ACCP Study Overview with Focus on Aerosols

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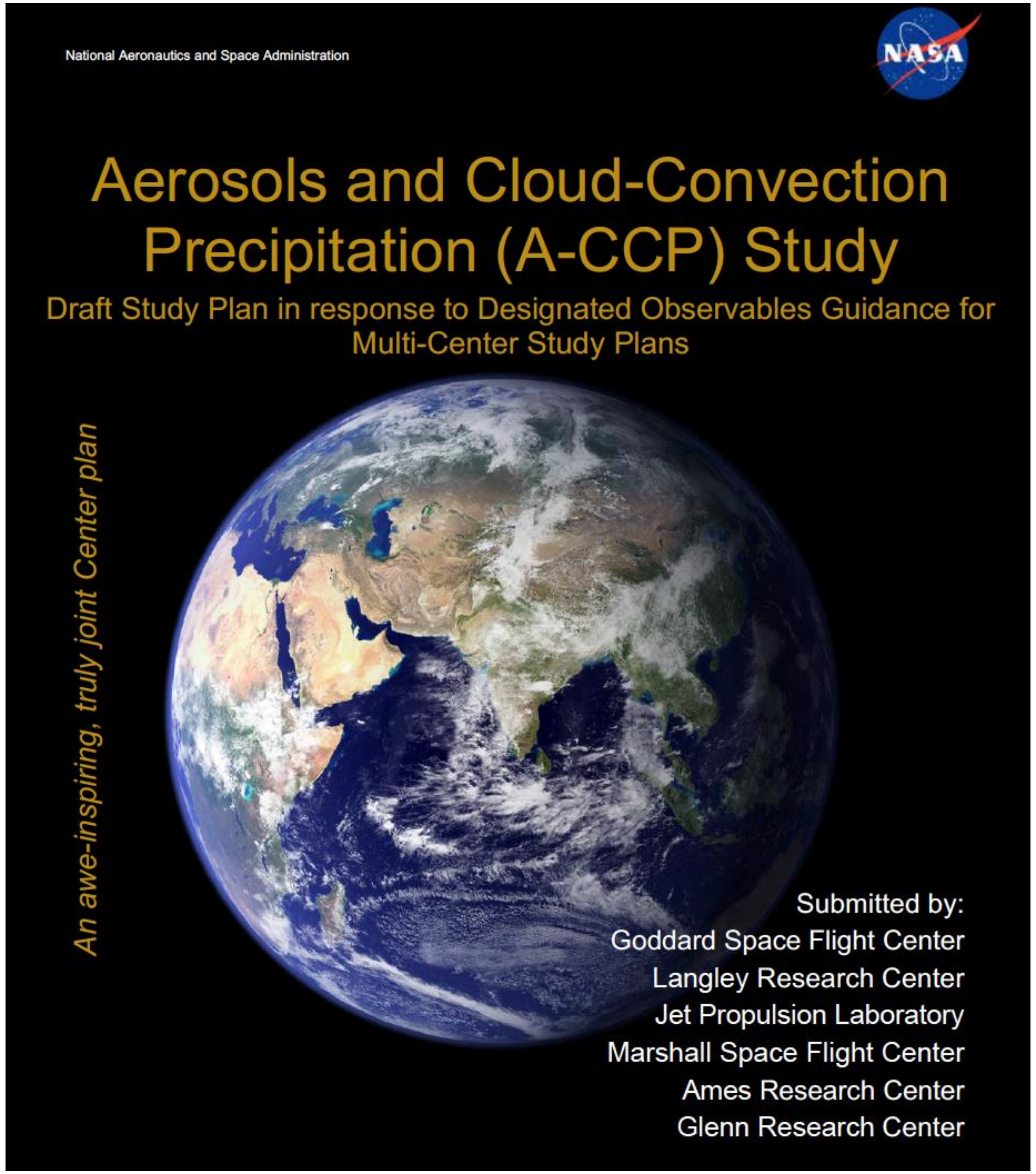
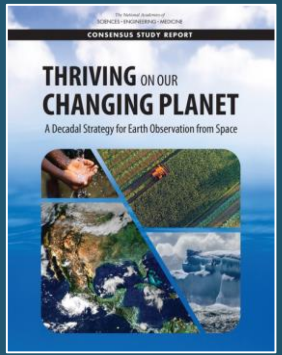
Talk Outline

1. Programmatic Basis
2. The Science of ACCP: Aerosols
3. Aerosol Goals and Objectives
4. The ACCP Study Approach
5. Key ACCP Aerosol Instrumentation
6. The Final 3 Architectures
7. Summary



Scientific and Programmatic Basis



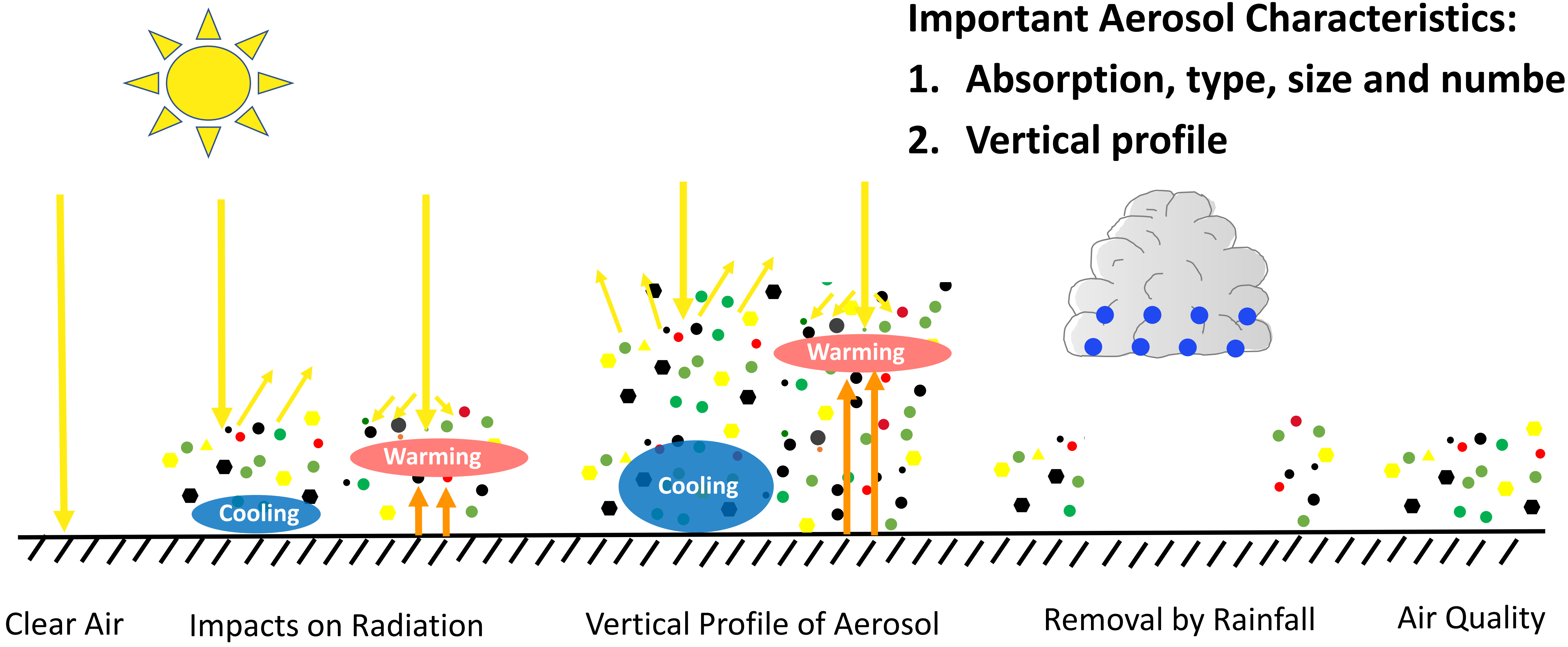
- The 2017 Decadal Survey recommended a new program element called *Designated Observables* with cost-caped missions to provide measurements essential to a comprehensive collection of Earth Science questions.
- ACCP combines 2 Designated Observables

