63rd General Meeting
15th & 16th of April 2026
Frankfurt, Germany

SPE International

Wellbore Positioning Technical Section

ISCWSA

The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)

A geocentric approach to enhance the precision of trajectories

Arthur de Calan

arthur.decalan@pathcontrol.com

PathControl

Speaker Bio

- 2 years experience as R&D engineer at PathControl, Paris
- 1 year as a software engineer, Tidewise, Rio de Janeiro, Brazil
- MSc at Arts et Métiers ParisTech (ENSAM, France), mechanical & electrical engineering
- MSc at EIA Colombia (country), Robotics & autonomous systems

Table of content

- Introduction to geodesy and coordinate reference systems
- Part 1: The conventional “projection” method
- Part 2: The geocentric method
- Conclusion
- Appendix, references & images

Introduction - CRS

Coordinate reference system

Datum

description : what "ties the coordinate system to the ground".

input : origin, scale and orientation of the axis

either : geodetic(long/lat), vertical, ECEF, projected, engineering, local

example : ETRS89 (ECEF), ED50, WGS84 (geodetic)

Geoid model grids : are part of the Datum

Coordinate system

description : how the coordinates are associated to a point : cartesian (XYZ), ellipsoidal (lat/long/elevat°), projected (NEV)

either : geodetic(long/lat), vertical, engineering, local, projected

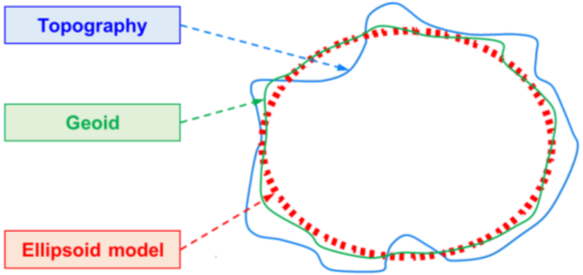
example : UTM 33N

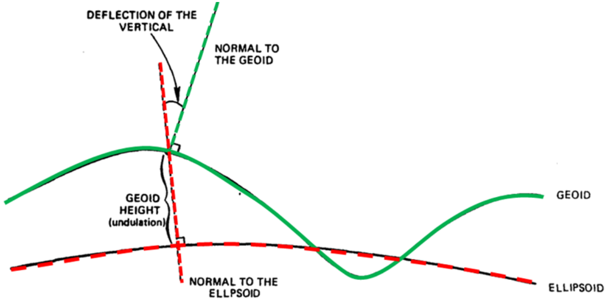
EPSG 4326 CRS = WGS 84 (dynamic datum) + UTM zone 33N (projected coordinate system)

Introduction - geodesy

Keywords and remarks on geodesy

- CRS: coordinates reference system
- Geoid: mathematical shape describing the undulation of the earth surface
- Ellipsoid: Surface tied to geoid, based on CRS
- Coordinate **transformation**: change from one datum to another (empiric, **low accuracy**)
- Coordinate **conversions**: change from one coordinate system to another (**high accuracy**)
- Change of CRS may be composed of **transformation + conversion**
- Compound CRS = horizontal CRS + vertical CRS

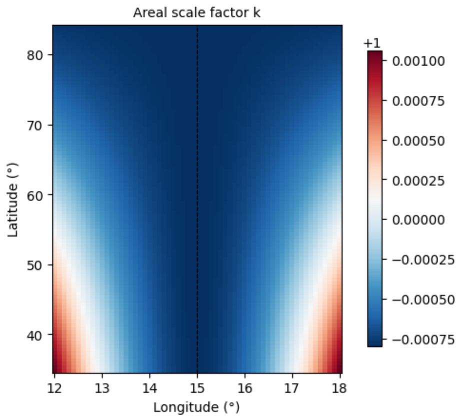




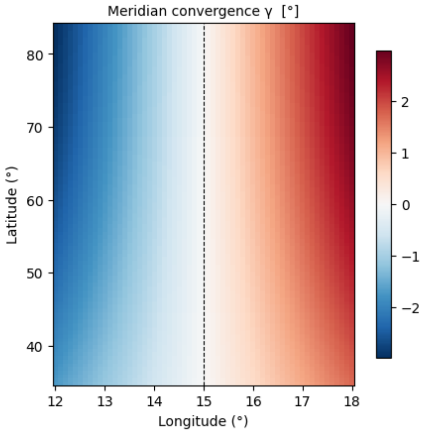
Part 1: The conventional "projection" method

What is the "projection" method ?

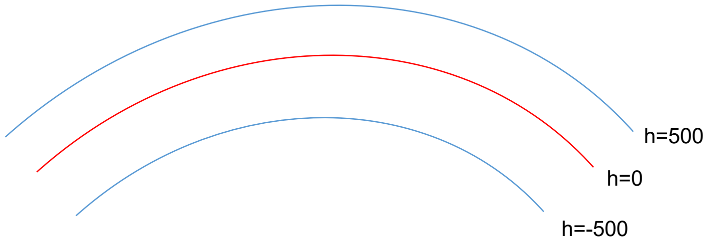
- *The fact of working in a projected/map CRS that involves geodetic distortion*
- *in fact, there are more distortion parameters than those 3*



Deflection of horizontal departure,
surface scale factor



Deflection of true north,
convergence



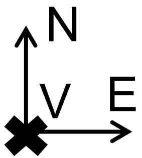
Deflection of vertical vector,
elevation scale factor

Part 1: The conventional “projection” method

What is the “projection” method ?

0. Given A position, 2 points A & B (MD, inclination, azimuth), calculate B position

Projection NEV reference system

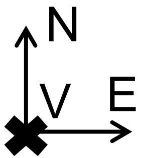


Part 1: The conventional “projection” method

What is the “projection” method ?

1. *Convert true azimuth to grid (apply convergence)*

Projection NEV
reference system

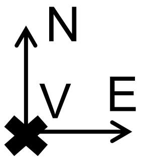


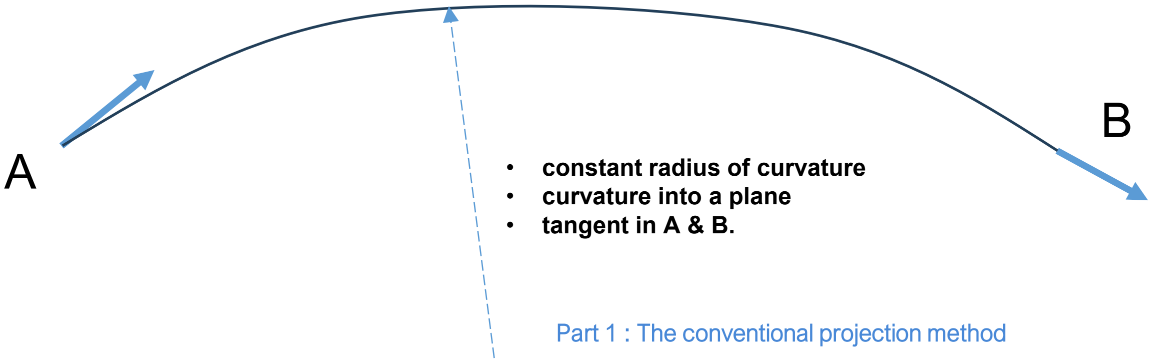
Part 1: The conventional “projection” method

What is the “projection” method ?

