range of intensities, coupled evolution of convective detrainment and impacts on in situ anvil properties and lifecycle, and sensitivity to perturbations in the ambient cloud environment. Cal/val for satellite measurements and retrieval algorithms.

New and Improved - a) global convective scale vertical motion profiles and correlated process metrics, and b) measurements of hydrometeor structure and environment aerosol properties, PoR measurements and capabilities, and global model analysis resolution/physics.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (3 of 4)		Qualifiers
					Minimum	**Enhanced**	
	√			5.0	In-cloud vertical air velocity		Profile, measure below melting layer; Velocity minimum |>2 m/s|
	√		(√)	4.0	Latent heating		Profile, vertical velocity constrained
√	√		(√)	4.0	Total liquid water path		Ice + liquid (full column)
	√		√	4.0	Cloud lifecycle categories		PoR or observing system temporal/area context
	√		(√)	4.0	Precipitation particle size		Profile, PSD char. diameter; multi-radar/radiometer frequency
	√		(√)	4.0	Precipitation rate, 2D @ surface		Swath-mapped precipitation rate
	√			4.3	Convective core size		Need swath view
√				3.8	Aerosol extinction		Profile, VIS, NIR
√				2.8	Aerosol effective radius		Profile
√				3.0	Aerosol non-spherical ext. fraction		Profile & column
√				3.3	Aerosol absorption		Profile
			√	4.0	Surface elevation		Topography
		S, D	√	3.5	Surface type		Land, water, coastline
		S, D	√	3.8	Surface classification		Land surface cover class
	(√)		v	3.8	Surface turbulent fluxes		Latent, sensible heat flux
√				3.7	Scattering ratio		Profile, UV

A+CCP	A	CCP	Objectives
🟩		▨	**O3** Convective Storm Systems **Minimum:** Relate vertical motion within convective storms to their a) cloud and precipitation structures, b) microphysical properties, c) local environment thermodynamic and kinematic factors such as temperature, humidity, and large-scale vertical motion, and d) ambient aerosol loading. **Enhanced:** Improve measurements of convective storm vertical motion and storm characteristics in (a) and (b) of the Minimum objective to better address deep convection and diurnal variability. Further relate items in the Minimum objective to latent heating profiles, storm life cycle, ambient aerosol profiles, and surface properties.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (4 of 4)		Qualifiers
					Minimum	Enhanced	
√				3.8	Aerosol Number Concentration		Profile
	√			3.8		Vertically integrated ice mass flux	ΔT GV
	√			3.9	Average vertical air velocity		ΔT GV
	√			4.1	Rate of change of ice water path		ΔT GV
	√			3.7		Height of maximum vertical motion	ΔT GV
	√			3.7		Magnitude of maximum vertical motion	ΔT GV

Approach

General Approach - Establish global convective structure climatologies that statistically characterize deep convective processes through measurement of convective scale vertical motion, cloud, precipitation, and surrounding column aerosol properties. Leverage temporal/spatial coverage of GEO and LEO PoR with ground-based observations and global/regional analysis systems.

Role of models - testing and evaluation of ACCP observational impacts on improved model physical representation of convective cloud processes.

Role of Sub-orbital - In situ and improved space-time sampling of coupled convective precipitation processes over a full range of intensities, coupled evolution of convective detrainment and impacts on in situ anvil properties and lifecycle, and sensitivity to perturbations in the ambient cloud environment. Cal/val for satellite measurements and retrieval algorithms.

New and Improved - a) global convective scale vertical motion profiles and correlated process metrics, and b) measurements of hydrometeor structure and environment aerosol properties, PoR measurements and capabilities, and global model analysis resolution/physics.

A+CCP	A	CCP	Objectives
🟩		▨	**O4** Cold Cloud and Precipitation Processes **Minimum:** Detect and quantify vertically integrated amounts of ice and liquid condensate (including precipitation) and relate these to vertical structure, cloud physical and radiative properties (including mixed-phase precipitation and snowfall), meteorological forcing and regime, orography, and surface properties. **Enhanced:** Enhancement of Minimum with an additional focus on: 1) vertical profiles of ice and liquid condensate, 2) cloud physical processes related to the density and microphysical characterization of snowfall and frozen precipitation in the column and near surface, and 2) characterization of atmospheric contributions to the surface water mass and energy balance at higher latitudes.

Approach (1 of 2)

General Approach

a) Multi-frequency, multi-sensor approach for improving snowfall rate and micro-physical properties (Grecu and Olson 2008, Grecu et al. 2018, Leinonen et al. 2018)

b) Characterization of vertical structures, profiles of snowfall rate and microphysical properties related statistically to forcing/regime, orography, sfc fluxes

c) PDFs of snowfall/cold cloud processes regionally, as a function of cloud depth (Kulie et al 2016); 2D histograms and contributions of snow rates in PDF to total snowfall, contributions as a function of GVs such as echo-top height, passive microwave TBs; climatologies of mixed-phase clouds

Role of Models – primary tool to integrate observations, test understanding & examine representation of cold cloud processes in models.

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, advance process understanding with in-situ & remotely sensed microphysical data.

New and Improved

a) Improved range of precipitation measurements

A	CCP	ODO	POR	Utility Score	Geophysical Variables (1 of 2) Minimum Enhanced	Qualifiers
√	√			4.3	Hydrometeor Vertical Feature Mask	
√				4.0	Cloud geometric-top temperature	
	√			4.8	Ice water path	
	√		(√)	5.0	Precipitation rate	Profile, near surface (<500 m)
	√		(√)	5.0	Precipitation phase	Profile
√	√		(√)	4.5	Total liquid water path	
√	√	S		4.3	Cloud phase	Profile
√	√		√	3.8	Cloud radiative effects, SW & LW	Broadband, all sky – clear sky TOA and sfc flux diff.
√				3.3	Scattering ratio	Profile, VIS
√				3.3	Full attenuation altitude	
			√	4.4	Environmental horizontal wind	Profile, from reanal.
			√	4.7	Environmental temperature	Profile, from reanal.
			√	4.5	Environmental humidity	Profile, from reanal.
			√	4.5	Surface elevation	Topography
		S, D	√	3.3	Surface type	Land, water, coastline
		S, D	√	2.8	Surface classification	Land surface cover class
	(√)		√	3.8	Surface turbulent fluxes	Latent, sensible

Approach (1 of 2)

a) Multi-sensor retrievals for constraints on both liquid and ice microphysical properties (e.g., precipitation rates, particle size, density of ice)

b) Possible information on vertical motion in regions of heavier snowfall rates

A+CCP	A	CCP	Objectives
🟩		▨	**O4** Cold Cloud and Precipitation Processes **Minimum:** Detect and quantify vertically integrated amounts of ice and liquid condensate (including precipitation) and relate these to vertical structure, cloud physical and radiative properties (including mixed-phase precipitation and snowfall), meteorological forcing and regime, orography, and surface properties. **Enhanced:** Enhancement of Minimum with an additional focus on: 1) vertical profiles of ice and liquid condensate, 2) cloud physical processes related to the density and microphysical characterization of snowfall and frozen precipitation in the column and near surface~~,~~ and 2) characterization of atmospheric contributions to the surface water mass and energy balance at higher latitudes.

Approach (1 of 2)

General Approach

a) Multi-frequency, multi-sensor approach for improving snowfall rate and micro-physical properties (Grecu and Olson 2008, Grecu et al. 2018, Leinonen et al. 2018)

b) Characterization of vertical structures, profiles of snowfall rate and microphysical properties related statistically to forcing/regime, orography, sfc fluxes

c) PDFs of snowfall/cold cloud processes regionally, as a function of cloud depth (Kulie et al 2016); 2D histograms and contributions of snow rates in PDF to total snowfall, contributions as a function of GVs such as echo-top height, passive microwave TBs; climatologies of mixed-phase clouds

Role of Models – primary tool to integrate observations, test understanding & examine representation of cold cloud processes in models.

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, advance process understanding with in-situ & remotely sensed microphysical data.

New and Improved

a) Improved range of precipitation measurements

A	CCP	ODO	POR	Utility Score	Geophysical Variables (2 of 2)		Qualifiers
					Minimum	Enhanced	
	√			4.3	Ice water content		Profile
	√			3.8	Liquid water content		Profile
	√			4.5	Precipitation particle size		Profile, all phases
√				3.8	Particle shape (aspect ratio, roughness)		
	√			4.5	Precipitation (ice) particle density		Profile
				4.8	Precipitation rate, 2D@surface		Swath-mapped precipitation rate
	√			3.5	In-cloud vertical air velocity		Profile
	√			3.8	Areal cloud fraction		
√				3.8	Blowing surface snow detection		
√	√	S	(√)	3.3	Cloud optical depth		
√				3.1	Scattering ratio		Profile, UV
√	√		√	3.6	Surface and TOA radiation fluxes		LW, SW broadband. Monthly fluxes

Approach (1 of 2)

a) Multi-sensor retrievals for constraints on both liquid and ice microphysical properties (e.g., precipitation rates, particle size, density of ice)

b) Possible information on vertical motion in regions of heavier snowfall rates

A+CCP	A	CCP	Objectives
🟩	▨		**O5** Aerosol Attribution and Air Quality **Minimum**: Quantify optical and microphysical aerosol properties in the PBL and free troposphere to improve process understanding, estimates of aerosol emissions, speciation, and predictions of near-surface particulate matter concentrations. **Enhanced**: Characterize changes in vertical profiles of optical and microphysical properties over space and time in terms of 3D transport, spatially resolved emission sources and residual production and loss terms.

Approach (1 of 2)

General Approach

a) Use ACCP measurements to estimate aerosol speciation using the following approaches:
   1) Optimal estimation algorithm using as prior aerosol state from an assimilation system that incorporates the aerosol PoR
   2) Empirical aerosol typing based on clustering of aerosol optical properties
b) Inverse calculations used to assess impact on emissions, and through revised emissions impact on forecasts of near-surface particulate concentrations
c) Model sensitivity studies, validated by ACCP data, used to gain insight into process parameterizations.
d) Complement and where possible expand on existing climate data records. Examine inter-annual variability of aerosol emissions, optical properties and impact on global AQ.

Role of Models – primary tool to integrate observations, test understanding & examine impacts and feedbacks.

A	CCP	ODO	POR	Utility Score Land: 0.7 Ocean: 0.3	Geophysical Variables (1 of 3)		Qualifiers
					Minimum	Enhanced	
√				(3,1.2)	Aerosol Extinction (Total)		VIS, NIR Profile (PBL,above)
√				(3,1.2)	Aerosol Non-spherical Extinction Fraction		VIS, NIR Profile (PBL,above)
√		S	(√)	(2,3)	Aerosol Optical Depth		UV, VIS, NIR Column,PBL
√				(1.8,2.6)	Aerosol Absorption Optical Depth		UV, VIS Column, PBL
√				(1.8,2.6)	Aerosol Fine Mode Optical Depth		UV, VIS Column, PBL
√			(√)	(0.7,1.1)	Aerosol Real Index of Refraction		UV, VIS Column, PBL
√			(√)	(0.7,1.1)	Aerosol Imaginary Index of Refraction		UV, VIS Column, PBL
√				(1.8,3)	Aerosol Non-Spherical AOD Fraction		UV, VIS Column, PBL
√				(1.2,3)	Aerosol Extinction to Backscatter Ratio		UV, VIS, NIR Column, PBL
√				4.8	Aerosol-Cloud Feature Mask		Profile

Approach (2 of 2)

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, advance process understanding with enhanced property measurement. Linking of optical to chemical aerosol properties.

New and Improved

a) Significant improvements of key aerosol variables (vertically/spectrally resolved aerosol absorption and extinction, fine mode fraction over land, etc.)
b) Improved global emissions and near surface aerosol characterization, with benefits for AQ analysis and forecasts.

A+CCP	A	CCP	Objectives
🟩	▨		**O5** Aerosol Attribution and Air Quality **Minimum**: Quantify optical and microphysical aerosol properties in the PBL and free troposphere to improve process understanding, estimates of aerosol emissions, speciation, and predictions of near-surface particulate matter concentrations. **Enhanced**: Characterize changes in vertical profiles of optical and microphysical properties over space and time in terms of 3D transport, spatially resolved emission sources and residual production and loss terms.

A	CCP	ODO	POR	Utility Score Land: 0.7 Ocean: 0.3	Geophysical Variables (2 of 3)		Qualifiers
					Minimum	**Enhanced**	
√				3.6	Scattering ratio		VIS Profile
√			(√)	4.1	Planetary Boundary Layer Height		
			√	4.2	Environmental Temperature		Profile
			√	4.2	Environmental Humidity		Profile
				(1.8,2.6)	Aerosol Effective Radius		Column, PBL
√			(√)	4.8		Aerosol PM2.5 Concentration	Surface
√				(2.8,1.8)		Aerosol Effective Radius	Profile (PBL,above)
√				(2.8,1.8)		Aerosol Absorption	UV, VIS Profile(PBL,above)
√				(3,2)		Aerosol Fine Mode Extinction	UV, VIS Profile (PBL,above)
√				(3,2)		Aerosol Extinction to Backscatter	UV, VIS Profile (PBL,above)
√				(3,2)		Aerosol extinction (total)	UV Profile(PBL,above)

Approach (1 of 2)

General Approach

a) Use ACCP measurements to estimate aerosol speciation using the following approaches:
   1) Optimal estimation algorithm using as prior aerosol state from an assimilation system that incorporates the aerosol PoR
   2) Empirical aerosol typing based on clustering of aerosol optical properties
b) Inverse calculations used to assess impact on emissions, and through revised emissions impact on forecasts of near-surface particulate concentrations
c) Model sensitivity studies, validated by ACCP data, used to gain insight into process parameterizations.
d) Complement and where possible expand on existing climate data records. Examine inter-annual variability of aerosol emissions, optical properties and impact on global AQ.

Role of Models – primary tool to integrate observations, test understanding & examine impacts and feedbacks.

Approach (2 of 2)

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, advance process understanding with enhanced property measurement. Linking of optical to chemical aerosol properties.

New and Improved

a) Significant improvements of key aerosol variables (vertically/spectrally resolved aerosol absorption and extinction, fine mode fraction over land, etc.)
b) Improved global emissions and near surface aerosol characterization, with benefits for AQ analysis and forecasts.

A+CCP	A	CCP	Objectives
🟩	▨		**O5** Aerosol Attribution and Air Quality **Minimum:** Quantify optical and microphysical aerosol properties in the PBL and free troposphere to improve process understanding, estimates of aerosol emissions, speciation, and predictions of near-surface particulate concentrations. **Enhanced:** Characterize changes in vertical profiles of optical and microphysical properties over space and time in terms of 3D transport, spatially resolved emission sources and residual production and loss terms.

A	CCP	ODO	POR	Utility Score Land: 0.7 Ocean: 0.3	Geophysical Variables (3 of 3)		Qualifiers
					Minimum	**Enhanced**	
√				3.0	Scattering ratio		UV Profile
√				3.0	Aerosol Plume-top Vertical Velocity		
√				3.0	Aerosol Plume-top Horizontal Velocity		
			√	4.3	Environmental Horizontal Wind		Profile
			√	4.0	Environmental Vertical Wind		Profile

Approach (1 of 2)

General Approach

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  1) Optimal estimation algorithm using as prior aerosol state from an assimilation system that incorporates the aerosol PoR
  2) Empirical aerosol typing based on clustering of aerosol optical properties
b) Inverse calculations used to assess impact on emissions, and through revised emissions impact on forecasts of near-surface particulate concentrations
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d) Complement and where possible expand on existing climate data records. Examine inter-annual variability of aerosol emissions, optical properties and impact on global AQ.

Role of Models – primary tool to integrate observations, test understanding & examine impacts and feedbacks.

Approach (2 of 2)

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, advance process understanding with enhanced property measurement. Linking of optical to chemical aerosol properties.

New and Improved

a) Significant improvements of key aerosol variables (vertically/spectrally resolved aerosol absorption and extinction, fine mode fraction over land, etc.)
b) Improved global emissions and near surface aerosol characterization, with benefits for AQ analysis and forecasts.

A+CCP	A	CCP	Objectives
🟩			**O6 Aerosol Wet Removal, Vertical Redistribution and Processing** **Minimum:** Relate the vertical structure of aerosol properties to cloud and precipitation properties to improve understanding of processes impacting aerosol vertical transport, removal, and overall lifecycle in light and moderate precipitation regimes (< 5 mm/hr). **Enhanced:** Extend minimum to include heavy precipitation regimes (> 5 mm/hr), aerosol processing (including gaseous and aqueous production) and vertical transport to UTLS region.

Approach – 1 of 2

General Approach

a) Use ACCP observations to estimate aerosol amount, size and optical properties using following approaches:
   1) Optimal estimation algorithm using as prior aerosol state from an assimilation system that incorporates the aerosol PoR
   2) Self-contained aerosol retrievals obtained with ACCP active and passive measurements and PoR if co-located.

b) Approach for Processing and Removal rely on geostationary passive aerosol data to characterize aerosol removal processes before and after clouds/precipitation events.

c) Changes in aerosol properties (size, absorption, etc.) will be used to characterize processing. Reduction in aerosol amount will be used to characterize removal, alongside concurrent cloud and precipitation properties.

d) Complement and where possible expand on existing climate data records. Examine inter-annual variability of aerosol processing and removal.

Role of Models – primary tool to integrate observations, test understanding & examine impacts and feedbacks.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (1 of 3)		Qualifiers
					Minimum	**Enhanced**	
	√		(√)	4.5	Total Liquid Water Path		
√	√	S	(√)	4.0	Cloud Optical Depth		
√	√	S	(√)	5.0	Cloud Droplet Effective Radius		
	√		(√)	4.5	Precipitation rate, 2D @ surface		< 2mm/hr
	√		(√)	4.0	Precipitation Phase		Profile, near-surface included
	√		(√)	4.8	Precipitation Rate		Profile, near-surface included, < 2mm/hr
			√	4.4	Environmental Temperature		Profile
			√	4.4	Environmental Humidity		Profile
			√	3.8	Environmental Horizontal Wind		Profile
			√	4.4	Environmental Vertical Wind		Profile
√			(√)	4.5	Planetary Boundary Layer Height		

Approach – 2 of 2

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, enhance process understanding with enhanced property measurement. Unless space component include multiple ACCP satellites on a train, a comprehensive campaign is necessary to address aerosol redistribution.

New and Improved

a) Significant improvements of key aerosol variables (vertically resolved aerosol absorption and extinction, fine mode fraction over land, etc.)

b) By means of the concurrent A and CCP measurements we will achieve significantly improved global analysis, model representation of key aerosol processes, and contextual PoR capabilities.

A+CCP	A	CCP	Objectives
🟩			**O6 Aerosol Wet Removal, Vertical Redistribution and Processing** **Minimum:** Relate the vertical structure of aerosol properties to cloud and precipitation properties to improve understanding of processes impacting aerosol vertical transport, removal, and overall lifecycle in light and moderate precipitation regimes (< 5 mm/hr). **Enhanced:** Extend minimum to include heavy precipitation regimes (> 5 mm/hr), aerosol processing (including gaseous and aqueous production) and vertical transport to UTLS region.

Approach – 1 of 2

General Approach

a) Use ACCP observations to estimate aerosol amount, size and optical properties using following approaches:
   1) Optimal estimation algorithm using as prior aerosol state from an assimilation system that incorporates the aerosol PoR
   2) Self-contained aerosol retrievals obtained with ACCP active and passive measurements and PoR if co-located.

b) Approach for Processing and Removal rely on geostationary passive aerosol data to characterize aerosol removal processes before and after clouds/precipitation events.

c) Changes in aerosol properties (size, absorption, etc.) will be used to characterize processing. Reduction in aerosol amount will be used to characterize removal, alongside concurrent cloud and precipitation properties.

d) Complement and where possible expand on existing climate data records. Examine inter-annual variability of aerosol processing and removal.

