Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

MIN-Fakultät
Fachbereich Informatik
Arbeitsbereich SAV/BV (KOGS)

IP2: Image Processing in Remote Sensing
1. Introduction and Gravitational Astronomy

Summer Semester 2014

Benjamin Seppke

Agenda

- Organizatorial Issues
- Definition of „Remote Sensing“
- History
- Applications
- Affordances
- Challenges
- Motivation for Image Processing
- Gravitational Astronomy at a glance

Organization of this Course (1)

- 11 lectures, covering Remote Sensing fundamentals and image processing applications
- 6 exercises, 1 per week
  - Given out: Tuesday after pre-discussion in lecture
  - Due to: Monday of next week (8 am)
  - Mail to: germer@informatik.uni-hamburg.de
  - First 4 exercises: Traditional (theoretic) questions
  - Last 2 exercises: Practical exercises on PCs
- Slides and exercise sheets will be available at Stine and at http://kogs-www.informatik.uni-hamburg.de/~seppke (plus additional information)

Organization of this Course (2)

- Topics:
  - Introduction and Gravitational Astronomy — 1 Lecture
  - Orbits, Acquisition Constraints and Missions — 1 Lecture
  - EM Radiation — 2 Lectures
  - Earth's Atmosphere — 1 Lecture
  - EO Sensors — 2 Lectures
  - Image Processing in RS — 3 Lectures
  - Knowledge Based Interpretation and Exam preparation — 1 Lecture
- Language issues:
  - Special notation:

Gravitational Astronomy
Himmelsmechanik

EM: Electromagnetic
EO: Earth observation
RS: Remote Sensing

Measurements and Observations

- Three different types:
  - Direct measurement
  - Remote measurement
  - Remote Sensing
- Example: Distance Measurements:

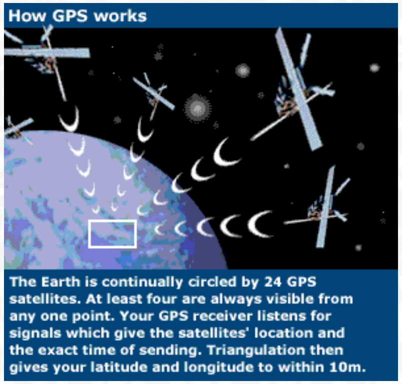
Direct measurement

http://www.mt-online.de

Remote measurement

http://www.augsburger-allgemeine.de

Remote sensing



http://www.news.bbc.co.uk

Remote Sensing

Fernerkundung

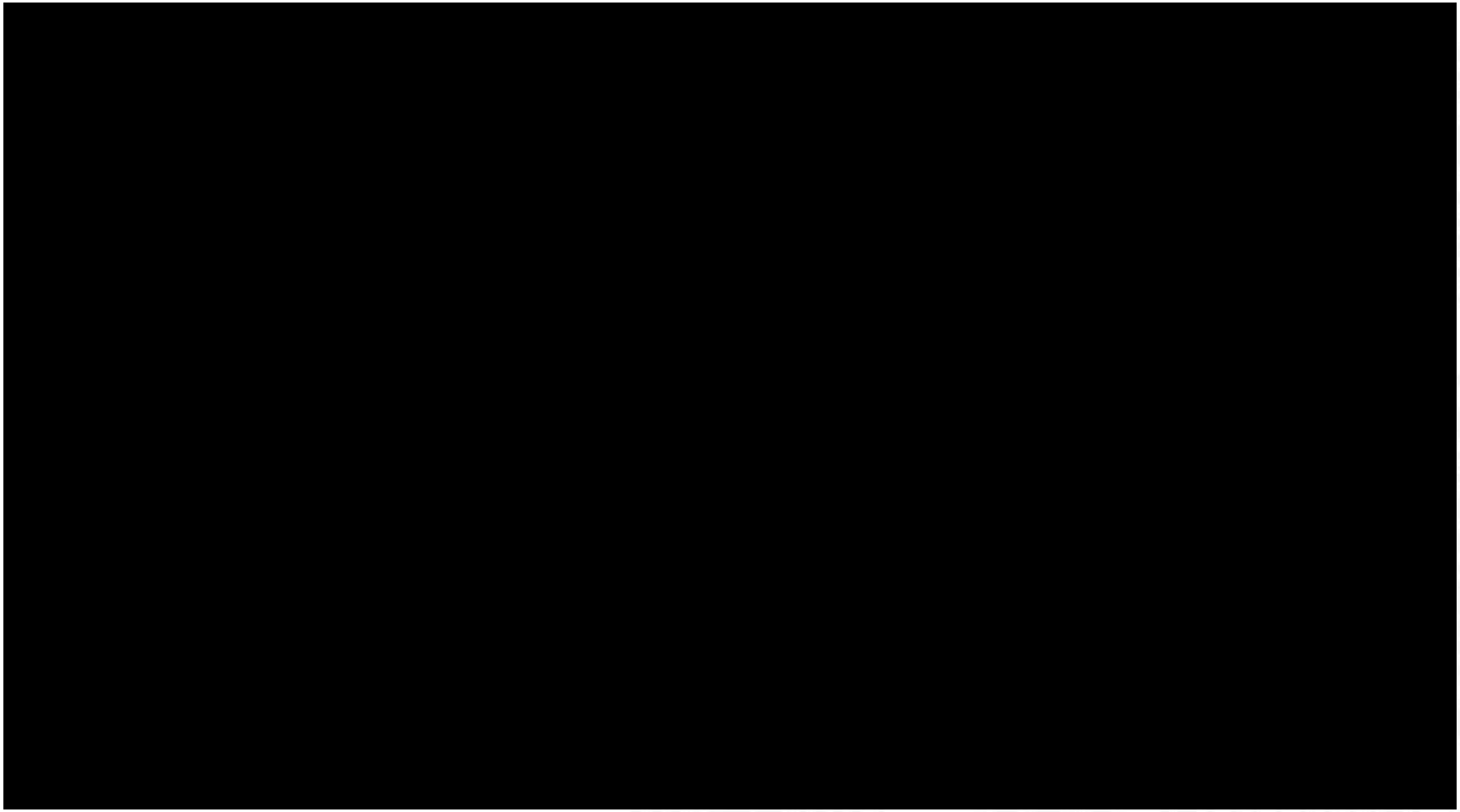
Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation.

