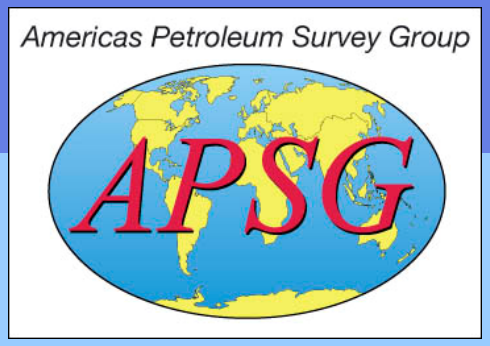


Datums, Coordinate Systems, Coordinate Reference Systems and Datum Transformations”

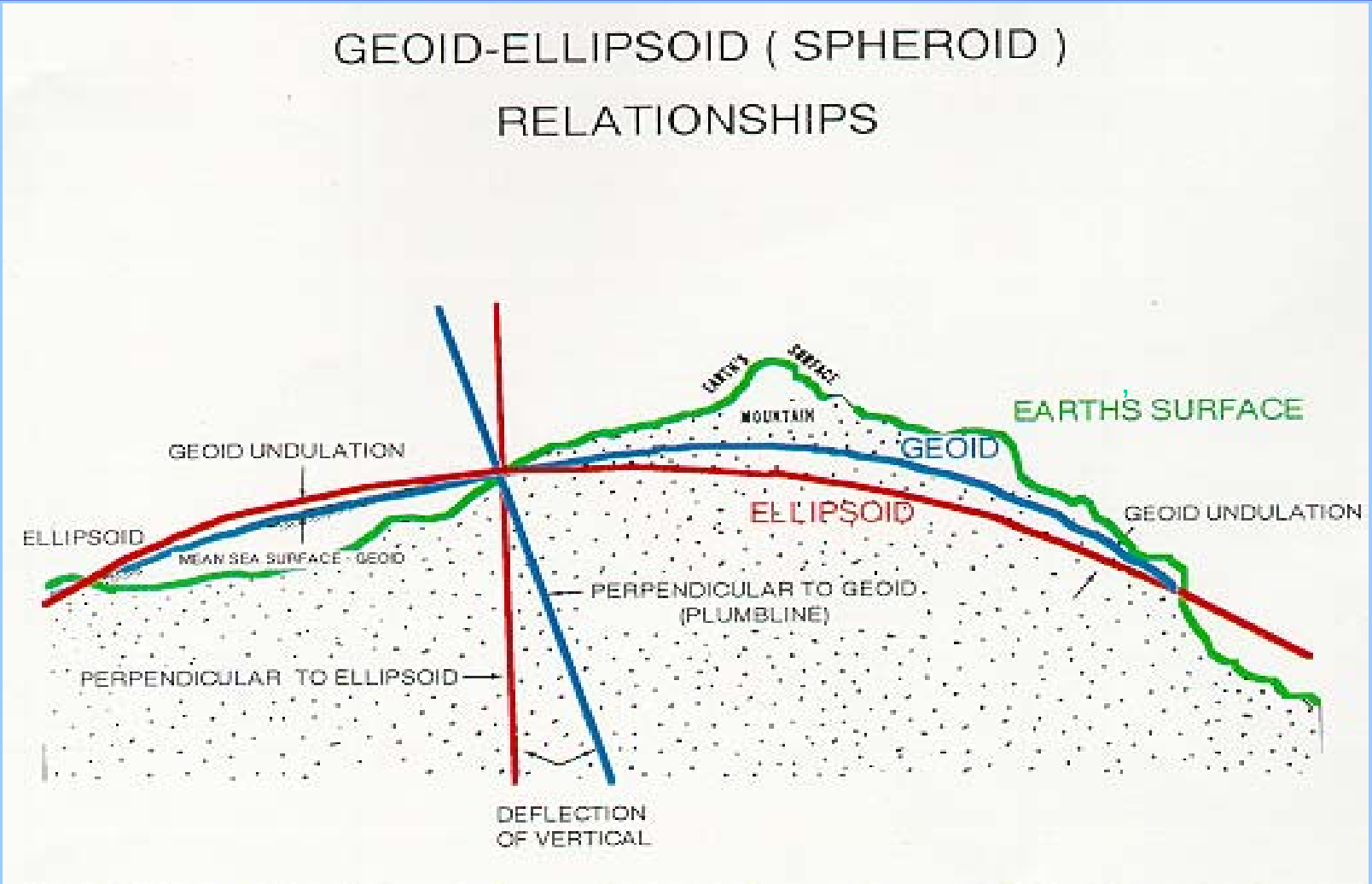
Geodesy & Map Projection Workshop
ESRI PUG 2004 – February 25, 2004

Jim Cain & Jon Stigant

Geodetic Terminology (ISO compliant)

- Topography
- Geoid
- Ellipsoid (or Spheroid?)
- Coordinate System (*i.e.*, system of axes)
- Prime Meridian
- Geodetic Datum
  - Local Datums
  - Geocentric Datums / Global Datums
- Ellipsoid and Datum are NOT synonymous!
  - Assuming otherwise can lead to a costly mistake.
- Geographic Coordinate Reference System (CRS)
  - GeogCRS have often been called “Datums”

