Understanding magnetic variation use in the simulator (FS9-FSX-P3D)

V1.3 – Hervé Sors

1) General calculation of magnetic variation (declination) by the simulator

Local magnetic variation (MV) is continuously calculated by the simulator from the MAGDEC.BGL file. It only depends on aircraft position (latitude/longitude) and data as coded in the above file. Format of MAGDEC.BGL and the way MV is calculated from it at any position is described in detail here

Magnetic variation data have to be updated on a regular basis so as to take into account secular variations of the magnetic variation field resulting from the fact north magnetic pole is continuously shifting. Until now, those variations were less than 0.5° per year in most regions and there was no need updating them more often than once a year. However, a faster drift has been recently observed (see Note 1).

Original MAGDEC.BGL data provided with FSX and P3D (all versions) is now 10 years old (2009) and most recent (2019) values differ by around 1-1.5° although larger changes are observed in some regions.

Aircraft magnetic heading (as displayed on a correctly aligned heading indicator and on the compass) will be reported by the simulator as:

Magnetic heading (MH) = True heading (TH) – MV

MV is a signed value being, by international convention, positive for East variations and negative for West variations (although an inverse convention is used internally in BGL files as well as for FSX/P3D XML compiler !).

The example below illustrates how data are calculated by the simulator:

Aircraft is on ground at threshold of runway 06L at KLAX and aligned on runway axe.

True heading (as reported by the simulator via the FSUIPC or SimConnect interfaces) is 83.0°. Magnetic variation at aircraft position (also retrieved from the simulator) is

12.0° (positive as East). Consequently, aircraft magnetic heading is 71.0°. In this example, magnetic variation is calculated by the simulator from an updated IGRF-12 2019 MAGDEC.BGL file (values on 1-Jan-2019).

You may check from NOAA online magnetic variation calculator that this value is correctly calculated at the current N33° 56' 57"-W118° 25' 51" position (WMM2015 or IGRF-12 model).

2) Runway magnetic bearing

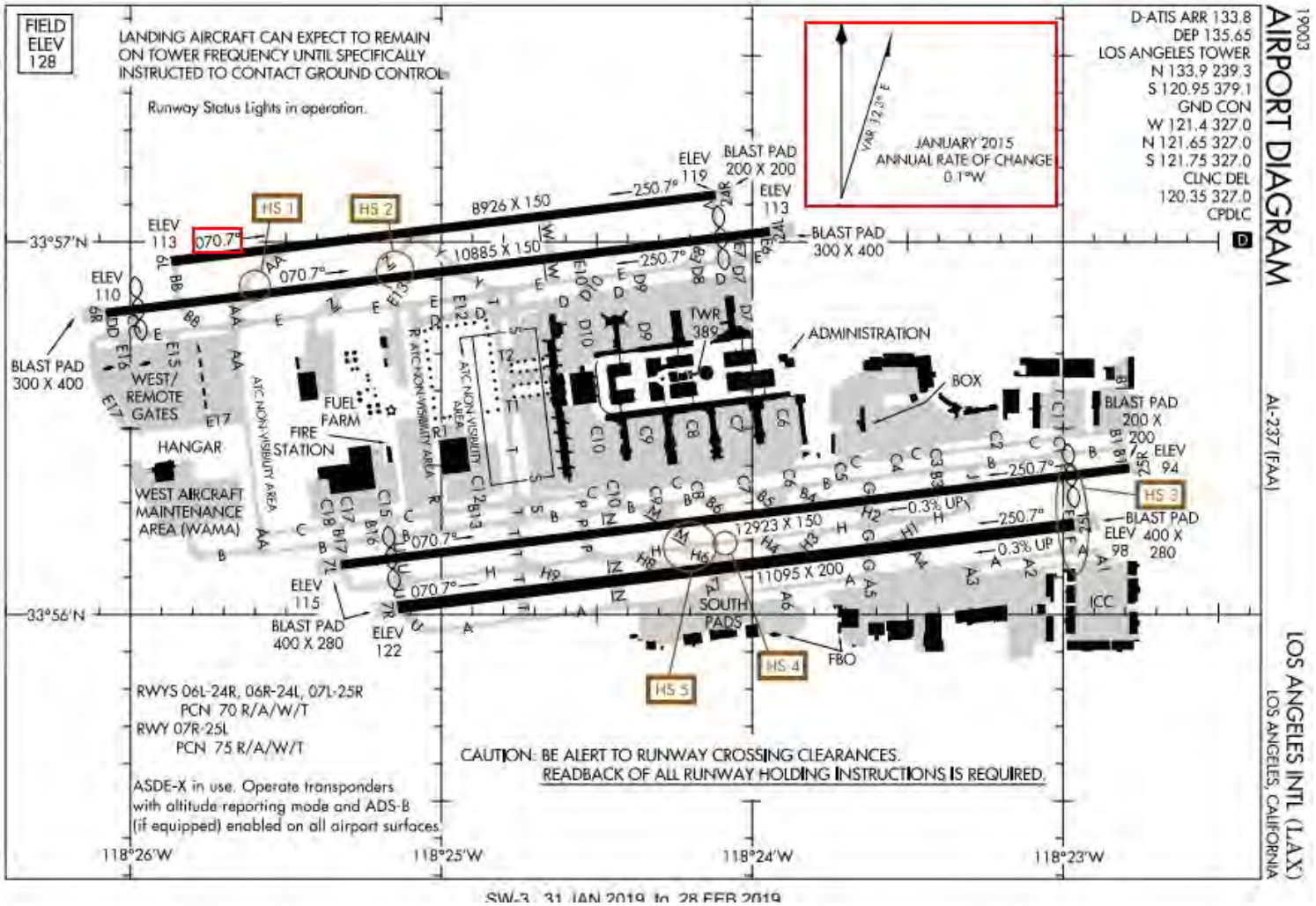
From time to time, you will notice that there is some disagreement between the magnetic bearing of a perfectly aligned aircraft on a runway and the corresponding runway value depicted on the airport diagram chart. At the condition runway physical orientation (that is its true bearing) is correctly modeled in the scenery, it is only because the "reference" magnetic declination (variation) used for charting airport data doesn't correspond to that calculated by the simulator.

