What is column integrated aerosol remote sensing telling us about cloud condensation nuclei?

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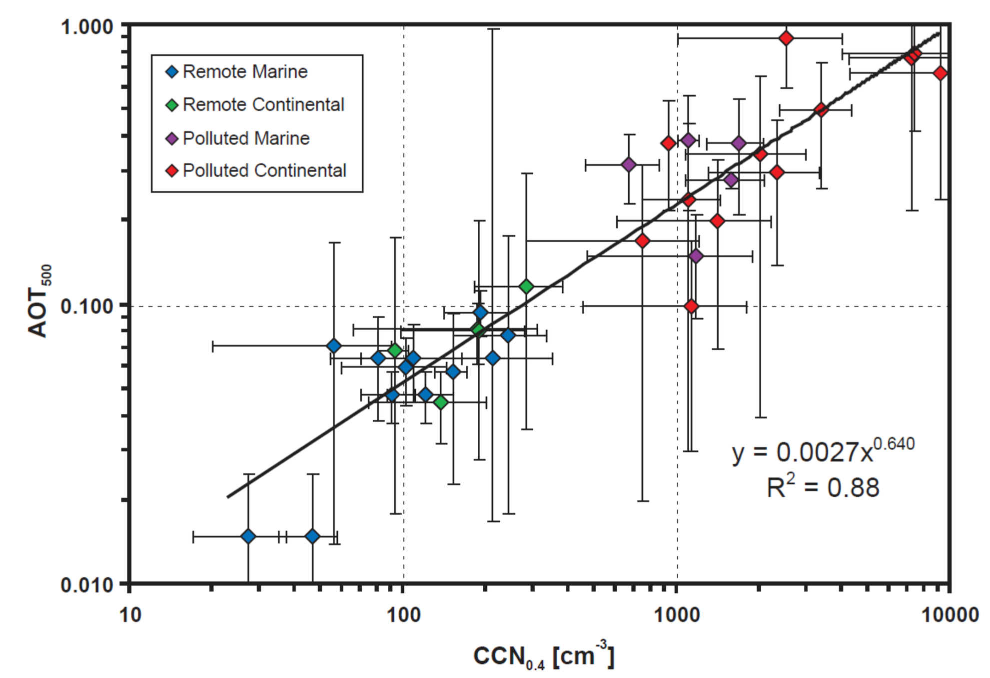
1. MOTIVATION

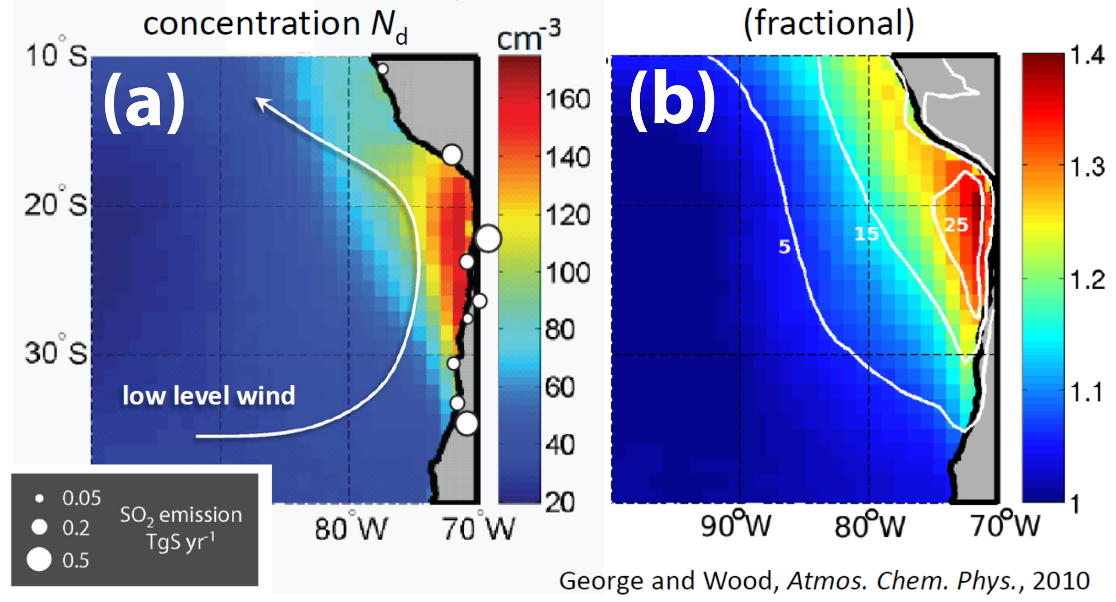
❒ AOD (Aeronet) correlated with cloud condensation nuclei (CCN) concentrations across a wide range of environments (Andreae 2009, Rosenfeld et al. 2008) - **figure at right**

❒ Does this relationship hold up for smaller regional and temporal scales used to derive estimates of aerosol indirect effects from space (e.g. Quaas et al. 2008)?

