Cloud microphysics observed during VOCALS-REx

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BROOKHAVEN NATIONAL LABORATORY

VOCALS Regional Experiment

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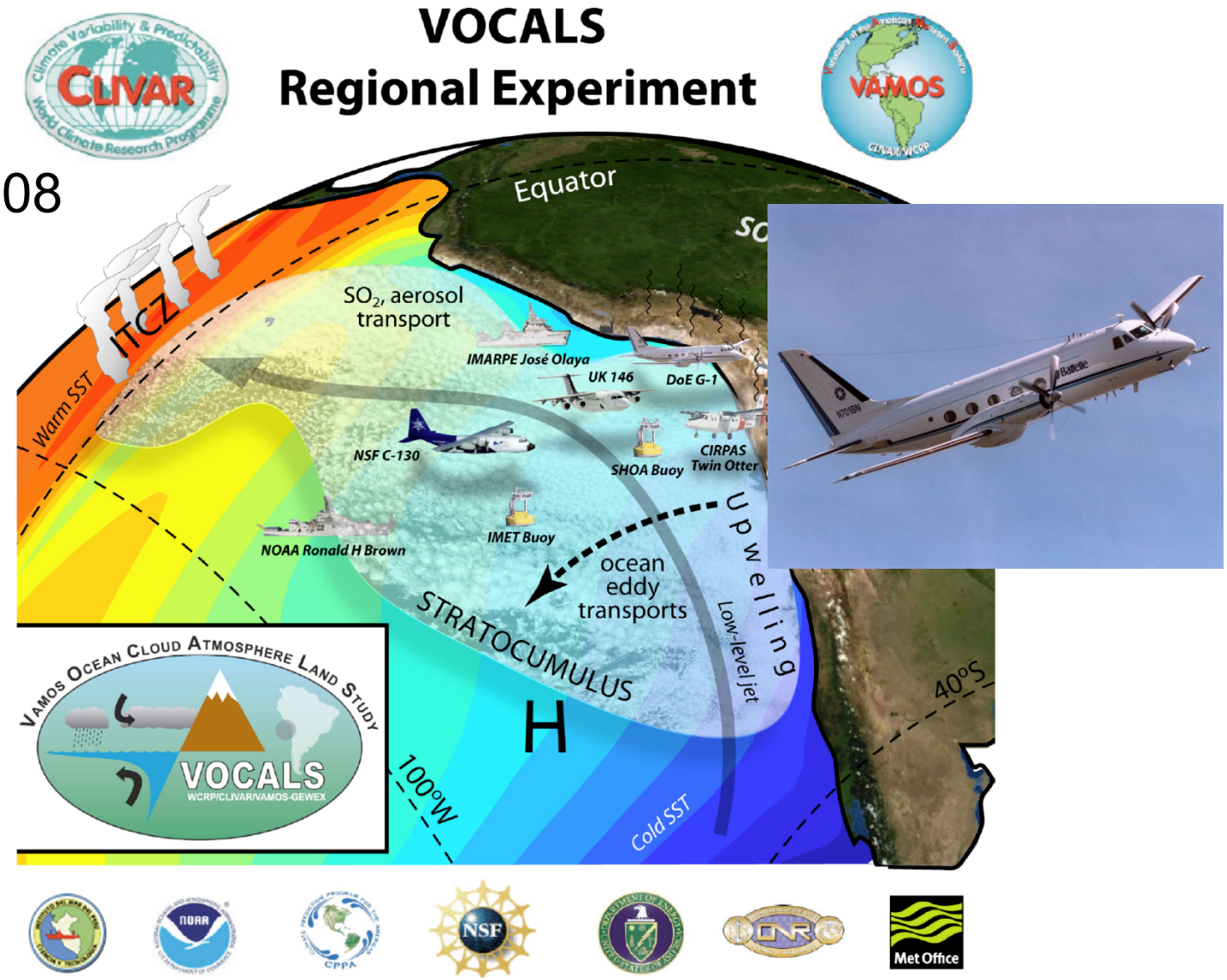
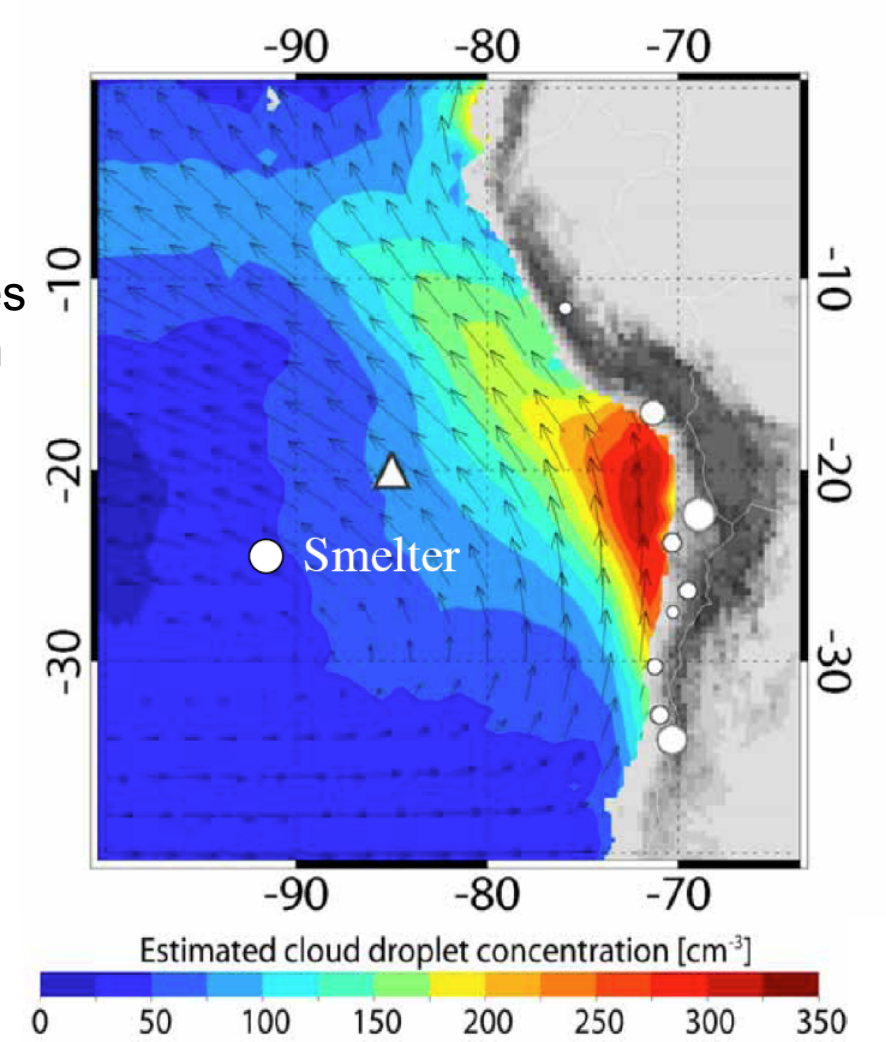


