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Evaluation of new hourly GOES AMVs with Expected Error

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Evaluation of Hourly GOES AMVs at ECMWF

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Introduction

NOAA/NESDIS is producing routinely GOES hourly AMVs on an experimental basis (J. Daniels 2011, pers. communication). The dataset is a candidate for operational implementation at NESDIS in the near future (to replace the current 3-hourly AMVs), and its characteristics are hence of interest to all NWP users. The dataset includes the so-called "Expected Error" (EE, Le Marshall 2004) for each AMV. The quantity provides an estimate of the expected total error in the AMV, estimated from past differences between AMVs and radiosondes. The derivation of the EE is based on regressions between AMV/radiosonde differences and a number of predictors, such as the vertical wind shear, a temperature lapse rate, and the components of the forecast-dependent quality indicator (Holmlund 1998).

A different method to provide situation-dependent estimates of the errors in AMVs has recently been developed and explored at the Met Office and ECMWF (Forsythe and Saunders 2009, Salonen and Bormann 2011). Here, the error is split into a height assignment error in terms of pressure (dependent on satellite, channel, pressure level, height assignment error) and a vector error. The height assignment error is estimated using best-fit pressure statistics from NWP, and is later translated to a wind error using the variation of the wind profile around the assigned pressure taken from a forecast wind profile. At ECMWF, the vector error is estimated from departure statistics in regions where the wind shear is small. In the following, this situation-dependent observation error will be referred to as SOE.

The aim of the present project is two-fold: firstly, departure statistics for the new hourly GOES winds are produced from monitoring the data against the ECMWF First Guess and these are compared to the statistics of currently operational GOES winds, in order to guide users for their potential future operational use. Secondly, the Expected Error estimate provided with the new GOES winds is evaluated in terms of departure statistics and compared to similar characteristics for the observation error model currently investigated at ECMWF and used at the Met Office.

Data and Experiments

The hourly AMV data provides better temporal coverage compared to the current operational data which is approximately 3-hourly. The GOES-E CONUS and GOES-W PACUS use images with a time interval of 15 minutes; the NHEM and SHEM for both satellites use 30 minutes images[1]. The coverage for the different sectors is shown in Figure 1 and Figure 2. The EE is included in the hourly GOES winds only, whereas no such information is provided with the operational data stream.

[1] For the NHEM sectors, winds are generated outside of the area covered by the CONUS sector or the PACUS sector (avoiding generating two sets of winds over those sectors).

The presented statistics have been derived for the time period of 8 August through 23 September 2011, using ECMWF's 12-hour 4DVAR assimilation system with a spatial model resolution of T511 (~40 km), an incremental analysis resolution of T159 (~125 km) and 91 levels in the vertical. To produce statistics that are not biased towards one of the two GOES AMV datasets, the experiment did not actively assimilate GOES AMVs, and therefore both datasets have been evaluated against the same short-term forecast.

Quality control plays an important role in the successful assimilation of AMVs. At ECMWF it primarily consists of blacklisting (e.g., excluding winds in problematic regions or excluding winds with low QI values) and a "first guess check". The latter excludes suspicious AMVs that deviate too far from the short-term forecast. Spatial thinning further reduces the number of assimilated winds to counter-act otherwise neglected spatial error correlations in the AMVs. Even though the GOES winds were not actively assimilated in the experiments used here, the normal usage flags have been set as part of the monitoring experiment as if the GOES AMVs had been used. This allows us to evaluate the sample of winds after the operational blacklisting, or the sample of winds that would have otherwise been used.

Results

General evaluation

Overall, departure statistics for the two GOES AMV datasets are fairly similar, except for a marked increase in the number of available winds. Vertical profiles of the background departures of the u-component and v-component are shown in Figure 3 and Figure 4, respectively, for the sample of winds that would have been actively used in the ECMWF system. There is little difference in the standard deviation between the control (red) and the hourly winds (black). However, there is a noticeable improvement in the u-component bias in the northern hemisphere and tropics, from about 850 to 400 hPa. The results are mixed for the v-component. The number of used winds is around 2-3 times as high as with the operational AMVs, somewhat dependent on the level.

Closer inspection reveals considerable improvements in the hourly GOES AMVs in low-level inversion regions. Geographic plots of the wind speed mean (Figure 5) and standard deviation (Figure 6) departure statistics show a significant improvement off the coast of Peru (15°S latitude) from GOES-13 low-level IR cloud tracking. A hint of this is also noted off the west coast of Africa (near Mauritania and Senegal) at 20°N latitude. This aspect has been pointed out to NOAA/NESDIS, and it is most likely a result of using more vertical levels for the background temperature forecast in the AMV processing, resulting in better cloud heights in this temperature inversion region. It addresses a long-standing short-coming previously identified in the monitoring of GOES low level AMVs.

The characteristics of the GOES AMVs have been investigated as a function of time of day (e.g., Figure 7), in terms of bias, RMSVD, and number of used winds, separated by region (S. Hemi, Tropics, and N. Hemi). Differences in the characteristic with time of day could arise as a result of different image intervals used for the tracking, different spatial sampling, or other aspects such as straylight effects. Of interest is the peak in the number of winds at about 0300 or 0400 UTC, especially in the southern hemisphere and tropics. This may be related to the satellite schedule and/or the position of the sun, as this is somewhat apparent with winds from GOES-11 (Figure 8) at about 0700 UTC. There is a 60 degree longitude difference between the two satellites, which corresponds to 4 hours, which is the same difference in the time of the peaks. Some abrupt variation of the speed bias with time-slot is noticeable. As biases in the short-term forecast are expected to be smooth in time, this is likely a feature of the AMVs or their spatial sampling (linked to the scanning schedule of the satellite).

Expected Error vs. Situation-dependent Observation Error

In the following we will investigate the ability of the EE and SOE to identify AMVs with larger errors and hence departures from the short-term forecast. During the course of this, it was discovered that the EE in the GOES hourly winds had not been set for many winds. This has been reported back to NOAA/NESDIS, and traced to a software issue at NOAA/NESDIS, affecting the GOES-E CONUS and GOES-W PACUS sectors. The following statistics will only use the winds with correctly set EE.

Salonen and Bormann (2011) have shown that standard deviations of first guess departures increase with increasing SOE, following approximately a 1:1 relationship for most AMV types. The GOES-13 AMVs show a similar relationship for the present study period, both for the control (Figure 9) and the hourly winds (Figure 10), although not quite 1:1 for all regions considered (e.g., Figure 11).

