

## Merry Christmas: 2009

I started this series of Christmas “cards” about 2005 and am continuing it. Perhaps it is boring to people that are not interested in old aviation stories. Then again, there may be a smattering of folks that find it interesting. Bill McManus was kind enough to publish this series on the Metro Club web page. A person that plays bridge has a mind which can digest technical explanations. Most of the stories are about the way we used to fly airplanes “way back when”.

So far, I write more about navigating old airplanes than flying old airplanes. I spent more time flying than I did navigating but it’s easy to write about the navigation methods we used because it just lends itself to paper and pen. After all, navigation is done on a paper chart. Professional flying is not like they show in the movies - everything going down in a blaze of glory. If you fly right, with very few mistakes, you do a lot of thinking about what you are going to do. As a result, you don’t have many surprises or excitement, everything falls into place and there is no story to tell. An exception is when the old airplanes malfunctioned. Modern jetliners are much more reliable mechanically than old airplanes.

My story about ILS was placed on the Metro Club web page about July of this year. That was a “mid-year card” and sandwiched between holiday seasons. That was an explanation of how professional pilots land in bad weather. The following story returns to the theme of navigation. It is an expansion of a story I briefly told for Christmas of 2006. I looked back on that and told myself I could do a better job of explaining about Altimetry. Altimetry was a method we used back in the 1940's and 50's. It is something no one uses anymore. A lot of aerial navigation methods we used were replaced when the Global Positioning System (GPS) became widespread at the end of the 20th century. We used to think that, if we could locate ourselves within plus or minus 25 miles, in bad weather over the North Atlantic, that was pretty good navigation. Nowadays GPS finds your position within a few feet. Modern air traffic control requires this accuracy because there are hundreds of airplanes in the air over the North Atlantic and they must have separation. In the 1940's and 50's there were very few aircraft airborne at the same time over the same ocean. The problem then was more of finding your way than an air traffic problem.

Finding drift angle with altimetry was made possible by the invention of the radar altimeter which measures true altitude above the ocean. It was a little black box which displayed the face of a 3 inch diameter cathode ray tube (CRT). It had a circular scale and the reflection lobe (signal which bounces back from the surface) rotated the circular scale every 5,000 feet. (You had to know your altitude within 5,000 feet). We could read the scale accurately to within about 20 feet.