2. Perform minimum curvature in NEV (projected CRS)

Projection NEV reference system





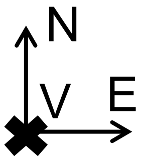
- **constant radius of curvature**
- **curvature into a plane**
- **tangent in A & B.**

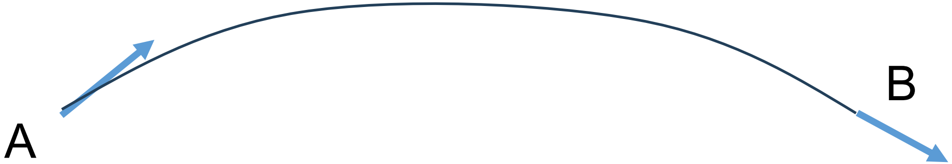
Part 1: The conventional “projection” method

What is the “projection” method ?

3. Convert true horizontal departures (NE) to map departures (scale factor effect)
4. Add (eventually) the elevation scale factor effect

Projection NEV reference system

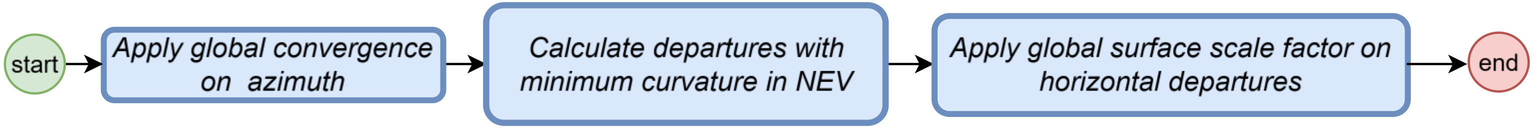




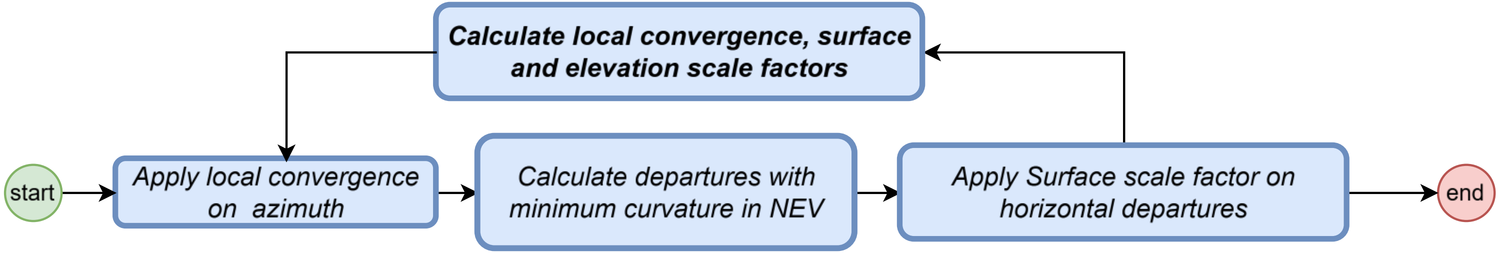
Part 1: The conventional “projection” method

***Global** vs **Local** projection methods*

1. **Global** projected method (**ESF** = 1 or averaged, **convergence** and **surface SF** taken at surface)



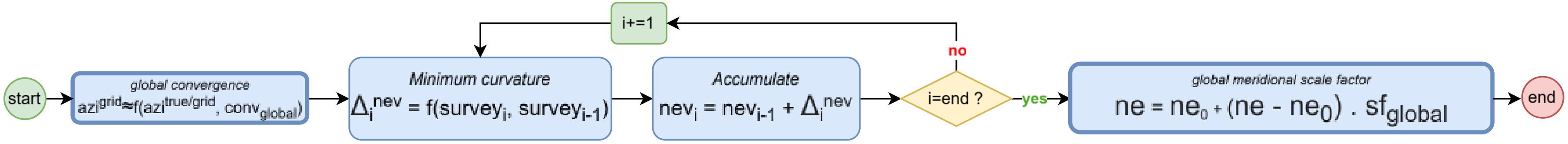
2. **Local** projected method (discrete **ESF**, **convergence** and **surface SF**)



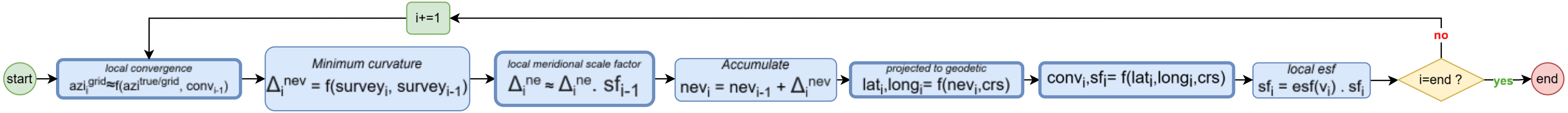
Part 1: The conventional "projection" method

***Global** vs **Local** projection methods*

1. **Global** projected method (**ESF** = 1 or averaged, **convergence** and **surface SF** taken at surface)



2. **Local** projected method (discrete **ESF**, **convergence** and **surface SF**)



Part 1: Conclusions

*The "projection" method introduces **approximations***

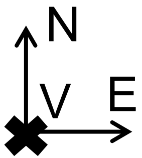
Global projection method	Local projection method
Uniform surface distortion (convergence, surface scale factor)	Discrete map distortion instead of continuous
Deflection of vertical effect ignored or averaged	Discrete deflection of vertical effect instead of continuous
Minimum curvature is not performed in a cartesian reference system	

Part 2 : Focus on the geocentric method

What is the "geocentric" method ?

0. Given A position, 2 points A & B (MD, inclination, azimuth), calculate B position

Projection NEV reference system



$$\begin{bmatrix} Md \\ Inc \\ Azi \end{bmatrix}$$

$$A = \begin{bmatrix} N \\ E \\ V \end{bmatrix}$$

B

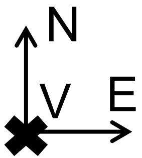
$$\begin{bmatrix} Md \\ Inc \\ Azi \end{bmatrix}$$

Part 2 : Focus on the geocentric method

What is the “geocentric” method ?