Role of Models – primary tool to integrate observations, test understanding & examine impacts and feedbacks.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (2 of 3)		Qualifiers
					Minimum	Enhanced	
√				(3,2)	Aerosol Extinction (Total)		VIS & NIR Profile (PBL,above)
				(3,2)	Aerosol Non-spherical Extinction Fraction		VIS & NIR Profile (PBL, above)
√		S	(√)	(1.8,3)	Aerosol Optical Depth		UV, VIS, NIR Column, PBL
√				(1.6,2.4)	Aerosol Absorption Optical Depth		UV & VIS Column, PBL
√				(1.8,2.7)	Aerosol Fine Mode Optical Depth		UV, VIS Column, PBL
				(1.8,2.7)	Aerosol effective radius		Column, PBL
√			(√)	(1.6,2.4)	Aerosol Real Index of Refraction		UV, VIS Column, PBL
√			(√)	(1.6,2.4)	Aerosol Imaginary Index of Refraction		UV, VIS Column, PBL
√				(1.8,2.7)	Aerosol Non-spherical AOD Fraction		UV, VIS Column, PBL

Approach – 2 of 2

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, enhance process understanding with enhanced property measurement. Unless space component include multiple ACCP satellites on a train, a comprehensive campaign is necessary to address aerosol redistribution.

New and Improved

a) Significant improvements of key aerosol variables (vertically resolved aerosol absorption and extinction, fine mode fraction over land, etc.)

b) By means of the concurrent A and CCP measurements we will achieve significantly improved global analysis, model representation of key aerosol processes, and contextual PoR capabilities.

A+CCP	A	CCP	Objectives
🟩			**O6** Aerosol Wet Removal, Vertical Redistribution and Processing **Minimum:** Relate the vertical structure of aerosol properties to cloud and precipitation properties to improve understanding of processes impacting aerosol vertical transport, removal, and overall lifecycle in light and moderate precipitation regimes (< 5 mm/hr). **Enhanced:** Extend minimum to include heavy precipitation regimes (> 5 mm/hr), aerosol processing (including gaseous and aqueous production) and vertical transport to UTLS region.

Approach – 1 of 2

General Approach

a) Use ACCP observations to estimate aerosol amount, size and optical properties using following approaches:
   1) Optimal estimation algorithm using as prior aerosol state from an assimilation system that incorporates the aerosol PoR
   2) Self-contained aerosol retrievals obtained with ACCP active and passive measurements and PoR if co-located.

b) Approach for Processing and Removal rely on geostationary passive aerosol data to characterize aerosol removal processes before and after clouds/precipitation events.

c) Changes in aerosol properties (size, absorption, etc.) will be used to characterize processing. Reduction in aerosol amount will be used to characterize removal, alongside concurrent cloud and precipitation properties.

d) Complement and where possible expand on existing climate data records. Examine inter-annual variability of aerosol processing and removal.

Role of Models – primary tool to integrate observations, test understanding & examine impacts and feedbacks.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (3 of 3) Minimum Enhanced	Qualifiers
√				(1.4,2.1)	Aerosol Extinction to Backscatter Ratio	UV, VIS Column, PBL
√				4.8	Aerosol-Cloud Feature Mask	Profile
√				(3,2)	Aerosol Effective Radius	Profile
√				(2.7,18)	Aerosol Absorption	UV & VIS Profile (PBL,above)
			√	3.6	Environmental Horizontal Wind	Profile (PBL,above)
			√	4.0	Environmental Vertical Wind	Profile (PBL,aboive)
√				(2.9,1.9)	Aerosol Fine Mode Extinction	UV, Vis Profile (PBL,above)
	√		(√)	4.8	Precipitation Rate	Profile,> 2mm/hr
√	√			4.0	Volumetric Cloud Fraction	
	√			4.0	In-Cloud Vertical Air Velocity	Profile, |> 2 m/s|
√				(3,2)	Aerosol Extinction to Backscatter Ratio	UV, VIS Profile (PBL,above)

Approach – 2 of 2

Role of Sub-orbital – cal/val variable retrievals, validate process interpretation, enhance process understanding with enhanced property measurement. Unless space component include multiple ACCP satellites on a train, a comprehensive campaign is necessary to address aerosol redistribution.

New and Improved

a) Significant improvements of key aerosol variables (vertically resolved aerosol absorption and extinction, fine mode fraction over land, etc.)

b) By means of the concurrent A and CCP measurements we will achieve significantly improved global analysis, model representation of key aerosol processes, and contextual PoR capabilities.

A+CCP	A	CCP	Objectives
🟩	▨		**O7** Aerosol Direct Effects and Absorption **Minimum**: Reduce uncertainties in estimates of: 1) global mean clear and all-sky shortwave direct radiative effects (DRE) to ±1.2 W/m^2 at TOA and the anthropogenic fraction, 2) regional TOA and surface DRE, and 3) Quantify the impacts of absorbing aerosol on atmospheric stability. **Enhanced:** Quantify the impact of absorbing aerosols on vertically resolved aerosol radiative heating rates and DRE commensurate with the uncertainties in global mean at TOA and surface.

Approach

General approach

a) Compute TOA SW aerosol direct radiative effect from observed aerosol and cloud properties (*e.g.,* Oikawa et al 2018; Thorsen et al 2019)
b) Estimate anthropogenic fraction of DRE using aerosol speciation approaches as in O5 and O6.
c) Estimate atmospheric heating due to aerosol absorption.
d) Characterize changes in atmospheric stability due to aerosol absorption

Role of models - used to estimate impacts of aerosol absorption on atmospheric heating and aerosol-cloud radiative interactions.

Role of Sub-orbital – validation of satellite retrievals, aerosol optical models.

New and Improved - Significant improvements in key aerosol variables (extinction profiles, absorption, size), especially over land.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (1 of 2)		Qualifiers
					Minimum	Enhanced	
√				(1.5,2.3)	Aerosol Extinction (Total)		VIS & NIR, Profile (PBL,above)
				(1.5,2.3)	Aerosol Non-spherical Extinction Fraction		VIS & NIR Profile (PBL, above PBL)
√		S	(√)	(3,2)	Aerosol Optical Depth		UV, VIS, NIR Column, PBL
√			(√)	(3,2)	Aerosol Absorption Optical Depth		UV,VIS Column, PBL
√			(√)	(2.7,1.8)	Aerosol Fine Mode Optical Depth		UV, VIS Column, PBL
				(2.7,1.8)	Aerosol Effective Radius		Column, PBL
√			(√)	(2.4,1.6)	Aerosol Real Index of Refraction		UV, VIS Column, PBL
√			(√)	(2.4,1.6)	Aerosol Imaginary Index of Refraction		UV, VIS Column, PBL
√				(2.6,1.7)	Aerosol Asymmetry Parameter		VIS Colum, PBL
√				(2.8,1.9)	Aerosol Non-Spherical extinction Fraction		UV, VIS Column, PBL
√				3.5	Aerosol Extinction to Backscatter Ratio		UV, VIS ~~VIS, NIR,~~ column
√				5.0	Aerosol-Cloud Feature Mask		Profile
			√	4.6	Environmental Temperature		Profile
			√	4.6	Environmental Humidity		Profile
√			√	4.4	Surface Albedo		
√	√			3.3	Cloud Optical Depth		
√	√		(√)	2.5	Cloud Droplet Effective Radius		
x	√			4.8	Areal Cloud Fraction		
√	√		√	3.5	Radiative fluxes (derived)		SW Surface, TOA

A+CCP	A	CCP	Objectives
🟩	▨		**O7** Aerosol Direct Effects and Absorption **Minimum**: Reduce uncertainties in estimates of: 1) global mean clear and all-sky shortwave direct radiative effects (DRE) to ±1.2 W/m^2 at TOA and the anthropogenic fraction, 2) regional TOA and surface DRE, and 3) Quantify the impacts of absorbing aerosol on atmospheric stability. **Enhanced**: Quantify the impact of absorbing aerosols on vertically resolved aerosol radiative heating rates and DRE commensurate with the uncertainties in global mean at TOA and surface.

Approach

General approach

a) Compute TOA SW aerosol direct radiative effect from observed aerosol and cloud properties (*e.g.,* Oikawa et al 2018; Thorsen et al 2019)
b) Estimate anthropogenic fraction of DRE using aerosol speciation approaches as in O5 and O6.
c) Estimate atmospheric heating due to aerosol absorption.
d) Characterize changes in atmospheric stability due to aerosol absorption

Role of models - used to estimate impacts of aerosol absorption on atmospheric heating and aerosol-cloud radiative interactions.

Role of Sub-orbital – validation of satellite retrievals, aerosol optical models.

New and Improved - Significant improvements in key aerosol variables (extinction profiles, absorption, size), especially over land.

A	CCP	ODO	POR	Utility Score	Geophysical Variables (2 of 2)		Qualifiers
					Minimum	Enhanced	
√	√		√	3.5	Radiative fluxes (derived)		LW Surface, TOA
√				(2,3)	Aerosol Effective Radius		Profile
√				(2,3)	Aerosol Absorption		UV,VIS Profile (PBL,above)
√				(1.8,2.7)	Aerosol Fine Mode Extinction		UV, VIS Profile (PBL,above)
√	√		√	3.7	Radiative heating rate, SW		Profile, aerosol
				(2,3)	Aerosol Extinction to Backscatter		UV, VIS Profile

A+CCP	A	CCP	Objectives
🟩			**O8** Aerosol Indirect Effect **Minimum**: Provide measurements to constrain process level understanding of *aerosol-warm cloud* interactions as a means to improve estimates of aerosol indirect radiative forcings. **Enhanced:** Provide measurements to constrain process level understanding of interactions of aerosol with *cold and mixed-phase clouds* as a means to improve estimates of aerosol indirect radiative forcing.

Approach

General Approach - Measure a suite of cloud and aerosol variables to improve estimates of aerosol indirect radiative forcing via process-level understanding. The observational strategy focuses on joint statistics to characterize physical processes and higher-level relationships between cloud, aerosol, precipitation, and radiation and comparisons with model simulations. (Chen et al 2016; Mulmenstad and Feingold 2018)

Role of Models - LES simulations will be used to test and understand process couplings (Feingold et al. 2016)

Role of Sub-orbital - More extensive validation of key satellite retrievals is needed, long-term surface observations combined with modeling will enhance process understanding (Sena et al 2016)

New and Improved - Significant improvements of key aerosol and cloud variables (aerosol amount and size, cloud LWP and microphysics including profiling, droplet concentrations, precipitation quantification)

A	CCP	ODO	POR	Utility Score Land: 0.3 Ocean: 0.7	**Geophysical Variables (1 of 3)**		**Qualifiers**
					Minimum	**Enhanced**	
√		S	(√)	(0,4.6)	Aerosol Optical Depth		UV, VIS, NIR Column, PBL
√				(0,4.4)	Aerosol Fine Mode Optical Depth		UV, VIS Column, PBL
√				(4.6,0)	Aerosol Extinction (Total)		VIS & NIR Profile (PBL,above)
√				(4,0)	Aerosol Non-spherical Extinction Fraction		VIS & NIR Profile (PBL,above)
√			(√)	(0,4.6)	Aerosol Absorption Optical Depth		UV-VIS Column, PBL
√				(0,4)	Aerosol Effective Radius		Column, PBL
√				5.0	Aerosol-Cloud Feature Mask		
√	√		(√)	5.0	Cloud Liquid Water Path		
√			(√)	4.8	Cloud Optical Depth		
√			(√)	5.0	Cloud Droplet Effective Radius		
√	√			4.8	Cloud Droplet Concentration		Cloud Layer
√				4.2	Cloud Top Phase		
√			√	4.5	Areal Cloud Fraction		
√	√			5.0	Cloud radiative effects, SW & LW		Broadband, all sky – clear sky TOA flux diff.
√				5.0	Cloud Albedo		
√				4.0	Scattering ratio		Profile, VIS
	√		(√)	4.2	Precipitation Rate		Profile, <2 mm/hr; near surface desired

A+CCP	A	CCP	Objectives
🟩			**O8** Aerosol Indirect Effect **Minimum**: Provide measurements to constrain process level understanding of *aerosol-warm cloud* interactions as a means to improve estimates of aerosol indirect radiative forcings. **Enhanced:** Provide measurements to constrain process level understanding of interactions of aerosol with *cold and mixed-phase clouds* as a means to improve estimates of aerosol indirect radiative forcing.

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A	CCP	ODO	POR	Utility Score Land: 0.3 Ocean: 0.7	Geophysical Variables (2 of 3)		Qualifiers
					Minimum	Enhanced	
√			(√)	4.3	Planetary Boundary Layer height		Lidar and reanalysis
			√	3.6	Environmental Horizontal Wind		Profile
			√	4.2	Environmental Vertical Wind		Profile
				4.8	Environmental Humidity		Profile
				4.8	Environmental Temperature		Profile
√				(4.8,0)		Aerosol Number Concentration	Profile (PBL,above)
√				(4.8,0)		Aerosol Effective Radius	Profile(PBL,above)
√	√			4.8		Cloud Droplet Concentration	Layer
√				3.0		Cloud Droplet Effective Variance	
√				4.3		Cloud Top Extinction	
√				4.7		Cloud Top Droplet Size	
√				5.0		Cloud Top Droplet Concentration	
√	√			4.7		Hydrometeor vertical feature mask	Cloud base height
	√			4.0		In-Cloud Vertical Air Velocity	|> 1 m/s|, Profile
	√		(√)	4.0		Precipitation Phase	Profile, near surface included/desired
			√	3.6		Diurnally Resolved Cloud Cover	
			√	3.9		Surface Turbulent Fluxes	Sensible, Latent Land and Ocean

A+CCP	A	CCP	Objectives
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A	CCP	ODO	POR	Utility Score	Geophysical Variables (3 of 3)		Qualifiers
					Minimum	Enhanced	
√	√			4.3	Ice Crystal Number Concentration		
√	√			4.7	Ice Crystal Particle Size		
	√			4.7	Cloud Top Droplet Effective Radius		
	√			4.7	Ice Water Path		
	√			3.8	Cloud-top vertical velocity		
	√			3.9	Cloud-top horizontal winds		
√				3.2	Scattering ratio		Profile, UV

Approach

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Consolidated Geophysical Variables (1 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
AABS.z	Aerosol Absorption (Profile)	O3,O5,O6, O7	SSA: 0.6-1.0	SSA: ±0.03	50 km	500 m	M	Nadir	UV-VIS	2, 6, 12
AAOD.ℓ	Aerosol Absorption Optical Depth (Column,PBL)	O5, O6, O7	SSA: 0.6-1.0	SSA: ±0.04	(1,50) km	N/A	I	100 km	*UV-VIS for column* *VIS for PBL*	2, 4, 6,12
				SSA: ±0.02	(1,25) km					
ACF	Areal Cloud fraction	O1, O4, O7, O8	0.0 - 1.0	0.1	O1,O4,O7: 200m O8: 100 m*	N/A	I, M	Nadir*	PoR: ABI, AHI, etc.; VIIRS * Lidar # Polarimeter or spectrometer	4,
					200 $m^{\#}$			$100km^{\#}$		
ASYM	Aerosol Asymmetry Parameter	O7	0.5-1.0	±0.02	1 km	N/A	I	100 km	*UV-VIS (scales listed are for column retrievals from polarimeter)*	3
ACFM.z	§Aerosol-Cloud Feature Mask (Profile)	O5,O6,O7, O8	N/A	1%, for OD > 0.1	Foot-print	100 m	I	Nadir	Lidar, includes cloud top/base height; *an aerosol detection accuracy of 90% is desired with a 1% false positive rate (i.e. aerosol layers contaminated with clouds); base height of opaque, non-precipitating clouds comes from HVFM*	1, 2, 3, 5, 6

§ Note: this is also an issue for polarimeter – not addressed yet

Consolidated Geophysical Variables (2 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
AEFR.z	Aerosol Effective Radius (Profile)	O3, O5, O6, O7, O8	0.1-0.5 μm	±20% for extinction > 0.05 km^{-1}	50 km	500 m	M	Nadir	Total attenuated backscatter profiles at UV, mid-visible and near IR; Attenuated molecular backscatter at UV and mid-visible wavelength; Volume depolarization ratio UV, VIS, NIR	1, 2, 6, 7, 12, 13, 14
AER.ℓ	Aerosol Effective Radius (Column, PBL)	O7, O8	0.1 to 1 μm	0.1 um or 10%	(1,50) km (1,25) km	N/A	I	100 km	*polarized radiances, 1 km resolution desirable to resolve cloud adjacency effects*	1, 2, 6, 12, 13, 14
AEXT.z	Aerosol Extinction (Profile, Total)	O5, O6, O7, O8	0.01–5 km^{-1}	Max of (0.02 km^{-1}, ±20%)	5 km	30 m	I	Nadir	Backscatter profiles at VIS, NIR *O3 match to O6, depth of trop., vicinity of convection; At least two wavelengths in order to retrieve AOT, Angstrom exponent, SSA, fine mode AOD, etc. for just the PBL portion of column. (±20% for retrieving fine mode AOD in PBL using the combination of measurements in VIS and NIR)*	1, 2, 6, 12, 13, 14
		O3			1 km				*Backscatter profile at UV for O5*	
AE2BR.z	Aerosol Extinction to Backscatter Ratio (Profile)	O5	10-120 sr	±25%	50 km	500m	I	Nadir		N/A
AE2BR.ℓ	Aerosol Extinction to Backscatter Ratio (Column,PBL)	O5, O6, O7	10-120 sr	±25%	(1,50) km	N/A				N/A
					(1,25) km	N/A				N/A

Consolidated Geophysical Variables (3 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
AEXTF.z	Aerosol Fine Mode Extinction Profile	O5, O6, O7	0.01–5 km^{-1}	Max of (0.02 km^{-1}, 20%)	50 km	500 m	I	Nadir	Total attenuated backscatter profiles at UV, mid-visible and near IR; Attenuated molecular backscatter at UV and mid-visible wavelength, Volume depolarization ratio UV, VIS, NIR	2, 6, 13, 14 (for inference of PM from AOD)
AIIR.ℓ	Aerosol Imaginary Index of Refraction (Column,PBL)	O5, O6,O7	0-0.1	±0.025	(1,50) km (1,25) km	N/A	I			4, 6 (to identify smoke)
ANC.z	Aerosol Number Concentration Profile	O8	10-1000 cm^{-3}	50%	50 km	500 m				2, 3, 5, 13,14
ANSPH.ℓ	Aerosol Non-spherical AOD Fraction (Column,PBL)	O5, O6, O7 O3	0-1	±10%	(1,50) km (1,25) km	N/A	I	100 km	*O7: column only*	4, 6
ANSPH.z	Aerosol Non-spherical Extinction Fraction Profile	O5 O3	0-1	±10%	50 km	500 m	I	Nadir	*Two wavelengths mainly because this gives information about the size range of* non-spherical particles such as smoke or dust)	6
AODF.ℓ	Aerosol Fine Mode Optical Depth (Column and PBL)	O5, O6, O7, O8	0.03-4	±0.02±0.05*AOT	(1,50) km (1,25) km	N/A	I	100 km	*O7: column only*	4, 5, 6, 12, 13, 14

Consolidated Geophysical Variables (4 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
AOD.ℓ	Aerosol Optical Depth (Column,PBL)	O3, O5, O6, O7, O8	0.03 - 4	±0.02±0.05*AOT	(1,5) km	N/A	I	100 km 300 km	Multi-angle radiance (UV,VIS), multi-angle DOLP - Multispectral radiance UV (aerosol absorption) & VIS (AOD, fine mode aerosol over water) - SWIR (surface properties and cirrus screening) *Swath refers to column; Nadir for PBL* *O7: column only* *O8: PBL only*	1, 3, 4, 5, 7 (12, 13, 14) for inference of PM from AOD)
ATHV	Aerosol Plume-Top Horizontal Velocity	O5		0.75 m s-1	500 m	NA	1-2 min	100 km	Derived from stereo camera pair	
ATVV	Aerosol Plume-Top Vertical Velocity	O5		1 m s-1	500 m	NA	1-2 min	100 km	Derived from stereo camera pair	
APM25	Aerosol PM2.5 Concentration (surface)	O5	20-150 $\mu g/m^3$	+/-20-25%	5 km	N/A				12, 13, 14
ARIR.ℓ	Aerosol Real Index of Refraction (Column,PBL)	O5, O6,O7	1.33–1.7	±0.025	(1,50) km (1,25) km	N/A	I			N/A
AVAV.z	Average vertical air velocity profile	O2, O3	2-20 m s^{-1}	2 m s^{-1}	3 km	250 m	1-2 min	Nadir	Derived from radar pair separated by 30-120 seconds	

Consolidated Geophysical Variables (6 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
BSS	Blowing surface snow detection	O4	N/A	N/A	1km**	N/A*	I	Nadir	Backscatter lidar; *sfc-30 m range bin; **need more input on requirement.	5
CA	Cloud albedo	O1, O8	0.1-0.8	5%*	2 km 1 km	N/A	I, M	100 km	This property would be derived from Level 2 microphysical products such as liquid water path/content, effective particle size, etc. The uncertainty in the albedo would be the aggregate uncertainty in the microphysical properties. *Relative change between states. *Merge Radar and Lidar derived cloud boundaries to derive cloud vertical profiles. A Vis/NIR imager is needed for cloud and aerosol optical depth*	4,
CAE	Cloud areal extent (High Cloud)	O2	> 4 km^2	For OD > 0.3 [IR]	2 km	N/A	I	Wide	PoR: ABI, AHI, etc. *Defines area of upper-level cloud, not cloud fraction*	1, 2, 4,
CDER	Cloud droplet effective radius	O1, O6, O7, O8	5-20 microns	For clouds with precip mode, 20%. For no precip mode, 10% for OD>2	1km	N/A	I	Nadir*, 100 km**	PoR: ABI, AHI, etc.; VIIRS **Bi- and mulitspectral techniques are sensitive to cloud effective radius. *Lidar ratio technique in fully attenuating clouds has the potential to effectively constrain cloud top cloud effective radius. Focused in-situ validation is needed to establish uncertainty.	