Reference magnetic declination used for airport charting is usually indicated on diagram charts (with the year of observation) and/or in the text part of the AIP. Usually all approach, departure, arrival charts also include a reference magnetic declination that is used to compute and represent radials and bearings. This magnetic declination value may or may not be the same on all charts for a given airport but usually information is consistent and regularly updated.

In any case, depending on the respective values of chart magnetic variation and of that provided by the MAGDEC.BGL file at airport position, there will be a more or less good agreement.

An example below:

As shown in the following KLAX airport chart, runway 06L magnetic bearing is reported to be 70.7° (and not 71.0° as in the simulator) due to the fact magnetic variation used for chart calculations is here 12.3°E (2015 value).
Runway true bearing is still 83.0°; it only depends on runway characteristics of real airport data; in the simulator, it is the true runway bearing as coded in the runway BGL subrecord. See Note 2 for a comparison here.



Should we then use a 2015 MAGDEC.BGL file so as to obtain a better fit. Evidently, no for several reasons:

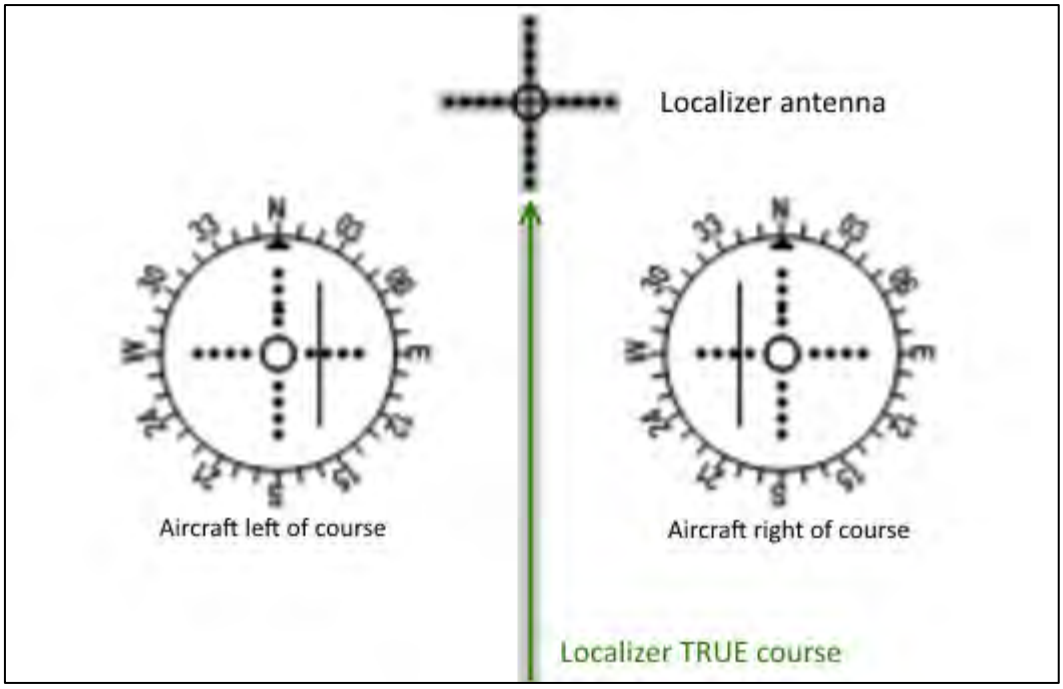
(i) There is no possibility to define different magnetic variation settings from one place to another in the simulator (there's a single MAGDEC.BGL file); MAGDEC.BGL data will apply to all airports worldwide; considering many of them have already updated data using latest MV (2019), it may result in discrepancies for many of them,
(ii) That's real life. Pilots aligned on KLAX 06L will read today a 71° magnetic heading if instrument precision allows that and not 70.7°.

