AESB2440: Geostatistics & Remote Sensing

Lecture 1: Introduction and Map Products

April 20, 2015

Roderik Lindenbergh

Dept. of Geoscience & Remote Sensing

TU Delft

Delft University of Technology

Contents

Course Overview

- Course aims, topics and running items
- Course Material

Course organization

- Involved staff
- Contact hours, Blackboard
- Exercises, Assignments, Examination
- Your Questions

Second hour:
Introduction to Digital Mapping

Facts, Geostatistics & Remote Sensing

Study: BSc Applied Earth Sciences
(NL: Technische Aardwetenschappen)

Year: second

Quarter: four

Course code: AESB2440

Expected students: 70

ECTS: 5

Study load: $5 \times 28 = 140$ hours in 5 weeks $\approx$ 28 hours/week

Preknowledge: Linear Algebra; Calculus; Signals and Systems; Matlab

Follow-up :

- Connects to second years fieldwork Vesc;
- Provides background in Statistics for third year courses and AES MSc tracks.

Ingredients

(Free) Remote Sensing data, In situ digital data, Sensors, Physics

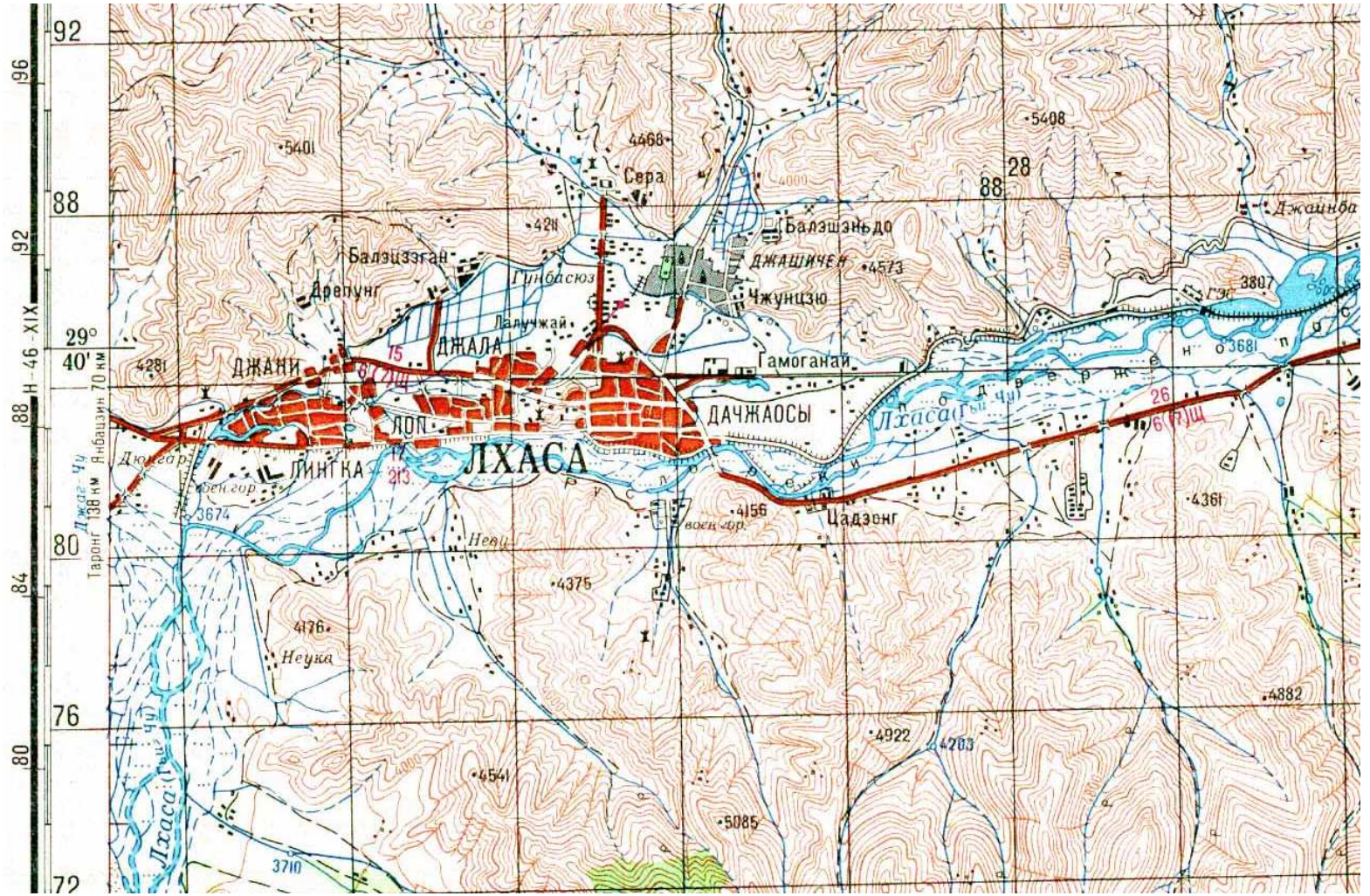
Mapping, (Free) Geographic Information Systems

Geometry, Statistics

Algorithms, Large Data sets

Terrain analysis, Interpretation, Geomorphology, Geology

Why look at old Sovjet maps?



http://maps.vlasenko.net/soviet-military-topographic-map/

GDEM + lakes + rivers

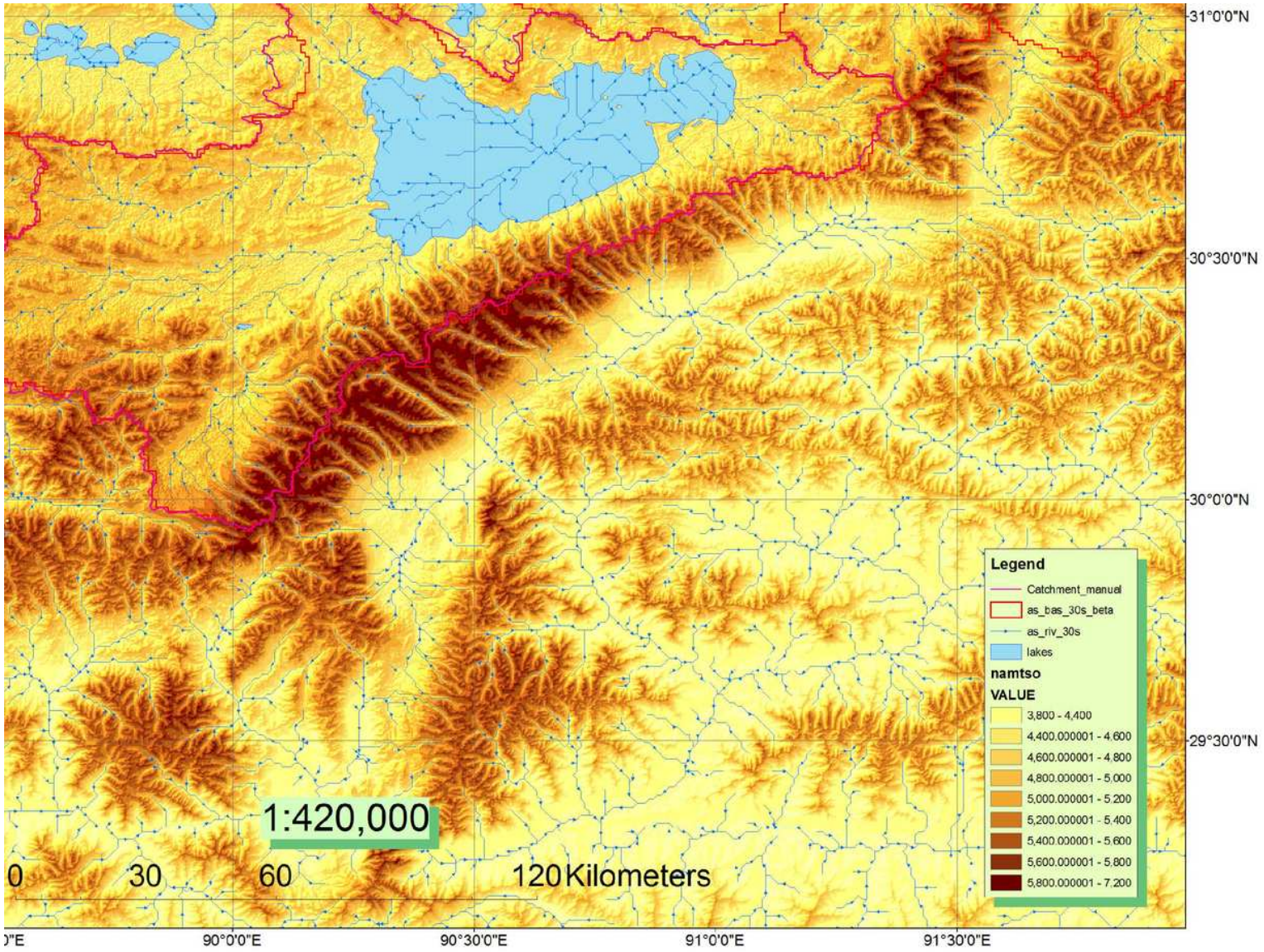


Image: Vu Phan Hien

Goal 1: use available data

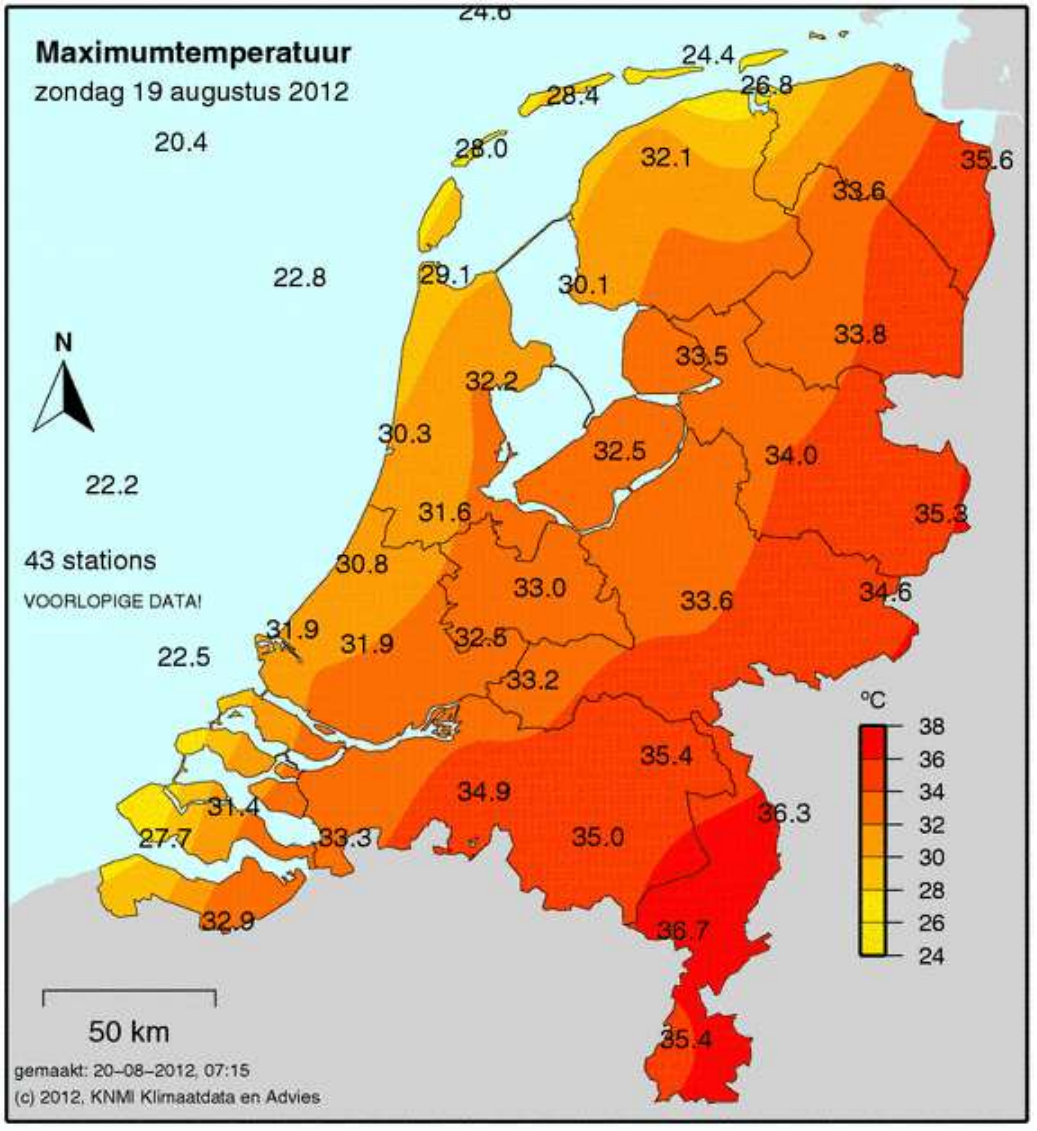
Many freely available remote sensing data sets

