FSOI using an Observation-Based Error Norm for the Met Office UKV model

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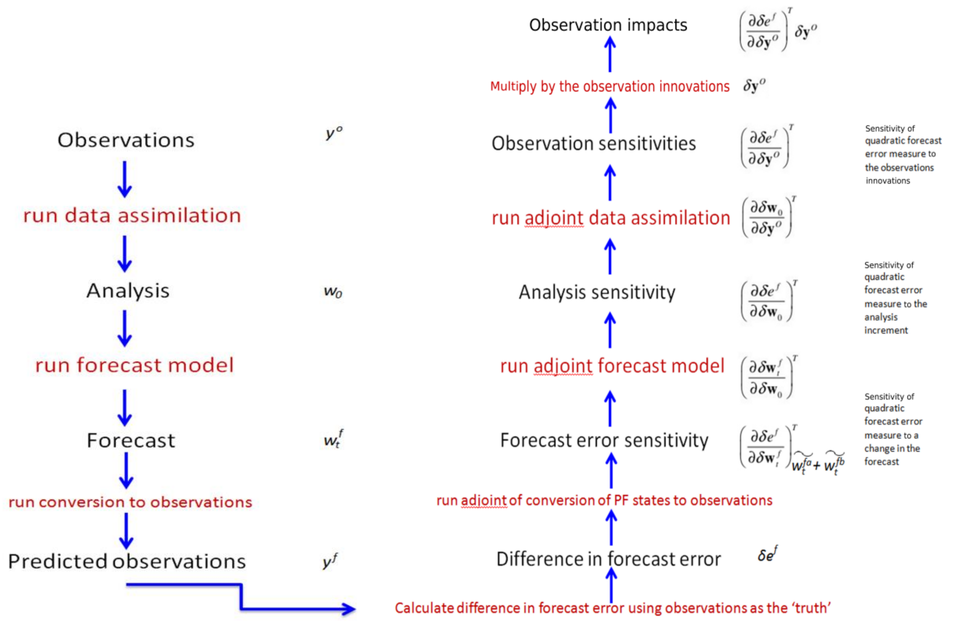
Abstract
FSOI (forecast sensitivity to observation impacts) calculations have been carried out for the 3-hour UKV forecast for trials of a four-week period over the Winter (mid-December 2014 to mid-January 2015), and 24 days over the Summer (June 2014) with a 7.5-km VAR grid for running the adjoint perturbation forecast (PF) model for the FSOI, but the standard 3-km VAR grid resolution for the data assimilation. The calculations used an observation-based error norm based on a quadratic measure of the fit to synop observations of temperature, relative humidity, 10-m wind speed and log visibility. Results show that the average total impact per run is beneficial over the combination of the two time periods. Synop relative humidity and openroad relative humidity show the largest beneficial impacts. Synop temperature and buoy pressure show the largest detrimental impact. It should be noted that these are only the impacts 3 hours into the forecast. Another set of trials over the same time period was carried out with the same set-up except that new covariances were used. The aim of these covariances was to improve the way the model used the observation data. The results of the FSOI show that the overall impact of the observations is increased, with the impact of the openroad temperatures also noticeably improved.

Introduction
The FSOI is a method for assessing the impact of observations. It assesses all observations simultaneously, avoiding the need for many separate OSE experiments.[1] The global FSOI (forecast sensitivity to observation impacts) system has been run successfully at the Met Office for many years[2]; it uses the analysis at 24 hours to derive an energy norm to assess the sensitivity to the observations. FSOI can only be assessed for much shorter timescales for the UKV since the PF model only remains a good approximation to the full non-linear model for short timescales because of highly non-linear processes such as convection. It is therefore not valid to use the analysis — which would be only 3 or possibly 6 hours later than the forecast. The two would be too closely related — the analysis 3 hours later being little better than the 3 hour forecast from the previous analysis. Therefore it is sensible instead to assess the forecast using an observation-based error norm.

Technical Set Up of the FSOI
The calculation of the FSOI for the UKV involves several steps.

