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The second aerosol indirect effect: LES simulations of boundary layer clouds. What is observable to support numerical simulations?

1 J. L. Brenguier

Météo-France, CNRS-GAME, France

jlb@meteo.fr / Fax : +33 56107 9627

Twomey developed the concept of aerosol indirect effect in the seventies by observing that increasing cloud droplet concentration at constant liquid water pass results in an increase of the total droplet surface, hence an increase of the cloud optical thickness. The impact of aerosol particles on cloud droplet concentration was well documented by a series of airborne experiments performed in the sixties by US and Australian research teams. The resulting change of the cloud optical properties was recently corroborated during the ACE-2 experiment with airborne radiation measurements over clean and polluted cloud layers.

Modifying the aerosol background however is also likely to impact cloud dynamics through either the precipitation cycle or the radiative budget. The Twomey effect, the impact on precipitation efficiency, and the increased absorption were then referred to as the first, second indirect, and semi direct effects, respectively. In fact, these phenomena belong to quite different categories. Concomitantly measuring droplet concentration, liquid water path, and reflected cloud radiances is sufficient for unambiguous detection and quantification of the first indirect effect. The experimental validation of the second or semi-direct effects raises a severe obstacle, namely to demonstrate that observed changes of liquid water path, cloud thickness or precipitation rate can be attributed to the aerosol and not simply to the natural variability of cloud dynamics. Even ship tracks, that reflect a local aerosol impact embedded in extended cloud layer, exhibit both an increase or a decrease of the liquid water path. Wider pollution plumes can be observed when a marine air mass enters an industrial coastal area. The contributions of the heat plume, or local orographic effects, are however likely to compete with the aerosol impact and prevent its detection. The design of a field experiment dedicated to the detection of the various aerosol impacts on the cloud life cycle therefore requires complementary observations of the aerosol, cloud microphysics and dynamical forcing.