1 Geodetic and Coordinate Reference Systems

reference frame

- reference points on the Earth and their corresponding coordinates

geodetic reference system (GRS)

- consists of

1. reference ellipsoid
2. the reference frame

- also called “datum””

coordinate reference system (CRS)

- consists of

1. reference ellipsoid
2. the reference frame
3. coordinate system

1.1 Coordinate Systems

For the projection of a spherical or ellipsoid onto a flat surface (e.g map) we need a coordinate system.

geocentric coordinates X, Y, Z

- Earth-centered system of locating objects in the solar system in three-dimensions along the Cartesian X, Y and Z axes Wikipedia
- not suitable for map projections

geographic coordinates ϕ, λ

- enables every location on Earth to be specified by a set of numbers, letters or symbols (Wikipedia)
- used to specify a location on a two-dimensional map
- angles
  - ϕ, λ
- semi-major and minor axis
  - a, b

geographic poles

- defined by the rotational axis

equator

- the section perpendicular to the rotational axis and through the center of the ellipsoid

1.1.1 Geographic Coordinates (latitude/longitude)

Representation	Example	Description
hddd° mm′ ss.ss″	N46°14′06.70″ E008°00′55.60″	degree (°), minutes (′), seconds(″) and decimal seconds
hddd° mm.mmm′	N46°14.1118′ E008°00.9267′	degree(°), minutes(′) and decimal minutes
hddd.ddddd°	N46.235197° E008.015445°	degree(°) and decimal degree

h = cardinal direction
d = degree
m = minutes
s = seconds

lines of latitude

- sections perpendicular to the rotational axis are parallel to the equator
- the degrees of latitude range from 90°S over 0° to 90°N (180 lines of latitude)
- ϕ

lines of longitude (meridians)

- sections through the poles
- the degree of longitude range from 180°W over 0° to 180°E
- steps are 10° (360 lines of longitude)
- λ

prime meridian

- the meridian through Greenwich

great circles

- sections through the center of the ellipsoid
- 1° on a great circle corresponds to about 111 km
- 360° correspond to 40073 km $\approx 2\pi \cdot 6378$ km

Wikipedia-Geographic-Coordinates

1.1.2 Universal Transverse Mercator (UTM) Coordinates

Format	Description
32 N 439596 / 5967780	zone, north hemisphere, easting / northing in meter

UTM Zone Coordinates projection

- universal transversal Mercator projection
- conformal transversal cylindrical projection
- intersection at poles

reference ellipsoid

- many different reference ellipsoids are used
- in the EU: GRS 80
- in USA: WGS 84 (WGS 1984) and NAD83

lines of latitude

- degrees range from 80° S over 0° to 84° N
- The polar regions are excluded

lines of longitude

- degrees range from 0° to 180°

zones

- 60 zones, each 6° of longitude in width
- first zone (1)
- longitude 180° to 174° W
- starts international Date Line (180°)
- zone numbering increases eastward
- last zone (60)
- longitude 174° to 180° E

central meridian

- longitude line in the middle of a zone
- steps are 6°, starts at 3°
- 3°, 9°, 15°, …, 177°

coordinate system

- each UTM zone is regarded as an individual Cartesian Coordinate System
- intersection of the equator with the central meridian is the origin of the Coordinate System

false easting

- the easting of the central meridian is shifted by 500.000 meters
- eliminates negative numbers

false northing

- the northing on the southern hemisphere is shifted by 10.000.000 meters
- eliminates negative numbers

utm-zone
example 1
32 N 439596 / 5967780

- The coordinate is on the north hemisphere (N) in UTM zone 32
- 32 zone = central meridian is at 9° eastern longitude
- The point located **60404** meters west of the central meridian of zone 32
- 500000 m - 439596 m = **60404** m
- The point is located 5967780 meters from equator to the North

example 2
32 S 439596 / 4032220

- The coordinate is on the southern hemisphere (S) in UTM zone 32
- 32 zone = central meridian is at 9° eastern longitude
- The point located **60404** meters west of the central meridian of zone 32
- 500000 m - 439596 m = **60404** m
- The point is located **5967780** meters from equator to the South
- 10000000 m - 4032220 = **5967780** m

Example	Description
32 U 439596 / 5967780	zone, band, easting / northing in meter