A similar relationship has been found for the EE. As part of the data processing, the EE values are put in 1 m s^{-1} bins (the observation errors are in 0.5 m s^{-1}). Figure 12 is again the high level IR winds, in the tropics, using the brightness temperature method. However, this figure depicts the OmB sdev vs. the EE. Again, a linear relationship, nearly 1:1, is evident: the greater the EE, the larger the OmB sdev.

The question arises: if the OmB sdev vs. observation error is linear and so is the OmB sdev vs. EE, will there be a relationship between the observation error and EE?

Figure 13 shows a relationship between the observation error and the EE: a visual inspection shows that as the EE ranges from 3 to 7 m s^{-1} with the observation error varying from 2 to 6 m s^{-1}. The correlation between the two is not very strong, suggesting that different aspects contribute to identifying AMVs with larger errors. It is also apparent that the SOE tends to be lower than the EE, possibly due to an underestimation of errors for low SOEs, apparent also from, e.g., Figure 9.

Conclusions

The experimental GOES hourly winds currently derived at NOAA/NESDIS have been evaluated through passive monitoring in the ECMWF assimilation system. The general characteristics of the hourly GOES AMVs are very similar, with the hourly winds providing around 2-3 times as many AMVs as the 3-hourly dataset. Some improvements are noticeable for low-level AMVs in inversion regions, most likely as a result of better height assignment due to the use of more vertical levels for the background profile in the winds derivation.

An evaluation of the EE and SOE shows that both quantities successfully identify AMVs with larger errors and therefore larger departures against the short-term forecast. The SOE tends to estimate smaller errors than the EE, and there is some indication that the SOE with the current parameterization investigated at ECMWF underestimates small errors. Interestingly, while the SOE share some similarities in their formulation (e.g., the explicit or implicit dependence on wind shear), the correlation between the two quantities is not very strong.

<u>References</u>

Forsythe M, Saunders R, 2008: AMV errors: A new approach in NWP. In *Proceedings of the 9th International Winds Workshop, Annapolis,* available from EUMETSAT, Germany.

Holmlund, K.: 1998: The utilization of statistical properties of satellite-derived atmospheric motion vectors to derive quality indicators, *Wea. Forecasting*, 13, 1093-1104.

Le Marshall, J., R. Seecamp, A. Rea , M. Dunn, J. Jung, J. Daniels and C. Velden, 2004: Error Characterization and Application of Atmospheric Motion Vectors over Australia and high Latitudes. In *Proceedings of the 7th International Winds Workshop, Helsinki*, available from EUMETSAT, Germany.

Salonen, K. and N. Bormann, 2011: Accounting for the characteristics of AMV observation errors in data assimilation. In *Proceedings of the 2011 EUMETSAT Satellite Data User's Conference*, Oslo, available from EUMETSAT, Germany (In press).

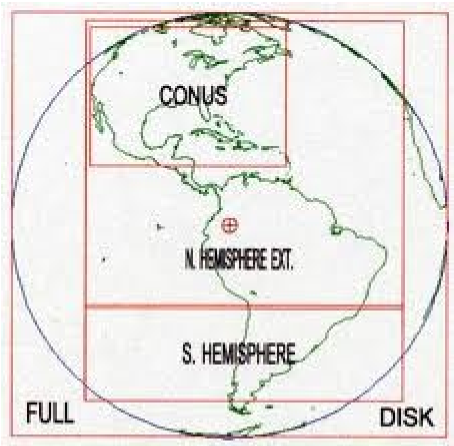

Figure 1: GOES-E routine scanning sectors.

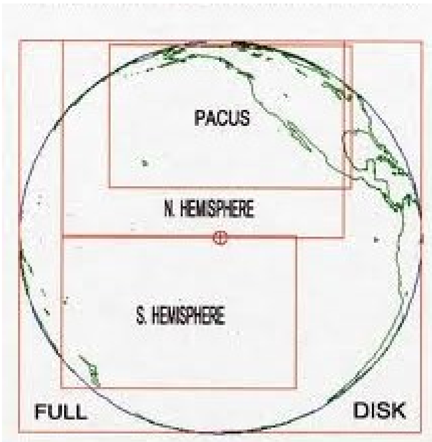

Figure 2: GOES-W routine scanning sectors.

