

Stability of Marine Cloud Layers: Computer Simulation and Experimental Verification

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LONG-TERM GOALS

Goals of this project are to identify physical processes that determine the dynamics of the marine-cloud layers and to quantify the roles of turbulence, convection and thermal radiation that play in formation, dissipation and stability of the marine cloud layers.

OBJECTIVES

Immediate objectives of our current research are to advance turbulence models, use efficient numerical scheme, develop computer simulation programs for the marine cloud layers and to compare computer results with published experimental data on the marine cloud layers so as to yield insights into the cloud's physical processes.

APPROACH

Studying the multidimensional cloud layers requires a model that permits high-resolution simulation of turbulence of different scales and domain sizes. For high resolution, detailed second-order-closure model of turbulence may be used, and for calculation efficiency, the large-eddy-simulation (LES) model may be developed. Two computer simulation programs, using the second-order-closure model and the LES model, respectively, have been developed under this program. Further efforts are being made to develop a hybrid model that is based upon a framework of the LES model but uses a database of turbulent energy values predicted by the second-order-closure model and appropriate effective turbulent length scales to calculate the turbulent-diffusion-coefficient values. In addition, confidence in the simulation model is established by comparing simulation results with experimental data from reliable sources.

WORK COMPLETED

Two turbulence models, using the second-order-closure and the LES model, respectively, have been formulated. A comparative study of finite-element and finite-volume procedures has been made. Out-of-the-core computer routines were used to solve directly the matrix equation resultant from the finite-element procedure. However, a tridiagonal-matrix algorithm (TDMA) can be used to conserve the computer storage space. It has been used to solve the matrix equation resultant from the finite-volume procedure. For experimental verification of theoretical results, efforts have been made in tracking the relevant experimental data from reliable sources. Several data sources such as TOGA-COARE

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(Tropical Ocean Global Atmosphere – Coupled Ocean Atmosphere Response Experiment), GCE (Goddard Cumulus Ensemble), FIFE (The First ISLCP Field Experiment), GDAAC (Goddard DAAC) and others were evaluated based on the time interval, grid-size and domain criteria. According to these criteria, two sources of data TOGA-COARE (experimental) and GCE model (Tao 1993) were examined in detail. The GCE model is maintained by Mesoscale Atmospheric Processes Branch (MAPB) at Goddard Space Flight Center (GSFC), NASA; it has been used to correlate the TOGA-COARE experimental data. Through cooperation with the NASA scientists and a permission of using their CRAY computer, Dr. Dhuria, a professor of Information sciences at UDC has decoded several sets of the GCE data and transmitted them to the author. These data are now being used to verify the UDC's model simulation results.

RESULTS

Details of UDC's cloud simulation models, using the second-order-closure model of turbulence and the LES model, respectively, have been published by Chi (1997 & 1998). Efforts have been made to retain the superior resolution with the second-order-closure model and the excellent calculation efficiency of the LES model. Consequently, a hybrid model is developed. It is based upon a framework of the LES model but uses a database of turbulent energy values predicted by the second-order-closure model and appropriate effective turbulent-length scales to calculate the turbulent-diffusion-coefficient values. Results of computer simulation are compared with the retrieved experimental data to established confidence in the model simulation.

Figures 1 and 2 show contours of the correlated experimental wind-stream-function values and the correlated experimental liquid-water-mixing-ratio values, respectively. Figure 3 shows several snapshots of the cloud liquid-water-mixing-ratio contours that have been predicted by the author's hybrid LES model under the same sea-surface flux and other boundary-condition values as provided by the correlated experimental data. Although predictions are not expected to have complete agreement with the experimental data (as precipitation is not considered in the present theory), a great degree of similarity can be observed between the predicted and the correlated experimental cloud contours.

IMPACT/APPLICATIONS

The hybrid turbulence model, under developed at UDC, is based upon a framework of the LES model but uses a database of turbulent energy values predicted by the second-order-closure model. The model does preserve details on turbulence but eliminates the need of continuous evaluation of the second-order turbulence equations. Successful completion of the model will enable predictions of the marine cloud layers using desktop computers. A preliminary evaluation of the model has shown excellent agreement between the simulation results and certain retrieved experimental data.

