An Overview of CHAPS

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Cloud Modeling and
Aerosol Working Group Meeting
San Francisco, CA

Outline

- Overview
- CHAPS science questions
- General sampling strategy
- Flight pattern
- Instruments
- Sampling issues
  - Number of clouds
  - Time in cloud
  - Identification of air that has been processed by clouds

Overview

- Primary Goal: to characterize and contrast freshly emitted aerosols above, within and below fair weather Cu
- The ‘big’ question: how do below-cloud and above-cloud aerosol optical and cloud nucleating properties differ downwind of a mid-size city relative to similar aerosols in air less affected by emissions?
- Strategy: look at aerosols properties in aggregate
- Key platforms

DOE Gulfstream

NASA King Air Be-2000

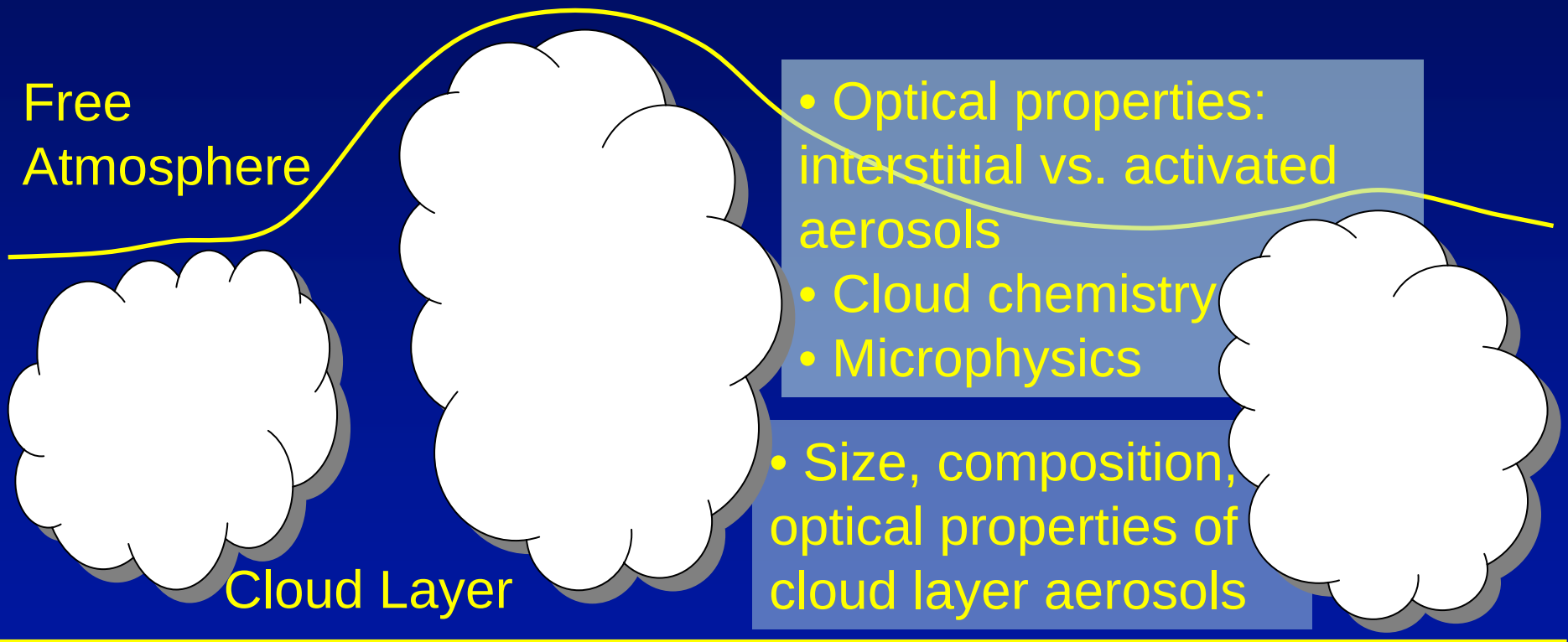
CHAPS Science Questions

- What are the differences in aerosols found below, within, and above Cu?
  - Optical properties
  - Nucleating properties
  - How do these properties differ inside and outside of the urban plume?
- Does the distribution of aerosol extinction vary in relation to proximity to individual Cu and fields of Cu?
- What are the differences between activated aerosols inside and outside of the urban plume?
- What are the differences between aerosols that have <u>not</u> been activated within and outside the urban plume?

General Sampling Strategy

- Size, composition, optical properties of free atmosphere aerosols

Free Atmosphere



- Optical properties: interstitial vs. activated aerosols
- Cloud chemistry
- Microphysics

