AEROSOL MEASUREMENTS IN RACORO

R outine
A RM Aerial Facility (AAF)
C louds with Low Optical Water Depths (CLOWD)
O ptical
R adiative
O bservations

Website
http://acrf-campaign.arm.gov/racoro/

Science and Operations Plan
http://www.arm.gov/publications/programdocs/doe-sc-arm-0806.pdf

RACORO Objectives

- **Conduct long-term, systematic flights in boundary layer, liquid-water cloud fields at the SGP measuring:**
  - Cloud microphysical and optical properties
  - Radiative fluxes
  - Aerosol properties and Atmospheric state
- **Obtain data needed to:**
  - Validate ACRF remotely-sensed cloud properties
  - Investigate aerosol-cloud interactions
  - Improve cloud simulations in climate models

"Cast of Thousands"

Steering Committee

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IOP Share

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Operations

- **CIRPAS Twin Otter**
- **Based near SGP**
- **22-Jan to 30-Jun-2009**
- **59 research flights, for a total of 259 hours**
- **QC'd data in archive 1-Jan-2010**

- **Simplified operation paradigm, compared to an IOP**
- **Long-term observations for good statistics**
- **1st time, long-term aircraft in-situ sampling of clouds**
- **Primarily triangular or paperclip patterns at multiple altitudes, with spirals, anchored at SGP.**

Comprehensive Payload

CATEGORY	MEASUREMENT	INSTRUMENT	PRINCIPAL INVESTIGATOR
CLOUD MICROPHYSICS	Liquid-Water Content	Particle Volume Monitor-100A	CIRPAS
		SEA Liquid-Water Content Probe	CIRPAS
	Drop Size Distribution	Forward Scattering Spectrometer Probe-100	CIRPAS
		Cloud Aerosol Precipitation Spectrometer	CIRPAS
		2D Cloud Imaging Probe)	CIRPAS
		2D Stereo Probe	Paul Lawson
	Cloud Extinction	Cloud Integrating Nephelometer	Hermann Gerber
RADIATION	Broadband fluxes	↑↓ Shortwave Kipp & Zonen	Anthony Bucholtz & Chuck Long
		↑↓ Longwave Kipp & Zonen	Anthony Bucholtz & Chuck Long
		↑ SPN-1	Anthony Bucholtz & Chuck Long
	Spectral fluxes	↑↓ Multi-filter Radiometer	Anthony Bucholtz & Chuck Long
		↑↓ HydroRad-3	Anthony Bucholtz & Chuck Long
	Spectral Radiances	↑ or ↓ HydroRad-3	Anthony Bucholtz & Chuck Long
		↑↓ Infrared Thermometer	Anthony Bucholtz & Chuck Long
AEROSOL	Cloud Condensation Nuclei	Dual-Column CCN Spectrometer (0.2% SS, Scan 0.8-0.2% SS)	CIRPAS
	Number Concentration	Ultrafine Particle Counter	CIRPAS
		2 Condensation Particle Counters	CIRPAS
	Size Distribution	Scanning Differential Mobility Analyzer	Don Collins
		Passive Cavity Aerosol Spectrometer Probe	CIRPAS
METEOROLOGY	Temperature	Rosemount Probe	CIRPAS
		Vaisala Probe	CIRPAS
	Water vapor	Chilled Mirror Hygrometer	CIRPAS
		Diode Laser Hygrometer	Glenn Diskin
	Wind-Turbulence and Updraft velocity	Gust probe	CIRPAS
	Conditions	Flight video	CIRPAS

- Interdisciplinary
- Redundancy
- Some new things
- Pair a slow measurement (“what we want”) with a related, fast one

- fast + slow
- fast
- fast
- slow
- fast

Aerosol Data Analysis

- **Influence of aerosol variability on cloud microphysical and optical properties**
  - beware splashing effects on in-cloud aerosol data
- **Role of chemistry vs. size in determining CCN number concentration and spectra**
- **Variability of aerosol optical properties in vicinity of clouds**
- **Mesoscale variability of aerosols**