	Aerosols	**Clouds, Convection, and Precipitation**
Observable Priorities	Aerosol properties, aerosol vertical profiles, and cloud properties to understand their effects on climate and air quality	Coupled cloud-precipitation state and dynamics for monitoring global hydrological cycle and understanding contributing processes including cloud feedback
Desired Observables	Backscatter lidar and multi-channel, multi-angle imaging polarimeter	Radar(s), with Doppler, with multi-frequency passive microwave and sub-mm radiometer

Profiles of Aerosol Properties

Important Aerosol Characteristics:

1. **Absorption, type, size and number**
2. **Vertical profile**



Slide Credit: Sue van den Heever

Needed Measurements

- **High-resolution profiles of aerosol properties**, including absorption and types → better quantify warming and anthropogenic contributions to forcing
- **Aerosol observations in the boundary layer** → advance our capabilities of identifying anthropogenic aerosols and links to human health
- **Simultaneous measurements of aerosol and precipitation processes** → better understanding of removal and redistribution processes

DS Science Related to ACCP

Weather & Air Quality

W-1 (MI): Planetary Boundary Layer Dynamics. What PBL processes are integral to the air-surface exchanges of energy, momentum, and mass, and how do these impact weather forecasts and AQ simulations?

W-2 (MI): Larger Range Environmental Predictions. How can environmental predictions of weather and air quality be extended to lead times of 1 week to 2 months?

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

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?

W-6 (I): Air Pollution Processes and Trends. What processes determine long-term variations and trends in air pollution and their subsequent long-term recurring and cumulative impacts on human health, agriculture, and ecosystems?

W-9 (I): Role of Cloud Microphysical Processes. What processes determine cloud microphysical properties and their connections to aerosols and precipitation?

W-10 (I): Clouds and Radiative Forcing. How do clouds affect the radiative forcing at the surface and contribute to predictability on time scales from minutes to subseasonal?

Climate Variability & Change

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?

C-5 (I-VI): Aerosols and Aerosol Cloud Interactions. A. How do changes in aerosols (including their interactions with clouds) affect Earth's radiation budget and offset the warming due to greenhouse gases? B. How can we better quantify the magnitude and variability of the emissions of aerosols so that we can better understand the response of climate to its various forcings?

Most Important

Very Important

Important

Hydrological Cycle

H-1 (MI): Coupling the Water and Energy Cycles. How is the water cycle changing and how are these changes expressed in the space-time distribution of rainfall, snowfall, and the frequency and magnitude of extremes?

C-8 (I): Causes and Effects of Polar Amplification. What will be the consequences of amplified climate change in polar regions on global trends of sea-level rise, atmospheric circulation, and extreme weather events?

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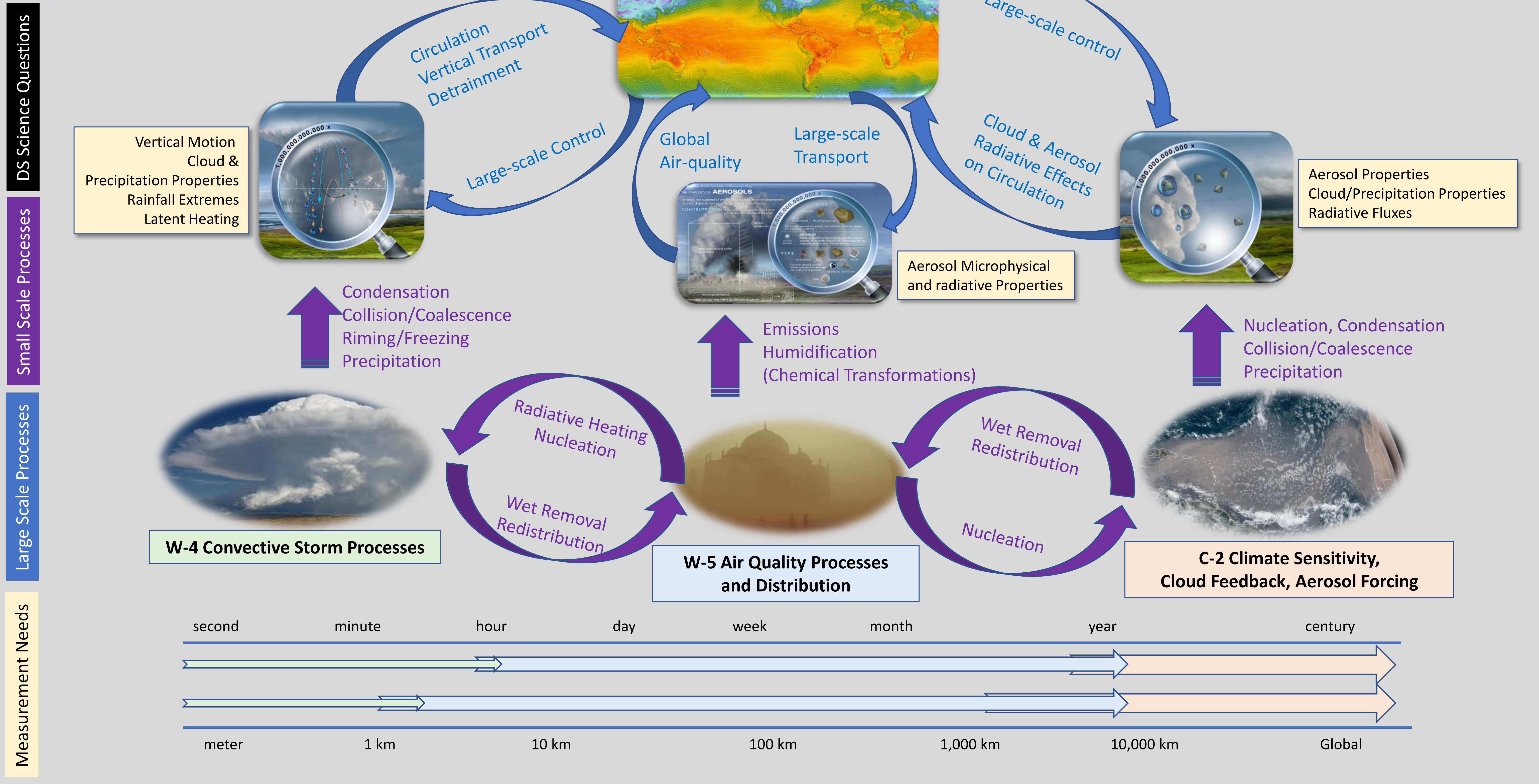
ACCP
Aerosols, Clouds, Convection and Precipitation

ACCP at a Glance



ACCP Science Objectives

O5 Mapping to DS

W-5 (MI): "What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?

ACCP Science Goal 4:

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

Objective 5:
Aerosol Attribution and AQ

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 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.