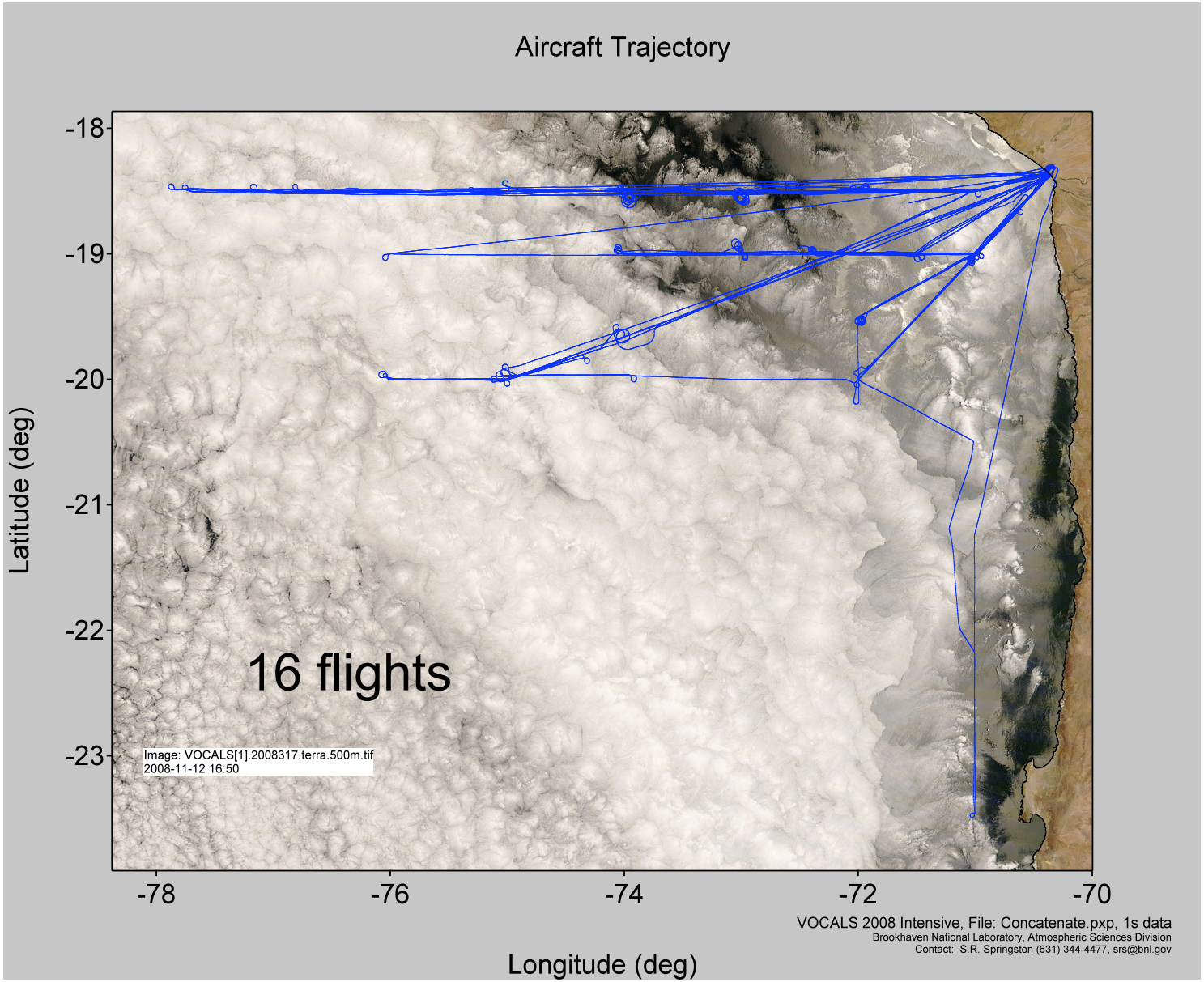
Scientific objectives

VOCALS--Hypothesis 1a:
Variability in the physicochemical properties of aerosols has a measurable impact upon the formation of drizzle in stratocumulus clouds.

Aerosol-Cloud-Drizzle Interactions:
Sampling strategy: Examine the gradients and variability in clouds and aerosols