T. M. Lillesand & R. W. Kiefer, 1987

- Refinements for this course:
  - Only objects at (or close to) the Earth's surface
  - High-altitude of sensor (above the object)
  - Measuring method is based on EM Radiation

Motivation

ESA Living Planet Symposium 2013 (Edinburgh)



Historical Outline

400 B.C. - 1850

4th century B.C.:

Camera obscura

Early 19th century:

1801: Johann Wilhelm Ritter: Discovery of Ultraviolet Radiation (UV)

Herschel: Discovery der Infrared Radiation (IR)

1839: Invention of Photography: Wedgewood, Talbot, Daguerre und Niepce (1839 first picture)

1840: Arago, Director of the Paris' Observatory propagates photography for field survey.

1849: Colonel Aimé Laussedat: Photography for the creation of topographical maps.

Historical Outline
1850 - 1900

1858: Gaspard Felix Tournachon: first aerial photography (Balloon, 80m altitude)

1880: Aerial photography from Kites

1863: Formulations of Maxwell's Equations

1887/88: Heinrich Hertz: Experimental proof of the existence of electromagnetic waves.

1889 Heinrich Hertz shows that solid bodies reflect radio waves

1890: Batut: First textbook, which covers aerial photography

1900: Aerial photography from pigeons at altitudes >100m

First "drones"

Historical Outline

1900 - 1955

1903: Invention of the airplane

1909: Wilbur Wright takes first picture from an airplane (Centocelli, Italien).

ca. 1935: Color-Photography, Infrared-Photography, RADAR-systems for discovering and monitoring of objects

WWar II: Research on spectral signatures w.r.t stealth-technology, various RADAR enhancements.

1946: Photography from V2-Rockets

1956: Colwell: First investigations for the classification of vegetation by means of aerial photography

ca. 1955: First imaging RADAR systems

Historical Outline
1955 - 2000

ca. 1955: First hi-resolution Synthetic Aperture Radar (SAR) in high altitudes from airplanes (military)
Civil use: from ~1965

1960: Development of the Laser
(used in Remote Sensing since ~1980)

1960: Tiros I, first meteorological satellite. On board: Low-resolution System, TV, 5-ch.Radiometer, Bolometer
Thermical Measurement

1961: Unmanned Mercury MA 4-Flug, first color picture from Orbit

>1965: NASA starts analyzing the combined use of multispectral and infrared imagery
⇒ Landsat-Program (after 1972).

Today

- Satellites provide a privileged viewpoint on the Earth
- Many Satellites in Orbit
  - Carrying different sensors for different tasks
  - Civil, Military
- Hi-Resolution is present!
- Large Infrastructures
  - European Space Agency
  - NASA
- Some Satellite Data even comes free of charge

  → Landsat-Archive

Pros and cons (1)

- **Advantages** of Remote Sensing
  - Synoptical measurements

    Synoptische Messungen

    Large areas on the Earth's surface can be acquired at once and at high velocity
  - Imaging of (otherwise) inaccessible parts of the Earth
  - High availability (yet)

Pros and cons (2)

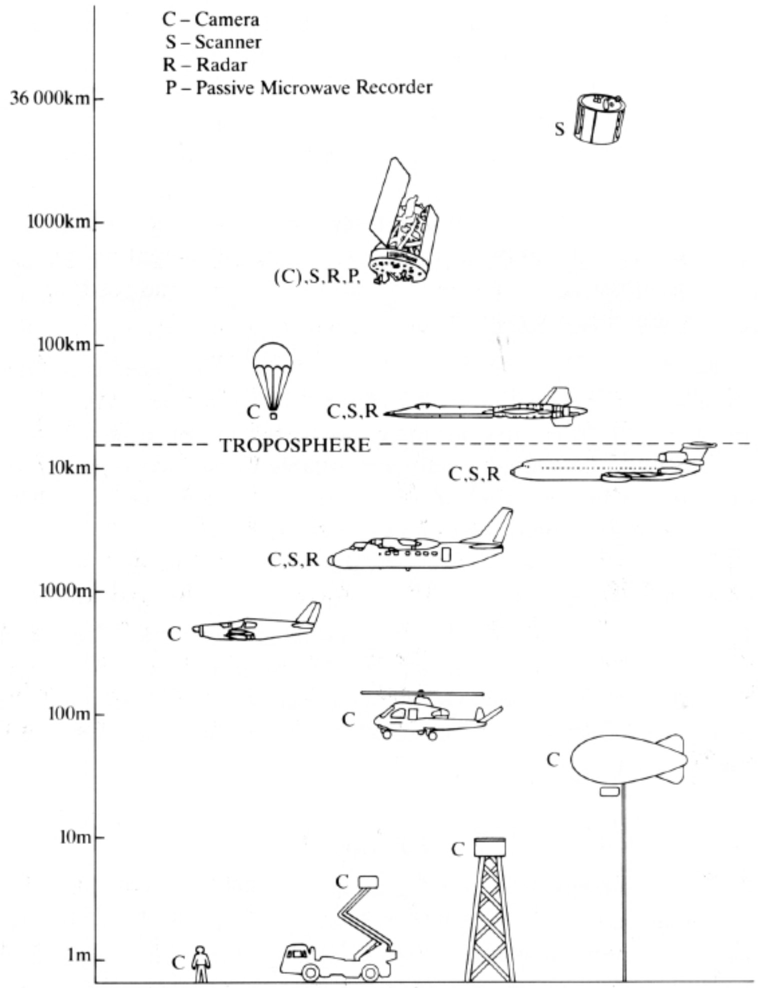
- **Disadvantages** of Remote Sensing
  - Measurements are restricted (close to) the surface
  - High technical efforts and huge budget needed
    - Typical development and start costs: ~ $ 150 Mil
  - Cost-benefit ratio is hard to determine
  - Only privileged countries can afford satellites. (Industrial + few emerging countries, like India)

