ABLOS Tutorial
Basic Geodetic Concepts

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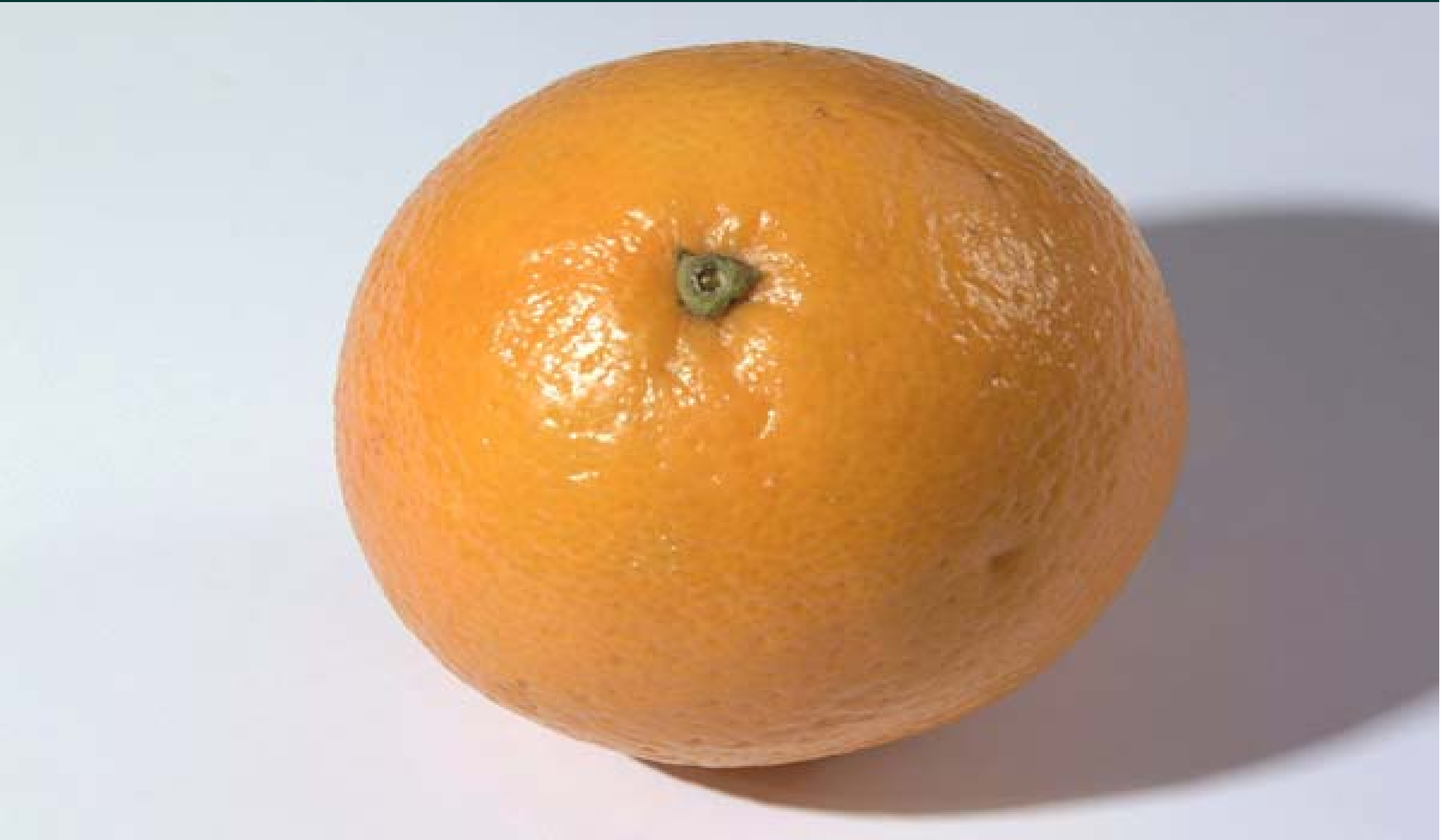
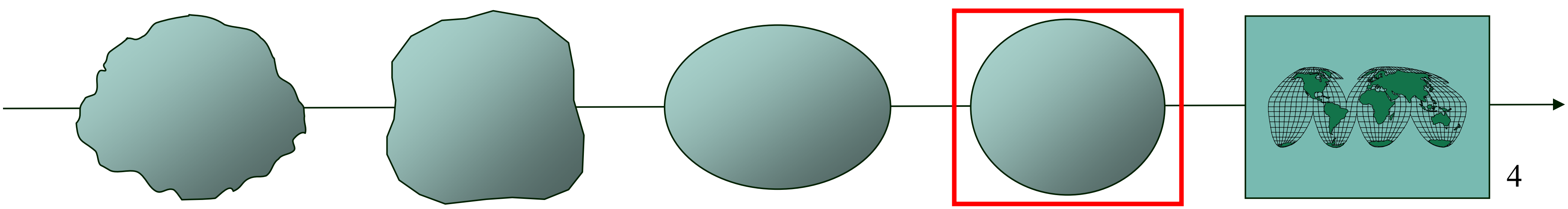
1. Introduction
2. Ellipsoids and Geoids
3. Sea Level
4. Datums
5. Projections
6. Loxodromes and Geodesics

Introduction 1.2



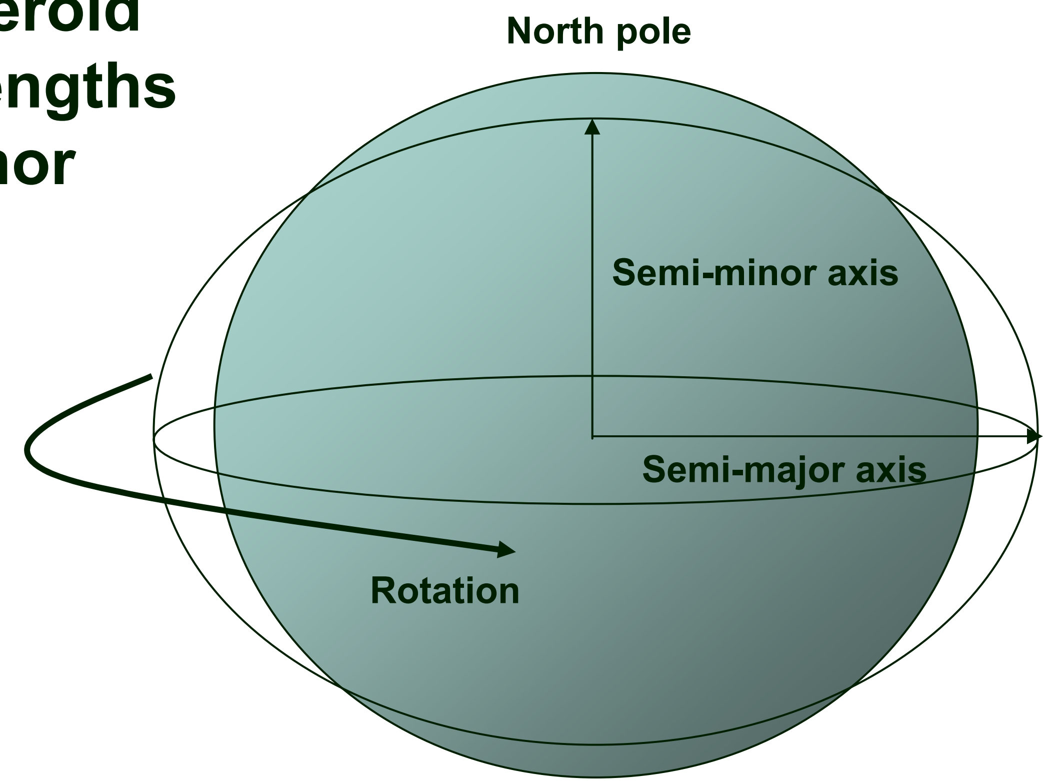
Ellipsoids and Geoids 2.1
The Spherical Earth

- **The earth is basically spherical in shape**
- **Eratosthenes made the first calculation of the earth's spherical size in about 250 B.C. using simple observations and geometry**
  - **Earth's circumference by Eratosthenes -- 25,000 miles 40,000km**
  - **Earth's actual circumference -- ~24,900 mi**



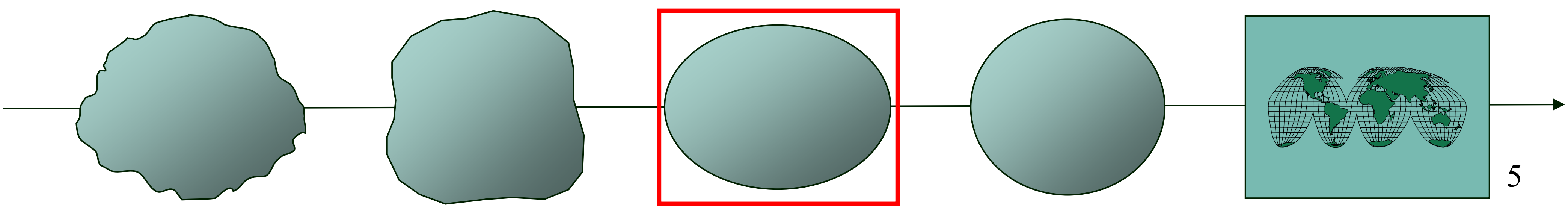
Ellipsoids and Geoids 2.2
The Ellipsoidal Earth

The shape of the ellipsoid/spheroid is determined by the relative lengths of its semi-major and semi-minor axes



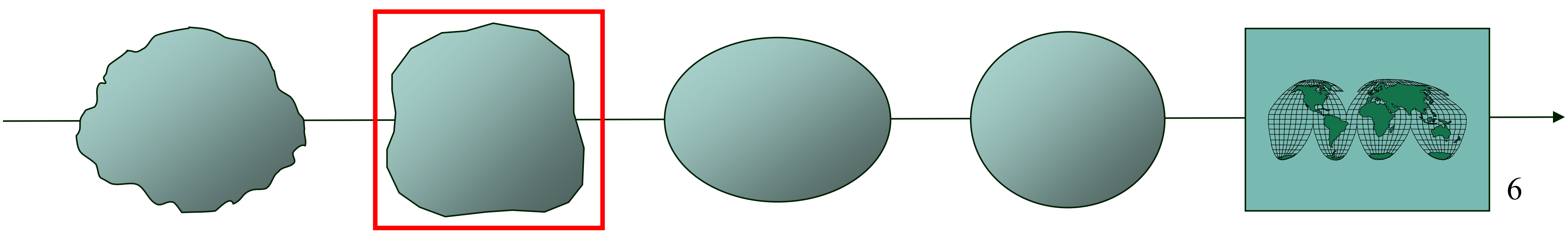
Semi-major axis is the equatorial radius

Semi-minor axis is polar radius and is parallel to the rotational axis of the earth



