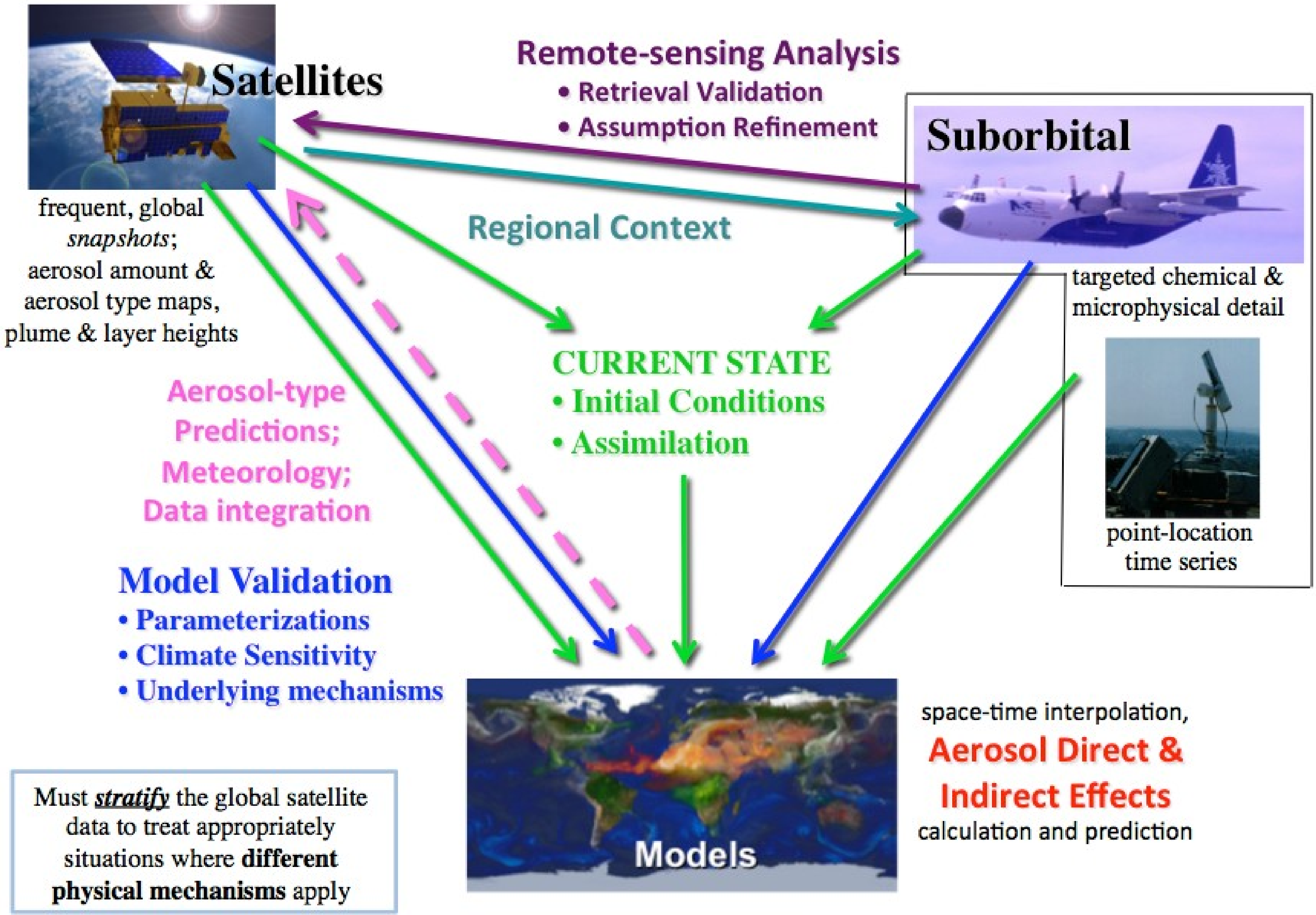


Adapted from: Kahn, Survy. Geophys. 2012

SAM-CAAM *Concept*
[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

[This is currently a ***concept-development effort***, not yet a project]

Primary Goals:

