論文内容の要旨

論文題目　Development of a Cloud Microphysics Data Assimilation System over Ocean for Improved Precipitation Prediction by Integrating Satellite Data
衛星観測データの統合活用による降水予報精度向上のための海洋上における雲微物理データ同化システムの開発

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Cloud amounts significantly control the earth's radiation budgets through the change in albedo for short-wave radiation and the out-going long wave radiation. Also, cloud systems cause large radiative and latent heat evaporation cooling/heating to the atmosphere. Inhomogeneous diabatic heating associated with clouds produces available potential energy and drives the atmospheric motion with various scales. In numerical simulation models, shortcomings of cloud parameterization considerably limit their predictability for short and medium-range predictions and bring large uncertainties to climate projection. Therefore there is a need of higher-resolution advanced regional models alongwith accurate inclusion of cloud microphysical processes in numerical models for reliable weather forecasting and climate prediction, which requires a reliable specification of the initial atmospheric conditions.

Therefore to have accurate estimate of the spatial distributions and temporal variations of the cloud microphysics parameters, we need to develop a variational data assimilation system for cloud microphysics based on satellite observations. This system has potential to assimilate passive microwave remote sensing observations into the cloud microphysics scheme and whose output can be used to improve initial conditions of the atmospheric model. By the downscaling manner, initial conditions for local grid scale model can be obtained for having reliable precipitation forecast over the ungauged basins. Furthermore the application and validation of such a cloud microphysics data assimilation system over the land can be further performed by coupling it with a land data assimilation system (LDAS). Adequate estimates of land surface variables can be obtained with this system by providing detailed spatial patterns of precipitation and quantitative precipitation data to the soil moisture data assimilation.

The selection of variational data assimilations scheme in the present research is also due to its characteristics of offering the possibility of achieving the optimal performance of Kalman filters with the computational efficiency of sub optimal methods. Also variational methods do not explicitly evaluate the large error covariance matrices which are propagated by Kalman filters. Instead, variational algorithms simultaneously process all of the data within a given time period (or “assimilation window”) and the adjustment process is simultaneous. The adjusted states at all times are influenced by all of the observations over the assimilation window.

It is believe that the initialization and forecast of the state variables of the variational cloud microphysics data assimilation system for warm and cold cloud processes might be improved by the assimilation of remotely sensed data. Therefore having such intention in mind, an efficient algorithm of one dimensional variational (1DVAR) Cloud Microphysics Data Assimilation System (CMDAS) for warm cloud processes and 1DVAR Ice Cloud Microphysics Data Assimilation System (IMDAS) for cold cloud rain processes have been developed. Both assimilation systems have been used to solve the initialization of the state variables using available in-situ and satellite observations over the ocean by considering the integrated cloud liquid water (ICLWC) and integrated water vapor (IWV) content as assimilation parameters.

The general framework of CMDAS and IMDAS includes the Kessler warm-rain cloud microphysics scheme and Lin ice microphysics scheme as the model operator respectively. The common framework of the two data assimilation systems consists of a 4-stream fast microwave radiative transfer model in the atmosphere and a heuristic minimization approach called Shuffled Complex Evolution (SCE), which is capable of minimizing the cost function without using an adjoint model (gradient vector). SCE can result in a robust global searching scheme that conducts an efficient search on the feasible space. Due to high computational cost problem, the environmental forcing effect is neglected at the moment in both systems.

Both assimilation systems are applied to the microwave radiometer data set obtained by the international cooperative observation experiment, "Wakasa Bay Experiment 2003", in Japan. The potential of the CMDAS and IMDAS are investigated to modify the cloud properties by considering the assimilation parameters of ICLWC and IWV and to introduce the heterogeneity into the initial state of the atmosphere. From these two assimilation systems, it is also possible to perform the sensitivity analysis under different weather events to see which has more potential to produce the better initial conditions and how much these improved initial conditions will have positive impact on the reliable estimation of precipitation by the Advanced Regional Prediction System (ARPS) model.

The simulation results of CMDAS and IMDAS with the observed AMSR-E Tb 89.0H GHz and 23.0H GHz values identify clearly their effects on the cloud distribution mapping and show the comparable structure of cloud system with Moderate-resolution Imaging Spectroradiometer (MODIS) image for cloud top. Both systems have improved the performance of cloud microphysics schemes significantly by the intrusion of heterogeneity into the external Global Reanalysis (GANAL) data, which resultantly improved atmospheric initial conditions. It also concluded that IMDAS comparatively work well compared to CMDAS due to capability of considering the all types of precipitation hydrometeors.

Furthermore, total precipitation rate derived by ARPS with improved initial conditions provided by CMDAS and IMDAS reveal a good agreement of the spatial distribution of the precipitation rate with precipitation rate derived by 3-D Doppler radar reflectivity data. But at a few places, it has been observed that ARPS has over-predicted the precipitation along with some spatial displacement which needs to explore in details.