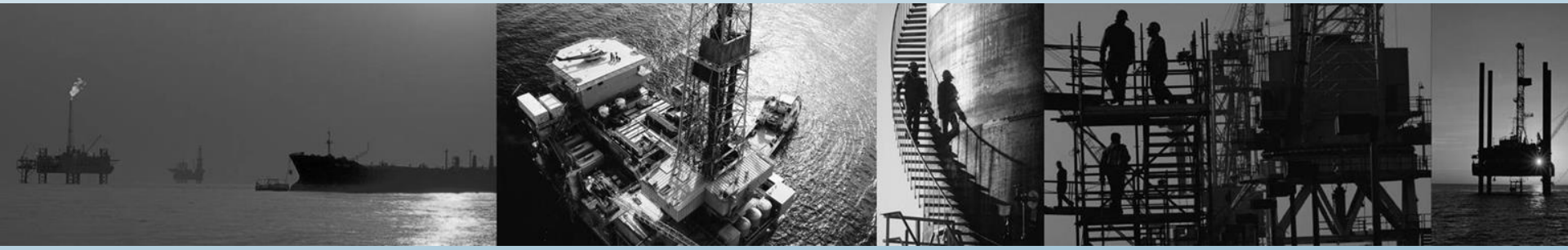
Experts in Geomatics, Surveying, Positioning,
Geospatial Data, and Mapping Sciences

Basic Geodetics



Bobby Saleh
Guidon Energy
b.saleh@guidonenergy.com

April 13, 2017

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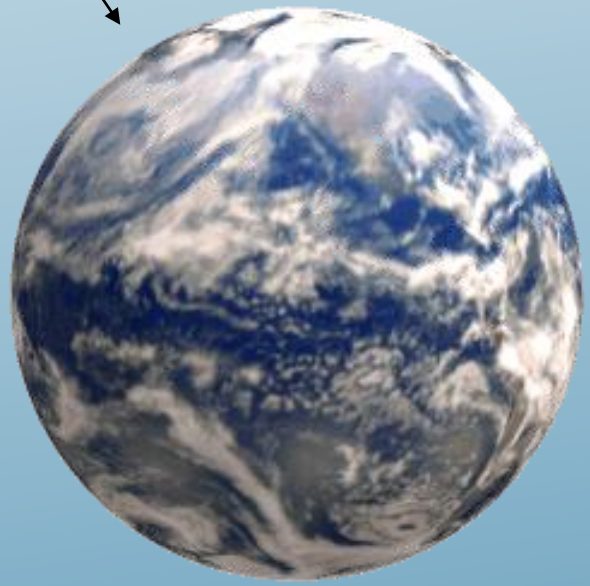
The Earth is NOT flat

Q: So what does this have to do with me ?

A: All of our data depends on accurate positions

- **Lease Holdings**
- **Seismic Acquisition**
- **Interpretation**
- **Surface Drill Locations**
- **Subsurface Drill Locations**
- **Reserves Calculations**
- **Reserves Replacement**
- **HSE**
- **Ultimately…..Profits!**



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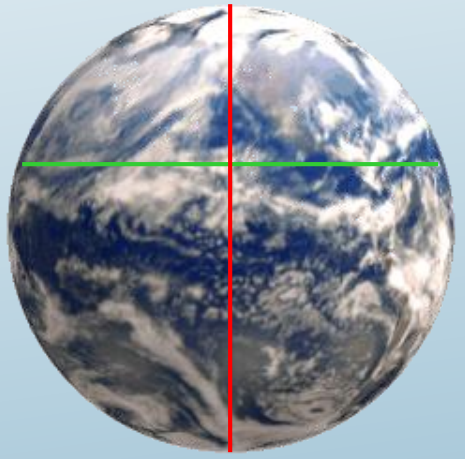
The Earth is Round (Well-Sort of ☺)

Various ways of dealing with this.
So how do we know where we are ?



Latitude

Longitude

- **That's easy – Right**
- **Well, Not exactly**
- **There are different Latitudes and Longitudes for the same points**
- **Depends on the DATUM**

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Datum

- **A Geodetic Datum is a STARTING Reference Point**
- **A Geodetic Datum is defined as 'An Ellipsoid attached to the Earth at a point'**

So "What is an Ellipsoid"?

