Hyperspectral Applications in Remote Sensing

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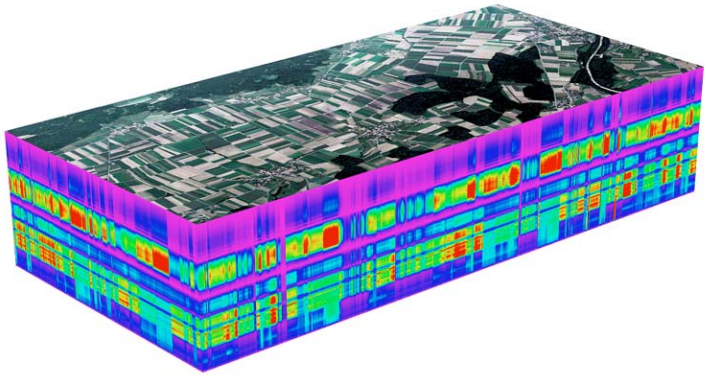
Advanced Imaging and Spectroscopy SSOM Engelberg Lectures 5.3.07

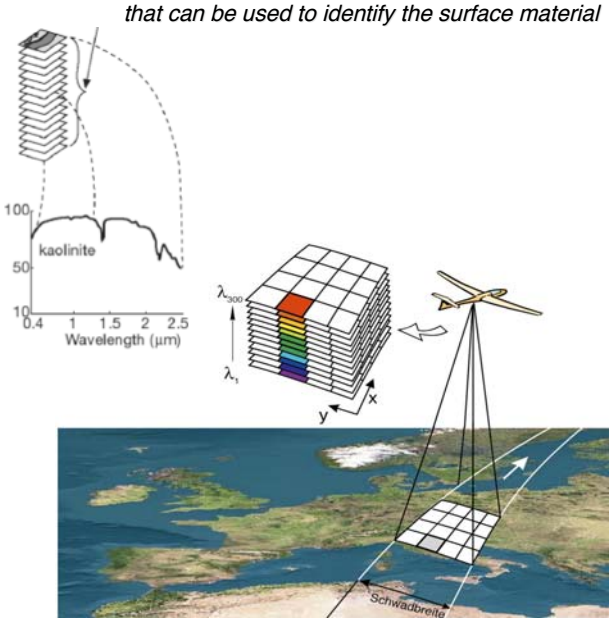
Hyperspectral Applications in Remote Sensing

Imaging spectrometry

Each pixel has an associated continuous spectrum that can be used to identify the surface material

spectral range: 380 - 2500 nm & ev. tir
spectral bands: 200 - 300
flying altitude range: 2 - 20 km





Definition of terms

Imaging spectroscopy

... is the art and science of analysing hyperspectral data

whereas

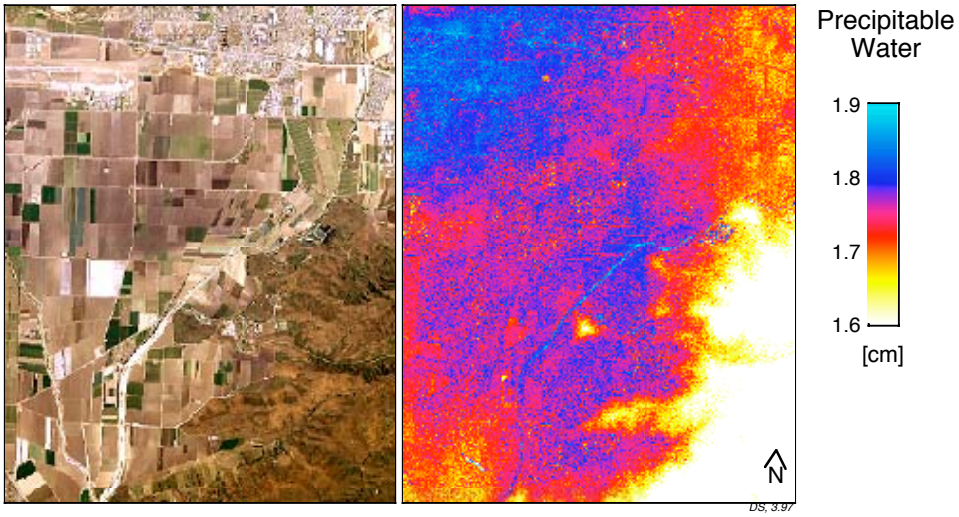
Imaging spectrometry

... is the engineering task and science of making the hyperspectral data available, e.g defining and building the instrument and taking the data in a meaningful way

in brief, hyperspectral remote sensing means

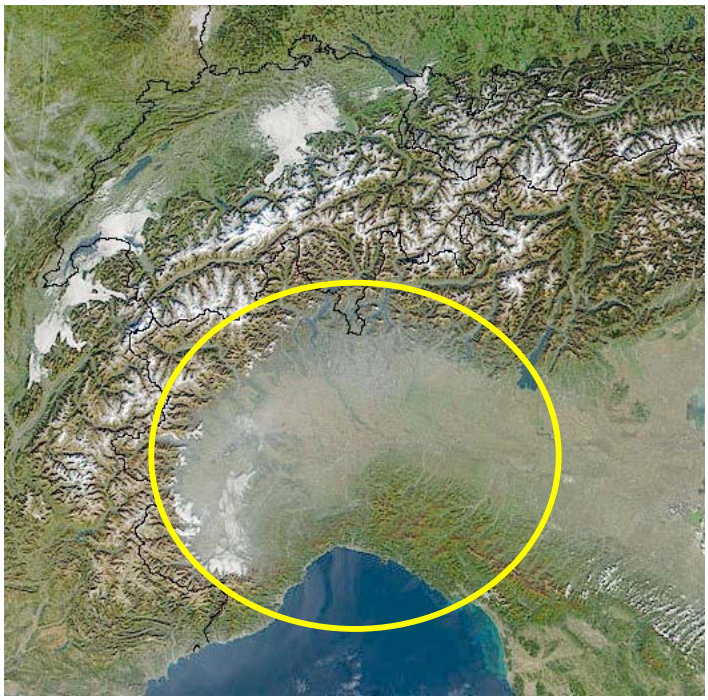
... taking data in a great number (>10) of spectrally contiguous bands with the aim of allowing for spectral analysis of measured objects