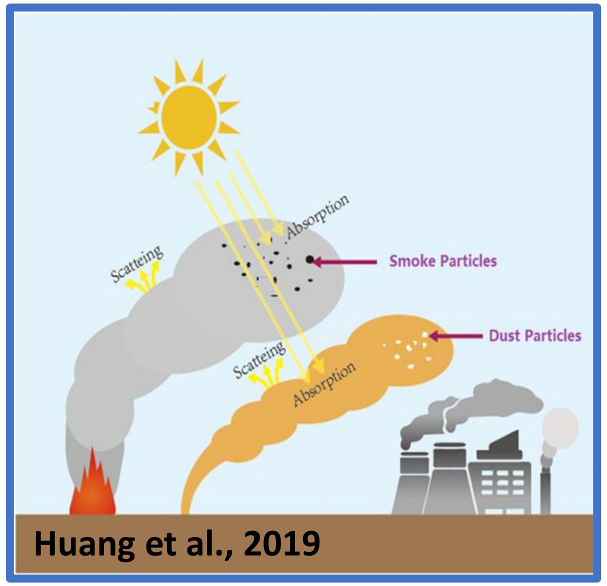
Other DS questions:

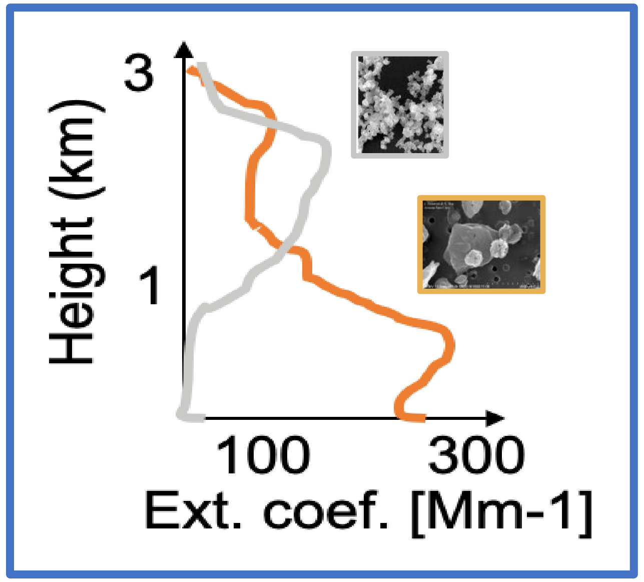
W-1 (MI): "What planetary boundary layer (PBL) processes are integral to the air-surface (land, ocean and sea ice) exchanges of energy, momentum and mass, and how do these impact weather forecasts and air quality simulations?"

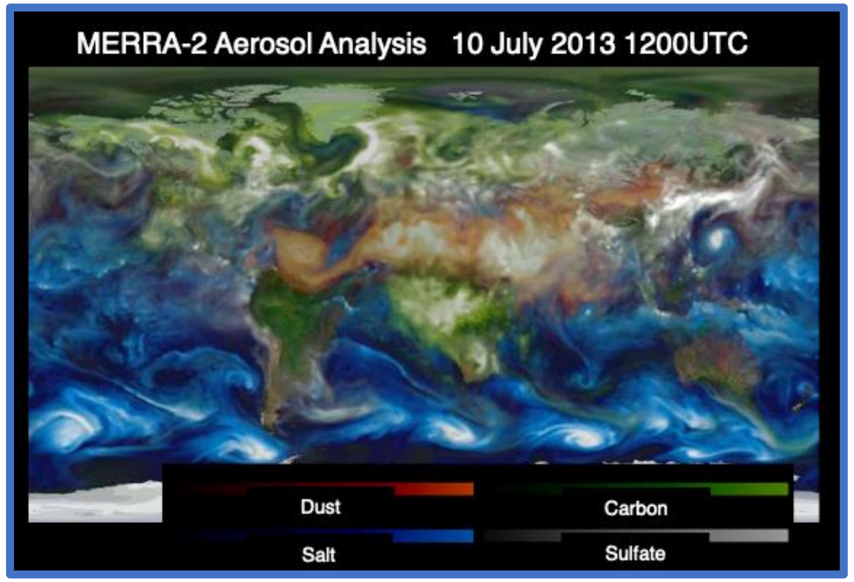
W-2 (MI): How can environmental predictions of weather and air quality be extended to seamlessly forecast Earth System conditions at lead times of 1 week to 2 months?

C-5 (I-VI): Impact of aerosols on global warming

O5: Attribution & AQ







- **Minimum:** Vertical aerosol attribution (PBL, above PBL), improved estimates of emissions –> better predictions
- **Enhanced:** changes in aerosol properties in space and time –> better process understanding

- **$PM_{2.5}$ on Health --** Poor AQ is leading cause of premature death; linkage between speciated $PM_{2.5}$ and health is insufficient
- **Inter-model diversity** in vertical aerosol attribution and near-surface $PM_{2.5}$ is due to uncertain emissions, speciation and processes (e.g., PBL, precipitation, transport, deposition and scavenging)

- Need to constrain model with **observations** to improve predictions of speciated aerosol profile:
  - **Space sensors:** Optical and microphysical aerosol properties in PBL and FT -- vertically/spectrally resolved (e.g., aerosol absorption and extinction, fine mode fraction, lidar ratio etc.)
  - **Program of Record:** GEO & LEO for off-swath total-column aerosol meas. and diurnal cycle; suborbital for processes, enhanced meas. and optical-chemical linkage to PM mass

O6 Mapping to DS

W-5 (MI): "What processes determine the spatio-temporal structure of important air pollutants and their concomitant adverse impact on human health, agriculture, and ecosystems?

ACCP Science Goal 4

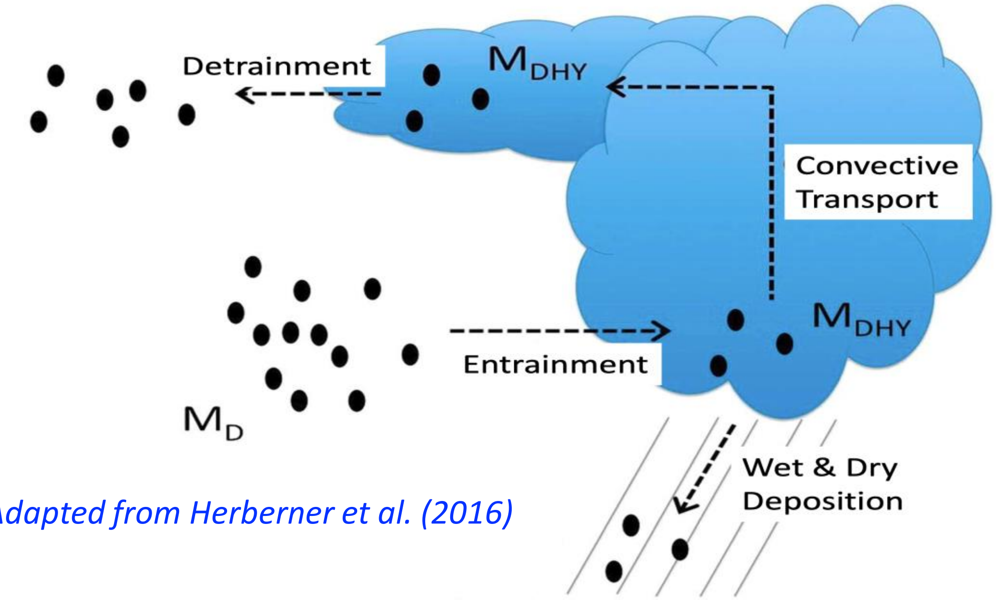
Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.

Objective 6
Aerosol Wet Removal, Vertical Distribution 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.

