Remote Sensing and Data Assimilation of Hydrological Components in the Coming Era of Earth Observation

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Soil moisture, snow and precipitation are key parameters in numerous environmental studies, including hydrology, meteorology, and agriculture. They play important roles in the interactions between the land surface and the atmosphere, as well as the partitioning of precipitation into runoff and ground water storage and absorbed solar energy into sensible and latent heat flues at the land surface. They are, therefore, important variables in many hydrologic, meteorological, and climatic investigations. Recent studies with the general circulation models (GCMs) using active land surface parameterization have shown that strong feedbacks existed between the soil moisture, snow, and precipitation anomalies and climate. Passive microwave remote sensing provides the most feasible technique to monitoring spatially distributed soil moisture and snow over land and precipitation over ocean in a large scale. The sensitivity to soil moisture of brightness temperature at low frequencies is a well-known phenomenon. Methods to estimate regional to global snow depth or snow water equivalent (SWE) have been developed based on snow particle scattering in microwave region. Radiation emission for liquid phase and scattering extinction for solid one are used basically for monitoring precipitation over ocean at high frequencies. The current techniques or algorithms need to be further improved or developed in order to obtain the required accuracy for atmospheric and hydrologic modeling. The key elements of the radiative transfer models, for example, vertical profiles of soil moisture, snow grain size and water vapor and air temperature, can not be obtained only by passive microwave remote sensing. To solve these issues, it is effective to assimilate passive microwave remote sensing data with numerical simulation schemes, Land Surface Schemes, Snow Physical Models, and Cloud Microphysics Models, which are embedded in GCMs or regional models. A Land Data Assimilation System (LDAS) has been developed by combining the SiB2 as a model operator and a 0-order Radiative Transfer Model (RTM) as observation operator. The validations of the LDAS were carried for different land surface classification with several types of vegetations and several land surface roughness conditions by using a ground-based passive microwave radiometer which has same set of frequencies of AMSR and AMDR-E. The results of the experiment shows a high performance of the LDAS and emphasize the relative importance of ground-based experiments and the impact of land surface heterogeneity when using coarse scale satellite database retrieval algorithms. To assess the efficiency of the new system, an idealized 2-dimensional numerical experiment was carried out in the mesoscale area of the Tibetan Plateau. The results showed significant differences compared with standard regional atmospheric model outputs; and were more consistent with the satellite microwave brightness temperature observations that improved the spatial distribution of soil moisture, which strongly affected the convection systems. It is well known that the 89 GHz channel shows sensitivity to the new amount of snow on the ground. A variational data assimilation method for new snow accumulation between two satellite overpasses has been developed by a simple snow physical model as a model operator and a radiative transfer model in microwave region as a observation operator. The old brightness temperature, the adjusted precipitation and the density of the fresh snow are input parameter for a radiative transfer model. The result is compared with the new brightness temperature and by iteration the precipitation data is adjusted until the modeled value agrees well with the new brightness temperature. Good results have been achieved using snow pit data from Sapporo and modeled brightness temperatures. The results of a sensitivity study indicate that the approach is especially sensitive to detect large amount of new snow on the ground, on the other hand the error is large for low precipitation events. Furthermore the results indicate that the sensitivity is to low to assimilate the new snow density. An 1-D Cloud Microphysics Data Assimilation Scheme (CMDAS) for mesoscale modeling has been developed over the Sea of Japan. The algorithm includes Kessler warm-rain cloud microphysics scheme, a radiative transfer model (RTM) in microwave region, and an optimization method named Shuffled Complex Evolution (SCE). Initially Kessler scheme without application of CMDAS was analyzed which showed homogeneous structure of brightness temperature (TB) due to homogeneity of external GANAL (Global Analysis) data provided from Japan Metrological Agency (JMA). In order to introduce heterogeneity by improving initial state of the atmosphere, CMDAS was operated by using the output from non-hydrostatic model known as Advanced Regional Prediction System (ARPS) as a first guess by using GANALdata set. RTM is solved using the discrete ordinate method (4 streams) and the Henyey-Greenstein phase function. The SCE method is used to minimize the difference between modeled and observed TB at 89 GHz horizontal polarization by adjusting the atmospheric parameter of cloud liquid water content (CLWC). The algorithm was applied for the period of the Wakasa Bay Experiment 2003 in Japan, which was part of the AMSR/AMSR-E validation project. The performance of algorithm has shown good qualitative and quantitative agreement of TB and integrated cloud liquid water content (ICLWC).