Applying them requires some knowledge on:

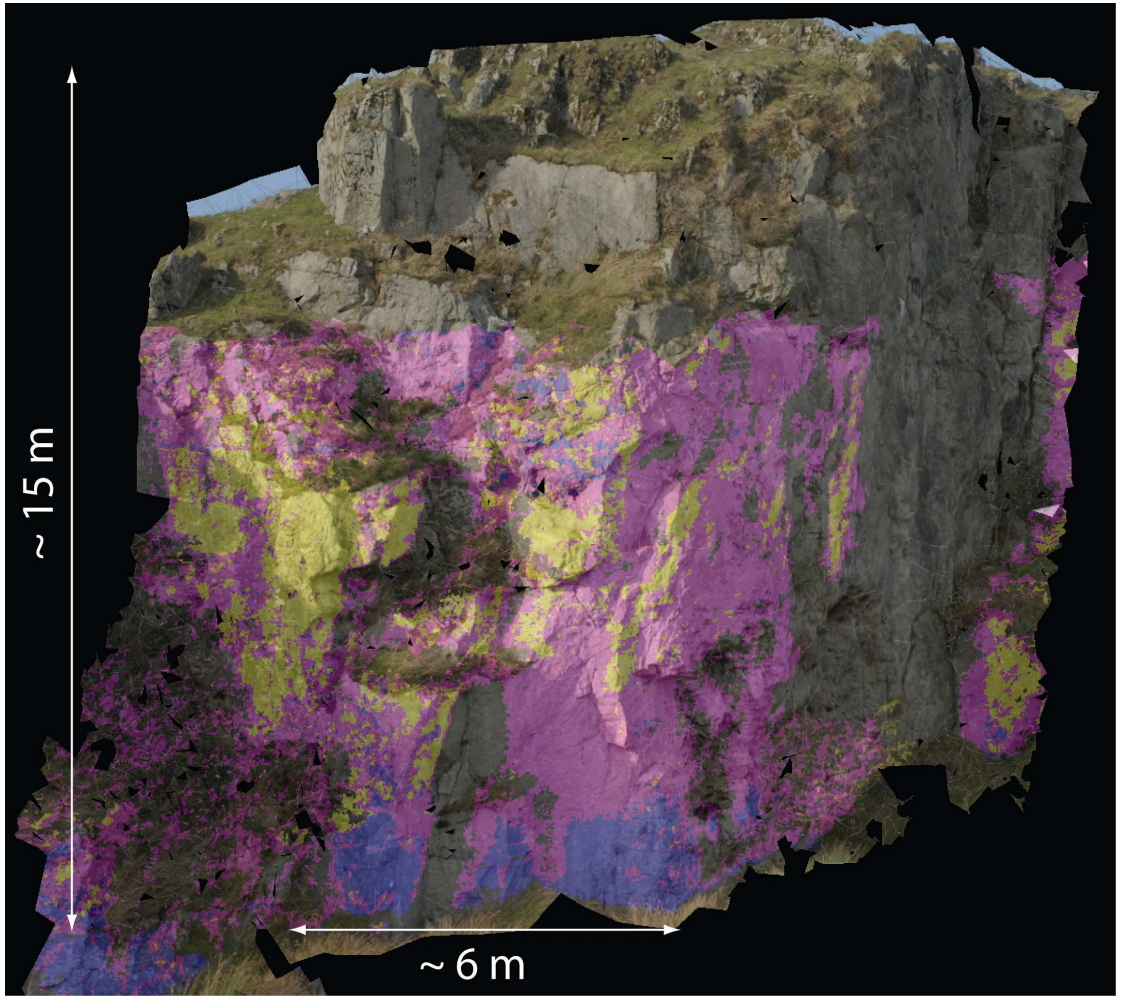
- What type of data is available: what is actually represented?
- What is the quality of available data? How do we describe quality?
- Data formats: how is the data digitally available
- Sensors: how was the data acquired
- Processing methods: how to extract information from the data, in theory
- Software: same, in practice
- Possible applications

Goal 2: get values where needed

Interpolation



Goal 3: Find out what is where



Classification

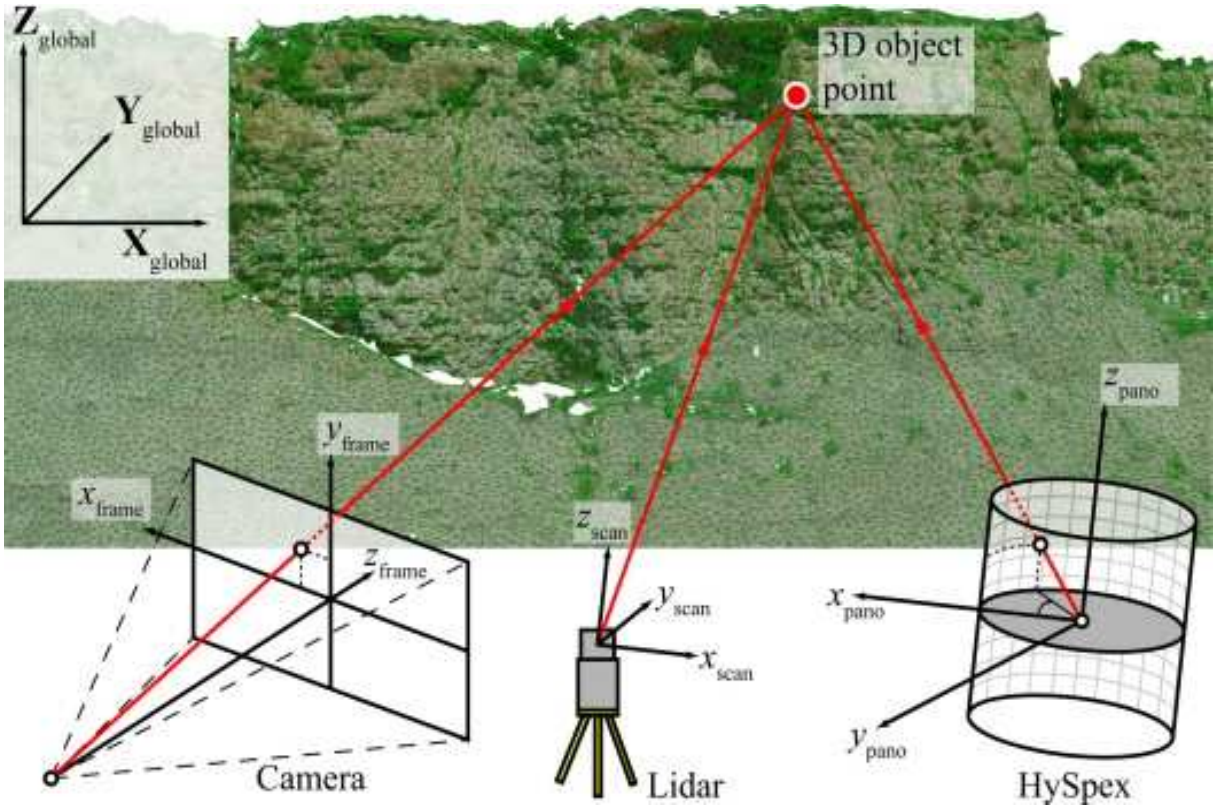
unaltered limestone

moderatly dolomitized limestone

highly dolomitized limestone

http://org.uib.no/cipr/Project/VOG/hyperspectral.htm

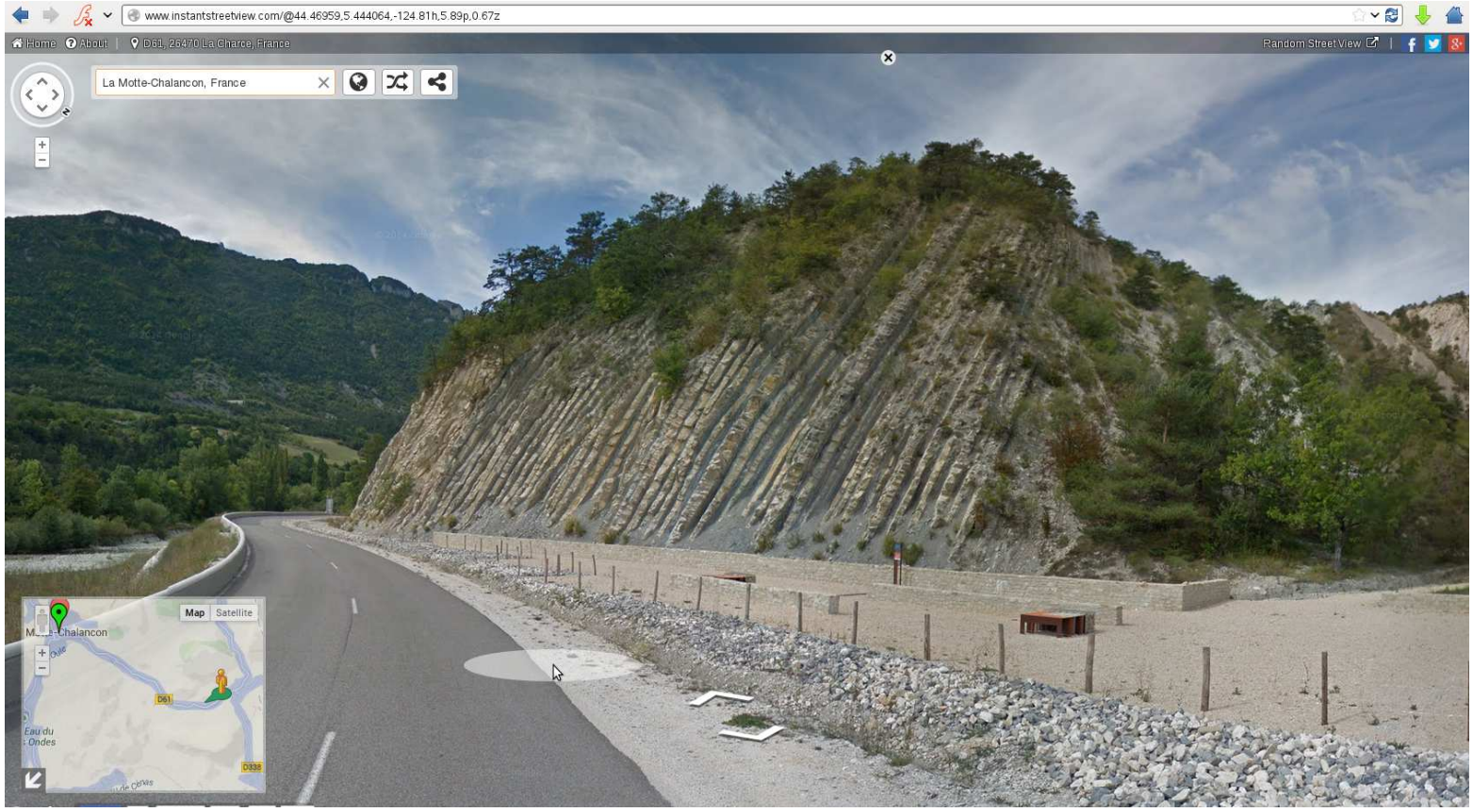
Overlay different data types



http://www.sciencedirect.com/science/article/pii/S0098300413000320#f0015

Simon J. Buckley, Tobias H. Kurz, John A. Howell, Danilo Schneider, (2013), Terrestrial lidar and hyperspectral data fusion products for geological outcrop analysis, Computers & Geosciences 54, pp. 249-258