- Size, composition, optical properties of cloud layer aerosols

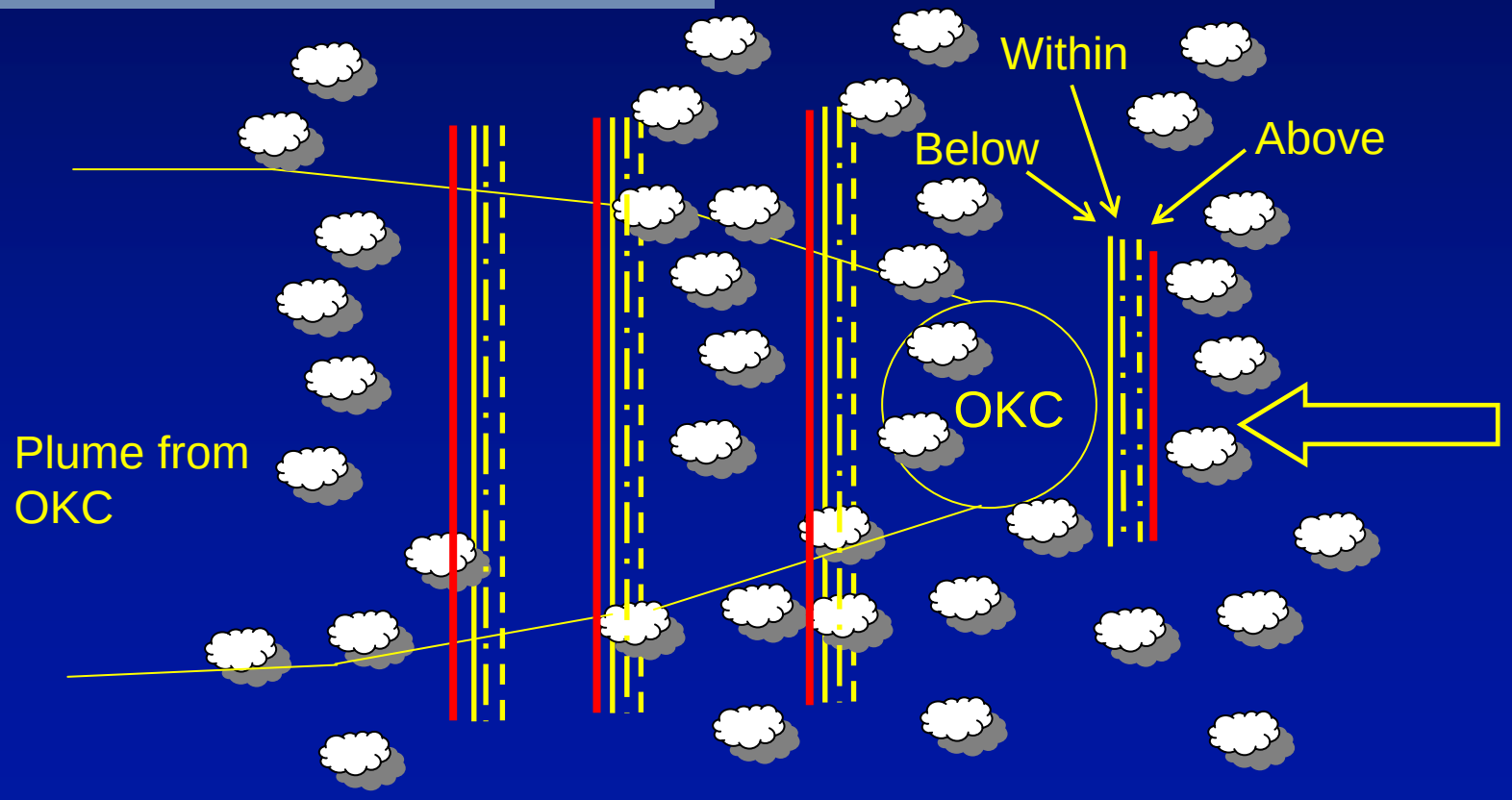
- Size, composition, optical properties of boundary layer aerosols

Dry Boundary Layer

CHAPS Flight Pattern

G-1: Below, through, above clouds

King Air: Sampling over G-1



Instruments

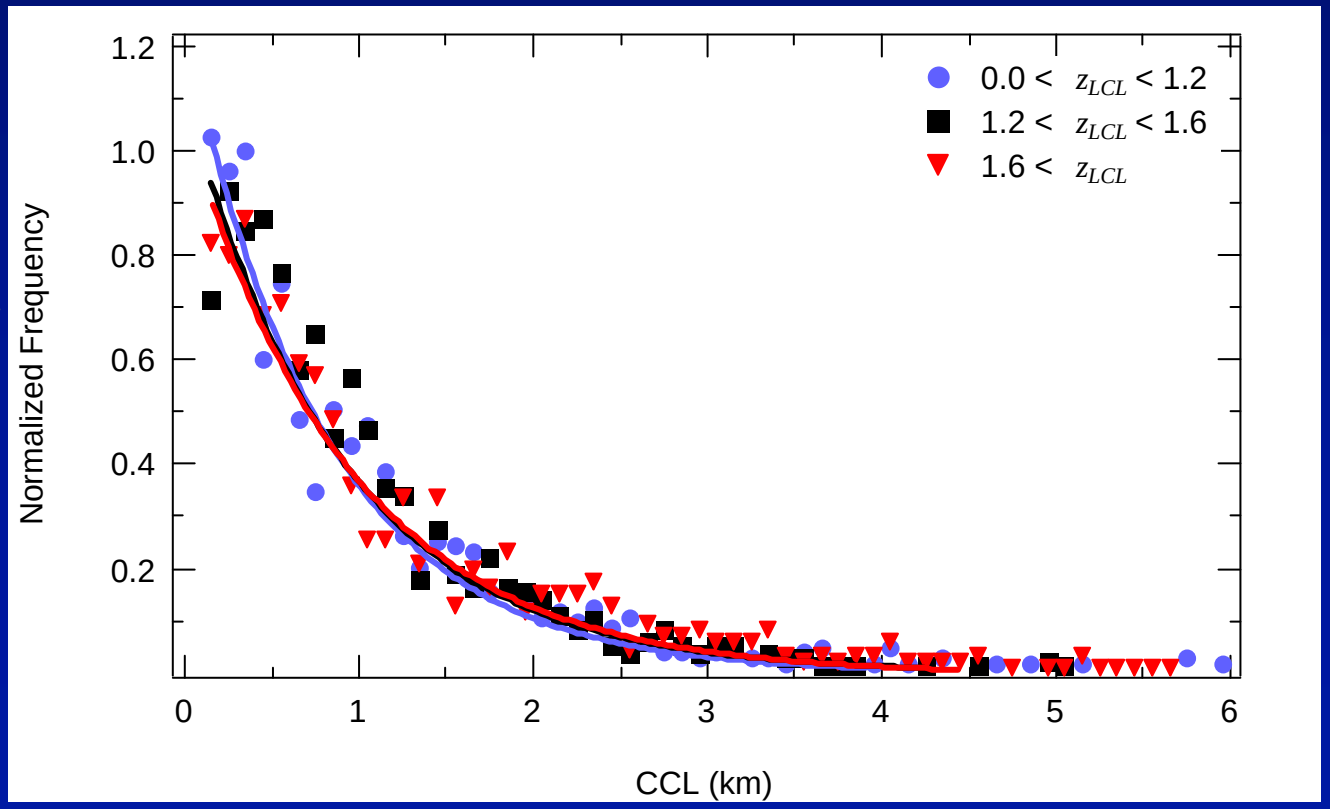
- Optical properties: Dual air stream
  - Two inlets used during cloud penetration
  - Counter Flow Virtual Impactor (CVI)
    - Selectively samples cloud drops
  - Standard inlet
    - Samples all aerosols
  - Identical instrumentation
  - Fast response, ~1 Hz
- Aerosol composition: Standard inlet
  - Detailed composition — AMS
  - Gas Chemistry

