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COMPARISON OF AMV HEIGHT ASSIGNMENT BIAS ESTIMATES FROM MODEL BEST-FIT PRESSURE AND LIDAR CORRECTIONS

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Abstract

Long-term model best-fit pressure statistics give valuable information about the height assignment uncertainties for AMVs and can be used to estimate systematic height assignment errors. An alternative source of information to estimate the systematic height assignment errors are space born lidars which provide independent cloud height information. The lidar observations have been shown to have great potential to correct the systematic errors in AMV height assignment. Results from comparing of the height assignment errors from the two approaches indicate that the two methods generally support each other. For IR and VIS AMVs the magnitudes of the systematic height error estimates are comparable especially at low levels. For WV winds and for high level IR winds some differences are seen in the magnitude. Shifts of 20-60 hPa are seen between the methods and typically the lidar correction is indicating more pronounced negative values, i.e. AMVs assigned too high in the atmosphere, than the best-fit pressure statistics.

INTRODUCTION

Atmospheric Motion Vectors (AMVs) are wind observations that are derived by tracking clouds or water vapour features in consecutive satellite images. AMVs are typically interpreted as single level wind observations assigned to a representative height which is cloud top for high and mid level clouds and cloud base for low level clouds. Comparison to radiosonde (Velden and Bedka, 2009) and lidar observations (Folger and Weissmann, 2014; Weissmann et al., 2013) as well as results from simulation framework (Hernandez-Carrascal and Bormann, 2013) suggest benefits from interpreting AMVs as layer averages or as single level wind but within the cloud. Height assignment is considered to be one of the most significant error sources for AMVs.

Taking into account the AMV height assignment uncertainties through situation dependent observation errors has been very beneficial in the European Centre for Medium-Range Weather Forecasts (ECMWF) system (Salonen and Bormann, 2013). An interesting question is could we further improve the use of AMVs by taking into account systematic height assignment errors. Investigations in the ECMWF system have shown promising results from using the traditional single-level observation operator together with the height re-assignment based on long-term model best-fit pressure statistics (Salonen and Bormann, 2015a). Experimenting with layer averaging observation operator has shown more mixed results.

In this article we concentrate on estimating the systematic height errors with two independent methods, model best-fit pressure and lidar height correction. The aim is to compare the systematic height error estimates in order to investigate and explain the similarities and differences. The results have been presented also in Salonen et al. (2015b).

ESTIMATING SYSTEMATIC HEIGHT ERRORS

Model best-fit pressure

The model best-fit pressure is defined as a pressure level where the observed wind and the model wind agree the best. Comparison of the best-fit pressure statistics for the Met Office and the ECMWF data assimilation systems has shown that the statistics are generally very similar to each other, suggesting that the pressure differences are not strongly dependent on the data assimilation system (Salonen et al., 2015c).

The main advantage of the best-fit pressure is that it can be defined for every AMV observation. Thus, height assignment error characteristics can be easily investigated for each satellite, channel and height assignment method, at all locations where AMVs are available. However, it is important to note that the best-fit pressure also includes contributions from errors in the model background and it is not always possible to define an unambiguous value for it.

When analysing the best-fit pressure statistics, it is necessary to ensure that the best-fit pressure provides a meaningful estimate for the pressure level of the observed AMV. A secondary or a very broad minimum can lead to best-fit pressures that are not very meaningful. Similarly, at times there is no good agreement between the AMV and the model wind at any pressure level, either due to tracking errors or large forecast errors. These kind of cases are filtered out from the statistics.

It is worth to emphasize that the systematic height error estimates must be based on long-term best-fit pressure statistics, typically at least one month worth of data.

Lidar correction

The CloudAerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) based lidar height correction method is described in Folger and Weissmann (2014). AMV winds are compared with radiosonde winds that are vertically averaged over layers of varying depth relative to the originally assigned AMV height and for layers relative to the CALIPSO lidar cloud-top height. On average, the best fit between AMVs and radiosonde winds is obtained for a 120 hPa deep layer below the lidar cloud top. The level of best fit is the mean pressure of that layer, i.e. a discrete level 60 hPa below the lidar cloud top.