Get your geometry right

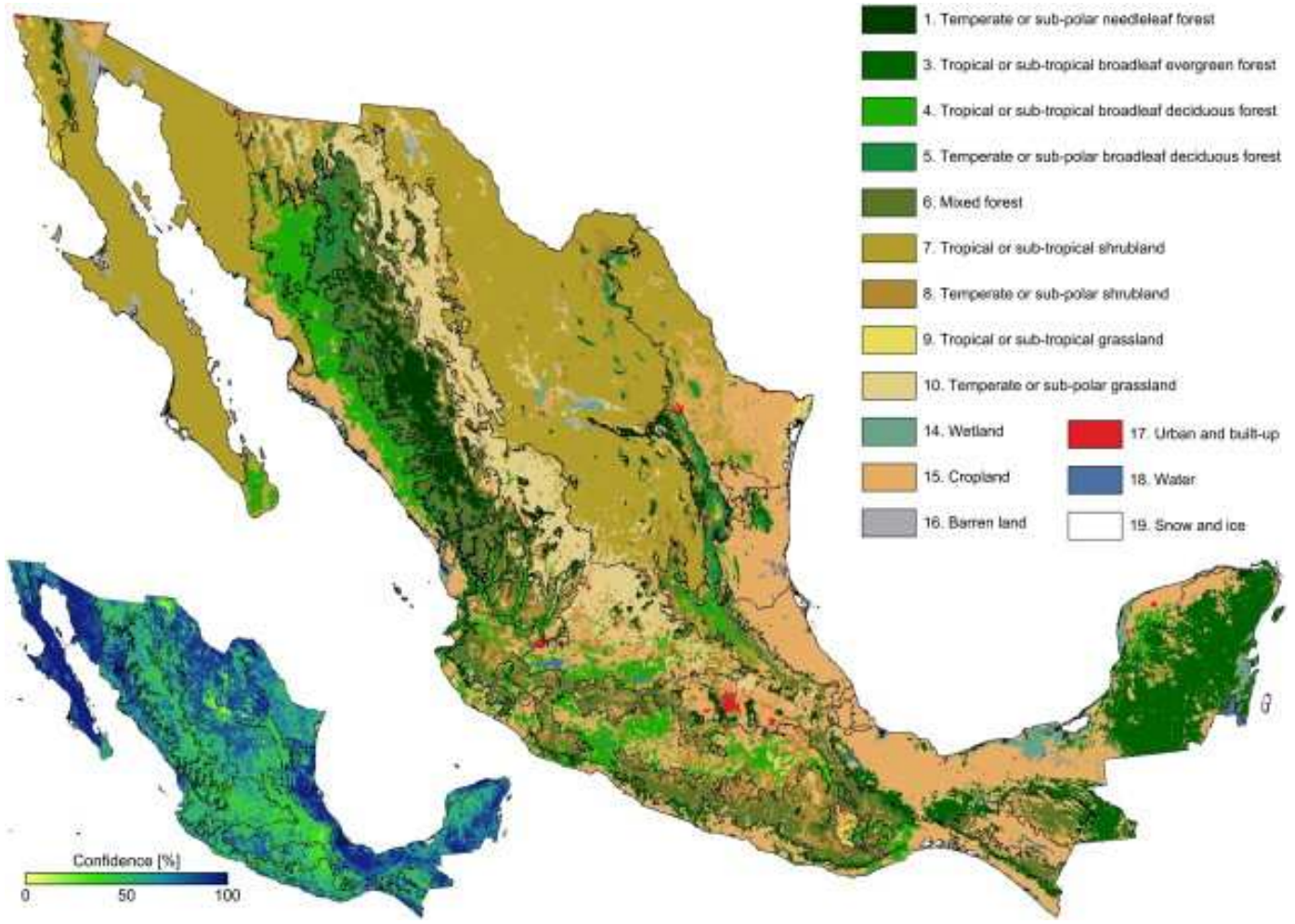


Source `http://www.instantstreetview.com/@44.46959,5.444064,-124.81h,5.89p,0.67z`

Question what are the paramaters?

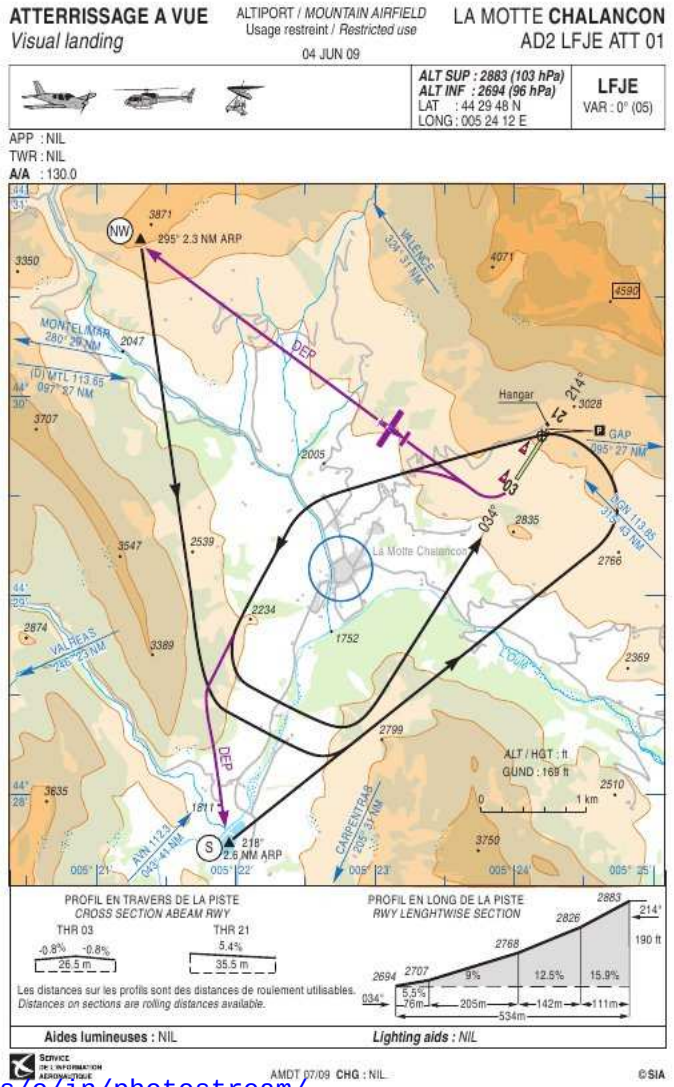
Answer: see https://developers.google.com/maps/documentation/streetview/

Goal 4: Quality of results



Source: R.R. Colditz et al., (2012), Generation and analysis of the 2005 land cover map for Mexico using 250m MODIS data, Remote Sensing of Environment, 123, pp. 541-552

Goal 5: prepare for Vesc



Source http://www.flickr.com/photos/karstenf/4864938907/sizes/o/in/photostream/

Course Software: QGIS

QuantumGIS: Please download and install Version 2.8 (Wien) on your laptop from http://www.qgis.org/

QuantumGIS Plugins: plugins exist and can be downloaded from within QGIS

A gentle introduction to GIS:
http://www.qgis.org/en/docs/gentle_gis_introduction/index.html

QGIS 2.6, user guide:
http://docs.qgis.org/2.6/pdf/en/QGIS-2.6-UserGuide-en.pdf

More QGIS documentation:
http://www.qgis.org/en/docs/index.html

Other software

Matlab: problems you cannot solve with QGIS

Whatever you can find or develop yourself

- Python, programming language compatible with QGIS.
- Google for solutions!

Additional lecture notes

Available on Blackboard in the Course Literature folder

Primer on Mathematical Geodesy,
C. C. J. M. Tiberius, Dept. of Geoscience & Remote Sensing

Reference systems for surveying and mapping,
H. van der Marel, Dept. of Geoscience & Remote Sensing

Background literature

A Modern Introduction to Probability and Statistics, F. M. Dekking, C. Kraaikamp, L. E. Meester, H. P. Lopuhaa, Springer, (2007)

Martin H. Trauth, Matlab Recipes for Earth Sciences

- TU Delft Library (also link via Blackboard)
  http://link.springer.com/book/10.1007/978-3-642-12762-5/page/1

D.D. Sarma, Geostatistics with Applications in Earth Sciences,

- TU Delft Library (also link via Blackboard)
  http://link.springer.com/book/10.1007/978-1-4020-9380-7/page/1

Wackernagel, Multivariate Geostatistics, Google books

- For this course: parts of Chapters 1 to 17;
- Missing on Google Books: pages 14, 15, 45
  http://books.google.nl/books/about/Multivariate_Geostatistics.html?id=Rhr7bgLWxx4C&redir_esc=y

Assignments

- Six practical assignments, one for each Exercise Class
- Max. 5 pages in PDF
- In groups of two
- Upload results on Blackboard
- Deadlines: see deadline page + assignment
- Deadline last assignment: Friday, June 12

Assignment Marks

– –	–	+/-	+	++	++B
3	4.5	6	7.5	9	10

Examination

- Written exam: Thursday, July 2, 14.00 - 17.00, LR-CZ J
- Resit: Wednesday, August 12, 14.00 - 17.00, CT-IZ 0.96

Exam preparation

- Exercises in the slides
- Theoretical aspects assignments
- Slides/Lectures
- Background material
- Check last years exam (but last year less statistics contents)

Faculty rules:
Results of both Assignments and Written Exam should be at least 5.

GRS, week by week

CiTG-AESB2440 - Geostatistics & Remote Sensing

Week (weken) 3.1-5.1, 5.6, 5.8 — Van 09 Feb 2015 tot 29 Aug 2015

	8:00–10:30	10:45–12:30	12:45–13:30	13:45–15:30	15:45–17:30
Mon				Geostatistics & Remote Sensing AESB2440 CT-CZ E 4.1, 4.4 Lindenbergh, Dr. R.C.	
Tue				Geostatistics & Remote Sensing AESB2440 CT-CZ F 4.1, 4.4 Lindenbergh, Dr. R.C.	
Wed		Geostatistics & Remote Sensing AESB2440 CT-IZ 1.98 4.1-4.4 Lindenbergh, Dr. R.C.			Geostatistics & Remote Sensing AESB2440 CT-IZ 1.98 4.1-4.4 Lindenbergh, Dr. R.C.
Thu					Geostatistics & Remote Sensing AESB2440 CT-IZ 1.98 4.1-4.3 Lindenbergh, Dr. R.C.
Fri		Geostatistics & Remote Sensing AESB2440 CT-IZ 2.02 4.1-4.3 Lindenbergh, Dr. R.C.		Geostatistics & Remote Sensing AESB2440 CT-IZ 2.02, CT-CZ F 4.1-4.3 Lindenbergh, Dr. R.C.	

Each course is followed by its corresponding exercise class.

Involved staff

Lecturer

Roderik Lindenbergh
Room 2.25
T: 015 - 27 87649
E: R.C.Lindenbergh@tudelft.nl

Instructors

Martin de Graaf
graafdem@knmi.nl
Room 2.25

Beril Sirmacek
B.Sirmacek@tudelft.nl
Room 2.05

Jie Zhou
J.Zhou-1@tudelft.nl
Glass room, 2nd floor

Leonoor Portengen
leonoor_25@hotmail.com
no room

Lecture Schedule, GRS

Nr.	Room	Day	Week	Date	Type	Topic
1	1.98	Mo	4.1	April 20	Lecture 1	Digital Mapping
2	1.98	Tu	4.1	April 21	Exercises 1	1st hour: Intro QGIS
3	1.98	We	4.1	April 22	Lecture 2	Probability
4	1.98	We	4.1	April 22	Exercises 2	
5	1.98	Th	4.1	April 23	Lecture 3	GNSS, errors, Inverse distance Interpolation
		Th	4.1	April 23	Deadline	Assignment Digital Mapping
6	1.98	Fr	4.1	April 24	Exercises 3	
7	1.98	Fr	4.1	April 24	Lecture 4	LIDAR + Det. Interpolation
8	1.98	We	4.2	April 29	Exercises 4	
9	1.98	We	4.2	April 29	Lecture 5	Distributions + Covariance
		We	4.2	April 29	Deadline	Assignment Det. Interpolation
10	1.98	Tu	4.2	April 30	Exercises 5	
11	1.98	Fr	4.2	May 1	Lecture 6	Least squares
12	1.98	Fr	4.2	May 1	Exercises 6	
		Tu	4.3	May 5	Deadline	Assignment GPS track
13	1.98	We	4.3	May 6	Lecture 7	Stochastic Interp. 1
14	1.98	We	4.3	May 6	Exercises 7	
15	1.98	Th	4.3	May 7	Lecture 8	Classification
16	1.98	Fr	4.3	May 8	Exercises 8	
		Mo	4.4	May 11	Deadline	Assignment Stochastic Interpolation
17	1.98	Mo	4.4	May 11	Lecture 9	Digital terrain analysis
18	F?	Tu	4.4	May 12	Exercises 9	
19	1.98	We	4.4	May 13	Lecture 10	Quality assessment
20	1.98	We	4.4	May 13	Exercises 10	
		Fr	4.4	May 15	Deadline	Assignment Classification
		Fr	4.8	June 12	Deadline	Assignment Slope Quality

Assignment overview + deadlines

Nr.	Deadline date	time	Topic
1	Thursday, April 23,	23.59	Digital Mapping
2	Wednesday, April 29,	12.59	Deterministic Interpolation
3	Tuesday, May 5,	23.59	GPS track
4	Monday, May 11,	11.59	Stochastic Interpolation
5	Friday, May 15,	23.59	Classification
6	Friday, June 12,	11.59	Slope Quality