Sampling Issues

- Statistical approach
  - Sample clouds along a horizontal leg — look at clouds in aggregate
  - Determine average cloud properties
  - No need to sample the same cloud repeatedly
- Two related issues
  - How many clouds?
  - How long in a single cloud?
- How to identify air that has been processed

How Long in a Cloud

- Cloud Chord Length (CCL) can be determined from instruments at ARM Central Facility
  - ARSCL, radar wind profiler
  - Samples cloud field like an aircraft
- Mean CCL ~1 km
- Approximately 60% of observed chord lengths greater than 0.5 km



From Berg and Kassianov (2005)

Identification of Cloud Processed Air

- Thermodynamic tracer of opportunity
- Variables that are conserved for dry and moist adiabatic processes
  - Equivalent potential temperature (θ_e)
  - Total water mixing ratio (r_{Total})
- Similar analysis has been done looking at mixing in clouds

Collaboration with CLASIC

- Both campaigns concerned with clouds and aerosols
- Contrasts between urban plume and background
- Twin Otter/G-1 intercomparisons
- ER-2 overflights
- ASP surface stations
  - Wind profiler
  - TSI
  - MFRSR
  - Aerosol racks?

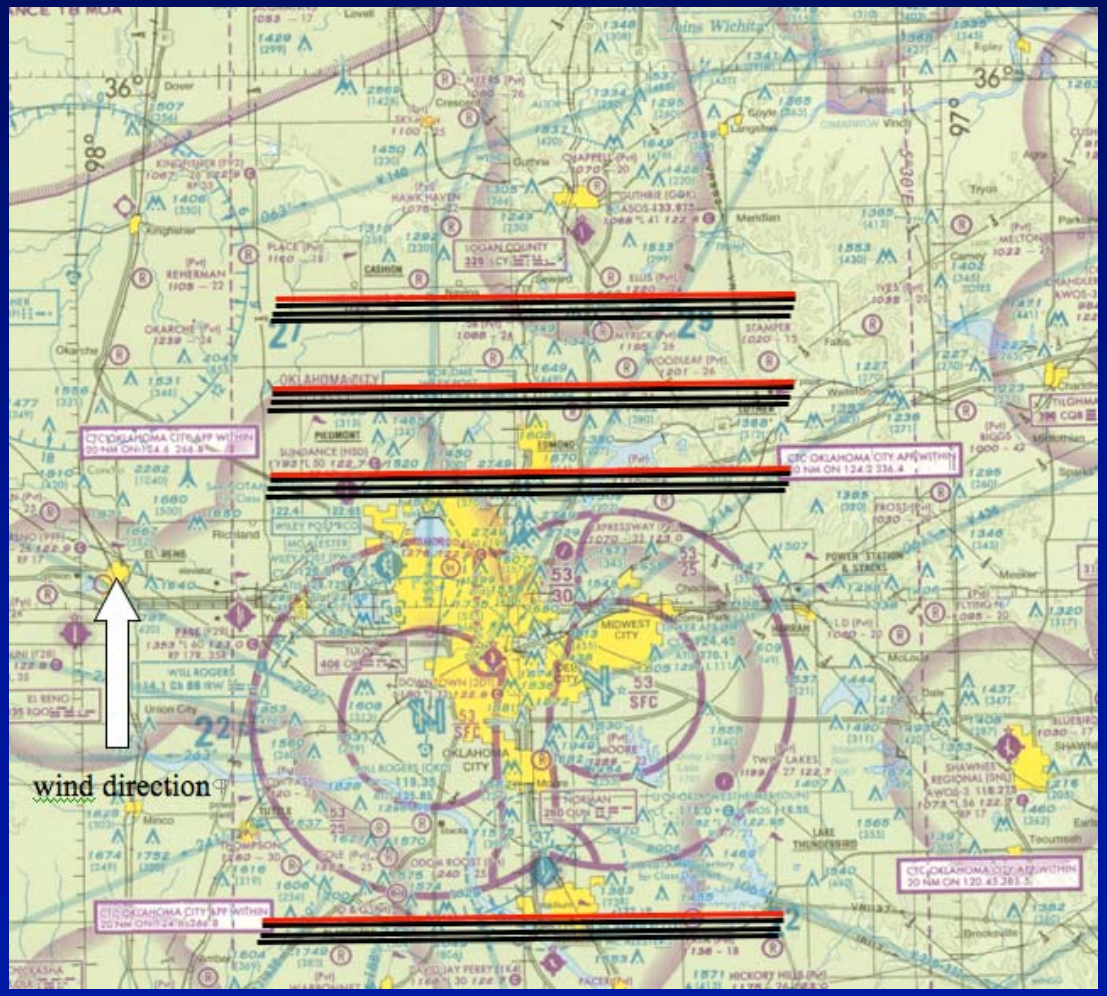
Conclusions

- Science questions
  - Changes to aerosols as they move through clouds
- Instrument platforms
  - G-1 and King Air
- Instruments
  - Dual air stream sampling
- Issues
  - Number of clouds
  - Length of time in clouds
  - Identification of air that has been processed by clouds
- Collaboration with CLASIC