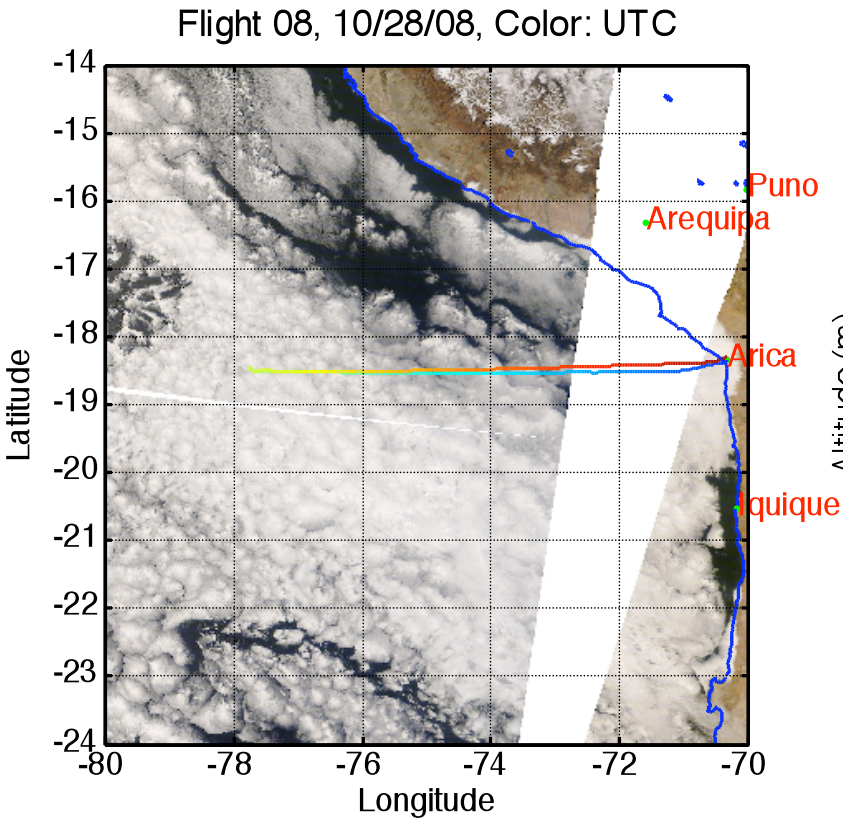
Dept. of Energy Gulfstream-1 flights

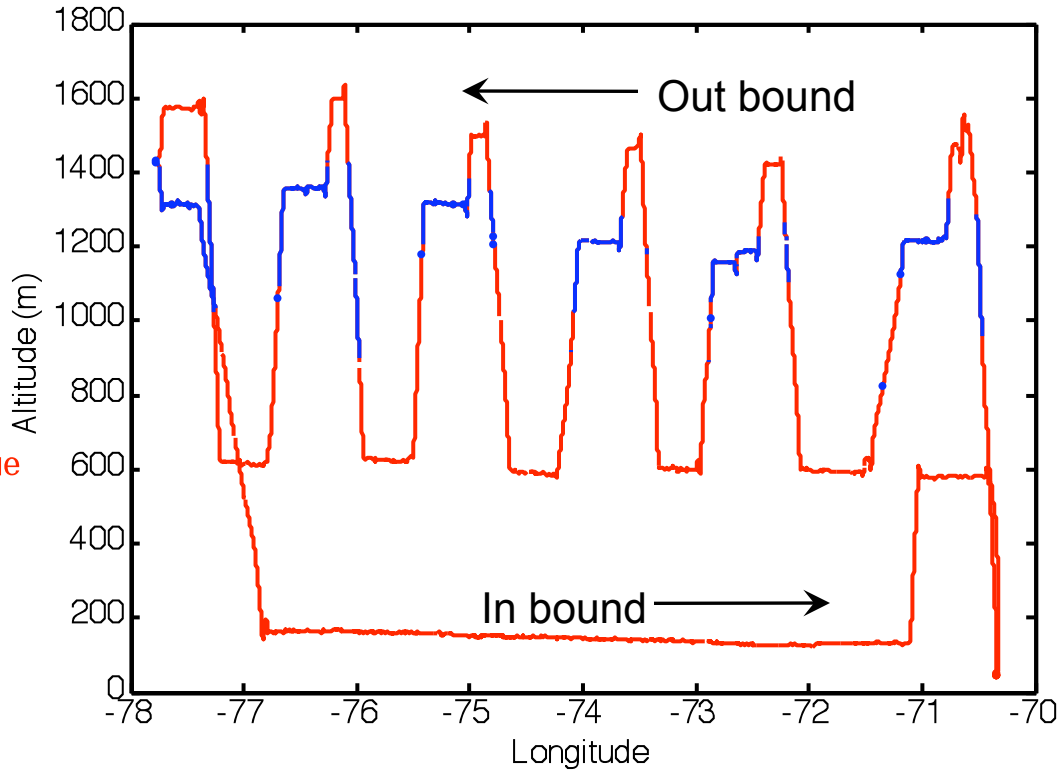


Relevant measurements

Property measured	Size range	Instrument	Time Resolution
Aerosol size spectrum	$0.1<D_p<3\mu m$	Passive Cavity Aerosol Spectrometer Probe (PCASP)	1 Hz
Droplet size spectrum	$1<r<28\ \mu m$	Cloud and Aerosol Spectrometer (CAS)	1 Hz
Droplet size spectrum	$20<r<450\ \mu m$	Cloud Imaging Probe (CIP)	1 Hz
Liquid water content	N/A	Gerber Probe	1 Hz

