Navigation

Robert French

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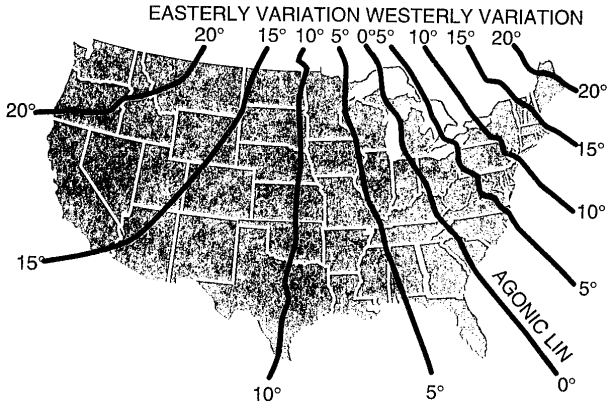
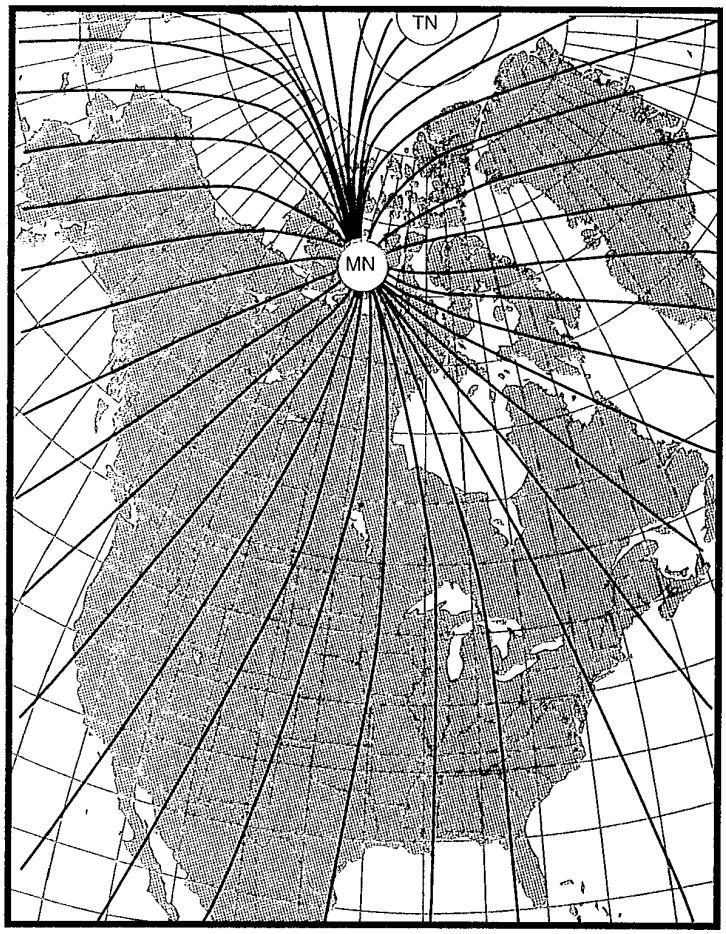
Gleim sections 2.1, 10.1-4, 11.5-8