Observation Platforms

- Ground-based:
  - People,
  - Poles,
  - Captive balloons

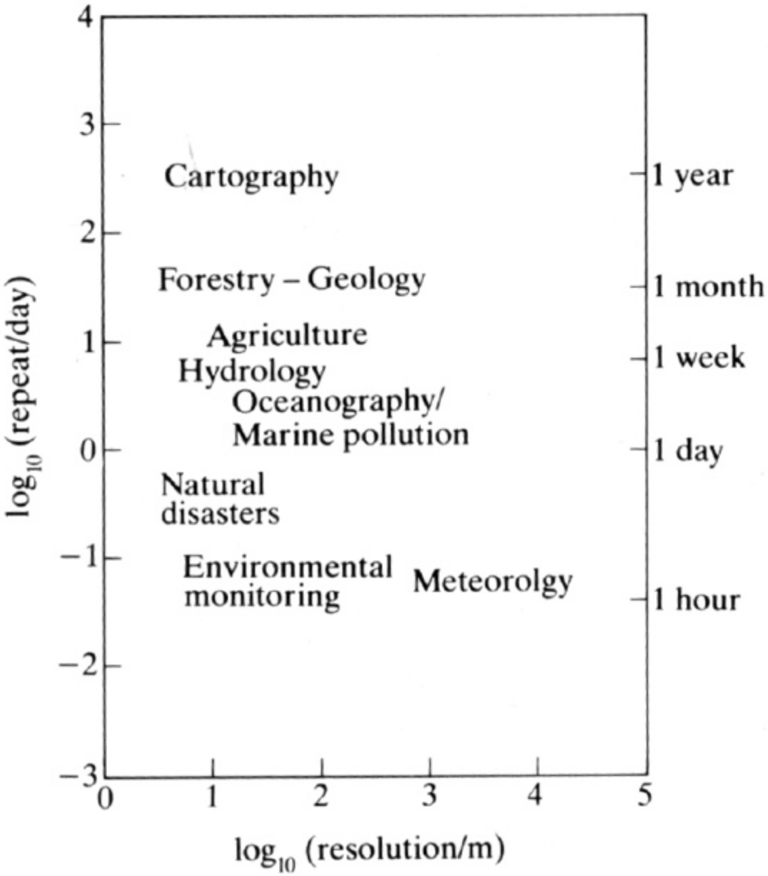
     *Fesselballons*
- Air-borne:
  - Aircrafts
  - Balloons
- Space-borne
  - Satellites
  - Space probes

Fig. 9.1. Remote sensing platforms, by height (schematic). (Reproduced by courtesy of the National Remote Sensing Centre, UK.)



Affordances vs. Applications

Observational requirements (resolution and repeat period) for various disciplines. (Adapted from Fraysse, 1984.)



Applications for Earth Observation (1)

- **Meteorology:**
  Measurement of air-temperature, pressure, humidity, wind velocity and direction
- **Oceanography:**
  Measurement of currents, temperature, altitude, wave spectra
- **Glacier science:**
  Monitoring of ice fields and sea ice
- **Geology, Geomorphology and Geodesy:**
  Classification of soil and rocks, observation of tectonic movements, measurement of the earth's properties (axis, size, gravitational field etc.)

Applications for Earth Observation (2)

- **Topography and Cartography:**
  Digital Terrain/Elevation Models (DEM), high-precision maps
- **Agriculture and Forestry:**
  Prediction of harvest, spreading of vermin, forest lost
- **Hydrology:**
  Monitoring of water reservoirs, prediction of (snow) melts
- **Climate Change:**
  Combination of Remote Sensing results with climate models, predict world climate change

Applications for Earth Observation (3)

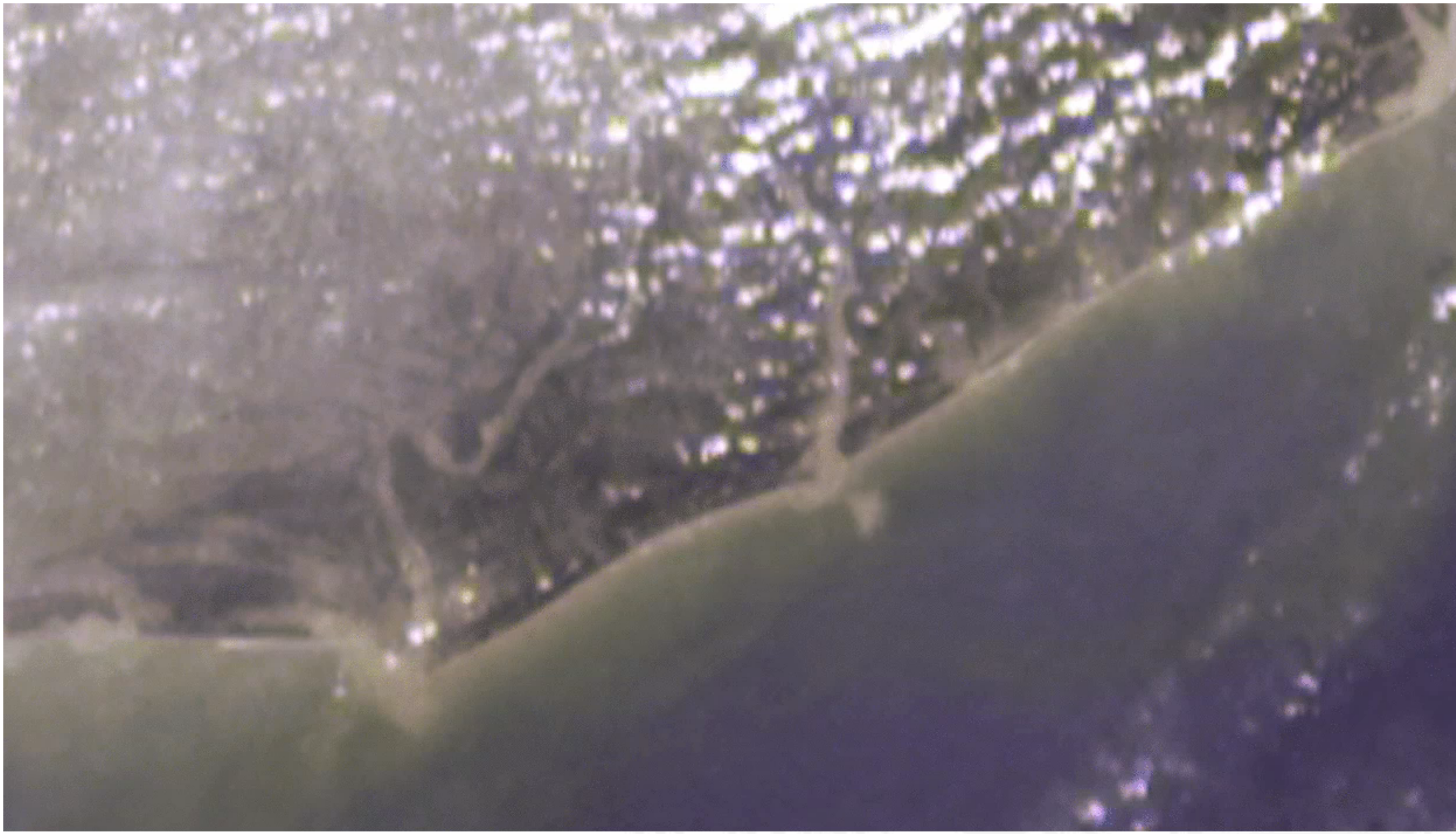
- **Disaster Control:**
  Prediction of earthquakes, warning for sand and dust storms, avalanches, floods, spreading of poisons in the air, monitoring of disasters in unreachable areas
- **Planning:**
  Creation of land use maps, finding acre and mining areas, traffic monitoring
- **Military applications:**
  Early warning systems, monitoring of vehicles and troops, terrain analysis