Imaging spectroscopy in the atmospheric science - example: quantitative water vapour determination



Example: aerosol detection

- aerosol = atmospheric particles (a.a. „Feinstaub“)
- interacts with radiation through absorption, scattering and reflection
- superimposed on ground signal -> eventual correction through an atmospheric code



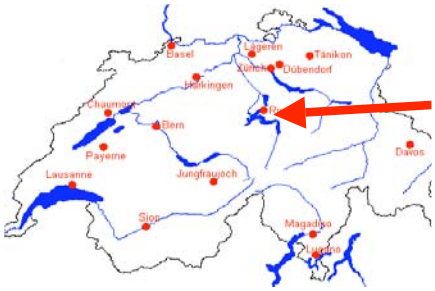
Terra-1MODIS image

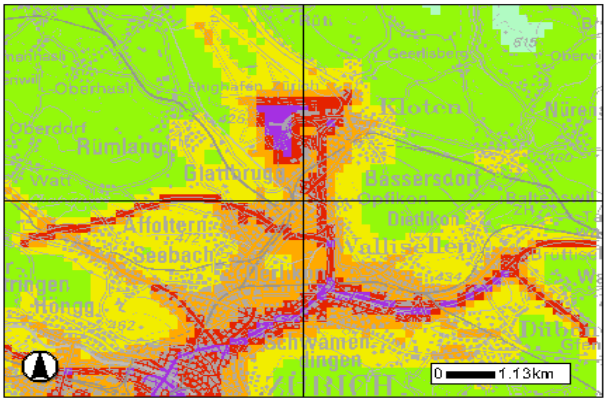
Quelle: visibleearth.nasa.gov

Air pollution determination

Spaceborne global NO_2 Measurements:
e.g. GOME (40 x 320 km²), OMI (24 x 13 km²)

Local In-Situ Measurements:
e.g. NABEL stations





Nitrogen dioxide levels 2000

- 0 - 5 µg/m³
- 5 - 15 µg/m³
- 15 - 25 µg/m³
- 25 - 30 µg/m³
- 30 - 35 µg/m³
- 35 - 45 µg/m³
- > 45 µg/m³

PK1000, PK500, PK200, GG25 © 2002 swisstopo (DV023277)

Source: BUWAL/METEOTEST using dispersion calculations under typical meteorological conditions

Airborne imaging spectroscopy allows to retrieve NO_2 (and CH_4) in local/regional scalewith a spatial resolution of ~ 30 m and a column retrieval precision of ~ 10%.

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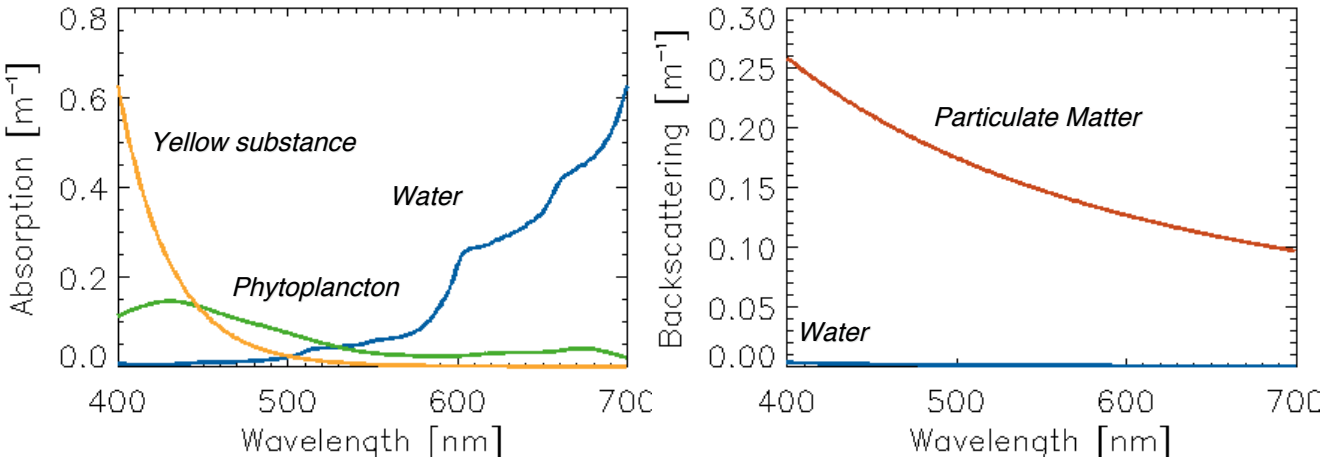
Detection of water pollution - spectral properties of water



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Water constituents - chlorophyll detection

Methodology:

