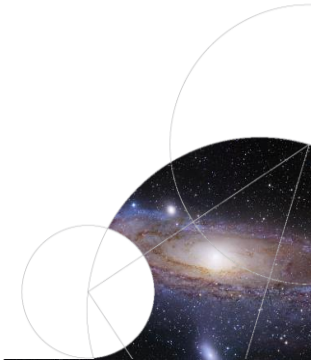
# Projection and transformations

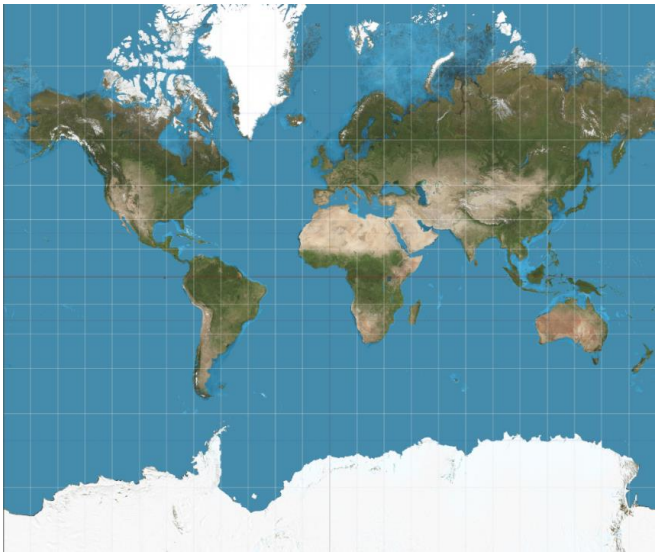
## Introduction to GIS



**Hans Skov-Petersen (hsp@ign.ku.dk)**

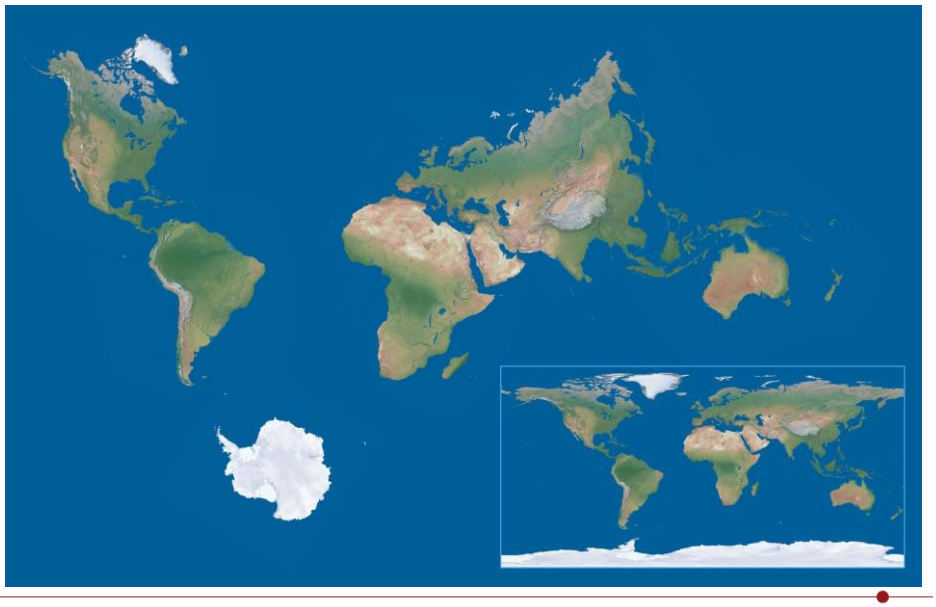


## Which has the largest area? Greenland or Africa?

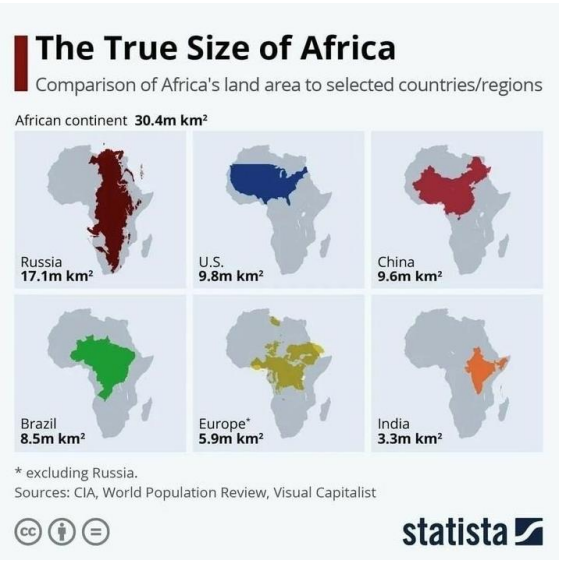


**Area proportions adjusted.**

Source:








https://www.facebook.com/SimonGerman600/photos/a.532428753835562/1346284192450010/

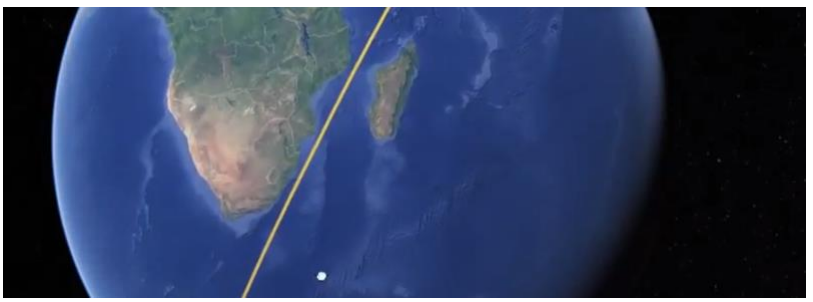
## Across the Pacific's?


Along a straight line?
Along a 'greater circle'?



## Straight lines

The longest path you can travel by ship in a straight line before encountering land! (Approximate)



Source:

## Is the Earth flat?

## Break out I:

**Discuss why or why not.**

**… and discuss why such a huge discrepancy in concept appear**



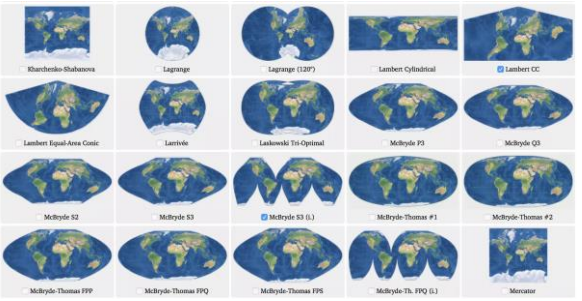
## Chat GPT…
## But start out thinking for yourself

**And… if the Earth was flat, we would all be out of work ☺**

**As a matter of fact**
**The Earth is flat**
**… at least on paper ☺ ☺ ☺**

**Topics of the day**

- Motivation of projections
- Ideal globes and ideal pieces of paper
- Types of projection
- On lengths and areas
- Universal Transversal Mercator system (UTM)
- A note on systems applied in Denmark
- Transformations






## Why projections?

Because **the earth is not flat** (sorry to say)
– and a (paper-) map is….

A map-projection is **a systematic way to transfer positions** from the surface of the earth to the plane of a paper. I.e. from a spherical to a cartecian coordinate system

Since the earth is spherical or double-bended and the paper is flat, **there is no perfect projections that maintains distances, shapes, areas etc. across the entire area of interest** – only approximation working more or less well for smaller or larger areas with respect to different aspects.

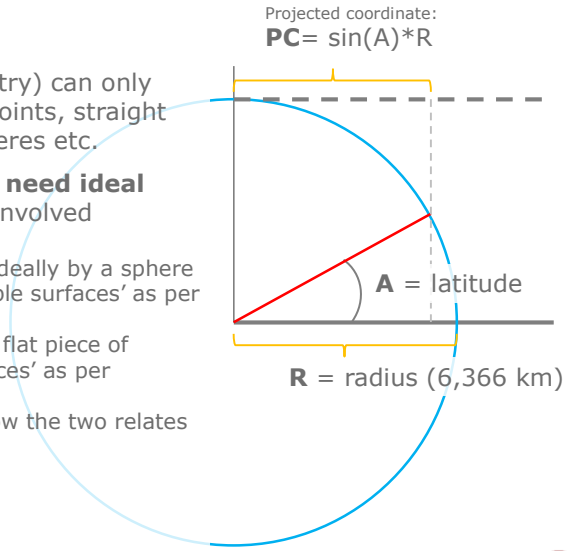
There are so many (varieties) of Projects: 71 are listed on
https://storymaps.arcgis.com/stories/ea0519db9c184d7e84387924c84b703f

## Two 'ideal' surfaces? (2D example)

Mathematics (and geometry) can only work in **ideal entities**: points, straight lines, planes, circles, spheres etc.