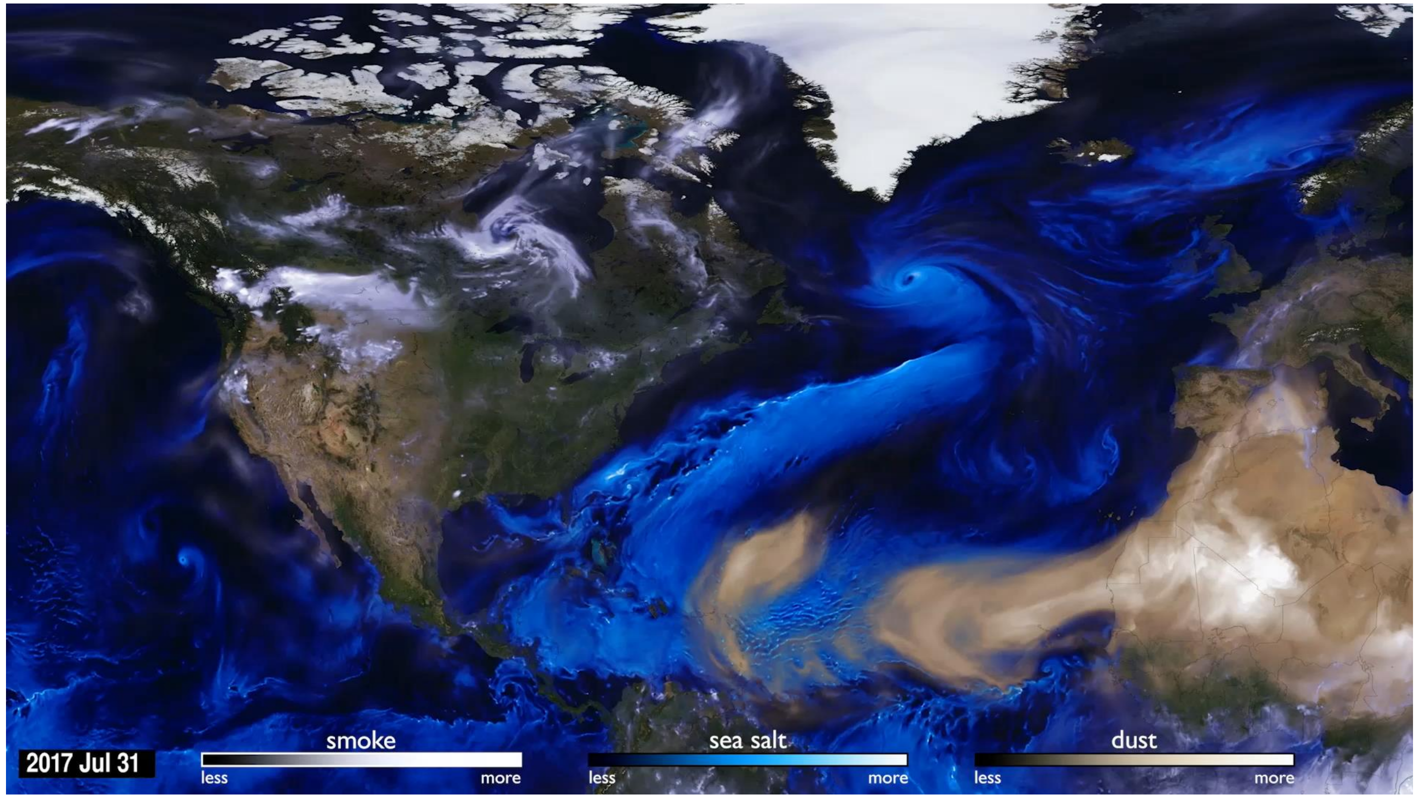
O6: Aerosol Removal and Redistribution



Adapted from Herberner et al. (2016)

- Earth-system models including atmospheric constituents and their interactions with the circulation inform past, present and future location, loading and species of aerosols and their impact on the climate system.
- Representation of aerosol processes in these models, most notably processing by clouds and microphysical processes that remove and transport aerosols can be advanced by ***near simultaneous*** vertically resolved observations of aerosols, clouds and precipitation microphysical properties.

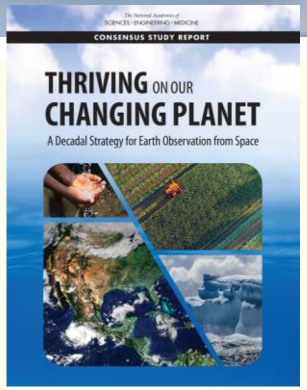
ACCP will provide transformative measurements of aerosols and convective cloud vertical motion (w)



Important Geophysical Variable(s):

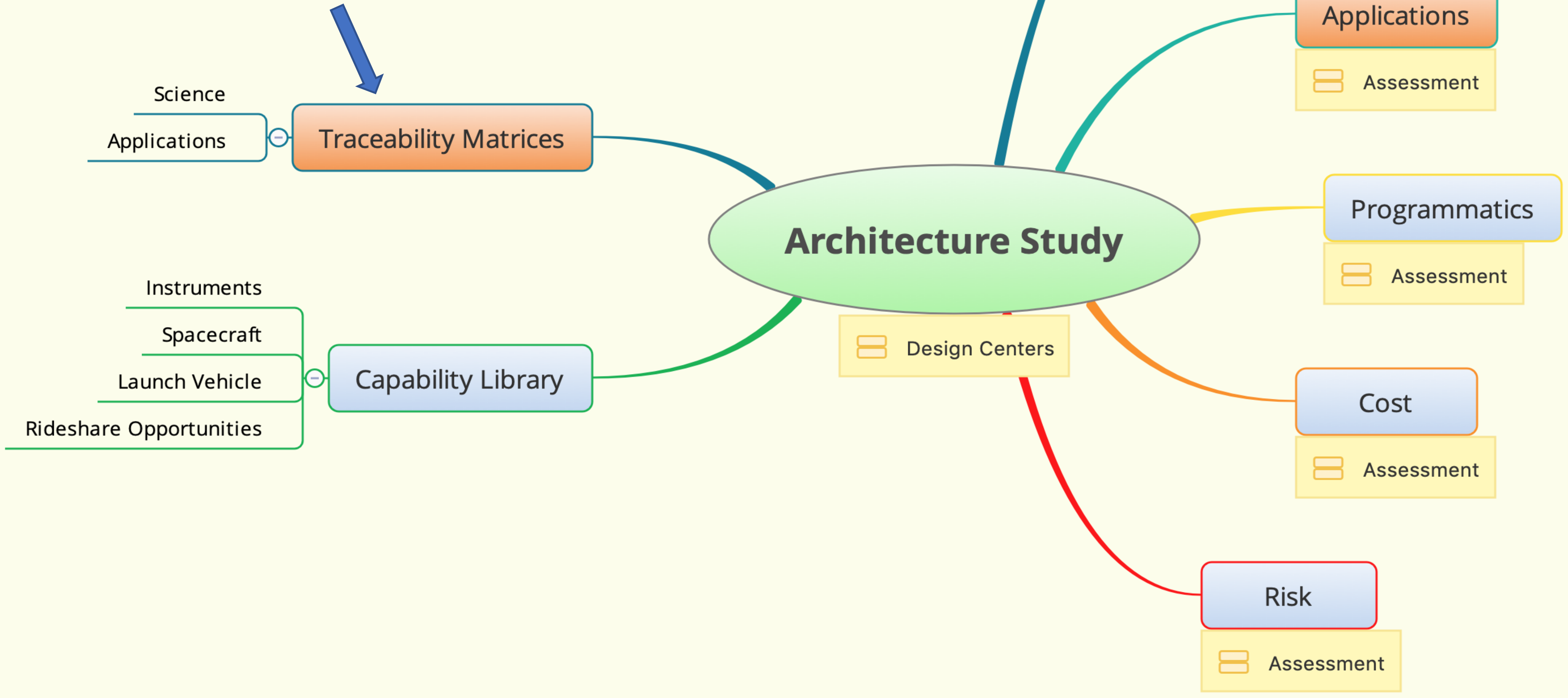
- Global profiles of aerosol extinction, including information on size and particle microphysical properties
- Global profiles of convective vertical motion**,** liquid/ice water path, profiles of precipitation rate, phase (ice, mixed, liquid), and type (C/S), cloud top height/temp, cloud top phase
- ACCP enables and enhances science by PoR:
  - GEO, LEO: vertically integrated/single level ACP properties and time evolution, organization and time/spatial coverage
  - Suborbital: higher fidelity remotely sensed aerosol, cloud and precip measurements and verifying in-situ observations. Below cloud A measurements, diurnal evolution.