Gradient in aerosol and cloud properties 10/28/08





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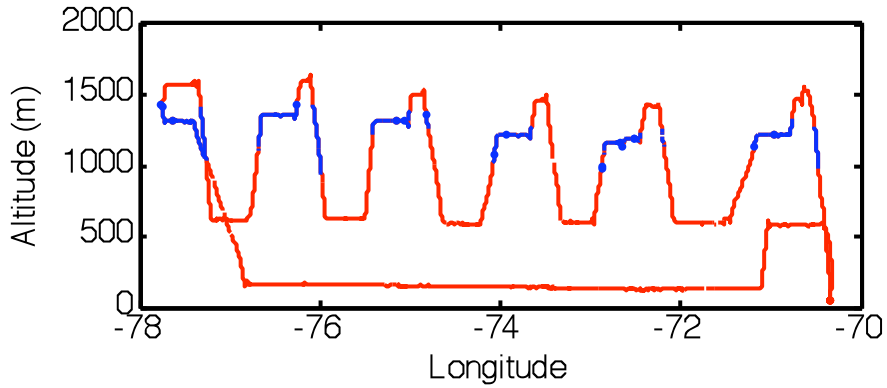
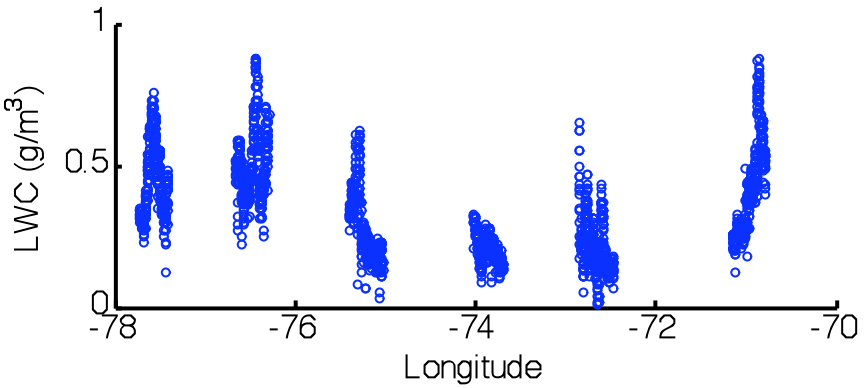
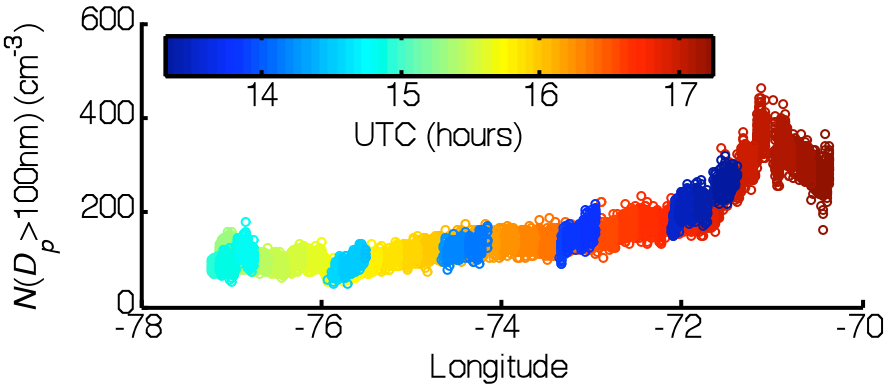
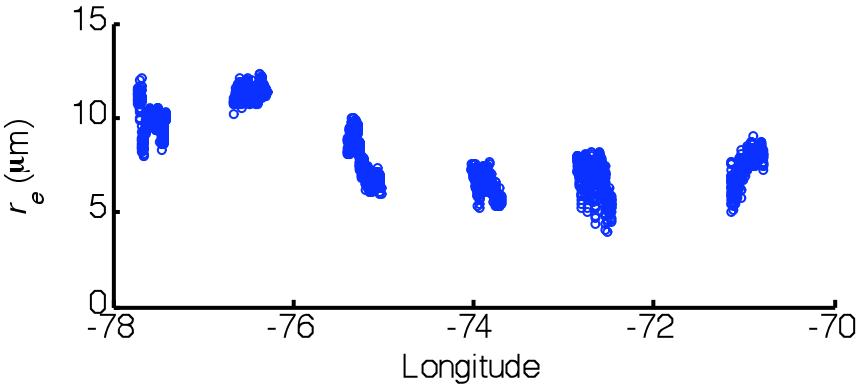
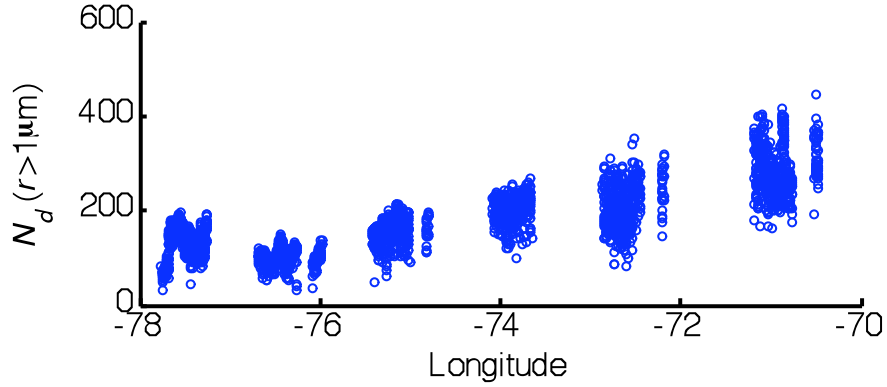
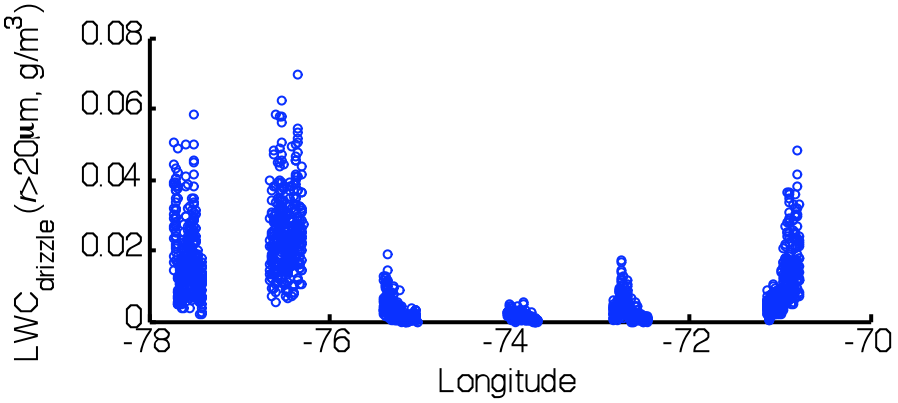