❒ Can field data be used to explore physical basis for connections between CCN and satellite aerosol properties?



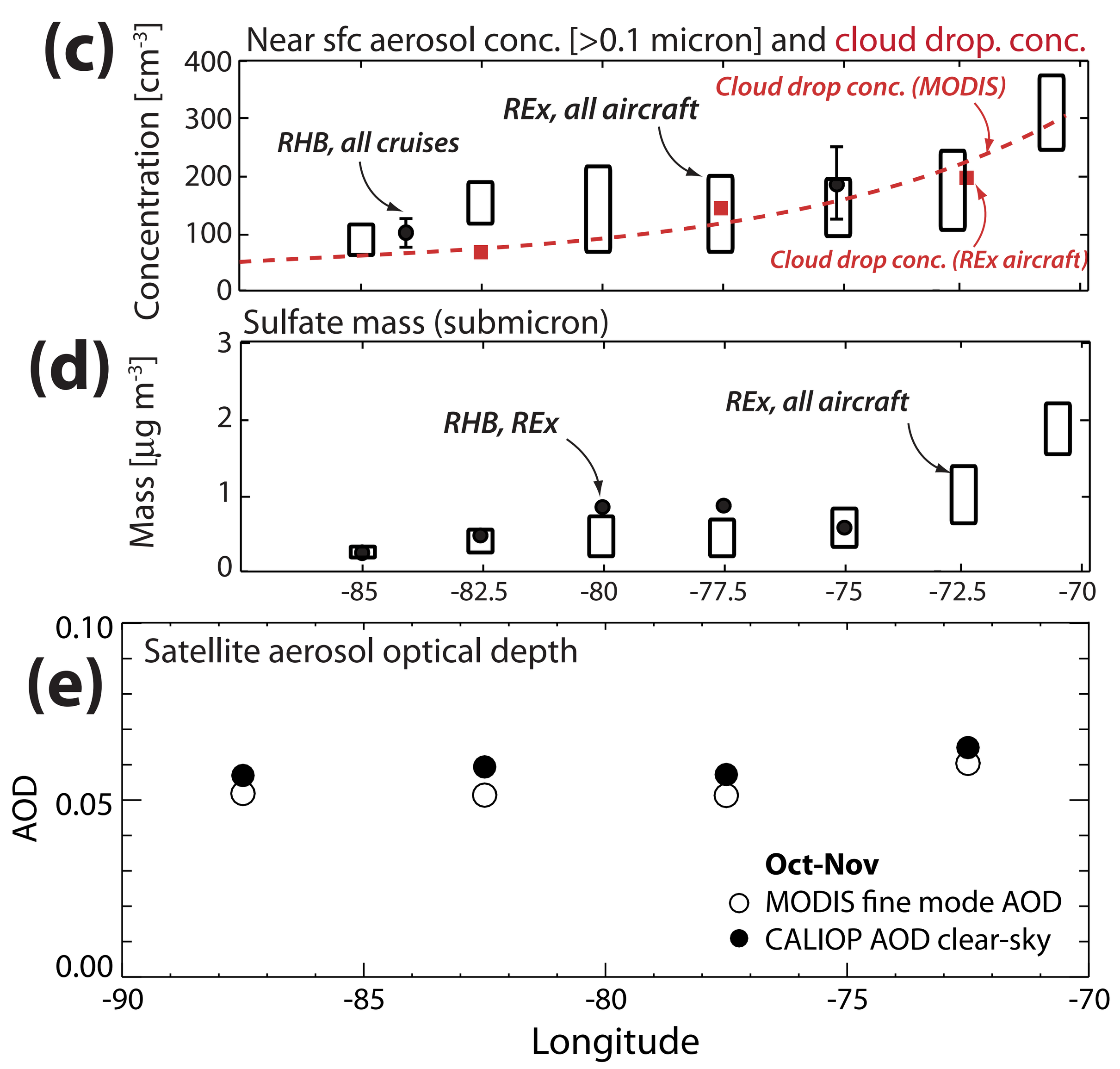
2. THE SOUTHEAST PACIFIC: A REGIONAL TESTBED



George and Wood, *Atmos. Chem. Phys.*, 2010

Offshore gradient in cloud droplet concentration is not matched by gradient of aerosol optical depth:

❒ Offshore gradient in cloud drop concentration observed by MODIS (**a**) and aircraft (**c**) over the southeastern Pacific during VOCALS-REx caused by pollution from Chilean smelters and cities (**d**, Allen et al. 2011) imply strong Twomey effect (**b**) as simulated with WRF (Wang et al. 2011)



❒ Extremely weak offshore gradient of satellite aerosol optical depth (**e**) from MODIS and CALIOP

Bretherton et al. (2010); Allen et al. (2011)

3. QUANTIFYING CONTRIBUTIONS TO AEROSOL OPTICAL DEPTH

❒ Break down aerosol optical depth into constituent parts

$$\tau = \sigma G_\sigma h$$

(dry extinction σ; Hygroscopic growth G_σ; aerosol layer depth h)