TRANSITIONS

Results of this study are being compared with data generated by the Goddard Cumulus Ensemble model. Dr. W. K. Tao is a senior scientist in MAPB at GSFC. He is the author of GCE model (Tao 1993) and maintains the system. Mr. Dan Johnson at GSFC operated the GCE model and generated the correlated experimental data for us to use at UDC. Dr. H. L. Dhuria of UDC has interpreted and transferred the UDC computer. Their cooperation has contributed to the performance of the program at UDC.

RELATED PROJECTS

The author and his coworker, Dr. Dhuria have been cooperating with several scientists in Mesoscale Atmospheric Processes Branch at Goddard Space Flight Center. For example, Dr. H. L. Kyle, Dr. W. K. Tao and Mr. Dan Johnson have provided us with valuable help in evaluating of papers and obtaining data to verify our models. Colorado State maintains a web site that contains the TOGA-COARE data sets. Distributive Active Archive Centers (DAAC) that include the Goddard DAAC (GDAAC) are government data centers. They are set up to distributing climate and environmental data to scientists and the general public.

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IN-HOUSE/OUT-OF-HOUSE RATIOS

One hundred percent of this work was done by an academic organization.

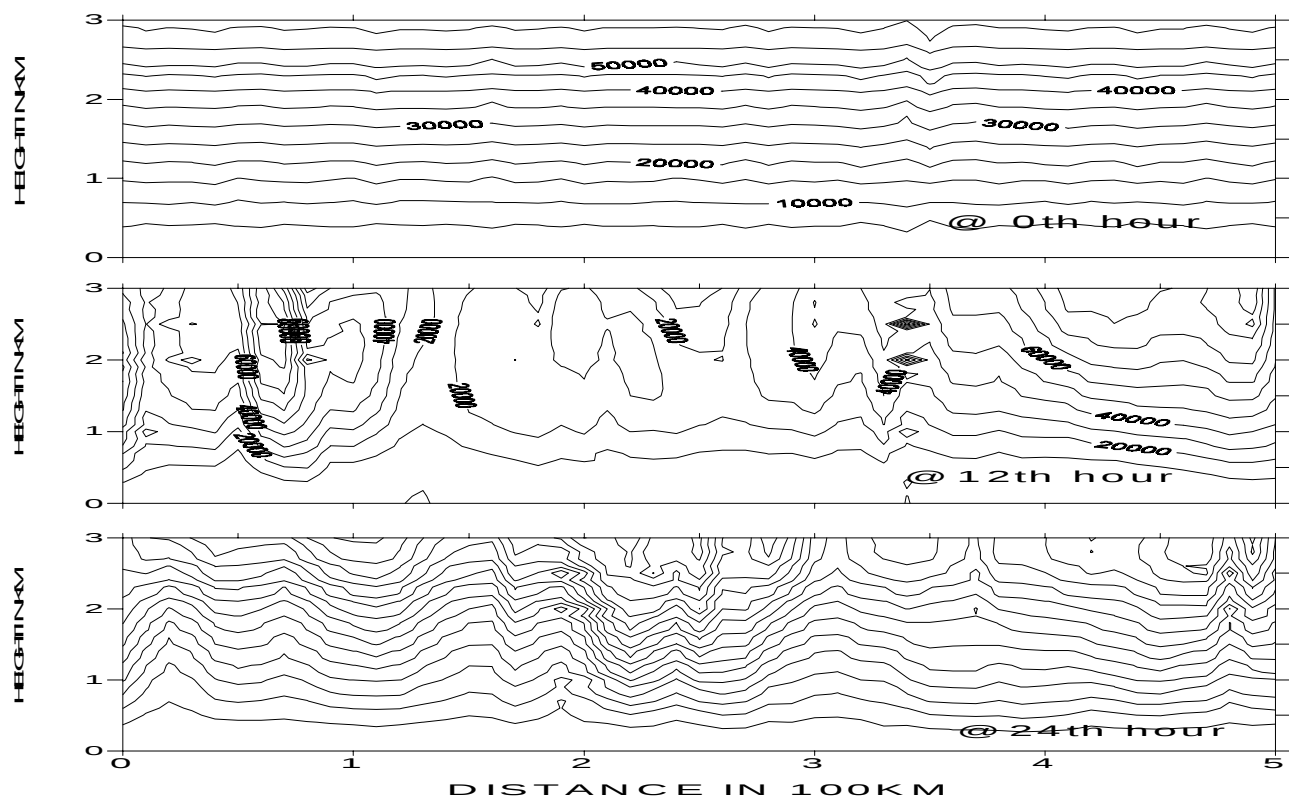


Figure 1: Experimental Stream Function Contours

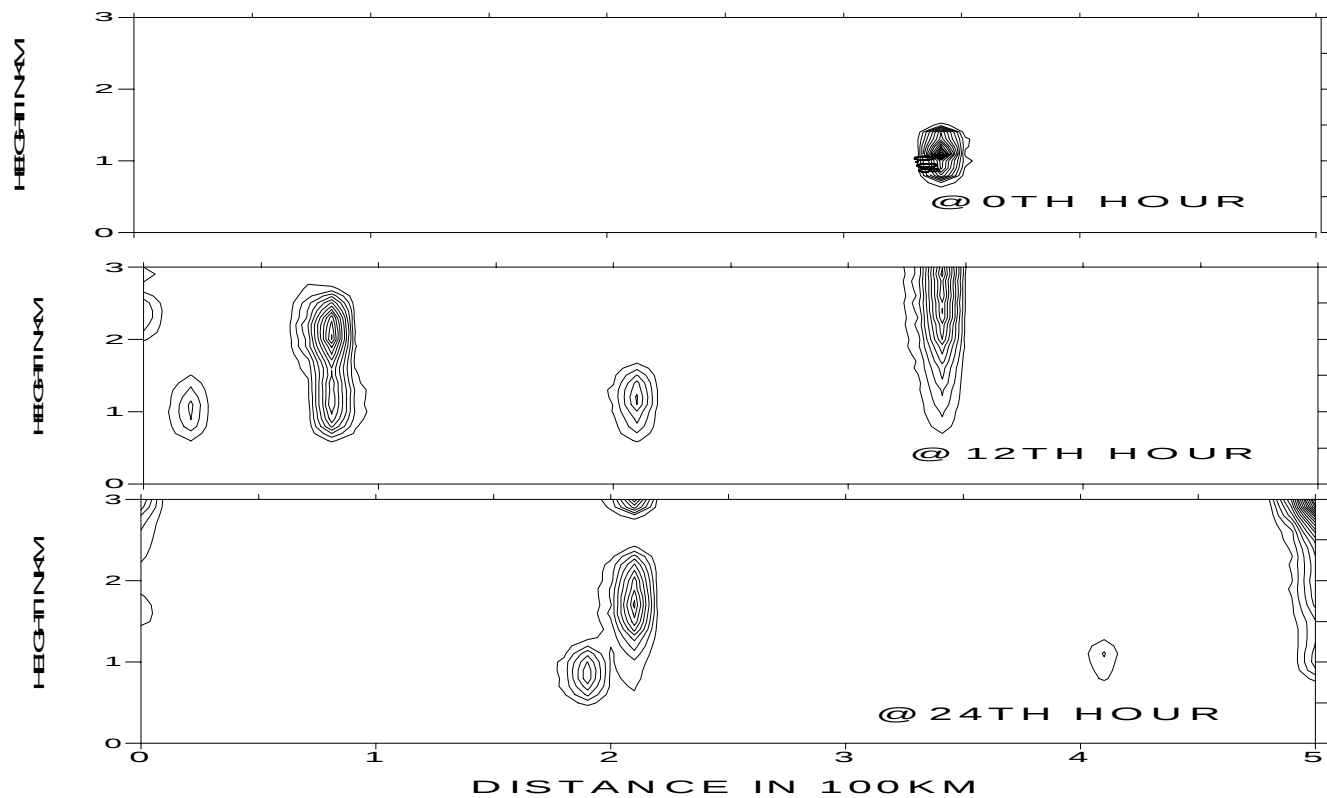


Figure 2: Experimental Cloud Contours

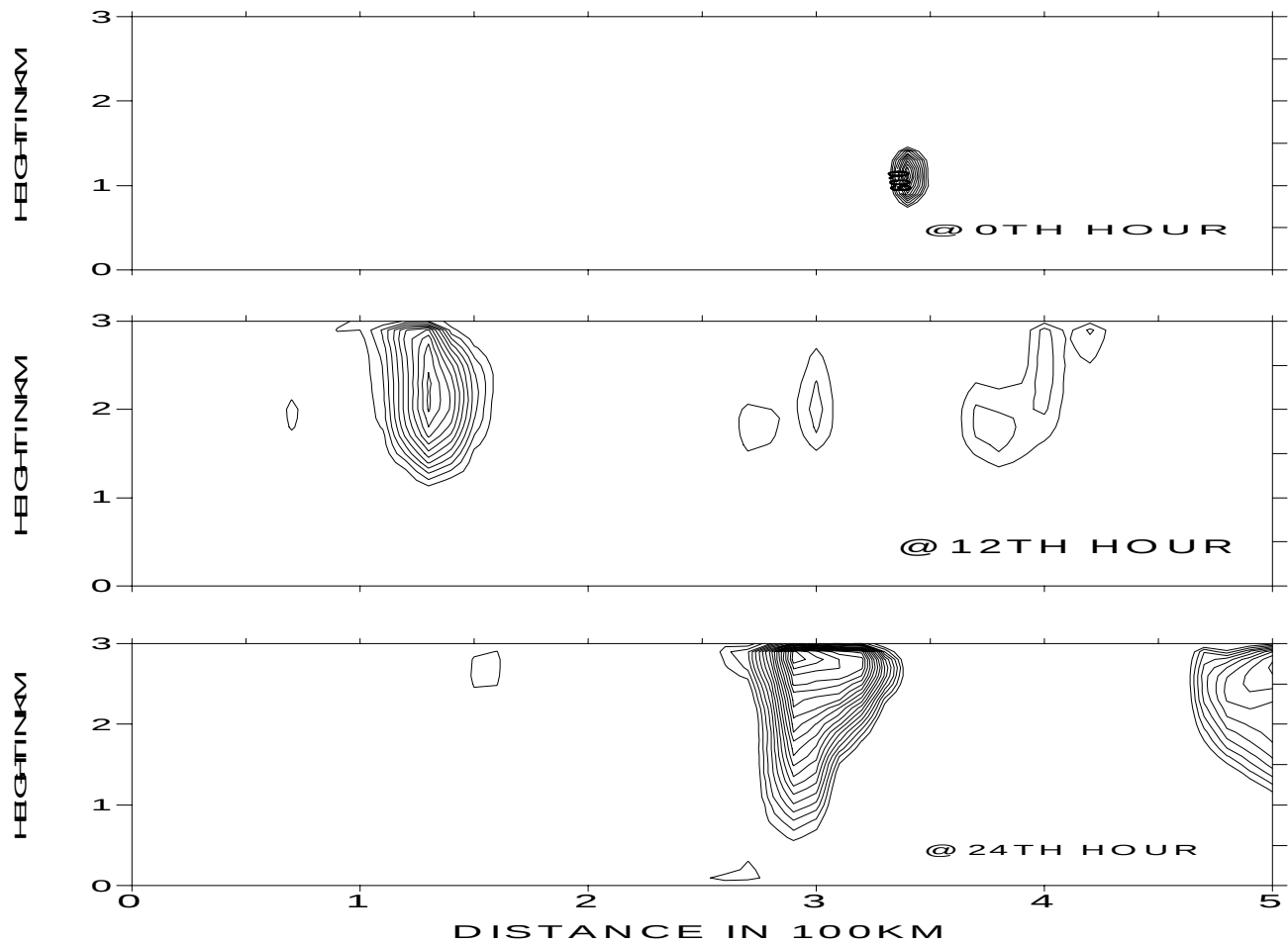


Figure 3: Predicted Cloud Contours