APSG Geodetic Workshop (Introduction)

Jim Cain
APSG Immediate Past Chair and Member,
OGP/EPSG Geodesy Subcommittee
jim.cain@cain-barnes.com

February 28, 2007

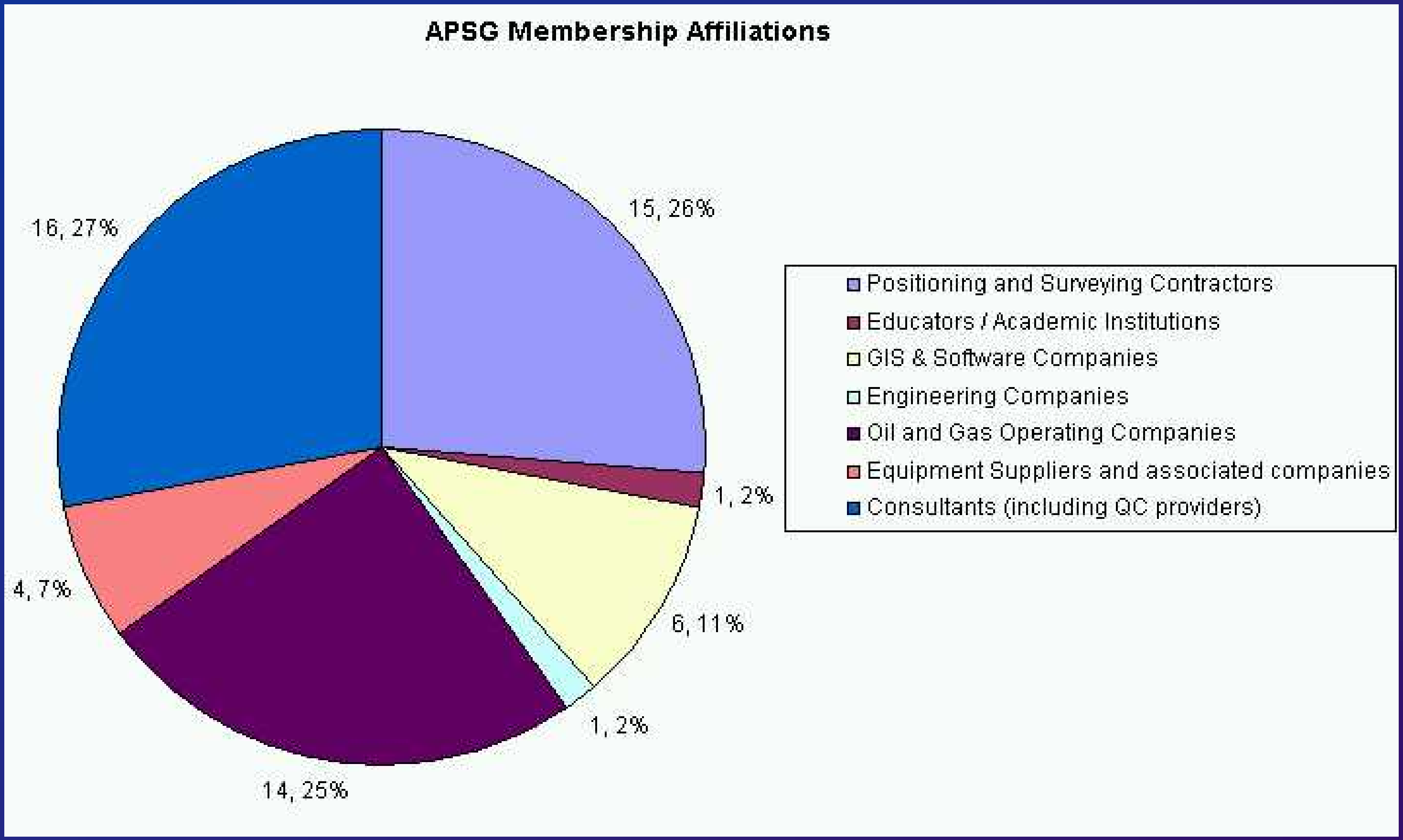
Cain & Barnes, L.P.
12418 Stafford Springs Dr
Houston, Texas 77077
1+832-215-5551
www.cain-barnes.com

www.apsg.info

APSG – Who Are We?

- The Americas Petroleum Survey Group (APSG) is an unincorporated association of individuals who desire to exchange geodetic and cartographic information relating to worldwide petroleum development. The purposes of the APSG are to advance survey technology relative to the worldwide petroleum industry and to disseminate information to APSG members in respect of worldwide petroleum geodesy, surveying, cartography, and spatial data management
- A primary APSG goal is to enhance education and awareness of geodetic issues within the GIS and G&G communities within our industries

APSG Membership Distribution by Sector



Recent APSG Initiatives (1)

- Guidance Note(s) on Geodetic Applications Software
  - First such GN limited to “Precision and Presentation” w/ Version 1.0 released following 15 Nov 2006 meeting
    - Stresses the requirement to match EPSG db terminology
    - Stresses EPSG dbase as a primary source for compliant algorithms, CRS, etc.
    - Does not express requirement for users to have unique object codes (per object type) as in EPSG db, but suggests it
  - Future Software GNs are expected to address other user concerns, but . . . .
    - Are not anticipated to cover detailed “Audits” of software routines
    - Exact topics to be covered in these Guidance Notes is still under review
  - Input is being sought from Software Developers and Suppliers as well as End Users.

APSG Guidance Note on Geodetic Software "Precision and Presentation"

Guidance Note

for

Geodetic and Cartographic Applications

(Precision and Presentation)

Revision history:

Version	Release Date	Amendments
1.0	15 November 2006	Initial Release
1.1	16 January 2007	Corrections and expansions in symbology suggested at November 2006 annual meeting.

Contents

Recent APSG Initiatives (2)

- Guidance Note on Geodetic Transformations for the Gulf of Mexico
  - Version 1.0 released 8 March 2006
    - NADCON CONUS recommended for all O&G work in US GoM
    - Superseded transformations (JECA, EnSoCo, NIMA) provided for historical reasons, should they be needed on legacy data
    - Use of EPSG dbase terminology used and stressed.
      EPSG codes are given for all transformations in the Guidance Note
  - Version 2.0 released 15 November 2006
    - Additional 2 JECA transformations for Mexican waters
    - Accuracy assessments of all JECA transformations for GoM
    - A few minor corrections brought about by user request

APSG Guidance Note on Geodetic Transformations for the Gulf of Mexico

Guidelines
for
Geodetic
Transformations to
NAD27 for use in
the Gulf of Mexico

Revision history:

Version	Release Date	Amendments
1.0	8 March 2006	Initial Release
2.0	15 November 2006	Add JECA Campeche transformations; add accuracy assessments to early transformations; correct typo errors in tfm steps from NAD27 > NAD83 > NAD83(HARN) > WGS 84 on page 2

Contents:

Current APSG Leadership (February 2007)

- Chair
  John Conner (EnSoCo, Inc.)
- Vice Chair
  Bruce Carter (BP Americas)
- Secretary/Treasurer
  Hugh Beattie, Exploration Geodesy, Inc.)
  Immediate Past Chair
  Jim Cain (Cain & Barnes, L.P.)

- Membership and Technical Advisory Committees Chair
  Barry Barrs (ExxonMobil)
- Education Committee Chair
  Jon Stigant (Devon Energy)

Next APSG meeting will be April 25th, 2007 at Schlumberger, Houston

Today's Workshop Schedule

Workshop: **28th February 2007, 1:00 to 4:15 p.m.**

1.	***Introduction:***		Jim Cain APSG Immediate Past Chairman Email: jim.cain@cain-barnes.com
2.	***Geodesy and Projections***		
		Presenter	Jim Cain Cain & Barnes, L.P. Houston, Texas. Email: Jim.Cain@cain-barnes.com
3.	***Positioning Issues Related to Seismic Data Loading***		
		Presenter	John Conner EnSoCo, Inc. Houston, Texas Email: jconner@ensoco.com
4.	***The Challenge of Enterprise-wide Spatial Data Management***		
		Presenter	Jon Stigant Devon Energy Houston, Texas Email: Jon.Stigant@dvn.com

Geodetic Datums and Projections as they apply to the Petroleum Industry

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Our task today is to convince you that …

-

Geospatial Data Management is Important!

I.e.,

Why you should care about Geodesy

Current Work Environment

- Distributed computing – Multiple users (many with little geodetic awareness)
- Multiple sources of data, often poorly labeled
- New data is usually on a global satellite datum, with legacy data on local datums / CRSs, sometimes on several different ones
- Little oversight or checking of often inadequate procedures

Coordination between different departments and groups is critical!

Conventional thinking is …

"In the past, the main source of positioning risk was during data acquisition"

There still remains the risk of positional errors during data acquisition – however . . . .

"Today, the main source of positioning risk is no longer data acquisition, but data management!"

Interpretation Systems with CRS Dependency on Spatial Databases

- Openworks/Landmark
- Finder/Geoframe
- Geographix
- Kingdom
- Trango
- Probe
- Petrel

Other Applications for CRS Manipulations

- ArcView / ArcGIS
- Blue Marble Geographic Calculator
- Geodetic Solutions Ltd
- ERMapper
- AutoCAD
- Atlas Seismic
- NADCON
- Proj5
- Excel
- Other Web-Based applications

Geospatial Data Types

- **Satellite and Aerial Images, LIDAR**
- **ASCII, Excel spreadsheets, MS Access DB**
- **Shapefile**
- **Digital Elevation Model**
- **Bathymetry**
- **DWG/DRG files**
- **Digitized data (Accuracy 0.06” at Scale)**

Do you know the geodetic references for all?

Datum?, Projection?

Reference to what type of height?

Orientation to what North reference?

What do all these terms mean? Do you know?

Geospatial Data is the basic framework that …

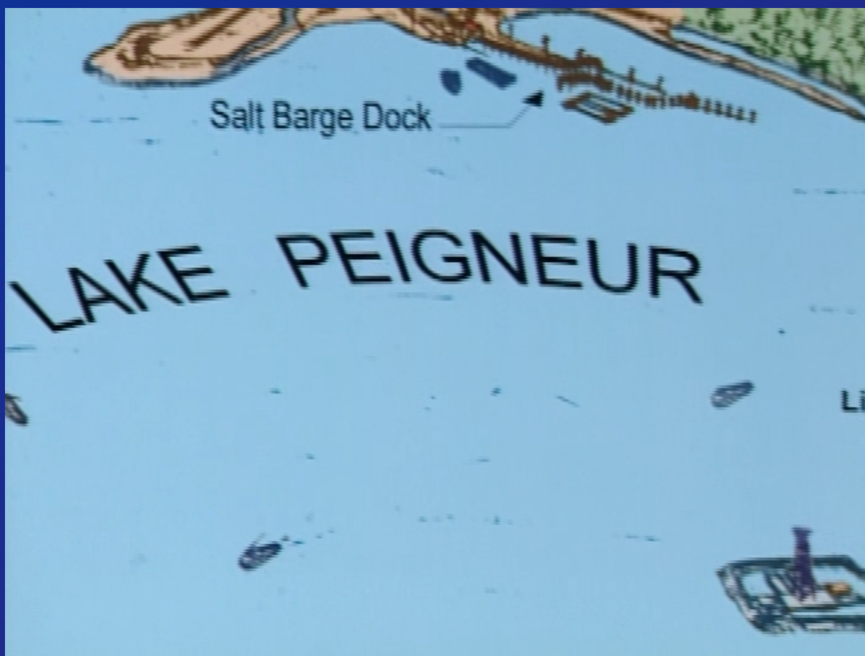
ties all aspects of the Upstream together:

- **Lease negotiations, prospect delineation, and permitting**
- **Seismic data are planned, acquired, and managed geospatially**
- **Well locations are selected relative to seismic**
- **Site surveys often run to ensure safety when the wells are drilled**
- **Wells are drilled based on results of above**
- **Facilities are often placed close to the wells**
- **Pipelines extend from wells to facilities**
- **Prospect handover or relinquishment**

This framework applies to surface, subsurface, and subsea

Look at one Historical Example

- **Lake Peigneur, LA was $48.9 million LOSS**



Why did this happen?

- The Salt Mine location and underground extent were well known and figured into Texaco plans to drill the well
- The planned location of the well was known and was designed to avoid the Salt Mine
- However, a positional error was made *somewhere* in the drilling planning, inadvertently placing the actual well directly over the mine shaft

. . . Could things get worse?

A raging torrent cascades down into the mine

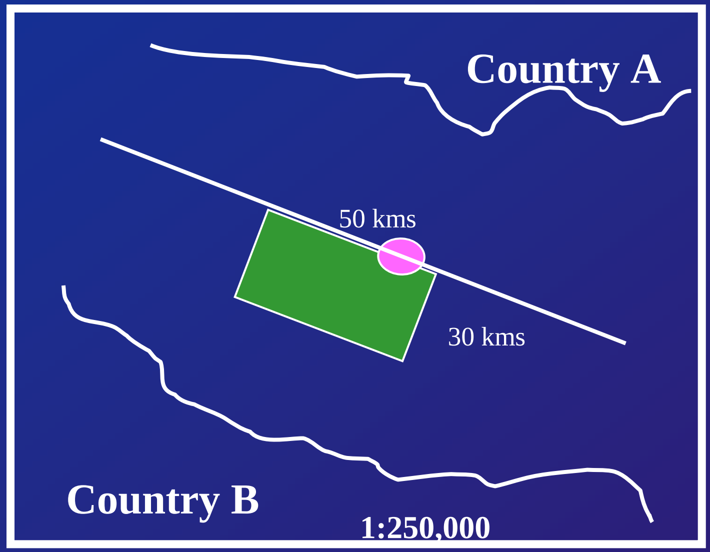
… with a significant positional error!

- Had the rig's positional error been discovered before drilling:
  - the mine would still be operating
  - the lake would be fresh water
  - the lake would still be 10 to 20 feet deep instead of 1300 feet deep
  - and the O&G operator would have saved $48.9 million dollars.

Let's now see the end of the Lake Peigneur movie

Case Study: Ownership

Navigational Chart Scale 1:250,000



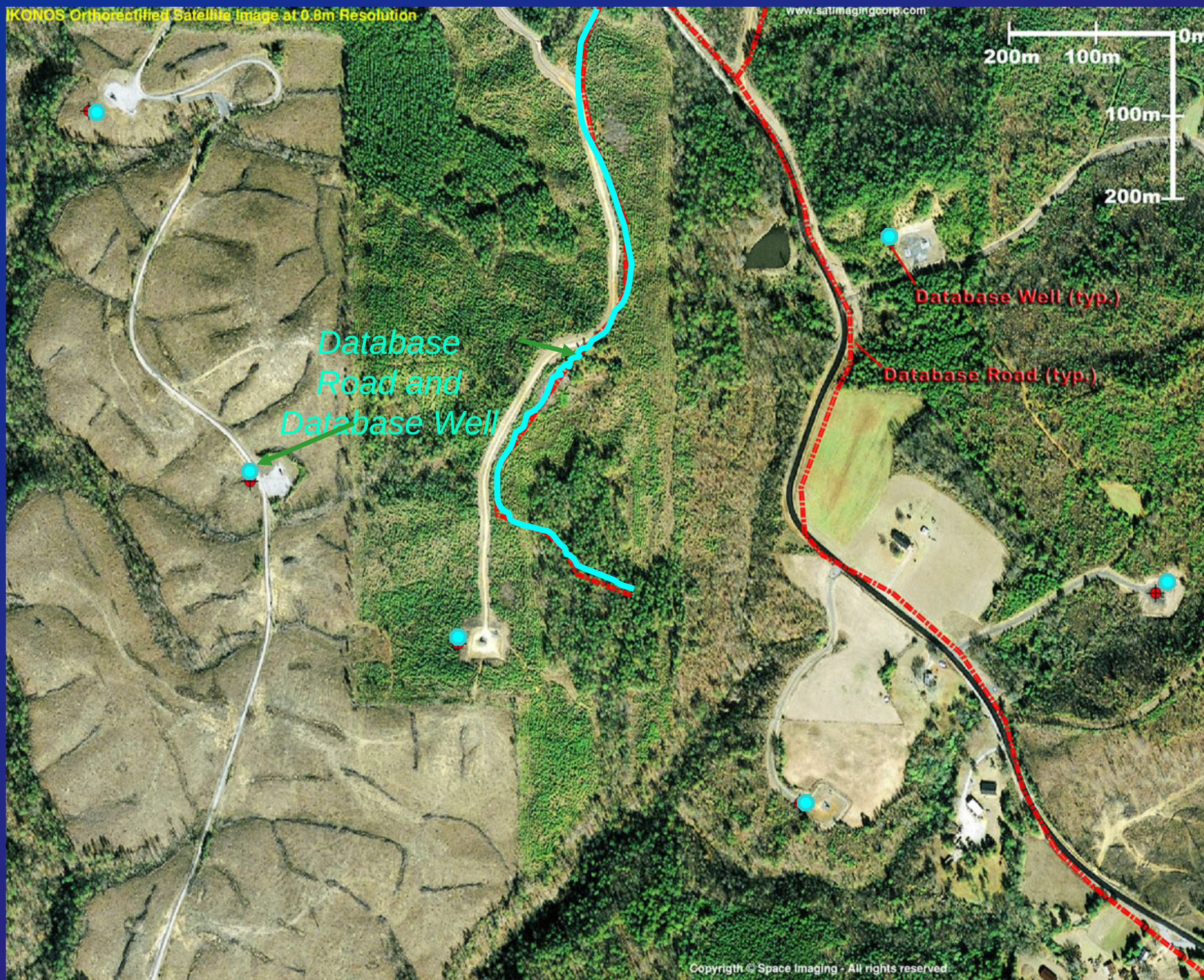
Datum – compilation for Regional chart

Rule of thumb for interpreters is 300 barrels per acre foot

A datum error of 400 meters orthogonal to the border contains 30,000 barrels per km-ft

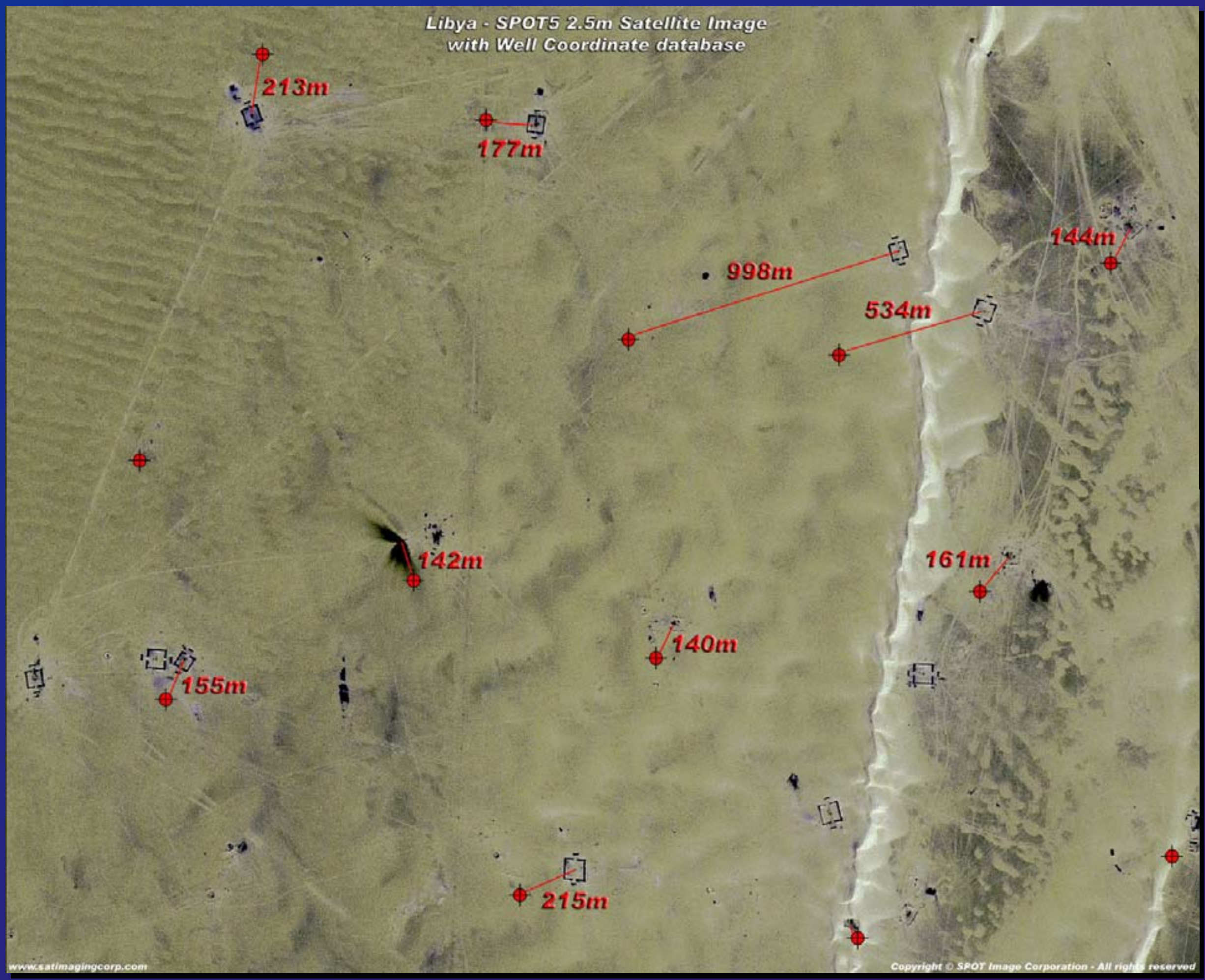
On a 5*5 km field this would represent an ownership uncertainty of 15 million barrels per 100 ft of pay

Infrastructure and Wells in Wrong Locations



Use of Photo Image courtesy of Satellite Imaging Corporation

Case Study: Well Positioning Database



Use of Photo Image courtesy of Satellite Imaging Corporation

Lessons learned

- Positioning errors can and do cost companies millions of dollars
- These same positioning errors can also put people in harms way

Before we go further – a few Definitions

- **Literally: Geodesy (γη = Earth δαιω = 1 divide) The science of the measurement and mapping of the Earth's surface.** (F. R. Helmert, 1880)

- **Branch of Mathematics dealing with the figure and area of the Earth or large portions of the Earth.** (Concise Oxford Dictionary)

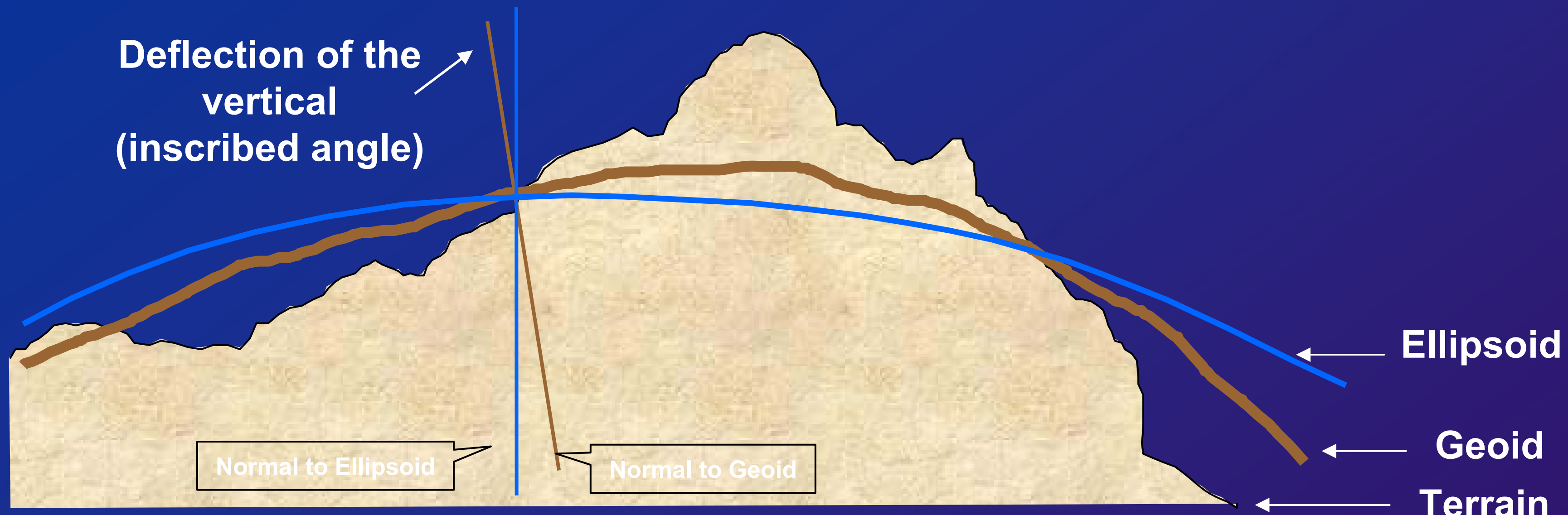
Geodesy Definitions (continued)

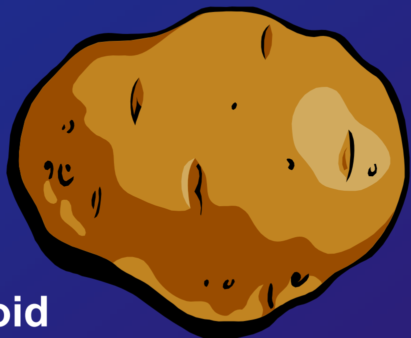
- Geodesy is defined as the study of the exact size and shape of the earth, the science of precise positioning of points on the earth (geometrical geodesy) and the impact of gravity on the measurements used in the science (physical geodesy)

Geodesy provides the frame of reference of all maps

<u>Sound geodesy</u> forms the basis for all <u>good maps</u>

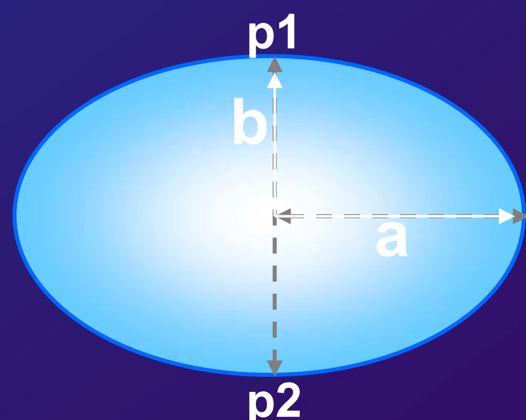
Geodetic Reference Surfaces





Geoid

Equipotential surface which approximates to MSL in the absence of other forces



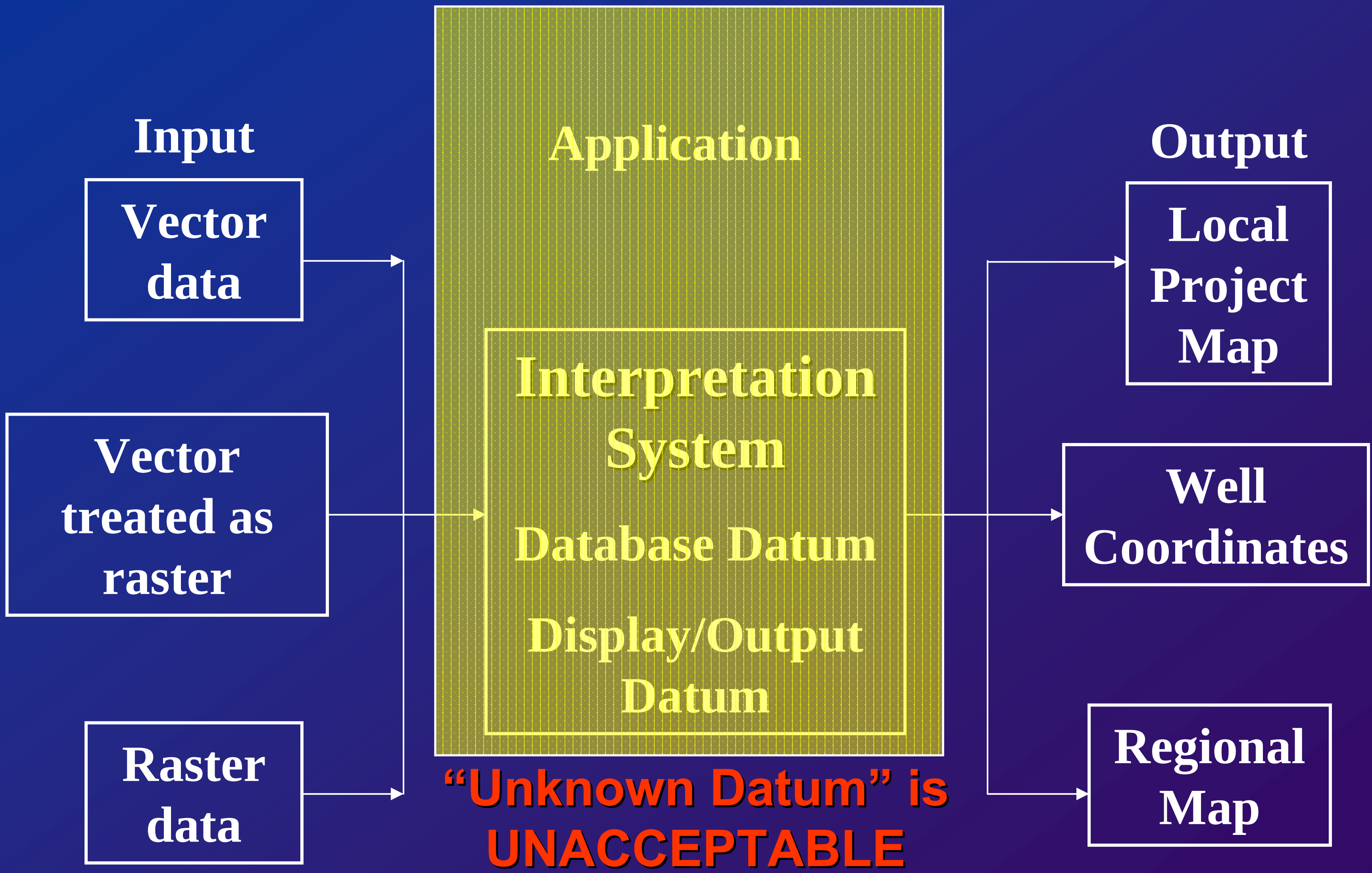
Ellipsoid $1/f = a/(a-b)$

Surface on which computations are made
p1-p2 is axis of earth ellipsoid rotation

Geodetic Terminology (ISO compliant)

- Topography / Terrain (= actual earth surface)
- Geoid (= equipotential earth's surface ~ MSL)
- Ellipsoid / Spheroid = Mathematical figure used for computations
- Coordinate System (*<u>only</u>* a system of axes in ISO)
- Prime Meridian (the meridian that is set to zero for a given datum)
- Geodetic Datum
  - Local / Astrogeodetic Datums
  - Geocentric Datums / Global Datums
- Ellipsoid and Datum are <u>NOT</u> synonyms!
  - **Assuming otherwise can lead to costly mistakes (as we will show later)**

Interpreting on “Unknown Datum”



Datums

***** WARNING ******

THERE IS ONE ESSENTIAL THING THAT YOU NEED TO KNOW ABOUT DATUMS…..