### Aerial Navigation: Altimetry

When aircraft first crossed the ocean in the 1930s, navigators relied on dead

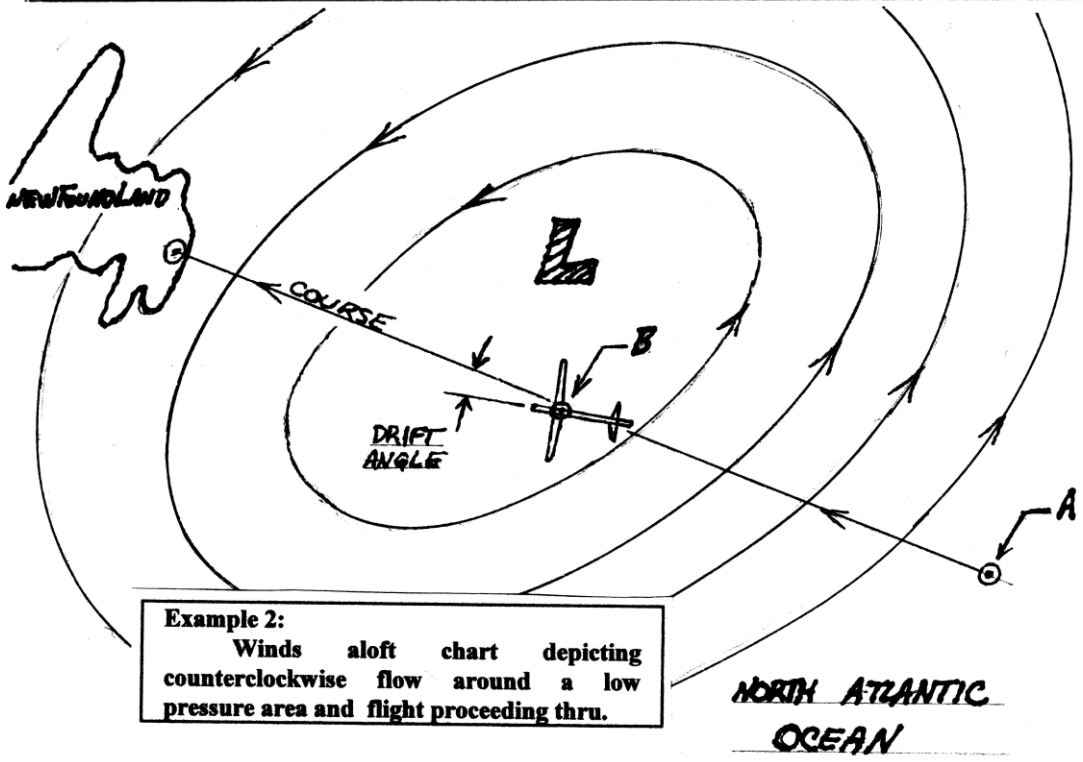
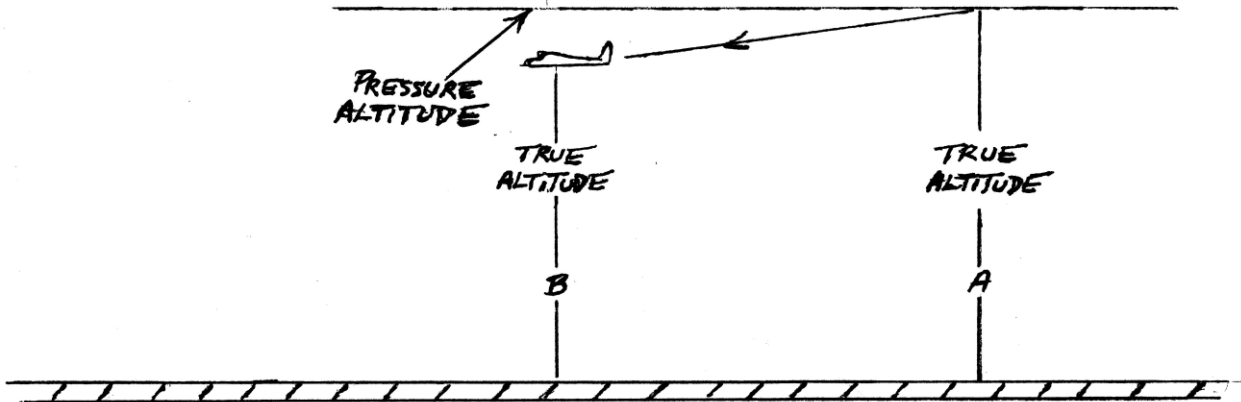
reckoning and celestial navigation to find their position. Bearings from radio stations provided another aid. This was “state of the art” in 1937 when Amelia Earhart tried her around the world attempt. About 1943, LORAN (acronym for LOng RANGE Navigation), provided military aircraft and oceanic airlines with another electronic aid. However these methods had their deficiencies. To use celestial navigators had to see the sun, moon or stars. This was not possible if the aircraft was in cloud or the sky was overcast, a frequent occurrence in low flying, propeller driven aircraft. Radio bearings from land based transmitters were unreliable, especially at long range. If equipped with a LORAN receiver, aircraft were often out of range, especially in the daytime and many areas of the world did not have LORAN coverage anyway. LORAN installations were mainly on both coasts of the US, Hawaii, Alaska and Canada. In other words, in weather and beyond the range of radio bearings and LORAN, the navigator was left with dead reckoning only.

In 1946, just after WWII, a technique for finding the drift angle of an aircraft was developed (drift angle is how many degrees the aircraft heading varies from its track over the ground). The aircraft must be equipped with a device to measure true altitude (radar altimeter). This method was especially useful during bad weather (no celestial and static interferes with radio and LORAN stations) or outside the range of electronic aids. This technique does not work over land because varying heights of terrain interferes with measuring true altitude above sea level. The aircraft must be flying a constant pressure level but coincidentally Oceanic Air Traffic Control requires aircraft to fly constant pressure levels. Beyond a hundred miles from the coast pilots set their altimeters on a standard setting of 29.92 inches of mercury (1013.2 millibar) thus they are flying constant pressure altitudes.

In this method, the component of the wind that deflects the aircraft off course can be calculated by measuring the change in true altitude over a given air distance. A navigator’s typical practice was observing the difference between pressure altitude and true altitude every 30 minutes. A formula was available that took into account the air miles between altimeter readings, the change in true altitude and coriolis effect\*. Coriolis effect was weak at the equator and increased with increasing latitude in the direction of the poles. Coriolis effect was a constant extracted from a published scale for the aircraft’s approximate latitude.

\*Webster’s dictionary: Coriolis force (kor-e-o’lis): the inertial force caused by the earth’s rotation that deflects a moving body to the right in the Northern Hemisphere and to the left in the Southern Hemisphere; this deflection is produced by the acceleration of any body moving at constant speed above the earth with respect to the rotating earth.

**Example 1:**  
 "Cross-section" of flight from pt A to pt B showing change in true altitude proceeding toward lower pressure.



**Example 2:**  
 Winds aloft chart depicting counterclockwise flow around a low pressure area and flight proceeding thru.