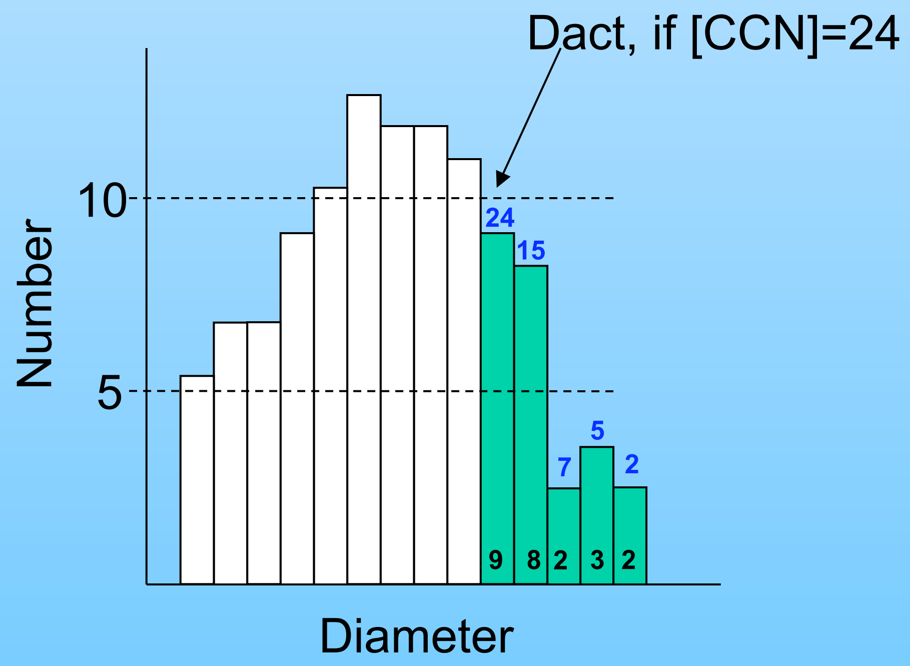
Cloud Activation – Activation diameter

- PCASP and DMA measure dry aerosol size distribution, e.g., number of particles as a function of diameter
- CCN counter measures number of particles that activate to cloud drops as function of supersaturation.

•Assume largest particles activate (true if all have same composition)

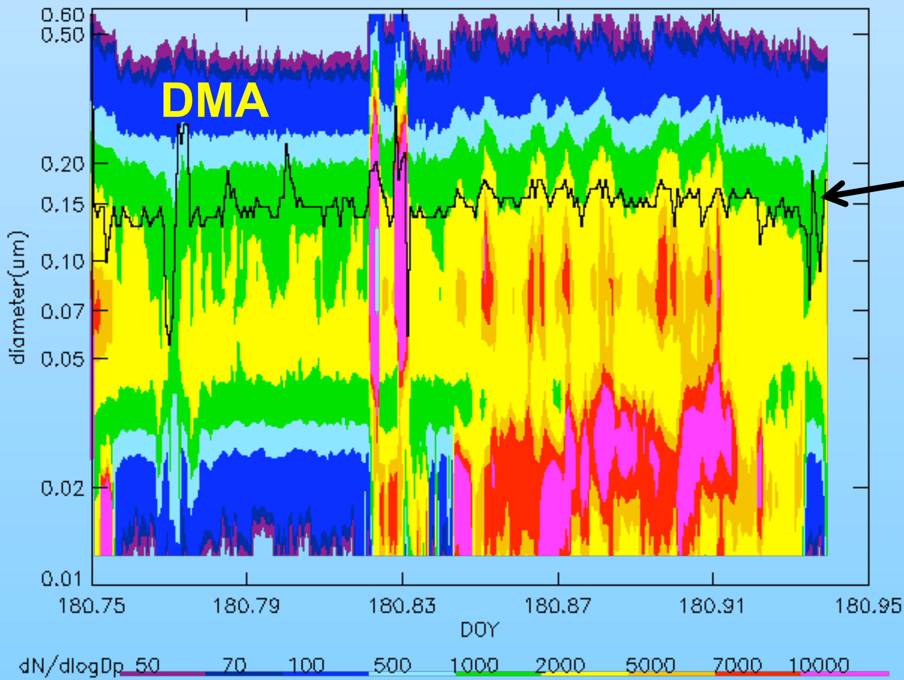
•Add up the particles from the DMA (or PCASP) from largest to smallest

