Miniature Multi-filter Continuous Light Absorption Photometer

John A. Ogren and Jim Wendell
Earth System Research Laboratory
National Oceanic and Atmospheric Administration
Boulder, CO

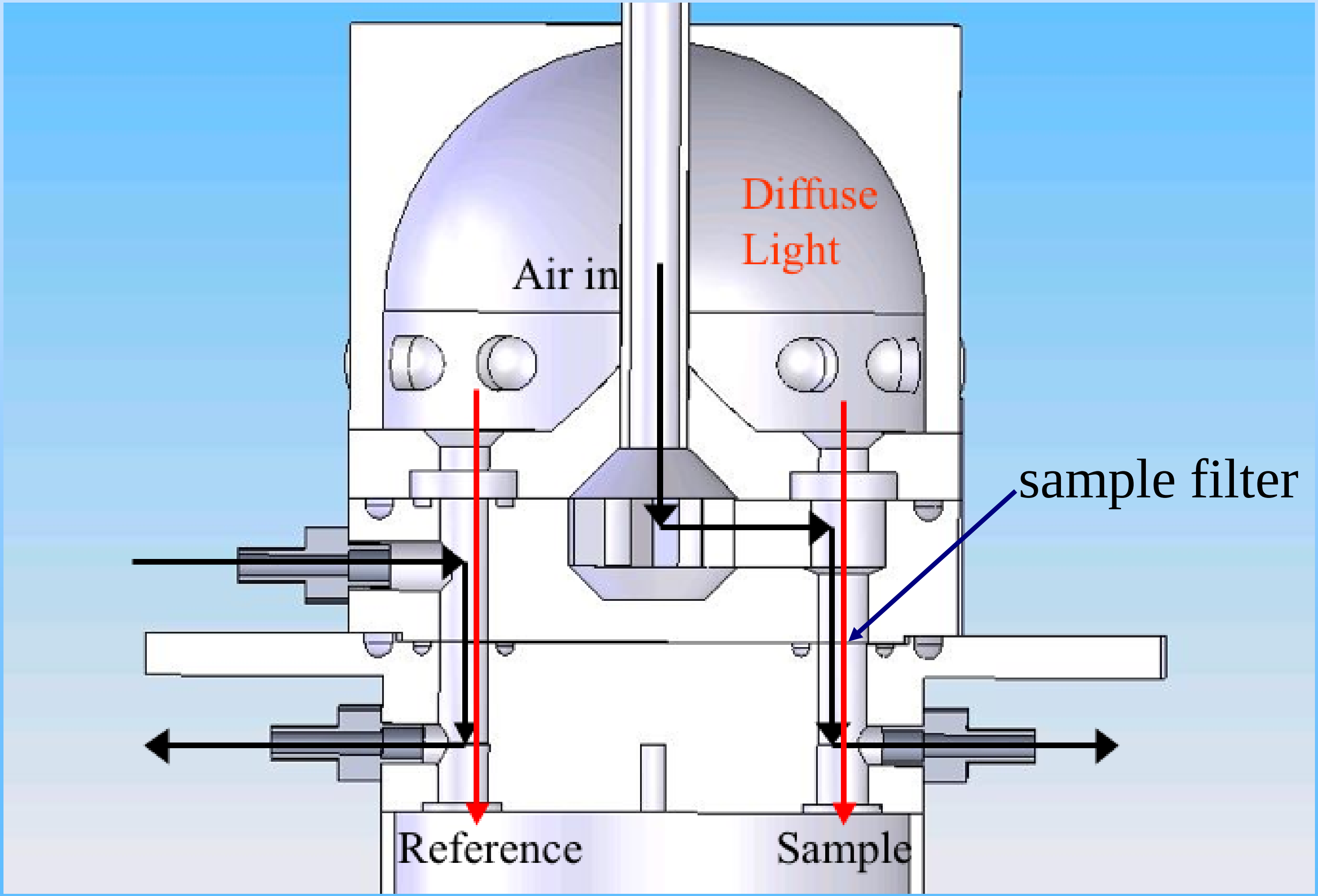
Motivation for new design

- **Aerosol light absorption is a crucial contributor to radiative climate forcing**
- **Current instruments all have shortcomings**
  - filter transmission
    - PSAP’s single filter requires frequent changes
    - aethalometer is poorly characterized
    - MAAP has best optics, but only a single wavelength
  - photoacoustic is expensive and only marginally sensitive enough
  - photothermal interferometer is promising but unproven
  - extinction minus scattering
    - cavity ring-down extinction device is expensive
    - difference measurement adds uncertainty

