Observations of the First Aerosol Indirect Effect in Shallow Cumuli

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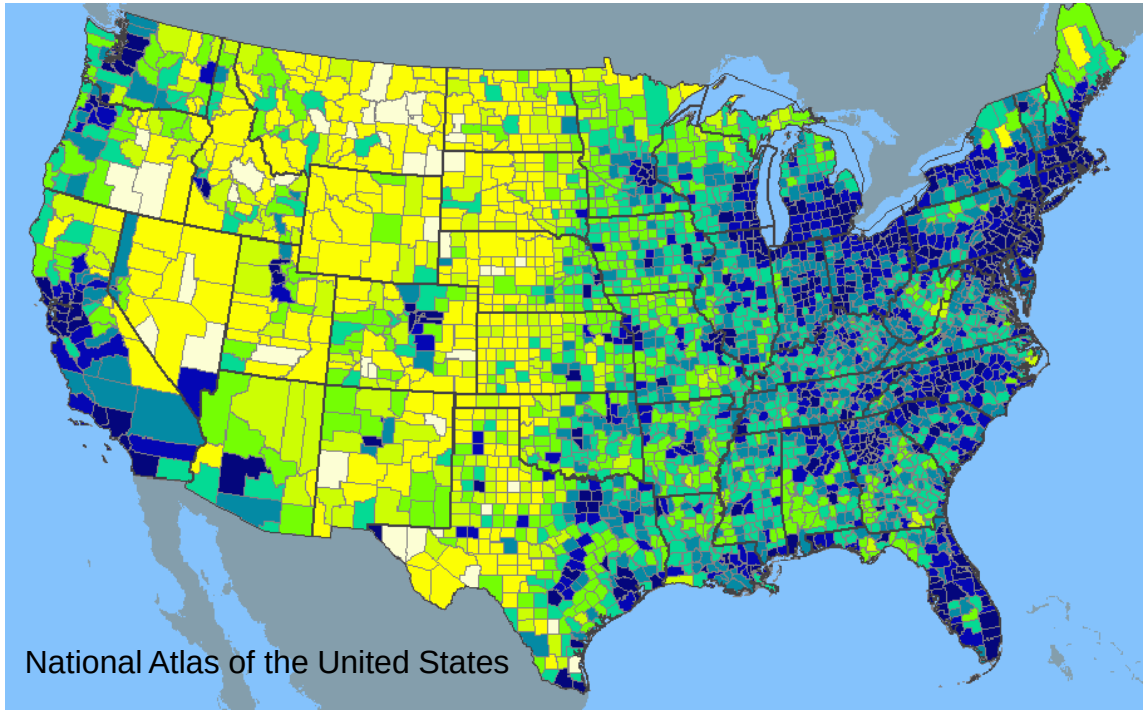
Motivation

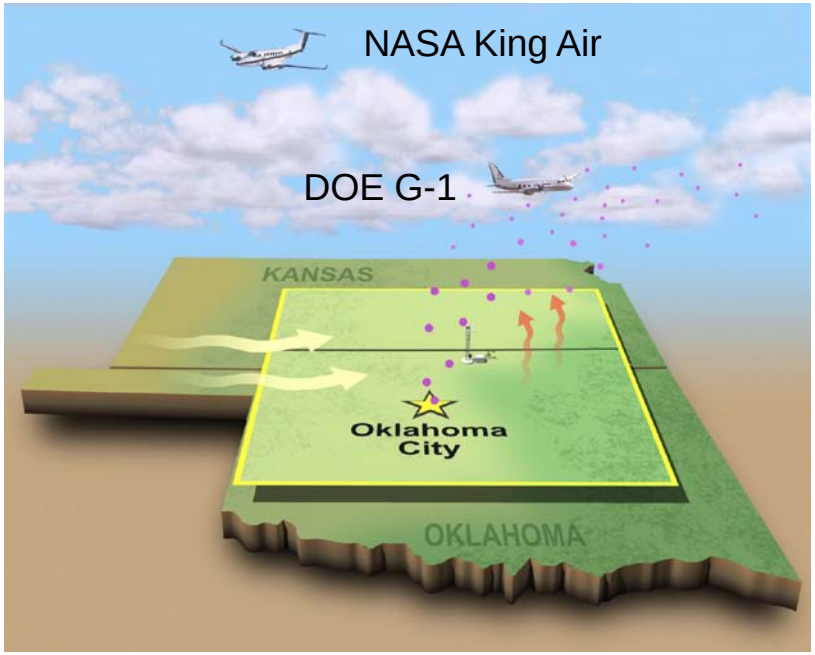
- Can the First Aerosol Indirect Effect (FAIE) be observed in the vicinity of a moderately sized city?
  - Cloud Droplet Number Concentration (CDNC)
  - Effective radius (r_{eff})
- If yes, how important is it to climate?
- Are cloud dynamics or aerosol effect more significant?