- **Interpret and *enhance ~19 years of satellite aerosol retrieval* products**
- ***Characterize statistically particle properties* for major aerosol types globally,**
  to provide detail unobtainable from space, adding value to all satellite aerosol data:

-- Improved aerosol property assumptions/initialization in satellite *retrieval algorithms*

Kahn et al., BAMS 2017

SAM-CAAM *Objective*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

Obtain ***aerosol intensive property PDFs*** required for key aerosol science objectives, but cannot be retrieved with adequate precision, or are ***entirely unobtainable***, ***from remote sensing****

- ***Hygroscopicity**** – Particle ambient hydration, aerosol-cloud interactions
- ***Mass Extinction Efficiency**** – Translate between retrieved optical properties from remote sensing & aerosol mass book-kept in models
- ***Spectral Light-Absorption*** – Aerosol direct & semi-direct forcing, atmospheric stability structure & circulation
- ***CCN Properties**** – At least part of the CCN size spectrum is too small to be retrieved by remote-sensing

SAM-CAAM is feasible because:
Unlike aerosol amount, ***aerosol microphysical properties tend to be repeatable*** from year to year, for a given source in a given season

Kahn et al., BAMS 2017

AeroCom Model *Mass Extinction Efficiencies*

Table 3.3

Model Sulfate	Mass load (mg m-2)	MEE (m2 g-1)	AOD at 550 nm	TOA Forcing (W m-2)	Forcing/AOD (W m-2)	Forcing/mass (W g-1)
AeroCom: Identical emissions used for year 2000 and 1750						
M UMI	2.64	7.6	0.02	-0.58	-29	-220
N UIO-CTM	1.70	11.2	0.019	-0.36	-19	-212
O LOA	3.64	9.6	0.035	-0.49	-14	-135
P LSCE	3.01	7.6	0.023	-0.42	-18	-140
Q ECHAM5-HAM	2.47	6.5	0.016	-0.46	-29	-186
R GISS**	1.34	4.5	0.006	-0.19	-32	-142
S UIO-GCM	1.72	7.0	0.012	-0.25	-21	-145
T SPRINTARS	1.19	10.9	0.013	-0.16	-12	-134
U ULAQ	1.62	12.3	0.02	-0.22	-11	-136

MEE values for aerosol species are **uncertain by *factors* of 3 or more**

Table 3.4

Model	POM						BC					
	Mass load (mg m-2)	MEE (m2 g-1)	AOD at 550 nm	TOA Forcing (W m-2)	Forcing/AOD (W m-2)	Forcing/mass (W g-1)	Mass load (mg m-2)	MEE (m2 g-1)	AOD at 550 nm x1000	TOA Forcing (W m-2)	Forcing/AOD (W m-2)	Forcing/mass (W g-1)
AeroCom: Identical emissions for year 2000 & 1750												
L UMI	1.16	5.2	0.0060	-0.23	-38	-198	0.19	6.8	1.29	0.25	194	1316
M UIO-CTM	1.12	5.2	0.0058	-0.16	-28	-143	0.19	7.1	1.34	0.22	164	1158
N LOA	1.41	6.0	0.0085	-0.16	-19	-113	0.25	7.9	1.98	0.32	162	1280
O LSCE	1.50	5.3	0.0079	-0.17	-22	-113	0.25	4.4	1.11	0.30	270	1200
P ECHAM5-HAM	1.00	7.7	0.0077	-0.10	-13	-100	0.16	7.7	1.23	0.20	163	1250
Q GISS**	1.22	4.9	0.0060	-0.14	-23	-115	0.24	7.6	1.83	0.22	120	917
R UIO-GCM	0.88	5.2	0.0046	-0.06	-13	-68	0.19	10.3	1.95	0.36	185	1895
S SPRINTARS	1.84	10.9	0.0200	-0.10	-5	-54	0.37	9.5	3.50	0.32	91	865
T ULAQ	1.71	4.4	0.0075	-0.09	-12	-53	0.38	7.6	2.90	0.08	28	211

Similar situation for particle:

- ***Hygroscopicity***
- ***Light Absorption***

CCSP 2009

SAM-CAAM *Implementation*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

- ***Dedicated Operational Aircraft*** – routine flights, 2-3 x/week, on a continuing basis
- ***Sample Aerosol Air Masses*** accessible from a given base-of-operations, then move; project science team to determine schedule, possible field campaign participation
- ***Process Data Routinely*** at central site; instrument PIs develop & deliver algorithms, upgrade as needed; data distributed via central web site, ***as with EOS data***
- Parallels the relationship between ***AERONET and MODIS / MISR*** during EOS era
- Fills gaps in satellite remote-sensing as ***IceBridge*** did for cryosphere
- Peer-reviewed paper with notional payload ***demonstrating feasibility***; subsequent selections based on agency buy-in and available resources

SAM-CAAM is feasible because:
Unlike aerosol amount, ***aerosol microphysical properties tend to be repeatable*** from year to year, for a given source in a given season

Kahn et al., BAMS 2017

SAM-CAAM *15 Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

1. AEROSOL PROPERTIES FROM *IN SITU* MEASUREMENTS & INTEGRATED ANALYSIS

	Abbrev.	Required Variable
1	EXT	Spectral Extinction
2	ABS	Spectral Absorption
3	GRO	Hygroscopic Growth
4	SIZ	Particle Size
5	CMP	Particle Type (a composition constraint)
6	PHA	Single-scattering Phase Function
7	MEE	Mass Extinction Efficiency
8	RRI	Real Refractive Index

Kahn et al., BAMS 2017

SAM-CAAM *15 Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

2. METEOROLOGICAL CONTEXT

	Abbrev.	Required Variable
9	CO	Ambient Gases ($CO + O_3 + NO_2$)
10	T; P; RH	Standard Ambient Meteorological Variables
11	LOC	Geographic Location

3. AMBIENT REMOTE-SENSING CONTEXT

	Abbrev.	Required Variable
12	A-EXT & A-ABS	Ambient Spectral Extinction & Absorption
13	A-PHA	Ambient Particle Phase Function
14	A-CLD	Ambient Cloud & Large-Particle Size/Type
15	HTS	Aerosol Layer Heights

Kahn et al., BAMS 2017

SAM-CAAM

A Concept for Acquiring Systematic Aircraft Measurements to Characterize Aerosol Air Masses

RALPH A. KAHN, TIM A. BERKOFF, CHARLES BROCK, GAO CHEN, RICHARD A. FERRARE, STEVEN GHAN, THOMAS F. HANSICO, DEAN A. HEGG, J. VANDERLEI MARTINS, CAMERON S. MCNAUGHTON, DANIEL M. MURPHY, JOHN A. OGREN, JOYCE E. PENNER, PETER PILEWSKIE, JOHN H. SEINFELD, AND DOUGLAS R. WORSNOP

SAM-CAAM aims to characterize particle properties statistically with systematic, aircraft in situ measurements of major aerosol air masses, to refine satellite data products and to improve climate and air quality modeling.

Backup Slides

<u>SAM-CAAM</u> *2017 Decadal Survey Impetus*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

• ***Item #1*** aimed at meeting the 2017 Decadal Survey ***objectives*** :

"Understanding clouds and aerosols and their impacts on climate and weather"

• ***Item #1*** under five ***priority mission observables*** identified in the Survey:

Aerosols and their effect on climate and air quality

• To characterize ***long-term trends and variations in*** global, vertically-resolved speciated ***particulate matter*** :