Design Features

- **Small size, low power, low cost**
- **High sampling efficiency for particle D_p < 10 μm**
- **Multiple filters, with automatic switching**
- **Tight integration with nephelometer**
  - climate forcing studies need both scattering and absorption
  - filter-based absorption instruments need scattering
  - similar wavelengths (~450, 550, 700 nm)
- **Heated optics block and sample inlet**
  - lab studies show PSAP sensitivity to changing RH
- **Transparent data acquisition**
  - raw data transmitted out serial port each second
  - internal data processing code publicly available
- **Suitable for aircraft and ground-based monitoring**

Cutaway of Instrument



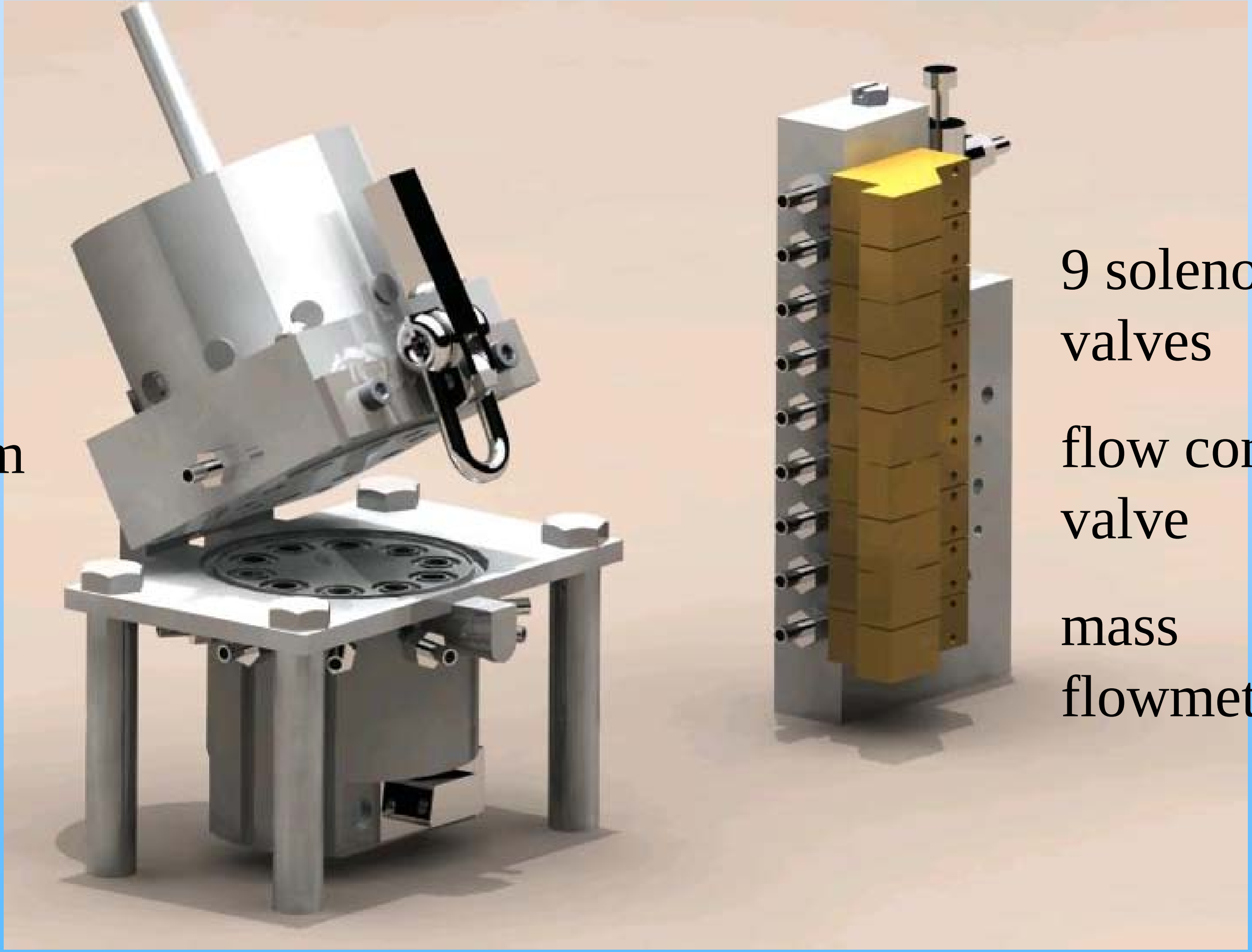
Separate Optical and Flow Control Blocks