Ellipsoid, Geoid and Height Relationships

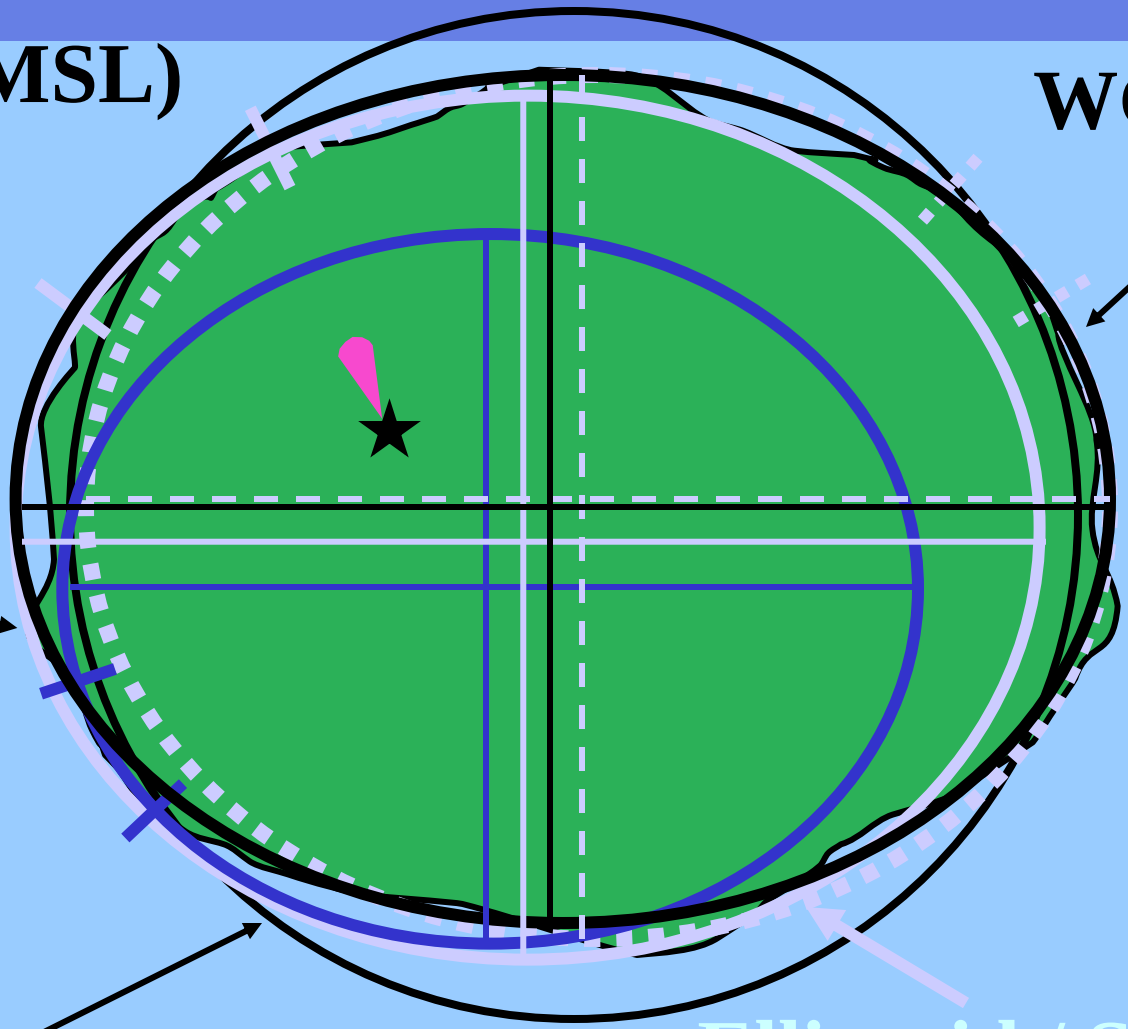


More Terminology and Basic Truths

- Latitude and Longitude are NOT UNIQUE!
  but vary from one GeogCRS to another
  (a GeogCRS is sometimes called a datum)
- Geodetic Transformations or “Datum Shifts” or “Datum Transformations”
- Map Projection
- Projected Coordinate Reference System (ProjCRS)

  A Projected CRS is sometimes called a Projection.

Representations of the Earth's Surface



Geoid (MSL)

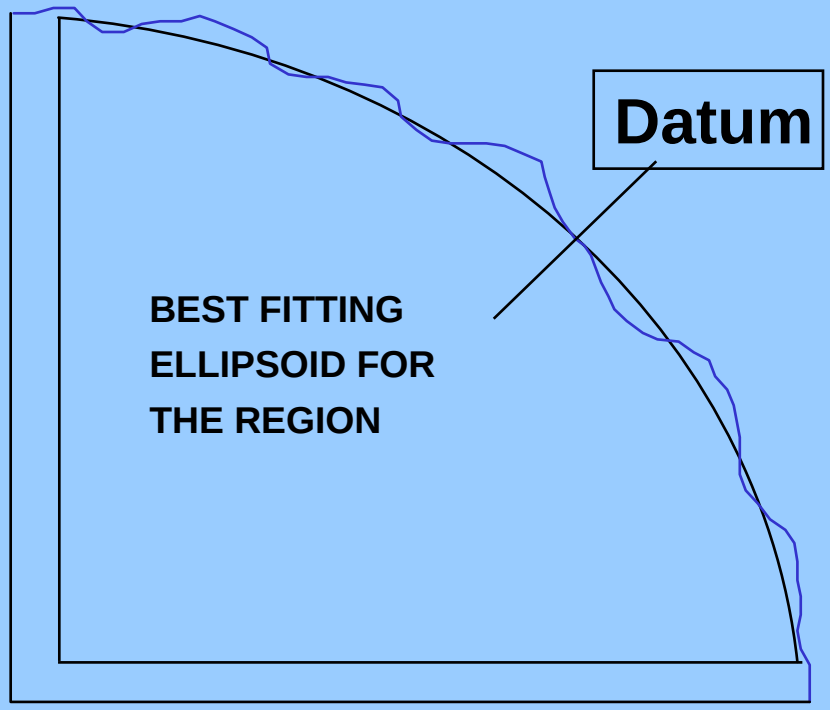
WGS72/84

Sphere

Ellipsoid / Spheroid

Astrogeodetic Datums

- DATUM = COORDINATE FRAME + REFERENCE ELLIPSOID
- Used for a specific region e.g. North America, Europe, South America etc.
- A coordinate frame is determined and an ellipsoid chosen to minimize the local geoid-ellipsoid separation.
- Not Earth centered!
- Hundreds have been defined for countries all over the planet



Some Reference Ellipsoids

Ellipsoid	Semi Major Axis	Inv. Flattening
Airy 1830	6377563.396	299.3249646
Modified Airy	6377340.189	299.3249646
Australian National	6378160	298.25
Bessel 1841 (Namibia)	6377483.865	299.1528128
Bessel 1841	6377397.155	299.1528128
Clarke 1866	6378206.4	294.9786982
Clarke 1880	6378249.145	293.465
Everest (India 1830)	6377276.345	300.8017
Everest (Sabah)	6377298.556	300.8017
Everest (India 1956)	6377301.243	300.8017
Everest (Malaysia 1969)	6377295.664	300.8017
Everest (Malay. & Sing)	6377304.063	300.8017
Everest (Pakistan)	6377309.613	300.8017
Modified Fischer 1960	6378155	298.3
Helmert 1906	6378200	298.3
Indonesian 1974	6378160	298.247
International 1924	6378388	297
Krassovsky 1940	6378245	298.3
GRS 80	6378137	298.257222101
South American 1969	6378160	298.25
WGS 72	6378135	298.26
WGS 84	6378137	298.257223563