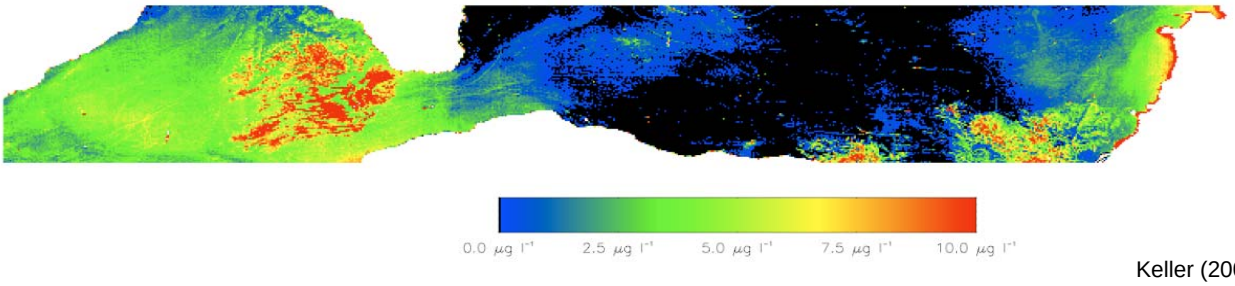
(1) correction for atmosphere effects,

(2) correction for air-water interface effects,

(3) inversion of the sub-surface radiation for the determination of the quality parameters such as chlorophyll a or suspended matter.

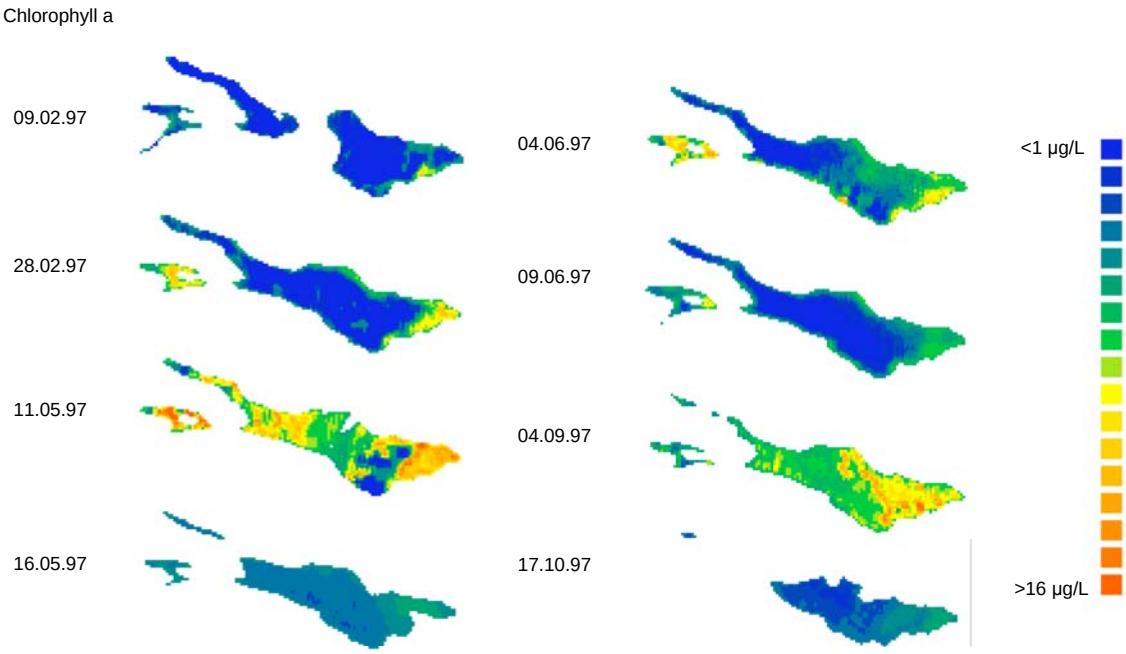
=> Comparison of different methods on CASI imaging spectrometer over Lake Zug

Chlorophyll a concentration from CASI in 1999 over Lake Zug (CH)



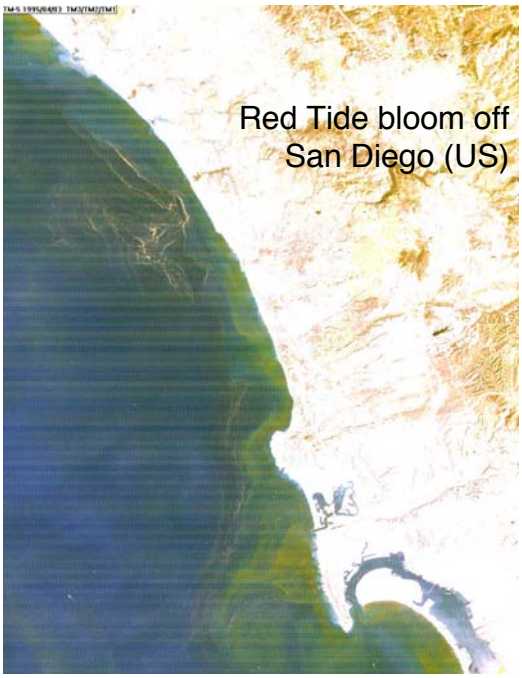
Keller (2001)

Chlorophyll a in Lake Constance (from MOS Data)

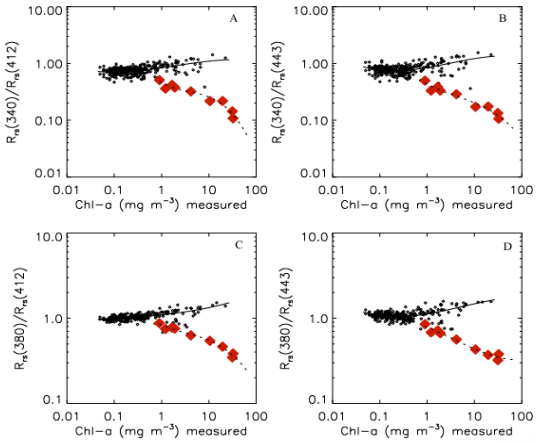


Algae detection in coastal waters

Exceptional blooms ("red tides" or Harmful Algae Blooms (HABs)) in coastal areas are detectable with airborne imaging spectroscopy.