There are some requirements that have to be fulfilled that an AMV is considered for the lidar height correction. The main point is that AMV and CALIPSO lidar observation have to be within a distance of 50 km and a time difference of 30 min. In addition, an outlier removal is performed. Only AMVs which are at maximum 100 hPa above and 200 hPa below the nearby lidar cloud top are taken into account. This interval is chosen to account for the fact that the lidar observation and the AMV may see different clouds because of the temporal and/or horizontal displacement and is based on the assumption that AMVs represent the wind below the actual cloud top.

Direct AMV height correction can only be applied to AMVs for which the collocated CALIPSO observations are available. However, a more general approach is possible when a mean adjustment calculated from a large sample of AMV/lidar collocations is considered (Folger and Weissmann, 2015). The mean adjustment is compared to the best-fit pressure based approach in this article.

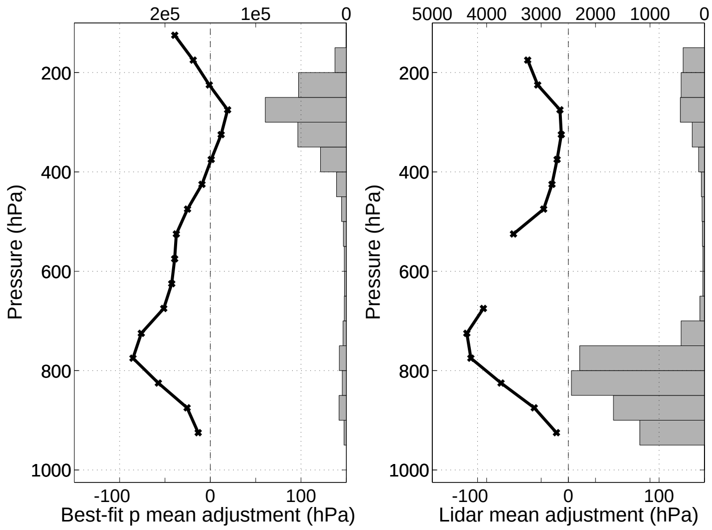

Figure 1: The best-fit pressure based systematic height error estimates (left panel) and the lidar correction based systematic height error estimates (right panel) for GOES-15 IR AMVs. The grey bars indicate the number of observations.

COMPARISON OF THE METHODS

Systematic height assignment error estimates obtained with the two independent methods have been compared for geostationary satellites Meteosat-7, Meteosat-10, MTSAT-2, GOES-13 and GOES-15. The considered period is 1.4-13.6.2013. CALIPSO lidar observations are not available for 10.4-15.4 and 16.5-27.5 and these days have been excluded from the comparison. Only AMVs with a forecast independent QI greater than 80 have been considered. The systematic height assignment error estimates are investigated separately for IR, VIS and WV channels but there is no additional separation based on height assignment method.

In the following, positive (negative) values indicate that the assigned AMV pressure is on average higher (lower) than the best-fit pressure/the lidar level of best fit. In terms of height that means that the observation is lower (higher) in the atmosphere than the best-fit pressure/the lidar level of best fit.

Figure 1 shows the best-fit pressure based systematic height error estimates (left panel) and the lidar correction based systematic height error estimates (right panel) for GOES-15 IR AMVs. The grey bars indicate the number of observations. The shapes of the curves are similar for both methods. This is generally the case for IR AMVs also from other satellites. At low levels typically the magnitudes of the systematic height error estimates are the same. At midlevels and high levels some differences in the magnitude are seen. Typically if there is a difference in magnitude, the lidar based estimate is more negative than the best-fit pressure based estimate.

For WV AMVs generally at the heights from which most of the AMVs originate similarities between the methods are seen. However, again there are some differences in the magnitude. Figure 2 shows the same as Fig. 1 but for Meteosat-10 WV AMVs at midlatitudes as an example of the results. A similar shape is seen in the curves but there is a 25-50 hPa shift between the methods. The lidar based values are more negative (or less positive) than the best-fit pressure based values.