National Atlas of the United States

CHAPS

- ASP study designed to look at changes in cloud microphysics and aerosol properties in the OKC plume
  - Conducted during June 2007
  - Two aircraft: DOE G-1, NASA King Air
- G-1
  - In situ measurements of aerosol optical and chemical properties
- King Air
  - HSRL Lidar, aerosol back-scatter, extinction

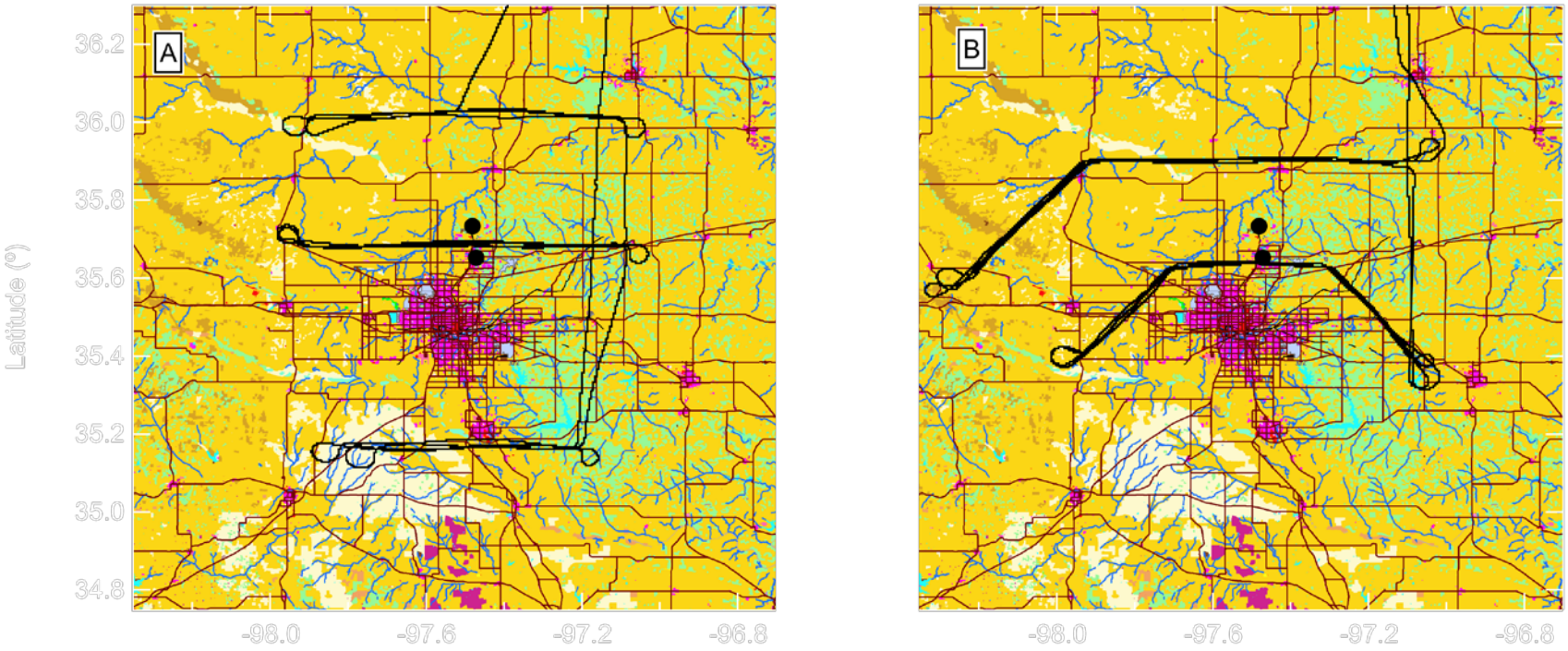


OVERVIEW OF THE CUMULUS HUMILIS AEROSOL PROCESSING STUDY

BY LARRY K. BERG, CARL M. BERKOWITZ, JOHN A. OGREN, CHRIS A. HOSTETLER, RICHARD A. FERRARE, MANVENDRA K. DUBEY, ELISABETH ANDREWS, RICHARD L. COULTER, JOHNATHAN W. HAIR, JOHN M. HUBBE, YIN-NAN LEE, CLAUDIO MAZZOLENI*, JASON OLFERT+, AND STEPHEN R. SPRINGSTON

