What does nature tell us about anthropogenic aerosol indirect effect?

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It is increasingly realized that clouds are at the heart of physical climate science. They are the most important player in the energy balance of the Earth by interacting with both shortwave and longwave radiation. Tiny changes in cloud properties can have major consequences for our climate. Here I concentrate on how aerosols affect two cloud regimes that may have competing impacts on the climate system. In one, aerosols invigorate maritime tropical convection at a large scale. The invigoration effect manifests in characters of precipitation radar reflectivity vertical profiles, cloud top ice particle size and cloud glaciation temperature. Furthermore, lightning, as a hallmark of strong convection, increases at a rate of 20-40 times per unit increase of aerosol optical depth. I will also discuss how aerosols are affecting cloud macroscopic size and its radiative implications. Aerosol-induced lightning changes also have interesting implications for ozone chemistry and wildfire activity. In the other, aerosols change cloud properties of trade cumuli at a large scale. They decreased cloud droplet size, decreased precipitation efficiency and increased cloud amount. In addition we find significantly higher cloud tops for polluted clouds. Changes in cloud properties caused by aerosols perturbed the energy balance by more than $20Wm^{\wedge-2}$, almost an order of magnitude higher than aerosol direct forcing alone. It highlights the strong leverage of AIE in this cloud regime. Furthermore, the precipitation reduction associated with enhanced aerosol leads to large changes in the energetics of air-sea exchange within trade wind boundary layer. Results from both regimes open up new opportunities for future research in reducing uncertainty surrounding AIEs and climate adaptation/mitigation.