Part B: Introduction to Digital Mapping

Digital Mapping, contents

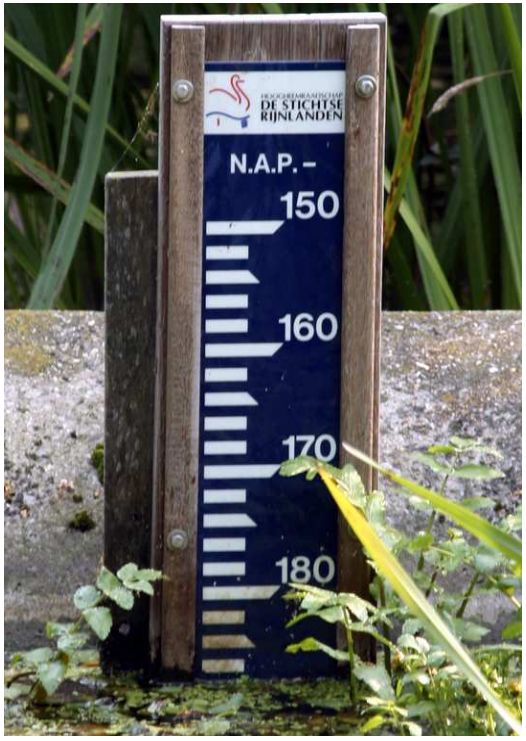
Coordinate Systems

- Geoids
- Global and Local Reference Systems
- Coordinate Transformations

Data sets

- ASTER GDEM
- Landsat ETM+
- Open Streetmap

Normaal Amsterdams Peil



NAP: now part of the European Terrestrial Reference System 1989

Position and height on the Earth

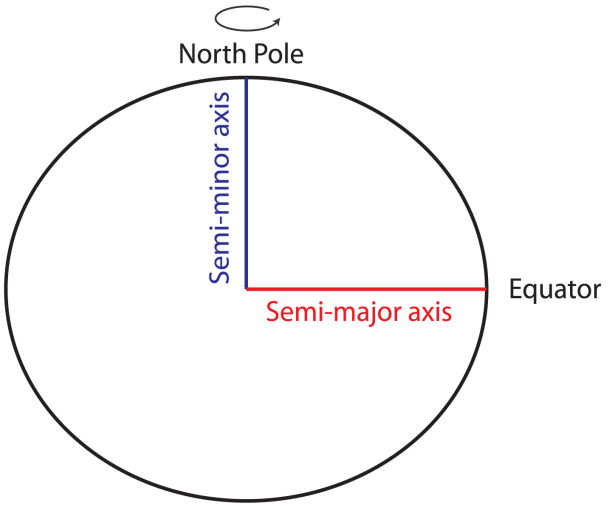
Position:
≈ horizontal location above, on or below some reference surface

Height:
≈ vertical distance above, on or below some reference surface

Relates issues:

- Where is the Earth in the solar system?
- Where are the other planets, asteroids, etc?
- How to fix a location on, say, Mars?
- Does a stable reference surface on Earth actually exist?

Ellipsoidal Coordinates



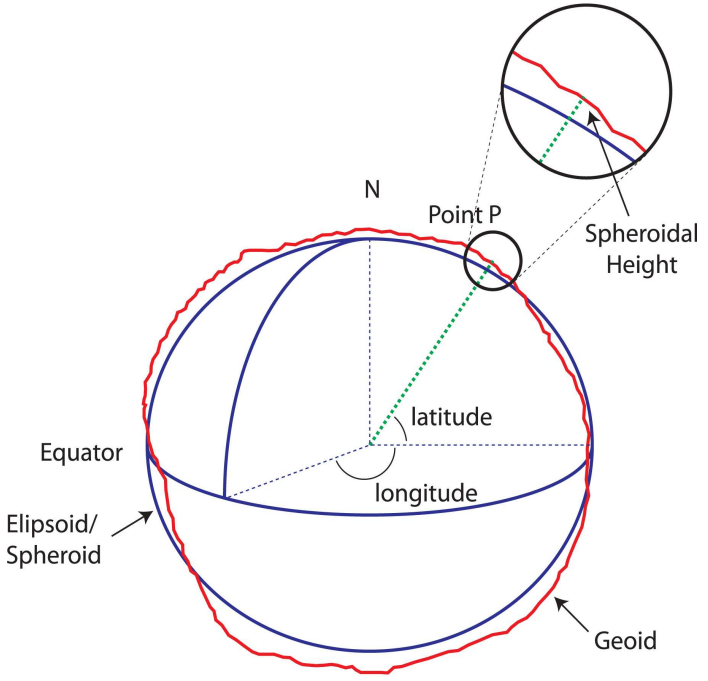
Idea: use simple Earth model

- 1st approximation:
  Earth is a sphere
- 2nd approximation:
  Earth is an ellispoid.

WGS84: common reference ellipsoid
(World Geodetic System, 1984)

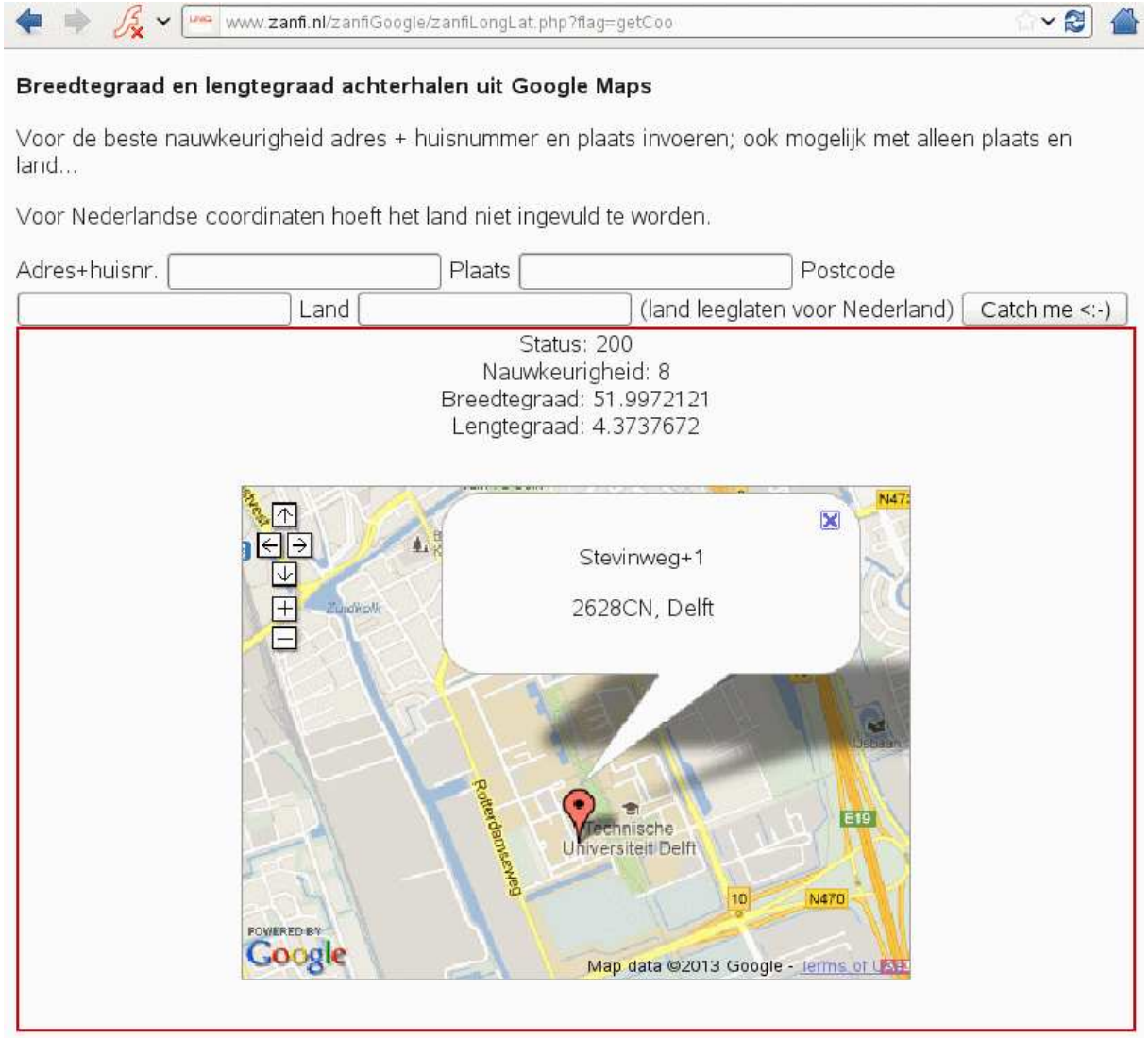
Spherical Coordinates in degrees:

- Latitude,
  From equator,
  up North and down South
- Longitude,
  From Greenwhich,
  up East and down West



http://www.icsm.gov.au/mapping/datums2.html

Coordinate Example



http://www.zanfi.nl/zanfiGoogle/zanfiLongLat.php?flag=getCoo

Problem with Ellipsoidal height

Ellipsoidal height has no physical interpretation.

$\Rightarrow$ refer heights to a meaningful equipotential surface

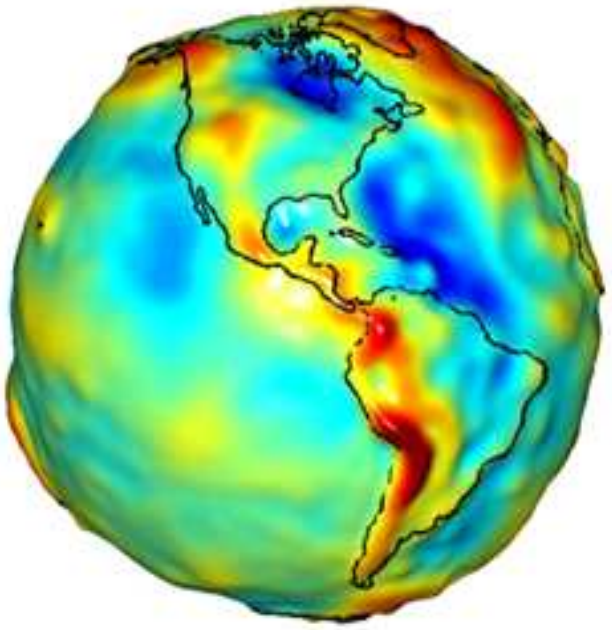
Geoid: surface of equal gravity that globally fits best the mean sea level

Orthometric height: distance along a plumb line to the geoid.

Example. The "height" of Mount Everest of 8848 m is the orthometric height, its WGS84 ellipsoidal height was determined as 8823.51m (at snow level)

(full story: http://www.leica-geosystems.us/en/The-Himalayas-Mt-Everest1_2709.htm)

Geoid

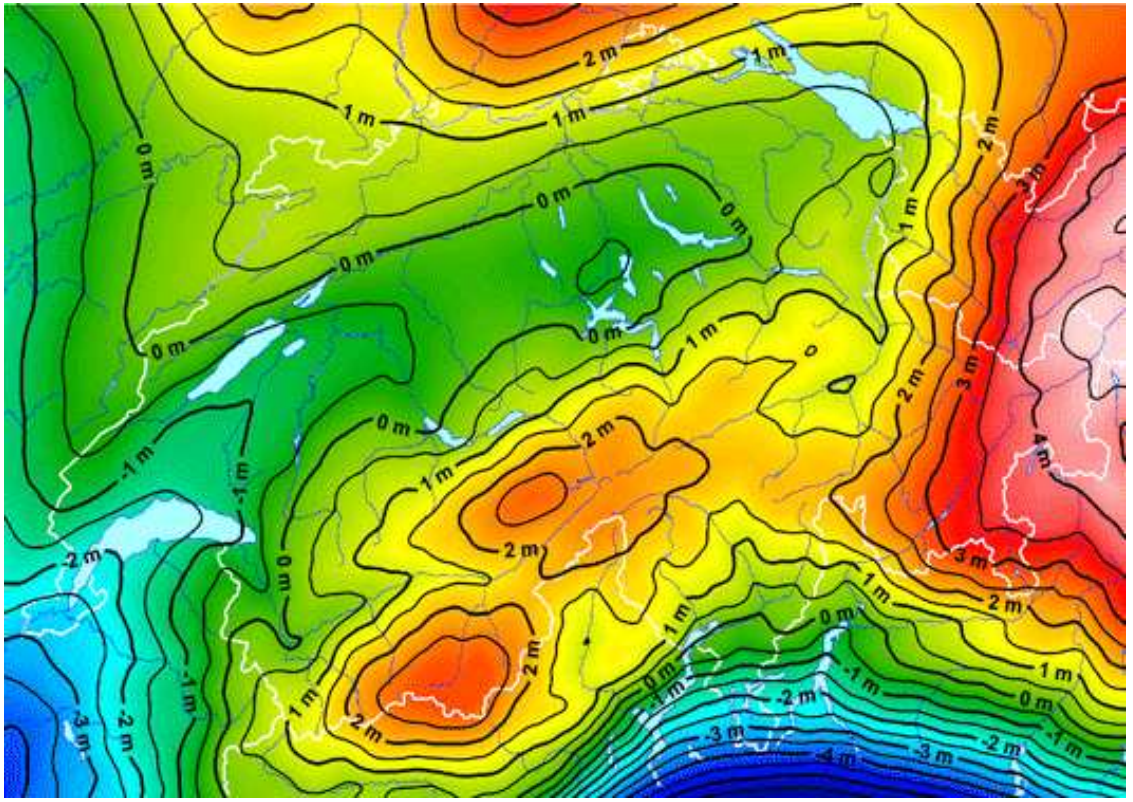


"A depiction of the Western Hemisphere geoid. Areas in yellow and orange have a geoid which is comparatively further from the center of the Earth."