Toxic Dinoflagellate blooms detection



Toxic Dinoflagellate blooms results in low nLw380 / nLw412 ratio!

Kahru & Mitchell (1998) © Scripps Institution of Oceanography

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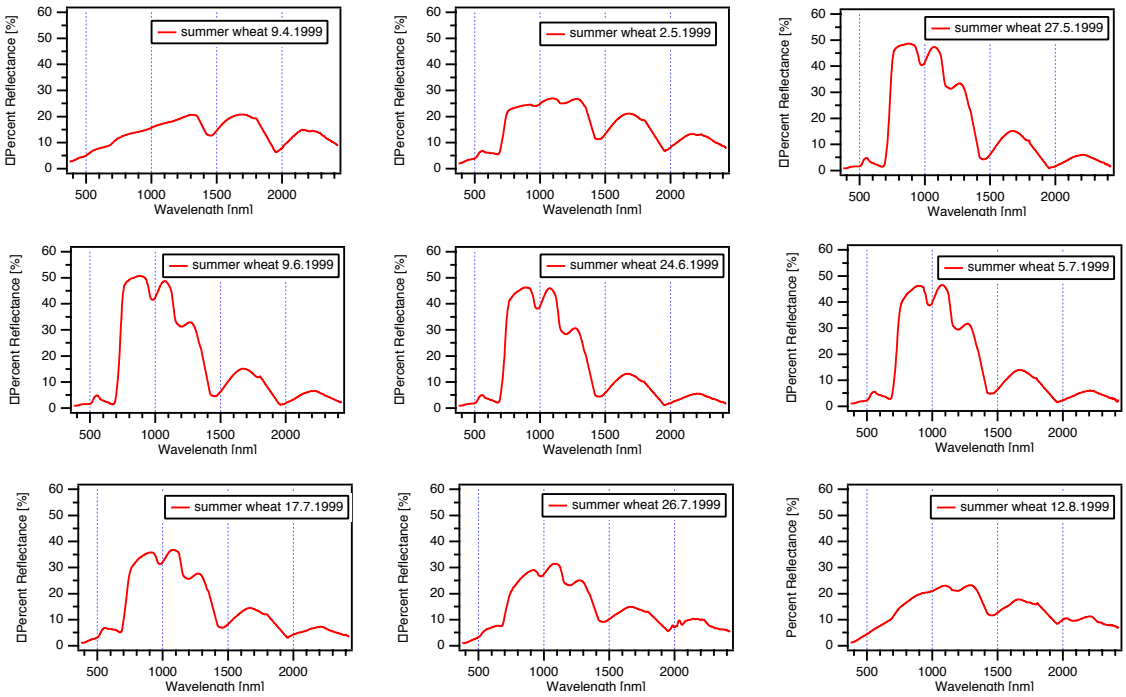
Spectral seasonal effects of land surfasce processes



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Kneubühler, 2002

Detemination of Plant Water Content

Spring Wheat July 16th 1999

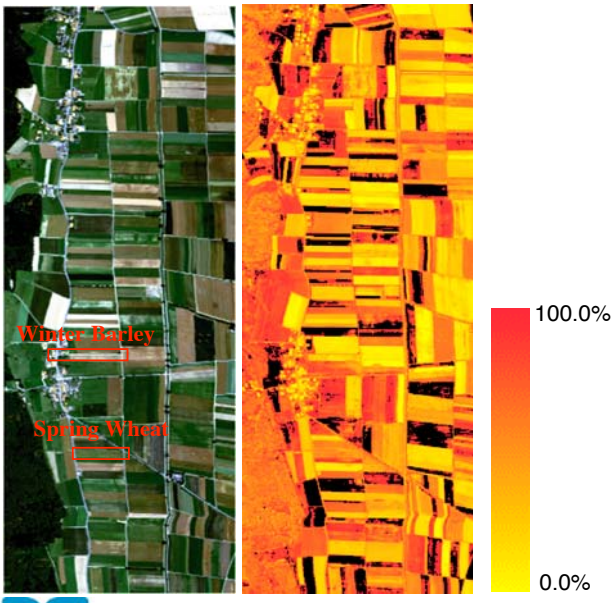
Plant Water [%] (average field value 50.4)

Winter Barley July 16th 1999

Plant Water [%] (average field value 17.94)

Plant Water Content retrieval using the stepwise multiple linear regression method and laboratory data