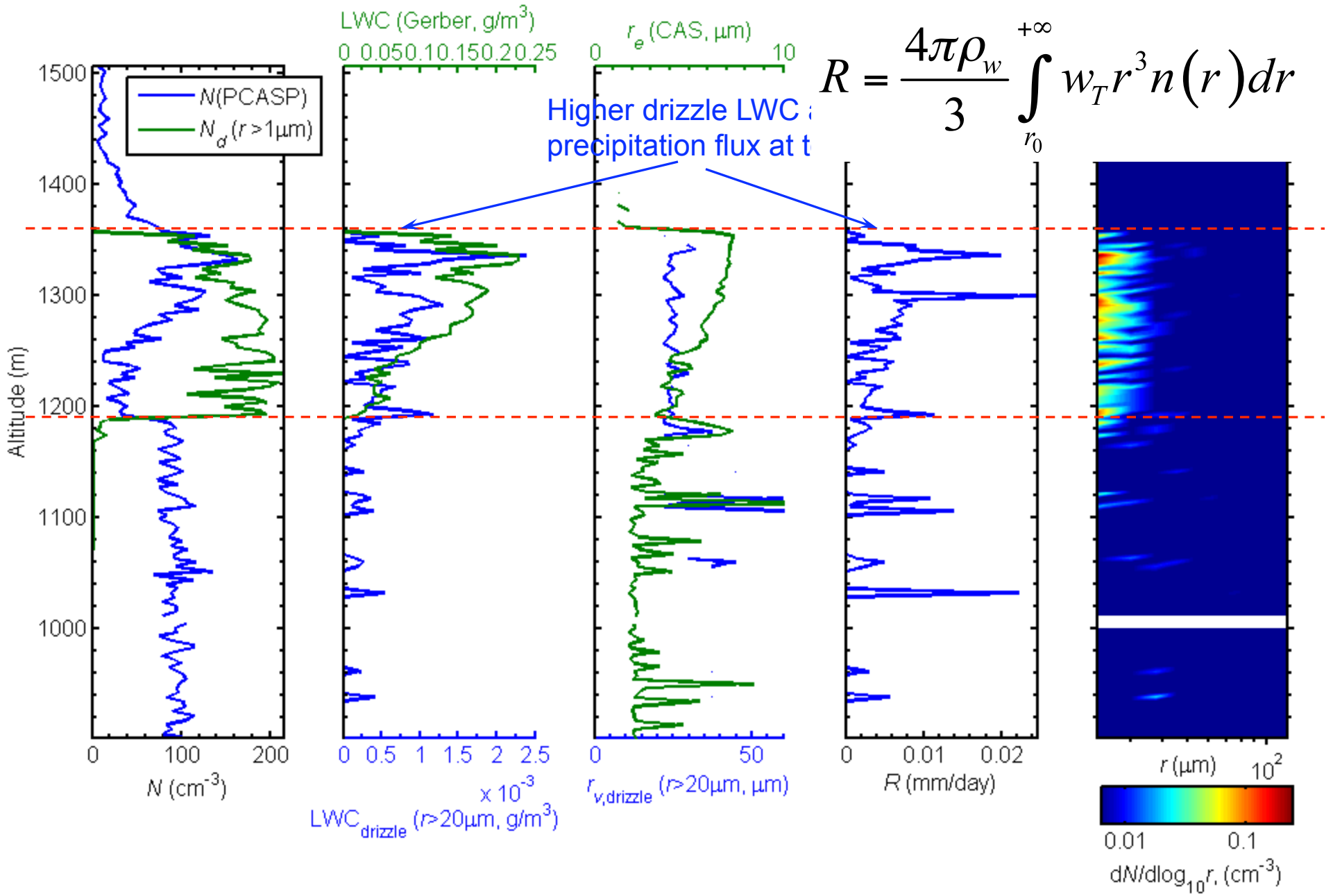






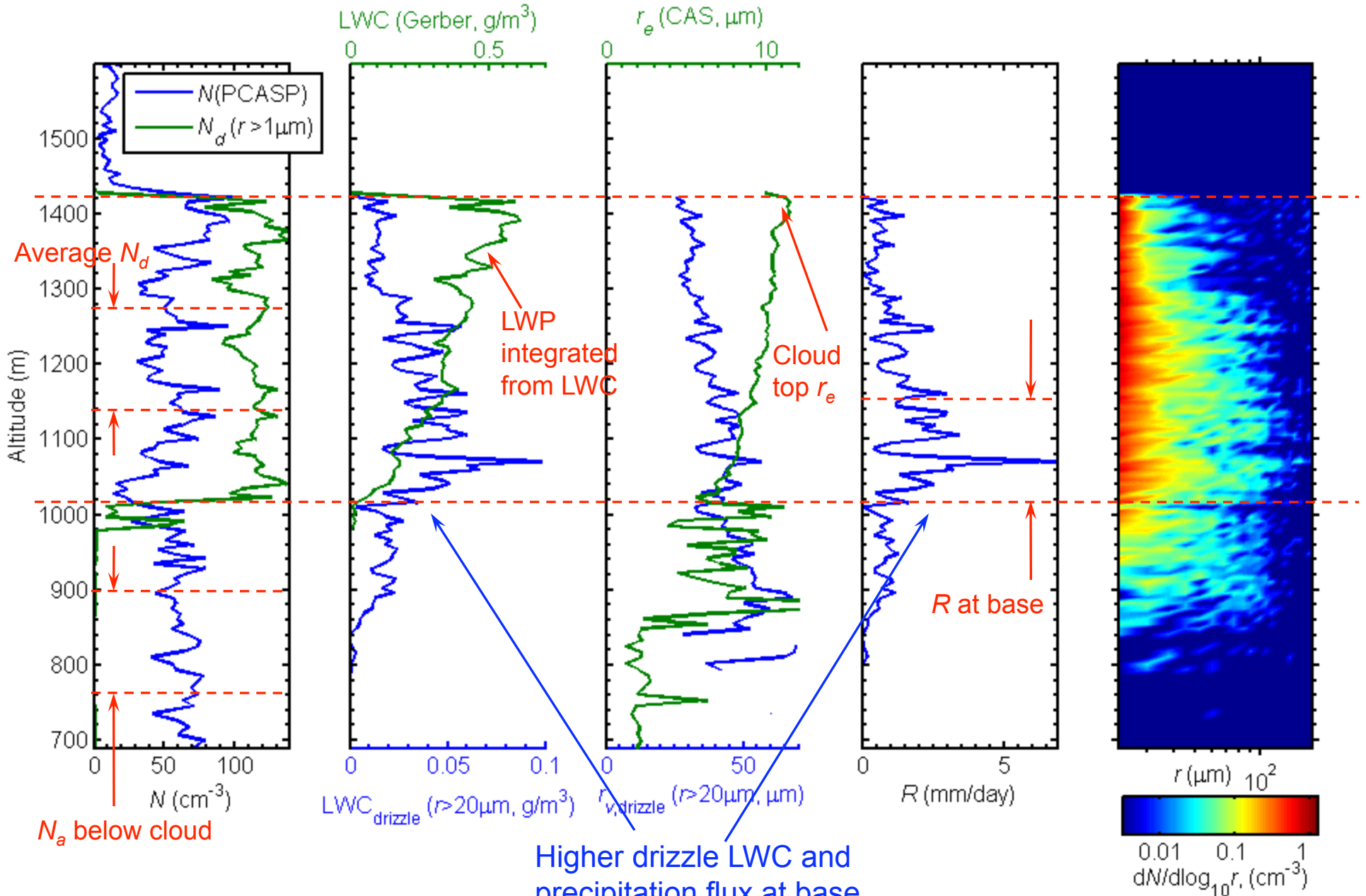


Vertical profiles of cloud microphysics

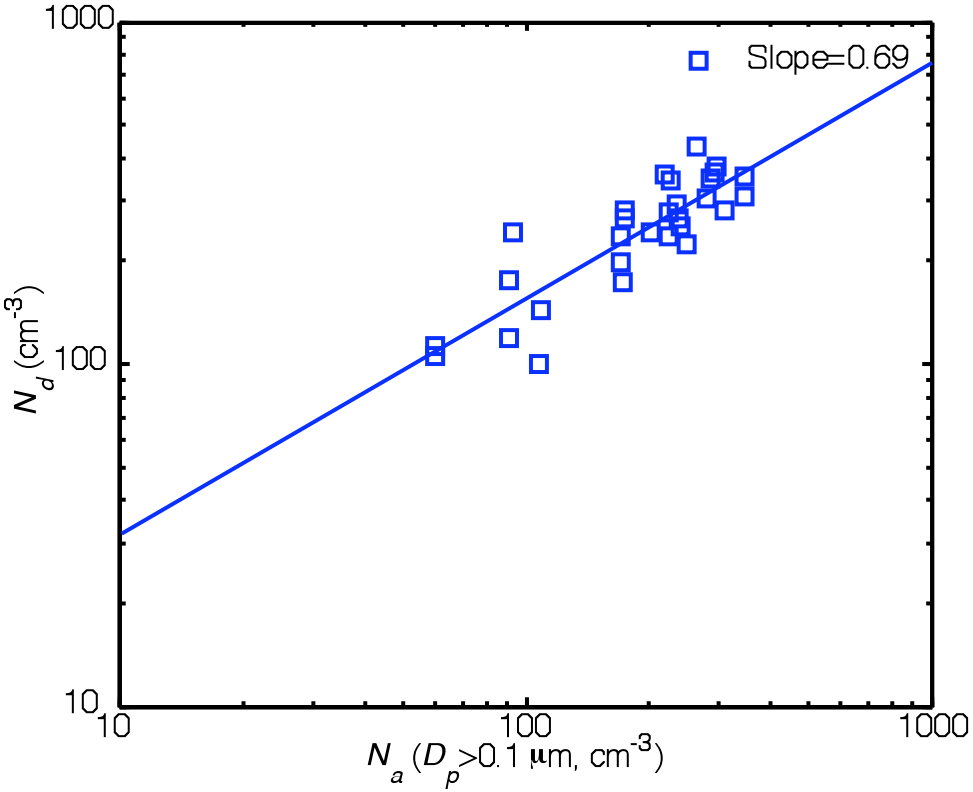


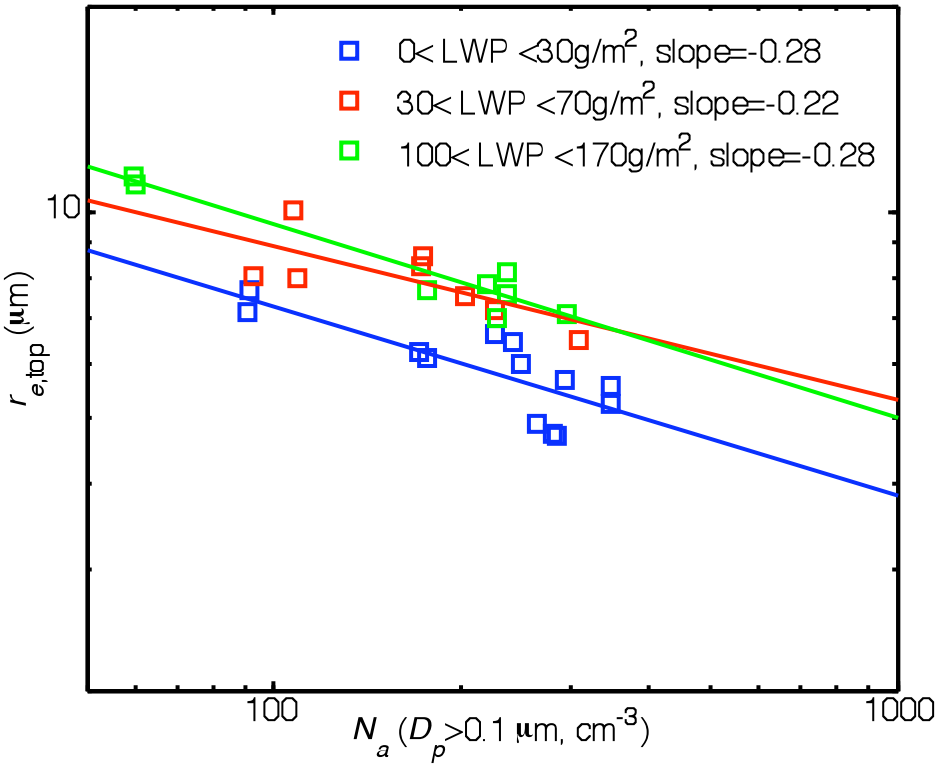
$$R = \frac{4\pi\rho_w}{3}\int_{r_0}^{+\infty} w_T r^3 n(r)\,dr$$

Vertical profiles of cloud microphysics



