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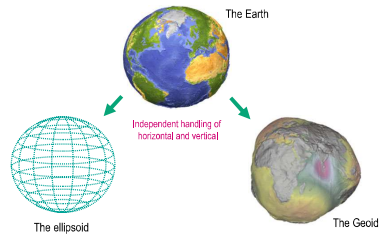
Lesson 6: SPATIAL REFERENCE SYSTEMS

Textbook 3.1

RICHARD KNIPPERS

REFERENCE SURFACES FOR MAPPING



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  - The Geoid - vertical datum
  - The Ellipsoid - horizontal datum
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  - Universal Transverse Mercator (UTM) projection
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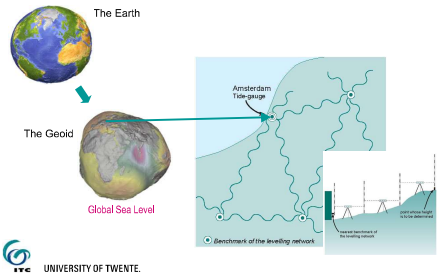
  - Projection change
  - 3D Datum transformations
  - 2D Cartesian transformations

THE GEOID - VERTICAL (HEIGHT) DATUM

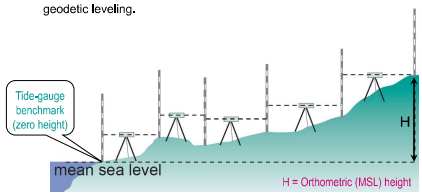


1

2

GEODETIC LEVELLING

- Starting from Mean Sea Level (MSL) points, the orthometric heights (H) of points on the Earth can be measured using a technique known as geodetic leveling.



AT WHAT HEIGHT DO WE LIVE? http://www.ahn.nl/postcodetool

Average height is 37.5 m above Amsterdam Zero (N.A.P.)

DIFFERENCES IN VERTICAL DATUM SYSTEMS

- Every country (or group of countries) has it's own Mean Sea Level - its own local vertical (height) datum.

MSL of Belgium is 2.34m lower than MSL of The Netherlands

GPS HEIGHT VERSUS N.A.P. HEIGHT

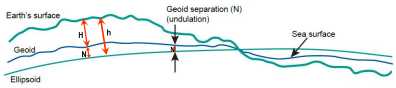
H_{NAP} = 107.5m (h_{WGS84}) - 43.6m (N) - 26.4m (ITC building) = 37.5m

Ellipsoid height | Geoid undulation(N) | Building height | Orthometric (MSL) height

3

4

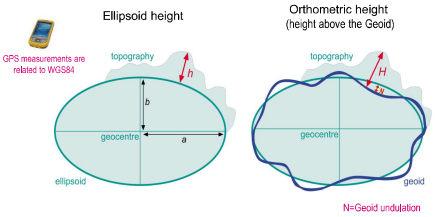
RELATION BETWEEN GEOID AND ELLIPSOID



H = Orthometric height (MSL height)
h = Ellipsoidal height
N = Geoid undulation (separation)
selisih antara ketinggian dari ellipsoid dan dan geoid

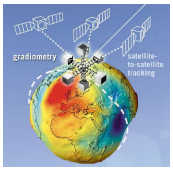
The Geoid will rise above or below the ellipsoid. The differences (geoid undulation (N)) globally vary between +/- 110 meters.

ELLIPSOID HEIGHT VERSUS ORTHOMETRIC HEIGHT



TRENDS IN MAPPING: GLOBAL VERTICAL DATUMS

- Global height datums (e.g. EGM2008, GGM02) can be determined with centimetres accuracy by satellites (e.g. GOCE, GRACE) that measure the earth's gravity.



