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Data assimilation experiment of water vapor data derived from a hyper-dense GNSS network using a nested LETKF system

OIGAWA, Masanori[1*] ; TSUDA, Toshitaka[1] ; REALINI, Eugenio[1] ; IWAKI, Yuya[1] ; SEKO, Hiromu[2] ; SHOJI, Yoshinori[2] ; SATO, Kazutoshi[3]

[1]Research Institute for Sustainable Humanosphere (RISH), Kyoto University, [2]Meteorological Research Institute (MRI), Japan Meteorological Agency (JMA), [3]Japan Aerospace Exploration Agency (JAXA)

Data assimilation of observation data with high spatial and temporal resolutions within a numerical weather prediction model is important, in order to provide it with accurate and detailed initial conditions, which generally result in improved forecast accuracy for localized heavy rainfall. Assimilation of water vapor data is especially important because water vapor has a powerful effect on the initiation and development of cumulonimbus clouds. Many assimilation studies reported on the significant and positive impact of assimilating GNSS (Global Navigation Satellite System) derived PWV (Precipitable Water Vapor) data, i.e. the vertically integrated water vapor amount, on the modification of the initial distributions of water vapor, as well as on the forecast accuracy of localized heavy rainfall. The Japan Meteorological Agency (JMA) routinely assimilates PWV data derived from the nationwide GNSS observation network (GEONET) operated by the Geospatial Information Authority of Japan (GSI), which has a horizontal resolution of about 20 km. It is expected, however, that the assimilation of PWV data with higher spatial resolution will be needed as the horizontal resolution of numerical models becomes higher. Therefore, we investigated the assimilation impact of high resolution PWV observations derived from a hyper-dense GNSS network with a horizontal resolution of about 1 km, which we installed near Uji campus of Kyoto University (Sato et al., 2013).

The data assimilation carried out in this report is based on a two-way nested Local Ensemble Transform Kalman Filter (LETKF) system (Seko et al., 2013). Experiments were performed involving a heavy rainfall event that occurred on 14 August 2012, which brought about 260 mm of accumulated rain amount in 6 hours. First, GEONET-derived PWV data were assimilated into an outer model, with horizontal resolution of 15 km. The analysis window and assimilation interval of this first experiment were 6 hours and 1 hour, respectively. Next, PWV data derived from the hyper-dense GNSS network were assimilated into an inner model, with horizontal resolution of 1.875 km. The analysis window and assimilation interval of this second experiment were 1 hour and 10 minutes, respectively. Surface observations and upper atmospheric sounding data used in operational analyses by JMA were also assimilated in both the experiments.

In an experiment without assimilation of any PWV data, the location of the reproduced rainfall region was shifted, and the precipitation intensity was lower, compared with the observation result. When GEONET-derived PWV were assimilated into the outer model and no PWV data were assimilated into the inner model, the location of the simulated rainfall system was improved, although there was no modification in precipitation intensity. When PWV derived from the hyper-dense GNSS network was assimilated into the inner model together with the assimilation of GEONET-derived PWV into the outer model, the precipitation intensity was also modified in addition to the modification of rainfall system location.

These results suggest the usefulness of assimilating high spatial resolution PWV data for heavy rainfall forecast. In the future, we are planning to investigate how the assimilation impact of high resolution PWV data will change depending on the number of observation points of the hyper-dense GNSS network. In this talk, assimilation results of slant water vapor data will also be reported, which is the accumulated water vapor amount along ray paths of radio signals from a receiver to GNSS satellites.

Keywords: Data assimilation, local heavy rainfall, Hyper-dense GNSS observation, nested LETKF