Effects of aerosol on droplet conc. and size





$$\frac{d \ln N_d}{d \ln N_a} \approx 0.69$$

$$\left.\frac{\partial \ln r_e}{\partial \ln N_a}\right|_{\mathrm{LWP}} \approx -0.28 \rightarrow -0.22$$

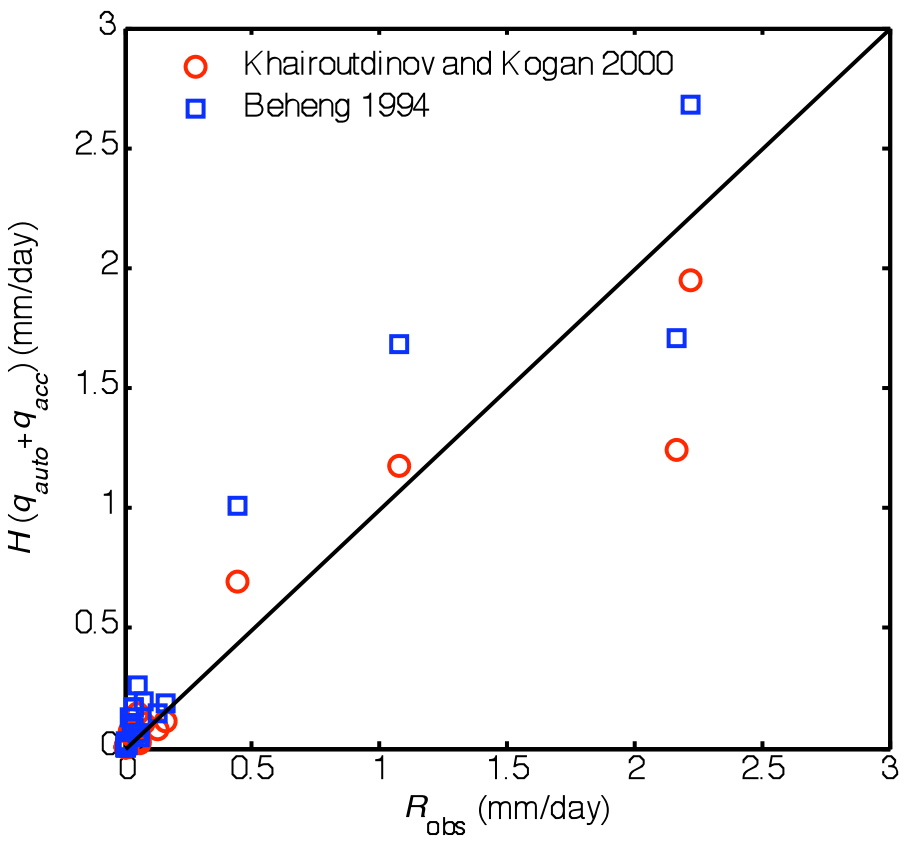
Autoconversion, accretion, and precipitation rate