ACCP Study: Approach



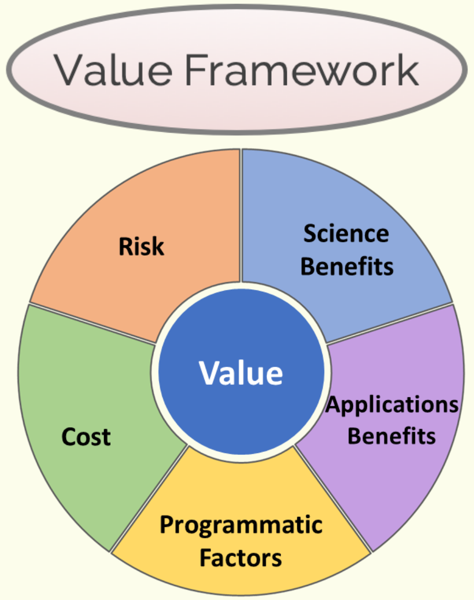
Relevant Decadal Survey Themes

- Climate Variability & Change (A&CCP)
- Weather and Air Quality (A & CCP)
- Hydrology (CCP)



Observing
System
Simulation
Experiments

Provide the quantitative framework for the Science Assessments



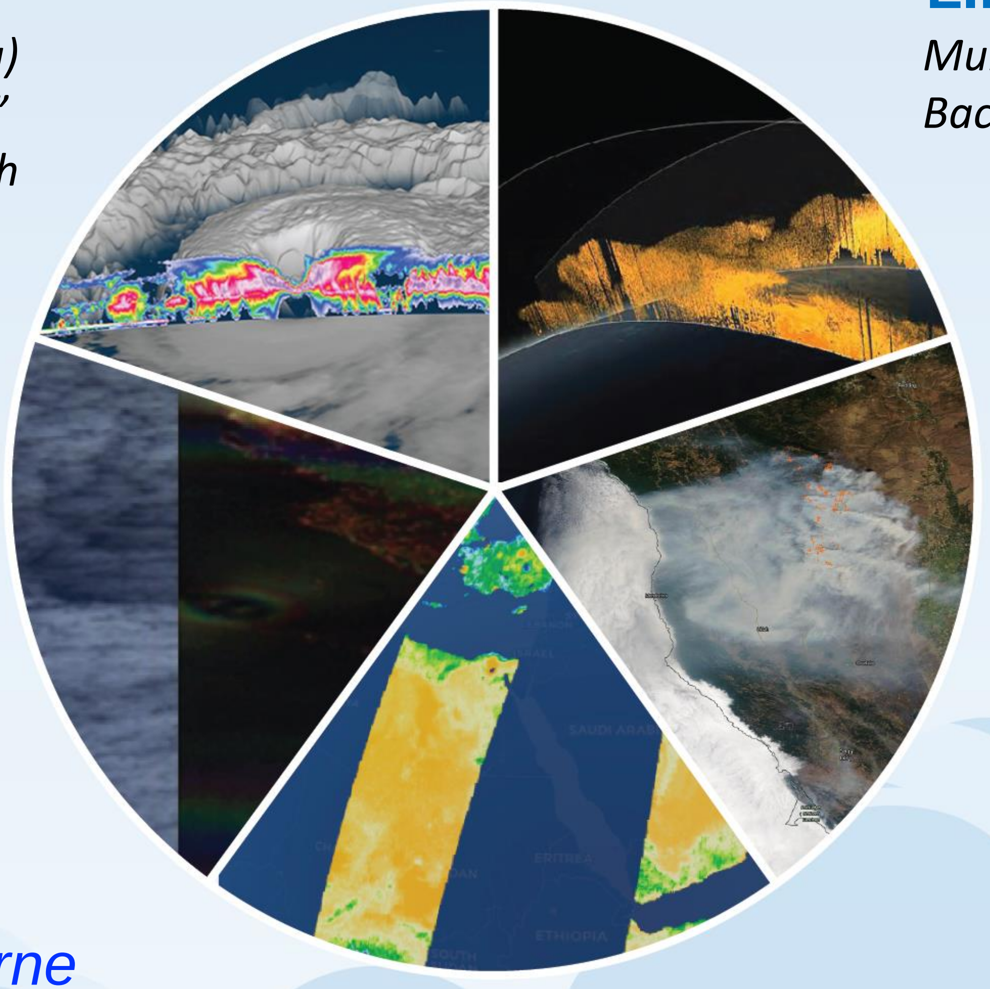
Key ACCP INSTRUMENTS

RADAR

Multi-wavelength (W, Ka and/or Ku)
Doppler or "Delta-T"
Ku radar may have swath

LIDAR

Multi-wavelength (532 and 1064 nm, maybe 355 nm)
Backscatter and/or HSRL (532 nm, maybe 355 nm)



POLARIMETER

Multi-wavelength (UV-VNIR-SWIR)
Multi-angle, 500m or 1 km footprint
Swath: 600 km or 1,100 km

SPECTROMETER

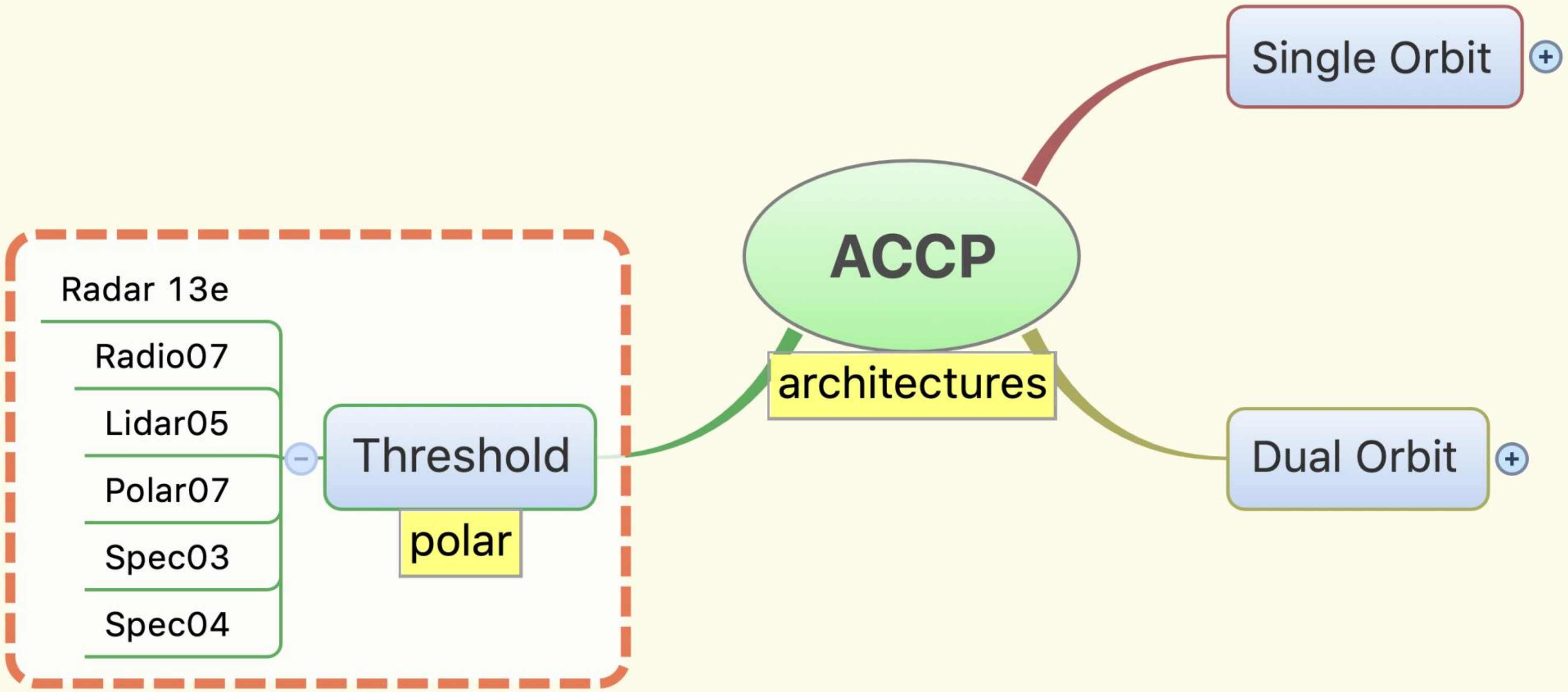
Multi-wavelength (UV-VIS-NIR-SWIR-LWIR-FIR) reflectances and brightness temperatures

