Investigating sources of error in numerical weather prediction with an OSSE

N.C. Privé[1,2] and R.M. Errico[1,2]

[1] Morgan State University, Goddard Earth Sciences Technology and Research, Baltimore, Maryland

[2] National Aeronautics and Space Administration, Global Modeling and Assimilation Office, Greenbelt, Maryland

The NASA/GMAO OSSE

An Observing System Simulation Experiment (OSSE) is a pure modeling study used when actual observations are too expensive or difficult to obtain. OSSEs are valuable tools for determining the potential impact of new observing systems on numerical weather forecasts and for evaluation of data assimilation systems (DAS). An OSSE has been developed at the NASA Global Modeling and Assimilation Office (GMAO, Errico et al 2013).

The GMAO OSSE uses a 13-month integration of the European Centre for Medium-Range Weather Forecasts 2005 operational model at T511/L91 resolution for the Nature Run. Synthetic observations are based on real observations during the period of 15 June to 5 August 2005. Errors are added to the synthetic observations to emulate representativeness and instrument errors.

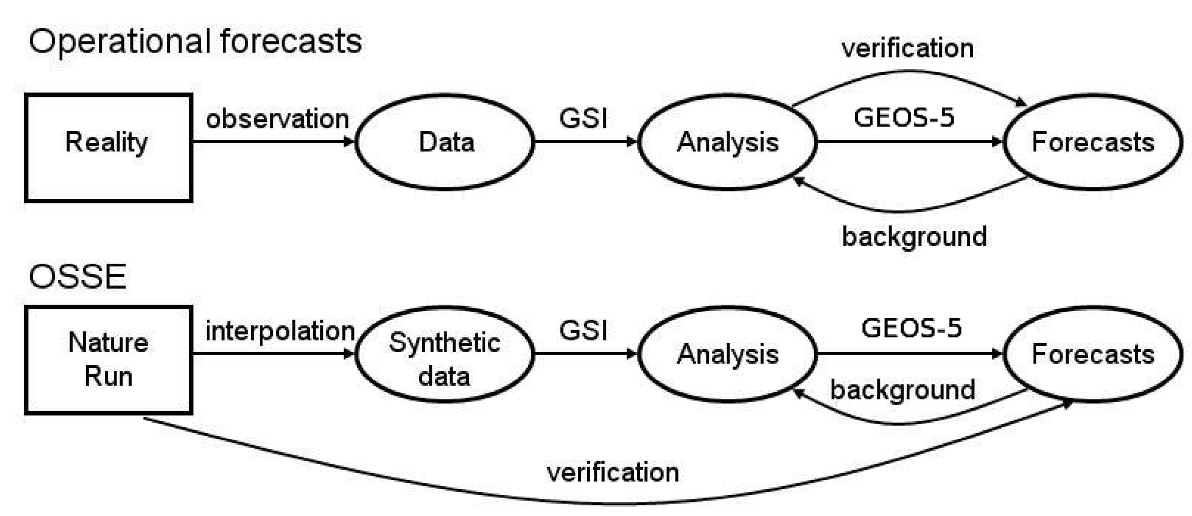

Figure 1. Schematic diagram illustrating the differences between an OSSE and operational numerical weather prediction.

The forecast model used by the GMAO OSSE is the Goddard Earth Observing System Model, Version 5 (GEOS-5) with Gridpoint Statistical Interpolation (GSI) DAS. Forecasts are run with horizontal resolution of 0.5º in latitude and 0.625º longitude with 72 vertical levels. The DAS is cycled at 6-hour intervals, with 120 hour forecasts launched daily at 0000 UTC. For a subset of experiments, an "identical twin" framework is used, in which the ECMWF Nature Run is replaced with a two-month free run of the GEOS-5 model.

Sources of Error

Five experiments are performed with the GMAO OSSE to explore the role of different error sources in numerical weather prediction (NWP). A Control experiment is run using the baseline OSSE system with a realistic global observation network and calibrated observation errors. To investigate the role of observation errors, a "No Error" (NE) case is run in which explicit observation errors are not added to the synthetic observations. A third case (DENSE) is performed using an "ideal observing network" consisting of a global grid of more than 80,000 rawinsonde observations at each cycle time. The final two experiments use the identical twin framework with (Twin Control) and without (Twin NE) added observation errors to explore the role of model error.