Accordingly, **projections need ideal representations** of the involved entities:

- The Earth – represented ideally by a sphere or an ellipsoid ('developable surfaces' as per Bolstad)
- The Cartesian system – a flat piece of 'paper' ('developing surfaces' as per Bolstad)
- …. and a description of how the two relates

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Two 'ideal' surfaces? (2D example)

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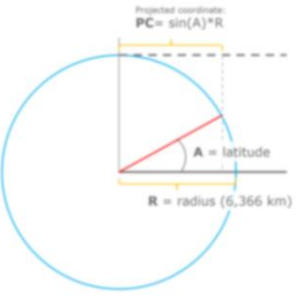
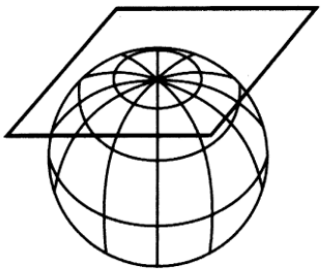
In cartography, the principle maintains, but it becomes more complicated because

- The earth is 3D
- And it is not even a sphere, but closer to an ellipsoid
- … which is in fact just another approximation

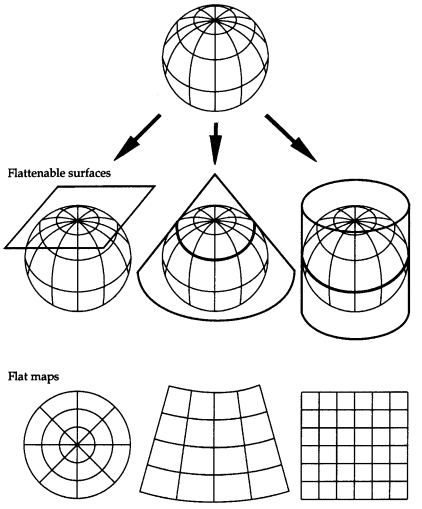


## Projections – ideal representation of relation

There are three basic types or forms of projection (three types of developing surfaces):

- **Azimutic** (positions are projected onto a plane)
- **Conic** (positions are projected onto a cone)
- **Cylindric** (positions are projected onto a cylinder) – often referred to as **Mercator**




Source: Mitchell, 1999

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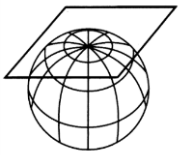
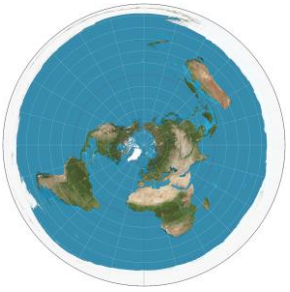
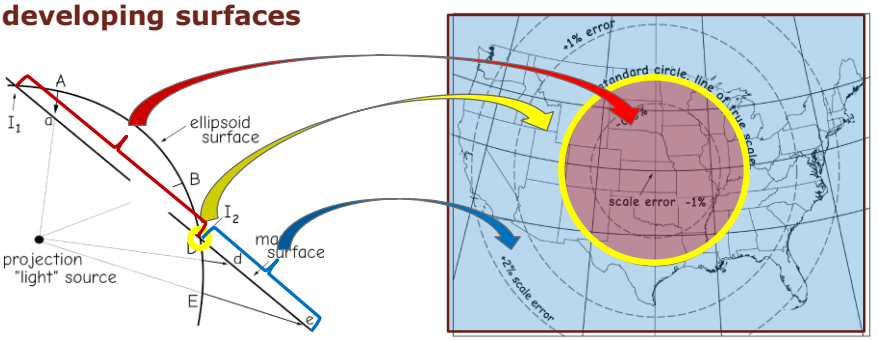
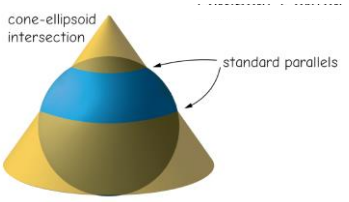
## Azimuthal equidistant projection

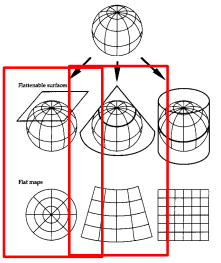




## Projections – cutting or intersecting developing surfaces





## Datum

A datum is a rather broad term describing the vertical and horizontal point of departure for projections and coordinate systems and reference points.