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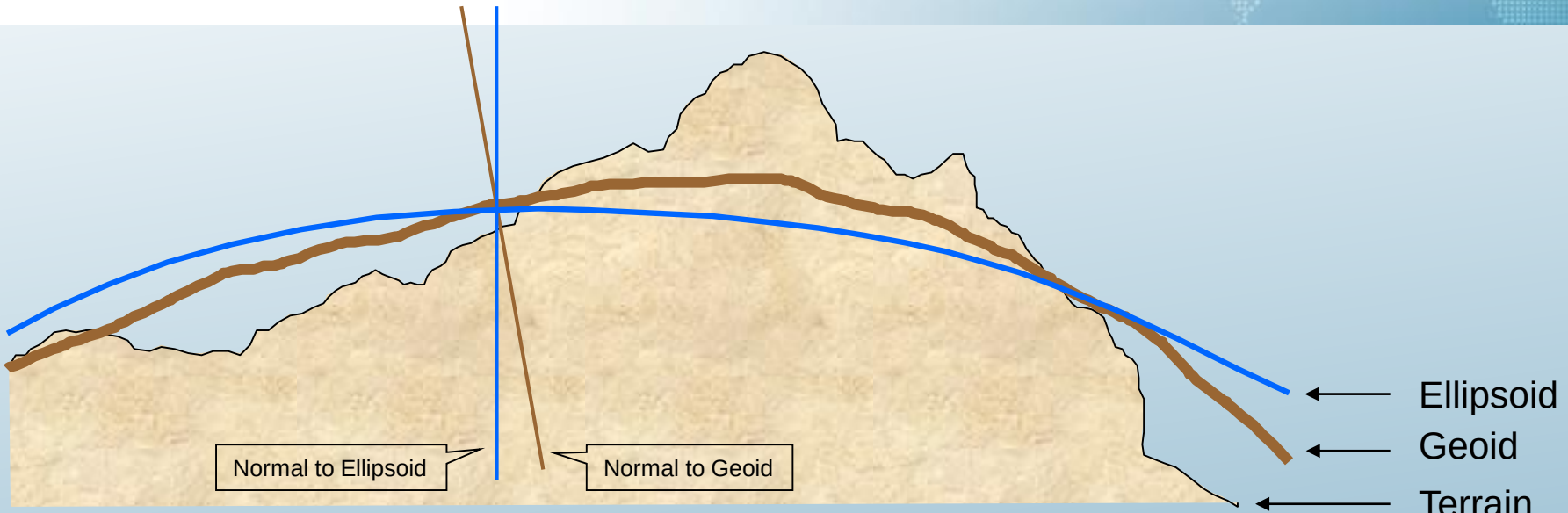
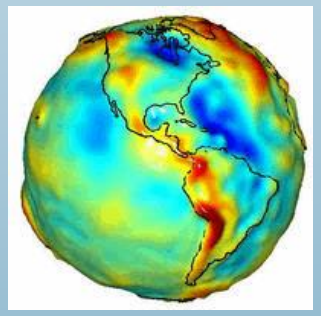
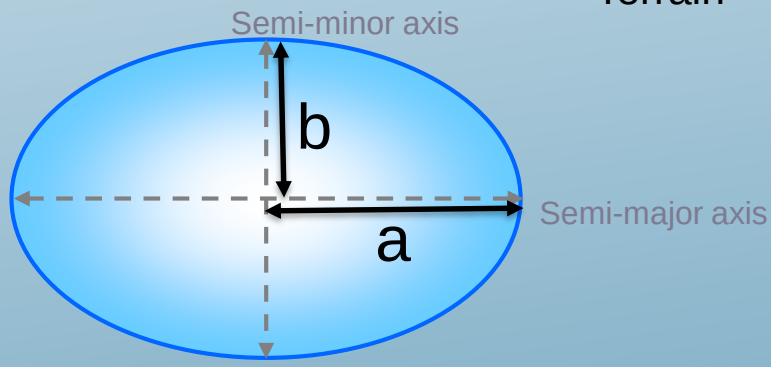
Reference Surfaces







Geoid

Equipotential surface which approximates to MSL

Ellipsoidal CS

Surface where Computations are made

1/f = a/(a-b) Flattening

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Analogy of a Datum

Example

> "You are here in Room 320. Room 320 is exactly the same size and shape as room 330 and 332."

This room is #320. The shape of the room is the Ellipsoid, the Room number is the Datum name (where the room is attached in the George R Brown Convention Center).

You got here by following the signs directing you to this room number 320 and are listening to 'Basic Geodetics Workshop'.

If you had gone to room 332 (same shape (ellipsoid), different datum (room number)) and you would be listening to a different talk!

You would be in a different (the wrong) place!

The datum name is absolutely essential to getting to the right location!

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Real World, Statue of Liberty – DATUM NAD 27

Why do we have problems with positions?

- **Statue of Liberty**
- **Known Location NAD 27**
  - Lon = 74 Deg 02 Min 42 Secs West
  - Lat = 40 Deg 41 Min 21 Sec North

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Real World, Datum NAD 83

- **Statue of Liberty**
- **Known Location NAD 83**
  - Lon = 74 Deg 02 Min **41** Sec West
  - Lat = 40 Deg 41 Min **22** Sec North

NAD27
74 Deg 02 Min **42** Sec West
40 Deg 41 Min **21** Sec North

Difference is **37** Meters (122 Feet)

Did it Move ?