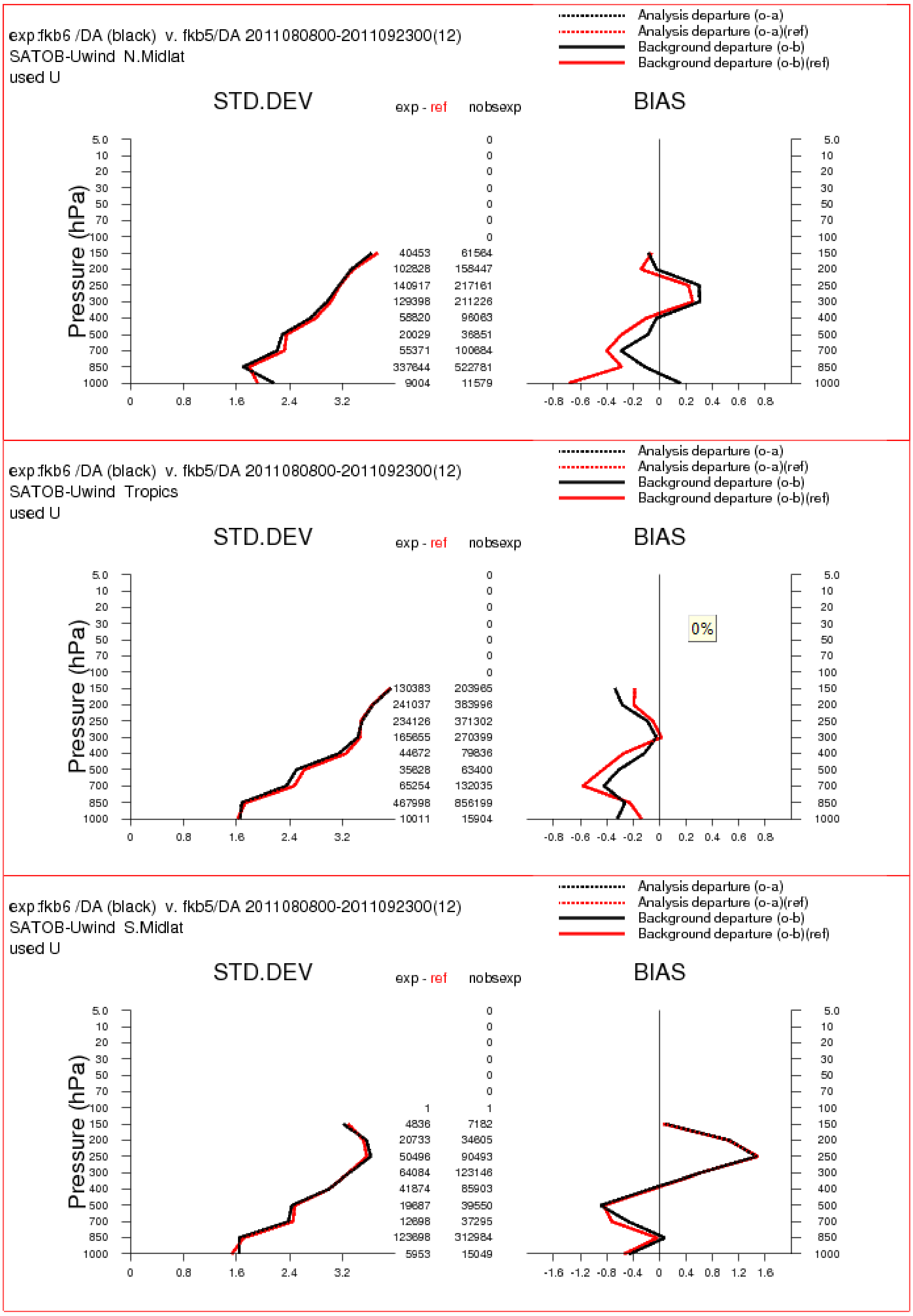

Figure 3: Vertical profile of background departures of standard deviation and bias for the u-component for 08 August through 23 September 2011. Red curve is the control; black curve from the hourly winds. The statistics are based on the sample of winds that would have been used if the GOES winds had been actively assimilated. The numbers between the two columns give the number of hourly winds (right) and the increase in the number of winds compared to the control (left).

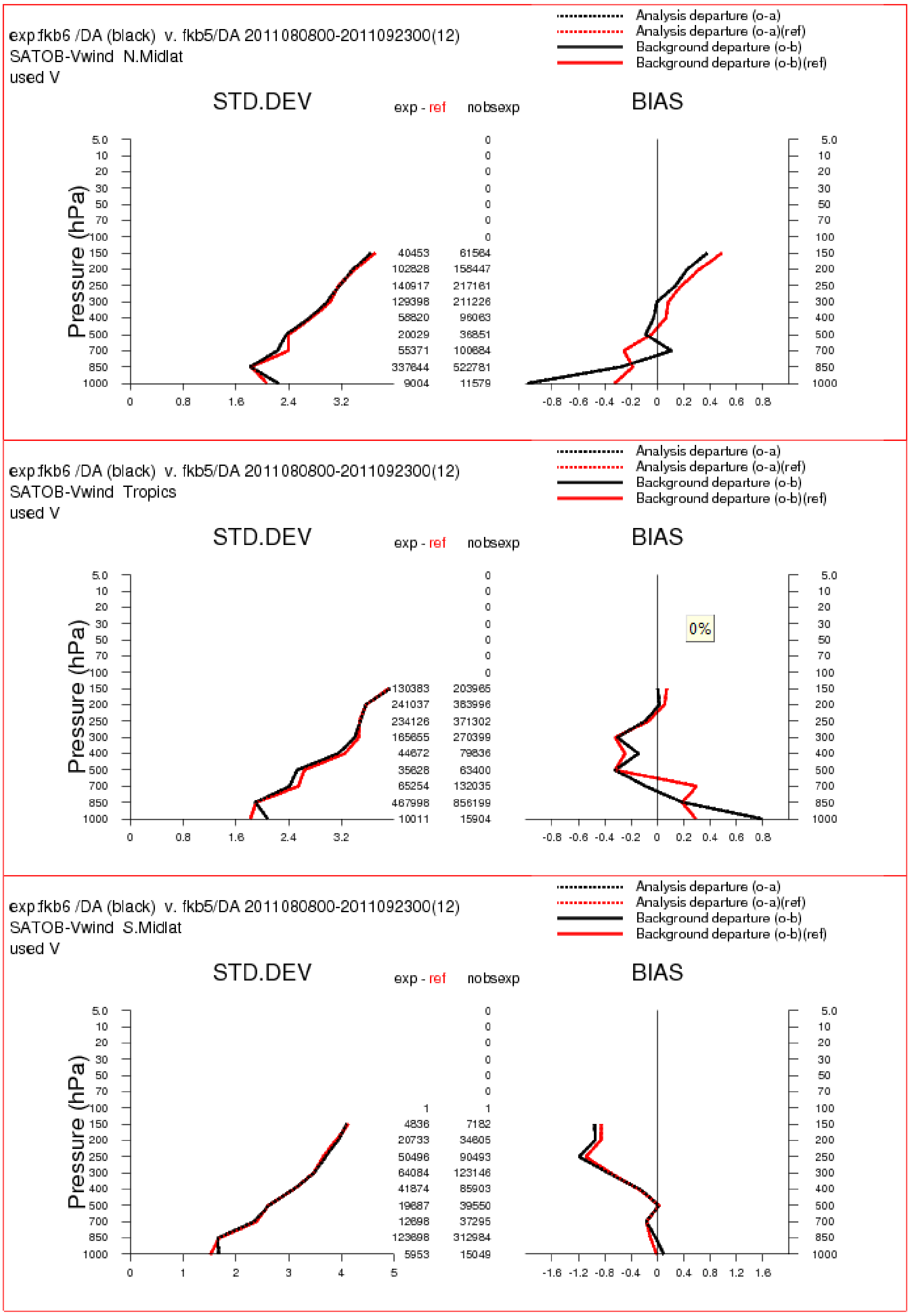

Figure 4: As Figure 3, but for the v-component.