Example for Disaster Control: Phuket (1)

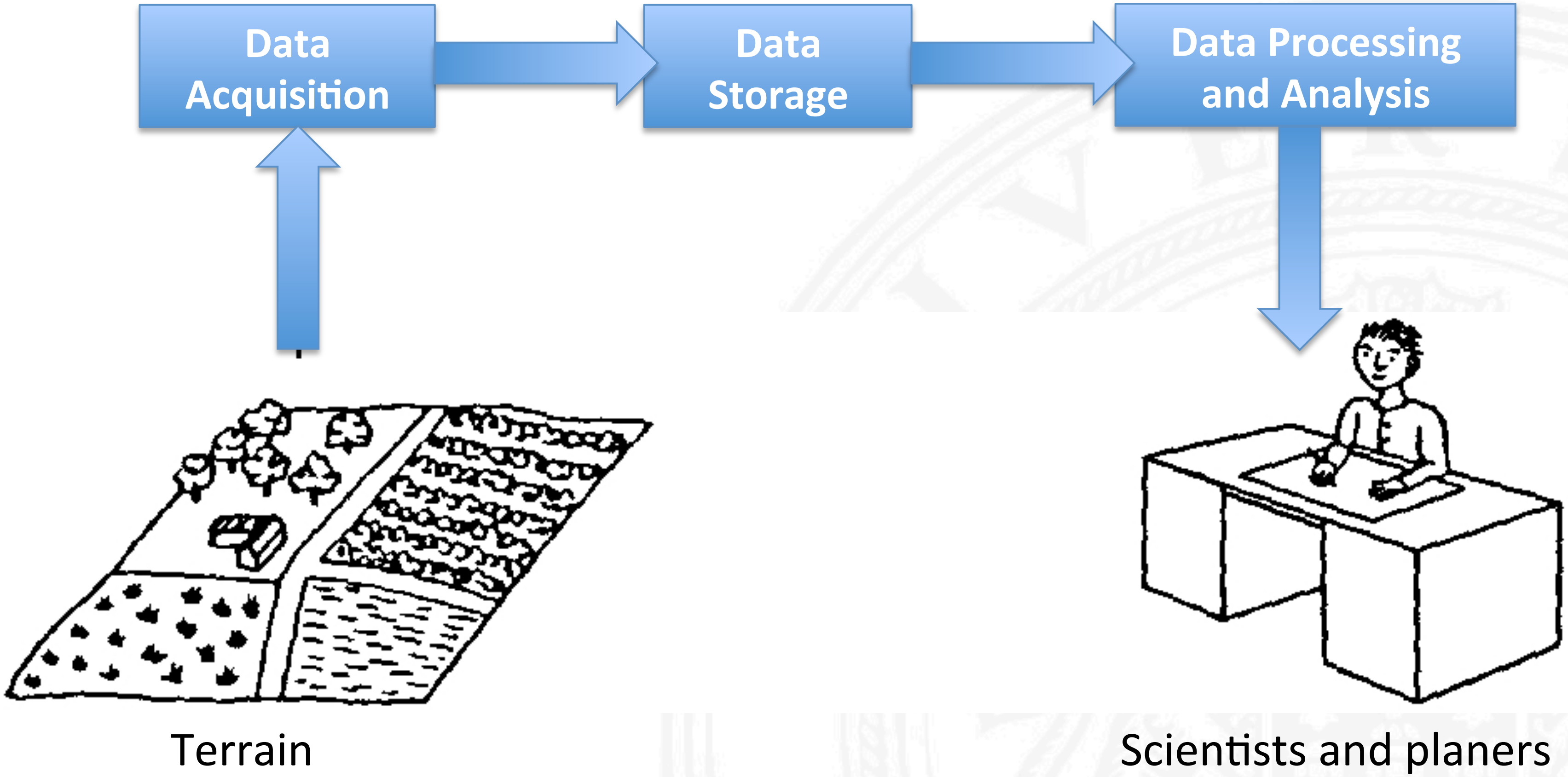
Phuket (Thailand)

- Left: 2002/11/15
- Right: 2004/12/31
- Satellite: Terra
- Sensor: ASTER multi-spectral radiometer
- Resolution: 15m

Example for Disaster Control: Phuket (2)



Scheme of a Remote Sensing System



Challenges

- High-resolution images → Big Data handling
- Sensor-Fusion of multi-modal sensors
- Large-scale vs. small scale features
- Availability of satellite data
  - Commercial interests
  - Available satellites
- Prediction instability
  - Global warming?
  - Climate change!

Literature

- Albertz, J. (2007). Einführung in die Fernerkundung : Grundlagen der Interpretation von Luft- und Satellitenbildern. Wissenschaftliche Buchgesellschaft, Darmstadt, 3. edition.
- Lillesand, T. M., Kiefer, R. W., and Chipman, J. W. (2008). Remote Sensing and Image Interpretation. Wiley, Hoboken, NJ, 6th edition.
- Richards, J. (2009). Remote sensing with Imaging Radar. Springer.
- Richards, J. A. and Jia, X. (2006). Remote Sensing Digital Image Analysis. Springer Verlag, Berlin - Heidelberg - New York, 4 edition.
- Floyd S. Sabins (2007): Remote Sensing: Principles and Interpretation. Long Grove, 3rd Edition, Waveland Press
- W. G. Rees (2012): Physical Principles of Remote Sensing, Cambridge Press

Gravitational Astronomy

- EO Satellites are artificial systems, which move without permanent thrust for longer time periods on an orbit around the Earth.
- As a first approximation, this motion can be described by means of the **two-body problem** *Zwei-Körper-Problem*

  → determine the motion of two point particles that interact only with each other.