1. *Conversion of inclination and azimuth into NEV tangent vectors*

Projection NEV reference system



B

$$\overrightarrow{\begin{bmatrix} tn \\ te \\ tv \end{bmatrix}}$$

$$\overrightarrow{\begin{bmatrix} tn \\ te \\ tv \end{bmatrix}}$$

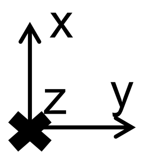
$$A = \begin{bmatrix} N \\ E \\ V \end{bmatrix}$$

Part 2 : Focus on the geocentric method

What is the “geocentric” method ?

2. *Conversion of NEV to XYZ tangent vectors, providing a CRS conversion*
3. *Conversion of NEV to XYZ A position, providing a CRS conversion*

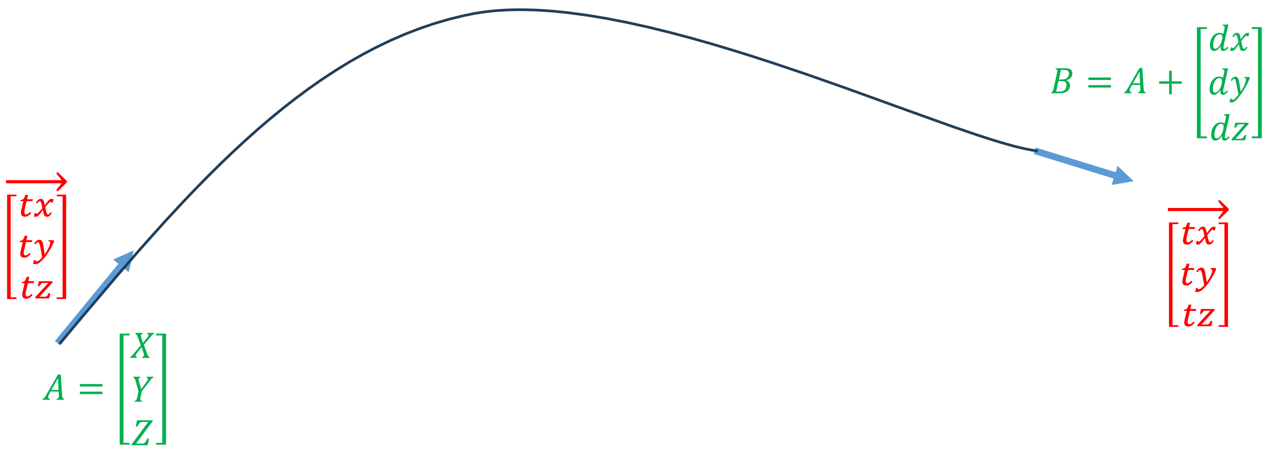
Geocentric XYZ
reference system



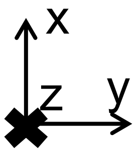
Part 2 : Focus on the geocentric method

What is the "geocentric" method ?

4. Minimum curvature in XYZ between A & B



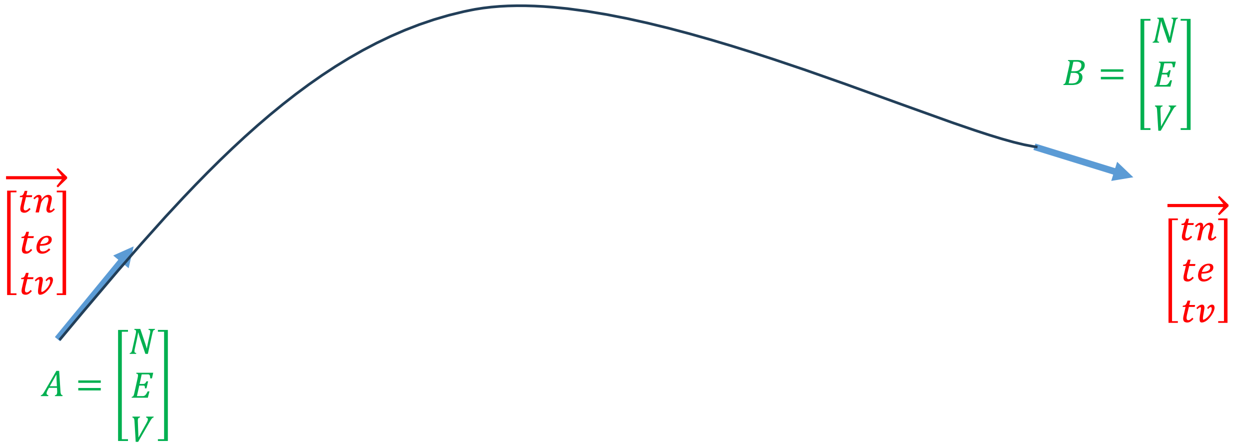
Geocentric XYZ reference system



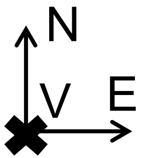
Part 2 : Focus on the geocentric method

What is the "geocentric" method ?

4. *Conversion of B position from XYZ to NEV, providing a CRS conversion*
5. *that's it !*



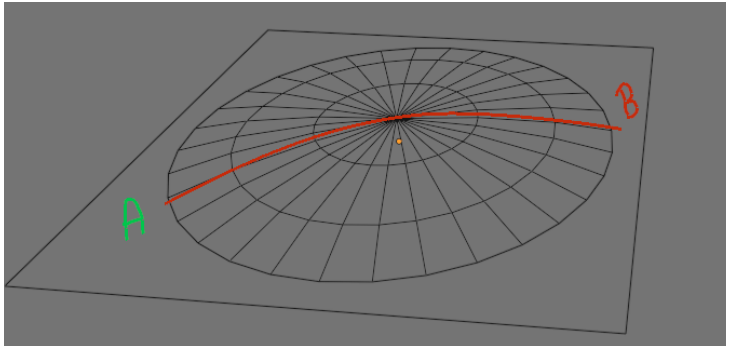
Projection NEV reference system



Part 2 : Focus on the geocentric method

Assessment of the geocentric method vs conventional method, ***horizontal wellpath***

1. *Starting from* ***A****, build* ***B*** *through a direct geodetic problem (Vincenty direct formula) solver (PROJ library)*