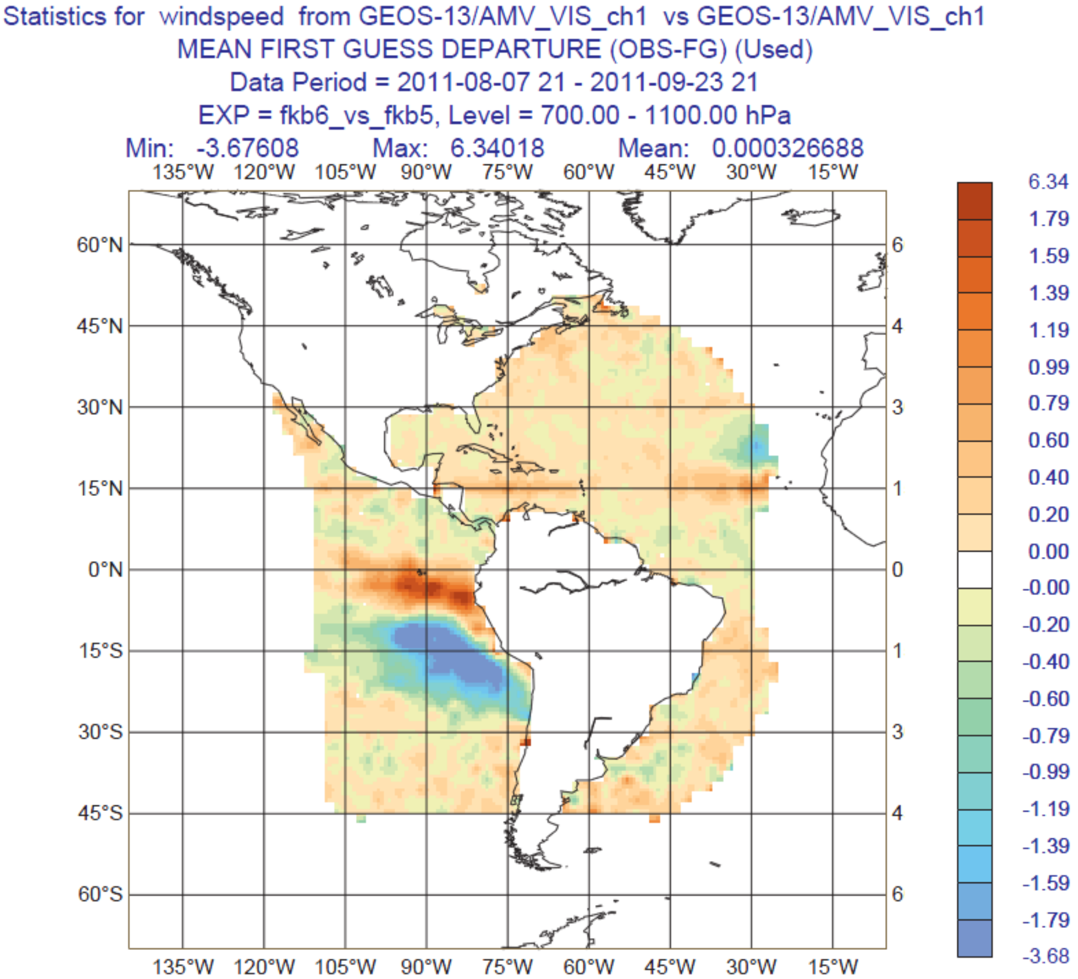

Figure 5: Difference of the speed bias againstthe first guess between the GOES-13 Hourly AMVs and the control for the low levels winds from the visible channel. The statistics are based on the sample of winds that would have been used had the GOES winds been actively assimilated.

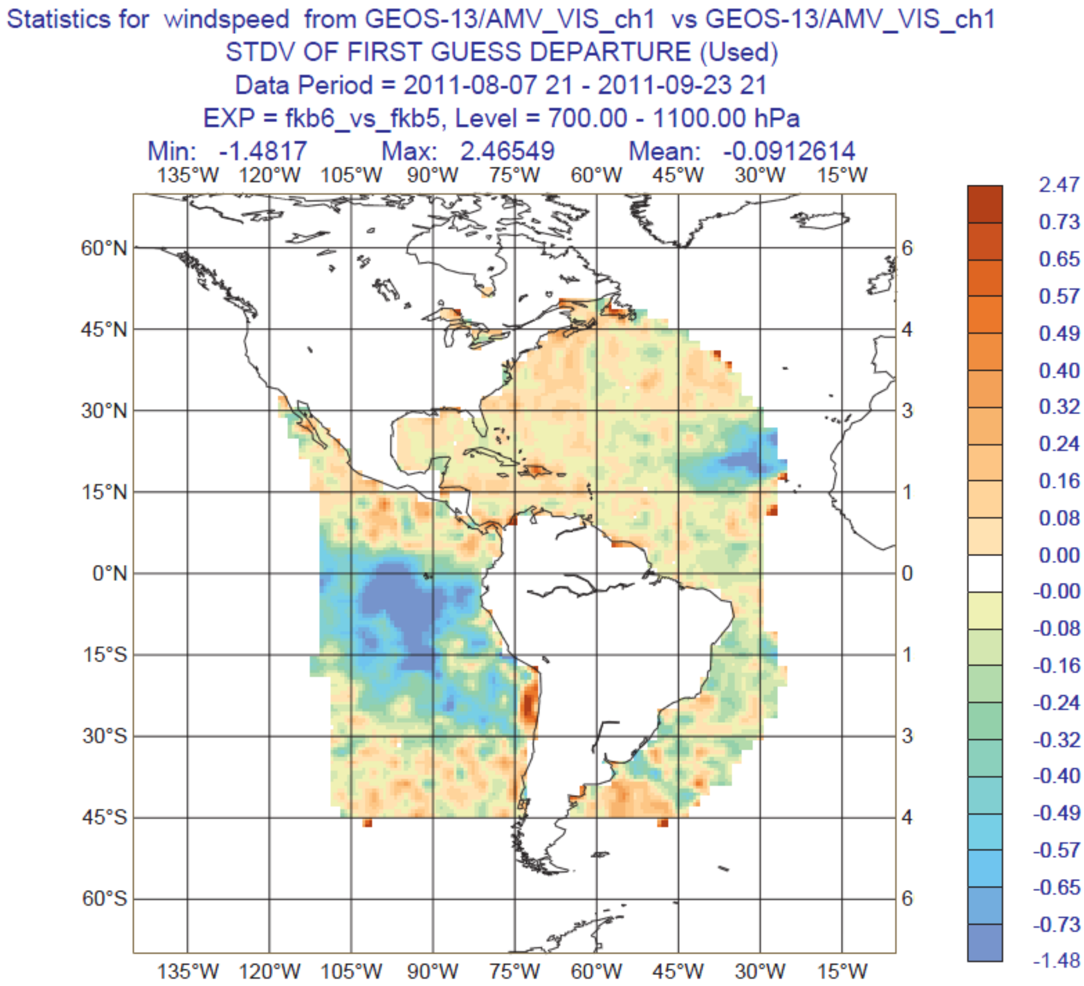

Figure 6: Difference of the wind speed standard deviation of the first guess departure between the GOES-13 Hourly AMVs and the control, for the low level visible winds. The statistics are based on the sample of winds that would have been used had the GOES winds been actively assimilated.

