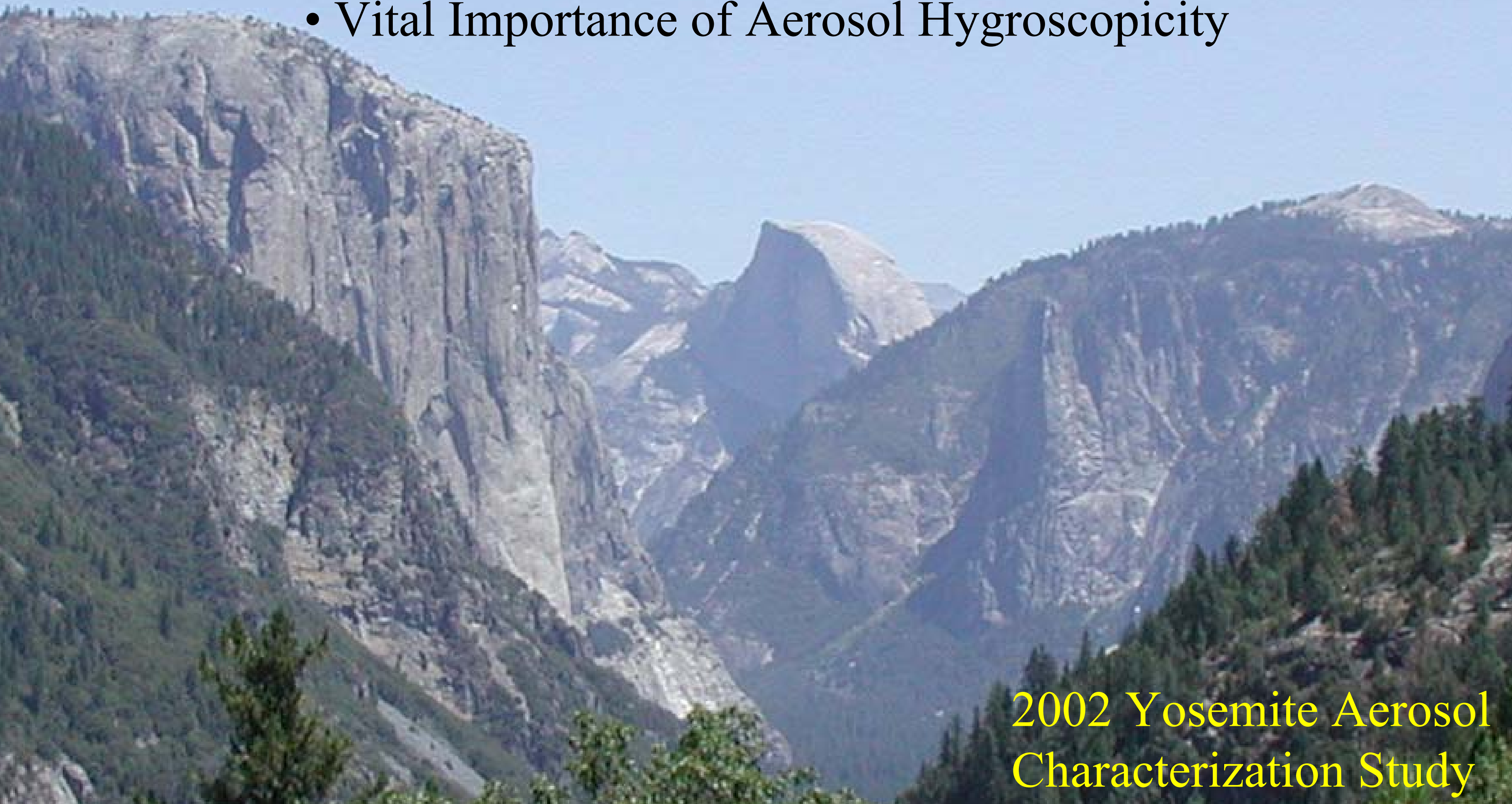
Hygroscopic and Cloud Nucleating Properties of Fresh Smoke from Biomass Burning

Picnic Rock Fire from ATS Simlab, April 2004

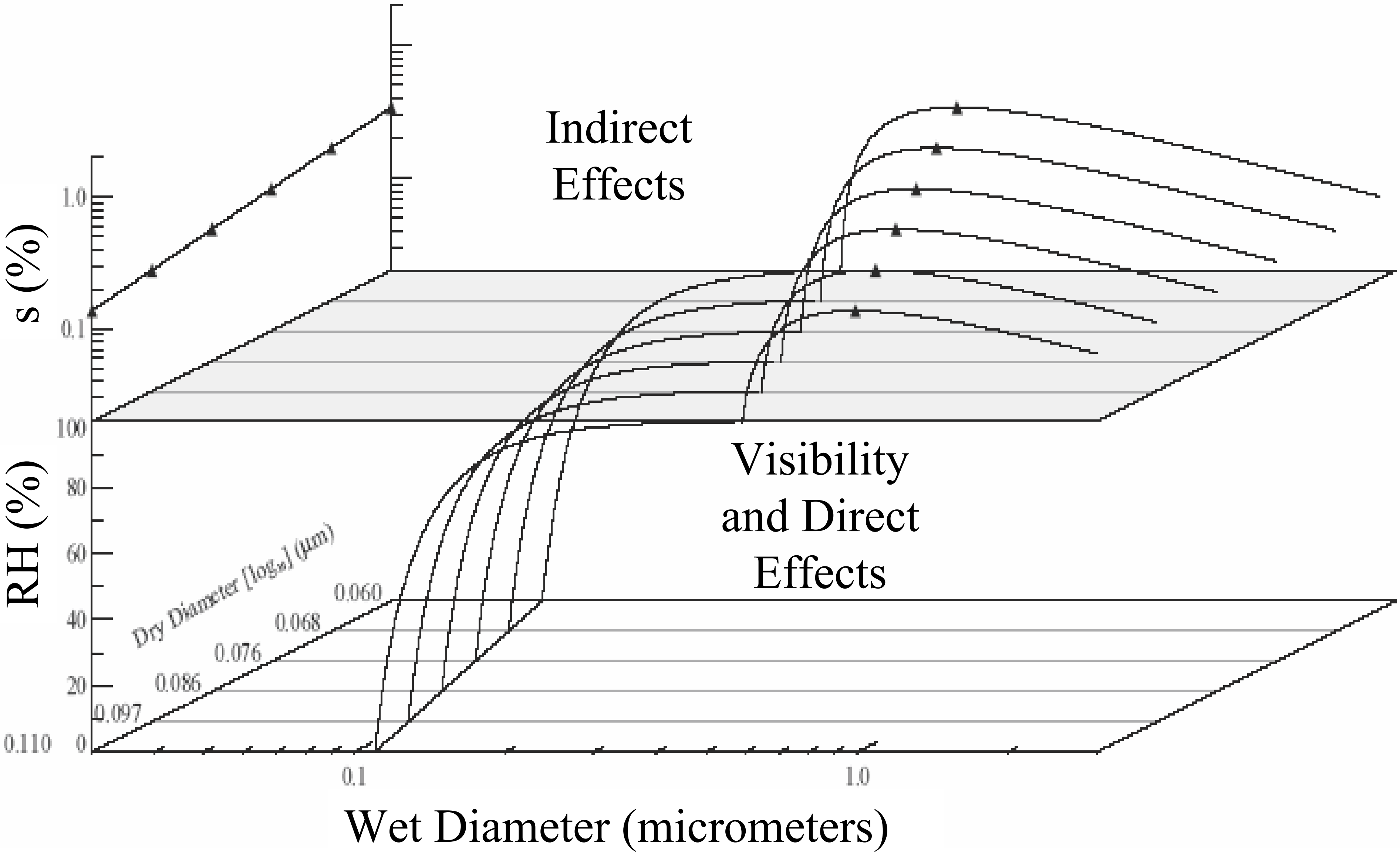
Motivation

- Fires in the West [Westerling et al., 2006]
- Visibility, Air Quality and Climate Effects
- Vital Importance of Aerosol Hygroscopicity



2002 Yosemite Aerosol Characterization Study

Subsaturated and Supersaturated Droplet Growth



Aerosol Hygroscopicity Parameter, κ
(Petters and Kreidenweis, 2006)

Hygroscopic growth (RH_w < 95%, T = 25˚C)	HTDMA (D_{wet} / D_{dry})	GF as f(RH_w)
CCN activity (RH_w > 100 %, T = 25˚C)	CCNc (DMT)	S_c as f(D_{dry})

Unifying parameter: κ
(relative hygroscopicity)