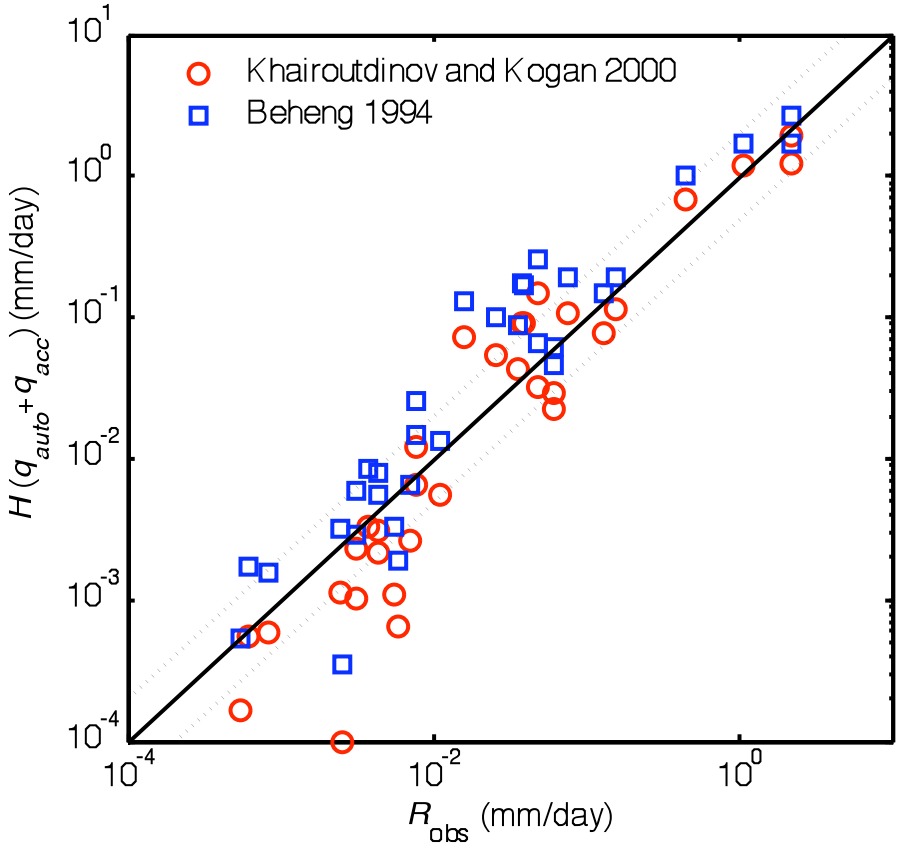
$$R = \int_0^H \left(q_{auto} + q_{acc} \right) dz \simeq H \left(q_{auto} + q_{acc} \right)$$

Autoconversion $R_{auto} = \Delta \int_{r_0}^{+\infty} w_T \left(\text{Cloud droplet}, \text{Cloud droplet} \right) dr \longrightarrow$ Drizzle drop

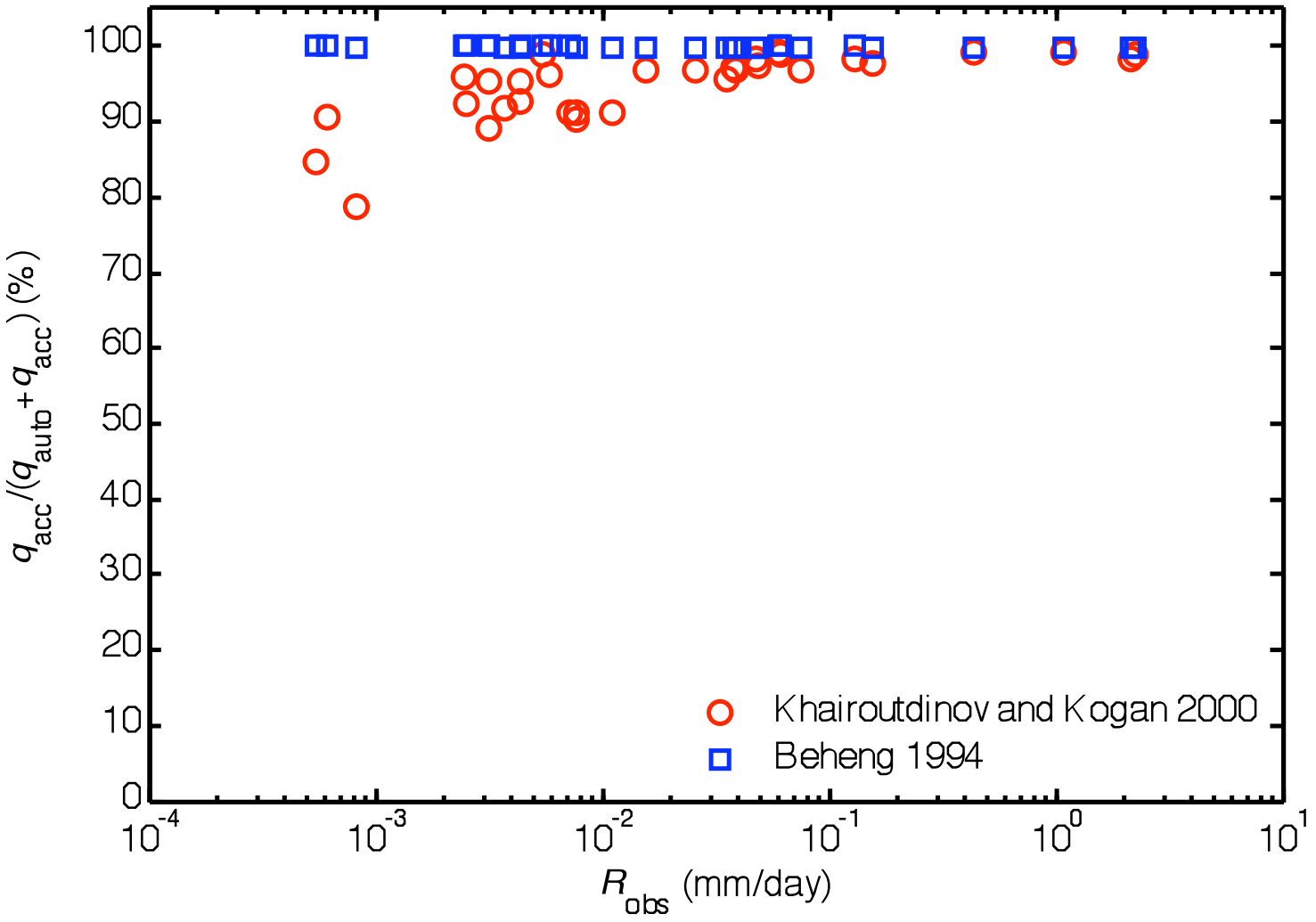
	Khairoutdinov and Kogan (2000)	Be[illegible]1994)
Accretion	Drizzle drop + Cloud droplet $\longrightarrow$ Larger drizzle drop	
q_{auto}	$A\rho^{-1.47} L^{1.[illegible]} N_d^{-1.[illegible]} V_d^{1.[illegible]}$	$C\rho^{-1.[illegible]7} L^{2.47} N_d^{-3.3}$
q_{acc}	$67\left(\mathrm{LWC}\cdot\mathrm{LWC}_{drizzle}\right)^{1.15}$	$6.0\mathrm{LWC}\cdot\mathrm{LWC}_{drizzle}$

