Ekonomická fakulta
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University of South Bohemia in České Budějovice

Geographic Information Systems 1
Lecture 10: GIS and Cartography

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Cartography = the branch of science dealing with the representation of the earth's surface and celestial bodies and the objects and phenomena on them in the form of cartographic work, as well as a set of activities in the processing and use of maps.

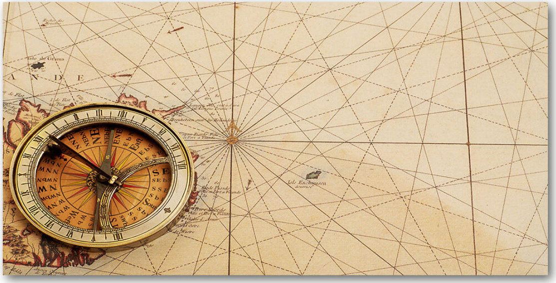
Cartography as an art, science and technology.

- from the time of the first manifestations of human culture ⇐ desire for knowledge and representation of the landscape in which people live and work,
- the oldest and most primitive landscape drawings date back to prehistoric times (on rock or bone tablets);
- a richer monument are the map drawings of the Babylonians (5th century BC) ⇒ the first map of the world on a clay tablet;

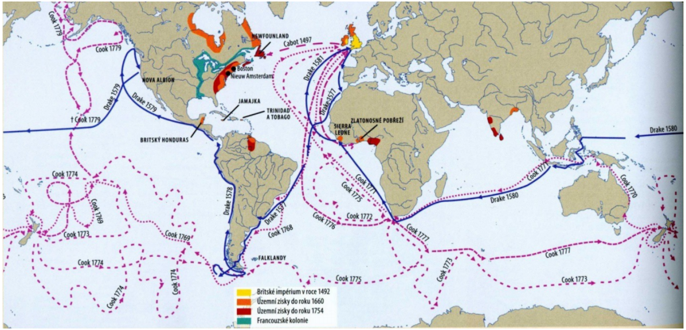
- the most significant contribution to the development of cartography was made by the Greeks in antiquity (Anaximandros, Aristotle, Eratosthenes, Thales, Ptolemy)
  - good knowledge of the shapes and dimensions of the Earth,
  - astronomical and mathematical knowledge,
  - = basics of today's advanced cartography

Ptolemy's map of the world

- the beginning of the Middle Ages - cartography in decline - geographical knowledge was of low level (the roundness of the Earth was suppressed) - the Church promoted the Bible as the only basis of knowledge;
- the results of ancient Greek cartography survived this time in the Arab world;
- 13th century - century invented in China **compass** ⇒ compass charts (portulans) - predecessor of today's navigation charts - used for maritime navigation in the 13th and 14th centuries.



- turn of the 15th and 16th centuries (Renaissance) ⇒ return to ancient education (Leonardo da Vinci, Nicolaus Copernicus, Giordano Bruno, Galileo Galilei) ⇒ remarkable turn in cartography ⇒ maps took on an earlier geometric character,
- great influence on the progress of cartography:
  - heliocentric system,
  - great sea voyages - Christopher Columbus (1492), Amerigo Vespucci, Vasco de Gama, Fernando Magallanés - geographical discoveries - discovery of America and voyages to India,



  - invention of the printing press - Jan Gutenberg(1440), invention of copperplate.

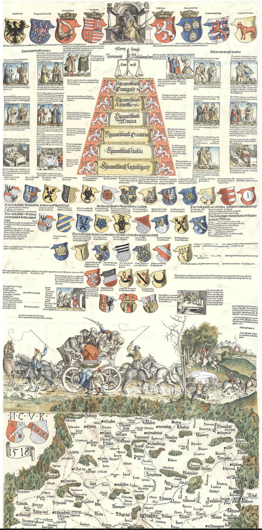
- the need to design new views to create maps of the world,
- mid-16th century - centre of cartographic work in the Netherlands - **Gerhard Mercator** - nautical chart of the world, Mercator's conformal cylindrical representation - to this day,
- a major advance in topographic measurement came with the invention of the **measuring table** (1570),
- 18th century - military and economic demands for detailed mapping - France (Cassini), Bohemia and Moravia - Jan Kryštof Müller, Germany - Lambert, Soldner, Gauss;
- triangulation - enabled precise determination of the Earth's shapes and dimensions and accurate mapping,
- the development of detailed mapping created a solid foundation for the representation of the Earth's surface - this principle of mapmaking in its basic features has survived to the present day.