κ from HTDMA

GF^{-3}

$$\frac{1}{a_w} = 1 + \kappa \frac{V_{dry}}{V_{wet}}$$

$$\frac{RH_w}{100} = a_w \exp\left(\frac{4\sigma_{s/a} M_w}{RT\rho_w D}\right)$$

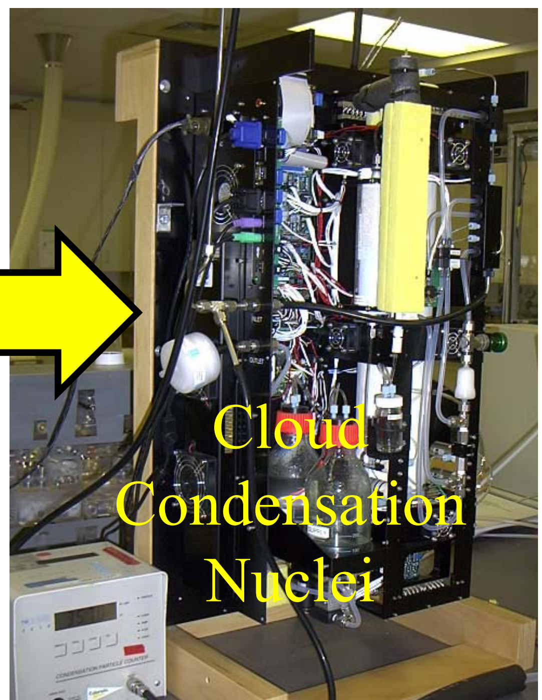
κ from CCN

$$\kappa = \frac{4A^3}{27 D_d^3 \ln^2 S_c}$$

$$A = \frac{4\sigma_{s/a} M_w}{RT\rho_w}$$

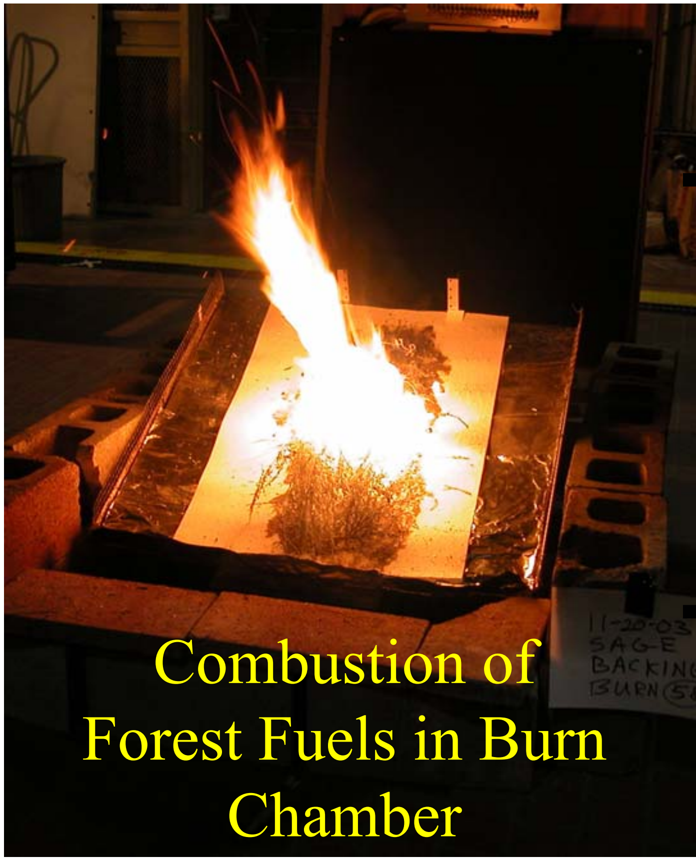
Single parameter quantifying sub- and supersaturated hygroscopic growth

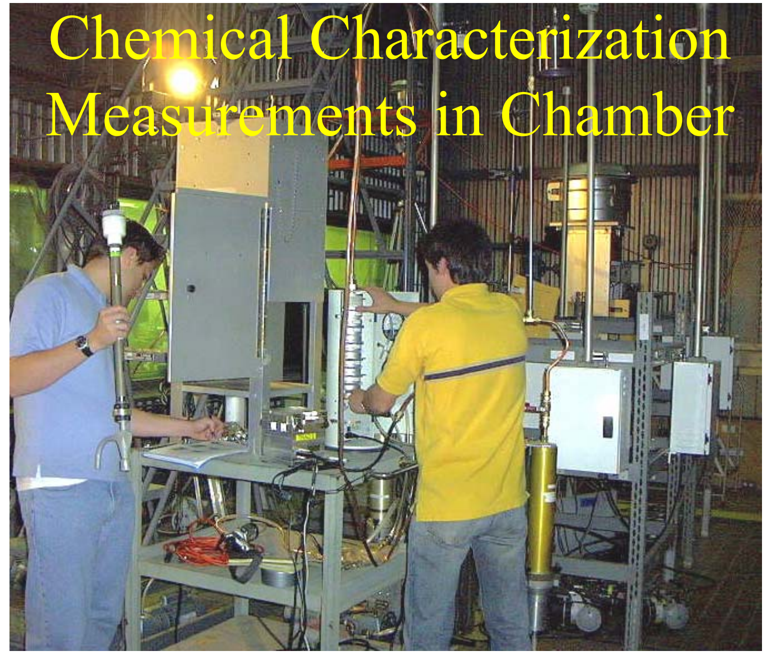
Why is This Important? Linkages between Problems, Measurement Methods, & Research Communities



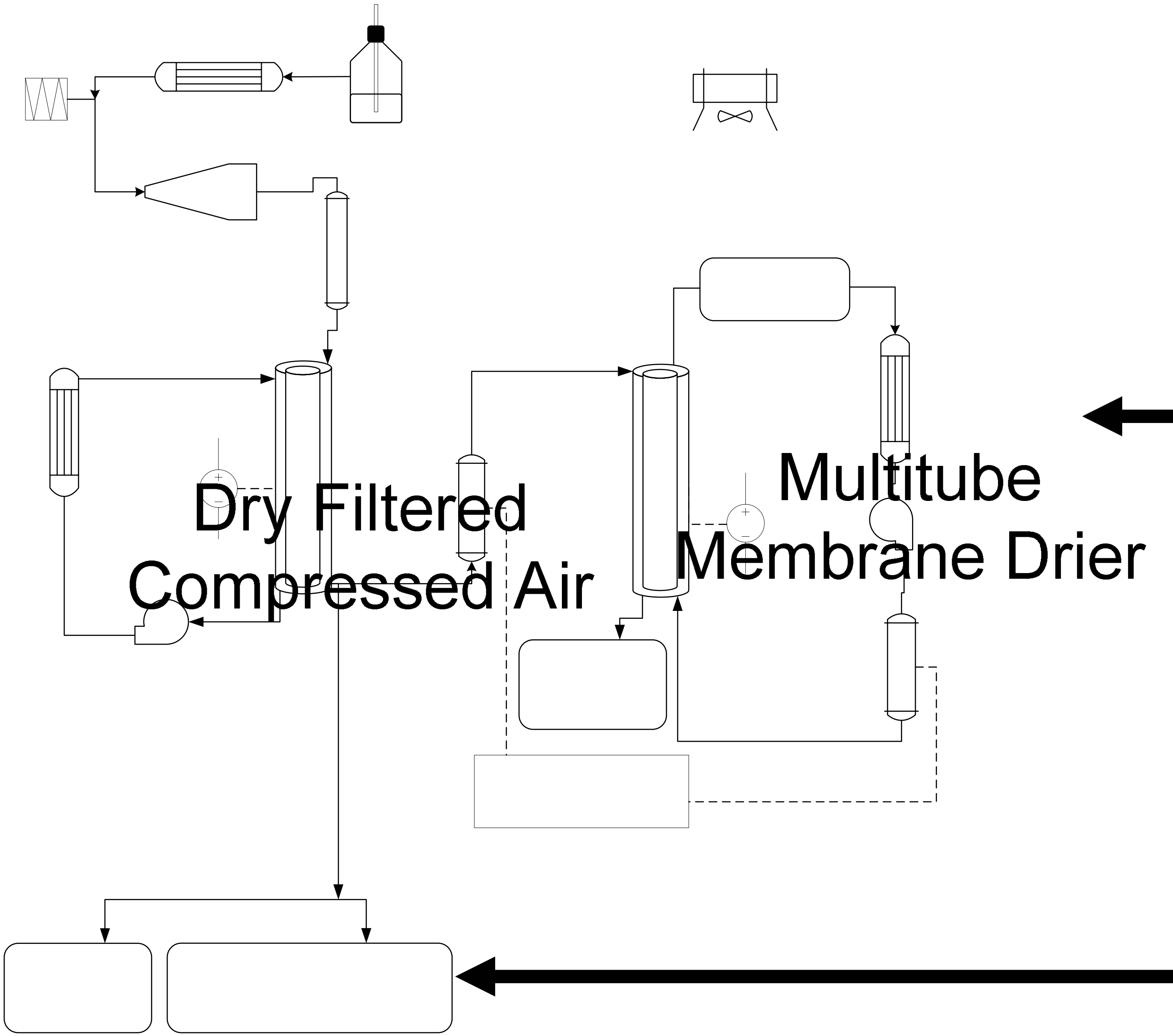
USDA/USFS Fire Science Laboratory
Missoula, MT

Fire Lab At Missoula Experiment (FLAME)

