A Comparison of Cloud Motion Vectors and Aircraft Winds

Paul R. Julian

The National Meteorological Center
National Weather Service
Washington D.C. 20233 USA

ABSTRACT

A series of colocation statistics have been gathered comparing high-altitude aircraft and satellite-derived cloud motion vectors(cmvs). The specific purpose was to examine the negative speed bias in the cmvs that has been evident for some time as revealed by comparisons with radiosonde winds and by nwp model comparisons. The bias statistics are stratified by producer, by latitude band, by speed category, and by the direction of the zonal flow. A gross error check is included to eliminate mis-located reports and/or transmission errors. Overall, the results indicate a linear speed bias that is a function of speed category, but independent of producer, latitude, or the direction of the zonal flow. Another consistent, and possibly new, result is a small positive speed bias for winds of less than 10mps.

1 INTRODUCTION

Some fifteen or sixteen years of operational use of wind vector estimates from synchronous satellite imagery have revealed an apparent persistent and imperfectly understood phenomenon: viz, an underestimate of the speed of the high-altitude (upper troposphere) cloud-motion vectors [hereafter CMVs] when compared with winds produced by other, in situ, measurements; or when compared with modern nwp data assimilation estimates. This bias, moreover, is traceable through the statistics given in the literature almost back to the beginnings of these comparisons. Thus, in spite of the significant amount of work by the producers of CMVs on refining altitude assignment, target definition, quality control, and other aspects of the determination of CMVs, the bias persists.

In an ECMWF Technical Memorandum [#111], by Per Kallberg, a scatter diagram of CMVs and colocated aircraft wind speeds was presented using data from The Global Experiment [FGGE]. This, I believe, was the first such comparison made, and serves as the motivation of the present work. In this scatter diagram, the low-speed bias of the CMVs is quite evident. Furthermore, there is evidence that the bias is a function of the wind speed itself. This feature has since been adequately demonstrated by the investigations of a number of individuals using comparisons to the EC analysis/forecast suite and to colocated radiosonde winds.

Considerable effort has gone into improving the altitude assignment procedures since a systematic altitude bias would translate into a wind speed bias, assunming that there is no cirrus in the stratosphere. The reasoning here is that in strong jet situations an altitude mis-assignment will be more serious than in a lighter-wind situation because of the stronger vertical shears present. The single feature of the accumulated statistics on the bias that does suggest an altitiude bias is the fact that the bias is a function of the wind speed itelf. Newer and more sophisticated altitude assignment procedures have produced a reduction in the bias, but the most apparently significant decrease occurred when the METEOSAT CMVs were produced with a new target processing, as well as a new altitude assignment, system. [e.g Woick, this workshop]

2 METHODS

The purpose of this Note is to exploit the CMV vs aircraft colocation procedure, rather than using radiosonde winds or nwp assimilation fields, to aggregate statistics which might give some insight into the speed bias problem.

Engineering system studies on modern aircraft navigation equipment, INS and OMEGA, as well as research aircraft experience, indicate that aircraft navigation winds are more accurate than radiosonde produced winds. The vertical averaging interval, on the order of a kilometer, for radar or radio-direction finding systems, makes them of a different sort when compared with CMVs. Finally, the statistics of wind vector fit to modern nwp assimilation wind fields suggests also that aircraft winds, in operational practice, are slightly superior to radiosonde winds. Aircraft winds are much more plentiful over the oceans than are radiosondes, making them a more attractive comparison for regions in which topography should not be a factor in CMV determination.

A series of CMV-aircraft colocation samples have been collected since September of 1990. Three distinct, independent samples have been produced, but the details of the sample stratification have differed. A brief summary is given in Table 1.
The idea of the study was to investigate the speed bias as a function of latitude, wind speed, and producer. These basic

distinctions auger information on the altitude assignment problem since, the effect of latitude being obvious, the three major producers have all used different altitude assignment algorithms. In the later samples, the decision was made to further stratify the statistics by wind direction-namely, if easterlies or westerlies were involved. This makes interpretation more complicated, because such a stratification is not independent of latitude or speed. However, the results seem to be interesting, as shall be evident.