Backup Slides

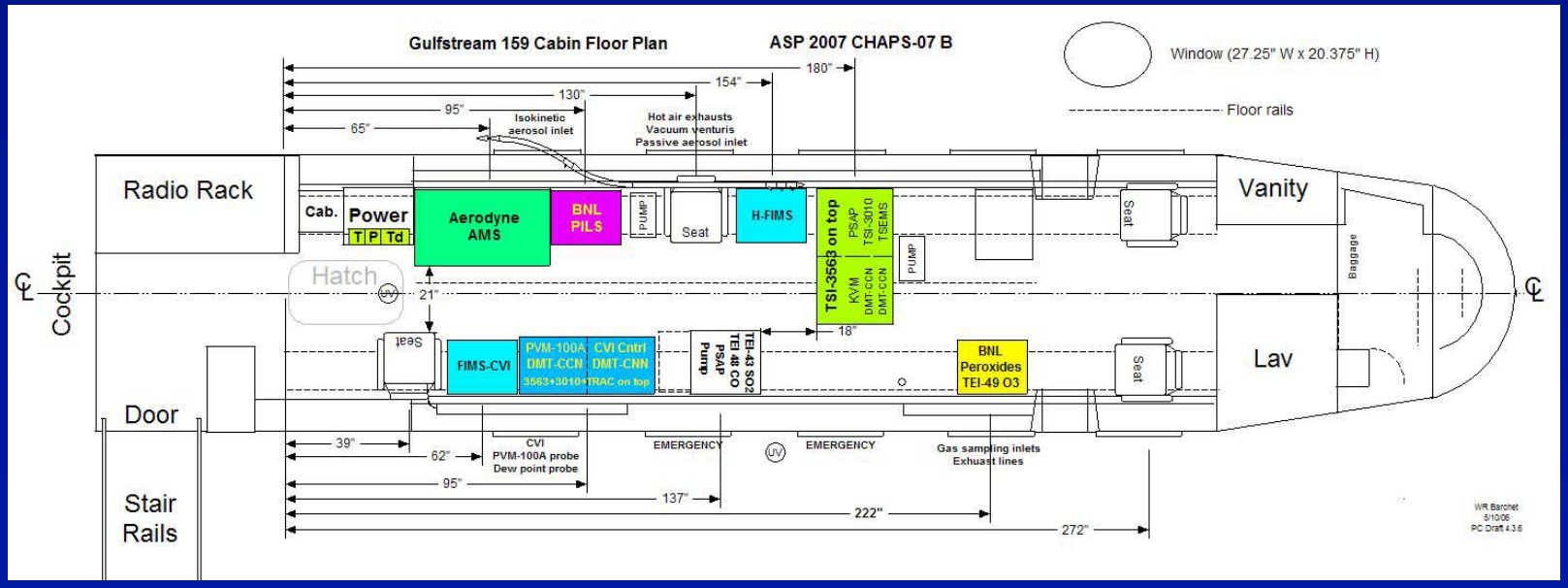
Flight Pattern: A Statistical Study

- G-1
  - Stacks of three legs
  - Below, in and above clouds
- NASA King Air
  - Single altitude above G-1
- Preliminary okay from FAA



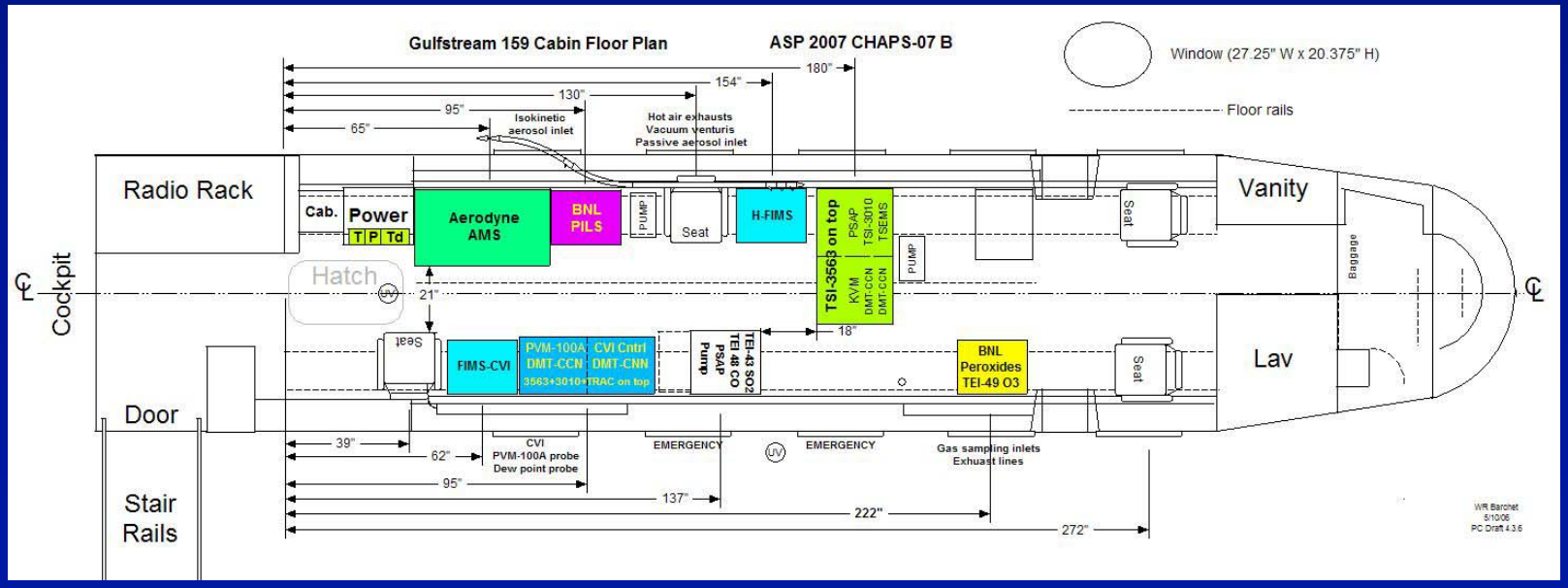
Instrument List: Dual Air Stream

- Aerosol scattering; Nephelometer
- Aerosol absorption; PSAP, LAPA
- CCN counters
  - Two per inlet
- Time-resolved aerosol collector
  - Single particle collection
- Water Vapor
- Aerosol size; Fast integrated mobility spectrometer
- Particle number