CHAPS Flight Pattern

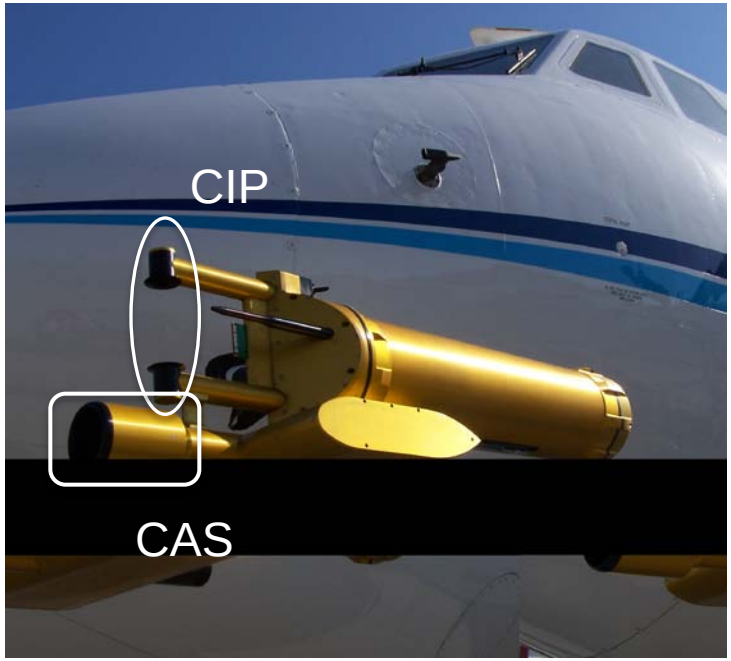
- Designed to sample inside and outside of OKC plume



- Two basic patterns: Upwind-downwind; half hexagon
- Below, within, and above the cloud layer