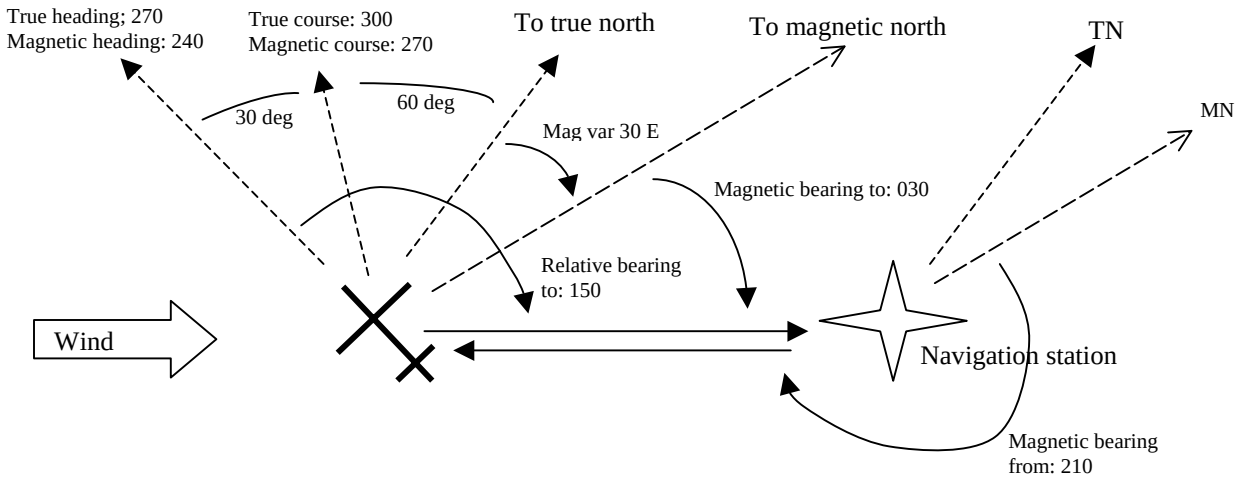
Navigation Concepts





Magnetic and True North

- *True north* is located at the geographic north pole
  - 0 or 360 degrees true points directly to the geographic north pole
  - Other degrees are measured clockwise from this point
- *Magnetic north* is located at the *magnetic north pole* which is about 1,300 miles away from the geographic north pole
  - 0 or 360 degrees magnetic points directly to the geographic magnetic north pole
  - Other degrees are measured clockwise from this point
- Because true north and magnetic north are in different places on the globe, the difference between them, called *magnetic variation*, varies depending on location
- The local magnetic variation can be found by looking at an aviation chart which displays *isogonic* lines, or lines along which the magnetic variation is constant
- If magnetic north is displaced to the east of true north, the variation is called *easterly variation*
- If magnetic north is displaced to the west of true north, the variation is called *westerly variation*



Courses, Headings, and Bearings

- A *true course* is the track of the airplane over the ground relative to true north
- A *magnetic course* is the track of the airplane over the ground relative to magnetic north

  MC = TC – East VAR (east is least, west is best)
  MC = TC + West VAR

- A *true heading* is the direction the nose of the airplane is pointed relative to true north
- A *magnetic heading* is the direction the nose of the airplane is pointed relative to magnetic north
- The difference between a *heading* and a *course* is due to wind and results in a Wind Correction Angle (WCA). Wind at altitude is always given relative to true north. Wind on the ground is given relative to magnetic north.

  TH = TC + Right WCA
  TH = TC – Left WCA

- A (true or magnetic) *bearing to* a station is the direction of that station from the airplane
- A (true or magnetic) *bearing from* a station is the direction of the airplane from that station
- *Bearing to* and *bearing from* are always different by 180 degrees
- *Relative bearing to* is (true or magnetic) bearing to minus (true or magnetic) heading (add 360 if negative)

  MH + RB = MB(to)

- A r*adial* is a line of position a particular magnetic direction *from* a navigation station
- The intersection of two non-parallel radials will give a single point in space

Compass Errors

- A compass has a variety of errors, both in steady state flight and while turning or accelerating. We will only talk about flight in the northern hemisphere.
- **During flight, a compass is only accurate when in straight-and-level unaccelerated flight**
- ***Magnetic deviation* is caused by the magnetic fields of metal and electrical equipment in the aircraft.** A small card will be posted on the compass indicating how to adjust for magnetic deviation depending on which direction you're flying.
- **A compass will indicate a turn to the north when accelerated while on an east or west heading, and a turn to the south while decelerated on an east or west heading**

ANDS = Accelerate North, Decelerate South

- ***Compass turning error*** **occurs when turning from a heading of north or south. A compass will lag (and at the start of the turn indicate a turn in the opposite direction) when turning from a north heading. A compass will lead (and at the start of the turn indicate a turn further in the direction of turn) when turning from a south heading.**