YOU NEED ONE!

Coordinate Reference System (CRS) Types

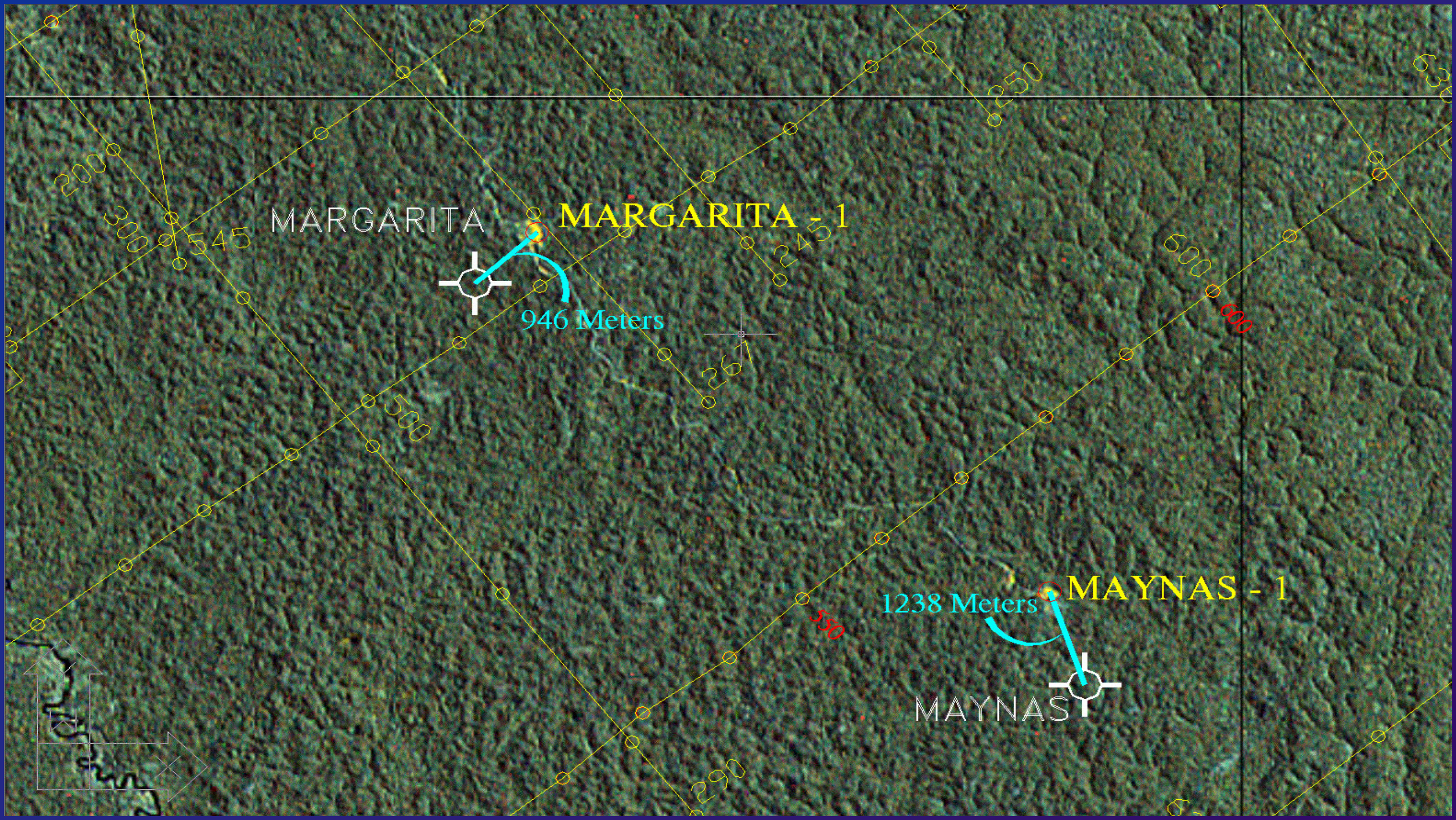
- ISO* and the EPSG** database of the OGP*** identify the following Coordinate Reference System (CRS) types:
  - Geographical 2D (lat/lon) and Geographical 3D (lat/lon/height with respect to the ellipsoid)
  - Geocentric (Earth-Centered, Earth-Fixed Cartesian)
  - Vertical (elevation or depth w.r.t. the geoid)
  - Projected 2D (mapping of an ellipsoid onto a plane)
  - Engineering (local “flat earth”)
  - Compound (combinations of any above 2D + Vertical)

* ISO is the International Standards Organization;
**EPSG is the (former) European Petroleum Survey Group, now part of OGP
*** OGP is the International Oil and Gas Producers Association

Case Study: Incorrect Application of Metadata

- **Seismic data was collected in WGS84 datum – (in a survey for an oil company Joint Venture)**
- **One of JV company's field navigation data was shifted to the local datum (and documented so) and**
- **This shifted data was supplied to processing contractor**
- **The processing contractor called the acquisition contractor and asked what datum was used for data acquisition**
- **The processing contractor then re-applied the datum shift**
- Result: Data more than 450 meters from its intended location due to a client failure to track and manage the process effectively

Case Study: Peru coordinate database problems



Use of Photo Image is courtesy of Satellite Imaging Corporation

Benefits of Good Geospatial Data Management

All the previous examples translate to LOST MONEY!

- **Positional Errors of the magnitude exhibited can cause Dry Holes.**
- **One Dry Hole in the US GoM can cost many $$ Millions**

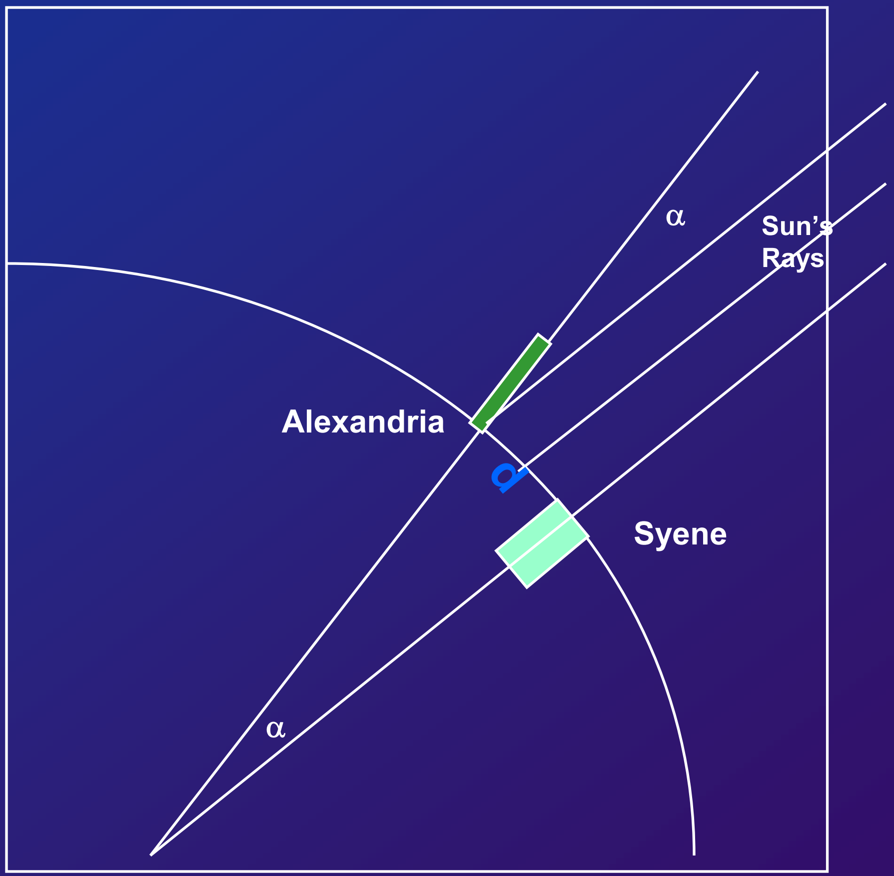
Good Spatial Data Management saves your company money!

A Bit of History – Ancient Worldviews

- Thales (625-547 BC) – a disc
- Anaximander (611-554 BC) – a cylinder
- Pythagoras (6th century) – a sphere

Eratosthenes: 245 BC

- At Syene (Tropic of Cancer), the sun's rays shone directly into well
- At Alexandria, shadow was 1/50 of a circle (about 7°)
- Eratostenes assumed the sun's rays were parallel
- The distance from Alexandria to Syene (d) 5000 stadia (1 stadia = 185.2 meters)
- Computed Earth's circumference = 250,000 stadia or about 28,750 miles
- Circumference 46,300 kms – about 15% too large



$$d:2\pi r = \alpha:360$$

Eratosthenes View of the World!

Some Famous Individuals in Geodetic History

- **Sir Isaac Newton (1642-1727),** ***London***
- **Moreau de Maupertuis (1698-1759),** ***France***
- **Pierre Bouguer (1698-1758),** ***France & Peru***
- **Charles Marie de la Condamine (1701-1774),** ***France & Peru***
- **Johann Heinrich Lambert (1728-1777),** ***Germany***
- **Adrien-Marie Legendre (1752-1833),** ***France***
- **Pierre-Simon Laplace (1749-1827),** ***Paris***
- **Carl Fredrick Gauss (1777-1855),** ***Germany***
- **Sir George Everest (1790-1866),** ***England & India***
- **Alexander Ross Clarke (1828-1914),** ***London***
- **Guy Bomford (1899-1996),** ***England & India***
- **Irene Fischer** ***(USA, retired but still active)***

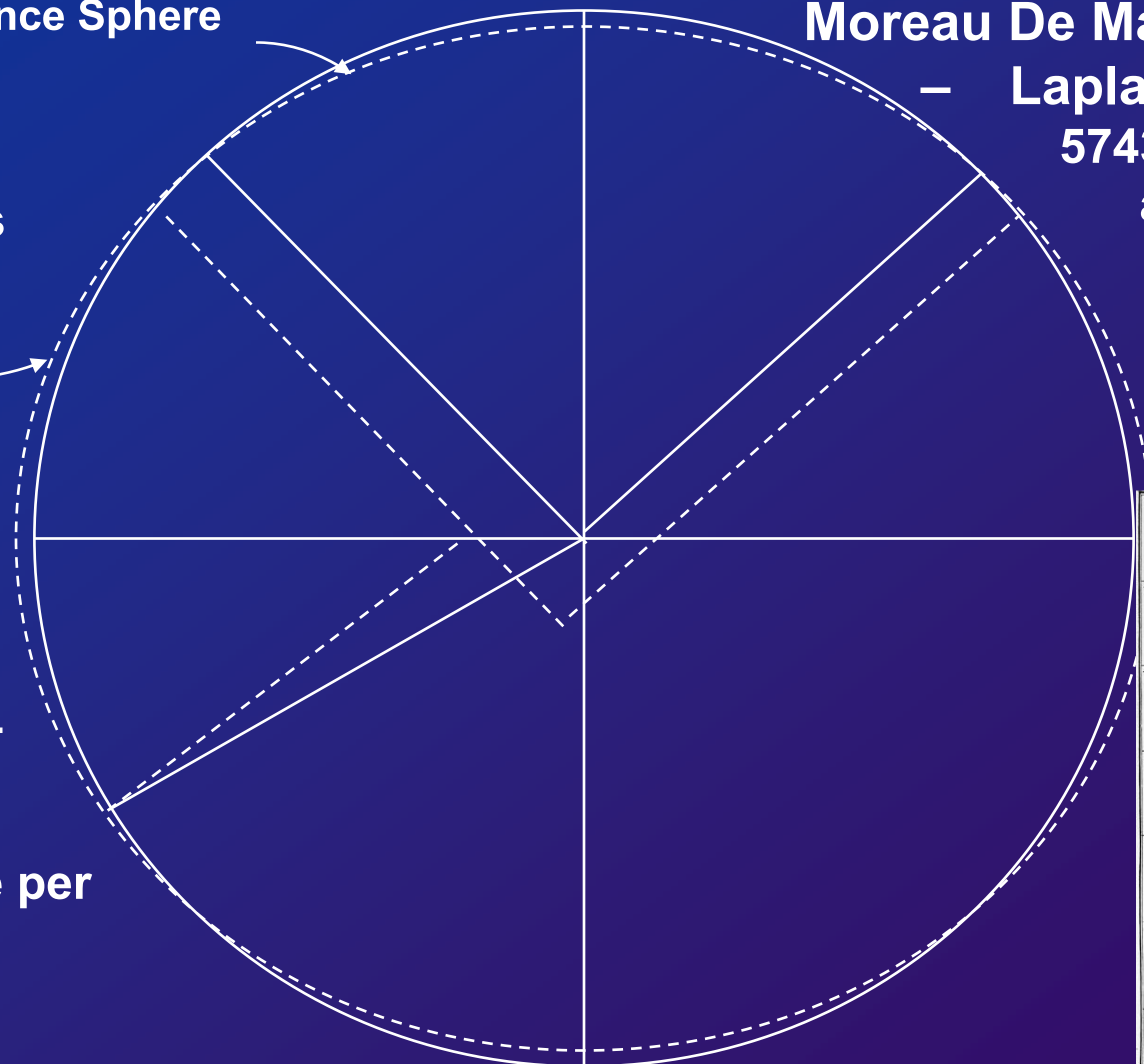
As well as: Mercator, Bessel, Airy, Hotine, Hayford, Cassini, Krüger, Snyder and many others

Arc Method of determining Earth's Size

Toise = 1.949 meters

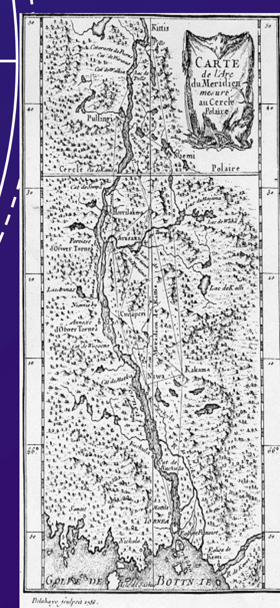
Moreau De Maupertuis – Lapland c1736

57437.9 Toise/ arc degree

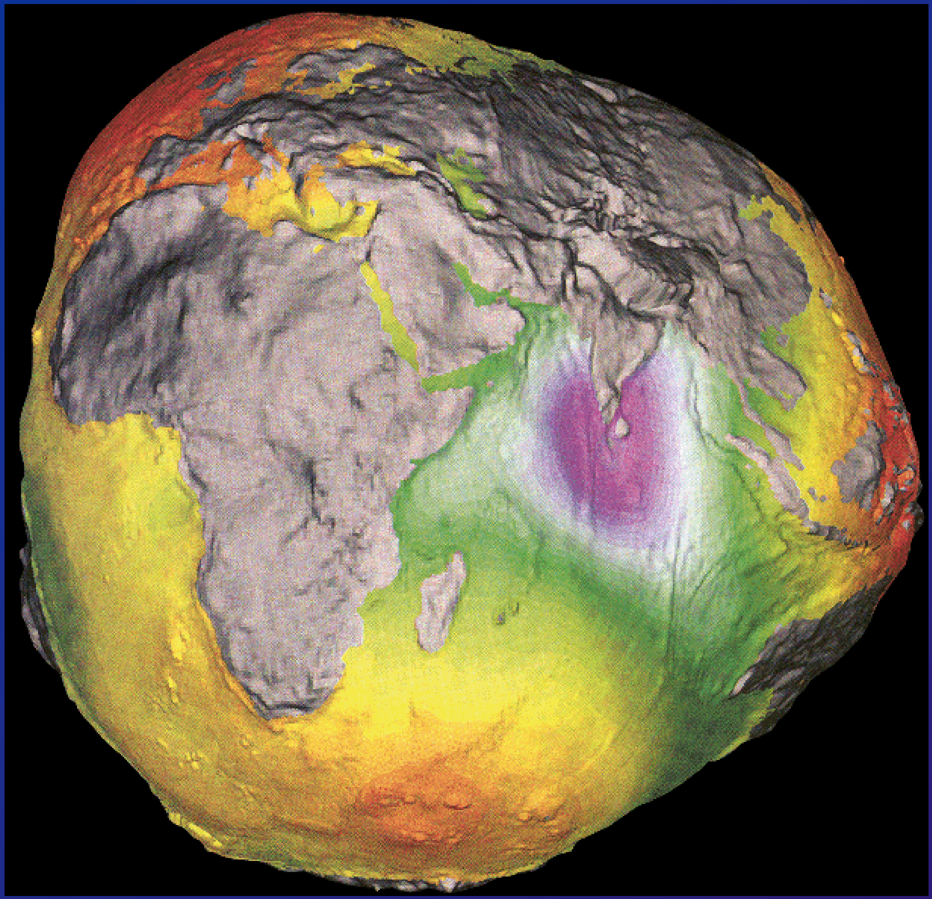


Bouguer/ Condamine – Peru c1740

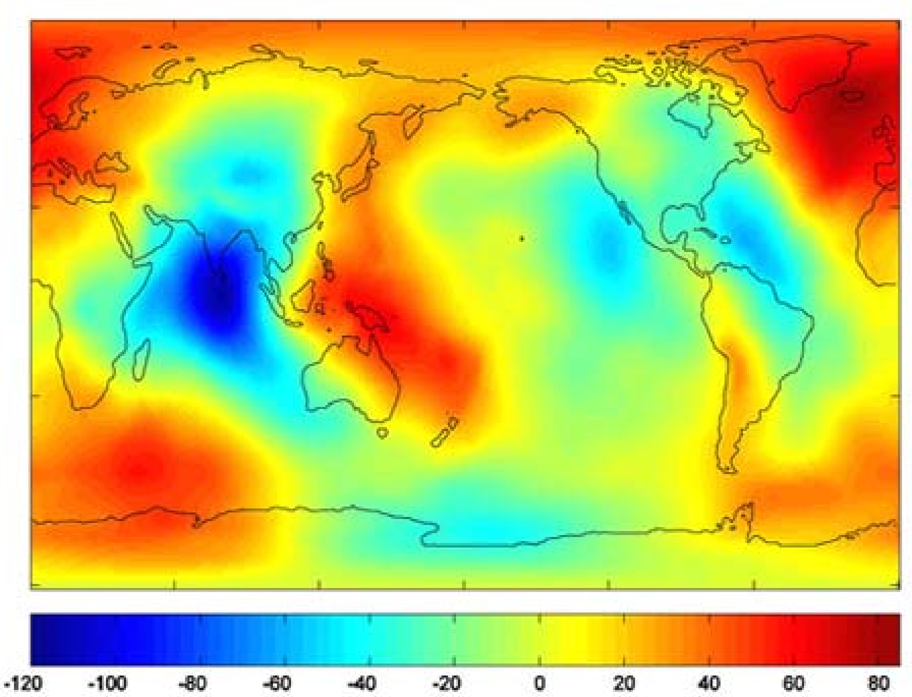
56753 Toise per arc degree



Geoid vs. Ellipsoid for making maps?



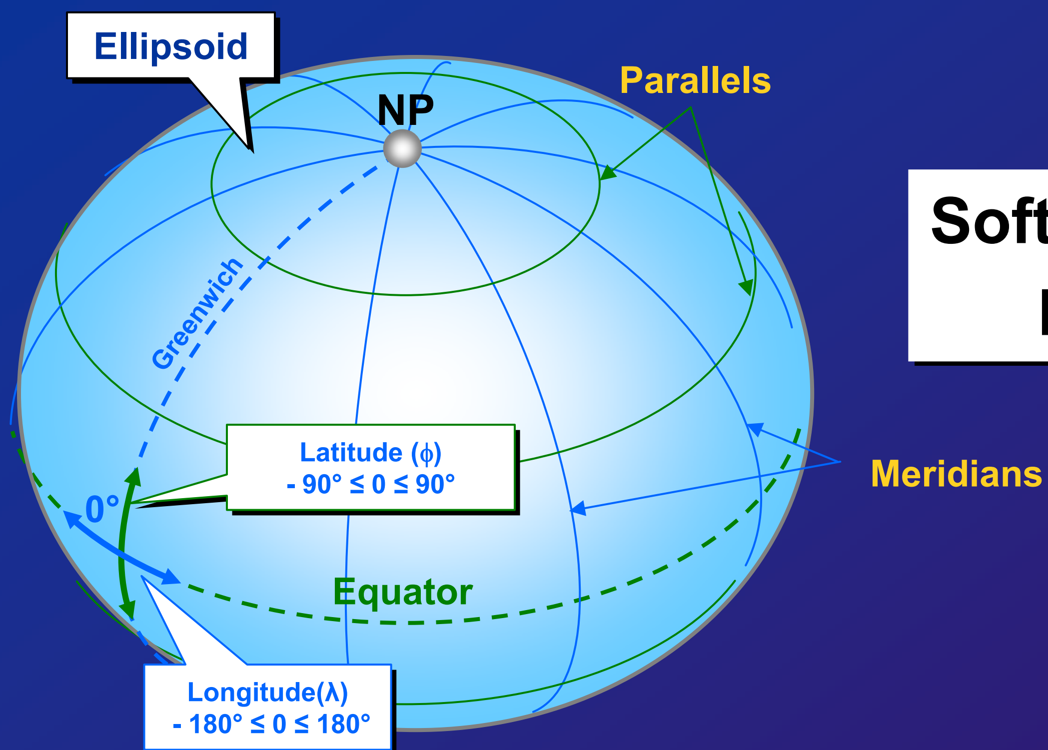
Geometric separation between reference ellipsoid and geoid is termed **geoidal undulation**



meters of separation

www.csr.utexas.edu/grace/gallery/animations/world_gravity/world_gravity_wm.html

Parallels and Meridians



Software Convention:
N,E (+); S,W (-)

Precisions are shown consistent to centimeter level

Degrees Minutes Seconds (DD MM SS.sss H)	34° 27' 17.453" N	118° 31' 32.684" E
Degrees Decimal Minutes (DD MM.mmmmm H)	34° 27. 29088' N	118° 31. 54473' E
Decimal Degrees * (DD.ddddddd H)	34.2881814° N	118.5257456° E
DMS in Sexigesimal Format (DD.MMSSsssss)	34.2717453° N	118.3132684° E

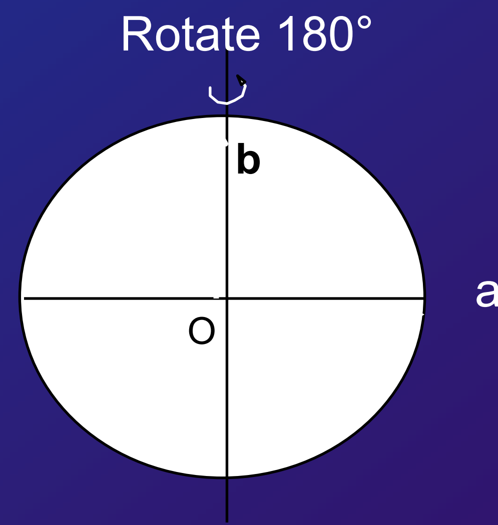
* difference is about 20 kilometers (12 statute miles) if DD.MMSSsss thought in DD.ddddddd format!

