International Association of Oil & Gas Producers

REPORT
373-21

JUNE
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Grid convergence

Acknowledgements

This guidance note is written and maintained by IOGP's Geodesy Subcommittee.

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About

The definition of grid convergence is ambiguous because textbooks 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. This guidance note clarifies the various terms and conventions in use.

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Revision history

VERSION	DATE	AMENDMENTS
1.0	July 2013	First release
1.1	Aug 2013	Erratum: Figures 1 and 2 corrected
1.2	June 2025	Minor update

Contents

Introduction

Grid convergence, sometimes simply called convergence, is the angle at a point on a map between the directions of True North and map Grid North. The definition of grid convergence is ambiguous, because textbooks on geodesy, cartography, navigation, and surveying are not consistent on how this angle is calculated. This has led to considerable confusion. Software where grid convergence is calculated may output a value without explicitly stating the convention applied. This guidance note clarifies the various terms and conventions in use. It is aimed at survey software developers and geomatics professionals using such software.

1. The sign of grid convergence

1.1 Terminology

Grid convergence, sometimes simply called convergence, is the angle at a point on a map between the directions of True North and map Grid North. It can be visualized 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, in the context of grid convergence, the synonym should be avoided.

Grid convergence is used to convert an *azimuth*[1], which is related to True North and defined on the surface of the ellipsoid, to a *bearing*,[2] which is defined in the map plane and is related to Grid North. This conversion is necessary in wellbore surveying and many other calculations.

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.

1.2 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:

- Gauss-Bomford convention.
- Survey convention.

1.2.1 The Gauss-Bomford convention

Guy Bomford[3] 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.**[4]

[1] Bomford, G. 1985. p. 96 and 183.
[2] Ibid
[3] Bomford, G. 1985. p. 184
[4] 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 visualize on a map or diagram that shows the projected meridians using Grid North as the reference direction, hence the modification of definition.

This definition conforms to the convention introduced by Carl Friedrich Gauss[5] in the early 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 summarized as follows.

Gauss-Bomford convention:

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

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

1.2.2 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 termed here 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.

[5] Gauss, C. F. 2011.

1.3 Sign convention diagrams

Figure 1 and Figure 2 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 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 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.

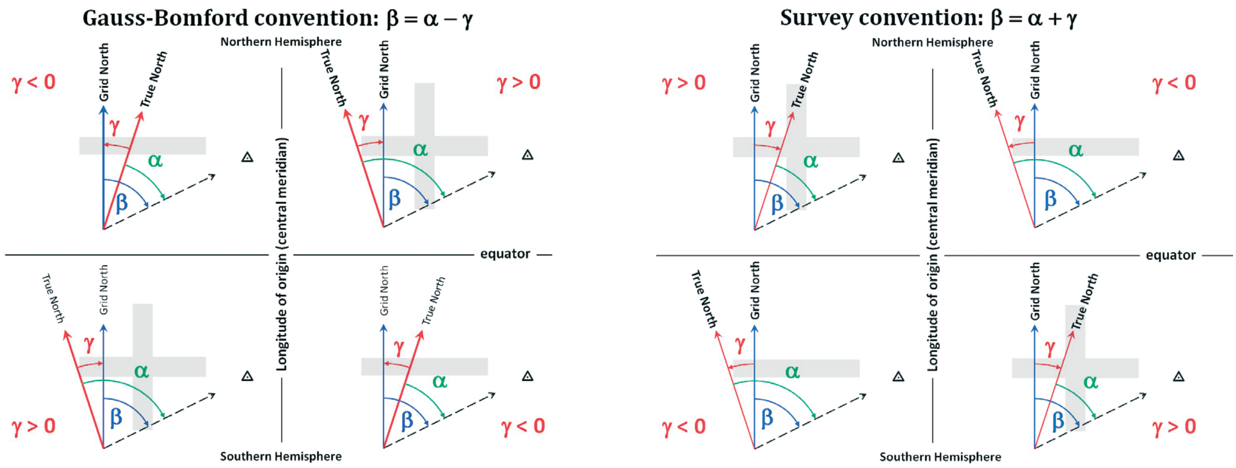

Figure 1 - The sign of grid convergence for transverse cylindrical projections. The sign of the grid convergence value is shown in each quadrant in grey.