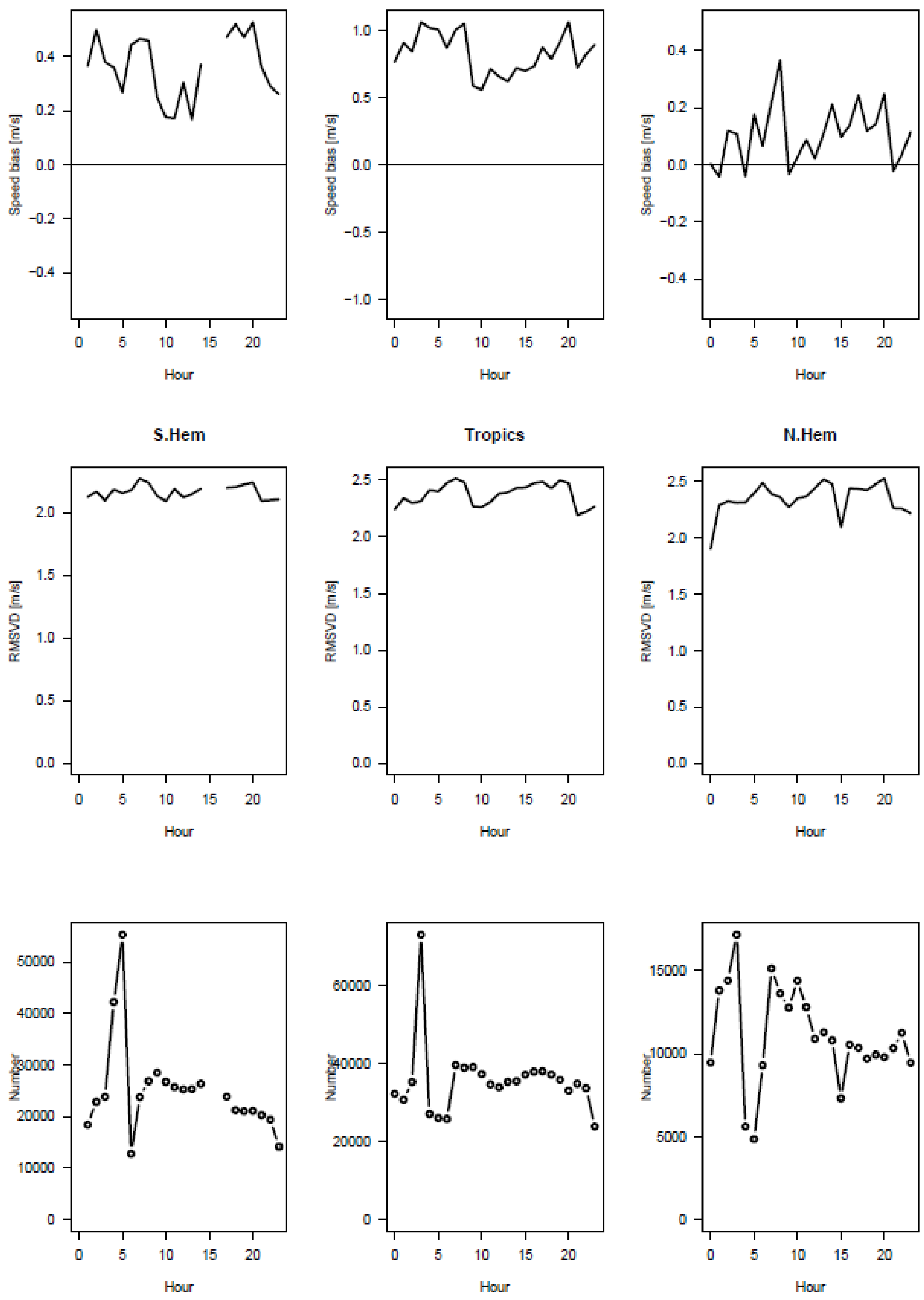

Figure 7: GOES-13 IR low-level plots of speed bias (top), RMSVD (middle) and number of hourly winds (bottom), for the sample of winds after blacklisting.