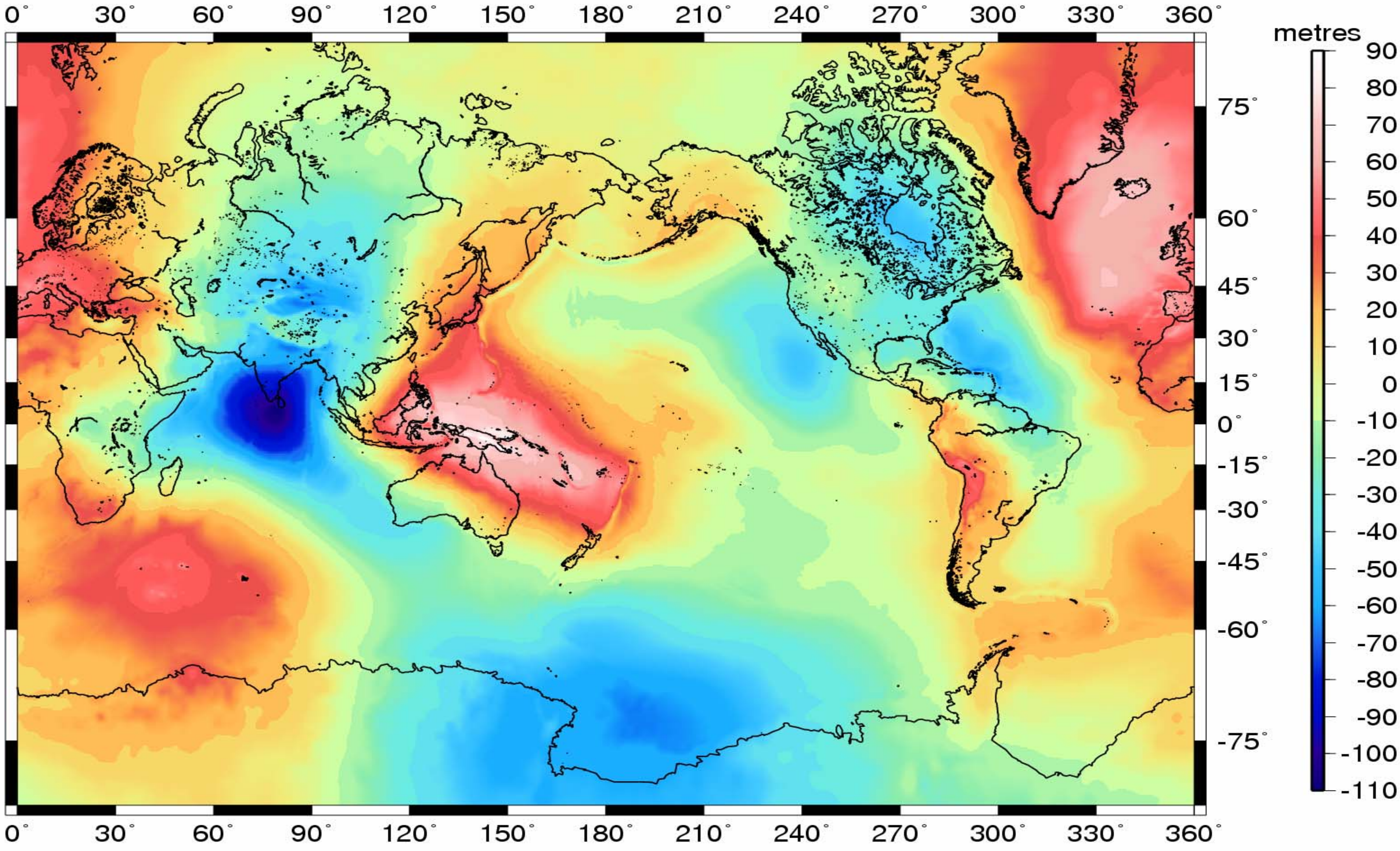
Ellipsoids and Geoids 2.3
The Geoidal Earth

- **The geoid is a level surface (equipotential surface) – mean sea level approximates this surface**
- **Variations in rock density and topography causes deviations up to 300 ft (100 m) in some locations**
- **Different than land or ocean bottom; doesn't necessarily correspond to land / water masses**
  - **highest point on geoid ≈ 75 m above ellipsoid (New Guinea)**
  - **Lowest point on the geoid ≈ 104 m below ellipsoid (south of India)**



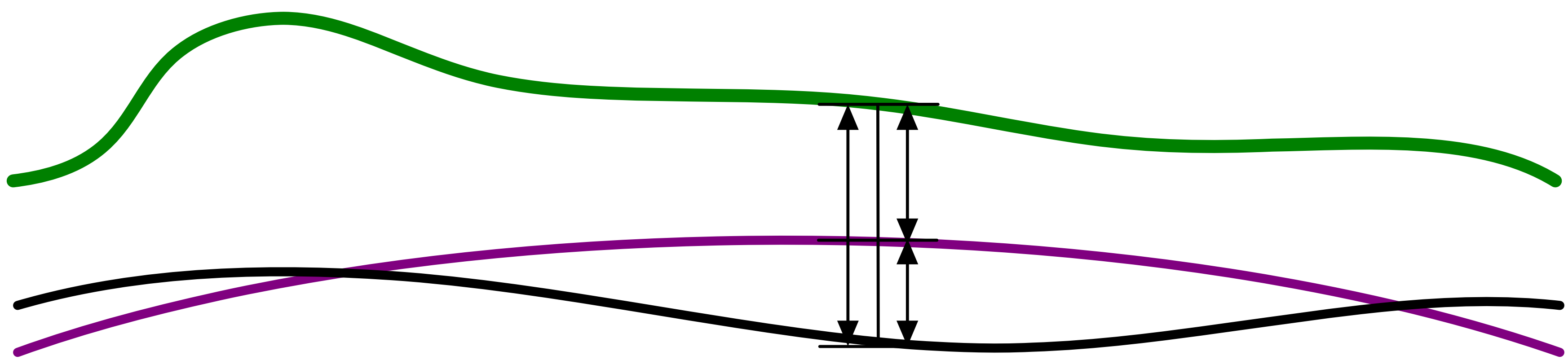
Ellipsoids and Geoids 2.4

EGM96 Global Geopotential Model

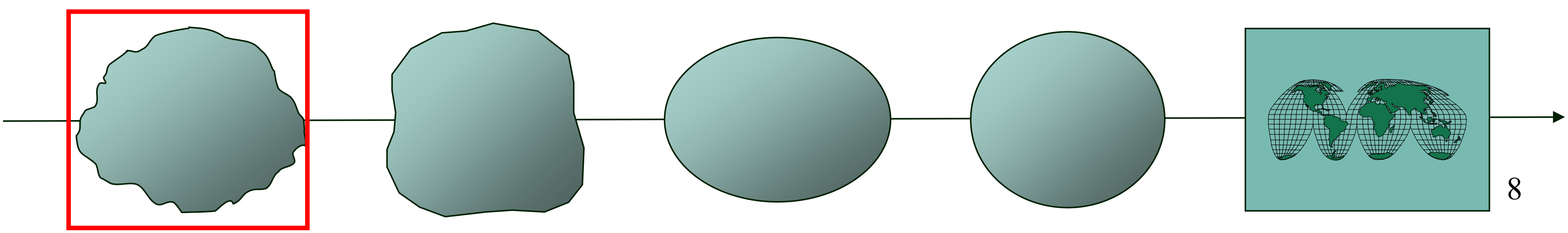


Ellipsoids and Geoids 2.5
Height Relationships

- **The geoid (*N*) models the difference between an equipotential surface and the ellipsoid**
  - **It approximates global MSL if all of the topography was removed**
  - **Heights are related by: $h = H + N$**
- **Ellipsoidal heights (h) are not always representative of fluid flows**
- **Orthometric heights (H) are related to gravity**



Note: in this case N < 0

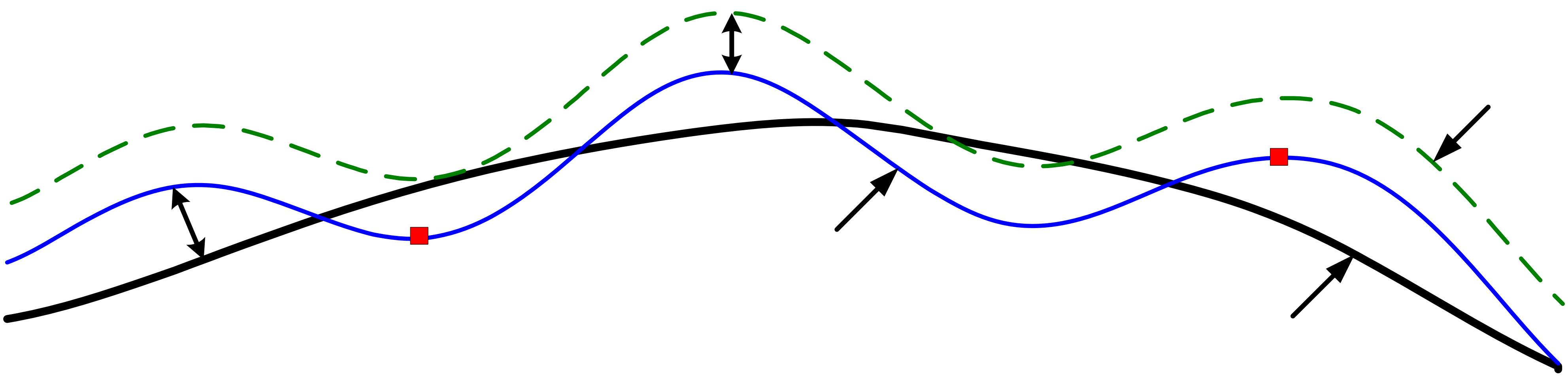


Terrain

Sea Level 3.1
Vertical Datum Relationships

The geoid approximates sea level but it is not the same

- **MSL affected by quasi-stationary sea surface topography and dynamic effects (tides, river flows etc)**
- **Vertical datums often related to sea level**