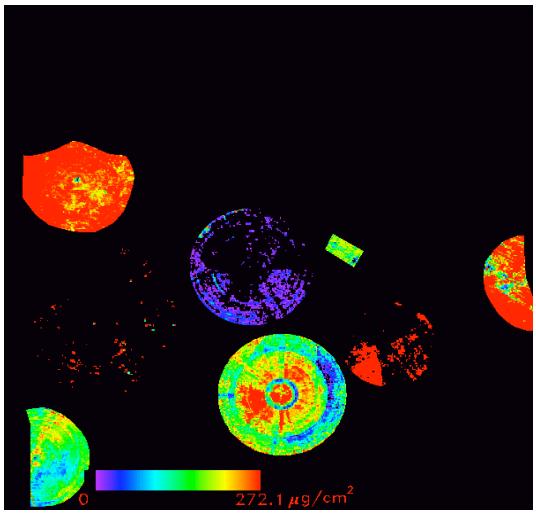
Limpach Valley HyMap Data Set

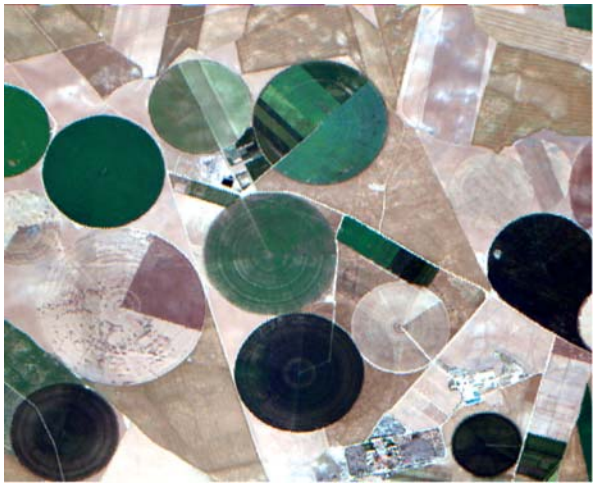


REMOTE SENSING LABORATORIES RSL Kneubuehler (2002)

Vegetation and Precision Farming

Leaf Chlorophyll map





RGB, Barrax (SP) HyMap Data

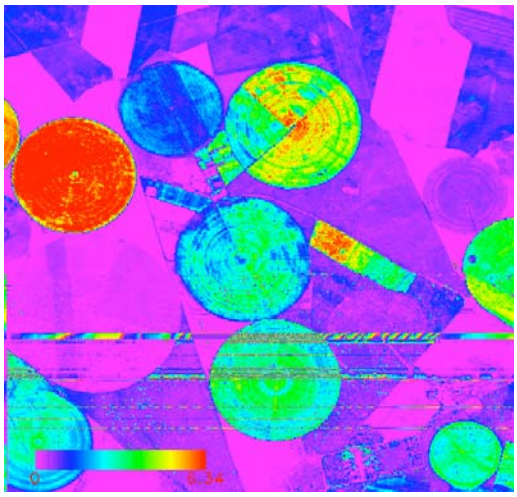
Leaf chlorophyll derived from HyMap 99 Data using a TCARI/OSAVI ratio and laboratory derived chlorophyll values

REMOTE SENSING LABORATORIES RSL Huber (2002)

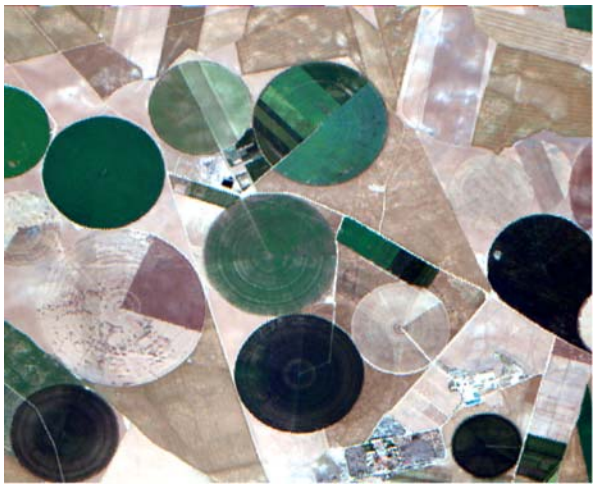
Vegetation and Precision Farming

Leaf Area Index (LAI)

LAI map derived from HyMap' 99 Data using the WDVI method (Clevers 1989)



LAI Map



RGB, Barrax (SP) HyMap Data

LAI and Chlorophyll are examples of derived vegetation parameters.
Products are used as input for ecology models.

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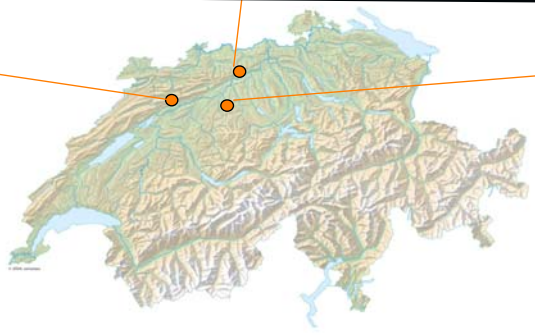
Huber (2002)

Estimation of biochemical parameters in mixed forests

HyMap data of 3 CH-test sites
- parameters as input into ecosystems models



N

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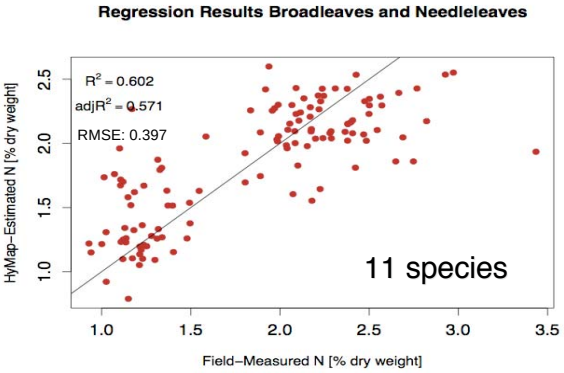
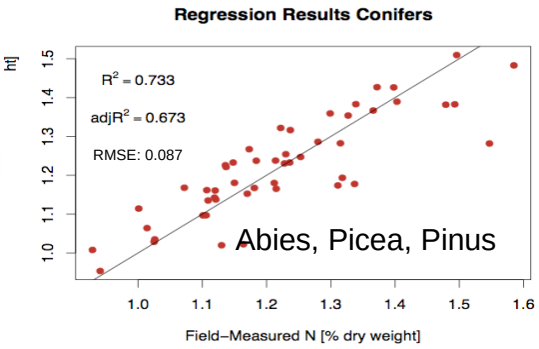
test sites