**Horizontal Datum:** Defines the position of points on the Earth's surface in terms of latitude and longitude. It provides a reference for horizontal positioning.

Common horizontal datums include:

- WGS 84 (World Geodetic System 1984)
- NAD 83 (North American Datum 1983)
- EUREF89 - European Terrestrial Reference System 1989, is primarily a horizontal datum.
- ED50 – the old European horizontal datum which you still find in some present geodata sets

**Vertical Datum:** Defines the elevation or height of points on the Earth's surface. It provides a reference for vertical positioning.

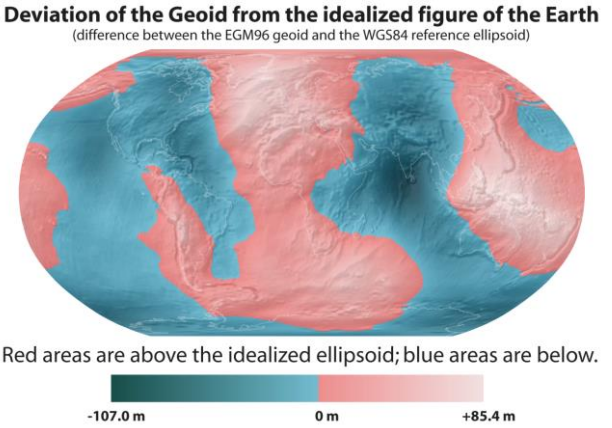
Commonly applied datum's (data) include

- EVRS - European Vertical Reference System
- The **Geoide** which is the global description of the 'true' shape of the Earth. It can be seen as the deviation between the ideal ellipsoid and reality

## Datum

Since the Globe is not entirely ellipsoidal, local vertical datum's are also applied to describe the differences between the **Geoide** and an reference ellipsoid

The **geoid is a 'field of gravity',** or to put it differently, the shape that the ocean surface would take if it was entirely covered by water, under the influence of the gravity and the rotation of the planet alone

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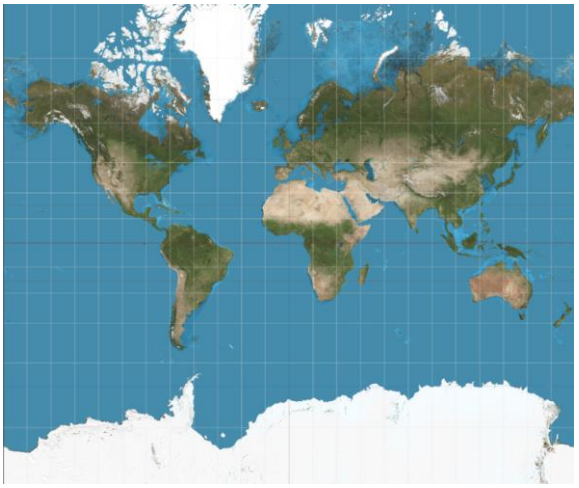
## Have a cup of coffee….

