Improvement of weather forecast by assimilating stable water isotopes

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Water vapor isotopes are sensible to phase transition and have characteristics that heavier molecules such as HDO or H218O more condense and less evaporate preferentially than common H2O. Because of these characteristics, the spatio-temporal distribution of water vapor isotopes exists. Paleoclimate, atmosphere dynamic field and so on are studied using these unique characteristics.
Yoshimura et al. (2014; hereafter Y14) conducted observation system simulation experiments (OSSE) and indicated HDO and H218O have the potential to constrain the atmospheric dynamic fields by assimilating these isotopes. Number of the data of water vapor isotopes are rapidly increasing. In this research, it will be quantitatively evaluated how much water vapor isotopes can constrain atmospheric dynamic field, and how big is the impact of the satellite-based water vapor isotope spectrometers on understanding of water circulation not using mocked data but actual data from the Infrared Atmospheric Sounding Interferometer (IASI) installed on MetOp satellite.
In this research, I have used Isotope-incorporated Global Spectral Model (IsoGSM) as a numerical model, and local ensemble transform Kalman filter (LETKF) as a data assimilation system. IsoGSM was constructed by incorporating gaseous forms of isotopic species (HDO and H218O) into the Scripps Experimental Climate Prediction Center (ECPC) Global Spectral Model (GSM) as prognostic variables by Yoshimura et al (2008).
In IsoGSM, water vapor advection, water condense of water evaporation while convention and isotope fractionation are written in detail. LETKF have characteristics which is better calculate efficiency and lighter than ordinary data assimilation system. Calculation process is following. 1. Make 20 perturbed ensemble members, 2. calculate first guesses, 3. data assimilation using LETKF, 4. make analysis values(forecast values), 5. make first guess by put analysis value as initial value into IsoGSM, then these 2-5 processes are repeated. I have conducted OSSE as preparation before using real data. We assumed that observation data were column average of δD and 600 hPa δD from satellite and surface δD and δ18O from GNIP, and GNIP was supposed to set about 400 points worldwide. In Y14, they conducted OSSE only January 2006, but I conducted OSSE for a long time to know how behavior are seen if we run for a long time.
The results are following. We compared assimilated results with non-assimilated results about RMSD of meteorological variables including assimilated variables both global and near GNIP points. Basically, although assimilated results are better accuracy than non-assimilated one in early calculation, as time goes by, assimilated results get worse. We checked also the results get worse as it goes higher. However, near GNIP points and assimilated variables are not necessary to be applicable to this. We checked kinetic energy then it was revealed that kinetic energy is bigger in higher wave than lower layer. Two potential remedies are to be considered. One is “to modify the model.” For example, we can change diffusion coefficient in horizontal diffusion to decrease kinetic energy. The other is “to improve the data assimilation system.” The height of assimilated isotopes is near surface, 600 hPa and column average, but these assimilated variables have influenced at altitude of 30 km. Since there is little physical interaction between the stratospheric variables and those assimilated variables, this influence was occurred superficially by numerical reasons. This might cause error in high layers. Therefore it would be effective to make some weighting to the influence of the assimilation.
For now, the experiments have been conducted by weighing each layer with diffusion coefficient times 1 in the lowest layer and times 10 or 100 in the highest layer. Because these experiments caused a few

changes, we will try modifying the data assimilation system further.