Source: http://oceanservice.noaa.gov/facts/geoid.html

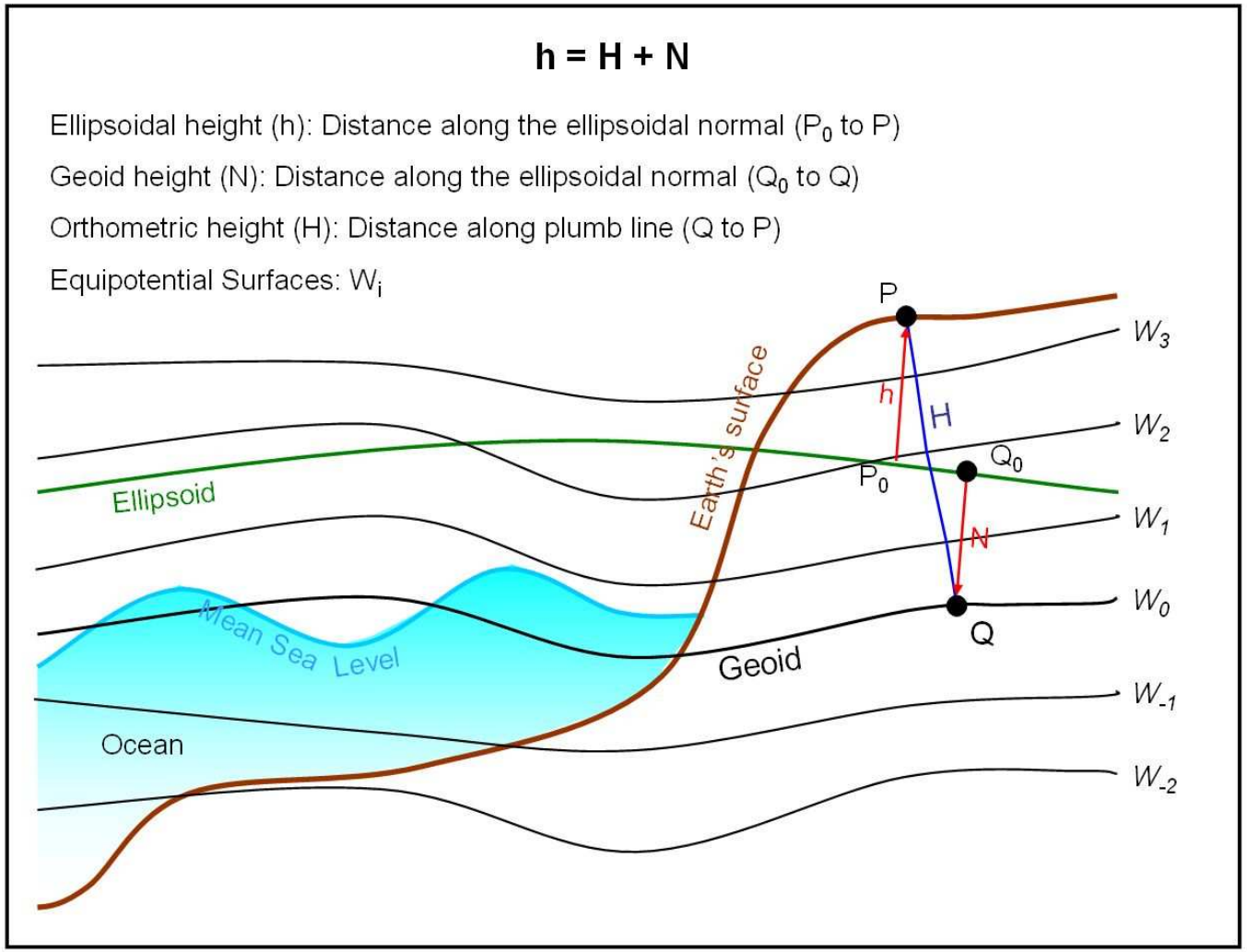
Example: Swiss geoid heights

Swiss geoid (CHGeo04) relative to the local reference ellipsoid.



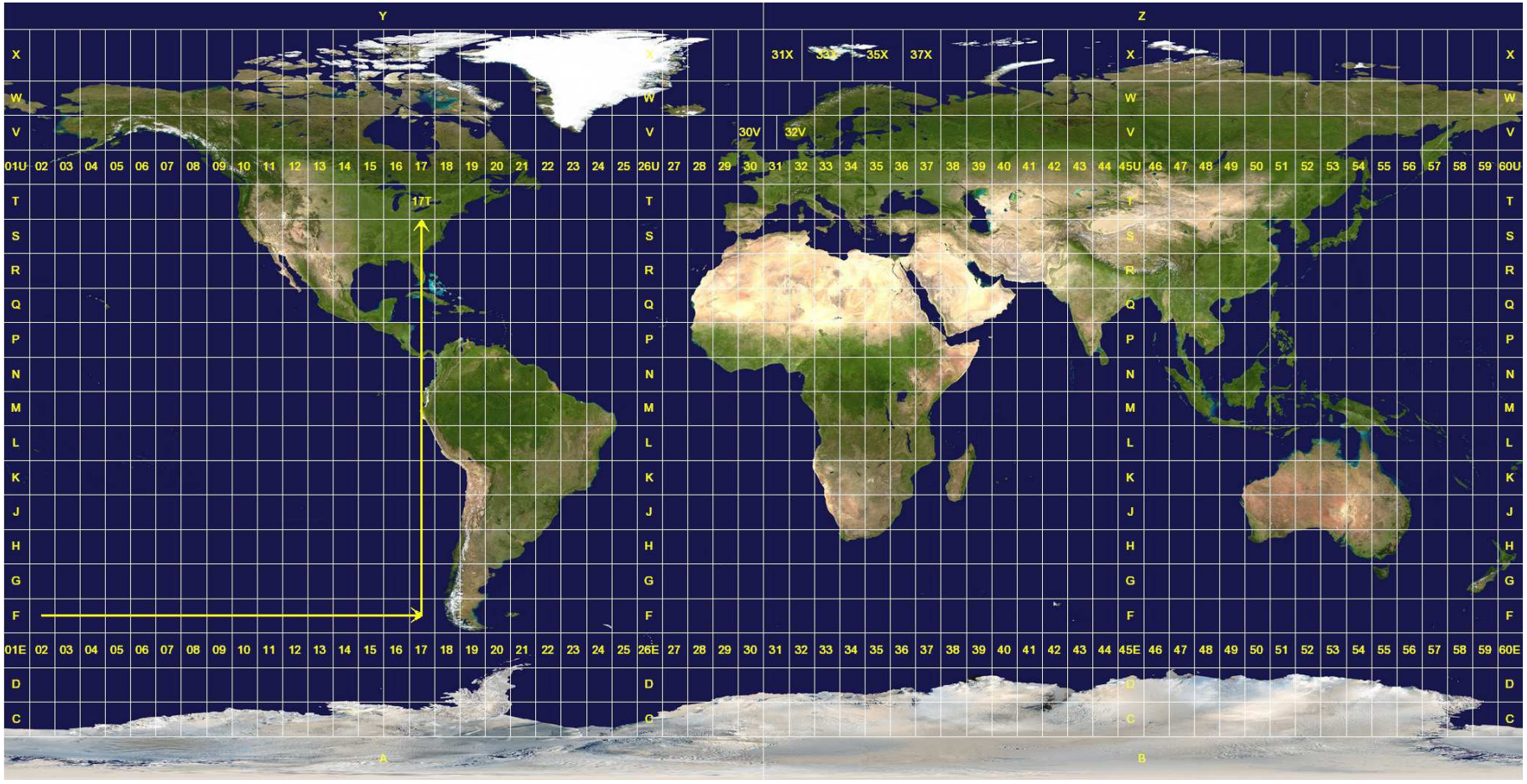
http://www.swisstopo.admin.ch/internet/swisstopo/en/home/topics/survey/sys/geoid.html

Three Heights



http://www.geod.nrcan.gc.ca/hm/gloss_e.php

60 UTM zones

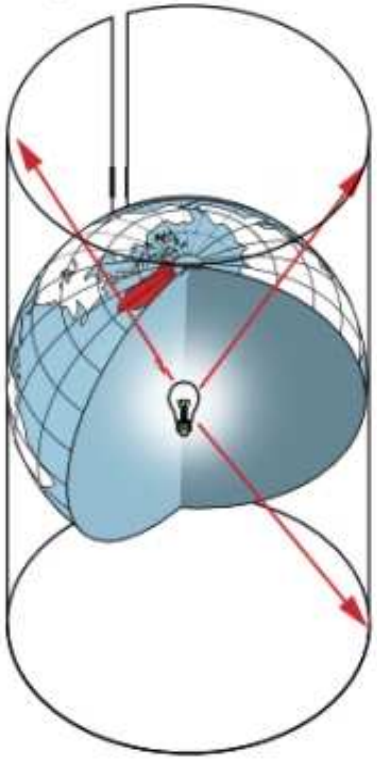


http://en.wikipedia.org/wiki/File:Utm-zones.jpg

Cylindric projection

Bij de Mercatorprojectie wordt het oppervlak van de aarde via een (denkbeeldige) lichtbron in de aardbol geprojecteerd op een cilinder die de aardbol precies omsluit.

Alle meridianen, de 'lengtecirkels' die in de polen samenkomen, worden op een Mercatorkaart verticale parallellen.

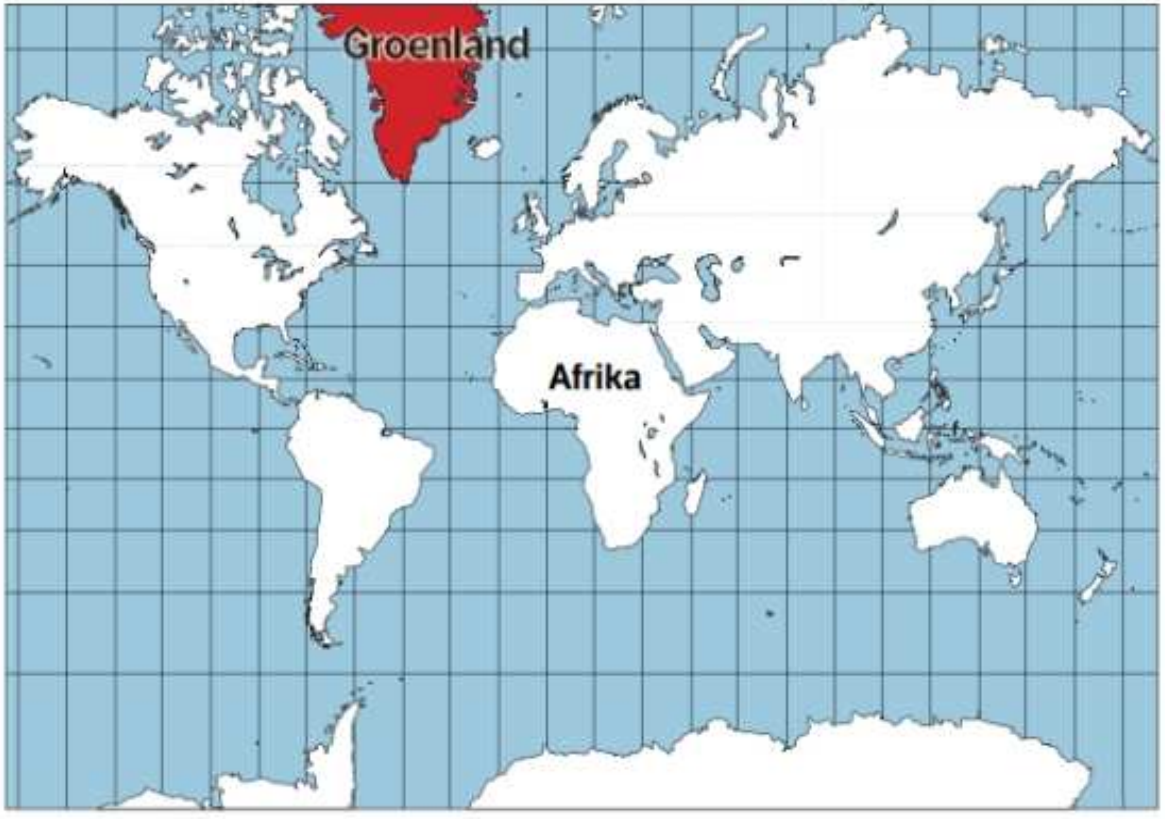


NRC 280214 / PB, FG

http://www.nrc.nl

Nadeel Mercator projectie

Het nadeel is dat deze projectie oppervlakten meer vervormt naarmate ze verder naar het noorden of zuiden liggen. Zo lijkt Groenland op een Mercatorkaart even groot als Afrika, terwijl het oppervlak maar een fractie is. Voordeel van deze projectie is dat een constante kompas-koers (in de scheepsvaart) op de kaart een rechte lijn is.