RADIOMETER

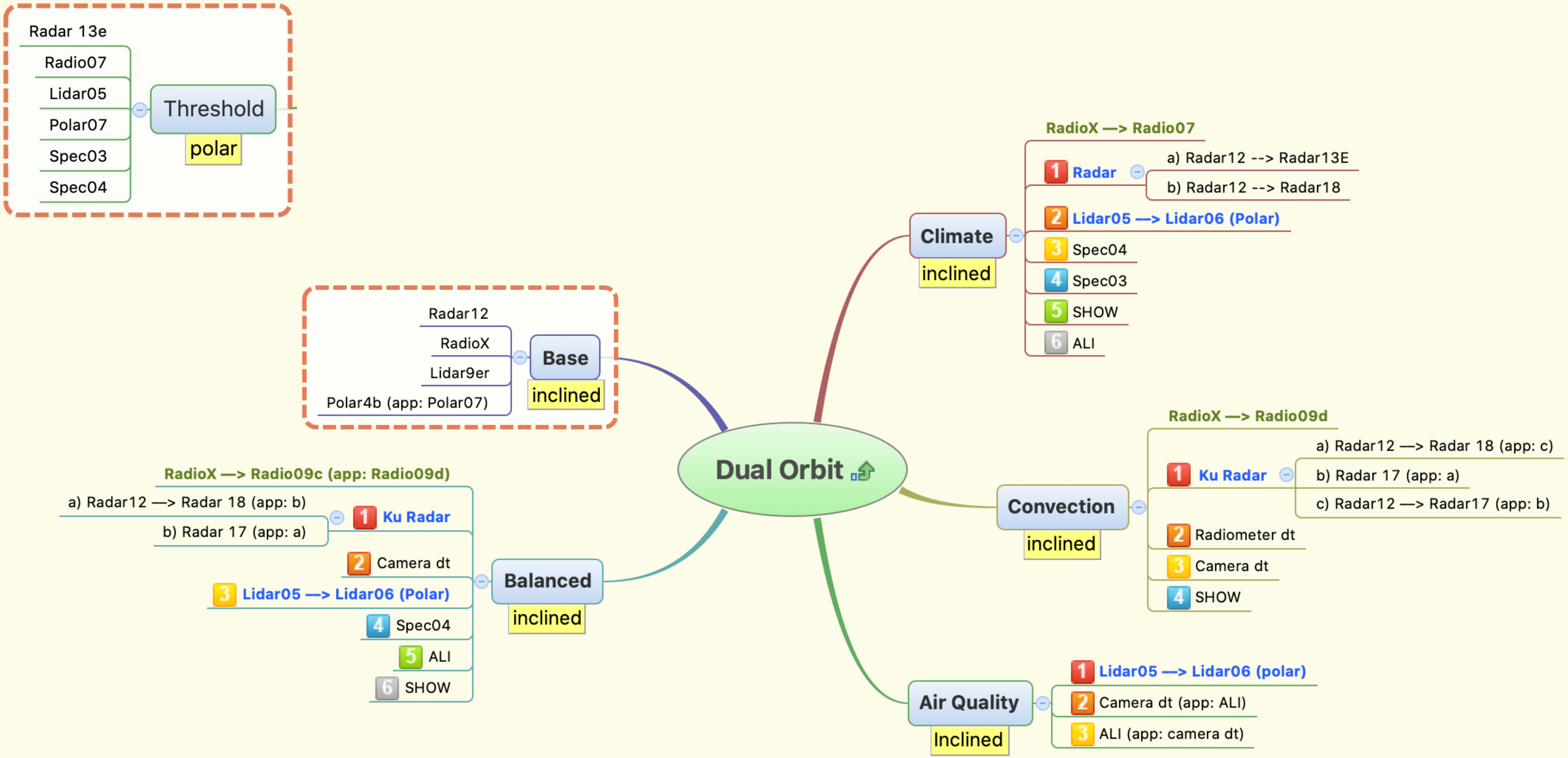
Multi-wavelength Microwave (~100-900 GHz)

ACCP requires a suite of spaceborne instruments to measure and characterize the complexity of hydrometeors and aerosols.*

**To also include as, or more capable, airborne in-situ and remote sensing instruments, deployed in synergistic/complementary suborbital campaigns.*



ACCP
architectures
Single Orbit
Dual Orbit
Threshold
polar
Radar 13e
Radio07
Lidar05
Polar07
Spec03
Spec04