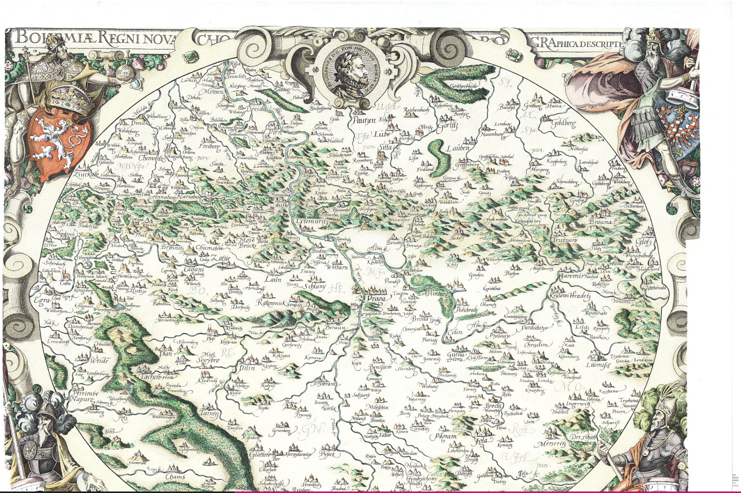
Old maps of our countries:

- map of Central Europe - Mikulas Kusa;
- **Klaudyán's map** of Bohemia - 1518 - orientation to the south;
- **Jan Criginger** - second independent map of Bohemia (1569);
- **Pavel Aretin** - map of Bohemia (1619);
- **Pavel Fabricius** - the first independent map of Moravia (1569),
- **Jan Amos Komenský** - the second independent map of Moravia (1627),
- **Lazaurus** - 1513 - the oldest map of Hungary (Slovakia),
- the cartographer **Jan Kryštof M ller**(1712 -1720) was commissioned to draw new maps,
- **Mikoviny** was responsible for the maps of some Slovak counties.

Klaudyán's map



Criginger´s map



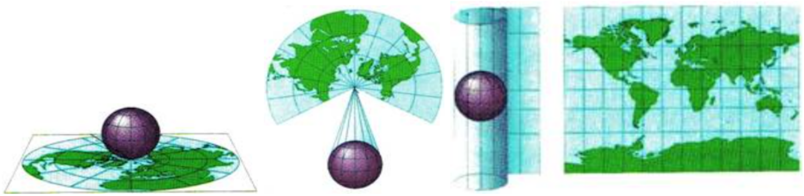
- **applied cartography** - science of maps - study of maps and work with them - analysis, properties, classification and documentation of maps;
- **mathematical cartography** - methods of displaying reference surfaces in the plane - properties of the display;
- **cartographic creation** - compilation of map image, selection of map elements, generalization, distortion;
- **cartographic polygraphy and reproduction** - a set of technical operations for the polygraphic processing of a map, i.e. printing;
- **mapping and morphometry** - measurements on maps, determination of morphometric characteristics.

- represents real space in the plane of the map using mathematically defined relations so that the distortion of the displayed objects is minimized;
- solves methods of projecting reference surfaces (sphere, ellipsoid) in the map plane;
- explains the properties of these mappings;
- gives instructions on how to use them when creating maps;
- the ideal representation of the Earth's surface is a large scale (1 : 20 000 000) on the ⇒ globe,
- the surface of the reference bodies cannot be developed into a ⇒ plane it is impossible to construct a map that is a faithful undistorted image of the Earth's surface;
- so that the distortions do not change randomly, mathematical cartography searches for suitable representations;
- the projection is clearly defined mathematically by the relation between the coordinates of points on both reference surfaces = **display equation**;

- the term **cartographic mapping** will be used to refer to the mutual assignment of a surface on two different reference surfaces;
- representation of objects, the representation of which cartography deals with (i.e. the Earth's surface and celestial bodies, phenomena on them and their relations) into the plane of a cartographic work (map);
- in some cases the relation can be realized by geometry (projection)⇒ then we talk about **projection** or -li perspective representation;
- the principle of cartographic representation consists in converting a geographical network from the surface of the earth to a plane or to a surface that can be developed into a plane;
- there is distortion - angles, lengths, area content - ***mathematical cartography - trying to make the distortion as small as possible***.