## Areadistortion in classic, Mercator maps

Africa:
30.370.000 km²

Greenland:
2.166.000 km²

Animation



Antarctica: 14.000.000 km²

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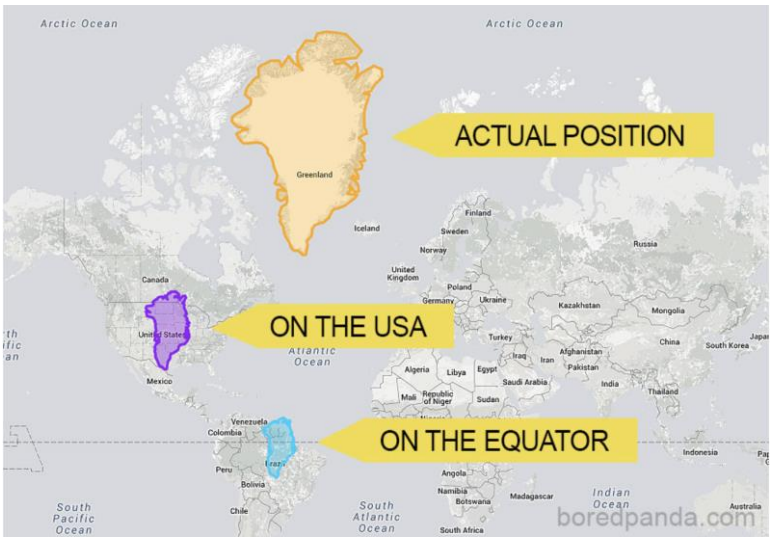
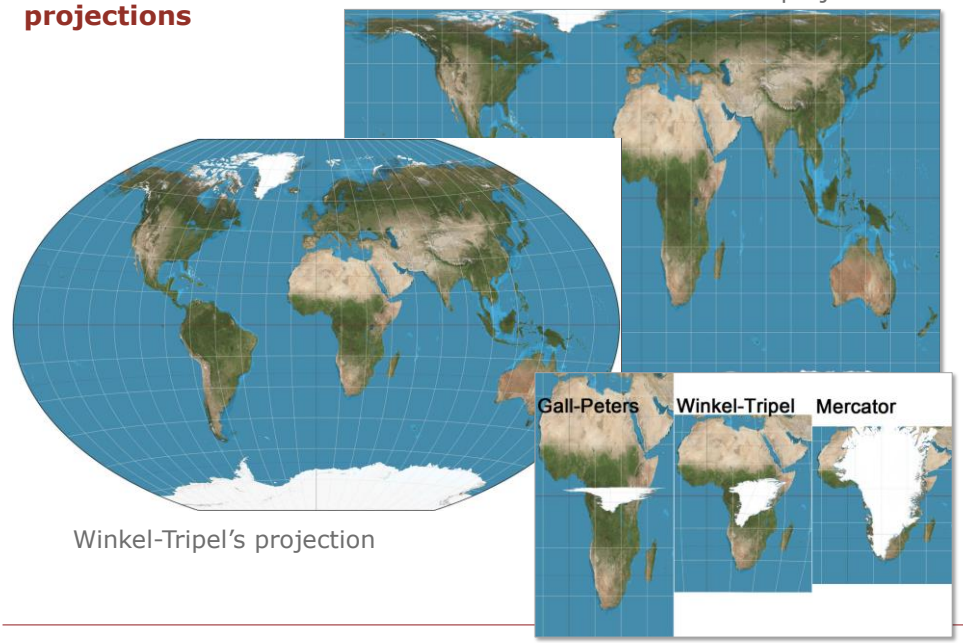
## If greenland – on a Mercator projection – was moved




Source:

## The area-correct (-ing) projections

Gall-Peters projection



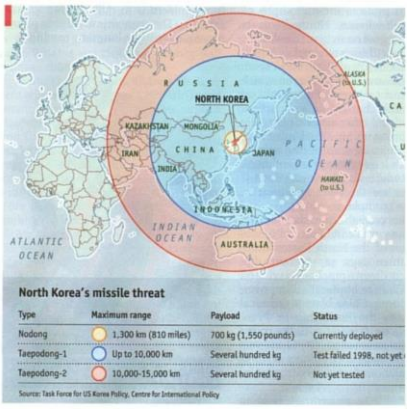

Winkel-Tripel's projection



## Swapping Africa and Greenland on a map according to a Mecator projection


Another example:
The true size map

## False estimation of distance – the Economist, 2003




"Flat-earth thinking. Thank you to those readers who pointed out that, by superimposing concentric circles on a Mercator projection, the map in our May 3rd issue (now corrected online) greatly underestimated the potential reach of North Korea's missiles. We stand corrected." —*The Economist*

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## Break out II:

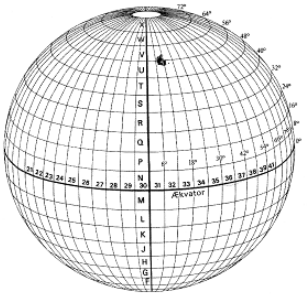
**Are projections a problem in relation to your work?**

