ACE Mission
Measurements for Models

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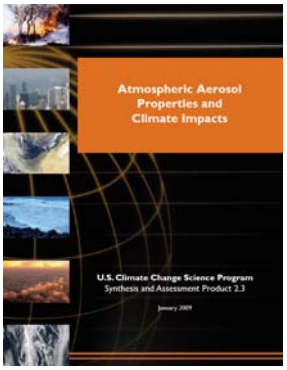
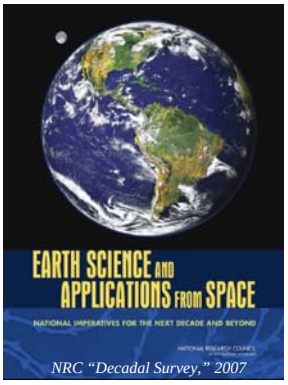
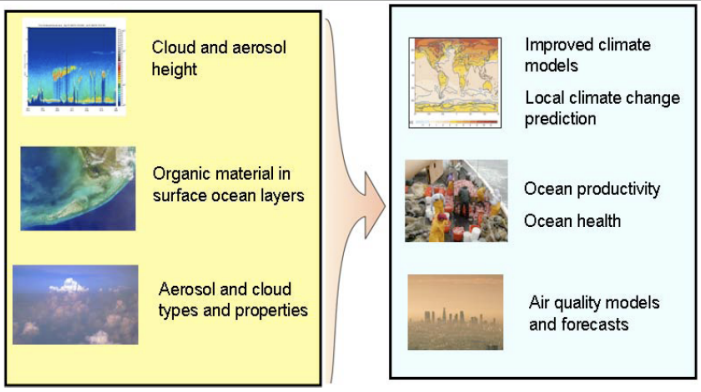
IPCC – AR4, 2007





NRC "Decadal Survey," 2007

Aerosol/Cloud/Ecosystem (ACE) Mission



NRC Decadal Survey, 2007

Primary Goals

- Quantify anthropogenic aerosol effects on the global energy and water cycles
  - scattering of sunlight
  - absorption of sunlight
  - activation as droplet and crystal nuclei
- Estimate carbon uptake by ocean ecosystems
  - dependence on aerosol deposition
- Forecast aerosol effects on air quality

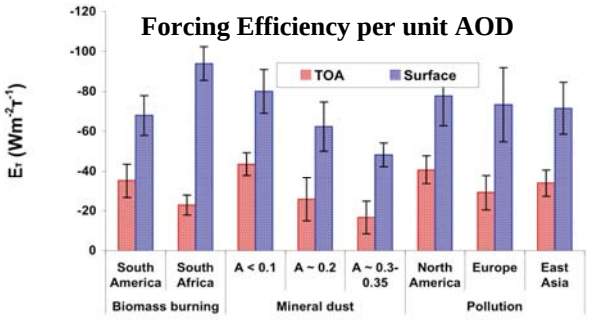
Aerosol Questions

1. What are the various terms, ***partitioned by size and composition***, *of* the global and regional ***aerosol life cycle***?
2. What is the impact of specific significant ***aerosol events*** such as wild fires, dust outbreaks, urban/industrial pollution, volcanic eruptions etc. on the local, regional and global aerosol burden?
3. What is the ***direct anthropogenic aerosol radiative forcing*** at the top-of-atmosphere, within-atmosphere and at the surface?
4. What is the ***aerosol radiative heating of the atmosphere*** due to absorbing aerosols, and how does this heating ***affect cloud development and precipitation*** processes?

Aerosol-Cloud Interaction Questions

1. How do ***aerosols*** and their perturbations from nominal background ***amounts and types affect*** the macrophysical, microphysical, and optical ***properties of clouds***?
2. How do aerosols affect the initiation and occurrence of ***drizzle and precipitation*** in clouds?
3. How do clouds respond to changes in the large-scale dynamical setting in which they form and do ***aerosol-induced changes in large-scale dynamics alter these cloud-dynamic interactions***?
4. What are the key ***mechanisms by which clouds process aerosols*** and influence the vertical profile of aerosol physical and optical properties?

AOD Alone is Not Enough



From: Zhou et al., JGR 2005

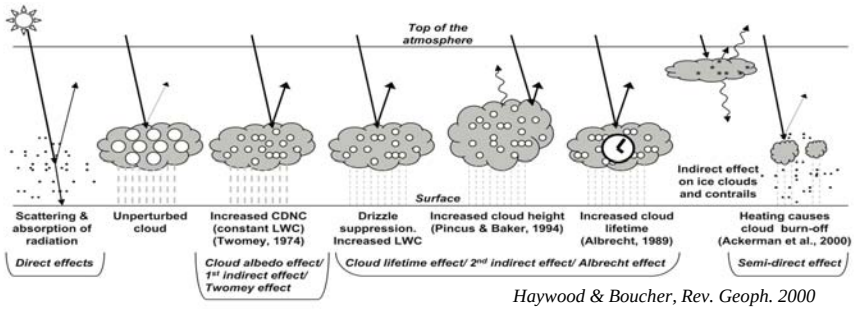
- ***Aerosol SSA, Vert. Dist.,*** and ***Surface Albedo*** critical, esp. for ***Surface Forcing***
- ***Source Attribution*** needed to identify ***Anthropogenic Component***
- For ***Model Comparison*** need particle ***Size, Shape, Composition, Density***

How Good is *Good Enough*?

