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An Evaluation of implementing 3D-VAR data assimilation on WRF

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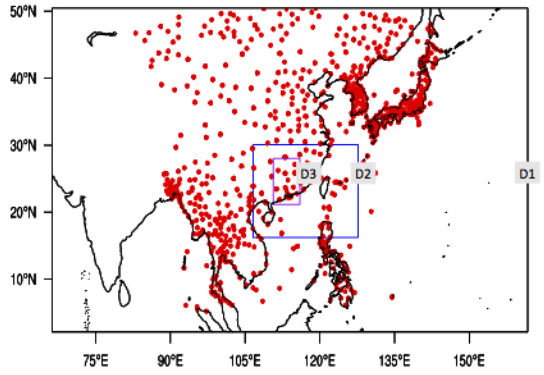
Abstract

An initial condition that closer represents the true atmospheric state can minimize errors that propagate into the future, which could theoretically leads to improvements in the forecast. This study aims to understand and evaluate the sensitivity of the model, as well as to quantify the improvements of the forecasts due to the act of applying data assimilation. Our observation data are provided by NCEP that includes Surface (METAR, SHIPS, etc.) and Upper-Air (RAOB, ACARS, etc.) data. Three Dimensional Variational (3D-VAR) data assimilation method is applied to assimilate the NCEP observation data onto our background state, which is generated by the WRF Preprocessing System (WPS). The improvements of the initial condition and the forecasts are systematically compared and are quantified in terms on 2m temperature, relative humidity, sea level pressure, wind speed and direction. We initialized a 4 days forecast (including 24 hours of spin up time) every 24 hours for the month of December (31 runs in total) while applying 3D-VAR on domain 1 and 2. Comparisons are done on domain 1 and 3 between observations. Preliminary results show that 3D-VAR has significantly improved the initial condition, which brings major improvements to 2m temperature on both domain 1 and 3 across the 96 hours of forecasts.

Domain configuration

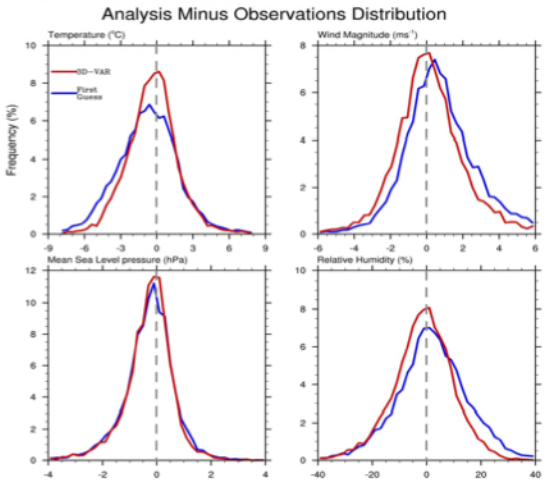


This is the domain setup of our model, domain1 (D1), domain2 (D2), domain3 (D3) with resolution of 27km, 9km, and 3km respectively. There are a total of 1000 stations in the format of SYNOP, METAR, SHIPS, BUOYS, SONDE and SOUNDINGS.

Evaluation on the initial conditions

A month of initial conditions were being examined, namely "First Guess" and "3D-VAR". "First Guess" is the control setup which is generated by WPS without any modification being done. "3D-VAR" is a set of initial conditions that are generated by WPS and went through the 3D-VAR data assimilation process.

By dividing the differences between the analysis and the observations into 40 bins, the results show that initial conditions with 3D-VAR being applied are more accurate with a mean difference closer to 0 and narrower spread (lower standard deviation, smaller range between lower and upper 5%). The larger kurtosis supports that the distribution curve is more leptokurtic, stating that the analysis is now lying more closely to the observations.



Evaluation of the forecasts (D1)

Within the first 24 hours of forecasts, initially, the RMSE of 2m temperature and relative humidity has been significantly corrected by 3D-VAR (Figure 1a). Even though the immense improvement is mostly dissipated after 24 hours due to imperfect model and boundary condition, there is a general trend in reduction of RMSE for all the variables except 10m wind. As for the bias, figure 1b shows that 3D-VAR reduces the bias of 2m temperature, relative humidity, and sea level pressure further beyond 24 hours. This shows that the improvements brought by 3D-VAR are not limited only within the 24 hours period in the regional model.

Fig 1a. RMSE

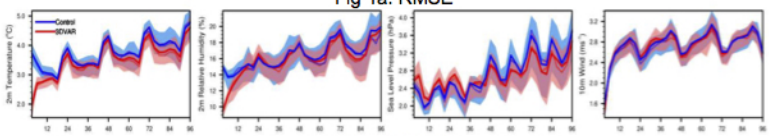
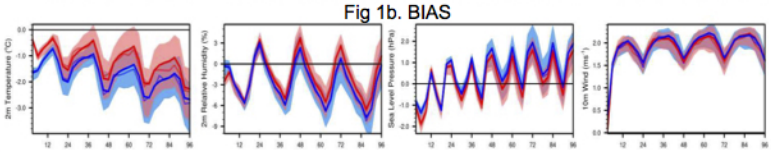


Fig 1b. BIAS



Evaluation of the forecasts (D3)

Although 3D-VAR is not applied here, more accurate information is passed down from previous domains contributing to the improvements on this domain. From figure 2a & 2b, there are observable improvements in all the variables, with 2m temperature and relative humidity again being the most significant and consistent. These improvements can be seen at 36 hours and have increased as time progressed. The result shows that 3D-VAR applied on a nested WRF are not only capable of correcting the bias but also constricting the error of the model, prolonging the improvements on child domains.

Fig 2a. RMSE

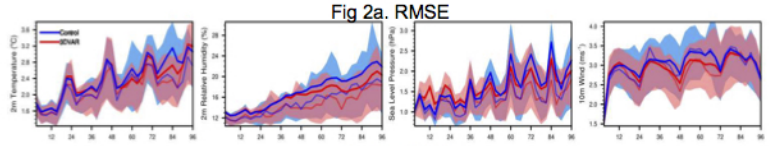


Fig 2b. BIAS

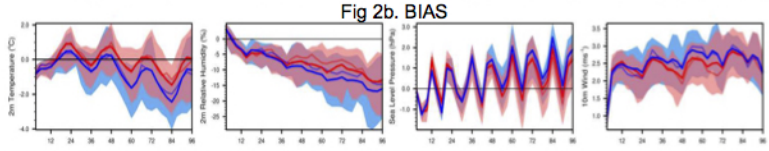


Figure 3. shows the prediction of the 2m temperature of a typical simulation between the forecast range of 48-72 hours. In this scenario, the RMSE of the 3D-VAR case is 2.4oC, 31% better than the control case which has an RMSE of 3.5oC. 3D-VAR contributes to a warmer environment that correlates more with the observations. It is shown that 98% of observations were more accurately represented (green dots).

Fig 3. Observations vs model (HKT 04:00:00 31/12/2015)