One possible explanation for the shift between the methods is that for the lidar correction the level of best fit is considered to be 60 hPa below the lidar cloud top at all heights. Folger and Weissmann (2014) show that a 100 hPa deep layer below the lidar cloud top also achieves very good results. In practise this means that the results for a level at 50 hPa below the lidar cloud top is basically almost equivalent to the 60 hPa considered in this comparison. This would result in lidar corrections of the same shape but shifted 10 hPa to the right. If the level of best fit varies slightly at different heights, the shift seen between

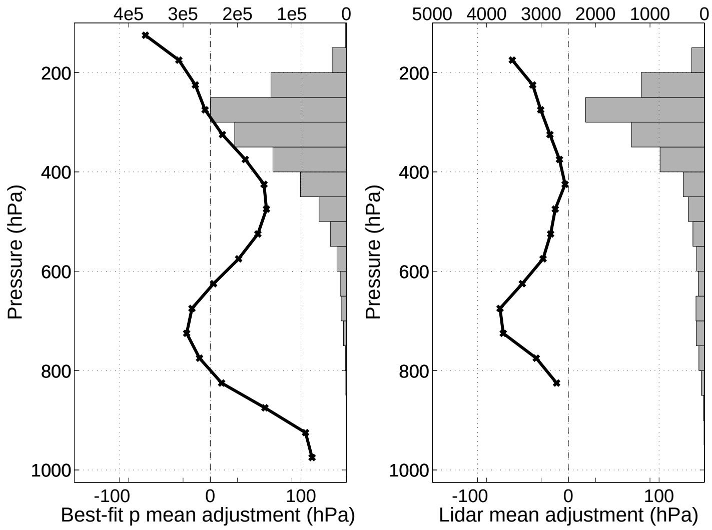

Figure 2: Same as Fig. 1 but for Meteosat-10 WV AMVs over midlatitudes.

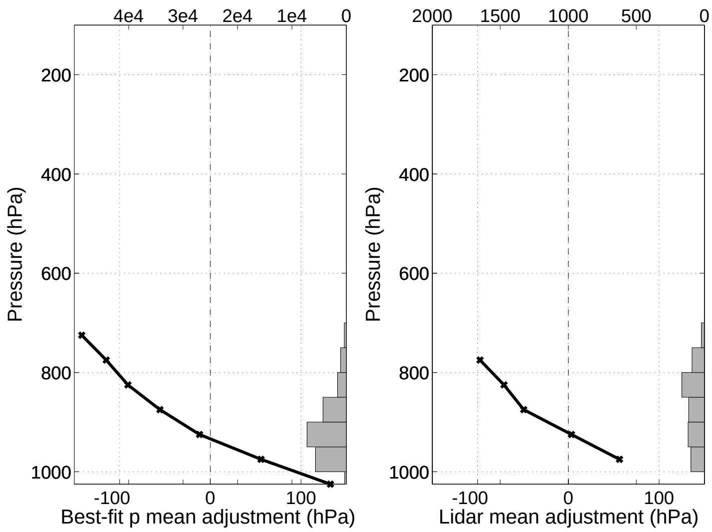

Figure 3: Same as Fig. 1 but for Meteosat-7 VIS AMVs over the midlatitudes.

the methods might decrease.

Figure 3 shows the same as Fig. 1 but for Meteosat-7 VIS AMVs at midlatitudes. In this particular case the best-fit pressure and lidar based systematic height error estimates are almost the same. Overall, for VIS AMVs a similar shape for both methods is seen both in the midlatitudes and tropics. If there is a difference in the magnitude, it is opposite to what is seen for IR and WV AMVs, i.e. the best-fit pressure bias is indicating more negative bias than the lidar correction.

CONCLUSIONS

The systematic height assignment errors for AMVs have been estimated with two independent methods, model best-fit pressure and lidar height correction. The comparison shows that the two methods generally support each other. For IR and VIS AMVs the magnitudes of the systematic height error estimates are comparable especially at low levels. For WV winds and for high level IR winds some differences are seen in the magnitude. Shifts of 20-60 hPa are seen between the methods and typically the lidar correction is indicating more pronounced negative values, i.e. AMVs assigned too high in the atmosphere, than the best-fit pressure statistics.

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