Instantaneous AOD &***SSA*** uncertainty upper bounds for ~1 W/m^2 TOA DARF accuracy: **~ 0.02**

From: *CCSP - SAP 2.3*, 2009

Effects of Aerosols on Clouds



Haywood & Boucher, Rev. Geoph. 2000

- **Aerosol *Particle Size* Matters**
  - -- Not easy for remote-sensing techniques to observe the smallest, most numerous CCN
  - -- Deducing small-size CCN from larger-particle distribution depends sensitively on ambient RH
- **Aerosol *Particle Composition* Probably Matters Too**
  - -- Remote-sensing not very sensitive to particle chemistry (***polarization*** should help)
- ***Location*, Location, Location**
  - -- Satellite remote-sensing cannot observe aerosol ***below*** most clouds; difficult observing aerosol near clouds as well
- ***Clouds, Ambient Meteorology*** Affect Aerosol Retrievals
  - --Aircraft are critical for this; satellites offer space-time extrapolation

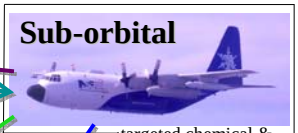
Measurements and Models

Satellites

frequent, global *snapshots*; AOD, aerosol air mass type

Remote-sensing Analysis
- Retrieval Validation
- Assumption Refinement

Sub-orbital



targeted chemical & microphysical detail

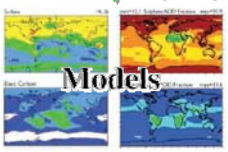
point-location time series

Regional Context

CURRENT STATE
- Initial Conditions
- Emissions
- Assimilation

Model Validation
- Emissions
- Aerosol & cloud distributions
- Aerosol-cloud relationships

Model Validation
- Processes
- Relationships

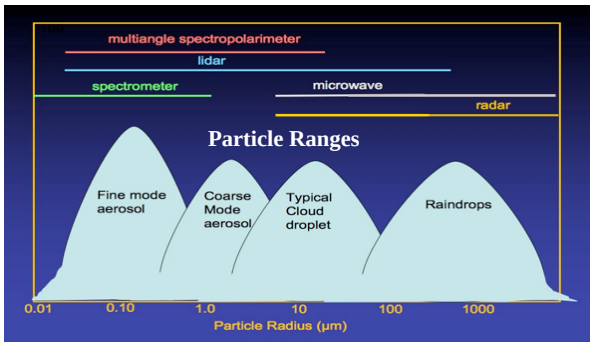


Models

PREDICTION

R. Kahn

Aerosol – Cloud Measurement Strategy



We need measurements that are sensitive to:
- particle size distribution from fine mode to raindrops
- aerosol and cloud particle optical properties including height
- cloud properties including particle sizes, phase and dynamics

Following the measurement suite pioneered by the A-Train, a combination of active and remote multi-wavelength sensors is needed.

Mark Schoeberl, AGU 2008

Aerosol Measurement Requirements

(a) ***AOD*** (UV-VIS-SWIR)
(b) ***Absorption AOD*** (UV-VIS-SWIR)
(c) Real part of the ***refractive index*** (UV-VIS-SWIR)
(d) Aerosol ***extinction profile***
(e) Single-scattering ***albedo profile***
(f) ***Particle morphology***, column and vertically resolved
(g) Column ***effective radius***, effective variance for
•coarse mode (supermicron) particles
•accumulation mode (0.10 μm to 1.0 μm) particles
(h) Column particle ***number concentration*** of coarse and accumulation modes
(i)Particle ***number concentration profile***

Aerosol retrievals must be free of cloud artifacts

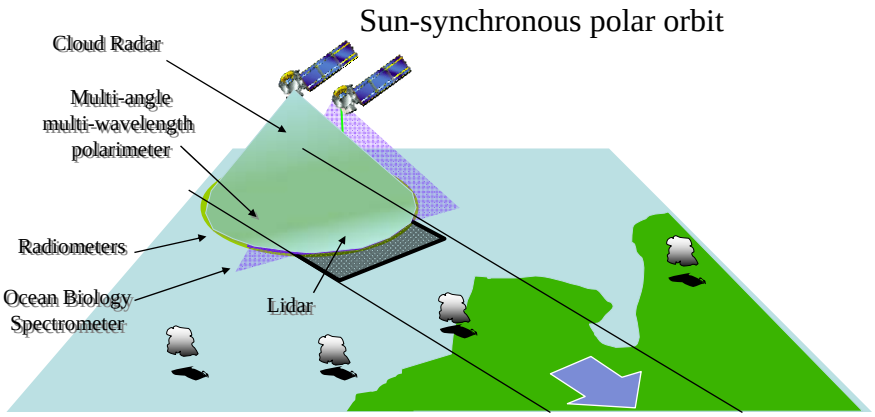
Cloud Measurement Requirements

(a) Cloud top, base heights
(b) Cloud top phase
(c) Precipitation detection
(d) Vertical motion
(e) Multilayer cloud detection
(f) Cloud occurrence and phase profile
(g) Precipitation occurrence and phase
(h) Cloud water content profile
(i) Cloud water path
(j) Cloud particle size profile
(k) Cloud optical depth
(l) Cloud extinction profile
(m) Cloud radiative effect
(n) Latent heating rate

ACE Instrument Requirements

Science Requirement	Instrument Type
Characterization of aerosol types and size distribution over a broad swath	Multi-angle, multi-wavelength polarimeter
Vertical distribution of extinction and other properties of aerosols/clouds	Backscatter multi-beam or HSR lidar (active)
Cloud microphysics	Dual frequency Doppler cloud radar (active)
Ocean color	Multi-band spectro-radiometer
Cloud height in the IR	IR imager
Cloud particle type and ice water path over a broad swath	High frequency μ-wave radiometer
Precipitation and liquid water path over a broad swath	Low frequency μ-wave radiometer
Temperature and humidity sounder	Needed if no sounder in close orbit

ACE: Coming in ~2020



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