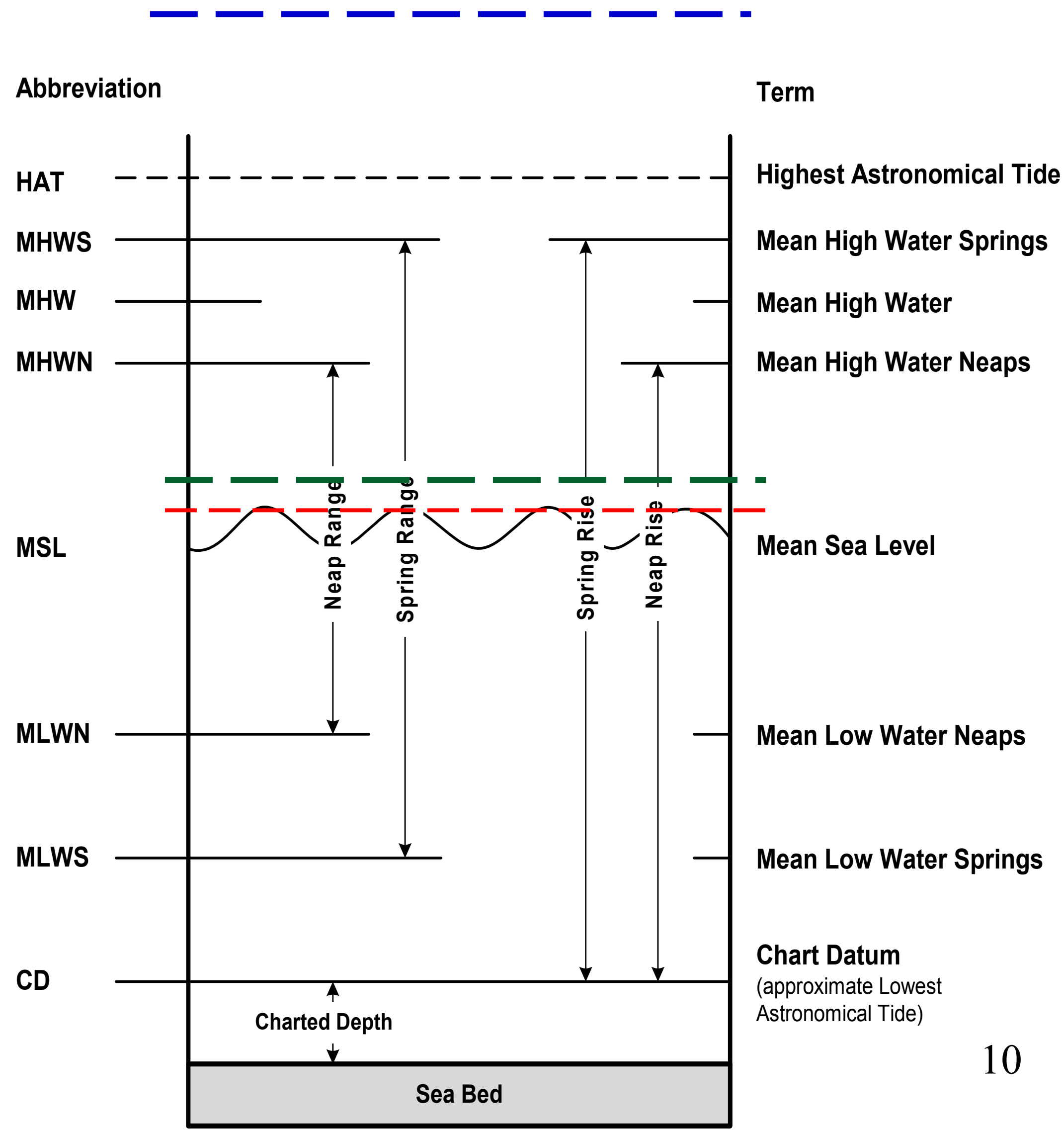


Sea Level 3.2
Which level?

- **Sea level derived height**
- **Geoid –** MSL approximates the geoid
- **Ellipsoid** – GPS derived heights (WGS84)
- **National vertical datums**

Which level

- GPS heights ≈ ≠ International datum
- WGS84 ≈ ≠ ITRF
- WGS84 ≠ Geoid
- Geoid ≈ ≠ MSL
- MSL ≈ ≠ a level surface
- MSL ≈ ≠ National vertical datum
- MSL ≈ ≠ Chart datum
- Chart datum ≈ ≠ a level surface
- Tidal range varies from place to place



DEPTHS IN METRES

SCALE 1:35000

Depths are in metres and are reduced to Chart Datum, which is approximately the level of Lowest Astronomical Tide.
Heights are in metres. Underlined figures are drying heights above Chart Datum; all other heights are above Mean High Water Springs.
Positions are referred to the WGS 84 compatible datum, European Terrestrial Reference System 1989 Datum (see SATELLITE-DERIVED POSITIONS note).
Navigational marks: IALA Maritime Buoyage System – Region A (Red to port).
Projection: Transverse Mercator.
Sources: The origin, scale, date and limits of the hydrographic information used to compile the chart are shown in the Source Diagram. Depths in upright figures are from older, smaller scale surveys. The topography is derived chiefly from Ordnance Survey maps.

Sea Level 3.4
Chart Datums: Warning

Typical Extract from chart legend:

- **"The differences between satellite-derived positions [i.e. WGS84] and positions on this chart cannot be determined;**
- **Mariners are warned that these differences MAY BE SIGNIFICANT TO NAVIGATION and are therefore advised to use alternative sources of positional information . . ."**

Datums 4.1
Introduction

Earth → Geoid → Reference Ellipsoid

Geoid: Serves as the datum for elevation data

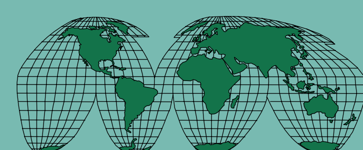
Reference Ellipsoid: Serves as the basis for geodetic and astronomic coordinates used by surveyors

Reference Sphere → (Mathematical transformation) → Plane → map projections

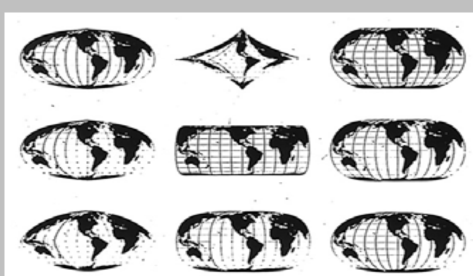
Reference Sphere: Produces the standard globe

Mathematical transformation

Plane



Produces planimetric maps

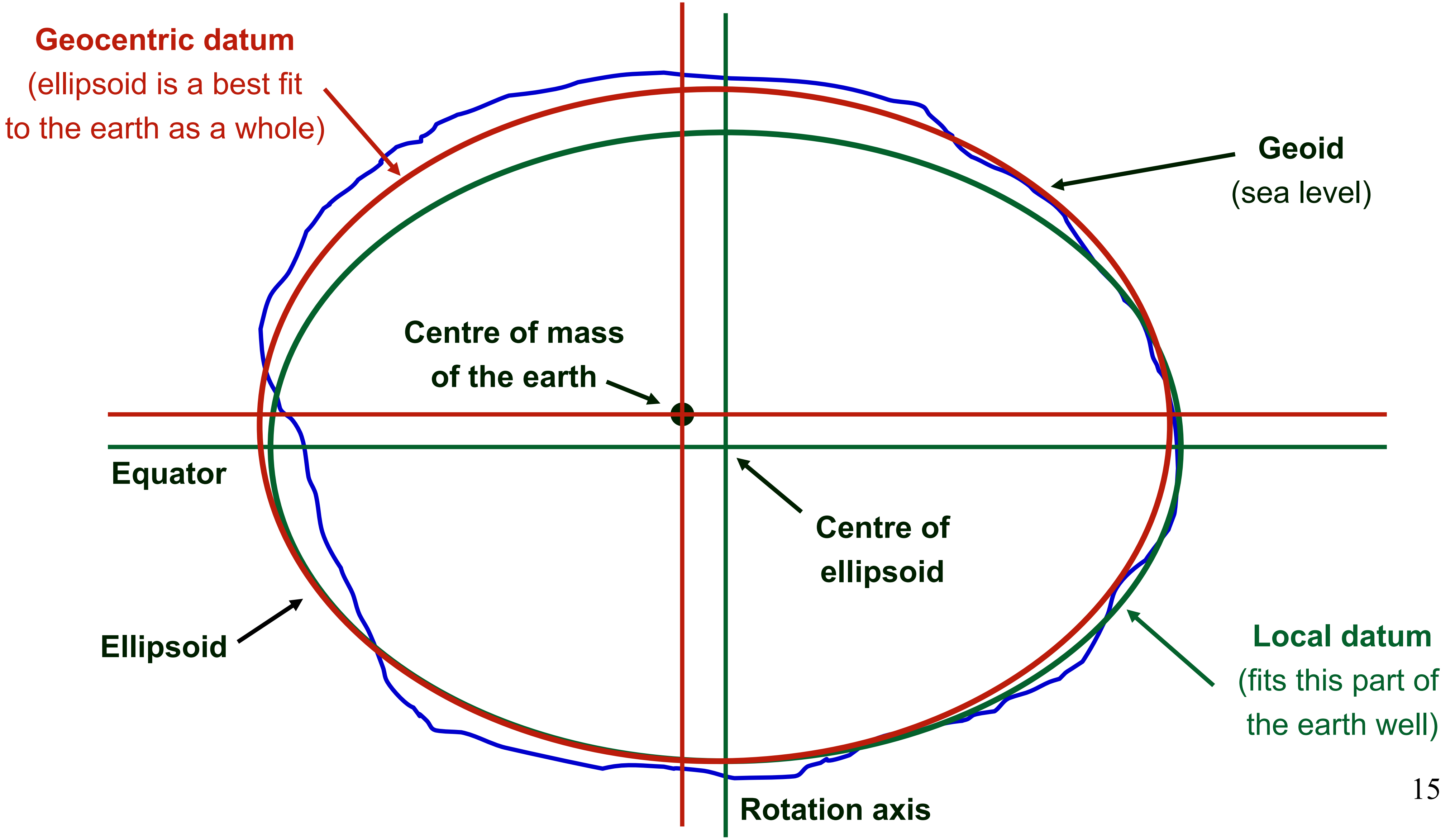


Produces new map projections

Datums 4.2
Definition

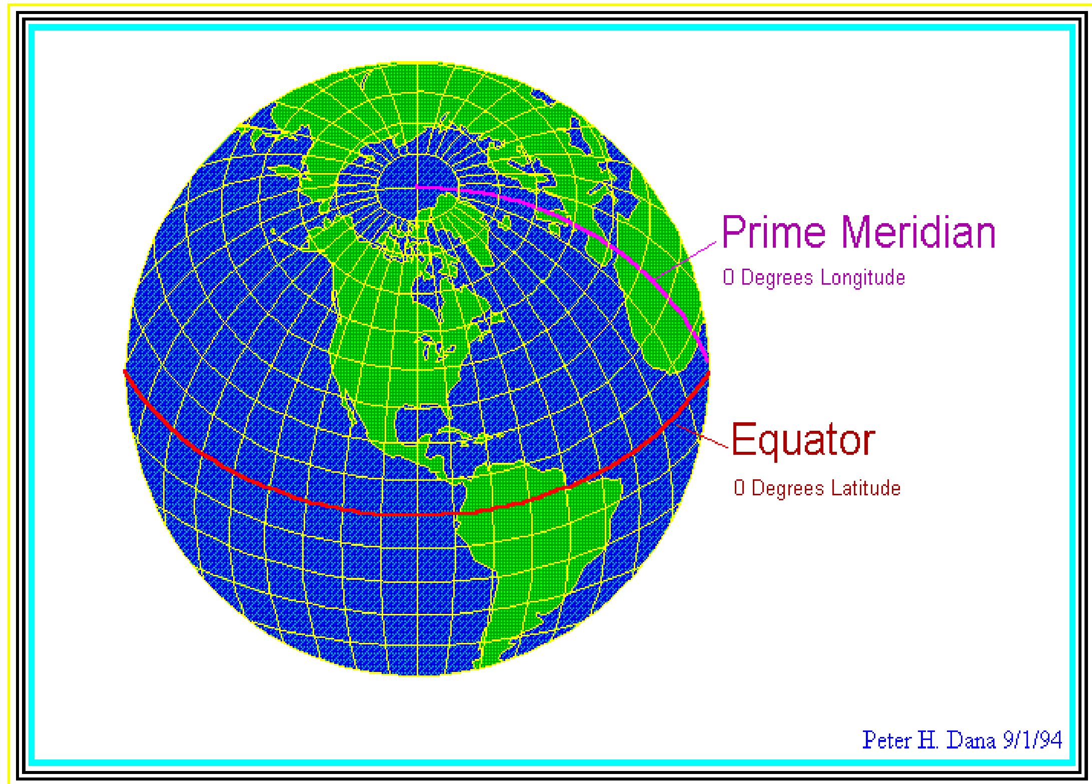
- **A mathematical model that describes the shape of the ellipsoid**
- **Can be described as a reference mapping surface**
- **Defines the size and shape of the earth and the origin and orientation of the coordinate system used.**
- **There are datums for different parts of the earth based on different measurements**
- **Different datums often apply to the same part of the earth**
- **Datums are the basis for coordinate systems**