inlet

light source

filter - 47 mm

electronics

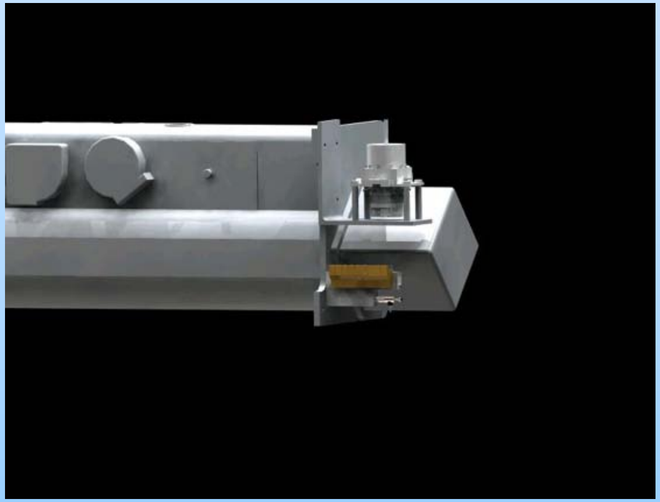


9 solenoid valves

flow control valve

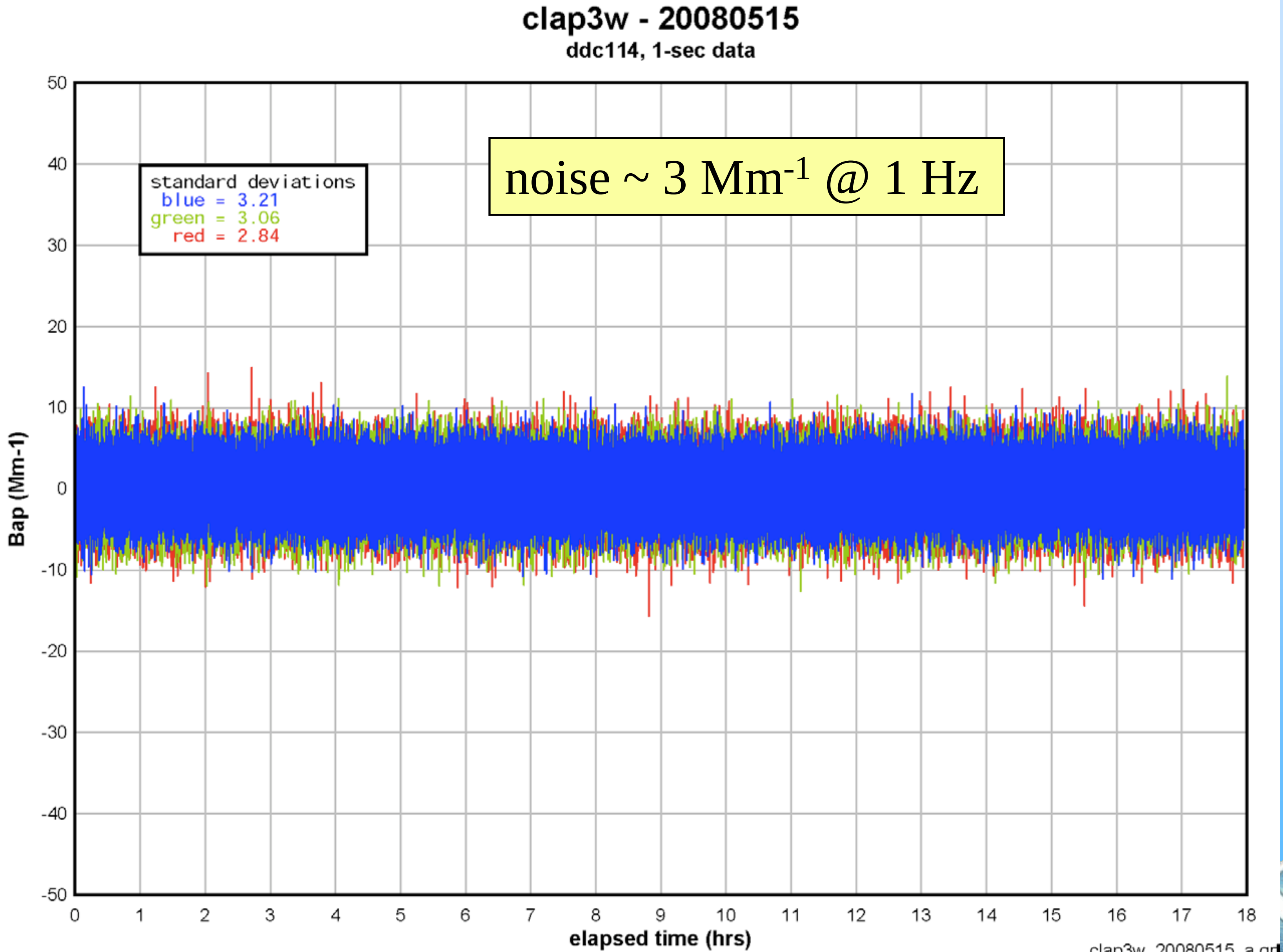
mass flowmeter

Integration with Nephelometer

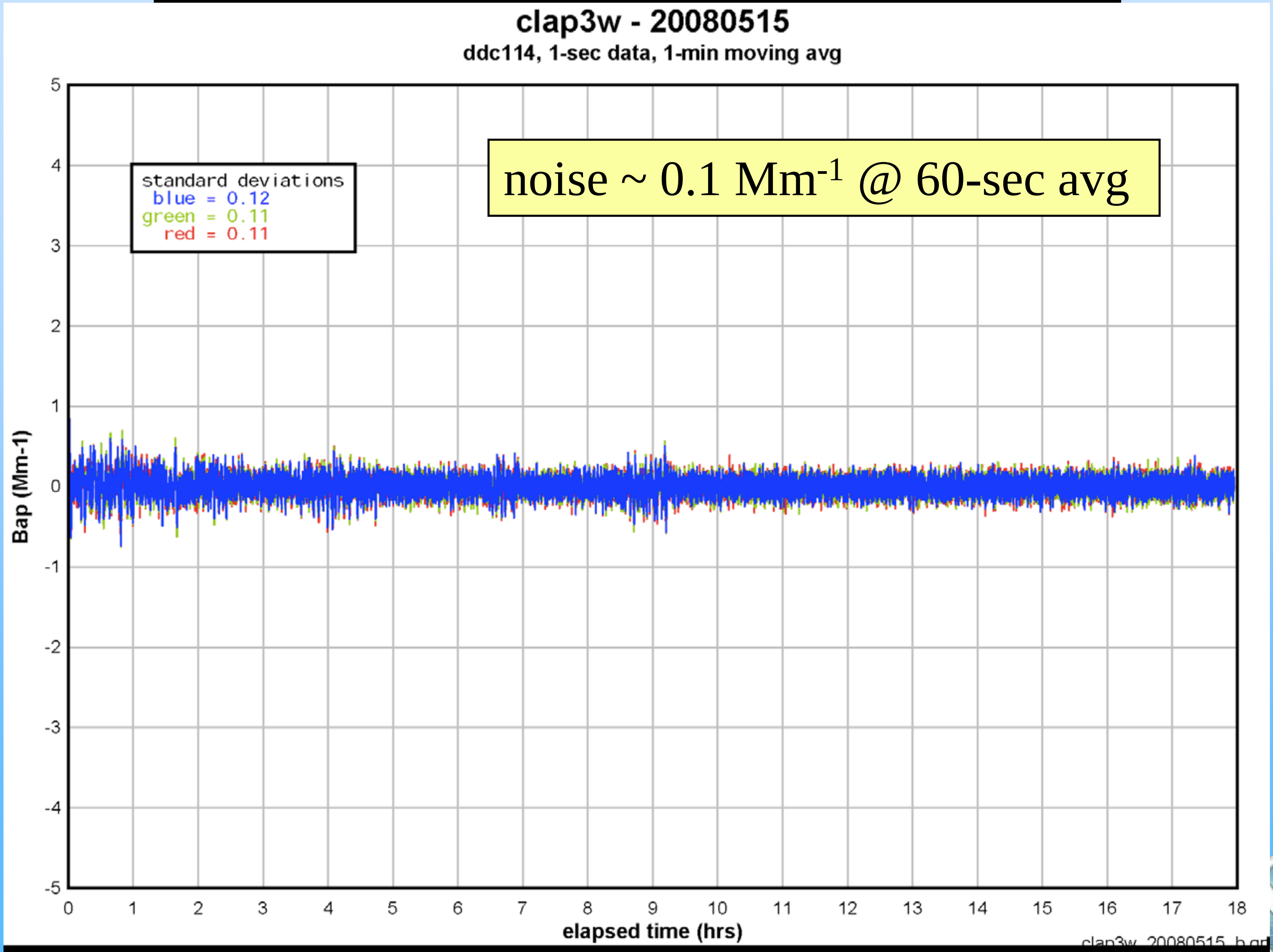


- **Need 3-wavelength nephelometer for scattering correction**
- **Tight physical integration to minimize inlet losses**
- **Sample from neph exhaust, also gives zero checks**

Prototype Performance - 1-sec



Prototype Performance - 1-min



Data Processing and Calibration

- **Address limitations of Bond et al (1999) scheme using a constrained two-stream radiative transfer model of particles+filter**
- **Calculations use optical depths (scattering, absorption, particles+filter), to include sensitivity of response to previously-deposited particles**
- **Calculations use asymmetry parameter derived from nephelometer for scattering correction**
- **Calibration with a variety of lab aerosols**
  - pure scatterers, liquids and solids, mixed particles
- **Multiple reference standards**
  - extinction minus scattering
  - photoacoustic

Conclusions

- **Filter-based measurements of aerosol light aren't the ideal approach, but they are**
  - practical and affordable
  - small, low power, light weight, and inexpensive
  - multiwavelength
- **Weaknesses…**
  - sensitivity to scattering by particles
  - sensitive to phase of particles (liquid particles have a different interaction with filter fibers than solid particles)
  - particles are deposited on a substrate, rather than remaining suspended in air
  - sensitive to changes in pressure and relative humidity

Background Information for Tonight's Tour of NOAA Cessna 206

ARM In-situ Aerosol Profiling (IAP)