Examples of Datums

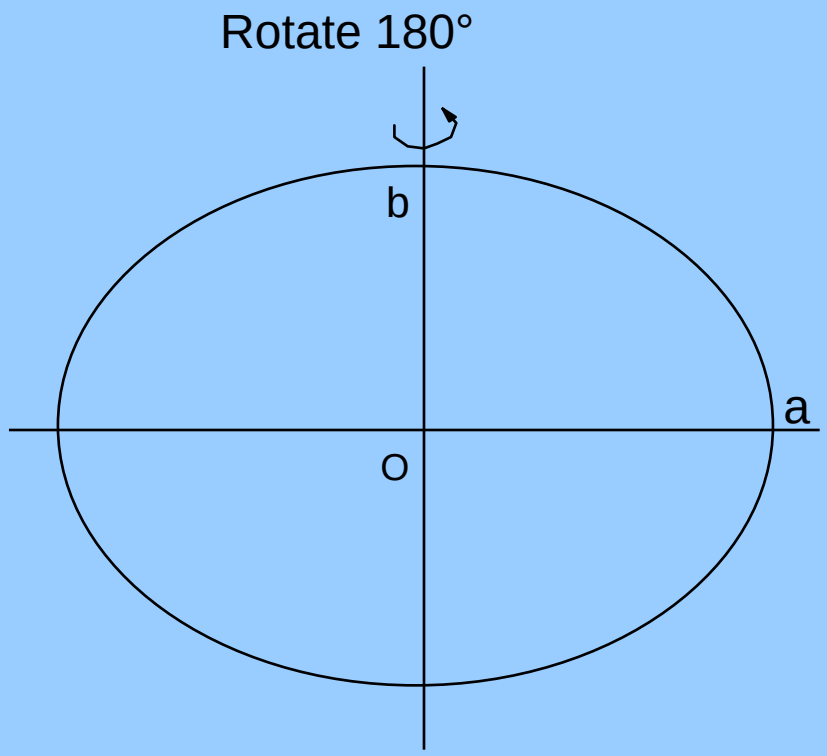
Datum Origin	+ Reference Ellipsoid	= Datum
11 main stns (UK)	Airy	OSGB36
many pts (global)	WGS72 ellipsoid	WGS72
1591+ pts (global)	WGS84 ellipsoid	WGS84
Potsdam	International 1924	ED50
La Canoa, Venez.	International 1924	PSAD56
Meades Ranch, KS	Clarke 1886	NAD27
Global, numerous pts	GRS80	NAD83
Herstmonceux, UK	Airy	OS(SN)70
Manoca Twr, Cmr.	Clarke 1880 IGN	MANOCA
Minna stn, Nigeria	Clarke 1880 RGS	MINNA
ITRF yyyy where yyyy = adj. year	GRS80	ITRS