The colocation window was one degree of latitude diameter, +/- 3 hours in time; and 400 meters in the vertical. A gross error check was included in order to eliminate mis-located reports and/or transmission and decoding errors.

TABLE ONE
CMV-Aircraft High-Level Wind Colocation Samples

Sample #	Dates	Stratification
1	Oct to mid-Dec 90	Producer Speed Category Latitude Band(50N-30S)
2	mid-Dec 90 to mid-March 91	Producer Speed Category Latitude Band(NH) East**/WestDirection
3	June to Aug 91	"

** inadequate sample, so all latitude bands combined for easterlies.

3 RESULTS

The results are presented, essentially, in a series of Figures. With the number of possibilities that follow from the breakdown given in Table 1, this series is rather large and cannot be reproduced in this contribution. A sample of the available material is shown instead. The intent is to show the speed bias of the high altitude CMVs as a function of producer, latitude, and speed category.

Figures 2 and 3 present the bias statistics for the winter 1990-91 and summer 1991 sample, for GOES and METEOSAT. Figure 4 (top) presents the summer 1991 bias data for GMS/Himiwara. In each Figure the ordinate is the speed bias in meters per second and the abcissa is wind speed category in 10 mps intervals. The stratifcation is by latitude band, as indicated. The number of samples in each point is not given, but ranges from 5 to a few hundred. In general, of course, the larger sample sizes are in the mid-latitudes at the moderate speeds. Since the reproducibility of the clear linear function of speed bias as a function of wind speed itself is very evident- in all samples, all producers, etc- the exact numbers entering into each point is only of secondary interest.

The bottom portion of Figure 4 gives the results of combining all three samples (Table 1) for the Latitude band 30-10N, but retaining the distinction of producer (GOES and MeteoSat). This combined sample has the following numbers of colocations:

TABLE TWO

Sample Size for Figure 3b

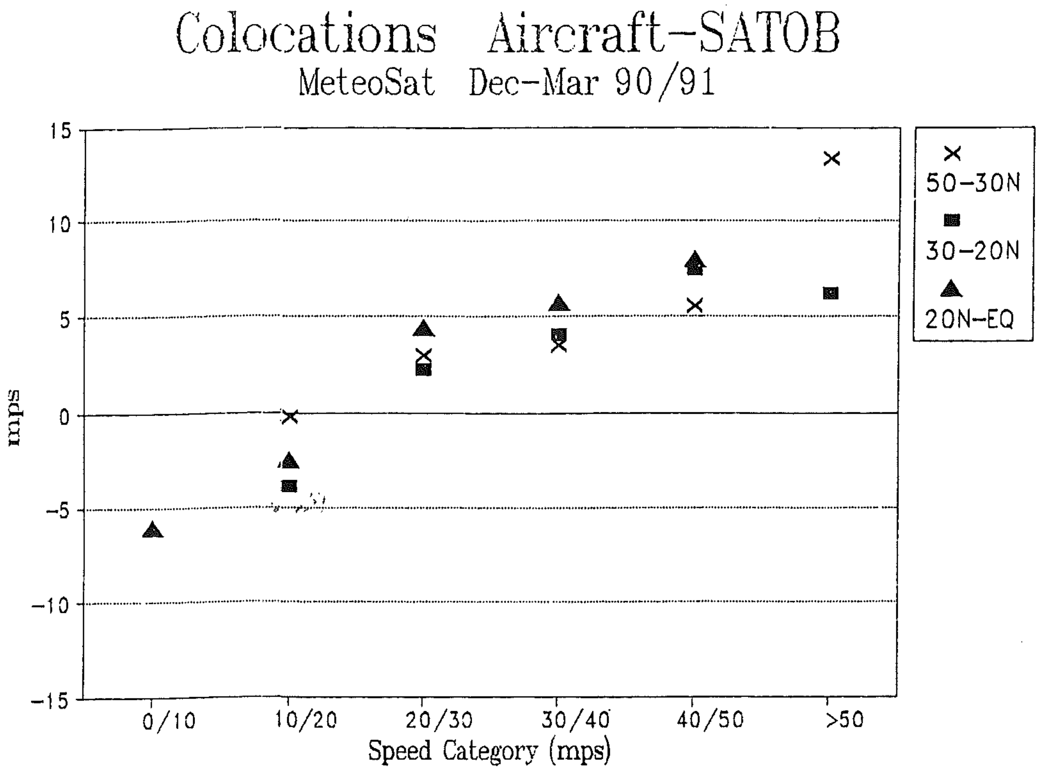
Speed Category	0/10	10/20	20/30	30/40	40/50	>50(mps)
METEOSAT	13	62	90	44	14	9
GOES	77	276	313	187	100	90