3) Airport magnetic variation (BGL files)

FS and P3D (all versions) include in the airport record fixed part, a magnetic variation value (offset 0x24, FLOAT variable). This variable *doesn't have any effect in the simulator*. It could be a "reference" value (for information only) or something that has been abandoned at some time during software development. In any case, this value may be unreliable and should not be used by any add-on. Note that there is no specific MV information for runway subrecords.

4) ILS localizer course (see also Note 3)

In the simulator, position of aircraft relative to ILS localizer is modeled and displayed on VOR receiver from *aircraft geographical position*, *localizer antenna position* and *localizer true course*. Localizer information (latitude, longitude and true course) is defined in the BGL ILS record. *It doesn't involve any magnetic variation effect.*



While aligned on an ILS localizer in a stable way, aircraft magnetic course (Amc) will be:

Amc = Localizer true course – Current MV at aircraft position

Again current MV at aircraft position is retrieved by the simulator from the MAGDEC.BGL file. Aircraft heading while flying the ILS may differ in case there is a significant cross wind component. Also note that localizer course may more or less differ from runway bearing in case it is an "offset" ILS.
Magnetic variation will not change significantly along an ILS approach. Consequently the ILS magnetic course (ILSmc) as coded in the simulator will be

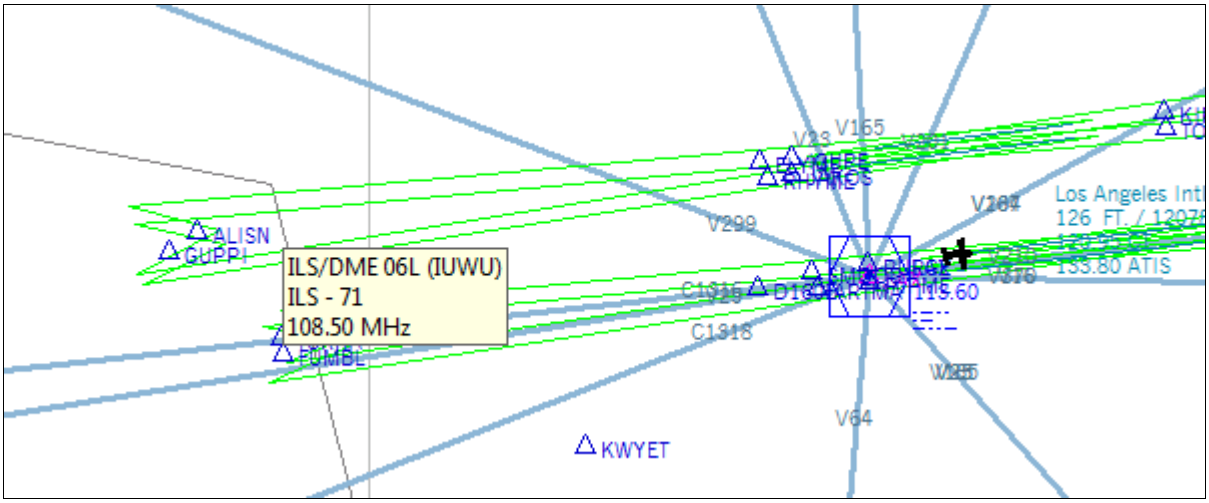
ILSmc = Localizer True course – MV at localizer position