Consolidated Geophysical Variables (7 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
CC	Convective classification	O3	Isolated, organized, deep, shallow	NA	0.5 - 5 km*	N/A	I I, ΔT, R	100 km	VIS/IR Geostationary PoR + Radar profile *Phenomenon and sensor dependent *Identify by org. (MCS, isolated conv, multi-cell etc.) and/or sub classes of intensity (weak, moderate, intense), depth (shallow, moderate, deep) etc.*	8, 9, 15
CCC	Convective cloud cover	O2	0 - 1	0.1	0.5-5 km*	N/A	I	100 km	PoR: ABI, AHI, etc., VIIRS; *Phenomenon and sensor dependent; convective classification at pixel scale, build cloud object, determine fraction of object area that is convective	
CCS	Convective core size	O3	1-5 km diameter	0.5-1 km	2 km	250 m	I, ΔT, R	≥20km	Radar reflectivity, Doppler, microwave TB *Threshold(s), peakedness criteria; Doppler, dZ/dt*	5, 8, 9, 15
CDC	Cloud droplet concentration	O8	10-500* cm^{-3}	100%	2km	N/A	I	Nadir	No single measurement constrains CDC. Requires synergy among observables that constrain various aspects of the droplet size distribution. ie. Lidar, reflectance, polarimetry, radar, etc. *may need to extend for continental clouds *Current estimate for uncertainty is ~80% for pixel-scale retrievals using vis/NIR reflectance, only if stringent conditions are met (unobstructed, overcast, optically thick, favorable viewing geometry).* *Uncertainty unknown but larger in more challenging conditions* *Other studies indicate a factor of > 2 uncertainty regardless of remote sensing method.*	2, 3, 4, 5
		O1, O8		50%	1km					

Consolidated Geophysical Variables (8 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
CLC	Cloud lifecycle categories	O2 (Minimum) O3 (Enhanced)	≥ 3 phases	N/A	2 km	N/A	R	Wide	VIS/IR Geostationary PoR *E.g, Cu, mature, decaying; alternatively, MCS approach such as Roca et al., 2017 and refs therein*	
CLWP	Cloud liquid water path	O1, O8	0.02-0.5 kg m^{-2}	0.02 for < 0.1 kg m^{-2} 50% for > 0.1 kg m^{-2}	500 m (Minimum) 200 m (Enhanced)	N/A	I	Context Only	• Vis, NIR Reflectance • Radar, Passive Microwave • Submm • Synergy of Reflectance, active and passive microwave, passive microwave and submm *Retrieval more difficult over land, submm has less sensitivity to surface than passive microwave*	2, 3, 5, 7
COD	Cloud optical depth	O1, O6, O7, O8	>0.1	20%>10 Precip mode: 50%<10 No precip mode: 15%<10	500 m (Minimum) 200 m (Enhanced)	N/A	I	Nadir	Vis/NIR Reflectance, Lidar, Radar *Observables used depend strongly on objective.* *For O4, COD may be strongly modulated by frozen hydrometeors and require some combination of radar, passive microwave, and reflectance.*	1, 3, 4, 5, 7
		O2	0.1-50	100%	500 m	N/A	I	Nadir		
		O4 (Enhanced)	>10	100%	200 m	N/A	I	Wide		
CP.z	Cloud phase profile	O4	Liquid, ice, mixed	10-25% FAR	2km	<250 m	I	Nadir	Polar. Back. Lidar; Radar dBZ profile	2, 5, 7

Consolidated Geophysical Variables (9 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
CRE LW	Cloud radiative effects — Longwave	O1,O2,O4, O8	0-200 Wm^{-2}	±5-10 Wm^{-2}	2km 1km	N/A TOA	Instantaneous	>50 km	Sensitivity of LW CRE of high ice clouds to changes in IWP. **NB This uncertainty requirement is coarser than the requirement for TICFIFRE science.**	4, 5
CRE SW	Cloud radiative effects — Shortwave	O1,O2,O4, O8	0-1000 Wm^{-2}	±20-40 Wm^{-2}	1km 0.5km				TOA, uncertainty based on 30-60 degree solar zenith & assumes a difference between two 'states. Derived from model calculations. While ' X-Y resolution is <20km the quoted uncertainty can be demonstrably met according to analysis @ 20km footprint (SSF equivalent) . Flux requirement wrt instantaneous solar (could normalize to 340 Wm-2) . We might do an interim SSF-like product for eval.	5
CTDC	Cloud top droplet concentration	O8	10-500 cm-1	100%	2 km	N/A	I	Nadir	No single measurement constrains CTDC. Requires synergy among observables that constrain various aspects of the droplet size distribution. ie. Lidar, reflectance, polarimetry, radar, etc.	5
CTDS	Cloud top droplet size	O1, O8	5-20 microns	10%	500 m	N/A	I	100 km	Vis/NIR reflectance from polarimeter Daytime retrievals	5
				30%	2km	N/A	I	Nadir	Lidar, nighttime retrievals *Lidar ratio derived from integrated depol and integrated attenuate backscatter can constrain cloud top effective radius. Accuracy depends on accuracy of derived lidar ratio.*	

Consolidated Geophysical Variables (9 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
CTDV	Cloud top droplet eff variance	01, 08	0- 2	0.05±50%	500m	N/A	I	100 km	Polarimeter (see Mishchenko 2004)	
CTE	Cloud top extinction	O8	1-50 km-1	100%	2km	N/A	I	Nadir	Lidar Vis/NIR Reflectance *This quantity can be related to the rate at which the lidar signal decays near cloud top. Accuracy depends cloud top structure and accuracy of attenuated backscatter signfal near cloud top.*	1, 3, 4, 5, 7
CTHV	Cloud-top horizontal velocity	O1, O8		0.75 m s-1	500 m	NA	1-2 min	100 km	Derived from stereo camera pair	
CTP	Cloud top phase	O1, O8	Liquid, solid, mixed	N/A	200 m	~1 OD	I	Nadir	Polarimetry, lidar depolarization, radar depolarization ratio, SWNIR reflectance *Expect fine resolution from lidar or imager*	
		O3			3 km					
					1 km		I,ΔT,R	≥20km		
CTT	Cloud geometric-top temperature (Kelvins)	O2, O3, O4	>170	0.5	2 km	N/A	I	Nadir	Thermal IR *Thermal IR needed. POR may not provide sufficient resolution for this objective.*	1, 3, 5, 7
					1 km		I,ΔT,R	≥20km		
CTVV	Cloud-top vertical velocity	O1, O8		1 m s-1	500 m	NA	1-2 min	100 km	Derived from stereo camera pair	

Consolidated Geophysical Variables (10 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
DARE, SW&LW	LW aerosol rad. Effect (flux)	O7			1km 50x50 mini gran	TOA & SFC	Inst. & diurnal integrated	>50km	O7-WG report, the ± 1.2 W/m2 is a global, annual mean	
	SW aerosol rad. Effect (flux)		-10-30% incident irradiance	±1.2 Wm^{-2}						
DRCC	Diurnally resolved cloud cover	O2, O3,	0.05-1.00	5%	2 km	N/A	I	Wide	Geostationary PoR (IR)	4,
		O1, O8	0.05-1.00	5%	2 km	N/A	I	Wide	*Context only*	
DRCH	Diurnally resolved cloud top height	O2, O3,	1-20 km	1000m	2	N/A	I	Wide	Geostationary PoR (IR) *PoR IR estimates boost uncertainty*	
EHW.z	Environmental horizontal wind profile	O1, O2, O3, O4, O6, O8	-80 - 80 m/s	<2 m/s	<25 km	<1 km	I	Global	Reanalysis Expectation that XY and Z resolution will be closer to 10 km, 0.5 km. *Enhanced for aerosol?	4,
		O5, O6	-80 - 80 m/s	<2 m/s	<25 km	<1 km	I,R	Global		
EH.z	Environmental humidity profile	O1, O2, O3, O4, O5, O6 O7, O8	0 - 100%	25%	<25 km	<1 km	I	Global	Reanalysis, limb sounder Expectation that XY and Z resolution will be closer to 10 km, 0.5 km.	
							I,R			

Consolidated Geophysical Variables (11 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
ET.z	Environmental temperature profile	O1, O2, O3, O4, O5, O6 O7, O8	-85ºC – 50°C	1.5°C	<25 km	<25 km	I	Global	Reanalysis Expectation that XY and Z resolution will be closer to 10 km, 0.5 km.	N/A
							I,R			
EVW.z	Environmental vertical wind profile	O1, O3, O6, O8	-50 – 50 cm/s	2 cm/s	<25 km	<25 km	I	Global	Reanalysis Expectation that XY and Z resolution will be closer to 10 km, 0.5 km.	N/A
		O5, O6	-50 – 50 cm/s	2 cm/s	<25 km	<25 km	I,R	Global		
FOAA	Full Attenuation Altitude (lidar backscatter reduced to x)	O1, O2, O3, O4	0-20 km	30 m	100 m	NA	I	Nadir	VIS; long-term stability required (±10m), implications for telescope FOV, laser footprint, sensor response; consistency with CALIOP/EarthCare. Can be derived from ACFM.	
									UV	
HMW	Height of max vertical motion	O2, O3	5-15 km	2 km	10 km	NA	1-2 min	>100 km	Derived from passive microwave radiometer pair	
HVFM	Hydrometeor vertical feature mask	O1, O2, O3, O4, O5	Cloud top: 0.5-20km	Cloud top (CT): 100m	CT: 1 km	CT: 100-200 m	I	Nadir	Lidar, A-Band, w-band Radar in non-precipitating conditions (liquid clouds), Radar for ice-layers, A-Band Spectroscopy, stereo imager *lidar (necessary to define cloud top height) can be combined with A-band spectroscopy to define cloud base height in ideal conditions (homogenous, moderate optical depth)* *Radar accuracy affected by sensitivity threshold*	1, 5, 7
		O1, O8	Cloud base: >250m	Cloud base (CB): 250m	CB: 2 km	250 m	I	Nadir		

Consolidated Geophysical Variables (12 of 18)		**Science Objectives**	**Desired Capability**						**Examples of Observables** *Notes*	**Enabled Apps**
			Range	**Uncertainty**	**Scales**					
					XY	**Z**	**T**	**Swath**		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
ICNC	Ice crystal number concentration (per liter)	O2, O8	0.1-1000	100%	2km	1 km	I	Nadir	Lidar Scattered sunlight Radar *Nothing directly constrains this moment of the DSD (0'th). Vis/NIR and Lidar are sensitive to 2nd moment. Additional indepedent information is necessary (I.e. radar)*	3, 5,
ICPS	Ice crystal particle size	O2, O8	O2: 10-60 O8: 100-1000 (microns)	O2: 50% O8: 100%	2km	1 km	I	Nadir		1, 3, 5,
IWC.z	Ice water content profile	O2	10^{-5} - 10 g/m^3	100%	2km	250 m	I, ΔT, R	Nadir	Multi-freq. radar constrained by high frequency and/or sub-mm radiometer; combine with lidar near top.	
IWP	Ice water path (kg m-2)	O2, O3, O4, O8	O2: 0.01-0.75 kg/m^2 O3: 0.5-10 O4: 0.05-0.2	O2, O3, O4: 100%	O2, O3: 5 km O4: 2 km	NA	I	Nadir	Radar-only would provide estimate of IWP for values in excess of 0.25 kg m-2. Radar-Lidar algorithms would provide best results in single phase (ice) layers; passive microwave > 85 GHz; submm has high sensitivity to ice *Uncertainty would be significantly reduced with some estimate of ice bulk density.*	1, 3, 5, 7
					1 km (O3)		I, ΔT, R	≥20km		

Consolidated Geophysical Variables (13 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
IVAV.z	In-cloud Vertical Air velocity profile	O2, O3	O2: 0.5-3 m/s (above 5 km) O3: 2-25 m/s (above 5 km)	O2: 0.5 m/s O3: max (2 m/s, 30%)	3 km	O2: N/A O3: 250m	I	Nadir	O2 minimum is profile in high clouds (above 5 km). Enhanced is profile in deep convection. Doppler shifted radial velocity, time differenced reflectivity (ΔZ~2 dBZ, 90sec, dZ/dh @120 s); Altitudes > 5 km (~melting level in tropics) *O3: Δx resolution of 3 km marginal for convection; capture mean level at/or above maximum mass flux. Enhanced will enable any subset, or all, of improved resolution, limited scanning, sequential sampling, or diurnal sampling).* *Radar ΔT when Doppler not available*	1, 2, 5, 7
		O1, O2, O3, O4, O6, O8	O2, O3, O4, O6 (full profile): 2-50 m/s O8: 1-6 m/s	O2,O3,O4, O6: max (2 m/s, 30%) O1,O8: 0.5 m/s	1 km	250m	I,ΔT,R	≥10 km		
LH.z	Latent heating profile	O3	-50–100 K/hr	30%	≤3 km	250 m	I, ΔT, R	Nadir	Radar reflectivity profile, C/S type, Doppler velocity, time differenced reflectivity (ΔZ~2 dBZ, 90sec) *Range represents Instantaneous convective observation; add velocity constraint; Highly derived from combination of sources*	1, 3, 5, 7

Consolidated Geophysical Variables (13 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
Light	Lightning	O3	0-60 fl/min	70% DE, 5% FAR, ±5 km	< 10 km	N/A	I, ΔT, R	Wide	PoR; E.g., group/flash rates and location, flash area, length, optical energy, multiplicity, polarity *Geo, LEO, airborne, ground-based; uncertainties defined by existing PoR measurement requirements*	
LWC.z	Liquid water content profile	O4								
MMW	Magnitude of max vertical motion	O2, O3	-10 to 25	2 m/s	10 km	NA	1-2 min	>100 km	Derived from passive microwave radiometer pair	
PAF	Particle asymmetry factor	O2	0.7-0.95	5%	2km	1 km	I	Nadir	Uncertainty based on Vogelmann and Ackerman, JAS 1995	

Consolidated Geophysical Variables (14 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
PS	Particle shape (aspect ratio, roughness)	O4	NV	NV	NV	NV	NV	NV	From space, polarized high frequency or sub-mm channels on passive MW radiometer. Possible target for suborbital measurements. Multi-angle polarimeter or polarimetric lidar	
PBLH	Planetary boundary layer height	O1, O5, O6 O8	2-5 km	200 m	5 km	N/A	I	Nadir	Lidar, maybe PoR (radio occultation)	2, 4, 5, 13, 14
PD	Precipitation discrimination (stratiform/convective)	O3	Convective, stratiform, other	N/A	3 km	NA	I	Nadir	Radar reflectivity profile *3 types- C, S, Other. Better with multiple radar frequencies (E) and vertically- resolved Doppler vertical motion*	1, 5
					1 km		I, ΔT, R	≥20km		
PPD.z	Precipitation (ice) particle density profile	O4	0.02-0.9	0.2	2 km	250 m	I	Nadir	Dual-frequency radar, passive microwave radiometer	5
PPS.z	Precipitation particle size profile	O3, O4	0.5 –4.0 mm	0.5 mm	≤ 3 km	250 m	I, ΔT, R	Nadir	Radar reflectivity, attenuation, dual-frequency ratio (DFR), combined TB and reflectivity/DFR. *Bulk median mass diameter D_m * typically liquid equivalent D_m is < 3 mm.*	5
PP.z	Precipitation phase profile	O1, O2, O3, O4,	Liquid, Solid, Mixed	N/A	3 km	250 m	I	Nadir	Z profile, bright band, Doppler velocity profile, LDR; e.g., Ka > ~-15 dB), differential reflectivity ΔZ~2dBZ , dual-freq. ratio, polarimetric VIS backscatter *Separation of stratiform liquid and frozen most straight forward. Enhanced would include approach for convective clouds, mixed phase, and the associated profile. Melting layer ID is implicit.*	1, 5, 7
				N/A	1 km	125 m	I, ΔT, R	≥250km		

Consolidated Geophysical Variables (15 of 18)		Science Objectives	Desired Capability						Examples of Observables Notes	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
PR.z	Precipitation rate profile	O1, O3, O4, O6	O1: 0.1 - 2 mm/hr O3:2 - 50 mm/hr O4:.01-10 mm/hr O6: 0.1 - 2mm/hr	O1, O3, O6 <100% O4: 200%	3 km	250 m	I	Nadir	Radar reflectivity; µwave radiances, submm radiances *Lower freq radar needed in enhanced for intense rains;* *Includes near surface precipitation estimate.*	1, 5, 7
		O2,O3,O4, O6	2-100 mm/hr	<100%	1 km	125 m	I, ΔT, R	≥250km		
PR2D	Precipitation rate, 2D @surface	O6	0.1-2 mm/hr	100% below 1 mm/hr, 50% above	≤ 25 km	N/A	I, ΔT, R	>500 km	Scanning passive µwave, >85 GHz, Submm *Contributes to horizontal mapping of precip.;* *Applications desires footprint of 10 km or less.*	1, 5, 7 8, 9, 10, 11
		O3, O4	(O3): 0.5-50 mm/hr (O4): 0.01-10 mm/hr	O3: < 50% @1 mm/hr; < 25% @>10 mm/hr O4: 200%	≤ 25 km	N/A	I, ΔT, R	>500 km		
RCIWP	Rate of change of IWP	O2, O3	0.25-5 kg m^{-2} min^{-1}	0.25 kg m^{-2} min^{-1}	5 km	NA	1-2 min	>100 km	Derived from passive microwave radiometer pair	

Consolidated Geophysical Variables (16 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
RadH.z	Radiative heating rate profile, SW & LW (cloud)	O2	-3.0 K day^{-1} to 1 K day^{-1} for longwave and 0 K day^{-1} to 2 K day^{-1} for shortwave	Longwave: 0.9 $Kday^{-1}$ for boundary layer clouds, 0.25 K day^{-1} for upper tropospheric clouds. Shortwave: 0.35 $Kday^{-1}$ for both clouds.	Zonal	1 km	M	Aggregated over geographic regions	This GV would be calculated from level 2 microphysical retrievals and the uncertainty would be tied to the uncertainty of the microphysical retrievals, the radiative parameterizations (I.e. conversion of microphysics to radiative properties) and the accuracy of the POR-derived thermodynamic profiles. *The range is for instantaneous heating rate computed with 137 layers in the atmosphere averaged over a month and over 1 degree zone* *The uncertainty is for zonal monthly mean hating rate* 137 layers seems extreme on the time and space scales required. Zonal seems too coarse. Thinking 2.5x2.5 is more in line with capabilities based on CloudSat/CALIPSO	4
	Radiative heating rate profile, SW (aerosol)				1 km	250 m	inst	>50km		
SA	Surface albedo	O7	0.1-0.8	NV	2 km	N/A	NV	NV	PoR	12, 13, 14 (for inference of PM from AOD)
SR.z	Scattering ratio profile	O1, O2, O3, O4, O5	0-80	0.05	100 m	240 m	NA	Nadir	*VIS; SR is required in the stratosphere for calibration* *30m sampling resolution, 240m variable resolution* UV	

