

An Ultrafine Sea-Salt Flux from Breaking Waves: Implications for CCN in the Remote Marine Atmosphere

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Sea-salt aerosol (SSA) is an important constituent of marine aerosol that influences both direct and indirect forcing. New data on the full distribution of particles produced by oceanic breaking waves reveal sizes as small 0.01 μm and with 60% of them smaller than 0.1 μm diameter. These distributions yield a new SSA source function (Clarke et al, 2006) that compares favorably with previously published estimates but extend it to sizes an order of magnitude smaller. When this new ultrafine SSA flux is applied to oceanic whitecaps it implies strong regional and temporal differences in the open-ocean surface number flux. In clean marine regions, we estimate this direct SSA flux contributes 5% to 95% of marine cloud condensation nuclei, CCN, with the rest accounted for by the flux of aerosol entrained from the free troposphere. These two fluxes appear to account for CCN concentrations in the clean MBL without requiring a nucleation source in the MBL.

This new source function was introduced into the GISS II-prime general circulation model with the size resolved aerosol physics model TOMAS and full coupled sulfur chemistry (Pierce and Adams, 2006). Calculated CCN at 2% supersaturation, CCN(0.2%), were made over the globe in the presence of anthropogenic, continental and natural sources. The presence of an ultrafine component of SSA increased calculated CCN(2%) over most oceanic regions by several to 10% relative to the SSA source functions without an ultrafine component. Increases over the Southern Ocean approached 40% or more. Moreover, the direct SSA flux into the CCN(2%) size range is less than the calculated number of CCN(2%), indicating that growth of ultrafine SSA into the CCN size range occurred due to condensed sulfate. These observations bring additional uncertainty to modeling cloud radiative forcing in regions where SSA is the dominant aerosol species.

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Pierce, J. R. and Peter Adams, Global evaluation of CCN formation by direct emission of sea-salt and growth of ultrafine sea-salt, *J. Geophys. Res.*, 111, D06202, doi:10.1029/2005JD006186