[NPG-2017-45]
Response to Referee #1
October 4, 2017

We gratefully thank Referee #1 for the constructive comments. The point-by-point responses to the comments are detailed below.

This research investigated an efficient methodology to accelerate the development for appropriate data selection strategies for new observing systems using the Ensemble Forecast Sensitivity to Observations (EFSO). The EFSO diagnostics are used to design potential data selection rules for data selection. The usefulness of this method is demonstrated with the assimilation of satellite precipitation data in a low resolution global model. It is shown that the EFSO based method can efficiently aid data selection that significantly improve the assimilation and forecasting results. The manuscript is well written and easy to follow. I suggest to accept it for publication after some revisions.

Comments 1. The key for EFSO is to evaluate gradient of error reduction to observations (Eq. 4 and 6). Could you please justify why an ensemble of 32 members can provide reasonable/accurate estimation of the gradient to precipitation? Precipitation processes are highly nonlinear, which may cause difficulties when adjoint method is used to calculate the gradient as mentioned in this manuscript and many published articles. Do you think the EFSO can deal well with this nonlinear issue?

We agree that the limited ensemble size is an issue for EFSO. On one hand, our experience is that although an ensemble size of 32 is relatively small, it could still be sufficient to produce reasonable results. In previous EFSO studies, Ota et al. (2013) and Hotta et al. (2017) used 80 ensemble members, Sommer and Weissmann (2014, 2016) used 32 and 40 ensemble members. In particular, the latter two studies focused on the application of EFSO in convective scales, and they obtained useful results.

On the other hand, we believe that our choice of a short evaluation forecast time, which is only 6 hours, is helpful to mitigate the nonlinearity issue. Within the 6 hours the nonlinear effect would not be too strong. Hotta et al. (2017) showed that the results using 6-hour evaluation forecast time are qualitatively similar to those using longer evaluation times, which is very beneficial to the practical use of the EFSO method.

In addition, a crucial element that leads to the success of our precipitation assimilation study is the use of Gaussian transformation. Without the Gaussian transformation the results were bad (Lien et al., 2016). Therefore, we need to compute the forecast sensitivity when the Gaussian transformation of the precipitation variable is performed. The authors speculate that the adjoint FSO would be able to produce reasonable sensitivity gradient in this case; however, the EFSO can still deal it with, which is one advantage of the EFSO method in this nonlinear problem.

2. It is good to see precipitation assimilation can improve the forecasts up to 5 days. But overall, RMSEs in wind and temperature are reduced about 3-5 % up to 5 days. Do you think this result can be reproduced at operational centers, e.g. NCEP, if the satellite precipitation was assimilated?

In our experiments, the impact of precipitation assimilation can be large because we used a CONTROL experiment assimilating only the rawinsonde data. In a modern operational NWP system that already assimilated many other conventional and satellite data, we believe that the impact should be much smaller. This design of CONTROL was also used in Lien et al. (2016), and we believe that it does not affect the main points of the current study. We will add this explanation in the revised manuscript after the open-discussion period.

3. Experimental design. Rather than a year run using a low resolution model (T62) with an ensemble of 32 members, results from a seasonal run of high resolution model and more ensemble members that are close to operational configurations might be more convinced.

We agree that the resolution is too low and the ensemble size is relatively small compared to the operational configuration. However, we think that the use of this intermediate setup does not hinder the objective of this study to demonstrate the methodology of using EFSO to accelerate the development of the quality control in data assimilation. Regarding the topic of precipitation assimilation, Kotsuki et al. (2017) recently showed that it is also useful with a global model at 112-km resolution (~T120) and with 36 ensemble members, although this topic is not the main focus of the current study.

Other comments: 1. Page 2, lines 15-24. Though adjoint-based FSO method faces some difficulties, for specific applications, it is still can give a good evaluation compared to OSE. Here is an example: Zhang, X.-Y., H. Wang, X.-Y. Huang, F. Gao, and N. A. Jacobs, 2015: Using adjoint-based forecast sensitivity method to evaluate TAMDAR data impacts on regional forecasts. Adv. Meteor., 2015, 427616, doi:https://doi.org/10.1155/2015/427616.

Thank you for pointing this out. We strongly agree that both FSO and EFSO are extremely useful. The main advantage of the ensemble based EFSO method, compared to the adjoint based FSO, is that the former does not require the development of the tangent linear model and adjoint model, which makes the implementation easier, especially for moist processes that are very difficult to linearize. We will make this clear in the revised manuscript and cite the reference you kindly provided.

2. Page 9, lines 18-19 Though there are some difficulties, adjoint models have been used in the operational data assimilation systems at ECMWF and UK Met office, which produce world-best global weather forecasts. EnKF has its merits but also has its limitations. The key for EFSO is to evaluate gradient of error reduction to observations (Eq. 4). Do you think an ensemble of 32 members can provide a good estimation of the gradient?

We do not deny the usefulness of the adjoint FSO. Regarding the issue of limited ensemble size, please see the response for Comment 1 above.

3. Figure 4. Can we assume precipitation obs over open waters have same quality? If Yes, however, the percentages of useful data from Pacific tropical region are much different. The explanation is reasonable and acceptable. Just wonder it might be good to mention that suggest to mention that rejected data, does not always mean they are bad data.

Thank you very much for pointing out the important point that "the data rejected (for improving the model forecasts) are not always bad-quality data." We believe that we have attempted to describe this point in the submitted manuscript:

"Therefore, we should not consider EFSO some kind of "intrinsic properties" or "quality" of the observation itself. The EFSO depends on the background state and the other observations assimilated at the same time." (P.5, L.9-11)

We will elaborate this point more clearly in the revised manuscript.

4. Figure 6. It is good to see precipitation assimilation can improve the forecasts up to 5 days. But overall, RMSEs in wind and temperature are improved about 3-5 % up to 5 days. Do you think the impact is overestimated?

Same as the response for Comment 2 above.

References

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