Datums 4.3
Local and Geocentric Datums



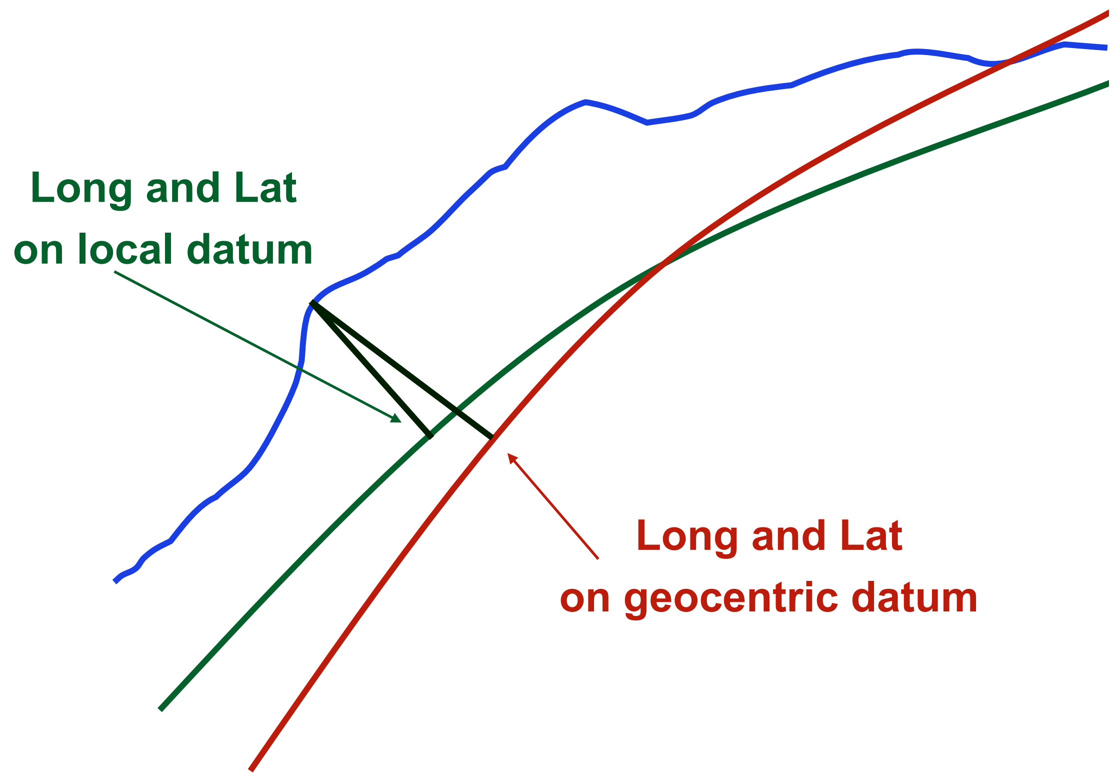
Datums 4.4
Geographic Coordinate Systems

- Defines locations on a spherical surface.
- A feature is referenced by its longitude and latitude values.
- Longitude and latitude are angles measured from the Earth's center to a point on the Earth's surface.
- Latitudes measured relative to the Equator (-90° to +90°)
- Longitudes measured relative to the Prime Meridian



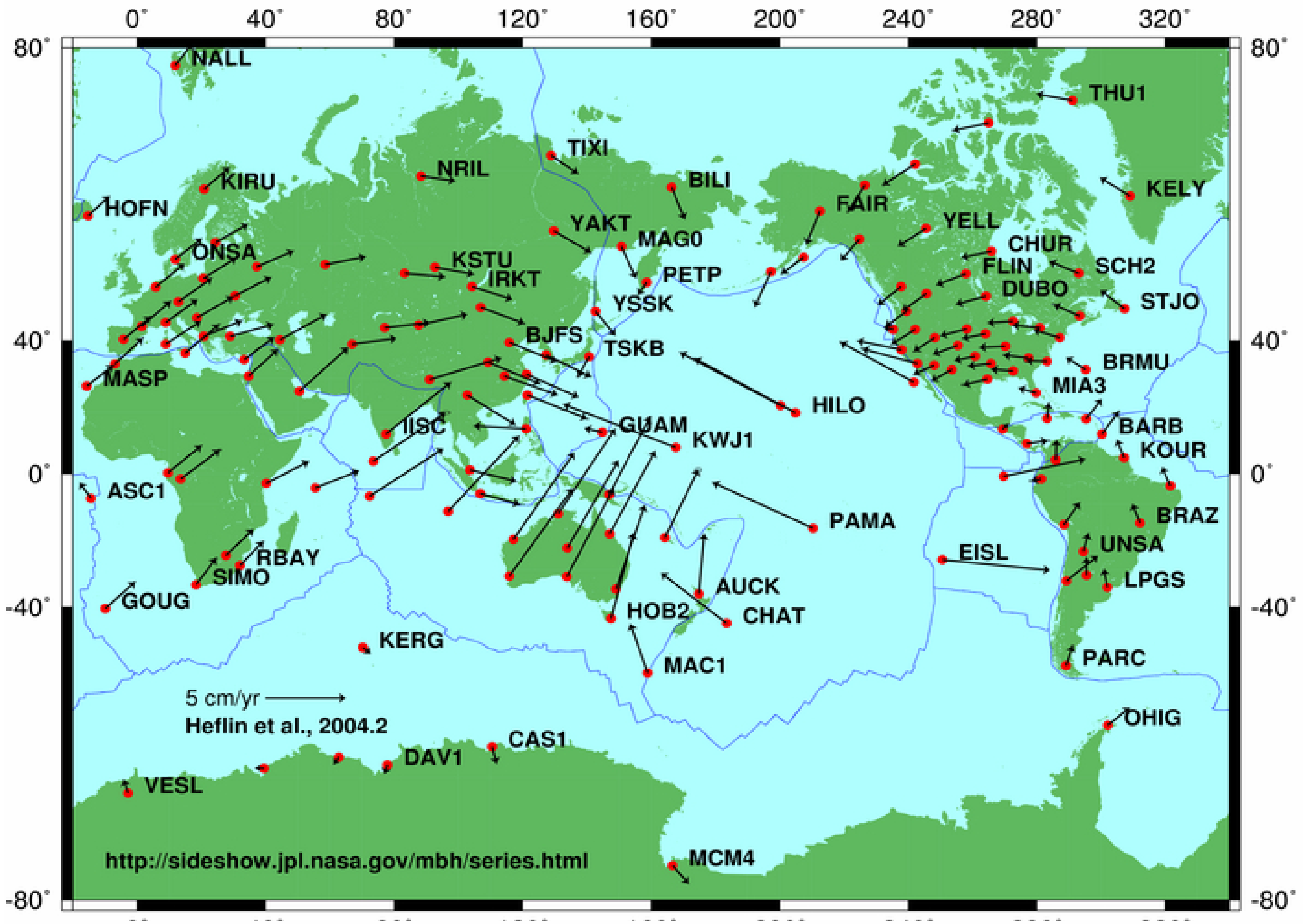
Datums 4.5
Different Longs and Lats

- **Different datums may result in different latitudes and longitudes**
- **With international boundaries it is CRUCIAL to specify the datum**
- **Transformation parameters between datums are usually determined by:**
  - **3 parameter**
  - **7 parameter**
  - **grid file**