Formulae of the Ellipsoid

$$e^2 = \frac{(a^2 - b^2)}{a^2}$$

$$e'^2 = \frac{(a^2 - b^2)}{b^2}$$

$$f = \frac{(a - b)}{a}$$



a = semi major axis
b = semi minor axis
e = eccentricity
f = flattening

Any two parameters may be used to adequately describe the reference ellipsoid, typically “a & 1/f”, or sometimes “a & b”; less frequently “a & e^2”

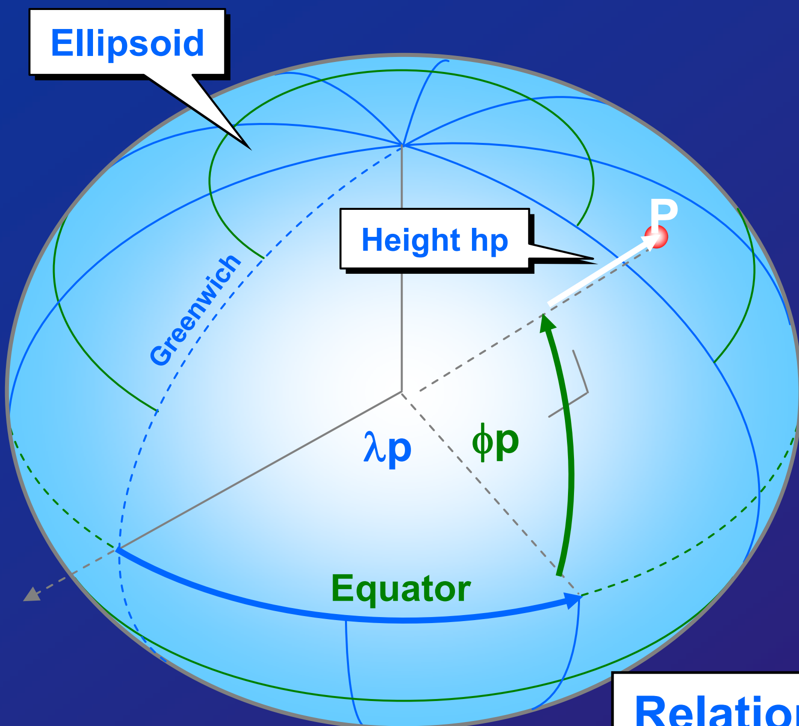
Some Ellipsoids have "Evolved" as the Foot/Meter Ratio has been modified

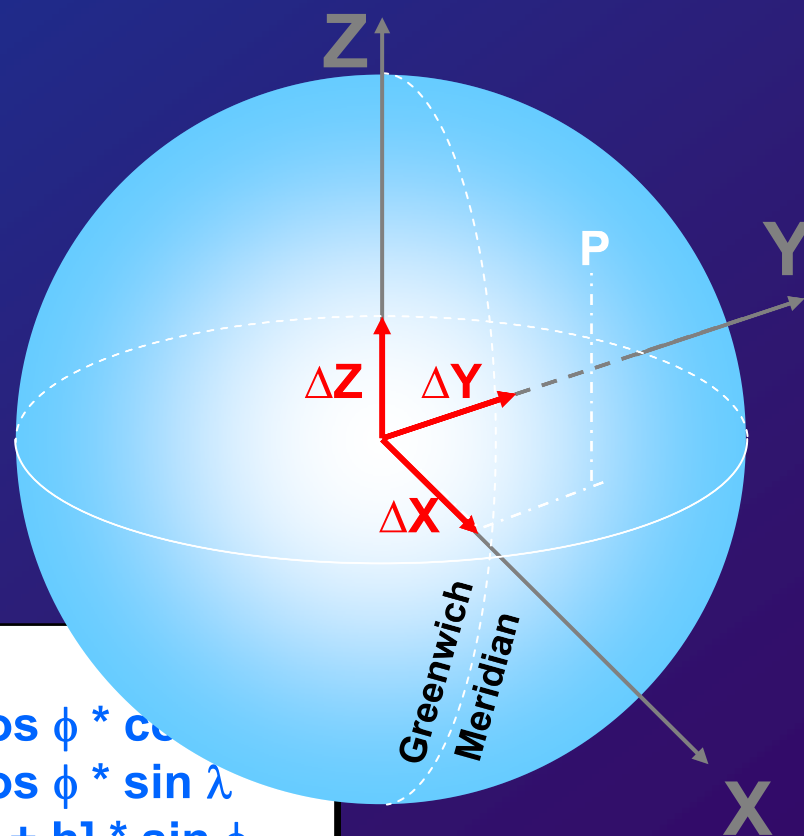
For Example,
EVEREST 1830 [20 922 931.8 "Indian Feet" when defined]

India 1937	6 377 276.345 m
Brunei & E. Malaysia 1967	6 377 298.556 m
West Malaysia 1969	6 377 295.664 m
W. Malaysia/Singapore 1967	6 377 304.063 m
(above also called "Everest Modified")	
Pakistan 1962	6 377 301.243 m
India 1975	6 377 199.151 m

Geodetic Coordinate Systems

Terrestrial Coordinate Systems





Relationships

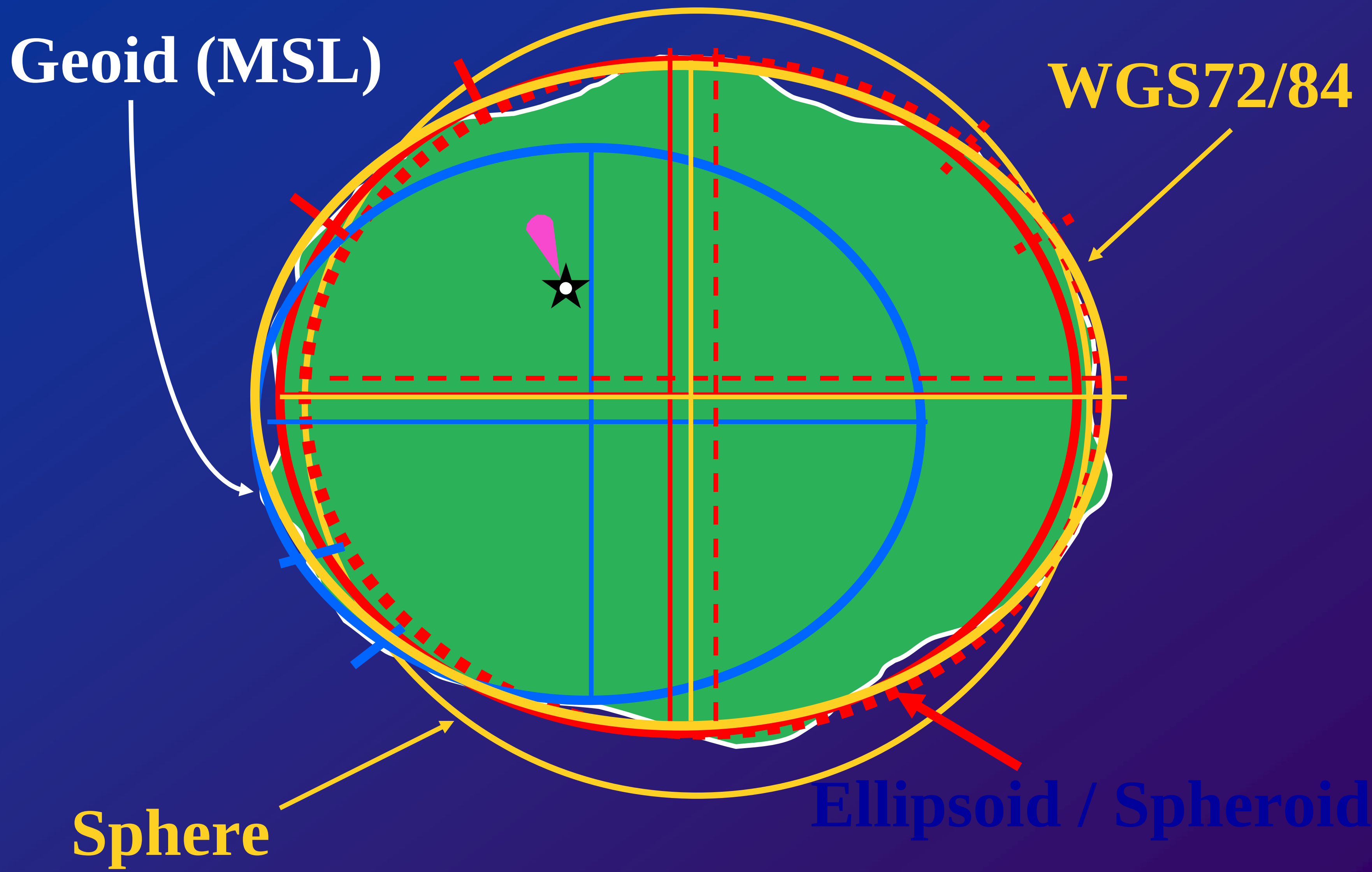
$X = (\nu + h) * \cos\phi * c$

$Y = (\nu + h) * \cos\phi * \sin\lambda$

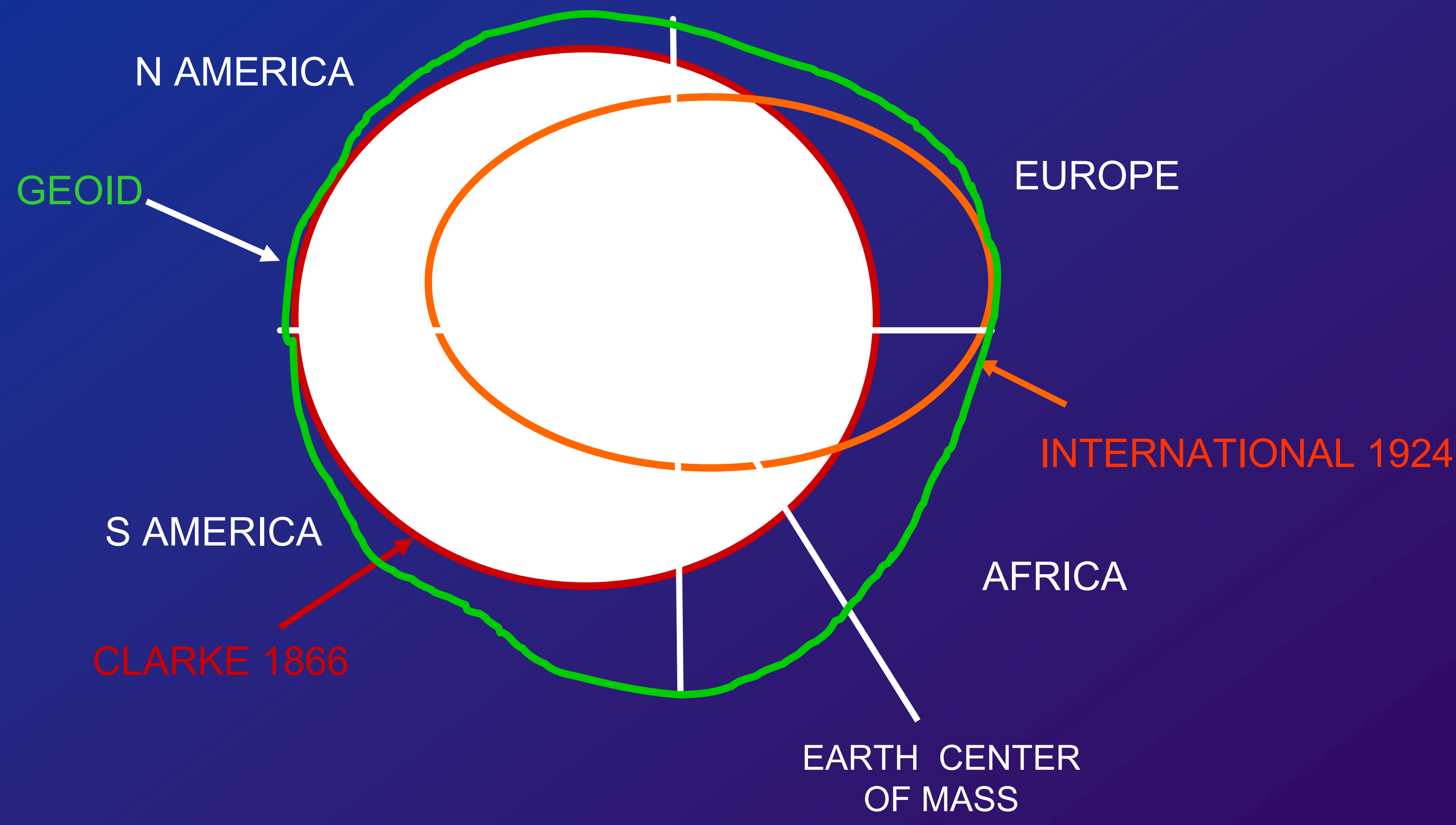
$Z = [(b^2 * \nu / a^2) + h] * \sin\phi$

Some older datums have a reference (0º) Prime Meridian at another place than Greenwich, e.g., Paris, Bogota, Djakarta

Datum & Ellipsoid Relationships



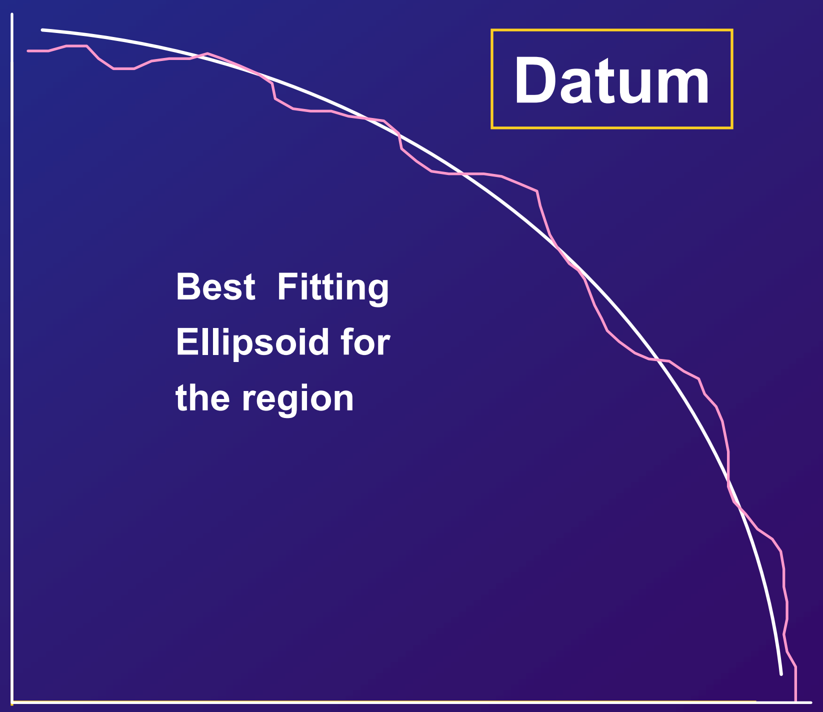
The Geoid and Two Ellipsoid Choices



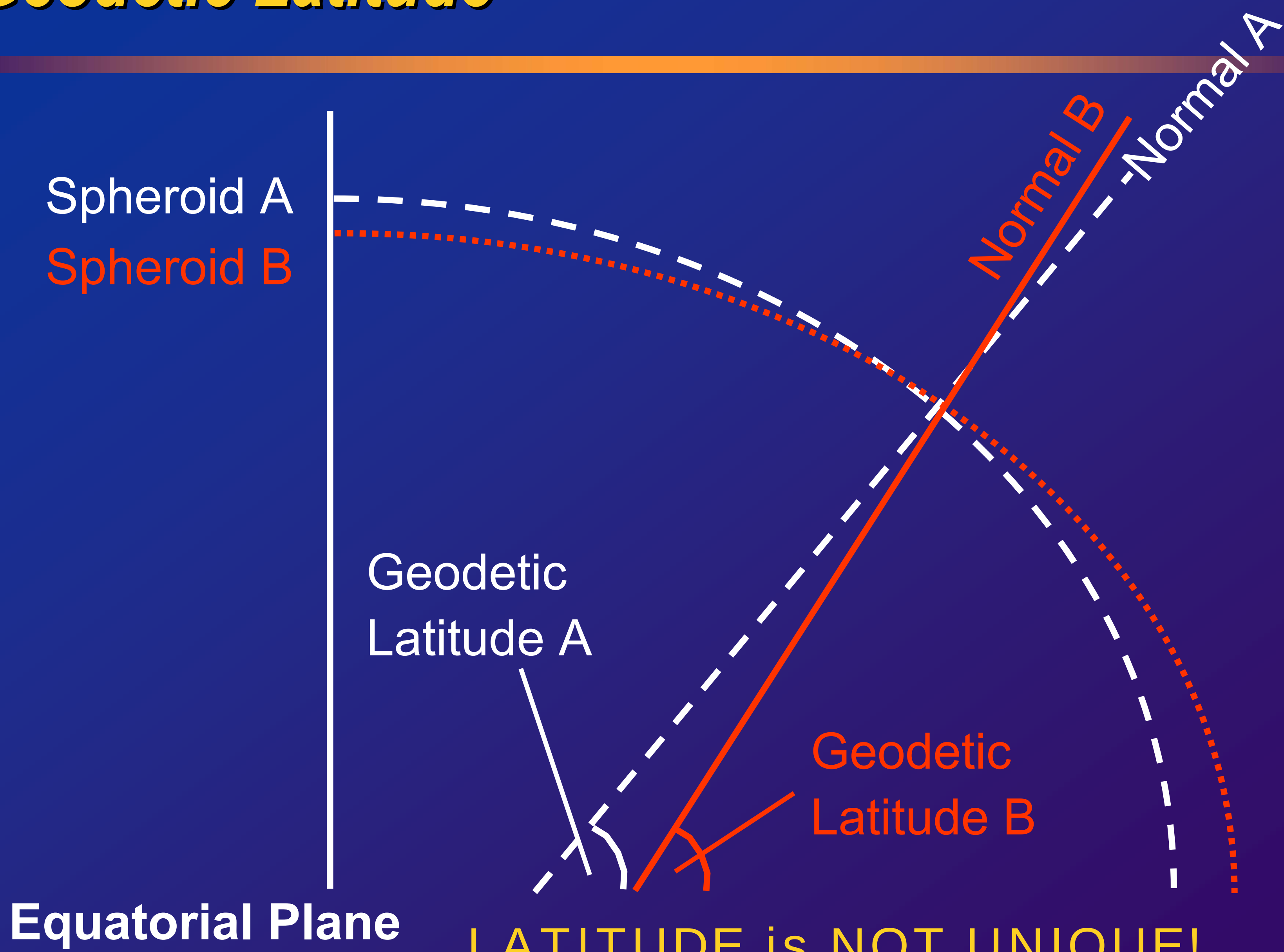
Astro-geodetic Datums

DATUM = Reference Ellipsoid <u>PLUS</u> the Datum Origin (or the fit of the ellipsoid to the earth)

- Used for a specific region; e.g., North America, U.K., Nigeria, Brazil, S. Chile, Western Europe, Fiji, etc.
- An origin and an ellipsoid are chosen to minimize local geoid-ellipsoid separation and deflection of the vertical.
- Not Earth centered!
- Hundreds have been defined for countries and regions all over the planet

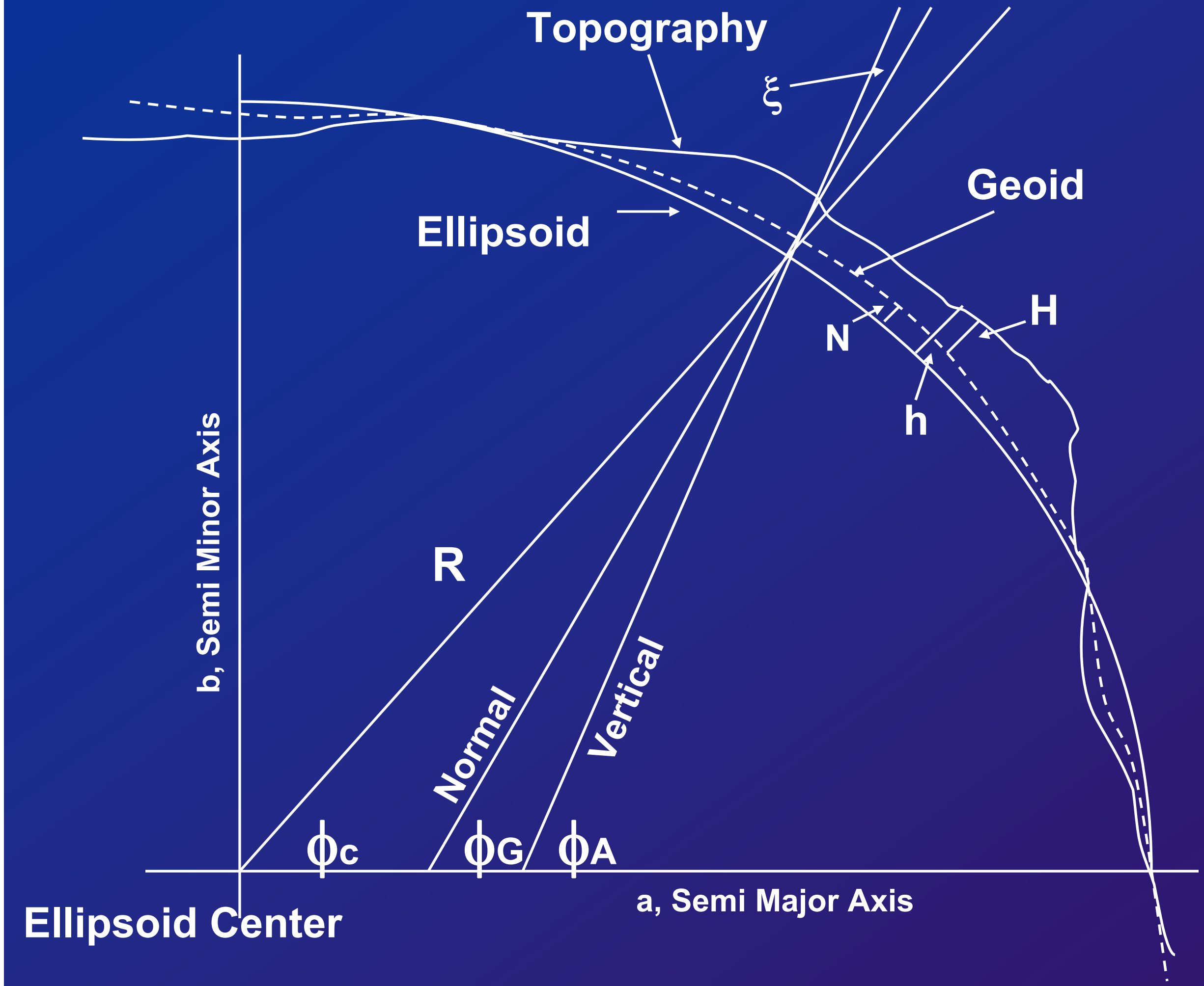


Geodetic Latitude



LATITUDE is NOT UNIQUE!

Relationship between Surfaces



ϕc Geocentric Latitude

R Geocentric Radius

H Elevation above Geoid/MSL

N Geoidal Height

h Ellipsoidal Height

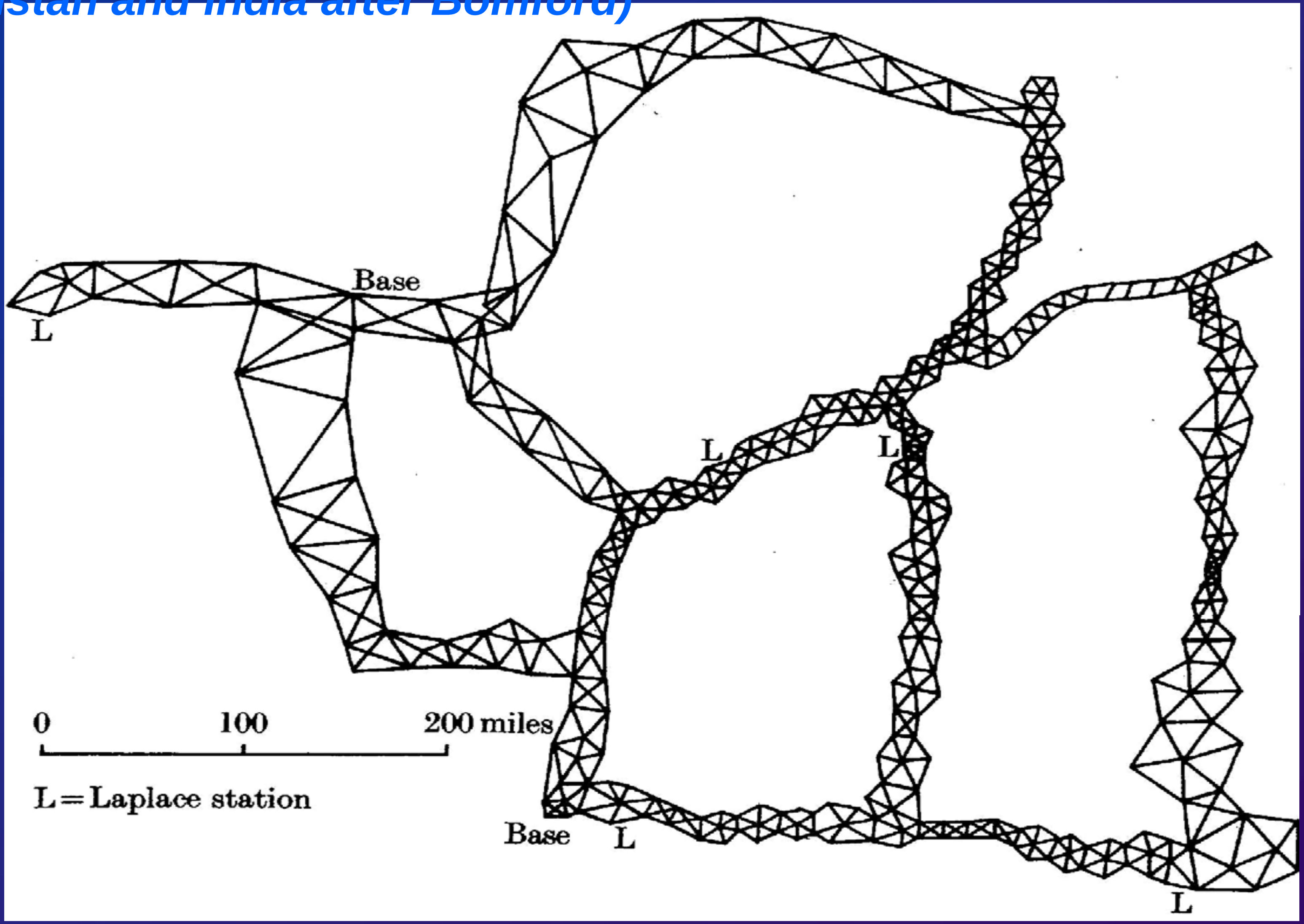
ϕA Astronomic Latitude

ϕG Geodetic Latitude

ξ Deflection of Vertical in the Meridian plane

Triangulation Network with Laplace Stations and Measured Baselines

(Pakistan and India after Bomford)



Astro-geodetic Survey of Nepal 1983

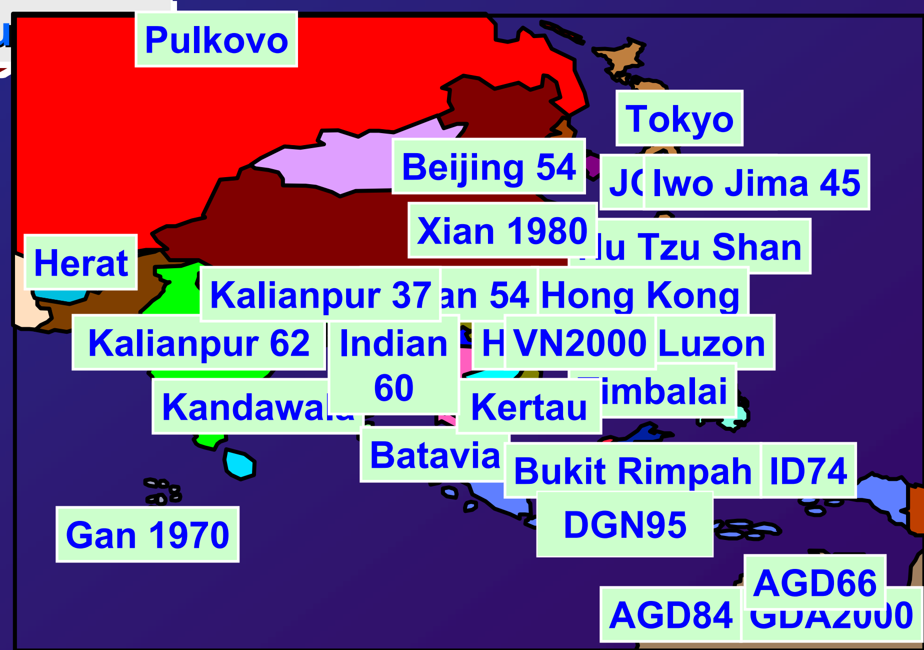
GeogCRS

- Geographic Coordinate Reference System (CRS) or GeogCRS
  - Result of combining a geodetic datum and a set of coordinate axes (or a coordinate system)
  - GeogCRS are often called "Datums" or "Coordinate Systems" in general traditional usage. However, upon rare occasions a Geodetic Datum may be associated with two (or more) sets of axes yielding more than one GeogCRS.