- Simplifications needed:
  - Earth's mass is spherically symmetric
  - Mass of Satellite is negligible
  - Gravitation is the only (external) force affecting the Satellite

  → **Kepler's laws** become applicable.

  Die Kepler`schen Gesetze

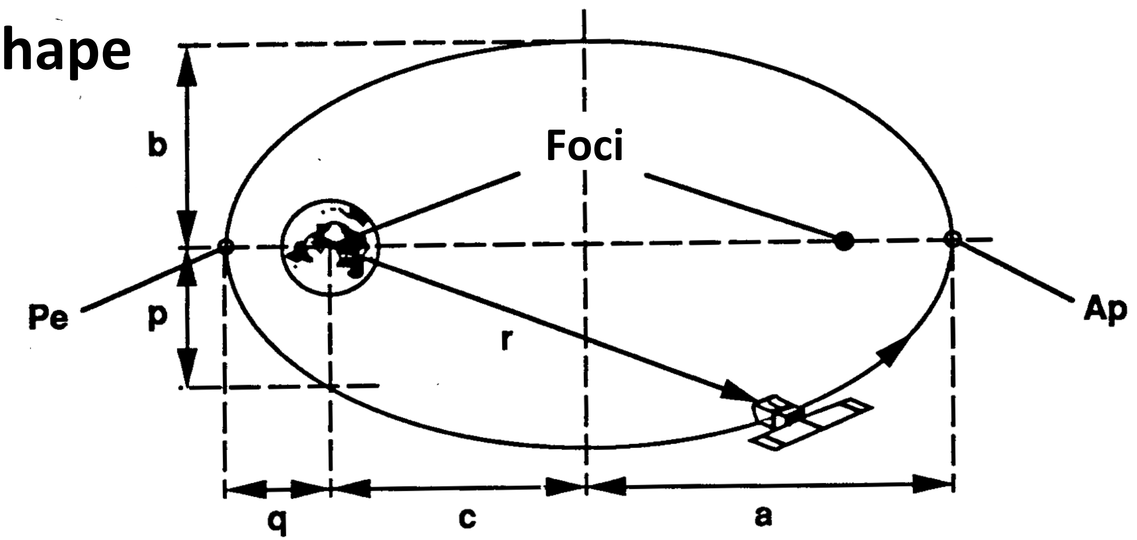
Kepler's Laws for EO Satellites

1. The orbit of every EO satellite is an ellipse with the Earth at one of the two foci.
2. A line joining an EO satellite and the Earth sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of an EO satellite is proportional to the cube of the semi-major axis of its orbit.

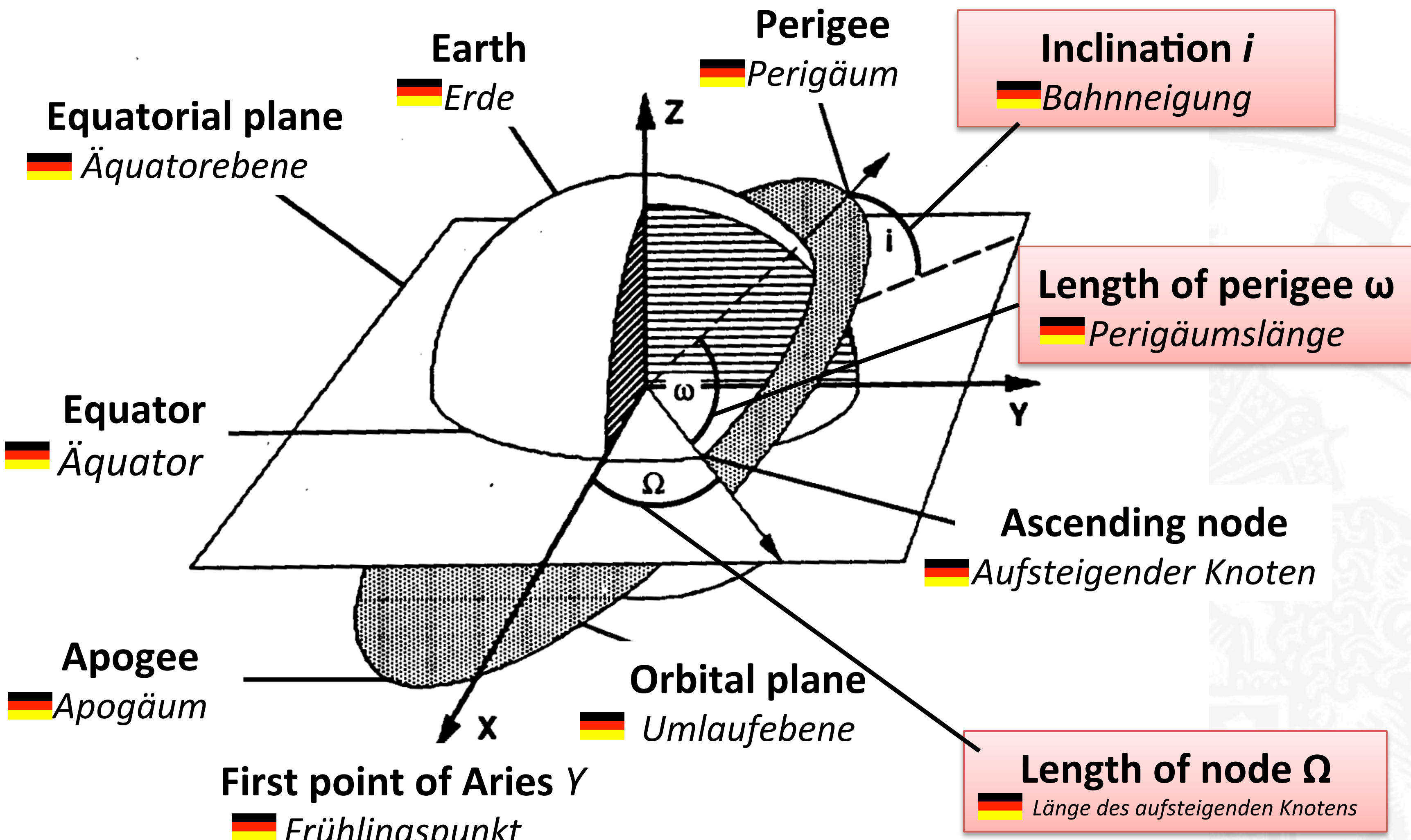
Orbital descriptors (1): Shape

- Semi-major axis a
- Semi-minor axis b
- Numerical Eccentricity e
- Orbital Period T