**Why?**

**Why not?**

## Projection, (Cartesian) coordinate system and axis units

- Projections
  - The projection per se (the sphere and the flat)
  - Coordinate systems
  - Units
- Scale
  - Size (e.g. 1:25000)
  - Quality (level of detail)
  - Cartographic generalization
  - Communication of…




| Ratio | 1:5000 | 1:1,000,000 |
|---|---|---|
| Verbal (nominal) | 1 cm represents 50 m | 1 cm represents 10 km |
| Graphical | 0 100 200 km | 0 10 20 30 40 km |



## Coordinate systems

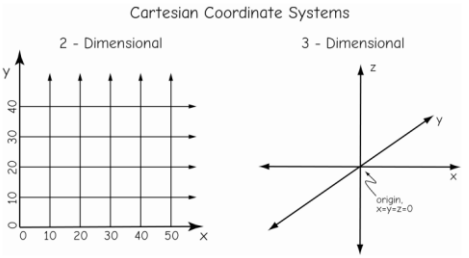



**Figure 2-5**: Two dimensional (left) and three dimensional (right) Cartesian coordinate systems.

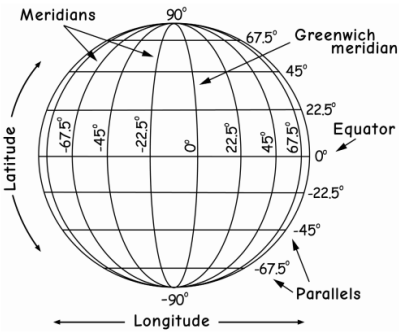



**Figure 2-7**: Nomenclature of geographic latitudes and longitudes.

## Non-Cartesian units: Degree, minute, second, and decimal degrees

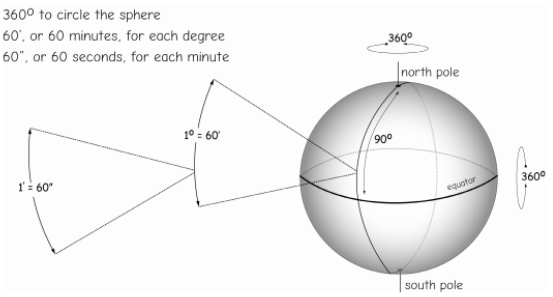
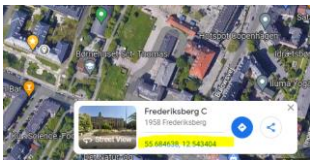



**Figure 2-10**: There are 360 degrees in a complete circle, with each degree composed of 60 minutes, and each minute composed of 60 seconds.




DD from DMS
DD = D + M/60 + S/3600
e.g.
DMS = 32º 45' 28"

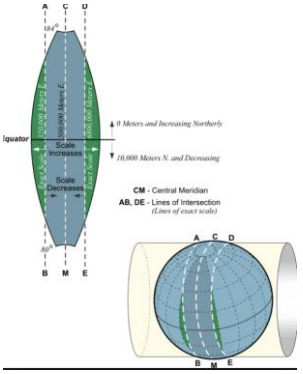
DD = 32 + 45/60 + 28/3600
= 32 + 0.75 + 0.0077778
= 32.7577778

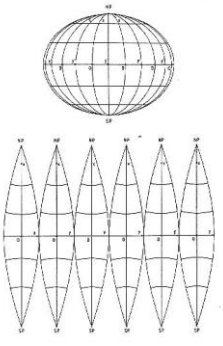
See a little video on lat/long and the Earth:
https://www.youtube.com/watch?v=swKBi6hHHMA
…. or more comprehensively:
https://www.youtube.com/watch?v=M2wL0lKF8ic

