Geomatics guidance note 21

International Association of Oil & Gas Producers

Grid convergence

Revision history

Report No.	Version	Date	Amendments
	1.1	August 2013	Erratum: Figures 1 and 2 corrected
373-21	1.0	July 2013	First release

1. Introduction and terminology

Grid convergence, sometimes called simply *convergence*, is the angle at a point on a map between the directions of True North and Grid North. It can be visualised as the angle at a point that a projected meridian makes with a line of constant easting on the map. The related term *meridian convergence* has multiple meanings, one of which is as a synonym for grid convergence, but as it is also used to describe the spacing of the meridians reducing towards the poles, the term is best avoided in this context.

Grid convergence is used to convert an *azimuth*, which is related to True North and defined on the surface of the ellipsoid, to a *bearing*, which is defined in the map plane and is related to Grid North. This is a necessary conversion in wellbore surveying and many other calculations. The definition of *azimuth* and *bearing* in the previous sentence originates from Guy Bomford's Geodesy (1985, p.96 & 183).

However, in survey practice the terms *azimuth* and *bearing* are often used as synonyms and thus one may come across the term *grid azimuth* instead of *bearing*. This is then supplemented with the term *true azimuth* to designate the corresponding direction on the ellipsoid. Conversely one may come across the terms *true bearing* and *grid bearing*. In this guidance note the terms *azimuth* and *bearing* are used in accordance with the definitions provided in the previous paragraph.

2. The sign of grid convergence

The definition of grid convergence is ambiguous, because text books on geodesy, cartography, navigation and surveying are not consistent on how this angle is calculated. In a world where navigation and surveying have become global activities, this has led to considerable confusion. This confusion may be found in software where grid convergence may be calculated without explicitly stating the convention applied.

Conventions

Two conventions exist when defining grid convergence, but without established names to differentiate them. Therefore, it should not be assumed that any application of grid convergence will use the names from this guidance note.

These two conventions are referred to in this guidance note as:

- The *Gauss-Bomford* convention
- The *Survey* convention

The 'Gauss-Bomford' convention

Guy Bomford (1985, p. 184) defines grid convergence as follows.

> Convergence is the angle between the meridian as represented in the plane and the N (North) grid line. It is positive when True North lies *west* of Grid North.[1]

This definition conforms to the convention introduced by Carl Friedrich Gauss (2011, p.146) in the early

[1] Bomford actually formulates the last sentence the opposite way around: "It is positive when Grid North lies east of True North". However, it is easier to visualise on a map or diagram that shows the projected meridians using Grid North as the reference direction, hence the modification of definition.

eighteenth century, but Guy Bomford's book is more widely known and more readily available. The Gauss-Bomford convention is used in many countries, e.g. the United Kingdom, France and the United States. Software originating in these countries often conforms to the Gauss-Bomford convention.

This definition can be summarised as follows.

Gauss-Bomford convention:

$$\beta = \alpha - \gamma$$

Subtract grid convergence (γ) from azimuth (α) to obtain bearing (β).

The 'Survey' convention

In surveying measurements often need to be corrected before they can be used in calculations, which are normally performed in a projected coordinate reference system. Examples are calibration constants and corrections for signal refraction. It is customary to define the relevant corrections so that they are added to the observed value.

This principle of grid convergence being a correction, applied to an observed direction, appears to form the basis for what is here termed the Survey convention for grid convergence. This principle leads to the following definition of grid convergence.

> Grid convergence is the angle to be added to an azimuth to obtain a bearing. It is positive when True North lies *east* of Grid North.

Survey convention:

$$\beta = \alpha + \gamma$$

Add grid convergence (γ) to azimuth (α) to obtain bearing (β).

This convention is used widely in Australia and New Zealand, but not to the complete exclusion of the Gauss-Bomford convention. Software originating in these countries often conforms to the Survey convention.

Sign convention diagrams

The following diagrams show the sign for grid convergence, calculated for the two conventions. The diagrams are provided for two most common types of map projection:

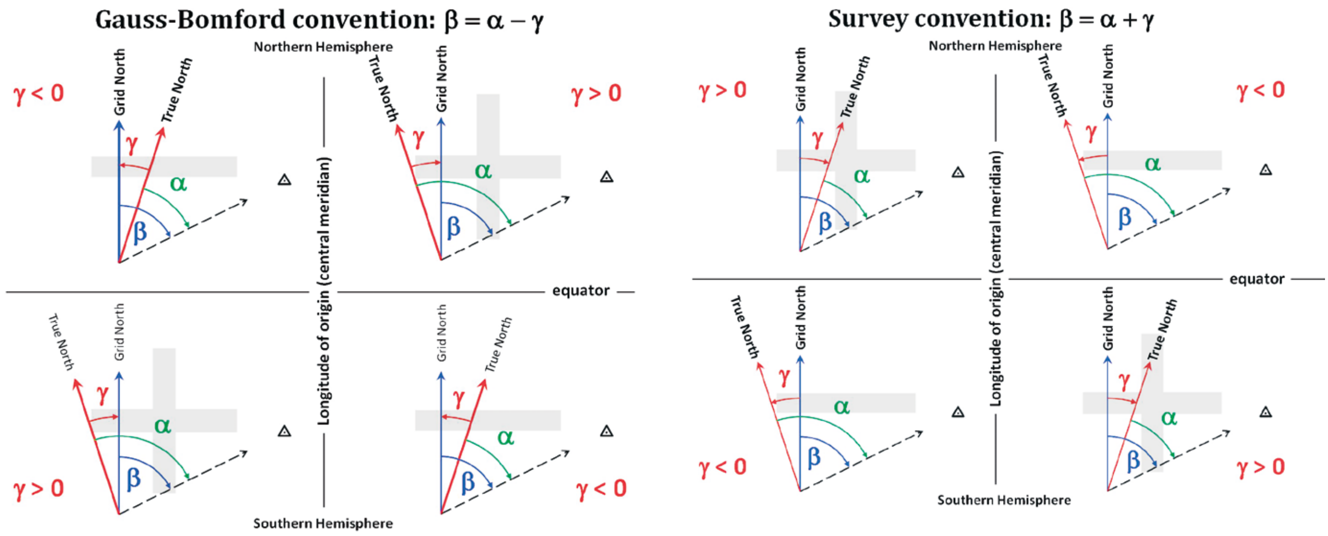
- Transverse cylindrical projections, such as Transverse Mercator;
- Normal aspect conic projections, such as Lambert Conic Conformal.

The diagrams for the conic projection methods show the relative directions of Grid North and True North for map projections where the latitude of natural origin (in the two standard parallel case slightly poleward of the mean of latitude of the two standard parallels) is in the *northern* hemisphere. When the latitude of natural origin is in the southern hemisphere the signs in all four quadrants are reversed.

The diagrams are *not* valid for skewed projection methods such as the Oblique Mercator and Oblique Conic as these do not have an identifiable meridian and parallel that serve as axes of symmetry. Nor in general are they valid for azimuthal projections, such as the Oblique Stereographic. Although these projection methods do have a meridian of symmetry, the change of grid convergence with latitude is more complicated.

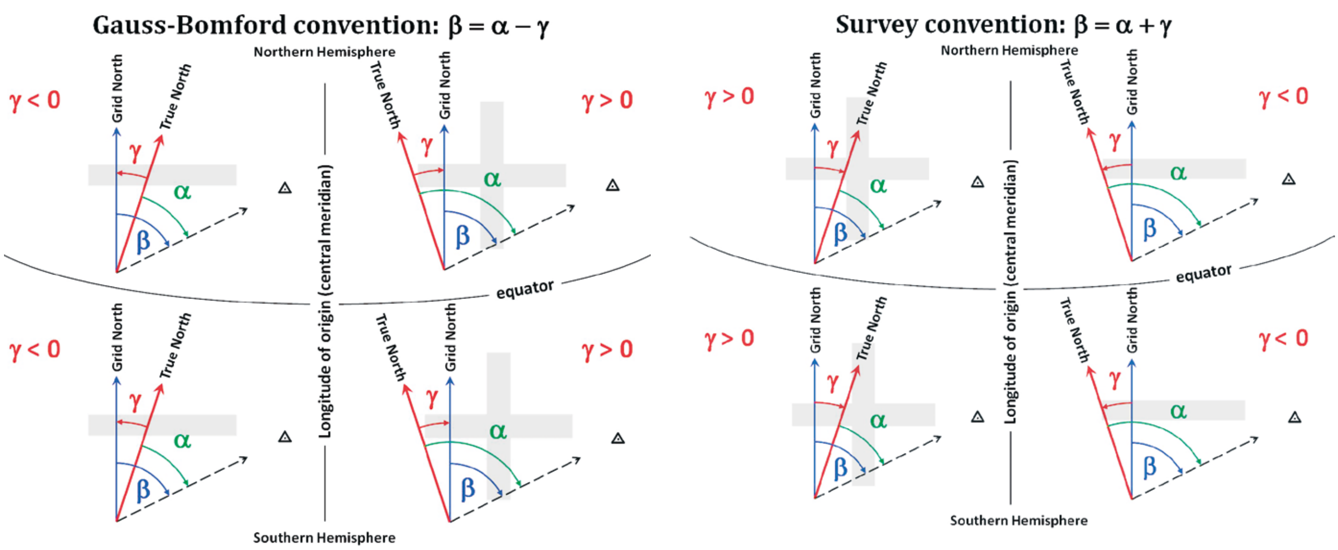
It is worth noting that a similar confusion does *not* exist for magnetic declination. Magnetic declination is always defined as the angle that needs to be added to magnetic bearing to yield the azimuth. This is analogous to the Gauss-Bomford convention, where magnetic bearing has taken the place of bearing.