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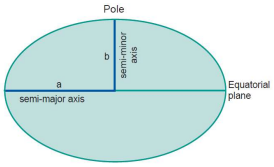
THE ELLIPSOID



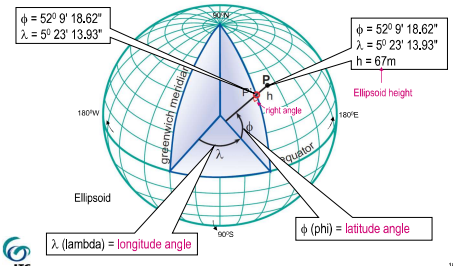
Typical values of the parameters for an ellipsoid:

a = 6378137.0m b = 6356752.31m

f = 1/298.26 e = 0.0818187

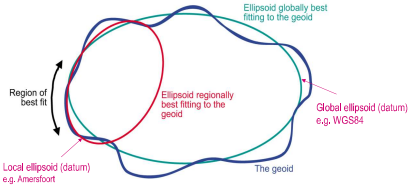
Flattening: f = (a-b)/a Eccentricity: $e^2 = (a^2 - b^2)/a^2$

GEOGRAPHIC COORDINATE SYSTEM



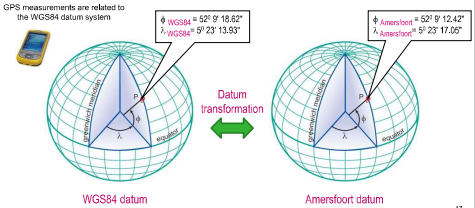
HORIZONTAL DATUM SYSTEMS

- There are many different ellipsoids defined. Each of them may have a different position and orientation to fit a particular region on earth (often a country). They are called horizontal datums (or geodetic datums).

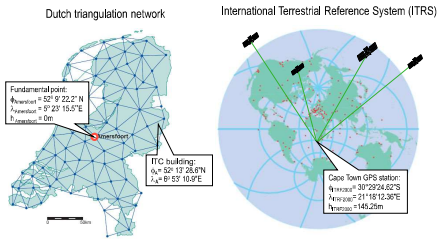


GEOGRAPHIC COORDINATE SYSTEMS

- The differences in geographic coordinates of one location can be up to several hundreds of meters (several seconds) depending on the used datum system.



LOCAL DATUM SYSTEMS VS GLOBAL DATUM SYSTEMS

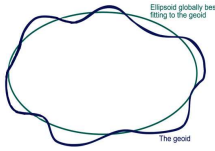


Local Geodetic datum
e.g. Amersfoort

Global Geodetic Datum
e.g. ITRF2000, ITRF2014, WGS84

TRENDS IN MAPPING: GLOBAL HORIZONTAL DATUMS

- Global ellipsoids and datums to approximate the earth-as-a-whole -with the aid of satellites- are becoming more in use (WGS84, ITRF2008, ETRS89, and others).
- Many countries use global datum systems to align and refine their local datum systems, making them suitable for data exchange and various geospatial applications.



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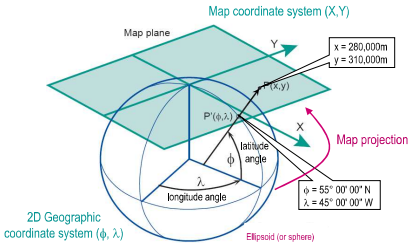
MAP PROJECTION PRINCIPLE



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MAP PROJECTION EQUATIONS (EXAMPLE)

- The equations for the Mercator projection (spherical assumption)

Forward mapping equation:

$$x = R(\lambda - \lambda_0)$$

$$y = R(ln(tan(\frac{\pi}{4} + \frac{\phi}{2})))$$

Earth radius, Central Meridian, Longitude angle, Latitude angle

Inverse mapping equation:

$$\phi = \frac{\pi}{2} - 2\arctan(e^{-\frac{y}{R}})$$

$$\lambda = \frac{x}{R} + \lambda_0$$

Y-coordinate, X-coordinate

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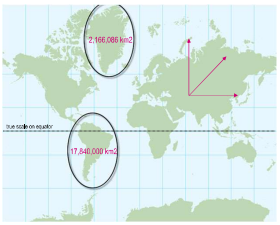
https://www.youtube.com/watch?v=vVX-PrBRtTY