Keywords: water vapor isotopes, data assimilation, numerical model

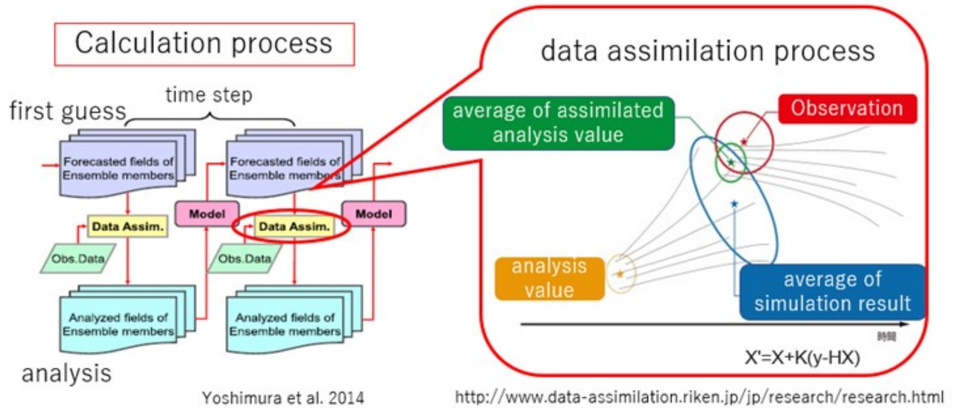

fig1. Calculation processes in the model and the data assimilation system.

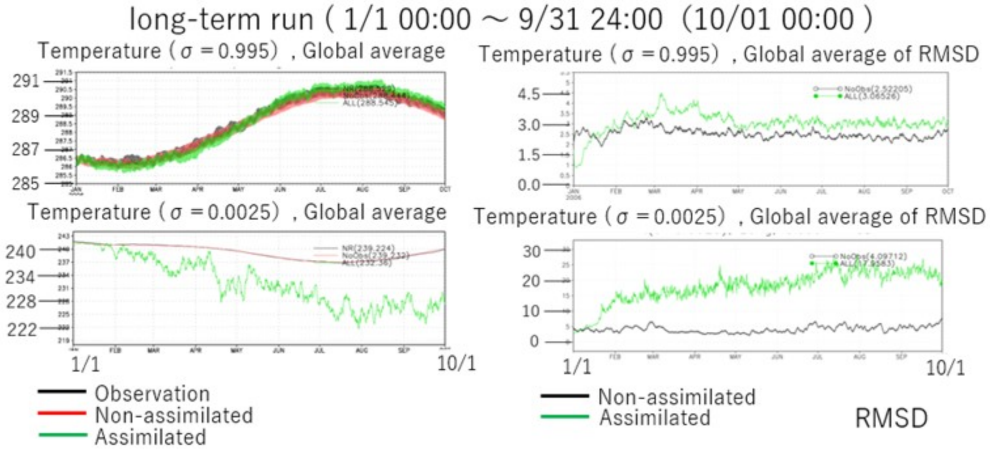

fig2. Time series of temperature (left) and RMSD of temperature (right).
Upper shows surface temperature, lower shows stratosphere.
σ means " sigma coordinate, σ =p/ps ."

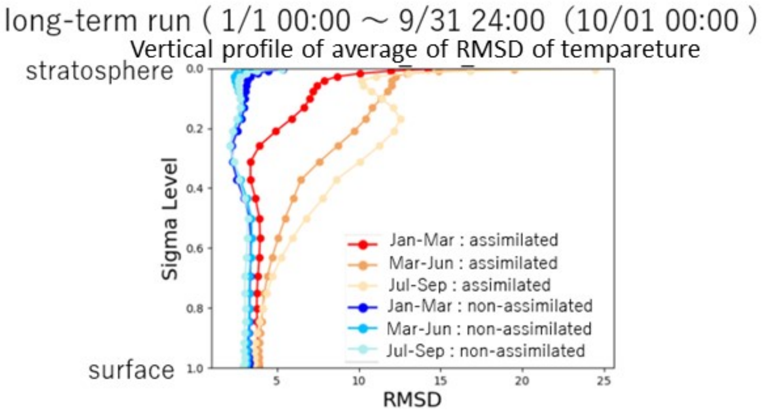

fig3. Vertical profile of RMSD (Temperature) for every 3 months As time goes by and get higher, assimilated data get worse. The cause of these bug is not identified concretely, but it is possible that assimilating isotopes near surface in upper layer yields bad something.