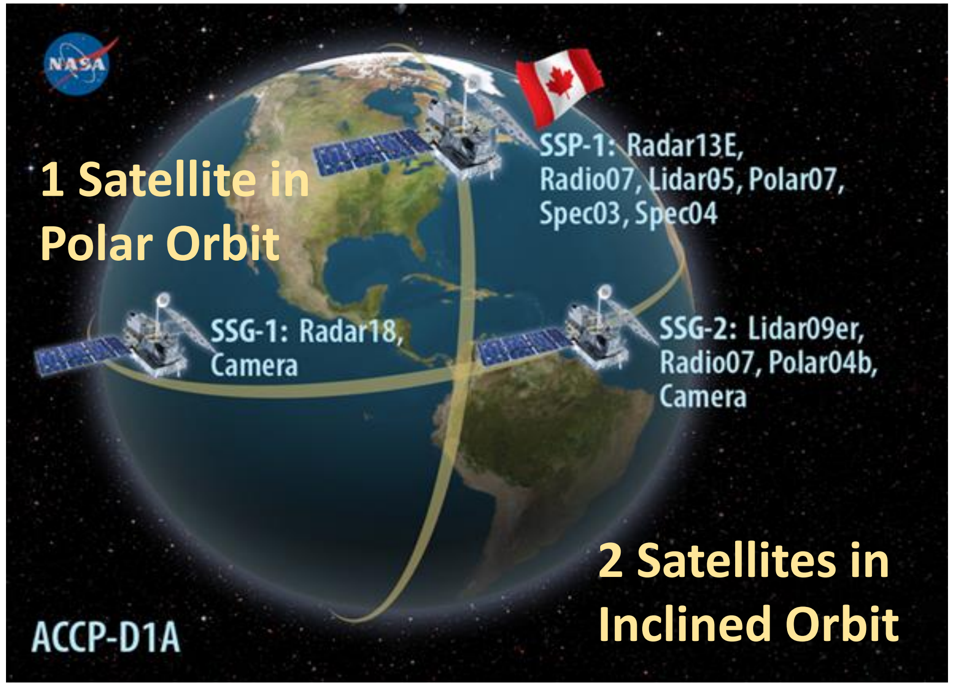


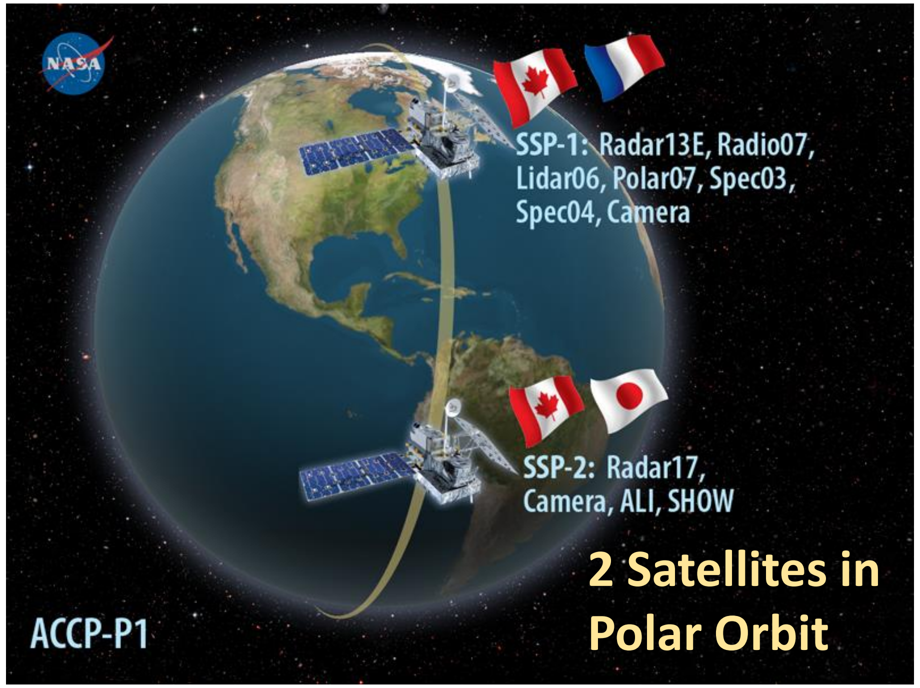
Dual Orbit
Threshold
polar
Radar 13e
Radio07
Lidar05
Polar07
Spec03
Spec04
Base
inclined
Radar12
RadioX
Lidar9er
Polar4b (app: Polar07)
Climate
inclined
RadioX —> Radio07
1 Radar
a) Radar12 --> Radar13E
b) Radar12 --> Radar18
2 Lidar05 —> Lidar06 (Polar)
3 Spec04
4 Spec03
5 SHOW
6 ALI
Convection
inclined
RadioX —> Radio09d
1 Ku Radar
a) Radar12 —> Radar 18 (app: c)
b) Radar 17 (app: a)
c) Radar12 —> Radar17 (app: b)
2 Radiometer dt
3 Camera dt
4 SHOW
Air Quality
Inclined
1 Lidar05 —> Lidar06 (polar)
2 Camera dt (app: ALI)
3 ALI (app: camera dt)
Balanced
inclined
RadioX —> Radio09c (app: Radio09d)
1 Ku Radar
a) Radar12 —> Radar 18 (app: b)
b) Radar 17 (app: a)
2 Camera dt
3 Lidar05 —> Lidar06 (Polar)
4 Spec04
5 ALI
6 SHOW

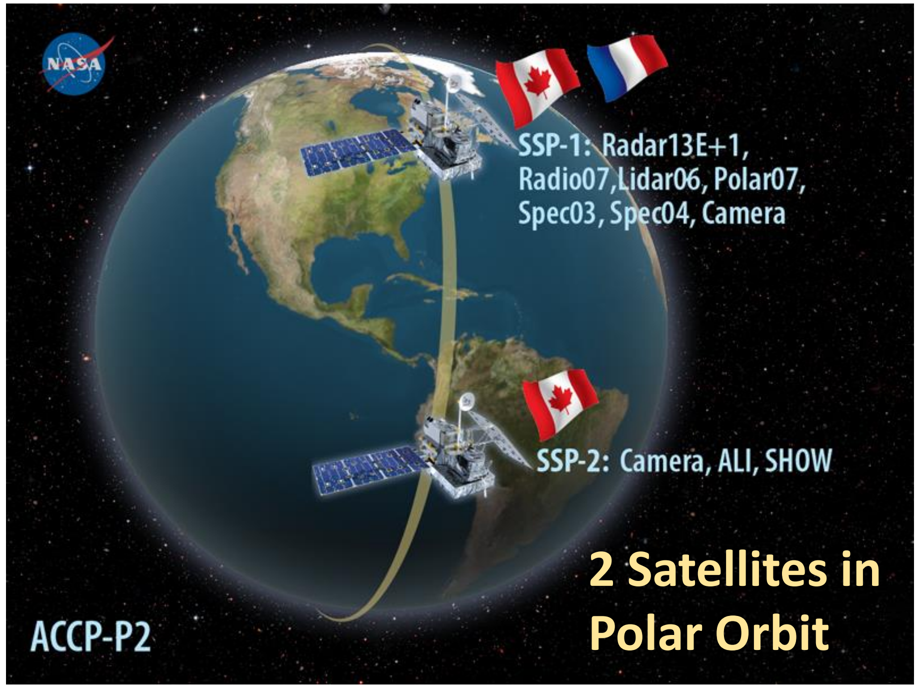
SATM Rel F/5 Goals/8 Objectives

Science Implementation Strategies

Top 3 Candidates Architectures







Early Science Dual Orbit Option D1A

Inclined Orbit Payload (Year 1):

- W, Ku Doppler Radar + μwave radiometer
- VIS-NIR Backscatter Lidar
- UV-VIS-SWIR Multi-angle polarimeter
- Pair of stereo cameras

Polar Orbit Payload (Year 3):

- W, Ka Doppler Radar + μwave radiometer
- VIS-NIR HSRL Lidar: 2β + 1α
- UV-VIS-SWIR Multi-angle polarimeter
- VIS and IR spectrometers for radiation

Later Science Single Orbit Option P1

Polar Orbit Payload (Year 3):