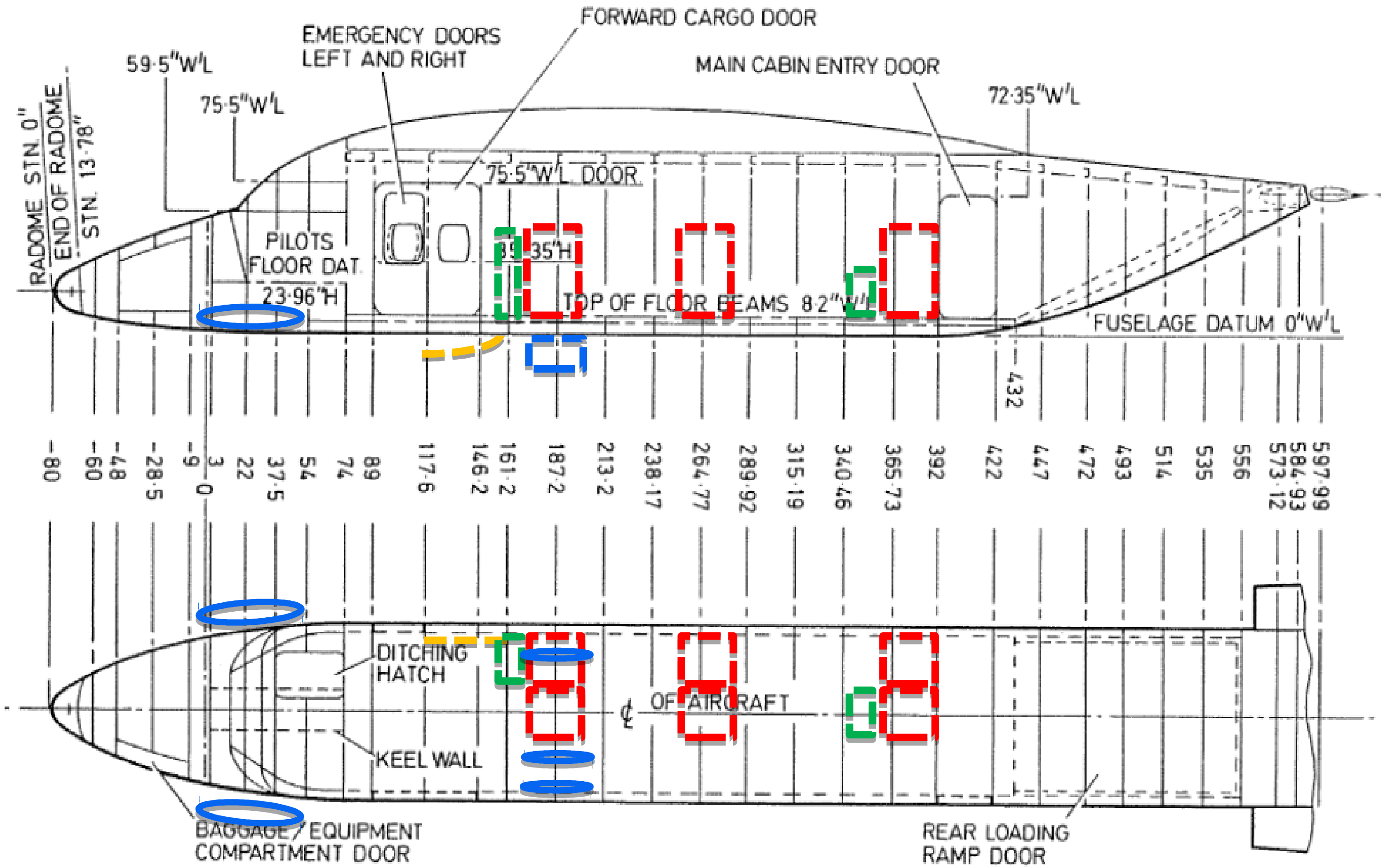
"Combine advanced space-based observations, ***aircraft & ground-based observations*** with chemical transport modeling…"

• Assessing the adverse effects of ***poor air quality*** :

"It is a challenge to provide observations from space-based platforms alone... The strategy requires ***a combination of space-based observations, and expansion of aircraft and ground-based observations***, in conjunction with… modeling...

A Notional SAM-CAAM Payload Could Fit on a NASA Shorts C-23B Sherpa

Notional Payload Accommodation



Schematic of a notional layout of the SAM-CAAM Payload Option C in the NASA C-23B Sherpa aircraft. Two-bay racks are shown in red, in-cabin floor-mounted instruments in green, external probes in blue, and the aerosol inlet in gold. The point of this notional payload is to demonstrate ***feasibility***.

