Cycling Proactive Quality Control in GFS model

Tse-Chun Chen[1,*] and Eugenia Kalnay[1]

[1]University of Maryland, College Park, MD, USA
[*]tcchen@umd.edu

Introduction

A fully flow-dependent Proactive Quality Control (PQC; Ota et al., 2013; Hotta et al., 2017) that rejects detrimental observations identified by ensemble forecast sensitivity to observation (EFSO; Kalnay et al., 2012) was proposed to resolve the forecast skill dropout issues (Kumar et al., 2017). Successful and encouraging results obtained from non-cycling experiments using Global Forecasting System (GFS) from the National Centers for Environmental Prediction (NCEP), that denying the detrimental observations identified by EFSO with 24-hr and 6-hr verification lead-time both reduced forecast errors in several forecast skill dropout cases. In this study, we begin the examination of cycling PQC using the same complex GFS model.

Method and Experimental Setup

PQC corrects the analysis based on the observational impact from EFSO. Suppose the desired PQC time is $t = 0$ in a DA system with 6-hour assimilation window, the procedures are as follows:

1. Run standard DA cycle from $t = -6$ to $t = 6$ to get the analysis at $t = 6$ for verification.
2. Obtain 12-hour and 6-hour forecasts from $t = -6$ and $t = 0$.
3. Perform 6-hour EFSO with the above information to determine which observations should be rejected at $t = 0$.
4. PQC update the analysis without the rejected observations.

In this study, we utilize the GFS-LETKF system developed by Lien (2014) to test cycling PQC in the complex and realistic model. The resolution of GFS is T62 in order to save disk space and computational time. The assimilated observations are the prepBUFR data provided by NCEP. The experimental period spans from Jan/01/2008 to Feb/06/2008 and the first 5 days are discarded as DA spin-up period. In addition, the LETKF DA scheme with ensemble size of 32 instead of the GSI Hybrid EnVar used in operation is chosen for simplifying the procedure and expedition of the experiments since PQC should have little or no dependence on the DA methods. We chose 6 hours as the forecast error verification lead-time for EFSO impact evaluation and reject approximately 10 % of the overall most detrimental observations.

Results

We show the monthly mean of the GFS forecast relative improvement (%) by cycling PQC in Figure 1. It is clear that for all regions and for the three listed key variables, the short-term forecast can be improved by as much as 10 % or more for higher latitudes. Then the improvement decreases with forecast time but saturates at around 5 % (not 0 %) even after 5 days.

The cycling PQC improvement is further broken down to direct impact (non-cycling PQC) and indirect (accumulated) impact (original analysis before PQC in cycling PQC experiment). As mentioned earlier, the direct impact comes from the PQC update from the original analysis at each cycle, which is equivalent to the non-cycling PQC. The main benefit of cycling PQC is the accumulation of the direct improvements throughout the past cycles that the improved forecast initiated from the PQC corrected analysis serves as a much accurate background and further boost the accuracy of the following analyses. We separate the indirect impact from the full impact by verifying the forecasts initiated not from the PQC corrected analysis but the original analysis before PQC. As we can see, the major advantage of cycling PQC is from the accumulation of past direct improvements and the independent direct improvement is only 2 % at most. It is also noticeable that the benefit from the direct impact has a larger contribution to the full impact in the tropics and the southern hemisphere comparing to that in the northern hemisphere. This indicates that the PQC improvement in the northern hemisphere has a shorter memory on average.

Discussion

The fact that the accumulation of past impact contributes to a major portion of the full impact of cycling PQC has two important implications. One is that the PQC improvement has a long-term memory and remains in the system even after several cycles of DA. Secondly, this supports the feasibility of implementing PQC in operational NWP. In order to deliver the forecast products on time, the operational centers need to initiate the forecast as soon as the analysis is completed, so we can only afford to