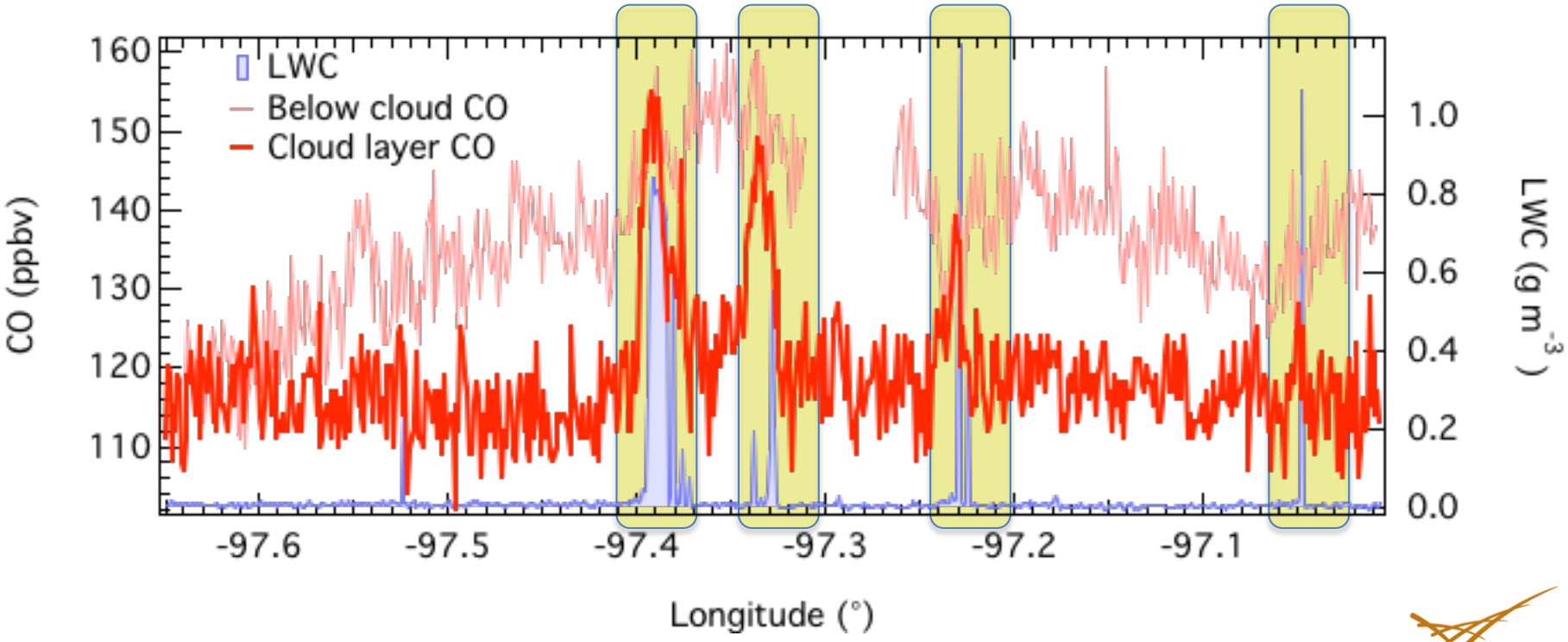
Instrumentation

- Cloud microphysics
  - DMT Cloud, Aerosol, and Precipitation Spectrometer (CAPS)
    - Cloud Imaging Probe (CIP): precipitation
    - Cloud Aerosol Spectrometer (CAS): 20 bins, 0.63-60 μm
- CO
  - Vacuum UV Fluorimeter
  - Used as a proxy for urban-sourced particles inside clouds
- Vertical velocity (*w*)
  - Gust probe mounted on nose of G-1



Can IE Be Observed: Cloud Processing

- CO measured below and within cloud layer
- Elevated levels of CO found in many clouds
  - Evidence of cloud venting



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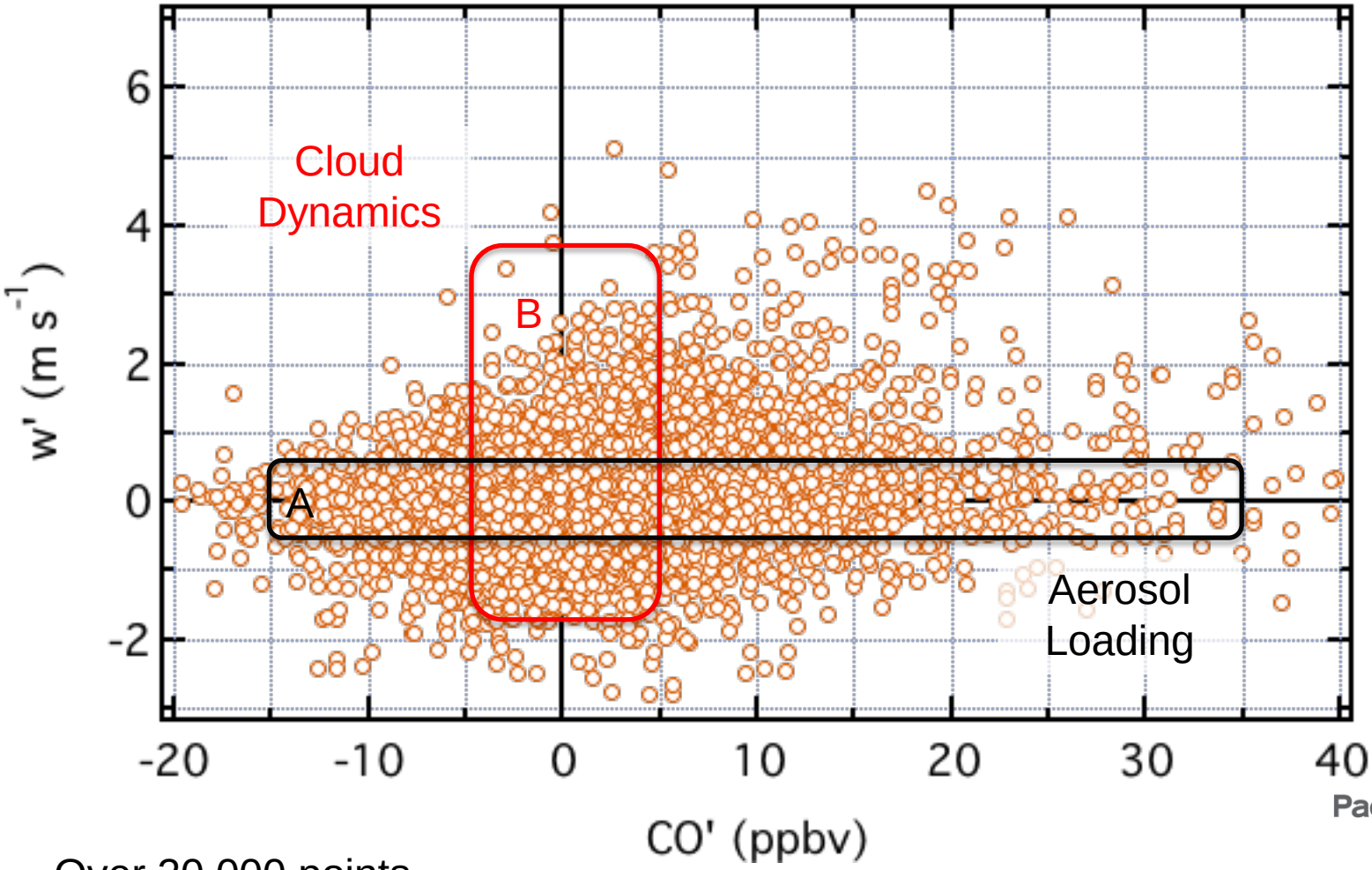
Can IE Be Observed: Data Processing