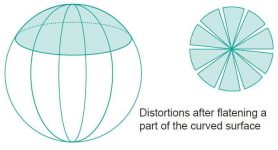
SCALE DISTORTIONS ON MERCATOR PROJECTION



Area distortions are significant towards the polar regions. Greenland appears to be larger but is only one-eighth the size of South America. Angles and shapes are correctly represented (conformal distortion property)

SCALE DISTORTIONS ON MAPS

- Any map projection is associated with scale distortions. The amount and which kind of distortions a map will have depends largely - next to size of the area being mapped - on the type of the map projection that has been selected.



Distortions after flatening a part of the curved surface

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DISTORTION PROPERTIES OF MAP PROJECTIONS

- Conformal mercator

Angles (with short sides) and shapes (of small areas) are shown correctly on the map.for example : road cross

- Equivalent (or equal-area)

Areas are correctly represented on the map.

- Equidistant

Distances from 1 or 2 points or along certain lines are correctly represented on the map.

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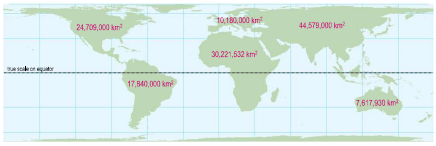
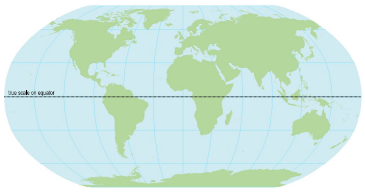
CYLINDRICAL EQUAL-AREA PROJECTION



Areas are correctly represented. Distortions of angles and consequently shapes are significant towards the poles

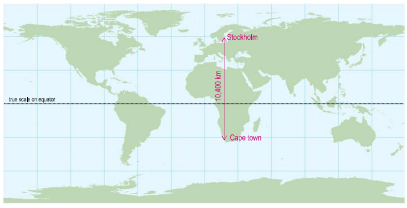
shape distortions

ROBINSON (Pseudo-cylindrical projection)



Neither conformal nor equal-area (both shape and area are reasonably well preserved)

EQUIDISTANT CYLINDRICAL PROJECTION (Plate Carrée)



Equidistant (true scale) along the meridians.
Reasonable area and angle distortions.

along equator is true, but if along from north to south it's not true

SELECTION OF A SUITABLE DISTORTION PROPERTY

- Conformal property

Maps which require measuring angles (e.g. aeronautical charts or topographic maps)

- Equivalent (or equal-area) property

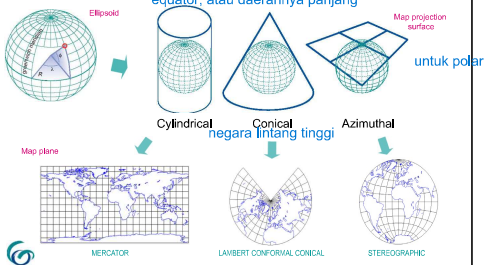
Maps which require measuring areas (e.g. thematic or distribution maps)

- Equidistant property

Maps which require reasonable area and angle distortions (e.g. thematic or presentation maps)