Datum Examples

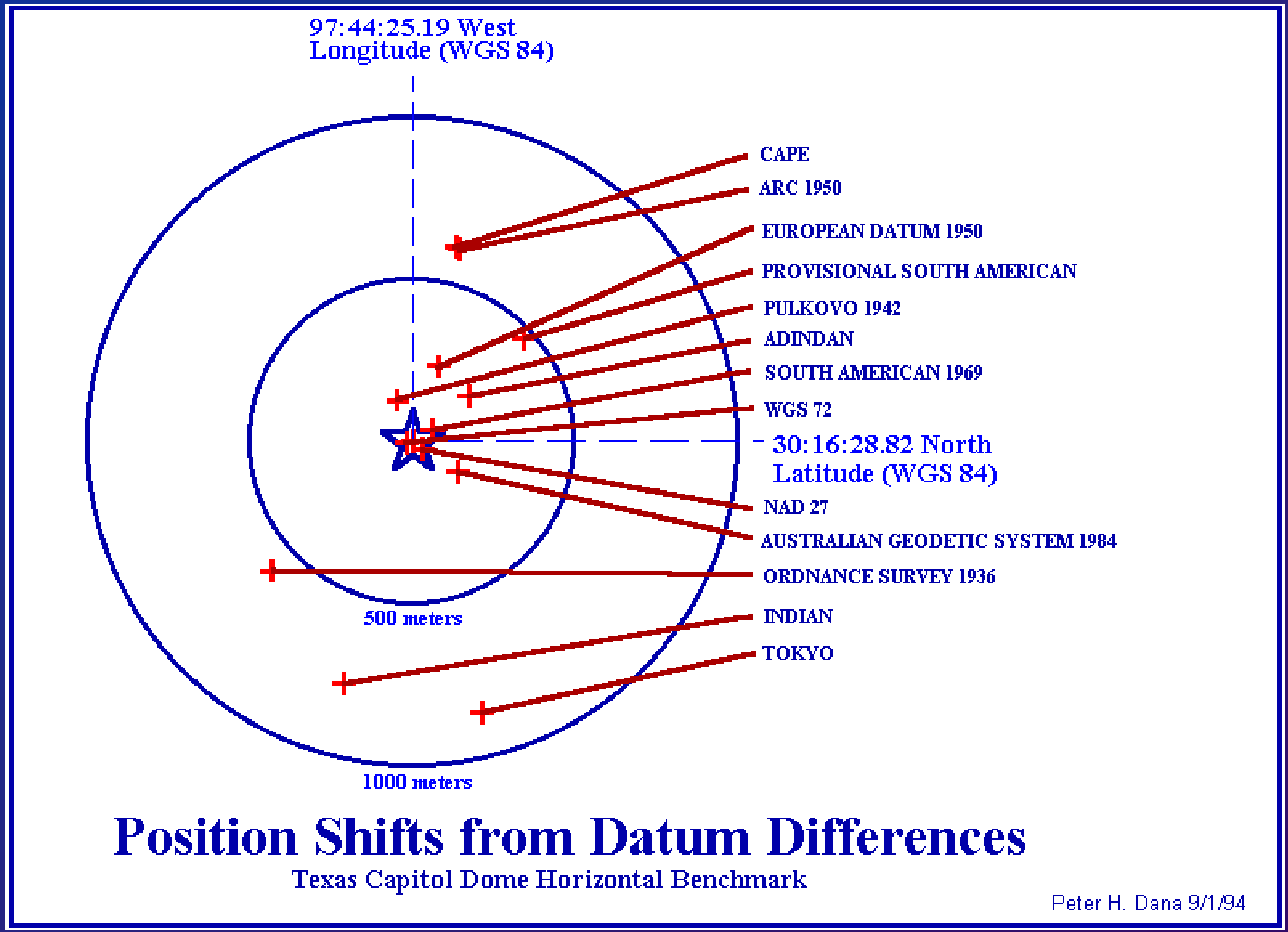
Datum Origin	PLUS	Reference Ellipsoid	=	Datum
11 main stations	+	Airy	=	OSGB36
Many points (global)	+	WGS72 ellipsoid	=	WGS72
1591+ points (global)	+	WGS84 ellipsoid	=	WGS84
Potsdam	+	International 1924	=	ED50
La Canoa, Venezuela	+	International 1924	=	PSAD56
Meade's Ranch, KS	+	Clarke 1866	=	NAD27
Many pts, North America	+	GRS80	=	NAD83
Herstmonceaux, UK	+	Airy	=	OS(SN)70
Manoca Twr, Cameroon	+	Clarke 1880 IGN	=	Manoca
Minna Station, Nigeria	+	Clarke 1880 RGS	=	Minna
Many points (global)	+	GRS80	=	ITRF yyyy
		Where yyyy is adjustment year		

Major World Datum Blocks



Over 350 well-defined
Horizontal Datums worldwide!

What if you get the Datum Wrong?



Courtesy of Peter H. Dana, The Geographer's Craft Project, Department of Geography, The University of Colorado at Boulder

When does a GeogCRS differ from a Datum?

- **When a *different* coordinate system (with different Axis Orientations and/or Units of Axis Measure) is used with a given datum**

  - Datum: **Ancienne Triangulation Francaise**
    GeogCRS: **ATF**
    ATF has angular lat/long units in "Grads" (1/400 of a circle)

  - Datum: **Ancienne Triangulation Francaise**
    GeogCRS **(an XOM Extension): ATF (Degrees)**
    ATF modified for user convenience (XOM) to have lat/long units in degrees rather than in grads.

  - **These are NOT the same and you could be far off location if the wrong "Coordinate System" (or wrong GeogCRS) is used.**

Mixing Datums: Texas and Montana

- West Texas
  Texas Central Zone
- NAD27
  - Lat: 32° N
  - Long: 105° W
- NAD83
  - 32° 00' 00.54" N
  - 105° 00' 01.87" W
- Differences
  - DE 158.8 ft (ftUS)
  - DN 60.9 ft (ftUS)
  - DR 170.0 ft (ftUS)

- Montana
  Montana South Zone
- NAD27
  - Lat: 45° N
  - Long: 112° W
- NAD83
  - 44° 59' 59.654" N
  - 112° 00' 03.075" W
- Differences
  - DE 222.0 ft (ftUS)
  - DN 30.0 ft (ftUS)
  - DR 223.7 ft (ftUS)

Different Datums (& GeogCRS)

ONE location offshore Brazil, represented on three different Datums (different GeogCRS).

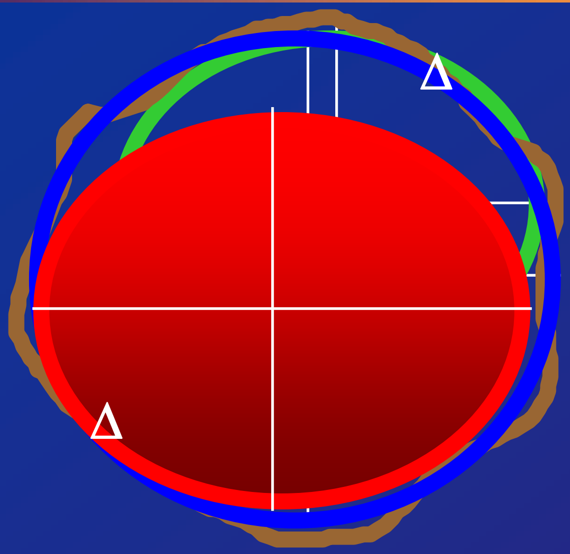
Geographic positions:

GeogCRS/Datum	Latitude	Longitude
Aratu	20º 36' 13.276" N	38º 56' 56.334" W
SAD69	20º 36' 17.428" N	38º 56' 50.124" W
WGS84	20º 36' 19.279" N	38º 56' 51.217" W

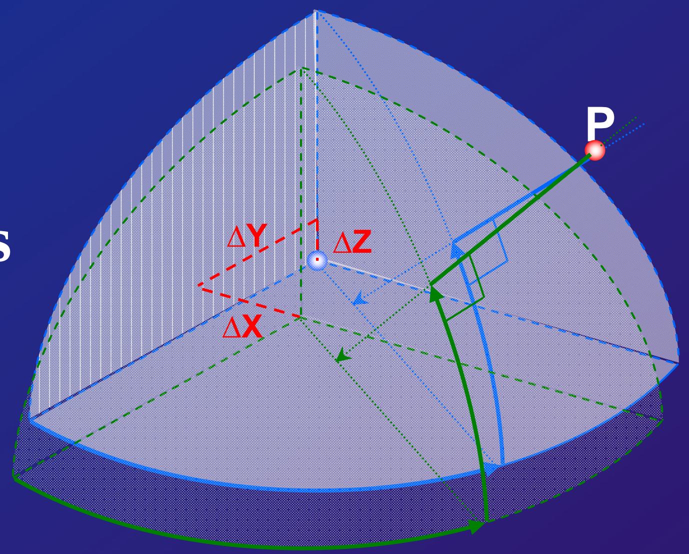
Differences in Lat/Long coordinates are evident.
But . . . What if you didn't have the Datum label?

Where is? 20º 36' 15.444" N 38º 56' 53.111" W

Mixing Datums: Brazil Example

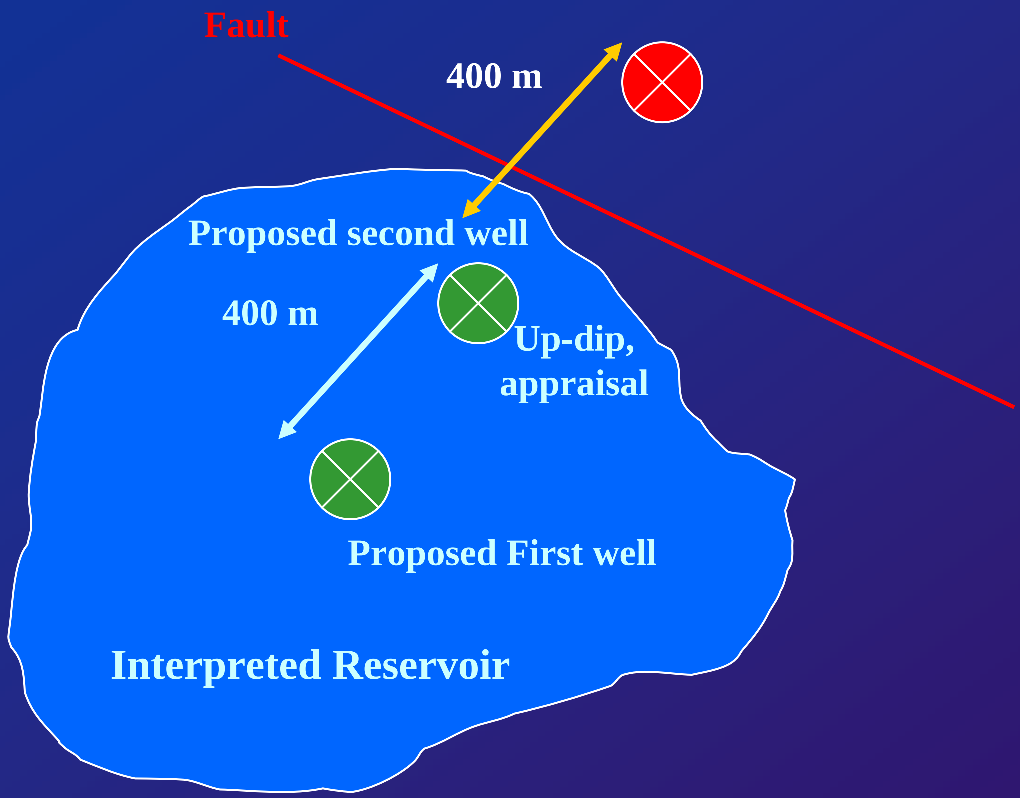


Positions for a Single Point



Datum	Latitude	Longitude	Local to WGS84	Local to Local
Aratu	**20º 36' 13.276"N**	**38º 56' 56.334"W**	**237 meters**	**221 meters**
SAD69	**20º 36' 17.428"N**	**38º 56' 50.124"W**	**65 meters**	
WGS84	**20º 36' 19.279"N**	**38º 56' 51.217"W**		

Exploratory & Appraisal Well Issues



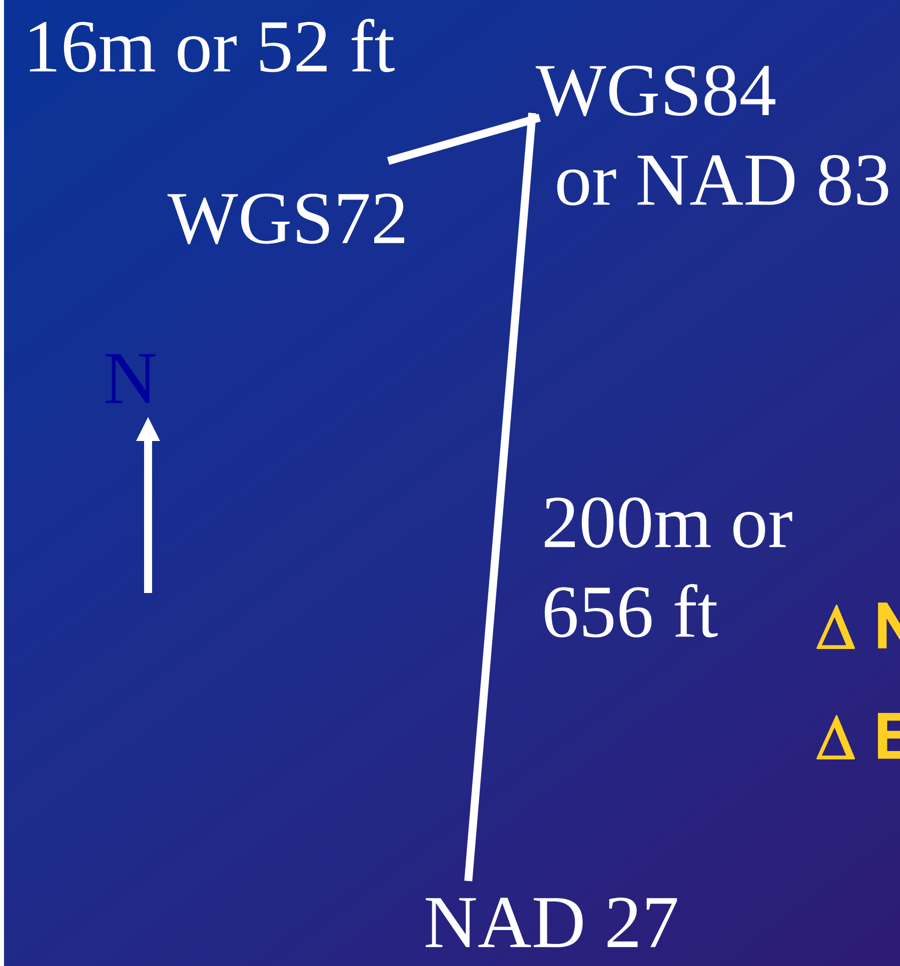
If you drill the first well in the second well location due to a geodetic mistake, then when you move 'up-dip' to drill the appraisal, you could end up on the wrong side of the fault!

How Many Datums are in the USA

- WGS84 (actually 4 different realizations, agree at 1-2m)
  - **Main GPS Satellite Datum**
- NAD83(NSRS2007) as of February 2007 **(NEW!)**
- NAD83(HARN) or NAD83(CORS) or NAD83(HPGN)
  - **Highly accurate onshore regional NAD 83 realizations**
- NAD83 [sometimes called NAD83(1986)]
  - **US national control network established using GRS80 global ellipsoid (GRS 80 differs slightly from WGS 84)**

- WGS72
  - **Datum used by the NNSS Transit satellite system 1970's/1980's**
- NAD27
  - **Primary Regional (Astrogeodetic) Datum for USA in use from 1927 through 1986; still used in oil and gas industry**

Different Datums for a Plotted Position in the Central Gulf of Mexico



WGS 84:
Lat: 27º 00’ 37.53” N,
Long: 92º 14’ 11.10” N

NAD 27 minus WGS 84:
Δ Latitude = -1.062”
Δ Longitude = -0.441”

Δ Northing = -199.88 m (-656 feet)

Δ Easting = + 13.76 m (45 feet)

NAD 27
Lat: 27º 00’ 36.47” N
Long: 92º 14’ 10.66” N

Common Myth:

“Latitude and longitude are all you need to uniquely define a point on the ground.”

NOT TRUE!

Latitude and Longitude coordinates are not unique unless qualified with a Datum or GeogCRS name!

Geodetic Transformations (Datum Shifts)

- How do we get from one GeogCRS (Datum) to another?
  - **Often, there are many choices available**
  - **How do you choose the correct transformation?**
- How did this profusion of transformations between the various datums occur?
  - **Little sharing of geodetic information**
  - **Operators needed more accurate coordinate transformations**
  - **Satellite receivers can measure them directly**

Geodetic Transformations (Datum Shifts) [cont'd]

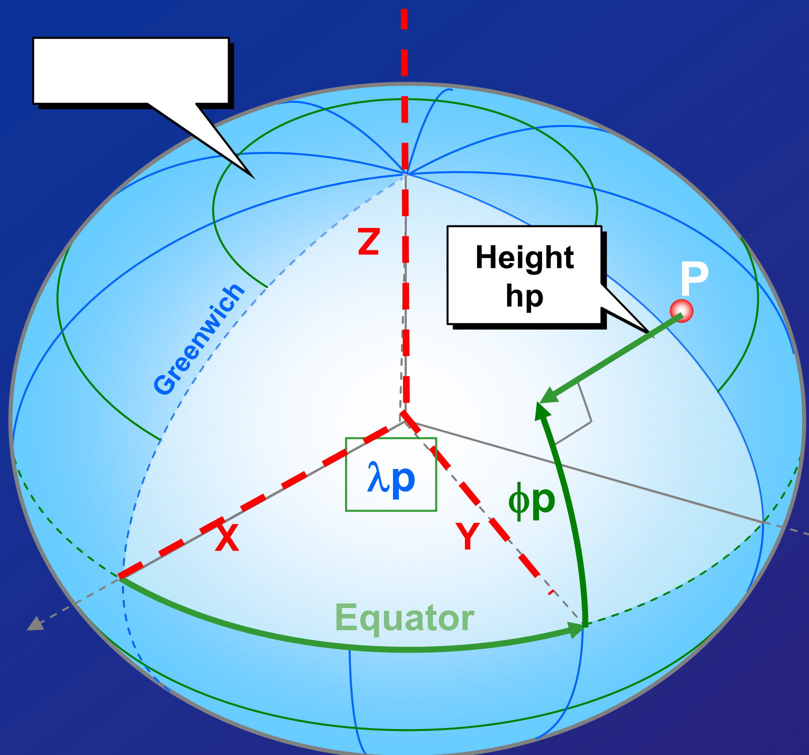
- Which transformation should I use?
- If I'm working in a "local" datum (GeogCRS), why do I need a datum shift at all?
  - **Most positioning work is done by GPS measurements solely linked to WGS 84 GeogCRS / Datum.**
  - **To obtain coordinates in a "local" CRS, *someone* MUST transform from WGS 84 that local GeogCRS.**
  - **If different datum shifts are used, then different geographic coordinates will be obtained.**

Geodetic Transformation Methods

- How do I get from GeogCRS1 to GeogCRS2
  (Datum1 to Datum2)
  - **Geocentric Translation (3-parameters)**
  - **7-parameter transformations (Special caution MUST be exercised here!)**
  - **Many other transformation methods exist, with limited applications**

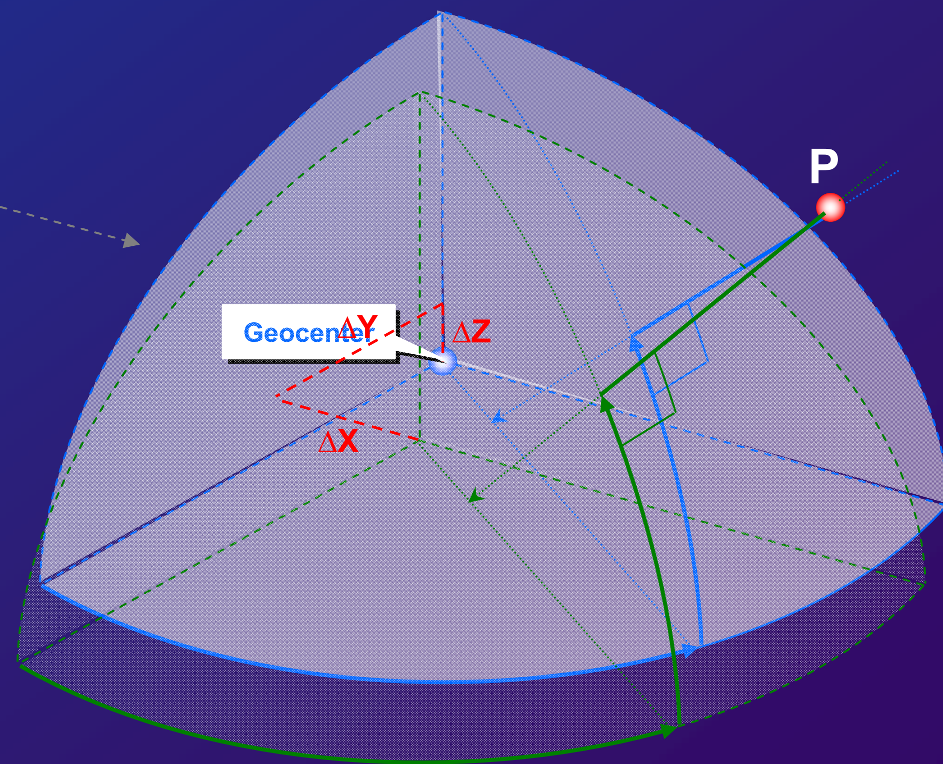
- Transformations are usually between two GeogCRS, but affine transformations can be between two Projected CRS (ProjCRS)

Geodetic Datum Shifts



Ellipsoid A (Global Datum)

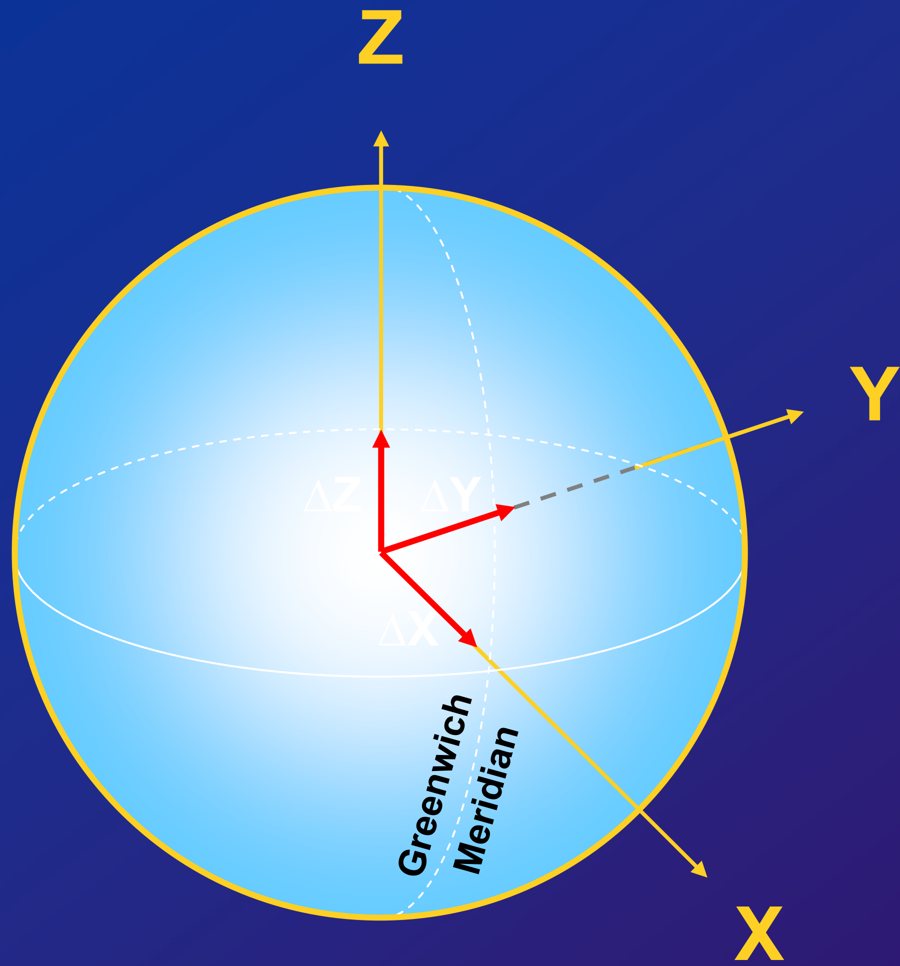
Ellipsoid B (Regional Datum)



If the geographical area is small, then

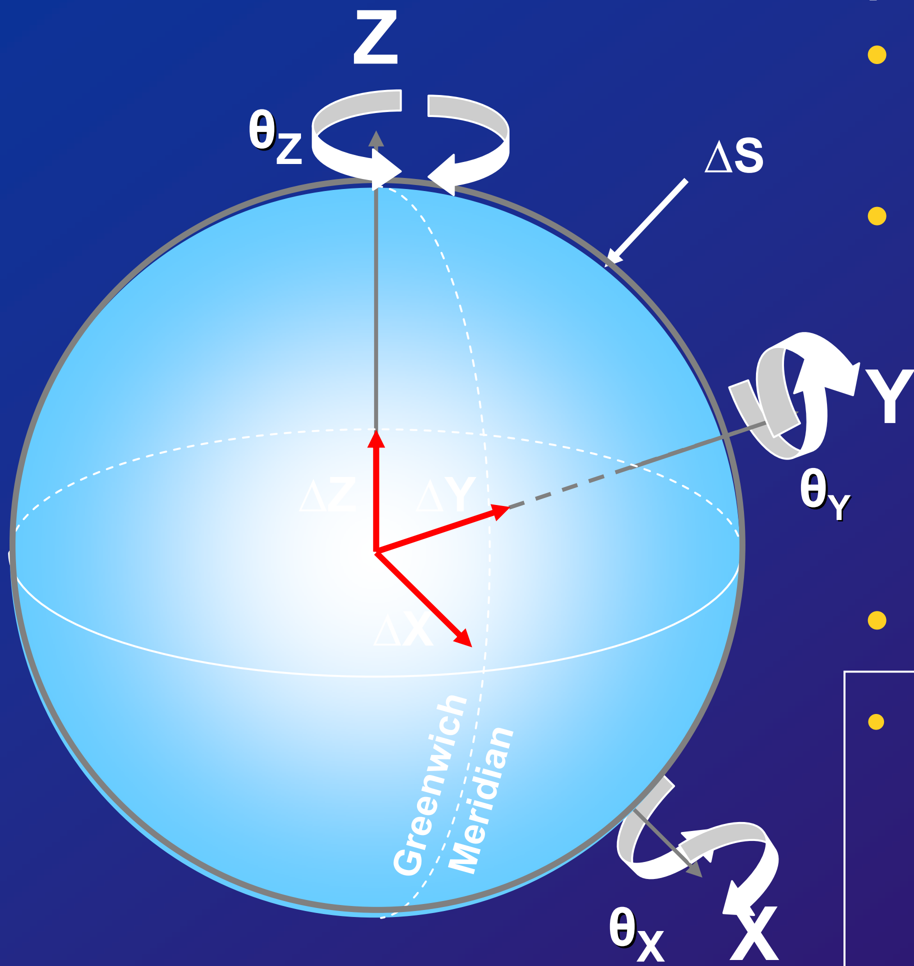
$$\begin{bmatrix}X_a\\Y_a\\Z_a\end{bmatrix} = \begin{bmatrix}\Delta X\\ \Delta Y\\ \Delta Z\end{bmatrix} + \begin{bmatrix}X_b\\Y_b\\Z_b\end{bmatrix}$$

3 Parameter Translation



- Geocentric Translations along the ellipsoid's coordinate axes, expressed as: ΔX, ΔY, & ΔZ
- This is the most common transformation method
- NGA/NIMA/DMA TR8350.2 tables use this method.