  Umlaufzeit



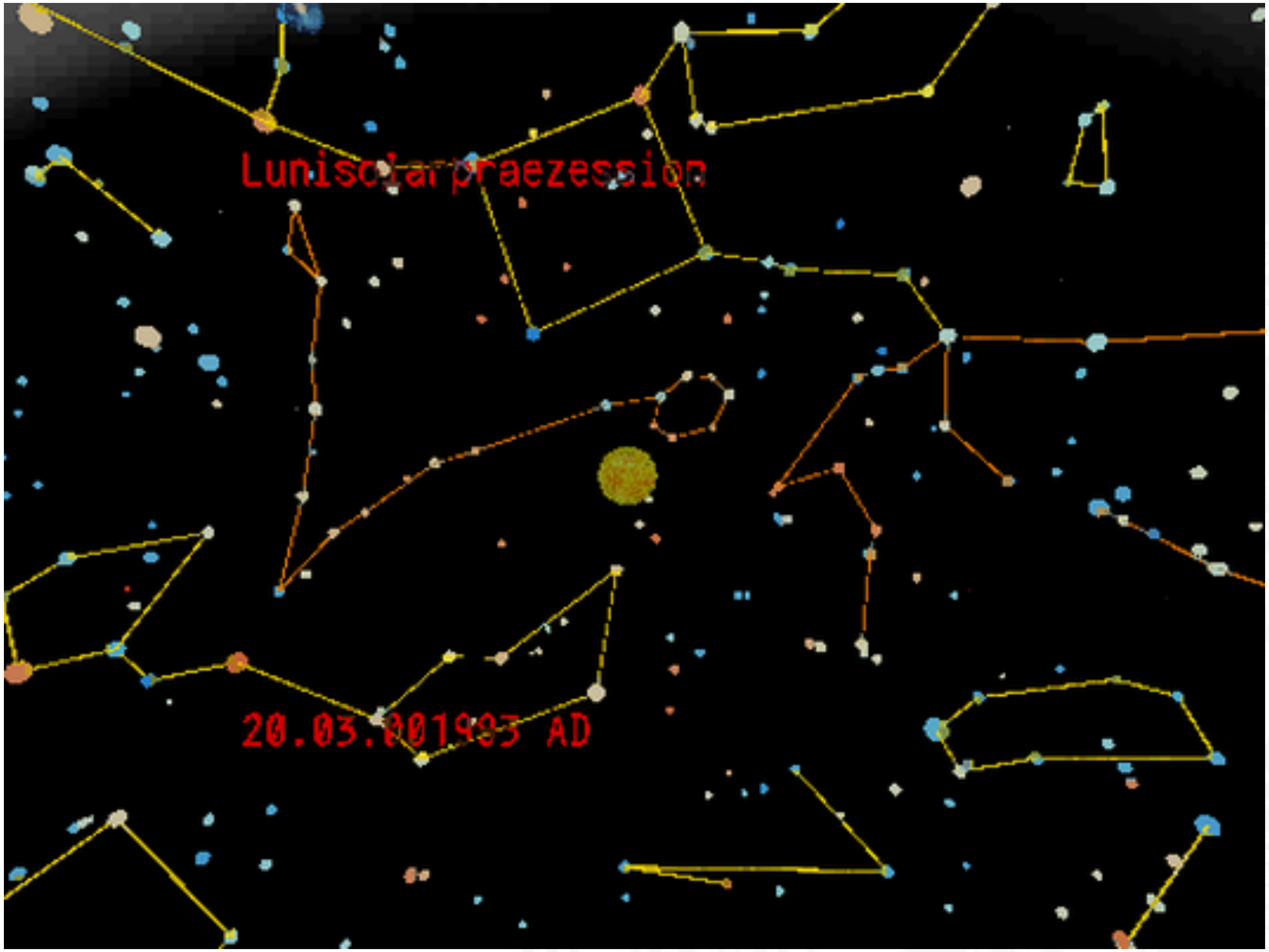
Orbital descriptors (2): Position



Orbital descriptors (3): Reference planes and Epochs

- The reference planes of the equator and ecliptic vary periodically due to precession and nutation
- The first point of Aries travels through each sign of the zodiac each ~25800 years
- Orbital elements and other position indices are useless, unless we know about the specific epoch, which defines the reference planes of:
  - Celestial equator
    Himmelsäquator
  - Ecliptic
    Ekliptik