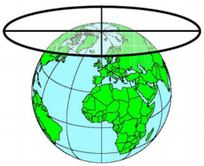
division according to 3 basic criteria:

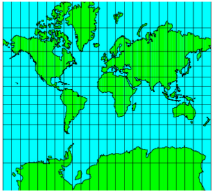
- projection surface,
- projection position,
- distortion characteristics.

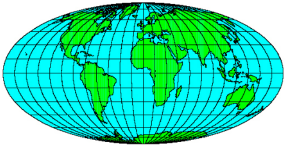


according to projection surface:

- **simple** (true, simple) - transferring the reference surface directly to the projection surface,
- **generic** (conventional, contractual) - the construction cannot be illustrated by means of a projection surface,
- **geodetic** - special types of projections with complex mathematical calculations, using a reference ellipsoid.

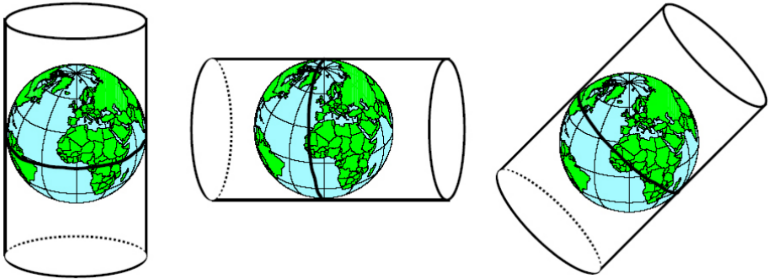






according to the position of the structural axis:

- **normal** (polar position) - world maps, maps of polar regions,
- **transverse** (transverse position) - least used - e.g. maps of hemispheres,
- **oblique** (general position).



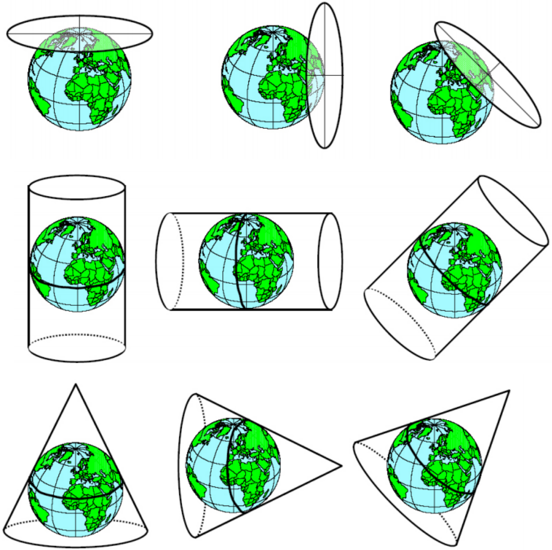
by properties in terms of **distortion**:

- **conformal** (orthomorphic) map projection the angles between lines in the map are indentical to the angles between the original lines on the curved reference surface. This means that angles (with short sides) and shapes (of small areas) are shown correctly on the map.
- **equal-area** (equivalent) map projection the areas in the map are identical to the areas on the curved reference surface (taking into account the map scale), which means that areas are represented correctly on the map.
- **equidistant** map projection the length of particular lines in the map are the same as the length of the original lines on the curved reference surface (taking into account the map scale).
- **equalizing** (compensating) - reduce both angular and area distortion, distortion values somewhere between conformal and equivalent.

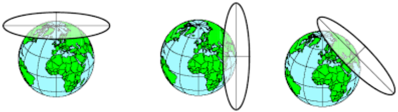
common characteristics:

- conversion of the reference surface into simple display surfaces (plane or mantle, cylinders or cones);
- there is only one variable in the projection equations, i.e. each of the plane coordinates can be expressed as a function of a single spherical (geographic) coordinate;
- in the normal position:
  - line images of meridians,
  - circular or line images of parallel lines,
  - intersection of these images at right angles (so-called orthogonal display).

- **azimuthal**
  - normal
  - transverse
  - oblique
- **cylindrical**
  - normal
  - transverse
  - obique
- **conical**
  - normal
  - transverse
  - oblique



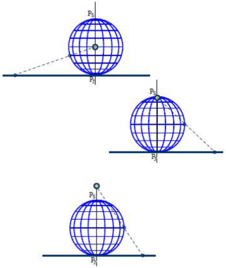
azimuthal projections - common characteristics:



- in the normal position:
  - line images of meridians,
  - circular or line images of parallel lines,
  - intersection of these images at right angles (so-called orthogonal display).
- can be used for any area of the Earth's surface - suitable for areas of irregular circular shape,
- the smallest distortion is at the point of contact and increases with increasing distance from it.

