CLOUD MOTION VECTORS FROM MISR: AN UPDATE

Roger Davies and Aaron Herber

Department of Physics, University of Auckland, 38 Princes Street, Auckland, New Zealand

Abstract

The MISR (Multi-angle Imaging SpectroRadiometer) instrument on the Terra satellite has been measuring stereo-derived height-resolved cloud motion vectors (CMVs) almost continuously since early in 2000. The stereo retrievals are insensitive to calibration drift, and the measurement accuracy is independent of latitude, from pole to pole. Because of this, MISR measurements provide a useful type of climate data record that can be analyzed for interannual differences or trends over the ten-year period as well as providing an independent comparative dataset to reanalysis wind products.

Comparison of MISR's operational product against $O(10^7)$ matched data from the NCEP reanalysis shows generally good agreement where the observing network influencing the reanalysis is sufficiently dense, and some interesting differences elsewhere. We detect speed biases at low altitudes, due to both a slow CMV bias over land, and a fast surface wind bias in the model data over ocean. The operational algorithm for wind retrieval has since undergone a number of improvements, the main effect of which is to significantly increase the coverage.

Over the 10-year intercomparison period, both MISR and reanalysis data indicate a reduction in low level wind scalar wind speed by ≈2 m/s over many regions of the globe, the exception being a regions of local increase of ≈2 m/s at high latitudes in the Southeastern Pacific.

COMPARISON BETWEEN MISR CMVS AND REANALYSIS WINDS

The operational dataset of MISR CMVs, covering approximately 10 years with the same product version number (17), was compared against the NCEP/NCAR Reanalysis Project dataset (Kalnay *et al.* 1996, Kistler *et al.* 2001). These data were matched in time, horizontally and vertically. Because MISR measures a domain average over $(70.4\ \text{km})^2$, and the reanalysis was on a 2.5° lat-lon grid, differences due to resolution and interpolation are to be expected. MISR measures at approximately 10:30 am local time from a sun-synchronous orbit, whereas the reanalysis data were interpolated from 6-hourly values. Over a 10-year time span, $\approx 22 \times 10^6$ MISR retrievals were matched against the reanalysis data. Complete details of this approach are contained in Herber (2010).

Figure 1 summarises the average difference in scalar wind speed between reanalysis and MISR, for winds below 3 km. Over land there is a noticeable slow bias, due in part to inclusion of near-surface retrievals based not on clouds, but on land features, and also due to orographic effects on clouds. These effects are absent over the ocean. Instead, between about 40°N and 40°S the bias averages -1.4 m/s, which is attributed to the effect of coarser resolution for the reanalysis winds. As the spatial domain increases, the average scalar wind speed decreases. This bias over the ocean changes to +0.2 m/s between 40°N and 60°N, as the reanalysis domain size decreases, and where there is ample observational data for the reanalysis. Over the Southern Oceans, from 40°S to 60°S, on the other hand, the bias is +0.9 m/s, and likely indicative of a positive speed bias in the reanalysis model in regions that lack observational data.

Figure 2 shows the zonally-averaged bias as a function of height, separately for land and ocean. The influence of topography on upper-level cloud motion vectors shows up as a slow bias several kilometers above mountains, especially evident at 35°N. Over oceans, the largest differences again occur over the southern high-latitude oceans.

The overall differences in the mean vector wind, the standard deviation (about the mean vector wind difference), and the rms vector differences between the reanalysis winds and MISR CMVs are summarised in Table 1. These differences all increase with height. While the agreement between MISR CMVs and the reanalysis winds are generally quite good, the rms difference is likely higher than it should be (Davies *et al.* 2007), due to known limitations in the MISR product. These limitations are gradually being removed, as discussed next.