Example 1 & 2

Example 1 is a depiction of an aircraft going from pt A to pt B over the ocean. Note that while the aircraft is flying a constant pressure altitude, say 8,000 feet, that it's

true altitude is decreasing because it is flying into lower air pressure. It is in the Northern Hemisphere so it encounters right drift. Note also that in example 2 the navigator has altered heading a few degrees to the left to maintain course. Experienced navigators that knew altimetry watched the change in true altitude. As soon as the change in true altitude began to reverse, they anticipated a change of heading in the opposite direction.

Example 2 is also the type of chart aircrews get flight plan briefings from the meteorologist. It contains forecast winds aloft for the aircraft's route and it is called a "contour" chart. When we flew unpressurized aircraft, the forecaster would make these up for the 850 millibar level (about 5,000 feet) and the 700 millibar level (10,000 ft). When the DC-6s, Connies and Stratocruisers were flying in the 1950s, the forecaster would provide the 500 millibar level (18,000 ft). The forecaster would estimate the true height above mean sea level each contour line would be.

### **The way it was:**

Imagine that you are pilot of a DC-4 working for TransOcean Airlines which has a government contract. It is December, 1951 and your flight originated at Wheelus, the U.S. AFB at Tripoli, Libya. You are hauling 40 G.I.'s on orders back to the States. Your crew and the passengers rested in the Azores but you are now westbound headed for Gander, Newfoundland where you will gas up and return to Andrews AFB near DC. You are an experienced former military pilot on inactive duty since 1949, hired by the Supplemental (or "non-sched") airline when the Korean War broke out.

You don't know why TransOcean hired your navigator but you don't trust his work. He got lost over the Sahara Desert eastbound and if it were not for the Air Force providing you a steer into Wheelus when you called "MAYDAY" on your radio call you would have had to walk through a lot of sand. The first half of this flight you experienced excellent weather and "Magellan" (your copilot's name for the navigator) had an easy time. It is night time and there is a sky full of stars so he had no need for anything other than celestial. You are an experienced navigator yourself and have been trying to teach this guy about altimetry. This DC-4 is an ex-PanAm airliner, one of the first to use altimetry, and it is equipped with a radar altimeter. You try to maintain your proficiency at navigation. More than an hour ago you relieved the navigator for a few minutes, took the sextant in hand and sighted three stars and plotted a fix. The fix was about 30 miles to the right of course so you altered heading left to 280 degrees to correct back to the 290 degree course. Then you asked Magellan if he was using altimetry as a backup. The forecast for the last half of the route is bad weather and you knew that celestial was not going to be available. Altimetry was not ordinary navigation in that you must have a beginning reading. If you had to rely on it then you had to have been recording the altimeter readings. The reluctant Magellan recorded a set of altimeters reading under your supervision. Pressure altitude and true altitude were the same; 8,000 feet. The navigator had a form for recording the readings, including a scale of coriolis constants. You returned to the cockpit just as the sky became overcast.

Two hours later and more than six hours enroute Magellan tossed his hands up and

complained that he did not have anything to navigate with. The aircraft was picking up ice and encountering moderate turbulence. There was a lot of snow static on the radio direction finders and they would not point to any station in Newfoundland. No celestial was available because you could not see the sky. There was heavy static on the LORAN receiver and the screen was full of “grass”. Magellan wanted to alter heading back to the right about 15 degrees based on “suspicion”. You hesitated to take the heading change and asked him about altimetry. What was his latest calculation on drift from altimetry? He was not taking advantage of it but you recalled that two hours before you watched him take a reading. That would be the basis of your drift calculation. You turned over control to Fred, the copilot, stepped out of the cockpit and took the readings yourself (the radar altimeter was located in the navigator’s area). Fred kept the aircraft at 8,000 feet pressure altitude but the radar altimeter was 7,800 feet. True altitude had decreased 200 feet in two hours at normal cruising speed, 175 knots. The air distance between readings was 350 miles. You read the coriolis force constant from the form for your approximate latitude of 45 North. It was 53. The form listed the formula for solving the crosswind component but you had memorized it anyway.

Crosswind component equals coriolis force (53) multiplied by change in true altitude (- 200 ft) divided by air miles between readings (350) or 30 knots (rounded). Two hours at 30 knots means the crosswind component had drifted you 60 miles to the right between readings. You mark this in on the E6B “computer” that every pilot has to solve drift angles. It is approximately 10 degrees of drift so your heading of 280 degrees and the 10 right drift has produced a course of 290, there is no need to change course.

You return to the cockpit but instruct Magellan to monitor the altimeters. When the true altitude stops decreasing and reverses you will alter heading to the right. The navigator has no confidence in altimetry until he has something else to fix your position. You break out of the weather a half hour later he can see the stars again. He plots a new fix which shows you are close to course.

Your copilot listens to the discussion about altimetry between the navigator and you after the latest celestial fix. Fred waits until Magellan is out of earshot and says to no one in particular: “*Skill and science win out over ignorance and superstition*”.



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