Figure 1: *The sign of grid convergence for transverse cylindrical projections*



The sign of the grid convergence value is shown in each quadrant in grey.

Figure 2: *The sign of grid convergence for normal aspect conic projections in the northern hemisphere*

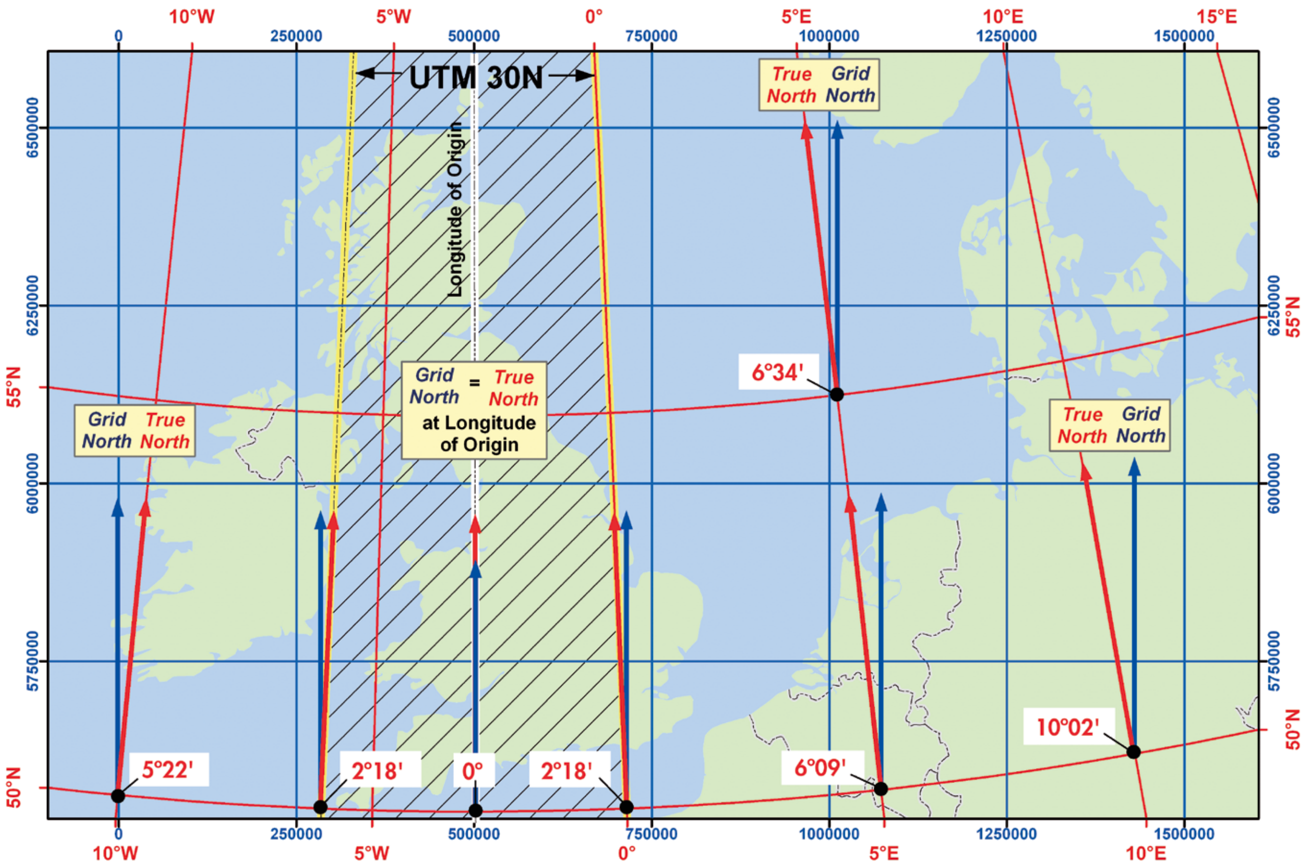


The sign of the grid convergence value is shown in each quadrant in grey. When the latitude of natural origin is in the southern hemisphere the signs in all four quadrants are reversed.