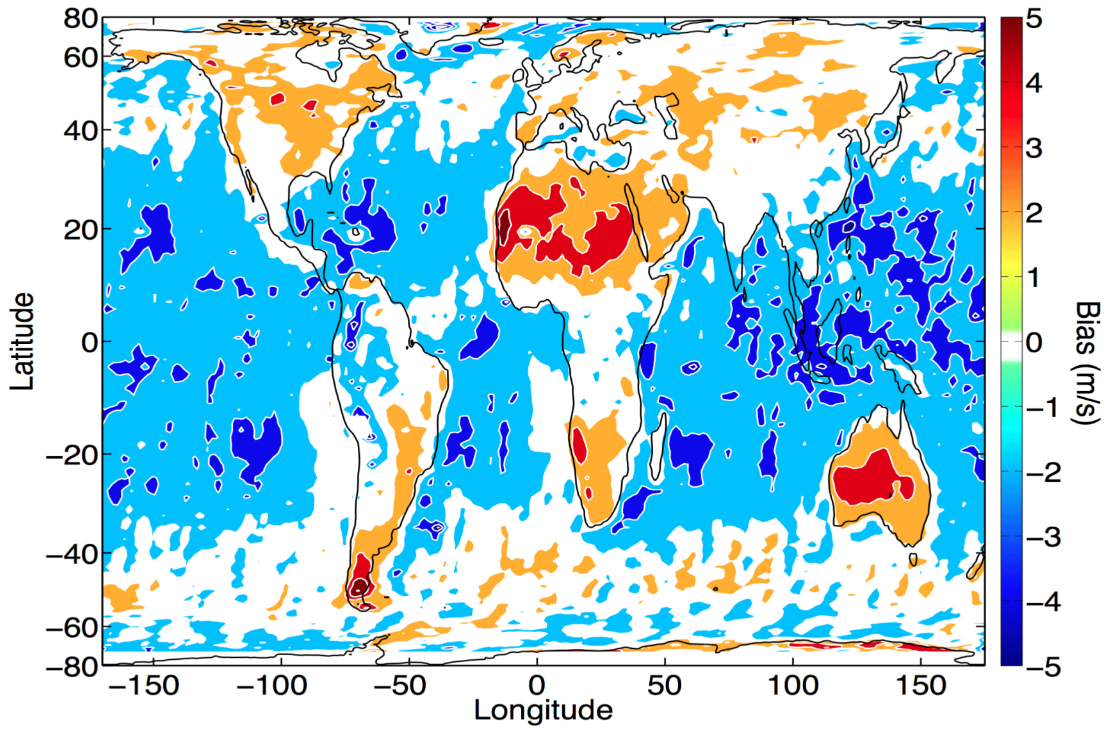

Figure 1: Scalar wind speed bias (reanalysis–MISR) averaged between 2000 and 2010, for altitudes below 3 km.

Height Range (km)	Over Land	Over Ocean
Mean Vector Difference (m/s)		
1–3	5.8	6.1
3–7	8.0	10.9
7–20	15.8	15.6
Standard Deviation (m/s)		
1–3	3.3	3.3
3–7	6.0	9.0
7–20	15.8	16.2
Rms difference (m/s)		
1–3	6.7	6.9
3–7	10.0	14.1
7–20	25.2	22.5

Table 1: **Overall MISR-reanalysis differences**

IMPROVEMENTS TO THE MISR STANDARD PRODUCT

As the MISR team has gained experience applying stereo matchers to high-resolution cloud images, and the available computational power has increased, new stereo matchers that are more exhaustive are being developed. The latest of these corrects for some of the limitations in Version 17 used in the previous section.

The main effect of the new matcher is to significantly improve the coverage, so that about 70% more winds are obtained at the 70.4 km domain size. The increased coverage is noted mainly at high latitudes, and as an increased number of upper-level winds.