If ILSmc differs significantly from the published magnetic ILS course as depicted on IAC charts, it means:
(i) either there is an error in properly coding the localizer position and/or its true course in the active scenery,

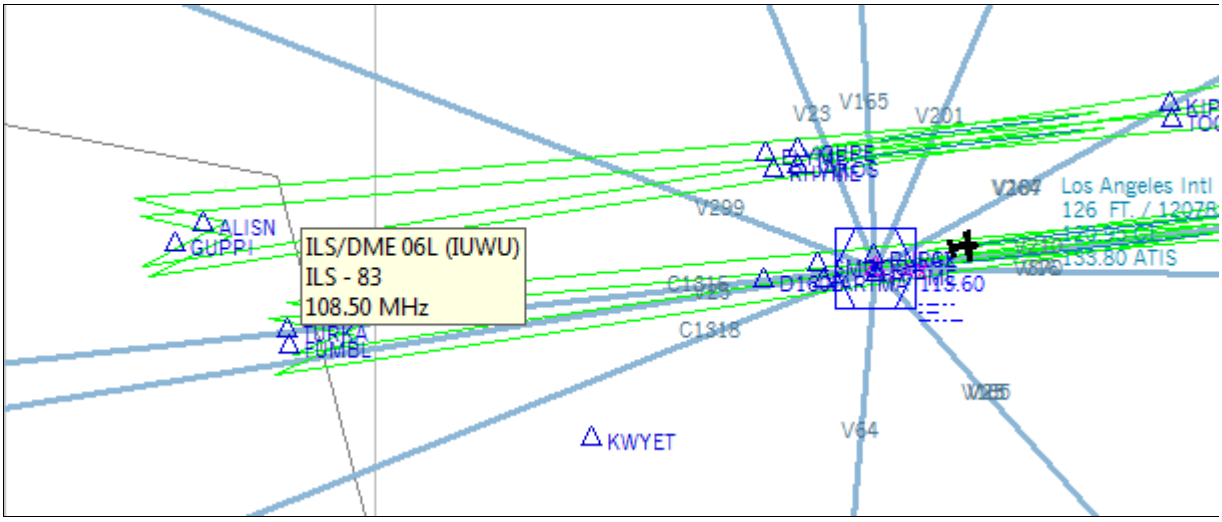
(ii) or the magnetic ILS course has not been updated on the approach chart since some time while local magnetic declination has changed (as for airport diagram, magnetic declination applied for ILSmc calculation is usually indicated on IAC chart and/or as part of ILS characteristics).
So, the problem is similar to that observed for runway magnetic bearing discrepancies and the same will occur in real life.

BGL ILS/VOR records include a magnetic variation value (offset 0x1C, FLOAT variable). Again *this variable doesn't have any effect on ILS tracking* (see also Note 3).
However, it is used by the simulator to calculate ILS magnetic course on map view and provide some of the GPS information (although ILS beam orientation is unchanged).

An example below:



Real values: Localizer 06L true course: 82.97° - BGL ILS MV: (12.00°, E12)



Modified values: Localizer 06L true course: 82.97° - BGL ILS MV: (0.00°, E0)

BGL ILS magnetic variation may also affect some GPS radial displays when ILS frequency is active as shown on the following picture (same settings as on the previous one).

5) VOR magnetic variation (station declination)

As indicated above, BGL VOR records include a magnetic variation value. For VORs (including VORDME and TACANs records introduced since P3Dv3), this value is the "station declination" that is the angular adjustment between the zero degree radial of the station and true north. In real life, station declination is determined at the time the station is calibrated. It should be kept as close to magnetic north as possible but, practically, some VOR stations may not be recalibrated on a regular basis.

Consequently station declination may significantly differ from actual magnetic variation in some cases. Station declination is ALWAYS used for charting information (airway orientation, radials from VORs, arrival and departure procedures using such facilities that are depicted as magnetic values). For better realism, *it is important station declinations are accurately set in BGL VOR/TACAN records from current AIP data* since it will have some effects on conventional radio navigation.