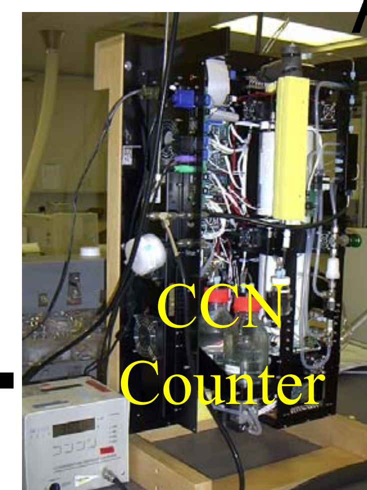




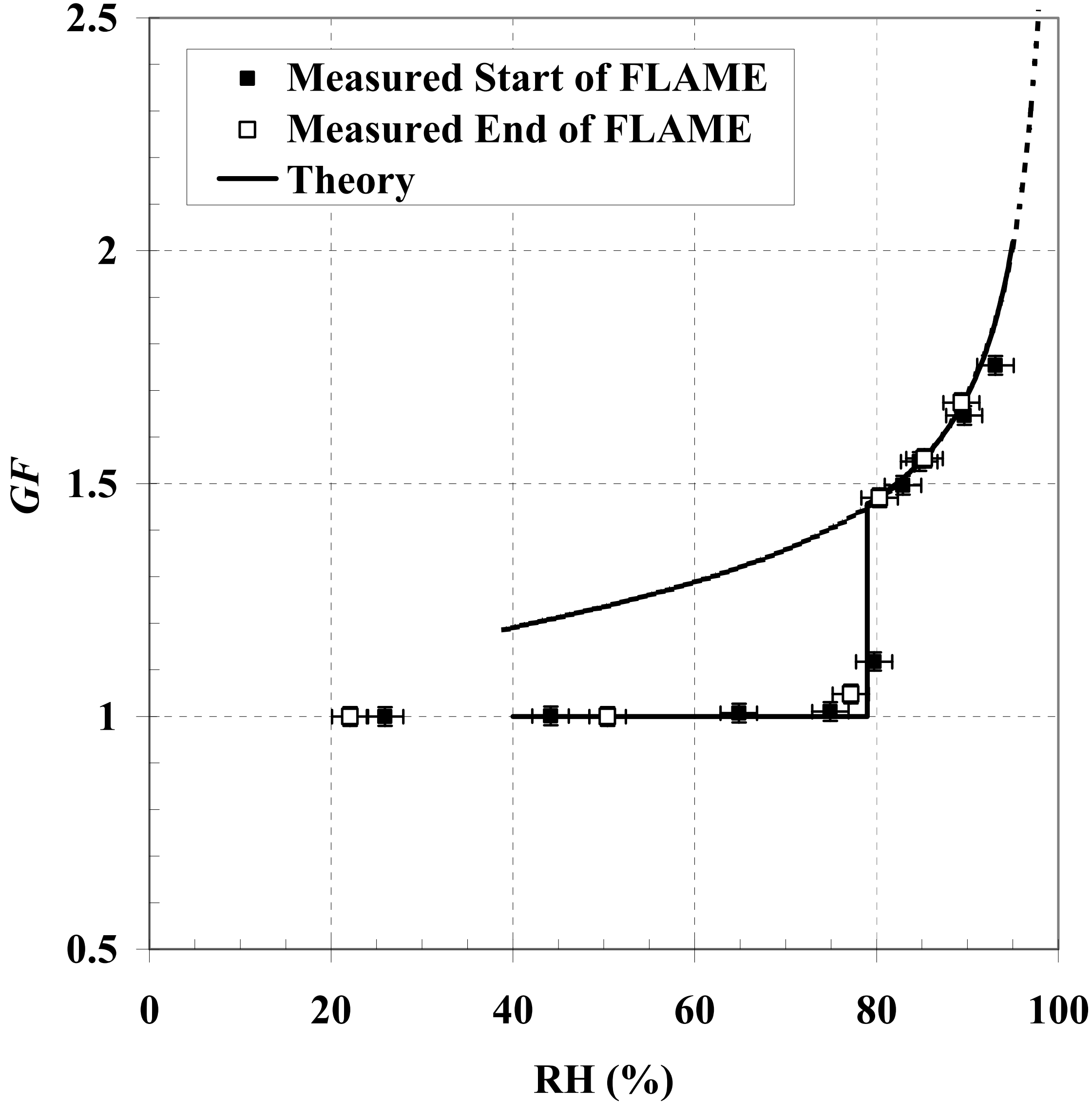
Experimental Setup-FLAME Prequel



Ato



Ammonium Sulfate at FLAME 2006



- Relatively Easy Onsite Measurement Validation

Experimental Procedure-Prequel to FLAME

1. Typical Biomass Fuel Samples

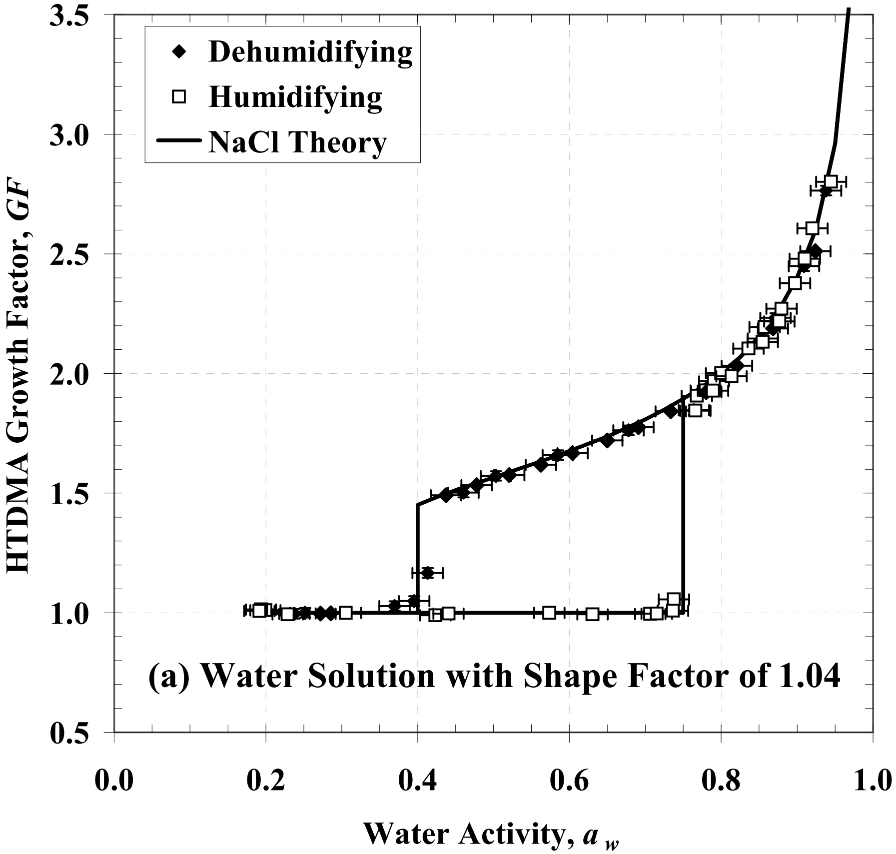
2. Laboratory Combustion of Fuel Samples

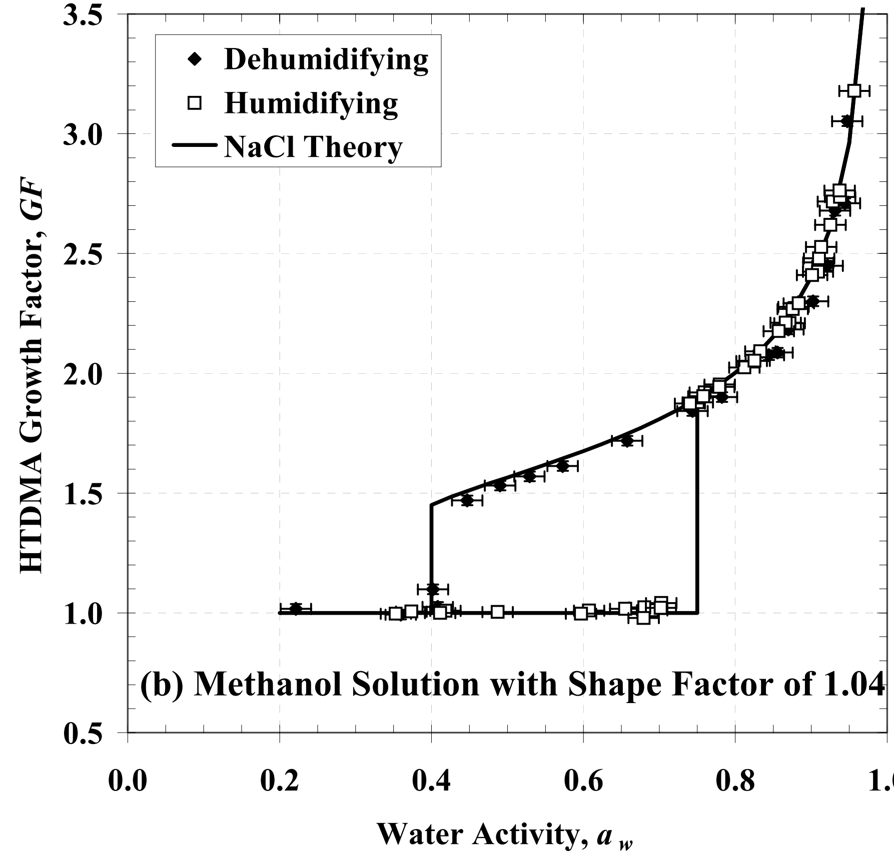
3. High Volume Filter Sampling of Primary Smoke $PM_{2.5}$ (quartz substrate)

