Lecture 5. How aerosols affect marine low level warm clouds and drizzle.

Background materials: *Mechanisms of the first and second indirect aerosol effects.*

Required reading:

Xue, H., and G. Feingold, Large eddy simulations of tradewind cumuli: Investigation of aerosol indirect effects. J. Atmos. Sci., 63, 1605-1622, 2006.

Guo, H., Penner, J. E., Herzog, M., and Pawlowska, H., Examination of the aerosol indirect effect under contrasting environments during the ACE-2 experiment, Atmos. Chem. Phys., 7, 535-548, 2007.

Recommended reading:

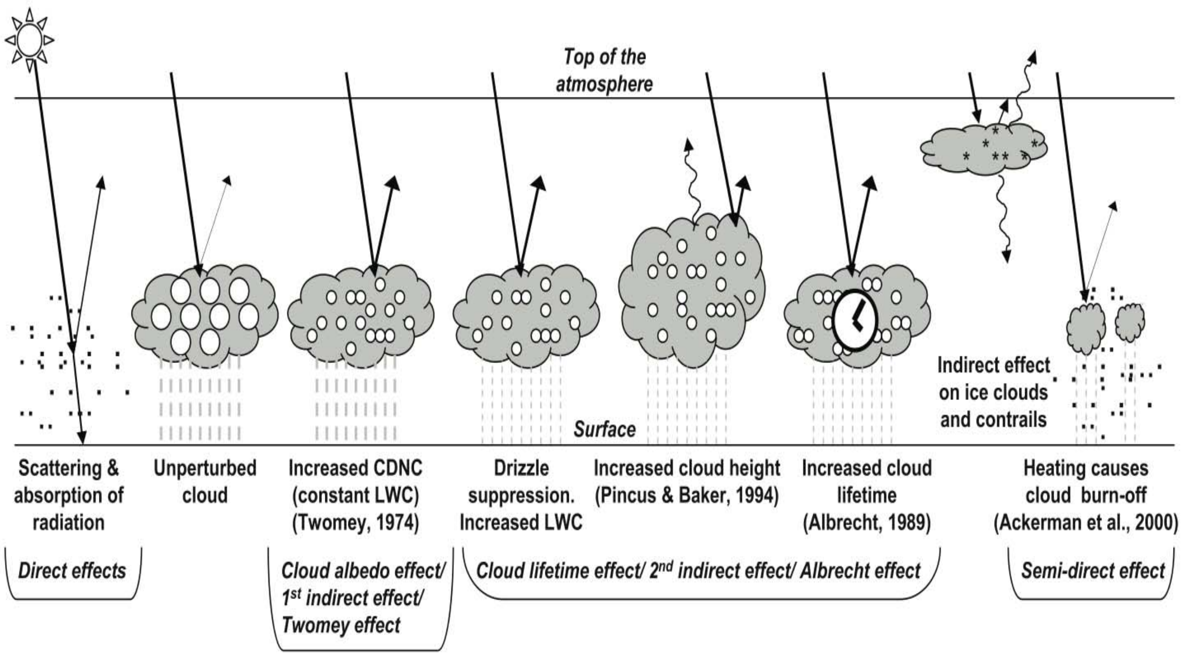
Pawlowska, H., and J. Brenguier, An observational study of drizzle formation in stratocumulus clouds for general circulation model (GCM) parameterizations, J. Geophys. Res., 108*(D15), 8630, doi:10.1029/2002JD002679, 2003.*

Lohmann U. and J. Fletcher, Global indirect aerosol effects: a review. Atmos. Chem. Phys, 5, 715-737, 2005.

V. Ramanathan, P. J. Crutzen, J. T. Kiehl, and D. Rosenfeld, Aerosols, climate, and the hydrological cycle . Science Vol. 294. no. 5549, pp. 2119 – 2124, DOI:10.1126/science. 1064034, 2001.

1. **Mechanisms of the first and second indirect aerosol effects.**

Recall Lecture 2 where direct effect and several indirect aerosol effects were discussed. Figure 3 of Lecture 2 schematically summarizes how these effects work.