Precession of the First Point of Aries
Platonic Year

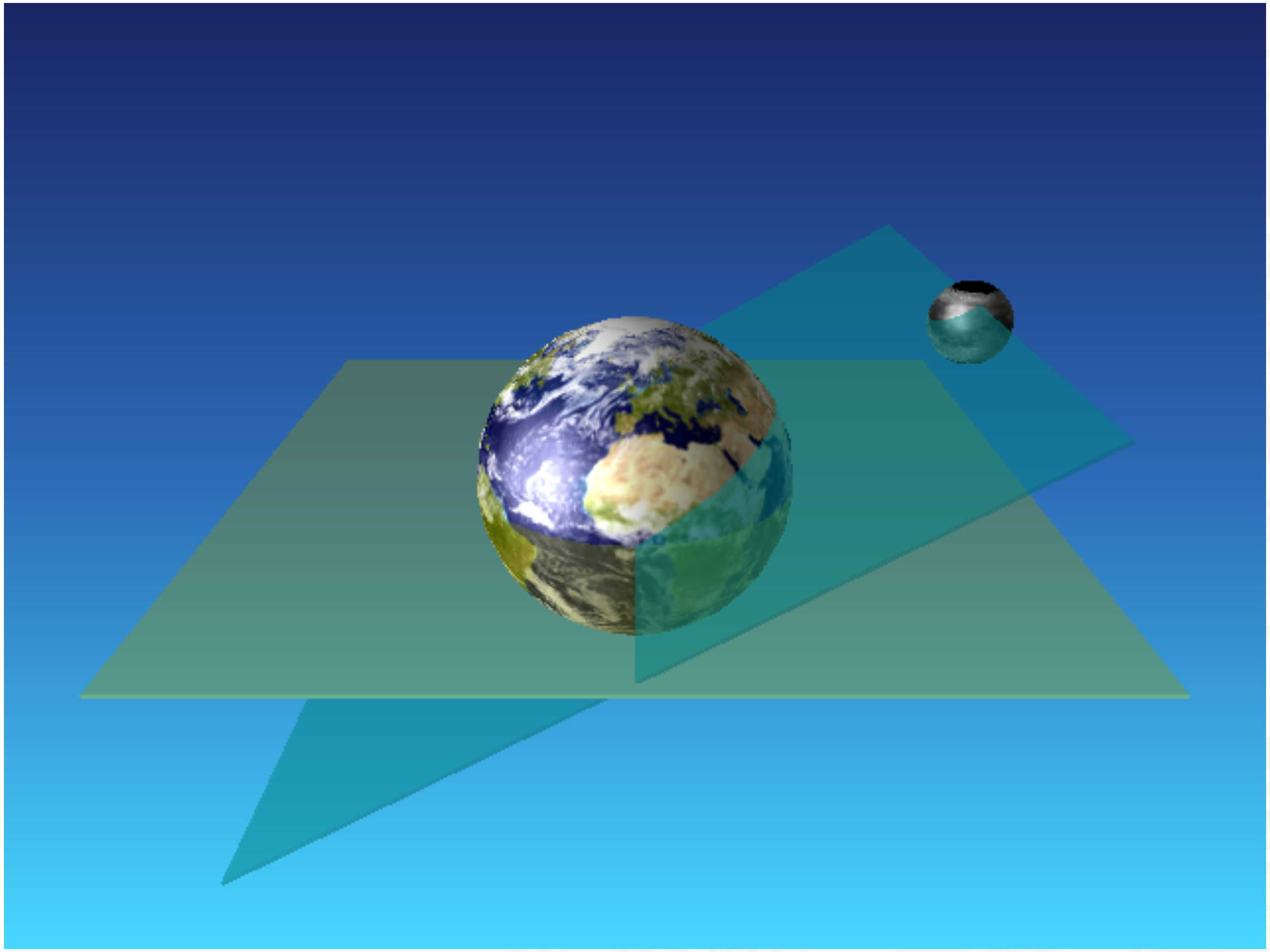


Perturbation

Bahnstörungen

- Satellite Orbits often deviate (widely) from gravitational definition. Perturbation may caused by:
  - Unequal mass distribution of the Earth
  - Rests of the Earth's atmosphere
  - The sun, the moon and other planets
- Effects:
  - Precession of the ascending node
  - Precession of the perigee
  - Extension of the draconian obital period

Perturbation (1): Precession of the Ascending Node



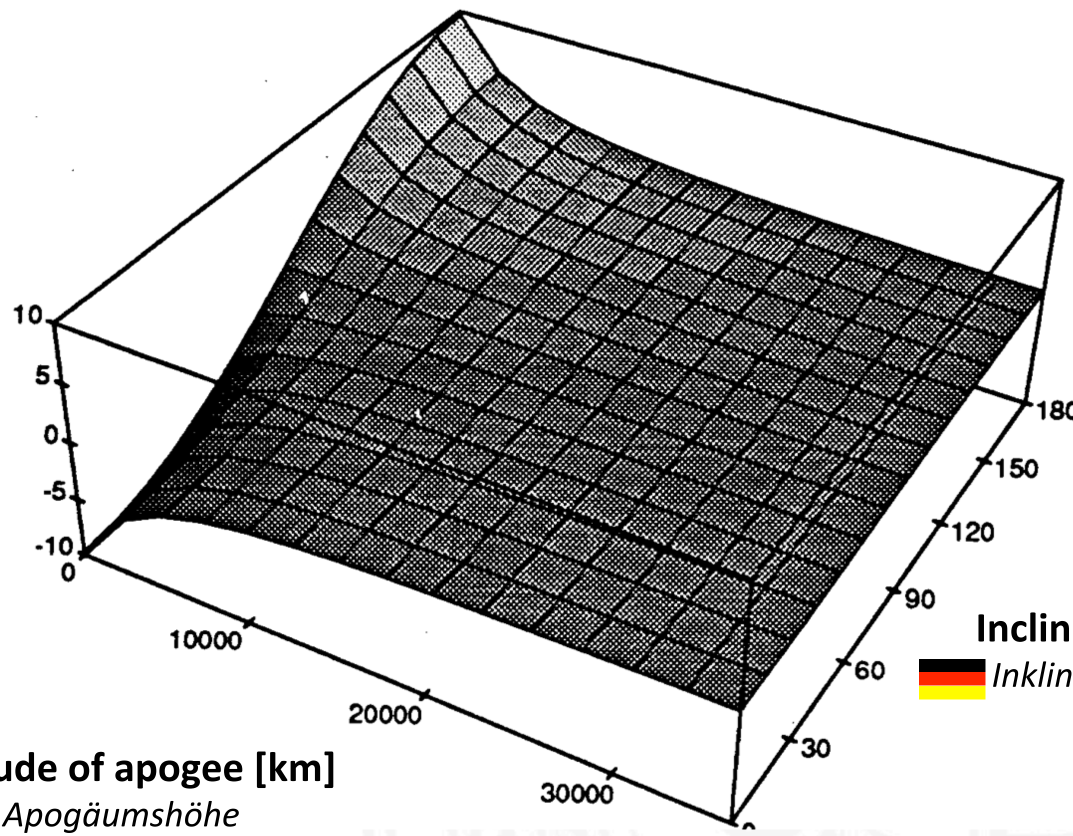
Perturbation (1): Precession of the Ascending Node

Altitude of perigee = 100 km

Perigäumshöhe

Precession [°/ day]

Präzession [°/ Tag]