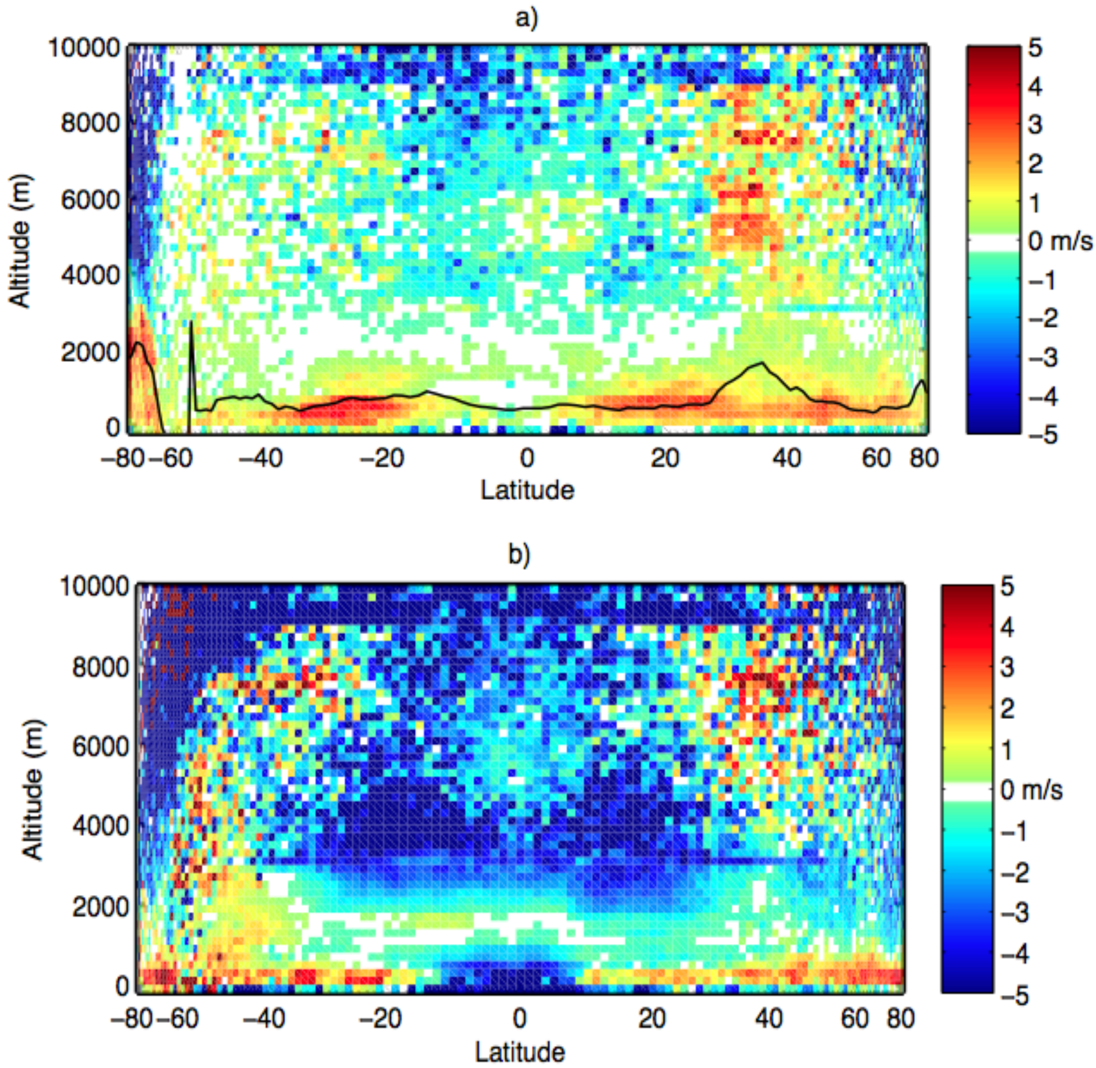

Figure 2: Zonally-averaged scalar wind bias (reanalysis–MISR) (a) over land. Solid line is the average topography (b) over ocean.

The new method removes some artefacts noted in the frequency distribution of retrieved wind directions. These had been too sparsely populated near to the E-W cardinal points. These improvements indicate that once the new method is implemented operationally and the MISR data reprocessed the summary statistics shown in Table 1 should show smaller differences, especially for upper level winds.

However, there is still at least one known major limitation in the standard MISR product that has yet to be fixed. There is an along-track bias in the wind speed that is dependent on the position across the 300 km swath of overlapped multiangle views. This bias appears to be zero at the swath center, and rises to about 3 m/s at the swath edge. For mid-low latitudes, the along-track component corresponds to the meridional wind component. Correction of this effect will be a major improvement.

10-YEAR TIME SERIES ANALYSIS OF MISR CMVS

The consistent processing of the MISR data, together with no calibration drift issues, and a uniform retrieval technique that is independent of latitude, allows us to examine the entire record for interannual fluctuations. These are summarised here as 10-year 'trends', noting that this is simply an indicator of the record's behaviour, and does not imply continued projection outside of the analysis interval.