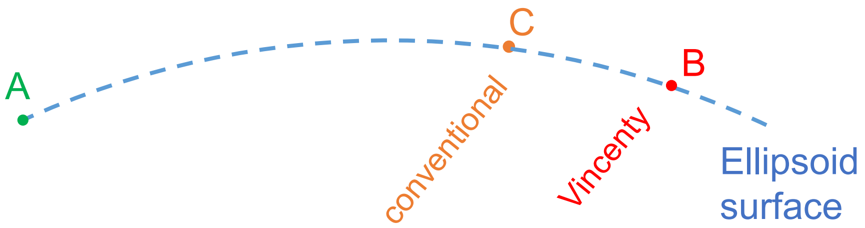


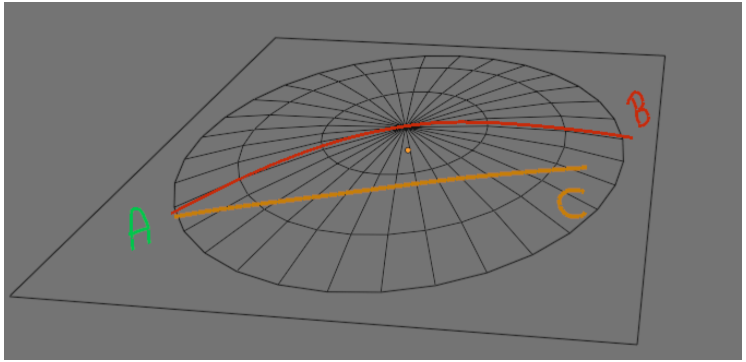
Input *: 2000m horizontal departure, 90° forward azimuth, CRS*
Comment : *the direct geodetic problem is not reversible because the ellipsoid is not a sphere*

Part 2 : Focus on the geocentric method

*Assessment of the geocentric method vs conventional method, **horizontal wellpath***

2. *Starting from **A**, build **C** with a conventional method*



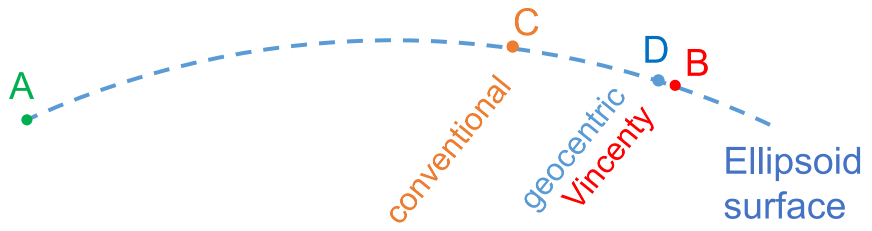


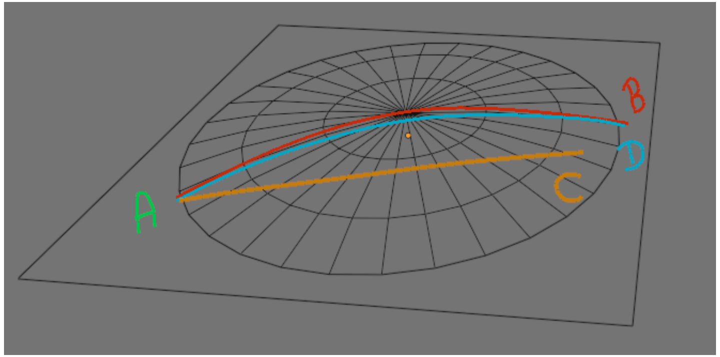
***Input** : 2000m horizontal departure, 90° forward azimuth, convergence and surface scale factor in A*
***Comment : A** & **C** are **colinear in NEV**, no minimum curvature here*

Part 2 : Focus on the geocentric method

*Assessment of the geocentric method vs conventional method, **horizontal wellpath***

*3. Starting from **A**, build **D** with a geocentric method*





Input *: 2000m horizontal departure, 90° forward azimuth, CRS*

BD : 10e-5 m

BC : 60 cm

Comments :

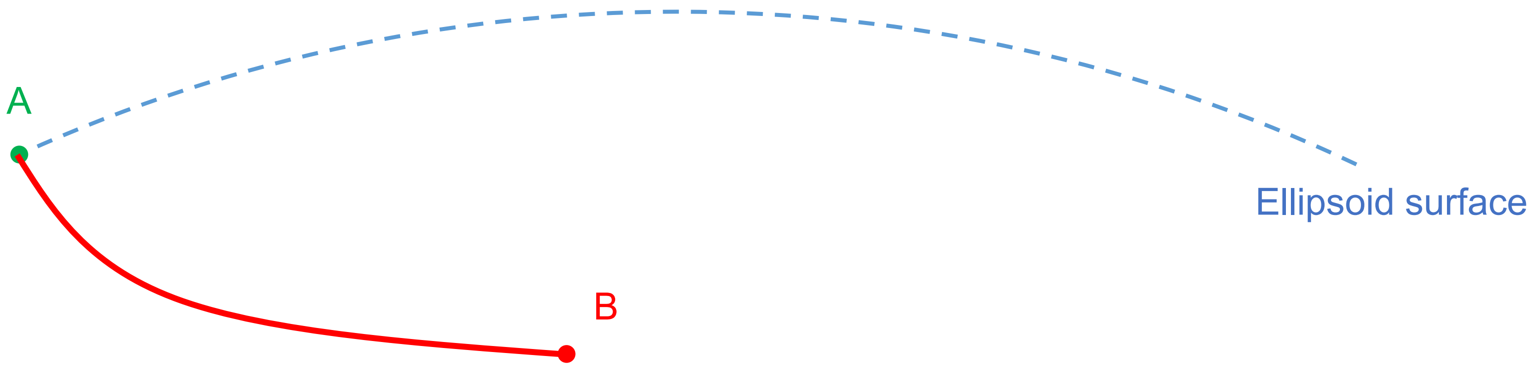
- *A & D tangents are **NO MORE colinear in XYZ***
- *Source of truth : **B** position*
- ***BD** distance is explained by the fact that the ellipsoid surface does not follow a minimum curvature shape*

Part 2 : Focus on the geocentric method

*Assessment of the geocentric method vs **conventional** method, **extending to any wellpath***

