A study on the optimal data assimilation system for the whole neutral atmosphere

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In the middle atmosphere, Rossby waves and gravity waves, which mainly originate from the troposphere drive the Lagrangian flow by momentum and heat transport. The thermal structure and the mean zonal wind structure in the thermal wind balance are much different from the state of radiative equilibrium. Recent studies suggest the presence of an interhemispheric coupling which occurs through a change in the upper mesospheric circulation.
Observations in the mesosphere are sparser than those in the troposphere, and the model predictability is not sufficient to simulate behaviors of the real atmosphere. Thus, global data estimated by the mesospheric data assimilation system is a key for quantitative evaluation of the momentum budget. However, the data assimilation for the atmosphere including the mesosphere has not yet been common. The purpose of this study is to develop the assimilation system and to make global data for the wide height region from the ground to the lower thermosphere.
The data assimilation was performed for the time period from January 10 to February 20, 2017, when one of the series of international observation campaigns called ICSOM, which first utilizing the atmospheric radar network, was performed. A sudden stratospheric warming occurred in the Arctic on February 1.
The forecast model is the Japanese Atmospheric GCM for Upper Atmospheric Research (JAGUAR; Watanabe and Miyahara, 2009). The model has horizontal a resolution of T42 (~300 km). Diffusion coefficients and a tuning parameter of non-orographic gravity wave parameterization in the model were modified by comparing with atmospheric radar observations in the summer mesosphere.
A conventional observation data set called PREPBUFR, which covers from the ground to the stratosphere, and the satellite temperature retrieval data from Aura MLS in the stratosphere and mesosphere were used. We adopted the method of 4-D Local Ensemble Transform Kalman Filter (4D-LETKF) for the data assimilation, and examined relevant values of the parameters which should be given for the data assimilation system. The parameters used in the assimilation for the troposphere and stratosphere may not necessarily be appropriate for those in the assimilation for the mesosphere and lower thermosphere. Only one out of several parameters in the assimilation system was changed to examine the impact to the analysis data. The analysis data obtained by each test assimilation were compared with MLS observations and MERRA-2 reanalysis data.
The tuned parameters for the assimilation were the number of ensemble members, the localization length, the assimilation window, and the covariance inflation coefficient. It was found that ~100 ensemble members which are much more than the default (30 members), longer localization length, and larger inflation are effective, although the assimilation window does not change the performance much.
The parameters regarding the treatment of observation data were also examined: the subtraction of the MLS observation bias by making a bias table as a function of time, latitude, and height, using less-biased SABER data which were not always obtained globally; the super-observation adjusting the density of observation data to the model resolution; the inflation of observation error during the startup time; and the degree of the gross error check. It was found that these parameters should be set differently for the mesosphere and lower thermosphere form the standard.
Last, the assimilation with the best parameter set was performed. It was confirmed that the obtained analysis data were plausible by comparing with the MLS observation, and with MERRA-2 reanalysis data

for the available height region, as shown in Figure 1. The analysis data were examined using theoretical framework of the Transformed-Eulerian-Mean equations from a viewpoint of the difference between before and after the sudden stratospheric warming during ICSOM campaign.

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