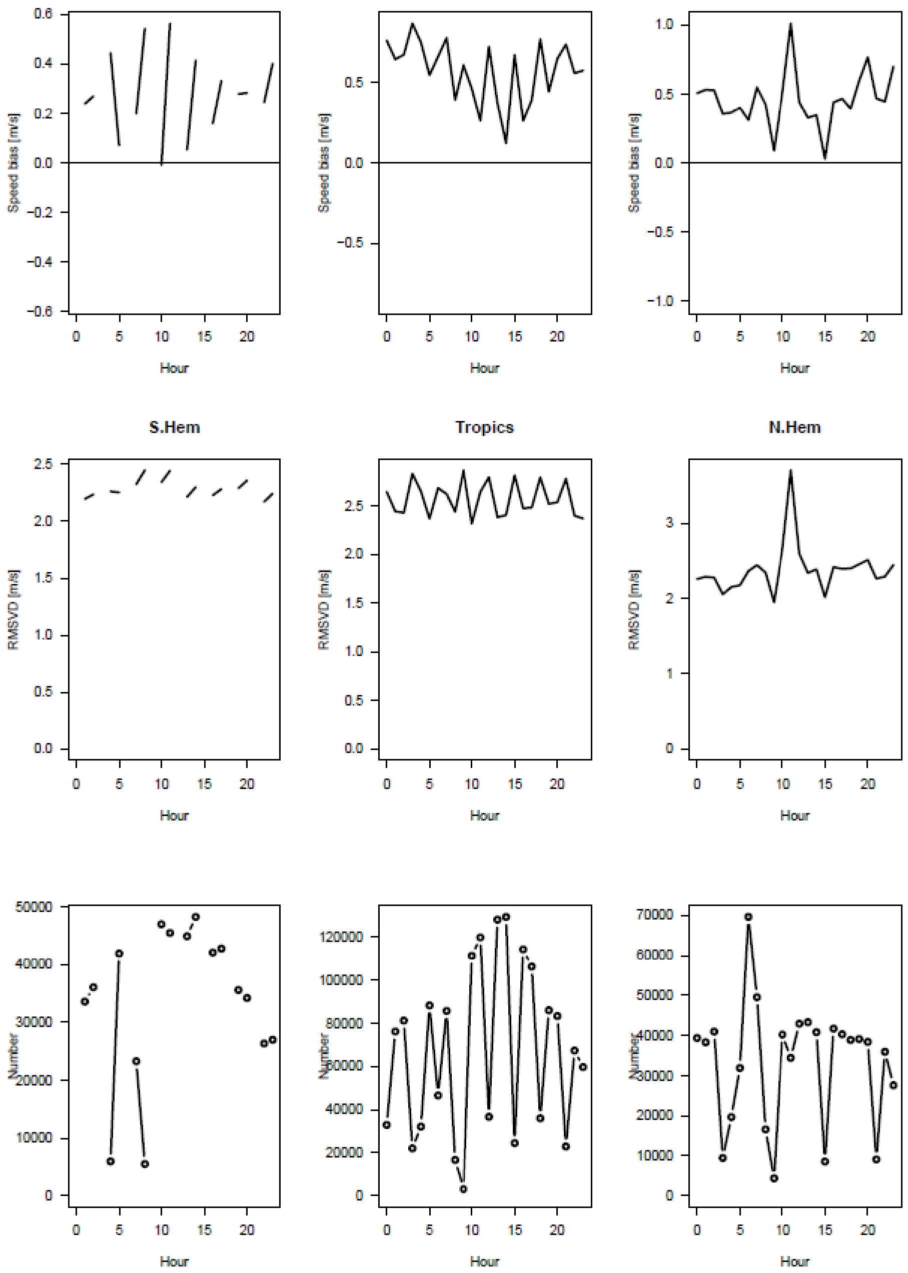

Figure 8: GOES-11 IR low-level plots of speed bias (top), RMSVD (middle) and number of hourly winds (bottom), for the sample of winds after blacklisting.

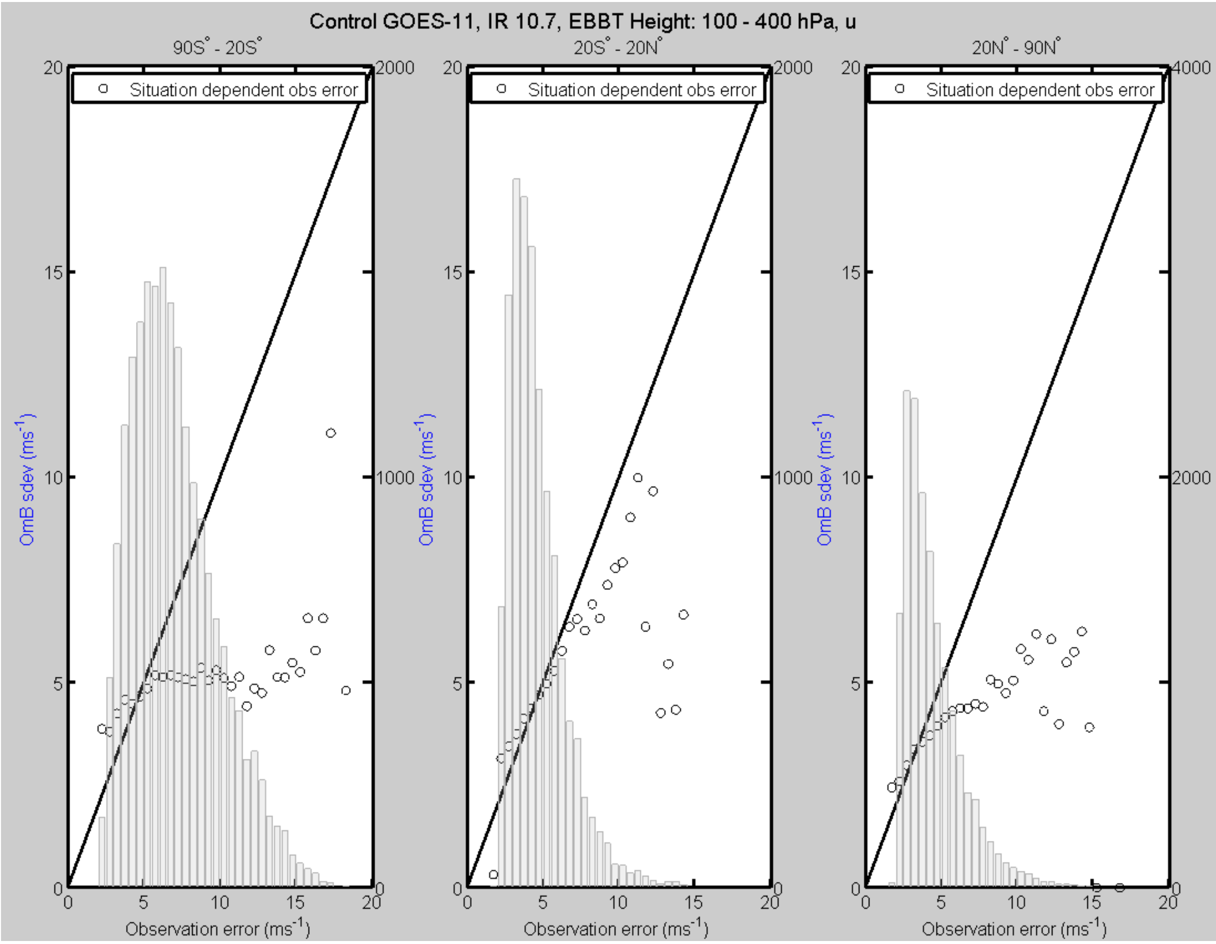

Figure 9: Standard deviations of the First Guess departures for the u-component vs. the SOE for the control GOES-11 IR cloud tracked winds at high levels, using the brightness temperature method. The three panels show statistics for the Southern Hemisphere (left), Tropics (middle), and Northern Hemisphere (right). The histogram bars give the number of winds in each bin (right y-axis). The statistics are based on the sample of winds after blacklisting.

