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2. **Title of Project:** The Numerical Simulation of Marine Boundary Layer Clouds

3. **Research Goal:** To obtain a better understanding of the formation, evolution and dissipation of marine boundary layer clouds.

4. **Objectives:** The primary objectives of the research are to numerically simulate stratus, stratocumulus, and cumulus clouds in the marine boundary layer. This includes the formation, evolution, and dissolution of the clouds and the area covered by the cloud fields. If a large enough domain can be covered, then the change from one type of cloud to another would be investigated. Also the change from open cell to closed cell type convection and the formation of cloud streets could be investigated.

   Another objective is to increase our understanding of conditions in the marine boundary layer. What determines the vertical profiles of humidity, temperature, and cloud characteristics in space and time? What causes the changing depth of the boundary layer? What are its interaction with the clouds in and out of the boundary layer?

   A third objective is to compare various numerical models among themselves and with observations. Such comparisons should indicate ways to improve the model and whether practical predictive cloud models for the marine boundary layer can be constructed.

5. **Approach:** Our approach is to use numerical simulations, compared with observations, to help gain an understanding of the basic physics and most important physical processes involved in marine boundary layer clouds. We are use numerical cloud models to do this.

6. **Tasks Completed:** The major emphasis during the second year of the grant has been to apply a traditional two-dimensional, time-dependent cloud model to the idealized soundings presented by Betts and Boers for clear, cumulus, broken, and stratiform regions. The original runs looked quite good until the cloud liquid water contents were examined. They were too large and indicated that, even though the dynamics of the model were stable, the microphysics was unstable. A cloud microphysical model and a one-dimensional steady state cloud model were run on the soundings to test the conservation of water substance and to check on the number concentration of cloud droplets that should be developed using the given soundings. These runs have been completed and give good agreement with the observations. They also confirmed that the 2D model results were erroneous with respect to the cloud liquid water contents. Essentially, the task of applying a traditional two-dimensional cloud model to marine boundary layer clouds has been accomplished.

   In addition, the task of running the Third International Cloud Modeling Workshop and preparing a report of the results has been completed. The World Meteorological Organization is in the process of printing the final report. One of the cases used in the Workshop was the marine boundary layer case applied in this study.

7. **Accomplishments:** The 2D cloud model runs were analyzed with respect to the high liquid water contents and the problems traced to the size of the eddy coefficients. They turned out to be too small so that numerical stability was not maintained for the cloud physics quantities. The solution of the problem has been to set a minimum value for the mixing coefficient and to change the time step stability requirement based on advection and turbulent mixing considerations.

   The runs with the cloud condensation model indicated that the droplets rising in a plume within the cloud will approach the Hocking "limit" (radius of 18 μm) at a height of 300 m above cloud base in the stratiform case. Liquid water contents at this height were about 0.5 g/kg and would be appropriate to initiate the formation of drizzle.

   Finally, the fraction of cloudiness has been determined from a satellite scene of the days cloud development. The results show the coverage as 0.1%, 15%, 78%, and 100% for clear, cumulus, broken, and stratus regions, respectively. The results compare well with the values reported by Betts and Boers.

8. Statistics:

Contributed Conference Presentations or Manuscripts: none. However, a thesis is in progress.

Graduate Students Supported

Kevin S. McGrath, second year Master of Science degree graduate student.

Undergraduate Students Supported

Jerome Holter, Junior, Electrical Engineering

Statement A per telecon
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