•When integrated number = [CCN]@0.2SS →activation diameter



CCN and Droplet Activation Diameter

June 29, cloud-free flight



Time series of DMA size distribution overlaid with activation diameter calculated for 0.2%SS.

- Activation diameter (D_{act}) was consistent from day-to-day of the campaign

$$\sum_{d=D_{act}}^{\infty} N(d) = N_{CCN}(0.2\%)$$

- D_{act} statistics (quartiles):
  0.17 - 0.21 μm (PCASP)
  0.13 - 0.16 μm (DMA)
  Note: DMA upper limit is 0.6 μm
- CCN properties suggest significant contribution from insoluble (less soluble) aerosol. This is supported by surface hygroscopicity measurements.
- Larger particles are preferentially scavenged in-cloud
- In-cloud splash issues affect some measurements (e.g., PCASP) and need to be dealt with.

Droplet Activation and Particle Composition

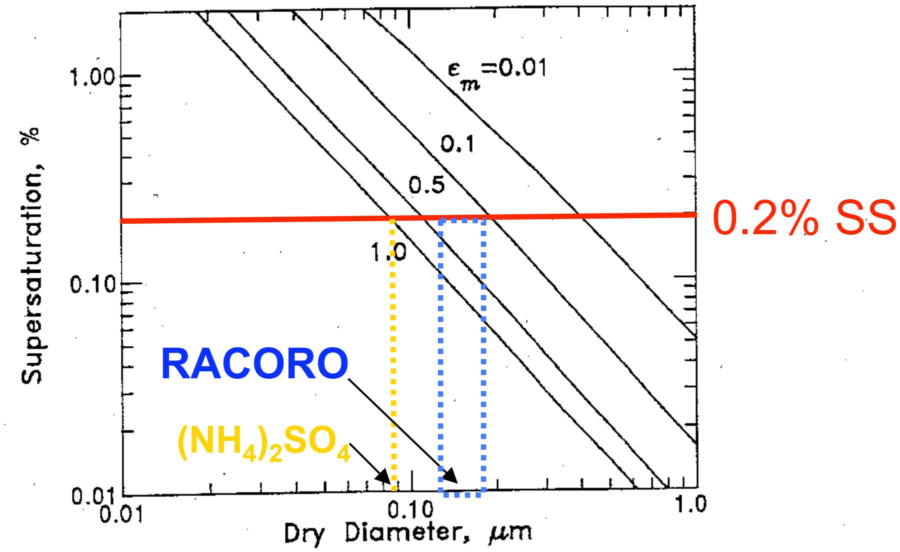


FIGURE 15.9 Critical supersaturation as a function of the particle dry diameter for different contents of insoluble material. The soluble material is $(NH_4)_2SO_4$.

From Seinfeld and Pandis, 1998

- **Median D_{act} 0.15 - 0.18 μm (dry) at 0.2% SS**
- **Suggests insoluble material makes up well over half of aerosol mass, possibly as much as 90%**
- **Alternatively, the soluble material is much less efficient than ammonium sulfate at activating cloud droplets**

FERRARI

HIGH SPEED
RACING LEAGUE

NASA King Air and HSRL

Photo by Hee-Jung Yang

- Joined RACORO from 3-26 June
- High spectral resolution lidar and research scanning polarimeter
- Flew in formation with Twin Otter at ~26k'