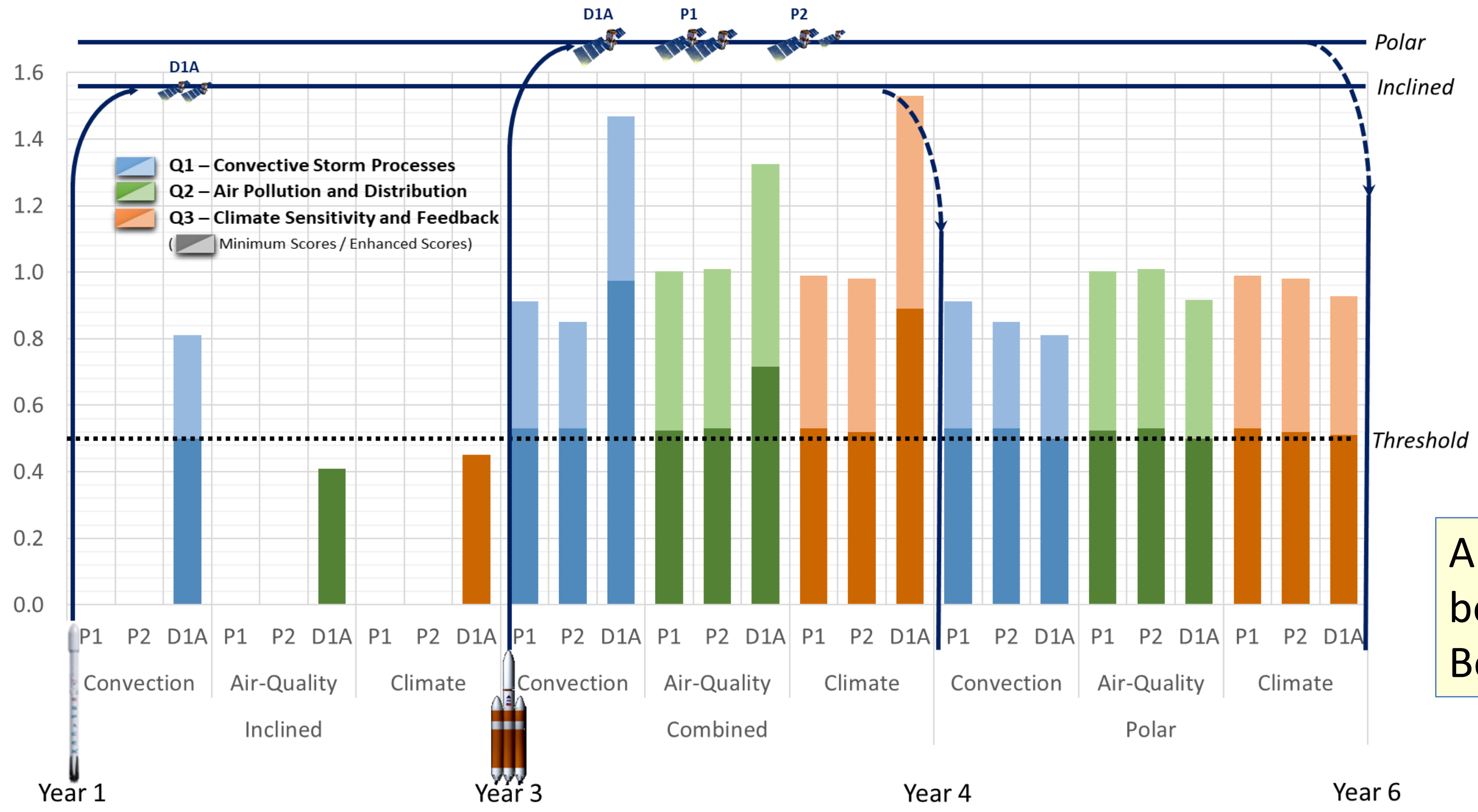
- W, Ka Doppler Radar (enhanced sensitivity)
- Ku Doppler Radar with swath (JAXA)
- μwave radiometer
- UV-VIS-NIR HSRL Lidar: 3β + 2α
- UV-VIS-SWIR Multi-angle polarimeter
- VIS and IR spectrometers for radiation
- Pair of stereo cameras
- Aerosol Limb Instrument (ALI)
- Humidity Limb Instrument (SHOW)

Later Science Single Orbit Option P2

Polar Orbit Payload (Year 3):

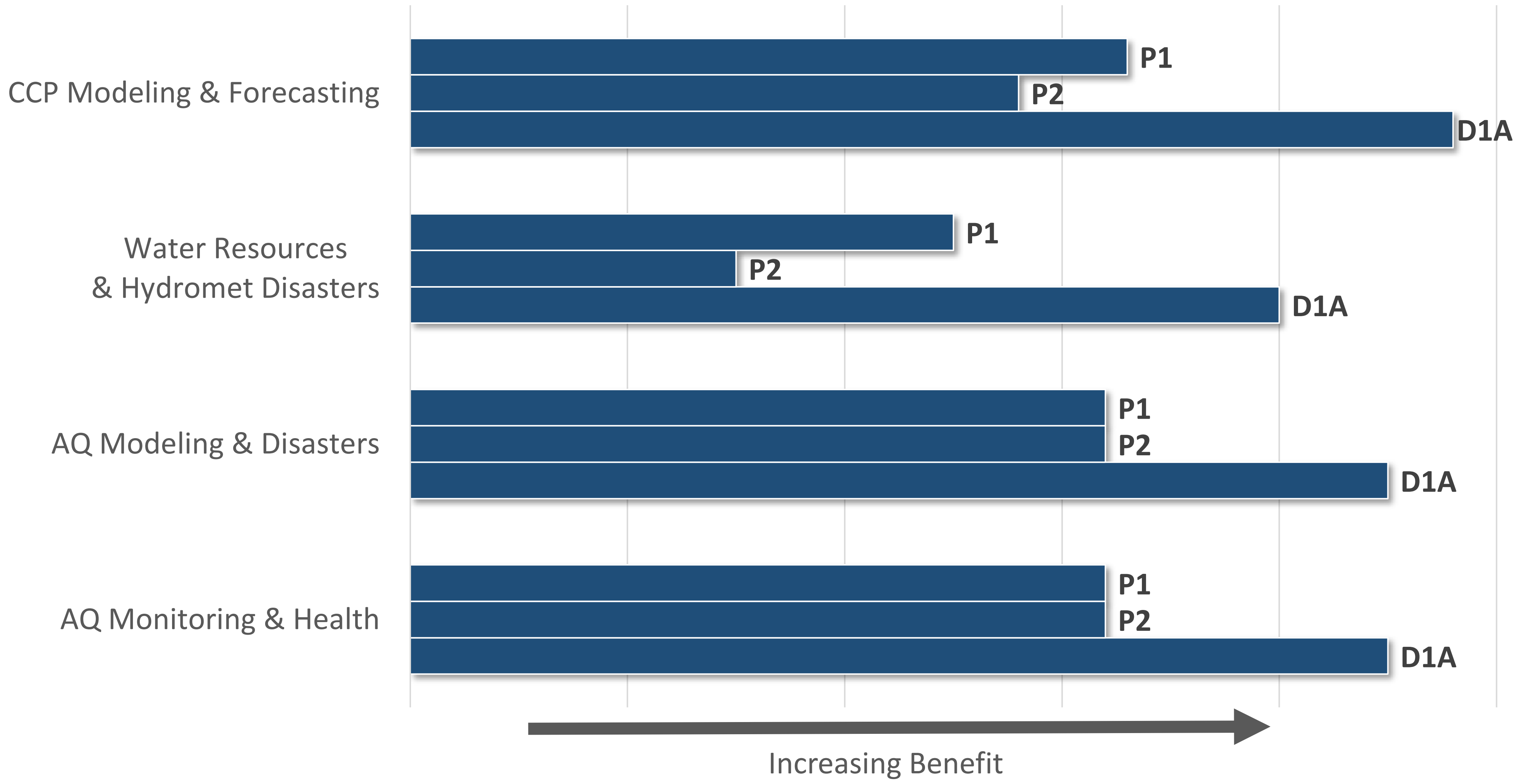
- W, Ka, Ku Doppler Radar (enhanced sensitivity, narrow swath)
- μwave radiometer
- UV-VIS-NIR HSRL Lidar: 3β + 2α
- UV-VIS-SWIR Multi-angle polarimeter
- VIS and IR spectrometers for radiation
- Pair of stereo cameras
- Aerosol Limb Instrument (ALI)
- Humidity Limb Instrument (SHOW)

Science Benefit Scores



Architecture D1A has better overall **Science** Benefit Score

Application Benefit Scores



Architecture **D1A** has better overall **Applications** Benefit Score

Summary

- ACCP made use of a rigorous *Value Framework* that led to the selection of 3 final architectures.
  - ➢ The dual orbit architecture D1A has been recommended by the ACCP Study Team
- The ACCP science goals are tightly connected to 2017 Decadal Survey questions
  - ➢ Air-quality figures as one of the most import science questions being addressed.
- The cornerstone of the ACCP orbital component are active sensors (lidars, radars) complement by very capable passive instruments (polarimeters, radiometers, spectrometers)
- ACCP includes both orbital and suborbital components
  - ➢ A second suborbital workshop is taking place in March—April 2021
  - ➢ Suborbital measurements will be a major contributor to addressing the A/Q science objectives.
- The ACCP Study officially started on October 2018 and it is now concluding
  - ➢ pre-Phase A is expected to start in April 2021, with KDP-A early in 2022