4. Aqueous or Methanol Extractions of Collected Samples

5. Aerosol Generation with Aqueous or Methanol Solution

NaCl in Water and in Methanol

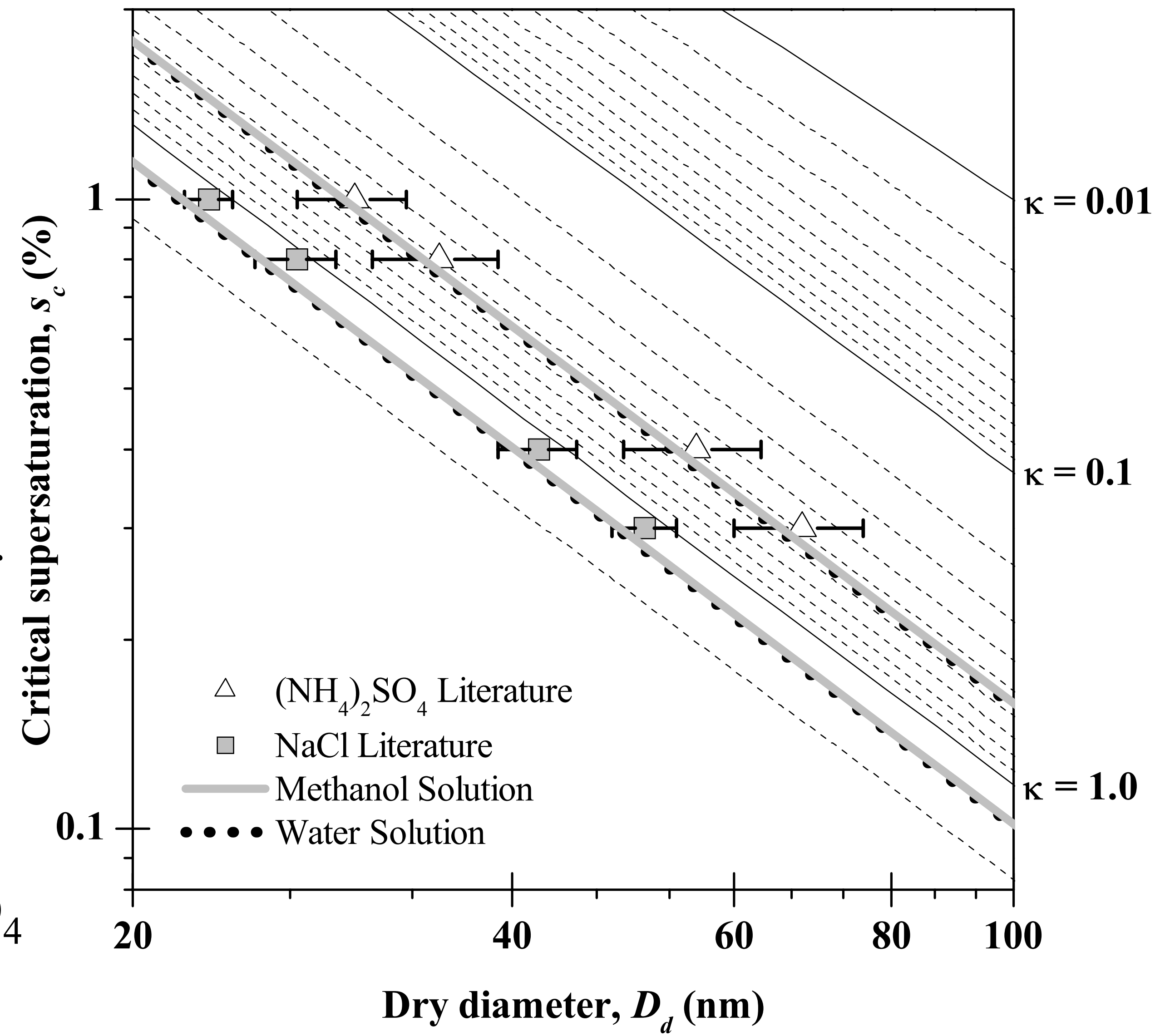




- No Perceptible Artifacts for Known Inorganic Aerosols in CH_3OH

Test Aerosol Critical Supersaturation from HTDMA

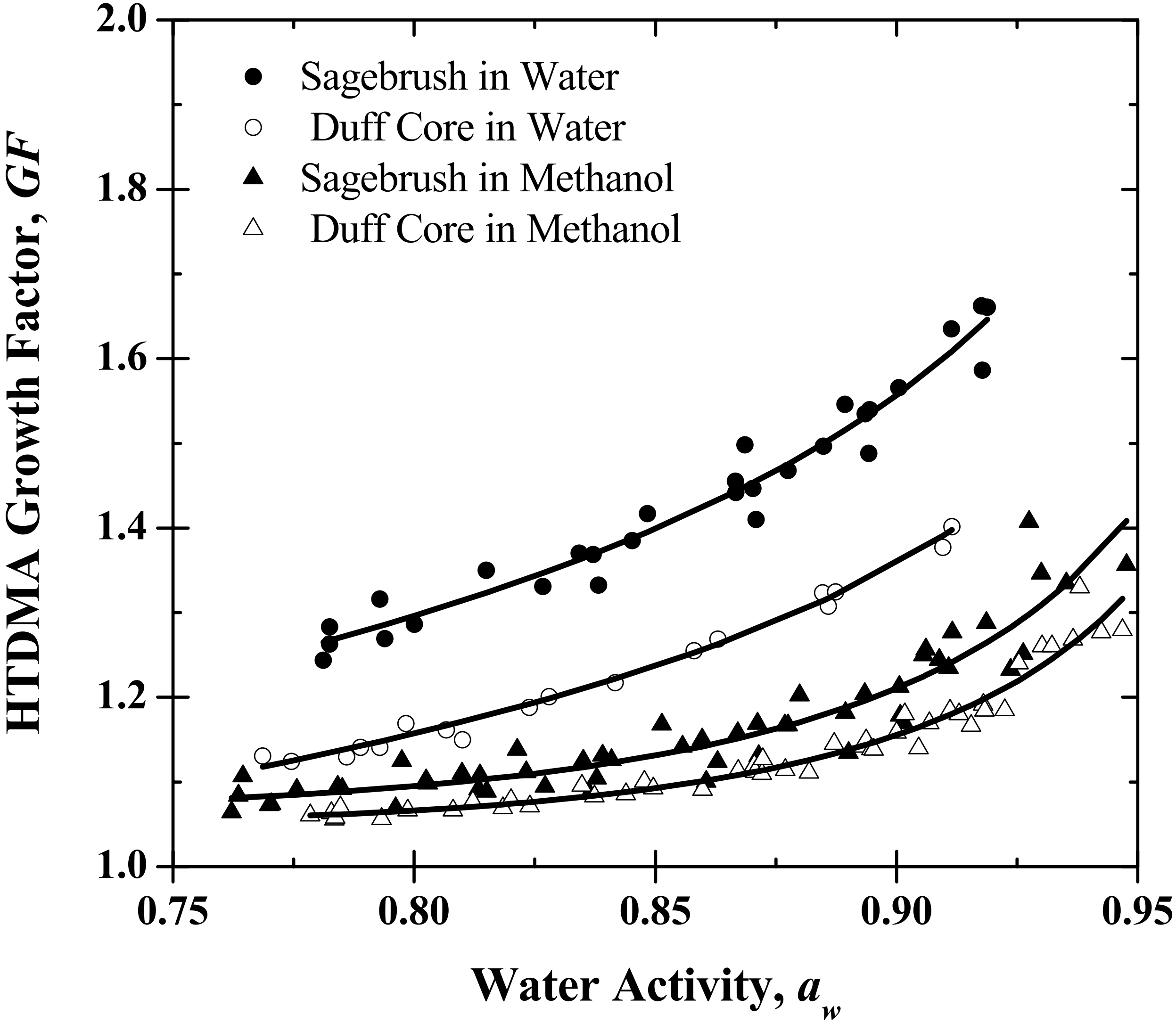
- Kappa plot