The conclusion to be drawn from this set of statistics seems clear: there is no discernable and consistent difference in the linear function of bias with wind speed when stratified by producer, season, latitude, or the direction of the zonal flow. This result should be interpreted in terms of the target definition, and altitude assignment uncertainties; and vertical and horizontal scale differences of the aircraft and CMV wind vectors. Moreover, this methodology is not dependent upon an assimilating model and should be considered, along with radiosonde wind comparisons, as a basis of CMV verification.

References

KALLBERG, P.:On the use of cloud track wind data from FGGE in the upper troposphere, ECMWF Technical Memorandum #111, Nov 1985.

WOICK, H.:Verification of cloud motion winds, this volume.



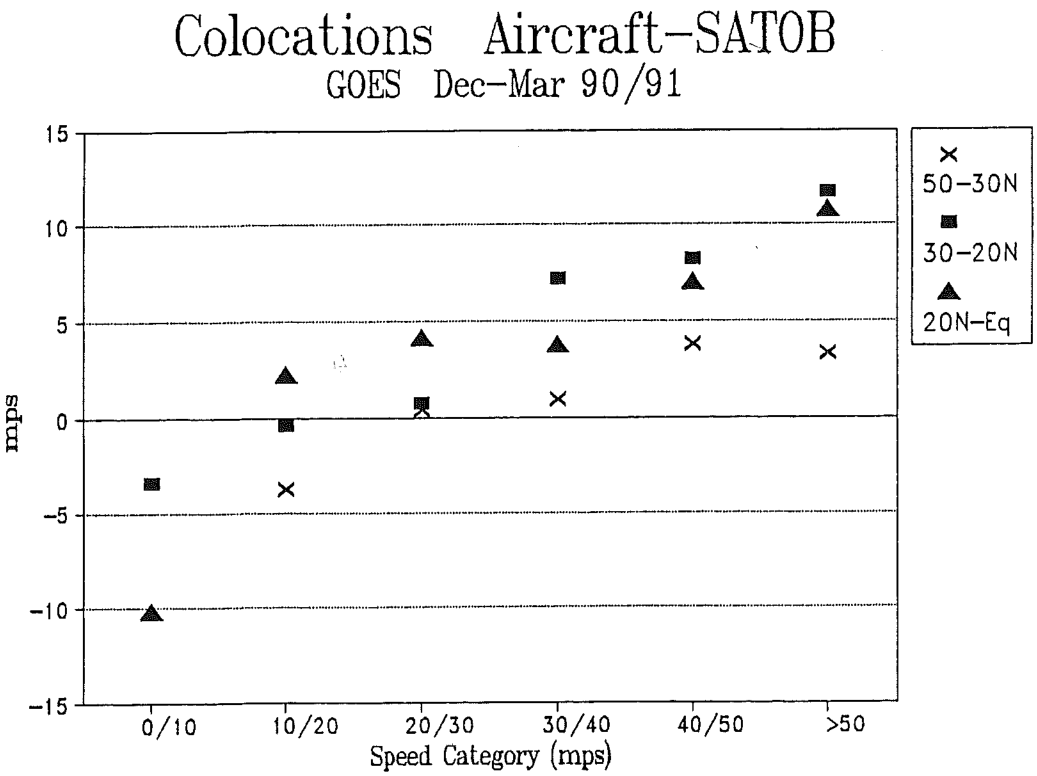
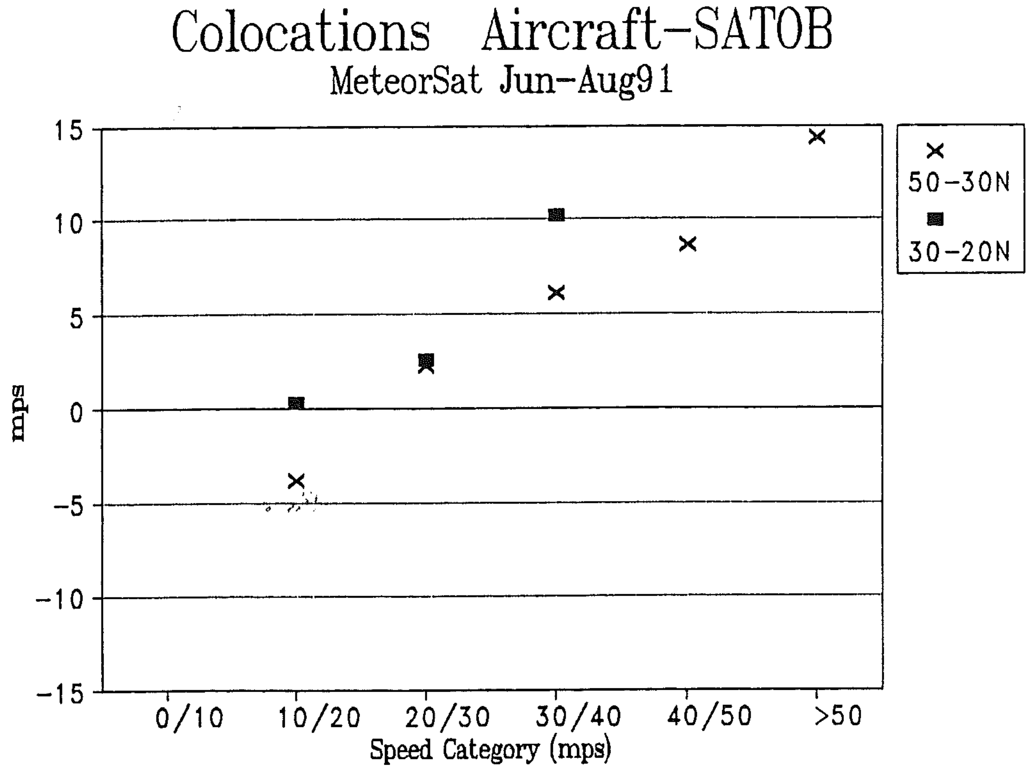


Figure 1. Bias statistics for METEOSAT (top) and GOES (bottom) for the Dec90 to March91 stratified by latitude and speed category. A positive bias indicates that the aircraft speed exceeds the CMV speed.