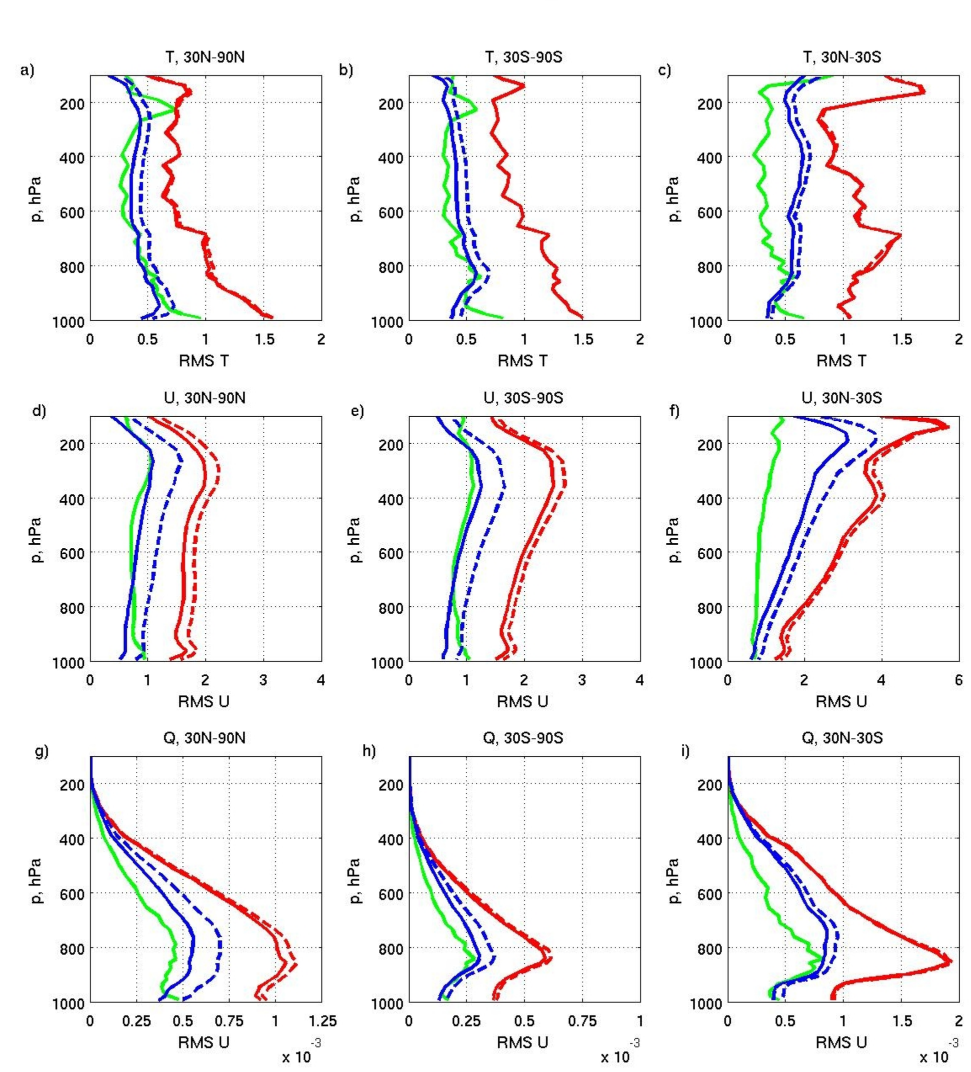

Figure 2. Areal averaged root-mean-square analysis error of the five cases in three regions: DENSE, green; NE, red dashed; Control, red solid; Twin NE, blue dashed; Twin Control, blue solid.

The root-mean-square analysis error for the month of July is shown for the five cases in Figure 2, verified against the Nature Run. The lowest error is seen in the DENSE case, where the observations strongly constrain the analysis state. The presence of explicitly added observation errors acts to degrade the analysis quality, most noticably in the twin framework.

Figures 3 and 4 illustrate the actions of the DAS when generating the analysis state. The time mean analysis increment indicates regions of model bias that are adjusted by observational data ingestion. The variance of analysis increment likewise shows regions of rapid non-bias error growth that are corrected by observations.