UTM Grid Coordinates band (latitude)

- indicates geographical latitude
- 8° hight

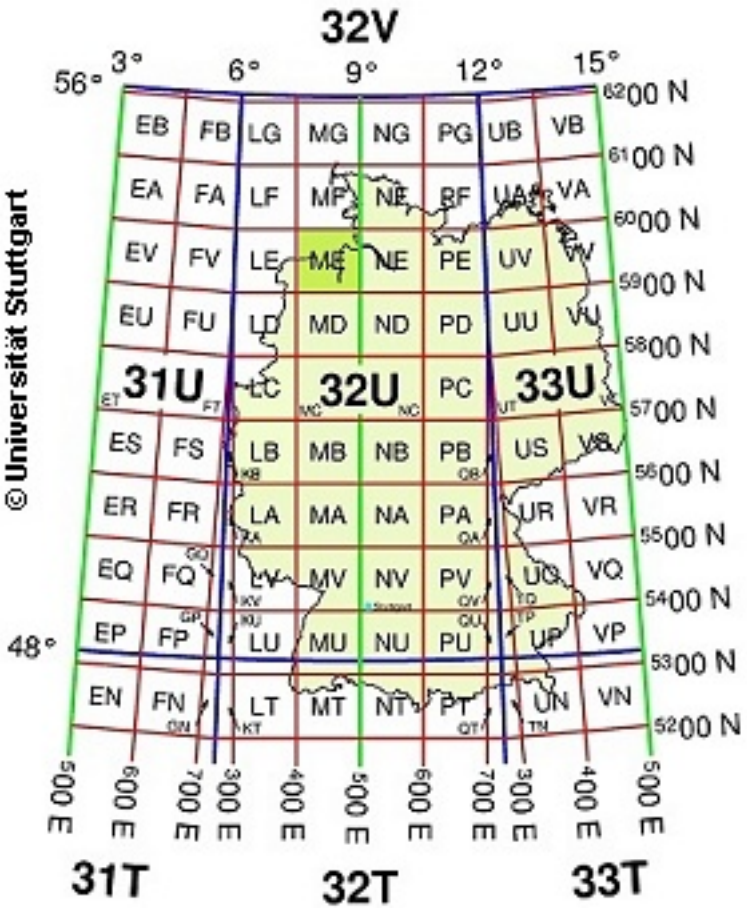
utm-grid
Wikipedia-UTM-Grid

1.1.3 MGRS

- UTM zones independent of the UTM bands, are divided into squares (100 km x 100 km)
- parallel to the central meridian
- denominated with letter pairs

Military Map Reading 201

- `http://earth-info.nga.mil/GandG/coordsys/mmr201.pdf`



1.1.4 Gauß-Krüger-Coordinates

Format	Description
4 405057.629 / 5368263.248	central meridian easting / northing in meter

projection

- transversal Mercator projection

- conformal transversal cylindrical projection

reference ellipsoid

- B.W. Bessel

zone

- 3° of longitude in width
- 1,5° to the east of central meridian
- 1,5° to the west of central meridian

central meridian

- longitude line in the middle of a zone
- central meridian are numbered
- first central meridian is at 3°

false easting

- the easting of the central meridian is shifted by 500.000 meters
- eliminates negative numbers

Example	Description
4 405057.629 / 5368263.248	central meridian easting / northing in meter

Example

- the coordinate is in the zone of the central meridian number 4
- 4th central meridian = 12° longitude
- the point is located **94 942.371** meters west of the central meridian
- y = 405057.629 m - 500000 m = **-94 942,371** m
- the point is located 5368263.248 meters from equator
- x = 5368263.248

1.2 further reading and videos

Intro to coordinate systems and UTM projection

- `https://www.youtube.com/watch?v=HnWNhyxyUHg`

NOAA - UTM

- `https://www.ngs.noaa.gov/TOOLS/utm.html`

Display Formats of UTM Coordinates - How to Deal with Them? (english & german)

- http://www.killetsoft.de/t_0901_e.htm

reddit - What is the difference between UTM and MGRS coordinate systems?

- https://www.reddit.com/r/CampingandHiking/comments/124y3c/map_question_what_is_the_difference_between_utm/

Coordinate System Jargon: geoid, datum, projection

- https://www.youtube.com/watch?v=Z41Dt7_R180