http://www.nrc.nl

2D projections and maps

UTM: Universal Transverse Mercator geographic coordinate system:

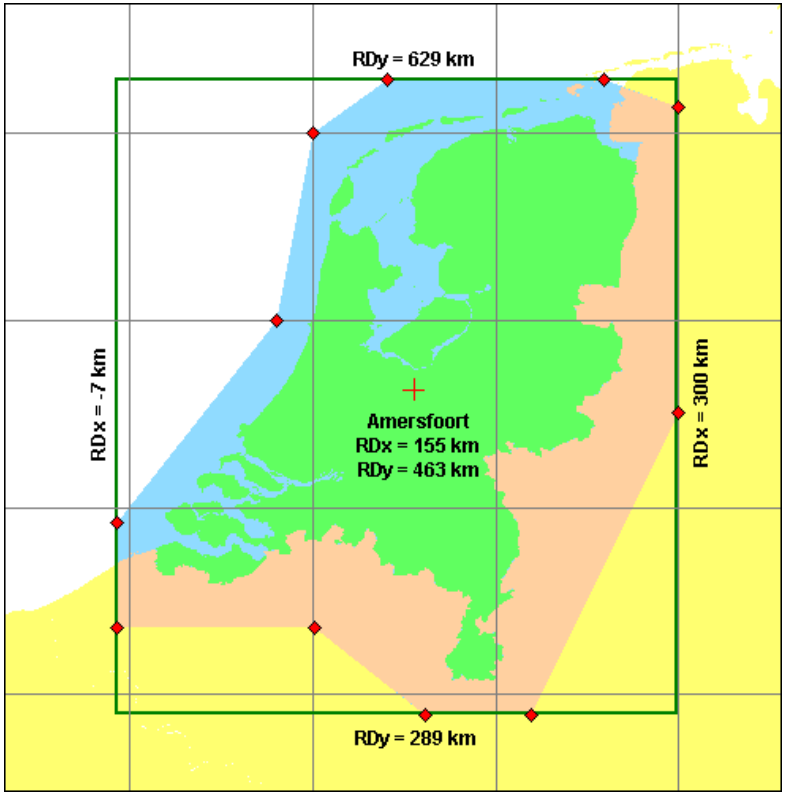
- Divides the earth into pole-to-pole zones of 6 degrees longitude
- 2D Cartesian coordinate system
  (Cartesian ≈ "normal" coordinate system with perpendicular axes)
- Each zone uses a transverse Mercator projection
  (transverse Mercator: see e.g. http://en.wikipedia.org/wiki/Transverse_Mercator_projection)
- A conformal projection
  (A projection is conformal if it preserves angles.)
- Projection minimizes distortion along a north-south line,
- Does not maintain true directions.

Kadaster coordinatentransformator:
https://rdinfo.kadaster.nl/rd/transformator.html

Question. How many UTM zones?

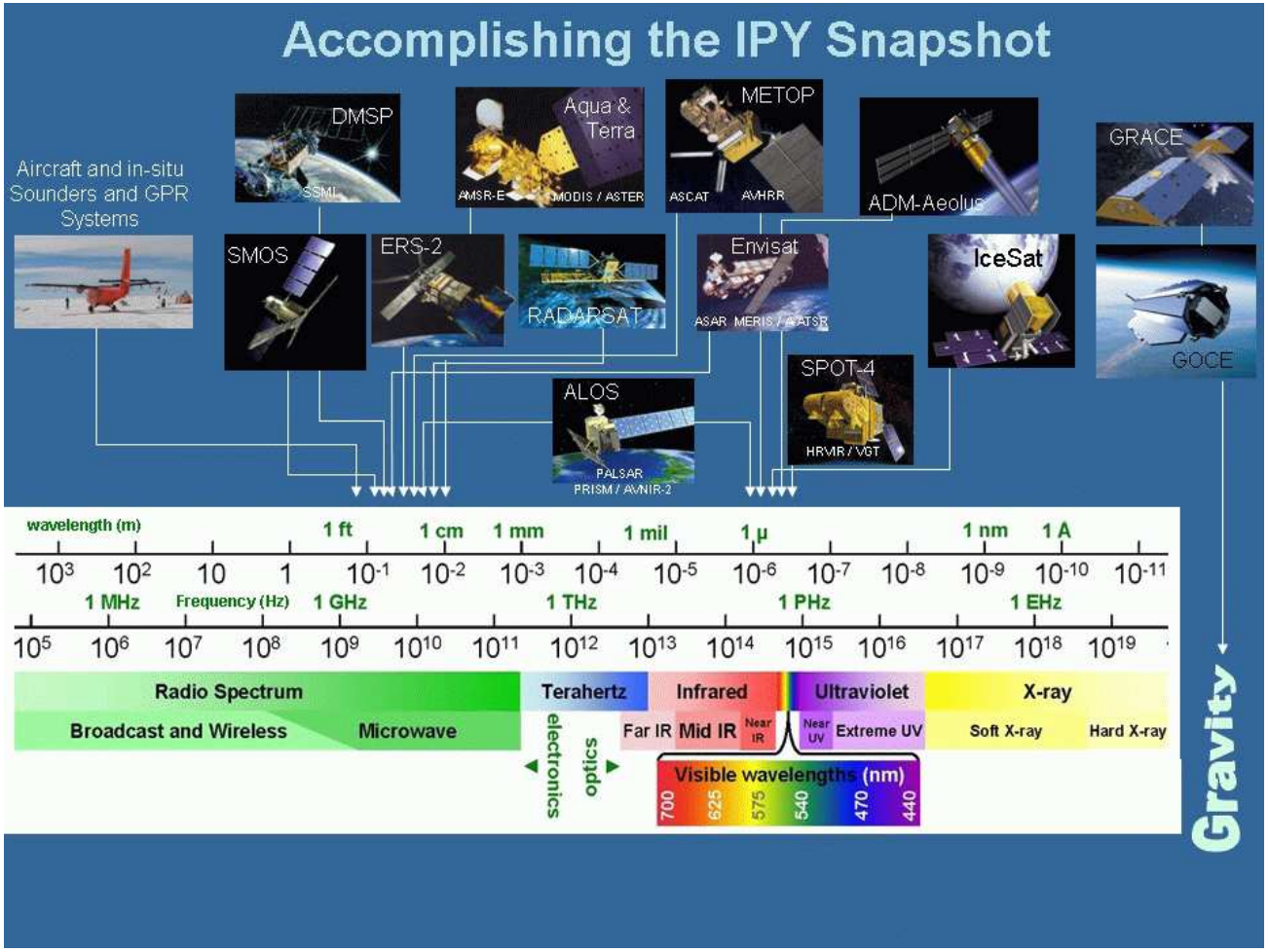
Dutch system: RDNAP

See: http://nl.wikipedia.org/wiki/Rijksdriehoekscoordinaten



Question. Where is the synthetic origin of the Dutch RD?

Remote Sensing

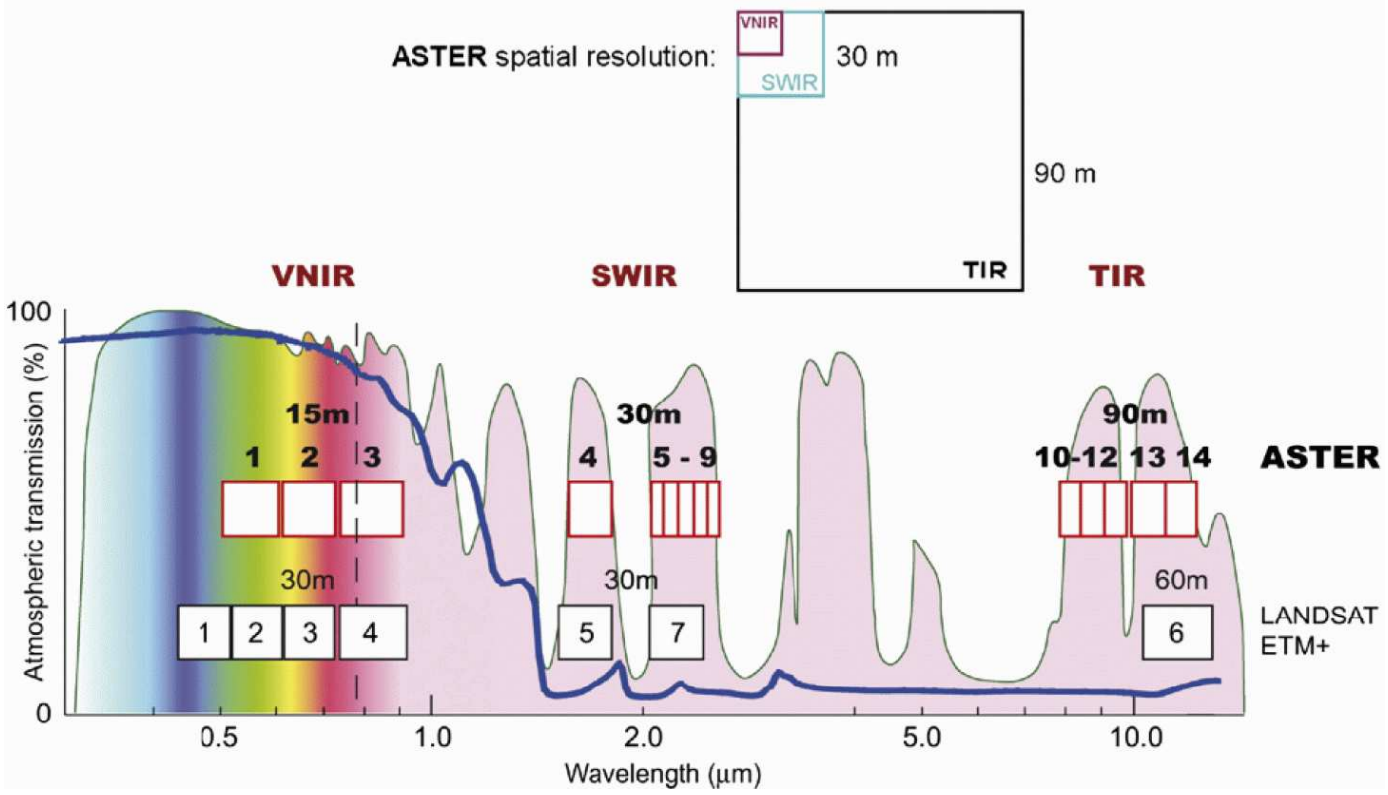


The figure only contains some sample missions that acquired data uses for the Int. Polar Year. There are many more satellite missions. Image source: http://www.earthzine.org/wp-content/uploads/2008/03/accomplishing.jpg

Read more: http://missionscience.nasa.gov/ems/index.html (Tour of the Electromagnetic Spectrum)

