Use of EFSO for Online Data Assimilation Quality Monitoring and Proactive Quality Control

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1. Introduction

An essential basis of the success of Numerical Weather Prediction (NWP) and Reanalysis is the massive amount of observations, growing in number and quality. Maintaining existing observing systems and developing new ones requires enormous resources, and the usefulness of the observed data should be evaluated. The direct comparison between a control run (with all the observations) and data denial runs known as Observing System Experiments (OSEs) is a straightforward evaluation approach. However, with millions of observation assimilated every 6 hours, this task is very challenging. First, the computationally expensive experiments limit the number of runs needed to separate the impact of observation subsets, so the discernibility is low. Second, the difference between including or not including a subset of observations may be insignificant even for 5-day forecasts, given that there are already a lot of additional observations assimilated. Hence accurate impact estimation of small subsets of observations is virtually impossible. To overcome these difficulties, we propose to use Ensemble Forecast Sensitivity to Observations (EFSO; Kalnay et al., 2012), the ensemble version of the FSO developed by Langland and Baker (2004), that attributes the forecast changes back to each observation using future analysis as verification, and hence provides an efficient estimation of the impact of each observation on the quality of the forecast.

2. Efficient Quality Monitoring of Data Assimilation using EFSO

EFSO efficiently quantifies the impact of each observation on any given short period of model forecasts and can be used as an online monitoring tool for the quality of data assimilation. As an example, figure 1 shows the time evolution of total 6-hour impact of each observing systems throughout a 1-month experiment. It is clear that most of the observing systems are beneficial at all times (e.g., the top 3 beneficial systems: commercial aircraft reports, GPSRO, and Radiosondes). However, there are several observing systems with occasional detrimental episodes, namely Profiler winds, PIBAL, Atlas buoy, Dropsondes, NEXRAD winds, and especially MODIS winds. It should be noted that these systems are all beneficial on a monthly average but there are some flow dependent conditions that lead to detrimental impact in certain times and locations. Making use of EFSO, it is possible to quickly identify data assimilation quality dropouts that depend on flow condition and have detrimental impact on the resulting forecasts.

3. Proactive Quality Control (PQC) based on EFSO

PQC, the fully flow dependent quality control scheme, was pioneered in Ota (2013) and Hotta (2017), in which EFSO was performed with respect to pre-identified forecast bust region and the regional EFSO-detected detrimental observations were rejected if belonging to net detrimental observing systems. The method (Hotta hereafter) was successful in the original motivation: to avoid occasional forecast busts associated with detrimental observations. We further devised two other data denial strategies, namely THReshold (THR) and Beneficial Growing Mode (BGM), showing that the forecast skill can be improved even further by PQC. In THR, the detrimental observations are rejected if the Moist Total Energy of the error impact is larger than 10^{-5} J-kg^{-1}. On the other hand, BGM, motivated by Trevisan (2010), only keeps observations that are beneficial to 6-hr forecasts and continue to be beneficial in 24 hours. We compare the three methods on 18 cases from Hotta (2017) in figure 2. The global-and-case averaged relative 5-day forecast error reduction, which is verified by its own analysis, by PQC-Hotta, -THR, -BGM methods are ~0.5%, 3%, and 5% respectively. These promising results demonstrate great potential in real applications. In operation, PQC-THR is unable to keep up with the latest forecast release, but it can improve the final analysis instead and thus improve future forecasts. Furthermore, PQC-BGM, which requires analysis 24 hours later and is not feasible in operations, can improve the quality of retrospective analysis products since future observations are available.

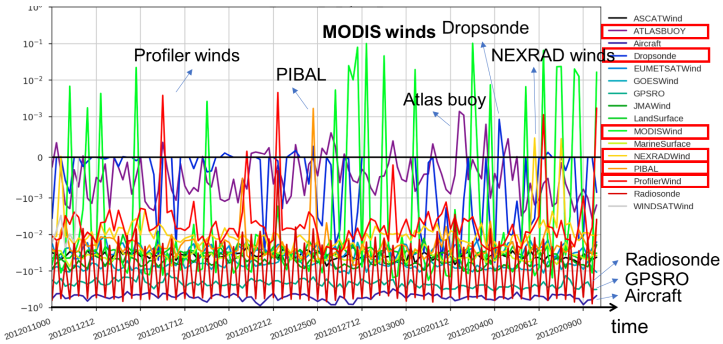

Figure 1. Time evolution of total impact (EFSO) for every non-radiance observation on 6-hour forecasts. Positive values mean the impact of the system is detrimental (marked in red boxes) and negative EFSO means beneficial impact.

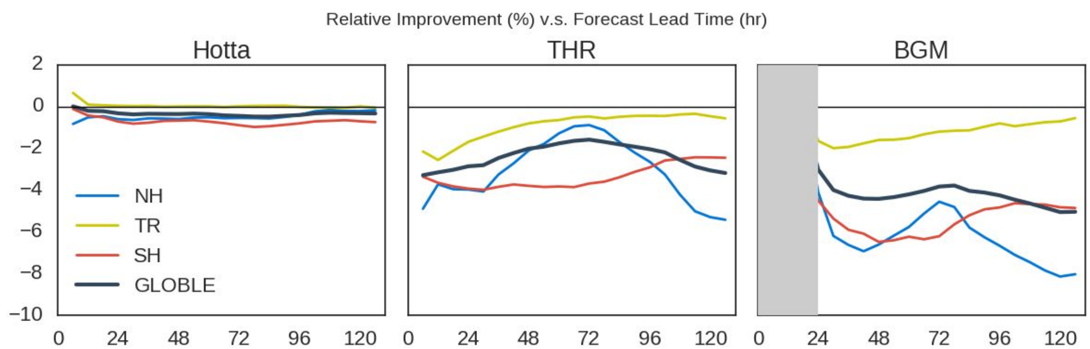

Figure 2. The relative reduction of 5-day forecast errors in %, measured by the Moist Total Energy (MTE) of the forecast error. Left: MTE obtained with the original PQC approach of Ota et al. (2013) and Hotta (2014), which is successful and gives a reduction of O(0.5%). The PQC-THR approach deletes all observations with a detrimental impact of 10^{-5} in MTE units. The PQC-BGM deletes all detrimental observations whose negative impact increases from 6 to 24h. Since it would require a 24h verifying analysis, BGM can only be carried out in a Reanalysis, when future observations and analyses are available.

References:

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