CLASSES OF MAP PROJECTIONS

equator, atau daerahnya panjang



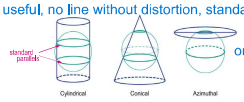
untuk polar

negara lintang tinggi

CLASSIFICATION OF MAP PROJECTIONS

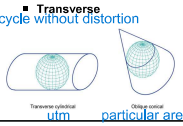
- Class
  - **Cylindrical**
  - **Conical**
  - **Azimuthal**
- Secant or tangent projection plane
- Property
  - **Equivalent (or equal-area)**
  - **Equidistant**
  - **Conformal**
  - ***Minimum-error***
- Aspect (orientation)
  - **Normal**
  - **Oblique**
  - **Transverse**

useful, no line without distortion, standard parallel



one cycle without distortion

2 line without distortion

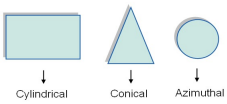


utm

particular area

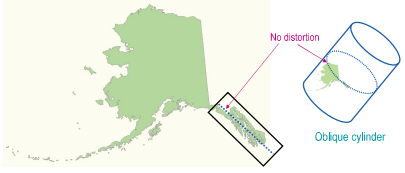
SELECTION OF A SUITABLE PROJECTION CLASS

- Normal cylindrical projections are typically used to map the World in its entirety. Conical projections are often used to map the different continents and mid-latitudes, whereas the normal azimuthal projection may be used to map the polar areas.
- Also consider the shape of the area to be mapped:



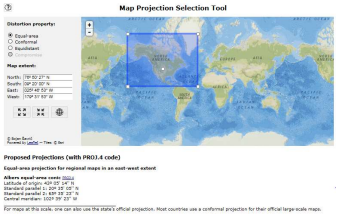
SELECTION OF A SUITABLE ASPECT

- The position (and orientation) of the projection plane is optimal when the projection plane is located along the main axis of the area to be mapped, or when the projection centre coincides with centre of the area.



MAP PROJECTION SELECTION TOOL

- The interactive Map Projection Selection Tool can help to select a map projection that is optimized for the geographical area and the map format.



http://projectionwizard.org

MAP COORDINATE SYSTEM OF THE NETHERLANDS IN QGIS

Dutch coordinate system

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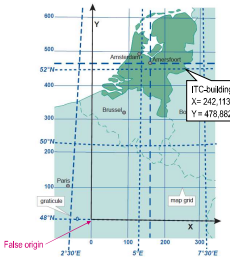
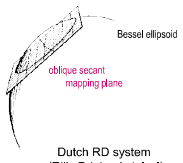
MAP COORDINATE SYSTEM OF THE NETHERLANDS



Projection: Stereographic
Geodetic datum: Amersfoort (Bessel ellipsoid)



Dutch RD system (RijksDriehoekstelsel)

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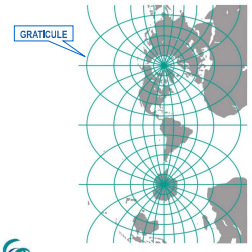
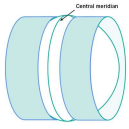
TRANSVERSE MERCATOR PROJECTION





Conformal Cylindrical (transverse secant) projection

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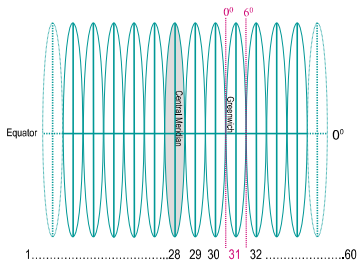
UTM GRID ZONE NUMBERING SYSTEM



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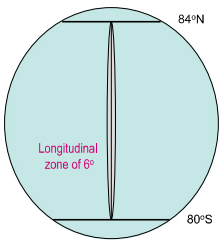
UTM GRID ZONES



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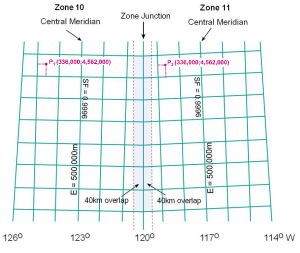
UTM GRID ZONE SYSTEM



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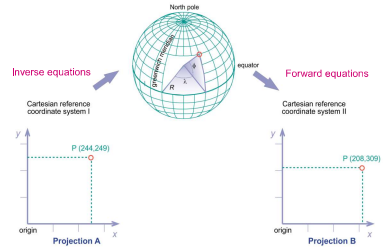
SHORT BREAK