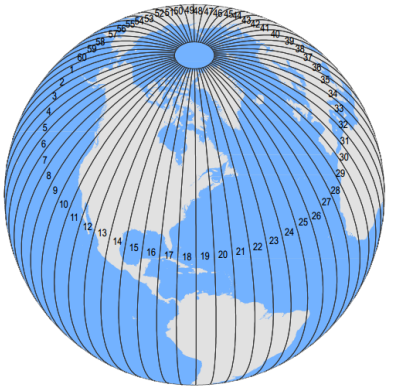


## Universal Transvese Mercator (UTM)
## A global projection/coordinate system

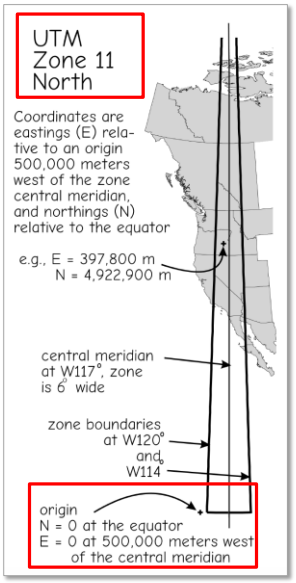
Based on a horizontal (transverse) cylindrical (Mercator) projection
It is constituted by
- 60 zones
- each 6º longitude wide
- from 80º North to 80º South

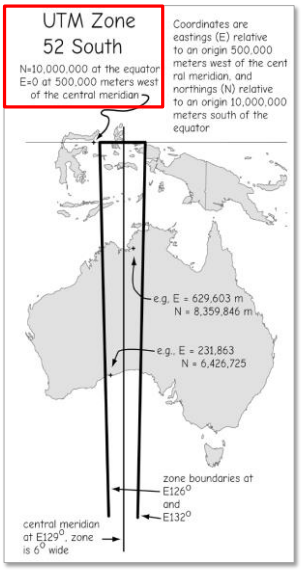




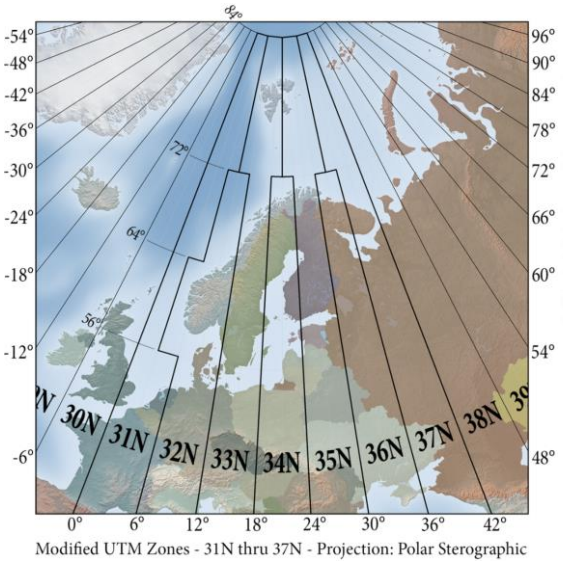
## Coordinates in UTM



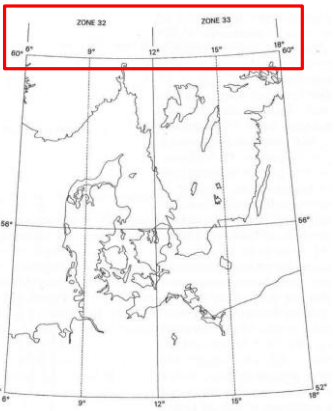





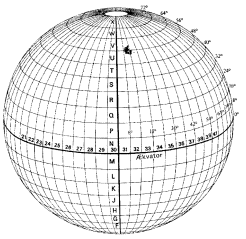

## Boarderline cases in UTM



Modified UTM Zones - 31N thru 37N - Projection: Polar Sterographic

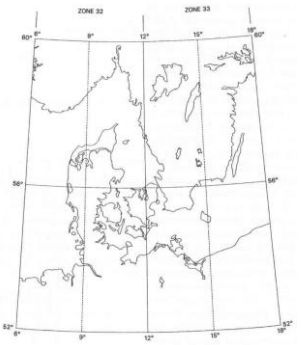



## Projections frequently used in Denmark



In scale from 1:10.000 – and lesser detailed - by far the dominating projection is:

- Universal Transversal Mercator (UTM), zone 32N (or 33N for Bornholm).
  - For newer maps the datum is Euref89 (related to the GRS80 datum applied to GNSS/GPS). In ArcGIS known as 'ETRS 1989 UTM Zone 32N'
  - For older, Danish maps the datum is - European Datum 1950 (ED50).
- In Denmark coordinates are typically in the order of 500.000, 6.100.000 (UTTM32N)




For higher precision (of the for smaller areas) other projects/datum's are applied. E.g. in relation to

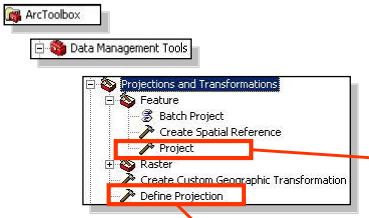
- Surveying
- Construction/civil engendering
- Landscape architecture

You frequently see application of 'local' systems.