- CO and *w*
  - Remove background CO — remove mean and trend
  - Mean *w* from gust probe is unreliable — remove mean and trend
  - CO' and *w'*
- Cloud microphysics
  - Drops greater than 3 μm
  - Find averages of:
    - Cloud droplet number concentration (CDNC)
    - Liquid water content (LWC)
    - Effective radius (r_{eff})
    - Relative dispersion—ratio of the standard deviation to the mean drop diameter

CHAPS Observations

- Over 750 cloud penetrations during CHAPS, most near cloud base



Over 20,000 points

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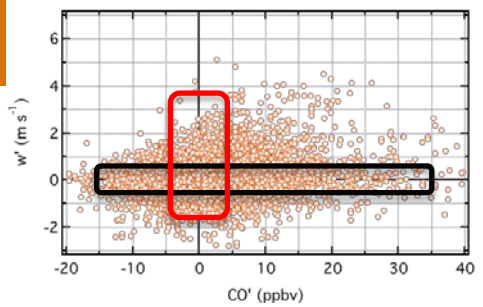
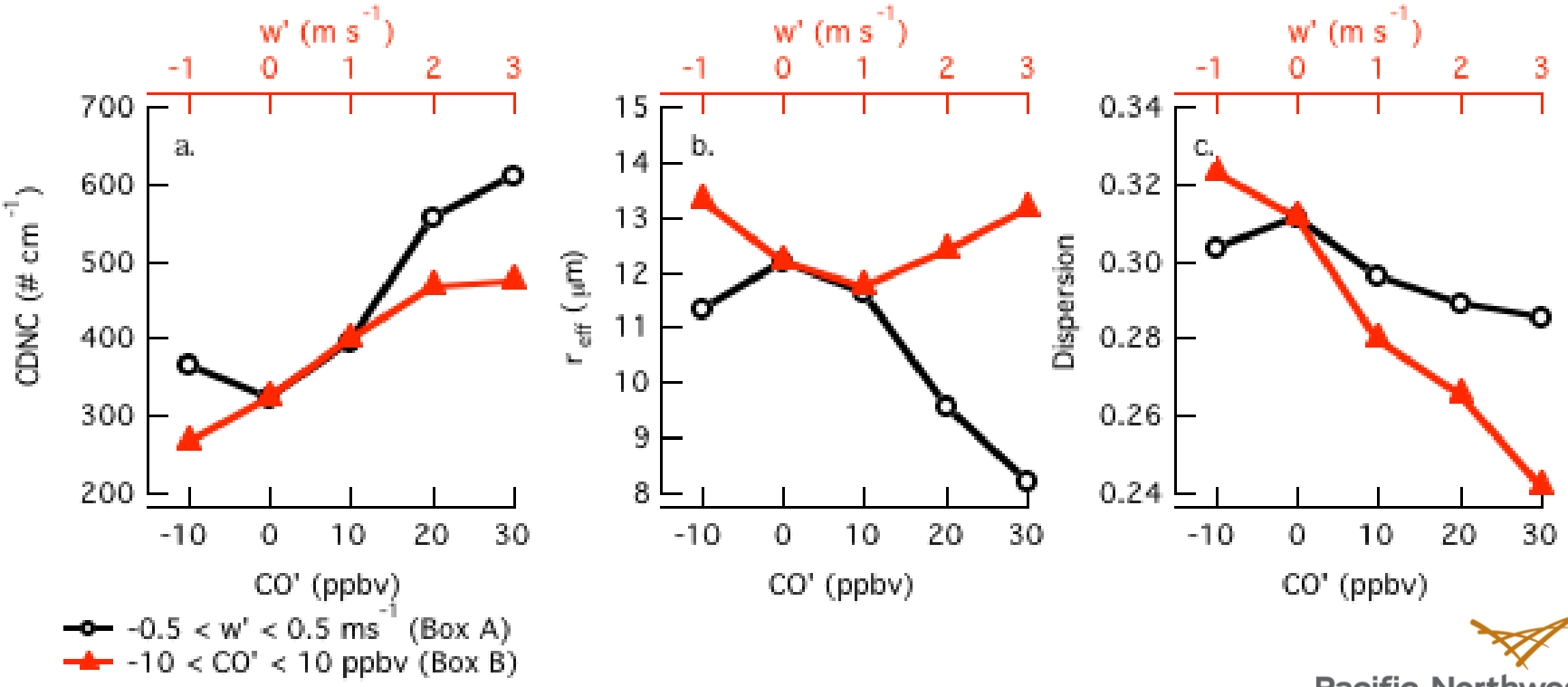
Changes in Cloud Microphysics