Formulae associated with the Ellipsoid

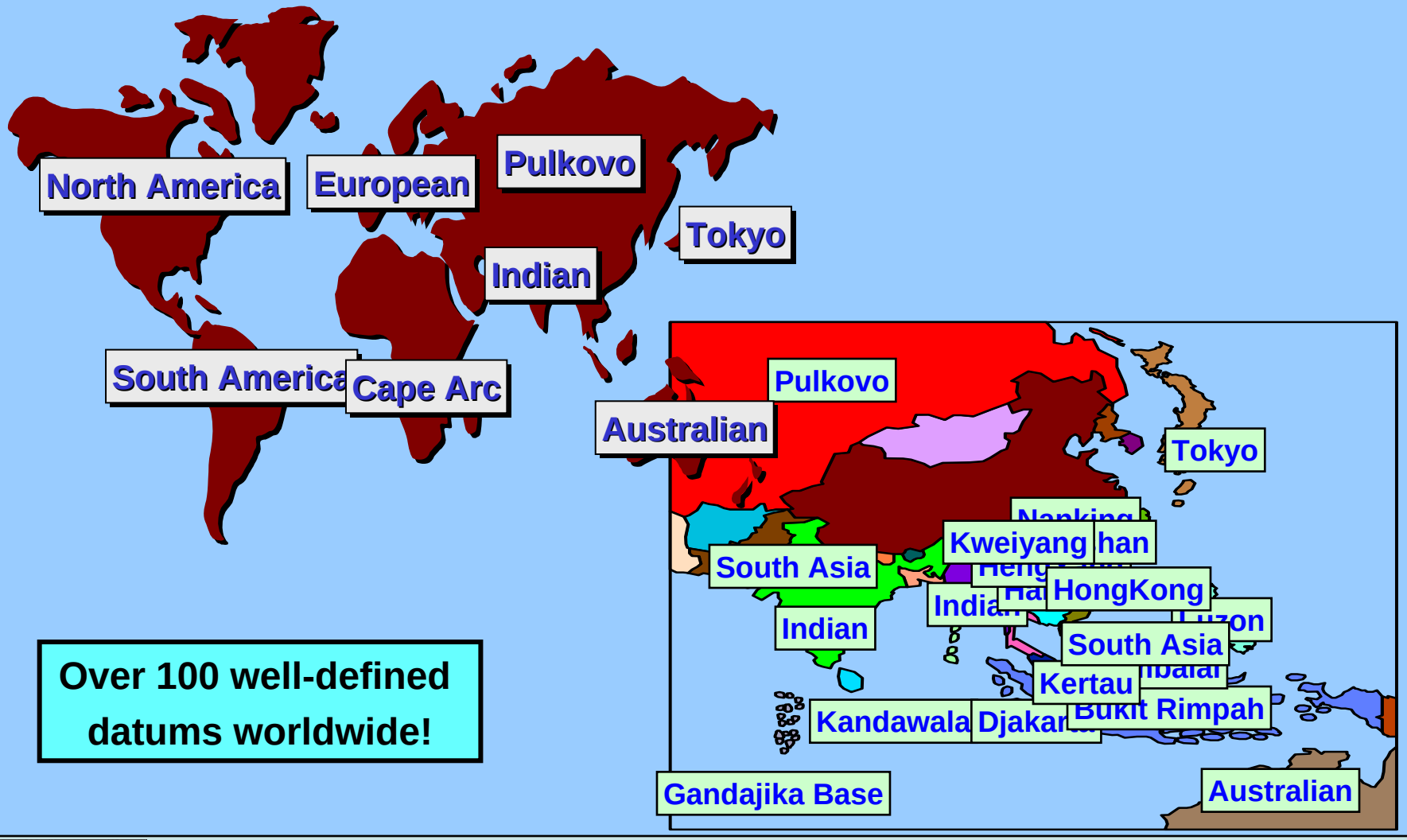
$$e^2 = \frac{(a^2 - b^2)}{a^2}$$

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

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

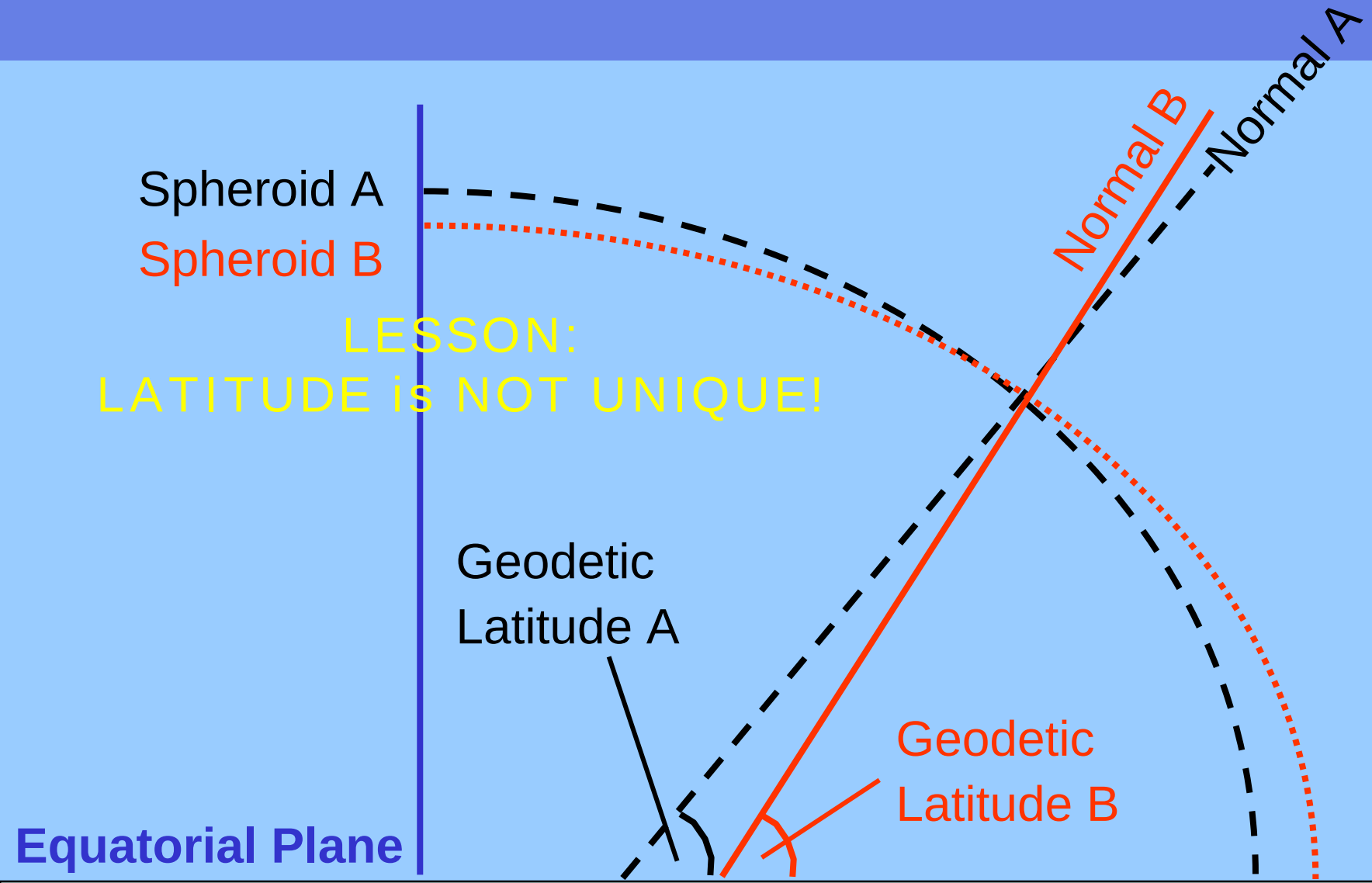


Major World Datum Blocks



Over 100 well-defined datums worldwide!

Geodetic Latitude



Latitude and Longitude are not Unique!

A single EXAMPLE POINT offshore Cameroon, West Africa in different GeogCRS/Datums.

Geographic coordinates:

GeogCRS/Datum	Latitude	Longitude
Manoca	N 04° 04' 17.179”	E 008° 29' 43.774”
Minna	N 04° 04' 12.077”	E 008° 29' 41.572"
WGS 84	N 04° 04' 14.504”	E 008° 29' 39.351”

(using GULF1977 transformation from Manoca to WGS84 and MPN 1994 transformation from Minna to WGS84)

Mixing Datums

- West Texas Central Zone — Texas
- NAD27
  - Lat: 32° N
  - Long: 105° W
- NAD83
  - 32° 00’ 00.54” N
  - 105° 00’ 01.87” W
- Differences
  - DE 158.8 ft
  - DN 60.9 ft
  - DR 170.0 ft
  - N 108.3 ft

- Montana South Zone — Montana
- NAD27
  - Lat: 45° N
  - Long: 112° W
- NAD83
  - 44° 59’ 59.654” N
  - 112° 00’ 03.075” W
- Differences
  - DE 222.0 ft
  - DN 30.0 ft
  - DR 223.7 ft
  - N 88.6 ft

Different Datums (& GeogCRS)

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

Geographic positions:

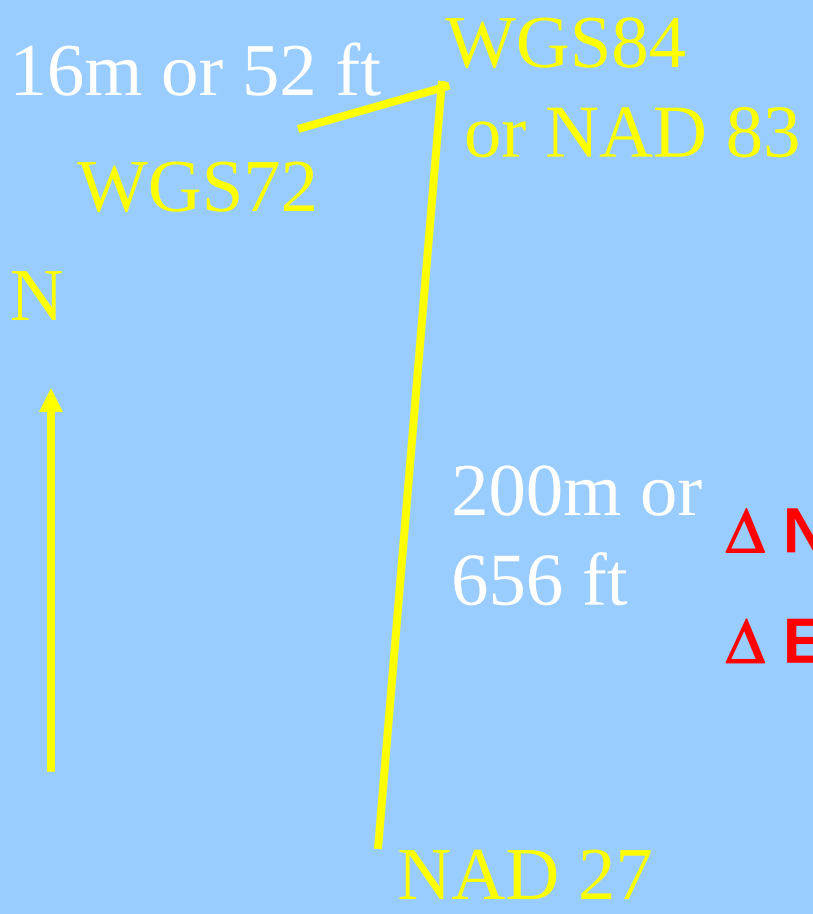
GeogCRS/Datum	Latitude	Longitude
Aratu	20º 36’ 13.2757”N	38º 56’ 56.3341”W
SAD69	20º 36’ 17.4283”N	38º 56’ 50.1240”W
WGS84	20º 36’ 19.2794”N	38º 56’ 51.2166”W

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

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

1” of Latitude = 30.0 meters?

