Basic concepts and challenges of remote sensing

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What is Remote Sensing?

**Definition:** Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object.

In modern usage, the term generally refers to the use of aerial or satellite sensor technologies to detect and classify objects on Earth (in the atmosphere, on the surface, in water).
Remote sensing of most atmospheric components makes use of their absorption properties.

Remote sensing of the Earth surface from satellite is restricted to the atmospheric windows.
Useful Wavelengths

**Atmospheric components**

Remote sensing requires detailed knowledge of optical properties

![FT spectrometer at DLR](image)

![Graph showing transmittance](image)

Remote sensing requires detailed knowledge of optical properties. The graph shows the transmittance of different wavelengths, with peaks indicating useful wavelengths for remote sensing. The FT spectrometer at DLR is used for analyzing these wavelengths.
Example: Microwave Humidity Sounder (MHS) on MetOp-A

Derives a 3D picture of atmospheric humidity
(5 channels ↔ 5 altitudes)

Channel 1 (89 GHz = 3 mm)

Data acquired over one complete satellite orbit

Water vapour concentration

Channel 1 (89 GHz = 3 mm)
Example: Global Ozone Monitoring Experiment-2 (GOME-2) on MetOp-A

Long-term monitoring of atmospheric trace gas constituents

- O$_3$ tot.
- NO$_2$ tot.
- NO$_2$ trop.
- SO$_2$
- HCHO
- BrO
- H$_2$O
- Clouds

Products
- 24/7
- 2h NRT

- 2007 - 2012
- Examples:
  - Global Ozone Monitoring Experiment-2 (GOME-2) on MetOp-A
  - Long-term monitoring of atmospheric trace gas constituents

Example: Monitoring and Prediction of the Ozone Layer

<table>
<thead>
<tr>
<th>Period</th>
<th>Model</th>
<th>Satellite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990-1999</td>
<td>![Model Image]</td>
<td>![Satellite Image]</td>
</tr>
<tr>
<td>2000-2009</td>
<td>![Model Image]</td>
<td>![Satellite Image]</td>
</tr>
<tr>
<td>2040-2049</td>
<td>![Model Image]</td>
<td>![Satellite Image]</td>
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</tbody>
</table>

The diagram shows the ozone concentration over different years, with the model and satellite images indicating the concentration changes over time. The graph below the images illustrates the ozone deviation percentage over universal time from 1960 to 2050, with data sources including E39CA (R2), Gamy et al., 2009; TOMS/OMI, Stolarski et al., 2006; GOME/SCIAMACHY/GOME-2, Loyola et al., 2009.
Useful Wavelengths

Earth surface

Remote sensing can utilize the atmospheric windows

Information is derived from geometry, surface structure, spectral properties, penetration depth
Example: Digital Elevation Model from Stereo Images

3D model of London derived from 5 viewing angles
Example: Bathymetry from Ocean Wave Patterns

Water depth near coastline, used e.g. to predict tsunami propagation
Example: Biological Parameters from Spectral Properties

Temporal development of plant productivity
Useful Wavelengths

Water constituents

Water is transparent only in the visible and near UV

Example: Chlorophyll and Suspended Matter

Results of an airborne campaign in Lake Constance (Bodensee)

Uncertainty: ± 17 %

Example: Primary productivity

Results of an airborne campaign at Lake Constance (Bodensee)

Result based upon
- P-I-curves from 15 years
- Chlorophyll
- Attenuation (from Chl, Y, SPM)
- PAR

Sensor Types

**Passive Sensors**
Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding areas.

*Examples:* CCD cameras, infrared sensors, imaging spectrometers.

**Active Sensors**
The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

*Examples:* RADAR, LIDAR.
Example for passive sensors: Hyperspectral Sensors

Imaging spectrometers allow spectroscopy by remote sensing

**Whiskbroom Scanner**
Simultaneously recorded:
N channels = 1 spectrum

**Pushbroom Scanner**
Simultaneously recorded:
N channels x M pixels =
M spectra of 1 image line
Example for Hyperspectral Applications

Remote sensing of shallow water areas

Atmosphere corrected with ATCOR-4
Inverse modeling with WASI-2D
Example for active sensors: TerraSAR-X and Tandem-L
Digital elevation model (Alaska)
Ice Thickness Changes from 2000 to 2011
South Patagonia Ice Field
Subsidence in Venice
Challenges of Remote Sensing

... all this must be done properly to get the shown nice results

- Sensor development
- Sensor launch
- Sensor calibration
- Georeferencing
- Atmosphere correction
- Determination of optical properties
- Model development
- Inversion
- Validation
- ...

Modern Sysiphus by Dluho. toonpool.com
Concept of Remote Sensing

Applications

Develop sensors to answer specific questions

“It is the theory that decides what can be observed.” (A. Einstein)

Models

Exploit information content of data sets

Technology
Concept of Remote Sensing

... and of much more, maybe also of Shaping interdisciplinary processes?

Thank you for your attention!