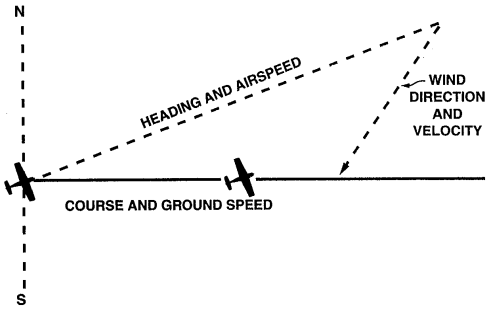
Determining Compass Heading

- The complete process for determining compass heading from true course is:

  TH = TC +/- WCA
  MH = TH +/- VAR
  CH = MH +/- DEV

Ded Reckoning

- Ded (Deduced) Reckoning is a method of navigation based solely on time, airspeed, distance, direction, windspeed and wind direction
- The goal is to find the desired compass heading and groundspeed
- The effect of wind can be visualized by use of the *wind triangle*
- Computation is usually done by using a flight computer, which may be a mechanical or electronic device



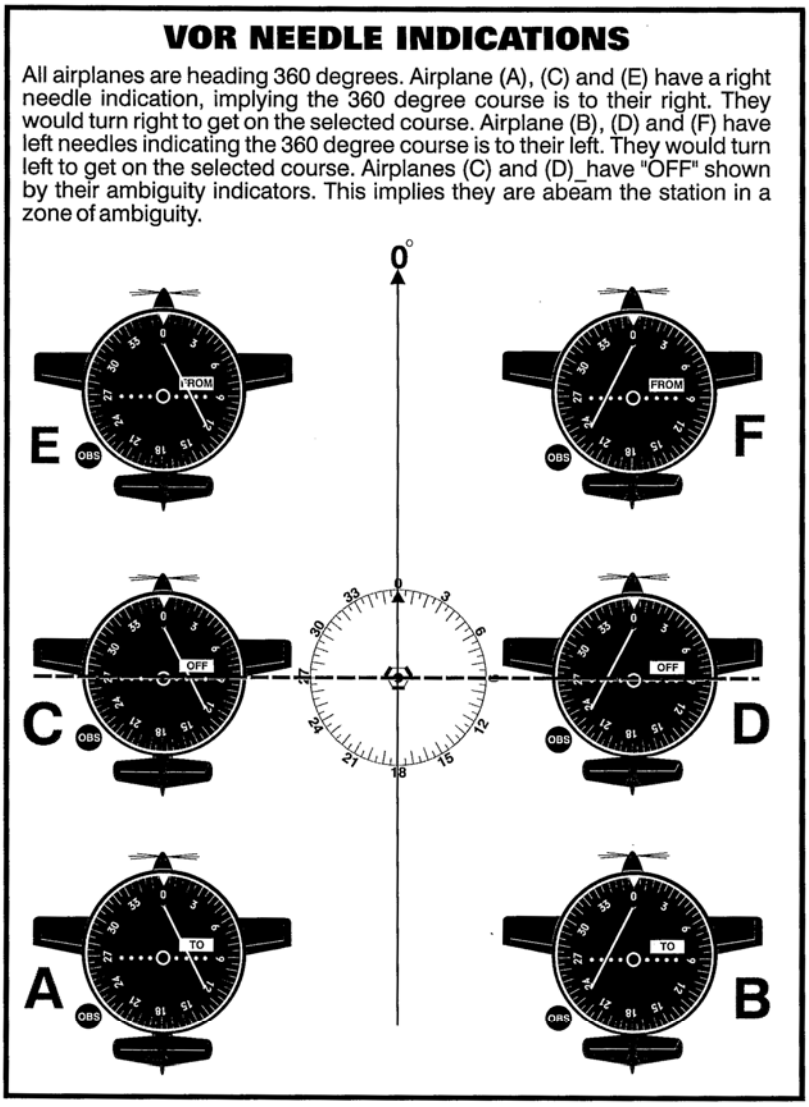
VOR and DME

- A VOR (VHF Omni-Range) is a ground-based radio station that broadcasts a VHF signal that allows a receiver to determine which radial he is on
- VORs have a limited range, usually 40-200nm, depending on altitude
- VORs are limited to line of sight
- DME (Distance Measuring Equipment) permits a properly equipped aircraft to determine its slant-range distance from the station
- A DME station is sometimes collocated with a VOR, in which case it is called a VOR-DME
- A military TACAN station provides the same information as a DME, as well as an (unavailable to civilians) military version of the VOR
- VOR and TACAN stations are sometimes collocated, in which case they are called VORTACs
- VORs and DMEs transmit a three-letter identifier in Morse code that can be monitored on the receiver. It is a good idea to verify a VOR's or DME's identifier before relying on the navigation signal.

Using a VOR

- A VOR receiver consists of several parts:
  - The *omni-bearing selector* (OBS) is a dial that rotates the outer compass ring
  - The *course-deviation indicator* (CDI) is a needle that indicates whether the airplane is to the left or right of course

  - The *TO-FROM indicator* indicates whether the station is in front of or behind the airplane. It indicates OFF (or blank) when directly over the station.
  - The *NAV flag* indicates whether a valid signal is being received
- The operation of a VOR is rather confusing
  - The top of the compass ring indicates a given radial from the VOR
  - If the OBS is turned until the CDI needle centers with a FROM indication, the airplane is on the radial indicated at the top of the compass ring and flying that heading will fly away from the VOR
  - If the OBS is turned until the CDI needle centers with a TO indication (180 degrees off the above example), the airplane is on the reciprocal radial and flying that heading will fly towards the VOR
  - If a radial is selected with the OBS, the CDI needle will indicate whether the airplane is to the left or right of course *assuming the airplane is flying in the same direction as the OBS selection*