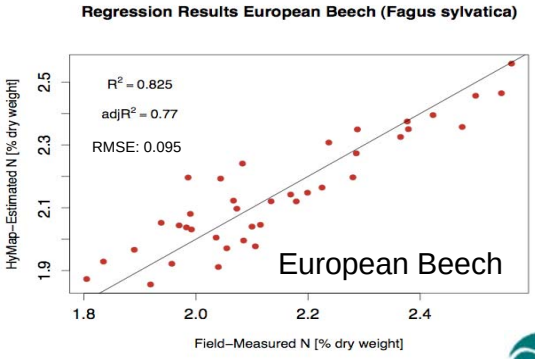
WSL

Regression results btw. nitrogen concentration and transformed reflectances





- Combined sample shows 2 plant functional types
- R^2 of deciduous sample increases with further partitioning among species
- Imaging spectrometer data can improve classification of plant functional types and single species relative to multispectral data



Huber et al, 2005, Proc. ISPMSRS

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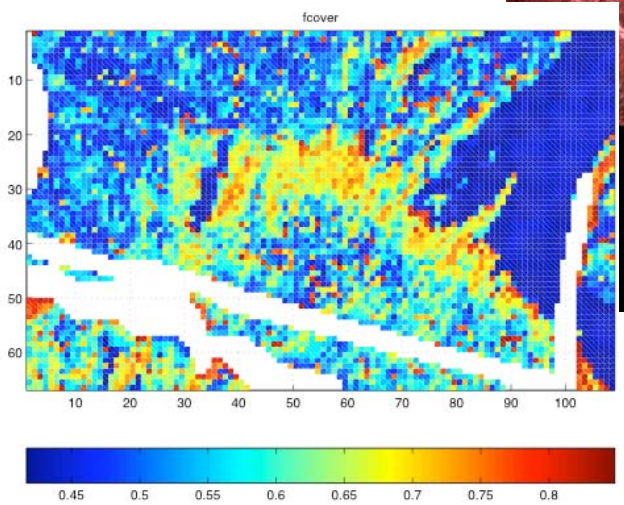
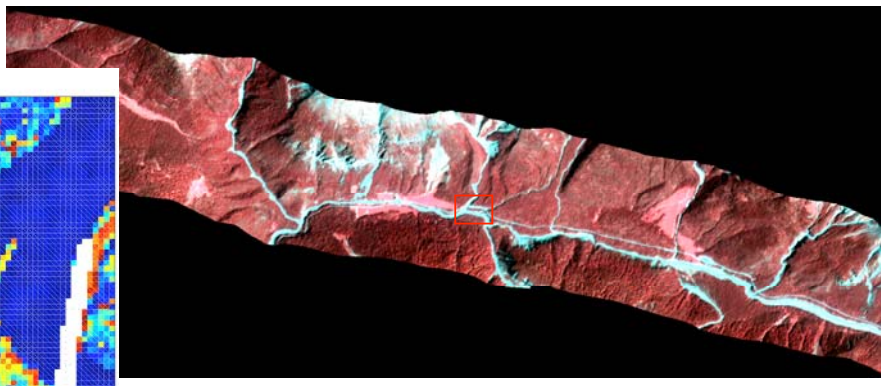
Forest fire research



Fractional Cover map



False-Color RGB, Swiss National Park (DAIS/ROSIS Data)

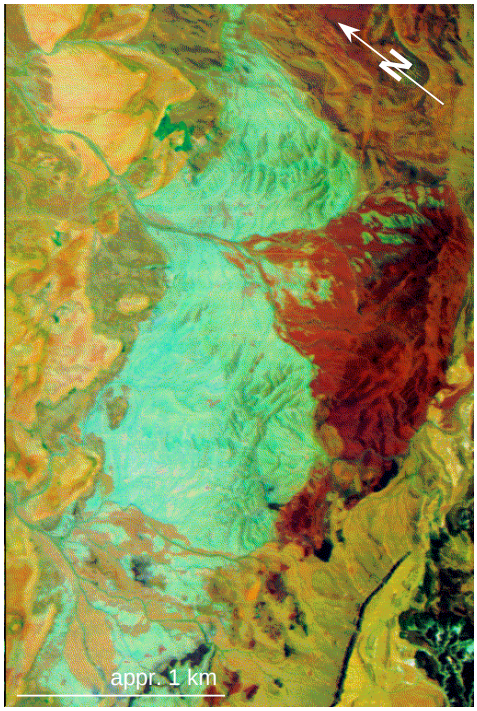
Example of derived biophysical and biochemical properties over the test sites in the Swiss National Park.

Products are used as input into fire models.