- Are HSRL light extinction and Twin Otter size distribution data consistent?
- How does aerosol size distribution vary within and near clouds?
  - beware of splashing artifacts in Twin Otter data
- Lots more coming soon in Rich Ferrare's talk

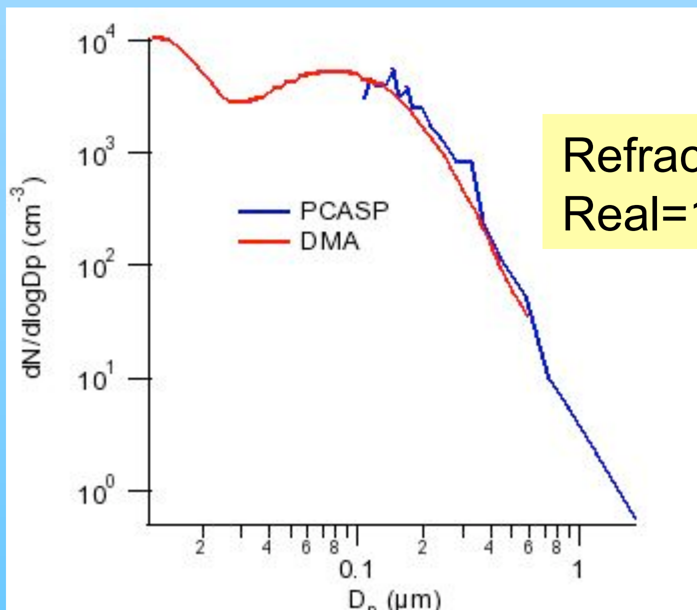
CIRPAS Twin Otter
In-situ aerosol size distribution instruments

Differential Mobility Analyzer (DMA)

- Size range: 0.01-0.6 µm
- Frequency: 1 scan/minute
- Basis for measurement: electrical mobility

Passive Cavity Active Spectrometer Probe (PCASP)

- Size range: 0.1-1.8 µm
- Frequency: 1 scan/second
- Basis for measurement: optical detection