## Projections and coordinate systems in ArcGIS

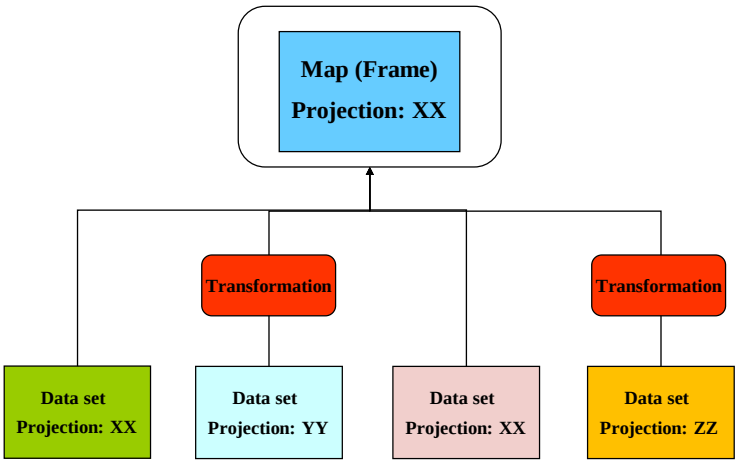
- Changing or redefining the projection setting of at data set only changes the label, NOT the content.
- I.e. it does NOT change the coordinates store in the data set




This one will create a new data set with a different projection (change the content, i.e. XY-coordinats)

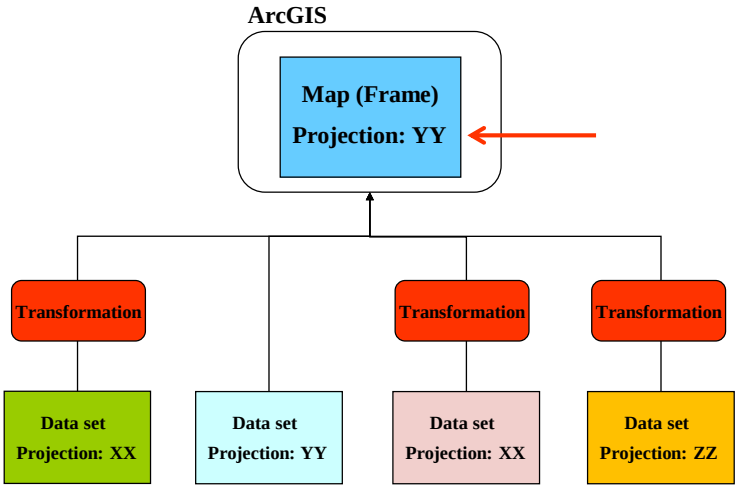
This one (or changing properties in ArcCatalog) will only change the lable (i.e. metadata), NOT the data itself.

## Projections and ArcGIS (1)



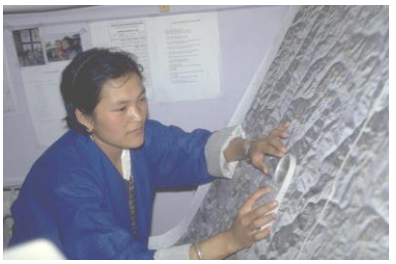



## Projections and ArcGIS (2)



## Transformation, by the way…

- Parametric 'translations' of coordinate values from one Cartesian system to another by a mathematical - affine of polynomic - formular
- Not to be confused with projection which addresses 'translation' between Cartesian systems and curved surface of a planet
- Transformation is well know as the process behind georeferenceing/ rectification, as you know it from rectification of aerial photos and scanned maps
- Transformations were also applied in the good old day when digital geo-data was automated directly from analogue maps or photos.





### Introduction to GIS

# I guess…
# that's it for today

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