3. *Starting from **A**, build **B** with a **conventional** method*

Comment : no source of truth here



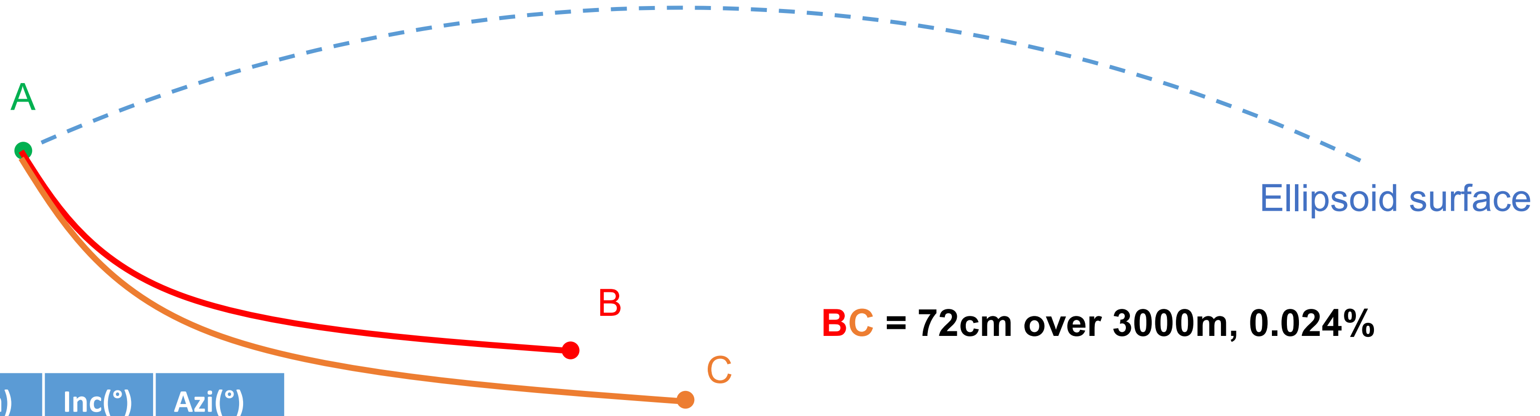
points	MD (m)	Inc(°)	Azi(°)
A	0	0	/
B&C	3000	90	45

Part 2 : Focus on the geocentric method

*Assessment of the **geocentric** method vs **conventional** method, **extending to any wellpath***

3. *Starting from **A**, build **C** with a **geocentric** method*

Comment : no source of truth here

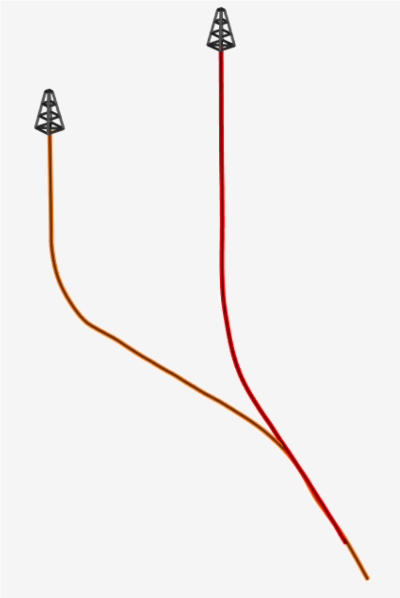


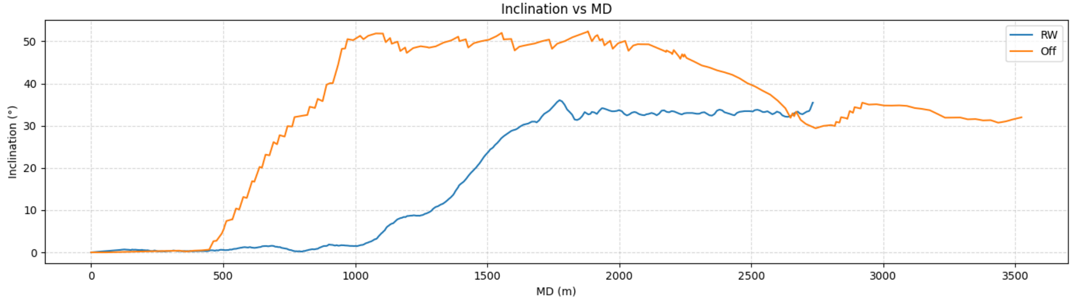
points	MD (m)	Inc(°)	Azi(°)
A	0	0	/
B&C	3000	90	45