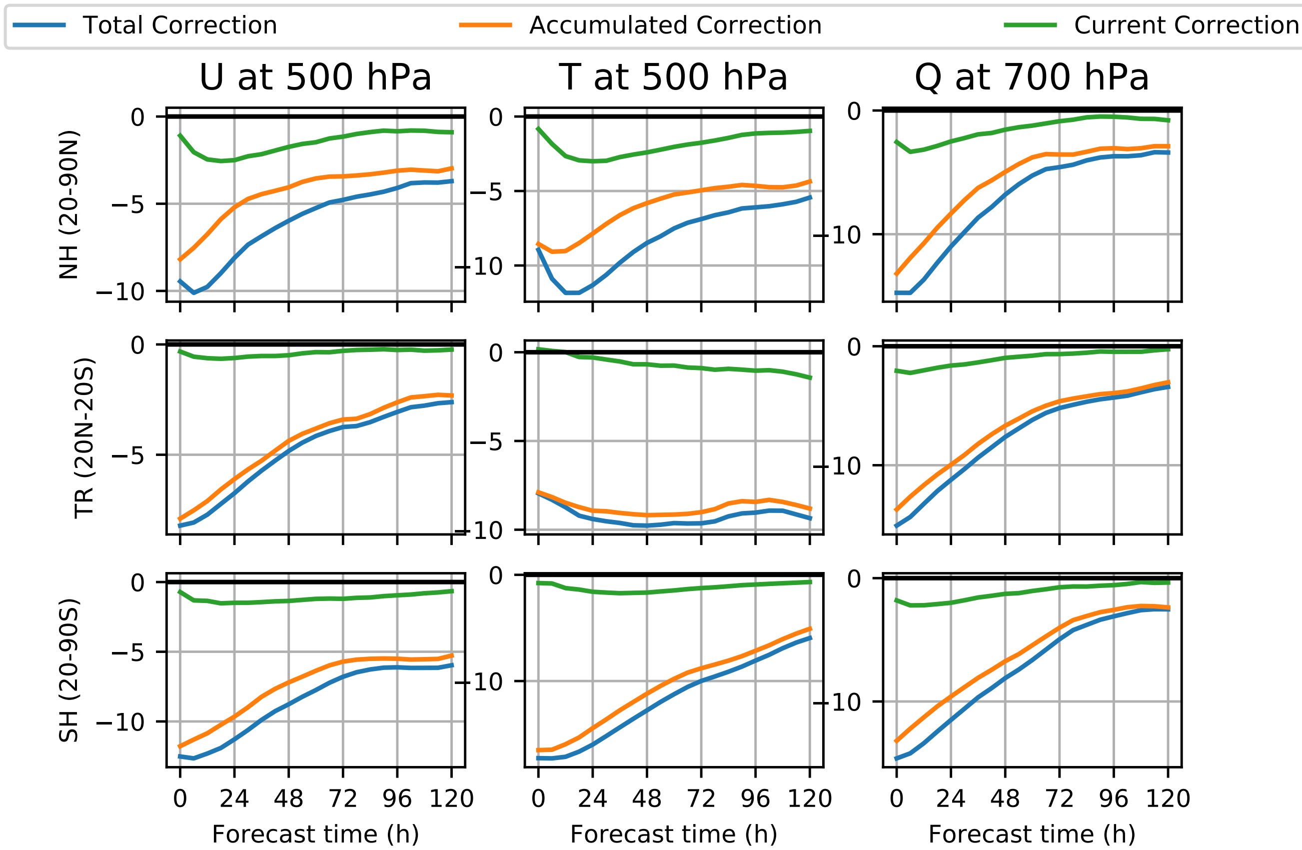

Figure 1. Monthly mean relative forecast error (RMSE) reduction percentage initiated from cycling PQC analysis, original analysis in cycling PQC experiment, and non-cycling PQC in u-component wind at 500 hPa, temperature at 500 hPa, and specific humidity at 700 hPa for the northern hemisphere (20N-90N), the tropics(20N-20S), and the southern hemisphere(20S-90S) throughout 5 days.

perform PQC after the current forecast is out, meaning the direct impact from PQC is not available in operation. Therefore, the huge portion of accumulated indirect impact sends a very encouraging message that even without the direct impact of the current observations we can still get a forecast improvement close to the full impact.

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