Practically, here are some of the implications (see further below for an example):

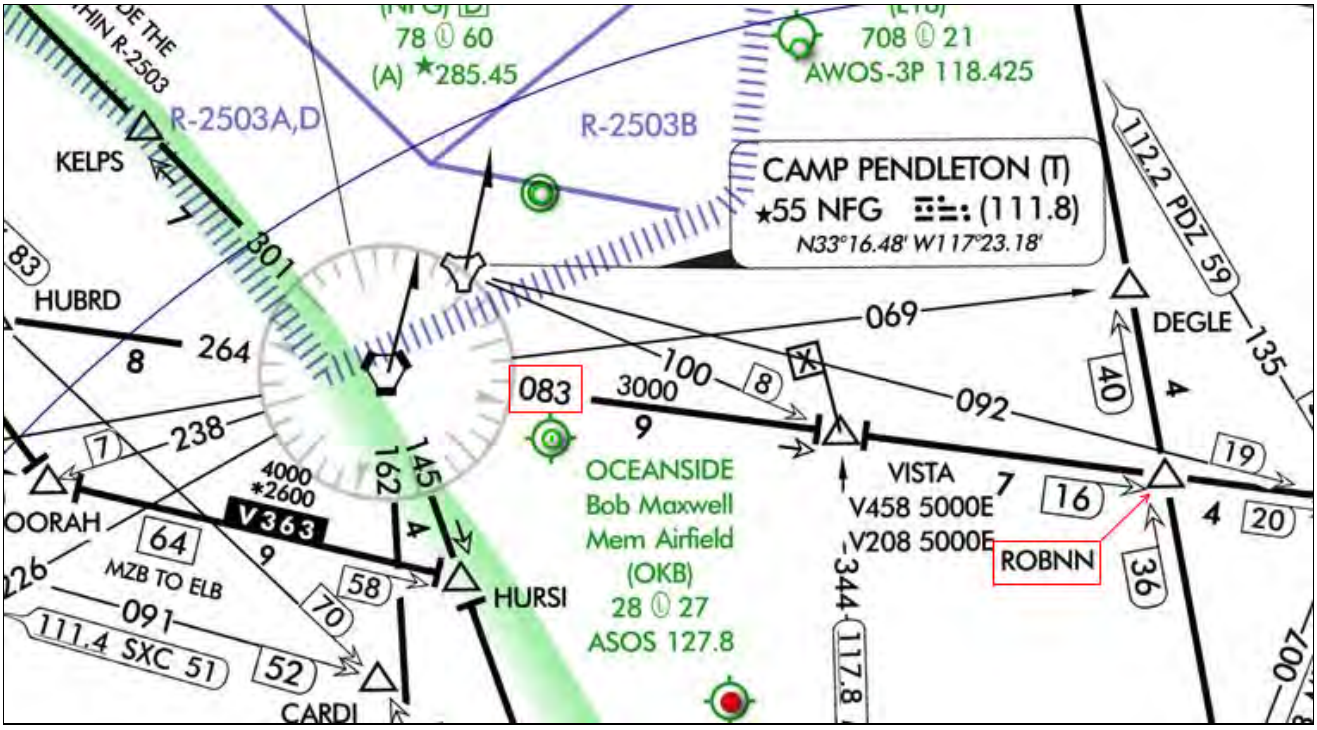
(i) if you are using dead reckoning, when you select a course based on the charted airways or compass roses, add the VOR declination to the charted radial before using it to select a course or heading,

(ii) if you are flying by reference to VORs, add the VOR declination to whatever your VOR receiver is saying before using it to select a heading,

(iii) if you are using GPS to fly along an airway, do not be surprised if your GPS indicates a bearing that differs from the charted VOR radial for that airway,

(iv) if you simply want to use a VOR to determine whether you are following an airway, then you do not need to worry about VOR declination. The charts conveniently tell you what VOR radial you'll have to set on your VOR course selector to stay on the airway path.

An example (flying airway V208 from Oceanside VOR to ROBNN intersection)



For proceeding from OCN to ROBNN on V208 you will just have to select the 083° radial of OCN VOR (115.30) on the VOR course selector and adjust heading so as the CDI remains centered. No more and no less.