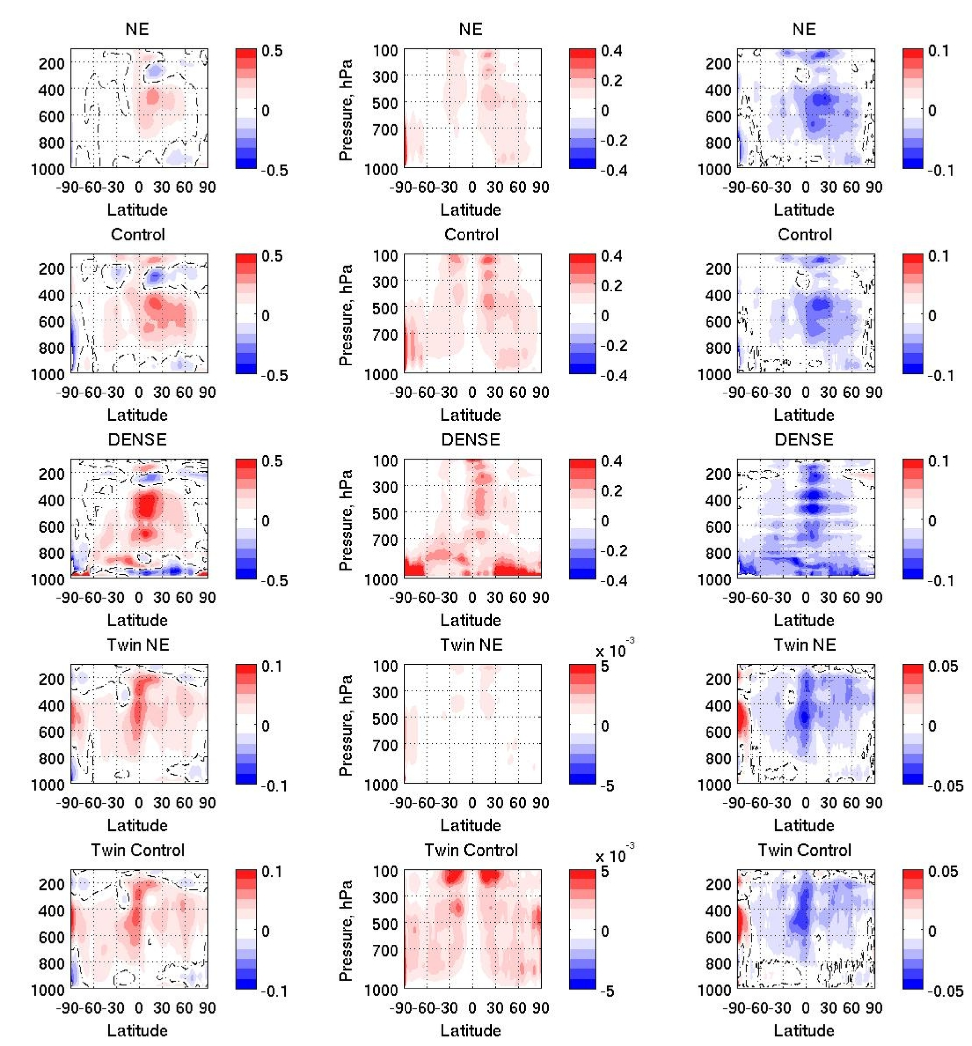

Figure 3. Data assimilation statistics of temperature (K) for the five cases. Left column, time mean analysis increment; center, variance of analysis increment; right, mean absolute error reduction.