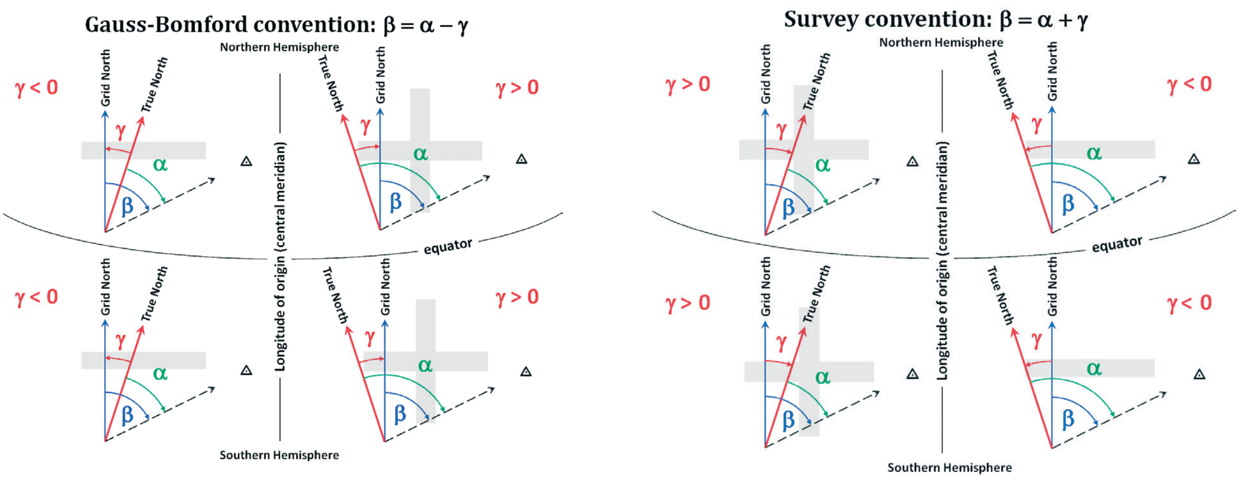

Figure 2 - The sign of grid convergence for normal aspect conic projections with latitude of origin in the northern hemisphere. The sign of the grid convergence value is shown in each quadrant in grey. When the latitude of natural origin is in the southern hemisphere, the signs in all four quadrants are reversed.

2. The magnitude of grid convergence

The magnitude of the value of grid convergence is a function of the map projection and the location within the map grid. 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.

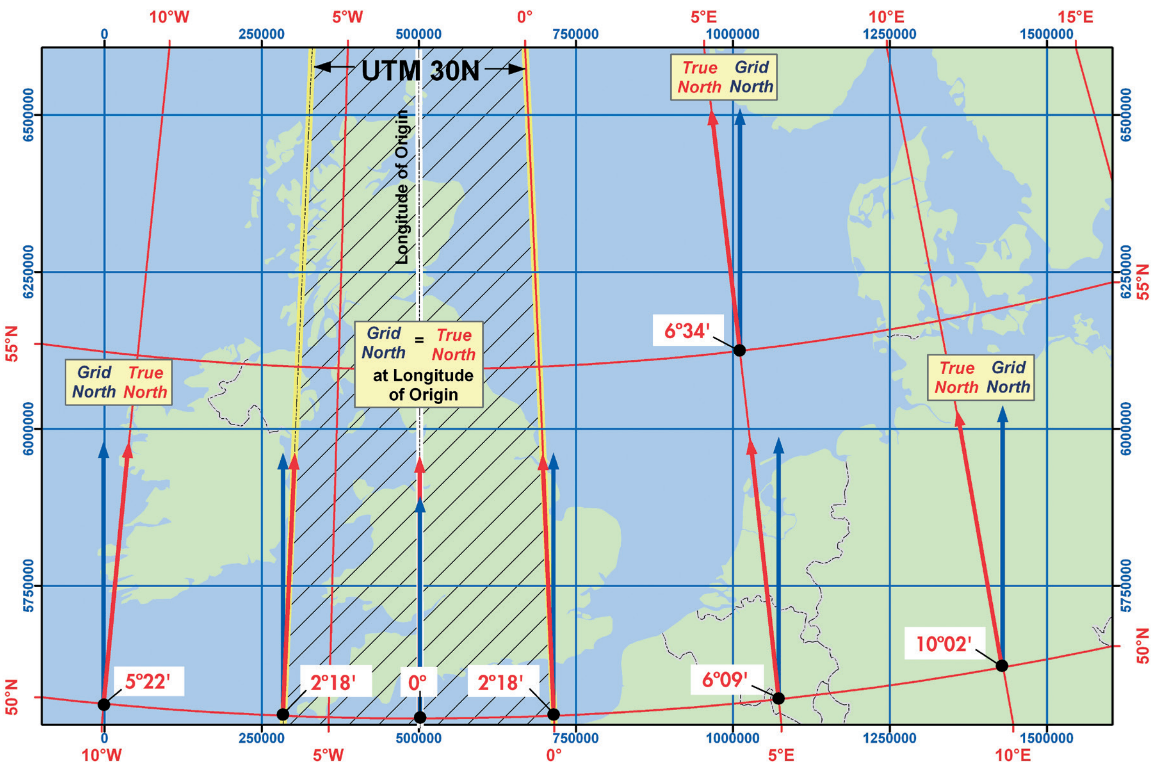

Figure 3 - The magnitude of grid convergence on a Transverse Mercator projection (ETRS89 / UTM zone 30N) with a longitude of origin 3°W.

3. Example

The 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	

4. Practical implications

A range of activities in the oil and gas and renewable energy industries require 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
- no differentiation between true and grid north on engineering drawings
- 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 should be recorded unambiguously in the metadata. Some regulators and some companies standardize on Grid North, others on True North. For 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 and include:

- Misinterpreting the convention for grid convergence leads to an angular error of twice the magnitude of the grid convergence. For the Table 1 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 5km, the error in bottomhole location would be nearly 400m. In the absence of grid convergence metadata, wellbore anti-collision planning would need to take this 400m 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 Table 1 example point 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 5km lateral offset, would result in an error in the bottomhole location of 410m.

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.

Recommended good practice is:

- to include a diagram showing the relationship between true north and grid north
- an audit trail should document the original value and corrected/converted value, when a correction is applied

References

Bomford G. *Geodesy*. 4th edition. Oxford: Oxford University Press, 1985. p. 96 and 183.

Bomford G. *Geodesy*. 4th edition. Oxford: Oxford University Press, 1985. p. 184.

Gauss C F. Werke. Vol. 9. Cambridge: Cambridge University Press, 2011. p. 146.

Further reading

IOGP Geodesy Guidance Notes are freely available from the IOGP Bookstore at
https://www.iogp.org/bookstore/portfolio-item/geomatics/.

Further material is available from the Geomatics Committee site:
https://www.iogp.org/geomatics/.

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