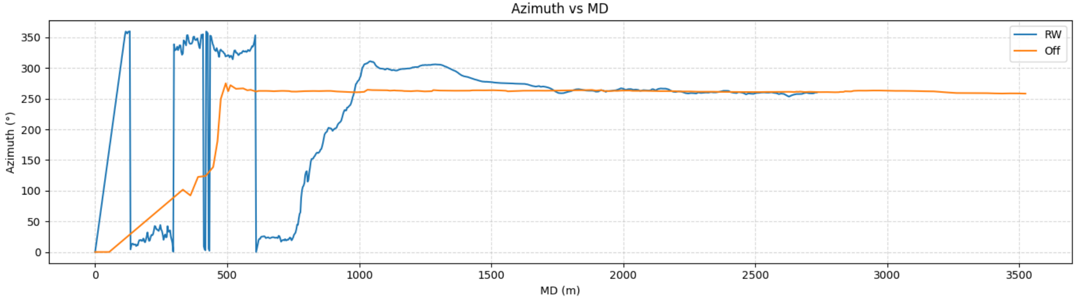
Part 2 : Well interception use case

*Assessment of the **geocentric** method vs **conventional** method*

Surface location : Lat. -60° , Long. 102°

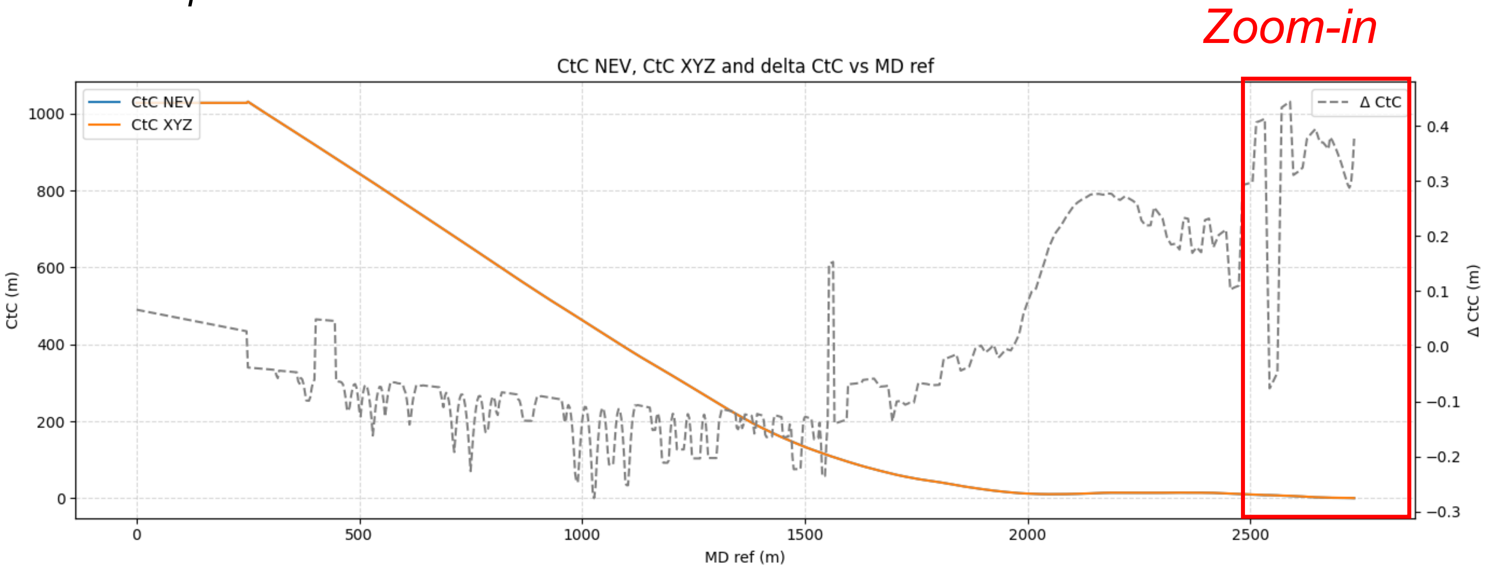






Part 2 : Well interception use case

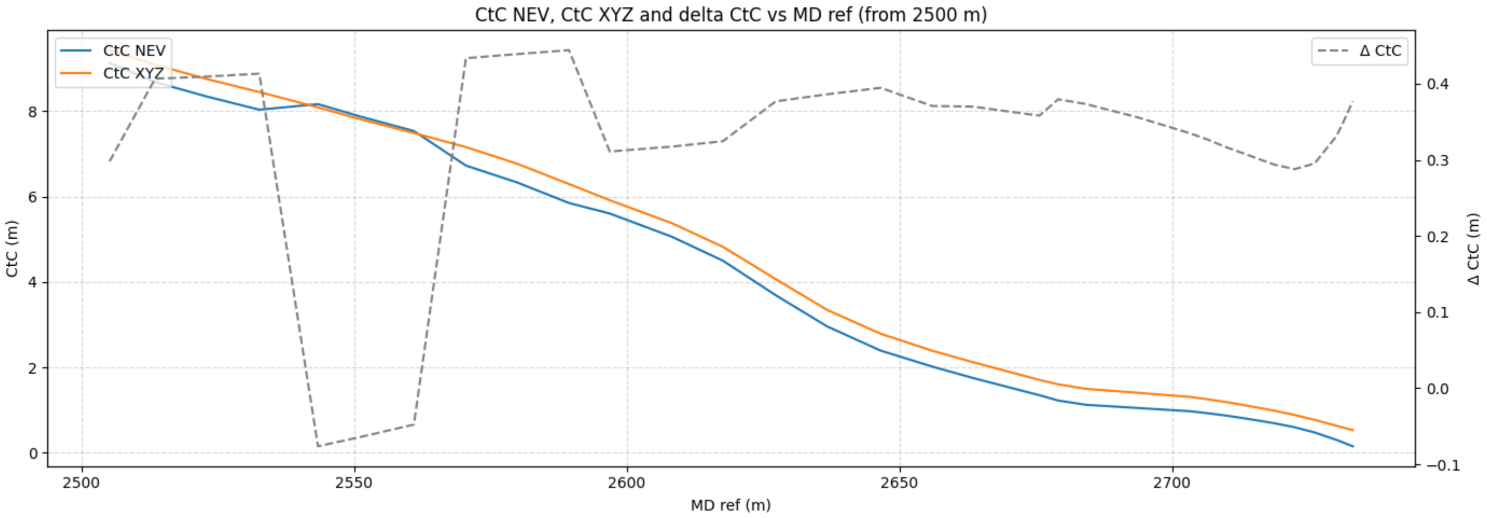
*Assessment of the **geocentric** method vs **conventional** method*
Center to center comparison



Part 2 : Well interception use case

*Assessment of the **geocentric** method vs **conventional** method*
Center to center comparison

Zoom-in



Nota : both minimum curvature and CtC calculus are made in XYZ reference system

Conclusions - *Approach comparison*

	Conventional method	Geocentric method
Core concept	Perform minimum curvature « as in a cartesian space », then correct from map distortion.	Perform conversions of survey station tangents from NEV to XYZ, then perform minimum curvature.
Specific error sources	• Uniform map distortion • Vertical deflection effect ignored or approximated • Erroneous coordinate system for minimum curvature	• Tied to the precision of the CRS conversions • Tied to the precision of the datum grids if applicable
Common error sources	The hypothesis of the minimum curvature as the most probable wellpath	

Conclusions

Facts :

1. We identified an error source
2. The magnitude of this error is to put into perspective **with the global error model**
3. **The influence of parameters** (CRS, surface location,MD, wellpath profile) on this error **has not been identified yet**
4. The error source affects the trajectory (NEV) not the survey (MD,Inc,Azi)
5. The geocentric method can be enhanced w/ dynamic CRS and datum grids

Way forward :

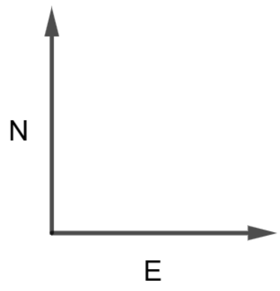
❌ Update every software to handle a geocentric approach (complicated, except for us)

✅ Introduce an error term that accounts for this (drawback : loosing information in magnitude and direction compared to applying the method)

Questions / Answers

Thank you for attending

Appendix - part 1 – “scale factor worse case”



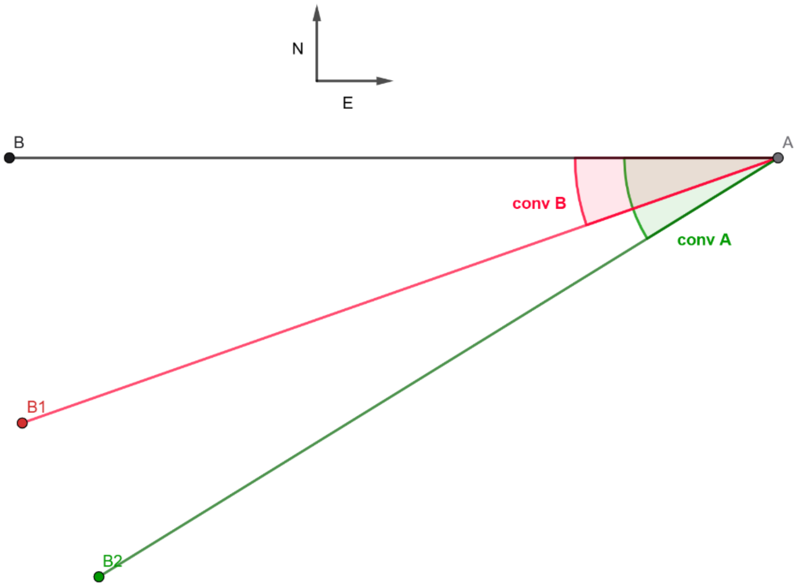
<u>Wellpath scenario:</u>

- Built to maximize the scale factor gradient along the wellpath
- “A” surface coordinates : lat 35° , long 18°
- Toward west
- 3000 m horizontal departure.
- CRS : UTM 33N, WGS84