- Data points are literature values from Kreidenweis et al. (2005)
- Equivalent results for water and methanol Solutions



κ ~0.6 for $(NH_4)_2SO_4$

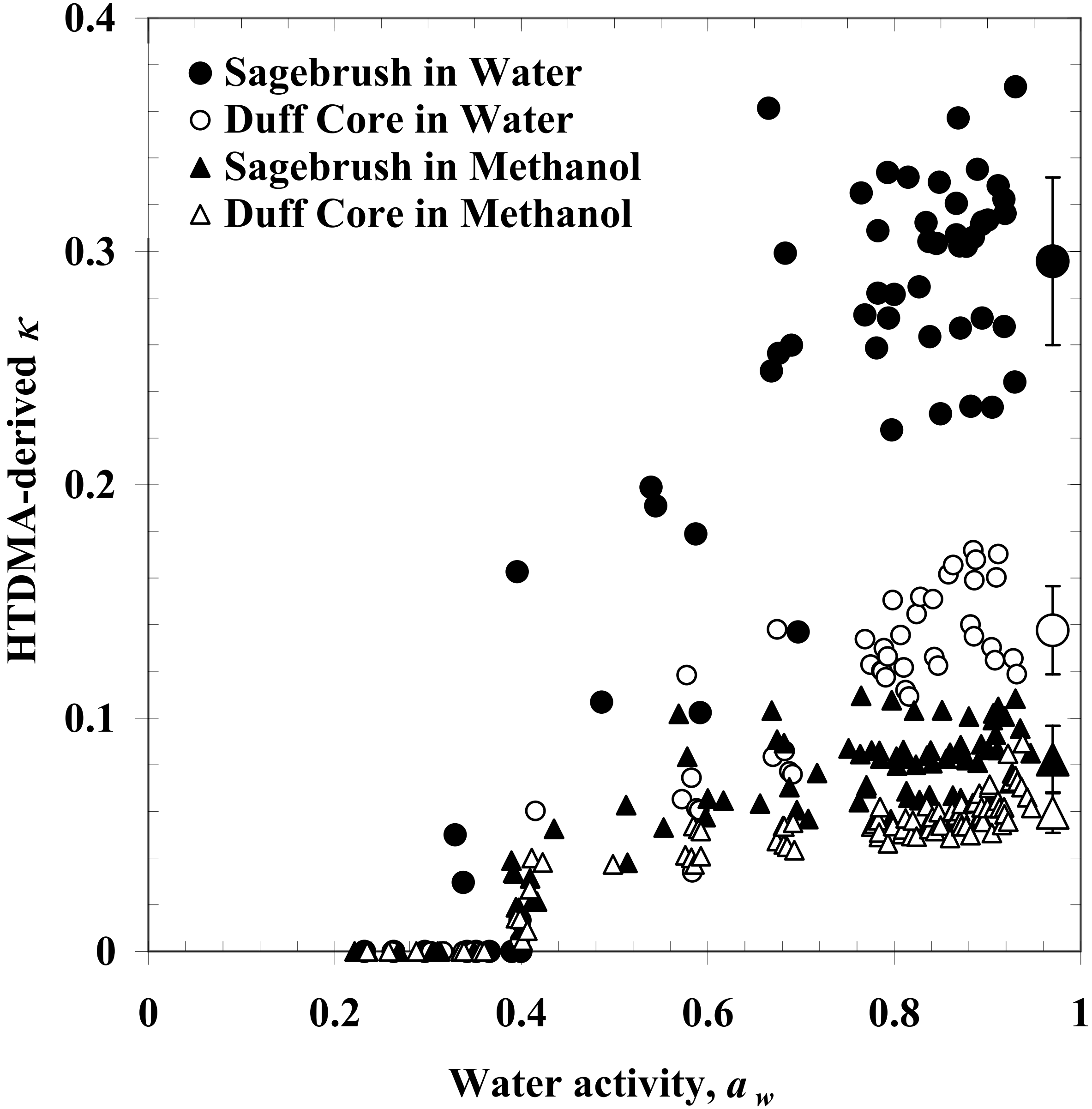
κ ~1.2 for NaCl

GF Summary for Aerosol Extraction Experiments



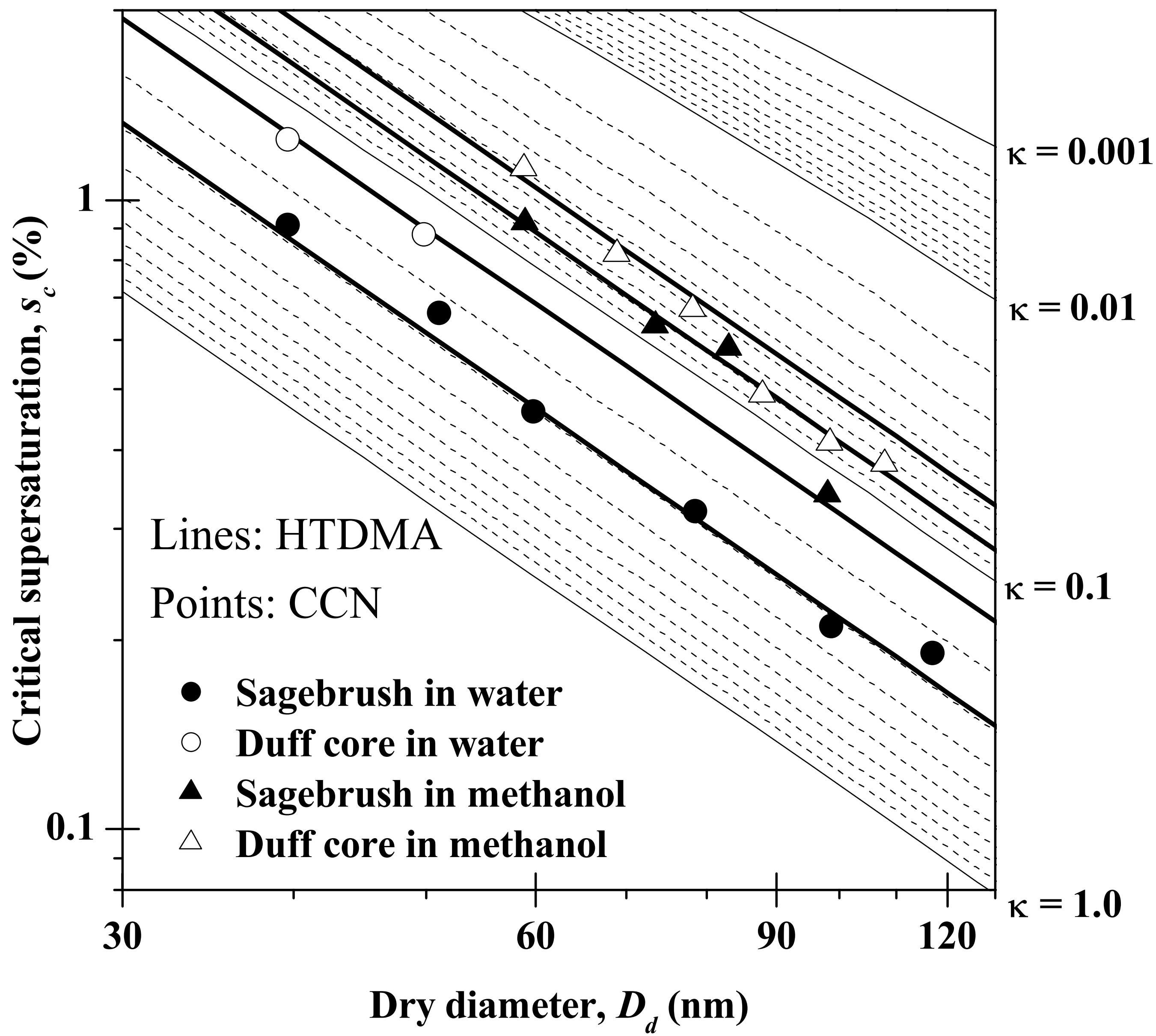
- Strong gradient in hygroscopicity for fuels-solvent matrix