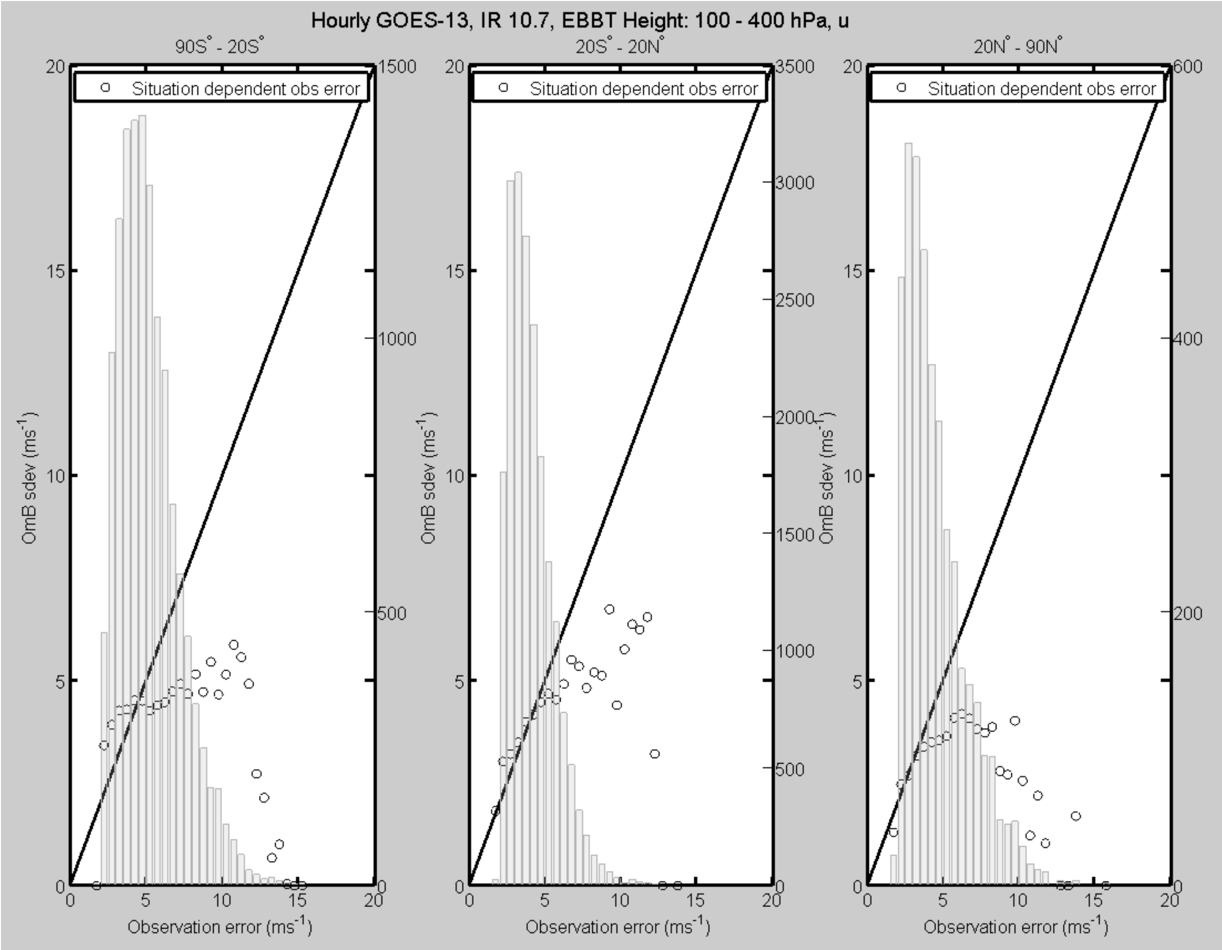

Figure 10: As Figure 9, but for the hourly winds.

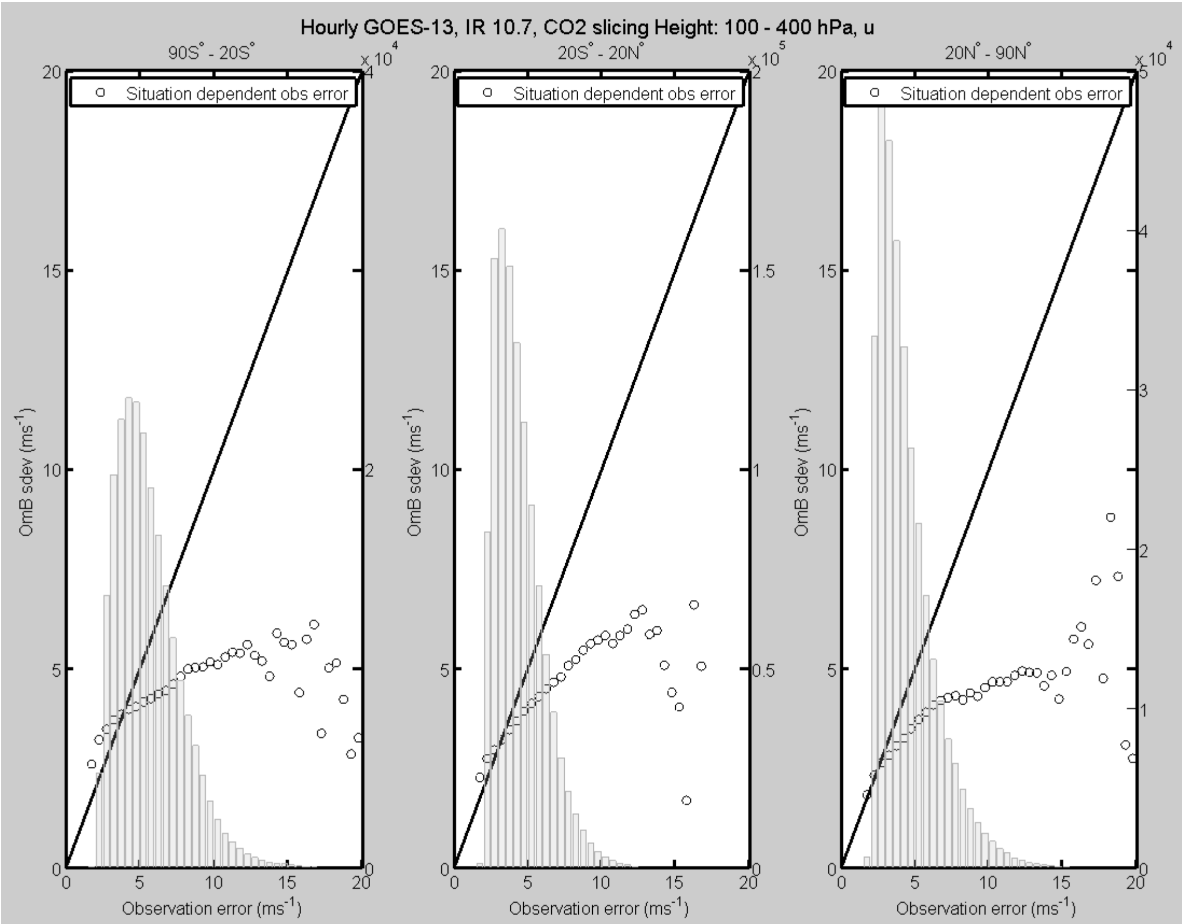

Figure 11: As Figure 10, but for the hourly GOES-11 IR cloud tracked winds at high levels, using the CO2 height method.