Kahn et al., BAMS 2017

SAM-CAAM *15 Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

1. AEROSOL PROPERTIES FROM *IN SITU* MEASUREMENTS & INTEGRATED ANALYSIS

1. Spectral extinction coefficient (EXT)
To constrain satellite AOD retrievals [six-channel, three-color CRD (two size cuts: 1 and 10 μm; four channels at low RH) + two for #3 GRO]
2. Spectral absorption (ABS) or single-scattering albedo
To constrain AOD retrievals and to determine atmospheric absorption and heating {dual three-channel filter absorption (two size cuts: 1 and 10 μm at low RH) [matched to (#1 EXT), (#6 PHA)] + refractory carbon}
3. Particle hygroscopic growth factor (GRO)
To connect particle properties over the full range of instrument and ambient RH conditions [two-channel CRD (from #1 EXT) at high RH + humidified OPC and PI-nephelometer]
4. Particle size (SIZ) (at least three bins in number concentration, though detailed size distribution probably needed to meet primary objectives)
As a complement to chemical composition discrimination; required for deriving #7 MEE [SMPS + Fine-OPC + Coarse-OPC + Active inlet to 50% at 10 μm]
5. Particle composition (CMP)
For source identification To classify measurements in terms of aerosol type as specified in most models, e.g., sea salt, sulfate, mineral dust, BC, brown carbon, especially important for aerosol–cloud interaction modeling To support deriving the anthropogenic fraction, which is needed to calculate direct aerosol "climate" forcing from space-based retrievals, and for air quality applications CMP would be constrained by analysis of detailed chemical and/or microphysical properties, such as elemental carbon (EC) concentration and particle shape [Dual filter stations (two size cuts)]

Kahn et al., BAMS 2017

SAM-CAAM *15 Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

1. AEROSOL PROPERTIES FROM *IN SITU* MEASUREMENTS & INTEGRATED ANALYSIS

6. Spectral single-scattering phase function (PHA) [all possible angles]
To constrain multiangle radiance AOD retrievals
To calculate radiation fields
Polarized: to help determine aerosol type, and to constrain remote sensing observations where polarized data are included
[PI-Nephelometer + dryer/humidifier, with PM_{10} size range and three wavelengths matched to #1 EXT and #2 ABS]
7. Mass extinction efficiency (MEE)
To translate between optical remote sensing measurements and model parameters
Derived from integrated analysis of particle size distributions, with density deduced from particle compositional constraints [derived from integrated analysis of measured variables]
8. Real Refractive Index (RRI)
To constrain AOD retrievals to the level of detail required for aerosol forcing
[inverted from PI-Nephelometer (from PHA #6) and Open-I-Nephelometer (from A-EXT #12)]

Kahn et al., BAMS 2017

SAM-CAAM *15 Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

2. METEOROLOGICAL CONTEXT

9. Carbon monoxide (CO; also possibly CO_2, NO_2, O_3)
As a tracer for smoke, to help distinguish smoke from urban pollution in some cases
[Cavity ringdown CO and NO_2 ICOS spectrometers + O_3]
10. Ambient temperature (T) and relative humidity (RH)
To help interpret ambient measurements
To translate between instrument and ambient conditions [T, P, RH]
11. Aircraft 3D location (LOC)
To relate aircraft measurements to any available satellite observations, and to model simulations [GPS]

Kahn et al., BAMS 2017

SAM-CAAM *15 Required Variables*

[Systematic Aircraft Measurements to Characterize Aerosol Air Masses]

3. AMBIENT REMOTE-SENSING CONTEXT

12. Ambient spectral single-scattering phase function (A-PHA) [all possible angles]
To constrain remote sensing AOD retrievals and assess in-aircraft measurements by comparing with ambient conditions To help calculate radiation fields Polarized: to help determine aerosol type, and to constrain remote sensing retrievals where polarized data are included [Open-I-Nephelometer + external CRD + surf. sun photometer and lidar targets of opportunity]
13. Ambient spectral extinction coefficient (A-EXT)
To constrain remote sensing AOD retrievals and assess in-aircraft measurements by comparing with ambient conditions [Open-I-Nephelometer (from A-EXT #12) + internal PI-Nephelometer (from #6 PHA) dry reference]
14. Large particle/cloud probe (A-CLD)
To provide some information about dust and other particles larger than the inlet size cut As an independent measure of possible cloud impact on the reliability of other data [Small Droplet Probe + Ice Probe]
15. Aerosol layer heights (HTS)
To determine flight levels for subsequent direct sampling To correlate with meteorological conditions As a constraint on trajectory modeling to identify aerosol sources and evolution [airborne backscatter lidar]

Kahn et al., BAMS 2017