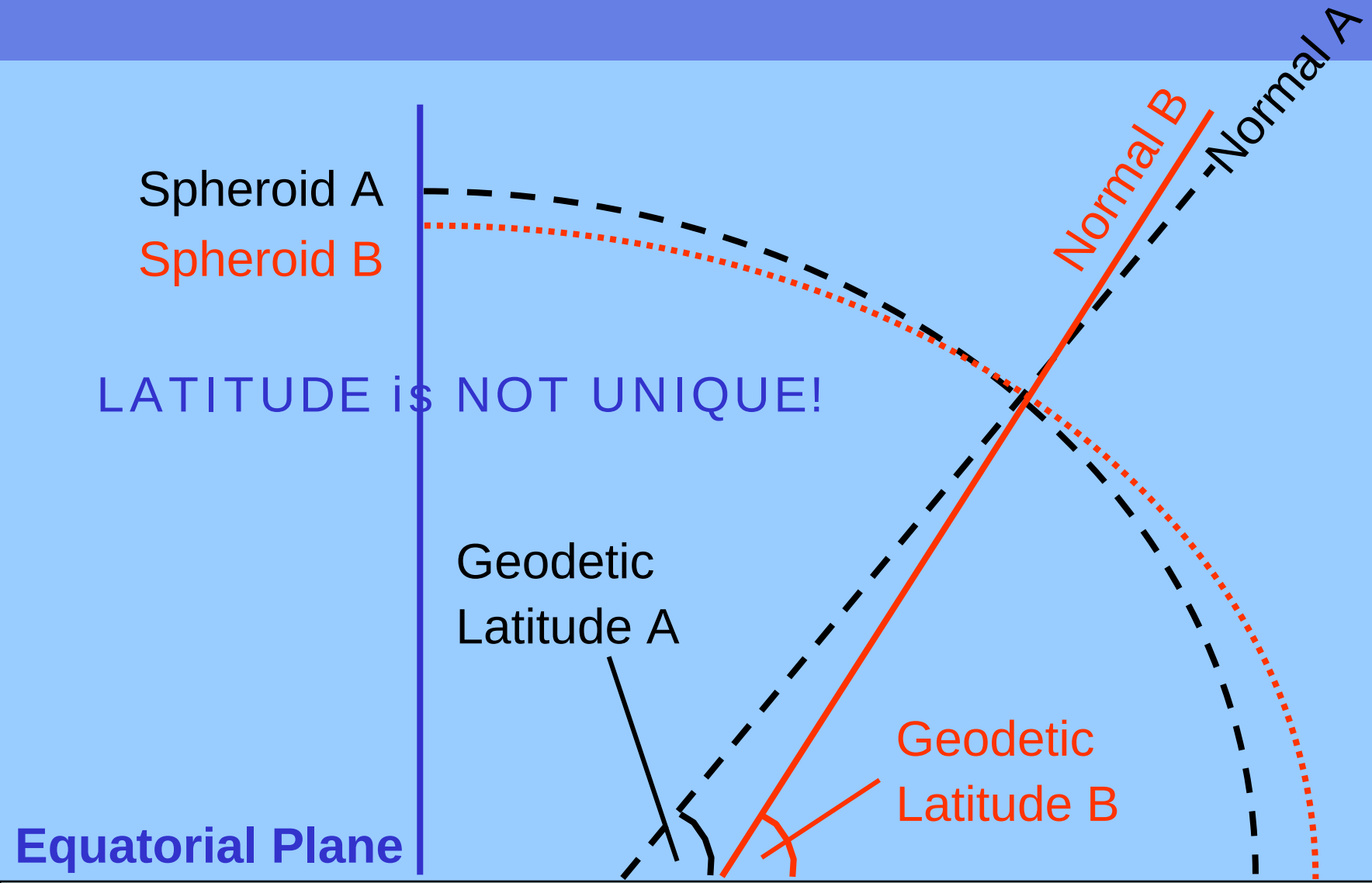
While working in one GeogCRS (Datum)

- **1” latitude = 30.9 meters,**
- **1” longitude = 30.9 meters * cos (latitude)**

This is NOT valid when geographic coordinates are on DIFFERENT datums.

- **–The example NAD27 and WGS84 latitude on the previous slide differs by only 1.06”, whereas the physical offset is approximately 199.9m (656 feet)**
- **–Why is this the case?**

Geodetic Latitude



If you remember nothing else.....

Major Point to Remember :

Latitudes and Longitudes 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 datum transformations between the various GeogCRS occur?
  - **Little sharing of geodetic information.**
  - **Operators needed more accurate transformations.**
  - **Satellite receivers could measure directly.**

Geodetic Transformations (Datum Shifts) continued

- Which transformation should I use?

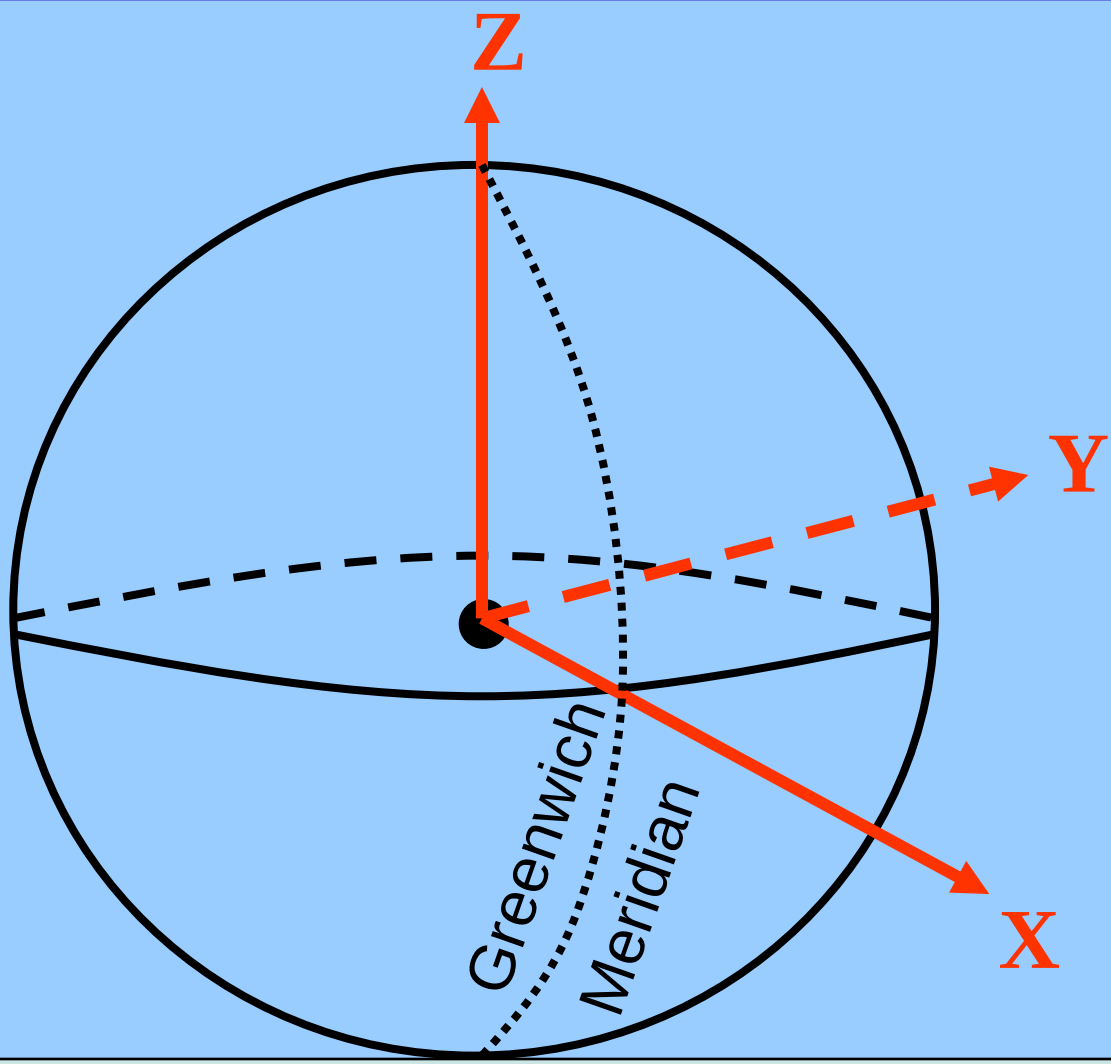
- If I'm working in a "local" datum (GeogCRS), why do I need a datum shift at all?
  - **Most positioning work in the energy sector is done by GPS measurements solely linked to the WGS 84 GeogCRS (& Datum)**
  - **To obtain coordinates in a "local" reference system, someone MUST transform from WGS 84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