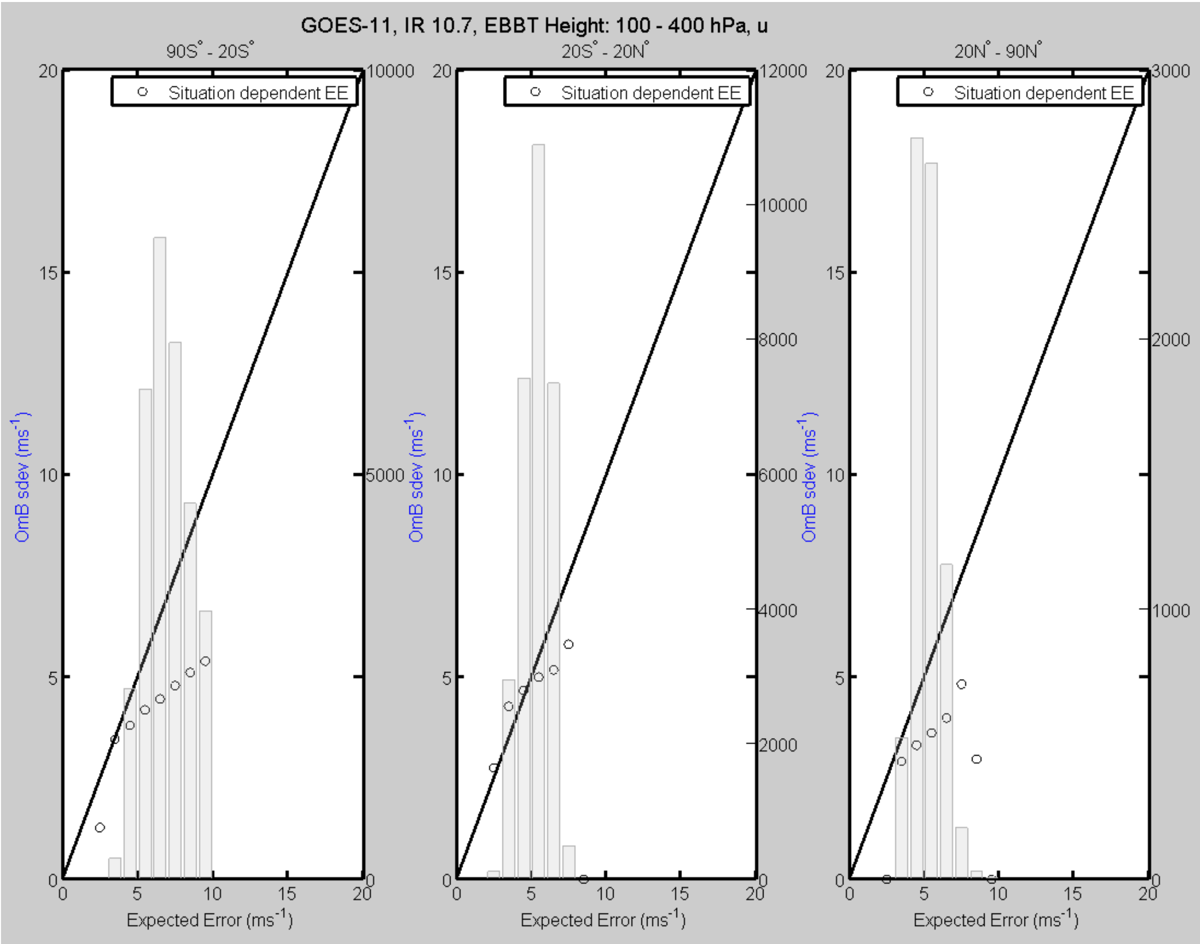

Figure 12: As Figure 10, but against the EE rather than the SOE.

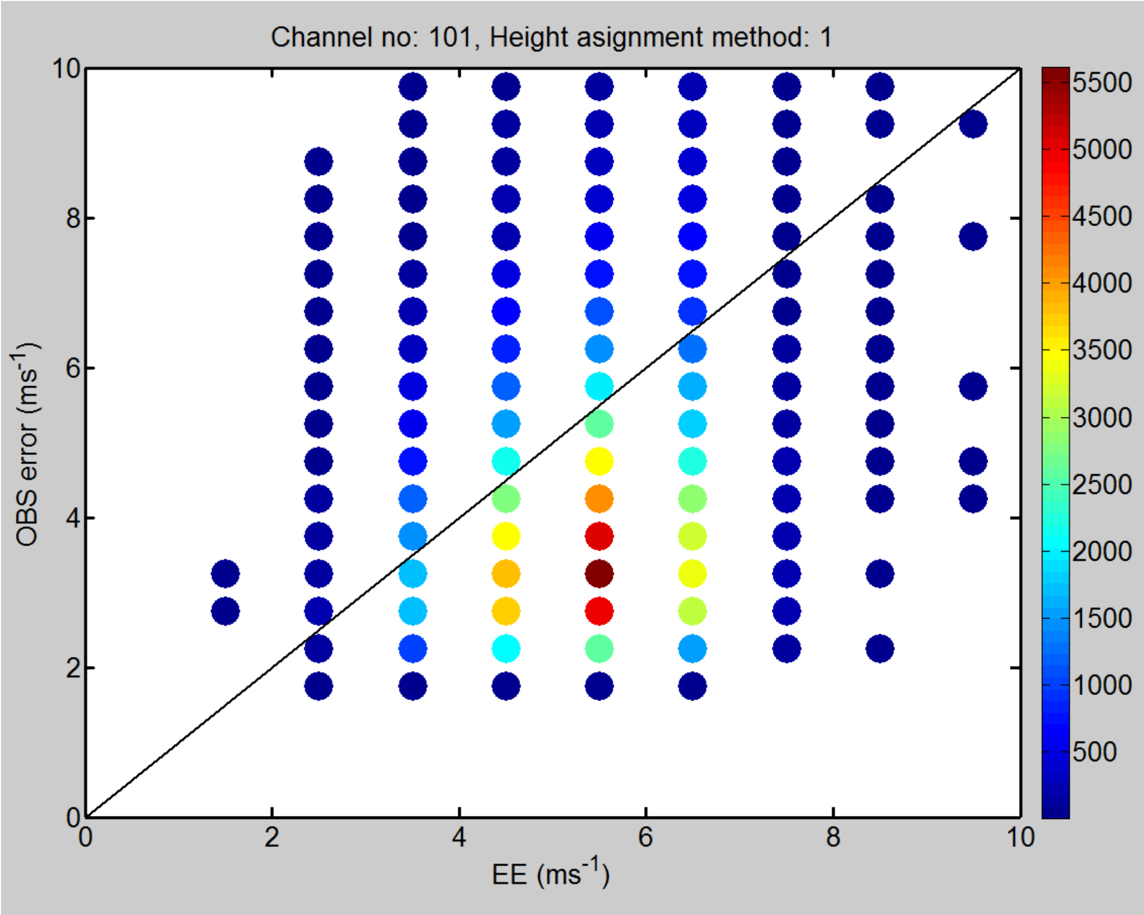

Figure 13: Histogram of SOE vs. EE for high level GOES-11 IR cloud tracked winds with the brightness temperature height method, tropics only.