COMPARISON OF INS HEADING AND GPS COG

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SUMMARY: In some cases in at-sea measurements there is no available measure of the ship heading. As an expedient, it is tempting to substitute the course over ground, COG, in place of HDG. They are relatively close, especially when the ship is in transit. We have examined measurements of COG and HDG during a trip on the Horizon Spirit, a 260 m container ship from Long Beach to Honolulu and return. A precision inertial navigation system, INS, provided HDG, and a GPS system provided the COG. We found that even with this large vessel steaming at 8–12 m s\(^{-1}\), there was typically a ±5° difference that correlated well with the winds. We have no measure of ocean currents and these can have an effect. But the strong correlation of the difference to winds suggests that winds are the dominant contributor. On top of the long term wind effect there is considerable short term variation which is caused by the ocean waves, mainly the longer period swell. This wallowing effect inserts a ±2° signal at a period on the order of 10 sec, the typical swell period.

Statement of the problem
This document is a brief examination of the differences between the ship heading and its course over ground. The ship speed over ground, SOG, and the course over ground, COG, are standard products from any GPS unit and are, basically, the velocity vector of the GPS antenna without regard to the platform that is carrying it. The heading, HDG, is the direction the platform’s north reference is pointing. On a ship the north reference is the bow—actually it is the bow-stern centerline. On a buoy or other platform the north reference vector must be defined. The (SOG,COG) vector and the HDG unit vector are referenced to an earth coordinate system, usually with x to the true east, y to the true north, and z vertically up. Actually many different coordinate systems are used and before using vector mathematics one should be aware of the coordinate system used.

Heading is a very important quantity for instrumentation. Without it one does not know where north is. HDG along with (SOG,COG) is an essential input to a transformation from apparent to true wind vectors. Yet while a simple instrument (simple today) like GPS provides (SOG,COG) heading requires a sophisticated inertial navigation system, INS. On a buoy or other platform it might be possible to use a compass corrected by the magnetic variation to true north. But a ship, especially a commercial steel ship, is a large bar magnet and a compass has no hope of working without considerable process of calibration.

If one does not have the HDG then the temptation is to use the COG as a substitute for it. When the ship is moving at a reasonable rate, the COG and HDG are very close. They differ when the ship slows down and maneuvers which is often the case for research ships.

Setting
The MAGIC project is operating on the container ship HORIZON SPIRIT a 260 m, 60000 ton (approx), container ship that carries cargo between Long Beach CA and Honolulu HA. In Feb 2012 a preliminary cruise
Figure 1: Data from MAGIC00, the preliminary cruise in Feb 2012, is used for this comparison. Trackline for MAGIC00 colored according to apparent wind speed. For this graphic, because the ship’s east and west tracks were exactly the same, the return track is displaced slightly northward.

(MAGIC00) was taken in order to become familiar with the working of the ship in anticipation of full deployment in Oct 2012. Some typical instrumentation was deployed during the cruise and is described in a technical memo m1104. Results from MAGIC00 are described in the tm1202 Magic00 Cruise Report.

Instrumentation and Methods
Instrumentation included a Kearfott SeaNav ring laser inertial gyro that provided every possible motion at a 50 Hz rate. The SeaNav data was subsampled to 10 Hz and to 1 Hz and these data were stored for analysis. We had several gps units operating and recorded the data each 5 sec. To compare to the hdg, the 5-sec data was interpolated down to a 1-Hz time base. These time series are called the “raw” data set. The 1 Hz hdg data were unit vectored averaged over a 2-minute averaging time. The 5-sec gps data were averaged over the same times. The 2-min data set is called the “avg” data set.

Errors in true wind calculations
The heading is used in the computation of true wind speed and direction. True winds require the apparent wind vector, HDG, and the ship’s (SOG,COG) vector. We computed true winds for the entire cruise by first using the HDG, also called YAW by the INS manufacturer, then using COG in place of HDG. The results are shown in figs 5 and 6.

The substitution makes a negligible error in the computed true wind speed; only a few tenths of a m s\(^{-1}\). However the error in direction shown by fig 3 appears in the true wind direction error.

A major use of the meteorological measurements is to calculate the air-sea energy flux using bulk transfer coefficient algorithms. In these calculations accuracy in the true wind speed calculations is crucial. The results here show that while the true wind directions can be in error by many degrees, the computed true wind speed is only slightly effected. And the speed is the most important contributor.
The sog and cog for the cruise MAGIC00. The top panel shows that the ship maintains a steady $11 \pm 1 \text{ m s}^{-1}$ speed going to Hawaii and $8 \pm 1 \text{ m s}^{-1}$ on the return to Long Beach. The bottom panel shows the GPS COG in blue and the actual HDG in red.

Notice during the Honolulu-Long Beach transit, HDG was greater than COG for days the first half and less than COG for the days 48.5–51 approx, and greater than COG for the remainder, days 51–55. The data in the cruise report shows that leg had strong starboard winds followed by port winds and to maintain the desired course the ship had to steer into the winds.

Figure 2: ISAR trackline of ssst for Leg 00.
Figure 3: The COG–HDG behavior described in fig 2 is clearly defined in this plot of their angular difference. A difference of $-4^\circ$ to $+5^\circ$ is a significant error.

Figure 4: A histogram of the angle differences shows that during the cruise examined here the difference is unbiased and has a spread on the order of $\pm10^\circ$. 

COG–HDG DIFFERENCE, 2-MIN AVG

COG–HDG HISTOGRAM
Figure 5: Comparison of computed true wind speed if HDG is used and if COG is substituted for the heading.

Figure 6: The comparison of computed true wind direction is COG is substituted for HDG.