7 Parameter Transformations



Parameters are:

- 3 translations
  ΔX, ΔY, & ΔZ
- 3 rotations, one about each axis:
  - r_X (θ_X)
  - r_Y (θ_Y)
  - r_Z (θ_Z)
- Scale change (Δs)

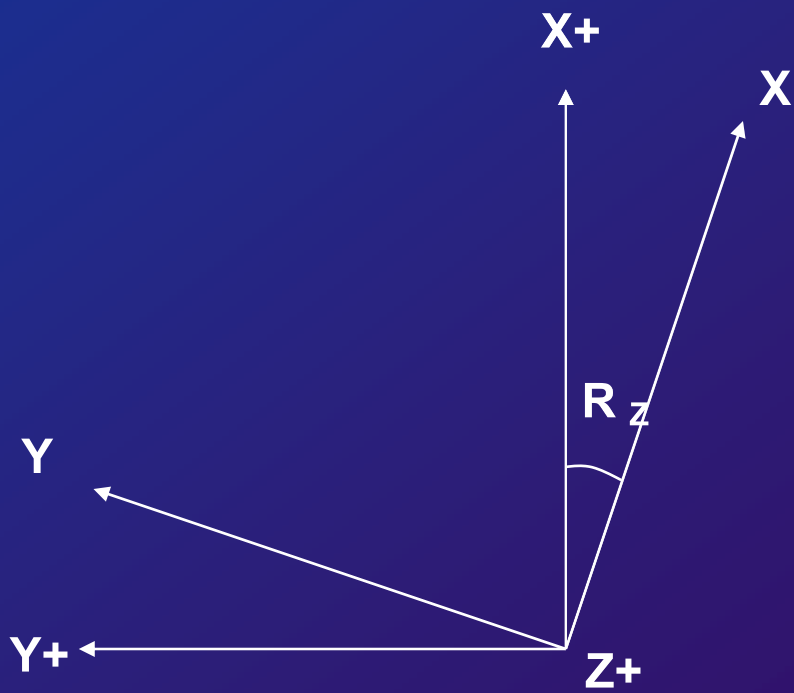
- There are 2 opposing rotation conventions and EITHER is acceptable (but needs to be documented)
- Maintaining documentation is critical!

7 parameter (and 10 parameter) Datum Transformations

- **CAUTION: two different rotation conventions for 7 parameter transformations are accepted for use.**
  - **Position Vector 7 parameter Transformation**
  - **Coordinate Frame Rotation**
- **BOTH are sanctioned by UKOOA**
- **How about 10 parameter transformations?**
  - **The Molodenski-Badekas transformation allows for rotation about a specific point.**
  - **Other ten parameter transformations allow for earth's crustal plate velocity!**

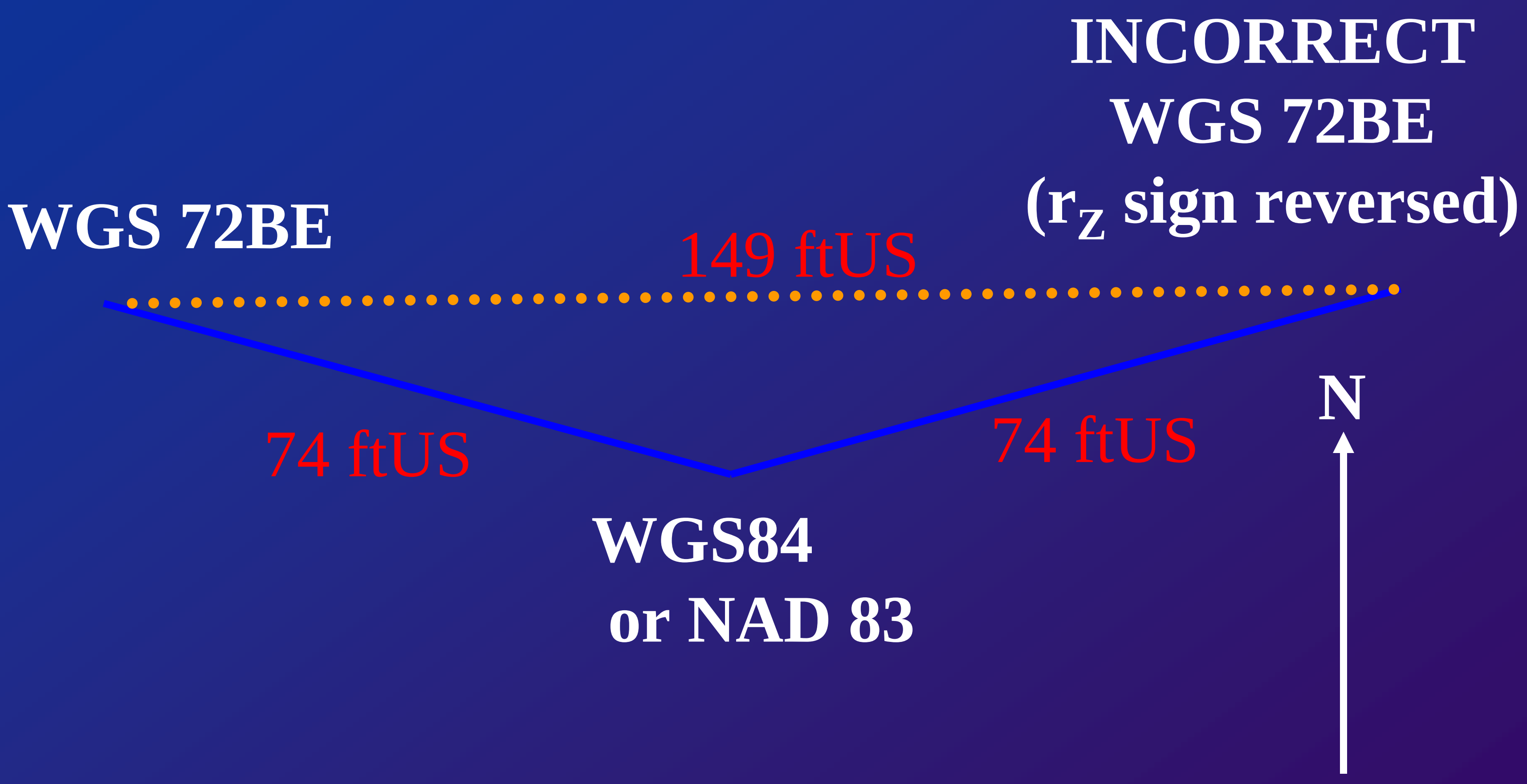
Coordinate Frame Rotation (about the Z-axis)

- θ_z, rotation about the Z axis is applied here.
- If you were on the earth looking up, the rotations would be reversed (to Position Vector Rotation)



Looking down on the earth from above the North Pole

Effect of Rotational Sign Error (7 parameter transformation)



Avoid Geodetic Problems

- To correctly define the coordinates of a point and provide accurate mapping, the details of the Coordinate Reference System (GeogCRS or ProjCRS) must be known and adequately documented
- Without this information, coordinates will often be misinterpreted, leading to positional inaccuracies and costly mistakes
- Geodetic Parameters are often completely ignored until after a problem has happened

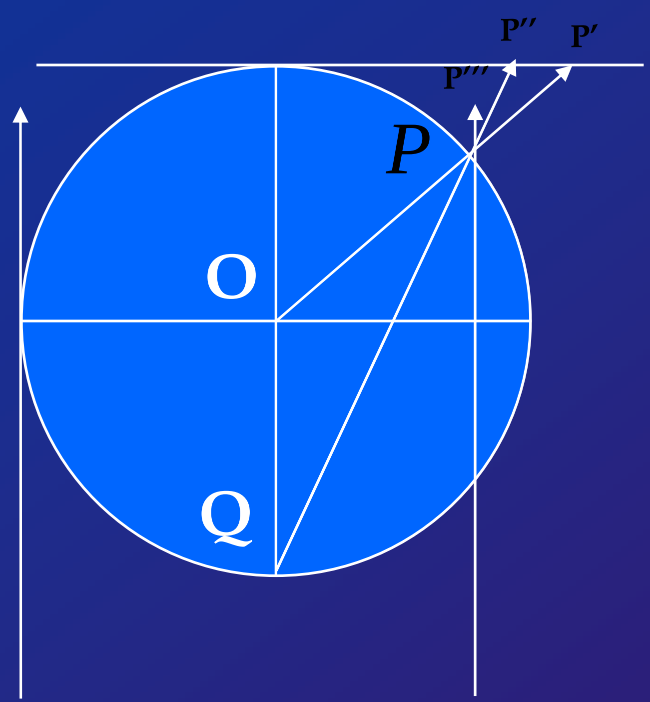
Document Everything !

- Document the geodetic data that is used
- Every document or chart that contains coordinates (Latitudes, Longitudes, Eastings or Northings) should be annotated with
  - Datum Name (NOT simply the ellipsoid)
  - Projection Data

    and where appropriate
  - Geodetic Transformation
    (and method if unclear)
    - Every 7-parameter transformation should specify *exact* method (rotation convention)!

Perspective Projections to a Plane

Azimuthal: Perspective projections in which the projection surface is a plane.

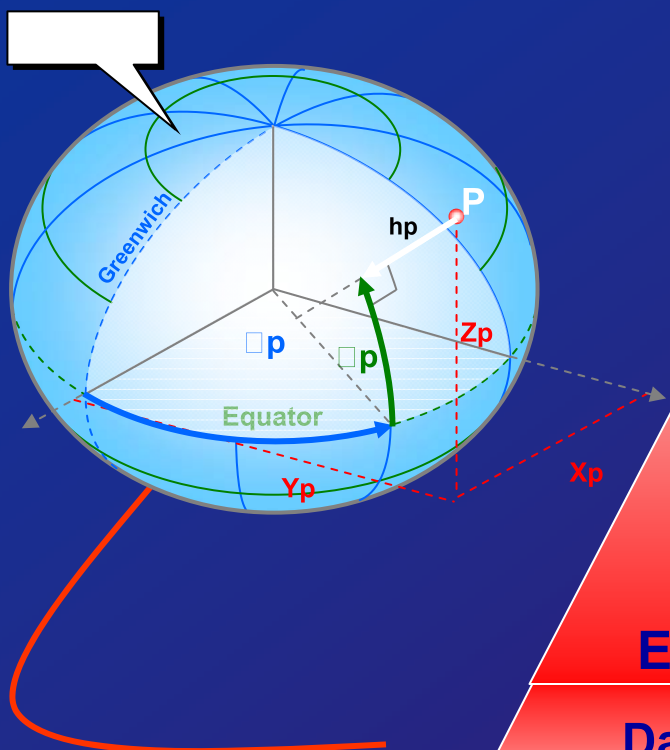


- **Gnomonic projection, P'**
  Perspective projection from the center of a sphere (O)
- **Stereographic projection, P''**
  Perspective projection from a point placed diametrically opposed to the point of tangency (Q)
- **Orthographic projection, P'''**
  Perspective projection from infinity

Different Projections Preserve or Distort specific Ellipsoidal Properties

- Shape and Angle **- local angles are shown correctly (e.g., all conformal projections)**
- Area **- correct earth surface area (e.g., Albers): important for mass balances and statistical information display**
- Azimuth **- all directions are shown correctly relative to the center**
- Scale **- preserved along particular lines (e.g., Equidistant)**
- Great Circles **- straight lines (Gnomonic)**

Hierarchy of Mapping



Projected CRS

is derivative

of the Datum

(Geog CRS)

Easting, Northing,

Elevation (above MSL)

Datum (includes ellipsoid)

is the Foundation

X,Y,Z Cartesian and/or Lat, Long, Ht

Remember . . .

Knowing the map projection and all its parameters is insufficient (even if the ellipsoid is known)!

…Unless associated with a Geographic Coordinate Reference System / Datum

The Map Projection <u>coupled with</u> a GeogCRS / Datum makes a Projected Coordinate Reference System (or ProjCRS)

Why Use Map Projections?

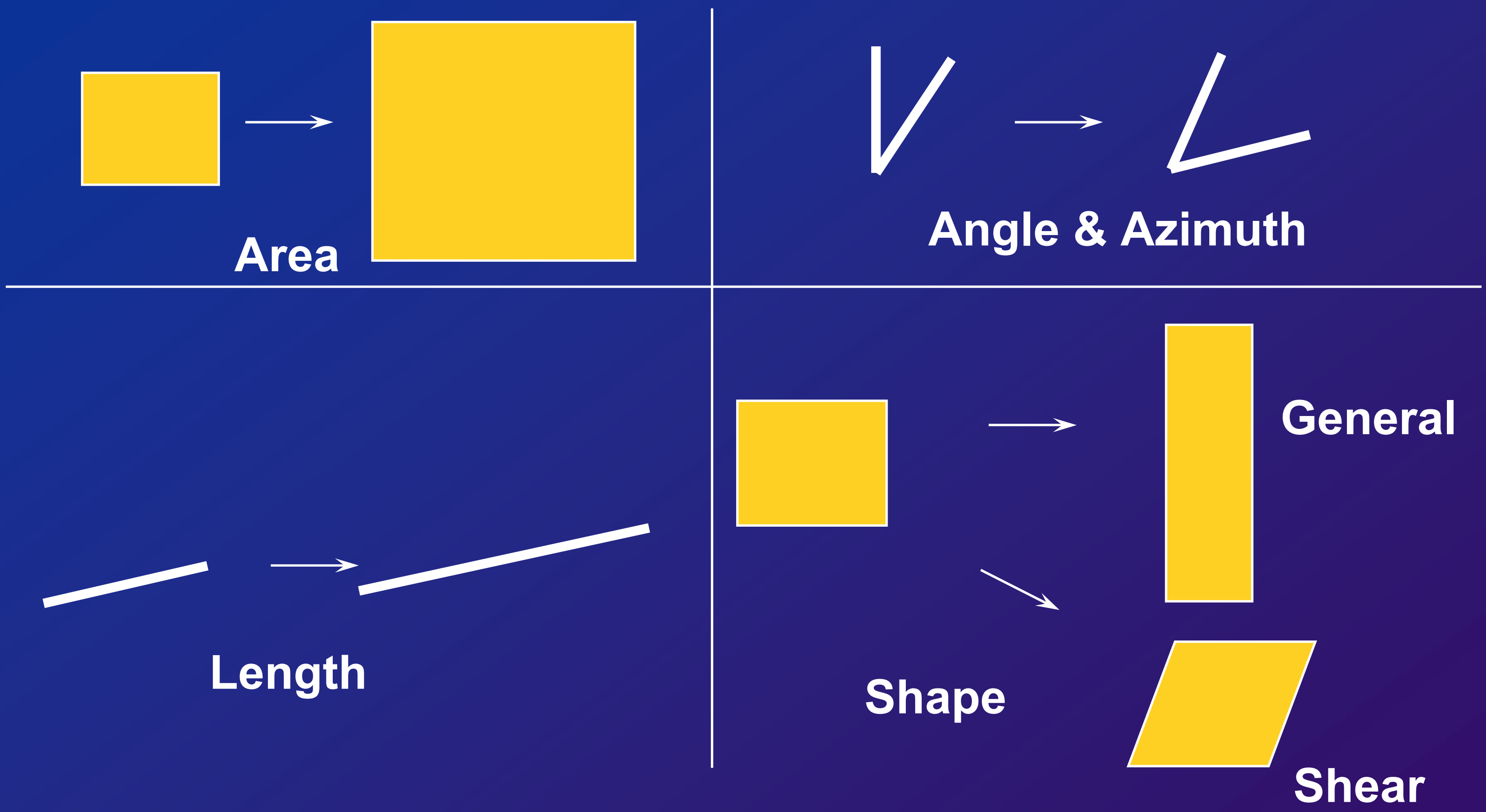
- Geographic Coordinates (Latitude & Longitude) are difficult to use analytically, so cartographers project the ellipsoid on to different surfaces to provide flat maps
- There are many different projections and the major ones used in topographic mapping & surveying will be discussed
- Coupled with a Datum and associated GeogCRS, each map projection generates a Projected Coordinate Reference System

Map Projections: Generation

- **Geometric**
  - Can be constructed geometrically - parallels and meridians usually simple shapes like circles and straight lines
- **Semi-Geometric**
  - Can be constructed in part or wholly with some computation
- **Conventional/Algorithmic**
  - Defined and computed mathematically and plotted via computer. Complex shapes to meridians and parallels

The most commonly used projections are conventional or algorithmic

Cartography Projection Distortion



Distortion is unavoidable in any projection

Shape and Scale for different Projection Types

- Conformality (Orthomorphism)
  - Angular integrity between points is retained
  - Scale distortion at a point is independent of direction/ is the same in all directions
  - Small shapes are honored
- Equidistant
  - Scale along certain lines is true
- Equal Area
  - True area is represented, but shape and local angles are generally distorted

Conformal (Orthomorphic) Projections

- **Preserved**
  - Shape. **Since scale distortion at a point is the same in all directions, relatively small shapes are preserved**
  - Angle. **Angular integrity between points is retained and thus local angles are correctly shown. This is essential for angular computations on a map**

- **Distorted**
  - Linear Scale: **varies from point to point, but uniform in all directions and easily computed and compensated**
  - Azimuth: **with respect to geodetic north (convergence). Varies from point to point, but easily computed and compensated**

Cartography: Distortions

Distortions in Scale and Azimuth are normal for ‘orthomorphic’ projections.

The distance between 2 points described by projection coordinates is not the same as the distance measured along the ground, by the ratio of the scale factor along the line.

The azimuth between 2 points described in projection coordinates will differ from the ‘true’ azimuth by the convergence angle

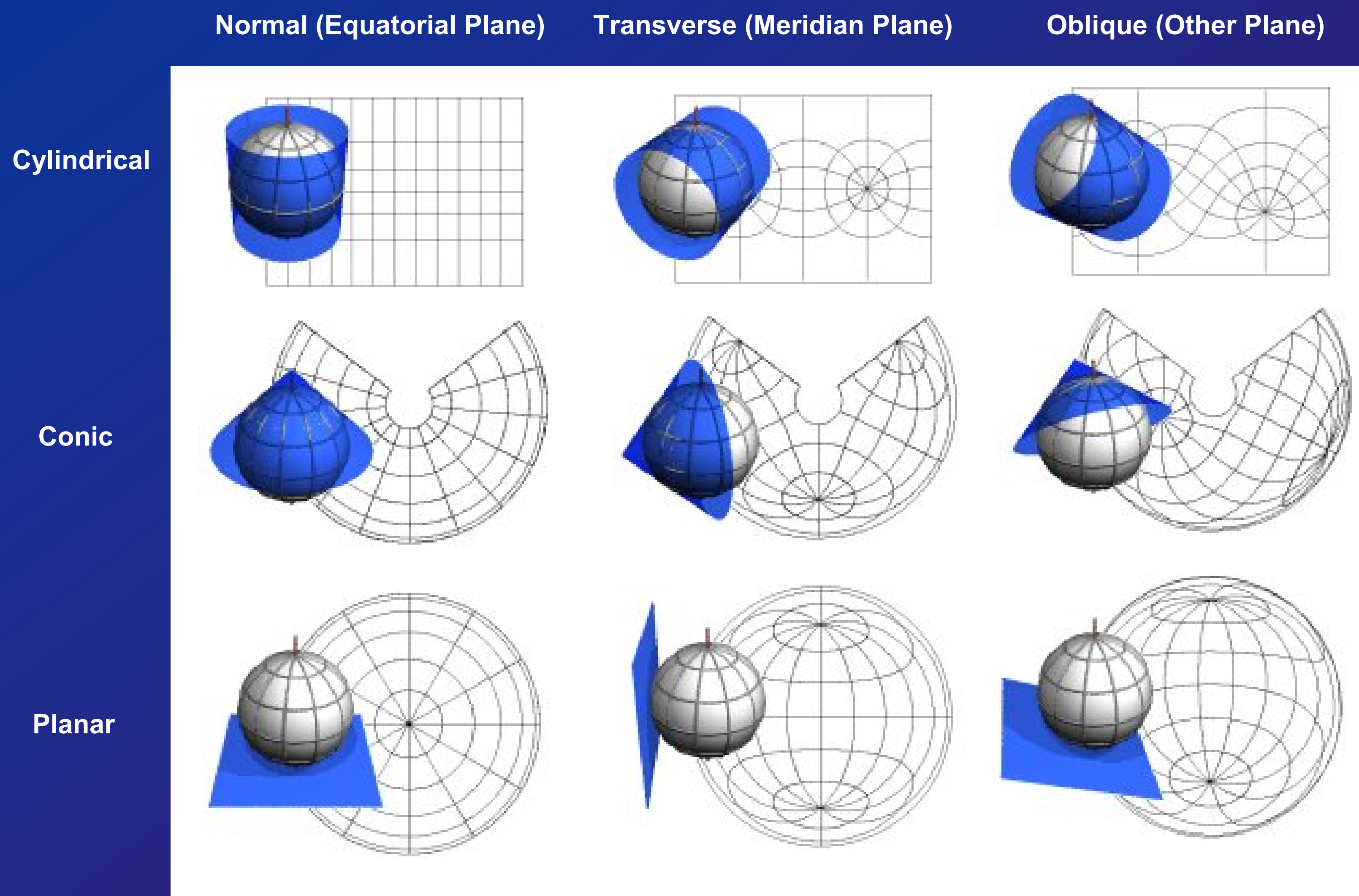
Factors in Selecting a Map Projection

- Specific property needed on the map? (equal area, good approximations of distances and azimuths in your work area, etc.)
- Shape and size of area to be represented
- Desirability of working with same maps already in use for your area (e.g., to match concession boundaries, legal definitions, legacy data, etc.)
- The last item above is of great importance. Different groups working the same area on different maps can generate many problems.

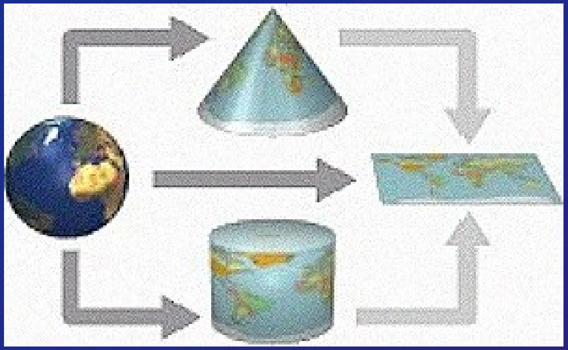
Major Types of Projections

- **Conformal Projections**
  - Maintain shape. Shape on the map represents actual shape as observed on the earth
  - Ideal for surveys and topographic mapping
  - Shape is maintained at the expense of area representation.   Map areas distort earth areas
- **Equal Area Projections**
  - Maintain area. Areas on the map are representative of corresponding areas
    observed on the ground
  - Ideal for displaying statistical data
  - Area is maintained at the expense of shape
    Map distances and angles may not correspond
    to actual distances and angles

Cartographic Secant Surfaces



Typical Map Projection Methods



- Mercator
- Transverse Mercator
- Universal Transverse Mercator
- Lambert Conformal Conic
- Others less frequently: Stereographic, Oblique Stereographic, Oblique Mercator, et. al.

Cylindrical Projections (examples)

- **Mercator** (used universally in Navigation charts)

- **Transverse Mercator** (very common in survey)
  - **Universal Transverse Mercator (UTM)**
  - **Gauss Krüger**
  - **Gauss Boaga**
  - **“modified UTM with shifted C.M.” => TM CM Hh**
  - **“modified UTM in US Survey Feet” => BLM**
  - **Transverse Mercator (general case)**

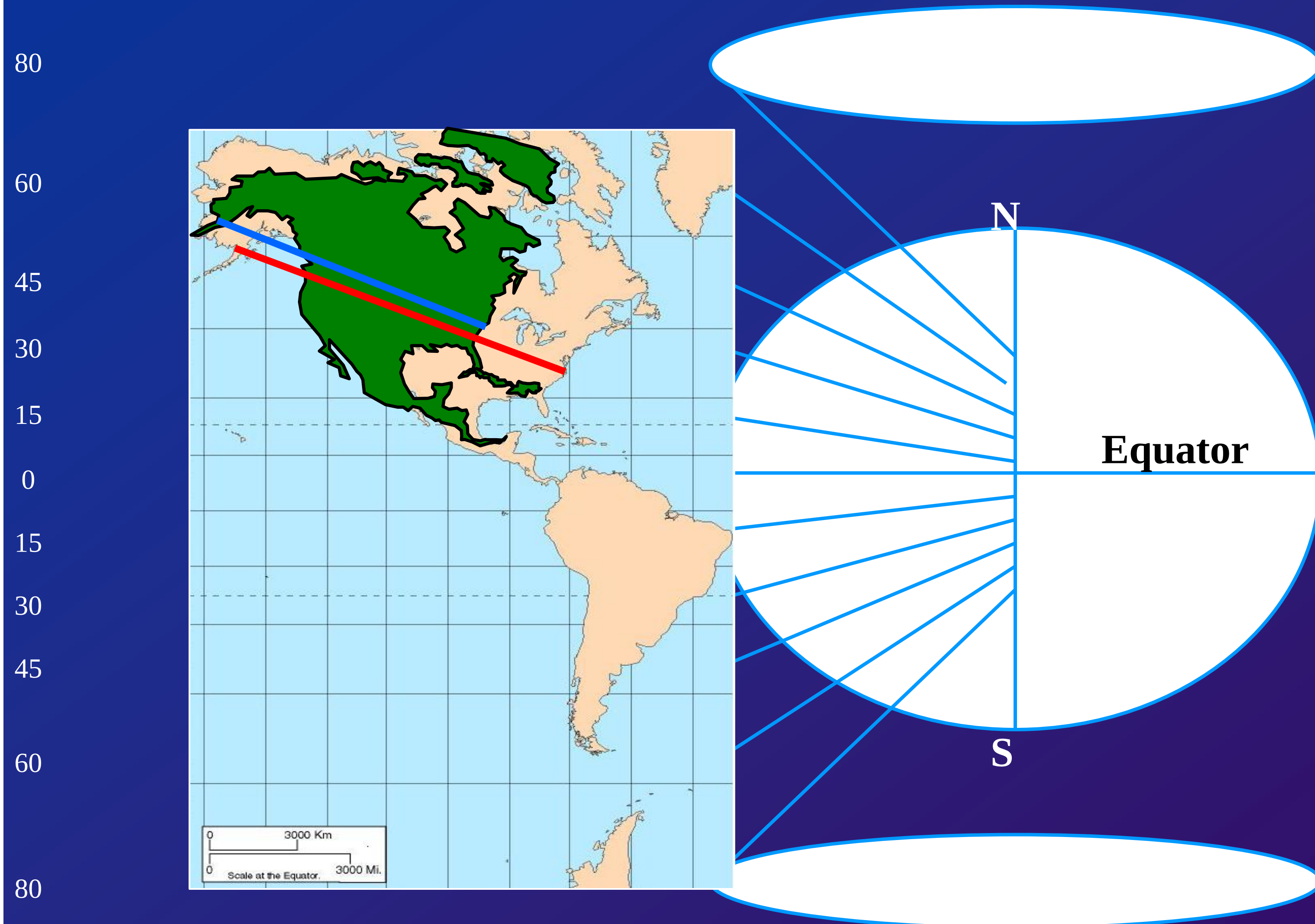
- Cassini-Soldner (***still encountered in Trinidad***)

- Oblique Mercator
  - **Oblique Mercator**
  - **Hotine Oblique Mercator**
  - **Swiss Oblique Cylindrical**

Mercator: Projection Method

- Cylindrical
- Usually Tangent
- Orientation - Equatorial
- Conformal (Shape is okay over small area)
- Not equal area, Not constant scale, Not perspective
- Rhumb Lines become straight lines, Great Circles are curved lines
- Cannot map above 80° - i.e. cannot include poles
- Used for navigational charts

Mercator Projection: Distortions



Scale Distortion (N:1)

[1/cos(lat)]