<u>*Mechanism of First indirect effect:*</u>

more aerosol particles -> more CCN->more CDNC but smaller sizes if LWC is constant -> more reflectivity from clouds (i.e. higher albedo) -> more negative radiative forcing

<u>*Mechanism of Second indirect effect (Albrecht effect):*</u>

more aerosol particles -> more CCN->more CDNC but smaller sizes -> suppression of precipitation (slowed down collision-coalescence) -> more negative radiative forcing

<u>Emerging questions</u>:

1) Do first and second indirect effects act in all types of clouds and for all types of aerosols?
2) How well are mechanists involved in second indirect effects understood?
3) What are implications for aerosol impacts on precipitations?

First indirect effect. Figure 1 below summarizes some measurements of number concentrations of cloud drop (CDNC) and aerosols in differing environments.

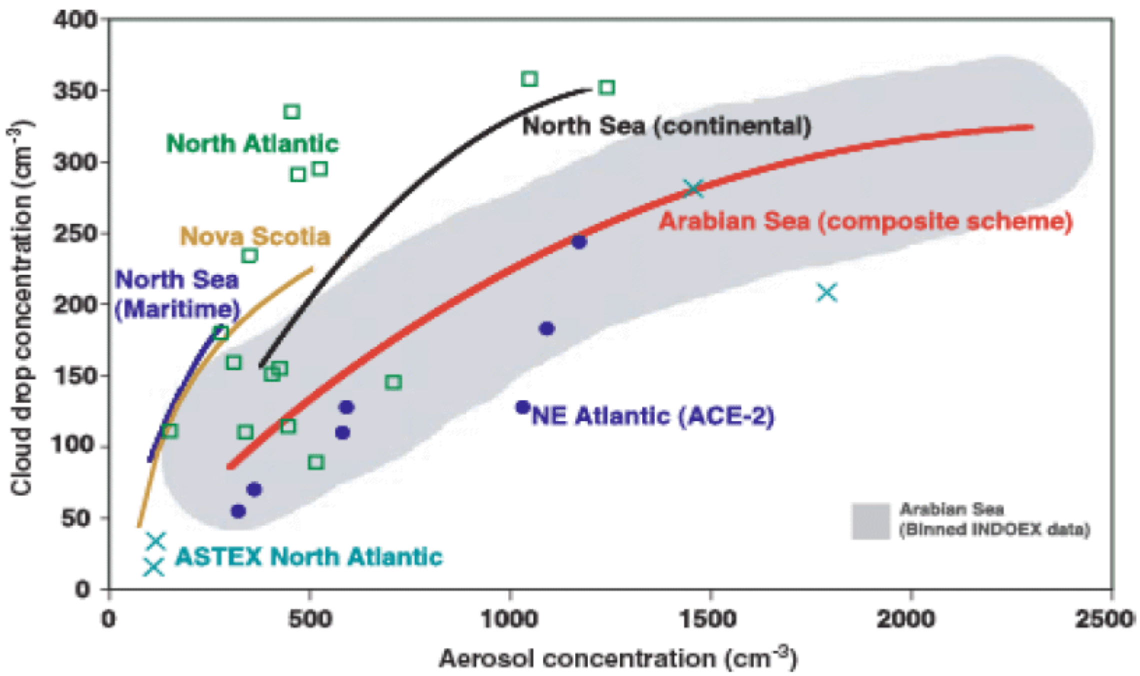


Figure 1. Aircraft measurements of CDNC aerosol number concentration. The thick red line is a theoretical parameterization based on INDOEX aircraft data for the Arabian Sea (Ramanathan et al., 2001).

Conclusions:

1) Measurements show that CDNC increases with increasing aerosol concentration. However, this relationship is not simple (linear) because of several possible reasons.
2) One reason is that CCN are only a fraction of the aerosol population and that this fraction varies significantly with the size distribution and chemical composition of the aerosol.
3) Another reason is that the fraction of available CCN that are actually activated in a cloud increases with the intensity of the updraft velocity at cloud base, and hence differences between activation in stratus (stratocumulus) and deep convective clouds (compare stratocumulus observed in ASTEX and some in ACE-2 versus deep convective clouds observed in North Atlantic).

4) Furthermore, the total aerosol concentration can vary from measurement to measurement depending on which instrument is used (sizes bigger than 2.5, 10, 20 nm) because, during nucleation events, the relative concentration of the smallest particles can be very high, while such particles can hardly be activated in clouds. This may introduce additional biases in establishing the linkages between CDNC and aerosol concentration.

How about the second indirect effect? (see Lecture 7)