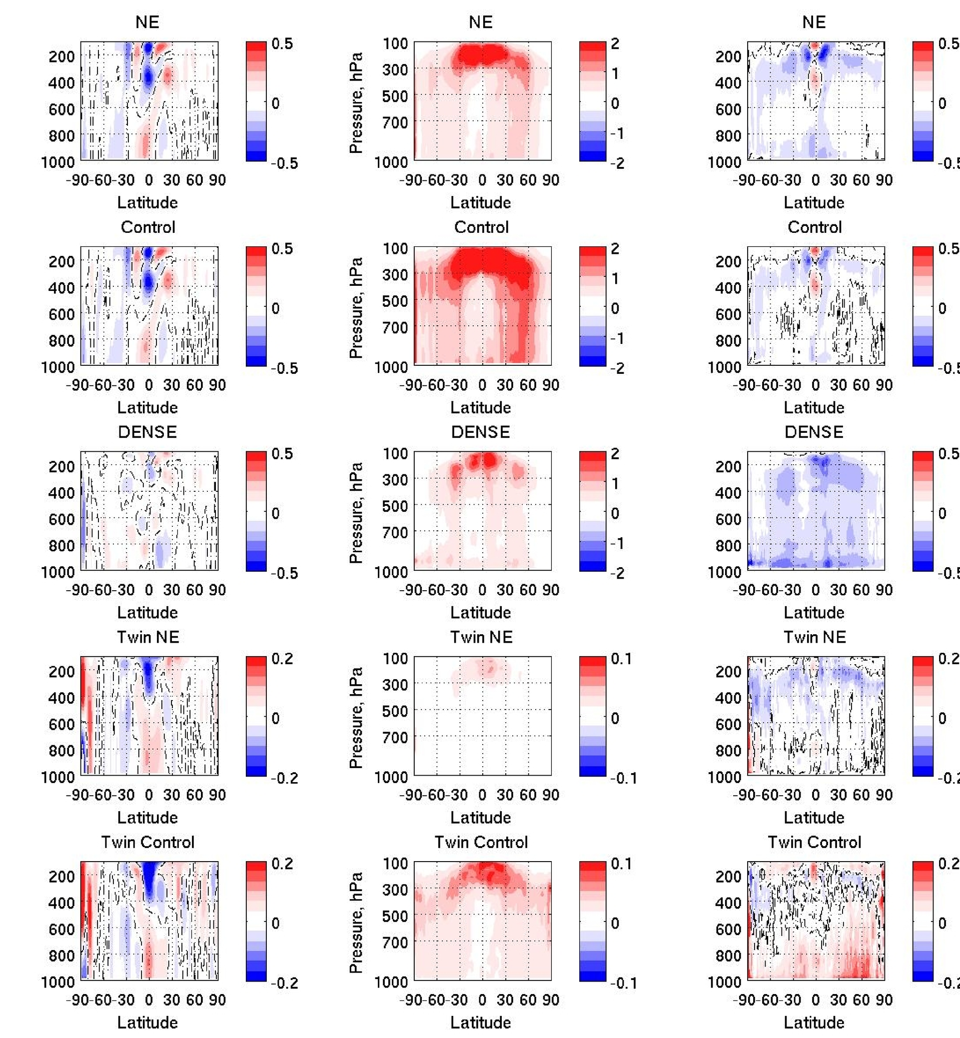

Figure 4. As in Figure 3, but for zonal wind u (m/s).

Both identical twin cases are found to have persistent areas with positive time mean analysis increments of temperature in the tropics, although there is no model bias in the twin framework. These regions of positive increment are believed to be due to excess convection that occurs during the initial forecast period after the data assimilation process destabilizes some areas.

The mean absolute error reduction (MAER) in Figures 3 and 4 measures the difference in the absolute value of the analysis error and the absolute value of the background error - negative values indicate regions where the DAS acts to improve the quality of the analysis compared to the background state. Most areas show improvements due to data ingestion, with particularly large improvements seen in the DENSE case. One exception is for the wind field of the Twin Control case, where the background errors are not properly weighted, resulting in a degraded analysis state.