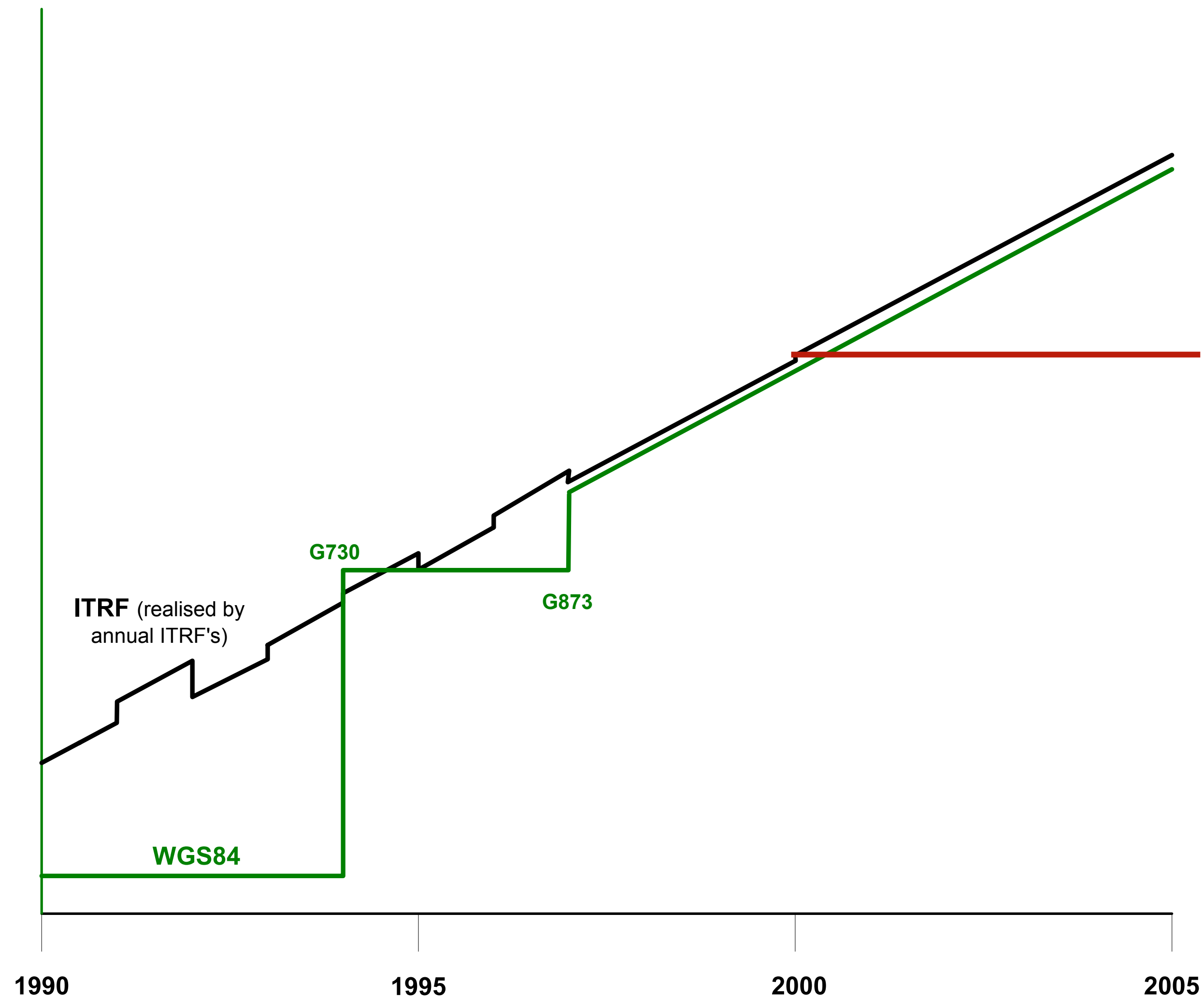
Datums 4.6

The Effect of Plate Tectonics – Site Velocities

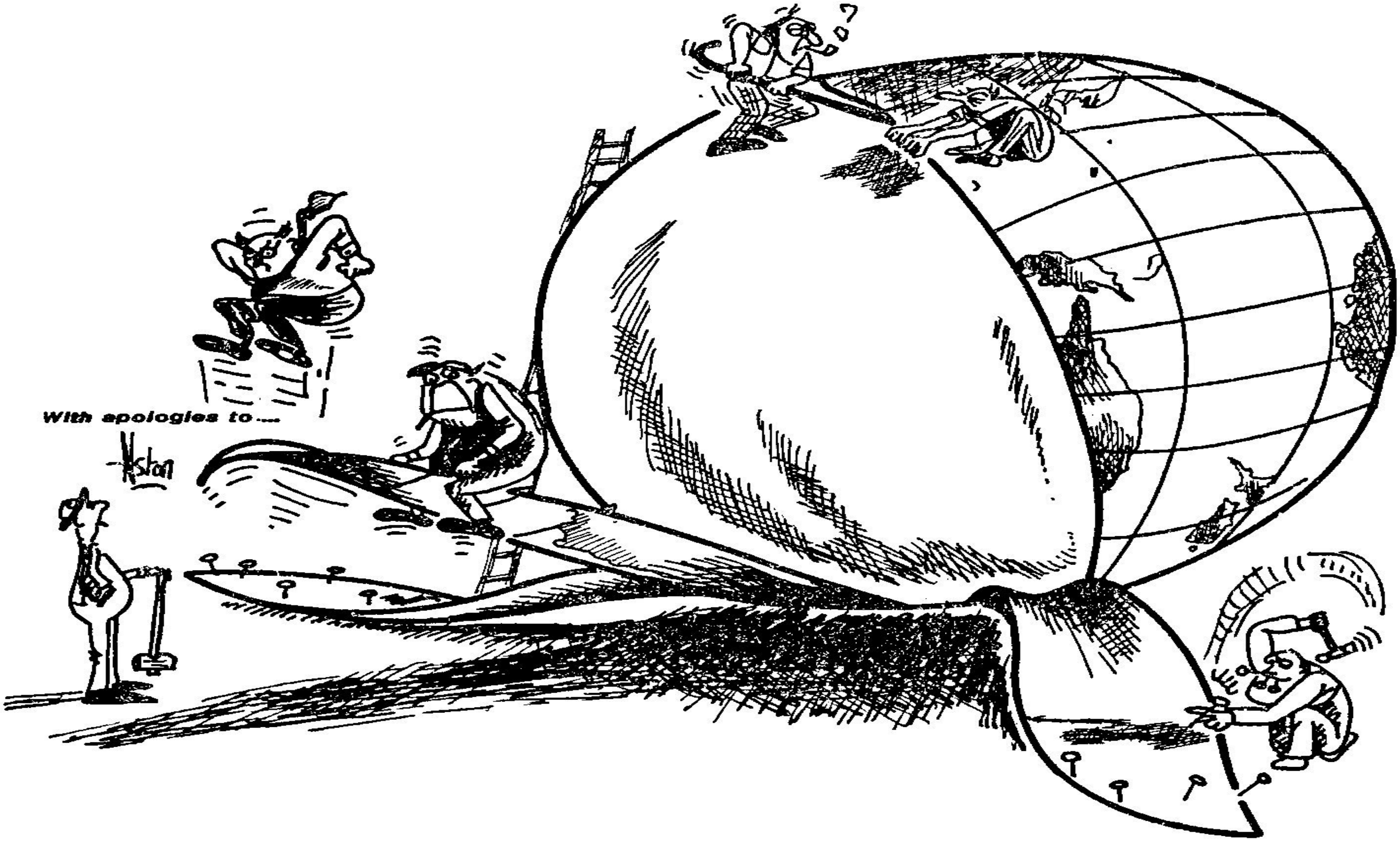


Datums 4.7
A Word of Warning

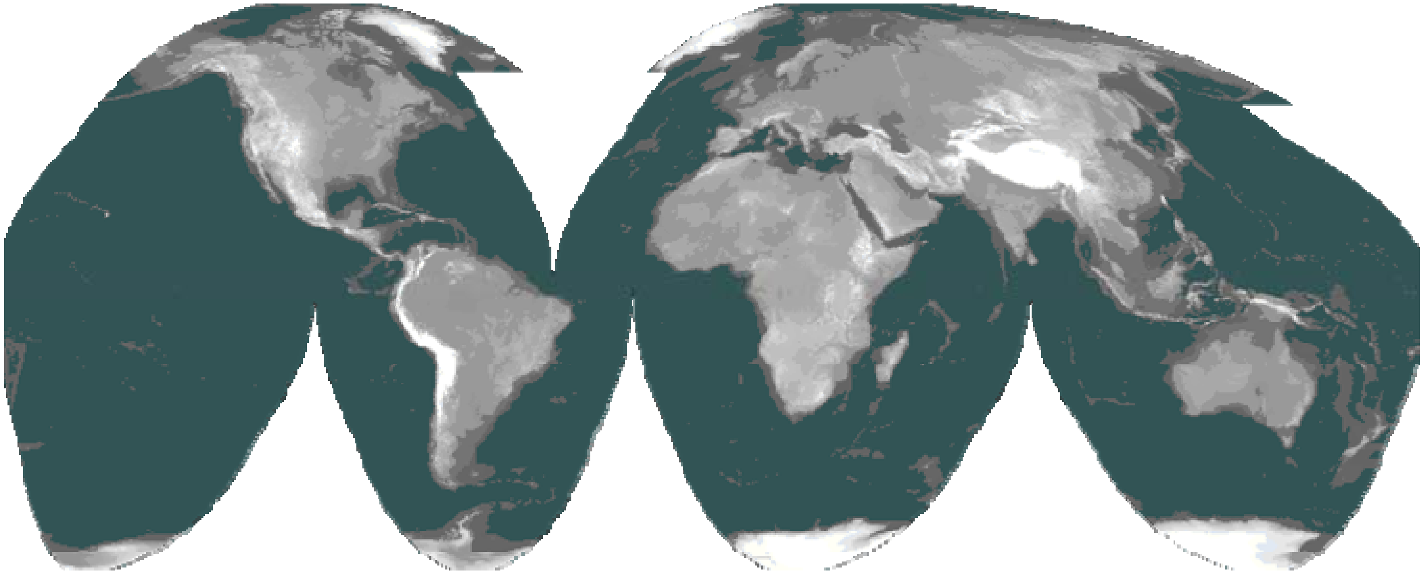
- International Datums
  - WGS84
  - ITRS (ITRF)
- WGS84 ≠ ITRS
- Fixed datums



Projections 5.1



How to fit a globe onto a 2-dimensional surface



Projections 5.3
Introduction

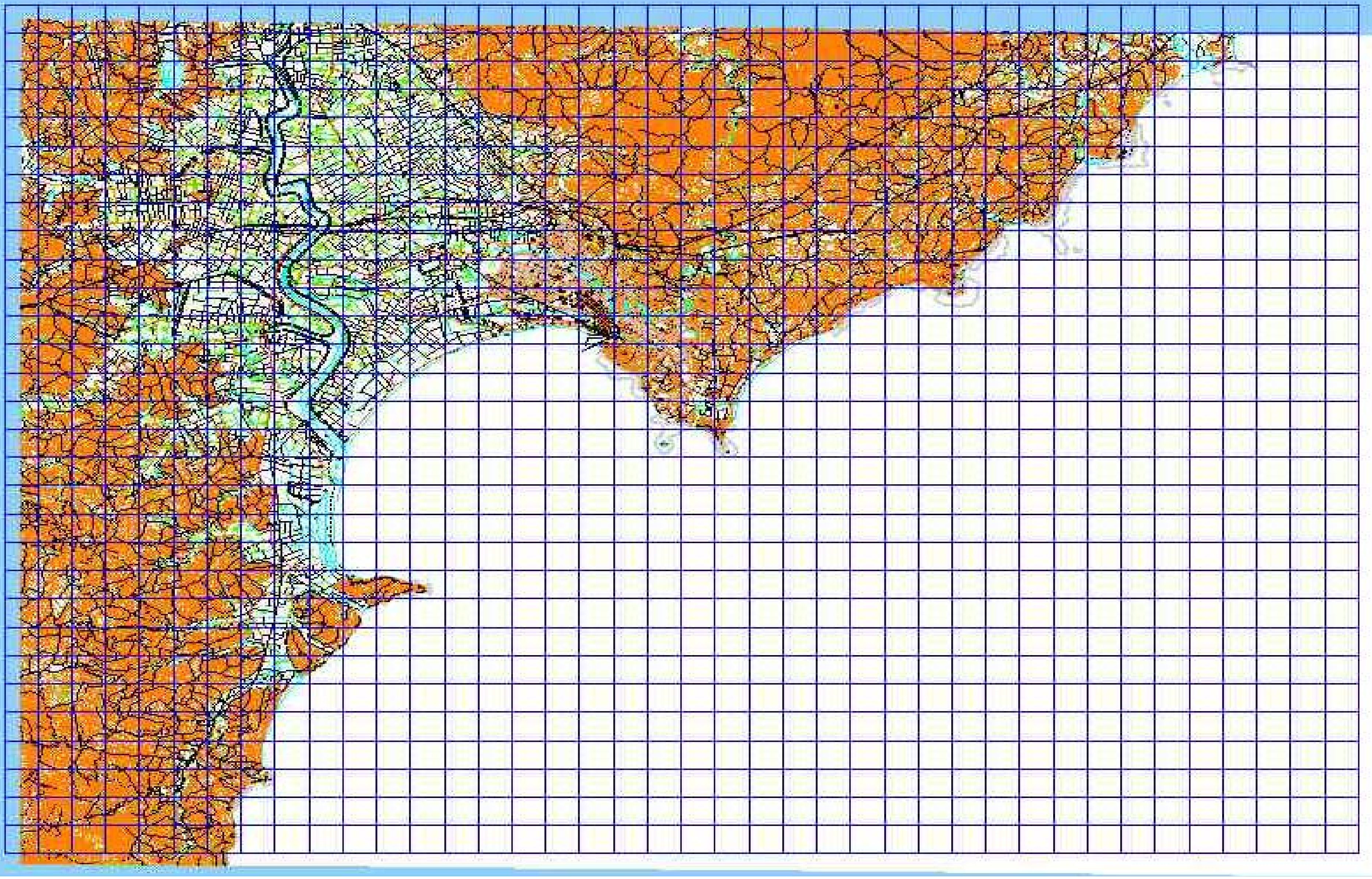
- **Method of representing data located on a curved surface (datum) onto a flat plane**
- **All projections involve some degree of distortion of:**
  - **Distance**
  - **Direction**
  - **Scale**
  - **Area**
  - **Shape**
- **Determine which parameter is important**