Spectral Data: Aster and Landsat

http://www.sciencedirect.com/science/article/pii/S0169555X07001602



Combination of different signal strengths in different spectral bands

$\Rightarrow$ Information on scattering material

False Colour Image: Map response in three suitable bands to RGB

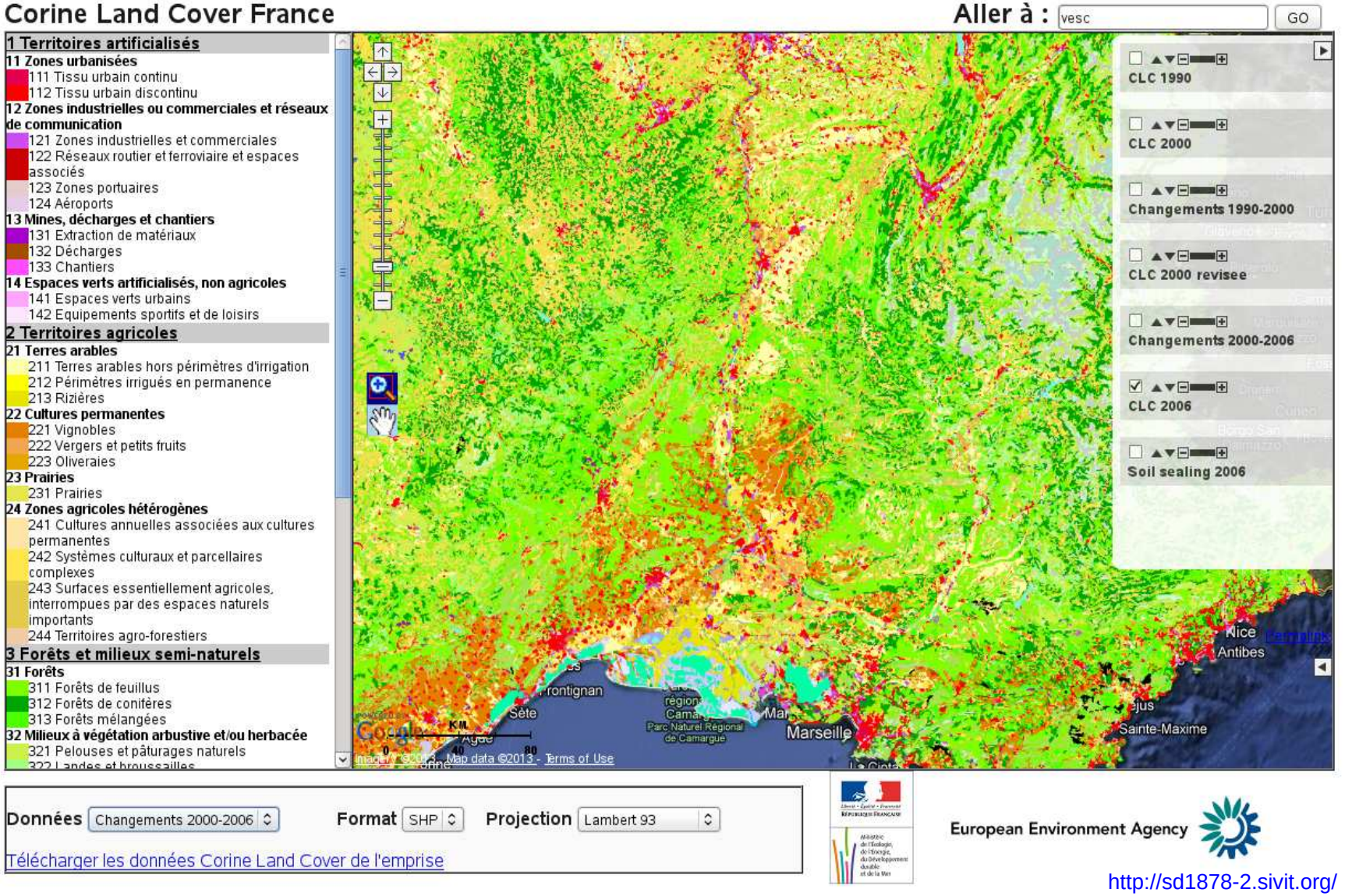
Landsat false colour image

Read more

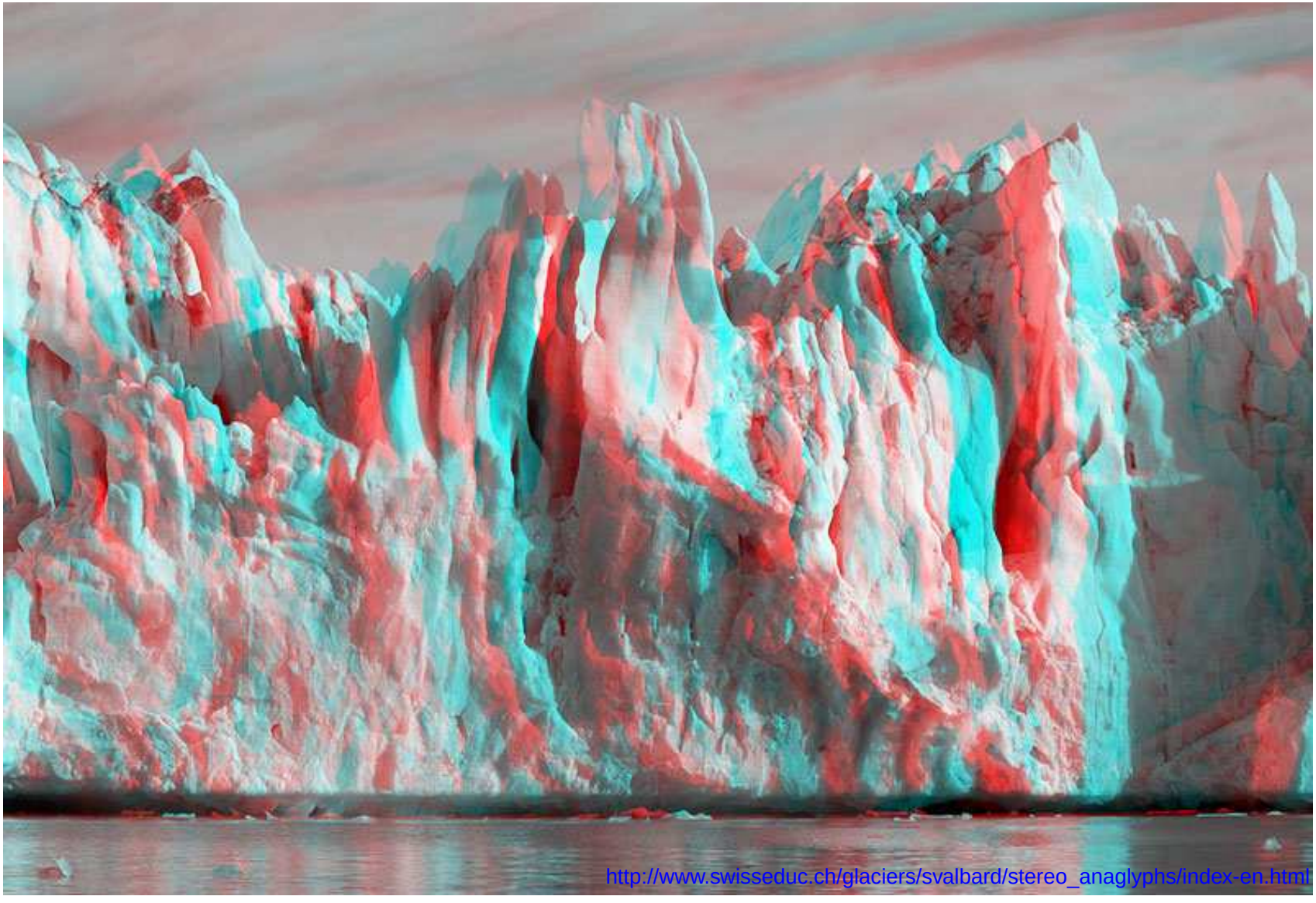
Why is that Forest Red and that Cloud Blue? How to Interpret a False-Color Satellite Image

http://earthobservatory.nasa.gov/Features/FalseColor/

Derived land cover product



Stereo Photos



Photogrammetry

Forward intersection procedure:

$$x - x_0 = -f \cdot \frac{m_{11}(X - X_C) + m_{12}(Y - Y_C) + m_{13}(Z - Z_C)}{m_{31}(X - X_C) + m_{32}(Y - Y_C) + m_{33}(Z - Z_C)}$$

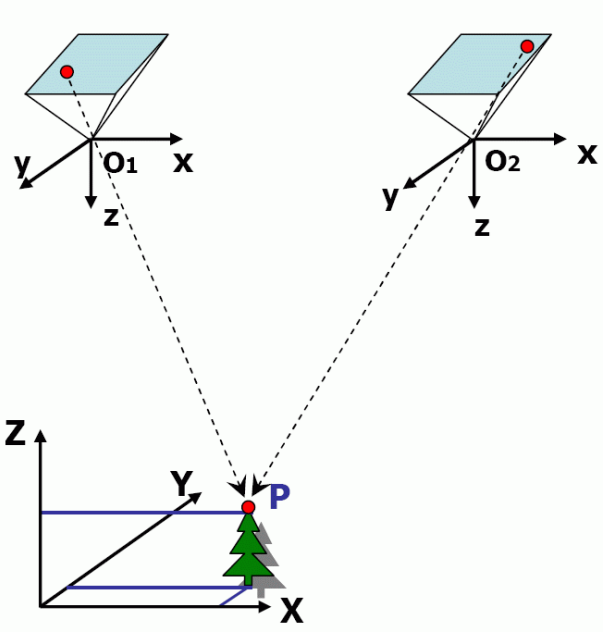
$$y - y_0 = -f \cdot \frac{m_{21}(X - X_C) + m_{22}(Y - Y_C) + m_{23}(Z - Z_C)}{m_{31}(X - X_C) + m_{32}(Y - Y_C) + m_{33}(Z - Z_C)}$$

Known parameters.

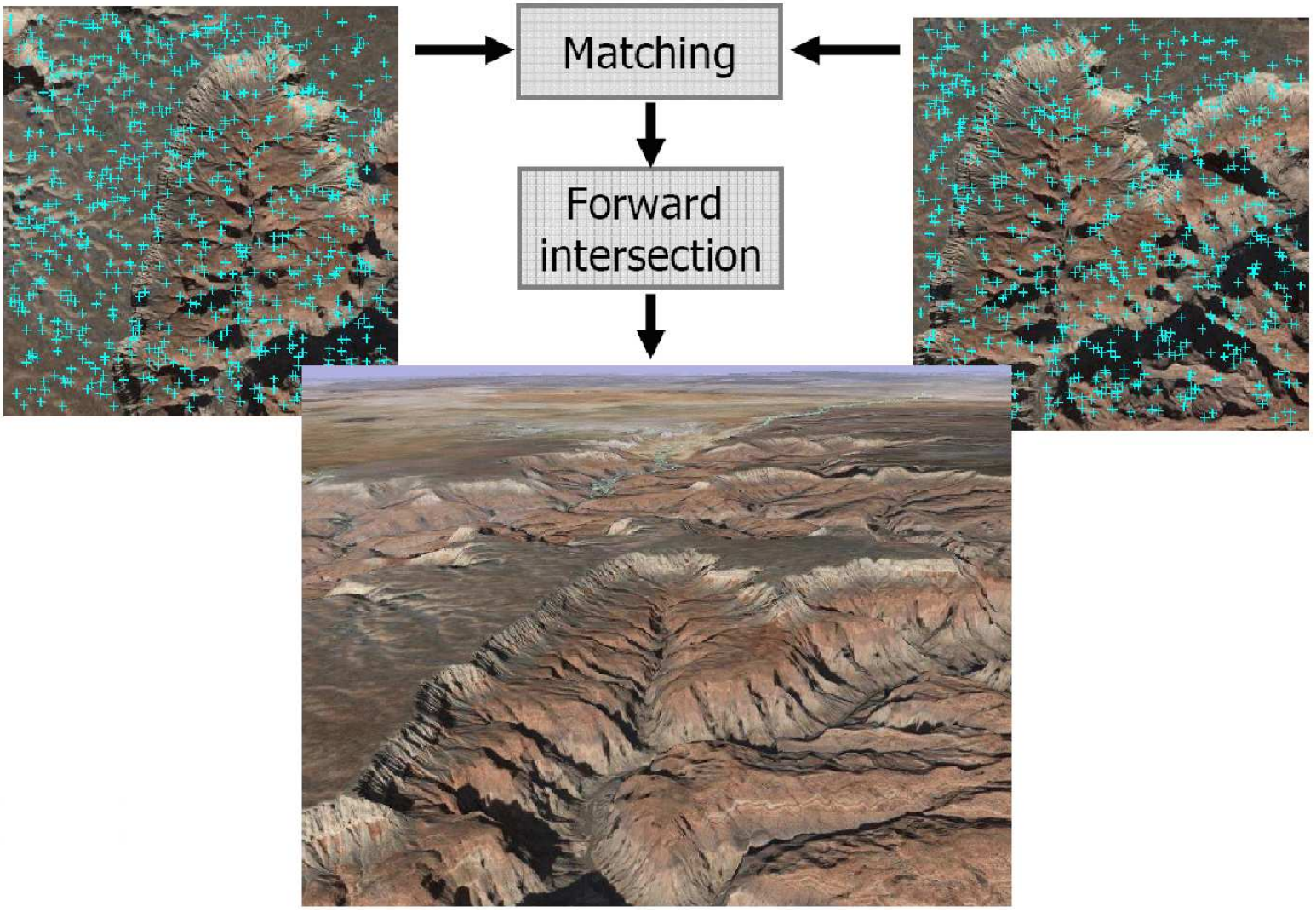
- 2D Image coordinates: x, y
- 3D Camera location: X_C, Y_C, Z_C
- Focal length: f
- Rotation matrix (m_{ij}), with $i, j = 1 \ldots 3$

Unknown parameters:

- 3D Object coordinates: X, Y, Z



Photogrammetric DEM generation



Photogrammetric DEM generation

+ Accuracies down to a few centimeters can be achieved;

+ Data over large areas can be obtained in a reasonable amount of time;