However, if you wish to fly along V208 without using VOR CDI information or want to estimate which heading you should initially set (in no wind conditions) for staying on the airway path, a bit more math is necessary.
According to FAA database, coordinates of OCN VOR and ROBNN intersection are:
OCN: N33° 14' 26.28 – W117° 25' 03.79 – Station declination is 15.0°E
ROBNN: N33° 12' 12.52 – W117° 06' 12.58
WGS84 calculated true track and distance from OCN to ROBNN are 097.9° and 15.97 NM respectively.
Considering OCN station declination is 15°E, the charted radial from OCN station to ROBNN is indeed 097.9-15.0 that is 082.9° (rounded on the chart to 083°)

However, current 2019 magnetic variation at OCN position is now 11.6°E; you may use the NOAA calculator to calculate this value that is also directly provided by some navigation databases such as Jeppesen and Lido.
Consequently actual magnetic track from OCN to ROBNN is 097.9-11.6 that is 086.3° (to be rounded to 086°) and it is the magnetic bearing our aircraft will have to follow for staying on the airway (and that differs by 3° from the published 083° value).
Of course, *this calculation will be accurate in the simulator only if the MAGDEC.BGL is up to date since current local magnetic variation is calculated from it*.

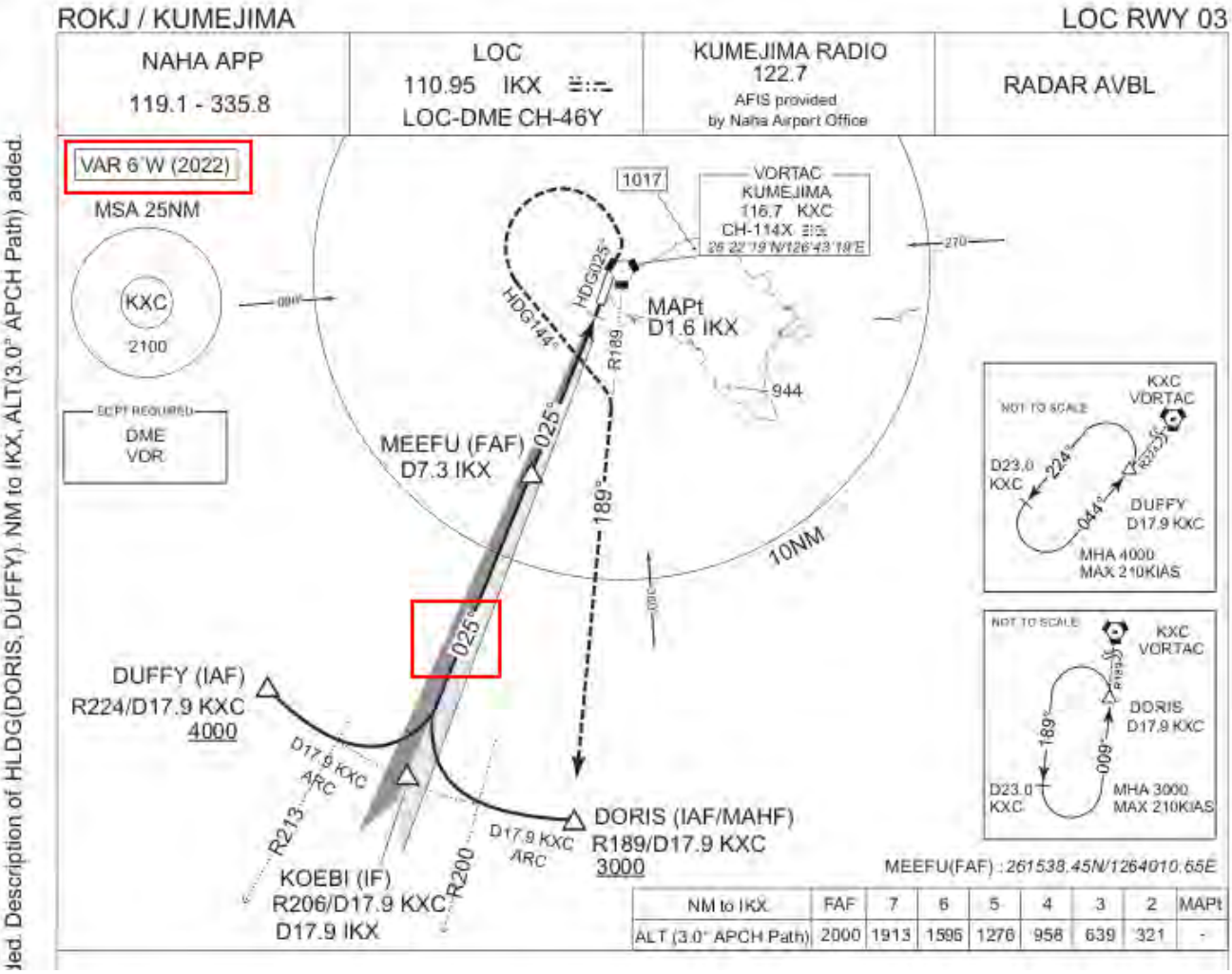
6) Possible FMC (and other) discrepancies