Hygroscopic Parameter vs. RH

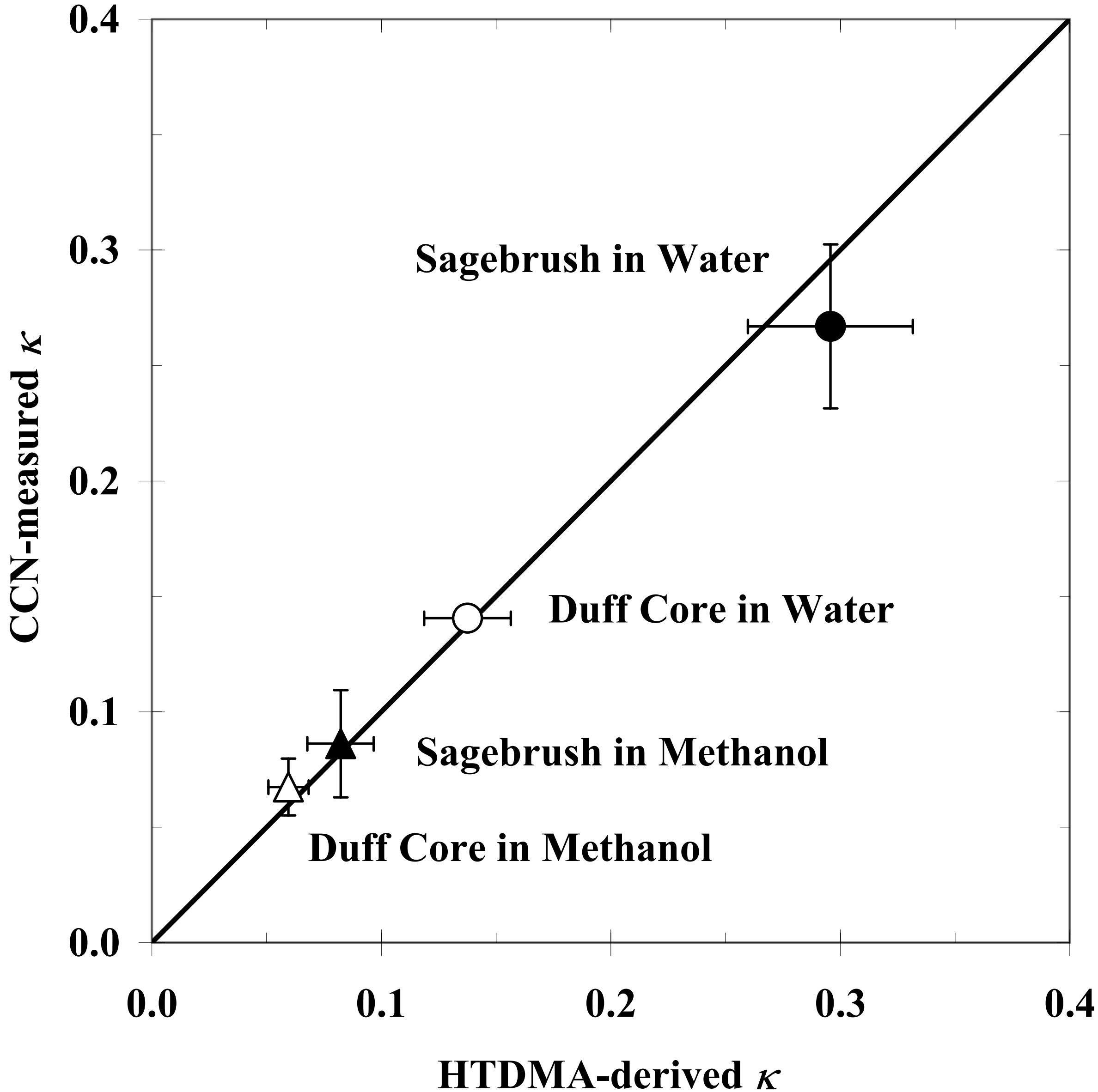


Smoke Extractions Critical Supersaturations

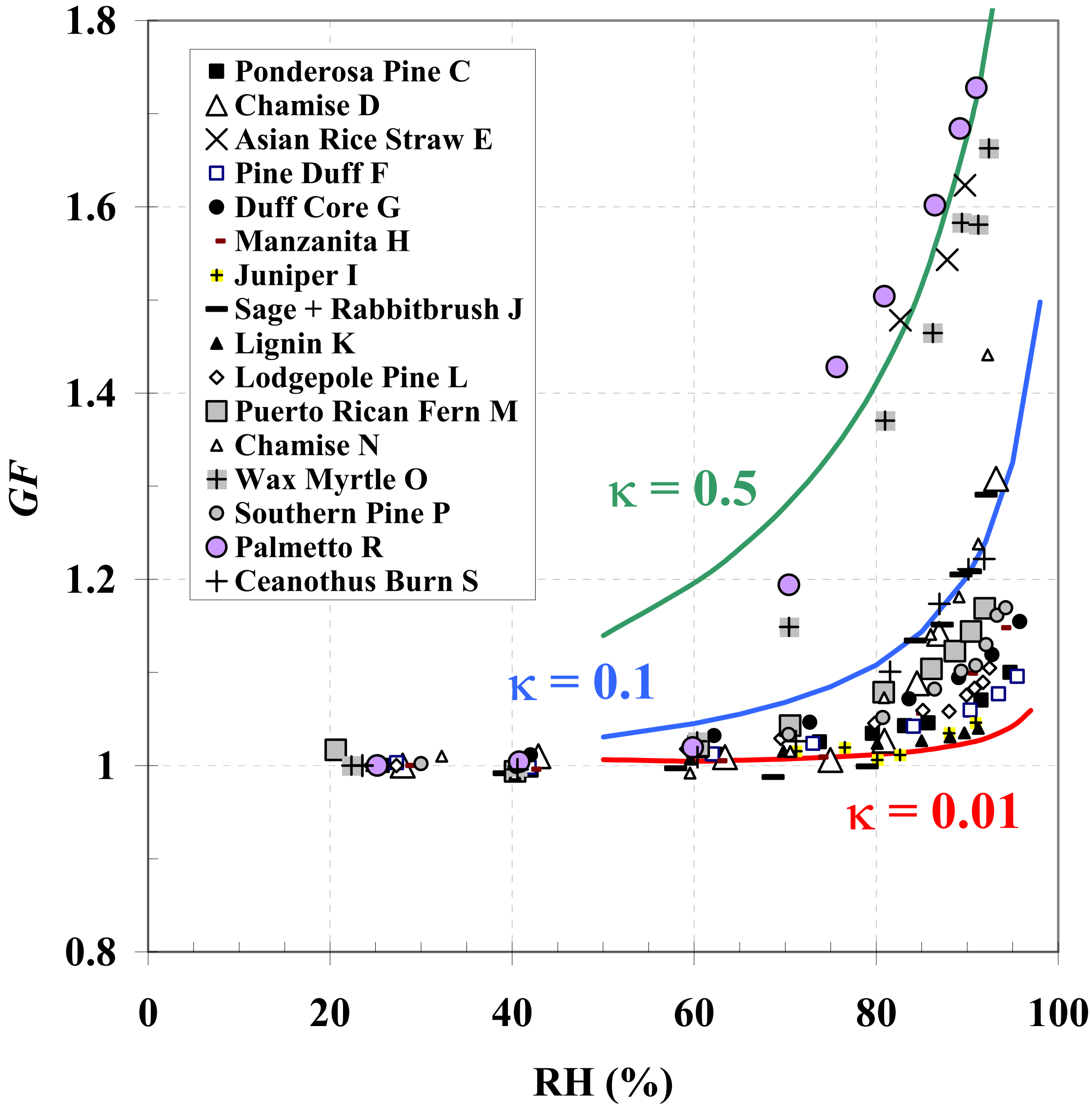
0.05 < κ < 0.3
for smoke
extractions



Summary of Extraction Experiments HTDMA and CCN Hygroscopicity



FLAME 2006
Growth Factors as a Function of Fuel Type

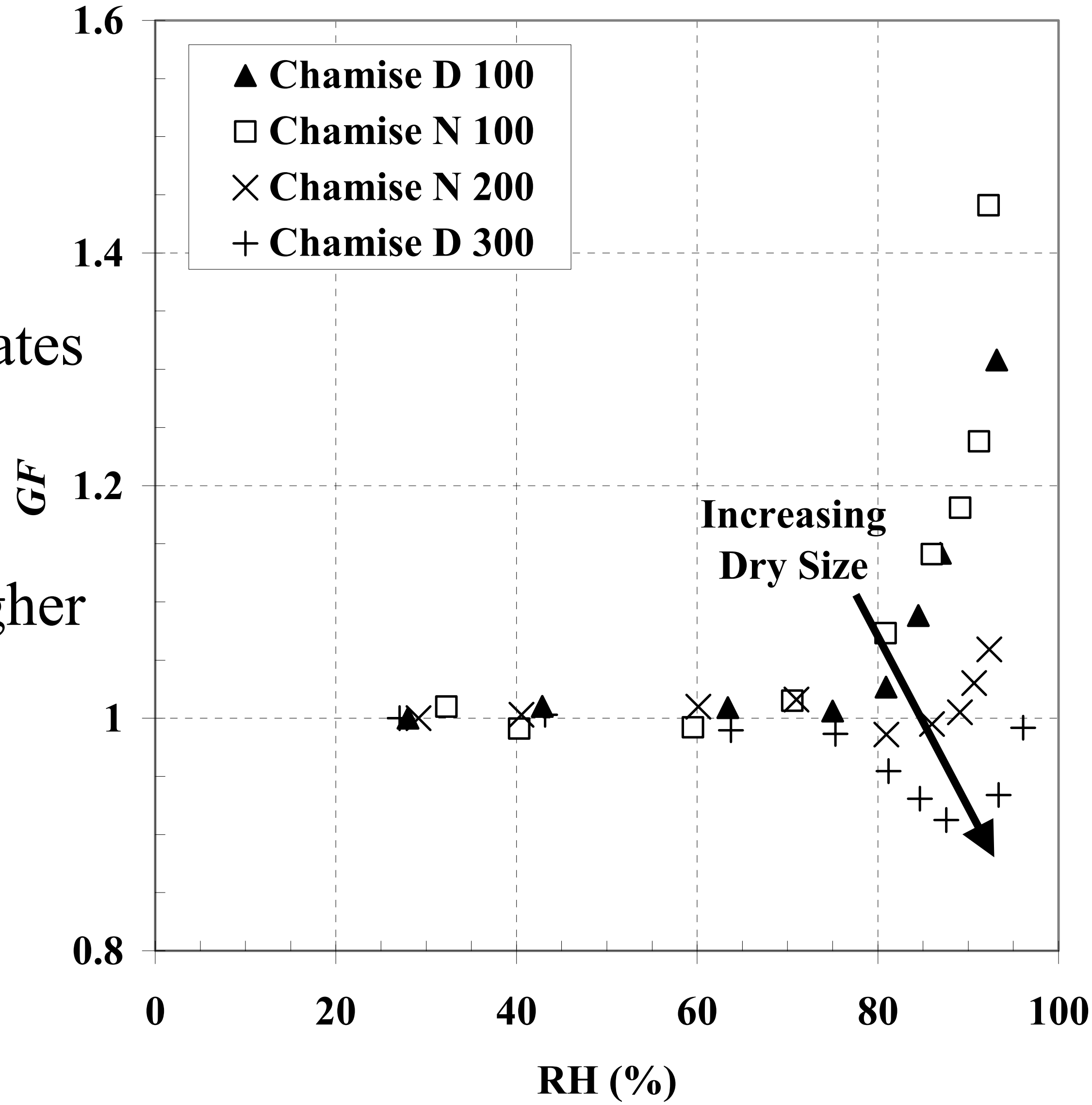


- Some fresh smokes really like water
- Most grouped near typical values for Yosemite aged smoke+SOA mixture

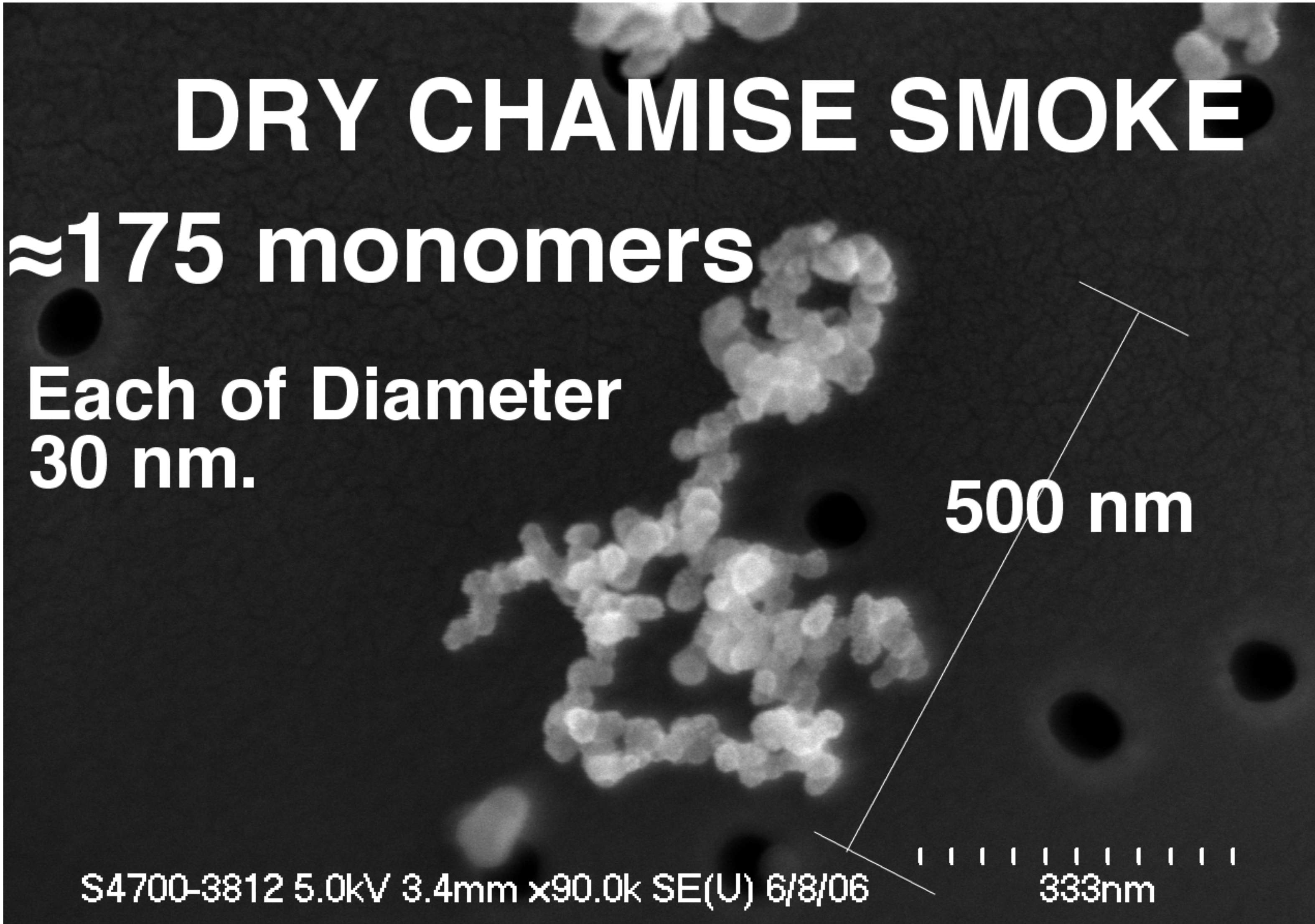
Chamise: Particle Shrinkage with Increasing RH