?

No

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Different Coordinates / Same Place

- **Liberty DID NOT move**
- **So what is different ?**
- **The DATUMS are different**
- **What are Datums again ?**
- **A Datum is a Starting Point**
  - **Geodetic Datums consist of:**
    - An Ellipsoid, attached to the earth origin is the ellipsoid center – The same point can have different coordinates depending on the datum!
    - Origin
    - Direction, an Azimuth
    - Geoid Separation at the origin

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Two Main Datums in the USA

- **Satellite Datum**
  - **WGS84 (Close Equivalent to NAD 83 in USA); Older Satellite Datum WGS72**
- **Regional Datum**
  - **NAD 27**
- **Rest of the World……**
- **Need to know these to deal with**
  - **Historical Data**
  - **Current and Future Operations**
  - **Matching the above in projects and analyses throughout E&P**

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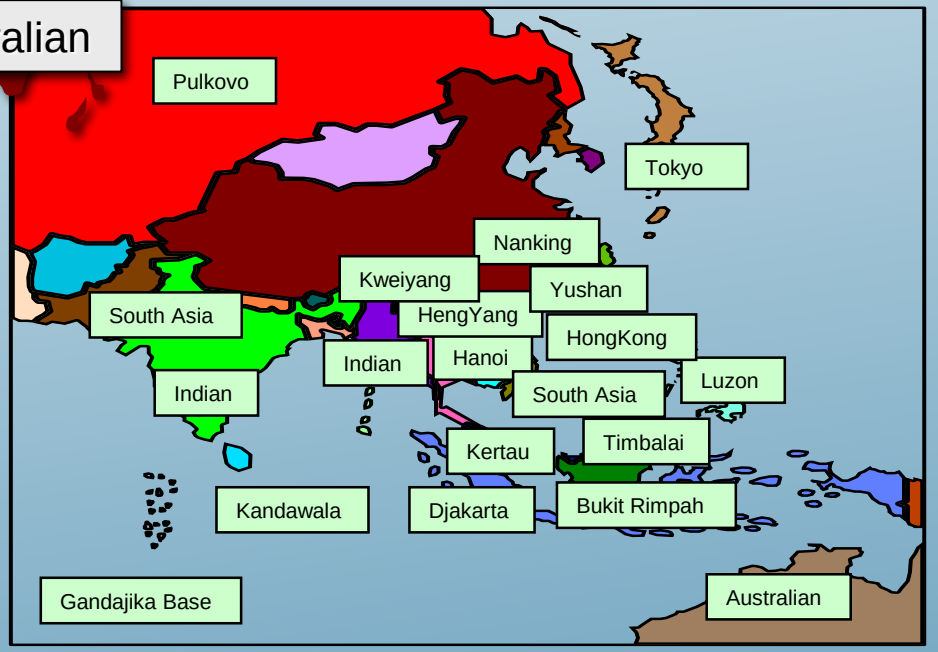
Major World Astro-Geodetic Datum Names



Over 100 Geodetic Datums (named CRS) worldwide!

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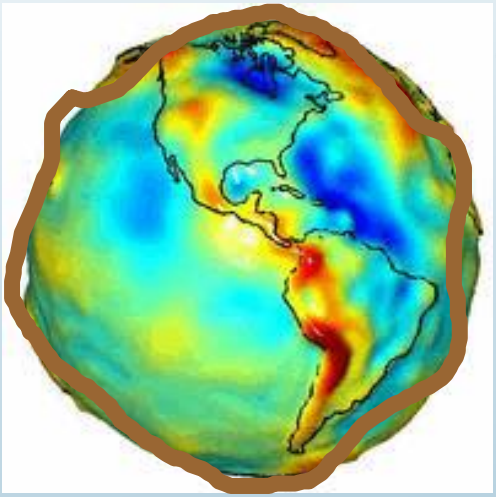
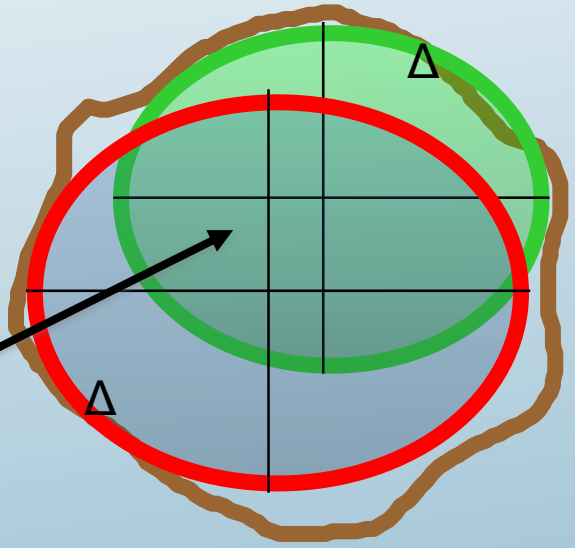
Geographic CRS Relationships