Geodetic Transformation Methods

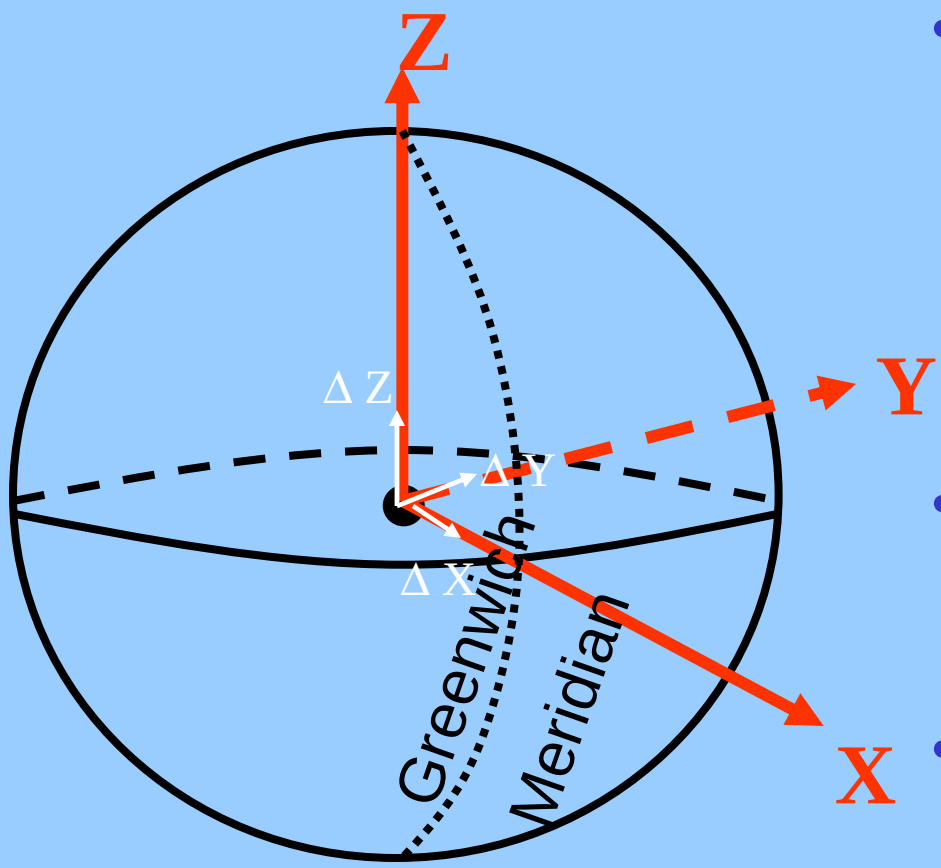
- How do you go from GeogCRS1 to GeogCRS2 (Datum1 to Datum2)
  - **Geocentric Translation (3-parameters)**
  - **7-parameter transformations (Special caution MUST BE EXERCISED here!)**
  - **Many other transformation methods exist, with limited applications**

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

Geocentric Cartesian Co-ordinates

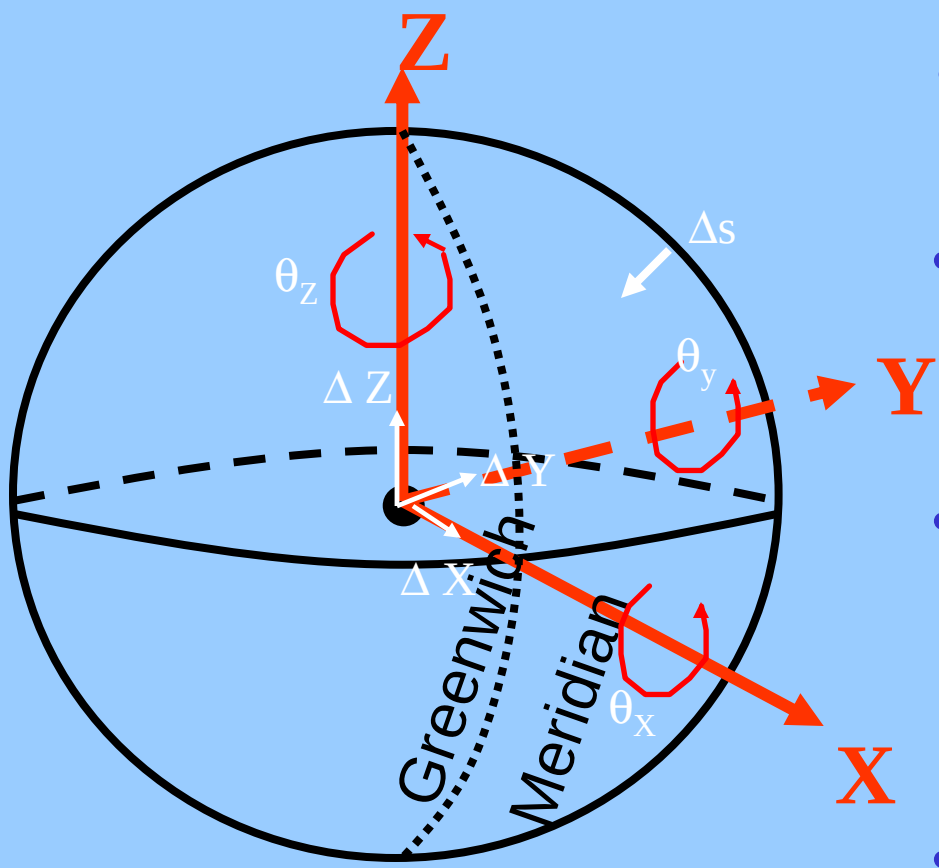


Geocentric Translations



- **Geocentric Translations along the ellipsoid's coordinate axes, expressed as:**
  Δ X, ΔY, & ΔZ
- **Most common transformation**
- **NIMA TR8350.2 tables use this method.**