- *w*': Changes in CDNC, r_{eff}, and dispersion
- CO': Changes in CDNC, and r_{eff}



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How Important: Light Scattering

- Total light scattering by cloud drops was not measured
  - Light scattering by aerosol was measured
- Modeled light scattering
  - Mie theory
  - Size distribution of cloud drops
  - Assume scattering is not affected by properties of CCN

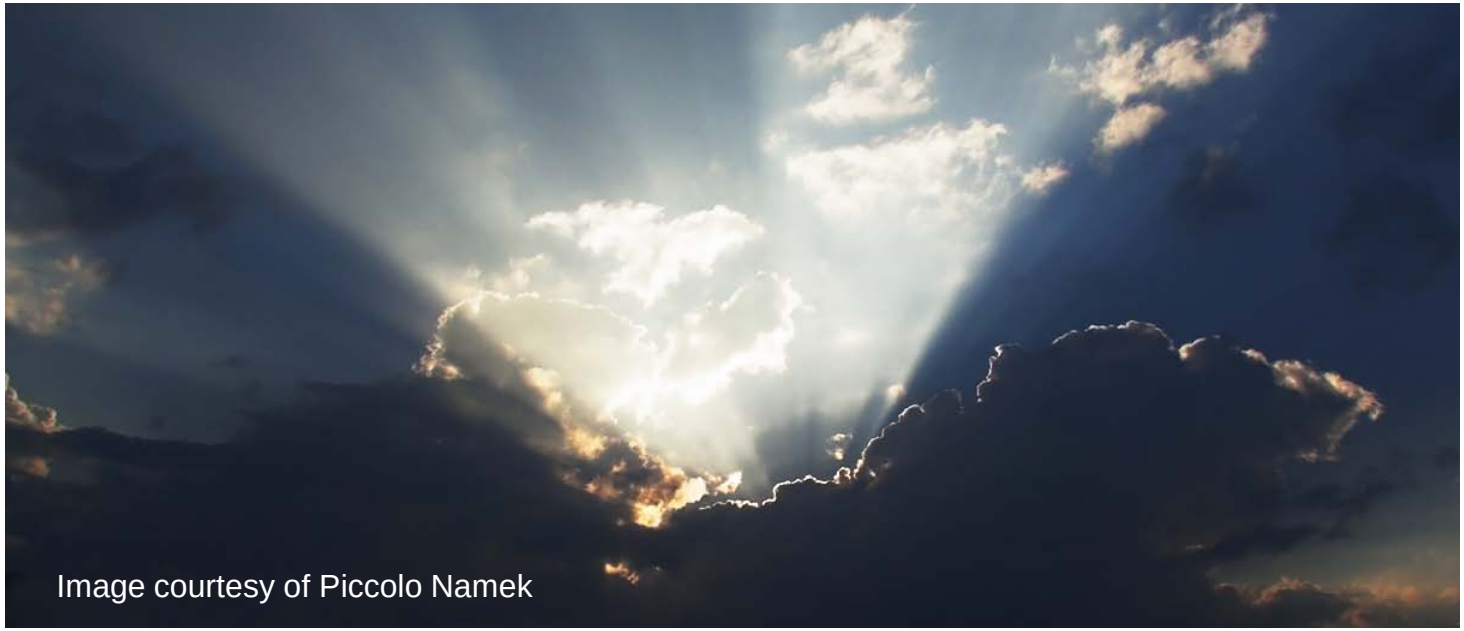
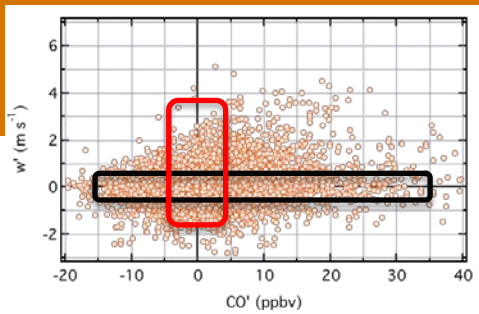
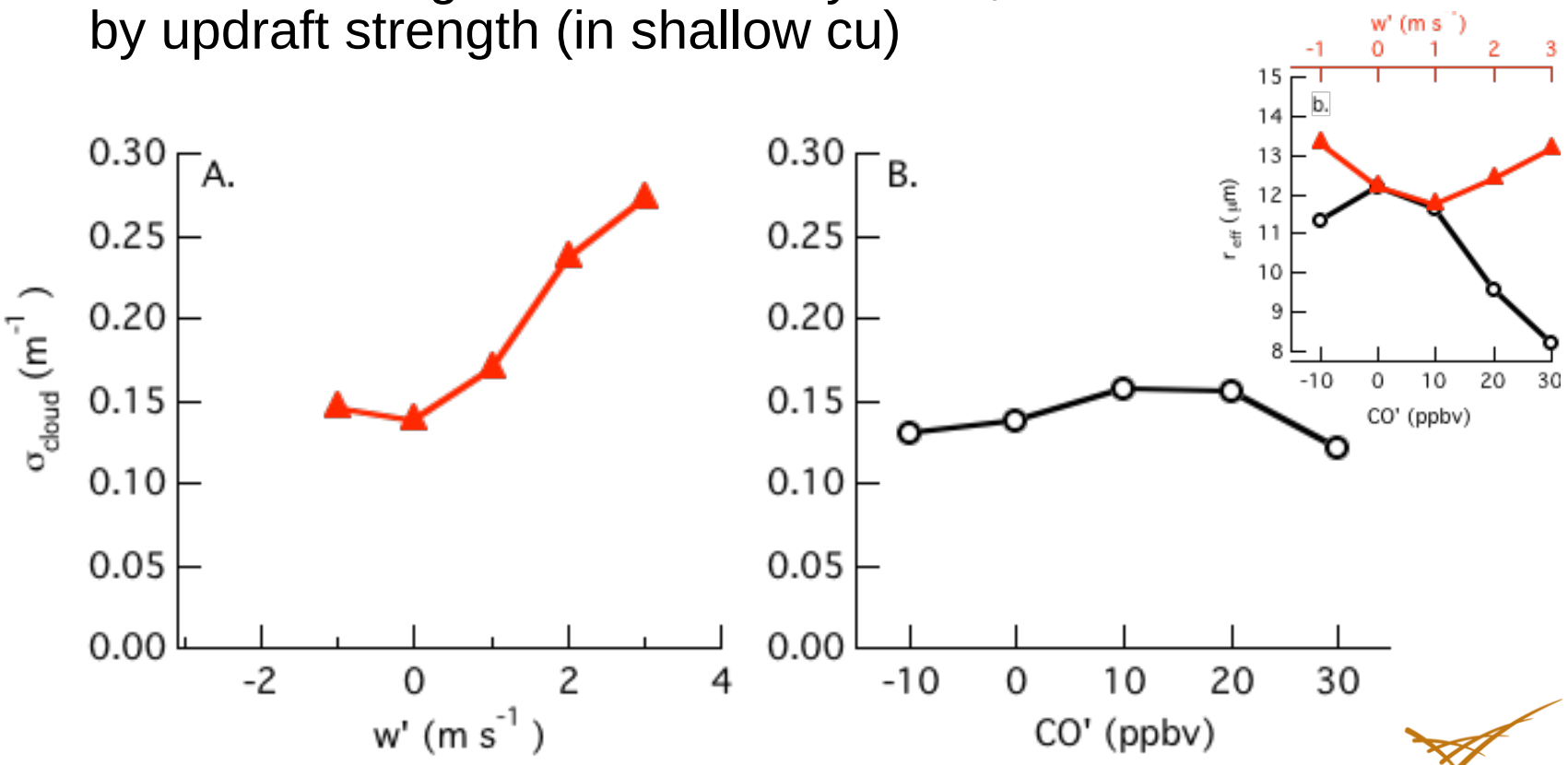