5 MINUTES!

FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

MAP PROJECTION CHANGE



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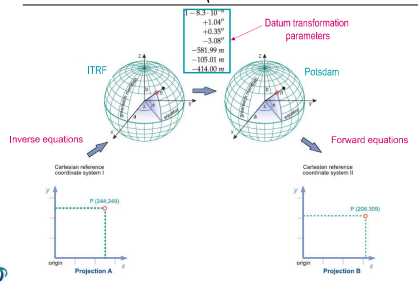
MAP PROJECTION CHANGE (INCL. DATUM TRANSFORMATION)



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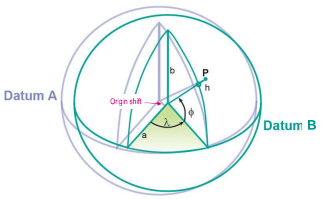
SHIFTS OF DATUMS



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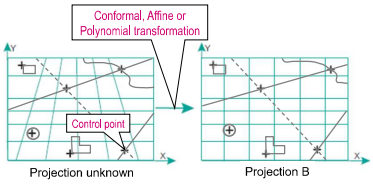
PROJECTION CHANGE VIA 2D CARTESIAN TRANSFORMATIONS



The unknown coordinate system is related to a known coordinate system based on a set of known points

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OVERVIEW OF COORDINATE TRANSFORMATIONS

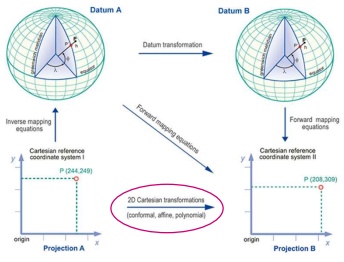

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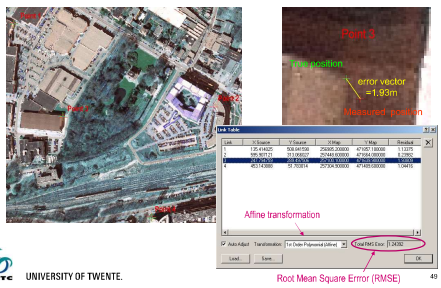
IMAGE RECTIFICATION

APPLICATION OF 2D CARTESIAN TRANSFORMATIONS



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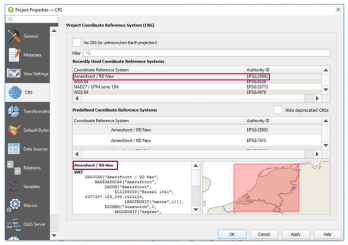
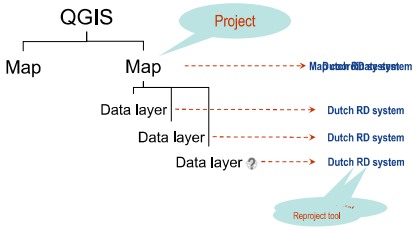
QGIS AND COORDINATE SYSTEMS
PROJECT COORDINATE REFERENCE SYSTEM



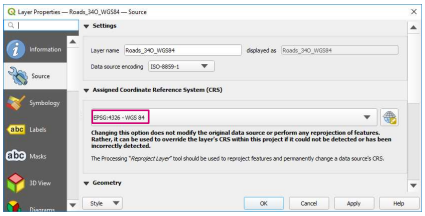
The coordinate system of the Project (map display)

EPSG:28992

QGIS AND COORDINATE SYSTEMS
ON-THE-FLY COORDINATE TRANSFORMATION



QGIS AND COORDINATE SYSTEMS
DATA LAYER



The coordinate system of a data layer may differ from the coordinate system of the project

MORE INFORMATION

http://kartoweb.itc.nl/geometrics

Thank you!

Post your questions in the discussion board!