1. Calculate a quadratic forecast error measure, to determine the error in the analysis and background forecast by comparing them to observations, e^f. The difference between these is the difference in forecast error, δe^f.
2. Run the adjoint of the conversion from PF states to observations, to convert this to the forecast error sensitivity — the sensitivity of the quadratic forecast error measure to a change in the forecast, $\left(\frac{\partial \delta e^f}{\partial \delta w_t^f}\right)^T_{\widetilde{w_t^{fa}}+\widetilde{w_t^{fb}}}$.
3. Run the adjoint of the forecast to calculate the sensitivity of the quadratic forecast error measure to the analysis increment, $\left(\frac{\partial \delta e^f}{\partial \delta w_0}\right)$
4. Run the adjoint of VAR to calculate $\left(\frac{\partial \delta e^f}{\partial \delta y_0}\right)$, the sensitivity of the quadratic forecast error measure to the observations.
5. Multiply this by the observation innovations to get the observation impacts, $\left(\frac{\partial \delta e^f}{\partial \delta y_0}\right)(\partial \delta y_0)$.



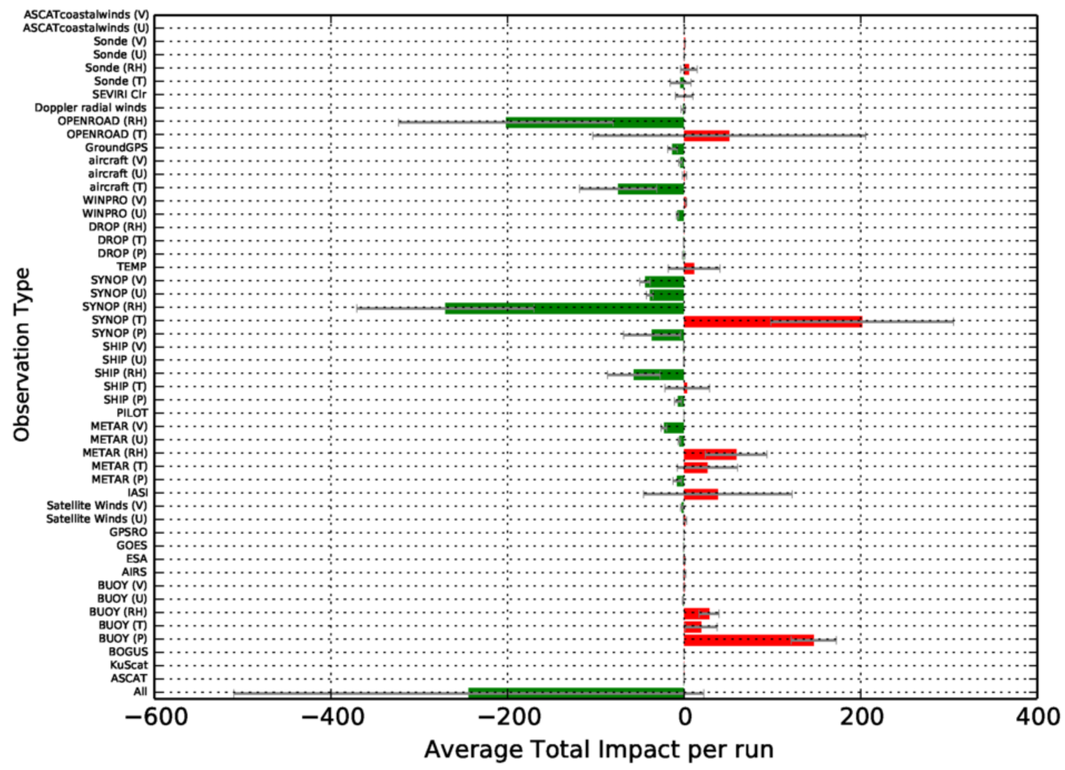


Figure 1 – Impacts of different observation types with PS36 setup

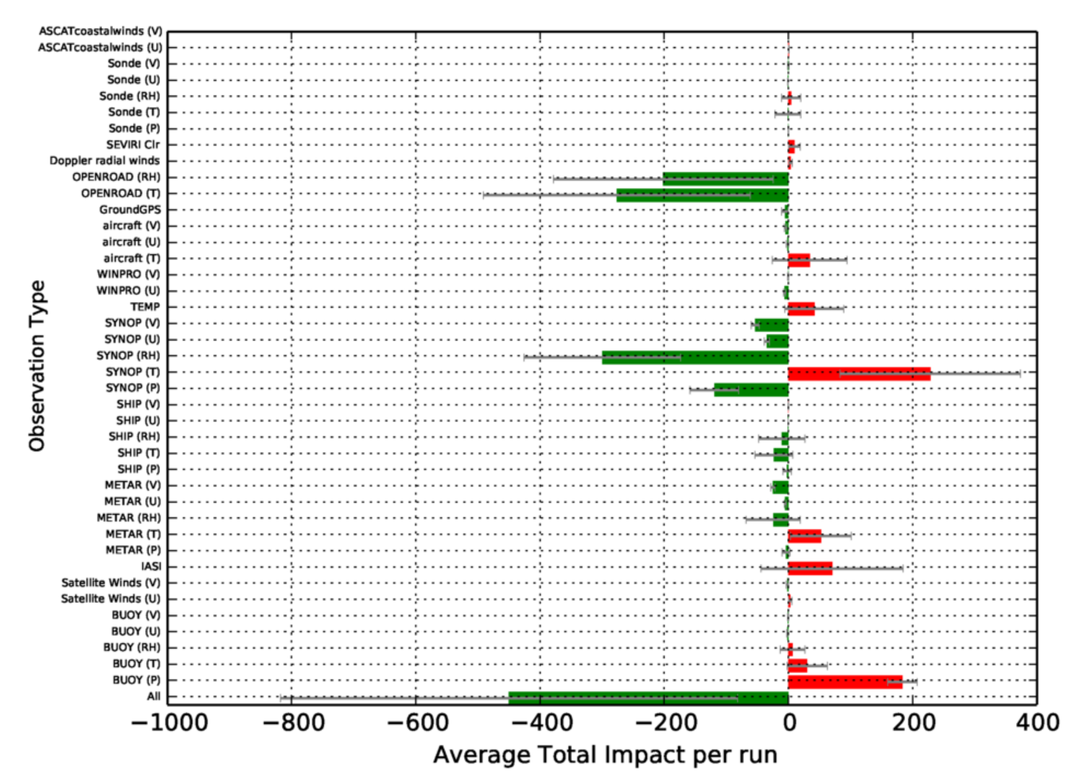


Figure 2 – Impacts from all the observation types after the new covariances are added

Trial Set-Up
The first trial was carried out using UKV suites based on Gareth Dow's standard PS36 Trial suite. PS36 does not include the new extended area which came in at PS38. Other changes in PS37 not included in PS36 are: swapped transform order covariances (probably the most significant change); a retuning of the vertically adaptive grid settings; changes to the microphysics of mixed phase clouds; and the addition of AIRS and CrIS infrared radiances.
The second trial was identical to the first except that it included the new covariances.

Results
These results are new and have not yet been investigated further. It is encouraging that the new covariances seems to enhance the impact of the observations overall, although there is still overlap within the error bars. In addition openroad temperature shows an enhanced beneficial signal, although again within the error bars there is overlap. Similarly the METAR relative humidity impact seems to have improved.
It is important to remember that the trials only show what observations are of benefit to the surface in the T+3 forecast in PS36. Upper air or ocean observations may show more benefit in later forecasts. The results look quite different to the global FSOI results; this is because global FSOI uses the T+24 analysis and uses an energy based norm that covers the whole model.

References

1: 2000, Baker and Daley, QJ, "Observation and background adjoint sensitivity in the adaptive observation-targeting problem", Vol: 126, Pages: 1431-1454
2: 2014, Lorenc and Marriott, QJ, "Forecast Sensitivity to Observations in the Met Office Global NWP System", Volume: 140, Pages: 209-224

Unfortunately, I am unable to come to the conference in person, so please e-mail any questions you may have to the address below.

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