Refractive index (assumed)
Real=1.53, Imaginary=0.01

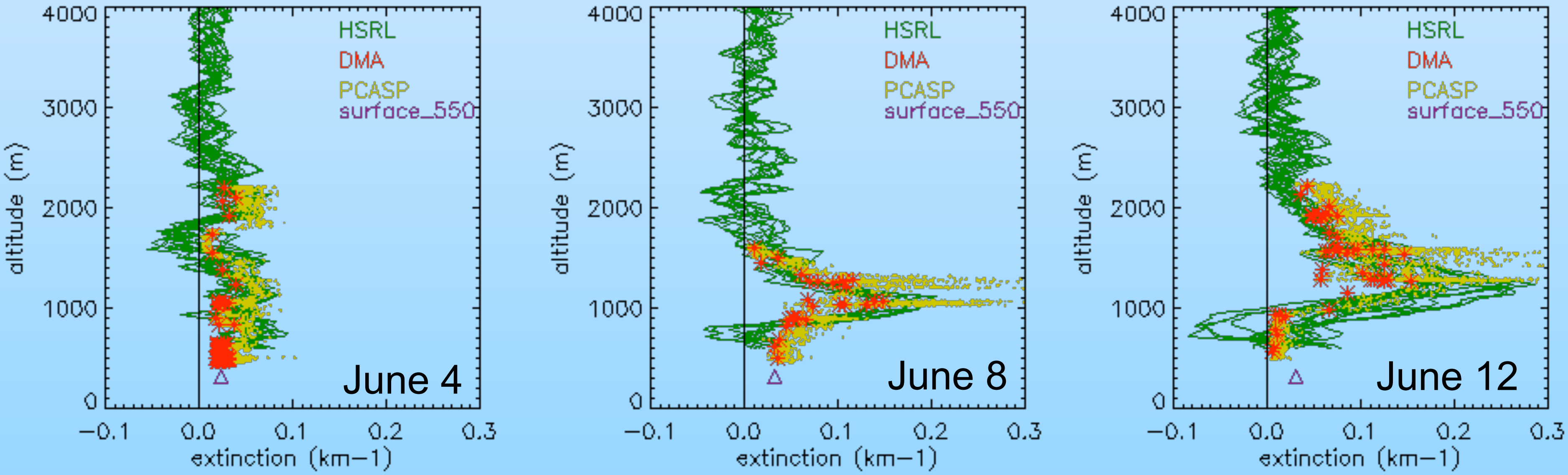
Mie Code

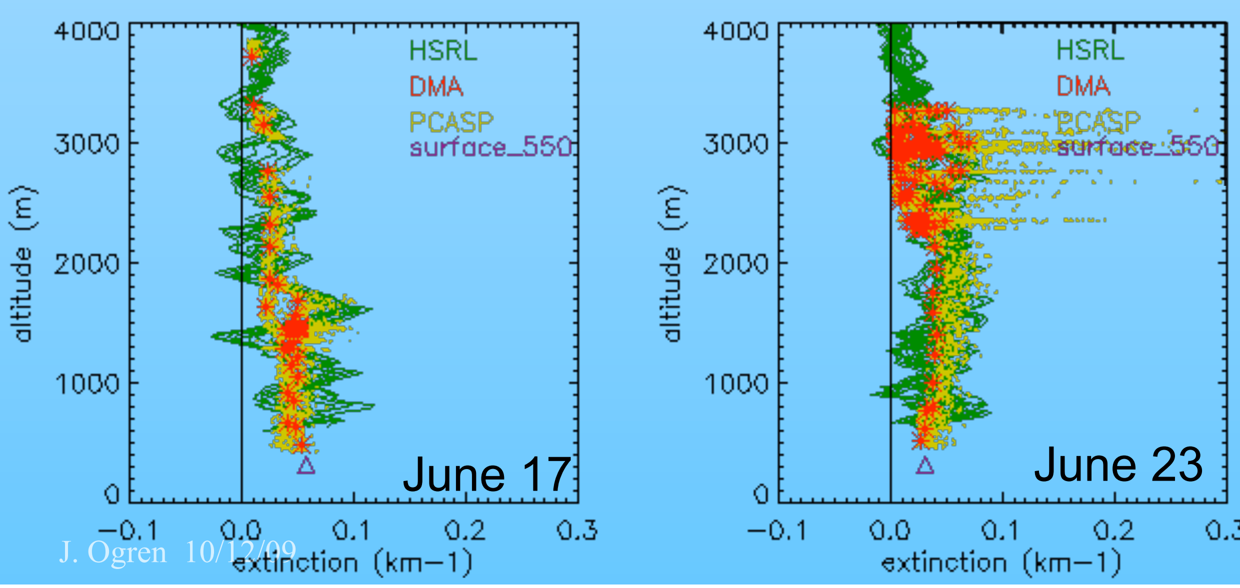
Aerosol Light Extinction
at 532 nm

From Don Collins presentation at AWG, March 2009

Data consistency – Airplane vs Surface and HSRL

Values adjusted to ambient RH using climatology, screened for cloud





<u>Generally good agreement</u>

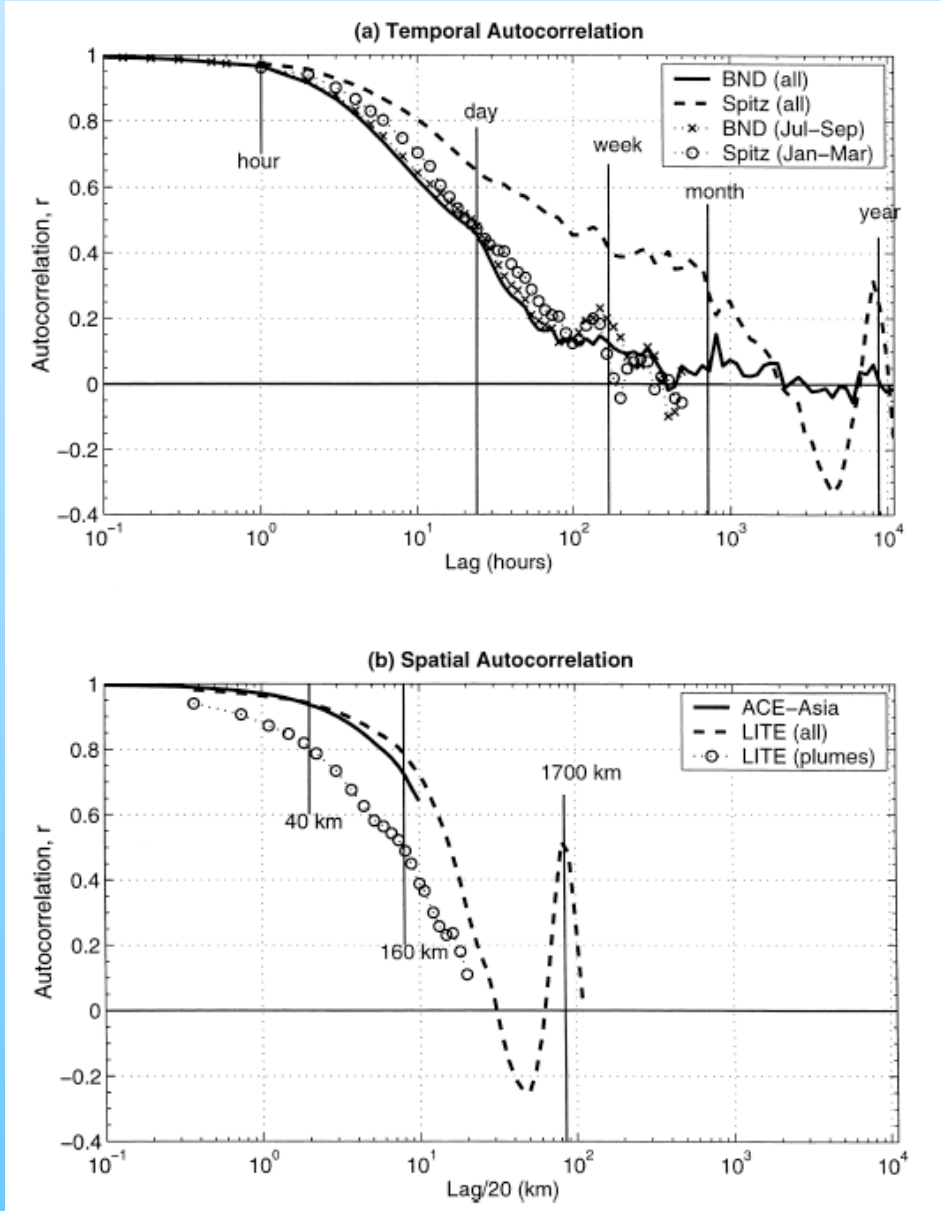
→surface & lowest level

→shape of profile

Noise occurs when RH>90%

f(RH) fit not appropriate at high humidity?

Mesoscale Variability



- **Anderson et al (JAS, 2003) found significant mesoscale variability (spatial and temporal) in aerosol optical properties**
- **What is the spatial and temporal autocorrelation of aerosol properties at SGP?**
- **How do the lagged autocorrelations differ for different aerosol properties?**
- **What is the relationship between spatial and temporal autocorrelations?**
- **During RACORO, we occasionally flew parallel to the wind vector for ~100 km on cloud-free days.**

RACORO/Aerosol Lessons Learned

- **Redundancy is crucial!**
  - instruments
  - science objectives
  - mission profiles
- **Suggest that AAF add an additional review step, after a project is approved:**
  - what capability could be added at minimal additional cost to the selected aircraft, which would add significant redundancy to the mission
  - e.g., a CIRPAS owns a nephelometer and PSAP, which could easily and cheaply have been added to Twin Otter payload