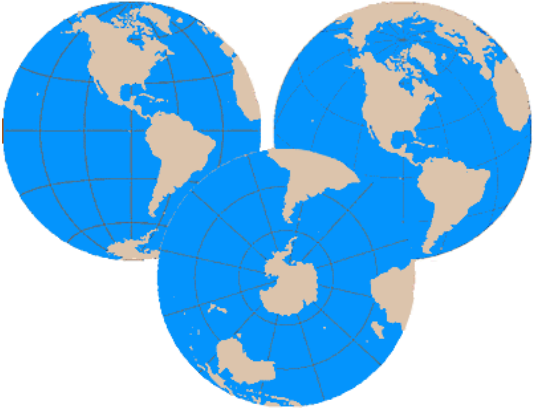
projections:

- **gnomonic** - Thales of Miletus, 7th century BC - projecting points of the Earth's surface from the centre of the Earth,
- **stereographic** - Hipparchos of Nicaea, 2nd century BC - projection of points of the Earth's surface from the opposite pole,
- **orthographic** - Appollonius, 3rd century BC - the centre of projection is at infinity, the rays are perpendicular to the imaging plane.



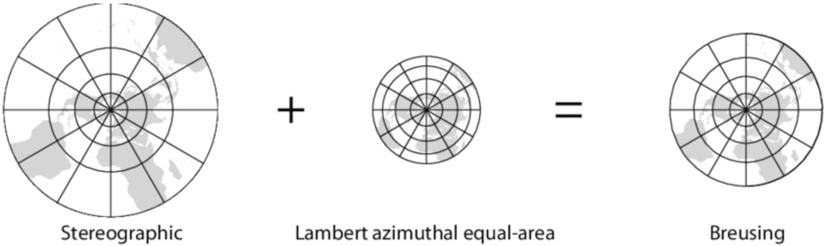
other azimuthal projections - examples of the most famous ones:

Lambert´s projection



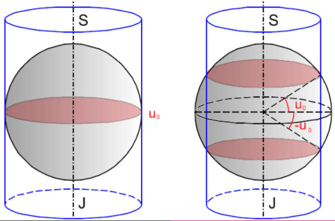
other azimuthal projections - examples of the most famous ones:

Breusing´s projection

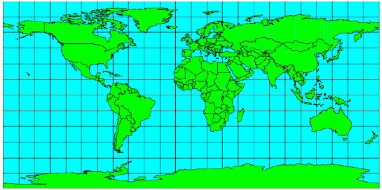


common characteristics:

- the imaging surface is the cylinder shell,
- the cylinder either wraps around the reference surface along a main circle (tangent cylinder) or intersects it in two mutually parallel side circles of the same radius (secant cylinder),
- formerly for world maps, but usually large distortions at the poles, replaced in atlases by general representations,
- the contact circle is chosen to form the axis of the imaged strip of territory,
- mostly in the normal position, in the transverse position for the display of dihedrals on the globe and for geodetic displays.



other cylindrical projections - examples of the most famous ones:
Marinos projection - Marinos of Tyre = "square view" - longitudinal along the meridian and equator, large distortion at the poles, transverse position used for globe belts

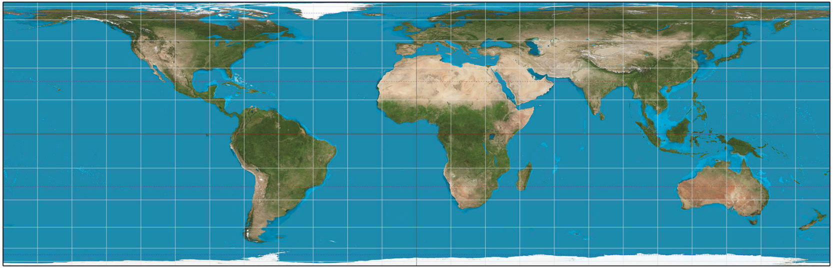


views derived from it:

- **Cassini-Soldner´s projection** - 1745 - cadastral maps (scale 1 : 2 880) of the Czech lands in the 19th century were created using Marin's cross-sectional view on an ellipsoid, several cylinders were used (i.e. the so-called multiplanar view),
- **rectangular** - intersecting cylinder ($\varphi_0 = \pm 40^o$), longitudinal in two intersecting parallels, compensating.

other cylindrical projections - examples of the most famous ones:

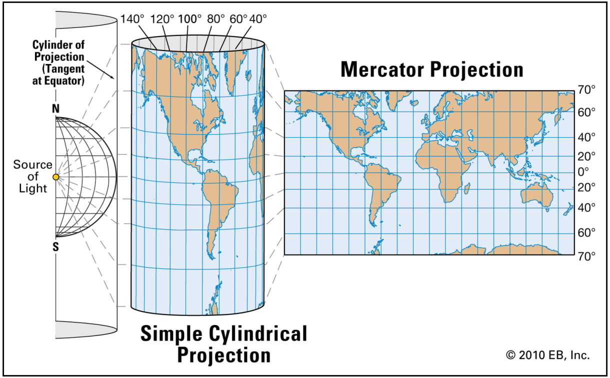
Lambert´s projection (Johann Heinrich Lambert - 1772) = orthographic projection on the cylinder casing - flattish, longitudinal share of the equator,



not used because it has a large angular distortion at the poles.

other cylindrical displays - examples of the most famous ones:

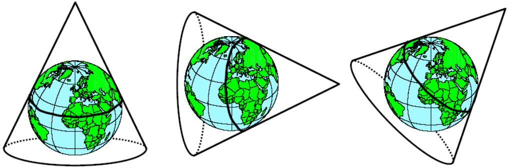
Mercator´s projection (Gerhard Mercator - 1569) = angular, used e.g. for geodetic maps, large area distortion,



originated from the needs of maritime transport (nautical charts, navigational aeronautical charts)

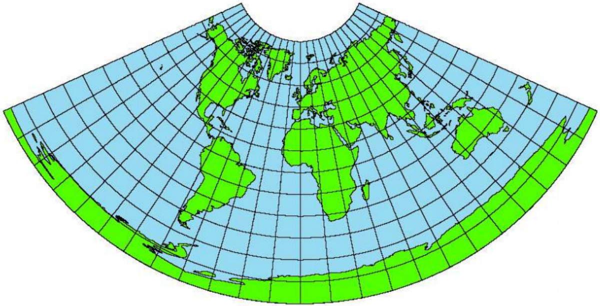
common characteristics:

- are created by imaging a reference surface on the cone shell (imaging surface), whereby have either one or two mutually concentric side circles in common with the reference surface,
- these circles may or may not be tangent, and in the case of two conserved circles they need not be a secant cone,
- in normal position: a parallel is preserved in length, meridian images form a cluster of rays (half-lines) passing through the origin of the coordinate system (cartographic pole), parallel images form parts of concentric circles centred at the origin.



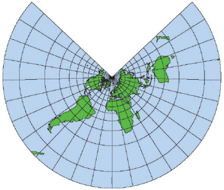
conical projections - examples of the most famous ones:

Ptolemy´s projection (Ptolemy - 1st century BC) = longitudinal along meridians and tangent parallels, used for geographical maps (up to 40% of maps in the School Atlas), large area distortion2.



conical projections - examples of the most famous ones:

Gaussian projection (Karl Friedrich Gauss - 1822) = angular, longitudinal along the tangent parallel,



wide use:

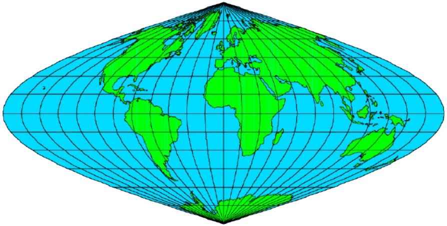
- in geodesy and aviation (on the ellipsoid),
- in an oblique position was used for detailed topographic maps of our territory (the so-called Křovák's projection),
- International aeronautical map 1 : 1 000 000
- International World Map 1 : 1 000 000.

common characteristics:

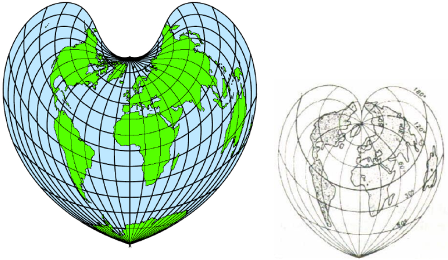
- the projecting surface must not be a plane, cylinder shell or cone shell,
- the conversion of the reference surface into a plane is done mathematically or geometrically by either not using a single surface at all or using several such surfaces simultaneously,
- In normal position, at least one of the display equations contains two variables, φ and λ,
- some of them don't have projection equations at all,
- used most often for world maps on a single sheet and usually in the normal position,
- these are most equal-area, compensating projections,
- in normal position, the images of the equator and the central (base) meridian are linear, perpendicular to each other.

general projections - examples of the best known:

Sanson´s projection



Bonne´s projection

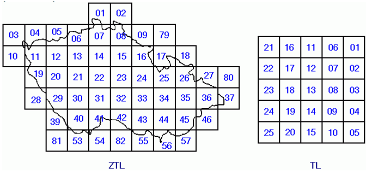


- used for geodetic purposes (i.e. precise surveying) and large-scale mapping,
- **conformal** – not to distort angles as a basic measuring element,
- are based on the reference ellipsoids (not the sphere),
- x has the meaning of y, y has the meaning of x.

in the Czech Republic important:

- **Gauss-Krüger´s projection**,
- **Křovák´s projection**,
- **UTM**.

- **nomenclature** = system of map sheet labels allowing spatial localization and determination of orthogonal coordinates of sheet corners,



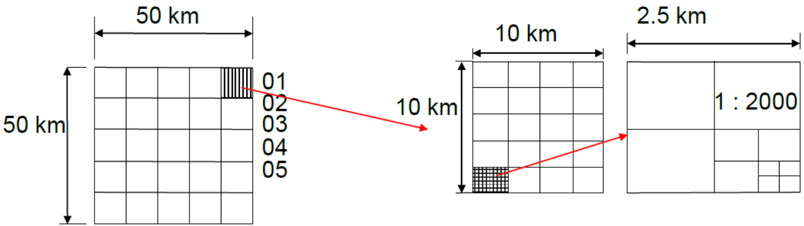
- **basic triangulation sheet** - determined by parallels with X and Y at distances of 50 km, 1:100 000, frame 50 x 50 cm ≅ 50 x 50 km, rectangular SW corner coordinates given for each sheet,
- **map sheet** = part of a map work defined by section lines - e.g. a map sheet of a 1 : 5 000 ⇐ base map by dividing the triangulation sheet into 4 columns and 5 layers → a network of 2.5 x 2 km rectangles.

triangulation sheet 1:100 000, 1:20 000

základní triangulační list 59
1 : 100 000

triangulační list 59-01

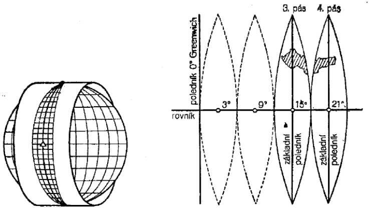
1 : 20 000



= plošná evidenční jednotka v bývalé Československé trigonometrické síti s rozměrem zobrazeného území 10x10 km, vzniklá rozdělením základních triangulačních listů (50x50 km). Triangulační list je evidenční jednotkou pro číslování trigonometrických bodů

Gauss-Krüger´s projection

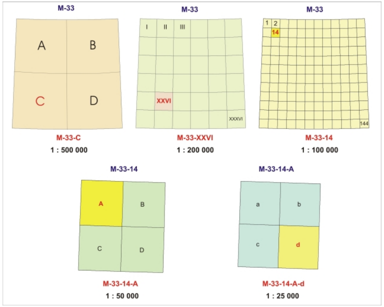
- derived by Gauss (19th century), elaborated by Krüger,
- conformal cylindrical projection,
- without using a reference sphere,



- 1952 for the Topographic Map of Czechoslovakia and Warsaw Pact countries (using Krasovsky ellipsoid),
- a narrow strip of territory, elongated along the touching meridian, is displayed on one cylinder,
- a system of spherical dihedrals of 6^o (from 1 cylinder tangent along the meridian).