B1: Built only with scale factor at point B
B2: Built only with scale factor at point A

[B1 B2] : 0.004% or 0.12 m on a 3000 m departure

Appendix - part 1 – “convergence worse case”



Wellpath scenario:

- Built to maximize the convergence gradient along the wellpath
- “A” surface coordinates : lat 75° , long 18°
- toward west
- 3000m horizontal departure
- CRS : UTM 33N, WGS84

B1: Built only with the convergence correction at point B
B2: Built only with convergence correction at point A

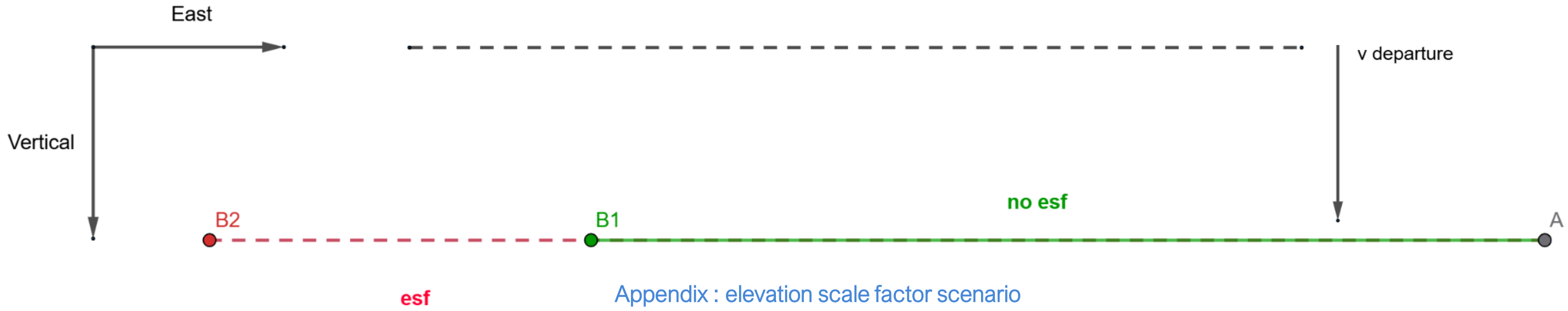
[B1 B2] : 0.14% or 4.33m on a 3000m departure

Appendix - part 1 – Elevation scale factor scenario

Wellpath scenario:

- Built to assess the effect of the elevation scale factor
- From A to B, toward west
- 1500m elevation below the ellipsoid
- 3000m horizontal departure
- B1 : built without any correction, full 3000m west departure
- B2 : 3000m west departure corrected from elevation scale factor at 1500m below the ellipsoid

[B1 B2] : 0.0235 % or 0.71m over a 3000m departure



Appendix : elevation scale factor scenario

Appendix - part 2 : ISCWSA wellbore use cases

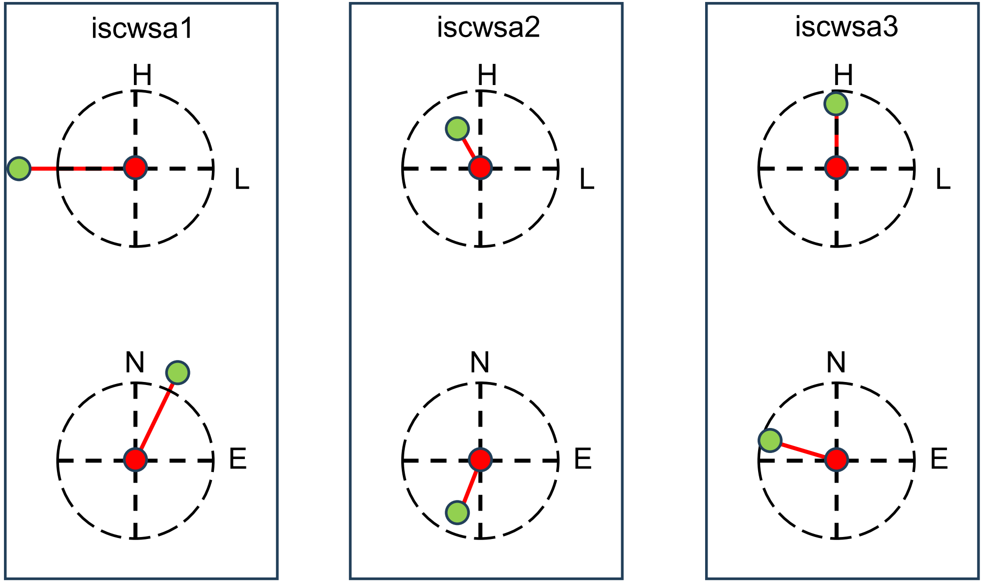
*Assessment of the geocentric method vs conventional method, **ISCWSA#123 wellbores***
Bottom hole position comparison

wellbore	MD (m)	Ctc (m)	Highside (°)	Radial distance (m)	Azimuth north (°)	Horizontal distance (m)	CRS
iscwsa#1	8000	5.32	-89.8	4.5	17.3	5.32	EPSG:32631 WGS 84 / UTM zone 31N
iscwsa#2	3810	0.36	-16.5	0.19	210.0	0.36	EPSG:32616 WGS 84 / UTM zone 16N
iscwsa#3	4030	0.29	90.0	0.29	280.2	0.29	EPSG:32755 WGS 84 / UTM zone 55S

Appendix - part 2 : ISCWSA wellbore use cases

*Assessment of the geocentric method vs conventional method, **ISCWSA#12345 wellbores***

Center to center comparison : collision avoidance and interception case study

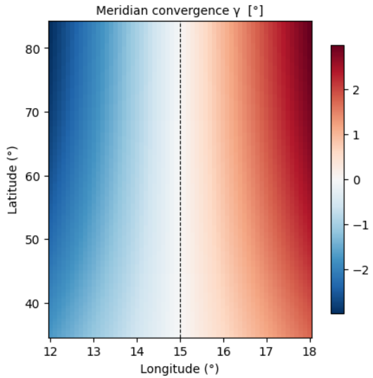


Appendix – part 2 – Mapping the bottom-hole position distance between both methods

Scenario :
- Define a specific wellpath
- Vary the surface coordinates parameters to map the entire CRS grid
- Calculate bottom-hole positions for both methods (XYZ vs NEV)
- Plot bottom-hole position distances

