Direct Aerosol Forcing of Climate

• **What are we after?**
  - Change in surface and top-of-atmosphere irradiances due to scattering and absorption of sunlight by anthropogenic aerosols, for the entire globe.

• **What do we need to measure?**
  - **AEROSOL AMOUNT**
    - Anthropogenic aerosol optical depth, $\delta_a$
    - Chemical measurements to determine anthropogenic fraction
  - **ABSORPTION vs. SCATTERING**
    - Single-scattering albedo of anthropogenic aerosols, $\omega_o$
  - **SCATTERING vs. ANGLE**
    - Angular scattering properties of anthropogenic aerosols (asymmetry parameter, backscatter fraction)
  - **WATER UPTAKE**
    - RH-dependence of scattering, absorption, angular scattering

• **What is our strategy?**
  - Models+satellites provide global distribution of AMOUNT
  - Monitoring from surface and airplanes gives
    - validation data for models and satellites
    - climatology of aerosol single-scattering albedo, angular scattering, and water uptake
  - Radiative transfer models derive forcing from AMOUNT and PROPERTIES
Observations of Direct Climate Forcing

- Global mapping of anthropogenic aerosol optical depth (AOD) by satellites and models
- Regional climatology of radiative forcing efficiency (RFE) from in-situ measurements
- Direct Climate Forcing (W m$^{-2}$)
  \[ \text{DCF} = \text{AOD} \times f_f \times f_{af} \times \text{RFE}_a \]

- $f_f =$ fine mode fraction of AOD
- $f_{af} =$ anthropogenic fraction of fine mode AOD

In-situ profiling needed
In-situ Aerosol Profiling Aircraft

- Information on aerosol properties aloft is scarce, satellites and surface stations give limited data.

- Light airplanes can be used to monitor vertical profiles of key aerosol properties at modest cost.

- Objectives:
  - obtain aerosol climatology aloft
  - determine relevance of surface climatology

- Summary: Cessna 172 or Cessna 206, profiles to ~4 km asl, aerosol light scattering and absorption, automated operation.

- DOE/ARM funding for Oklahoma project, >600 flights since 3/2000
- NOAA funding to sample over another continental U.S. site with an enhanced payload. Start flying June 2006.
Seasonal Variation of Average Aerosol Profiles over Oklahoma: Aerosol Amount

Notes: Results are for 324 profiles from March, 2000 – March, 2003 over the DOE/ARM site. Aerosol radiative properties reported at 550 nm wavelength, RH<40%, and particle diameter below 1 µm.
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Vertical Profile of RFE over Oklahoma

DOE/ARM funded research
March 25, 2000 - April 17, 2006, 616 flights
NOAA Airborne Aerosol Observatory

- **Objective:** Obtain a climatology of aerosol properties aloft for testing models and satellite retrievals
- **Stair-step flight patterns from surface to 15k’ (occasionally 18k’), 2-3 flights per week**
- **Underfly satellites when possible (A-Train)**
  - requires clear sky and overpass nearby
- **Most profiles in vicinity of CMDL aerosol monitoring station near Bondville, IL**
  - possibly relocate to Trinidad Head, CA for springtime maximum in transport from Asia
- **Status:** installation on Turbo Cessna 206 in May 2006, flights beginning June 2006

  - **Aerosol chemistry**
    - major ions, water-soluble organic carbon
    - eventually add trace elements, gravimetric mass
  - **Aerosol size distribution**
  - **Aerosol optics**
    - light scattering, absorption, hygroscopic growth
  - **Gases**
    - continuous O₃, carbon-cycle flasks
Variations in Radiative Forcing Efficiency

Only one site with vertical profiles