• Larger particles were 'fluffier' soot agglomerates

• Collapsing of agglomerates into more spherical particles at higher RH

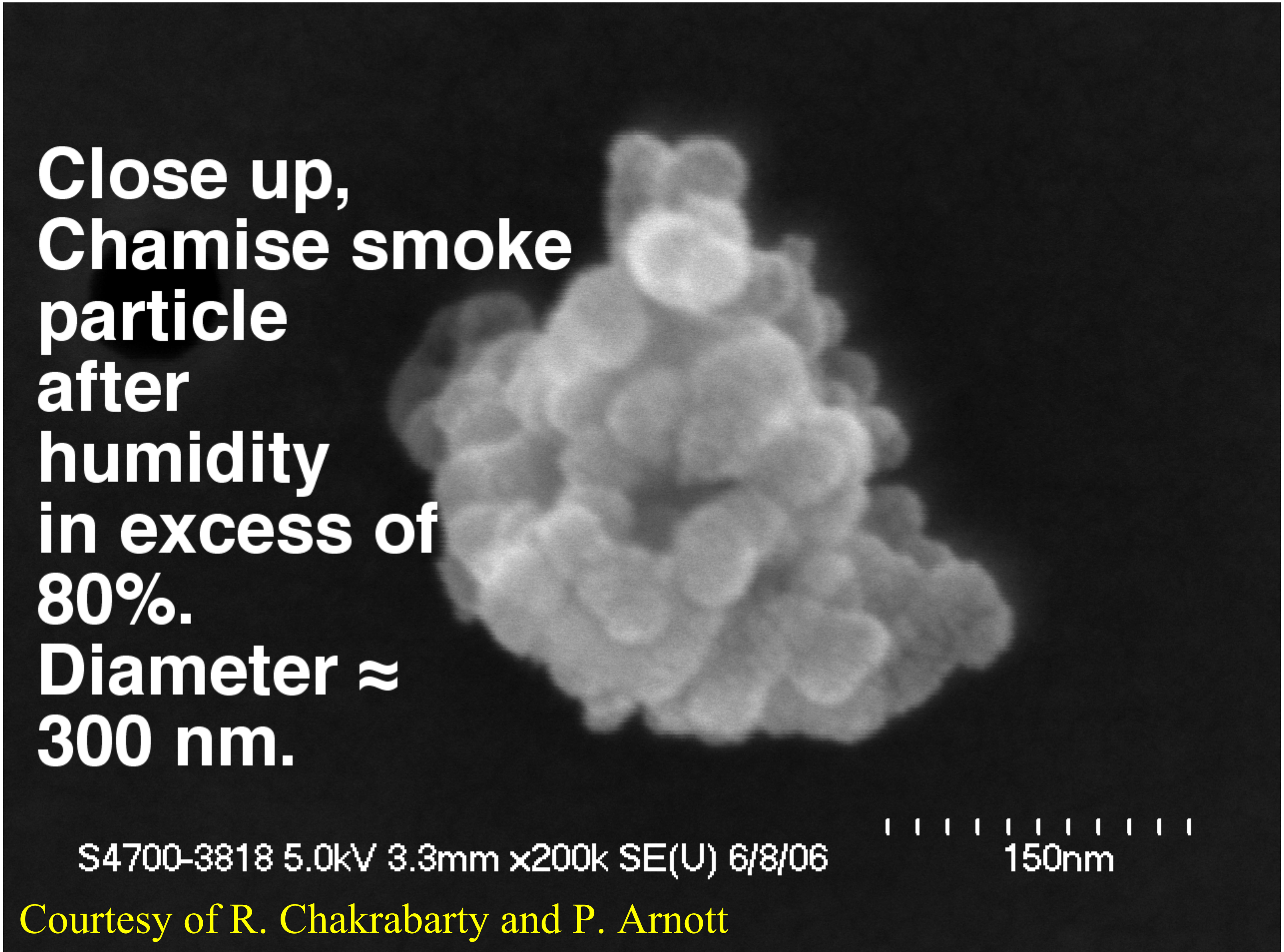


Chamise: “Dry” Particle



Courtesy of R. Chakrabarty and P. Arnott

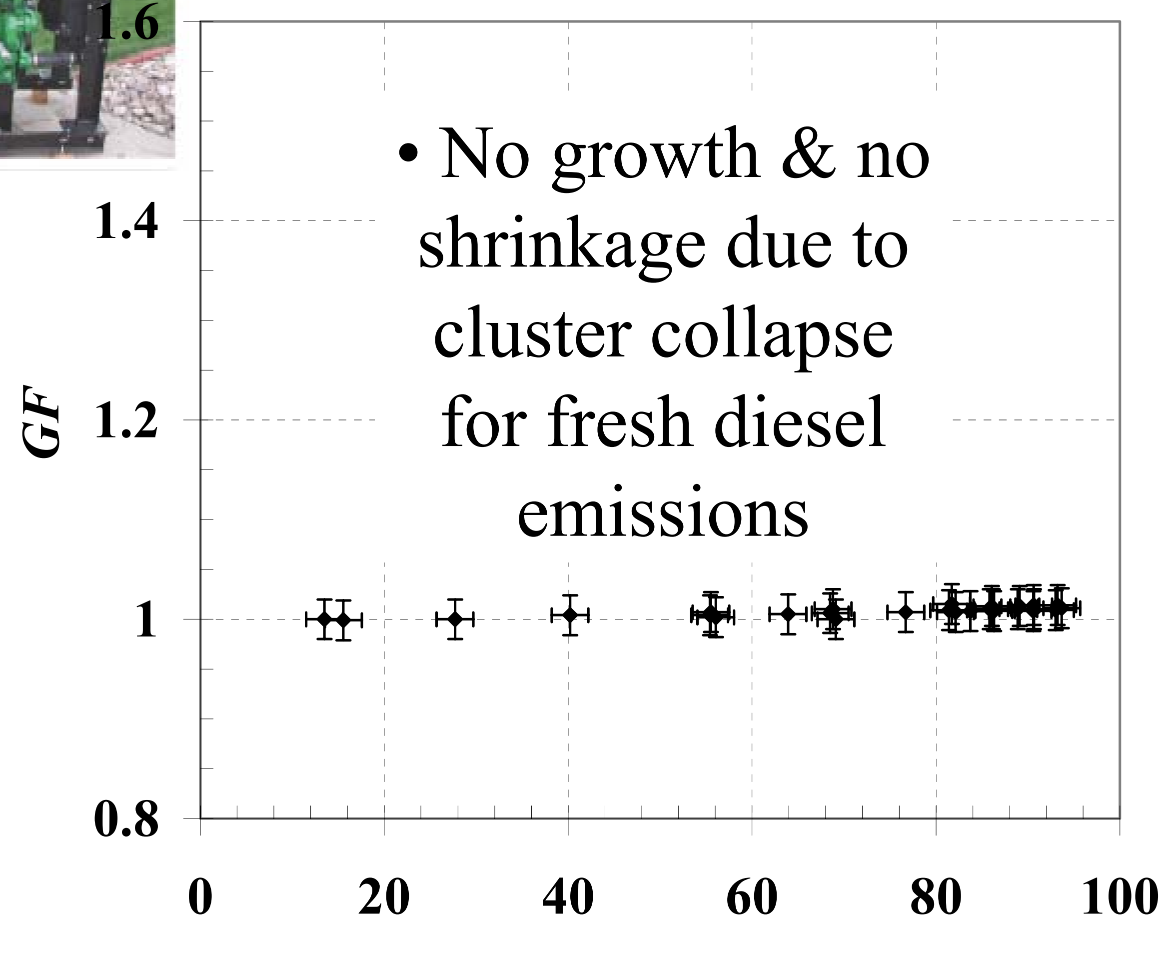
Chamise: “Wet” Particle



Courtesy of R. Chakrabarty and P. Arnott

Fresh Diesel Emissions Water (non) Uptake

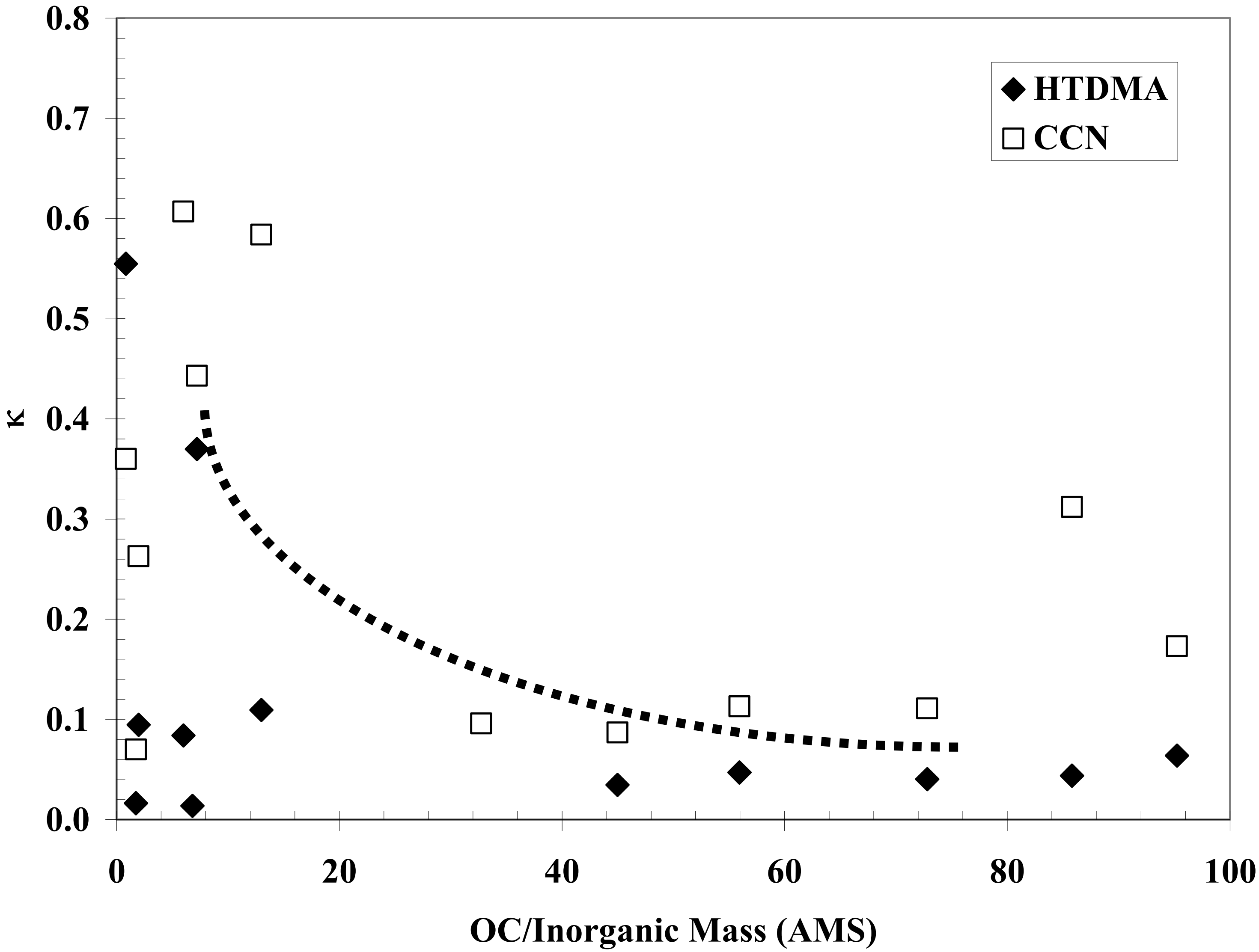
9 November 2006



- No growth & no shrinkage due to cluster collapse for fresh diesel emissions

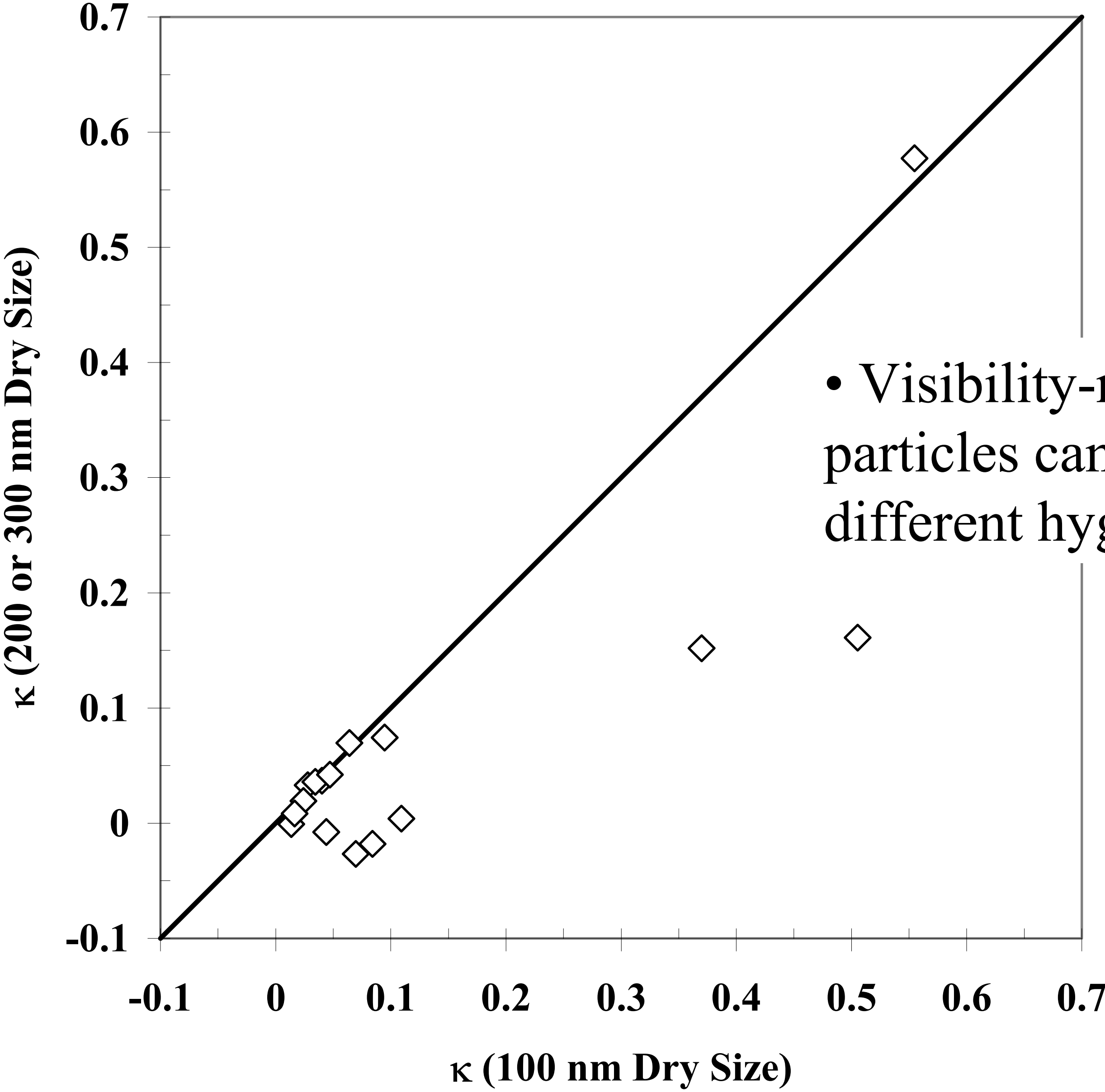
- Role of small quantities of organic/inorganic constituents on soot clusters for growth

FLAME 2006: Hygroscopicity as Function of Composition



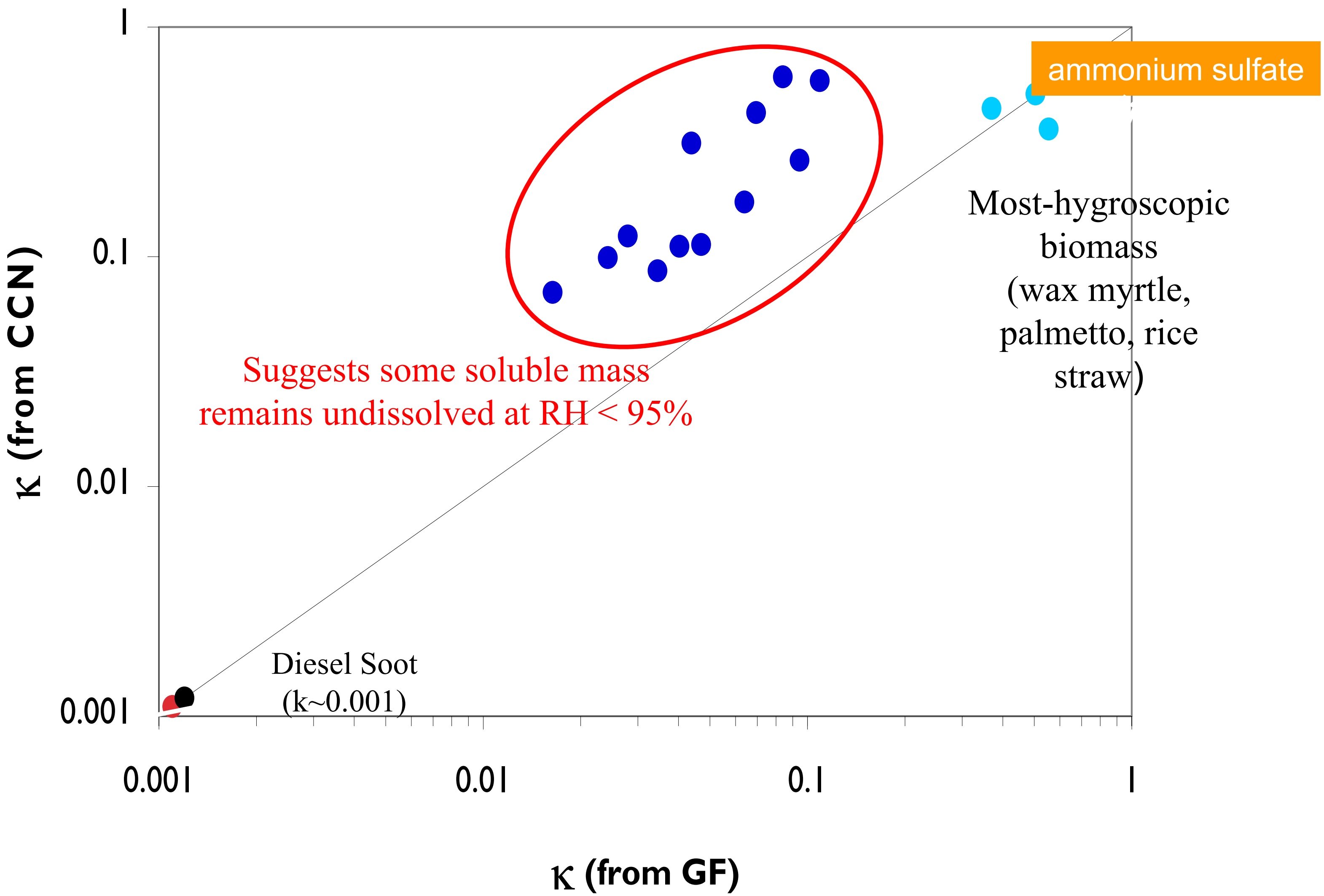
- Similar to relationship for Yosemite 2002 smoke+SOA aerosol

κ for Small and Large Particles