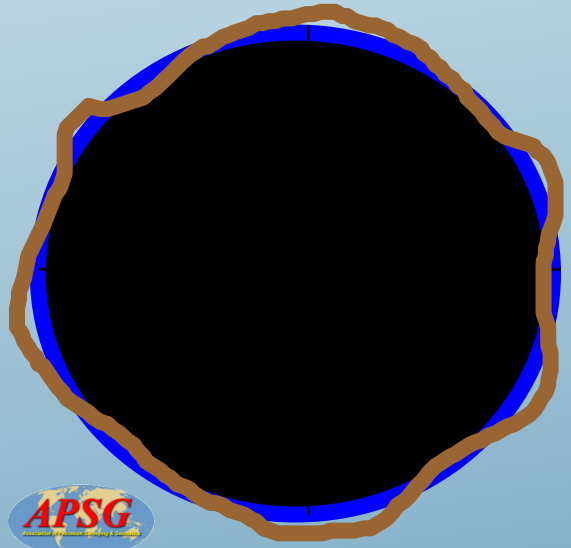


Geoid

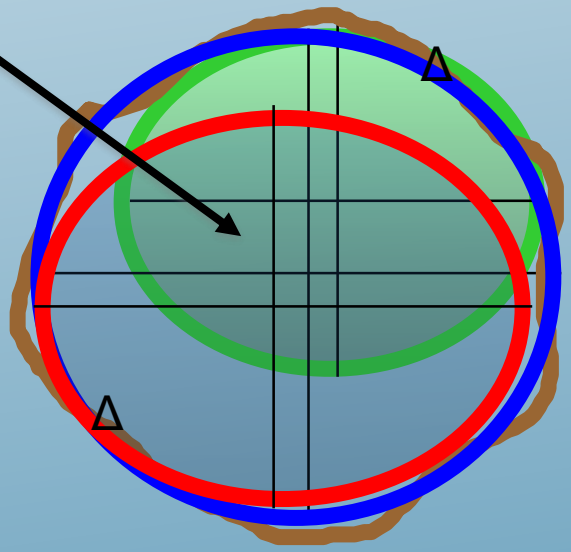
Green and Red Datums: (Regional) Geographic CRS'



Note different ellipsoids have center in different place depending on where they are attached to the earth!



Need Coordinate Transformation between Geographic CRS'