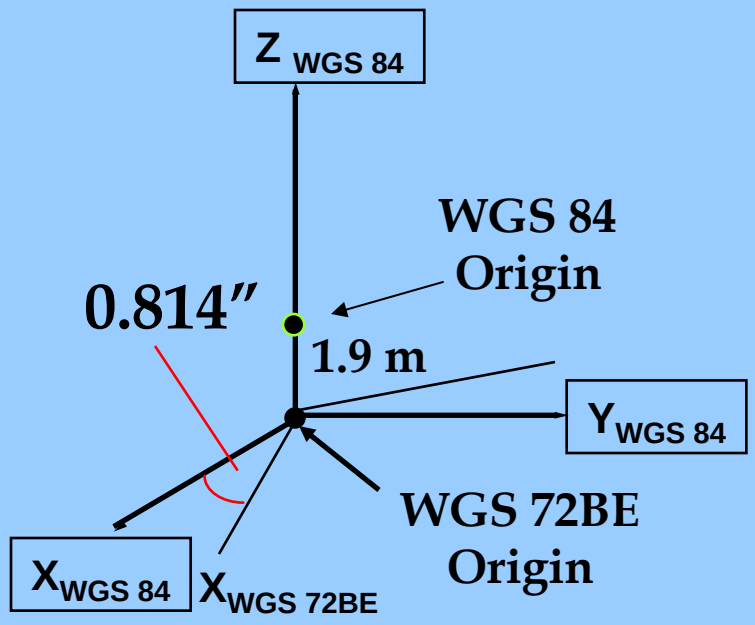
7-Parameter Transformations



- Parameters are:
- **3 translations**
  Δ X, ΔY, ΔZ
- **3 rotations, one about each axis: rX, rY, rZ (or θ_X, θ_Y, θ_Z)**
- **Scale change (or Δs)**

Local to WGS 72BE to WGS 84 Datum

- Many transformations from Local Datums to WGS72 BE were obtained using Transit Satellite Receivers.
- Combined with WGS72BE to WGS 84, these yield transformations from Local Datum to WGS 84.
- Scale and Rotation terms are important and cannot be ignored.



Δ-scale = -0.38ppm for WGS 72BE to WGS 84

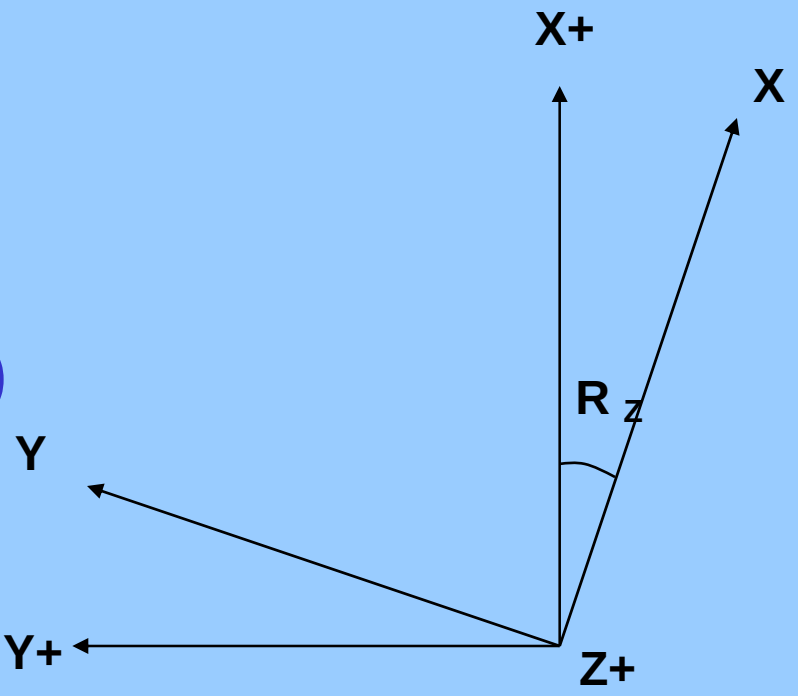
7-parameter (and 10-parameter) Datum Transformations

- 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 transforations?
  - The Molodenski-Badekas transformation allows for rotation about a specific point.
  - Other ten-parameter transformations allow for earth's velocity!

Coordinate Frame Rotation (about the Z-axis)

- θz, 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)



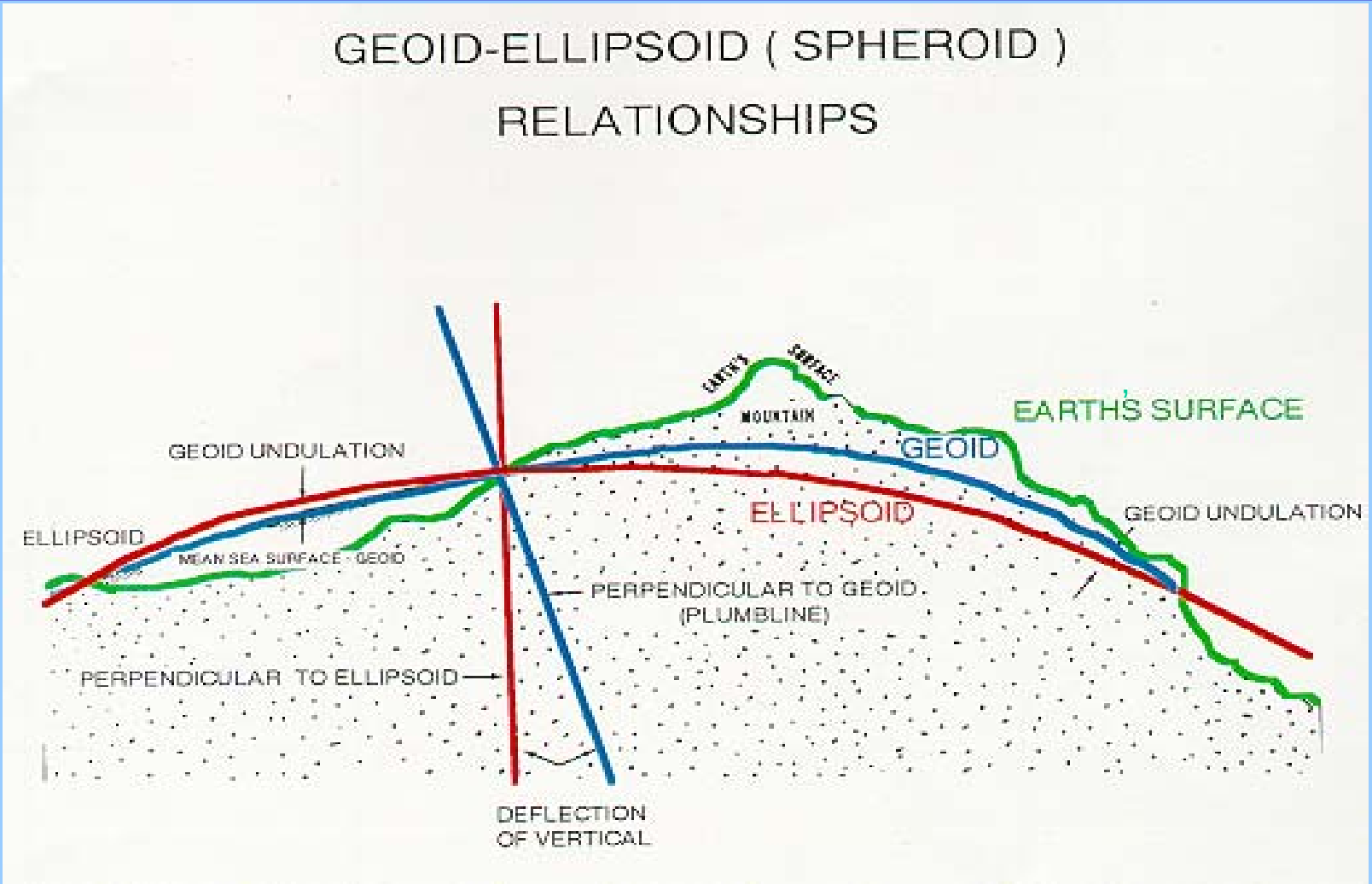
Looking down on the earth from above the North Pole

