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Marine Aerosols: Hygroscopocity and Aerosol-Cloud Relationships

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LONG-TERM GOALS

The long-term goal of this project is to predict the radiative properties of the marine atmosphere based on aerosol and cloud properties.

OBJECTIVES

The objective of the project is to improve our ability to simulate marine stratocumulus clouds as a function of aerosol properties and the large-scale meterology.

APPROACH

The proposed research consists of laboratory, aircraft experiment, and modeling studies that address the hygroscopic properties of aerosols and aerosol-cloud relationships in marine stratocumulus (MSc) clouds. A CIRPAS Twin Otter field experiment is proposed to take place in July 2011 over the eastern Pacific Ocean off the coast of Monterey, CA. That experiment will address the response of MSc to aerosol perturbations. Collaboration with Professors Bruce Albrecht of the University of Miami and Armin Sorooshian of the University of Arizona is planned in this experiment. Laboratory experiments will be carried out aimed at characterizing the hygroscopic characteristics of mixed inorganic/organic aerosols. The overall goal of the proposed research is to improve our understanding of marine aerosols and their effects on MSc.

We will carry out further development and evaluation of aerosol-cloud relationships in the marine boundary layer. Much work has been carried out directed at understanding the response of marine stratocumulus to perturbations in marine aerosols, including large eddy simulation (LES) and field measurements, the latter including Twin Otter missions such as MASE I and MASE II and those involving other platforms such as DYCOMS and VOCALS, going back to the original MAST campaign. The MAST mission was the first to systematically probe the cloud properties in ship tracks, which have continued to serve as a well-defined example of marine aerosol-cloud perturbations. Important theoretical work remains to be done to fully understand aerosol-cloud relationships in marine stratocumulus. In addition, most of the cloud microphysical modeling done independently or in

conjunction with field missions has yet to be reflected in atmospheric models. It is proposed to continue to carry out microphysical modeling and LES studies with the goal of deriving analytical treatments appropriate for atmospheric models. In addition, the Twin Otter field experiment noted above will involve marine aerosol-cloud measurements. These will involve cloud microphysics closure, which will assess the extent to which model prediction of cloud droplet number concentration, drizzle, and cloud thickness agree with those measured.

WORK COMPLETED

Model description

The Weather Research and Forecasting (WRF) model, designed to improve weather forecasting and explore meteorological features across scales from cloud to synoptic, is a broadly used prognostic model in the atmospheric research community. We have implemented a detailed bin-resolved microphysical scheme (Geresdi 1998; Rasmussen et al., 2002; Xue et al. 2010) in the WRF model as a three-dimensional large eddy simulation model. The detailed bin-resolved microphysical scheme predicts both mass and number concentration, following the moment-conserving technique (Tzivion et al. 1987; Reisin et al. 1996). Cloud drops are divided into 36 size bins with radius ranging from 1.56 μm to 6.4 mm and with mass doubling between bins. Aerosols are divided into 40 size bins in the radius range 0.006 to 66.2 μm.

The microphysical processes include aerosol activation, drop condensation/evaporation, collision-coalescence, collisional breakup, sedimentation and regeneration of aerosols (Fig. 1). Aerosol activation is determined by supersaturation and critical radius based on Kőhler theory. A hygroscopicity parameter, which describes the relationship between dry particle diameter and cloud condensation nucleus activity, is also included to model the composition-dependence of the solution water activity (Petters and Kreidenweis, 2006). The efficiencies of collision-coalescence between drops are derived from the data of Hall (1980). The collisional breakup of water drops is included, following Feingold et al. (1988). The aerosol regeneration mechanism allows the aerosols to be released by evaporated drops; aerosols are conserved in the domain unless the drops fall to the surface. Cloud droplets are defined as drops with radius < 40 μm, while drops with radius ≥ 40 μm are classified as raindrops. Scavenging and dry deposition of aerosol particles are not yet included in the scheme. Other modules applied in the model include a radiation scheme (radiative rapid transfer model RRTM), surface layer scheme (Monin-Obukhov scheme) and turbulence scheme (1.5 order TKE closure).

The model will be used to investigate the dynamical responses of marine stratocumulus clouds (MSc) to aerosol perturbations. Considering different environmental conditions (sea surface temperature, free tropospheric humidity, large scale divergence, etc) as well as aerosol composition, cloud thickness responses and dynamical effects can be explored to study the aerosol-cloud-precipitation interactions. The model is being prepared and tested for use in modeling data to be obtained in next summer's Twin Otter marine stratocumulus experiment.

RESULTS

No publications have yet resulted from this project.

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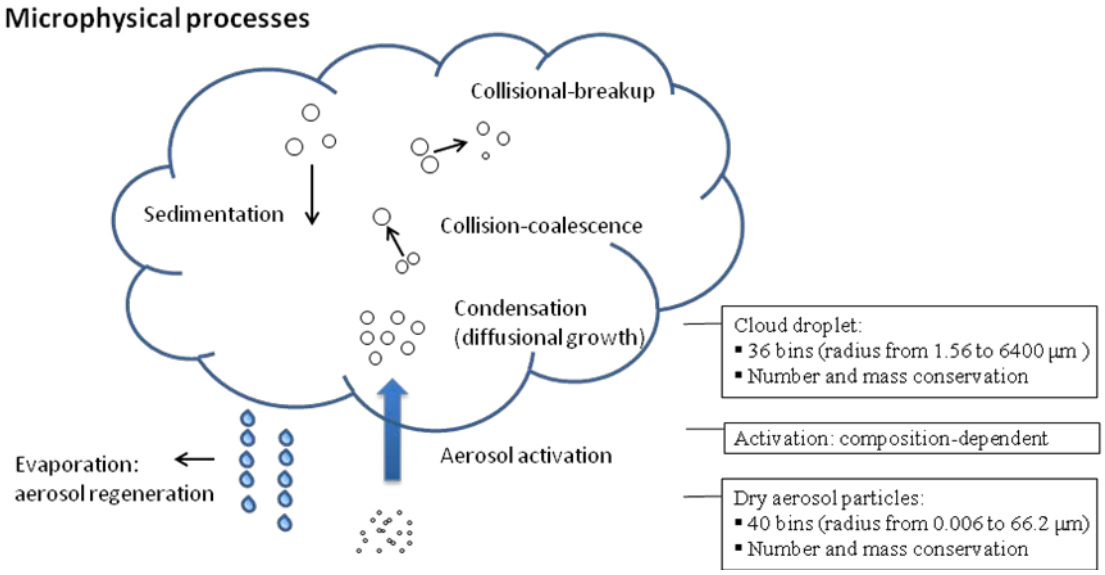

Figure 1. Important microphysical processes in marine cloud formation and evolution. Boxes on the right hand side of the figure note aspects of the bin-microphysical model that will be used in modeling marine stratocumulus.