Blue Datum: (Global) Geocentric CRS

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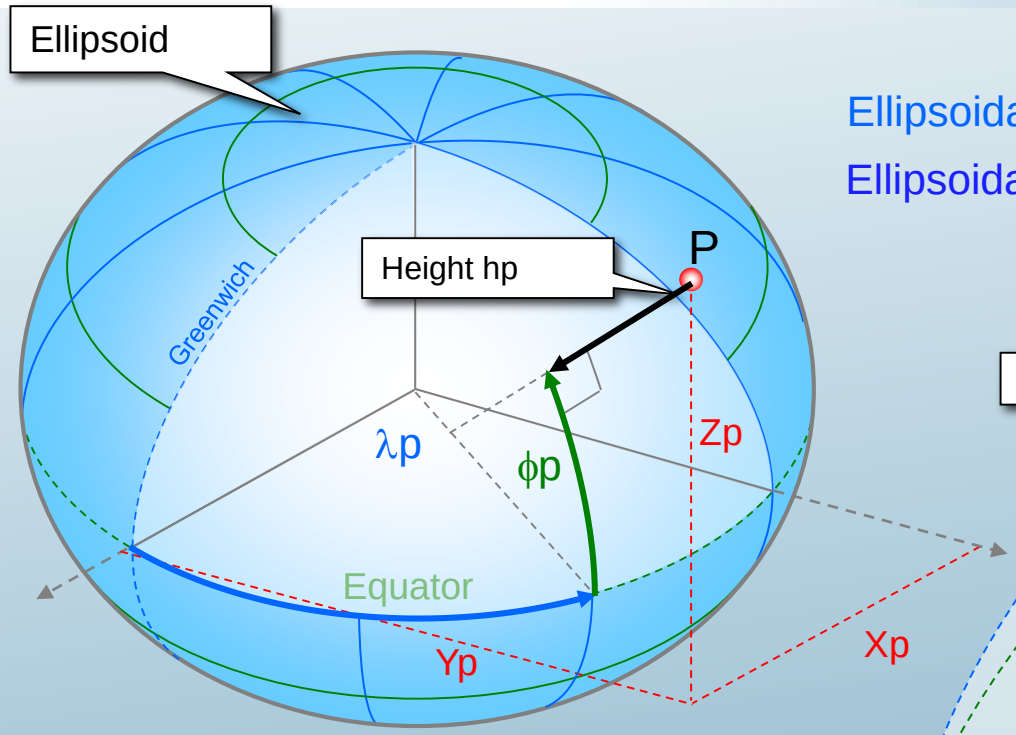
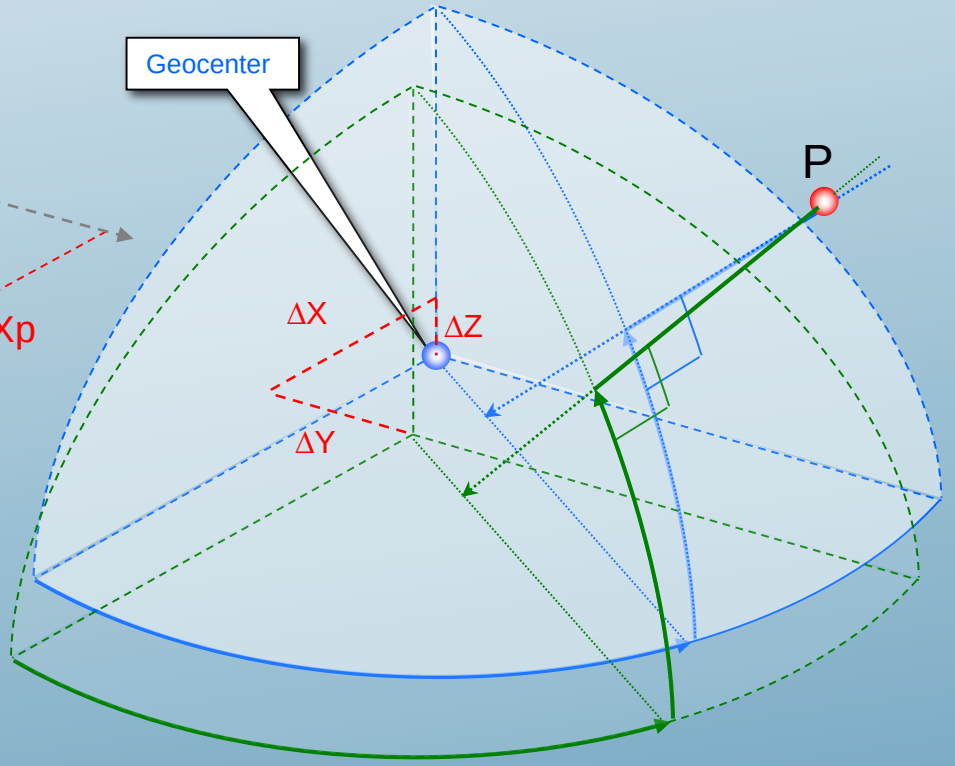
Coordinate Operations – 3-ParameterTransformations



Ellipsoidal CS A (Blue Datum, Geocentric Datum)

Ellipsoidal CS B (Green Datum, Geographic Datum)



e.g. NAD83 to NAD27

ΔX = 8 meters

ΔY = -160

ΔZ = -176

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Changing Datums – Coordinate Transformation

- **Satellite Datum is always WGS 84 or equivalent (e.g. NAD83 in US or ETRF89 in Europe)**
- **In the field or office we are converting from Satellite Datum to Local Datum OR the Reverse**

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Coordinate Transformations

What you do need to know?

- **Transformation Parameters - Two most common types**
  - 3 Parameter, very commonly used
  - 7 Parameter, not common, but you will see them – get expert assistance with this
  - NTv2 (NADCON in the USA)
- **Where do you get the transformation parameters ?**
  - The EPSG Geodetic Parameter Registry
    - http://www.epsg-registry.org/
  - From Geodesists, Surveyors
  - Software packages - e.g. ArcGIS

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Brazil Geodetic CRS

Brazil Geodetic CRS	Datum Name	Ellipsoid	Usage
Geographic 2D	**Aratu**	International 1924	Brazil S of 3˚ S coastal and offshore areas
Geographic 2D	**PSAD56**	International 1924	Northern South American Continent
Geocentric 2D	**SAD69**	GRS 1967 (Modified)	Latin America (Replaced Corrego Alegre)
Geocentric	**ITRF2005**	GRS 80	Worldwide
Geocentric, Geographic 3D, 2D	**Sirgas 2000**	GRS 80	Latin America
Geographic 3D	**WGS 84**	WGS 84	Worldwide

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Brazil Coordinate Transformations (Espirito Santo)