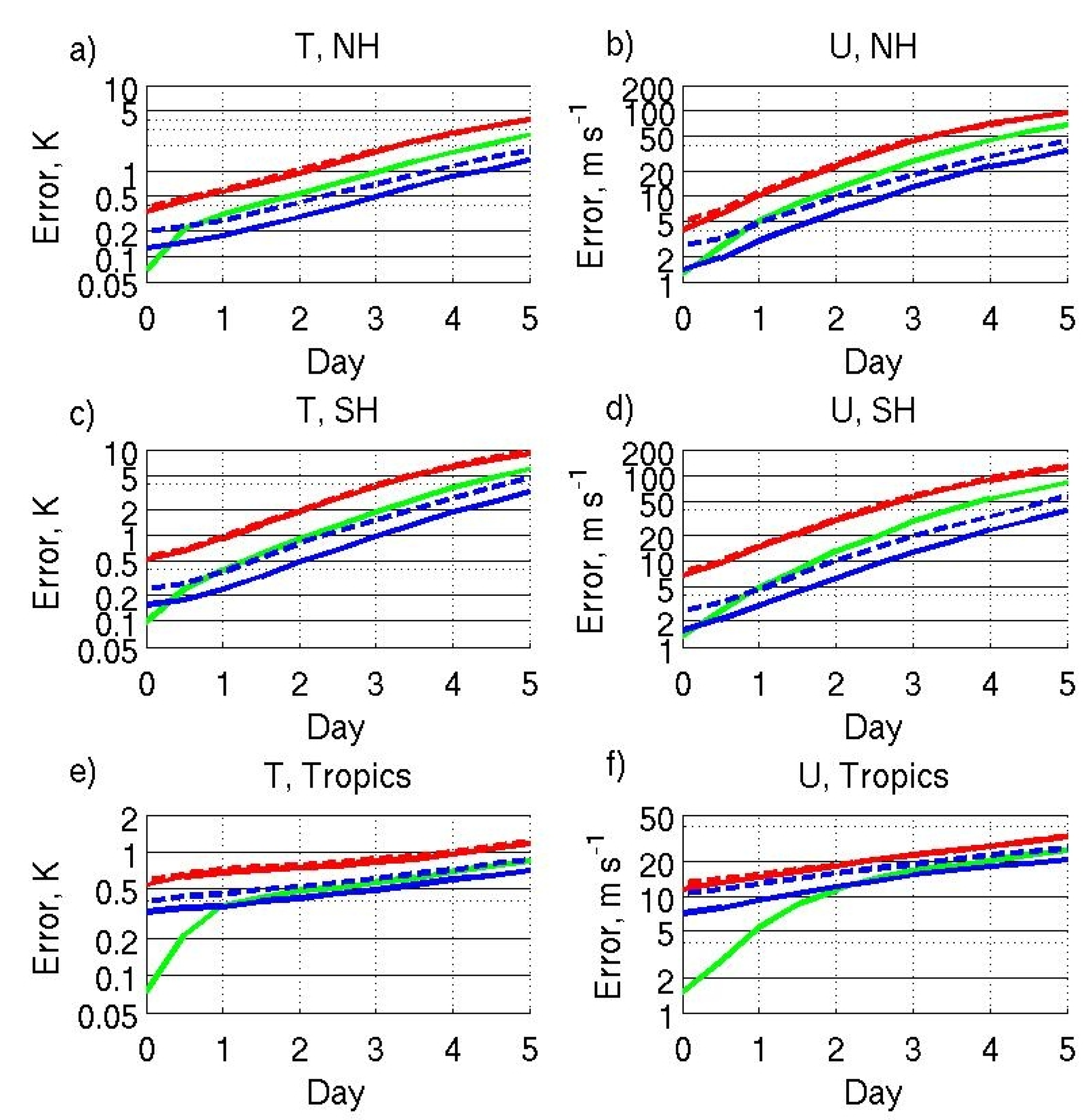

Figure 5. Variance of forecast error as a function of time. Left, temperature at 500 hPa (K2); right, zonal wind at 250 hPa (m2 s-2). Green, DENSE case; solid blue, Twin NE; dashed blue, Twin Control, solid red, NE; dashed red, Control.

The forecast error variances are shown in Figure 5. The rapid initial growth of the forecast error in the DENSE case is a result of model error processes. From day 2 to day 4, the rate of forecast error growth is nearly identical in all five cases.

Observation error has little impact on the forecast error in the ECMWF NR cases, with the Control and NE curves approaching over the forecast period, presumably due to the efficiency of the DAS in removing uncorrelated errors (Privé et al, 2013). In contrast, the Twin Control case shows greater error than the Twin NE case throughout the entire forecast period.

References

Errico, R. M., R. Yang, N. Privé, K.-S. Tai, R. Todling, M. Sienkiewicz, and J. Guo, 2013: Validation of version one of the Observing System Simulation Experiments at the Global Modeling and Assimilation Office. Quart. J. Roy. Meteor. Soc., **139**, 1162-1178.

Privé, N. C., R. M. Errico, and K.-S. Tai, 2013. The influence of observation errors on analysis error and forecast skill investigated with an observing system simulation experiment. J. Geophys. Res. - Atmos, **118**, 5332-5346. doi: 10.1002/jgrd.50452.