Instrument List: Aerosol Composition and Size

- Hygroscopicity; H-FIMES
- Size
  - SMPS; 0.1 - 3 μm
  - PCASP; 0.17-3 μm
  - CAPS; 0.5-50 μm
- EC Mass
  - DMT Particle Soot Photometer
- Bulk composition; AMS
- Particle ionic composition; PILS



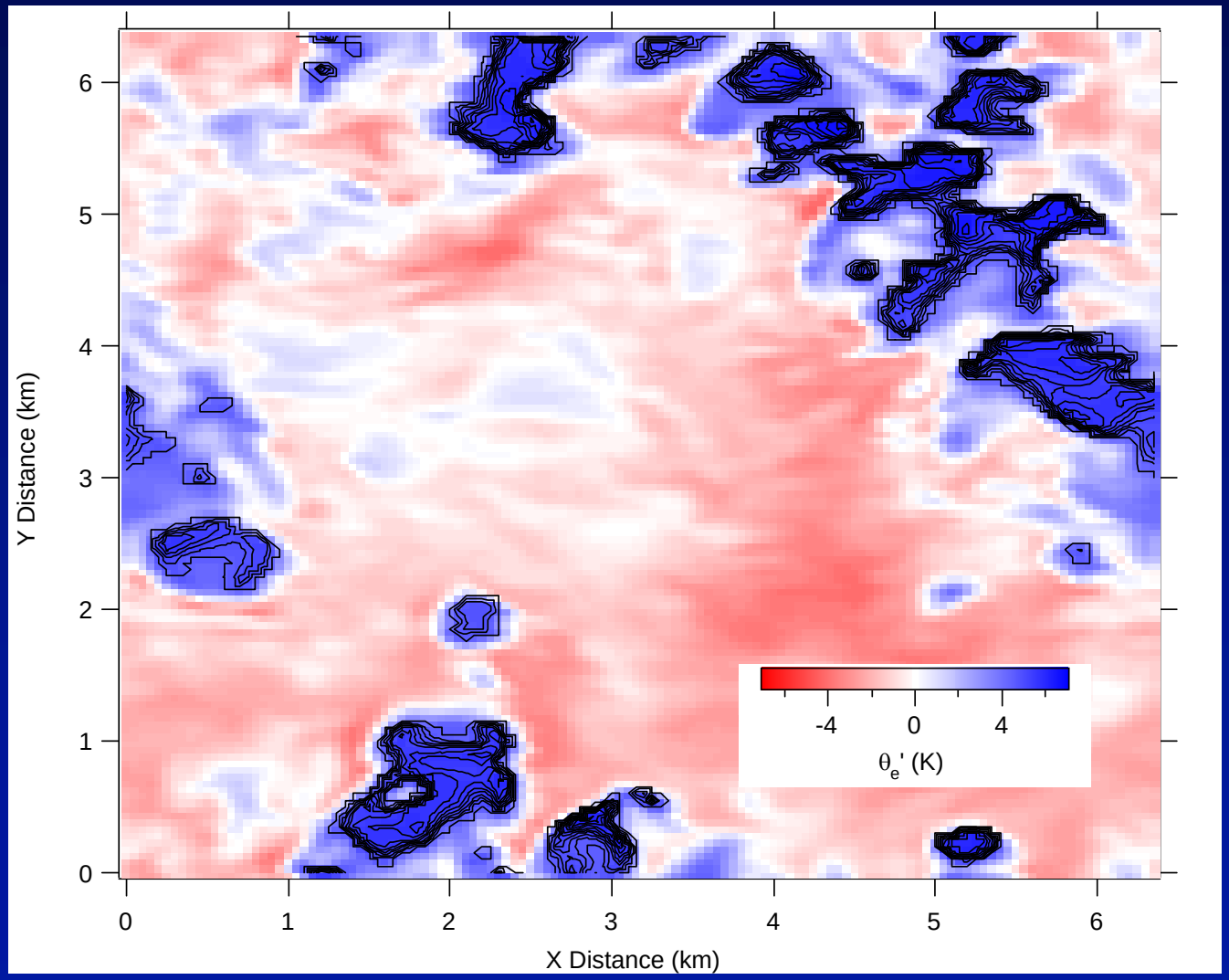
Instrument List: Gas Chemistry

- CO
- SO_2
- O_3
  - NOAA B2B System
- H_2O_2

LES of Fair Weather Clouds

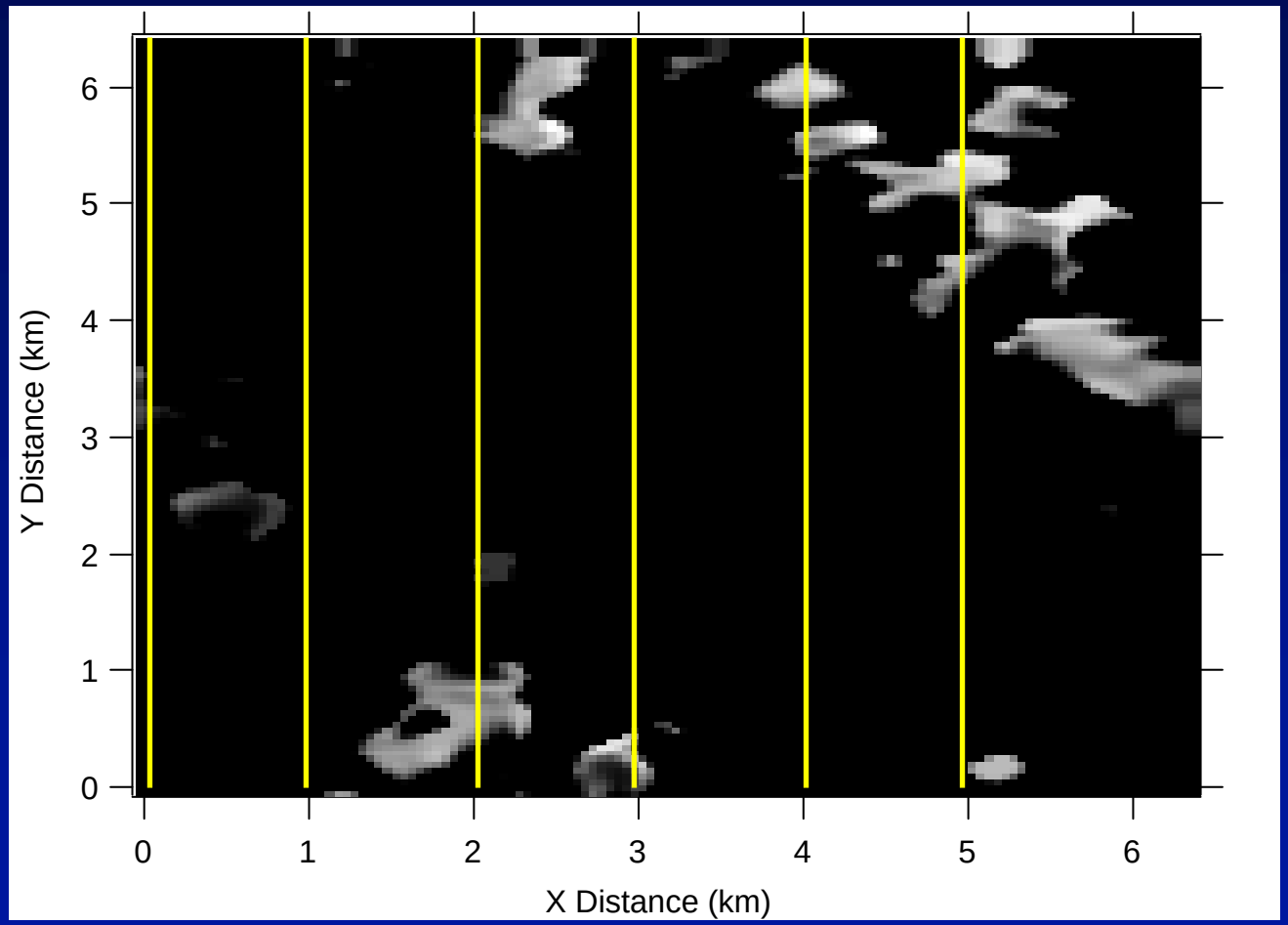
- LES of cloud field