Three longitude bins: 80-85°W, 75-80°W, 70-75°W

dX is the increase from offshore to coastal bin; *X* is the mean value

$$\frac{d\tau}{\tau} = \frac{d\sigma}{\sigma} + \frac{dG_\sigma}{G_\sigma} + \frac{dh}{h} = \frac{dN_a}{N_a} + 3\frac{dD_3}{D_3} + \frac{dG_\sigma}{G_\sigma} + \frac{dh}{h}$$

0.09-0.17 ≈ **0.72** **-0.38** **[0.0-0.24]** **-0.25** = 0.09-0.33 (sum RHS) **Closure!**

- $\frac{d\tau}{\tau}$: *CALIOP vs MODIS*
- $\frac{dN_a}{N_a}$: 0.72; $\frac{dN_d}{N_d}$ = **0.80**; ACI ≈ 1 (Painemal and Zuidema 2013)
- $\frac{dD_3}{D_3}$: Scattering-weighted mean diameter D_3 decreases from 0.28 to 0.25 μm
- $\frac{dG_\sigma}{G_\sigma}$: **Highly uncertain** since it depends upon vertical profile of relative humidity in clear sky - difficult to assess using aircraft (see box below)
- $\frac{dh}{h}$: MBL depth decreases from 1.5 to 1.2 km near coast

Large increase in aerosol concentration toward coast offset by reductions in particle size and MBL depth

DRY SCATTERING CLOSURE

$$\frac{d\sigma}{\sigma} = \frac{dN_a}{N_a} + 3\frac{dD_3}{D_3}$$

0.3 ≈ **0.72** **-0.38** = 0.34 **Closure!**

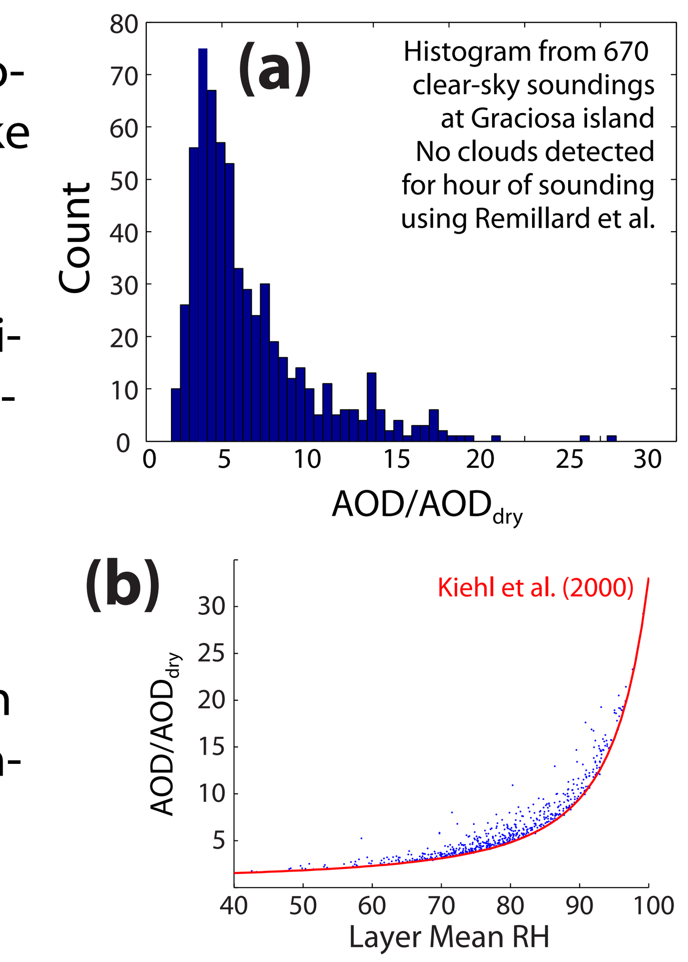
- $\frac{d\sigma}{\sigma}$: *Nephelometer*
- $\frac{dN_a}{N_a}$: *PCASP*
- $\frac{dD_3}{D_3}$: *Aerosol size distribution* — *smaller particles near coast (see Kleinman et al 2012)*

ESTIMATING HYGROSCOPIC GROWTH

❒ G_σ depends upon RH profile and aerosol water uptake

❒ Boundary layer column integrated hygroscopic growth $G_\sigma = AOD/AOD_{dry}$ estimated from Kiehl et al. f[RH] - strongly variable (**a**) due to variations in mean RH in the PBL (**b**).

❒ Aerosol *f*(RH) variability currently under investigation using Graciosa wet/dry nephelometer measurements.



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BOTTOM LINE:

❒ Geographical/temporal variability in aerosol size, boundary layer depth, and vertical relative humidity structure all play a role in reducing information content in aerosol optical depth about accumulation mode aerosol (CCN) concentration

❒ Systematic exploration of factors controlling deviations necessary to ascertain when/where spaceborne aerosol optical properties can be used to estimate CCN concentration.