Projections 5.4
Introduction

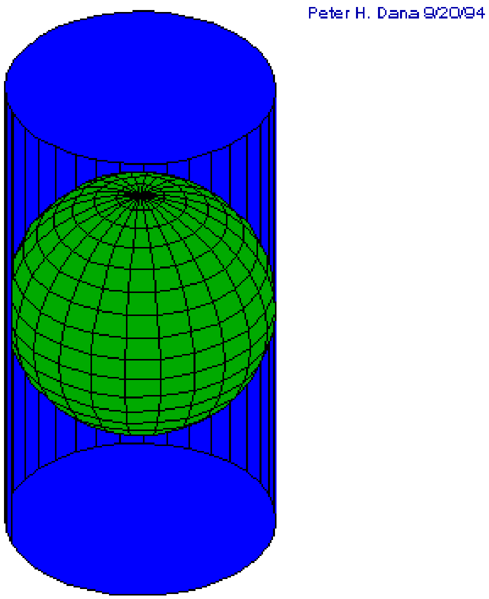
- A Projection is referenced to a datum but a datum is not referenced to a projection
- Projections can be used with different datums
- The same projection with a different datum gives different coordinates for the same place
- The same datum with a different projection gives different coordinates
- To transform from one projection to another

  projection 1 → datum 1 → datum 2 → projection 2

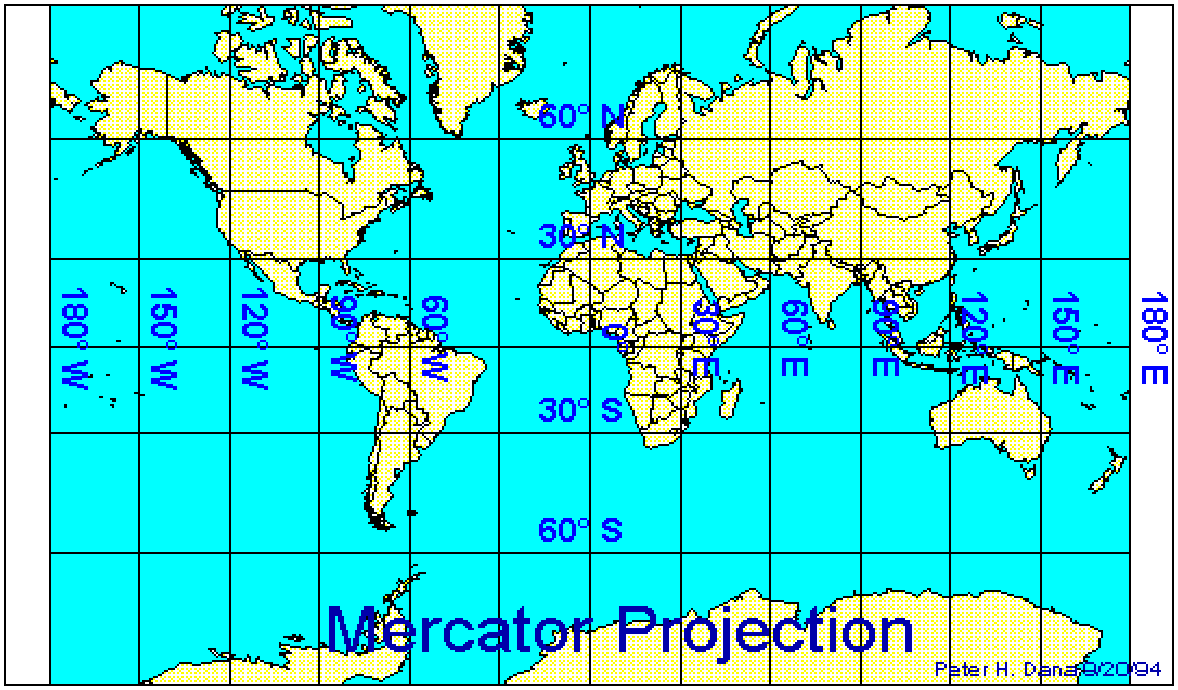
Projections 5.5
Different Datum – Different Grid