Consolidated Geophysical Variables (17 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
SCL	Surface classification	O4 O3	> 10 classes	N/A	<0.25 °	N/A	M	Global	E.g., GLDAS2 Land surface (MODIS), POR? *Land cover (water, vegetation, desert, snow etc.)*	
SEL	Surface elevation	O4 O3	- 0.5 - 9 km	< 100 m	< 1 km	<100 m	N/A	Global	PoR topography database (E.g., SRTM) *Identify orography*	
SRB	Surface radiation budget	O4	0-500 Wm^{-2}	2% LW, 7% SW	1 x 1 deg	N/A	M	Nadir	This GV would be calculated from level 2 microphysical retrievals and the uncertainty would be tied to the uncertainty of the microphysical retrievals, the radiative parameterizations (I.e. conversion of microphysics to radiative properties) and the accuracy of the POR-derived thermodynamic profiles. *Includes surface albedo, emissivity; cloud/precipitation radiative properties* *Monthly mean, skin temperature may be an issue, as well as low cloud microphysics.*	
STF	Surface turbulent fluxes	O4 O1, O3	0 - 1500 W/m^2 (Latent) -300-1500 W/m^2 (Sensible)	Ocean: < 20% Land: < 30%	< 25 km	N/A	I, R	Global	1-6 hour PoR analyses (e.g.,MERRA-X, ERA-X, GLDAS, SeaFlux-HR etc.) *LH/S heat fluxes- ranges include documented extremes over Land/ocean. New NASA-funded activities (Seaflux-HR) may help.*	

Consolidated Geophysical Variables (18 of 18)		Science Objectives	Desired Capability						Examples of Observables *Notes*	Enabled Apps
			Range	Uncertainty	Scales					
					XY	Z	T	Swath		
Minimum	**Enhanced**	**IMPORTANT**: Desired Capabilities and Observables are preliminary. Click here for additional information.								
STP	Surface type	O4 O3	Ocean, land, coast	N/A	1 km	N/A	N/A	Global	Numerous PoR high resolution land/water masks *Land/water surface boundaries*	
TLWP	Total liquid water path	O4	0.01-0.2 kg m^{-2}	100% over water	2 km	N/A	I	Context only	• Vis, NIR Reflectance • Radar, Passive Microwave • Submm • Synergy of Reflectance, active and passive microwave • Synergy of passive microwave and submm *See Cloud LWP above; Extends IWP to liquid part of the column (full column precip+cloud), combination of microwave and submm reduces uncertainty*	1, 2, 3, 5, 7
		O1, O3	0.02 - 60 kg/m^2	50%	1 km	N/A	I, ΔT, R	Nadir		
VCF	Volumetric cloud fraction	O1, O4	0-1.	20%	100 km^2	250-500m	I	≥20km	Scanning radar, W or Ka band	4, 5, 7
VIIMF	Vertically Integrated Ice Mass Flux	O2, O3	0.1–20 g m^{-2} s^{-1}	100% if < 10 50% if > 10 g m^{-2} s^{-1}	6 km	NA	1-2 min	>100 km	Derived from passive microwave radiometer pair	

Consolidated Observables (1 of 6)		Geophysical Variables	Desired Capabilities							Instrument Class and Notes	Desired Mission Capabilities
			Range	Uncer-tainty	Resolution				Altitude		
					Δx	Δz	Swath				
Min. Enh.	Channels/Angles	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.									
Refl.λ Radar Reflectivity	W Band	CTH, CBH, CDC, CDER, CLWP, CP.z, CVS, IWP, PD, PP.z, PR.z,TLWP	< -25 dBZ @ 5000m	1.5 dBZ	1.5 km	500 m	Nadir	20 km	250 m – 20 km	Radar oversampled at ½ footprint recommended. σ_0 reference values: σ_0 (land)=? σ_0 (ocean)=10 dB	Polar orbit. Altitude < ~550 km. Equatorial crossing time between 0100-0600 local standard time.
			< -20 dBZ @ 1000 m			250 m					
			< -5 dBZ @ 250 m			125 m					
		ICNC, ICPS, CTDC, PPD.z, PPS.z, VCF	< -35 dBZ @ 5000m			500 m					Inclined orbit in addition to polar. Altitude < ~400 km. Inclination of 65° or smaller.
			< -30 dBZ @ 1000 m			250 m					
			< -15 dBZ @ 150 m			125 m					

Consolidated Observables (1 of 6)			Geophysical Variables	Desired Capabilities							Instrument Class and Notes	Desired Mission Capabilities
				Range	Uncer-tainty	Resolution				Altitude		
						Δx	Δz	Swath				
Min.	**Enh.**	**Channels/Angles**	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.									
Refl.λ Radar Reflectivity		Ka Band	CP.z, CTH, CVS, IWP, PD, PP.z, PR.z, TLWP, CC	< 10 dBZ @ 5000m	1.5 dBZ	3 km	500 m	Nadir	20 km	500 m – 20 km	Radar oversampled at ½ footprint recommended. σ_0 reference values: σ_0 (land)=? σ_0 (ocean)=12 dB	Polar orbit. Altitude < ~550 km. Equatorial crossing time between 0100-0600 local standard time.
				< 12 dBZ @ 1000 m			250 m					
				< 20 dBZ @ 250 m			125 m					
			CCS, PPD.z. PPS.z, VCF	< 0 dBZ @ 5000 m			500 m					Inclined orbit. Altitude < ~400 km. Inclination of 65° or smaller.
				< 2 dBZ @ 1000 m			250 m					
				< 10 dBZ @ 250m			125 m					
		Ku or X	CP.z, CVS, CC, CCS, IWP, PD, PP.z, PPD.z, PPS.z, PR.z, TLWP	>10 dBZ	1.5 dBZ	3 km	500 m			0.5 - 10 km	Radar oversampled at ½ footprint recommended.	Preferred in inclined, but acceptable in polar

Consolidated Observables (1 of 6)			Geophysical Variables	Desired Capabilities						Instrument Class	Desired Mission Capabilities
				Range	Uncertainty	Resolution			Altitude		
						Δx	Δz	Swath			
Minimum	Enhanced	Channels/Angles	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.								
Doplr.λz Radar Doppler Velocity		W Band	CC, PD, PP.z, VAV.z LH.z, PPD.z, PPS.z, SVM.z	±25 m s^{-1}	<0.5 ms^{-1}	See desired capabilities for reflectivity		Nadir	See ranges for reflectivity	Radar oversampled at ½ footprint recommended	Polar orbit. Altitude < ~550 km. Equatorial crossing time between 0100-0600 local standard time. Doppler optional if in inclined orbit?
		Ka Band	CC, PD, PP.z, VAV.z	±25 m s^{-1}	<3 m s^{-1}						
		Ku or X	CC, LH.z, PD, PP.z, PPD.z, PPS.z, SVM.z,VAV.z	±50 m s^{-1}	<3 m s^{-1}						Inclined orbit. Altitude < ~400 km. Inclination of 65° or smaller. Doppler at W and either Ka or Ku, or all three.

Consolidated Observables (2 of 6)		Geophysical Variables	Desired Capabilities						Instrument Class	Desired Mission Capabilities
			Range	Uncertainty	Resolution			Altitude		
					Δx	Δz	Swath			
Minimum Enhanced	Channels/Angles	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.								
Tb.λ Brightness Temperature	W Band	IWP	100-280 K	1.5 K	2 km	–	Nadir 20 km		Radar oversampled at ½ footprint recommended	
			50-280 K	0.5 K	1 km	–				
	Ka Band	IWP, TLWP	100-280 K	1.5 K	3 km	–				
			50-280 K	0.5 K	1 km	–				
	> 85 GHz, submm	TLWP, IWP, PR2D	80-300 K	1–2 K	< 25 km	–	> 100 km		Passive microwave radiometer	~166, 183, 325 GHz preferred for snowfall
	<85 GHz	TLWP, PR2D	100-300 K	1–2 K	< 25 km	–	> 100 km		Passive microwave radiometer	
Depol.λz Linear Depolarizarion Ratio	W Band	CP.z, PD, PP.z, PPD.z	-35 – 0 dB	2 dB	1 km	125 m	20 km	250 m – 20 km	Radar	2nd transmit, or, just second receive channel for orthogonal polarization (slant 45 or linear basis)
	Ka Band	CP.z, PD, PP.z, PPD.z	-30 - 0 dB	2 dB						

Consolidated Observables (3 of 6)			Geophysical Variables	Desired Capabilities						Instrument Class	Desired Mission Capabilities
				Range	Uncertainty	Resolution			Altitude		
						Δx	Δz	Swath			
Minimum	Enhanced	Channels/ Angles	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.								
TAtbsCo.λz Molecular+Particulate Attenuated Co-polarized Backscatter Profiles (Superseded by HSRL enhanced **RayAtbs.λz, MieAtbsCo.λz** and **MieAtbsCo.λz** measurements when available)		VIS NIR	**AOD.ℓ, AODF.ℓ, AAOD.ℓ,AEXT.z, AABS.z,AEXTF.z,AE.I,AE.z, ACFM.z,ANC.ℓ,AE2BR,AE2BR.ℓ, AEFR.I,AEFR.z,ARIR.ℓ,AIIR.ℓ, ANSPH,ANSPH.z,APM2.5,AVE, BSS,CA,CBH,COD,CTDC,CTDS, CTE,CTH,ICNC,IWP,PANC,PBLH**			100 m	30 m 10 m	100 m	-2 to 42 km	Backscatter Lidar	Note: Δx & swath meant to imply continuous along-track coverage; Swath means receiver footprint diameter View angle: 0.3 to 5 degrees
TAtbsX.λz Molecular+Particulate Attenuated Cross-polarized Backscatter Profiles (Superseded by HSRL enhanced **RayAtbs.λz, MieAtbsCo.λz** and **MieAtbsCo.λz** measurements when available)		VIS NIR	Same as for **TAtbsCo.λz**							Backscatter Lidar	
Rad.λ Radiances		VIS NIR UV				100 m	---	100 m	---	Lidar	from lidar background monitor

<table>
<tr><th colspan="3" rowspan="3">Consolidated Observables
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<tr><th rowspan="2">Range</th><th rowspan="2">Uncertainty</th><th colspan="3">Resolution</th><th rowspan="2">Altitude</th></tr>
<tr><th>Δx</th><th>Δz</th><th>Swath</th></tr>
<tr><th>Minimum</th><th>Enhanced</th><th>Channels/ Angles</th><td colspan="9">IMPORTANT: Desired Capabilities are preliminary. Click here for additional information.</td></tr>
<tr><td colspan="2">RayAtbs.λz
Attenuated Rayleigh Backscatter Profiles</td><td>UV
VIS</td><td>AOD.ℓ, AODF.ℓ, AAOD.ℓ, AEXT.z, AABS.z, AEXTF.z,AE.ℓ AE.z,ACFM.z,ANC.I,AE2BR, AE2BR.ℓ,AEFR.ℓ,AEFR.z,ARIR.ℓ, AIIR.ℓ,ANSPH,ANSPH.z,APM2.5, AVE,BSS,CA,CBH,COD,CTDC, CTDS,CTE,CTH,ICNC,IWP,PANC, PBLH</td><td></td><td></td><td>100 m</td><td>10 -30 m</td><td>100 m</td><td>-2 to 42 km</td><td>HSRL Lidar</td><td rowspan="3">Polar Orbit (O1, O4, O7, O9);
Note: Δx & swath meant to imply continuous along-track coverage;
Swath means receiver footprint diameter;
View angle: 0.3 to 5 degrees</td></tr>
<tr><td colspan="2">MieAtbsCo.λz
Attenuated Mie Co-polarized Backscatter</td><td>UV
VIS</td><td>Same as for RayAtbs.λz</td><td></td><td></td><td>100 m</td><td>10 – 30 m</td><td>100 m</td><td>-2 to 42 km</td><td>HSRL Lidar</td></tr>
<tr><td colspan="2">MieAtbsX.λz
Attenuated Mie Cross-polarized Backscatter</td><td>UV
VIS</td><td>Same as for RayAtbs.λz</td><td></td><td></td><td>100 m</td><td>10 - 30 m</td><td>100 m</td><td>-2 to 42 km</td><td>HSRL Lidar</td></tr>
</table>

Consolidated Observables (5 of 6)			Geophysical Variables	Desired Capabilities						Instrument Class	Desired Mission Capabilities
				Range	Uncertainty	Resolution			Altitude		
						Δx	Δz	Swath			
Minimum	**Enhanced**	**Channels/Angles**	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.								
Rad.λ Radiances (Maps to MODIS/VIIRS)		**UV:** 400-470nm **VIS:** 635-680nm **SWIR:** 1.6-2.2μm # Channels: 5	**Land and Ocean:** **AOD.ℓ, APM25, COD, CF** **Ocean only:** **AODF.ℓ , AE.ℓ**		5%	500 m	—	100 km	—	Multispectral Radiometer	
Rad.λ Radiances (Maps to AVIRIS/PACE)		**UV-SWIR:** 400nm-2.2μm 10 nm resolution	**AOD.ℓ, AODF.ℓ, AE.ℓ** **APM25, AVE, COD, CF**		7%	500 m		100 km		Imaging Spectrometer	
Rad.λα Multi-angle Radiances (Maps to MISR)		**UV:** 400-470 nm **VIS:** 550-870 nm # Channels: 4 # Angles: 5	**AOD.ℓ, AODF.ℓ, AAOD.ℓ, AE.ℓ, ASYM, ANSPH, AVE, APM25, CF, CTH**			500 m	—	100 km	—	Multi-angle Radiometer	
DOLP.λα*(Rad.λα) Multi-angle Degree of Linear Polarization		**UV:** 350-470 nm **VIS:** 530-870 nm # Channels: 5 # Angles: 5	**AOD.ℓ, AODF.ℓ, AAOD.ℓ, AE.ℓ, ASYM, ANSPH, ANC.ℓ, ARIR.ℓ, AIIR.ℓ, AVE, APM25, COD,CTDC,CTDS, CTH**		Max(3% Rad, 0.005 DOLP	500 m	—	100 km	—	Multi-angle Polarimeter	
(DOLP.λα)*(Rad.λα) Polarized radiances (Maps to APS/HARP, SPEX)		Hyperspectral range (400-700 nm) or hyper-angular channel (40+ angles, ~1 deg. between -60, +60 deg. at 670 or 865 nm).	**AOD.ℓ, AODF.ℓ, AAOD.ℓ, AE.ℓ, ASYM, ANSPH, ANC.ℓ, ARIR.ℓ, AIIR.ℓ. AVE, APM25, COD,CTDC,CTDS, CTH**		Max(3% Rad, 0.005 DOLP)		—	100 km	—	Multi-angle Polarimeter	Moderate bandwidth (10-30 nm) channel centered close to wavelength or within given range

Consolidated Observables (6 of 6)			Geophysical Variables	Desired Capabilities						Instrument Class	Desired Mission Capabilities
				Range	Total Uncertainty	Resolution			Altitude		
						Δx	Δz	Swath			
Minimum	**Enhanced**	**Channels/Angles**	**IMPORTANT**: Desired Capabilities are preliminary. Click here for additional information.								
Rad.λ Radiances (Maps to MODIS+OMI)		**UV:** 355 nm	**AOD.ℓ, AAOD.ℓ, AODF.ℓ, AE.ℓ , APM25, COD, CF**			250 m	—	300 km	---	Multispectral Radiometer	Moderate bandwidth (10-30 nm) channel centered close to wavelength or within given range
Rad.λ Radiances (Maps to PACE+SWIR)		350nm-2200 nm (5 nm resolution) imaging spectrometer	**AOD.ℓ, AODF.ℓ, AE.ℓ, ARIR.ℓ, AIIR.ℓ, APM25, AVE, COD, CF**		7%	500 m	—	300 km	—	Imaging Spectrometer	
Rad.λα Multi-angle Radiances (Maps to MISR + SWIR)		**SWIR:** ~1680, ~1880, ~2260 nm # Angles: 5.	**AOD.ℓ, AODF.ℓ, AAOD.ℓ, AE.ℓ, ASYM, ANSPH, ANC.ℓ, ARIR.ℓ, AIIR.ℓ, AVE, APM25, COD, CTH**		5%	250 m	—	300 km	---	Multi-angle Radiometer	Moderate bandwidth (10-30 nm) channel centered close to wavelength or within given range
(DOLP.λα)∗(Rad.λα) Multi-angle Degree of Linear Polarization (Maps to MAIA)		**SWIR:** ~1680, ~1880, ~2260 nm. # Angles: 5.	**AOD.ℓ, AODF.ℓ, AAOD.ℓ, AE.ℓ, ASYM, ANSPH, ANC.ℓ, ARIR.ℓ, AIIR.ℓ, AVE, APM25, COD,CTDC,CTDS, CTH**		5%	250 m	—	300 km	---	Multi-angle Polarimeter	Moderate bandwidth (10-30 nm) channel centered close to wavelength or within given range
Rad.λ Radiances		**VIS:** ~620 nm	**ATHV, ATVV, CTHV, CTVV**			40m		100 km		Stereo Cameras	2 angles (nadir & 30º; ±6.3º)

Applications thematic Areas	Enabled Applications	End User Examples	Most Relevant Geophysical Variables	Most Relevant Observables	ACCP Goal
Disaster Monitoring and Modeling	**Disaster modeling:** Volcanic plume, smoke aerosol vertical distribution and extent for transport modeling, aviation, public health	NOAA, FAA, NCAR, VAACs, private aviation weather forecasting companies, airlines	Aerosol Type Aerosol Extinction Aerosol Optical Depth Cloud Extinction Cloud Optical Depth	Cloud and Aerosol Profiles Cloud Mask	Goal 4 Aerosol Processes
	Disaster monitoring and modeling: flood, landslide, post-fire debris flow	Government, Private modeling companies, operational forecast centers	Precipitation rate, 2D @surface		G2 Storm Dynamics
	Disaster risk: Parametric and risk modeling (Reinsurance, microinsurance)	Reinsurance, insurance and microinsurance industries	Precipitation rate, 2D @surface		G2 Storm Dynamics
Air Quality and Health (Public and Ecosystem)	**AQ Rule and Regulation Making**: Determining patterns of air pollution exposure to determine impacts of regulations, areas that need greater monitoring efforts, conduct source apportionment	EPA, state AQ agencies, international AQ agencies, legislatures (e.g., California A.B. 617)	Aerosol Type Aerosol Extinction Aerosol Optical Depth Cloud Mask, and cloud and aerosol profiles	These stakeholders might not have the expertise to create the 2D surface particulate matter concentration L4 product (that they require) from relevant observables.	Goal 4 Aerosol Processes
	Estimating air pollution: exposure and impact on health outcomes to assess health risks	CDC, WHO, NIH, health researchers at universities/hospitals (e.g., Global Burden of Disease), nonprofits and environmental justice groups	Aerosol Extinction Profile, Aerosol-Cloud Feature Mask (Profile), Aerosol Optical Depth, Aerosol Number Concentration	Many of these stakeholders will likely not have the expertise to create the L4 product (that they require) from relevant observables.	Goal 4 Aerosol Processes
	Health and Ecological Forecasting/Monitoring: Vector- and water-borne disease monitoring/modeling (e.g. malaria).	DOD Health Agency, FEMA, UNICEF, Epidemico, DHS, Pandemic Prediction and Forecasting Science and Technology, USDA, CDC, PAHO, CONAE	Precipitation rate, 2D @surface		Goal 2 Storm Dynamics and Goal 3 Cold Cloud and Precipitation
	Health insurance and reinsurance, e.g., pollution exposure risks	reinsurance industry (e.g., SwissRE), health insurance industry	2D surface particulate matter concentrations, Aerosol Extinction Profile, Aerosol-Cloud Feature Mask (Profile), Aerosol Optical Depth, Aerosol Number Concentration	These stakeholders will likely not have the expertise to create the L4 product (that they require) from relevant observables.	Goal 4 Aerosol Processes