Image courtesy of Piccolo Namek

Volume Scattering Coef. (σ_{cloud})



- σ_{cloud} is a function of w' but not CO'
  - Total scattering is dominated by LWC, which is dominated by updraft strength (in shallow cu)



- Why doesn't σ_{cloud} change with CO'?

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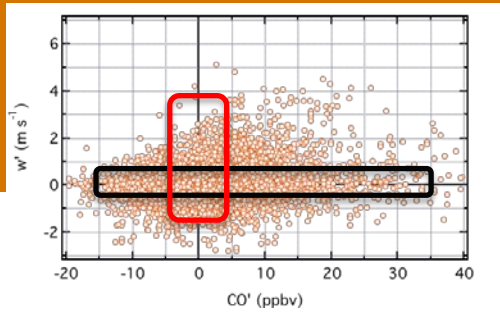
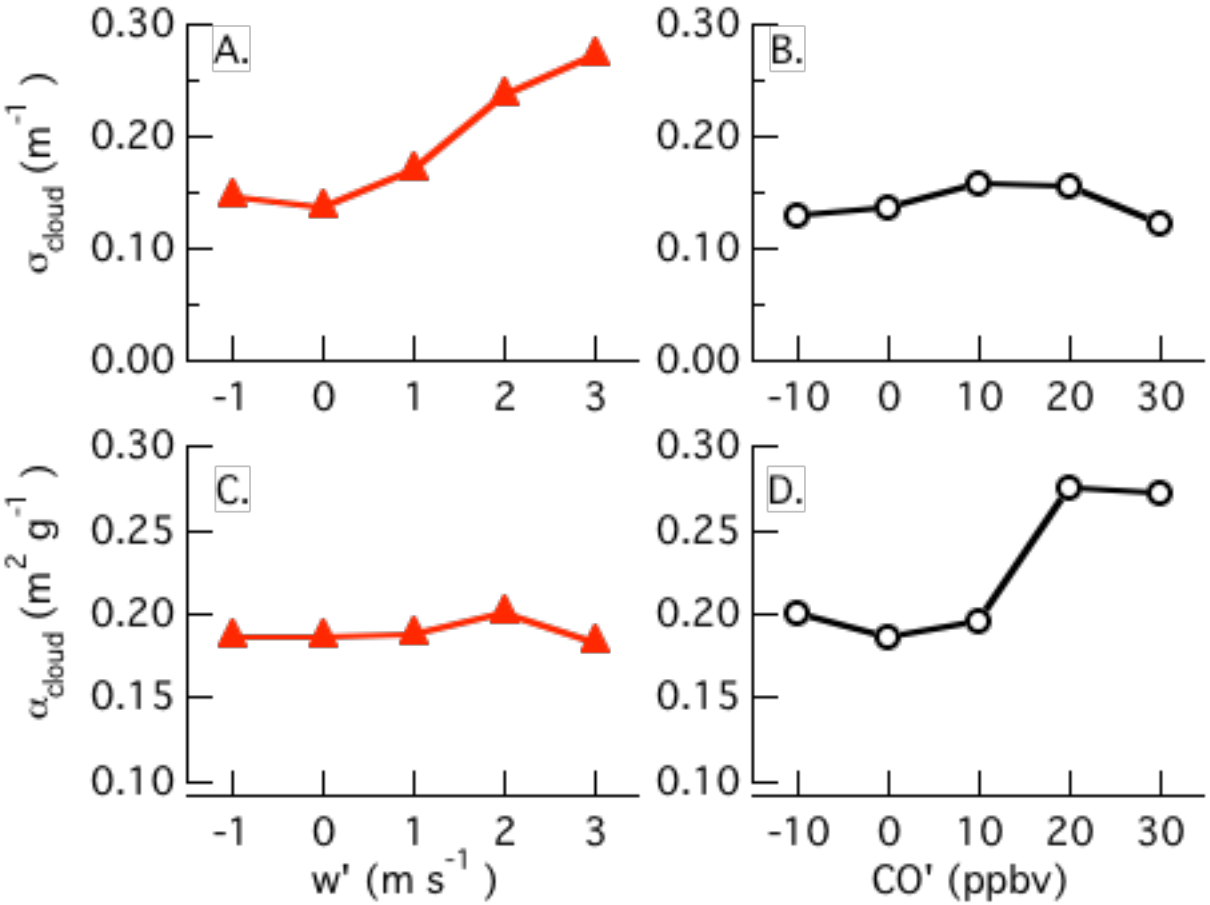
Normalized Scattering



- LWC does not change much with CO', but it isn't constant
- Normalized scattering by LWC, α_{cloud} ($m^2\ g^{-1}$)



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Conclusions

- Can FAIE be observed in the vicinity of a moderately sized city?
  - Changes in CDNC and r_{eff}, were observed with increased aerosol loading, consistent with FAIE
  - Changes in dispersion with aerosol loading were not observed
- If yes, how important to climate?
  - Changes to normalized scattering were observed—potential impact on COD.
- Both cloud dynamics and aerosol effects are important

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Questions?

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Supporting information

Introduction

- Increase in number of particles (for a given LWC) leads to decrease in r_{eff} And change in cloud albedo (Twomey 1977)
- First Aerosol Indirect Effect (FAIE) has been documented:
  - Continental and maritime stratiform clouds
  - Cumuli near large cities
- FAIE has not been documented downwind of more moderate sized cities
- Cumulus Humilis Aerosol Processing Study (CHAPS) designed to provide additional measurements