Cessna 172XP
3/2000 - 6/2005

Cessna Turbo 206
9/2005 - 12/2007

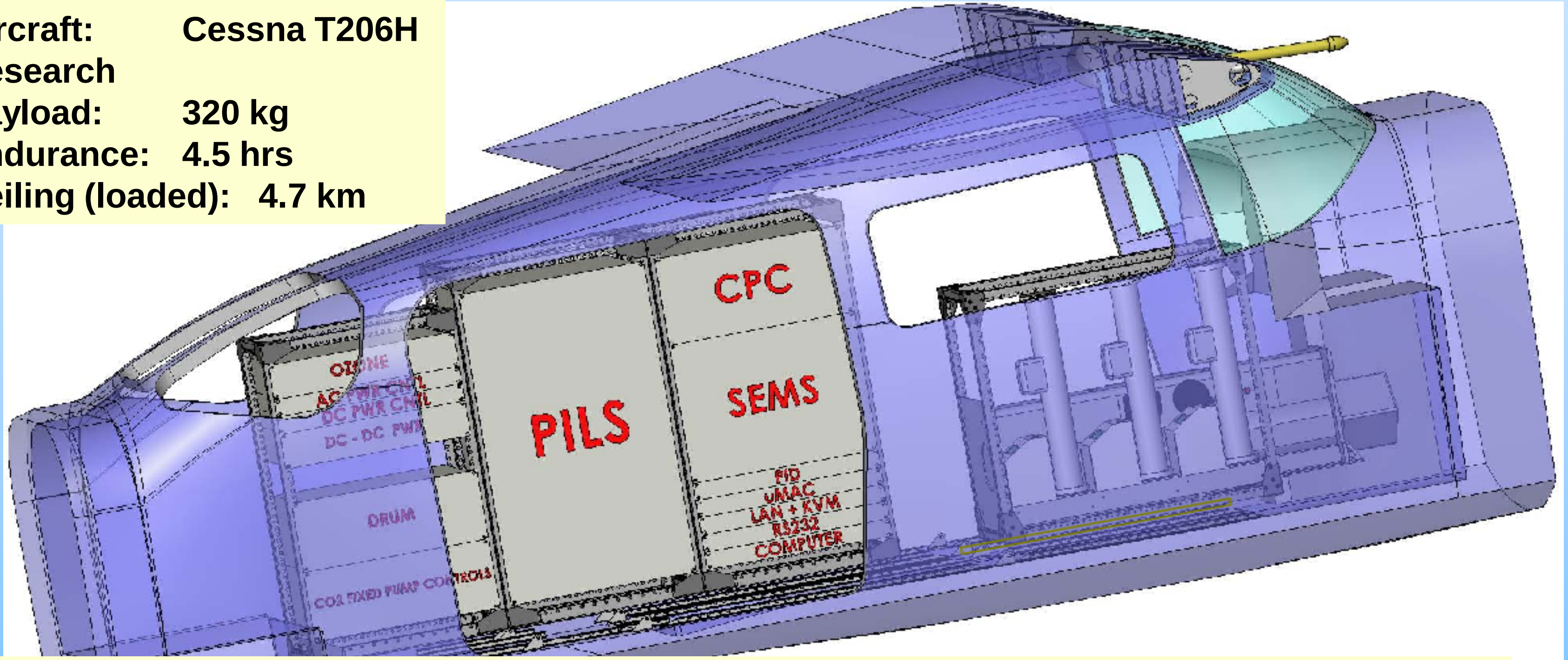
- **Objectives**
  - obtain aerosol climatology aloft
  - determine relevance of surface climatology to vertical column
- **Measurements**
  - Light absorption, scattering, and hemispheric backscattering
  - RH-dependence of scattering
  - Temperature and RH
  - Flask samples for trace gases (CO_2)
- **Flights (2000-2007)**
  - 9 levels, 0.5-3.7 km asl (172XP)
  - 12 levels, 0.5-4.6 km asl (206)
  - Temperature and RH
  - average ~100 profiles per year
- **“KISS” approach**
  - Keep it simple, stupid!

NOAA Airborne Aerosol Observatory

- Based at Champaign, IL
- Cessna T206H
- Routine vertical profiles, 10 levels, 1.5-15kft
- Aerosol optical, chemical, microphysical, and hygroscopic growth measurements
- Trace gas (flask) and ozone (continuous) measurements
- Operates in automated “UAV” mode, no operator on-board
- Flights started in 2006, 2-3 flights per week
- Underfly CALIPSO whenever possible
- Much more information at http://www.esrl.noaa.gov/gmd/aero/net/aao/index.html

NOAA Airborne Aerosol Observatory

Aircraft: Cessna T206H
Research Payload: 320 kg
Endurance: 4.5 hrs
Ceiling (loaded): 4.7 km



Chemical Properties

- **Major ions**
  - PILS sampler
  - analysis by IC
- **Trace elements and total mass (planned)**
  - DRUM sampler
  - analysis by PIXE, β-attenuation
- **Gases (O_3, carbon-cycle flasks)**

Radiative Properties

- **Light scattering, backscattering, and absorption**
  3 wavelengths,
  no size cut,
  <40% RH
- **Scattering vs. RH**
  1 wavelength,
  1 μm size cut,
  <40%, 65%, 85% RH

Microphysical Properties

- **Number concentration**
  D > 10 nm
- **Size distribution**
  20 < D < 500 nm

http://www.esrl.noaa.gov/gmd/aero/net/aao/index.html