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Depiction of stratocumulus clouds top entrainment in resolved and parameterized models using stable isotope ratios from ORACLES

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Stratocumulus clouds over the eastern side of ocean of basins form in regions of locally low surface temperature and an overlying stable atmosphere. These clouds play a central role in the radiative balance of the atmosphere because of their high reflectivity and their capacity to absorb longwave radiation. Aerosols from biomass burning, industrial activity and other natural sources influence the behavior of stratiform cloud decks because of the differing roles that the aerosols can have on the cloud environment. Key to understanding the interplay between aerosols and liquid cloud behavior is evaluating the rates with which dry air dilutes the cloudy layers and how aerosols influence the condensation and evaporation rates, which are assessed using the disequilibrium state of isotope ratios in clouds.

Stable isotope ratios of water in vapor and condensed phase vary due to differences in moisture source (evaporation over oceans vs continents), and due to fractionation effects that accompany condensation. These properties allow measurements of isotope ratios to be used to identify how air is exchanged between layers above within and below stratocumulus clouds. Isotope ratios of cloud water and vapor were both measured with the Water Isotope System for precipitation and Entrainment Research (WISPER) system during the three-year NASA ObseRvations of Aerosols above CLouds and their intEractionS (ORACLES) in the southeast Atlantic. Using these data alongside other gas phase and aerosol tracers reveals substantial difference in the characteristics of vertical mixing in cases where biomass burning aerosols are in contact with the cloud layer. Using an isotopic characterization of mixing, as a measure of dilution of the cloudy layer by drier air entrainment, is described as a control on the cloud characteristics. The characteristic behavior can be reproduced in detailed process models that resolve the cloud scale motions, while the results are poorly reproduced by a global scale climate model. Consequently, the findings show inadequate treatment of mixing by clouds-scale in global scale models is a significant shortcoming in evaluating the distribution of clouds, and cloud feedbacks.