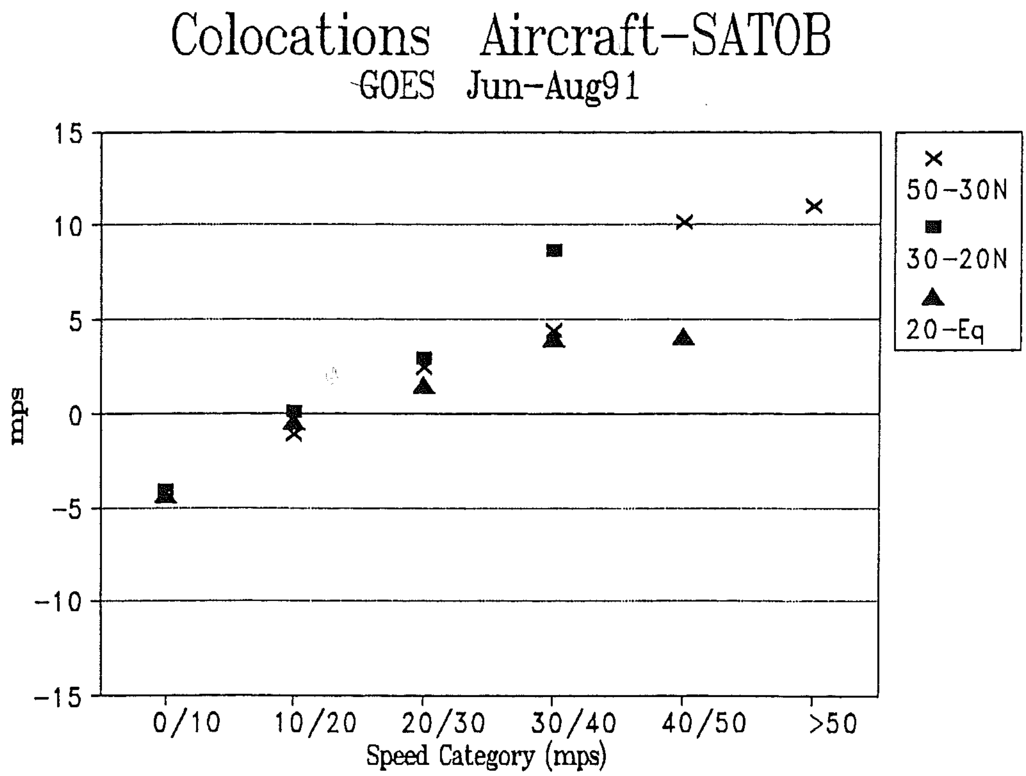
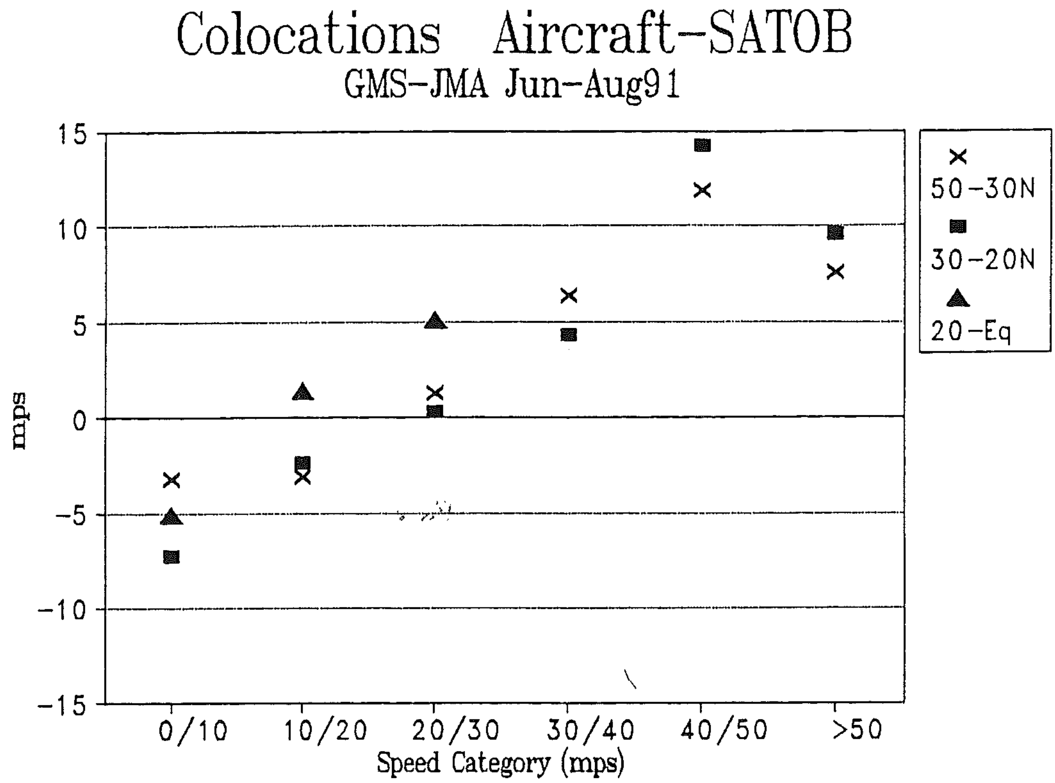