While using published charts and VOR/ILS information is still the basis of conventional radionavigation, modern FMC, some GPS as well as some planning software make use of an internal database of airport and ILS data as well as waypoint/navaids coordinates. Additionally, some include their own magnetic variation calculation while others make use of the simulator data (based on the MAGDEC.BGL file).
Usually, such FMC internal databases can be updated from specialized providers such as Navigraph (Jeppesen) or NavDataPro (LIDO). FMC calculations will be performed accordingly.
Considering navigation databases are built from official airport and navaid data (including ILSs), some discrepancies may occur on the basis of what is described above in (2) and (4) if current simulator magnetic variation (as calculated from the MAGDEC.BGL) differs from the one that is recorded in the databases. It is a normal situation as long as airport/nav magnetic variations are not updated to more recent values.
Then, you shouldn't worry observing from time to time a 1-2° difference between a magnetic FMC ILS course and aircraft current magnetic course while aligned on a localizer. It is not the result of any coding or database error.

Very occasionally, some other discrepancies are due to an incorrect (or lack of updated) information on published charts. In such a case, it is simply a publisher error. This is especially the case when magnetic variation of some ILS/LOC approach charts is updated and associated localizer magnetic course is not.

An example is shown below:
Magnetic course of the IKX LOC 03 is charted as 025° on Kumejima (ROKJ) airport. Latest chart was issued on 3-Nov-2022 indicating an updated magnetic variation of 6°W (2022). From published coordinates of runway 03-21, calculated WGS84 runway true course is 21.2°. ILS is aligned with runway. Consequently, localizer magnetic course should have been reported as 027° and not 025° and it is certainly the case while flying this approach. While Jeppesen published the original unchanged Japanese value, LIDO made the correction in its database.
So, do not always trust values that are reported on charts since they may not be always properly updated, at least for a period of time.

INSTRUMENT APPROACH CHART



7) Other BGL magnetic variation information

BGL NDB and waypoint records also include a “magnetic variation” FLOAT value (offset 0x1C for NDB records and 0x10 for Waypoint records)
At this time, I’m unsure it is used by the simulator and I didn’t see any effect changing them on limited tests. Some database publishers provide magnetic variation values for such facilities, usually based on currently calculated magnetic variation at NDB or waypoint position. However it is still possible magnetic variations of NDB and waypoints, as coded in the BGL files, are used in some default route planning or stock GPS calculations (e.g. approaches). This has to be investigated further on.

Additional notes

(1) During the 20th century, north magnetic pole has moved continually northwestward at a relatively slow rate (around 10 km/year). Since 1970 its rate of motion has accelerated to approximately 50 km/year and, as of early 2019, the magnetic north pole is now moving eastward from Canada towards Siberia at a rate of approximatively 55 km/year. The increased speed with which the magnetic north pole has moved prompted authorities to officially update the World Magnetic Model (WMM) before 2020 (WMM2015v2). WMM as well as the International Geomagnetic Reference Field model (IGRF) are typically updated every 5 years (last update in 2015). The WMM is the standard model used for navigation by FAA, NATO, the US department of Defense and by smartphone operating systems. For other users, choice between WMM and IGRF is arbitrary. MAGVAR.BGL file for a given year can be built from one of these models.
NOAA WMM home page
NOAA WMM FAQ
IGRF

(2) KLAX runway 06L/24R threshold coordinates are:
06L: N33° 56' 56.80 – W118° 25' 52.18
24R: N33° 57' 07.57 – W118° 24' 07.02
Calculated 06L true bearing is 82.99° (WGS84)
This one is perfectly modeled in the stock simulator scenery (true bearing: 82.97°)

(3) Not being correctly aligned on a runway axe while on a final ILS approach with a centered LOC needle is NEVER the result of any "wrong" magnetic variation. It could be due to (i) either an "offset" ILS (and this is indicated on charts) (ii) or a wrong coding of localizer antenna position and/or localizer true course by reference to runway axe.
Such ILS "misalignments" should be analyzed and corrected by retrieving proper runway and ILS information from active scenery BGL either using graphical software (such as Airport Design Editor) or an analytical/edition application (such as Airport Inspector and Editor).