3. The magnitude of grid convergence

The magnitude of the value of grid convergence is a function of the map projection. For a normal-aspect or transverse-aspect map projection, convergence increases away from the map projection's longitude of origin. In addition, for a given longitude offset, the value increases with latitude. The magnitude of grid convergence is symmetrical about the longitude of origin in normal and transverse aspect projections as well as in oblique azimuthal projections.

Figure 3: *The magnitude of grid convergence on a Transverse Mercator projection (ETRS89 / UTM zone 30N) with a longitude of origin 3°W*



4. Example

The example point below is calculated for a Transverse Mercator projection (a member of the transverse cylindrical class) and is in the northern hemisphere. It lies east of the map projection's longitude of origin, i.e. in the top right quadrants in the two cases in Figure 1. At this location True North is west of Grid North.

Table 1: *Grid convergence at the London Eye (ETRS89 / UTM zone 30N)*

Example (*Gauss-Bomford* convention)

Point:	The London Eye, London, UK			
Latitude:	51°30′12.00″N			
Longitude:	0°07′10.04″W			
CRS:	ETRS89	EPSG code:	4258	
Easting:	699,913.0			
Northing:	5,709,734.4			
Grid convergence:	**+2°15′19″**			*Note the positive value!*
CRS:	ETRS89 / UTM zone 30N	EPSG code:	25830	

Example (*Survey* convention)

Point:	The London Eye, London, UK			
Latitude:	51°30′12.00″N			
Longitude:	0°07′10.04″W			
CRS:	ETRS89	EPSG code:	4258	
Easting:	699,913.0			
Northing:	5,709,734.4			
Grid convergence:	**–2°15′19″**			*Note the negative value!*
CRS:	ETRS89 / UTM zone 30N	EPSG code:	25830	

5. Practical implications

A range of activities in the oil and gas business may require the grid convergence to be applied in calculations. These include survey calculations in support of surface engineering work and mapping activities, the planning and drilling of wells and the handling and interpretation of well trajectory data in subsurface software. In practice these activities are vulnerable to errors associated with grid convergence.

Frequently encountered errors are:

- unknown north reference of azimuth and bearing data
- grid convergence not applied while it should have been applied or *vice versa*
- grid convergence applied with the wrong sign (as discussed in section 2)
- grid convergence applied twice
- grid convergence not modified upon a change of projected CRS, *i.e.* change of map projection (zone)

The first consideration when azimuth data is used is having knowledge of the north reference. This ought to be recorded unambiguously in the metadata. Some companies standardise on Grid North, others on True North. For yet other companies it varies by facility.

The second consideration is whether grid convergence should or should not be applied. For example it should be applied in deviated wellbore positioning when the facility reference direction is True North and wellbore coordinates are referenced to a projected coordinate reference system (map grid). It should not be applied if the facility reference direction is Grid North and the wellbore coordinates are referenced to the same map grid.

The consequences of making an error in the application of grid convergence can be severe:

- Misinterpreting the convention for grid convergence leads to an angular error of twice the magnitude of the grid convergence. For the example point above, the error made in incorrect knowledge of grid convergence sign convention is 2 x 2°15'19" or 4°30'38". For a well with a lateral offset of 5 km the error in bottom hole location would be nearly 400 m. In the absence of grid convergence metadata, wellbore anti-collision planning would need to take this 400 m uncertainty into account.
- An error made as a result of using the grid convergence for the wrong grid zone is the difference in the two values. Using the Gauss-Bomford convention, grid convergence at the test point (see section 4 above) is +2°15'19" in UTM zone 30N. However, the same location has a different grid convergence in UTM zone 31N, *viz.* −2°26'33", again assuming the Gauss-Bomford convention. The angular error made is 4°41'52", which, for a well with 5 km lateral offset, would result in an error in the bottom hole location of 410 m.

Staff should verify whether the software used in their company to handle well deviation data has built-in functionality that allows calculation of and compensation for grid convergence. The sign convention applied by the software should be established.

6. References

Bomford, G. (1985) *Geodesy,* 4th edition, Oxford: Oxford University Press.

Gauss, C. F. (2011) *Werke*, Vol. 9, Cambridge: Cambridge University Press.

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