0 °	**1**
48 °	**1.5**
60 °	**2**
71 °	**3**
76 °	**4**
80°	**6**

Example: Transverse Mercator 1

Nigeria – Minna Datum & GeogCRS

- **Projection** **Nigeria West Belt TM**
- **ProjCRS** **Minna / Nigeria West Belt**
- **Central Meridian** **4º 30' E**
- **Latitude of Origin** **4º 00' N**
- **CSF** **0.99975**
- **FE** **230 738.26**
- **FN** **0**
- **Units** **Meters**

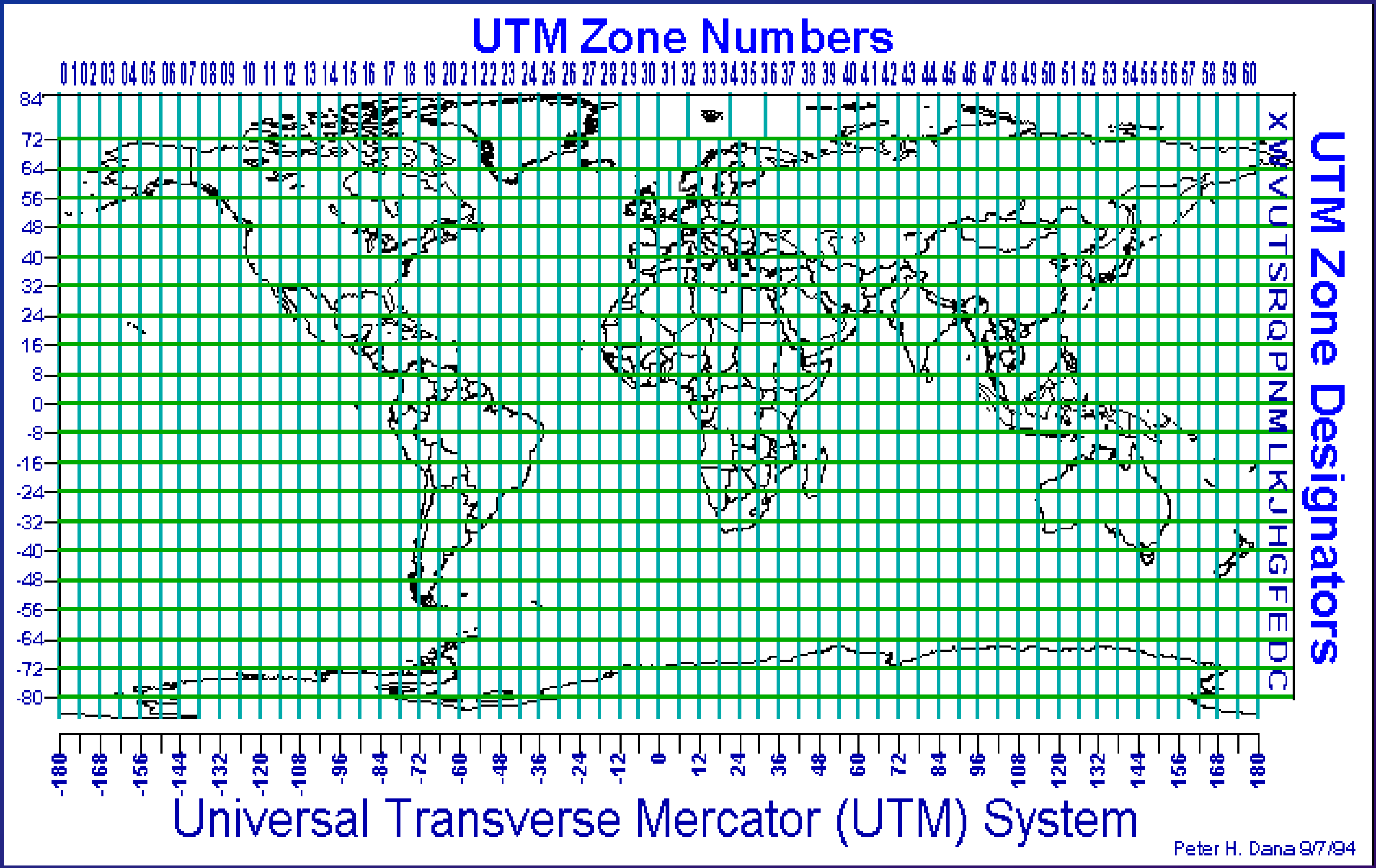
Example: Transverse Mercator 2

Angola - Camacupa Datum & GeogCRS)

- Projection TM12SE Transverse Mercator
- ProjCRS Camacupa / TM 12 SE
- Central Meridian 12º 00’ E
- Latitude of Origin 0º 00’ N
- CSF 0.9996
- FE 500 000
- FN 10 000 000
- Units Meters

For Angola, Shell uses TM 12 SE,
ExxonMobil uses TM 11.30 SE
Others often use UTM 32 S or 33 S

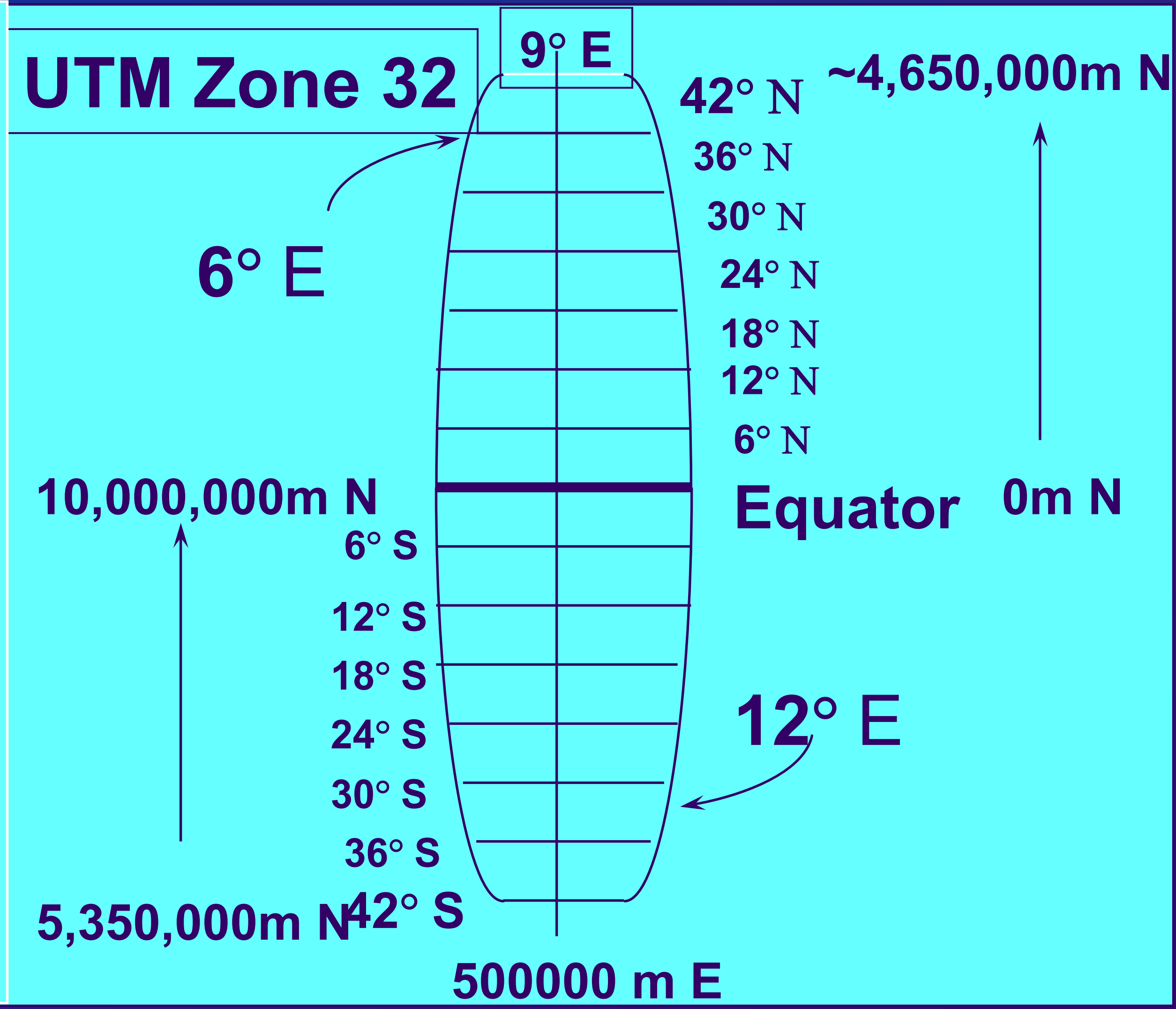
UTM Zones


UTM Zone Numbers
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
84 72 64 56 48 40 32 24 16 8 0 -8 -16 -24 -32 -40 -48 -56 -64 -72 -80
X W V U T S R Q P N M L K J H G F E D C
UTM Zone Designators
-180 -168 -156 -144 -132 -120 -108 -96 -84 -72 -60 -48 -36 -24 -12 0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180
Universal Transverse Mercator (UTM) System
Peter H. Dana 9/7/94

UTM Example

UTM
6° Zones (CM every odd 3°)
Zone # 1-60 fm 177° W thru Greenwich to 177° E.
Units Meters.

Origin CM
FE 500,000 mE
FN 0m N (N h) or 10,000,000m N (S h) at Equator

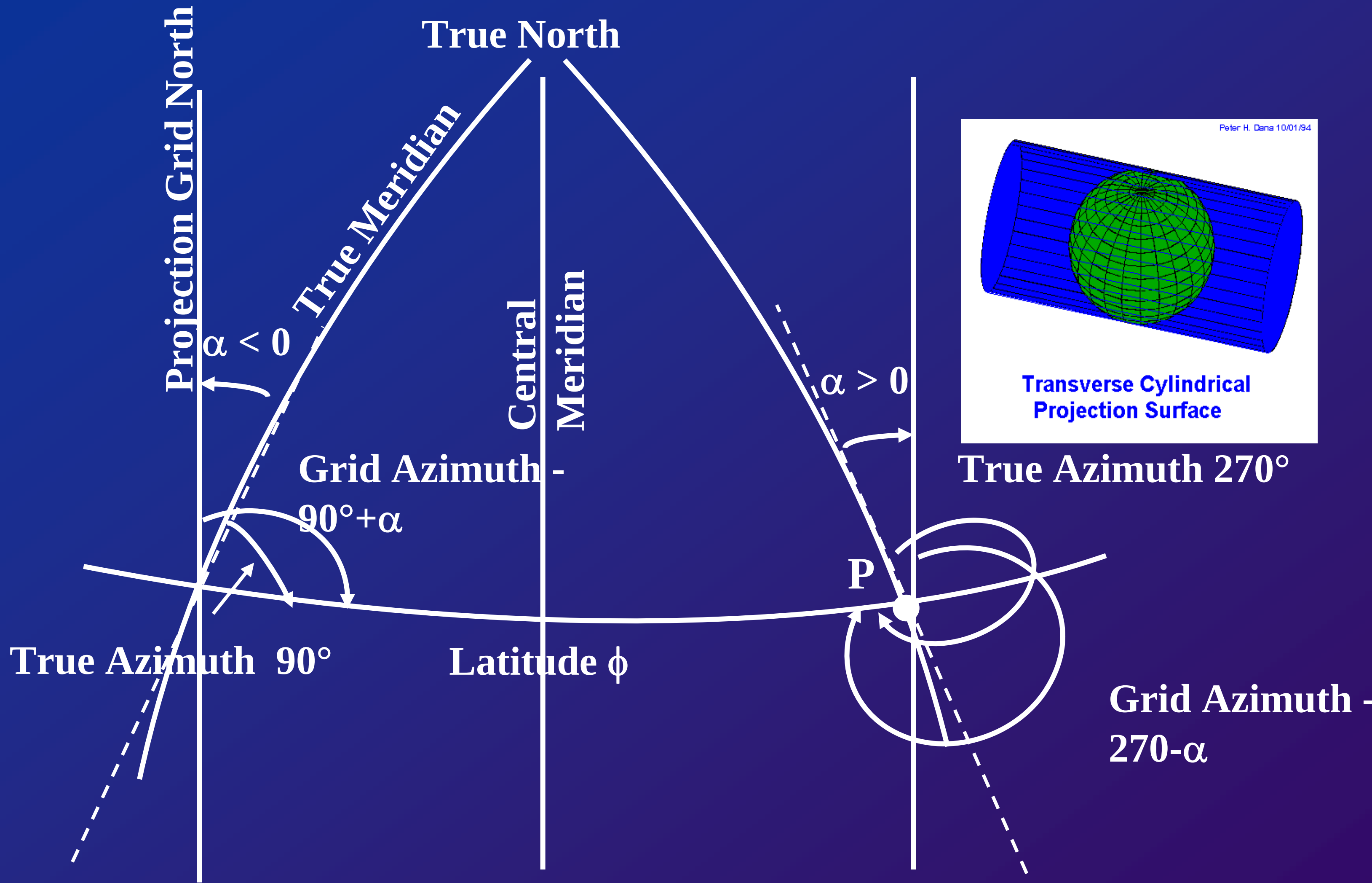


TM / UTM / Gauss-Krüger Projection Methods

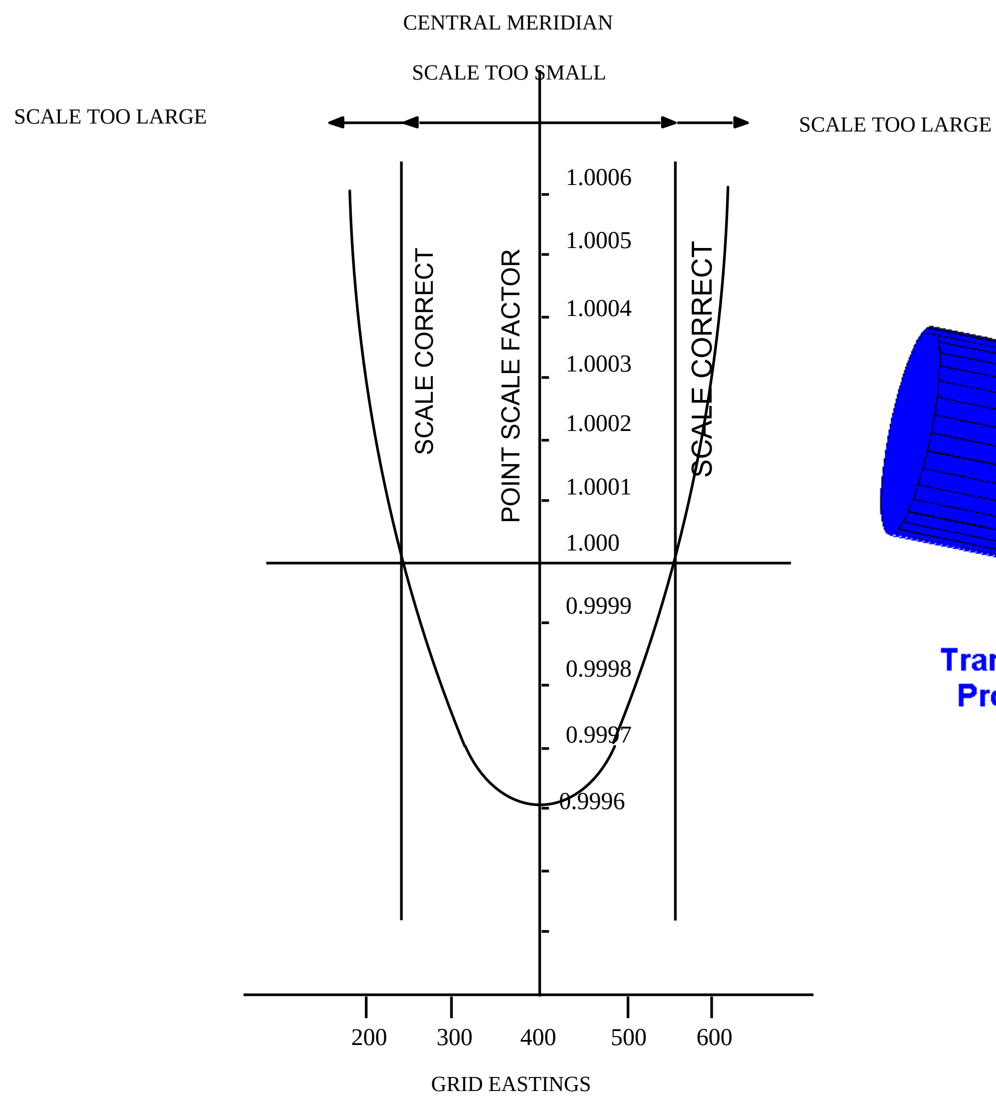
- Cylindrical, with Transverse (Polar) Orientation
- Secant (UTM always, Gauss-Krüger never, TM usually)
- Conformal Algorithmic (non-geometrical) construction
- TM is used in predominantly N-S geographic areas - many USGS* and other national map series including a large number of US SPCS** grids (US SPCS Scale Factor (SF) at Central Meridian (CM) allows 1:10,000 scale error) at limits on SPCS zone.
- UTM used for large scale charts and surveying worldwide
- UTM SF of 0.9996 at CM allows max of 1:2,500 scale error
- Gauss-Krüger (G-K): (SF at CM=1.0000) used throughout the Soviet and Chinese areas of influence, as well as in Argentina and elsewhere.
- Adjoining TM maps in same zone match at E/W edge

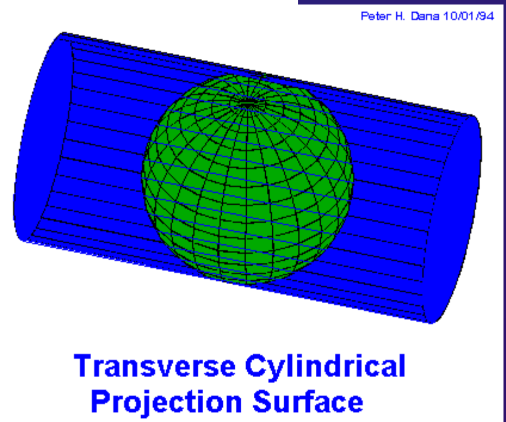
** USGS = U.S. Geological Survey; ** SPCS = State Plane Coordinate*

TM: Convergence



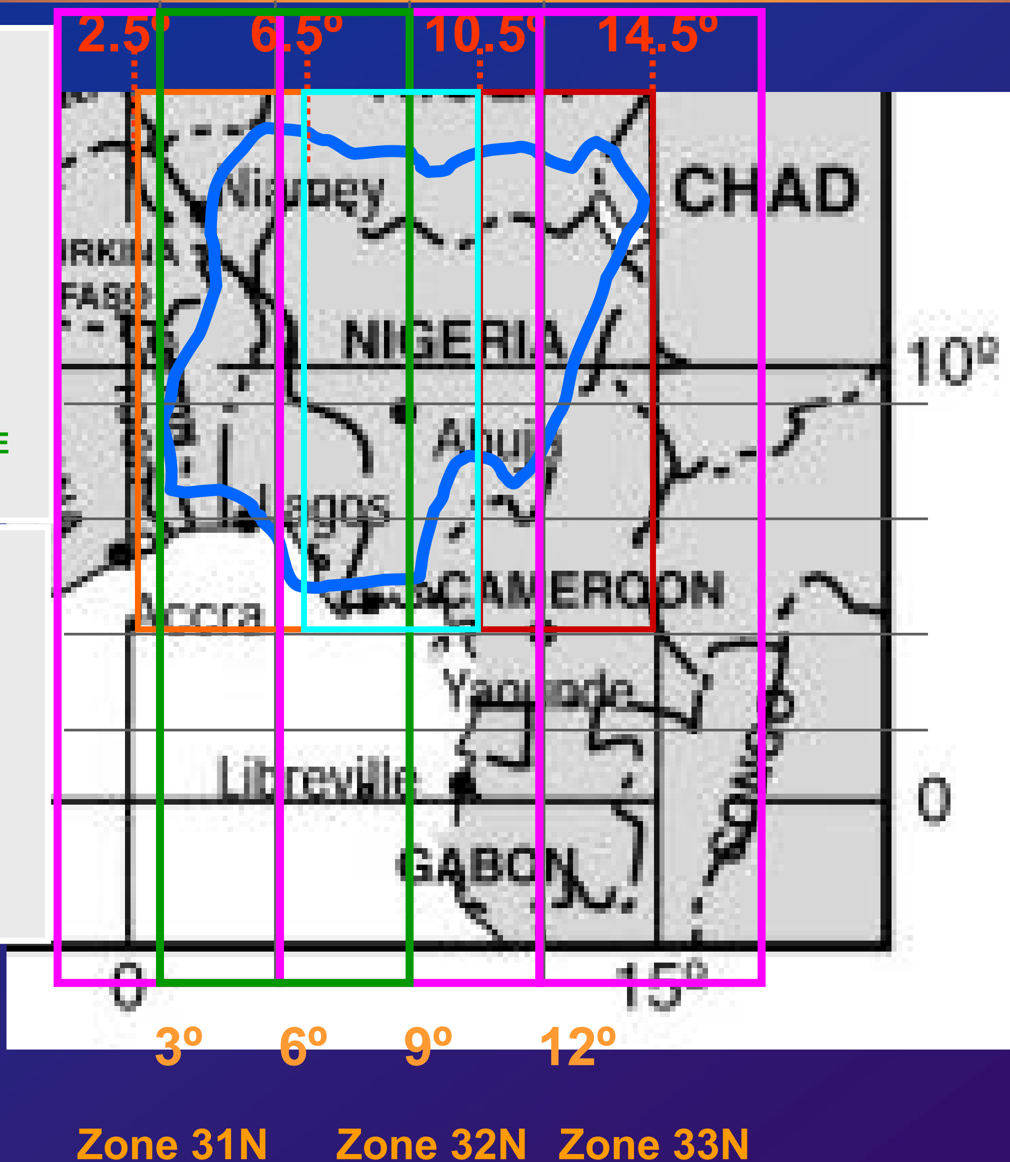
UTM: Scale Factor Distribution





Nigeria ProjCRS: Multiple Options

Lat/Lon graticule
Nigeria West Belt
Nigeria Mid Belt
Nigeria East Belt
UTM Zones
XOM's TM 6 NE



Nigeria XOM TM 6 NE
Lat Origin 0º
CM 6º E
CSF 0.9996
FN 0º
FE 500,000
Units Meters

Nigerian (TM) Belts
Lat Origin 4º
CM West 4.5º E
Mid 8.5º E
East 12.5º E
CSF 0.99975
FN 0º
FE West 230738.26
Mid 670553.98
East 1110369.7
Units Meters

UTM Zones
Lat Origin 0º
CM 31N 3º E
32N 9º E
33N 15º E
CSF 0.9996
FN 0º
FE 500,000
Units Meters

UTM Options: Northern South America

Datum	Ellipsoid	Projections (zones)
Aratu	International 1924	UTM 22-24 S
Corrego Alegre	International 1924	UTM 21-25 S
PSAD56	International 1924	UTM 17-22 N, 17-22 S
SAD69	GRS 1967 or International 1967	UTM 18-22 N, 17-25 S
SIRGAS 2000	GRS80	UTM 18-22 N, 17-25 S
WGS84	WGS84	UTM 18-22 N, 17-25 S

Total of over 60 ProjCRS – UTM only!

Mixing Projections: Brazil Example

Datum	Latitude	Longitude	Local to WGS84	Local to Local
Aratu	20º 36’ 13.2757”N	38º 56’ 56.3341”W	236.7 m	220.56 m
SAD69	20º 36’ 17.4283”N	38º 56’ 50.1240”W	65.12 m	
WGS84	20º 36’ 19.2794”N	38º 56’ 51.2166”W		

Datum	Easting UTM 24S	Northing UTM 24S	Local to WGS84	Local to Local
Aratu	505,316.4 meters	2,278,317.4 meters	214.7 m	208.8m
SAD69	505,495.9 meters	2,278,424.1 meters	58.4 m	
WGS84	505,464.2 meters	2,278,473.1 meters		

Coordinates are of the **SAME** physical point

Southern Hemisphere (G-K & UTM)

- In Argentina, Gauss-Krüger projections with “latitude of origin” of -90º are used with Campo Inchauspe Datum. Some software will not accept this, compensating by shifting “latitude of origin” to the equator.
- This generates (on the International ellipsoid), a False Northing (FN)=10,002,288 meters, similar to 10,000,000 meter FN used with the UTM projections in the area.
- Example for a <u>single given location</u>

Datum/Projection	Eastings	Northings
C.I./Arg2 G-K	2607750.31m	4793966.59m
C.I./UTM 19 S	607707.20m	4793761.92m

If UTM False Northing is used with the Campo Inchauspe G-K ProjCRS, you will have 2,288 meters in error North – South!

This HAS occurred and it CONTINUES to occur!

Confusion: X,Y vs. Y,X – Which is North? (G-K versus UTM)

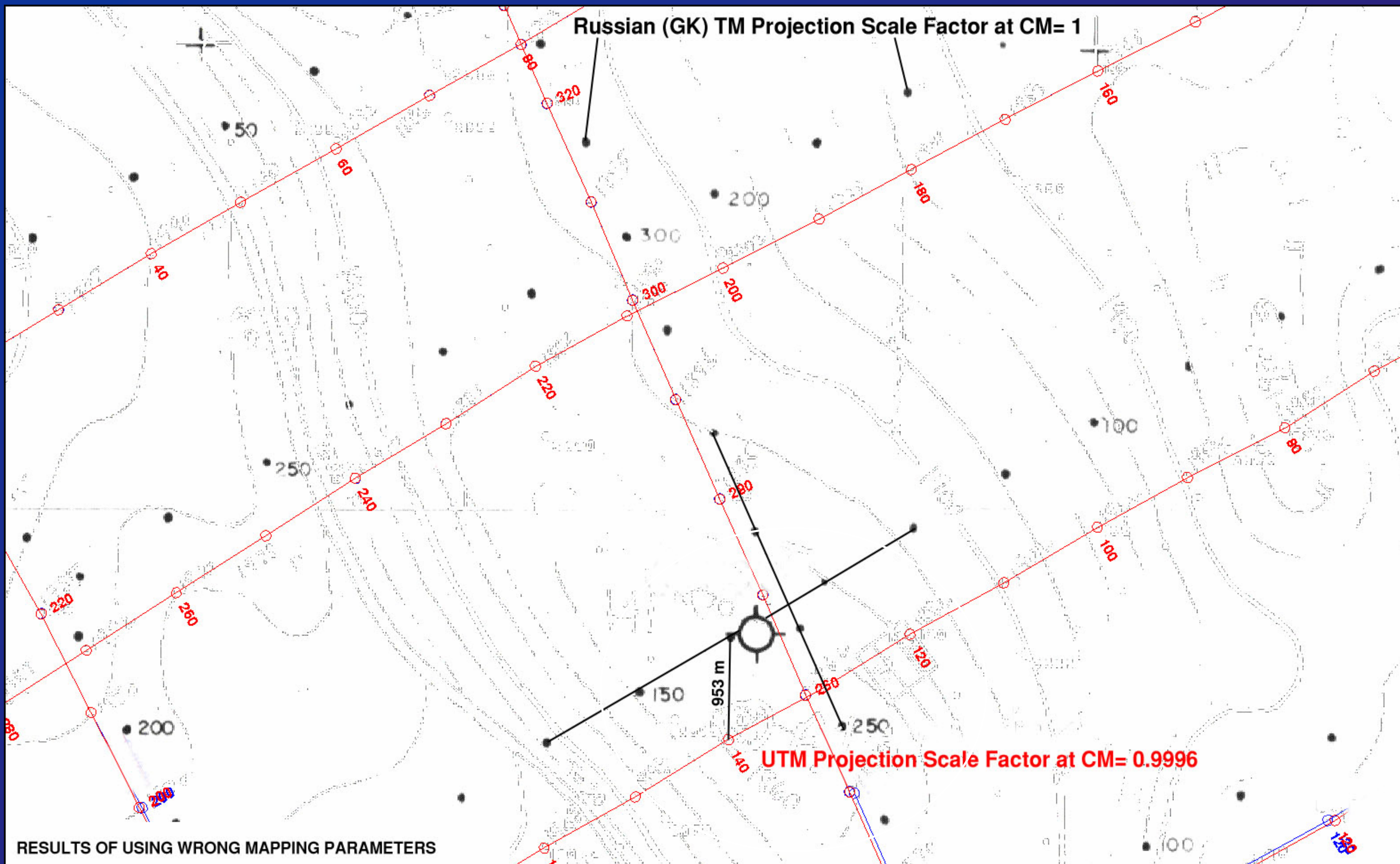
- Similar to the prior example, but using the X, Y grid notation as used in the specific ProjCRS and showing how these can be readily confused.
- In Gauss-Krüger (G-K) projections,
  X = Northing and Y = Easting
- In Universal Transverse Mercator (UTM) projections,
  X = Easting and Y = Northing
- For example a <u>single given location</u> in Brandenburg, Germany would show the following (both in "local usage")

Datum/Projection	X (Northing)	Y (Easting)
Pulkovo 1942(83)/G-K 5	5790850.78m	5796433.22m

These E,N values could easily be confused

Always use E = Eastings and N = Northings (get in the habit!)