Geodetic Coordinate Transformations					
From	To	Usage	dX	dY	dZ
Aratu	WGS 84 (1)	Oil & Gas ± 10 m Espirito Santo (Mean three basins)	-158	315	-148
Aratu	WGS 84 (7)	Oil & Gas ± 7 m Espirito Santo	-162.904	312.531	-137.109
Aratu	WGS 84 (12)	Oil & Gas ± 5 m Espirito Santo	-161	310	-145
Aratu	WGS 84 (15)	Oil & Gas ± 5 m Espirito Santo	-161.11	310.25	-144.64
Aratu	SIRGAS (3)	Oil & Gas ± 0.5 m Espirito Santo	-161.11	310.25	-144.64
PSAD56	WGS 84 (8)	Miltary Accuracy ± 10 m Amazon Cone	-291.87	106.37	-364.52
SAD69	WGS 84 (1)	Miltary Accuracy ± 19 m South America	-57	1	-41
SAD69	WGS 84 (4)	Miltary Accuracy ± 8 m Brazil Onshore & Offshore	-60	-2	-41

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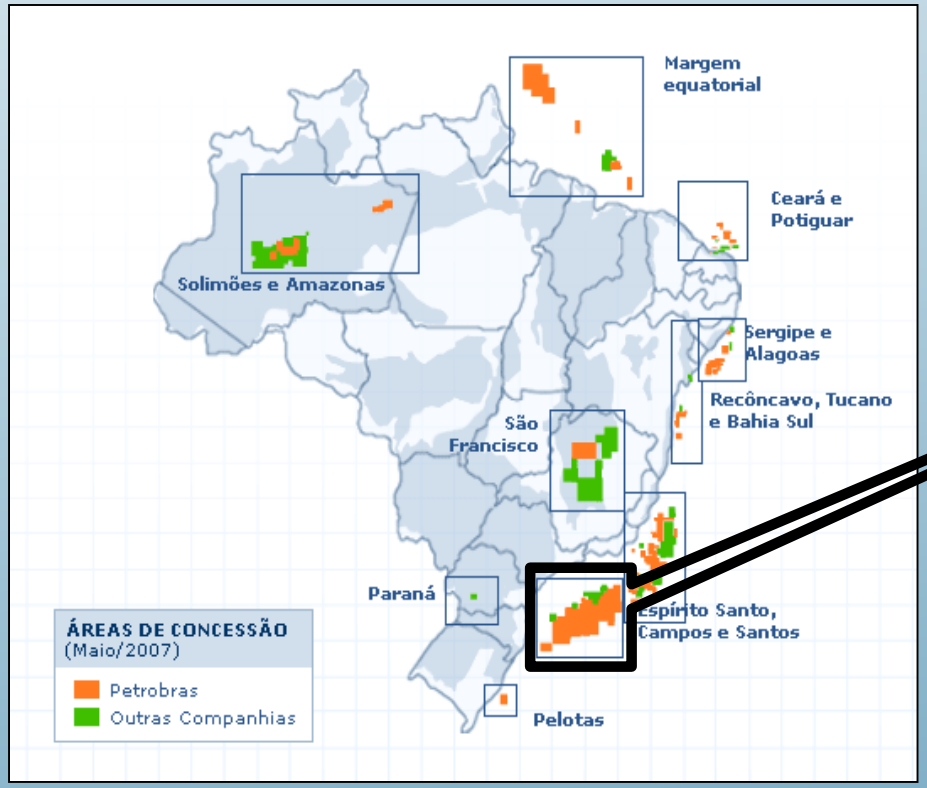
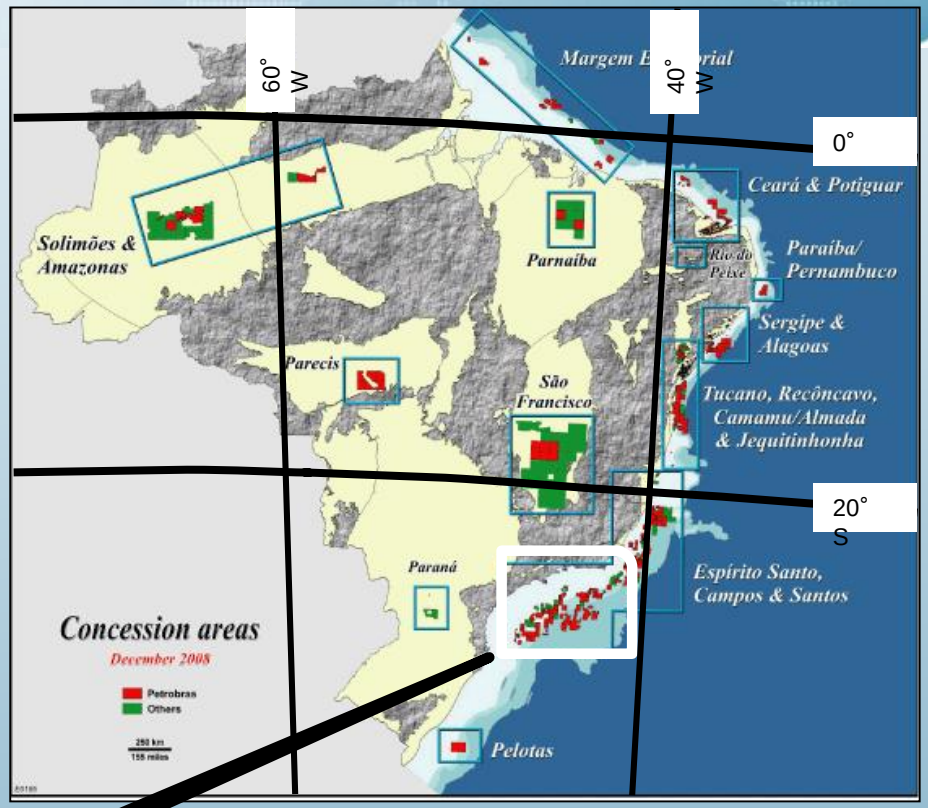
Brazil CRS & Exploration Areas