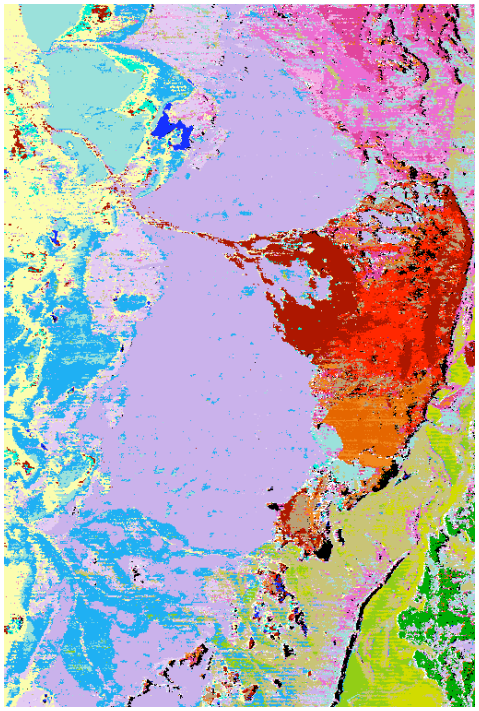
Koetz et al. (2004)

Mineral Identification based on Spectral Mixture Analysis

DAIS Hyperspectral Data of Makhtesh Ramon/Israel



Color Composite of bands 1,20, 48



Result of Mineral Classification *(E.Ben-dor)*

Stratigraphy/Lithology

q	alluvium
kumi	chert
ku1	limest./dolomite
kuh	dolomite
klh	sandstone
ji	sandstone
ja2	dolomite
ja2	'chocolate' clay
ja1	dolomite/sandst.
ja1	bauxite
trm3	limestone
trm2	gypsum
trm1	limestone
trs2	limestone
trs1	limestone/marl
β	basalt
ν	arfv (edsonite (unalt.)
ν	arfv. (propylitic-alt.)
ν	arfv. (kaolinitic-alt.)
ν	arfv. (potassic-alt.)

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Preprocessing of hyperspectral image data

PARGE
Parametric
geocoding
result

Overlay of AVIRIS "high altitude" and "low altitude" scenes over a digital terrain model (Ray Mine, Arizona, USA)

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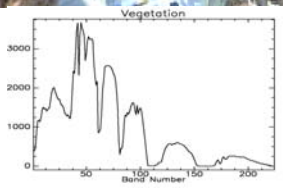
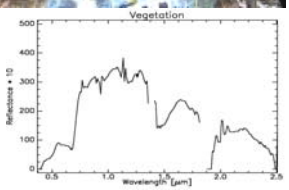
Atmospheric/radiometric preprocessing of hyperspectral image data using ATCOR4

Roh



Illumination

Korrigiert



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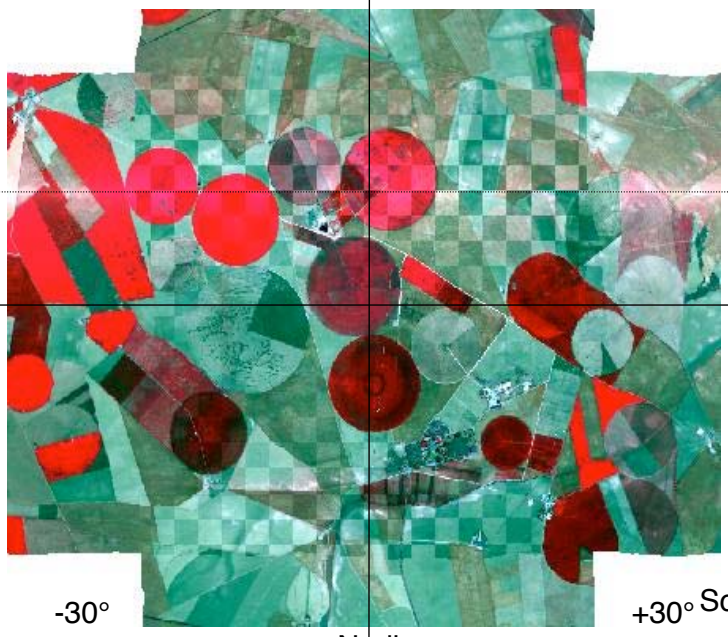
DAISEX'99 - HyMap Hot Spot Effect (Beisl, 2001)