  - 128 x 128 x 128 grid
  - $\Delta X = \Delta Y = 50$ m
  - $\Delta Z = 40$ m
- Fair weather GEWEX GCSS study (Brown et al. 2001)
  - Based on conditions from ARM Central Facility

Sample LES Clouds



Z = 1.3 km Contour = cloud water

LES Cloud Field



Z = 1.3 km

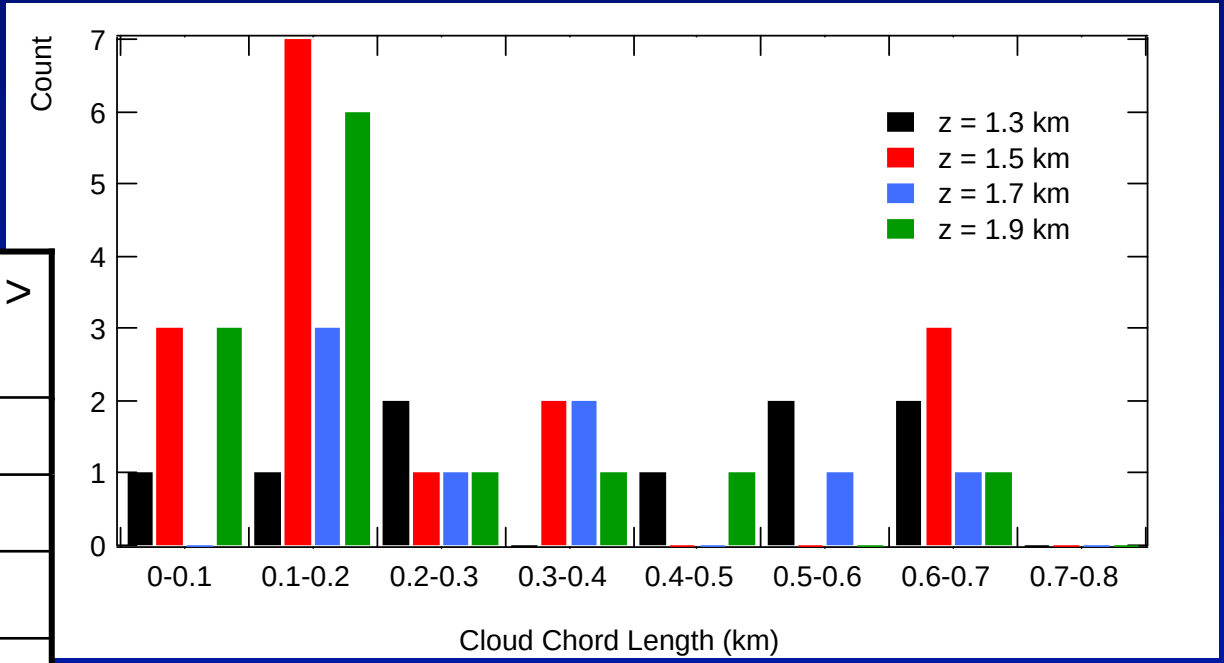
Cloud fraction = 10%

Simulation courtesy of M. Ovtchinnikov

Sample Histograms

- Track cloud chord lengths along each leg
  - Used two time periods ~ 70 km long leg