Datums:
Aratu, PSAD56, SAD69, WGS84, ITRF2005, SIRGAS





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Mixing Datums: Brazil Example

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

Coordinates are of the SAME physical point

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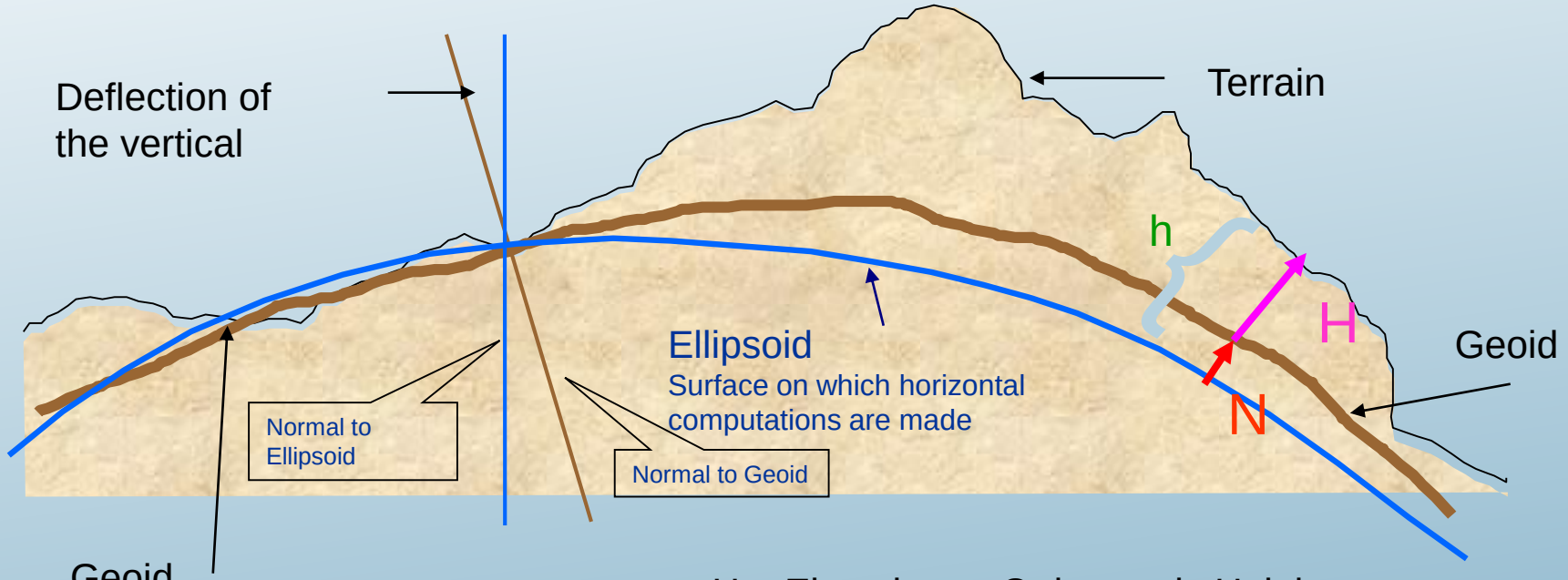
Vertical Referencing I