Case Study: Land Seismic in the Wrong Projected CRS → 950m errors

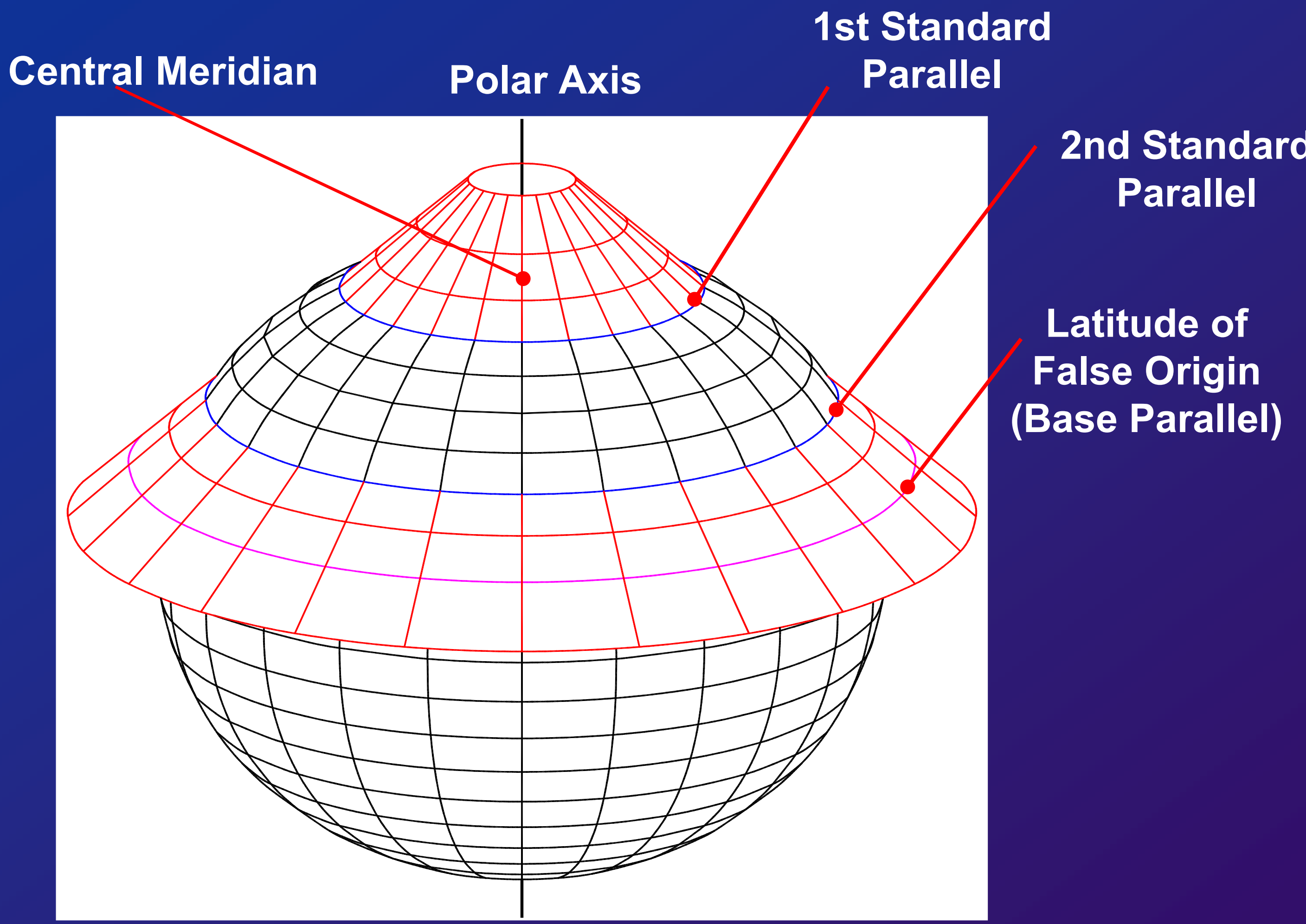


Example courtesy of Satellite Imaging Corporation

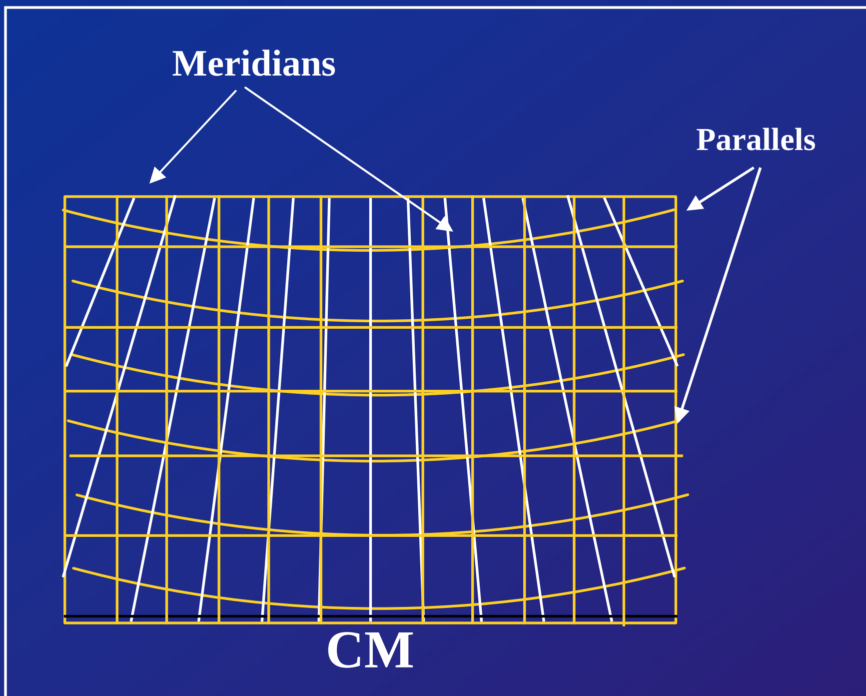
Conical Projections

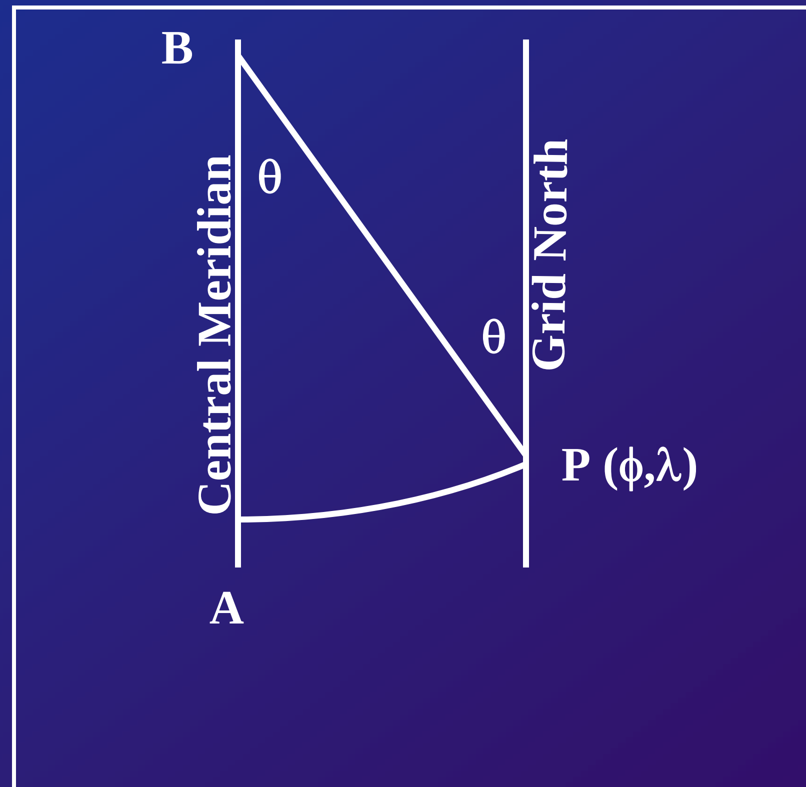
- **Lambert Conic Conformal**
  - 1 standard parallel or 2 standard parallels
  - 2 standard parallels (Belgium variant) (older maps only)
  - (old maps only)
  - Krovak Oblique Conformal Conic (Czech Republic)
- **Lambert Conic "Near Conformal"**
  - Army Map Service, 1 standard parallel
  - (not supported in ESRI ArcGIS 9.2)
- Lambert Conic Conformal projections **minimize North-South distortions**
- Used extensively in US State Plane Coordinate system (SPCS) for E-W oriented areas (e.g., KY, TN.) Also used in Texas with 5 zones to cover the required latitudes)

Lambert Conic Projection (Northern Hemisphere)



Lambert Conic Convergence

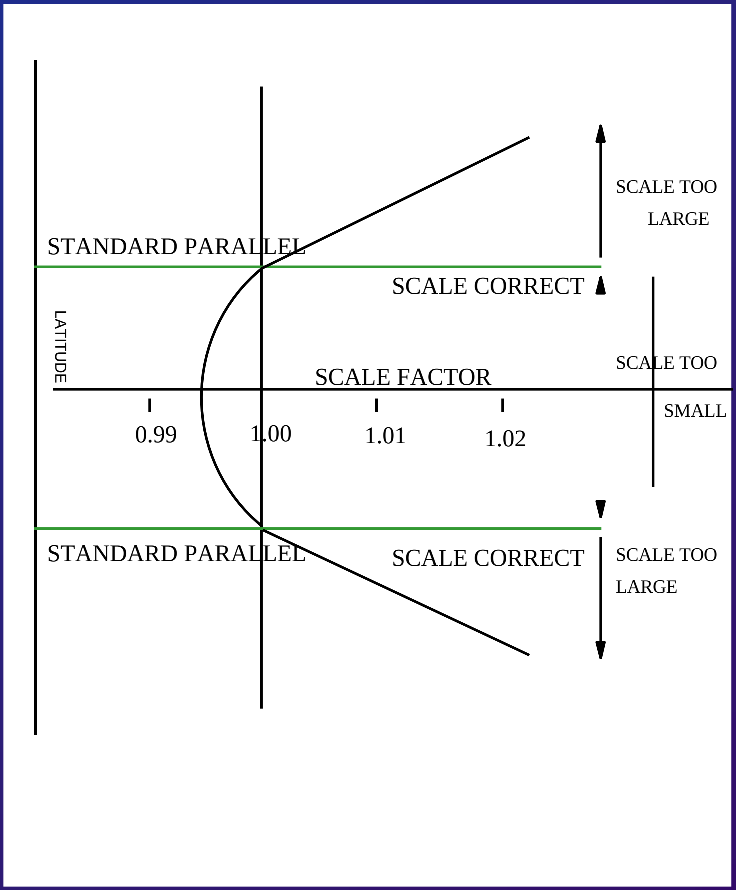




Parallels of latitude project as circular arcs concave to the nearest pole. Meridians of longitude are straight lines converging towards the nearest pole. Meridians and Parallels are orthogonal.

Lambert Conic Scale Distortion

- Scale is constant in the E-W direction but varies in the N-S direction
- Scale is correct along the standard parallels. Too large outside them and too small inside them
- Variation in scale in N-S direction is shown opposite
- The projection is limited in N-S extent by the amount of distortion allow



Lambert Conformal Conic Projections

- Conic, Polar orientation
- Secant (2 Standard Parallels) or Tangent (1 S.P.)
- Conformal (Shape distortion is very small)
- Algorithmic
- Great Circles are (approximately) straight lines
- Parallels are arcs of concentric circles expanding in distance at edges, contracted between standard parallels
- Meridians are straight lines
- Used for mapping areas of large E/W extent including some US States (SPCS) and world series aeronautical charts, hurricane tracking charts

Example: Lambert ProjCRS, USA

- Geodetic Datum: North American Datum of 1927
- Coordinate System: Lat (degrees, Long (degrees)
- Projection Type: Lambert Conformal Conic (2 SP)
- Projection Name: Louisiana South Zone
- ProjCRS Name: NAD 27 / Louisiana South Zone
- Central Meridian: 91º 20’ W
- Latitude of Origin: 28º 40’ N
- Latitude 1st Standard: 29º 18’ N
- Latitude 2nd Standard: 30º 42’ N
- False Easting: 2 000 000.00
- False Northing: 0.00
- Units: US Survey Feet (ftUS)

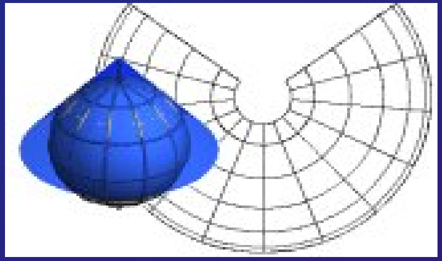
Other Projections of Interest

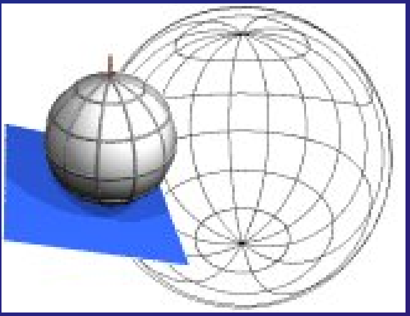
- Albers Equal Area Projection
  - Used when equal area proportionality is important.
- Lambert Azimuthal Equal Area Projection
  - An alternate equal area projection
- Stereographic Projections
  - Projection on to a tangential plane from the point on the opposing diameter of the ellipsoid
  - Used for polar areas
  - Oblique Stereographic to map specific shaped areas
- American Polyconic Projection (brought back into usage for offshore Brazil by the Brazilian government)
  - Neither conformal nor equal area
  - Distortion free only along the longitude of origin

Syria Examples: Lambert and Oblique Stereographic

Syria – Deir ez Zor Datum (Levant)

- **Projection Method: Lambert Conic Conformal (1 SP)**
- **Projection: Syria Lambert**
- ProjCRS: Deir ez Zor / Syria Lambert or Levant / Syria Lambert
- **Central Meridian: 37º 21’ E**
- **Latitude of Origin: 34º 39’ N**
- **Central Scale Factor: 0.9996256**
- **False Easting: 300,000 meters**
- **False Northing: 300,000 meters**
- **Units: Meters**

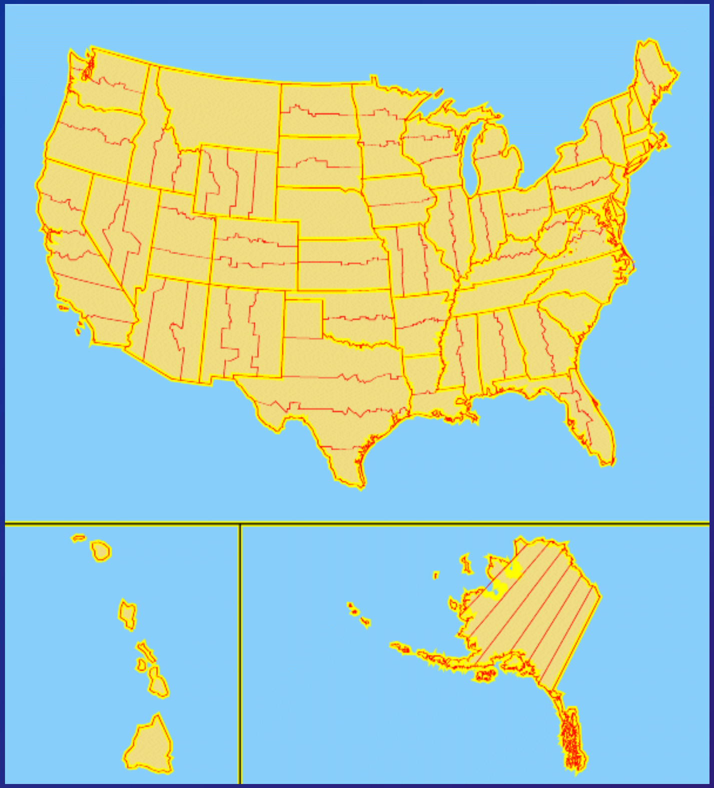




Syria – Deir ez Zor Datum (Levant)

- **Projection Type: Oblique Stereographic**
- **Projection: Levant Stereographic**
- ProjCRS: Deir ez Zor / Syria Stereographic or Levant / Syria Stereographic
- **Central Meridian: 39º 09’ E**
- **Latitude of Origin: 34º 12’ N**
- **Central Scale Factor: 0.9995341**
- **False Easting: 0 meters**
- **False Northing: 0 meters**
- **Units: Meters**

State Plane Coordinate System (SPCS)



- Designed to be accurate to 1:10,000
- Different projections used:
  - Transverse Mercator for States with large N/S extent
  - Lambert conformal conic for States with large E/W extent
  - Some states use both projection types due to their shapes (NY, FL, AK)
  - Oblique Mercator used for Alaska panhandle
  - Different kinds of feet used in different states! (35 ftUS + 5 Int'l ft + 10 not-committed)

Given Projection information, Grid Coordinates and Spheroid Name

I have coordinates (lat/long and/or UTM 32 N) of a <u>single location</u> and know I am on “Clarke 1880” spheroid.

Do I know where I am? **No, I do not!**

Datum/GeogCRS	Easting	Northing
Manoca	444000.00	450000.00 m
Minna	443932.01	449843.39 m
WGS84	443864.57	449959.35 m

<u>All are UTM zone 32 N map projection in meters)</u>

<u>Manoca & Minna both use “Clarke 1880” ellipsoid</u>

Datum1/Datum2	Δ Easting	Δ Northing
Manoca to Minna	67.99 m	156.61 m
Manoca to WGS 84	185.63 m	40.62 m
Minna to WGS 84	67.44 m	-115.96 m

One reference ellipsoid can be used with many datums

Mixing Projected Coordinates on same UTM Zone, but different Datums

- West Texas
- NAD27 / UTM Zone 13N
  - **Easting: 500,000m**
  - **Northing: 3540248m**
- NAD83 / UTM Zone 13N
  - **Easting: 499951m**
  - **Northing: 3540452m**
- Differences (ftUS)
  - **DE 161.1 ft**
  - **DN 669.3 ft**
  - **DR 688.3 ft**

- Montana
- NAD27 / UTM Zone 12N
  - **Easting: 421182m**
  - **Northing: 4983220m**
- NAD83 / UTM Zone 12N
  - **Easting: 421117m**
  - **Northing: 4983427m**
- Differences (ftUS)
  - **DE 213.7 ft**
  - **DN 680.1 ft**
  - **DR 712.9 ft**

Projection Scale and Orientation Distortion

NAD27 Lat	29° 00’ 45.7”
NAD27 Long	89° 03’ 47.6”
La.S E	2,725,640 ft
La.S N	133,025 ft
UTM E	299,039.7 m
UTM N	3,210,971.4 m

Type	Line Length	Orientation
Ell	99,990.4 ft	91_08.2/271_17.3
La. S	100,000 ft	90
UTM	99,992.9 ft	92_08.3

NAD27 Lat	29° 00’ 24.748”
NAD27 Long	88° 45’ 01.753”
La.S E	2,825,640 ft
La.S N	133,025 ft
UTM E	329,496.5 m
UTM N	3,209,834.5 m

Type	Line Length	Orientation
Ell	99,987.3 ft	181° 08.1’ / 001° 08.0’
La. S	100,000 ft	180°
UTM	99,997.2 ft	182° 08.0’

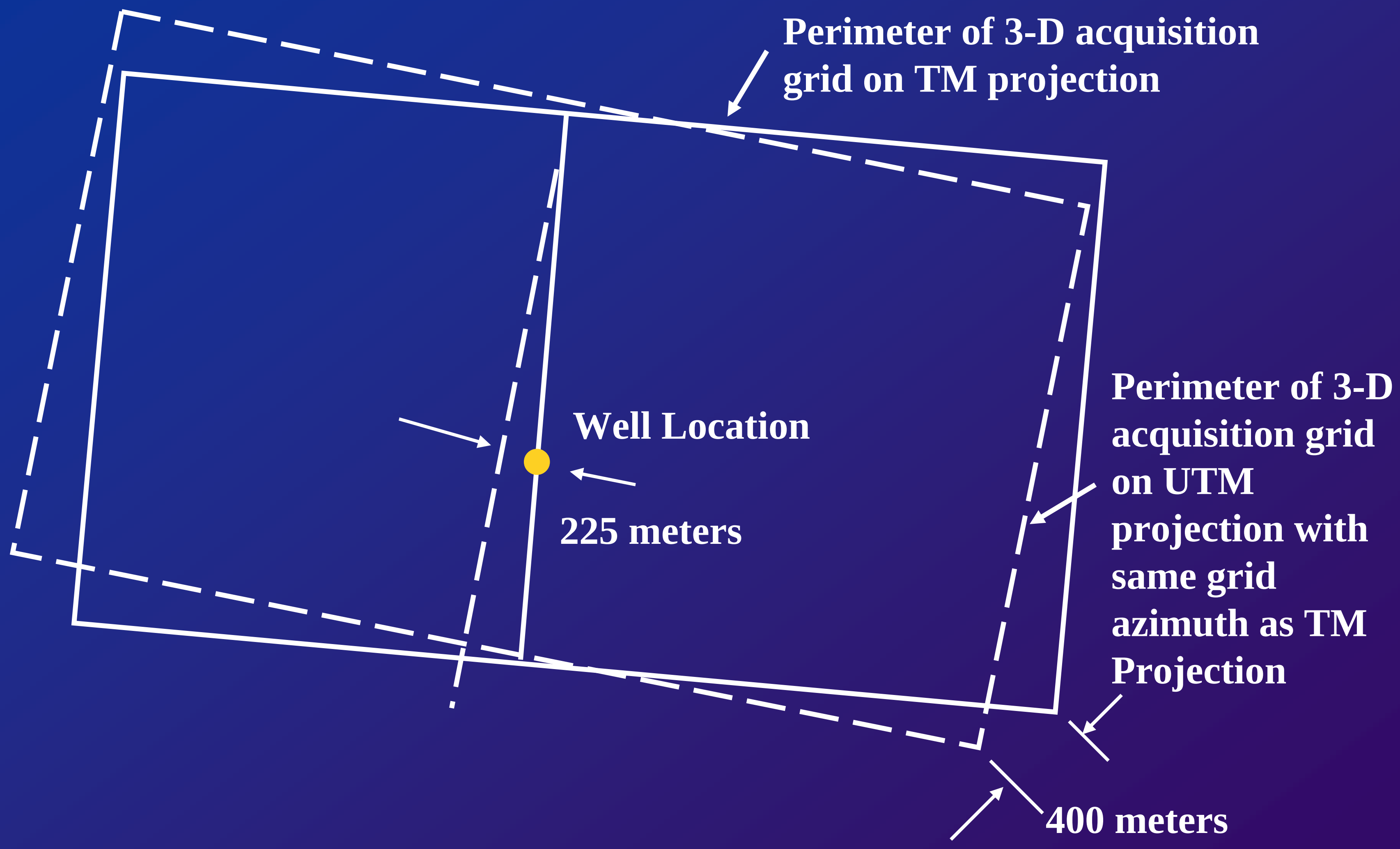
Type	Line Length	Orientation
Ell	99,988.1 ft	181° 17.5’ / 001° 17.3’
La. S	100,000 ft	180°
UTM	99,983.9 ft	182° 08.1’

NAD27 Lat	28° 44’ 15.9”
NAD27 Long	89° 04’ 09.9”
La.S E	2,725,640 ft
La.S N	33,025 ft
UTM E	297,905.3 m
UTM N	3,180,513.3 m

Type	Line Length	Orientation
Ell	99,983.3 ft	091_08.1/271_17.1
La. S	100,000 ft	090
UTM	99,988.8 ft	92_07.8

NAD27 Lat	28° 43’ 55.1”
NAD27 Long	88° 45’ 27.064”
La.S E	2,725,640 ft
La.S N	33,025 ft
UTM E	328,360.9 m
UTM N	3,179,380.5 m

Wrong handling of heading reference



More Confusion in Geodesy

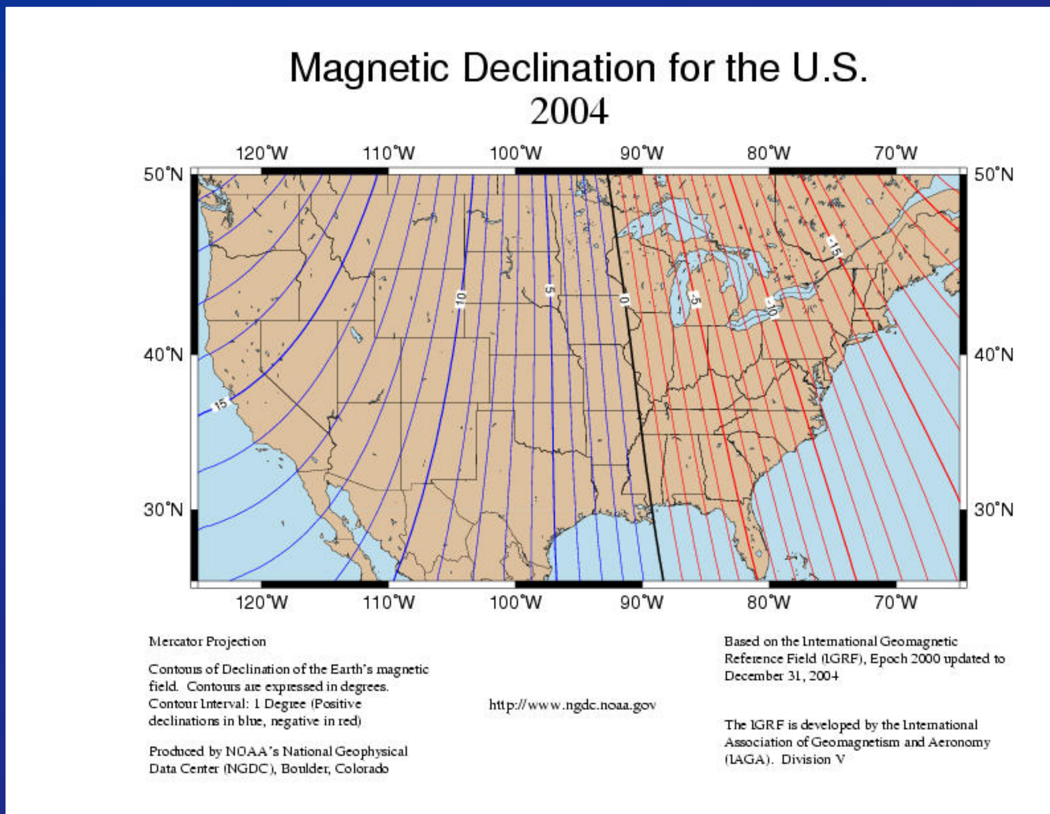
Reference Orientations: (3 "major" Norths)

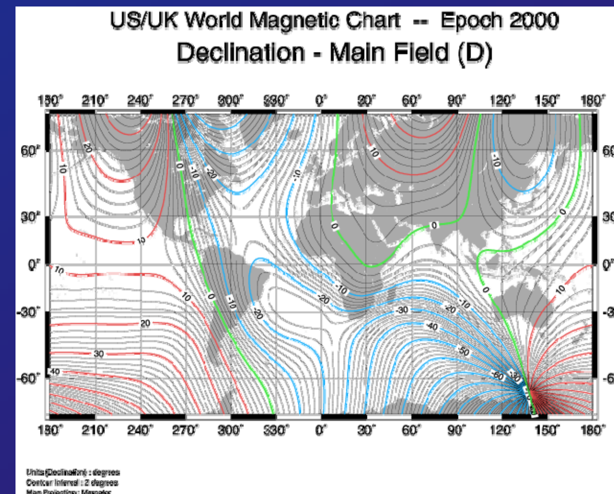
- True North = Direction of the meridian at a point
- Grid North = Differs from True North by convergence
- Magnetic North = Differs from True North by Declination

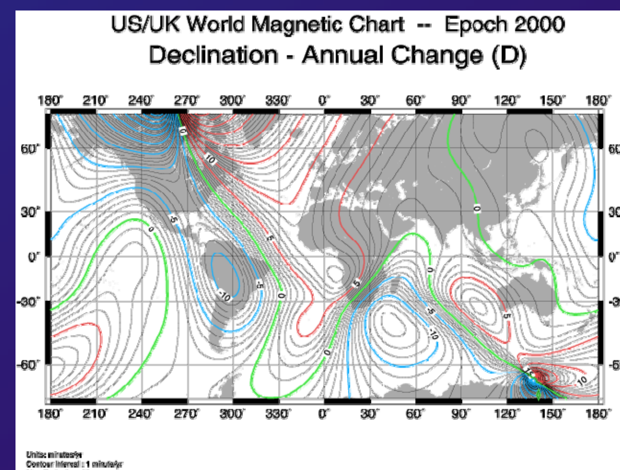
Reference Units: (13 different feet and 2 meters)

- Biggest Problem = U.S. Survey Ft vs. International Ft
- Other Feet = Clarke's Foot, Sears 1922, 2 for Benoit (both 1895), Gold Coast Ft., 4 Indian Ft. (1865, 1937, 1962 & 1975) and 2 British Feet (1865 & 1935),
- Currently 2 meters = Intl Meter and German Legal Meter
- Other linear units include Chains, Links, and Yards (in almost as many variations as the foot to meter relationships)

Magnetic Declination







Montana 45N, 112W on Jan 18, 2004
14.35º E changing by 6' West per year

Brazil (Campos) 23S, 41W on Feb 24, 2004
22.4º E changing by 6' East per year

Downhole Surveys: Varying "North" Orientation References

- From various well documents and databases
  - Casing MWD: Magnetic (referenced to Magnetic North)
  - Below Casing: Inertial (referenced to True North)
  - Rig orientation: (referenced to Grid N or True N?)
- When data are merged:
  - Was the magnetic data adjusted to grid or true N?
  - Has the rig orientation used the same North reference?
  - Is all this documented for other departments / users?
- Do specifications lead to consistent results?
- Was there QC of the onsite methods and data?
- Is there a clear and informative report?