-30°

-17°

Airplane Motion Bar2_12

Nadir

Scanning Direction Bar2_12

+30°

-30°

+30°

Scan Angle

Scanning Direction Bar1_12

Nadir

Airplane Motion Bar1_12

Solar Azimuth 170/180°
Solar Zenith 17°

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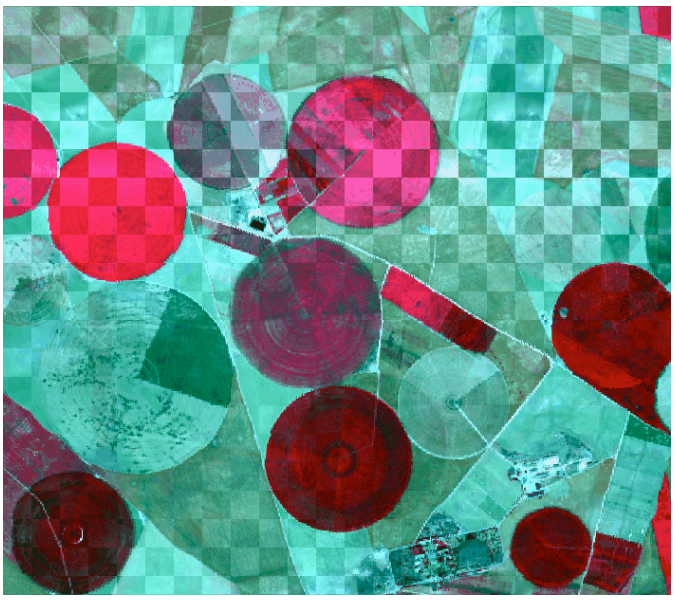
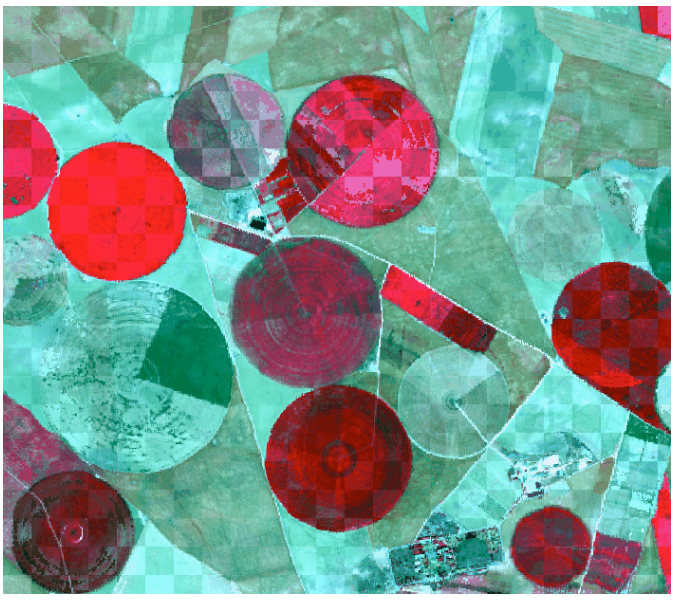
BRDF correction using the Ambrals-method (Beisl, 2001)



before



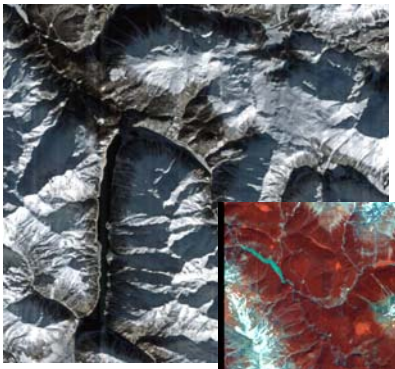
after

esa

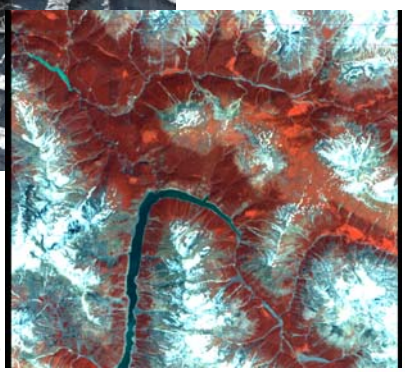
CHRIS/PROBA - a spectro-directional sensor

CHRIS: 37 bands (400 - 1000 nm), 18m GSD, 5 angles (+55°, +36°, 0°, -36°, -55°)
Multitemporal and multidirectional experiments in Switzerland:

- Swiss national park: Reflectance differences in coniferous forests
- Swiss midlands: Spectro-directional phenological studies



Winter 2004



Summer 2004

National park

June 2005

July 2005

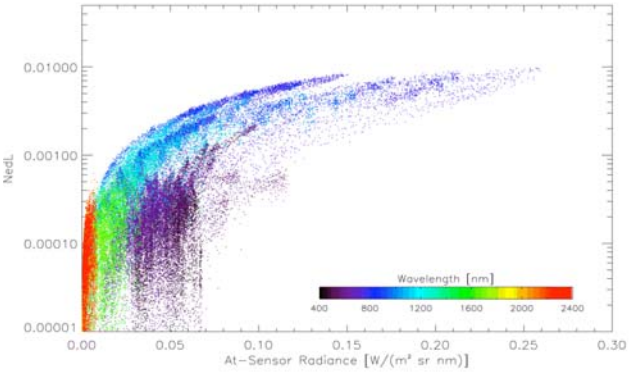
Vordemwald

August 2005

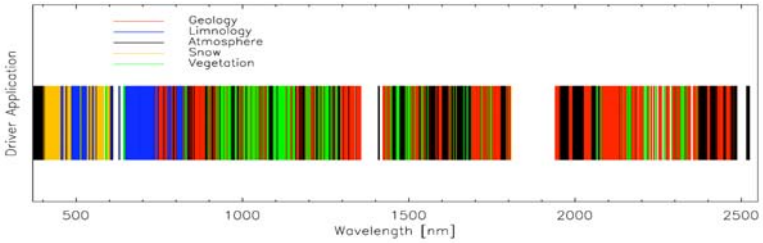
Simulation, Cal/Val of Spaceborne Sensors

Definition of application-driven user requirements

Modeled LAI as a function of NedL and at-sensor-radiance to determine SNR requirements for imaging spectrometers.



Driver application for the radiometric requirement



Schlaepfer & Schaepman (2002)

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Summary

Combined air- and spaceborne hyperspectral remote sensing has a huge potential in assessing and monitoring the Earth's ecosystem

The greatly improved capabilities for the estimation of quantitative parameters and variables enable a much better understanding of Earth system processes ("from pixels to processes").

APEX, the airborne flexible, programmable imaging spectrometer with extreme radiometric, spectral and spatial properties will certainly serve as a development tool for upcoming and future spaceborne systems.

Such an instrument with a broad range of applications must be hyperspectral, a dedicated single use optimized system may be multi- or superspectral (10- 20 applications specific bands such as the ESA Sentinel II).

Hyperspectral research with APEX bears great potential not only for science but offers opportunities for further industrial developments.