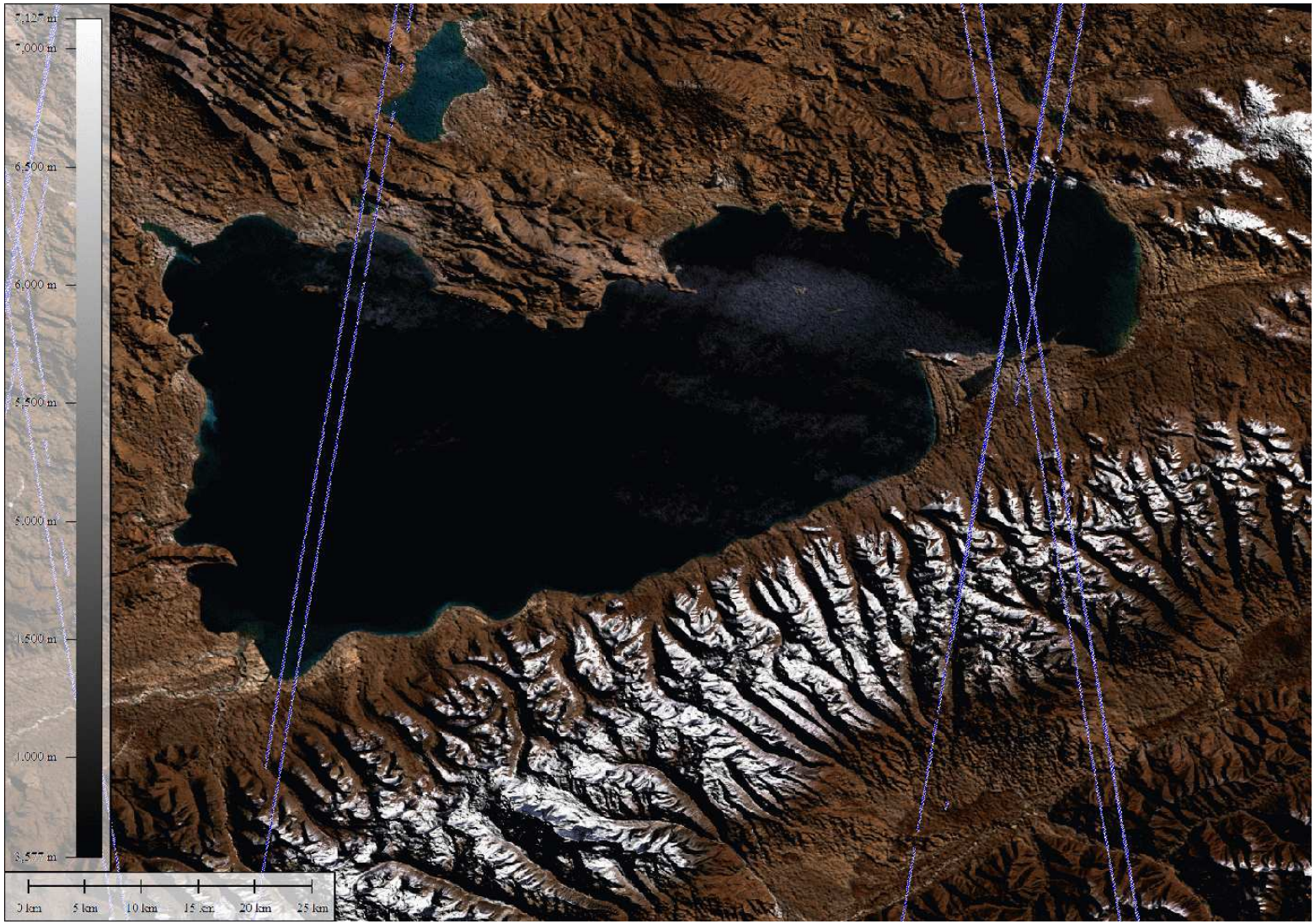
+ Process can be automated;

+ Costs vary depending on the extent of the area, platform and Georeferencing method.

- Enough texture is needed (problem on e.g. snowy areas)

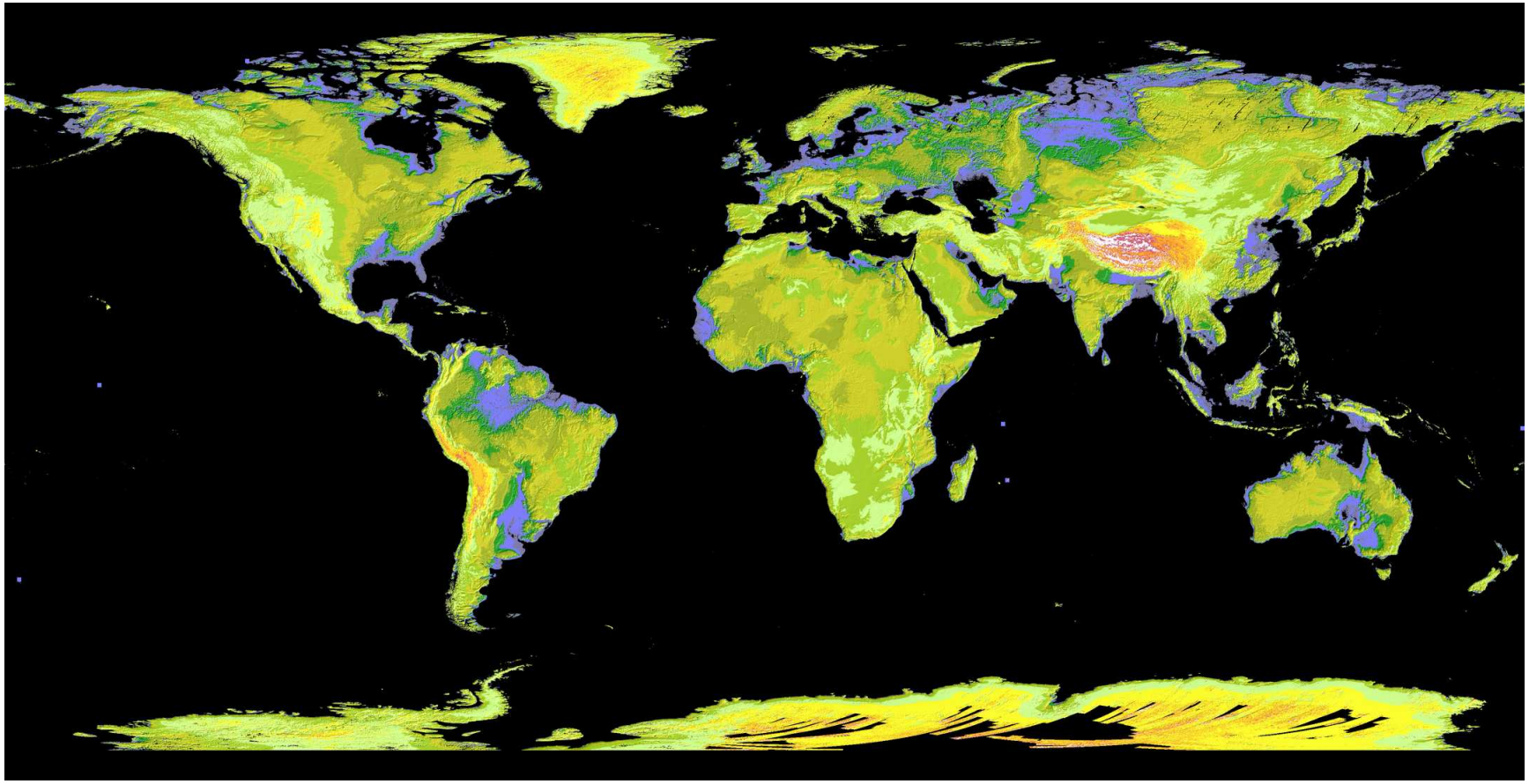
- Obtaining suitable Ground Control Points is sometimes difficult

Aster GDEM + Landsat + ICESat



http://www.angelcorp.be/?project=Validation of ASTER loc=projects

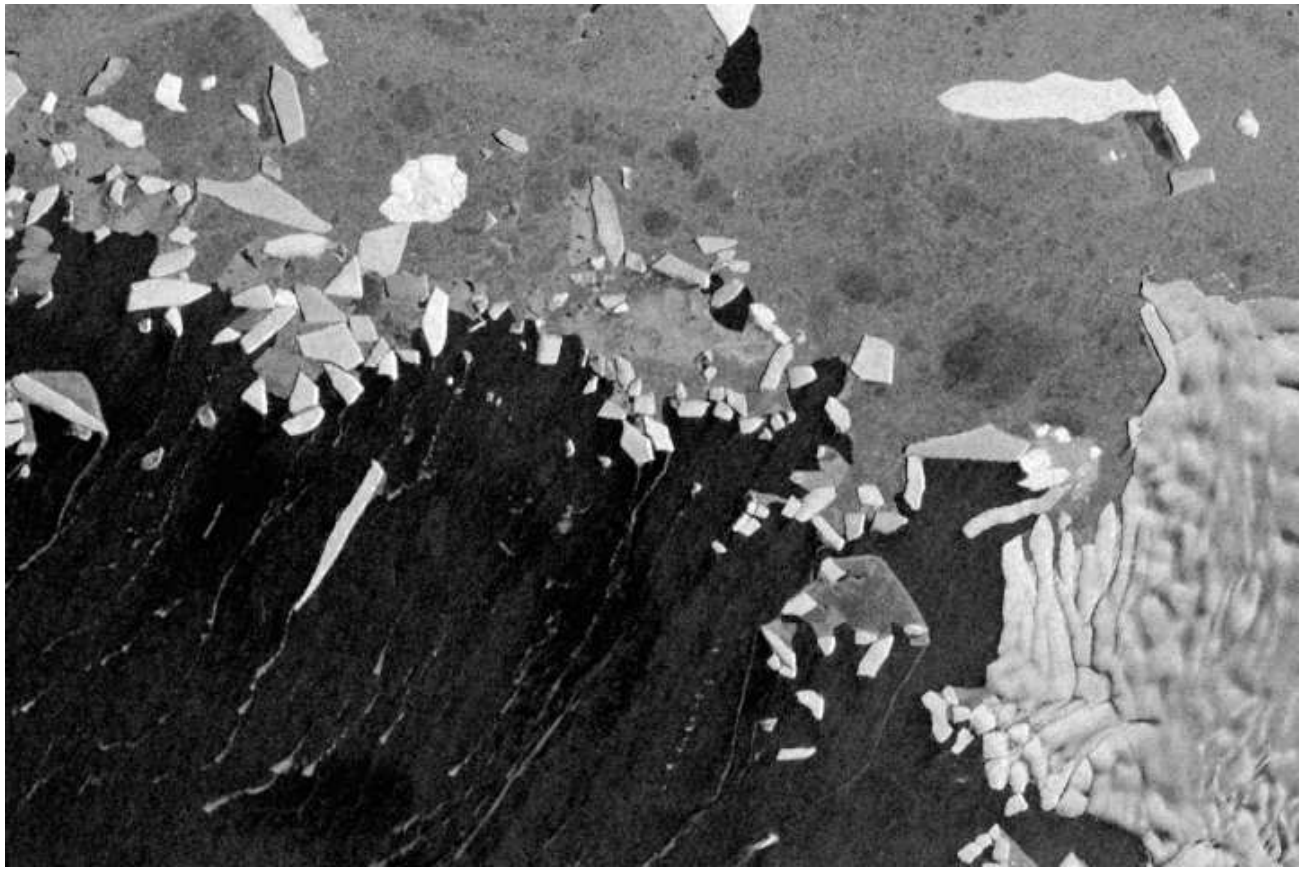
Aster GDEM world map



http://asterweb.jpl.nasa.gov/

http://digitalelevation.wordpress.com/2009/07/02/aster-gdem-download-tutorial/

http://earthobservatory.nasa.gov/



Free subscription to weekly mail with best satellite images via http://earthobservatory.nasa.gov/IOTD/

Some free data sources

Landsat

http://landsat.usgs.gov/Landsat_Search_and_Download.php

ASTER GDEM

http://asterweb.jpl.nasa.gov/

SRTM, (alternative Digital Elevation Model

http://srtm.usgs.gov/index.php

Land cover data:

http://globalmonitoring.sdstate.edu/projects/fao/pages.land/e006n44.html

Digital Map Room, TU Delft library:

http://studenten.tudelft.nl/en/students/faculty-specific/architecture/facilities/tu-delfts-map-room/digital-data/

Open Streetmap:

http://www.openstreetmap.org/ and, as smartphone app: http://osmand.net/

Conclusions

Good news: There is many useful remote sensing data, more then any person can handle.

- Terrain models
- Image data
- Spectral data
- Other data: Radar, Gravity, GPS, . . .

Many applications in Earth Sciences

Bad news: Handling these data has issues:

- Different coordinate systems
- Different resolutions
- Data of different quality
- Too little or too much data
- …