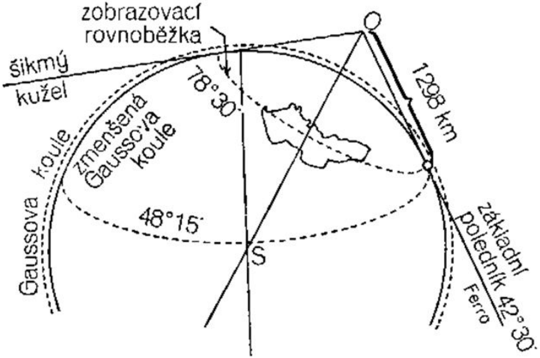
Gauss-Krüger´s projection

- The coordinate Y is expressed by the number of bands (3rd or 4th from Greenwich), a constant offset of the origin by 500 km to the W and the eigenvalue of the coordinate calculated in the original coordinate system,
- coordinate system S-42



Křovák´s projection - author: Ing. Josef Křovák = actually a combination of two views - properties:

- conformal projection,
- cone in oblique position - the design reflects the shape of the area: elongated and slightly curved,
- double projection: ellipsoid → sphere: Gaussian conformal projection from ellipsoid to sphere; sphere → plane: Lambert conformal conic projection,
- S-JTSK basis,
- usage: State map derived from SMO-5, Base map of the Czech Republic at scales 1:10 000, 1:50 000, 1:100 000, 1:200 000; ZABAGED, DKM at scale 1:1 000
- only CZ, SK.


zobrazovací
rovnoběžka
šikmý
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O
1298 km
78°30'
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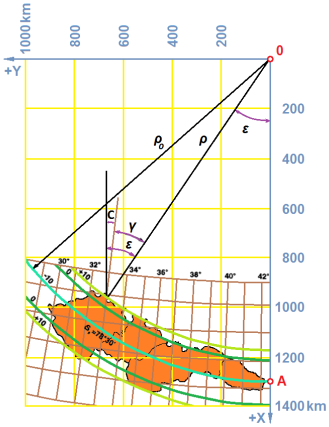
Ferro


1000 km
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600
400
200
0
+Y
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400
600
800
1000
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1400 km
+X
A
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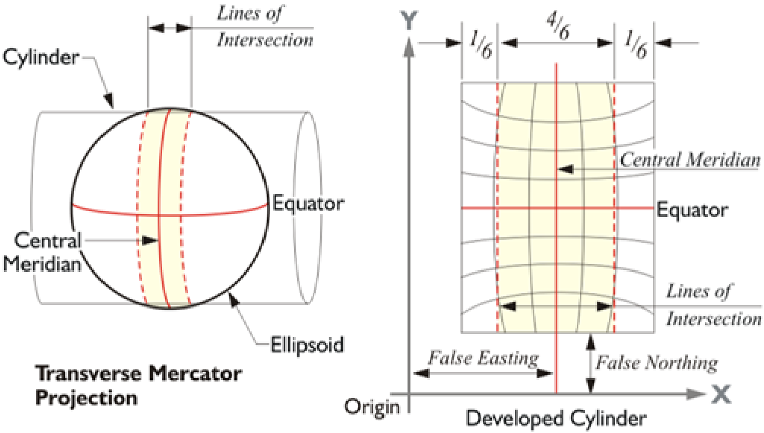
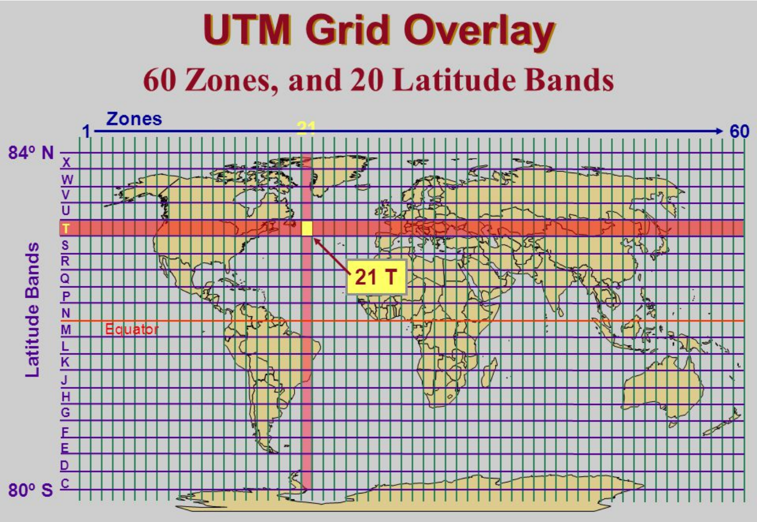
UTM (Universal Transverse Mercator)



UTM (Universal Transverse Mercator)



Thank you for your attention.