Figure 2. Bias statistics for METEOSAT (top) and GOES (bottom) for the June-August 1991 sample stratified by latitude and speed category. A positive bias indicates that the aircraft speed exceeds the CMV speed.



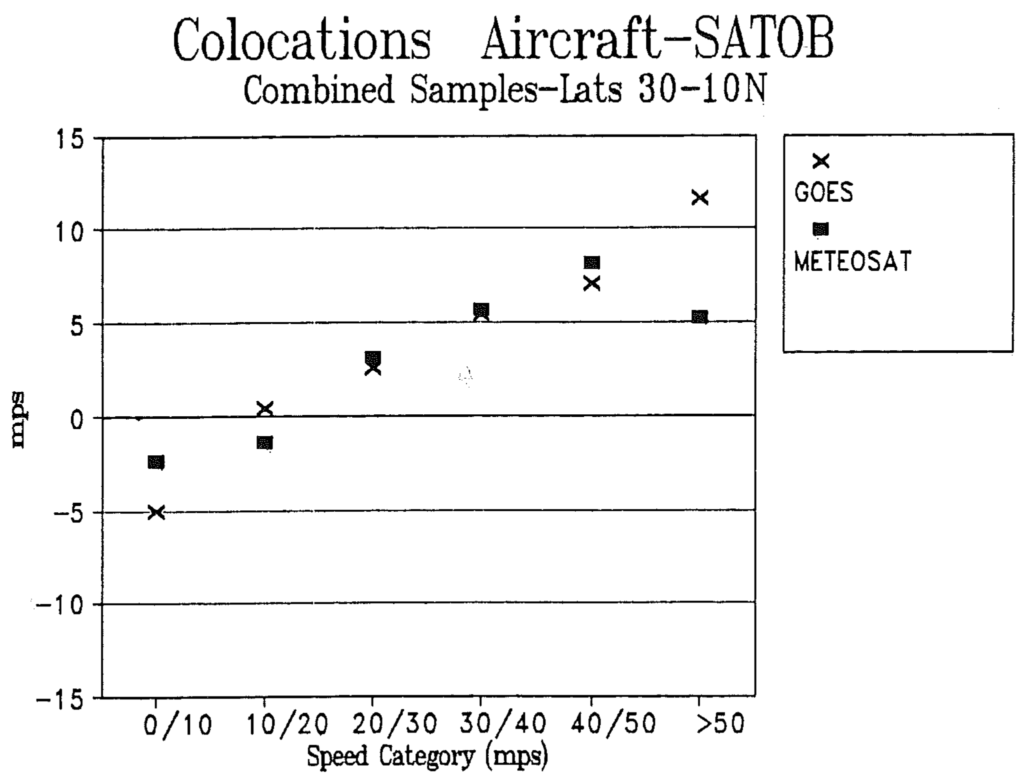


Figure 3. Top. Bias statistics for the June-August 91 sample for GMS/Himawara stratified by speed category and latitude. Bottom. Bias statsitics for all three samples combined (Table 1) for METEOSAT and GOES stratified by speed category.