Precipitation flux: parameterization vs. observation

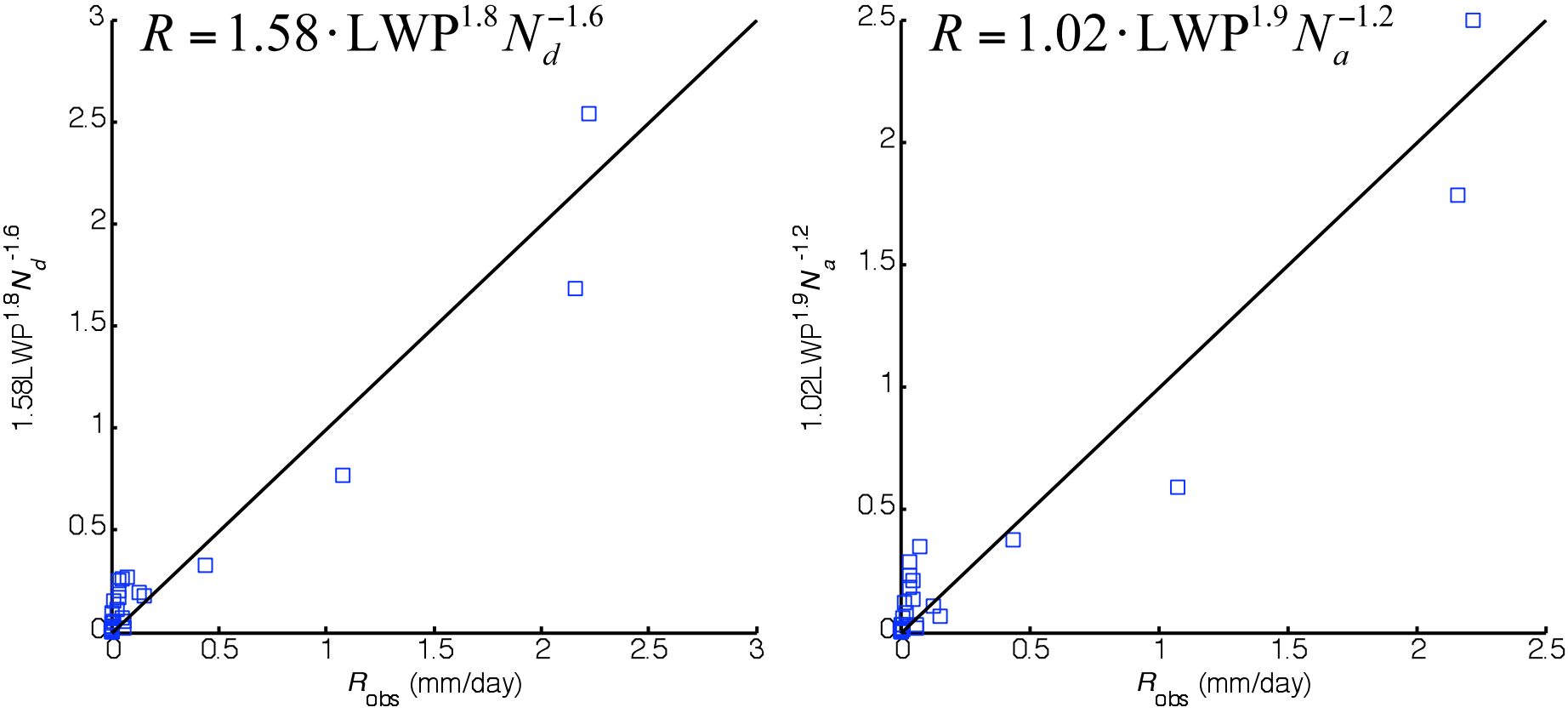




Relative role of autoconversion and accretion



Effects of aerosol on precipitation flux



Previous study (Comstock et al., 2004, EPIC):

$$R = 0.37 \cdot \mathrm{LWP}^{1.75} N_d^{-1.75}$$

Summary

- Strong gradients in aerosol and cloud properties observed during VOCALS-REx.
- Observed impacts of aerosol on droplet concentrations and size were similar to previous in-situ studies.
- Precipitation fluxes at cloud base calculated from two parameterizations agree with observations, and production of drizzle mass was dominated by accretion.
- Aerosol has a measurable impact on precipitation flux at cloud base. The precipitation flux can be estimated using cloud bulk properties (LWP and N_d).

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