- Visibility-relevant vs. CCN-active particles can have substantially different hygroscopic properties

Missoula Comparison of derived κ's



- Effects of aerosol mixing or very low solubility compounds on water uptake properties?

Summary

- Based on κ, consistent hygroscopic growth properties for inorganic aerosols

- Consistent hygroscopic growth properties for extractions from FLAME Prequel

- For FLAME 2006, CCN measurements give larger κ for low hygroscopicity cases

Acknowledgments

CSU Atmospheric Chemistry
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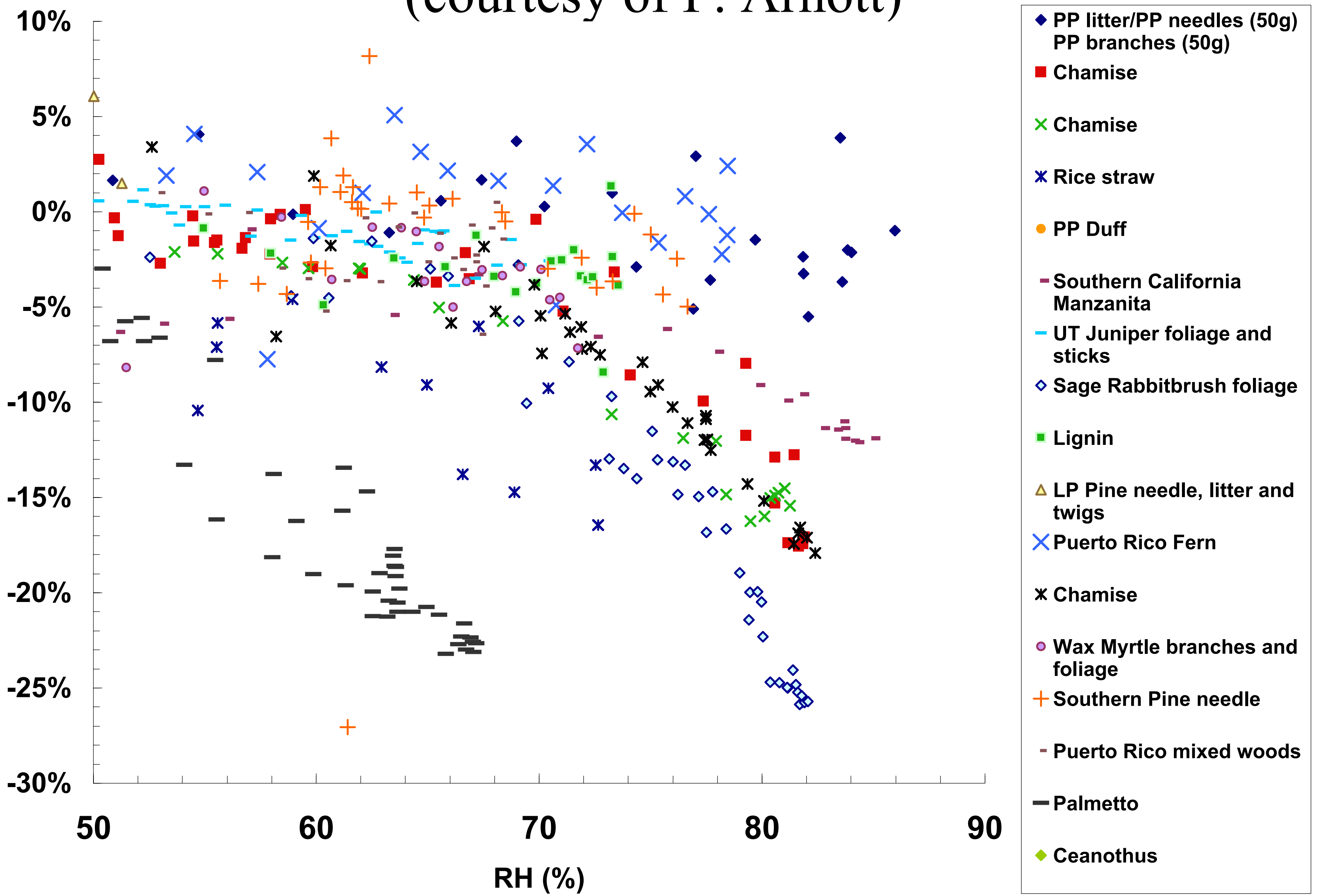
U.S.D.A./U.S.F.S. Fire Science Laboratory at Missoula
Desert Research Institute

Absorption as a Function of RH (courtesy of P. Arnott)



Affect of Aerosol Aging on Organic Hygroscopicity (Petters et al.. 2006)