Applications thematic Areas	Enabled Applications	End User Examples	Most Relevant Geophysical Variables	Most Relevant Observables	ACCP Goal
Health (Public and Ecosystem) and Air Quality	**Operational Air Quality Forecasting:** Air Quality Alerting and monitoring for extreme air quality events	Federal (NOAA, EPA) and state AQ agencies, public and private companies, onprofits and environmental justice groups	Aerosol Extinction Profile, Aerosol-Cloud Feature Mask (Profile), Aerosol Optical Depth, Aerosol Number Concentration	Extinction profiles, multiangle radiance and polarization parameters	Goal 4 Aerosol Processes
Infrastructure and Development	**Energy Planning:** Estimate radiative fluxes for solar insolation (e.g., rainfall over time to remove dust from panels, deposition of acidic aerosols, dust/aerosol warnings/forecast to rotate/close panels). Estimate wind availability for wind energy production.	NWS, NOAA, CTM, EPA, state AQ agencies, other modeling communities; solar power companies and entities wishing to invest in solar power, such as city governments	Cloud Fraction, Radiative Fluxes, Precipitation Rate 2D@surface, Aerosol Number Concentration, Aerosol Extinction Profile, Aerosol Optical Depth		Goal 4 Aerosol Processes and Goal 5 Aerosol Impacts on Radiation
	Energy Planning: Hydropower potential and modeling	Private Agriculture companies, NGOs, World Bank	Precipitation rate, 2D @surface	radar reflectivity, microwave brightness temperatures	Goals 2 Storm Dynamics and Goal 3 Cold Cloud and Precipitation
	Transportation and logistics: supply chain, road network maintainence, urban planning	Cargill, MARS, World Food Programme, CONAE, EcoClimaSol, Global Water and Environmental Security Analyst Defense Intelligence Agency, OXFAM, World Bank GFDRR, FEMA, NGA, State Department	Precipitation rate, 2D @surface , precipitation profile, snowfall vertical motion profile	radar reflectivity, doppler motion, microwave brightness temperature	Goals 2 Storm Dynamics and Goal 3 Cold Cloud and Precipitation
Water Resources and Agriculture	**Agricultural modeling and monitoring**: Water Resource Management influencing freshwater availability	Government agencies, agricultural insurance and precision agriculture, water resource managers	Precipitation rate, 2D @surface	radar reflectivity, microwave brightness temperatures	G2 Storm Dynamics and Goal 3 Cold Cloud and Precipitation
	Hydrologic Modeling: drought analysis/forecasting for fire weather, agriculture, and ecosystem health	USDA Forest Service, Private Agriculture companies, farmers, Timber companies, Prescribed burn associations	Precipitation rate, 2D @surface	radar reflectivity, microwave brightness temperature	Goal 1 Cloud Feedbacks, Goal 2 Storm Dynamics, and Goal 3 Cold Cloud and Precipitation

Applications thematic Areas	Enabled Applications	End User Examples	Most Relevant Geophysical Variables	Most Relevant Observables	ACCP Goal
Water Resources and Agriculture	**Hydrologic Modeling:** Total water fluxes at watershed including snowmelt, snow cover, and watershed analysis for irrigation	Hydropower (e.g. Indonesia Hydro Consult), water managers	Precipitation rate, 2D @surface	radar reflectivity, microwave brightness temperatures	Goals 2 Storm Dynamics and Goal 3 Cold Cloud and Precipitation
Weather, AQ, and Climate Modeling and Forecasting	**Aerosol & Precipitation Interactions:** Air Quality modeling and forecasting (transport, scavenging, wet deposition, dry deposition, chemical transformation)	NWS, NOAA, EPA and State Agencies, ECMWF, NRL, JMA	Aerosol Optical Depth, Vertical air velocity profile, Precipitation rate profile, Aerosol Extinction Profile, Aerosol Effective Radius Profile, Cloud Liquid Water Path, Ice Water Path, Aerosol Number Concentration, Precipitation rate at surface, Cloud Droplet Concentration, Precipitation Phase Profile, Particle Size Profile	Microwave and IR Brightness Temperatures, UV/VIS reflectance, Attenuated backscatter and depolarization ratio profiles, radar reflectivity	Goal 4 Aerosol Processes and Goal 5 Aerosol Impacts on Radiation
	Air Quality Forecasting: Forecast initialization and verification	Federal and state AQ agencies, EPA, NOAA, NRL, ECMWF, JMA, UKMET, NASA, NCAR, SMC-Canada, Air Force	Aerosol Extinction Profiles, Aerosol Types, Aerosol Optical Depths	Attenuated backscatter and depolarization ratio profiles	Goal 4 Aerosol Processes
	Climate Modeling: Global Climate Smoke Aerosol Transport and Aerosol and Aerosol/Cloud Feedback		Aerosol Extinction Profile, Aerosol-Cloud Feature Mask (Profile), Aerosol Number Concentration, Aerosol Optical Depth, Aerosol Extinction Profile, Cloud base height, Ice crystal particle size, Ice water path, Latent heating profile water path, Cloud droplet concentration, Cloud optical depth, Cloud Top Height, Cloud top phase, Cloud Top Temperature, Ice crystal number concentration, Total liquid water path		Goal 1 Cloud Feedbacks, Goal 4 Aerosol Processes and Goal 5 Aerosol Impacts on Radiation
	Climate Modeling: Parametrization of clouds, particle distribution for aerosols and precipitation	FEMA, ECMWF, JMA, BOM, UKMET, NASA, NCAR	Aerosol Extinction Profile, Aerosol-Cloud Feature Mask (Profile), Aerosol Optical Depth, Aerosol Number Concentration, Cloud Droplet Effective Radius, Cloud Optical Depth, Cloud Top Droplet Concentration, Cloud Droplet Concentration, Cloud Liquid Water Path , vertical air velocity profile, Precipitation particle size, Precipitation Rate, Ice water path, Radiative heating	Radar Reflectivity, Radiances(VIS,IR), Lidar backscatter, OTHER AEROSOL-related observables	Goal 1 Cloud Feedbacks, Goal 3 Cold Cloud and Precipitation and Goal 4 Aerosol Processes
	Operational Air Quality Forecasting: Tracking dust, wildfire smoke, and volcanic plumes	Federal (NOAA) and state AQ agencies, EPA, public and private companies	Aerosol Layer Heights Aerosol Non-spherical Fraction	Cloud and Aerosol Masks Aerosol Layer Types	Goal 4 Aerosol Processes

Applications thematic Areas	Enabled Applications	End User Examples	Most Relevant Geophysical Variables	Most Relevant Observables	ACCP Goal
Weather, AQ, and Climate Modeling and Forecasting	**Numerical Weather Prediction:** Coupling of aerosols within NWP modeling	NWP Centers (NOAA, NRL, ECMWF, JMA, NCAR), USDA, AFWA	Aerosol extinction profile, Cloud droplet concentration, Cloud phase profile, Precipitation particle size profile, Vertical air velocity profile	Cloud and Aerosol Profiles Cloud Mask, Radar reflectivity, Lidar Backscatter, Radar Doppler Shift	Goal 2 Storm Dynamics
	Numerical Weather Prediction: Development & Verification of Cloud/Convective Parametrizations	NWP Centers (NOAA, NRL, ECMWF, JMA, NCAR), USDA, AFWA	Precipitation phase profile, Vertical air velocity profile, Precipitation particle size profile, Cloud phase profile, Cloud droplet concentration	Radar reflectivity, Radar Doppler shift, VIS reflectance, Thermal IR brightness temperature, microwave brightness temperature	Goal 2 Storm Dynamics
	Numerical Weather Prediction: Representation of initial conditions and data assimilation	NOAA, ECMWF, JMA, MeteoFrance, KNMI, BOM, UKMET, NASA, NCAR	Cloud top temperature, cloud optical depth, cloud phase profile, precipitation phase profile, vertical air velocity profile	Microwave Radiances, IR Radiances, Attenuated backscatter and depolarization ratio profiles, radar reflectivity	Goal 2 Storm Dynamics
	Weather Forecasting: Atmospheric Rivers	NASA, NOAA, NCAR, FEMA, National Hydromet. Agencies	Precipitation rate near surface, Convective core size, Cloud top temperature, Vertical air velocity profile	Doppler Radar reflectivity, Microwave brightness temperature, Thermal IR brightness temperature	Goal 2 Storm Dynamics
	Weather Forecasting: Aviation hazards related low clouds and fog, smoke, dust or icing	NOAA, FAA, NCAR, Airlines, Private Sector Aviation Forecasting Companies	Cloud base height, cloud top height, cloud top temperature, cloud phase profile, cloud optical depth, Aerosol optical depth, Aerosol Extinction Profiles, Aerosol Speciation	radar reflectivity, doppler motion, vis reflectance, IR brightness temperature, Extinction profiles, multiangle radiance and polarization parameters	Goal 1 Cloud Feedbacks, Goal 2 Storm Dynamics, Goal 3 Cold Cloud and Precipitation and Goal 4 Aerosol Processes
	Weather Forecasting: Monitoring and nowcasting of convective storms and hazards	NOAA, NWS, EUMETSAT, Commercial aviation	Precipitation discrimination, Cloud top temperature, Precipitation rate profile, Vertical air velocity profile, Precipitation phase profile	Radar Reflectivity, Radar Doppler shift, Thermal IR brightness temperature, Microwave brightness temperature, UV/VIS reflectance, Attenuated backscatter and depolarization ratio profiles	Goal 2 Storm Dynamics and Goal 3 Cold Cloud and Precipitation
	Weather Forecasting: Pre-fire weather monitoring for wildfire response and management.	NOAA, USFS, USGS, USAF, National Guard	Precipitation rate near surface, cloud base height	VIS reflectance, IR brightness temperatures	Goal 1 Cloud Feedbacks, Goal 2 Storm Dynamics, and Goal 3 Cold Cloud and Precipitation
	Weather Forecasting: Tropical cyclone development and forecasting	NWS, NOAA, ECMWF, Meteo-France, NRL, HRD, DoD	Vertical air velocity profile, Precipitation rate profile, Cloud top temperature, Aerosol Optical Depth, Precipitation phase profile	Radar Reflectivity, Radar Doppler shift, Thermal IR brightness temperature, Microwave brightness temperature, UV/VIS reflectance, Attenuated backscatter and depolarization ratio	Goal 2 Storm Dynamics

Handling “Different Observing Modes"
Day, Night, Nadir and Off-Nadir Benefit Scoring

- SITs will compute *Quality Scores* for each of these Observing Modes:
  1. Nadir, daytime (nd)
  2. Nadir, nighttime (nn)
  3. Off nadir, daytime (od)
  4. Off nadir, nighttime (on, for CCP only)
- Using SALT defined *Utilities*, VF Team will calculate *Benefit Scores* for each one of these Observing Modes
- SALT has defined relative weights for each one of these Observing Modes, for each objective
- The VF Team will compute the final Science Benefit Score as a weighted average:

$$B = w_{nd} * B_{nd} + w_{nn} * B_{nn} + w_{od} * B_{od} + w_{on} * B_{on} \quad \text{(per objective)}$$

- See next slide for weights being proposed by SALT-A for SATM Release F

Weights of B-scores for Observing Modes

Objective	Nadir Day	Nadir Night	Off Nadir Day	Off Nadir Night
1	0.25	0.25	0.25	0.25
2	0.25	0.25	0.25	0.25
3	0.25	0.25	0.25	0.25
4	0.25	0.25	0.25	0.25
5	0.43	0.42	0.15	x
6	0.40	0.40	0.20	x
7	0.70	0.10	0.20	x
8	0.80	0.10	0.10	x

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Geostationary Operational Environmental Satellite – R Series (GOES-R/S/T/U)	NOAA NASA	GEO	2016-2038 GOES-R (≤2025) GOES-S (<2029) GOES-T (>2020) GOES-U (>2026)	2016-2038	Advanced Baseline Imager (ABI)	0.47**, 0.64*, 0.87**. 1.38, 1.61**, 2.25, 3.9, 6.2, 6.9, 7.3, 8.6, 9.6, 10.3, 11.2, 12.3, 13.3 (µm) Spatial(nadir): * = 0.5 km, ** = 1.0 km, others = 2 km	GOES-E = 75°W and GOES-W = 135°W Two views of North / South American Sectors Temporal: FD=10 min; CONUS=5 min; MESO=30 sec
					Global Lightning Mapper (GLM)	777.4 nm	Lightning Mapper
Meteosat – Third Generation (MTG-I1,I2,I3,I4)	EUMETSAT ESA	GEO	2021-2041 Launch 2021, 2025, 2029, 2032	2021-2041	Flexible Combined Imager (FCI)	0.44**, 0.51**, 0.64*, 0.87**, 0.91**, 1.38**, 1.61**, 2.25*, 3.8**, 6.3, 7.3, 8.7, 9.66, 10.5, 12.3, 13.3 (µm) Spatial(nadir): * = 0.5 km, ** = 1.0 km, others = 2 km	0°E Multipurpose VIS/IR radiometer, Temporal: FD=10 min, Europe=2.5 min
					Lightning Imager (LI)	777.4 nm	Lightning imager
Himawari (8,9)	JMA	GEO	2014-2031 (H8 ≤ 2022) (H9 ≥ 2022)	2014-2031	Advanced Himawari Imager AHI	0.47**, 0.51**, 0.64*, 0.86**, 1.61, 2.25, 3.9, 6.2, 6.9, 7.3, 8.6, 9.6, 10.4, 11.2, 12.4, 13.3 (µm) Spatial(nadir): * = 0.5 km, ** = 1.0 km, others = 2 km	H8/9 = 141°E (H9 replaces H8) Multipurpose imaging VIS/IR radiometer; Temporal: FD=10 min, Japan =2.5 min; MESO=30 sec
GEO-KOMPSAT (2A)	KARI KMA ITT	GEO	2018-2028	2018-?	Advanced Meteorological Imager (AMI)	0.47**, 0.51**, 0.64*, 0.87**, 1.38, 1.61, 3.8, 6.2, 6.95, 7.34, 8.59, 9.625, 10.4, 11.2, 12.4, 13.3 (µm) Spatial(nadir): * = 0.5 km, ** = 1.0 km, others = 2 km	K2A = 122°E Multipurpose imaging VIS/IR radiometer (ABI, AHI heritage) Temporal: FD=15 min; NH = 5 min; MESO = 30 sec

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Meteosat (MTG-S1,S2)	EUMETSAT COM ESA	GEO	2023-2039	2023-2039	Infrared Sounder (IRS)	MWIR: 1600 to 2250 cm-1 (4.44–6.25 µm) LWIR: 680 to 1210 cm-1 (8.26–14.70 µm)	Medium-resolution IR imaging Fourier-interferometer, hyperspectral (0.625 cm-1 wavenumber), full-disc coverage
					Ultraviolet, Visible and Near-Infrared Sounding (UVN) (Sentinel-4)	UV: 305–400 nm, 0.5 nm spectral resolution VIS: 400–500 nm, 0.5 nm spectral resolution NIR: 755–775 nm, 0.12 nm spectral resolution	Scanning SW (UV) spectrometer, European region coverage (30 to 65° N latitude, 30° W to 45° E longitude), better than 10km spatial resolution
GEO-KOMPSAT (2B)	KARI KORDI NIER	GEO	2019-2029	2019-?	GEMS	300 – 500 nm, 0.6 nm spectral resolution	Medium-resolution spectroradiometer; SE Asia regional coverage (5S-45N latitude, 75-145E longitude)
					Advanced GOCI	380, 412, 443, 490, 510, 555, 620, 660, 680, 709, 745, 865, 643.5(PAN) (nm)	Multipurpose imaging VIS/IR radiometer; Korea/Japan regional coverage (10 times/day) + once daily full disk, spatial resolution ≤ 250m

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Global Precipitation Measurement (GPM)	NASA JAXA	LEO (Non-sun synch;incline= 65°;alt=407km)	2014-2019	2014-2032+/-5	Dual-frequency Precipitation Radar (DPR)	13.6 (Ku-band), 35.55 (Ka-band) [GHz]	Electronic scanning planar array with swath width of 245 km at 13.6 GHz, 125 km at 35.55 GHz; Coverage: +/-66° latitude every 5 days Spatial resolution: 5km horizontal, 250 m vertical
					GPM Microwave Imager (GMI)	10.65(V,H), 18.7(V,H), 23.8(V), 36.5 (V,H), 89.0 (V,H), 166.0 (V,H), 183.31+/-7(V), 183.31+/-3(V) [GHz]	Conical scanning imager at 53deg zenith angle with 850 km swath width; Coverage: +/-70° latitude every 2 days Spatial resolution varies with frequency: 19x32km at 10.65 to 4.4x7.2km at 89-183.
Global Change Observation Mission-Water (GCOM-W1)	JAXA	LEO (Sun-synch, cross EQ at 1330LST; incline=98°;alt=700km)	2012-2017	2012-2027	Advanced Microwave Scanning Radiometer v2 (AMSR2)	6.925(V,H), 7.3(V,H), 10.65(V,H), 18.7(V,H), 23.8(V,H), 36.5(V,H), 89.0(V,H) [GHz]	Conical scanning imager at 55° zenith angle with 1450 km swath width; Coverage: Global once/day Spatial resolution varies with frequency: 35x62 km at 6.925 to 3x5 km at 89
Earth Clouds, Aerosol and Radiation Explorer (EarthCARE)	ESA JAXA	LEO (Sun-synch, cross EQ at 14:00LST.;incline=97°;alt=393km; 92.5min period)	~2021-2024	?	Atmospheric Lidar (ATLID)	355 [nm]	High Spectral Resolution Laser at +/-3° of along-track; Coverage: Global every 16days Spatial resolution: 30 m horizontal and 100 m vertical;
					Cloud Profiling Radar (CPR)	94.05 [GHz]	Doppler capability; Nadir only; Minimum sensitivity of –35dB; Coverage: Global every 16days Spatial resolution: 750m horizontal x 400m vertical
					Multi-Spectral Imager (MSI)	670-865 [nm] (VNIR), 1670-2210 [nm] (SWIR), 8.8-12.0 [μm] (TIR)	Pushbroom scanning; 15 km swath Coverage: Global every 8days(IR), 16days(SWIR); Spatial resolution: 500m pixel
Green-house gas Observing Satellite (GOSAT-3)	JAXA	LEO (Sun-synch; polar orbit)	2022-2027	2022-2032	Advanced Microwave Scanning Radiometer v3 (AMSR3)	6.925(V,H), 7.3(V,H), 10.65(V,H), 18.7(V,H), 23.8(V,H), 36.5(V,H), 89.0(V,H), 166(V,H), 183 [GHz]	Frequencies will be likely similar to AMSR2 with addition of 2 channels at higher microwave freq.
Weather System Follow-on-Microwave (WSF-M 1, 2)	DoD	LEO (polar orbit)	2022-?	2023-2033	Microwave Imager	10-89 [GHz]	Frequencies will be likely similar to GMI, but without high-frequency channels