  - The CDI needle is only correct when flying towards the VOR with a TO indication, or away from the VOR with a FROM indication
  - If the TO/FROM indication is backwards, the CDI needle will displace to the "wrong" side – this is called *reverse sensing*
  - The VOR indication is independent of the airplane heading! It only matter which radial is dialed in using the OBS.
- With two VOR receivers (or a single one and switching frequencies) it is possible to determine radials from two different stations, and thus a position in space



VOT

- VOR receivers can be checked by use of a VOT (VOR Test Facility)
- VOTs are available at some airports and broadcast a constant signal that should cause the received to indicate 180 degrees TO or 360 degrees FROM (think Cessna 182) regardless of the location of the airplane relative to the VOT

ADF

- An ADF (Automatic Direction Finder) consists of a needle on a compass card that displays the direction to a selected NDB (Non-Directional Beacon) or AM radio station transmitting tower
- ADF is not necessarily line of sight, but may be distorted near large objects (like mountains)
- The ADF needle always indicates somewhere even if there is no valid signal
- It's important to listen to the ADF signal to make sure it's valid at all times
- A *moveable card* ADF automatically turns the compass card to select the airplane's heading at the top
  - The head of the needle will point to the magnetic bearing TO the station
  - The tail of the needle will point to the magnetic bearing FROM the station
- A *fixed card* ADF always shows "0" at the top
  - The head of the needle will point to the relative bearing TO the station
  - The tail of the needle will point to the relative bearing FROM the station

LORAN-C

- LORAN-C is a ground-based navigation system that can tell latitude and longitude within a very small error
- LORAN-C was original developed for maritime use, but is now available throughout the continental U.S.
- Not very many airplanes have LORAN-C receivers
- LORAN-C is being phased out in favor of GPS

GPS

- GPS (Global Positioning System) is a satellite-based navigation system that can tell latitude and longitude with an extremely small error (around 10 feet) anywhere in the world
- **There are 24 GPS satellites in low-earth orbit. There are at least 5 satellites observable by a user anywhere on the Earth at all times.**
- **Three GPS satellites are required to render a 2-D position + correct time**
- **Four GPS satellites are required to render a 3-D position + correct time**
- GPS receivers are able to tell time to an extreme degree of accuracy