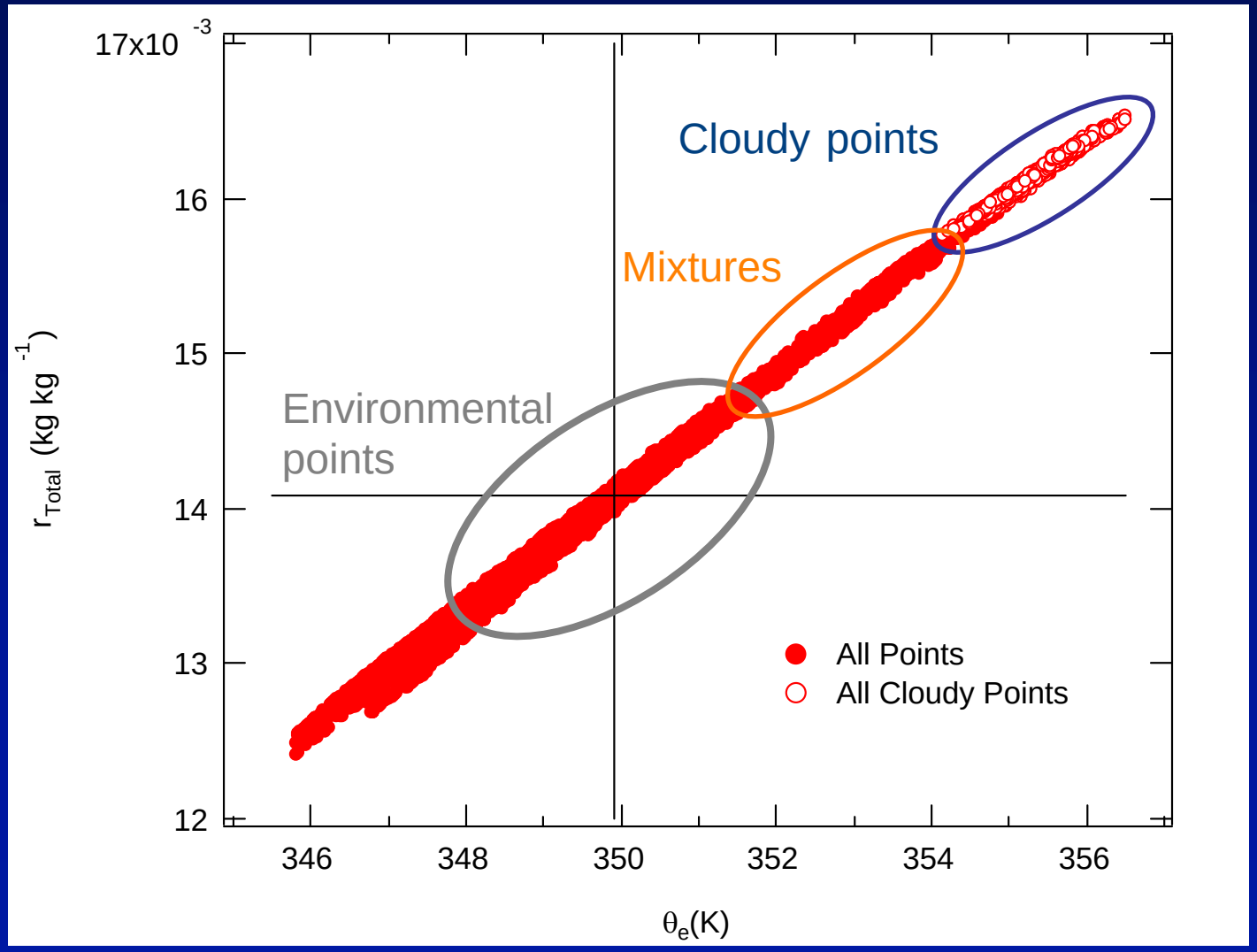
Z (km)	# Chords	# Chords > 0.3 km
1.3	9	5
1.5	16	5
1.7	8	4
1.8	13	4