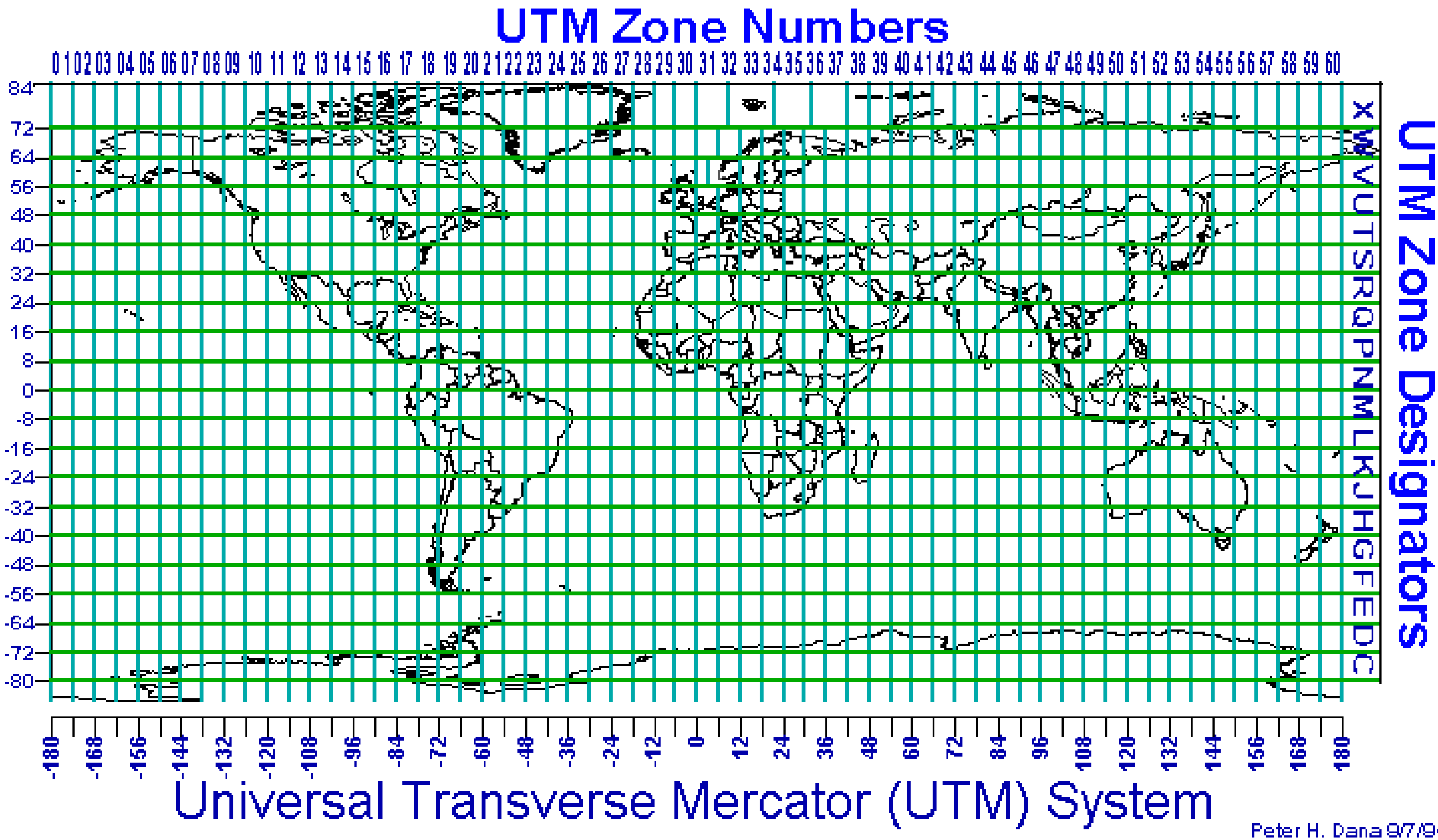
- **Mercator, Transverse Mercator**



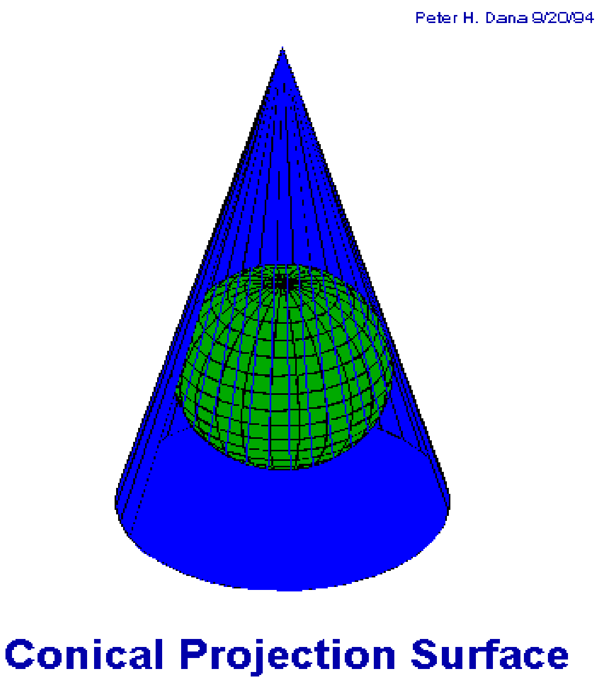
Cylindrical Projection Surface

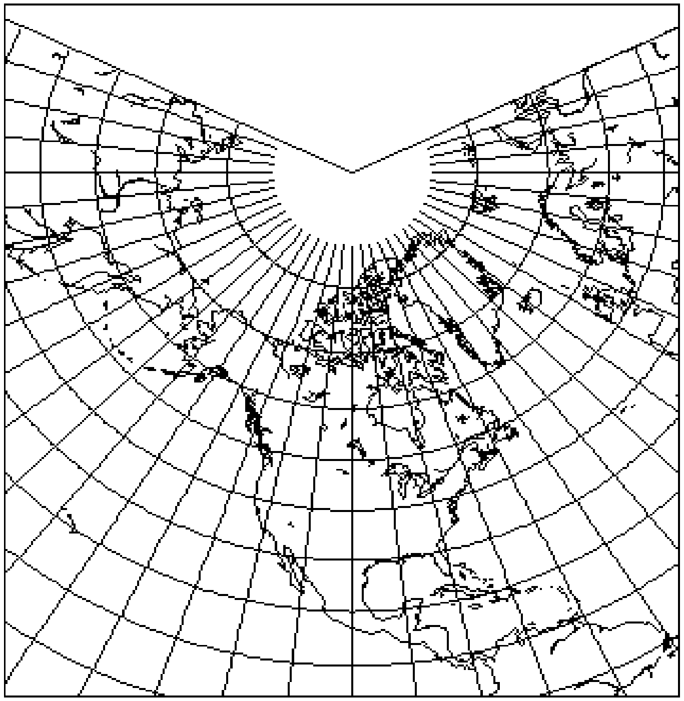


Projections 5.7
Universal Transverse Mercator



- **Lambert Conformal Conic**

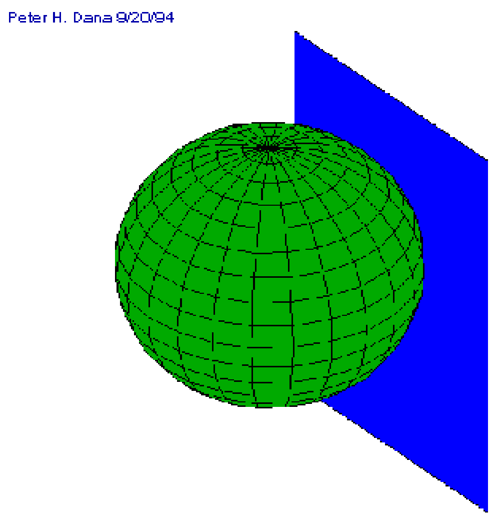




Standard parallel 40°N latitude, northern USA

Projections 5.9

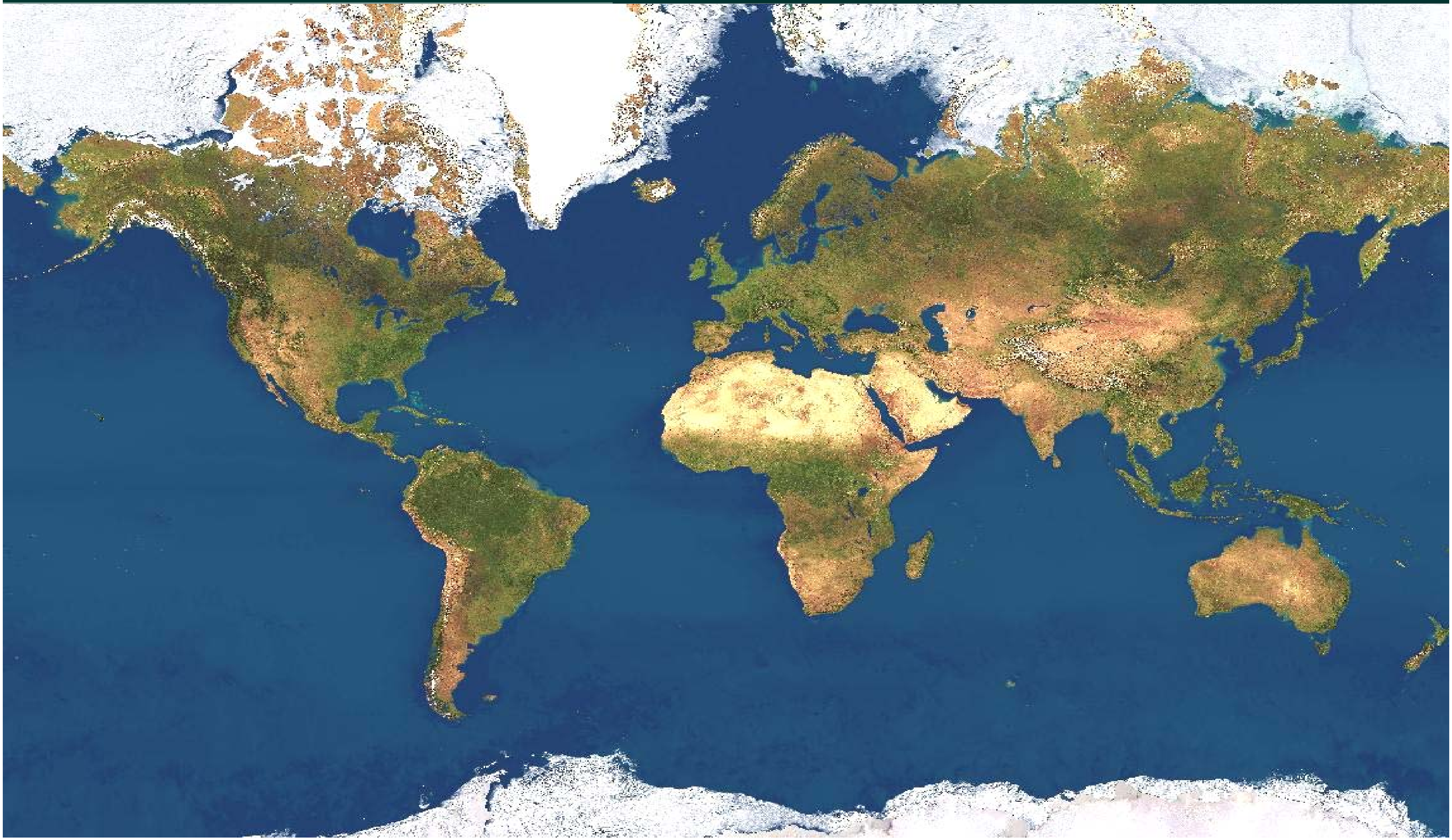
Planar



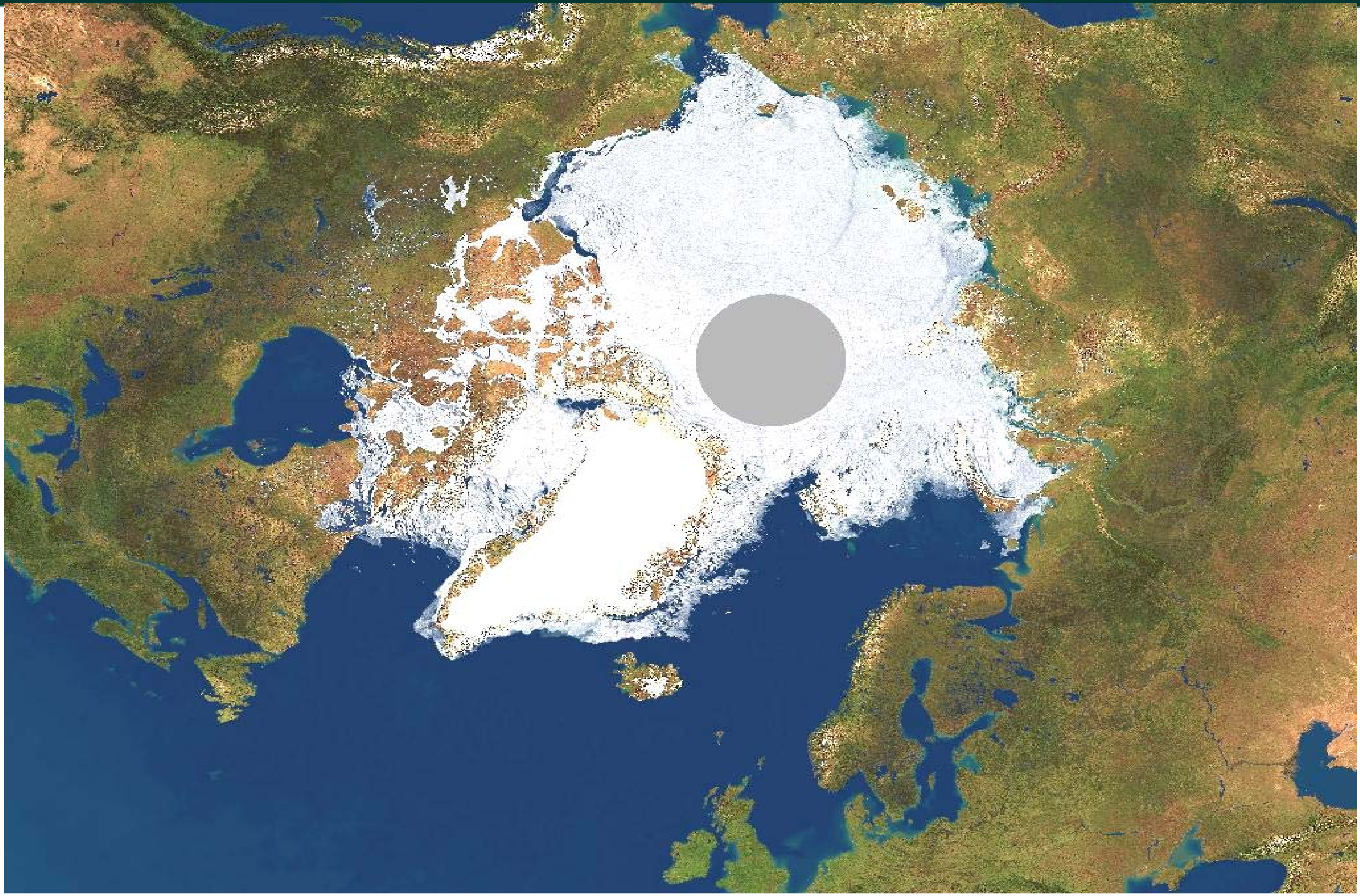
Planar Projection Surface

N & S America gnomonic projection
(Image from geocities.com)

Projections 5.10
Mercator



Projections 5.11
Polar Stereographic



When are straight lines not straight lines

- **Geodesic – shortest distance between two points – on the ellipsoid (approximates to great circle)**

- **Loxodrome (or rhumb line) – line of constant bearing.**
  - Line crossing all meridians at the same angle
  - Straight on Mercator projection