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Joint Polar Satellite System (JPSS) JPSS-1/NOAA-20 JPSS-2 JPSS-3 JPSS-4	NOAA EUMETSAT NASA	LEO (Sun-synch, Z= 824 km, incline = 98.7º, period = 101 mins) ~13:30 Equator x-ing (Ascending)	2017-2038 JPSS1 ≥ 2017 JPSS2 ≥ 2021 JPSS3 ≥ 2026 JPSS4 ≥ 2031 (each 7 years)	2017-2038	Advanced Technology Microwave Sounder (ATMS)	22 channels from 23.8 GHz –183.3 GHz	Absorption band MW radiometer, cross-track scanning
					Clouds and the Earth's Radiant Energy System (CERES/RBI	CERES: 0.3-5μm, 8-12μm, 0.35-125μm	Broad-band radiometer; RBI de-manifested from JPSS-2; still scheduled for JPSS-3/4
					Ozone Mapping and Profiler Suite - Nadir (OMPS-N)	Mapper: 300-420nm Profiler: 250-310nm	High-resolution nadir-scanning SW (UV) spectrometer
					Ozone Mapping and Profiler Suite- Limb (OMPS-L)		Limb-scanning SW (UV) spectrometer; scheduled for JPSS-2/3/4
					Cross-track Infrared Sounder (CrIS)	*Nominal Mode* (NSR): 1,305 spectral channels (SWIR: 3.92-4.64μm; MWIR: 5.71-8.26μm; LWIR: 9.14-15.38μm) *Full Spectral Resolution Mode* (FSR): 2211 spectral channels in SWIR, MWIR, LWIR	Medium-resolution IR spectrometer NSR spectral resolution: 0.625 (LWIR), 1.25 (MWIR), and 2.5 (SWIR) cm-1 FSR spectral resolution: 0.625 cm-1 in all bands
					Visible Infrared Imaging Radiometer Suite (VIIRS)	*M-bands***: 0.41, 0.44, 0.49, 0.55, 0.67, 0.75, 0.87, 1.24, 1.38, 1.61, 2.25, 3.7, 4.0, 8.6, 10.8, 12.0 (μm) *DNB*** : 0.7 μm *I-Bands**: 0.64, 0.87, 1.6, 3.7, 11.4 (μm) Spatial(nadir): * = 0.375 km, ** = 0.75 km	Multipurpose VIS/IR spectrometer M-bands, DNB: 750m spatial resolution (nadir) I-bands: 375m spatial resolution (nadir)

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Metop-SG (A1,A2,A3)	EUMETSAT DLR COM CNES ESA	LEO Sun-sync, Z=830 km ~9:30 Equator x-ing (descending)	2021-2042 Metop-A1 ≥ 2021 Metop-A2 ≥ 2029 Metop-A3 ≥ 2036 (each = 8.5 years)	2021-2042	Microwave Sounder (MWS)	23.8 – 229.0 GHz	Absorption-band MW radiometer
					Radio Occultation (RO)	1575.42, 1176.45, 1575.42, 1176.45 (MHz)	GNSS radio occultation receiver
					UVNS (Sentinel-5)	270-300, 300-370, 370-500, 685-710, 710-750, 750-775, 1590-1675, 2305-2385 (nm)	High-resolution nadir-scanning SW spectrometer
					Infrared Atmospheric Sounder Interferometer - New Generation (IASI-NG)	645, 655, 663, 690 (cm-1) 690 – 2420 cm-1 (0.25 cm-1 sampling) 2420, 2450, 2600, 2700, 2760 (cm-1)	IR sounder (Fourier transform spectrometer)
					Multi-viewing, Multichannel, Multi-polarization Imager (3MI)	Polarized: 0.410, 0.443, 0.49, 0.55, 0.67, 0.865, 1.37, 1.65, 2.13 (µm) Total Radiance: 0.763, 0.765, 0.91 (µm) Spatial(nadir) = 4 km	Multi-channel/direction/polarization radiometer, swath width > 2200km 14-angles
					METimage	0.443, 0.55, 0.668, 0.752, 0.763, 0.865, 0.914, 1.24, 1.375, 1.63, 2.25, 3.74, 3.959, 4.05, 6.725, 7.325, 8.54, 10.69, 12.02, 13.345 (µm)	Multipurpose VIS/IR radiometer, ~2670km swath width (500m nadir spatial resolution)

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Metop-SG (B1,B2,B3)	EUMETSAT CNES ESA	LEO	2022-2042	2022-2042	RO	1575.42, 1176.45, 1575.42, 1176.45 (MHz)	GNSS radio occultation receiver
					ICI	183.31 – 664 GHz	Ice cloud imaging MW radiometer
					MWI	18.7 – 183.31 GHz	Multipurpose imaging MW radiometer
					SCA	5.355 GHz (C band)	Radar scatterometer
Sentinel-2 (C)	ESA COM	LEO	2021-2029	2021-2029	MSI	442.7, 492.4, 559.8, 664.6, 704.1, 740.5, 782.8, 832.8, 864.7, 945.1, 1373.5, 1613.7, 2202.4 (nm)	High-spatial resolution pushbroom optical imager, 290km swath; 2 satellite constellation in same descending orbit, phased 180° apart
Sentinel-3 (C)	ESA EUMETSAT COM	LEO	2023-2029	2023-2029	Ocean and Land Colour Instrument (OLCI)	21 channels, 0.4 – 1.02 µm 400, 412.5, 442.5, 490, 510, 560, 620, 665, 673.75, 681.25, 708.75, 753.75, 764.37, 767.5, 778.75, 778.75, 865, 885, 900, 940, 1020 (nm) ** these bands are programmable Resolution = 300 m (nadir)	Medium-resolution pushbroom spectroradiometer; 1270 km swath Note 100% overlap with SLSTR-nadir
					Sea and Land Surface Temperature Radiometer (SLSTR)	0.55*, 0.66*, 0.87*, 1.38*, 1.61*, 2.25*, 3.7**, 10.8**, 12.0 (µm) Spatial: *VIS/NIR/SWIR at 0.5 km, TIR at 1 km Gains: **Dual gain (for monitoring fires)	Multi-channel/direction radiometer; dual-view scan (1420km swath nadir, 750km swath aft)
Sentinel-6 (B)	ESA EUMETSAT NASA NOAA COM CNES	LEO	2025-2030	2025-2030	TriG		GNSS radio occultation receiver
					AMR-C		Advanced MW radiometer

Mission Family	Agency	Orbit	Operating Period		Relevant Instruments		Notes
			Designed	Likely	Name	Channels	
Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)	NASA SRON	LEO	2022-2025 + 2	2022-2032 (fuel)	Ocean Color Imager (OCI)	340 nm - 890 nm, continuous at 5 nm spectral resolution; 940, 1038, 1250, 1378, 1615, 2130, 2260 nm Resolution = 1 km at nadir	MODIS + SeaWiFS + OMI heritage PACE includes two demonstration multi-angle polarimeters (HARP-2 and SPEXone) but will have low confidence to be running in 2028

Aerosol Absorption Optical Depth AAOD		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

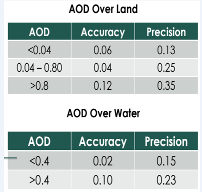
Aerosol Angstrom Exponent AE (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
JPSS (NOAA-20+)	LEO 13:30 eq. x-ing, ascending	-1.0 - 3.0 (water only)	Metric Ocean (Best / Good) Accuracy 0.050 / 0.001 Precision 0.377 / 0.370	0.75 km nadir		daily	3000 km	Reflectance in VIS/NIR/SWIR (NOAA-VIIRS heritage)		NOAA Enterprise Algorithm Resolution varies on native pixel size AE Reported only over water; reported at 0.55/0.86 mm
		0.0 - 2.0 (Land and Water)	Land: ? water: ?	6 km nadir		daily	3000 km	Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS/SeaWIFs heritage)		NASA MODIS-like ("Deep-Blue/SOAR") aerosol approach: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution varies on native pixel size • Water: AE defined as 0.55/0.87 • Land: AE defined as 0.41/0.48 over 'bright' surface, 0.48/0.67 over 'dark'.
		-1.0 – 3.0	Land: Ocean: ±(0.4) Requires AOD>0.2	6 km nadir		daily	3000 km	Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS heritage)		NASA MODIS-like ("Dark-Target") aerosol approach: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution varies on native pixel size • Ocean: Reported at 0.55/0.86 and 0.86/2.2 µm, but only validated at 0.55/0.86.

Aerosol Index of Refraction AIR		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Aerosol Angstrom Exponent **AE (2)**		**PoR Capability**						**Relevant Observables**		**Notes**
		Range	**Uncertainty**	**Resolution**						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
ABI (GOES-S/T/U)	GEO (75°W and 135°W)	-1.0 - 3.0 (water only)	**Metric** | **Ocean (Best / Good)** **Accuracy** | 0.050 / 0.001 **Precision** | 0.377 / 0.370	2 km (nadir)		10 min	FD / CONUS	Reflectance in VIS/NIR/SWIR (NOAA-VIIRS heritage)		NOAA algorithms (TBD) Resolution varies on native pixel size AE Reported only over water; reported at 0.55/0.86 mm
		0.0 - 2.0 (Land and Water)	Land: ? water: ?	TBD		TBD	FD		Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS/SeaWIFs heritage)	NASA MODIS-like ("Deep-Blue/SOAR") aerosol approach: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution varies on native pixel size • Water: AE defined as 0.55/0.87 • Land: AE defined as TBD (wavelengths) • Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33).
		-1.0 – 3.0	Land: Ocean: ±(0.4) Requires AOD>0.2	10 km nadir		10 min	FD		Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS heritage)	NASA MODIS-like ("Dark-Target") aerosol approach: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution varies on native pixel size • Ocean: Reported at 0.55/0.86 and 0.86/2.2 μm, but only validated at 0.55/0.86. • Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33).

Aerosol Angstrom Exponent AE (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

<table>
<tr><th colspan="2" rowspan="2">Aerosol Optical Depth
AOD (τ)
Mid-Visible (1)</th><th colspan="6">PoR Capability</th><th colspan="2" rowspan="2">Relevant Observables</th><th rowspan="3">Notes</th></tr>
<tr><th rowspan="2">Range</th><th rowspan="2">Uncertainty</th><th colspan="4">Resolution</th></tr>
<tr><th>Instrument</th><th>Orbit</th><th>XY</th><th>Z</th><th>T</th><th>Swath</th><th>Standard</th><th>Possible</th></tr>
<tr><td colspan="2" rowspan="4">ABI
(GOES-S,T,U)

GEO (75°W and 135°W)</td><td>0.0 – 5.0</td><td>
AOD Over Land
<table><tr><th>AOD</th><th>Accuracy</th><th>Precision</th></tr><tr><td><0.04</td><td>0.06</td><td>0.13</td></tr><tr><td>0.04 – 0.80</td><td>0.04</td><td>0.25</td></tr><tr><td>>0.8</td><td>0.12</td><td>0.35</td></tr></table>
AOD Over Water
<table><tr><th>AOD</th><th>Accuracy</th><th>Precision</th></tr><tr><td><0.4</td><td>0.02</td><td>0.15</td></tr><tr><td>>0.4</td><td>0.10</td><td>0.23</td></tr></table></td><td>2 km nadir</td><td></td><td>10 min

? min</td><td>FD and CONUS</td><td colspan="2">Reflectance in VIS/NIR/SWIR (NOAA-VIIRS heritage)</td><td>NOAA Baseline (ABI-AOD)

• Time/Swath given for FD mode
• Resolution varies on native pixel size
• Range/Unc. are for AOD at 0.55 μm,
• Other variables include spectral AOD</td></tr>
<tr><td>0.0 - 5.0</td><td>Land:
$\pm(0.15\tau + 0.05)$

Ocean:
$\pm(0.10\tau + 0.04)$</td><td>10 km nadir</td><td></td><td>10 min</td><td>FD</td><td colspan="2">Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-DarkTarget Heritage)</td><td>“Dark-Target” aerosol approach: (single view)
• Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc.
• Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33).
• Resolution varies on native pixel size</td></tr>
<tr><td>0.0 – 4.0</td><td>Land:
$\pm(0.15\tau + 0.05)$</td><td>1 km</td><td></td><td>?</td><td>gridded</td><td colspan="2">Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-MAIAC Heritage</td><td>“MAIAC approach” (time/space aggregation)
• Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc.
• Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33).
• Resolution is constant (gridded)</td></tr>
<tr><td>0.0 – 3.0</td><td>Land:
?
Ocean:
?</td><td></td><td></td><td>?</td><td>FD</td><td colspan="2">Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-DeepBlue Heritage</td><td>“Deep-Blue/SOAR” aerosol approach: (single view)
• Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc.
• Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33).
• Resolution varies on native pixel size</td></tr>
</table>

Aerosol Optical Depth AOD (τ) Mid-Visible (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
AHI (Himawari)	GEO (141° E)	0.0 – 5.0?	??	2 km nadir ?		1 hour	FD and Japan	Reflectance in VIS/NIR/SWIR (JAXA heritage)		JAXA products • Resolution varies on native pixel size • Range/Unc. are for AOD at 0.55 μm,
		0.0 - 3.0	Land: ±(0.15τ + 0.05)	6 km nadir		?	FD?	Reflectance in VIS/NIR/SWIR		YAER algorithm (single view + minimum reflectance technique)
		0.0 - 5.0	Land: ±(0.15τ + 0.05) Ocean: ±(0.10τ + 0.04)	10 km nadir		10 min	FD		Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS Heritage) Note, there is no 1.38 μm (cirrus channel).	"Dark-Target" aerosol approach: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33). • Resolution varies on native pixel size • no 1.38 μm cirrus band may impact quality
		0.0 – 4.0	Land: ±(0.15τ + 0.05)	1 km		10 min	FD		Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-MAIAC Heritage	NASA "MAIAC-like" (time/space aggregation) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33). • Resolution is constant (gridded)
		0.0 – 3.0	Land: ? Ocean: ?						Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-DeepBlue Heritage	"Deep-Blue/SOAR" aerosol approach: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support needed (e.g., ROSES-19 A.33). • Resolution varies on native pixel size

Aerosol Optical Depth AOD (τ) Mid-Visible (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
AMI (GEO-KOMPSAT 2A)	GEO (122°E)	?	?				FD / Korea	Reflectance in VIS/NIR/SWIR		Presumably there is an at-launch product from Korea. Need to ask
		0.0 - 5.0	Land: ±(0.15τ + 0.05) Ocean: ±(0.10τ + 0.04)	10 km nadir		10 min	FD	Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS Heritage) Note no 2.25 μm band		NASA heritage algorithms("Dark-Target and/or "Deep Blue/SOAR") approaches: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution varies on native pixel size • No 2.25 μm band may impact quality
		0.0 – 4.0	Land: ±(0.15τ + 0.05)	1 km		10 min	FD	Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-MAIAC Heritage		NASA "MAIAC-like" (time/space aggregation) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution is constant (gridded) • No 2.25 μm band may impact quality
FCI (MTG-I1,2,3,4)	GEO (0°E)	?	?				FD / Europe			Presume at least one ESA algorithm Note presence of 0.91 μm water vapor band
		0.0 - 5.0	Land: ±(0.15τ + 0.05) Ocean: ±(0.10τ + 0.04)	10 km nadir		10 min	FD	Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS Heritage) Note no 2.25 μm band		NASA heritage algorithms("Dark-Target and/or "Deep Blue/SOAR") approaches: (single view) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution varies on native pixel size
		0.0 – 4.0	Land: ±(0.15τ + 0.05)	1 km		10 min	FD	Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-MAIAC Heritage		NASA "MAIAC-like" (time/space aggregation) • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Resolution is constant (gridded)

<table>
<tr><th colspan="2" rowspan="2">Aerosol Optical Depth
AOD (τ)
Mid-Visible (4)</th><th colspan="6">PoR Capability</th><th colspan="2" rowspan="2">Relevant Observables</th><th rowspan="3">Notes</th></tr>
<tr><th rowspan="2">Range</th><th rowspan="2">Uncertainty</th><th colspan="4">Resolution</th></tr>
<tr><th>Instrument</th><th>Orbit</th><th>XY</th><th>Z</th><th>T</th><th>Swath</th><th>Standard</th><th>Possible</th></tr>
<tr><td rowspan="4">VIIRS on JPSS (NOAA-20+)</td><td rowspan="4">LEO
(13:30 equator x-ing)</td><td>0.0 – 5.0</td><td><table><tr><th>Metric</th><th>Land (Best / Good)</th><th>Ocean (Best / Good)</th></tr><tr><td>Accuracy</td><td>0.018 / 0.047</td><td>0.030 / 0.049</td></tr><tr><td>Precision</td><td>0.112 / 0.138</td><td>0.046 / 0.060</td></tr></table></td><td>0.75 km nadir</td><td></td><td>1 or 2 per day</td><td>3000 km</td><td colspan="2">Reflectance in VIS/NIR/SWIR (NOAA-VIIRS heritage)</td><td>NOAA Enterprise Algorithm
Resolution varies on native pixel size
Range/Unc. are for AOD at 0.55 μm, based on ATBD paper, rather than specifications.</td></tr>
<tr><td>0.0 - 3.0</td><td>Land:
±(0.20τ + 0.05)
Ocean:
±(0.10τ + 0.03)</td><td>6 km nadir</td><td></td><td>1 or 2 per day</td><td>3000 km</td><td colspan="2">Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS/SeaWIFs heritage)</td><td>NASA MODIS-like (“Deep-Blue/SOAR”) aerosol approach: (single view)
• Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc.
• Resolution varies on native pixel size
• Uses 0.41 μm (“Deep-Blue”) bands</td></tr>
<tr><td>0.0 - 5.0</td><td>Land:
±(0.15τ + 0.05)
Ocean:
±(0.10τ + 0.04)</td><td>6 km nadir</td><td></td><td>1 or 2 per day</td><td>3000 km</td><td colspan="2">Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR (NASA-MODIS heritage)</td><td>NASA MODIS-like (“Dark-Target”) aerosol approach: (single view)
• Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc.
• Resolution varies on native pixel size</td></tr>
<tr><td>0.0 – 4.0</td><td>Land:
±(0.15τ + 0.05)</td><td>1 km</td><td></td><td>1 or 2 per day</td><td>3000 km</td><td colspan="2">Reflectance/Radiance in VIS/NIR/SWIR/Thermal IR NASA-MAIAC Heritage</td><td>NASA “MAIAC-like” (time/space aggregation)
• Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc.
• Resolution is constant (gridded)</td></tr>
</table>

Aerosol Optical Depth AOD (τ) Mid-Visible (5)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
SLSTR (Sentinel-3)	LEO	?		4.5km		?	?	Reflectance in VIS/NIR/SWIR + dual view (ATSR heritage),		ESA at launch algorithm This is near real-time processing
OLCI + SLSTR (Sentinel 3)	LEO	?						Dual view reflectance + mutlispectral VIS/NIR at high spatial resolution		This is a synergy product for the two sensors on Sentinel-3, uses bands from both sensors.
OCI (PACE)	LEO	See NASA algorithms on VIIRS (JPSS)		10 km		Every 1 or 2 days		VIS/NIR/SWIR spectral bands		MODIS-Dark target and/or Deep Blue/SOARa and/or MAIAC heritage over land and ocean. "At-launch" algorithms TBD
				1 km	?	Every 1 or 2 days		VIS/NIR/SWIR spectral bands + O2A/B + UV		MODIS + OMI synergy Use O2A/B bands to estimate layer height? Use UV to estimate aerosol absorption?

Aerosol Optical Depth AOD (τ) Mid-Visible (6)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
3MI (Metop-SG A1,2,3)	LEO (9:30 equ xing)		Water: $\pm(0.05\tau + 0.05)$ Land: ?					Multi-angle polarized reflectance at, e.g., 0.443, 0.67, 0.865µm		POLDER heritage https://www.atmos-meas-tech.net/11/6761/2018/ https://www.atmos-meas-tech.net/4/1383/2011/amt-4-1383-2011.pdf
			Water: 0.10τ or 0.05 Land: 0.15τ or 0.10	3.5 (at nadir)				Multi-angle polarized reflectance plus SWIR		POLDER/GRASP heritage (expectations from Dubovik)
METImage (Metop-SG A1,2,3)	LEO (9:30 equ xing)		?					Similar image/channels as VIIRS on JPSS		No official L2 aerosol products, but no reason why cannot follow the NASA heritage.