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

H = Elevation or Orthometric Height

N = Geoidal Height

h = Ellipsoidal Height

$h \approx H + N$

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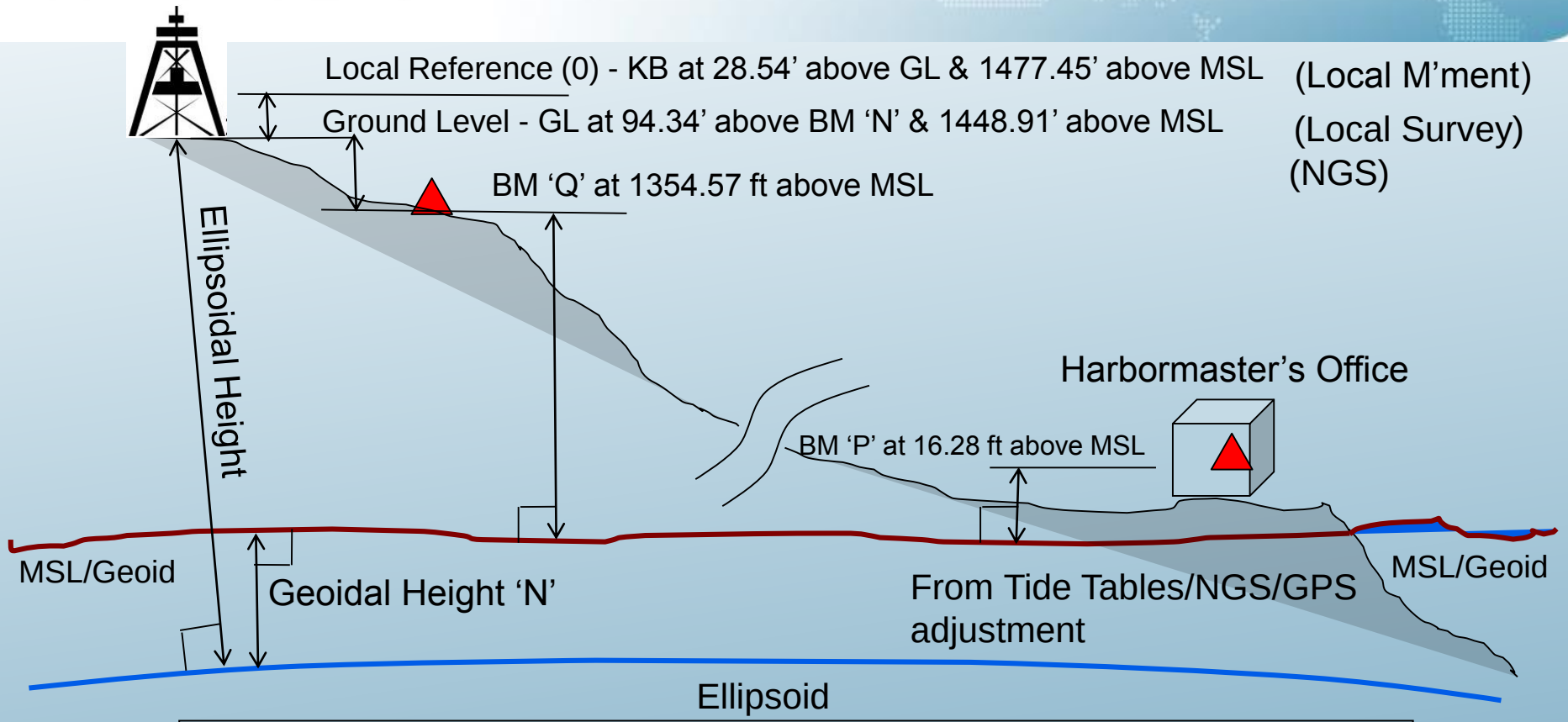
Vertical Referencing II



Notes:
Offshore, use tide tables for nearest port or use co-tidal tables for rig KB
If GPS used, recorded heights will be referenced to the ellipsoid surface, unless adjusted by measurement process (e.g.kinematic)
Close Management and supervision of acquisition, reporting, processing and loading of well data is essential. Note in this regard the possible change in ground level, GL, due to well pad preparation

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Summary of Lat and Long

- **Given a Lat and Long**
- **You MUST Have**
  - **Datum and ellipsoid parameters**
- **Example**
  - **NAD 27 Datum**
  - **Semi Major Axis – 6378206.4**
  - **Flattening – 294.97869820**
- **In most cases the Datum includes the name and definition of the ellipsoid – its size, axes, axes order, orientation and units. This complete dataset is known as a Geographic 'Coordinate Reference System' or 'CRS'**

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Summary

- **Geodetic Datum with associated Coordinate System (Ellipsoid) is required to be uniquely sure of the location**
- **Latitude and Longitude are not unique without the Datum name**
- **Usually Survey in WGS84 (GPS Satellite)**
- **Need Transformation parameters to convert to regional (local datum eg NAD27)**
- **Most countries have at least two and often three or four different datums**
- **EPSG Geodetic Parameter Registry is excellent source. There are many less reliable sources – online access at http://epsg-registry.org/.**
- **This can be complicated. If you are not trained, get expert help. It can save putting a $150 million well in the wrong place!!!!**

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