Identification of Cloud Processed Air

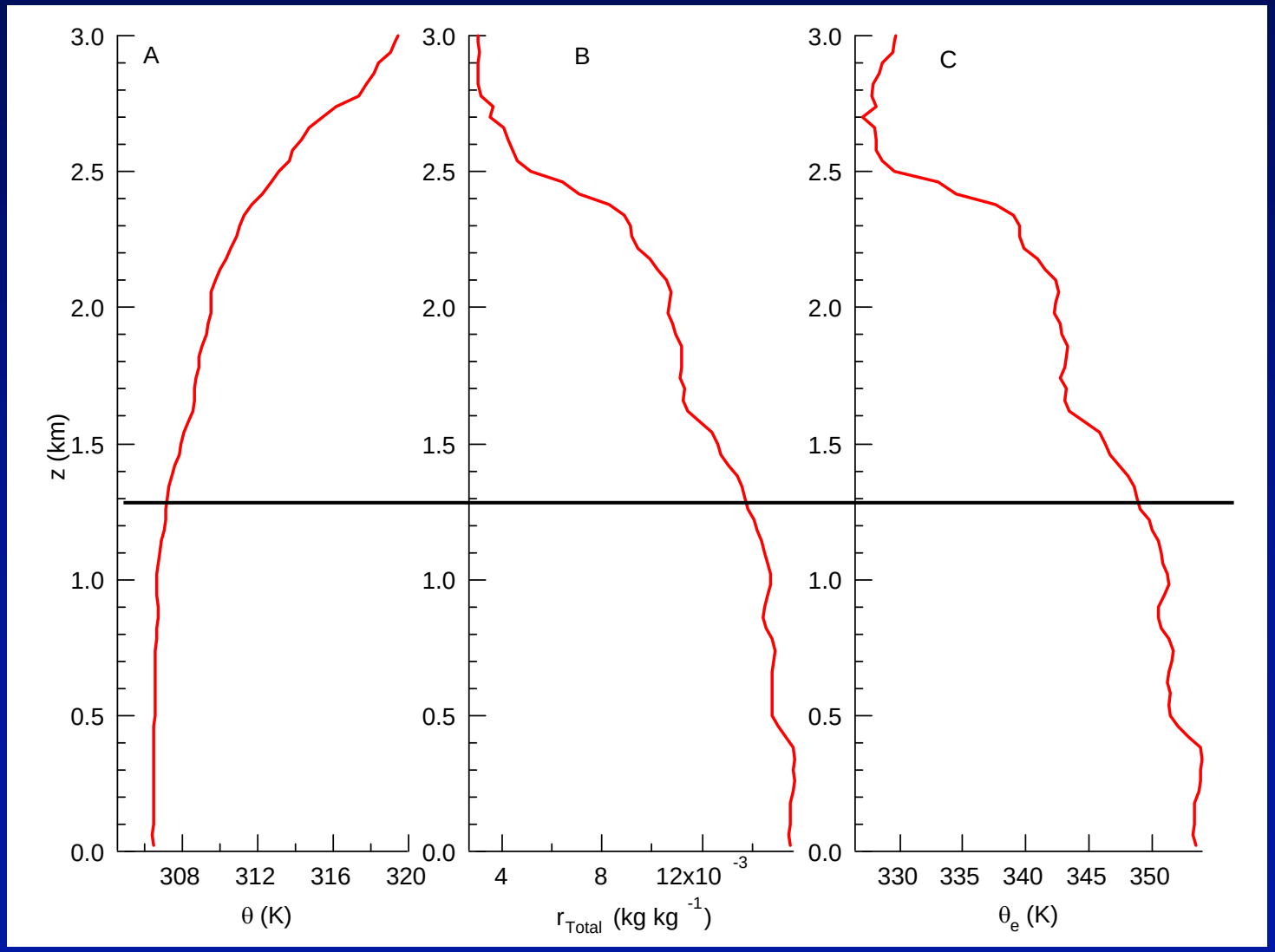
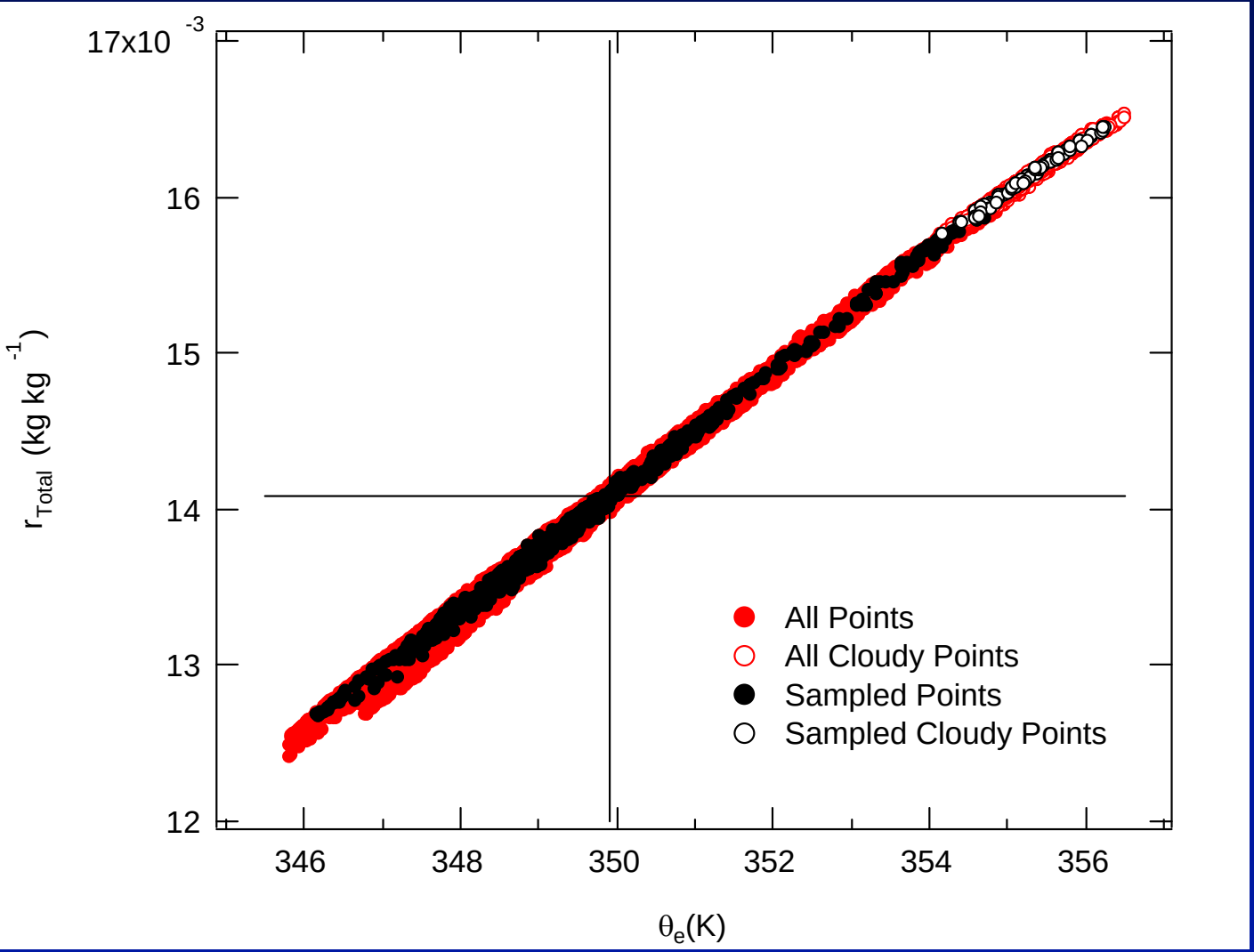
- Thermodynamic tracer of opportunity
- Variables that are conserved for dry and moist adiabatic processes
  - As air parcels rise, these values do not change
  - Equivalent potential temperature (θ_e)
    - $\theta_e = \theta \exp[L_v r_s / (C_p T)]$
  - Total water mixing ratio (r_{Total})
    - Water vapor + cloud water
- Similar analysis has been done looking at mixing in clouds

Sample LES Mixing Diagram



Z = 1.3 km

LES Sample Profiles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