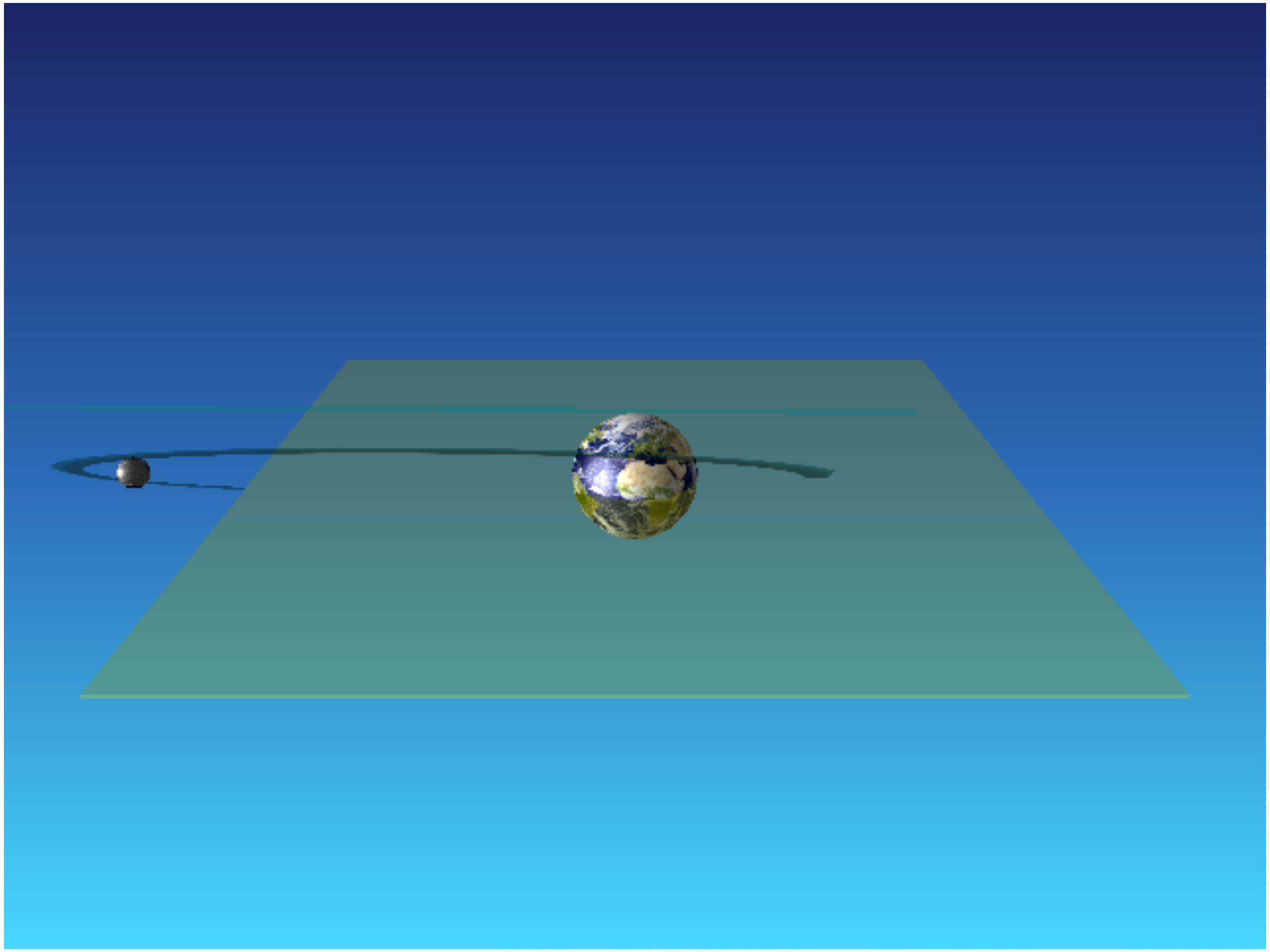
Inclination [°]

Inklination [°]

Altitude of apogee [km]

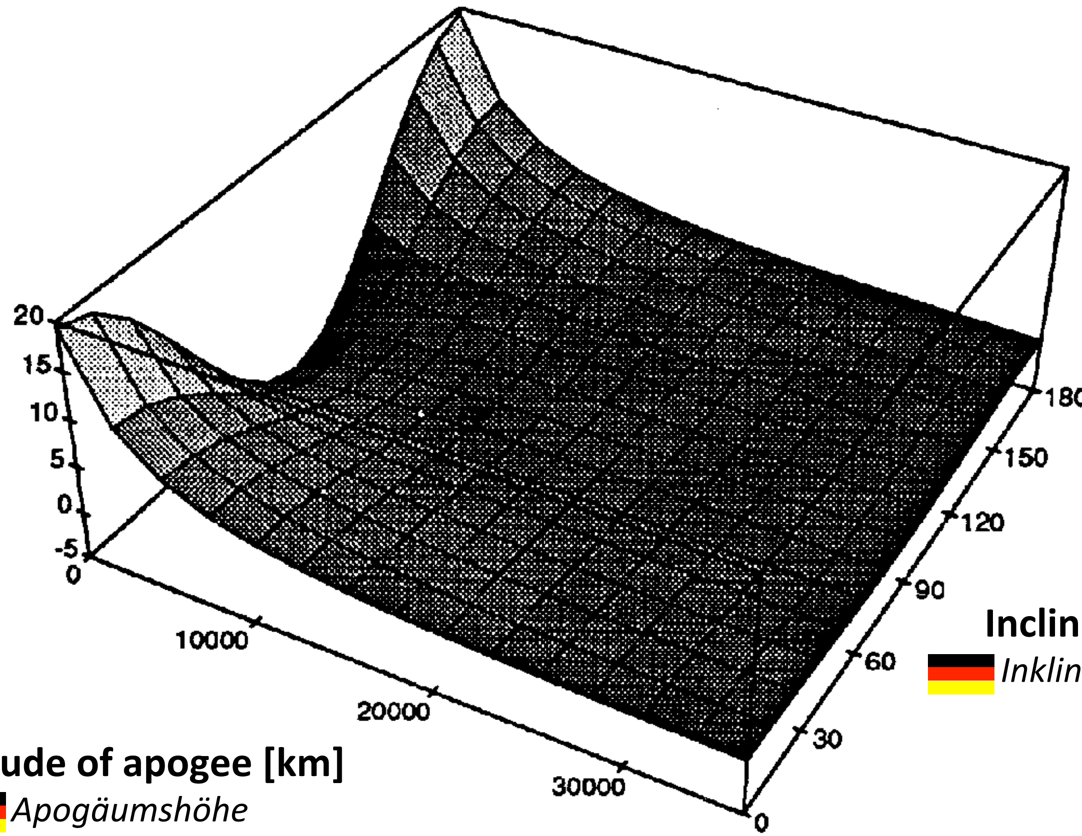
Apogäumshöhe

Perturbation (2): Precession of the Perigee



Perturbation (2): Precession of the Perigee

Altitude of perigee = 100 km
Perigäumshöhe



Precession [°/ day]
Präzession [°/ Tag]

Inclination [°]
Inklination [°]

Altitude of apogee [km]
Apogäumshöhe

Earth’s Gravity Field