Session Review . . .

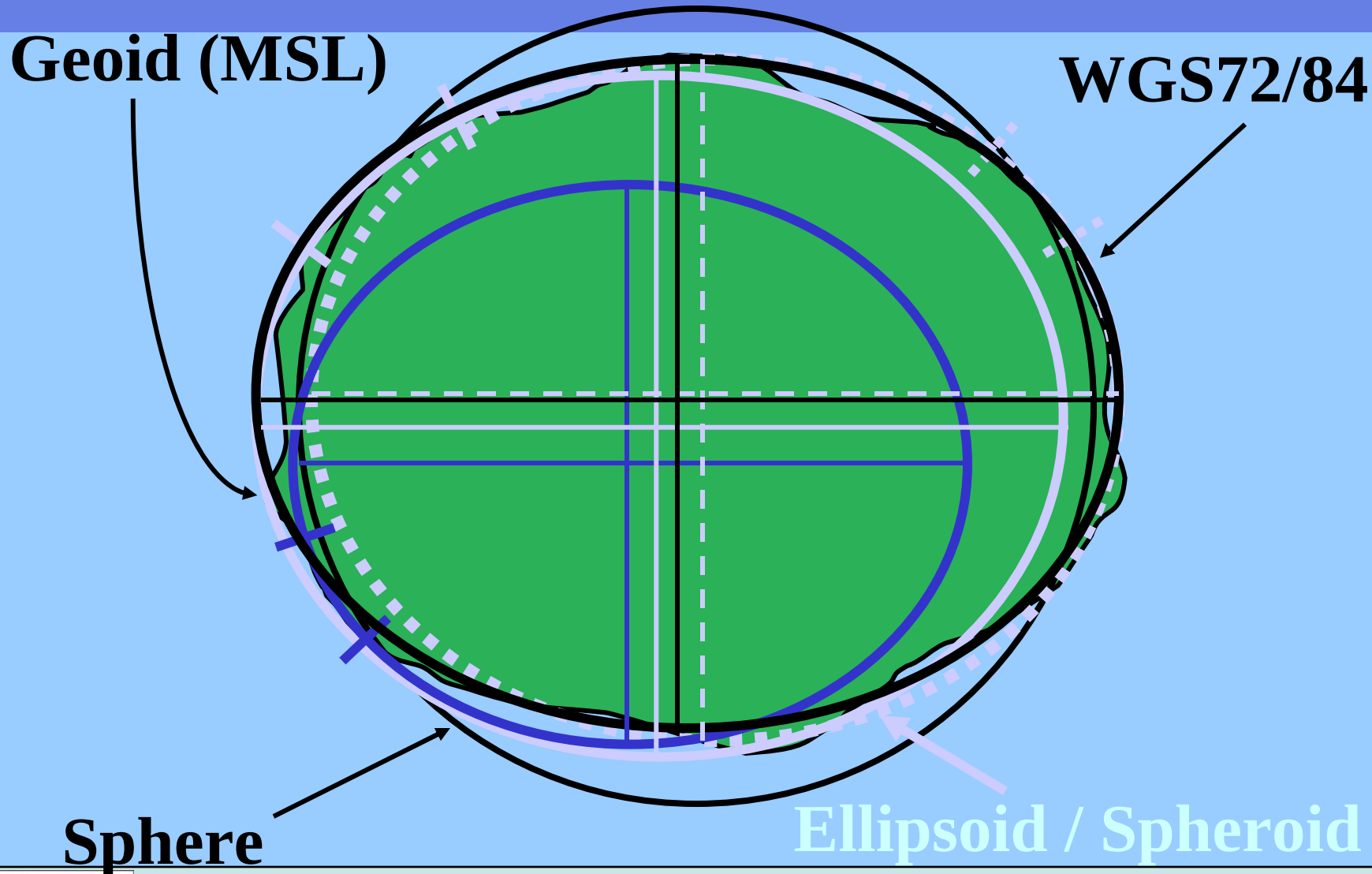
Before we finish this module -

Just a few reminders!

Ellipsoid, Geoid and Height Relationships



Representations of the Earth's Surface



Latitude and Longitude

ARE

NOT

UNIQUE!

Latitude an Longitude coordinates must be combined with a Geographic Coordinate Reference System (GeogCRS) / Datum in order to guarantee uniqueness.

A Geodetic Datum

Is simply

An ELLIPSOID of Revolution

Coupled TO THE EARTH
at a specific location
(or in a specific manner)

Problems in Geodesy

- **To correctly define the coordinates of a point and provide accurate mapping 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 the 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 method (rotation convention)!**

Session Summary

- **Thus far today, we have covered geodetic Datums, Ellipsoids, Geographic Coordinate Reference Systems (GeogCRS) and various transformations between different GeogCRS (or “Datums”).**

- **After the break, Jon will discuss Map Projections and Projected Coordinate Reference Systems (ProjCRS)**

EPSG database (www.epsg.org)

The EPSG database comprises:

Coordinate Reference Systems

- Geographic and Projected CRS
- Vertical and Engineering [local] CRS
- Compound CRS

- **Geodetic Transformation Data**
  - Concatenated Data [sequential steps are required]
  - Single geodetic transformations of all types
  - transformations between vertical systems
- **Ancilliary Data**
  - Ellipsoids, Prime Meridians, Units of Measure, etc.
- **Associated reports and forms to access data.**
- **Database available in SQL and MS Access**

Other References

- EPSG Guidance Note 7. Download free from European Petroleum Survey Group's website at

  www.epsg.org

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

  www.nima.mil/GandG/geolay/toc.htm

End of Part I

Questions or comments, please?…..

Break Time (before Part II)

Time for a
short break