Aerosol Optical Depth AOD (UV)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
OCI (on PACE)	LEO		MAX(0.3τ or 0.1)					Spectral reflectance in 300-500 nm		OMI-heritage multi-wavelength algorithm • retrieves Absorption Aerosol Index, assumes layer height, Lambertian Effective Reflectance • At-launch algorithms TBD
								VIS/NIR/SWIR spectral bands + O2A/B + UV		• Use O2A/B bands to estimate layer height? • Use VIS/NIR/SWIR to estimate AOD and aerosol size?
OMPS (on JPSS)	LEO (13:30 equator x-crossing, ascending)		MAX(0.3τ or 0.1)					Spectral reflectance in 300-500 nm		OMI-heritage multi-wavelength algorithm • retrieves Absorption Aerosol Index, assumes layer height, Lambertian Effective Reflectance • No current algorithm
UVNS / Sentinel-5	LEO						2670 km			
UVS / Sentinel-4 on	GEO (Europe)			3.5 x 8 km (Europe)		1 hr	NH / Europe			https://sentinel.esa.int/web/sentinel/missions/sentinel-4/data-products
GEMS (on KOMPSAT-2B)	GEO (Korea)	0-5	20% or 0.1@ 400nm	3.5 x 8 km (over Seoul)		1 hr	NH / Korea	Spectral reflectance in 300-500 nm		http://tempo.si.edu/presentations/June2016/08-GEMS-JKim-TEMPOstm.pdf
TEMPO?	GEO (US)		±0.1	9 x 5 km		1 hr	NH / US	290-490 & 540-740 (Hyp.)		http://tempo.si.edu/presentations.html

<table>
<tr><th colspan="2">Aerosol Optical Depth, Fine Mode
AODF</th><th colspan="6">PoR Capability</th><th colspan="2">Relevant Observables</th><th rowspan="3">Notes</th></tr>
<tr><th rowspan="2">Instrument</th><th rowspan="2">Orbit</th><th rowspan="2">Range</th><th rowspan="2">Uncertainty</th><th colspan="4">Resolution</th><th rowspan="2">Standard</th><th rowspan="2">Possible</th></tr>
<tr><th>XY</th><th>Z</th><th>T</th><th>Swath</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td></tr>
</table>

Work in Progress

Aerosol Single Scatter Albedo Aerosol SSA		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Aerosol Single Scatter Albedo Aerosol SSA (UV)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
UVSN/Sentinel-5	LEO						2670 km			https://sentinel.esa.int/web/sentinel/missions/sentinel-5/data-products
UVS/Sentinel-4	GEO			8		1 hr				https://sentinel.esa.int/web/sentinel/missions/sentinel-4/data-products
GEMS (KOMPSAT-2B)	GEO			3.5x8 km (over Seoul)		1 hr				http://tempo.si.edu/presentations/June2016/08-GEMS-JKim-TEMPOstm.pdf

Cloud Albedo CA		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			XY	Z	T	Swath	**Standard**	**Possible**	
CERES/RBI	LEO			20km				TOA radiance in 3 broadbands (0.3-5µm, 8-12µm, 0.35-125µm)		Cloud albedo derived from TOA radiances, co-located imager observations, and angular distribution models (e.g., VIIRS).

Cloud Effective Radius **CER (1)**		**PoR Capability**						**Relevant Observables**		**Notes**
		Range	**Uncertainty**	**Resolution**						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
ABI (GOES-S,T,U)	GEO	Liquid and Ice: 2.5-100µm	Liquid: ~4µm Ice: ~5µm	2km nadir	N/A	15 min 5 min 5 min	Full Disk CONUS Meso	Reflectance at 2.25µm		• NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP/CLAVR-x) • SZA < 65° (degraded product between 65° and 82°)
		Liquid: 2-32µm Ice (D_e): 5.83-134.9µm	Liquid: ~40% Ice: ~15-42%	2km nadir	N/A	15 min 5 min 5 min	Full Disk CONUS Meso	Radiance at 3.9, 11.2, 12.3µm (8.5 and 13.3µm under future consideration)		• NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) • SZA > 82°
		Liquid: 4-30µm Ice: 5-60µm	TBD	2km nadir	N/A	TBD	All scan modes possible	Reflectance at 1.61, 2.25, 3.9µm		**NASA Continuity Cloud Products (CLDPROP):** • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products (MOD06, CLDPROP) in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33). • Daytime only
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk	Reflectance at 2.25		JAXA Himawari Products: • Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Product (CLDPROP)** notes under ABI

Cloud Effective Radius CER (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
AMI (GEO-KOMPSAT 2A)	GEO							Reflectance at 1.61, 3.8µm		
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	Reflectance at 1.61, 3.8µm		See **NASA Continuity Cloud Product** (**CLDPROP**) notes under ABI
FCI (MTG-I1,2,3,4)	GEO							Reflectance at 1.61, 2.25, 3.8µm		
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product** (**CLDPROP**) observables under ABI		See **NASA Continuity Cloud Product** (**CLDPROP**) notes under ABI

Cloud Effective Radius CER (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
VIIRS (NOAA-20+)	LEO	Liquid and Ice: 2.5-100µm	Liquid: ~4µm Ice: ~5µm	750m nadir	N/A	once daily	3060km	Reflectance at 2.25µm		• NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP) • SZA < 65° (degraded product between 65° and 82°)
		Liquid: 2-32µm Ice (De): 5.83-134.9µm	Liquid: ~40% Ice: ~15-42%	750m nadir	N/A	once daily	3060km	Radiance at 3.7, 10.8, 12.0µm (8.6µm under future consideration)		• NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) • SZA > 82°
		Liquid: 4-30µm Ice: 5-60µm		750m nadir	N/A	once daily	3060km	Reflectance at 1.61, 2.25, 3.8µm		**NASA Continuity Cloud Products (CLDPROP):** • MOD06 heritage • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts. • Daytime only
3MI (Metop-SG A1,2,3)	LEO							Multi-angle polarized reflectance at, e.g., 0.443, 0.67, 0.865µm		• Cloud top CER • Requires adequate angular sampling of the cloud bow region, scattering angles roughly 135-165°
METImage (Metop-SG A1,2,3)	LEO			500m nadir				Reflectance at 1.63, 2.25, 3.74µm		
MSI (Sentinel-2)	LEO								Reflectance at 1613.7, 2202.4nm	Spectral channel capabilities available

Areal Cloud Fraction/Areal Extent ACF/CAE (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			XY	Z	T	Swath	Standard	Possible	
ABI (GOES-S,T,U)	GEO	cloud (conf, prob) clear (conf, prob)	Comparison with CALIOP: ~91% detection rate, ~4% false detection, ~5% missed cloud	2km	N/A	15 min	Full Disk	Reflectance at 0.64, 1.38, 1.61µm Radiance at 3.9, 6.9, 7.4, 8.6, 11.2, 12.3µm		NOAA Enterprise Cloud Mask
				2km	N/A	15 min	CONUS			
				2km	N/A	5 min	Meso			
		cloud (conf, prob) clear (conf, prob)	TBD	2km nadir	N/A	TBD	All scan modes possible	Reflectance at 0.47, 0.64, 0.87, 1.38, 1.61, 2.25µm Radiance at 3.9, 8.6, 11.2, 12.3µm		**NASA Continuity Cloud Mask (CLDMSK):** • Cloud detection consistent with NASA EOS-MODIS/SNPP-VIIRS products • Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33).
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk			JAXA Himawari Products: • Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Mask (CLDMSK)** observables under ABI		See **NASA Continuity Cloud Mask (CLDMSK)** notes under ABI

Note: Because cloud fraction is ill-defined (depends on FOV, aggregation scale, etc.), the PoR Capabilities are in terms of pixel-level cloud detection.

Areal Cloud Fraction/Cloud Areal Extent ACF/CAE (2)		**PoR Capability**						**Relevant Observables**		**Notes**
		Range	**Uncertainty**	**Resolution**						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
AMI (GEO-KOMPSAT 2A)	GEO									
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Mask** (**CLDMSK**) observables under ABI		See **NASA Continuity Cloud Mask** (**CLDMSK**) notes under ABI
FCI (MTG-I1,2,3,4)	GEO									
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Mask** (**CLDMSK**) observables under ABI		See **NASA Continuity Cloud Mask** (**CLDMSK**) notes under ABI
VIIRS (NOAA-20+)	LEO	cloud (conf, prob) clear (conf, prob)	Comparison with CALIOP: ~91% detection rate, ~4% false detection, ~5% missed cloud	750m nadir	N/A	twice daily	3060km	Reflectance at 0.41, 0.67, 0.87, 1.38, 1.61, 2.25µm, plus 0.7µm DNB Radiance at 3.7, 4.0, 8.6, 10.8, 12.0µm		NOAA Enterprise Cloud Mask
		cloud (conf, prob) clear (conf, prob)		750m nadir	N/A	twice daily	3060km	Reflectance at 0.41, 0.44, 0.55, 0.67, 0.87, 1.24, 1.38, 1.61, 2.25µm Radiance at 3.7, 8.6, 10.8, 12.0µm		**NASA Continuity Cloud Mask (CLDMSK):** • MOD35 heritage • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts.
METImage (Metop-SG A1,2,3)	LEO									

Ice Water Path IWP (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
ABI (GOES-S,T,U)	GEO	~0-6375 g m^{-2}	65 g m^{-2}	2km nadir	N/A	15 min	Full Disk	Derived from COT (reflectance at 0.64µm) and CER (reflectance at 2.25µm)		• NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP/CLAVR-x) • SZA < 65° (degraded product between 65° and 82°)
						5 min	CONUS			
						5 min	Meso			
		~0-1525 g m^{-2}	N/A	2km nadir	N/A	15 min	Full Disk	Radiance at 3.9, 11.2, 12.3µm (8.5 and 13.3µm under future consideration)		• NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) • SZA > 82°
						5 min	CONUS			
						5 min	Meso			
			TBD	2km nadir	N/A	TBD	All scan modes possible	Derived from COT (reflectance at 0.64 or 0.87µm) and CER (reflectance at 1.61, 2.25, 3.9µm)		**NASA Continuity Cloud Products (CLDPROP):** • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33). • Daytime only
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk	Derived from COT and CER		JAXA Himawari Products: • Not explicitly available, but can be calculated from existing products • Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Product (CLDPROP)** notes under ABI

Ice Water Path IWP (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
AMI (GEO-KOMPSAT 2A)	GEO				N/A					
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible			See **NASA Continuity Cloud Product** (**CLDPROP**) notes under ABI
FCI (MTG-I1,2,3,4)	GEO				N/A					
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product** (**CLDPROP**) observables under ABI		See **NASA Continuity Cloud Product** (**CLDPROP**) notes under ABI

Ice Water Path IWP (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
VIIRS (NOAA-20+)	LEO	~0-6375 g m^{-2}	65 g m^{-2}	750m nadir	N/A	once daily	3060km	Derived from COT (reflectance at 0.64μm) and CER (reflectance at 2.25μm)		• NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP) • SZA < 65° (degraded product between 65° and 82°)
		~0-1525 g m^{-2}	N/A	750m nadir	N/A	once daily	3060km	Derived from COT and CER (radiance at 3.7, 10.8, 12.0μm)		• NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) • SZA > 82°
				750m nadir	N/A	once daily	3060km	Derived from COT (reflectance at 0.67, 0.87, or 1.24μm) and CER (reflectance at 1.61, 2.25, 3.8μm)		**NASA Continuity Cloud Products (CLDPROP):** • Algorithm heritage: MOD06 • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts. • Daytime only
3MI (Metop-SG A1,2,3)	LEO							Multi-angle polarized reflectance at, e.g., 0.443, 0.67, 0.865μm		• Cloud top CER • Requires adequate angular sampling of the cloud bow region, scattering angles roughly 135-165°
METImage (Metop-SG A1,2,3)	LEO			500m nadir						
MSI (Sentinel-2)	LEO									Spectral channel capabilities available

Cloud Lifecycle Categories CLC		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Cloud Liquid Water Path CLWP (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
ABI (GOES-S,T,U)	GEO	~0-8750 $g\ m^{-2}$	17-47 $g\ m^{-2}$	2km nadir	N/A	15 min	Full Disk	Derived from COT (reflectance at 0.64µm) and CER (reflectance at 2.25µm)		- NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP/CLAVR-x) - SZA < 65° (degraded product between 65° and 82°)
						5 min	CONUS			
						5 min	Meso			
		~0-674 $g\ m^{-2}$	14.7 $g\ m^{-2}$ or 29.5%	2km nadir	N/A	15 min	Full Disk	Derived from COT and CER (radiance at 3.7, 10.8, 12.0µm)		- NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) - SZA > 82°
						5 min	CONUS			
						5 min	Meso			
			TBD	2km nadir	N/A	TBD	All scan modes possible	Derived from COT (reflectance at 0.64 or 0.87µm) and CER (reflectance at 1.61, 2.25, 3.9µm)		**NASA Continuity Cloud Products (CLDPROP):** - Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. - Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33). - Daytime only
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk	Derived from COT and CER		JAXA Himawari Products: - Not explicitly available, but can be calculated from existing products - Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Product (CLDPROP)** notes under ABI

Cloud Liquid Water Path CLWP (2)		**PoR Capability**						**Relevant Observables**		**Notes**
		Range	**Uncertainty**	**Resolution**						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
AMI (GEO-KOMPSAT 2A)	GEO				N/A					
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible			See **NASA Continuity Cloud Product** (**CLDPROP**) notes under ABI
FCI (MTG-I1,2,3,4)	GEO				N/A					
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Product** (**CLDPROP**) notes under ABI
GMI (GPM)	LEO	0-600 g/m2	10 g/m2	15 km	N/A	Varies	904 km	Multichannel microwave radiances		

Cloud Ice Water Path CLWP (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
VIIRS (NOAA-20+)	LEO	~0-8750 g m^{-2}	17-47 g m^{-2}	750m nadir	N/A	once daily	3060km	Derived from COT (reflectance at 0.64µm) and CER (reflectance at 2.25µm)		- NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP) - SZA < 65° (degraded product between 65° and 82°)
		~0-674 g m^{-2}	14.7 g m^{-2} or 29.5%	750m nadir	N/A	once daily	3060km	Derived from COT and CER (radiance at 3.7, 10.8, 12.0µm)		- NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) - SZA > 82°
				750m nadir	N/A	once daily	3060km	Derived from COT (reflectance at 0.67, 0.87, or 1.24µm) and CER (reflectance at 1.61, 2.25, 3.8µm)		**NASA Continuity Cloud Products (CLDPROP):** - MOD06 heritage - JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts. - Daytime only
3MI (Metop-SG A1,2,3)	LEO									
METImage (Metop-SG A1,2,3)	LEO			500m nadir						
MSI (Sentinel-2)	LEO									Spectral channel capabilities available

Cloud Optical Thickness COT (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
ABI (GOES-S,T,U)	GEO	Liquid and Ice: 0-158	Liquid: ~25% Ice: ~30%	4km nadir	N/A	15 min	Full Disk	Reflectance at 0.64μm		- NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP/CLAVR-x) - SZA < 65° (degraded product between 65° and 82°)
				2km nadir		15 min	CONUS			
		Liquid and Ice: 0-32	Liquid: 22-28% Ice: 15-32%	4km nadir	N/A	15 min	Full Disk	Radiance at 3.9, 11.2, 12.3μm (8.5 and 13.3μm under future consideration)		- NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) - SZA > 82°
				2km nadir		15 min	CONUS			
		Liquid and Ice: 0-150	TBD	2km nadir	N/A	TBD	All scan modes possible		Reflectance at 0.64 or 0.87μm (surface type dependent)	**NASA Continuity Cloud Products (CLDPROP):** - Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. - Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33). - Daytime only
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk	Reflectance at 0.64μm		JAXA Himawari Products: - Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI		See **NOAA Enterprise Product** observables under ABI	See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible		See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI	See **NASA Continuity Cloud Product (CLDPROP)** notes under ABI

Cloud Optical Thickness **COT (2)**		**PoR Capability**						**Relevant Observables**		**Notes**
		Range	**Uncertainty**	**Resolution**						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
AMI (GEO-KOMPSAT 2A)	GEO							Reflectance at		
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Product (CLDPROP)** notes under ABI
FCI (MTG-I1,2,3,4)	GEO							Reflectance at		
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		See range under ABI	TBD	2km nadir	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Product (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Product (CLDPROP)** notes under ABI

Cloud Optical Thickness COT (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
VIIRS (NOAA-20+)	LEO	Liquid and Ice: 2.5-100μm	Liquid: ~4μm Ice: ~5μm	750m nadir	N/A	once daily	3060km	Reflectance at 0.67μm		• NOAA Enterprise **Daytime** Cloud Optical and Microphysical Properties Product (DCOMP) • SZA < 65° (degraded product between 65° and 82°)
		Liquid and Ice: 0-32	Liquid: 22-28% Ice: 15-32%	750m nadir	N/A	once daily	3060km	Radiance at 3.7, 10.8, 12.0μm (8.6μm under future consideration)		• NOAA Enterprise **Nighttime** Cloud Optical and Microphysical Properties Product (NCOMP) • SZA > 82°
		Liquid and Ice: 0-150		750m nadir	N/A	once daily	3060km			**NASA Continuity Cloud Products (CLDPROP):** • Algorithm heritage: MOD06 • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts. • Daytime only
3MI (Metop-SG A1,2,3)	LEO									
METImage (Metop-SG A1,2,3)	LEO			500m nadir						
MSI (Sentinel-2)	LEO									Spectral channel capabilities available

Cloud Radiative Effects (SW/LW) CRE		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Cloud Top Height CTH (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
ABI (GOES-S,T,U)	GEO	0-15km	~1km	10km	N/A	60 min	Full Disk	Radiance at 11.2, 12.3, and 13.3µm		NOAA Enterprise ABI Cloud Height Algorithm (ACHA)
		0-15km	~1km	10km	N/A	60 min	CONUS			
		0-20km	~1km	4km	N/A	5 min	Meso			
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	Radiance at 11.2, 12.3, and 13.3µm (additional IR absorption channels possible)		**NASA Continuity Cloud Products (CLDPROP):** • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33).
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk			JAXA Himawari Products: • Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI

Cloud Top Height CTH (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			XY	Z	T	Swath	**Standard**	**Possible**	
AMI (GEO-KOMPSAT 2A)	GEO									
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI
FCI (MTG-I1,2,3,4)	GEO									
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI

Cloud Top Height CTH (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
VIIRS (NOAA-20+)	LEO	0-20km	~0.75km	750m nadir	N/A	twice daily	3060km	Radiance at 8.6, 10.8, 12.0 µm		NOAA Enterprise AWG Cloud Height Algorithm (ACHA)
		0-20km	~0.75km	750m nadir	N/A	twice daily	3060km	Radiance at 8.6, 10.8, 12.0 µm		**NASA Continuity Cloud Products (CLDPROP):** • Algorithm heritage: currently NOAA ACHA, additional approaches under consideration • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts.
3MI (Metop-SG A1,2,3)	LEO									
METImage (Metop-SG A1,2,3)	LEO			500m nadir						
MSI (Sentinel-2)	LEO									

Cloud Top Phase CTP (1)		PoR Capability						Relevant Observables	Notes
		Range	Uncertainty	Resolution					
Instrument	Orbit			XY	Z	T	Swath	Standard Possible	
ABI (GOES-S,T,U)	GEO	warm liq, supercooled liq, mixed, ice	~90% agreement with CALIOP	2km	N/A	15 min	Full Disk	Radiance at 7.3, 8.6, 11.2, 12.3μm	NOAA Enterprise Cloud Type and Cloud Phase Algorithm
				2km	N/A	5 min	CONUS		
				2km	N/A	5 min	Meso		
		liq, ice, undetermined	N/A	2km	N/A	TBD	All scan modes possible	Cloud-top temperature (radiance at 11.2, 12.3, and 13.3μm), spectral liq/ice CER (reflectance at 1.61, 2.25, 3.8μm)	**NASA Continuity Cloud Products (CLDPROP):** • Algorithm heritage: MOD06 (daytime only) and NOAA ACHA (day and night) • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts.
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk		JAXA Himawari Products: • Daytime only
		See ABI	See ABI	See ABI	See ABI	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI	See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI	See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI

Cloud Top Phase CTP (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
AMI (GEO-KOMPSAT 2A)	GEO									
		See ABI	See ABI	See ABI	See ABI	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI
FCI (MTG-I1,2,3,4)	GEO									
		See ABI	See ABI	See ABI	See ABI	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI

Cloud Top Phase CTP (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
VIIRS (NOAA-20+)	LEO	warm liq, supercooled liq, mixed, ice	~88% agreement with CALIOP	750m	N/A	twice daily	3060km	Radiance at 8.6, 10.8, 12.0µm		NOAA Enterprise Cloud Type and Cloud Phase Algorithm
		liq, ice, undetermined	N/A	750m	N/A	once or twice daily	3060km	Cloud-top temperature (radiance at 8.6, 10.8, 12.0 µm), spectral liq/ice CER (reflectance at 1.61, 2.25, 3.8µm)		**NASA Continuity Cloud Products (CLDPROP):** • Algorithm heritage: MOD06 (daytime only) and NOAA ACHA (day and night) • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts.
3MI (Metop-SG A1,2,3)	LEO									
METImage (Metop-SG A1,2,3)	LEO									
MSI (Sentinel-2)	LEO									

Cloud Top Temperature CTT (1)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
ABI (GOES-S,T,U)	GEO	180-300K	~4.75K	2km	N/A	15 min	Full Disk	Radiance at 11.2, 12.3, and 13.3μm		NOAA Enterprise ABI Cloud Height Algorithm (ACHA)
		180-300K	~4.75K	2km	N/A	5 min	Meso			
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	Radiance at 11.2, 12.3, and 13.3μm (additional IR absorption channels possible)		**NASA Continuity Cloud Products (CLDPROP):** • Retrievals consistent with NASA EOS-MODIS/SNPP-VIIRS products in assumptions, forward models, etc. • Seed money provided for algorithm porting, further support sought (see, e.g., ROSES-19 A.33).
AHI (Himawari 8,9)	GEO			5km nadir	N/A	10 min	Full Disk			JAXA Himawari Products: • Daytime only
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI

Cloud Top Temperature CTT (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
AMI (GEO-KOMPSAT 2A)	GEO									
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI
FCI (MTG-I1,2,3,4)	GEO									
		See ABI	See ABI	See ABI	N/A	See ABI	See ABI	See **NOAA Enterprise Product** observables under ABI		See **NOAA Enterprise Product** notes under ABI
		TBD	TBD	TBD	N/A	TBD	All scan modes possible	See **NASA Continuity Cloud Products (CLDPROP)** observables under ABI		See **NASA Continuity Cloud Products (CLDPROP)** notes under ABI

Cloud Top Temperature CTT (3)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
VIIRS (NOAA-20+)	LEO	180-300K	~3.65K	750m nadir	N/A	twice daily	3060km	Radiance at 8.6, 10.8, 12.0 µm		NOAA Enterprise AWG Cloud Height Algorithm (ACHA)
		180-300K	~3.65K	750m nadir	N/A	twice daily	3060km	Radiance at 8.6, 10.8, 12.0 µm		**NASA Continuity Cloud Products (CLDPROP):** • Algorithm heritage: currently NOAA ACHA, additional approaches under consideration • JPSS/NOAA-20+ products expected following SNPP-VIIRS efforts.