Md	Inc	Azi
0	0	0
500	25	30
600	50	60
1000	70	90
1300	90	120
4000	90	180

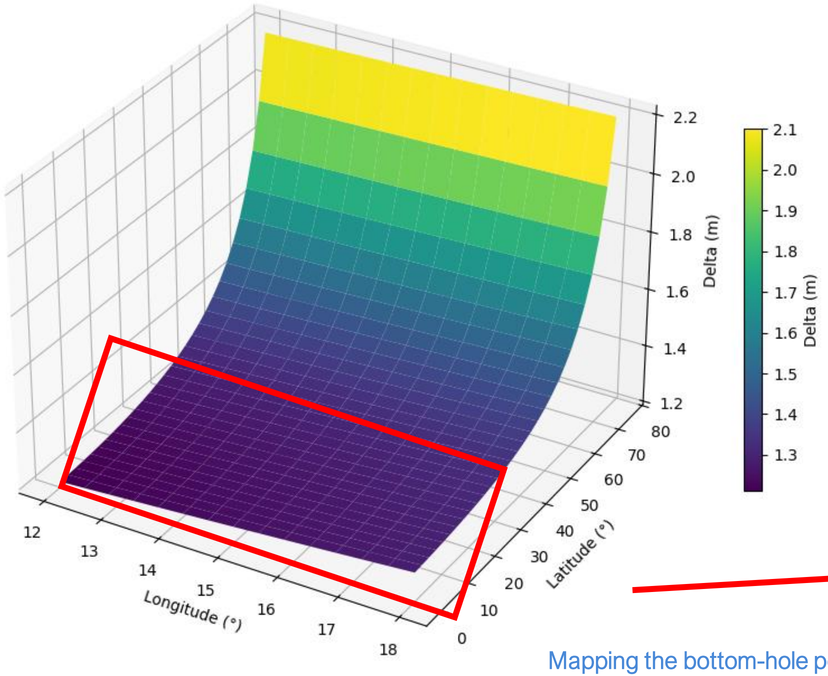
wellpath scenario

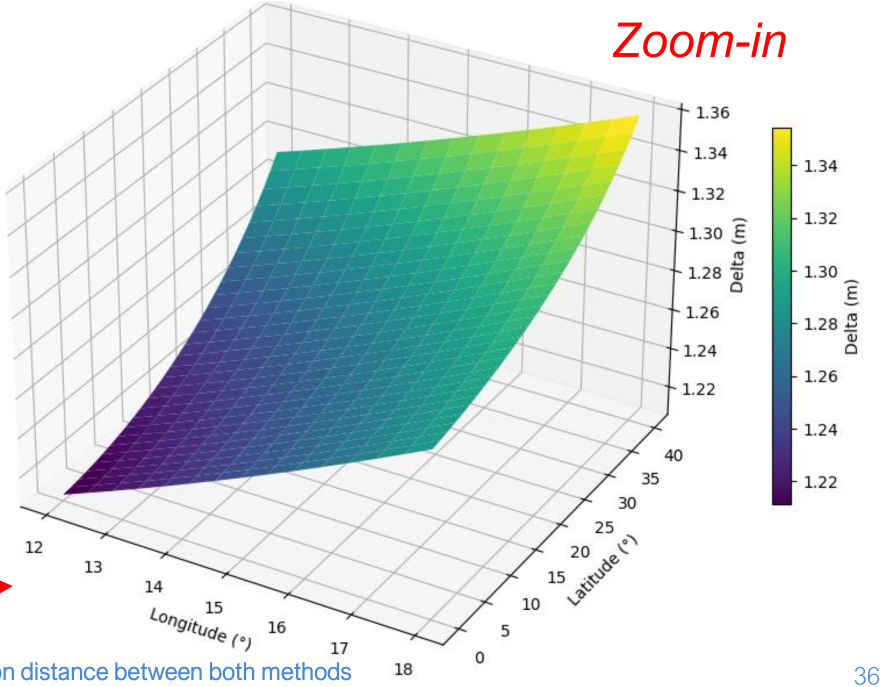


Surface coordinates grid (UTM 33N)

Appendix – part 2 – Mapping the bottom-hole position distance between both methods

Bottom-hole position distance (XYZ - NEV) function of surface coordinates, **for a given wellpath**





Appendix – part 2 – Mapping the bottom-hole position distance between both methods

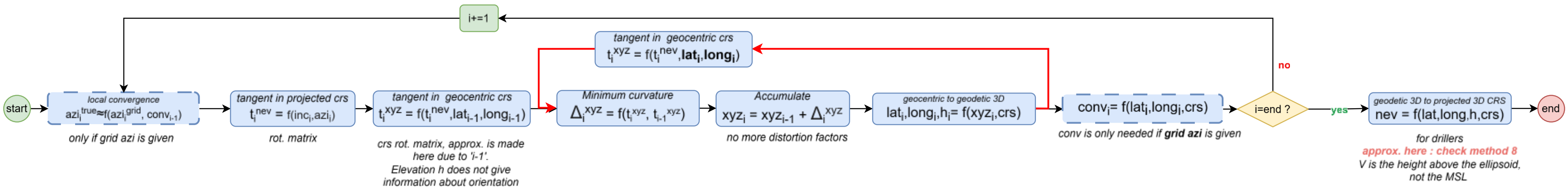
Surface plots **possible** interpretation

Identification of phenomena introduced by the conventional method :

- latitudes & longitudes contribute to the bottom-hole position deflection
- Performing minimum curvature in a projected reference system introduces error in spite of surface map distortion : it misconsiders gravity vector deflection. We can call it “depth-related horizontal distortion”
- The surface/map distortion error aggregates on top of that

Appendix – geocentric & geodetic flowcharts

Main geocentric algorithm flowchart :



The whole geodetic/geocentric flowchart reflexion : download link

References

[1] PROJ contributors (2026). PROJ coordinate transformation software library. Open Source Geospatial Foundation. URL https://proj.org/. DOI: 10.5281/zenodo.5884394

[2] OSGeo, "Open Source Geospatial Foundation," osgeo.org. [Online]. Available: https://www.osgeo.org.

[3] Klokan Technologies GmbH, "EPSG.io — Coordinate Systems Worldwide," *epsg.io*. [Online]. Available: https://epsg.io.

[4] IOGP Geomatics Committee, Geodesy Subcommittee, "Coordinate Transformations in the US Gulf of Mexico OCS," IOGP Report 373-26. [Online]. Available: https://www.iogp.org/bookstore/product/iogp-report-373-26-coordinate-transformations-in-the-us-gulf-of-mexico-ocs/.

Images

[1] ISCWSA ebook V09.10.17

[2] https://community.emlid.com/t/coordinate-systems-transformation-grids/38584

[3] https://spotlight.unavco.org/how-gps-works/gps-and-tectonics/gps-and-tectonics.html

[4] Welltrack, PathControl