We live in a 3-D World !

A graticule of curved parallels and curved meridians (latitudes and longitudes) intersecting orthogonally on the ellipsoid.

Ellipsoidal heights are measured along the normal, the straight line perpendicular to the ellipsoid surface.

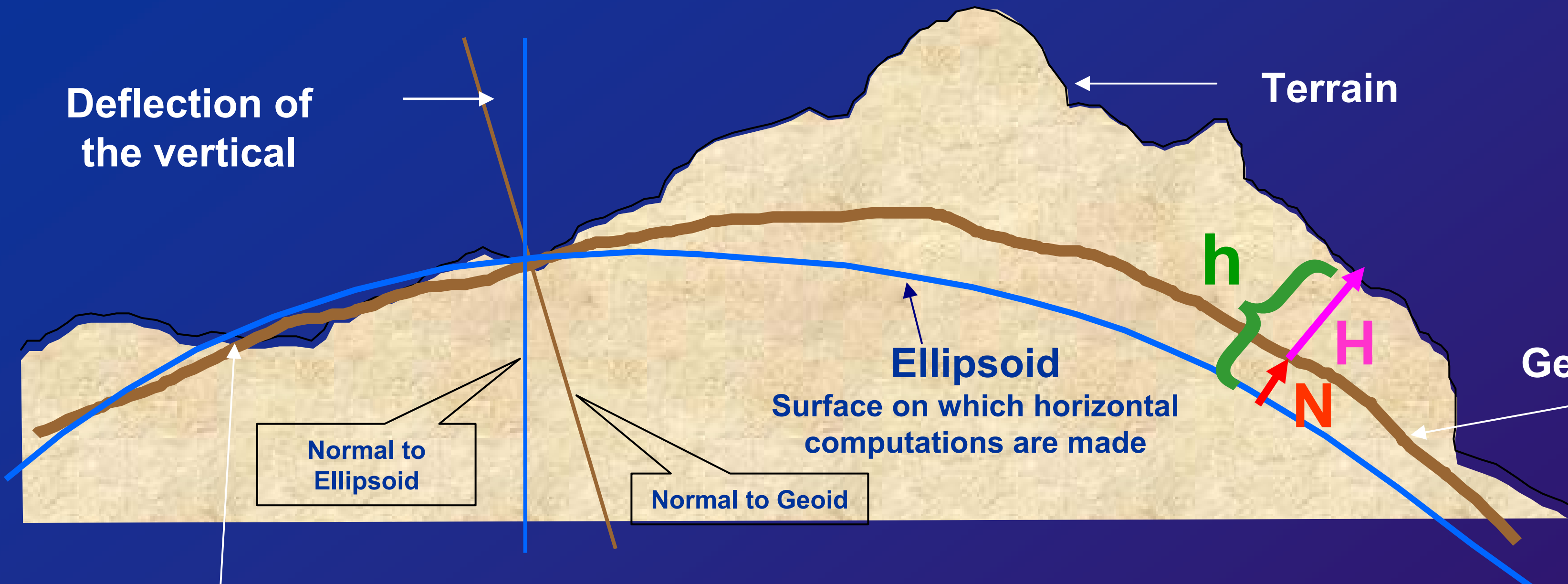
CRSs used that address all 3 dimensions include:

3-D Geocentric (all from ellipsoid center)

3-D Geographic (w/Ellipsoidal heights)

Compound w/ either a 2-D ProjCRS or a 2-D GeogCRS coupled with a gravity and/or tidal based vertical CRS

Vertical Reference Surfaces



Geoid

Equipotential surface which approximates to MSL in the absence of other forces

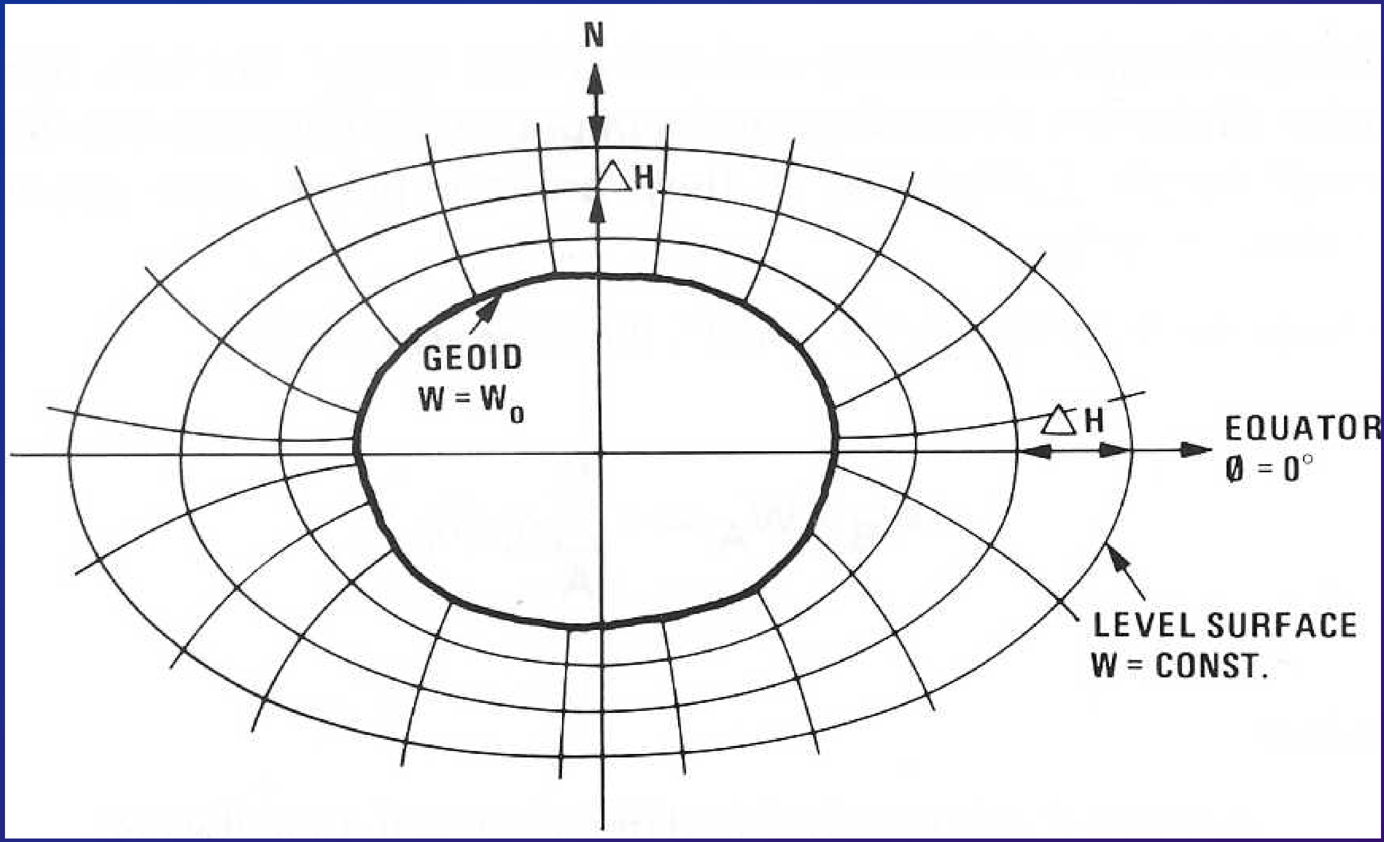
H = Elevation or Orthometric Height (surface height above the geoid).

N = Geoidal Height (sometimes erroneously called Geoidal Undulation).

h = Ellipsoidal Height (surface height above the ellipsoid) is approximately equal to the sum of the above two. That is, $h \approx H + N$

This relationship is not exact as the measurements are in slightly different directions

Geopotential Surfaces, the Geoid, Plumb Lines



Elevations are measured w.r.t. the geoid, the (physical) surface whose equipotential value (W) is that of Mean Sea Level ($W=W_0$). Elevations with respect to the geoid are called "orthometric heights"

Vertical Datums

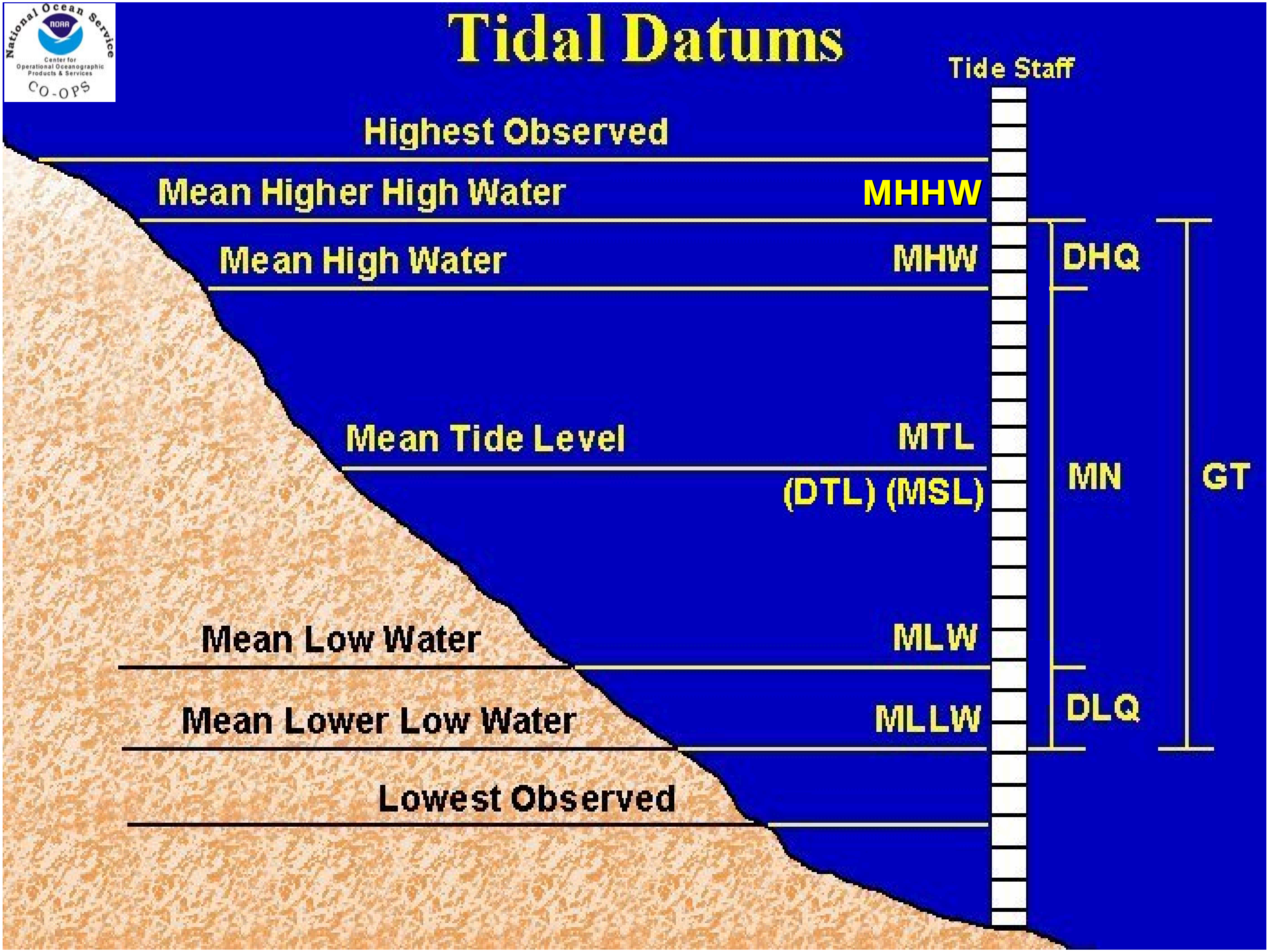
A Vertical Datum is a set of fundamental elevations to which other elevations are referred. This set may be a single elevation or derived from many individual reference elevations

Vertical Datum Types

Local – **“Kelly-Bushing”, “ground level”, “sea level”, and assorted other local references**

Geodetic – **Either directly or loosely based on Mean Sea Level at one or more points at some epoch (NGVD 29, NAVD 88, OSU91A, EGM96, etc.)**

Tidal – **Defined by direct observation of tidal variations over some period of time at a specific location (or locations). Examples: (MSL, LAT, MLLW, MLW, MHW, MHHW, etc.)**



National Ocean Service
NOAA
Center for Operational Oceanographic Products & Services
CO-OPS
Tidal Datums
Tide Staff
Highest Observed
Mean Higher High Water
MHHW
Mean High Water
MHW
DHQ
Mean Tide Level
MTL
(DTL) (MSL)
MN
GT
Mean Low Water
MLW
Mean Lower Low Water
MLLW
DLQ
Lowest Observed

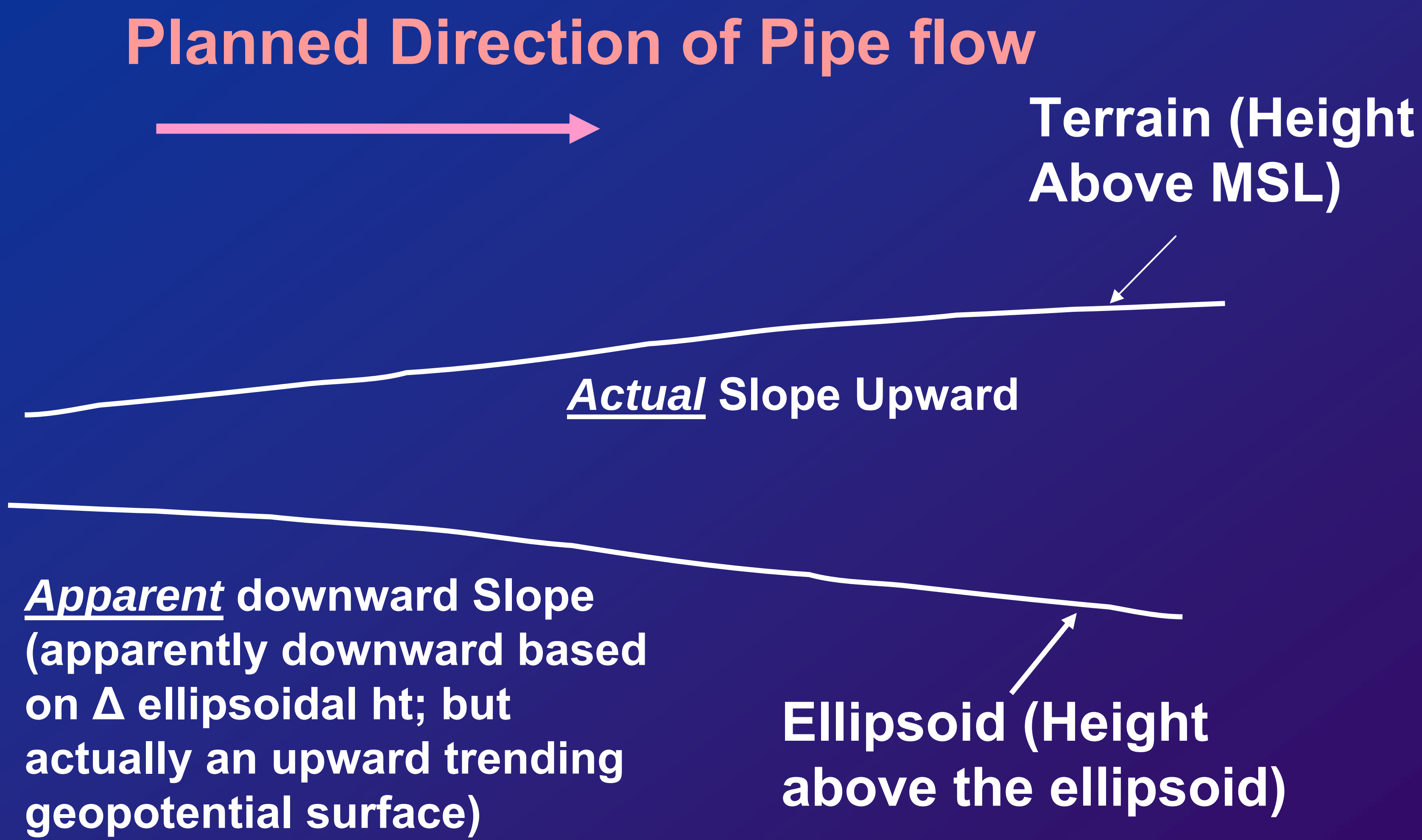
Vertical Datums / Vertical CRS

Examples of specific Vertical Datums / VertCRS derived from Tidal Measurements over significant periods

- Australian Height Datum
- Bandar Abbas, Fao (Iran)
- Caspian (Azerbaijan, etc.)
- DHHN85 & 92 (Germany)
- EVRF2000 (Europe)
- IGLD 1985 (Great Lakes)
- KOC WD (Kuwait Wells)
- Kuwait PWD (Kuwait)
- Lagos 1955 (Nigeria)
- Ordnance Datum Newlyn (UK)
- Belfast Lough (Ireland)
- MSL (not recommended)
- NGVD29, NAVD88 (USA)
- Normal Nul (NN54) (Norway)
- Normaal Amsterdams Peil (Netherlands)
- PDO Height Datum 1983 (Oman)
- Yellow Sea, Yellow Sea 1956 & 1985 (China)

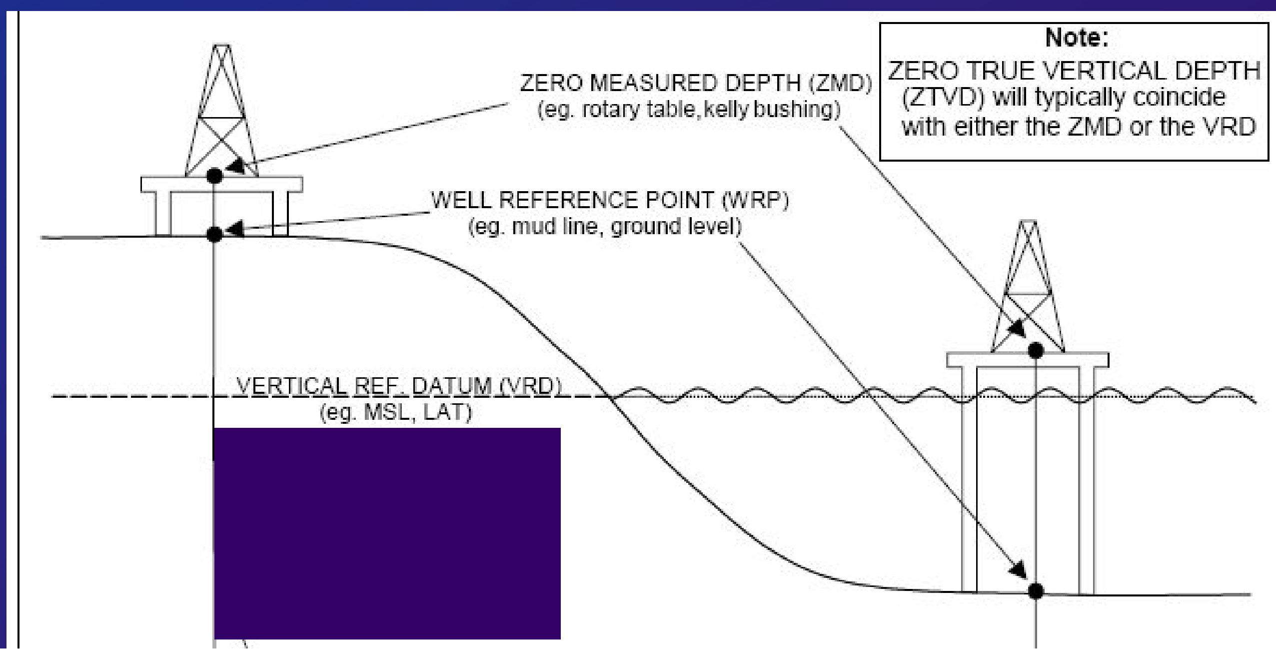
The EPSG database lists ~100 vertical datums worldwide that were derived from tidal and leveling observations. Some countries (including the USA) have more than one such vertical datum.

Wrong Vertical Reference!



Local Vertical Datums / CRS: the Danger of their Use

- The use of elevations or heights referenced to “Kelly Bushing”, “Rotary Table” , “Drill Floor” and/or other drilling equipment references is valid only so long as the same drilling rig is used.
  – Once these heights enter a database as “heights” with no other vertical reference surface, it is difficult if not impossible to relate them to a “proper” vertical CRS.



Summary of Spatial References

- **Know the references – Always ask!**
  - Datum (GeogCRS)
  - Projection (ProjCRS)
  - Elevation/Height (what "type" of height?)
  - Orientation (what "type" of North is referenced?)
  - Units of measurement (if feet, what kind of feet?)

- **QC, audit and record references in detail especially when transferring data between functions**
  - In Field
  - From field to office
  - When downloading data from DB or web
  - When converting data before or during loading
  - From function to function
    - Field/DB to Processing
    - Processing to Interpretation
    - Interpretation to Drilling
    - Drilling to Construction

If in doubt, get help

Common Problems when handling Positioning Data

- Latitude/Longitude provided without reference to a Datum or Geographic Coordinate Reference System
- Easting/Northing provided without reference to Projected Coordinate Reference System (each of which is also integrally tied to a specific Geodetic Datum)
- Assumption often made that two interpretation projects are on the same local datum, when that may not be the case
- Incorrect parameters selected when converting geographic coordinates (Lat/Longs) to projected coordinates (Easting/Northing) values

Common Problems when handling positioning data

- Assuming an incorrect UTM Zone
- Not using the correct units (e.g., wrong type of foot unit for US domestic data)
- Digitizing positions from maps with incomplete or nonexistent geodetic parameters . . . and then improperly assigning them a “fake” (unknown or assumed) geodesy
- Also concerning digitized data, not respecting original source map scale.
- Assuming: “It is in the database so it must be accurate…..”

To ensure you do not have these problems

Make sure when working with positioning data that you have complete geodetic information.

For Latitude/Longitude data:

- **Name of the Datum and Geographic CRS**

For Easting/Northing data:

- **Complete name of the Projected CRS**

  OR

- **Datum Name and Complete Projection Name (including zone # and/or other specific identifier.)**

It is usually best to also ask for the specific parameters on above to ensure that the parameters match names given

QC Actions

- **When you receive 3-Parameter Datum Shifts**

  Make sure that the shifts are defined from the desired Datum1 / GeogCRS1 to Datum2 / GeogCRS2

- **When you receive 7-Parameter Datum Shifts**

  Make sure that you understand what rotation convention your application uses

  Have the provider give you a test point so that you can verify that you are achieving the same results

Example Parameter list for ProjCRS

ProjCRS Name: NAD83(HARN) / Texas Central (ftUS)

which implicitly tells us:

Datum Name:	NAD83(HARN)
Ellipsoid Name:	GRS80
Semi-major axis:	6378137
Inverse Flattening:	298.25722210
Prime Meridian:	Greenwich
Units:	Meter
Projection:	SPCS83 Texas Central zone (US Survey feet)
Latitude of False Origin:	29 deg 40 min N
Longitude of False Origin:	100 deg 20 min W
Lat. of 1st Std Parallel:	31 deg 53 min N
Lat. of 2nd Std Parallel:	30 deg 07 min N
Easting at False Origin:	2296583.33 ftUS
Northing at False Origin:	9842500 ftUS

Remember!

Latitudes and Longitudes
are not unique
unless qualified with Horizontal Datum name!

Heights are not unique
unless qualified with Vertical Datum and units

Orientations are not unique
unless qualified with "type" of North reference

EPSG database (www.epsg.org) comprises:

- Datums & Coordinate Reference Systems
  - Geographic 2D, Geographic 3D, Geocentric and Projected CRS
  - Vertical, Engineering [local] and Compound CRS
- Geodetic Transformation Data
  - Concatenated Ops [sequential steps are required]
  - Single geodetic transformations of all types
  - Transformations between vertical systems
- Ancillary Data
  - Ellipsoids, Prime Meridians, Units of Measure, etc.
- Associated reports and forms to access data
- Database available in SQL and MS Access 97

References

- *EPSG Guidance Note 7-2* and *EPSGv6.x* geodetic database, **download both free from OGP Surveying and Positioning Committee website hosted by OGP at**

  www.epsg.org

- "*Geodesy for the Layman*", U.S. National Imagery and Mapping Agency, **download free from NIMA's G&G website at:**

  http://earth-info.nga.mil/GandG/publications/geolay/toc.html

- APSG <u>Geodesy Tutorial</u> (ESRI PUG 2004 and 2007) **at: www.apsg.info**

References continued

- "*Map Projections - A Working Manual*" **by J.P.Snyder, published by the USGS as Prof Paper No.1395,**
  available from U.S. Geological Survey at

  http://pubs.er.usgs.gov/pubs/pp/pp1395

Questions or comments, Please?.........