Cloud Vertical Structure CVS		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Work in Progress

Convective Classification CC		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
ABI (GOES-R)	GEO	≥3 classes	N/A	< 2 km at nadir (varies with spectral band) km	N/A	15-min	Full Disk	Radiances at 0.64µm; Cloud top height and temperature (radiances at 11.2, 12.3, 13.3 µm); Cloud top phase (radiances at 7.3, 8.4, 11.2, 12.3 µm) Cloud optical depth (radiances at 0.64, 2.2, 3.9, 11.2, 12.3 µm)		W+E satellites covers ~150°E longitude eastward to ~0°E longitude Methods: Texture and cloud depth/top trends from VIS/IR
						5-min	CONUS			
						30-sec	Mesoscale			
AHI (Himawari)	GEO	≥3 classes	N/A	< 2 km at nadir (varies with spectral band) km	N/A	10-min	Full Disk	Radiances at 0.64µm; Cloud top height and temperature (radiances at 11.2, 12.3, 13.3 µm); Cloud top phase (radiances at 7.3, 8.4, 11.2, 12.3 µm) Cloud optical depth (radiances at 0.64, 2.2, 3.9, 11.2, 12.3 µm)		Covers ~65°E longitude eastward to ~35°W longitude Methods: Texture and cloud depth/top trends from VIS/IR
						2.5-min	Japan/ Target Area			
						30-sec	Landmark/Mesoscale			
DPR (GPM)	LEO	≥ 3 classes	N/A	5+ km	250 m	Varies	245 km	Radar reflectivity factor		Precipitation-based observable. Can characterize as deep/shallow convection Methods: 2ADPR, Univ.

Convective Cloud Cover CCC		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Environmental Horizontal Wind Profiles **EHW.z**		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
ABI (GOES-16+)	Geostationary	> 10 m/s	2-7 m/s	Varies based on channel, availability of trackable features	Low - Mid-High	15 min	Full Disk	Atmospheric Motion Vectors – Vis, IR, Water Vapor channels		
						5 min	CONUS			
						30 s	Meso			
AHI (Himawari 8/9)	Geostationary	> 10 m/s	2-7 m/s	Varies based on channel, availability of trackable features	Low - Mid-High	10 min	Full Disk	Atmospheric Motion Vectors – Vis, IR, Water Vapor channels		
						2.5 min	Japan			
						30 s	Meso			

Environmental Humidity Profiles EH.z		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
CrIS/ATMS (JPSS)	Polar	0-100 %	35%	25 km	1 km	2/day	2600 km	Combined microwave and IR radiances		

Environmental Temperature Profiles ET.z		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
CrIS/ATMS (JPSS)	Polar	-80-50 C	1.5 K	25 km	1 km	2/day	2600 km	Combined microwave and IR radiances		

Environmental Vertical Wind Profiles EVW.z		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
CrIS/ATMS (JPSS)	Polar	T: -80-50 C RH: 0-100 %	T: 1.5 K Absolute Humidity: 35%	25 km	1 km	2/day	2600 km	Combined microwave and IR radiances		

Latent Heating Profile LH.z		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Work in Progress

Lightning Light		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
Geostationary Lightning Mapper (GLM) - GOES-16+	Geostationary	0-60+ flashes/min	70% Detection Efficiency, 5% False Alarm Rate	10 km	N/A	< 1 s	Full Disk	Data structure - Events, Groups, Flashes Notable products – Event/Group/Flash Rates, Flash Area, Flash Duration, Flash Optical Energy		Measures total lightning
Lightning Imager (LI) - MTG	Geostationary	0-60+ flashes/min	70% Detection Efficiency	10 km	N/A	< 1 s	Full Disk	Data structure - Events, Groups, Flashes Notable products – Event/Group/Flash Rates, Flash Area, Flash Duration, Flash Optical Energy		Measures total lightning
Lightning Mapping Imager (LMI) - FY4	Geostationary	0-60+ flashes/min	90% Detection Efficiency, 10% False Alarm Rate	10 km	N/A	< 1 s	China	Data structure - Events, Groups, Flashes Notable products – Event/Group/Flash Rates, Flash Area, Flash Duration, Flash Optical Energy		Measures total lightning

Particulate Matter Concentration PM		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Work in Progress

Planetary Boundary Layer Height **PBLH**		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Precipitation Discrimination (Stratiform/Convective) PD		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
DPR (GPM)	LEO (incline=65°)	3 classes	< 13%	fp (~5km@ nadir)	250 m	Varies with latitude	245 km	Reflectivity profile		Parameter represented as 3 classes (stratiform/convective/other) in the 2ADPR product. Method relies upon both horizontal variability of the reflectivity and the vertical profile of reflectivity at Ku- and Ka-bands (Awaka et al., 2016 doi: *10.1175/JTECH-D-16-0016.1*) Uncertainty is taken from Le et al., 2016 (doi: 10.1175/JTECH-D-15-0253.1)

Precipitation Particle Size PPS.z		PoR Capability						Relevant Observables		Notes
Instrument	Orbit	Range	Uncertainty	Resolution				Standard	Possible	
				XY	Z	T	Swath			
DPR (GPM)	LEO (incline=65°)	0.5-4.0 mm	0.25 mm	fp (~5km@ nadir)	250 m	Varies with latitude	245 km (Ku-band) 125 km (Dual-frequncy Swath)	Reflectivity profile at Ku-band (more accurate with dual-frequency profile at Ku- and Ka-band)		From the GPM DPR algorithm. Parameter represented as the melted particle mass-weighted mean diameter (Dm) in the GPM 2ADPR product. Method: Uses single frequency (Ku-band) used except for inner swath where dual-frequency technique is used as well. These are detailed in Seto et al., 2016 (doi: 10.1109/IGARSS.2016.7730023) Uncertainty given as MAE for 2ADPRv6 and is relative to the GPM VN (from Petersen et al., 2019 Springer book chapter). For convective precipitation, the uncertainty is higher, especially when the dual-frequency is used in v6 of 2ADPR.
DPR+GMI (GPM)	LEO (incline=65°)	0.5-4.0 mm	0.32 mm	5km@ nadir	250 m	Varies with latitude	125 km (Matched Swath)	Reflectivity profile at Ku- and Ka-bands, Brightness Temperatures		From the GPM Combined Algorithm. Parameter represented as melting particle mass-weighted mean diameter (Dm) in the GPM 2BCORRA product. Method: A combination of radar+radiometer measurements, a priori scattering tables and environmental information as detailed in Grecu et al. 2016 (doi: 10.1175/JTECH-D-16-0019.1). Uncertainty given as MAE for v5 of Combined Algorithm. and is relative to GPM VN (from Petersen et al., 2019 Springer book chapter).

Precipitation Phase Profile PP.z		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
DPR (GPM)	LEO (incline=65°)	3 classes	<5-10% (top of ML) <6-13% (bottom of ML)	5 km	250 m	Varies with latitude	245 km (Ku-band) 125 km (Dual-frequency)	Reflectivity profile at Ku- and/or Ku/Ka-band (aka dual-frequency ratio)		Method: Identification of a melting layer via detection of a Ku-band reflectivity bright band and the dual frequency ratio (DFR) profile (see Le and Chandrasekar, 2013, doi: 110.1109/TGRS.2012.2224352) Uncertainty based on for DFR method only (from Le and Chandrasekar, 2013)

Precipitation Rate Profile PR.z		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
DPR (GPM)	LEO (incline=65°)	0.2-110 mm/h	<~40% @ 1 mm/h <~30% @ 10 mm/h	5 km	250 m	Varies	245 km	Radar reflectivity factor		Liquid precipitation only Uncertainties are based on near surface rainfall for 2ADPRv5 from Fig 4 of Skofronick-Jackson et al., 2018, doi: 10.1002/qj.3313)
DPR+GMI (GPM)	LEO (incline=65°)	0.2-110 mm/h	<40% @ 1 mm/h <25% @ 10 mm/h	5 km	250 m	Varies	245 km	Radar reflectivity factor, Brightness temperature		Liquid precipitation only Uncertainties are based on near surface rainfall for GPM Combined Alg. v5 from Fig 4 of Skofronick-Jackson et al., 2018, doi: 10.1002/qj.3313)

Precipitation Rate, 2D Surface **PR2D (1)**		**PoR Capability**						**Relevant Observables**		**Notes**
		Range	**Uncertainty**	**Resolution**						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
DPR (GPM)	LEO (incline=65°)	0.2-110 mm/h	<~40% @ 1 mm/h <~30% @ 10 mm/h	5 km	N/A	Varies	245 km	Radar reflectivity factor		Liquid precipitation only Uncertainties are based on near surface rainfall for 2ADPRv5 from Fig 4 of Skofronick-Jackson et al., 2018, doi: 10.1002/qj.3313)
DPR+GMI (GPM)	LEO (incline=65°)	0.2-110 mm/h	<40% @ 1 mm/h <25% @ 10 mm/h	5 km	N/A	Varies	245 km	Radar reflectivity factor, Brightness temperature		Liquid precipitation only Uncertainties are based on near surface rainfall for GPM Combined Alg. v5 from Fig 4 of Skofronick-Jackson et al., 2018, doi: 10.1002/qj.3313)
GMI (GPM)	LEO (incline=65°)	0.2-110 mm/h	75%@ 1mm/h 25%@10 mm/h	Varies based on frequency	N/A	Varies	885 km	Brightness temperature		Method: Bayesian retrieval such as that in the GPROF Algorithm (Kummerow et al. 2015, doi: 10.1175/JTECH-D-15-0039.1) Uncertainties are based on GPROFv5 results from Fig 4 of Skofronick-Jackson et al., 2018, doi: 10.1002/qj.3313)

Precipitation Rate, 2D Surface PR2D (2)		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	
AMSR2 (GCOM-W1)	LEO (Sun-synch, cross EQ at 1330LST; incline= 98°)	0.2-110 mm/h	Similar to GMI	Varies based on frequency	N/A	Varies	1450 km	Brightness temperature		AMSR3 should also provide this record as well other Passive Microwave Radiometers planned on future missions (e.g., WSF-M, MetOP). Method: Bayesian retrieval such as that in the GPROF Algorithm (Kummerow et al. 2015, doi: 10.1175/JTECH-D-15-0039.1) Uncertainties are based on GPROFv5 comparisons from Kidd et al., 2017 (doi: 10.1002/qj.3175)
IMERG (GPM constellation+Geostationary IR)	LEO+GEO	0.2-110 mm/h		0.1°	N/A	30-min	Global			This is the Integrated Multi-Satellite Retrievals for GPM (IMERG) product created by NASA from multiple other LEO- and GEO-based products and is precipitation gauge corrected (see Huffman et al. 2017)

Precursor Gas Concentration PGC		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Work in Progress

Radiative Fluxes RadF		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

<table>
<tr><th colspan="2" rowspan="2">Surface Albedo
SA</th><th colspan="6">PoR Capability</th><th colspan="2" rowspan="2">Relevant Observables</th><th rowspan="3">Notes</th></tr>
<tr><th rowspan="2">Range</th><th rowspan="2">Uncertainty</th><th colspan="4">Resolution</th></tr>
<tr><th>Instrument</th><th>Orbit</th><th>XY</th><th>Z</th><th>T</th><th>Swath</th><th>Standard</th><th>Possible</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="2"></td><td></td></tr>
</table>

Surface Radiation Budget SRB		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Surface Turbulent Fluxes (Land/Ocean) STF		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			**XY**	**Z**	**T**	**Swath**	**Standard**	**Possible**	
GMI (GPM)	LEO	0-1500 W/m2 LHF -300-1500 W/m2 SHF	20% Ocean 30% Land	25 km	N/A	Varies	904 km	Microwave radiances combined with reanalysis model inputs (+ IR over land)		

Total Liquid Water Path TLWP		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	**Orbit**			XY	Z	T	Swath	**Standard**	**Possible**	

Water Vapor Advection WVA		PoR Capability						Relevant Observables		Notes
		Range	Uncertainty	Resolution						
Instrument	Orbit			XY	Z	T	Swath	Standard	Possible	

Work in Progress

<table>
<tr><th rowspan="2">Aerosol Parameters</th><th colspan="11">PoR Capability</th><th colspan="2">Relevant Observables</th><th rowspan="3">Notes</th></tr>
<tr><th rowspan="2">AOD (VIS)</th><th rowspan="2">AOD (UV)</th><th rowspan="2">AE</th><th rowspan="2">F - AOD</th><th rowspan="2">SSA</th><th rowspan="2">AAOD</th><th rowspan="2">Refr</th><th colspan="4">Resolution</th><th></th><th></th></tr>
<tr><th>Instrument / Orbit</th><th>XY</th><th>Z</th><th>T</th><th>Swath</th><th>Standard</th><th>Possible</th></tr>
<tr><td rowspan="4">VIIRS (JPSS)
LEO</td><td><table><tr><th>Metric</th><th>Land (Best / Good)</th><th>Ocean (Best / Good)</th></tr><tr><td>Accuracy</td><td>0.018 / 0.047</td><td>0.030 / 0.049</td></tr><tr><td>Precision</td><td>0.112 / 0.138</td><td>0.046 / 0.060</td></tr></table></td><td colspan="2"><table><tr><th>Metric</th><th>Ocean (Best / Good)</th></tr><tr><td>Accuracy</td><td>0.050 / 0.001</td></tr><tr><td>Precision</td><td>0.377 / 0.370</td></tr></table></td><td></td><td>N/A</td><td>N/A</td><td>N/A</td><td>0.75 km (nadir)</td><td>N/A</td><td>1 or 2 daily</td><td>3000 km</td><td colspan="2">Multi-spectral in VIS/NIR/SWIR
VIIRS heritage
NOAA Enterprise Algorithm</td><td></td></tr>
<tr><td>Ocean:
±(0.04 + 10%)
Land:
±(0.05 + 15%)</td><td>N/A</td><td>Ocean:
±0.4
Land:
N/A</td><td>Ocean:
Land:</td><td>N/A</td><td>N/A</td><td>N/A</td><td>6 km (nadir)</td><td>N/A</td><td>1 or 2 daily</td><td>3000 km</td><td colspan="2">Multi-spectral in VIS/NIR/SWIR
MODIS “Dark-Target” hertiage</td><td>Single view</td></tr>
<tr><td>Land:
±(0.15τ + 0.05)
Ocean:
±(0.10τ + 0.04)</td><td>N/A</td><td></td><td></td><td>?</td><td>?</td><td>N/A</td><td>6 km (nadir)</td><td>N/A</td><td>1 or 2 daily</td><td>3000 km</td><td colspan="2">Multi-spectral in Deep Blue VIS/NIR/SWIR
MODIS “Deep Blue/SOAR hertiage</td><td>Single View</td></tr>
<tr><td>Land:
±(0.15τ + 0.05)</td><td>N/A</td><td>N/A</td><td></td><td></td><td></td><td></td><td>1 km (gridded)</td><td>N/A</td><td>daily</td><td>N/A</td><td colspan="2">“MAIAC heritiatge”</td><td>Multi-view aggregation</td></tr>
<tr><td rowspan="2">OCI (PACE)
LEO</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>10 km</td><td>N/A</td><td>1/day</td><td>?</td><td colspan="2"></td><td>See VIIRS (JPSS) At;launch algroithm</td></tr>
<tr><td>YES</td><td>YES</td><td>YES</td><td>YES</td><td>YES</td><td>YES</td><td>N/A</td><td>?</td><td>?</td><td>1/day</td><td></td><td colspan="2">Multispectral VIS/NIR/SWIR + UV + O2A and O2B bands</td><td>MODIS + OMI heritage</td></tr>
</table>

DS Traceability Goals 1-2

2017 Decadal Survey Goals (from Appendix B)	**ACCP 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 Goals (from Appendix B)	ACCP 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. **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). **W-1a** Determine the effects of key boundary layer processes on weather, hydrological, and air quality. **W-3a** Determine how spatial variability in surface characteristics modifies region cycles of energy and water	**G3** Cold Cloud and Precipitation *Quantify the rate of falling snow at middle to high latitudes to advance understanding of its role in cryosphere-climate feedbacks.*
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 Impacts on Radiation *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)

Conventions for Variable List Table

- Table entries are color-coded depending on whether the variable is needed to satisfy **Minimum** or **Enhanced** Objective.
- Color code for Essential GVs: **Minimum Essential GV** **Enhanced Essential GV**
- Each Column on the left identify potential sources for the geophysical variable:
    - A – typical aerosol payload (e.g., lidar, polarimeter)
    - CCP – typical CCP payload (e.g., radar, microwave radiometers)
    - ODO – complementary observations from other 2017 Decadal Survey *Designated Observables:* "S" denotes the Surface Biology and Geology (SBG), and "M" denotes Mass Change.
    - PoR – Program of Record
    - PEA – Potential Enabled Application listed on the table to the left.
- The check mark √ indicates that the geophysical variable is needed for meeting the objective. The check mark (√) indicates that the geophysical variable coming from the PoR may contribute to the objective but by itself it is insufficient to fully meet the objective.

Geophysical Variable Table Conventions

- Table entries are color-coded depending on whether the variable is needed to satisfy **Minimum** or **Enhanced** Objective.
- Desired capabilities:
  - The spatial/temporal scales give the averaging context for the precision/accuracy for the geophysical variable
    - XY is the horizontal scale, while Z is the vertical scale
    - T is the temporal scale with these conventions: I – Instantaneous (at the time resolution of the sensor), H – hourly, R – Diurnal, ΔT – Sequential sample at TBD delta-T (e.g., 2-minutes), D – daily, W – weekly, M – Monthly, A – annual.
  - For swath, wide typically refers to geosynchronous platforms such as GOES
  - When a variable is required with a different accuracy/precision or scale for the enhanced objective, multiple values are provided following the color convention above.
- Example of Observables. Within each Objective, groups of observables are labelled (1), (2), ..., and referred by these numbers in subsequent rows.