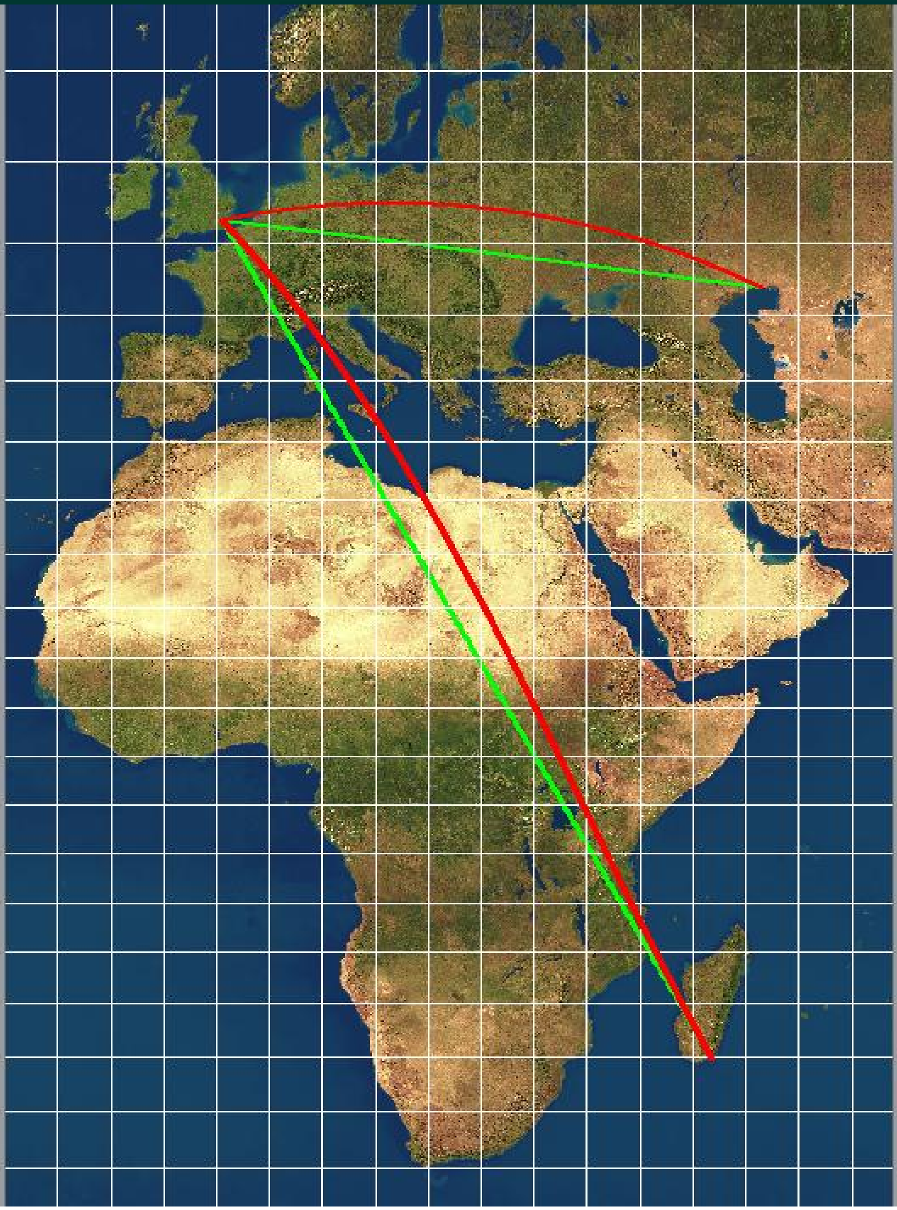
Geodesics and Loxodromes 6.2
Mercator

Loxodrome

Mercator

Loxodrome (plot as straight lines)

Geodesic

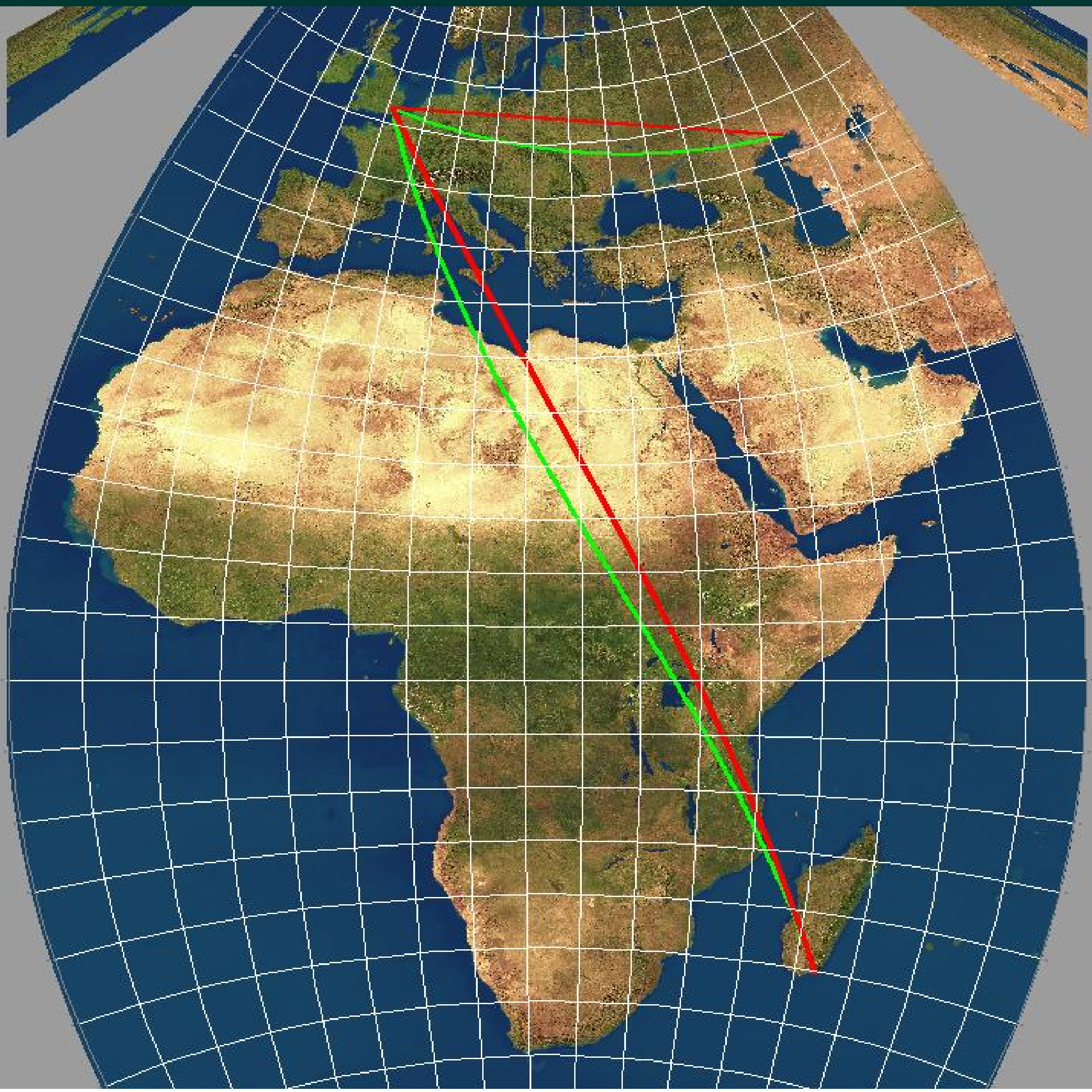


Geodesics and Loxodromes 6.4

Transverse Mercator

Loxodrome

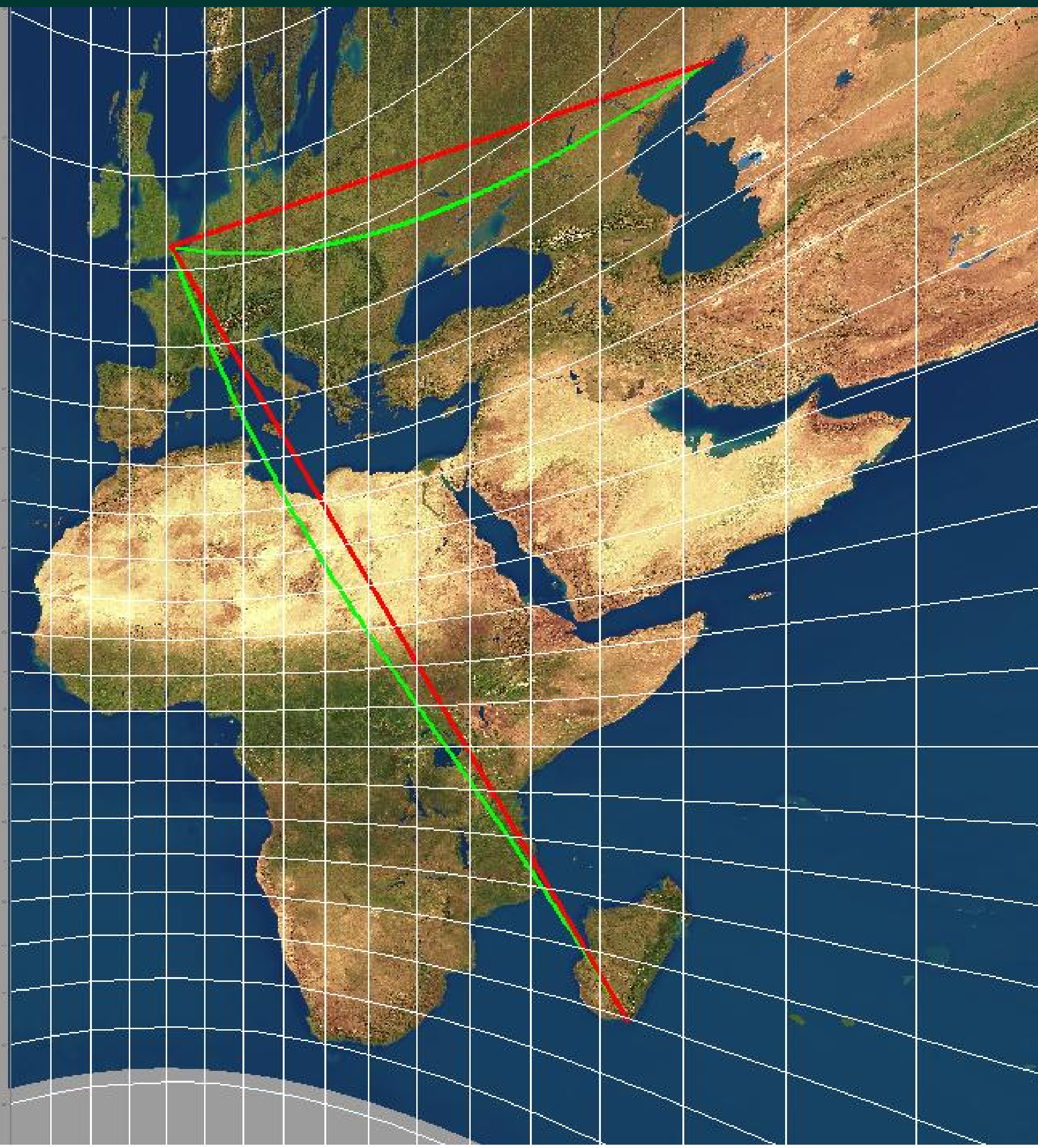
Geodesic



Geodesics and Loxodromes 6.5
Gnomic (planar)

Loxodrome

Geodesic (plot as straight lines)



Important Points to Remember

- The Earth
  - is like an orange
  - the geoid approximates sea level but it is not the same – a level surface
- Vertical datums
  - can be based on many surfaces
  - not all surfaces are level
- 2D and 3D datums
  - different datums may result in different latitudes and longitudes
  - with international boundaries it is CRUCIAL to specify the datum
- Projections
  - projections can be used with different datums
  - the same projection with a different datum gives different coordinates for the same place
  - the same datum with a different projection gives different coordinates
- Geodesics and Loxodromes
  - straight lines do not always plot as straight lines

Acknowledgements

This presentation is made up of data from many sources. The author would like to thank Robin Cleverly and Matt Amos for making material available.