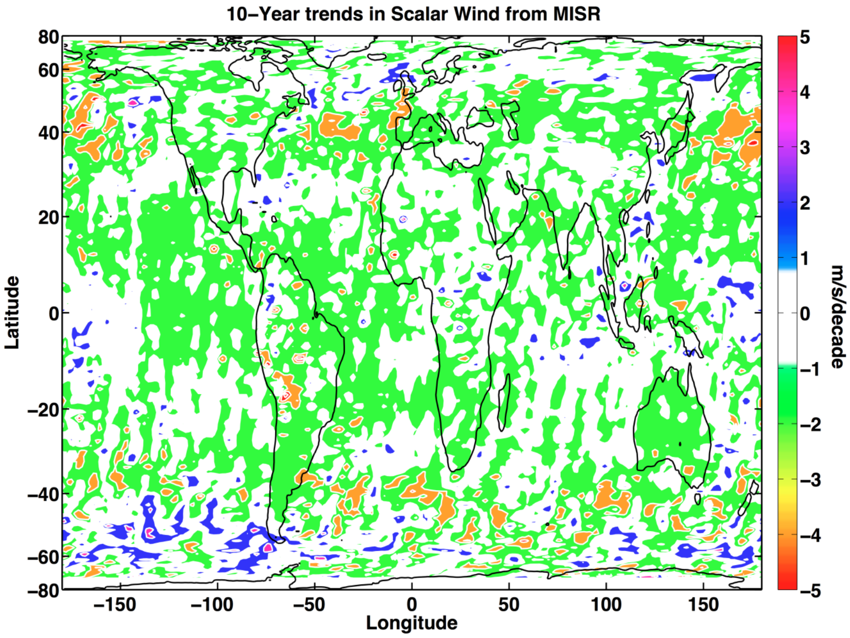

Figure 3: **MISR CMV changes 2000–2010, below 3 km, at 1-sigma level.**

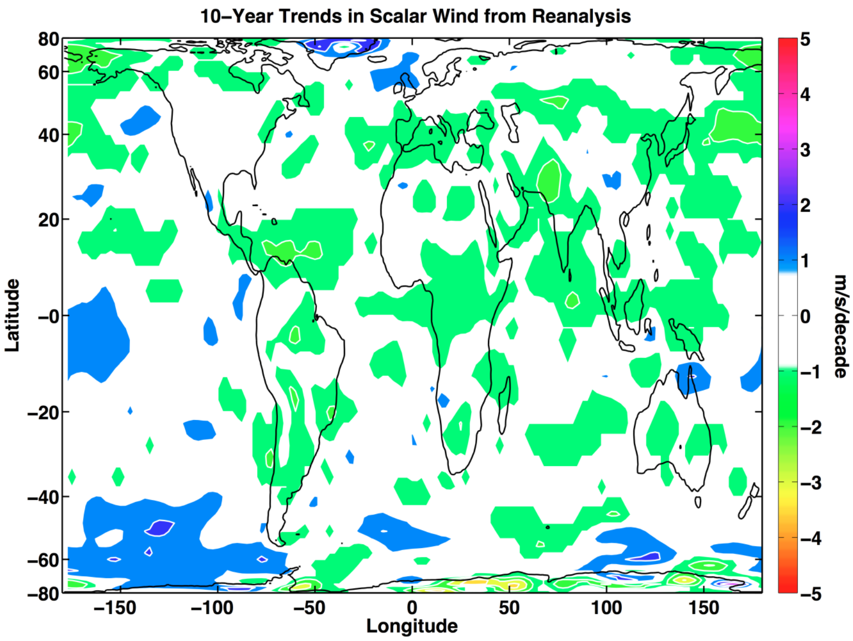

Figure 4: **Same as Fig. 3, but for reanalysis winds.**

Figure 3 shows the results from MISR CMVs, retaining those changes that are statistically significant at the 1-sigma level. Figure 4 shows a similar figure obtained using only reanalysis data over the same period.

It is interesting that both Fig. 3 and Fig. 4, despite being obtained independently, show very similar trends in winds. The scalar wind appears to have dropped in speed by 1 to 2 m/s over much of the globe during the last decade. Both figures also show a local increase in speed of about 2 m/s over parts of the Southeast Pacific at high latitudes. The MISR data provide more detail, having higher spatial resolution. They also show slightly larger changes in wind speed over the decade. Lower wind speeds at low altitude generally imply reduced evaporation rates over the ocean, with implications for the global hydrological cycle, so these observations present interest for deeper studies in the future.

ACKNOWLEDGEMENTS

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REFERENCES

Davies, R., Á. Horváth, C. Moroney, B. Zhang, & Y. Zhu (2007) Cloud motion vectors from MISR using sub-pixel enhancements. *Remote Sensing of Environment*, **107**, 194–199.

Herber, A. (2010) *Comparative Study of Stereo-Derived MISR Winds with Reanalyses*. M.Sc. thesis, University of Auckland, 95pp.

Kalnay, E., *et a*l. (1996) The NCEP/NCAR 40-year reanalysis project. *Bulletin of the American Meteorological Society,* **77**(3), 437–471.

Kistler, R., et al. (2001) The NCEP-NCAR 50-year reanalysis: Monthly means CD-ROM and documentation. *Bulletin of the American Meteorological Society,* **82**(2), 247–267.